## Appendix B -- Section J “Special Information and Supplementary Documentation”

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<td>Andreas Dönbrack¹, Sarah Jones², and Martin Weissmann¹</td>
<td>¹ Institut für Physik der Atmosphäre, DLR, Germany</td>
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<td></td>
<td>² Institute für Meteorologie und Klimaforschung, Universität Karlsruhe / Forschungszentrum Karlsruhe, Germany</td>
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Cyclogenesis over the western Pacific frequently excites Rossby wave trains that propagate rapidly eastward, reaching North America within a few days. These wave trains frequently trigger high impact weather events over the U.S., North Atlantic, and even Europe. Furthermore, analyses and forecast errors over western Pacific also propagate rapidly downstream to affect the quality of forecasts over the U.S. Recent studies have shown that these cyclogenesis events are strongly influenced by upper tropospheric wave packets that propagate eastward from Asia into the western Pacific. One of the foci of the U.S. participation in THORPEX PARC is to test the downstream effects of improved analyses along the upper tropospheric Asian waveguides on improving the analyses and forecasts of cyclogenesis over western Pacific, which can subsequently lead to improvements on the forecasts of the downstream impacts of these cyclogenesis events.

I will be conducting research studies on understanding the dynamics and predictability of rapid cyclogenesis over the western Pacific, in particular, the interactions between upper level wave packets and surface rapid cyclogenesis. Part of the research effort will be complementary to PARC – these studies will provide theoretical guidance to PARC on what kind of observations will be useful, as well as the geographical location of observations that could potentially have high impacts. Another part of the research will make use of the improved analyses provided by the improved data coverage due to PARC to improve our understanding of the dynamics governing these cyclogenesis events. Support for these research efforts has been requested in the proposal “Dynamics and predictability of the interactions between wave packets and explosive cyclogenesis over western North Pacific” submitted to NSF ATM Climate and Large-scale Dynamics Program. As it stands, in the proposal no funding for foreign travel has been requested. Supplementary funding for foreign travel will be needed for active participation in PARC.
Mid-latitude-Tropical Interactions - A Prospective from the Subtropics

Yi-Leng Chen
Department of Meteorology, University of Hawaii, Honolulu, HI 96822
Ph: (808)-956-2570; Email: yileng@hawaii.edu

Scientific summary – During the cool season (early fall to spring) over the Hawaiian Islands, localized heavy-rainfall and high-wind events pose significant hazards to society. The recent Manoa Valley Flood on October 30, 2004 caused more than 100 million dollars damage to 32 buildings on the University of Hawaii-Manoa campus. On average, five to six flash floods occur per year with numerous high-wind events (Schroeder 1977; Zhang et al. 2005 a,b). Frequently, these events are associated with storms that are of extratropical origins and intrude into the subtropics as they move across the North Pacific. Furthermore, some of the intense winter storms over the Northwest Pacific with persistent strong surface winds could produce ocean swells to move across the North Pacific resulted in high surfs as high as 40 feet along the north and west facing shores. On the other hand, secondary cyclogenesis along the southern end of the cold front would result in strong pre-frontal southwesterly wind that brings warm, moisture air from the south, providing a favorable environment for the development of the heavy rainfall. After frontal passages, strong, gusty winds dominate with frequent high-wind events (Zhang et al. 2005b). The PARC field campaign will provide the much needed data for the study of impact of cyclogenesis over East Asia on the subsequent evolution of synoptic systems that affect the Hawaiian Islands. We would like to use PARC and COSMIC data (in collaboration with Bill Kuo) to improve weather analysis and the initial conditions for high resolution numerical models.

We also would like to study the development of tropical storms over the western Pacific. The studies on interactions between the tropical storms and upper-level troughs in the westerlies or TUTT (Tropical upper- level trough) cells, have focused on the storm outflow and the environmental circulations in upper levels (e.g., Sadler 1978). There is very little information concerning the origin, evolution of TUTT cells and 3-D circulation patterns associated with these interactions. We would like to revisit storm-environment interactions through the analysis and numerical simulations of these events.

References:

Relationship to international T-PARC measurements – focus on tropical cyclone genesis/monsoon trough and winter cyclogenesis.

Field activities: PI and his students plan to participate in the field experiment.
Scientific background: The predictability of an extratropical transition is affected by the structure and motion of the tropical cyclone, the structure and motion in the midlatitudes into which the tropical cyclone is moving, and the subtropical anticyclone. Thus, the extratropical transition may be viewed as a “three-body problem” in which very different tracks and intensifications as an extratropical cyclone (and subsequent downstream impacts) may occur depending on the characteristics of the three circulations. The midlatitude contribution has been examined by contrasting the impact of the midlatitudes cyclones to the northwest and to the northeast of the poleward-moving tropical cyclone, and by comparing mesoscale model predictions with and without the tropical cyclone. In conjunction with Professor Liz Ritchie, a simulation of three midlatitude troughs approaching an idealized tropical cyclone again demonstrated the important role of the midlatitude trough phasing. Recently, the interaction of tropical cyclones in various positions southeast of the midlatitude trough has been simulated to determine the tropical track impact on the extratropical cyclone intensity.

Our primary hypothesis is that the tropical cyclone structure and track are critical factors in the extratropical transition, and to a large extent these are determined during and following tropical cyclogenesis. The western North Pacific has a much larger variety of tropical cyclone structures (ranging from midgets to monster typhoons) than in the Atlantic because of the different pre-tropical seedlings from which they form. Whereas some form from waves in the easterlies as in the Atlantic, most western North Pacific tropical cyclone form from monsoon depressions and thus have a larger size from the beginning and do not become small. In addition midgets, which may later become larger in a different environment, and monsoon typhoons form in a different environment. Because of the different wind and convective structures in the tropical cyclones, the contributions to extratropical transition and the subsequent downstream impacts will be different.

Relationship to international T-PARC measurements: What is required are in situ observations to determine the relative roles of the three “bodies” in extratropical transition, and these will be available in T-PARC. This project will take advantage of several T-PARC data sets. First, the Driftsondes and targeted satellite observations from the Japan geostationary satellite will provide the environmental conditions during the various tropical cyclogenesis events. The NRL P-3 with the ELDORA will provide the in situ measurements in the critical convergence zone at the eastern end of the monsoon trough during cyclogenesis. Subsequent measurements of the structure from the NRL P-3, the Taiwan DOTSTAR, and (hopefully) the Japan aircraft will provide somewhat continuous measurements to supplement the rapid-scan satellite observations during the period leading to recurvature and extratropical transition. These data sets will provide the initial and validation data sets for high-resolution numerical model simulations, and those fields will be the basis for understanding the physical mechanisms leading to structure changes that affect extratropical transition. Ensemble prediction systems will also be analyzed to examine the tropical cyclone-related contributions.

Field activities: The first investigator will be involved in the tropical cyclogenesis planning and international coordination activities, including some time in Guam. Collaborations with the lead scientists for ELDORA and the NRL P-3, with the NRL, CIMMS, and CIRA satellite groups are planned.
Improving ensemble based deterministic forecasts of tropical cyclone position

Brian J. Etherton
Department of Geography and Earth Sciences
University of North Carolina Charlotte
9201 University City Boulevard, Charlotte NC, 28223
704-687-5984 betherto@uncc.edu

Scientific summary

Pre-Emptive forecasting using the Ensemble Kalman Filter

An Ensemble Kalman Filter (EnKF) estimates the error statistics of a model forecast using ensembles. One use of an EnKF is data assimilation, creating an ‘increment’ to the first guess field at the observation time. Another use of an EnKF is to propagate error statistics of a model forecast forward in time, as has been done for targeted observations. Combining these two uses of an ensemble Kalman filter, a ‘pre-emptive forecast’ can be generated. In a pre-emptive forecast, the increment to the first guess field is, using ensembles, propagated to some future time, added to the future control forecast, resulting in a new forecast. This new forecast requires no more time to produce than the time needed to run a data assimilation scheme.

In a paper currently in review in *Monthly Weather Review*, a barotropic vorticity model was run to produce a 300-day ‘nature-run’. The same model, run with a different vorticity forcing scheme, served as the forecast model. Pre-emptive forecasts were more accurate than the control model forecasts. An important result of this study is that the accuracy of the pre-emptive forecasts improved significantly when (a) the ensemble based error statistics used by the EnKF were localized using a Schur product and (b) a model error term was included in the background error covariance matrices.

The proposed work is that I, and a post-doc, will generate pre-emptive forecasts of tropical cyclone position using members of the global ensemble TIGGE (or, alternatively, the present suite of ensemble forecasts from ECMWF, NCEP, CMC, and others) and observations taken in T-PARC. We will also investigate how to best estimate and incorporate model error into the pre-emptive forecast scheme, as well as the best means of localizing the background error covariance matrix.

Relationship to international T-PARC measurements

The focus of this work will be on improving model forecasts of tropical cyclone track and intensity. We will make use of all observations taken in T-PARC that address tropical cyclones. It is important, in the framework of Numerical Weather Prediction, to determine which observation types have the greatest benefit to computer model forecasts. The observations from the following sources are ones we will use in our experiments:

- Tibetan plateau (radiosonde, profilers, surface stations)
- Russian radiosonde network Rapid scan satellite data requested from GMS/JMA
- Typhoon genesis region/monsoon trough (May and August; US driftoonde)
- Typhoon recurvature/landfall (Aug-Sept; Taiwan DOTSTAR, is funded; proposed China, Japanese and Korea contributions)
- NRL P-3 with ELDORA Doppler radar and dropsondes (Aug-Sept -- NSF deployment pool with possible NRL/ONR contribution)
- NSF HIAPER with DLR Doppler lidar, dropsondes and new cloud radar (Approx Sept-Oct)
Scientific summary

The focus of our current research has been to document the structural evolution of tropical cyclones at all phases of their lifecycles (from genesis – whether tropical or subtropical – through to extratropical transition or decay). We characterize storm structure in terms of the Cyclone Phase Space (CPS; Hart 2003; Evans and Hart 2003) and have clustered individual storm analyses in this space (without regard for which storms they represent) to demonstrate the common structural modes (purely tropical or purely extratropical – weak and strong cases), as well as modes representing subtropical formation, extratropical transition, and occlusion.

We have demonstrated the efficacy of the CPS-structure based diagnostic for evaluating (initially) tropical cyclone forecasts (Evans et al. 2006). The importance of the structure forecast derives from its relationship with the intensity and significant weather associated with the storm. Should the storm structure be incorrectly analyzed (or forecast), the distribution of the associated precipitation field and damaging winds (and therefore waves and storm surge) will be in error.

Ensemble forecasting can potentially provide useful guidance on the predictability of the synoptic situation being forecast – including the evolution of individual systems. Thus, we have begun to develop a mixture-based modeling approach for processing global model ensembles based on the structural evolution of a target storm. This mixture-based modeling approach is designed to cluster storm “tracks” through some space. Given the focus on storm structure, we cluster both the physical (i.e. lat, lon) storm tracks as well as the forecast track of the storm through the CPS. These clusters will be compared to the “environmental clustering” approach of Harr, Jones and Anwender to evaluate the agreement of the two approaches. The goal in both cases is to provide model guidance to the operational forecaster.

Relationship to international T-PARC measurements This proposal focuses on the structural representation of tropical cyclones from genesis through their complete lifecycle to either decay or extratropical transition. It thus addresses a variety of the key foci of T-PARC. We propose (1) to process the ensemble forecasts in realtime as guidance for the field phase; and (2) to use supplementary model forecasts (for example, data withdrawal experiments) to assess the effectiveness of the various data strategies at capturing the evolving storm structure.

New proposal or supplemental request New proposal. A related proposal is being submitted to NSF for review this month (August 2006), but may not be through in time for this submittal, so I am making this a small, independent proposal.

Estimate of, proposed duration, and start date and justification
Proposed duration: 2 years
Start date: 1 January 2008
Justification: This start date will allow for tailoring of the ensemble clustering to a realtime data feed and testing, to ensure reliability once the experiment begins. The year subsequent to the field phase of T-PARC is included to allow for post-experiment testing of supplementary model forecasts (for example, data withdrawal experiments) to assess the effectiveness of the various data strategies at capturing the evolving storm structure.

Field activities: The PI (Evans) and one of her graduate students will be participating in the field phase. The graduate student has expressed an interest in being active in data collection, if at all possible.
GMAO research interests relevant to THORPEX/PARC

Ron Gelaro

The NASA Global Modeling and Assimilation Office (GMAO) is generally interested in conducting investigations of the global observing system to evaluate existing observation suites and identify which possible new instruments have the greatest potential for adding useful information to the observation network. Although the spectrum of the GMAO’s objectives in this area is broad and in many cases driven by interests in satellite data assimilation beyond weather prediction, they all depend to some degree on issues in data assimilation and predictability that lie at the heart of THORPEX.

In the context of THORPEX/PARC, the GMAO is interested in utilizing its recently developed GEOS-5 global data assimilation system and accompanying suite of adjoint-based diagnostic tools to conduct observing system research aimed at improving the analysis and prediction of extreme Pacific weather events that impact North America. The GMAO has developed adjoint versions of both the GEOS-5 finite-volume atmospheric model and the Gridpoint Statistical Interpolation (GSI) analysis system. The GSI, developed at National Centers for Environmental Prediction (NCEP), is expected to become the operational analysis system at both NCEP and GMAO in the near future. With the adjoint of the complete GEOS-5 system, sensitivities can be determined with respect to observational data, background fields or assimilation parameters, all computed simultaneously. It also allows for estimation of the impacts of any subset of data (aggregated, e.g., by data type, channel or location) on standard forecast measures. The GMAO is interested in using these tools to investigate which components of the observing system provide significant benefit to the prediction of extreme events, and whether potentially important gaps in the observing system can be identified. We would be especially interested in assessing the impact of augmentations of the routine observing system during THORPEX/PARC field activities. We would also be interested in using these tools to provide targeting guidance or other products to assist mission planning, etc.

In the longer term, the GMAO hopes to develop improved adaptive observing techniques and intelligent data selection strategies for optimizing the use of high-density satellite observations. We believe that advancement in these areas requires, among other things, improved understanding of how non-modality and scale selectivity, which are implicit characteristics of error growth on short time scales, affect the data assimilation problem. The fact that errors change shape with time implies that the mitigation of background errors on their dominant scales alone may be inadequate for reducing the analysis errors that most effectively create those and subsequent forecast errors. The potential of non-modality to limit the constraining effects of observations thus requires investigation if assimilation systems are to be properly assessed and optimally designed to mitigate error growth. Since all optimal assimilation systems are cycling, it is also conceivable that, through scale interaction during production of the next background, large scale corrections are also able to correct the small scales. While investigation of these issues can certainly occur outside the context of THORPEX/PARC, previous experiences in, e.g., FASTEX and NORPEX show that the focused research environment and supplemental data sets resulting from such campaigns tend to accelerate progress significantly.
THORPEX-PARC Statement of Research Interests

Gregory J. Hakim
University of Washington

My interest in THORPEX-PARC is deeply rooted in much of the research on dynamics, predictability, and data assimilation that I and my research group have performed during the past seven years. Starting in 1999, I have explicitly written THORPEX-based research into my NSF proposals.

Specific research topics that we have explored in recent years that directly relate to our interest in THORPEX-PARC include: the dynamics of baroclinic wave packets, observations of and theory for error growth in baroclinic waves, ensemble-based data assimilation, and extratropical transition events over the western North Pacific ocean.

While much is known about the main extratropical Rossby wave guides over Asia and the North Pacific, less is known about the detailed sources of wave activity in these guides, and less still about the origin and dynamics of forecast errors in these waves. THORPEX-PARC will directly address these issues by focusing on error sources over the western North Pacific. In particular, graduate student Ryan Torn is working with me to explore predictability issues related to western North Pacific typhoons undergoing extratropical transition using an ensemble Kalman filter (EnKF). This research relates directly to the planned field activities of THORPEX-PARC.

Data assimilation is widely recognized as a crucial element for THORPEX research. While much attention is focused on the potential for improved analyses and forecasts with improved data assimilation techniques, it has become clear that data assimilation may be used as a tool to better understand the dynamics of weather systems and the growth of errors in these systems. This basic-science application of data assimilation research is a major thrust of my research efforts, and I expect to apply these ideas to THORPEX-PARC research. Finally, we also have interest in more application-oriented data assimilation. A pseudo-operational real-time EnKF has been cycling at the University of Washington since December 2004. Given the success of this system, which is competitive with major operational center results, we plan to extend the domain to encompass the entire Pacific for THORPEX-PARC, and assimilate field observations in real-time.
SCIENTIFIC SUMMARY

Background: It has become evident that the extratropical transition (ET) of a tropical cyclone has far-reaching effects on the midlatitude circulation. Furthermore, there is a large amount of variability in the occurrence and amplitude of the downstream impacts. Forecasts of the downstream impacts have reduced skill, and the variability among ensemble members during extratropical transition events suggests that the predictability associated with ET events is low.

If the downstream impact of the ET of a tropical cyclone is treated as a Rossby-wave response to the movement of the momentum and moisture associated with the decaying tropical cyclone, then it is necessary to understand the horizontal and vertical distributions of these fields associated with the ET event. Furthermore, the variability in the downstream response will be determined by the variability in the interactions between the decaying tropical cyclone and the midlatitude circulation into which it is moving. During extratropical transition, the physical and dynamical processes may be related to such factors as: i) remnant deep convection in the decaying tropical cyclone core; ii) warm frontogenesis that occurs in conjunction with upslope of low-level, warm, moist air of tropical origin over the cool, dry air of the midlatitudes, and iii) divergent outflow from the decaying tropical cyclone that may result in a local jet streak; which then contributes to the development of the extratropical cyclone and the downstream wave pattern.

Objectives: Based on the framework of the three primary regions associated with an ET of a decaying tropical cyclone, it is hypothesized that more accurate characterization of the processes within these regions, and the interrelationships among these regions and the midlatitudes, will lead to increased understanding and prediction of the occurrence, amplitude, and extent of the downstream response to the ET event. Primary objectives are to understand the critical physical processes that define the characteristic type of extratropical transition and to define the linkages between these processes and the downstream variability that results from the extratropical transition event. Additional objectives include development of methodologies for observation strategies of the extratropical transition and the interface between the extratropical transition and the midlatitude circulation into which it is moving, and utilization of those methodologies for reducing analysis uncertainty and model forecast error. The methodologies should include a spectrum of observing strategies, targeting, and analysis that includes conventional, special, and remotely-sensed observations. Increased understanding of the forcing of a downstream wave pattern will have profound impacts on forecasts of high-impact weather patterns over North America. The accomplishment of several of these objectives will be coordinated via collaborations with other investigators at the Navy Research Laboratory and the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin. These collaborations provide a comprehensive capability with proven accomplishments in model sensitivity studies, and advanced satellite data processing and usage for improved understanding of many atmospheric phenomena.

Relationship to international T-PARC measurements

The proposed project is closely tied to several T-PARC components. Measurements from the tropical component will be utilized to examine the roles of tropical cyclone structure and structure change during formation and intensification as they impact the extratropical transition and interactions with the midlatitude circulation. These measurements will include aircraft-based dropwindsondes and radar data, dropwindsondes released from Driftsondes, and data from polar orbiting and geostationary satellites.
Measurements during the ET component of T-PARC will be utilized to identify critical physical mechanisms that impact downstream predictability and the capability to properly observe the critical components such that they be adequately initialized in a numerical forecast model. These observations will include aircraft-based dropwindsondes and radar data, and data from polar-orbiting and geostationary satellites.

Field activities:
The first investigator proposes to be a leader in the planning and execution of the North American component of PARC. While the investigator will not bring instruments to the field, close collaboration with observation sources, developers, and operators will occur such that the necessary observations are obtained to accomplish the proposed objectives. Observations essential for this research include ELDORA for mapping the four-dimensional kinematic and moisture distributions, dropwindsondes, water vapor and wind lidars.

The investigators will participate fully in the field program, primarily during the ET component, which includes time at the experiment operations center and flight operations center in Japan, Okinawa, or Guam. Additionally, it is anticipated that several students will participate A significant portion of participation is included for post field data analysis. Collaborations with lead scientists from the Navy Research Laboratory, and the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin are planned.

NEW PROPOSAL:
This will be a new proposal with a start date set such that the investigators may play significant roles in guiding the design of the T-PARC program.
January 27, 2006

Dr. David Parsons
Co-chair of the North American Regional Committee
THORPEX

Dear Dave:

I am very excited by the planned Pacific Asian Regional Campaign (PARC), and I am expressing my interest in participating in it. If NSF issues a call for PARC proposals, I intend to submit a proposal requesting support for one student.

The area of research that interests me most in PARC is adaptive observations. So far the focus in adaptive observations has been on observations launched on airplane flights, and therefore they require planning for weather events several days in advance. As a result, I believe, their impact, though apparent, is much smaller than optimum. A different focus is to select optimal observation locations for the next few hours, something that would be most useful for the future generation of satellites, and would improve the 1-14 days forecasts more efficiently than the present approach. For example, incoherent lidar instruments to measure winds planned for the future by NASA are very energy consuming, so that they are planning to ideally observe only 10% of the time (and spend only 10% of the energy), but in locations that provide 50% of the positive impact. Recent work of my student Junjie Liu indicates that using our Local Ensemble Transform Kalman Filter (developed at the University of Maryland), a simple and inexpensive use of the ensemble spread gives results that are optimal for short-range adaptive observations (and better than all previous results obtained with the Lorenz-Emmanuel model). However, when preparing adaptive observations for longer-range launching, the much more expensive minimization of the local analysis error covariance Pa (as in Bishop et al, 2001 but within the data assimilation system) becomes superior to the ensemble spread. A combined method, pre-selecting the most promising locations with the zero-cost ensemble spread, and then estimating the minimum Pa only among those pre-selected points, was found to be much less expensive and give similar results as the minimum Pa method. I would like to take opportunity of the dense PARC observations to test this promising approaches with real data assimilation and predictions with the LETKF.

I am looking forward to this opportunity to participate in the PARC program.

Sincerely,

Eugenia Kalnay
Distinguished University Professor
Phenomenological and predictability studies of high-impact weather events over North America with origins over East Asia and the western North Pacific

Daniel Keyser and Lance F. Bosart
Department of Earth and Atmospheric Sciences
University at Albany
State University of New York
Albany, NY 12222

The PI (Keyser) and Co-PI (Bosart) intend to continue their NSF-funded research project, “Synoptic-Dynamic Studies of Atmospheric Predictability” (ATM-0434189; 1 November 2004–31 October 2007), through a three-year renewal starting in FY08 that fits within the scope of the THORPEX Pacific–Asian Regional Campaign (PARC), presently scheduled for June–December 2008. As stated in the Executive Summary of the PARC planning document, “The PARC … will focus on … i) western Pacific and Asian typhoons from genesis to extratropical transition/decay, and ii) downstream high-impact weather events over North America, the Arctic and other locations whose dynamical roots and/or forecast errors are driven by aspects of the life cycle of typhoons and other intense cyclogenesis events over east Asia and the western Pacific.” Both of these foci relate directly to the PI’s and Co-PI’s long-term collaborative research interest in addressing atmospheric predictability from a so-called phenomenological perspective, which complements the conventional dynamical and probabilistic perspectives that form the foundation for modern numerical weather prediction (NWP) in general and ensemble prediction in particular. Addressing predictability from a phenomenological perspective requires documenting the evolution of high-impact weather events that occur on time scales lying between the mesoscale (<1 day) and intraseasonal climate (>2 weeks), and that challenge the capabilities of state-of-the-art NWP models. This perspective is being developed by focusing on the role of precursor disturbances originating from the tropical and arctic sides of the midlatitude Rossby waveguide in exciting and reconfiguring wave trains. These respective tropical and extratropical influences on the midlatitude Rossby wave regime may be classified as “tropical–extratropical interactions” (TEIs) and “arctic–extratropical interactions” (AEIs).

Following completion of the field phase of PARC, the PI and Co-PI will analyze and interpret predictability globally and regionally for the period of the field campaign in terms of: (i) the ability of operational global NWP models to forecast the evolution of high-impact weather events over North America; (ii) the behavior of large-scale flow regimes in which these weather events occur; and (iii) the transitions between flow regimes that take place in conjunction with the occurrence of selected weather events. In the context of this framework, attention will be focused on three types of TEIs and AEIs that may be considered “hard to predict” and that are associated with adverse societal and economic impacts. These respectively involve the following precursor disturbances: recurving and transitioning tropical cyclones, mesoscale tropopause-based coherent structures, and intense surface anticyclones and associated cold surges. The role of each of these precursors in exciting and reconfiguring wave trains on the Pacific jet stream will be investigated, with particular emphasis on episodes of TEIs and AEIs that occur over the western North Pacific and East Asia, and that result in high-impact weather events over North America. Comprehensive multiscale case and diagnostic studies will be conducted for these episodes to establish the synoptic-dynamic context for understanding how initial-analysis and model-physics errors place bounds on predictability. In conjunction with the multiscale case and diagnostic studies, factors limiting predictability will be investigated further through the synoptic evaluation of the skill of the operational National Centers for Environmental Prediction Global Forecast System globally and regionally on a daily basis for forecast projections out to two weeks for the field phase of PARC; this evaluation will be extended to ensemble forecast products for selected “hard-to-predict” high-impact weather events over North America, large-scale flow regimes, and regime transitions.
Statement of Interest in THORPEX-PARC

Bill Kuo, COSMIC and MMM Division

COSMIC (Constellation Observing System for Meteorology, Ionosphere and Climate) is a joint U.S.-Taiwan mission, which will be launched at the end of March 2006. COSMIC will provide approximately 2,500 GPS radio occultation (RO) soundings per day uniformly distributed around the globe. The six COSMIC satellites will be deployed into their final orbits using the differential precession technique, which will take about 13 month. COSMIC will use advanced signal tracking technique, known as the open-loop tracking, for GPS RO measurements. With this new tracking technique (which has already been demonstrated in the current SAC-C mission), we anticipate 90% of the COSMIC GPS RO soundings will penetrate below 1 km. The ability to take measurements within the boundary layer (particularly over the tropics) will provide valuable information for meteorological research and operational forecasting. The GPS RO soundings have many unique characteristics. It is of high vertical resolution and high accuracy; it does not suffer from satellite-to-satellite variations; and it does not suffer from instrument drift. These characteristics make it extremely valuable for climate monitoring. Because of ray geometry, GPS RO measurement is not a point measurement. Rather, the horizontal scale of the GPS RO measurement along the ray path is approximately 250 km, and the cross-ray scale is on the order of a few hundred meters. This is very different from the traditional meteorological measurement such as the radiosonde, or the traditional nadir-viewing satellite microwave or infrared sounders. Before the COSMIC data are used effectively in weather prediction and climate monitoring, it would be valuable to assess the accuracy of COSMIC GPS RO soundings.

My personal interests in THORPEX-PARC falls within the following two areas: (i) COSMIC GPS RO sounding validation, and (ii) assessing the relatively importance of various remote sensing and in-situ data. The HIAPER aircraft has a highly accurate GPS navigation system. It also has a very accurate suite of measurements for in-situ instruments. The loci of COSMIC GPS RO soundings can be predicted about two weeks in advance, because the positions of the GPS satellites and COSMIC satellites can be estimated fairly accurately in advance. THORPEX-PARC provides a unique opportunity for validating the COSMIC GPS RO soundings, particularly over the atmospheric boundary layer. With the precise navigation of HIAPER, we can fly the aircraft along the ray perigee points (the point of the ray path that is closest to Earth) of the GPS RO soundings. We can also fly the HIAPER aircraft along the ray path, which would allow us to study the impact of horizontal gradients on ray bending and the Abel inversion (which is used to derive refractivity). Dropsondes from HIAPER and Driftsonde systems also provide valuable information for GPS RO sounding validation.

We have developed advanced variational and ensemble-based data assimilation systems based on the Weather Research and Forecasting (WRF) model for the assimilation of GPS RO soundings. THORPEX-PARC provides a great opportunity to assess the relative importance of various types of remote sensing and in-situ measurements on the regional weather analysis and prediction over the western Pacific. I am interested in performing assimilation of THORPEX-PARC, COSMIC, and other operationally available data using the advanced WRF-based variational and ensemble-based data assimilation systems, and to assess their impact on regional weather analysis and prediction. The THORPEX-PARC measurements would be valuable both for data assimilation and for forecast validation.
PARC Statement of Interest in Participation

Jeffrey K. Lazo, Rebecca Morss, and Barbara G. Brown – NCAR

A significant component of THORPEX is the Societal and Economic Applications (SEA) outlined in the THORPEX Science Plan and Implementation Plan. This document indicates our interest in participating in SEA work on the THORPEX Pacific-Asian Regional Campaign (PARC). We propose to undertake three related efforts: (1) a basic-to-applied research study to understand and estimate the societal benefit of PARC; (2) in-depth user-specific investigations of use and benefits of PARC-related forecasts; and (3) diagnostic, user-focused evaluations of the quality and performance of PARC forecasts. These three proposed efforts are not exhaustive; as the PARC program and associated SEA community develops further, there are several additional possible SEA research areas related to PARC activities and Pacific predictability that we may also be interested in pursuing.

UNDERSTANDING AND ESTIMATING SOCIETAL BENEFIT OF PARC: This research effort will first work closely with other PARC activities to understand the costs and potential end-user benefits of PARC and how these relate to investments in PARC and in related aspects of the meteorological observing and forecasting system. We will then build a corresponding systems model or influence diagram to characterize the likely net societal benefit of implementing various observing and forecast system improvements investigated by PARC. In doing so, we will incorporate other related knowledge on societal aspects of meteorological and other science and technology research and development (R&D) efforts. After developing the underlying conceptual framework, we will work with PARC researchers, administrators, and others to develop and aggregate the knowledge required to apply the framework to estimate the overall costs and benefits of different observing and forecast system improvements proposed by PARC. This will include a sensitivity analysis to identify key uncertainties affecting the results. We will also identify remaining uncertainties, biases, and omissions in the underlying conceptual model, as well as related needs for meteorological, social science, and interdisciplinary research. The framework and results may also be adapted and extended to analyze the costs and benefits of the PARC program as a whole.

USER-SPECIFIC FORECAST USE AND BENEFITS: This research will investigate the use of weather forecast information and its value in decision-making for specific groups of forecast users in Western North America and/or other Pacific regions affected by PARC forecasts. This will include research on users’ perceptions of and preferences for different types of weather forecast information, the role of different types of forecast information in users’ decisions, and the value of different types of forecast information services. The effort will focus on current and improved short- to mid-term (up to 14 days) weather forecast information related to PARC, including probabilistic forecasts and other information about forecast uncertainty. Possible user groups to study include households (the public), water managers, energy sector decision makers, and/or emergency managers. One method we intend to use is a non-market valuation survey, leveraging off an existing state-of-the-art survey, and comprehensive multivariate analysis of the results. Other methods to be used, depending on the specific research questions and user groups selected, might include mental modeling interviews and other quantitative or qualitative survey/interview methods.

DIAGNOSTIC, USER-FOCUSED EVALUATIONS OF THE QUALITY AND PERFORMANCE OF PARC FORECASTS: Diagnostic approaches for the meteorological evaluation of PARC forecasts will provide information that can be incorporated in the forecast improvement process, and will provide a link between the forecasts and users’ actions through decision making processes and systems. Traditional forecast verification approaches cannot fulfill these functions, due to their reliance and focus on single-measure scores to summarize forecast performance. Basic research and development are required to develop approaches that meet the decision-making needs of specific forecast users. In application to PARC, this research will focus on specific types of decision makers, such as forecasters and water managers. In collaboration with specific users (and in coordination with the projects described above), new forecast evaluation methods will be developed that meet the needs of these specific users, and these approaches will be applied to PARC forecasts. In addition, new methods will be investigated that attempt
to represent overall economic benefit. The use of the information provided by these new methods will be evaluated and the results of these investigations will be applied to further improve the methodologies.
Effect of Tropical Cyclones on Tropical Intraseasonal Oscillations: TPARC Observational Analysis, Data Assimilation and Modeling

PI: Tim Li
Department of Meteorology, University of Hawaii, 2525 Correa Rd., Honolulu, HI 96822. Tel: 808-956-9427, Fax: 808-956-9425, Email: timli@hawaii.edu

Co-PI: Melinda Peng
Naval Research Laboratory, 7 Grace Hopper Ave., Monterey, CA 93943. Tel: 831-656-4704, Email: melinda.peng@nrlmry.navy.mil

Planning Letter

Studies using analyzed fields have shown that there is a correlation between the active phase of the tropical Intraseasonal Oscillation (ISO) and tropical cyclone (TC) genesis, suggesting that the ISO may set up favorable conditions for TC development. In this study, we propose to study this relationship from the other perspective; namely, we propose to study how TCs influence ISOs. It is widely known that the convective heating is the major energy source for the tropical ISO. Tropical cyclones, though transient with shorter life cycles, produce a large amount of heat and play important roles in the global circulation and energy budget. However, current General Circulation Models (GCMs) have little capability in simulating TCs and thus do not carry the effects of TCs in model simulations.

We hypothesize that TCs may influence/initiate ISOs through both direct and indirect effects. The direct impact is through TC Rossby wave energy dispersion. It is well known that a mature TC is subjected to Rossby wave energy dispersion due to change of the Coriolis force with latitude. While a TC moves northwestward due to beta draft and mean flow steering, it emits Rossby wave energy southeastward. Due to the large-scale control of ISO, a group of TCs may form during a particular period when an ISO is active. Energy dispersion associated with these TCs as a group may feed back to the ISO through energy accumulation by confluent monsoon background flows. Thus the group of TC energy dispersion may have a direct impact on the ISO intensity and/or structure. The indirect impact is through changing the mean state, including the western North Pacific monsoon trough and underlying SST. The change of the mean state may further impact the period, propagation and strength of ISOs.

We propose to apply various data assimilation schemes to include the realistic TC effect in the analysis fields. Years of satellite-retrieved data, including the AMSR-E, TRMM, AIRS, AMSU and SSM/I products, combined with the TPARC in-situ observations, will be used to assimilate realistic TC structure and energy dispersion effect. Two global models will be used for the proposed study. One is the Navy Operational Global Atmospheric Prediction System (NOGAPS) and the other is the European Center Hamburg (ECHAM) GCM model. The effects of TCs will be included in both idealized and realistic setting. In the realistic setting, the NAVDAS 3DVar system will be used in which we regard a reconstructed 3D TC structure field [derived either from a 4DVar typhoon reanalysis (Zhang et al. 2007) or a bogus data assimilation approach based on observed TC central minimum sea-level pressure (MSLP) and AMSU-measured temperature profiles (Zhu et al. 2004)] as “observation” and assimilate the “observational” data into the model analysis field. For the idealized setting, two approaches will be adopted. First, the two global models will be run freely for a number of years with specified observed SST; then a nudging of the model MSLP (and/or wind fields) toward the observed values (based on 3-hourly JTWC best track) will be conducted. By analyzing cases with and without the nudging, the net TC effect on ISOs may be diagnosed. Secondly, we determine the model climatology of TC genesis by setting up a criterion at 850hPa vorticity field. Then we develop a strategy to include a “smart climatology” heating profile for vortices exceeding the threshold strength. By comparing simulations with and without the heating profile, the effect of TCs on ISOs may be estimated.

Various diagnostic tools (including wave activity flux analysis to reveal Rossby wave energy dispersion and accumulation, momentum and energy budget analysis to reveal the role of nonlinear interactive terms between synoptic and intraseasonal motions, and wavenumber-frequency analysis to reveal ISO structure, propagation and amplitude characteristics) will be adopted to analyze the aforementioned assimilation
fields and idealized model simulations. The specific scientific issues we plan to investigate include: a) How do TCs modulate ISOs through the aforementioned direct and indirect effects? b) How do the TC impacts on ISOs depend on the models with different convective parameterization schemes? and c) How is energy transferred or interchanged between TC and ISO scales?

The proposed research has a potential to improve our understanding and the prediction of intraseasonal variations. Climatology of TC heating profiles constructed from satellite-retrievals can be very useful for TC intensity study, a high priority goal in weather prediction.
Assessing Operational Forecasts of Winter Heavy Rain Systems during Extratropical Transition, Transit across the Northern Pacific, and Landfall on the Continental U. S.

Chungu Lu and Huiling Yuan
Cooperative Institute for Research on the Atmosphere (CIRA), Colorado State University, Fort Collins, CO, and NOAA/ESRL/GSD, Boulder, CO

Edward Tollerud, NOAA/ESRL/GSD, Boulder, CO

During December 2008 two field experiments at different ends of the North Pacific will be occurring simultaneously: the winter storm period of T-PARC in the western Pacific, and the fourth year of the American River Basin study of the Hydrometeorological Testbed (ARB-HMT) in the Sierra Nevada Mountains of northern California. These two experiments both include enhanced observations in addition to detailed ensemble modeling and assimilation foci. Since a principal objective of the T-PARC winter study is to identify and describe storm systems and processes in the western Pacific that ultimately become extreme precipitation events in the mountains of the western United States and Canada, these two field efforts together provide an excellent opportunity for end-to-end detailed modeling studies of these systems. In particular, they offer the possibility to assess the sensitivity of coastal United States heavy precipitation forecasts (their QPF component) during these events to accurate initialization of their formative stages over the western Pacific Ocean.

In order to draw definitive conclusions about the relationship between storms in these far-removed regions, it is necessary to track their propagation across a wide region of the North Pacific that is poorly observed from either land or ocean. It is also necessary to assess the performance of models during this period of propagation as well as during their landfall. Satellite observations are the obvious choice for these tasks, especially satellite-derived precipitation swathes and moisture profiles. We intend to pursue these two tasks: tracking and description of the propagation of systems across the ocean basin, and verification of the ensemble quantitative precipitation forecasts (QPF) produced by the GFS for these storms.

The verification component of this study will require innovative use and careful processing of satellite data. QPF verification, in particular, might be best served by using diagnostic measures of observed and predicted rainfall that are in addition to conventional precipitation verification algorithms like the Equitable Threat Score (ETS) or the root mean square (RMS) error. Examples could be object-based algorithms that key on satellite-defined properties including precipitation entity size, shape, intensity, etc., and their statistical relationship to the same entities in the prognostic fields. Since the transport of moisture is perhaps the most critical aspect of this study, we will also attempt to portray and verify moisture entities (swathes, layers, and regions) in models and observations.

We are preparing a two-year proposal to NSF to conduct this research.
Understanding and predicting the influence of observations on numerical forecasts of cyclones in the tropics and mid-latitudes

PI: Dr Sharanya J. Majumdar
RSMAS Division of Meteorology and Physical Oceanography, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149.
Phone: (305) 421 4779. E-mail: smajumdar@rsmas.miami.edu

Scientific Summary

Our proposed research aims to contribute towards several scientific goals of T-PARC: (i) "improved understanding of the dynamics and factors that limit the predictability of typhoons, extratropical transition events, other intense cyclogenesis events and associated downstream high-impact weather", (ii) "understanding error growth and scale interactions" and (iii) "testing new strategies for adaptive observing and modeling".

Adaptive sampling methods have to date been used to identify locations in which targeted observations may reduce forecast errors. In fact, these methods are considerably richer than their present use as "target identifiers", since (A) their 3-dimensional perturbation structure can be diagnosed to understand dynamically how data assimilation influences error propagation and growth, and (B) quantitative predictions of the reduction in forecast error variance due to any spatial and temporal distribution of observations can be made.

The Ensemble Transform Kalman Filter (ETKF) adaptive sampling technique attempts to predict the reduction of forecast error variance due to any set of observations via the "signal variance". However, the limited ensemble data available to date have induced dominant sampling errors and severely compromised the performance of the ETKF. The THORPEX Interactive Grand Global Ensemble (TIGGE) offers the opportunity to make significant improvements to the covariance structure in the ETKF, which will enable the detailed investigation of (A) and (B) above. In T-PARC, we propose to evaluate and understand ETKF signal variance evolution for typhoon prediction, and contrast its characteristics and accuracy against signal variance in the mid-latitude storm track.

The structure of the influence (or "signal") of specific datasets on forecasts of tropical and extra-tropical cyclones will be investigated via "data denial", in which the datasets are removed prior to assimilation. The operational data assimilation scheme at NCEP and/or available ensemble filters will be used. Since the ETKF attempts to predict the variance of signals, the projection of ETKF signal variance onto the signals will be used to diagnose the ability of the ETKF to capture the influence of observations on forecasts.

The influence of different variables and scales of observations will be investigated using the ETKF and data denial. For example, the following question can be addressed by comparing the assimilation of synoptic-scale wind fields versus those in the cyclone core: Does the absence of an accurate environmental wind field limit the predictability of cyclone development or downstream Rossby wave propagation more than the absence of inner-core data? An example of identifying the important variables for observation is to examine the differences between assimilating wind versus humidity in specific layers.

Relationship to International T-PARC Measurements

(a) Tropical cyclone motion and structure: Assimilation of data from driftsondes, rapid-scan winds and Taiwanese dropsondes collected in the vicinity of typhoons.
(b) Extratropical transition and Winter Cyclone Prediction: Assimilation of data from manned and unmanned aircraft, driftsondes, and satellites collected in the core and environment of the decaying typhoon or extra-tropical cyclogenesis region.

New NSF Proposal

**Timeline (3 years)**

8/1/07-7/31/08: Develop ETKF software for use with TIGGE and test data-denial software for existing routine satellite and rawinsonde data. Develop diagnostic tools. These developments will be used to help guide the experimental design.

8/1/08-1/31/09: Participate in T-PARC, run ETKF to assist with observational deployments. Perform data-denial retrospectively with T-PARC and routine data.

2/1/09-7/31/10: Perform diagnoses and evaluations described in scientific summary.

**Field Activities**

The PI is interested in leading or participating in a mission planning team during September-October 2008, with an emphasis on data sampling strategies for driftsondes and unmanned aircraft in both the tropical and extratropical phases. He is in contact with senior personnel at Aerosonde Inc. on the logistics of setting up a base for unmanned aircraft in September 2008 to address some central objectives of T-PARC.

The PI also plans to be involved in the winter storm component in December 2008.

Given the timeline of proposal submission and review, the earliest that a new student can begin graduate school is August 2008. Hence, the student will be involved in a limited amount of field work, while taking classes during his/her first semester (Fall 2008). The main activity of the student will be to conduct evaluations and diagnostic studies described in the scientific summary.
To Whom it May Concern:

This is a Letter of Support for the THORPEX Pacific Area Regional Campaign (PARC). The proposed program complements and augments efforts at the NOAA/AOML Hurricane Research Division (HRD) to understand and describe tropical cyclones during their entire life cycles with the ultimate goal of improving track, intensity, and rainfall forecasts. An important component of this effort is to gather comprehensive datasets and provide data to operational centers for assimilation into numerical modeling systems. Forecast improvements are critical to emergency managers at the local, state, national, and international levels, mariners, including the U.S. Navy, NASA, and other U.S. Federal agencies responsible for the well-being of millions of people and for billions of dollars of assets.

Since 1996, HRD and its predecessor organizations have run an annual tropical cyclone field program in the Atlantic and Eastern Pacific basins. Historically, observations have been gathered mainly in mature hurricanes, with less emphasis on the periods of tropical cyclogenesis and cyclolysis. NOAA took important steps in rectifying this in 2005 by sampling the genesis regions of tropical cyclones in the Gulf of Mexico and Eastern Pacific basins in collaboration with NASA’s Tropical Cloud Systems and Processes Experiment, and by collaborating with Environment Canada by flying two missions into Tropical Storm Ophelia (2005) as it underwent transition while approaching Nova Scotia and became a powerful North Atlantic storm. HRD scientists also led the effort to complete the first successful penetration of a tropical cyclone core by an unmanned aerial vehicle in Ophelia, and collaborated with the National Science Foundation-funded Hurricane Rainband and Intensity Change Experiment. HRD scientists continue to collaborate with Taiwanese scientists during the multi-year Dropwindsonde Observations for Typhoon Surveillance near the Taiwan Region. The data obtained in all these programs have been used in operational and research models to test targeting and data assimilation strategies, especially in next-generation non-hydrostatic models such as the Weather Research and Forecast Model, and to gain important insights into structural and intensity changes of tropical cyclones.

HRD is especially interested in studying data sets to test new ideas about tropical cyclone intensity and structure change. The proposed work is a good opportunity to do new and important research through augmentation of pre-existing efforts. To that end, HRD is interested in participating in and providing expertise and experience during the PARC to help address the proposed research goals. In return, HRD would like acknowledgement of our contribution to the field program and resulting research.

Sincerely,

Frank Marks, Director
frank_marks@noaa.gov
(202) 361-4221
Statement of research interest in the THORPEX Pacific-Asian Research Campaign

Professor Clifford F. Mass
Department of Atmospheric Sciences (Room 612), Box 351640
University of Washington
Seattle, Washington  98195

e-mail: cliff@atmos.washington.edu
Telephone: (206) 685-0910 (Voice), (206) 543-0308 (Fax)

My group at the University of Washington maintains a strong interest in The Pacific Campaign (PARC), with many of our current and future activities directed towards understanding the limits of current predictability over the Pacific and in developing ways to improve it. The following are a partial list of some of the directions we would like to take in concert with PARC over the next several years:

1. Document current forecast skill over and downstream of the Pacific for a range of major forecast models. This will include not only basic statistics, but a detailed examination of the performance for major storms and understanding the origins of large forecast failures.

2. Evaluating new data assimilation approaches such as EnKF and 4DVAR using current and future data collections. Some of this work would be in concert with Professor Greg Hakim's group.

3. Evaluating the value of lightning data and unmanned vehicles (UAVs) for improving analyses and forecasts over the Pacific. Part of this work will include OSSE's to determine the value of new observing platforms prior to field experiments.

Additional funding will be required to take on several of the tasks noted above.
Research Interest in the Pacific Campaign of THORPEX

Lynn McMurdie
Department of Atmospheric Sciences
Box 351640
University of Washington
Seattle, WA 98195
Phone: (206) 685-9405 Email: mcmurdie@atmos.washington.edu

Short-term (<72 h) forecast errors still occur despite recent improvements in modeling systems and data assimilation, especially over western North America. Cases with large short-term sea level pressure errors at coastal stations along the west coast (>15 mb) have been documented (McMurdie and Mass 2004) and have continued to occur in each winter season since that study. Our primary research interest is to document these short-term forecast errors for a variety of major operational model systems, such as the Global Forecast System model of National Centers for Environmental Prediction, and for a variety of locations, such as along the west and east coasts of North America. This will identify periods of low short-term predictability and their regional distribution. In addition, we are interested in investigating factors that contribute to the periods of low short-term predictability. For example, an important question is whether the periods of low predictability can be related to particular flow regimes, or related to the incidence of downstream development. Phenomena originating in the western Pacific, such as rapid cyclogenesis off the Asian continent or extratropical transition of tropical cyclones, can excite downstream development. This may in turn produce a period of low predictability at downstream locations, such as along the west coast of North America. These relationships between upstream phenomena and downstream predictability have not been adequately explored or documented.

A primary scientific object of The Observing-System Research and Predictability Experiment (THORPEX) Pacific Asian Regional Campaign (T-PARC) is to understand the dynamical linkages between high impact weather events over North America to specific weather phenomenon over the western Pacific, and to improve the forecast skill of these high-impact events. Our research interest in the documentation of forecast skill over North America and adjacent waters and how that skill varies with upstream activity in the western Pacific will be an important contribution to the goals of T-PARC.

Currently, the documentation of short-term forecast errors is occurring under an existing NSF grant that ends in June 2008. The results from this grant will provide information about the current status of predicting high-impact weather events and provide guidance for the planning stages of T-PARC. The results will also form a baseline from which to document forecast skill improvements resulting from the additional data collected during T-PARC. The exploration of the role of upstream weather activity in the western Pacific and downstream predictability is not a specific part of the current grant. Therefore, in order to be involved during the T-PARC field activities and subsequent analysis, a new NSF proposal would be required. The proposed start date for the new grant would be June 2008 and span three years. An estimate of costs is given at the end of this paper.

Our involvement with the T-PARC field phase would primarily be during the later part of the experiment when cyclogenesis off the Asiatic continent and/or extra-tropical transition of tropical cyclones would have the potential to effect short-term predictability of winter cyclones. We expect to have PI and student participation in the field activities, if there are funds available.

Notice of Planned NSF Grant Proposal Incorporating T-PARC Data Analysis

P.I.: M. T. Montgomery (NPS) & co-P.I.: R. W. Moore (ETH/Zurich)

This notice is to communicate our intent to submit a NSF Grant Proposal (summer 2007) that will include as part of its observational analysis component all data collected during the WINTER PHASE of T-PARC. The subject of the pending project is a study of diabatically-dominated winter storm dynamics and implications for atmospheric predictability.

Recent theoretical and observational research has identified a moist baroclinic growth mechanism that has no dry counterpart. A cyclonic disturbance can form and amplify via the near constant production of potential vorticity (PV) associated with cloud diabatic processes, even in the absence of significant upper-level forcing. This type of disturbance, where the PV tendency due to diabatic heating acts in a similar manner to that of the meridional advection of PV in a classical Rossby wave, has been termed a diabatic Rossby vortex [(DRV); Moore and Montgomery 2004, 2005].

The DRV growth mechanism has been shown to play a role in a number of rapidly deepening extratropical cyclones (Wernli et al. 2002; Moore et al. 2007). In addition, the low-level, dipole temperature advection pattern reminiscent of the DRV growth mechanism has been identified as an important part of the transformation stage of extratropical-transitioning tropical cyclones (Klein et al. 2000; Harr and Elsberry 2000). Both of these types of atmospheric phenomena can be associated with severe weather and have important downstream impacts to life, property and commerce.

During the first year of the pending project, a set of carefully designed idealized mesoscale model simulations will be conducted to further examine the fundamental dynamical processes at work in DRV formation and evolution in the middle latitude storm track. In the second year, these idealized mesoscale model simulations and model-based, case-study analyses will be combined to examine possible avenues via which the DRV growth mechanism can aid explosive cyclogenesis and extratropical transition. The impact of DRVs on atmospheric predictability will be carried out in years three and four through an analysis of TIGGE data.

Concurrent with the above work in year two, we plan to analyze the data collected during the winter phase of T-PARC to critically examine the results of the study. DRV dynamics involve processes spanning a significant range of temporal and spatial scales (from the convective to synoptic scale). At present, no observational dataset of sufficient resolution exists to properly evaluate the DRV dynamics that have been predicted in high-resolution mesoscale model simulations. The T-PARC dataset (specifically driftsonde data) will be invaluable in helping to evaluate the current state of knowledge regarding the DRV and its importance in the midlatitude moist atmosphere.

References


Statement of research interest in the THORPEX Pacific-Asian Research Campaign

Michael C. Morgan
Department of Atmospheric Sciences
University of Wisconsin – Madison
mcmorgan@wisc.edu

My research interests are very similar to science goals iii, iv, and v described in section 1 of the THORPEX Pacific-Asian Research Campaign (PARC) science overview document. My research group has been conducting research in the areas of predictability of large-scale cyclones (LSCs) over the North Pacific and relationship of these phenomena to downstream flow predictability over N. America, tropical cyclogenesis from pre-existing, lower tropospheric (potential) vorticity disturbances, tropical cyclone (TC) track and intensity change, and the problem of extra-tropical transition of TCs. Below, I describe relevant work currently being funded by and recently proposed to NSF that will benefit from the data and (re-)analyses made possible by PARC.

I have been recently awarded funding from NSF (though August 2008) to conduct research into the predictability of cyclone life-cycles using adjoint-derived forecast sensitivities as well as into the development of a climatology of forecast errors and the sensitivity of forecast errors over N. America to initial conditions for forecast periods from 24h to 72h. Results of the proposed research will be useful in better focusing the design of forecast impact studies wherein changes to the initial conditions of model forecasts are made to understand how changes to particular weather systems (e.g., upper troughs and jet streaks) will affect a particular forecasted phenomena. For a given forecast lead time, this study will also identify the relative importance of those antecedent features which control cyclone and frontal intensity. The proposed work will also allow for a better understanding of the flow-regime dependence of short-to-medium range predictability over N. America.

In a proposal submitted recently to NSF, an examination of the synoptic patterns and dynamical processes associated with the phenomenon of N. Pacific large-scale cyclogenesis which is characterized by a persistent (10 days or greater), enhanced jet stream flow pattern that develops over the N. Pacific, and which is related to hemispheric teleconnection patterns like the PNA. The overall impact the onset and subsequent persistence of this flow pattern has on numerical weather prediction over both the N. Pacific and N. America will be determined through an examination of the spatial patterns of errors in weather prediction models for periods before, during, and after occurrences of this enhanced jet flow pattern. A sufficient understanding of the nature and dynamical processes associated with this circulation event will facilitate describing overall uncertainties associated with weather system changes and improving medium and long-range prediction. The specific questions to be addressed (relevant to PARC) include:

1. What is the characteristic initial location and structure of dynamical precursors to LSC onset?

2. What is the predictability of both LSC onset and the subsequent downstream predictability over N. America following LSC onset?

For both the currently funded research and the proposed research, I expect the observations taken during PARC will be quite valuable. Specifically, additional driftsonde measurements may prove quite useful in better resolving the structure of short-range forecast errors in the western and central Pacific relevant to producing initial condition (or more specifically, background) errors in medium-range forecasts. These observations would also be helpful in assessing the relationship between these errors (and their subsequent evolution) with synoptic waves. Additionally, the increased temporal frequency and spatial coverage might help resolve whether LSCs and the PNA teleconnection pattern with which they are frequently associated, are the result of forcing from tropical convection or are primarily triggered by mid-latitude baroclinic waves. As these LSCs are observed to have a significant downstream impact on weather over the N. America into the Atlantic, the proposed research would complement the PARC science goals associated with ET in the western Pacific with regard to Rossby wave trains and
downstream propagation. The on-going work on cyclone life-cycles could be used to understand how sensitive ET cyclone structure is to the initial baroclinic wave and TC vortex. Finally, as both research projects described above will involve the interpretation, calculation, and use of adjoint-derived forecast sensitivities (and hope to make use of the adjoint of the NAVDAS to calculate sensitivities with respect to observations), this proposal will also complement the PARC goals of testing adaptive sampling strategies.

In short, I intend to make use the observations and resulting reanalyses afforded by PARC in my on-going and proposed research. Additionally, I believe that my research group’s work with adjoint sensitivities prior to PARC may be of use in the planning of field operations during the field campaign. I hope to contribute in this effort.
Proposed Use of NCAR’s Developing Regional Nested Climate Modeling Capabilities for the THORPEX Pacific Asian Regional Campaign (T-PARC)

David Parsons, Mitch Moncrieff, Joe Tribbia and Greg Holland
NCAR/ESSL

NCAR is developing the capability to undertake simulations with high resolution, non-hydrostatic grids within their global climate modeling system. This collaboration between the Mesoscale and Microscale Meteorology (MMM) and the Climate and Global Dynamics (CSG) Divisions brings together the modeling capabilities of the Weather Research and Forecasting (WRF) and the Community Climate Modeling system. The goal is to also have this nested modeling capability linked to the research data assimilation systems at NCAR. The research capabilities of this modeling system includes tropical channel modeling and high resolution regional grids for “downscaling” the effects of climate change and “upscaling” the effects of important physical and dynamic processes on the global earth system.

The upscaling capabilities are extremely well suited to the research goals of the THORPEX Pacific Asian Regional Campaign (T-PARC). The basic research goals of T-PARC include testing the hypothesis that the improved treatment of high impact weather over the western Pacific and eastern Asia will lead to increases in predictive skill over North America and other ‘downstream” locations. This hypothesis is based on the role of organized tropical convection and intense cyclogenesis in triggering and/or amplifying upper-tropospheric wave trains on the primary Asian and Pacific waveguides. For T-PARC, we propose to use the NCAR Nested Regional Climate Model (NRCM) with high-resolution grids over the East Asia and Western Pacific region. Improved prediction should come about from the improved representation of the intensity, location and evolution of these high impact events and their interaction with the Asian/Pacific wave-guides. The high-impact weather events include organized, persistent deep convection, tropical cyclones, the extratropical transition of these cyclones, and other intense middle latitude cyclogenesis events. We will test the hypotheses that improvements in medium range prediction at locations downstream will result from i) improved representation of physical or dynamic processes afforded by higher resolution modeling; 2) improved initial conditions (e.g., research assimilation techniques, assimilation of higher resolution research measurements, assimilation on higher resolution grids). Ideally these modeling simulations will be ensemble simulations conducted daily with the model initialized with operational and special T-PARC measurements. The simulations will allow provide insight into the general predictability of weather events by assessing whether a prediction of an observed event that is considered a forecast “failure” in a deterministic simulation is simply a prediction that lies within the uncertainty of the initial conditions and model physics. Such a global research modeling system would complement the operational THORPEX Interactive Grand Global Ensemble.
THORPEX AND IPY NEEDS IN ALASKA DURING THE PACIFIC ASIAN REGIONAL CAMPAIGN-NORTH AMERICAN PREDICTABILITY EXPERIMENT

James Partain
NOAA/NWS Alaska Region
Chief, Environmental and Scientific Services Division

BACKGROUND - THE IMPORTANCE OF UNDERSTANDING CLIMATE CHANGE IN ALASKA FOR NWS OPERATIONS

The pace of climate change in the arctic, including Alaska, has been well documented in the last several decades, as noted by surface temperature warming trends at locations across Alaska. The extent and thicknesses of multi-year sea ice has decreased, leading to more impacts from coastal storms in the spring and fall and numerous impacts to transportation, subsistence activities and hydrological issues. Fall freeze-up has been occurring later and Spring break-up has come earlier. Glaciers are retreating and permafrost is melting.

The impacts in Alaska to NWS service programs as a result of the climate changes are tremendous and varied. Aviation impacts include more frequent icing conditions, lower visibility, and altered flying “paradigms” for Alaskan pilots. The public has noted more frequent weather extremes. The marine environment has witnessed more frequent high-impact events, especially in areas of reduced sea ice. Coastal erosion and water quality impacts are the most notable concerns. Wildfires continue to have a very great impact in Alaska, as more variable moisture conditions have combined with the spruce-bark beetle infestation to contribute to record numbers of wildfires and acreage burned in each of the last several years. A greater variability in river volume has created increased flooding and erosion. Subsistence and cargo operations have been impacted by changing river flows, and ice-dammed glaciers have caused lake releases. Rising sea-levels may have eventual tsunami impacts, and resuspension of relic volcanic ash (ash deposited decades ago, now being exposed again due to glacier retreat) can cause many problems, especially for aviation and agriculture.

BACKGROUND - THE IMPORTANCE OF OBSERVATIONS AND NUMERICAL MODELS IN ALASKA FOR NWS OPERATIONS

Observations form the backbone of weather forecasts and warnings in that the vertical, spatial and temporal distributions of moisture, temperature, and kinetic energy essentially define “weather”. Observations also provide important ground-truth for forecasters, both in that it provides the sense of “now”, as well as helping them calibrate the numerical models for the upcoming forecast period.

In Alaska, guidance from numerical models is especially critical for forecasts & warnings beyond 6-hours. NWS atmospheric models generally do worst at the poles. Alaska in particular suffers with poor model quality due to its position within and downstream of one of the most data-sparse, yet dynamic weather regimes on the planet. Recent observing system tests have proven the value of targeted observations to improving our models. And improved models lead to improved and more confident services by forecasters and decision-makers who rely upon their products and services.

THORPEX, IPY, THE PACIFIC ASIAN REGIONAL CAMPAIGN-NORTH AMERICAN PREDICTABILITY EXPERIMENT

One of the major impacts of ex-tropical cyclones we face in Alaska is on coastal storms impacting western Alaska, usually in the late summer/early fall. These storms have an especially great impact now that the coastlines are more sensitive to wave action, due to permafrost melt and sea-ice retreat. These storms require more lead-time to allow local emergency managers to plan for and mitigate the anticipated impacts from the storms, and to allow time to evacuate threatened coastal communities. In the longer term, the new impacts of these storms on coastal erosion and inundation are requiring a tremendous
amount of planning (at great social and economic cost) to relocate communities that are under threat of literally being wiped off the map.

Many of the more significant such storms since 2000 have been former tropical cyclones recurving from the tropics and transitioning into strong extra-tropical storms. These storms are often quite difficult for numerical atmospheric models to properly diagnose and predict. In addition, poor data assimilation over the oceans often leads to run-to-run model inconsistency, which directly translates to lack of forecaster confidence, and therefore shorter lead-times for decision-makers.

Given the goal of the PARC-NAP to advance our understanding and the predictability of high-impact weather over North America, whose forecast errors and dynamical roots lie in process over Asia and the western Pacific, the NWS in Alaska is prepared to fully support and participate in the PARC-NAP activities during the IPY.
Preproposal: Use of NRL P-3 and ELDORA in TPARC

David J. Raymond and Carlos López
Department of Physics and Geophysical Research Center
New Mexico Tech
Socorro, NM 87801
raymond@kestrel.nmt.edu

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The predictability of the development of Rossby wave trains from the extra-tropical transition of tropical cyclones in the Western Pacific depends on both understanding the atmospheric processes involved and obtaining correct initial and boundary conditions. Only by incorporating both of these factors can we expect to improve numerical model predictions.

Atmospheric convection is likely to be a key process in the extra-tropical transition of tropical cyclones; convection transports heat, moisture, and momentum and alters the distribution of potential vorticity in the atmosphere. This gets to the essence of how convection associated with a tropical cyclone can initiate a Rossby wave train. Challenges to our understanding of convection in this environment are expected to be even more severe than in purely tropical situations, due to the frequently strong atmospheric shears and the importance of quasi-geostrophic processes.

By a combination of dropsondes and Doppler radar measurements, the NRL P-3 with ELDORA can be used to characterize many aspects of convection. In particular, convection’s effect on the potential vorticity field can be evaluated. Thus, the NRL P-3 is able to document what is arguably the single most important subgrid-scale process in extra-tropical transition. The P-3 data can also be used for testing numerical models of convection in a context in which such convection plays a crucial role in the global circulation.

A particular advantage of TPARC for this type of work is the plan for extensive dropsonde observations from driftsondes and from high-altitude aircraft belonging to Taiwan and Japan. These data will provide the all-important environmental context for the smaller-scale observations taken by the NRL P-3. In turn, the NRL P-3 data will document crucial processes in the regions found to be important to the development of Rossby wave trains.

We have considerable experience in the planning and execution of field programs and in the analysis of airborne Doppler radar and dropsonde data. We propose to help plan the missions of the NRL P-3 and ELDORA in TPARC in cooperation with the other investigators, to participate in the field phase of the program, and to analyze the data in a way that will be useful for making comparisons with cloud resolving models, including our own.
Targeted Observing: It is anticipated that NRL adjoint-based targeting products will be made available in real-time during PARC for different applications, including forecasts of tropical cyclones throughout their life-cycle. Observations collected during PARC will be used to examine and compare the utility of different targeted observing methods, including adjoint-based and ensemble-based methods. The utility of targeting products produced with and without moist process or estimates of analysis error variance will be examined by comparing, singular vector targets using moist physics and analysis error variance estimates. The benefits of data assimilation adjoint tools for quantifying observation impact will also be examined. Data denial experiments will be performed with Navy operational forecast systems to quantify the impact of observations in sensitive and non-sensitive regions and the impact of new in-situ and satellite observations.

Forecast Error: The ability to diagnose the sources of forecast error in the tropical and subtropical ocean regions is particularly difficult and complex because 1) in situ observations are sparse and 2) model error is significant. The PARC data set will result in analyses of significantly increased fidelity. Comparison of twin data assimilation cycle-forecast experiments, performed with and without the full PARC data set, will provide information on potential forecast gains from improved analyses (as well as information about the limitations on forecast skill resulting from model error). These improved analyses will also be used to examine the relationship between, for example, convection and wave dynamics within the MJO. Proper diagnosis and simulation of this relationship is deemed critical for skillful MJO forecasts.
Statement of research interest in the THORPEX Pacific-Asian Research Campaign

David Reynolds
Meteorologist-in-Charge of the NWS Weather Forecast Office (WFO) in Monterey, CA

My interest is in West Coast flooding and the impacts of intra-annual tropical convection on mid-latitude cyclones along the West Coast. This can include recurving tropical systems or the MJO. As you correctly point out we do know there are correlations to west coast flooding and these types of events. However many times these systems have no impact on the West Coast. This implies a lack of understanding in knowing what "other" factors need to be in place for the tropical convective activity to have an impact on California.

To have an effective watch warning program for major flooding, the NWS must be able, with confidence, alert the emergency management community some 5 to 7 days days ahead of such an event so preparations can be made. In fact a ten day to two week lead time would allow reservoir managers to begin evacuating reservoirs to hold the potential flood waters. This is where a robust ensemble approach providing calibrated probabilities of high impact events can be invaluable. The current very active MJO now progressing across the western Pacific is a classic case of needing to know what impacts this will have on California. We already have saturated basins and this could cause major problems. Current models are struggling with this pattern change and are not providing much guidance as to what will happen.

As we approach the event, the focus turns to the accuracy of the QPF, i.e., what is the volume and intensity of rainfall expected over the basin in the next 24 to 72 hrs and what will the magnitude of the inundation be from the flooding. This requires a much more focused approach, like the current Hydrometeorological testbed being run in the American River Basin and what was done in 2003 over the Russian River Basin. It will require moving from the current Sacramento Model to distributed models with more in-situ observations then are currently available from the opertional network.

Bottom line this needs to be a seamless approach from week two down to tomorrow if we want Emergency Managers to respond to our watches and warnings with sufficient time to save both property and lives.
Statement of Work

Istvan Szunyogh

Dr. Szunyogh is an expert on atmospheric predictability and has an extensive experience with evaluating the impact of observations collected in field programs. He is also one of the two co-chairs of the Predictability and Dynamical Processes Working Group of THORPEX. He hopes to contribute to the PARC program as one of the leaders of the international effort and also as the leader of a research group based at the University of Maryland.

As a co-chair of the PDP WG, he will be responsible for collecting input from the international community on predictability and dynamical processes related scientific issues. The PDP WG, which has recently established 10 Interest Groups on different aspects of atmospheric predictability, is in an excellent position to reach out to a wide range of scientists working in the area of atmospheric predictability. Dr. Szunyogh will be responsible to communicate the information collected through PDP WG to the THORPEX Executive Board, in order to help the planning of the international field activities. In particular, he will lead the efforts to design an observational component that will help further explore the role of the Asian wave-guides in extra-tropical cyclo-genesis over the North-Pacific.

As a leader of a research group at the University of Maryland (UMD), he will be responsible to design and supervise analysis/forecast and predictability experiments with the Local Ensemble Transform Kalman Filter data assimilation system developed at the University of Maryland. In its current form, the LETKF system is capable to assimilate all operationally assimilated observations, with the exception of satellite radiances, in a fully 4-dimensional setting, using flow dependent error covariance information. Currently, the LETKF is the computationally most efficient data assimilation system that has these advanced features. It is also one of the three ensemble-based data assimilation schemes considered for testing at the National Centers for Environmental Prediction. The LETK has also been successfully used for basic predictability research at UMD. We expect that by the end of 2006 the LETKF will also have the capability to assimilate satellite radiances. The UMD team will start its PARC related research in 2007. In the initial phase, the goal will be to carry out analysis/forecast experiments to aid the planning phase of the field program. During and after the field program the goal will be to evaluate the effects of the extra observation on predictability.
The Use of Multi-Scale Modeling System to Study Precipitation Processes

Wei-Kuo Tao
NASA/Goddard/Laboratory for Atmosphere

Deep convection in the western Pacific region is usually in the form of super cloud clusters (SCCs) with horizontal scales (in satellite imagery) of 2000-4000 km. Each SCC is composed of many individual westward-moving cloud clusters that have a typical lifetime of 2-3 days and a spatial extent of 500-1000 km. Each cloud cluster is composed of mesoscale convective systems (MCSs) with horizontal scales of 200-300 km and life spans of less than two days. The MCSs can be further decomposed into many individual cloud ensembles with scales less than 100 km. These large-scale convective systems are part of Madden-Julian Oscillation (MJO). Therefore, successful simulation of the MJO may ultimately depend on the successful simulation of the individual life cycles of cloud clusters embedded within the SCC. Therefore, a multi-scale modeling system that couples a cloud-resolving model (CRM), a land surface model and a global circulation model (GCM) is required to study the development and organization of tropical large-scale cloud systems. The use of the GCM allows global coverage and the use of the CRM allows for explicit simulation of cloud processes and their interactions with radiation and surface processes. The role of surface temperature distribution and variation on tropical and extratropical convective processes can be also studied by the multi-scale modeling system.

The following questions provide the scientific focus for the multi-scale modeling system for PARC:

(1) What are the characteristics of the diurnal cycle of precipitation (planetary boundary layer) and what are the major physical processes that determine these characteristics over tropical oceans and land? What are the relative contributions of the convective and stratiform precipitation regions (associated with mesoscale convective systems) to the amplitude and phase of the diurnal cycle?

(2) What is the sensitivity of the strength and evolution of simulated convective systems and tropical cyclones to vertical and horizontal grid resolution? What is the impact of vertical grid spacing on the structure of the melting layer, water vapor at high altitude and precipitation processes in the stratiform region?

(3) What are the physical processes that affect cloud formation, organization, and evolution [i.e., MCSs and SCCs] in the Tropics? What is the impact of precipitation and changes in the planetary boundary layer, including water vapor, stability, convective available potential energy (CAPE), and convective inhibition (CIN) on surface temperature variation as well as land-ocean distribution?

(4) What is role of precipitation processes, their interaction with the surface, their influence on regional and global hydrological cycles with regard to climate variations, and their contribution to the regional and global energy budget?

It is expected that observations from both PARC and satellite missions (i.e., the Tropical Rainfall Measuring Mission - TRMM, and the proposed Global Precipitation Measurement - GPM) can improve simulations and forecasts of severe weather events such as MCSs, fronts, monsoons, cyclones, and typhoons. In addition, observations from PARC can be used to provide initial conditions for multi-scale modeling systems and to validate their results.
The Thorpex PARC: A Look at the Assimilation of Satellite Observations in Global NWP in Event-Specific, High-Forecast Impact Cases such as the Extratropical Transition of Western North Pacific Tropical Cyclones

Christopher S. Velden
University of Wisconsin – CIMSS, Madison, WI

**Background:** While satellite observations and more sophisticated data assimilation systems have contributed to recent improvements in global model forecast skill, there remains elements of predictability uncertainty associated with anomalous atmospheric flow events. It has become evident that one such event is the extratropical transition (ET) of a tropical cyclone, which can have both local and downstream effects on the midlatitude circulation. Since these events are primarily marine in nature, they are often poorly observed from conventional data sources. Satellites can provide a wealth of time-continuous measurements in and around these rapidly-evolving systems, but it is unclear if contemporary data assimilation systems are making optimal use these data. Before adequate diagnostic and process studies can be performed on ET events using global analyses and forecast fields, it is imperative to investigate the integrity of these analyses along with the associated structure/dynamical/kinematic characteristics. Such an investigation should also yield clues on the degraded predictability of these events.

**Objectives:** It is hypothesized that operational objective analyses of ET events are not adequately capturing the highly-anomalous and fast-evolving structure and energy transformations, and this may be in part due to poor handling and assimilation of satellite observations. Primary objectives are to employ Thorpex PARC observations to: 1) document cases of poorly-forecast ET events by operational global models and examine the initial analyses for evidence of the above, 2) Validate satellite observations and signatures in a four-dimensional sense, 3) Identify where targeted satellite data could positively impact the initial analyses and 4) Perform data assimilation studies to test the above. It is believed this study will shed light on analysis deficiencies that can result in forecast degradation. It will also provide improved analyses for diagnostic and process studies, and the lessons learned can be applied to numerical weather prediction (including the H-WRF model system now under development). The accomplishment of several of these objectives will be coordinated via collaborations with other investigators at the Navy Research Laboratory, the Naval Postgraduate School, the Japan Meteorological Agency, and the NCEP Joint Center for Satellite Data Assimilation.

**Project Participation:** The investigator proposes to play an active role in the planning and execution of the North American component of Thorpex PARC, and to be the principle focal point for satellite data collection and analyses. Close collaboration will be established and maintained with international colleagues (and satellite data centers/sources) participating in PARC, such that the necessary observations are obtained to accomplish the proposed objectives.
The Pacific Asian Regional Campaign 2008 (PARC), a major international THORPEX field campaign, will take place between June and December of 2008 and will focus on advancing knowledge, improving prediction and society’s response to i) western Pacific and Asian typhoons from genesis to extratropical transition/decay, and ii) their effects on the downstream high-impact weather events over North America, the Arctic and other locations. PARC is unique and timely because its focused region has been less comprehensively studied in the past. In particular the life span of 7 months field campaign will allow collect various in-situ and remotely sensed data in the western North Pacific. These data can be further assimilated into high-resolution models to produce dynamically consistent reanalysis. Both the in-situ and the reanalyzed datasets will be used by research community to improve our understanding of many scientific issues with the ultimate goal to improve the predictability of high-impact weather events in East Asia and North America.

My primary interests with the PARC in-situ and reanalyzed datasets will be to study both physical and dynamical processes that lead to tropical cyclone genesis, structure and intensity changes, and the extratropical transition. I have a current support (October 2004-September 2007) from National Science Foundation (NSF) with the focus on the study of processes leading to tropical cyclone intensity change through cloud revolving model simulations and diagnostics. The natural extension for the next step is to examine those processes/mechanisms revealed from numerical simulations in real tropical cyclones. This will be my target for the renewal of the current NFS grant. I will propose to use the datasets from PARC campaign to verify my findings from numerical experiments. I will also expand my focus to include both the tropical cyclone genesis and extratropical transition over the western North Pacific.

Another area in which my colleagues and myself at the University of Hawaii are interested is the potential effect of upstream high-impact events over the western Pacific on Hawaiian weather in early winter from October to December. Evidences show the connection of torrential rainfall events in Hawaii with the strong perturbations (cyclones, typhoons, etc.) in the far Northwest Pacific. The PARC datasets may allow us to detail this connection and to investigate the involved physical processes/mechanisms.

In summary, my colleagues and myself at the University of Hawaii will use the PARC datasets intensively to conduct several studies both on tropical cyclones in the western Pacific and the high-impact weather in Hawaii. We believe that the research outcomes will benefit the society and will also promote science. We wish a great success of the PARC field campaign and also a subsequent follow-up program to support the data management and research and to make sure a sufficient use of the datasets.
Statements of research interests

Xiaolei Zou, Florida State University

We are extremely interested in using the field data from the Pacific Asian Regional Campaign 2008 (PARC), along with other satellite data (GPS radio occultation data from COSMIC and other satellite data such as radiance and TOMS ozone), to improve the prediction of western Pacific and Asian typhoons genesis and development, and to study the downstream impact of typhoons over east Asian and the western Pacific on the prediction of high-impact weather events over North America. Specifically, we are interested in an improved utilization of weather information, which include the following research areas:

1. The most effective use and an optimal mix of the field data from PARC and other available satellite data during the PARC field campaign through an integration of observational data with computational models to reduce false alarms and missed events of typhoon genesis. An increased understanding of which physical and dynamical processes control the genesis process and what data provide sufficient information for describing the key processes could be expected given the new PARC opportunities.

2. Improved visualization of typhoons by integrating advances in graphic technology into typhoon research to improve our ability to effectively display key elements of observed and predicted typhoons, to enable novel, profound insights of the physical, dynamical and numerical aspects of typhoon evolution, and to provide a new set of tools usable by the scientists, students, forecasters, as well as non-meteorologists.

3. Making the PARC for education and vice versa.

4. A two-way connection between developed and developing nations.

The high-resolution non-hydrostatic modeling will be conducted for improved short-range (<3 days) predictions of various aspects of the lifecycle of a tropical cyclone near the east Asian coast through an innovative typhoon initialization approach. Both the adjoint sensitivity study and direct forward forecast experiments at various resolutions will be used to study and quantify the desired improvement of the medium range (3-10 day) predictions of floods, wide-spread severe weather outbreaks and damaging extratropical cyclones over the downstream regions such as North America owning to an improved description of upstream weather conditions in the west Pacific and east Asian. Conducting basic research closely connected with the science goals of PARC mentioned above is extremely attractive due to our previous experiences with hurricane initialization, use of various satellite data (GPS radio occultation data, TOMS ozone data, QuikSCAT, cloud motion vectors, radiances), graduate education and collaborations with scientists in Asian.
Statement of the interest in the THORPEX Pacific Asian Research Campaign:

New Algorithm for Dynamic Covariance Localization in application to Ensemble Data Assimilation and Targeted Observations

PI: Milija Zupanski, CIRA/Colorado State University

SUMMARY

Background:

Realistic weather and climate systems deal with the dimension of the state vector and/or observation vector can be of the order of $O(10^8)$, while a feasible number of ensembles in ensemble data assimilation (EnsDA) is of the order of $O(10^1)$-$O(10^2)$. A common approach to address the shortage of global degrees of freedom is to introduce a spatial localization of error covariance. There are several issues that need to be addressed: 1) relation between the local and global solution, 2) limitations of the geometry of local domains, and 3) computational overhead due to localization. The first issue is a fundamental one. It is obvious that one could increase the degrees of freedom by defining smaller and smaller local domains, which would correspond to decreasing the band-width of the error correlation matrix, ultimately obtaining a diagonal matrix. The unwanted impact of this, however, is that narrow-banded correlation matrix will produce unrealistic global solution. In atmospheric applications the localization creates noise in the solution, typically seen as gravity waves in the ensuing model prediction. The second issue reflects a need for time-dependent, irregularly-shaped local domains, in response to the system’s dynamics. At present, the local sub-domains are of simple shape, such as a rectangle or a circle in 2-dimensional space. In reality dynamics creates significant correlations between sub-domains, resulting in irregularly-shaped local domains. Finally, the computational overhead due to localization has to be small since an EnsDA system is computationally challenging and expensive already. Operational practice in weather/climate centers and challenging cloud-resolving global model simulations will push for ever higher model resolution, ultimately creating a bottle-neck for EnsDA applications, unless there is a serious effort to create an improved, general methodology for localization.

Objectives:

The above mentioned issues related to error covariance localization have been inadvertently addressed in computer science, mostly through unsupervised learning algorithms for clustering and dimension reduction. In this research we propose to exploit machine learning algorithms in designing a dynamical localization technique feasible for high-dimensional weather and climate EnsDA applications. The following questions will be addressed: (1) which unsupervised learning algorithms for clustering and dimension reduction are best fitted for use in high-dimensional weather and climate ensemble data assimilation, (2) what, if any, are the required modifications of existing learning algorithms, and 3) what is the impact of improved localization on targeted observations techniques and ensemble data assimilation?

Most important implication of this research will be in demonstrating the value of the dynamic localization methodology in complex, high-dimensional weather and climate applications. The outcome of this research will be an advanced, user-friendly algorithm for error covariance localization, applicable to targeted observations and to EnsDA. The new algorithm will be available for use on a stand-alone basis, allowing an efficient implementation with any EnsDA or targeted observation algorithms.

- PI: 2 month/year
- Research Scientist/Associate: 1 month/year
- Post-doc: 12 month/year
Asian THORPEX Regional Campaign (Asian TReC) in 2008 consists of the following scientific objectives.
- To understand the mechanism of the recurvature of tropical cyclones over the western North Pacific
- To understand the interaction of tropical cyclone with mid-latitude front systems
- To understand the internal/external factors to determine the tropical cyclone intensity
- To understand the tropical cyclogenesis and its relation with MJO activities
- To understand the extratropical transition of tropical cyclones in mid-latitude

To accomplish the above science objectives, we will focus on the following research components among East Asian countries.

1) Global ensemble Forecast
All operational centers, CMA, JMA and KMA, have global ensemble forecast systems. The operational ensemble products will be available during the TReC period. In addition, We are also ask the THORPEX Interactive Grand Global Ensemble (TIGGE) to help the Asian TReC to provide the ensemble forecast information.

2) Sensitivity Analysis
One of the challenging research areas is "sensitivity analysis" to identify the targeting area, where the ensemble forecasts give us larger spread. There are several techniques for this, but at this moment we cannot get the unique area several techniques converge. Also we have to develop a moist assimilation technique for tropical cyclone and heavy rainfall events. The JMA is now developing the moist Singular Vector method for these heavy convective systems.

3) Targeting Observation
Based on the sensitivity analysis we now make a targeting observation, by deploying available platforms, such as dropsonde observation by jet aircraft like DOTSTAR. Japan will apply funding to the Ministry of Education, Culture, Sports, Science and Technology to perform dropsonde observation like DOTSTAR. There is a research program, which has already been approved and funded by KMA for tropical cyclones and heavy rainfall events, starting from 2006 as 5-year program.

4) Regional Ensemble Forecast
The data from the targeting observation will be assimilated into the forecast model to run the global ensemble forecast once again. Then we would like to run the regional ensemble forecast model using the initial conditions from some members in the global ensemble forecast run. The main objective in this component is to estimate short-term rainfall forecast in quantitative manner.

The observation period for Asian TReC in 2008 (Asian component of PARC) would be from mid-June to mid-September, covering both heavy rainfall period and typhoon season.

The participating organizations for Asian TReC are as follows.

(China)
Chinese Academy of Meteorological Sciences, Chinese Meteorological Administration plus members of the Academic Community in China
(Japan)
- Japan Meteorological Agency
- Japan Marine Science and Technology Center (JAMSTEC)
- Kyoto University
- Nagoya University
- Tohoku University
- Tsukuba University
- University of Tokyo

(Korea)
- Korean Meteorological Administration
- Cheju National University
- Ehwa Womans University
- Kongju National University
- Kyungpook National University
- Seoul National University
- Yonsei University
DOTSTAR  
(Dropsonde Observation for Typhoon Surveillance near the TAiwan Region)  
Chun-Chieh Wu  
Department of Atmospheric Sciences, National Taiwan University

In light of the heavy damage done by typhoons to Taiwan year by year, the National Science Council (NSC) of Taiwan places a great premium on typhoon research, and therefore funds US$ 1 million for the "National Priority Typhoon Research" project each of the recent three years (from August 1, 2002 to July 31, 2005), especially including the field experiment, "Dropsonde Observations for Typhoon Surveillance near the Taiwan Region (DOTSTAR)". The DOTSTAR is an international research program conducted by meteorologists in Taiwan [led by myself, along with Prof. Po-Hsiung Lin of NTU and Dr. Tien-Chiang Yeh of Central Weather Bureau (CWB) as CO-PI’s], partnered with scientists at the Hurricane Research Division (HRD) and the National Centers for Environmental Prediction (NCEP) of the National Oceanic and Atmospheric Administration (NOAA). This project marks the beginning of a new era for the aircraft surveillance of typhoons in the western North Pacific.

Built upon work pioneered at NOAA’s Hurricane Research Division (HRD), the key to the project is the use of airborne sensors -- dropwindsondes, which are released from jet aircraft flying above 42,000 feet in the environment of a tropical cyclone. These sensors gather temperature, humidity, pressure, and wind velocity information as they fall to the surface. Information from the surveillance flights is transmitted in near real-time to the CWB of Taiwan, as well as to the NCEP, FNMOC, and JMA. The data are immediately assimilated into the numerical models of CWB, NCEP (AVN/GFDL), FNMOC (NOGAPS/COAMPS/GFDN), UKMET, and JMA. The DOTSTAR are expected to provide valuable data which can help increase the accuracy of TC analysis and track forecasts, to assess the impact of the data on numerical models, to evaluate the strategies for adaptive/targeted observations, to validate/calibrate the remote-sensing data, and to improve our understanding on the TC dynamics, especially over the TC’s boundary layer (Wu et al. 2005, BAMS).

On September 1, 2003, the first DOTSTAR mission was successfully completed around Typhoon Dujuan. NOAA remarked upon the successful collaboration in a press release. On November 2, the second mission was launched while the aircraft flew over the center of Typhoon Melor. Ten more flights have been conducted for Typhoons Nida, Conson, Mindulle, Megi, Aere, Meari, Nock-Ten and Namadel in 2004, with 193 dropsondes released. An average 20% improvement for the 12-72h track forecasts over the NCEP-GFS, NOGAPS and GSM has been demonstrated. Seven flights have been conducted for Typhoons Haitang, Matsa, Sanvu, Khanun, and Longwang in 2005. In total, the DOTSTA have conducted 19 surveillance flight missions for 15 typhoons, with 99 flight hours and 313 dropsondes released.

Multiple techniques have been used to help design the flight path for the targeted observations in DOTSTAR: (1) the area with the largest forecast deep-layer-mean wind bred vectors from the NCEP Global Ensemble Forecasting System at the observation time, (2) the Ensemble Transform Kalman Filter, which predicts the reduction in forecast error variance for all feasible deployments of targeted observations, and (3) the NOGAPS singular vectors that identify sensitive regions. Recently we have proposed a new theory (Wu et al. 2005, to be submitted to JAS) to identify the sensitive area for the targeted observations of tropical cyclones based on the adjoint model. By appropriately defining the response functions to represent typhoon’s steering flow at the verifying time, a unique new parameter, the Adjoint-Derived Sensitivity Steering Vector (ADSSV) has been designed to clearly demonstrate the sensitivity locations at the observing time. The ADSSV are being implemented and examined in DOTSTAR, as well as the hurricane surveillance program of NOAA’s Hurricane Research Division in the Atlantic in 2005 (Etherton et al, 2006, 27th Conference on Hurricanes and Tropical Meteorology).

We are planning to undertake surveillance missions in 2005-2008, respectively, while taking part in the THORPEX Pacific Campaign (PARC) of 2008. As the DOTSTAR research team continues to harvest important data and gain valuable experience, we believe that future typhoon observations will reach full
maturity, enabling significant progress in both academic research and typhoon forecasting. It is hoped that DOTSTAR will shed light on typhoon dynamics, enhance typhoon track forecasting accuracy, place Taiwan at the forefront of international typhoon research, and make a significant contribution to the study of typhoons in the northwestern Pacific and East Asia region.

Some detailed information on DOTSTAR is available at http://typhoon.as.ntu.edu.tw/DOTSTAR/English/home2_english.htm.
THE CANADIAN PARTICIPATION TO THE  
2008 THORPEX PACIFIC REGIONAL CAMPAIGN (PacTReC 2008)  
by Pierre Gauthier  
co-chair of the North American THORPEX regional committee  
Meteorological Service of Canada  

Introduction  
THORPEX is about improving our capability to forecast high impact weather with a particular emphasis on better using observations. The Pacific campaign of 2008 is part of the THORPEX strategy to organize observation campaign by deploying adaptive observations based on recent advances in data assimilation methods. In 1997, the FASTEX campaign was the very first to use sensitivity tools based on adjoint modeling to target observations over those regions where initial conditions were deemed to be crucial to correctly forecast the development of weather systems in their early stages. This particular dataset has been studied extensively by many scientists and the results have shown that the impact of targeted observations depends critically on the assimilation methodology.  

Subsequent campaigns followed like for instance the North Pacific Experiment (Langland et al., 1999) which took place over the Pacific region and more recently the Atlantic THORPEX regional campaign (A-TReC 2003). In the US, the Ensemble Transform approach (Bishop et al., 2001; Majumdar et al., 2001) has been used for many years for the Winter Storm Reconnaissance Program, which deploys adaptive observations over the North Pacific during winter seasons.  

A Pacific THORPEX regional campaign (Pac-TReC) is currently planned for 2008 (some time in between August and December). The goal of the campaign is to study the medium range forecasts (0 to 14 days) initiated by the excitation of Rossby wavetrains by convection in the Tropics. Following the June workshop in Seattle, it was agreed that this effort has to be coordinated with an observation campaign in Asia to study typhoons. This is of particular interest to Canada since several high impact weather forecasts depend critically on systems that do come in from the Pacific. It is also well known that secondary instabilities permit the development of weather systems by amplifying small waves over the larger scale patterns of the Rossby wave trains. These systems have a significant impact over the West coast of Canada in particular. This campaign is a golden opportunity for Canada to benefit from the combined means that will be deployed on this occasion to better understand the development of those weather systems over the Pacific.  

There are two important elements on which Canada can contribute in a unique way: data assimilation and deployment of observations over the North West Pacific. In recent years, the Meteorological Service of Canada has developed a 4D variational data assimilation (4D-Var) to support the global and regional analysis/forecast system. The 4D-Var assimilation was implemented in March 2005 in the global suite of the Canadian Meteorological Centre (CMC) (Laroche et al., 2005; Gauthier et al., 2005). Moreover, an Ensemble Kalman filter has also been developed and implemented to support the Ensemble Prediction System of CMC (Houtekamer et al., 2005). Having these two approaches available puts MSC in a unique position to do intercomparison studies on the impact of different types of observations within an operational framework.  

In past years, observation campaigns have taken place over the Atlantic to study the extra-tropical transition of Tropical cyclones. As part of the PacTReC 2008, a similar campaign could be organized over the North Pacific to deploy dropsondes from aircraft or using other observation strategy (e.g., aerosondes). During this campaign, the effort in the US will be focused over the Tropics. Our aircrafts have a limited range but could nevertheless deploy observations in regions located near the West Coast of North America and identified as sensitive by the targeting information.
A number of activities are presented below that relate to the objectives of the PacTReC 2008. At the moment, they are only proposed activities.

**Extratropical Transition of Tropical Cyclones over the Pacific**

This section is only a placeholder for the moment except for sub-section 2.1 that was provided by John Gyakum

Some of the activities could be partly related to IPY-THORPEX (components 2 and 3). One aspect that we need to stress is that the collected data should be transmitted over the GTS in real time. This is now a solved problem but we need to be aware that this is necessary to get those observations used by us in Canada and also by other NWP centres.

*The impact of surface fluxes on extra-Tropical marine cyclogenesis forecasting (J. Gyakum)*

A proposal has recently been submitted to CFCAS by John Gyakum (McGill University).

Our objective is to help Canadian stakeholders by (a) improving our understanding of the occurrence and our predictions of extreme and hazardous marine weather, (b) improving models for marine weather, adapted to Atlantic Canada’s regional context, and (c) improving knowledge of ocean and atmosphere processes, particularly as they are related to air-sea interfacial fluxes, leading to better marine environmental prediction. Our specific concern is extra-tropical hurricanes and severe weather storms, taking into account the interactive atmosphere-ocean system in which changes in each component of the system can affect positive or negative feedbacks of other components. We propose to study the air-sea interfacial processes and their interplay with the dominant tropospheric processes that are important in determining extra-tropical midlatitude hurricane growth and development. This proposal represents a contribution to the Canadian component of the international interdisciplinary THORPEX (The Observing Research and Predictability EXperiment) research programme aimed at “(...) accelerating improvements in the accuracy of 1 to 14-day high-impact weather forecasts for the benefit of society and the economy (...)”. These storms tend to affect all economic and social aspects of coastal communities in the Atlantic Provinces, as well as even inland areas. Associated heavy rainfall, flooding potential, winds and storm tracks tend to be poorly forecast, and have impact on all societal activities, for example marine transportation, recreational activities and offshore resource development. To improve forecasts, it is important to understand how severe storms intensify and decay. Air-sea moisture and heat exchanges are important factors in the control of these severe storms, in terms of their ability to intensify, their development, and their interactions with the dominant internal tropospheric dynamics that defines the storm tracks. We propose to use diagnostic studies and sensitivity experiments, and to include analysis of field data and simulations of storm development.

*Deployment of adaptive observations (dropsondes and other measurements) (P.Gauthier, S. Laroche)*

Given the short flight time of our planes, these observations (dropsondes mainly) would be similar to what has been previously deployed during ET campaigns over the Atlantic. However, we would benefit from the targeting information produced in the US (NRL and NCEP). Given that these observations will be part of the larger data set generated from the participating countries, this would be a good argument to justify the cost of this component. However, it could also be possible to produce our own targeting information that could tailored to more specific objectives. Up to now this has not been exploited in previous ET campaign.
Assessing the impact of observations in assimilation/forecast systems

There was a lot of interest to use our 4D-Var (with meso-global) and the Ensemble Kalman filter to evaluate their dependence on the assimilation system of different observing system strategies. This would be done in preparation to the campaign with observations generated at NASA/NCEP from OSSEs (nature run and generation of the whole set of synthetic observations). Once the campaign is on we would do the same with the actual observations. Sub-elements to this are

- Sensitivities with respect to observations evaluated with tools developed here and compared to similar ones available at NRL and ECMWF
- Study the impact of observations on the ensemble forecasts to evaluate the gain in accuracy in the forecasts

Assessing the impact of observations in assimilation/forecast systems
(P. Houtekamer, S. Laroche and P. Gauthier)

In 2005, the CMC has implemented two conceptually different methods for 4D global data assimilation. A 4D-Var system is used to obtain a high-resolution analysis for a deterministic forecast. An ensemble Kalman filter (EnKF) is used to provide an ensemble of initial conditions at somewhat lower resolution for the medium-range ensemble prediction system of CMC. Given that both implementations originated and run at the same centre, it should be possible to run both algorithms in a configuration that permits a clean comparison. This involves in particular using exactly the same version of the nonlinear prediction model and using exactly the same nonlinear forward interpolation operators and observation error statistics. Both algorithms must be configured such that they can conveniently run on the supercomputer in a comparable amount of computer time.

The EnKF algorithm can be seen as an approximation to the Kalman filter equations while 4D-Var is issued from a more general Bayesian framework that extends it to include non-Gaussian probability distributions and nonlinear operators. However, both algorithms, need to include some approximations and simplifications. A careful comparison of the two algorithms will likely lead to a better understanding of the limitations of operational 4D assimilation methods. The improved understanding will almost certainly permit improvements to both operational methods. It is not a priori evident which algorithm is most suitable for global atmospheric data assimilation. The 4D-Var algorithm (Lorenc, 2003) may provide a better fit to detailed observations and provide more balanced initial conditions. It is not clear which algorithm will make better use of observations with corresponding nonlinear forward operators. The EnKF likely benefits from using the full nonlinear forecast model for the transport of error covariances and from transporting the error covariances to subsequent assimilation cycles. Both algorithms will suffer from biases in the model, the forward operators and the observations. One avenue that is also explored at MSC is to use the background-error covariances estimated from the EnKF in the background-term of 4D-Var.

The impact of different observation types can be evaluated with EnKF and 4D-Var based methods. In the context of the EnKF, one will perform two data-assimilation cycles, one with and one without the observations of interest. The use of the additional observations should lead to a reduction in the ensemble spread, in both the EnKF system and in the resulting medium-range ensemble forecasts. This reduction is a prediction for the amount of improvement in the ensemble mean forecast. This prediction can subsequently be verified using actual observations.

The design of the variational system is modular and is capable to solve the primal (3D-Var) and dual (PSAS) form of the variational problem (El Akkraoui, 2004). Following Baker and Daley (2000), this makes it possible to evaluate the sensitivity to changes in the observations of a given forecast as a function of the assimilation method. This would permit to study how the impact of observations vary with
respect to the assimilation method (3D or 4D-Var), background-error representation (flow-dependent or not), and characteristics of the tangent linear and adjoint model used (e.g., simplified physics).

The EnKF group is currently adding time interpolation of the ensemble of prior estimates in the assimilation window to the EnKF implementation. The use of a different set of analysis variables is also being investigated. The EnKF group expects that the resulting improved EnKF algorithm can be used for an interesting comparison with 4D-Var.

Following the implementation of 4D-Var at MSC on March 15, 2005, the next step will be to first upgrade the global model to new physical parameterizations, and increased horizontal and vertical resolution (from 100 km to 35 km). At the same time, the plan for 2005-2006 will be to add several new satellite observation types and prepare for upcoming new satellite instruments. A significant restructuring of the code is underway to gain computational efficiency and at the same time, to facilitate the development and technology transfer process. In this new framework, the observation operators (nonlinear, tangent linear and adjoint) will be shared by both the variational and EnKF assimilation systems. A number of diagnostic tools in observation space are also shared by the two systems.

The 4D-Var assimilation system of MSC includes several types of observations which is likely to increase significantly in the next year. The next section presents work that could serve the THORPEX scientific objectives. One important issue that needs to be looked at is to modify the assimilation framework to better handle the presence of biases in both the observation and model component. This is an important issue that needs to be looked at.

Testing observing strategies through OSSEs (PI to be determined)

In preparation for the 2008 Pac-TReC, a number of Observing System Simulation Experiments (or OSSEs), will be proposed to evaluate the impact of observation strategies for adaptive observations. Given the high dependence on the assimilation methodology, the simulated data could be assimilated with our own systems to compare with the impact obtained with the systems being used in the US (i.e., the Grid-point Statistical Interpolation system, or GSI). This work would have to be done in close collaboration with the group that will generate the synthetic observations.

Improved use of satellite observations

Severe weather cases are often initiated by small changes to the initial conditions that trigger baroclinic or convective instability. In recent years, it has been shown that using the adjoint of a NWP model to perform sensitivity studies can identify such changes. With the advent of variational assimilation methods and in particular of 4D variational methods, satellite data have been shown to have an impact that now compares to the more conventional radiosonde and surface observations. Many techniques have recently been proposed to measure the impact and all revolve around the estimation of the background and analysis error covariances, the ratio of which provides the actual information content extracted from observations. This of course depends on the level of uncertainty in the background state used by the assimilation and where the additional information can be the most useful. In a recent paper, Fourrié and Rabier (2004) have shown that taking into account the flow-dependent characteristics of the background-error covariances may lead to quite a different view of what are the most important channels to retain from a high-resolution spectrometer instrument such as AIRS (Advance Infra-Red Sounder). Estimation of the flow-dependent background-error covariances can be based on ensemble methods and/or singular vectors.

Even though the assimilation methodology has changed considerably over the last ten years, all methods rely on statistical estimation principles with varying degrees of complexities in the implementation method. Variational methods have the advantage that they provide a natural framework for the introduction of new types of observations. They are also more flexible for the introduction of new
covariance models to be used in the background term (Derber and Bouttier, 1999; Gauthier et al., 1998; Buehner, 2004). In recent Observing System Experiments (OSEs), Kelly and Bouttier (1999) and Zaitseva et al. (2003) have shown that it is now possible to more efficiently extract information from satellite data. The variational framework offers, extended to 4D-Var, then makes use of synoptic data as time series.

**Testing new data selection strategies. (P. Gauthier and L. Garand)**

It is possible to use the same information used to target observations but to better select the satellite data to be used in the assimilation. This has never been attempted yet. A Ph.D. project is funded by the Canadian Foundation for Climate and Atmospheric Sciences (CFCAS) to examine the channel selection algorithm of Fourrié and Rabier (2004) applied to the channel selection of infrared radiances from the AIRS and IASI instrument.

**Assimilation of precipitation in the context of THORPEX (G. Deblonde, J.F. Mahfouf and A. Zadra)**

Improvement of high impact weather forecasts over North America in the medium range could be achieved by sampling clouds and precipitating systems over the tropical Pacific Ocean (as shown in a case study by Mahfouf et al., 2005). Indeed it is known that the development of phenomena such as “the pineapple express”, where extra-tropical transitions interact with tropical cyclone development, can lead to severe storms over the Western coast of Canada. However, in the Canadian Meteorological Centre operational data assimilation system, satellite radiances are only assimilated in clear sky conditions. Special Sensor Microwave/Imager (SSM/I) brightness temperatures provide very useful information on cloud and rain over the oceans because the surface emissivity can be relatively well modeled. Recently a methodology, used at the European Centre for Medium Range Weather Forecasts (Marécal and Mahfouf, 2000, 2002, 2003, Moreau et al. 2004, Mahfouf et al. 2005), has been developed to assimilate SSM/I brightness temperatures (or other similar microwave instruments) in cloudy and rainy atmospheres. A one-dimensional variational (1D-Var) assimilation method allows to adjust model temperature and humidity profiles using either SSM/I brightness temperatures (Tb) or retrieved surface rain rates (derived from SSM/I Tb). Moist physical schemes are needed as part of the forward operator to map the model state into observation space. The 1D-Var column integrated water vapor analyses used as pseudo-observations are then assimilated in 4D-Var. A stand-alone prototype 1D-Var system (Deblonde et al., 2005) is currently being generalized to be incorporated in the 4D-Var assimilation system. The Pacific THORPEX regional campaign (Pac-TReC) will provide an excellent opportunity for validation and verification (through in-situ and remotely sensed observations) of the assimilation of data in cloudy systems in particular because it coincides with the tropical cyclone season. Adjoint sensitivity studies with respect to observations in precipitating systems will also be performed using the Global Environmental Multi-scale model with linearized moist physical processes (Zadra et al. 2004). Finally, this activity will lead to the improvement of the skill of the model forecast components that directly impact the global atmospheric water cycle and the high-impact weather over North America.

**Evaluation of the impact of changes to the synoptic scales on local forecasts**

This would use the global analyses/forecasts as initial conditions to the GEM-LAM over the Pacific region (PYR) and perform an assessment of the weather elements. This could (should) involve AIRG (Brian Mills) and PYR. This would also nicely fit with the preparation for the 2010 Olympics and relates to the socio-economic impact theme of THORPEX. It is very likely that there could be a second Pac-TReC during the Olympics if the results show that there is an improvement in the final weather products.
Testing two different approaches for mesoscale ensemble forecasting: The ensemble Kalman filter and the singular vector initialization (Martin Charron, Jean Côté, MSC)

A project is currently funded by CFCAS to study two different approaches for mesoscale ensemble forecasting: the ensemble Kalman filter and the singular vector initialization. This provides support for one post-doctoral fellowship at the Department of Atmospheric and Oceanic Sciences, McGill university.

The principal objective of this project is to develop a credible and informative probabilistic counterpart to the deterministic regional forecast model over North America that is operational at CMC. Two approaches (SV and the EnKF) will be developed and validated. Furthermore, since an EPS is likely to produce poor results when model errors are not taken into account in the system, some outstanding issues related to model deficiencies and how they can be integrated in a regional EPS will have to be addressed. The development of stochastic parameterizations of model errors will be an important part of this research project since a significant source of forecast errors is thought to come from model deficiencies. In particular at the mesoscale in summer, the parameterized convection is likely to be an important source of model error, and a way to stochastically perturb deep convection will be sought (see e.g. Lin and Neelin, 2003). Other parameterizations, such as condensation, orographic blocking, turbulent mixing, etc. might also be randomized. Empirical methods to simulate model errors will also be investigated.

A case of severe weather over the West coast (contribution from Chris Doyle)

(Note: Weather forecasters in British Columbia are well aware of the Tropical origin of some of the high impact weather that can hit the West coast. This is an account of a particular event based on an internal report from the Pacific-Yukon Regional weather office of MSC).

A tropical storm undergoing conversion to an extratropical system (and feeding considerable moisture into the rosby wave) contributed significantly to the intensity of a severe flooding rainfall event that occurred in BC in January 2005. In this case, nearly all of the South-coastal BC snowpack below 1800 m was fully ablated, and the restoration of a climatologically normal snowpack did not occur until mid-March. If this happens in January 2010, the Olympics will be in serious trouble - but less trouble if we can predict these events with a decent lead time.

Antecedent conditions have contributed to the seriousness of this event, both over coastal BC and throughout the southern Interior. Prior to the onset of heavy precipitation on Monday, all of British Columbia was under the influence of a prolonged arctic outbreak. Very deep trapped cold air was in place in every interior valley, most mainland inlets and in interior sections of Vancouver Island. In many cases, surfaces were deeply and solidly frozen.

The initial impulse to affect the south coast on Saturday, January 15th, brought frozen and freezing precipitation to south coastal BC and snow to the southern Interior that spread to the central interior early Sunday. Although coastal zone temperatures moderated to above zero by early Sunday, temperatures in mainland inlets and valley areas of Vancouver Island remained below zero, and the accumulation of either snow or freezing rain increased in these locations.
Erosion of the cold air, especially in valleys of the southern interior, Alberni Valley of Vancouver Island and the eastern Fraser Valley, continued in a very gradual fashion on Monday and Tuesday. Surface temperatures at Abbotsford, BC, did not rise above 0°C until 2:00 AM on Tuesday the 17th. Above zero conditions were not measured at Kelowna until noon on the 18th. Consequently, for much of coastal BC the heavier rains that began on Monday initially fell onto a frozen surface, in many cases covered by a layer of snow and freezing rain. Over the southern interior, snow changed to freezing rain over western section at many locations on Monday. Freezing precipitation spread into eastern valleys on Tuesday, with above zero temperatures finally reaching the valleys of the southeast late on Tuesday evening.

The combination of snow and/or frozen surfaces and heavy rain over the coastal zone and North Shore Mountains initially created serious run off problems including local flooding and ponding. Frozen soils can not absorb rainfall at a rate sufficient to prevent high run off. As the rains continued into Tuesday, and soil ice melted, hydrogeomorphological effects including slope slippage, bank failures and landslides began to occur, especially over the North Shore Mountains of the Fraser Valley and over interior valleys of Vancouver Island. Over the southern interior, prolonged freezing rain took its toll on tractability. Highways were closed in many locations due to accidents and, as the internal dynamics of the alpine snow pack began to change, avalanches began. As moisture spread further east, significant snowfalls began early Monday over the Columbia ranges and Southern Rockies and avalanches have been reported since then with increasing frequency.

The fully tropical characteristics of this event became evident on Wednesday the 18th (Fig.1). As the baroclinic band shifted slightly to the north, much of the southern Fraser valley came into the warm sector of the system with temperature reaching 18°C in a well mixed (breezy) atmosphere at Abbotsford, where winds were gusting to 57 km/h during the day. This is 13°C above normal. Victoria reached 16°C; a new record.

Rapid warming in the alpine above valleys of the southwestern interior has created significant run off. This has lead to sudden river ice jam conditions, as run off rapidly increases river levels. The sudden influx of water into the river bed lifts massive and thick ice sheets on previously solidly frozen rivers, causing fractures, buckling, and the creation of ice dams. Water levels quickly rise upstream of ice dams causing upstream flooding. Moving ice blocks in this kind of regime can cause significant damage to flow control structures and bridges.
Impact of high-resolution on Tropical convection and its relationship to the MJO

This project is about using the Canadian NWP model at very high resolution on the Earth simulator. Many of the observations to be collected will be to better understand convection and cloud properties in the Tropics. However, numerical models still have great difficulty at capturing the MJO and we need to first diagnose well the problem and examine how to improve the parameterizations of the global model. A better understanding of these issues can be gained from a high resolution integration.

Associated with the development of Rossby wave trains, there are local instabilities that can develop and it is also proposed to investigate the propagation of the sensitive regions with time by using singular vectors computed over the life time of the episode (Zadra et al., 2004).

**Numerical Modelling of the Madden-Julian Oscillation (MJO), Diagnostics and Northern Hemisphere Teleconnection** (Gilbert Brunet)

Collaborators: Bertrand Denis, Michel Desgagné, Wataru Ohfuchi¹, Mel Shapiro² and Claude Pelletier

Background and Rationale: Internationally, the increasing demand for weather and environmental prediction with increasing accuracy and with added economic value has led to significant attention being given to investments in Numerical Weather Prediction (NWP). The costs of high impact weather events on society are becoming increasingly high in terms of damage to infrastructure, injury, and loss of life. NWP research is hence focused on improving detection and more accurate and timely prediction of high impact weather. An important source of weather variability in the northern hemisphere is linked to teleconnections between the mid-latitude and tropical regions. Rossby wave trains are central to these teleconnections. Their tropical excitation can be explained by different trigger mechanisms where SST and deep convection play an important role; the propagation time of the signal between the two regions is the order of one to two weeks. The premise of this project is that better understanding of atmospheric and dynamical processes involved in the excitation and propagation of these teleconnections, along with advances in modelling, data assimilation, and observing systems, will result in more accurate forecasts and an improved estimate of their uncertainties. The ultimate goal of this work is to obtain a measurable reduction of their societal impacts. This project will put emphasis on the challenging phenomena of the excitation of Rossby wave trains by Madden Julian Oscillation (MJO) events (see Ferranti et al., 1990). The MJO is one of the most important modes of tropical low-frequency variability that is associated with a large-scale region of significant convection. It is known to be responsible for poleward radiation of Rossby wave trains affecting intra-seasonal variability.

Specific Objectives: There is a growing demand on NWP for improved forecasts of very small-scale convection phenomena that have large-scale impact through cascade effects, like in the MJO phenomena. R&D activities will probably require increased model resolution, better vertical extension, and micro-physics to improve forecasts of variability associated with the MJO. This is a multi-scale problem, which involves processes that occur at scales of kilometers to hundreds of kilometers, from storm-scale to regional-scale, and further down the cascade, and can affect remote regions with the poleward radiation of Rossby wave packets. The purpose of this study will be to assess the importance of these entirely different factors in properly simulating this cascade process, and hence help us to understand the uncertainties and challenges of accurately modeling the track and intensity of these MJO excited Rossby wave packets. This project will hopefully devise a future numerical forecasting strategy at MSC for these tropical-mid-latitude dependencies and their predictability. The proposed forecasting strategy could be an operational reality in the next decade.

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¹ Atmosphere and Ocean Simulation Research Group, Earth Simulator Center, Japan
² NCAR
Research Plan: The MSC NWP R&D strategy is based on the unified NWP model called GEM: One modeling component focuses on medium and long range weather prediction and involves global modeling with appropriate physics and variational data assimilation packages. A second component focuses on very fine space scale and short time nested or variable grid modeling at the regional/urban level. The MJO is actually not well simulated by NWP models, and won’t be for the foreseeable future. A longstanding NWP R&D strategy needs to be established to tackle this outstanding problem.

To address this problem, we propose to carry out simulations and sensitivity experiments using high-resolution numerical models, theoretical studies, and comparison of model results with observations or analyses. In particular, the GEM models will be used to simulate cases of MJO and radiation of Rossby wave packets. In view of these high-resolution simulation studies, we propose to do an unprecedented convective-scale to continental-scale simulation in collaboration with the Earth Simulator Center (ESC). This simulation and others with lower resolution will be used to comment on the expected implication for numerical weather forecasting of the MJO. More specifically, diagnostics studies (like in Charron and Brunet, 1999) and sensitivity experiments will be made to determine the important parameters that affect MJO and Rossby wave radiation that affect the North American and European regions.

Schedule and Milestones:

- Year 1: Developing the GEM model configuration strategy.
- Year 2: Developing and using the diagnostic tools on low dimension (low resolution or small domain) simulations. Production of a high resolution simulation on the ES on a large domain.
- Year 3: Completing the diagnostics and dissemination of the results.

References


Statement of Interest in THORPEX Pacific Asian Regional Campaign

Andreas Dörnbrack1, Sarah Jones2, Martin Weissmann1

1 Institut für Physik der Atmosphäre, DLR, Germany
2 Institute für Meteorologie und Klimaforschung, Universität Karlsruhe / Forschungszentrum Karlsruhe, Germany

It is common wisdom in European weather services that the downstream impact of tropical cyclones leads to markedly reduced predictability for western and central Europe. Following extratropical transition (ET) in the Atlantic a transformed tropical cyclone can cause a significant direct impact, but the number of systems that actually reach Western Europe is limited. Far more important is the indirect impact through the excitation / modification of Rossby wave packets on the midlatitude tropopause during ET that can create the conditions necessary for explosive extratropical cyclogenesis. Operational numerical weather prediction models do not currently capture this process, resulting often in poor consistency between forecasts initialized at different times or using different models.

As described in the proposal for a Pacific campaign, the mechanisms by which an ET event can excite or modify Rossby waves on the tropopause are not yet well understood. During the THORPEX North Atlantic Regional Campaign (NA-TReC) in 2003 plans were in place to make essential observations to improve our knowledge of these mechanisms. Unfortunately no suitable events occurred during the timeframe of the NA-TReC. Since there are on average significantly more ET events in the western North Pacific, an observational programme there would be much more likely to provide the necessary observations. The basic mechanisms related to the excitation and propagation of Rossby waves on the tropopause are the same in the western North Pacific and North Atlantic. Thus, the gain in knowledge from the proposed Pacific campaign can be applied to improve weather forecasts for Europe.

Our specific interests are in investigating the impact of systematic targeted observations on the predictability downstream of a tropical cyclone undergoing ET. The proposed contribution would have an observational and modelling component. The observational contribution would consist of the DLR Falcon with the Doppler wind lidar (Weissmann et al., 2005), the water vapour differential absorption lidar (DIAL, Poberaj et al. 2002), and, possibly, dropsondes. The modelling contribution would consist of idealized and case study modelling to support the experimental planning and data impact studies following the experiment using data both from the Falcon and from other observational platforms. In the context of THORPEX we aim to collaborate with European operational centres for this work, in particular with ECMWF/UKMO/DWD.

The wind lidar measurements from NA-TReC showed that wind lidar observations have a higher impact on analysis and forecast than other instruments due to low instrumental and representativeness errors (Weissmann and Cardinali, 2006). Preliminary results using lidar water vapour observations indicated similar results. The measurements during PARC will provide a data set to quantify the impact of lidar observations on the forecast skill of NWP models more representatively, and determine the role of airborne and satellite-based lidars in the future routine observing system and research campaigns.