Wind Measurements in the WMO Global Observing System

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Overview

1. The WMO Global Observing System (GOS) and the Rolling Review of Requirements
2. NWP-based Data Impact Studies and Diagnostics
   • OSEs
   • FSO
   • OSSEs
3. Role of the WMO Impact Workshops
4. Sample results from Fifth WMO Impact Workshop
5. Sample OSSE Results
6. Key guidance regarding wind observations
7. Final remarks
1. Rolling Review of Requirements

- WMO Congress: *All components of (WI)GOS shall use the RRR to design networks, plan evolution and assess performance (WIGOS is the WMO Integrated Global Observing System, of which the GOS is one element)*

- The RRR is the process used by WMO to collect, vet and record user requirements for all WMO application areas and match them against observational capabilities

- Gap analysis results in *Statement of Guidance*, one per application area, that provides a narrative of how well a given application area is supported by WIGOS; to be supported by a quantitative gap analysis module (in development)
WMO Application Areas Supported by the RRR

1. Global numerical weather prediction (NWP)
2. High-resolution numerical weather prediction
3. Nowcasting and very short range forecasting
4. Seasonal and inter-annual forecasting
5. Aeronautical meteorology
6. Atmospheric chemistry*
7. Ocean applications
8. Agricultural meteorology
9. Hydrology
10. Climate monitoring
11. Climate applications
12. Space weather
Requirements in the RRR

• Requirements are “technology free”, specified in terms of geophysical variables rather than measurands (e.g. temperature rather than radiances)

• **For** each variable and each application areas, requirements on:
  • Spatial (horizontal and vertical) and temporal resolution, uncertainty, data latency, required coverage area, source, and level of confidence

• Each requirement is expressed in terms of three separate values:
  • Threshold (observations not useful unless this is met)
  • Break-through (optimum cost-benefit ratio)
  • Goal (exceeding this provides no additional benefit)

• Requirement values are collected by Expert Teams operating under the Commission for Basic Systems and other WMO Technical Commission, and the process is informed by the wider community e.g. though the WMO Impact Workshops engaging the NWP and data assimilation community
<table>
<thead>
<tr>
<th>Area</th>
<th>Climate</th>
<th>Wind (horizontal)</th>
<th>Depth/decade</th>
<th>Res</th>
<th>Res</th>
<th>Cyc</th>
<th>Level</th>
<th>Date</th>
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<td>Climate AOPC</td>
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<td>3 m.s⁻¹</td>
<td>7 m.s⁻¹</td>
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<td>100 km</td>
<td>200 km</td>
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<td>HT</td>
<td>Climate Modelling Research</td>
<td>3 m.s⁻¹</td>
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http://www.wmo-sat.info/oscar/variables/view179
2. NWP-based Impact Assessment Methodologies

• Why use NWP-based assessment methods?
  • Objective, quantitative metrics:
  • NWP poses a well-defined prediction problem with a “right” answer
    • (and an infinity of wrong ones)
  • Well-defined measures for quality of output
  • Well-established methodologies for assigning merit (or blame) to individual observing systems
NWP-based Impact (I)
OSE (or data denial)

- OSEs (Observing System Experiments) are based on data denial (or addition):
  1. Run a control with operational data
  2. Add (or subtract) data to be tested
  3. Compare
- Impact focuses on the medium to long range
- Results show the impact of withdrawing (or adding) certain data

Jung et al., WMO Impact Workshop in Sedona, May 2012
FSO (Forecast Sensitivity to Observations) are based on the adjoint of the model/analysis system or an ensemble approach.

- Measure of the contribution to the reduction of 24 h forecast error.
- Approach focuses exclusively on the short (quasi-linear) range.
- Results show the impact of observations in the presence of all other observations.
- Relative rather than absolute measure of impact.

Gelaro et al, Fifth WMO Impact Workshop, Sedona 2012
NWP-based Impact (III)  
OSSE

• Observing System Simulation Experiments  
  • Assessment of new (simulated) observing systems

• Advantages
  • Only “truly objective” way of assessing the potential impact of new (potential) observing system
  • Assessment done with actual operational data assimilation/NWP systems

• Disadvantages
  • Costly to set up; EVERYTHING (including the atmospheric state and all other observations) must be simulated
    • Important to avoid conflict of interest
    • Somewhat tuneable
  • Difficult to project the state of the art of NWP and data assimilation - and the rest of the Global Observing System - several years ahead
3. WMO Impact Workshops

Five Workshops held so far:

- 1\textsuperscript{st} - Geneva, 1997
- 2\textsuperscript{nd} – Toulouse, 2000
- 3\textsuperscript{rd} – Alpbach, 2004
- 4\textsuperscript{th} – Geneva, 2008
- 5\textsuperscript{th} – Sedona (AZ, USA), May 22-25 2012

Workshops aim to bring together major NWP centers and representatives from the research community to discuss the contribution to forecast skill of various elements of the global observing system; guidance to participants provided well in advance of Workshop itself.
Sedona in brief

• The largest WMO Impact Workshop so far:
  – 3½ days
  – 59 participants from 13 countries
  – 40 presentations distributed in three sessions
• Ample discussion time during and after the sessions
• Very broad attendance from NWP community
• Space agencies and other observing system managers also represented
  – They are keenly aware of the power of NWP diagnostics as aids for decision making
  – Some trepidation among core participants about potential impact of results
4. Sample Results from Fifth WMO Impact Workshop in Sedona, May 2012

- Satellite data are important
- Conventional observations are re-emerging, especially RAOBs and aircraft observations (AMDAR)
- Wind observations of all kinds show a strong impact
ECMWF Data Coverage (All obs DA) - AMSU-A
25/Jul/2012; 06 UTC
Total number of obs = 720247
No Satellite / No Conventional Data
(JCSDA w/ NCEP GFS)

Strong impact of satellite data overall in both hemispheres
Radiosonde and aircraft

Coverage map for RAOB (125–250 hPa)

Coverage map for RAOB (600–800 hPa)

Coverage map for Aircraft (125–250 hPa)

Coverage map for Aircraft (600–800 hPa)
All observation types have positive impacts on average.
For the total impact, 1: aircraft, 2: AMSU-A, 3: radiosonde, 4: IASI, 5: GPSRO
For impact per 1 obs., 1: radiosonde, 2: GPSRO, 3: aircraft, 4: Scatterometer wind, 5: marine surface observation

*Ensemble-based FSO diagnostics, NCEP GFS, Ota et al., WMO, Sedona, May 2012*
Radiosonde and aircraft

**RAOBs:** Mid- to lower troposphere; as expected based on sensitive structures.

**Aircraft:** Upper troposphere; this is where we have data!

Radiosonde observations on mid- to lower troposphere have larger impacts compared to the aircraft observations.
Radiosonde impacts

Total impacts of radiosonde (12UTC October 21 to 06UTC October 28)

Most observations have positive impacts on average

Relatively large impacts for East Asia, Western US, Canada, and South America.
FNMOC and GMAO Observation Impact Monitoring

Current Operations

**Gelaro et al., Sedona May 2012**

*GEOS-5 24h Observation Impact Summary*

17 May 2011-15 May 2012 00z
Global Domain, Total Impact

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http://gmao.gsfc.nasa.gov/products/forecasts/systems/ob/s_impact/

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much larger relative impact of AMVs in Navy system
300mb Wind Speed (2010)  GFS / ECMWF

Root-Mean Square of Analysis Differences: 300mb Wind Speed

Note the very significant effect of in-situ wind observations:
Radiosondes and Commercial Aircraft

Langland, Sedona 2012

Langland and Maue 2011
Observation impact in global NWP

The highest ranked contributors for the forecast error reductions are:

- AMSU-A, AIRS/IASI, radiosonde, aircraft, AMVs
- GPS-RO also has substantial impact, but the data volume is declining approaching the end of COSMIC lifetime.

Several satellite sensors contribute to forecast skill. There is not a single, dominating one:

- More complementarity is seen, compared to previous years.
- The GOS has become more resilient, but this resilience is threatened by expected decline of the operational polar orbiting satellites.
- When one observation type is missing or removed, the contribution of other systems tend to increase without fully compensating.

These are (or include) wind measurements!

(slide shown by Erik Andersson, Workshop Chair, at EMS, September 2012)
Workshop Recommendations

Augment the profiling network e.g. by extending coverage of ascending and descending aircraft observations to regional airports.

There is a need to invest in enhanced wind observations in the tropics and over the oceans especially.

Study observation impact that is more closely related to high-impact weather (including TCs) and service delivery to customers and forecast users.

Encouraged studies of impact per observing system or per observation linked to their cost.

Define appropriate impact metrics for:
- humidity and
- regional NWP including precipitation and other surface weather elements.

(slide shown by Erik Andersson, Workshop Chair, at EMS, September 2012)
5. Sample OSSE Results

- JCSDA has conducted a series of OSSEs to study the impact of potential configurations of a space-borne wind lidar mission on the forecast skill of NCEP’s Global Forecast System.
- Standard OSSE set-up using ECMWF-provided Nature Run, complete simulated Global Observing System, including candidate Doppler Wind Lidar observations.
- Perturbation experiment in which DWL observations were withheld from the assimilation.
## Types of simulated observations included in JCSDA OSSE

### Set A (2005-6 period)
- AIRS (Aqua),
- AMSU-A (Aqua, NOAA-15, 16, 18),
- AMSU-B (NOAA-15, 16, 17),
- HIRS2 (NOAA 14),
- HIRS-3 (NOAA 15, 16, 17),
- HIRS-4 (NOAA-18),
- MSU (NOAA-14),
- MHS (NOAA-18)
- GOES sounder (GOES-10, 12)

All conventional data available in 2005-2006

### Set B (2011-12 period)
- IASI(METOP-A), AIRS(AQUA),
- ATMS(NPP), CrIS(NPP)
- HIRS-2(NOAA14),
- HIRS-3(NOAA 15, 16,17),
- HIRS-4(NOAA 18, 19, METOP-A),
- AMSUA(NOAA 15, 16, 17,18,19, AQUA, METOP-A),
- AMSUB(NOAA 15, 16, 17),
- MSU(NOAA 14), HSB(AQUA),
- MHS(METOP-A,NOAA18,19),
- SSMIS(DMSP F16), SEVIRI(MSG)
- GOES sounder (10,12, and 13)
- GPSRO
- ASCAT
- WINDSAT

All conventional data available in 2011-12
JCSDA Calibration Experiments

Compare impact of removal of RAOB wind in real and simulated experiments

REAL

Simulated

(a) REAL_CTRL
(b) REAL_NOUV

P500-hPa AC (NH)

(b) REAL_NOUV

P500-hPa AC (SH)

(a) SIMU_CTRL
(b) SIMU_NOUV

P500-hPa AC (NH)

(b) SIMU_NOUV

P500-hPa AC (SH)
Wind Lidar OSSEs

- Impact experiments for GWOS mission concept
  - NASA Tier-3 Decadal Survey mission concept
  - Four telescopes, full vector winds on either side of spacecraft
  - Two technologies, direct and coherent detection
- Experiments funded under Wind Lidar Science element of NASA’s ROSES 2007 (Kakar)
- GWOS observations simulated by Simpson Weather Associates using DLSM
500hPa HGT anomaly correlation coefficients

(T382)
RMSE: 200, 850hPa Wind error in tropics

(T382)
6. General guidance regarding wind observations

• Wind observations are still very much needed
• … and not just for NWP
• NWP is a foundational activity for most (all?) forecast application with a range beyond 6 hours
• Climate application; e.g. monitoring and understanding

• The lack of vertically resolved wind observations remains the most serious shortcoming of the WMO Global Observing System
7. Final Remarks

- The WMO Rolling Review of Requirements is a structured process for collecting, vetting and recording user requirements for all WMO application areas, and for matching them against observational capabilities (both conventional and space-based).

- Both subjective (user consultation) and objective (mostly NWP-based) methods are used for collecting user requirements.

- The resulting guidance from WMO has been very consistent for more than two decades: Global coverage of vertically resolved wind observations remains at the top of the list of