Report on data assimilation activities: workshop on OSEs and CBS

Pierre Gauthier

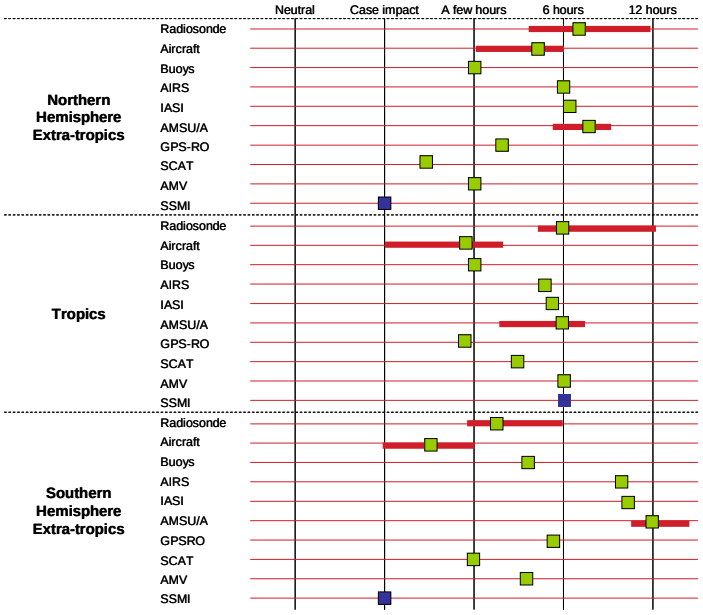
Presentation at the *24th WGNE meeting*
5-7 November, Montréal, CANADA

UQÀM Department of Earth and Atmospheric Sciences
Université du Québec à Montréal

Introduction

- **Report from the *4th WMO workshop on the Impact of Various observing systems in NWP***
  - Organized by Jean Pailleux, John Eyre, Ko Koizumi
  - CBS OPAG on Integrated Observing Systems (OPAG-IOS)
  - Expert Team on the Evolution of the GOS (ET-EGOS)
  - Previous workshop was in Alpbach, Germany, in 2004
  - Participation from several NWP centres from all continents
  - Proceedings are 'in press'
- **Link with the THORPEX DAOS-WG**
- **Objective of the workshop**
  - Evaluation of the impact of observations through Observing System Experiments (OSEs)
  - Results in recommendations on the value of observations to the ET-EGOS
- **Significant changes since the previous workshop**
  - GPS radio-occultations
  - METOP (2006)
  - High resolution spectral IR sounders (AIRS, IASI) are now assimilated by several centres
  - Adaptive strategies are now considered (more on the in the THORPEX DAOS-WG presentation)

Synthesis of the results from OSEs



- Impact on wind and mass
- Impact on humidity

Impact in Global NWP systems

- **NWP systems are using several types of satellite-based observing systems (MW, IR, GPS, AMV)**
  - Synergic relationship between temperature and wind observations
  - Only a small fraction of the total amount of received observations is assimilated
    - → Cloudy radiances are difficult to assimilate
    - → Surface emissivity must be considered to assimilate channels that peak in the lower troposphere
    - → Observation error correlation and model resolution require data thinning (screening) for optimality
  - Bias correction is essential
    - → Requirements for reference observations for calibration
    - → Adaptive bias correction schemes are now used at several centres with good results
- **Stratosphere is now included in several NWP models**
  - Analysis relies exclusively on satellite data
  - Bias correction is benefiting from GPS radio-occultation which can be used, to some extent, as reference observations

Global NWP systems (cont'd)

- **Gap in observations of wind profiles**
  - ADM-AEOLUS
  - Canadian SWIFT instrument
- **Availability of data in real time**
  - Requires development on telecommunication systems to accelerate the retransmission
  - Extends to research satellite instruments that can be assimilated (e.g., MODIS, AIRS)
- **Current OSEs focus on the impact of observations on forecasts of the first week**
  - Assessment of the impact on forecast of the second week will require to pay attention to the impact of analyses surface fields and the stratosphere
  - OSEs may not be sufficient since this is a concern for ensemble prediction
- **Stratospheric extension raises questions about observation requirements for the stratosphere**

Regional systems

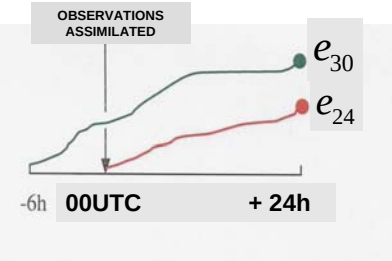
- **Regional models are currently less dependent on satellite radiances than global models**
  - Results were presented by HIRLAM, Météo-France and COSMO on the use of satellite measurements in regional systems (e.g., SEVIRI, ATOVS, MODIS winds, GPS surface data)
  - Studies related to surface emissivity over land are highly required for regional NWP in order to fully exploit satellite observations
- **Regional systems benefits from observations such as radiosondes, Doppler wind radars, GPS surface data, AMDAR**
  - Real time distribution of radar data requires agreements on pre-processing and transmission standards
  - Recommendation: implementation of a global exchange of radar radial wind and reflectivities as a first priority, and then GPS surface networks
- **Design of OSEs for regional systems shows of lot of variability and due to significant differences in the systems (3D/4D-Var, observations used, model characteristics)**
  - More emphasis of the verifications on relevant metrics for the application of these systems (e.g., precipitation, air quality)

New developments on measuring the impact of observations

- **Provide more detailed information on the impact of observations**
- **Can be used as a complement to OSEs to evaluate the impact of observations in the observing environment in which they are normally used**
- **Methods that can be used**
  - Degrees of Freedom per Signal (DFS): measures the impact of observations on the analysis
  - Adjoint based sensitivities with respect to observations: measures the impact of observations on the reduction of forecast error
    - → Adjoint based sensitivities are now produced routinely at NRL and GMAO is working to do the same
    - → ECMWF (Cardinali) presented results using the same method
    - → Environment Canada is also investigating the approach

Observation Impact Methodology

(Langland and Baker, 2004)

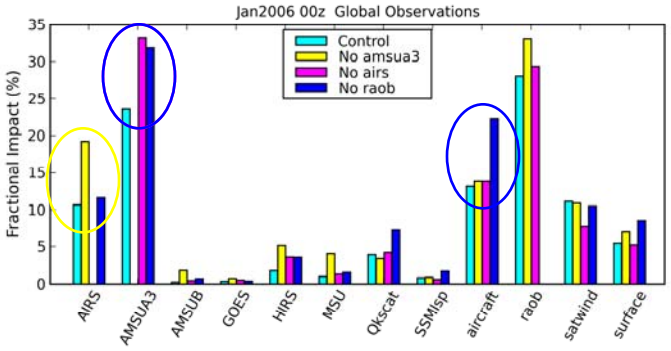


Observations move the model state from the "**background**" trajectory to the new "**analysis**" trajectory

The difference in forecast error norms, $e_{24} - e_{30}$, is due to the combined impact of all observations assimilated at 00UTC

Combined Use of ADJ and OSEs (Gelaro *et al.*, 2008)

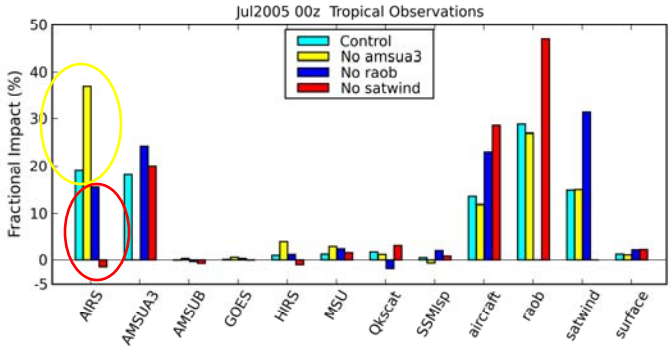
…ADJ applied to *various* OSE members to examine how the mix of observations influences their impacts



- Removal of AMSUA results in large increase in AIRS (and other) impacts
- Removal of AIRS results in significant increase in AMSUA impact
- Removal of raobs results in significant increase in AMSUA, aircraft and other impacts (but not AIRS)

Combined Use of ADJ and OSEs (Gelaro *et al.*, 2008)

…ADJ applied to *various* OSE members to examine how the mix of observations influences their impacts



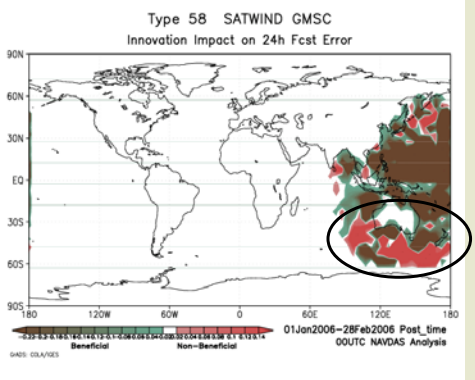
- Removal of AMSUA results in large increase in AIRS impact in tropics
- **Removal of wind observations** results in significant **decrease** in AIRS impact in tropics (in fact, AIRS degrades forecast without satwinds!)

Example 1: AMV impact problem (from R. Langland, NRL)

Date: Jan-Feb 2006

Issue: Non-beneficial impact from MTSAT AMVs at edge of coverage area

Action Taken: Data provider identified problem with wind processing algorithm.



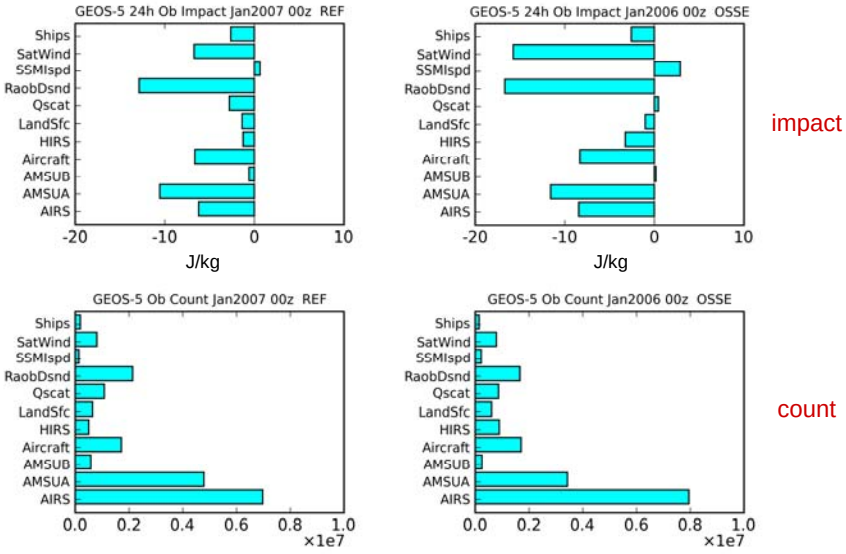
Observing System Simulation Experiments (OSSEs)

- **Joint effort involving NOAA, NASA/GMAO and ECMWF who produced the high resolution nature run**
- **Objective: validation of an OSSE**
  - Observation impact of synthetic observations created from the nature compares to what is measured in assimilation systems with existing observations
  - Requires that observations from the nature run take into account the presence of clouds, include representativeness error, etc.
  - Assessment of the impact has been evaluated using adjoint based sensitivities with respect to observations
  - Preliminary results are very encouraging
- **A credible OSSE framework would be extremely valuable**
  - to investigate scenarios to determine the optimality of observing networks (e.g., GPS constellation)
  - Optimize the design of satellite platforms before their deployment.

OSSE calibration for Jan 2006 vs. Jan 2007 reference **First Results**

Impact of **various observing systems** on GEOS-5 24h forecast error

REAL OBS **OSSE**



Conclusions

- **Almost all centres were able to identify positive impacts on forecast skill of practically all parts of the observing system**
  - Quality of the Global Observing System
  - Increasing level of maturity of the models and assimilation systems used to ingest the information for numerical weather prediction.
- **Lack of profile-type observations in polar latitudes**
  - Effort should be made to maintain the existing radiosonde sites, and/or find new systems to observe the vertical structure of the atmosphere (wind, temperature, humidity) in the polar areas.
- **Highest priority in terms of observation requirements is to add more profile observations in many data-poor areas**
  - All the AMDAR opportunities should be used to improve the wind and temperature data coverage, especially in data-poor areas like the inter-tropical regions or Central and South Africa
  - Remote radiosonde stations are still of exceptional value
- **Comparison of results from OSEs indicate some common characteristics on the impact of observations**
  - Results depend on numerous factors (differences in assimilation systems and NWP model, in periods, metrics used, observations assimilated)
  - Discussion on establishing a common ground for all participants (difficult in practice, given the cost of completing those OSEs)