Forecast Sensitivity - Observation Impact (FSOI) Inter-comparison Experiment

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FSOI Comparison Study Motivation

- Several NWP centers compute FSOI routinely to monitor/understand/tune their DA system. Opportunity to compare impacts in systems with different DA methods and different mix of assimilated observations.
- Impact of AMVs and other wind observation data.
- Satellite vs. in-situ data, TLM/ADJ vs ensemble DA.
- Are relative impact of various observation types comparable?
- Can we learn from similarities/differences to improve NWP systems and DA procedures?

- NWP Centers that participated: NRL, GMAO, EMC, Met Office, JMA
FSOI vs. data-denial (OSE) experiments

- FSOI quantifies impact of all assimilated observations on a selected forecast metric ... shows if any observation [or set of observations] decreases or increases forecast error ...
- OSE shows impact of one selected change to the observation system on all aspects of forecast ... not able to partition impact of various observation types
Forecast Sensitivity – Observation Impact (FSOI)
Langland and Baker (Tellus, 2004)

NAVGEM ADJOINT

Adjoint-derived (single outer-loop) observation impact

\[ \delta e \approx d^T K^{-1} \left[ M_b^T e(x_b^f) + M_a^T e(x_a^f) \right] \]

Innovation vector

Ensemble-derived observation impact

\[ \delta e \approx d^T R^{-1} L (H X_a^{0}) X_a^{fT} \left[ e(x_b^f) + e(x_a^f) \right] \]
Experimental Design

• **Time period:** 3-month DJF 2014-15, 00UTC & 06UTC analysis times

• **Verification:** 24h forecast against self-analysis

• **Metric:** global total dry energy (surface-100hPa)

• **Adjoint:** dry plus moist physics, as available

• **Ensemble:** flow-following localization

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Results shown here are preliminary

[only global summary plots of impact at 00UTC will be shown]
## Participating NWP Centers

<table>
<thead>
<tr>
<th>NWP Centers</th>
<th>NRL</th>
<th>GMAO</th>
<th>Met Office</th>
<th>JMA Adjoint</th>
<th>JMA Ensemble</th>
<th>EMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis System</td>
<td>4DVar In Observation Space</td>
<td>Hybrid 3DVar</td>
<td>4DVar</td>
<td>4DVar</td>
<td>LETKF re-centered via 4DVar</td>
<td>EnKF re-centered via 4DEnVar</td>
</tr>
<tr>
<td>FSOI Technique</td>
<td>Adjoint</td>
<td>Adjoint</td>
<td>Adjoint</td>
<td>Adjoint</td>
<td>Ensemble</td>
<td>Ensemble</td>
</tr>
</tbody>
</table>
| Experiment Resolution | Model: T425L60  
Adjoint: T119L60 | Model: 25km DA: 50km En: 100km | Model: N320 (40km) Adjoint: N216 (60km) | Model: TL959L100  
Adjoint: TL319L100 | Ensemble: (x50) TL319L100 | Ensemble: (x80) T254 |
| Specific Considerations | Super-obbing for AMVs | QC = channel selection + dynamical observation error | ~30% cycles discarded due to spurious impacts | | | | | | | | | | | Additional thinning of observations except for aircraft data |
Observation Count at 00UTC

- Radiosonde
- Ship
- Buoy
- Land Surface
- Aircraft
- PIBAL
- GPSRO
- Geo Wind
- MODIS Wind
- AVHRR Wind
- AIRS
- AMSUA
- MHS
- ATMS
- CrIS
- HIRS
- IASI
- Seviri
- GOES

Observation Count per Analysis

- JMA_adj
- GMAO
- NRL
- MET
- JMA_ens
- EMC
Fractional Ob Impact: Satellite Radiances

Ensemble DA Methods

- AIRS
- AMSUA
- MHS
- ATMS
- CrIS
- HIRS
- IASI
- Seviri
- GOES
Fraction of Neutral Impact-Observations

Ensemble DA Methods

- Radiosonde
- Ship
- Buoy
- Land Surface
- Aircraft
- PIBAL
- GPSRO
- Geo Wind
- MODIS Wind
- AVHRR Wind
- AIRS
- AMSUA
- MHS
- ATMS
- CrIS
- HIRS
- IASI
- Seviri
- GOES
FSOI Inter-comparison Summary

- Largest AMV impacts in Navy Global system
- Smallest AMV impacts in EMC & JMA ensemble-DA systems
- Impacts depend on amount of AMV and other observation data that is assimilated
- Thinning or super-ob procedures
- Assimilation method: TLM/ADJ vs. ensemble
- Ensemble methods appear less-accurate at quantifying sensitivity for observations with small individual impacts (e.g., satellite obs) ...
Questions about the FSOI inter-comparison study?
Observation Impact at 00UTC: Observation Count

Radiances

Other Observations
Observation Impact at 00UTC: Impact per Observation

24-h Observation Impact Summary
Global Domain, 00Z DJF 2014-15
Impact per Observation

- AIRS
- AMSU-A
- MHS
- ATMS
- CrIS
- HIRS
- IASI
- Seviri
- GOES

Impact per Observation (J/kg)

- Large impact-per-ob...

**10^{-6}**

**10^{-4}**

Radiances

Other Observations

**TOTAL**
Observation Impact at 00UTC: **Impact per Observation**

**Radiances**

- AIRS
- AMSUA
- MHS
- ATMS
- CrIS
- HIRS
- IASI
- Seviri
- GOES

**Other Observations**

- Radiosonde
- Ship
- Buoy
- Land Surface
- Aircraft
- PIBAL
- GPSRO
- Geo Wind
- MODIS Wind
- AVHRR Wind

Impact per Observation (%): $10^{-3}$, $10^{-2}$
Impact < 0 à Beneficial
Impact > 0 à Detrimental
ε = 10 - 10
Impact < -ε à Beneficial
Impact > ε à Detrimental
-ε < Impact < ε à Neutral

Observation Impact at 00UTC: **Fraction of Beneficial Observations**

- **JMA_ens 24-h Observation Impact Summary**
  - Global Domain, Fraction of Beneficial Observations

- **JMA (Ensemble) 24-h Observation Impact Summary**
  - Global Domain, 00Z DJF 2014-15
  - Fraction of Beneficial Observations

- **Observation Count per Analysis**
FSOI TLM/ADJ vs. Ensemble methods

Only ~20% of the forecast error metric projects onto ensemble structures, so observation sensitivity may be not well-represented with ensemble methods [Problems with ensemble localization, inflation factors and other issues]. Implications for FSOI with ensemble methods, and also for ensemble DA itself, such as 4dENS-Var, as opposed to 4DVAR with TLM/ADJ.

Observation impact with ensemble method is artificially changed by ensemble “inflation factors.”