The status and evolution of the Global Observing System (GOS) of WMO

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The status and evolution of the GOS of WMO

• The GOS
• Planning its evolution – WMO/CBS activities
  • the GOS and NWP
• The future GOS
• What can the GOS do for THORPEX?
• What can THORPEX do for the GOS?

• Acknowledgements:
  • WMO/CBS Expert Team on “Observational Data Requirements and the Redesign of the GOS”
  • Paul Menzel
  • Jim Purdom
The Global Observing System (GOS)

- The World Weather Watch (WWW) of WMO
  - Global Observing System
  - Global Telecommunications System
  - Global Data Processing System

- Global Observing System
  - surface-based component
  - space-based component
The Global Observing System (GOS)

• ... provides surface- and space-based observations of the state of the atmosphere and the Earth’s surface
• for:
  • weather analyses, forecasts, advisories and warnings,
  • climate monitoring and environmental activities,
  • carried out under programmes of WMO and of other relevant international organizations.

• The GOS is operated by National Meteorological Services, and national or international satellite agencies,
• and involves several consortia dealing with specific observing systems or specific geographic regions.
The Global Observing System (GOS)
The surface-based sub-system of the GOS

- Observing stations on land
  - ~10000 stations; observing at least 3-hourly; p, w, T, hum

- Observing stations at sea - ships and buoys
  - ~6000 ships, 700 buoys; observing as land stations, + SST and waves

- Upper-air observing stations
  - ~900 radiosondes and pilots; 12-hourly; p, w, T, hum profiles

- Observations from aircraft
  - ~3000; p, w, T; mainly flight level, some ascent/descent profiles

- Other platforms
  - solar radiation, lightning, tide-gauge, ...
  - wind-profilers, Doppler radars, ...
GOS component: surface observations

Data Coverage: Surface (10/11/2004, 6 UTC, qu06)
Total number of observations assimilated: 10128

LNDSYN (5840)  SHPSYN (1663)  BUOY (2625)
GOS component: upper-air profiles

Data Coverage: Sonde (9/11/2004, 0 UTC, qg00)
Total number of observations assimilated: 1201
Data Coverage: Aircraft (10/11/2004, 6 UTC, qu06)
Total number of observations assimilated: 9769

AMDARS (8847)  AIREPS (812)  TCBOGUS (96)  BOGUS (14)
The space-based sub-system of the GOS

Three “constellations”:

• operational meteorological polar-orbiting satellites
• operational meteorological geostationary satellites
• environmental research and development satellites
The space-based GOS

[Diagram showing various satellites and orbital paths, including:
- Meteo R 3M (Russian Federation)
- GOES-E (USA) 75W
- Meteosat (EUMETSAT) 0 Longitude
- MSG (EUMETSAT) 63E
- NPOESS (USA)
- Metop (EUMETSAT) 76E
- FY-1 (China)
- FY-2 (China)
- GOMS (Russian Federation) 76E
- GOMS (Japan) 140E
- MTSAT (Japan)
- GOES-W (USA) 135W
- GOES-E (USA) 135W
- Geostationary Orbit
- Subsatellite Point
- Atmospheric Chemistry Missions
- Oceanographic Missions
- High resolution Land use Missions
- Atmospheric Chemistry Missions
- High resolution Land use Missions]
The spaced-based sub-system of the GOS

operational satellites
GOS component: ATOVS

temperature and humidity

Data Coverage: ATOVS (10/11/2004, 6 UTC, qu06)
Total number of observations assimilated: 16224

6689 NOAA-15 ATOVS, Min: 206, Max: 206, Mean: 206
9535 NOAA-15 ATOVS, Min: 207, Max: 207, Mean: 207
GOS component: satellite winds

Data Coverage: Satwind (10/11/2004, 6 UTC, qu06)
Total number of observations assimilated: 5971

SATOB (765)  GOESAMW (2441)  ESAHRVW (751)  ESACMW (786)
ESAHRW/VW (1228)
GOS component: SSM/I
ocean surface wind speed, ...

Data Coverage: SSM/I (10/11/2004, 6 UTC, qu06)
Total number of observations assimilated: 7707
The spaced-based sub-system of the GOS

research and development satellites
ECMWF Data Coverage (All obs) - ATOVS
10/NOV/2004; 00 UTC
Total number of obs = 239468
ECMWF Data Coverage (All obs) - AIRS
10/NOV/2004; 00 UTC
Total number of obs = 62816
Data Coverage: Scatwind (10/11/2004, 6 UTC, qu06)
Total number of observations assimilated: 8768

Seawinds Scat (8768)
Aqua and Terra / MODIS - 1 km WV images
GOS component – MODIS polar winds
GOS component - radio occultation data

- Referencing GPS
- Occulting GPS
- Fiducial Network (JPL/GFZ)

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The future GOS

Planning the evolution of the GOS
– WMO/CBS activities
• RRR addresses the question:
  • how well do present/planned/proposed observing systems meet user requirements (URs) for each “application area” within WMO programmes?

• Aims of RRR
  • to inform WMO members how well their requirements for observations are or will be met
  • to provide material to aid dialogue of WMO and its members with “observing system providers” (member states and space agencies)

RRR is intended to provide general guidance - it does not remove the need more detailed studies in connection with the design of specific systems
The RRR process

CREATE AND UPDATE

User requirements database

CRITICAL REVIEW

CR output

GENERATE STATEMENT OF GUIDANCE

CREATE AND UPDATE

Observing system capabilities database

Statement of Guidance
Use of RRR – application areas

• To assess requirements for observations for “application areas” within WMO programmes:
  • synoptic meteorology
  • global NWP
  • regional NWP
  • nowcasting
  • seasonal and inter-annual forecasting
  • aeronautical meteorology
  • atmospheric chemistry
  • JCOMM ocean applications
  • agrometeorology
  • hydrology
  • climate monitoring
  • climate research
  • ...

RRR applied to global NWP
Observation requirements for global NWP

- 3D wind
- 3D temperature
- 3D humidity
- surface pressure

- surface variables:
  - sea surface temperature
  - ice/snow cover, snow depth (water equivalent)
  - vegetation, soil moisture

- cloud and precipitation

- other variables that modify radiation or act as tracers:
  - ozone, aerosols
... the critical atmospheric variables not adequately measured by current or planned systems are:

- wind profiles at all levels
- temperature profiles of adequate vertical resolution in cloudy areas
- precipitation
- soil moisture
- surface pressure
- snow equivalent water content

[See WMO web site for more details]
STATUS

WMO Members have tasked CBS to
• study the redesign of the GOS
• develop an Implementation Plan

Implementation Plan
• drafted by CBS Expert Team on “Observational Data Requirements and Redesign of the GOS”
• considered by the Implementation Coordination Team for the Integrated Observing System in Sept 2004
• to be presented to CBS for ratification in Feb 2005
The impact of the changes to the GOS in the next decades will be so massive that new revolutionary approaches for science, data handling, product development, training and utilization will be required …

There is an urgent need to study comprehensive strategies for anticipating and evaluating changes to the GOS.”

Evolution or revolution?
Candidate Observing Systems

- The future GOS should build upon existing components, both surface- and space-based, and capitalize on existing and new observing technologies not presently incorporated or fully exploited.

- Each incremental addition to the GOS should be reflected in better data, products and services from the NMHSs.
The future GOS – vision for 2015

for the space-based component

• 6 operational GEOs, all with multi-spectral imager (IR/VIS); some with hyper-spectral sounder (IR)

• 4 operational LEOs optimally spaced in time, all with multi-spectral imager (MW/IR/VIS/UV), all with sounder (MW), 3 with hyper-spectral sounder (IR), 2 with altimeter, 3 with conical-scan MW or scatterometer

• Several R&D satellites: constellation of small satellites for radio occultation (RO), LEO with wind lidar, LEO with active and passive microwave precipitation instruments, LEO and GEO with advanced hyper-spectral capabilities, GEO lightning

• Improved inter-calibration and operational continuity
The future spaced-based GOS - vision for 2015
for the surface-based component

Radiosondes
   • stable GUAN
   • some automatically launched
   • data distributed at high vertical resolution

Commercial aircraft observations
   • in-flight and ascent/descent data
   • high temporal resolution
   • available from most airports
     • including currently data void airports in Asia, Africa and S.America
   • observations of temperature & wind, plus humidity on some aircraft
   • possibly supplemented with UAVs
for the surface-based component

Surface observations

- automated systems
- land sensors at high spatial resolution, supporting local applications such as road weather
- ocean platforms (ship, buoys, profiling floats, moorings) in adequate number to complement satellite data

Radar observing systems measuring

- radial winds
- hydrometeor distribution and size
- precipitation phase, rate and accumulation
- multiple cloud layers, including base and top height
The future GOS – vision for 2015

for the surface-based component

Also
• ground-based GPS water vapour
• wind profilers
• …

Data collection and transmission
• digital in a highly compressed form
• computerized data processing
• role of humans in observing chain reduced to minimum

Automation to enable
• targeting of observation in data sensitive areas
• optimal operation of sondes, ASAP systems, aircraft in flight
What can the GOS do for THORPEX?

• The GOS is the observational backbone of most THORPEX activities

• THORPEX is not entering into “redesign” or “optimization” of the GOS in a vacuum – the GOS is complex and requires high-level international cooperation

  • For the timeframe of THORPEX, the space-based component of the GOS has a well-defined, stable operational arm with a dynamic research component – stable but not stagnant

  • Surface-based component more amenable to change on shorter timescales – how to optimize it to complement the space-based component?

• Based on WMO/CBS work, some questions for THORPEX have already been posed …
What can THORPEX do for the GOS?

- Help to ensure a stable baseline GOS against which the improvements envisaged by THORPEX can be measured

- Provide important contributions to GOS re-design, through:
  - sensor development
  - field campaigns
  - observing system design studies

- Answer specific re-design questions, addressing more sophisticated issues than covered by the RRR process …
What can THORPEX do for the GOS?

Some (initial) questions:

• What are the specific observing requirements for high-impact weather?

• What are the key observation system configurations that would help to identify the sources of cyclogenesis in tropics?

• What are the geographic areas where AMDAR has most input/value?

• What is the optimal vertical resolution of AMDAR profiles?

• What is the contribution of the Siberian radiosonde network to NWP and what alternative network configurations should be considered?

• What is the contribution of surface soil moisture data to tropospheric forecasting skill?
What can THORPEX do for the GOS?

… some (initial) questions:

- What is the contribution of stratospheric observations to tropospheric forecasting skill?
- What is the contribution of stratospheric in situ observation systems?
- How should we specify the adaptive component of the GOS?
- What are the global downstream effects of observation targeting?
- What strategies can be learned from THORPEX on how to introduce observation targeting into operations, in particular if more than one WMO member is to be involved?
Concluding remarks

• The GOS is an evolving complex of observing system components

• The present GOS has many gaps; all applications could be improved by additional and/or re-designed systems

• Activities within WMO/CBS will give guidance to “observing system providers” → increased benefits from future investments in observations

• THORPEX results will help us answer key questions affecting GOS evolution
End
Observations used in NWP

ERS-2 382,299
Geo-stationary satellites
Cloud motion vector SATOB 26,674
Polar-orbiting satellites
SATEM 94,985
TOVS
AIREP AMDAR ACAR 55,921
Buoys - drifting moored 6,106 469
SHIP 4,706
SYNOP 44,616
Profilers 555
TEMP 1,234 Pilot 737
Impact of Evolution

- The impact of the changes to the GOS in the next decades will be so massive that new revolutionary approaches for science, data handling, product development, training, and utilization would be required.

- There is an urgent need to study comprehensive strategies for anticipating and evaluating changes to the GOS.
Observational Data Requirements and Redesign of the Global Observing System

- Evolution of the GOS
  - 42 recommendations
    - final report of CBS/IOS/ICT-2
      (14-18 October 2002).

- Recommendations reflected:
  - Statements of guidance in 11 application areas
    NWP, synoptic met,
    nowcasting, SIA fcst,
    marine wx fcst, atm
    chem,
    aero met, agro met,
    hydrology, ...
  - Results from regional programmes such as COSNA, EUCOS and NAOS
  - Conclusions from the March, 2000, Toulouse Workshop on Impact of Various Observing Systems on NWP
  - Numerous OSEs
### Current Era
- POES
- GOES
- TRMM
- TOPEX
- EOS
- QUIKSCAT

### Near Focus
- NPP
- EO
- NPOESS
- ABI/HES

### Advanced Concepts
- Hyperspectral
- Imaging Lidars
- Geo Soil Moist Sensors
- CO₂ Lidar
- Ocean Mixed Layer Lidar
- Synthetic Aperture Radiometry
- New Initiatives

#### NOAA lead Missions

#### NASA leveraged Missions
European Missions to future GOS

**Current Era**
- **MSG**
- **ERS**
- **ENVISAT**

**Near Focus**
- **Earth Watch & Explorer**
- **METOP**
- **MTG**

**Advanced Concepts**
- Hyperspectral
- Wind Lidars
- Geo Soil Moist Sensors
- Cloud Lidar
- Broadband Radiation Imager
- New Initiatives

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**EUMETSAT lead Missions**
**ESA leveraged Missions**
**Japanese Missions to future GOS**

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<th>Near Focus</th>
<th>Advanced Concepts</th>
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<td>• GMS</td>
<td>• GCOM</td>
<td>• Hyperspectral IR</td>
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<td>• ADEOS (GLI)</td>
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**JMA lead Missions**

**NASDA leveraged Missions**
## Chinese Missions to future GOS

### Current Era
- FY1 (leo)
- FY2 (geo)

### Near Focus
- FY3 (leo)
  - VIRR
  - MODI
  - IRAS
  - MWAS
  - MWRI
  - TOM/OP
- FY4 (geo)
  - Imager
  - Sounder

### Advanced Concepts
- Hyperspectral
- Conical MW
- New Initiatives

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<th>Operational Missions</th>
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• Two 128x 128 Infrared focal plane detector arrays with 4 km footprint size
• One 512 x 512 Visible focal plane detector array with 1 km footprint size
• Field of Regard 512 km x 512 km at satellite sub-point
• Ten second full spectral resolution integration time per Field of Regard
Lidar Wind Measurements:
The Atmospheric Dynamics Mission (ADM-Aeolus)
2015 Vision for GOS

For the Space based component, there will be

6 operational GEOs
- all with multispectral imager (IR/VIS)
- some with hyperspectral sounder (IR)

4 operational LEOs
- optimally spaced in time
- all with multispectral imager (MW/IR/VIS/UV)
- all with sounder (MW)
- three with hyperspectral sounder (IR)
- all with radio occultation (RO)
- two with altimeter
- three with conical scan MW or scatterometer

Several R&D satellites serving WMO members
- Constellation small satellites for radio occultation (RO)
- LEO with wind lidar
- LEO with active and passive microwave precipitation instruments
- LEO and GEO with advanced hyperspectral capabilities
- GEO lightning
- Possibly GEO microwave

All with improved intercalibration and operational continuity.
For the Ground based component, there will be

Automation to enable
- targeting of observations in data sensitive areas
- optimal operation of
  - radiosondes
  - ASAP systems
  - aircraft in flight

Rawin sondes
- optimized utilization
- stable GUAN
- supplemented by
  - AMDAR ascent/descent
  - ground based GPS water vapor information
  - wind profilers
  - satellite soundings

- rawin sondes automatically launched
- computerized data processing
- real-time data transmission
- high vertical resolution

Commercial aircraft observations
- of temperature & wind plus humidity on some aircraft
- in-flight and ascent/descent data
- high temporal resolution
- available from most airports including currently data void airports in Asia, Africa and South America.
- possibly supplemented with UAVs

Surface observations
- automated systems
- land sensors at high spatial resolution, supporting local applications such as road weather
- ocean platforms (ship, buoys, profiling floats, moorings) in adequate number to complement satellite measurements

Radar observing systems measuring
- radial winds
- hydrometeor distribution and size
- precipitation phase, rate, and accumulation
- multiple cloud layers, including base and top height.

Data collection and transmission
- digital in a highly compressed form
- entirely computerized data processing
- role of humans in observing chain reduced to minimum
- information technology in all areas of life will provide new opportunities for obtaining and communicating observations
- for satellite data in particular
- use of ADM including regional/special DCPC in the context of FWIS
- DB for special local applications in need on minimal time delay and as backup
Cost-benefit considerations

What is the relationship between
- user requirements,
- observing system capabilities, and
- cost-effective systems?

Some definitions:
- the “maximum requirement” is the level beyond which additional observing system performance would not add significantly more value (for the application)
- the “minimum requirement” is the level below which the observing system would provide no significant value
Cost-benefit curve for an observing system
Main messages:

- the “optimal”, most cost-effective system does NOT in general meet the maximum user requirement (as defined in the RRR process)

- near the maximum user requirement, large increases in cost result in only small increases in benefit (“diminishing returns”)

Features of RRR

- Generate and maintain databases of **user requirements** (URs) and **observing system capabilities** (OSCs)

- URs should be:
  - "technology-free" - should not pre-judge the technology to meet them
  - specified separately for each "application area", e.g. global NWP, regional NWP, nowcasting, seasonal/inter-annual forecasting, …
  - specified in terms of a "range" - maximum and minimum

- **Critical Review** (CR) - objective comparison of URs and OSCs

- **Statement of Guidance** - interprets output of CR - highlights key points and priorities - requires judgement