Data Assimilation Ensemble Technique for Assessing Observing System Impact applied to Simulated ADM-Aeolus Data Assimilation

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Acknowledgments:
ESA (Mission Science Division & Aeolus project team)
Aeolus Mission Advisory Group
Richard Barnes, Kelvyn Robertson (Met Office)
Overview

♦ ADM-Aeolus Data Simulations
  ♦ Performed with LIPAS, predate operational processors
  ♦ Sensitivity to input clouds

♦ Assimilation Ensemble Technique for Impact Assessment
  ♦ Principles (alternative to OSSEs)
  ♦ Application to simulated Aeolus data
  ♦ Calibration with radiosondes and information content
Previous data simulations for ADM-Aeolus
Yield (%age of data meeting mission requirements) at 10 km

- 90% of Rayleigh data have accuracy better than 2 m/s
- In priority areas (filling data gaps in tropics & over oceans)
- Complemented by good Mie data from cloud-tops/cirrus (5 to 10%)
- Tan & Andersson QJRMS 2005

LIPAS simulations pre-date operational processors
Data simulations for ADM-Aeolus
Yield (%-age of data meeting mission requirements) at 5 & 1 km

- 5 km: 75% of Rayleigh have accuracy < 2 m/s (also 15% Mie not shown)
- 1 km: 66% of Mie have accuracy < 1 m/s (aerosol & cloud returns)
- Adequate transmission through overlying cloud
ADM-Aeolus data simulations - comparison with radiosondes/mission spec

♦ Aeolus median like obs error assigned operationally to radiosondes

♦ Aeolus HLOS observations expected to receive appreciable weight

Rayleigh

Mie

Without representativity
(cf mission spec – dash-dot)

With cross-track representativity
(cf radiosonde – dashed)
ADM-Aeolus data simulations - Effects of model cloud cover (2)

- Mid-latitude example
- QC implications, Task 2
- Tails of Rayleigh error distributions underestimated, median barely changed
Overview

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**Assimilation of prototype ADM-Aeolus data**

New observed quantity introduced into 4d-Var (2004 system)

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**Observation Processing**

**Data Flow at ECMWF**

1. **Non-IFS processing**
   - “Bufr2ODB” Convert BUFR to ODB format
   - Recognize HLOS as new known observable

2. **Observation Screening**
   - IFS “Screening Job” Check completeness of report, blacklisting
   - Background Quality Control

3. **Assimilation Algorithm**
   - IFS “4D-VAR” Implement HLOS in FWD, TL & ADJ Codes
   - Variational Quality Control

4. **Diagnostic post-processing**
   - “Obstat” etc (Lars Isaksen) Recognize HLOS for statistics
   - Rms, bias, histograms

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Prototype Level-2B (LIPAS simulation, includes representativeness error)
Assimilation studies for ADM-Aeolus

-Assimilation ensembles for data impact assessment
  - Original motivation: use ensemble spread as proxy for short-range forecast errors (background errors)
  - By extension, good data reduce ensemble spread
  - DWL impact
  - Radiosonde/profiler impact - provides calibration
- Additional diagnostics related to information content
  - Entropy reduction
  - Degrees of freedom for signal
- Tan et al 2007, QJRMS 133:381-390
OSE

Reference | Observations | NWP-System | Verification | Result
---|---|---|---|---
Real atmosphere | Assimilation/ forecast | Compare to reference | Impact assessment |

OSSE

Reference | Observations | NWP-System | Verification | Result
---|---|---|---|---
Nature run | Assimilation/ forecast | Compare to reference | Calibrate | Impact assessment

Ack: Werner Wergen (DWD)
Data impact on ensemble forecasts - zonal wind spread at 500 hPa

- Radiosondes and wind profilers over Japan, Australia, N. Amer, Europe
- DWL over oceans & tropics
- Some features more obvious at 200 hPa ...
Data impact on ensemble forecasts - zonal wind spread at 200 hPa

- **Radiosondes and wind profilers over Japan, Australia, N.Amer, Europe**
- **DWL over oceans and tropics**
Profiles of 12-hr Fc impact, Southern Hemisphere

Spread in zonal wind (U, m/s)
Scaling factor ~ 2 for wind error

Tropics, N. & S. Hem all similar

Simulated DWL adds value at all altitudes and in longer-range forecasts (T+48, T+120)

Differences significant (T-test)
Supported by information content diagnostics
Global information content - consistent

♦ Mike Fisher for Entropy Reduction & DFS

\[ S \sim \log(\det(P^A)) \]
\[ \sim \text{tr}\left(\log\left(J''^{-1}\right)\right) \]
\[ J'' = 4d\text{-}var\ Hessian \]
\[ P^A = \text{analysis error covar.} \]

♦ DWL data are accurate and fill data gaps

♦ subject to usual caveats about simulated data

<table>
<thead>
<tr>
<th></th>
<th>TEMP/PILOT</th>
<th>Simulated DWL</th>
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<tbody>
<tr>
<td>Data considered</td>
<td>u,v to 55 hPa</td>
<td>HLOS</td>
</tr>
<tr>
<td>Entropy_Reduction</td>
<td>4830</td>
<td>3123</td>
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<tr>
<td>(&quot;Info bits&quot;)</td>
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<tr>
<td>Deg_Free_Sig</td>
<td>3707</td>
<td>2743</td>
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<tr>
<td>N_Obs</td>
<td>90688</td>
<td>50278</td>
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<tr>
<td>Info bits per obs</td>
<td>0.053</td>
<td>0.062</td>
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<tr>
<td>N_Obs/Deg_Free_Sig</td>
<td>24.5</td>
<td>18.3</td>
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<tr>
<td>Redundancy</td>
<td></td>
<td>2 − 3 %</td>
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Conclusions

- Assimilation Ensemble Technique for Impact Assessment
  - Alternative to OSSEs
  - Applied to simulated Aeolus data
  - Calibration with radiosondes and information content
  - Revisiting calibration against OSEs - in progress
  - Prepares assimilation system technically for new data
  - Worth considering for candidate missions
Analysis Ensembles for Data Impact (2)

- Impact = Spread(Ensemble-1) - Spread(Ensemble-2)

- A reduction in spread (negative values) should indicate data benefits

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“DWL”
(Control + simulated DWL)

“Control”
(2004 observing system including TOVS & AIRS)

“NoSondes”
(TEMPS & PILOTs blacklisted)

“DWL_NoSondes”
(NoSondes + simulated DWL)
```

Radiosonde impact

Radiosonde impact 2

DWL impact

DWL impact 2

DWL + Sondes
Quality Control Examples: Std + Aeolus-optional QC for DWL -- active

Radiosonde U-wind

Option improves departure statistics
Assimilation of prototype ADM-Aeolus data
Reception of L1B data and L2B processing at NWP centres

Level-1B data
(67 1-km measurements)

Non-IFS processing

Observation Screening

IFS “Screening Job”
Check completeness of report, blacklisting
Background Quality Control

IFS “4D-VAR”
Implement HLOS in FWD, TL & ADJ Codes
Variational Quality Control

“Obstat” etc (Lars Isaksen)
Recognize HLOS for statistics
Rms, bias, histograms

Analysis

July 2008    ADM-Aeolus Impact Assessment – LWG Wintergreen & JCSDA          Slide 19
Facts and figures for ADM-Aeolus

- ESA point of contact – Dr Paul Ingmann
- Mission Experts Division, ESA/ESTEC, The Netherlands

<table>
<thead>
<tr>
<th>Orbit</th>
<th>Sun-synchronous</th>
<th>Dawn-dusk</th>
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<tr>
<td>- inclination &amp; altitude</td>
<td>97 °</td>
<td>408 km</td>
</tr>
<tr>
<td>Mass - total &amp; “ALADIN” lidar component</td>
<td>1100 kg</td>
<td>450 kg</td>
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<tr>
<td>Transmitter</td>
<td>Nd:YAG, frequency tripled to 355 nm</td>
<td>150 mJ</td>
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<tr>
<td>- laser type &amp; pulse energy</td>
<td></td>
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<tr>
<td>- pulse repetition freq. &amp; duty cycle</td>
<td>100 Hz</td>
<td>10 s every 28 s</td>
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<tr>
<td>Receiver - telescope diameter</td>
<td>1.5 m</td>
<td></td>
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<tr>
<td>- spectrometers</td>
<td>Fizeau (Mie)</td>
<td>Dual edge etalon (Rayleigh)</td>
</tr>
<tr>
<td>Average power demand</td>
<td>1400 W</td>
<td></td>
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<tr>
<td>Launch date &amp; mission lifetime</td>
<td>2008</td>
<td>3 years</td>
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Assimilation of prototype ADM-Aeolus data

**Quality Control for Aeolus data**

- Most QC parameters taken from conventional wind obs
  - Background errors & quality control thresholds (BgQC+VarQC)
  - Aeolus-specific Background Quality Control (recommended option)
    - **Capping of observation error in bg departure classification**
      
      
      Set $B = (\text{obs-bg}) / ES(\text{obs-bg})$, accept obs iff $\text{abs}(B) < 4$.

      In standard BgQC for Aeolus, $ES = (\sigma_o^2 + \sigma_b^2)^{1/2}$.

      Aeolus option: $ES = (s_o^2 + \sigma_b^2)^{1/2}$, where $s_o = \min(\sigma_o, 2.5 \text{ ms}^{-1})$

- Testing with LITE period, LIPAS-simulated Level-2B data
  - Gaussian + non-Gaussian errors (instrument bias, input wind bias)
  - Operational model (Cy26r1) at full/reduced resolution, ERA40/NoSSMI