Intercomparison of Observation Sensitivity Experiments

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Background

- A goal of THORPEX is to improve our understanding of the ‘value’ of observations provided by the current global network
  - optimize the use of current observations
  - inform the design/deployment of new obs systems

- In 2007, DAOS-WG proposed a comparison of observation impacts in several forecast systems, facilitated by the emergence of new (adjoint-based) techniques

- Experiments for a baseline observation set were designed by DAOS members from NRL, GMAO, EC, ECMWF, Météo-France

...so far, results obtained for 3 systems: NRL, EC, GMAO
Estimation of Observation Impact

- Based on LB04, or extensions of that method (nonlinear DAS)

\[
\delta \epsilon \approx (K^T g, d)
\]

adjoint analysis scheme

\[
g \sim M^T_a(x^f_a - x^f) + M^T(x^f - x^f)
\]
adjoint model

- Impact computed for all observations simultaneously
- The impact of any subset of observations, \( S \), can be easily quantified using a partial sum

\[
\delta \epsilon_S \approx \sum_{i \in S} (K^T g)_i d_i
\]

Observations in Baseline Comparison

Conventional observations
- Raobs, pibals, dropsondes
- Commercial aircraft
- Land surface
- Ship surface
- Buoys

Satellite observations
- AMSU-A (3 satellites)
- Geo-satellite winds
  - Vis, IR and WV
- MODIS polar winds
- SSM/I surface wind speed
- QuikScat surface wind

- Each center used their usual data selection and QC procedures, error statistics and observation operators
- NRL and GMAO assimilated SSM/I speeds but no Profiler winds; EC did the opposite (neither type has large impact)
Experiment for the Baseline Observation Set

- January 2007, every 6 hours, 124 assimilation times
- Baseline set of observations assimilated (next slide)
- 24h global forecast error (dry TE norm) vs. own analysis
- Dry physics in adjoint model

- **NRL** – NOGAPS forecast and adjoint T239L30 NAVDAS **3D-Var** analysis and adjoint 0.5°
- **GMAO** – GEOS-5 forecast 0.5°/L72, adjoint 1.0° GSI **3D-Var** analysis and adjoint 0.5°
- **EC** – Meso-Strat GFS forecast 0.4°/L80, adjoint 1.5° **4D-Var** analysis and adjoint 1.5°
Comparison experiments for NRL, GMAO and EC systems completed (published) for baseline set of observations.

Despite differences in DA algorithms, RTMs and data handling, overall quantitative results similar for all systems.

Largest overall impact provided by AMSU-A, but also raobs, satwinds and aircraft.

Details of impact differ between forecast systems: impacts per-ob, -channel, -region.

Only a small majority of assimilated observations improve the forecast.

Much improvement comes from a large number of observations with small individual impacts.

Daily average observation impacts
Global domain: 00+06 UTC assimilations  Jan 2007

AMSU-A, Raob, Satwind and Aircraft have largest impact in all systems.
Impacts per-observation
Global domain: 00+06 UTC assimilations Jan 2007

Impact per-ob varies significantly between forecast systems
GEOS-5 has smallest impact per-ob ...2-3x more obs assimilated, other factors?

Observation impacts: NOAA-18 channel 7
Global domain: 00+06 UTC assimilations Jan 2007
Impacts binned by observation location (2°x2°)

Common areas of improvement and degradation in all systems
More mixed pattern of improvements and degradations in EC GDPS, especially in SH
Observation impacts: Satwinds 700-300h Pa
Global domain: 00+06 UTC assimilations  Jan 2007
Impacts binned by observation location (2°×2°)

More uniformly beneficial use of Satwinds in NOGAPS
Coherent patterns (areas) where these data degrade GEOS-5 and GDPS forecasts

Fraction of obs that reduce forecast error
Global domain: 00+06 UTC assimilations  Jan 2007

All observation types (except SSMI speed in GEOS-5) are in the range 50%-54% beneficial
Observation impact vs. innovation: AMSU-A ch.7
Global domain: 00 UTC 21 Jan 2007

NRL NOGAPS

GMAO GEOS-5

EC GDPS

Most total error reduction comes from a large number of observations with relatively small individual impact

Some General Conclusions

- Adjoint technique established as a feasible approach for inter-comparison studies (consistent implementations)
- Results complement/extend (not replace) knowledge obtained from OSEs: includes all observations, impacts as function of channel, location, or other attribute
- Allows some attribution/interpretation of strengths and weaknesses of individual forecast systems vs. general methodologies employed
- Some aspects of results may have implications for targeting:
  
  Does small majority of beneficial obs + accumulated benefit of a large number of small individual impacts favor "extended enhancement" over "targets of the day"?

Where do we go from here?

- Should we continue to promote/conduct coordinated inter-comparison experiments (adjoint method + selected OSEs)?
  
  ...collection and unification of results is very time-consuming!

- How to make such experiments more relevant and comprehensive? ...new data types, other metrics and verification domains (currently 24-h dry global energy)

- As forecasts improve, will verification of 24-48h forecasts against analyses be useful?

- Is it feasible/practical to use this technique to measure the impact of emerging data types such as cloud- and rain-affected observations, precipitation?