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)

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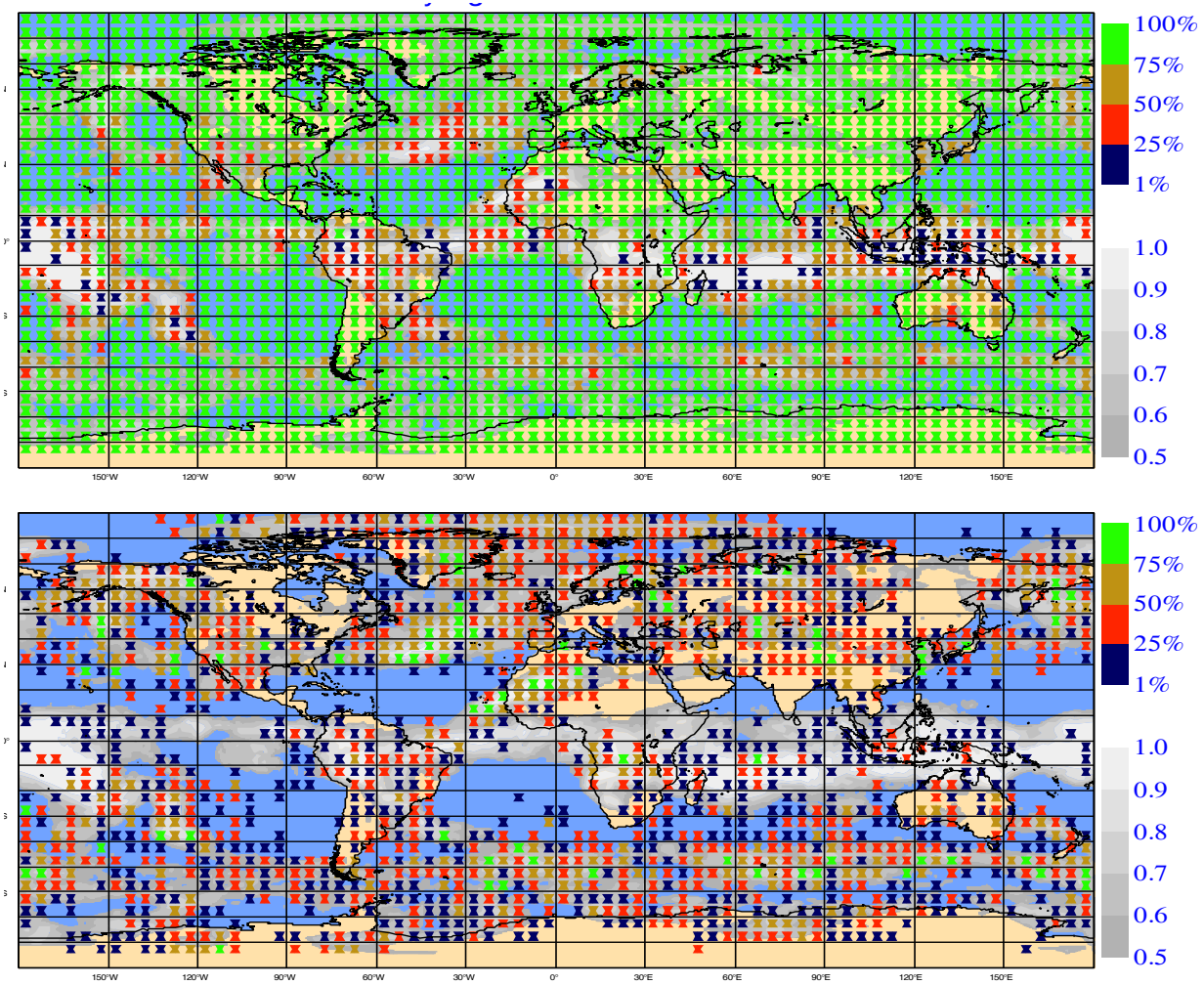
Overview

- 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

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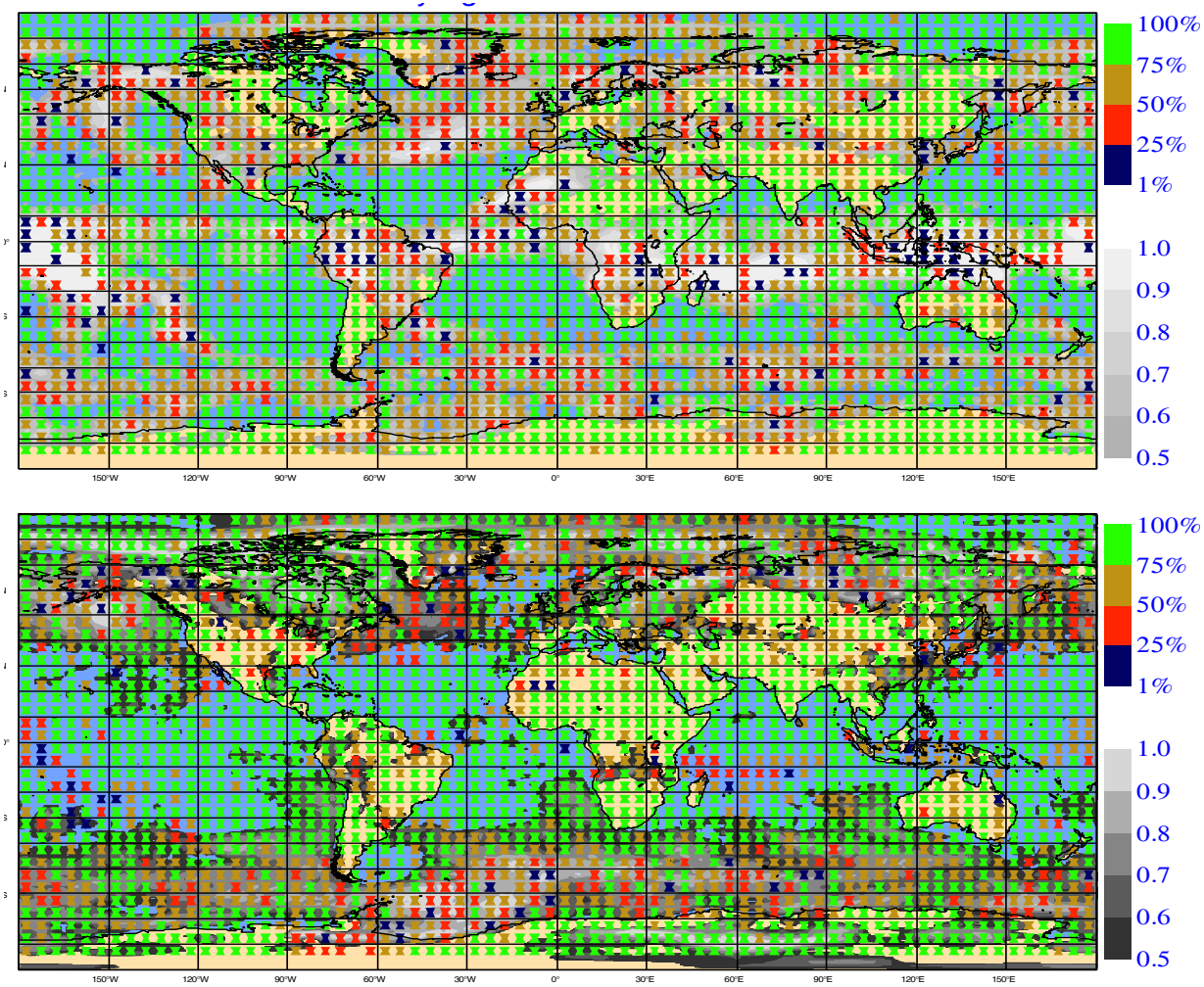
Data simulations for ADM-Aeolus

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



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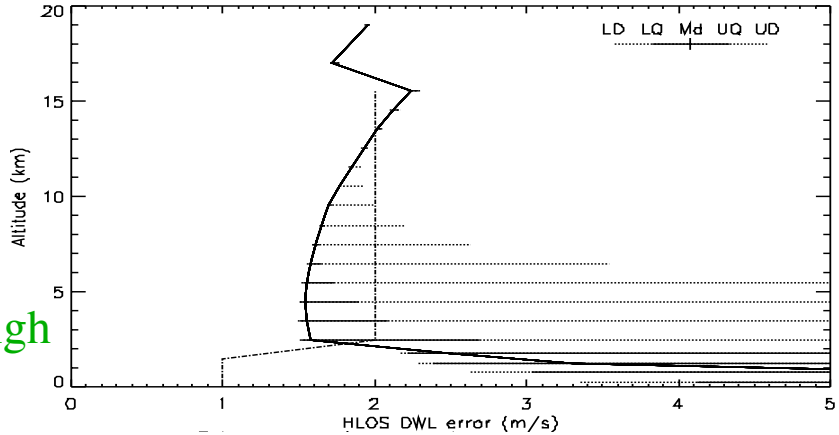
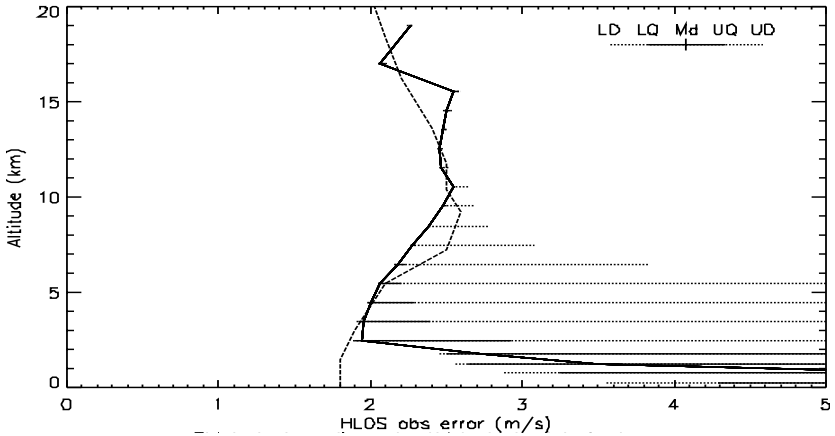
ADM-Aeolus data simulations - comparison with radiosondes/mission spec

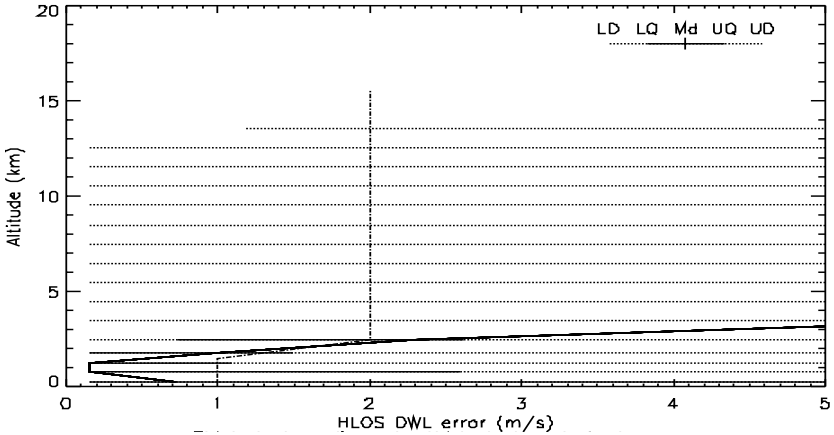
- Aeolus median like obs error assigned operationally to radiosondes
- Aeolus HLOS observations expected to receive appreciable weight

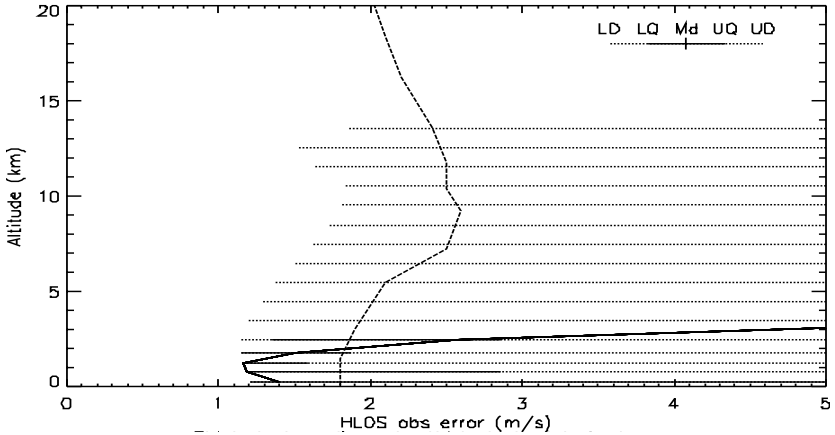
Rayleigh





Mie





Without representativity
(cf mission spec – dash-dot)

With cross-track representativity
(cf radiosonde – dashed)

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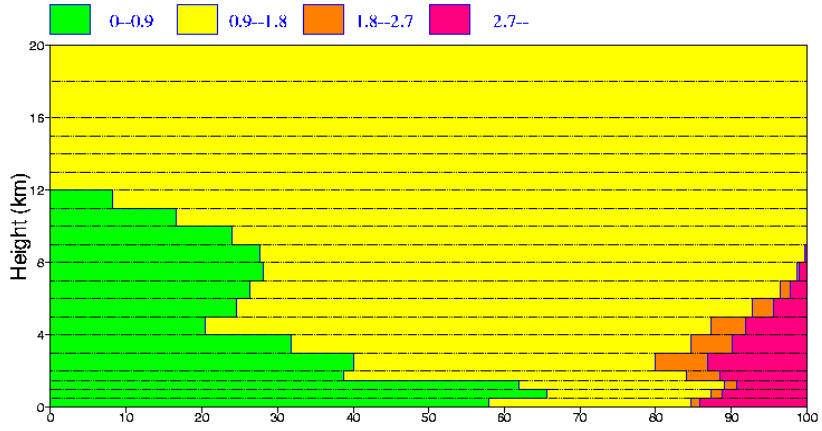
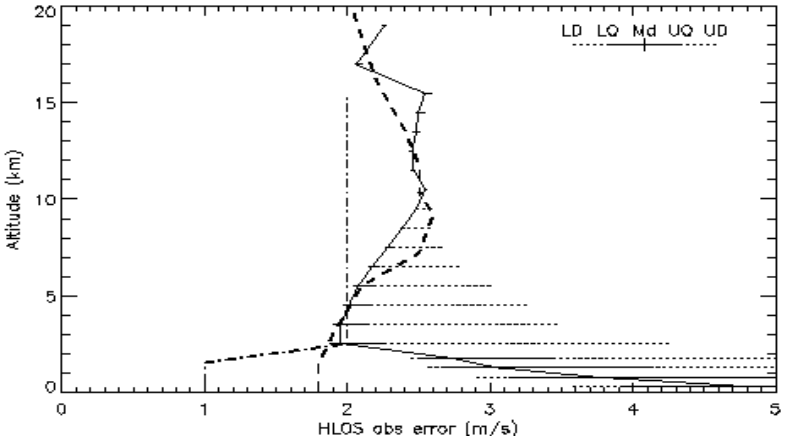
ADM-Aeolus data simulations – Effects of model cloud cover (2)

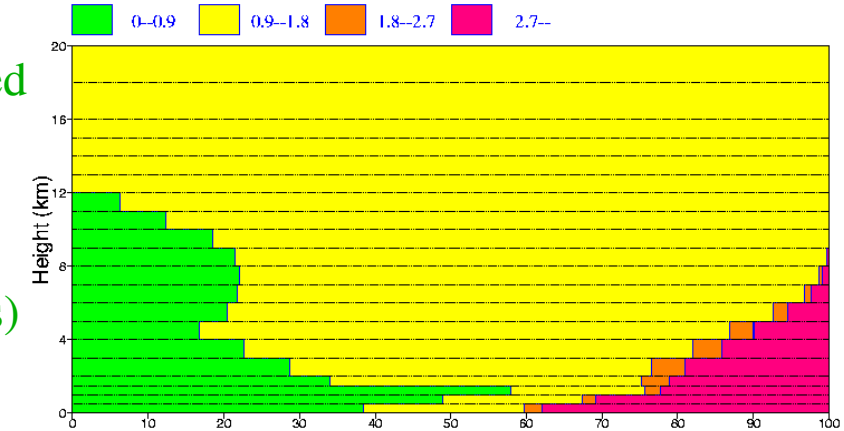
- Mid-latitude example
- QC implications, Task 2
- Tails of Rayleigh error distributions underestimated, median barely changed

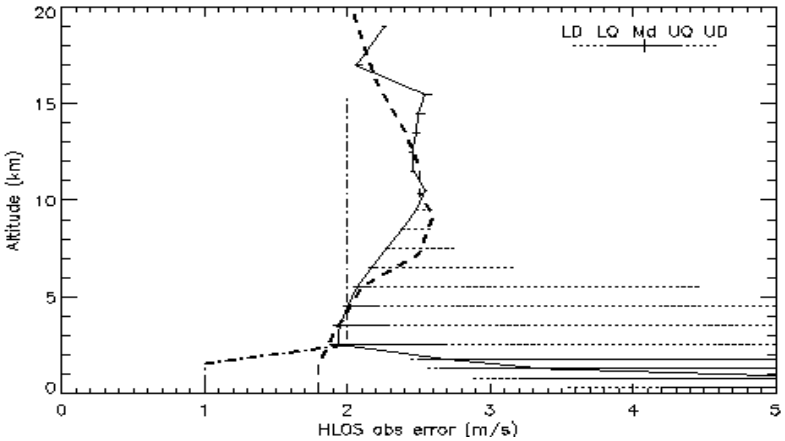
Model





Observed cloud cover (LITE midlats)





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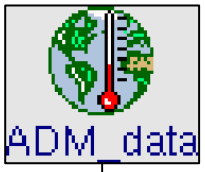
Assimilation of prototype ADM-Aeolus data

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



Prototype Level-2B (LIPAS simulation, includes representativeness error)

Observation Processing

Data Flow at ECMWF

Non-IFS processing	"Bufr2ODB" Convert BUFR to ODB format Recognize HLOS as new known observable
Observation Screening	IFS "Screening Job" Check completeness of report, blacklisting Background Quality Control
Assimilation Algorithm	IFS "4D-VAR" Implement HLOS in FWD, TL & ADJ Codes Variational Quality Control
Diagnostic post-processing	"Obstat" etc (Lars Isaksen) Recognize HLOS for statistics Rms, bias, histograms

→ *Analysis*

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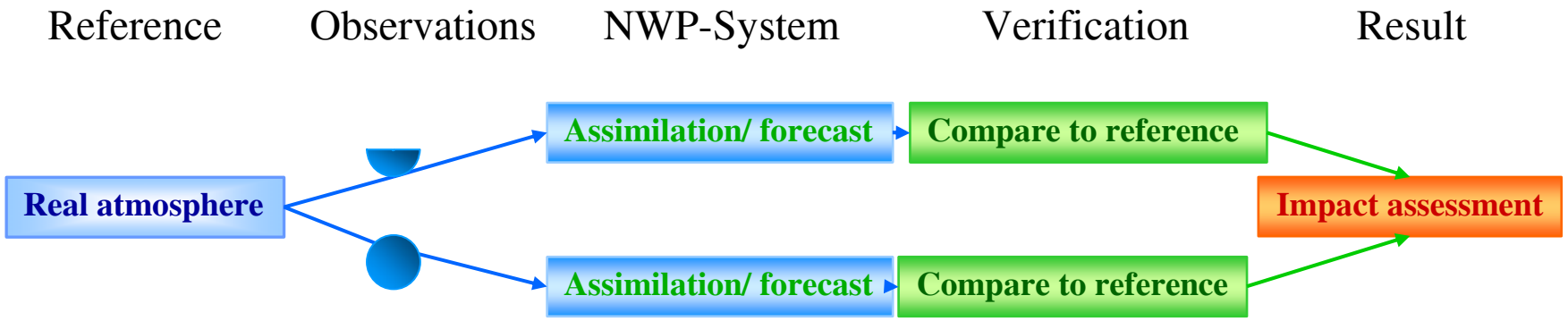
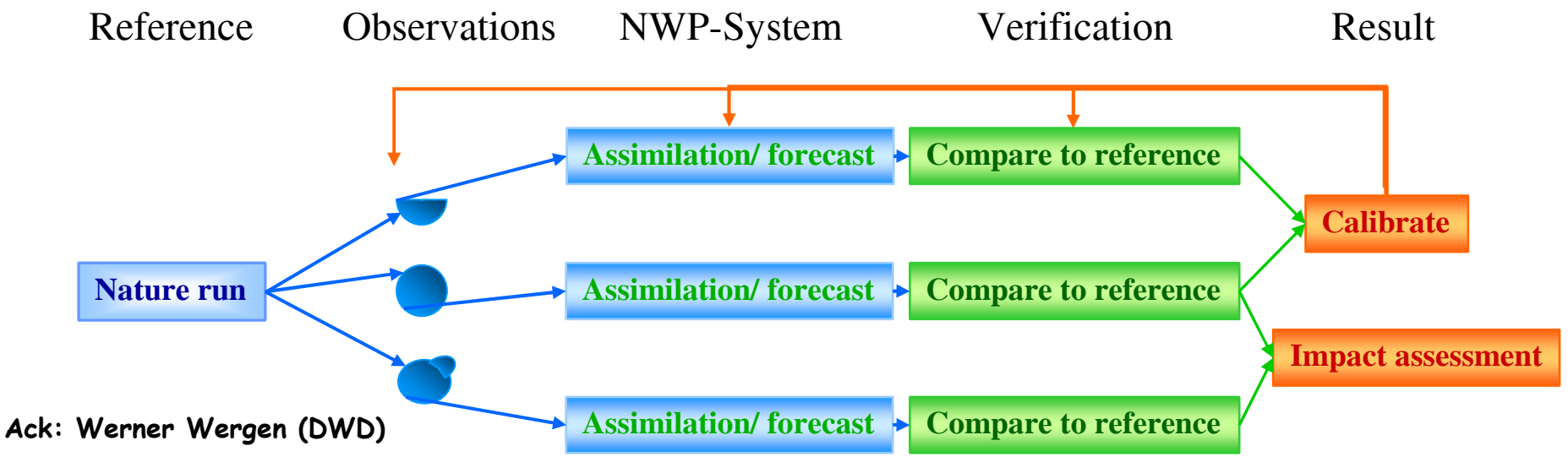
Assimilation studies for ADM-Aeolus

- 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



OSSE



Ack: Werner Wergen (DWD)

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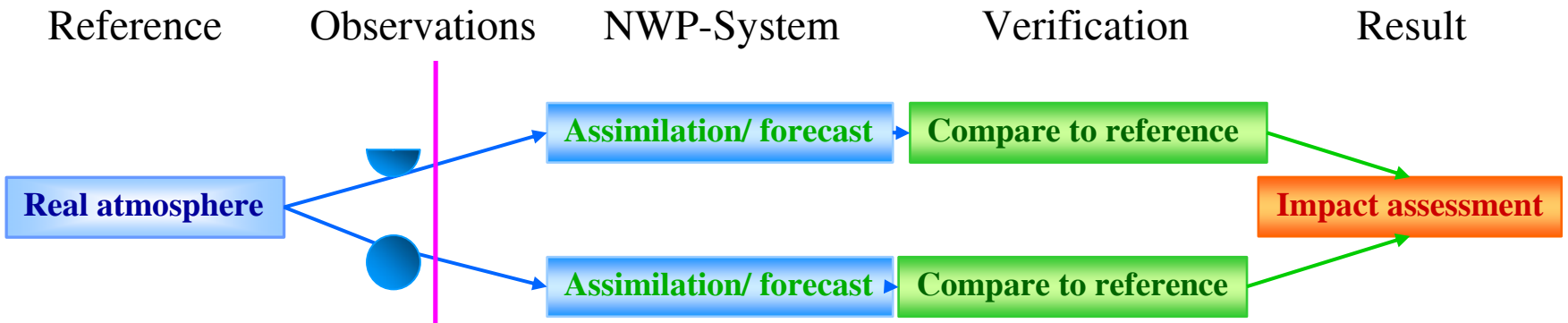
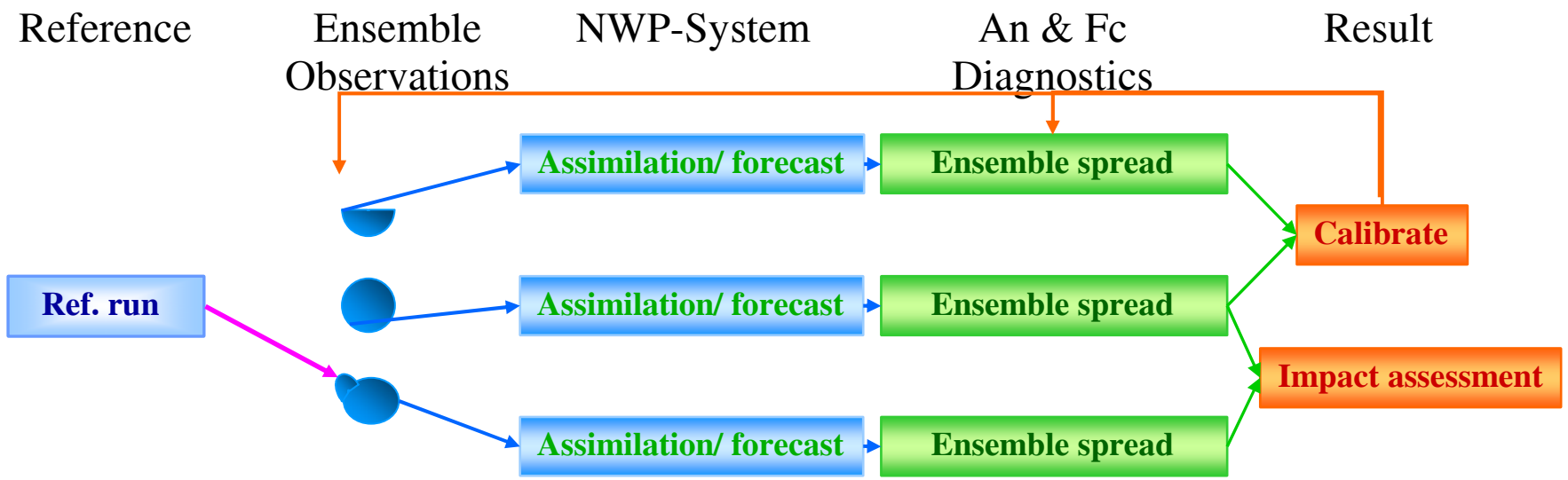
OSE



Assimilation Ensemble



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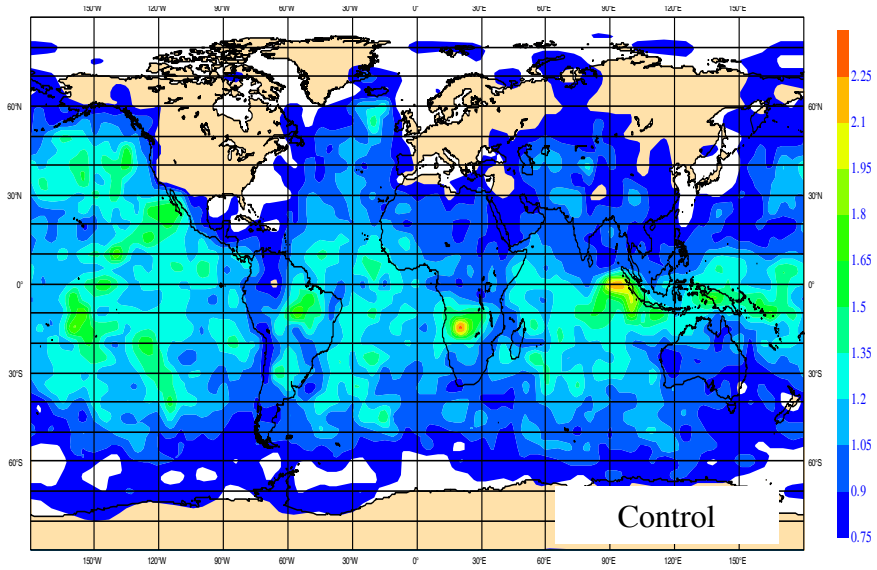
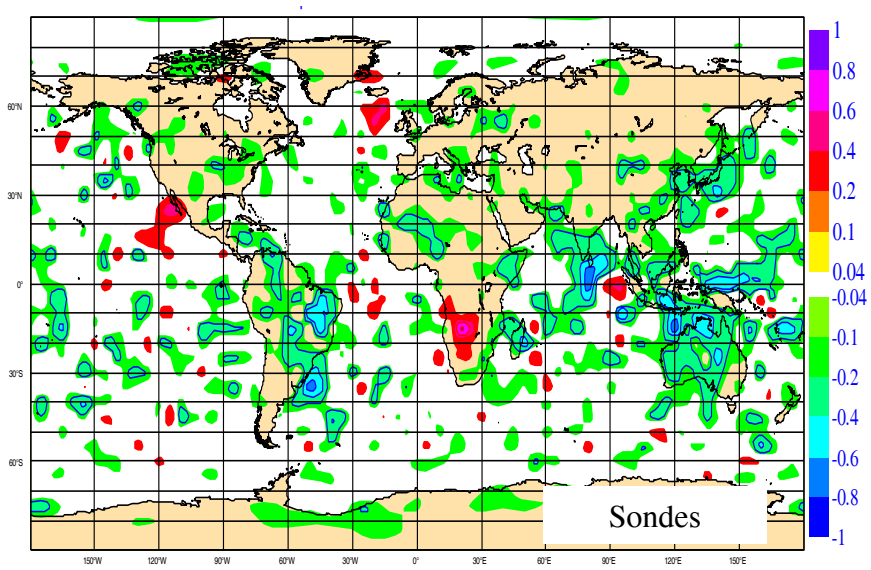
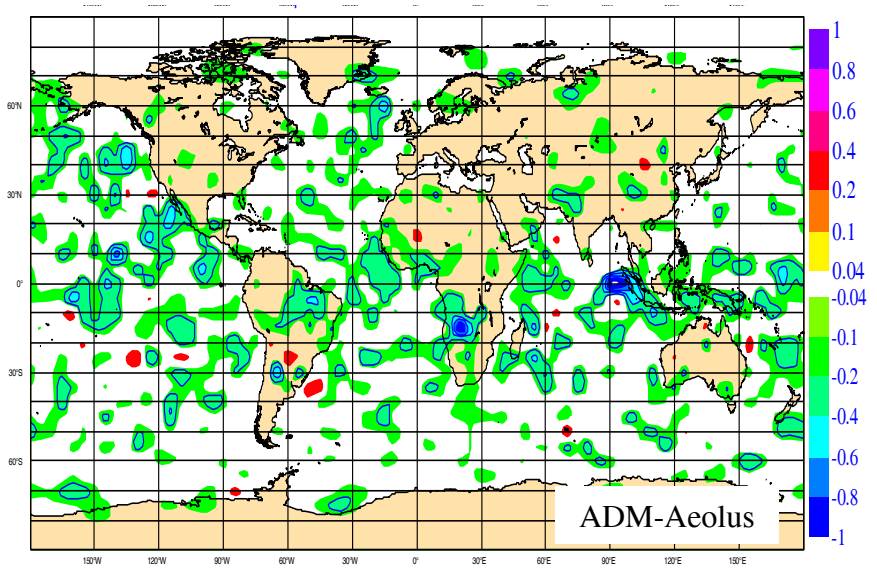
Data impact on ensemble forecasts - zonal wind spread at 500 hPa







- Radiosondes and wind profilers over Japan, Australia, N.Amer, Europe
- DWL over oceans & tropics
- Some features more obvious at 200 hPa …

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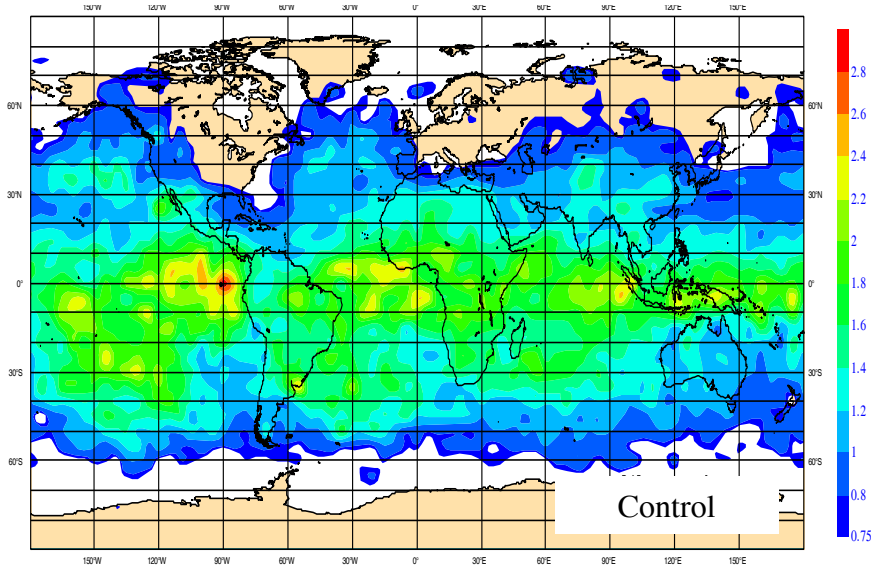
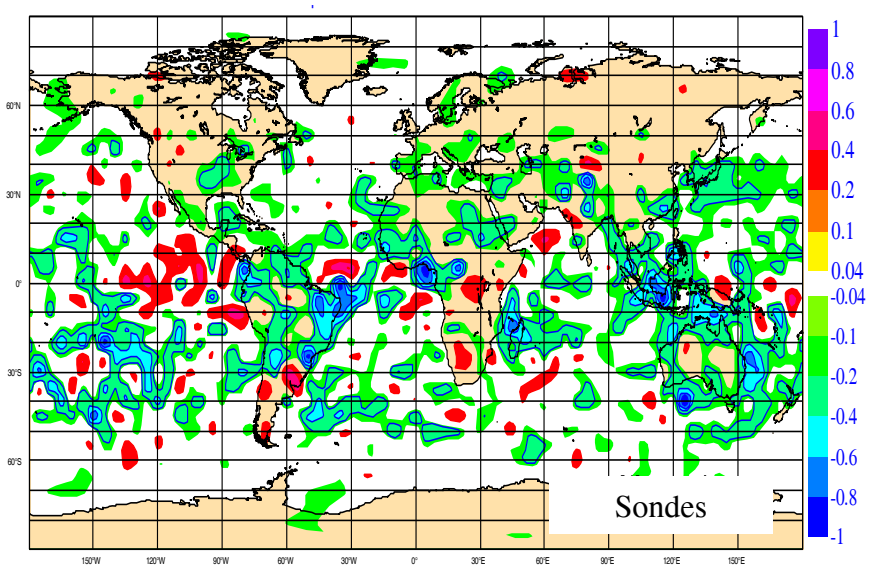
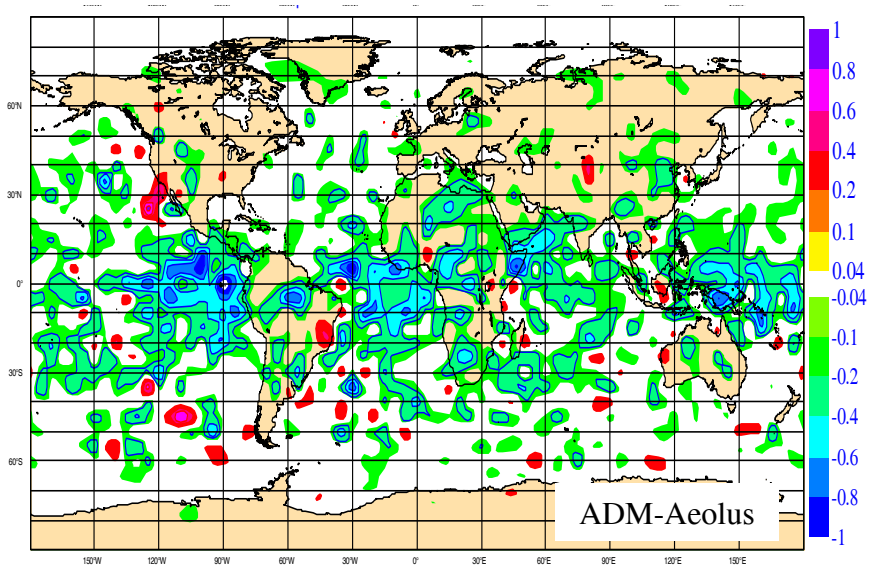
Data impact on ensemble forecasts - zonal wind spread at 200 hPa







- Radiosondes and wind profilers over Japan, Australia, N.Amer, Europe
- DWL over oceans and tropics

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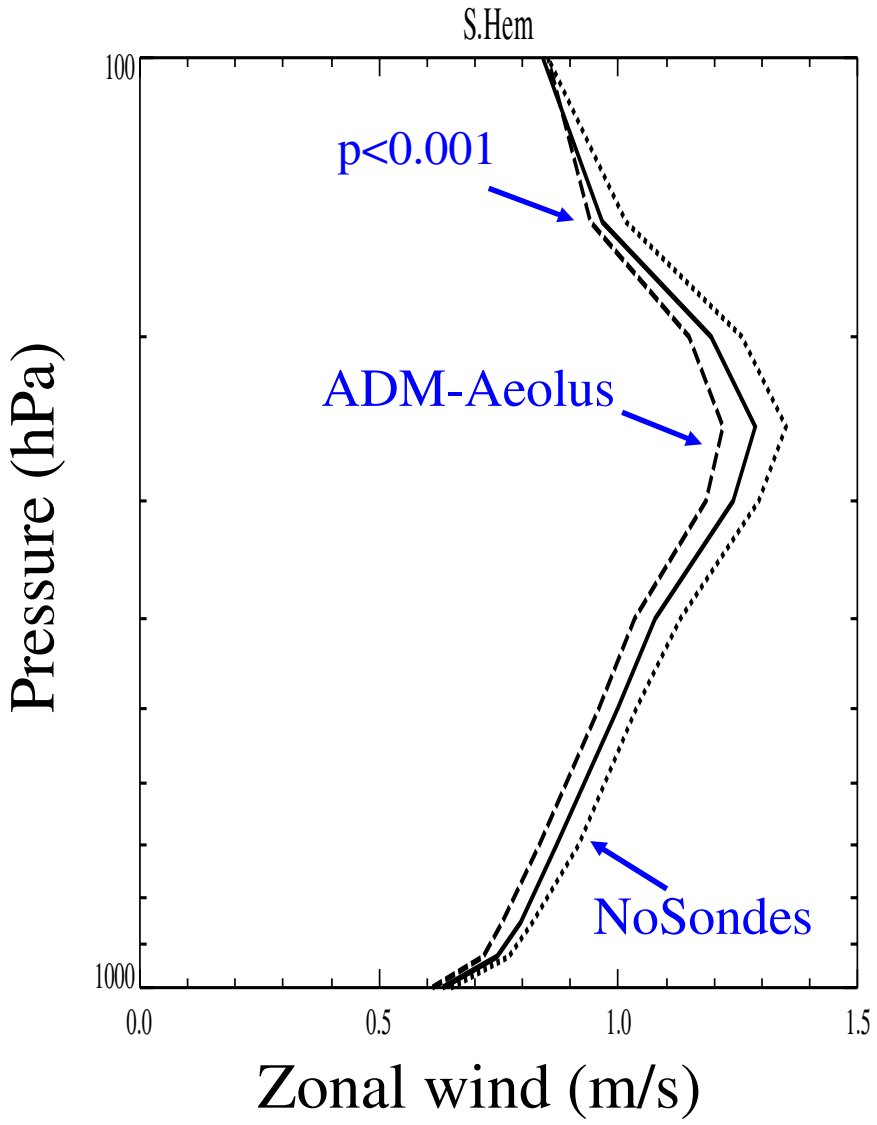
Profiles of 12-hr Fc impact, Southern Hemisphere



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

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Global information content - consistent

- Mike Fisher for Entropy Reduction & DFS
  - $S \sim \log(\det(P^A))$
    $\sim \mathrm{tr} (\log (J'' {}^{-1}))$
  - J'' = 4d-var Hessian
  - P^A = analysis error covar.
- DWL data are accurate and fill data gaps
  - subject to usual caveats about simulated data

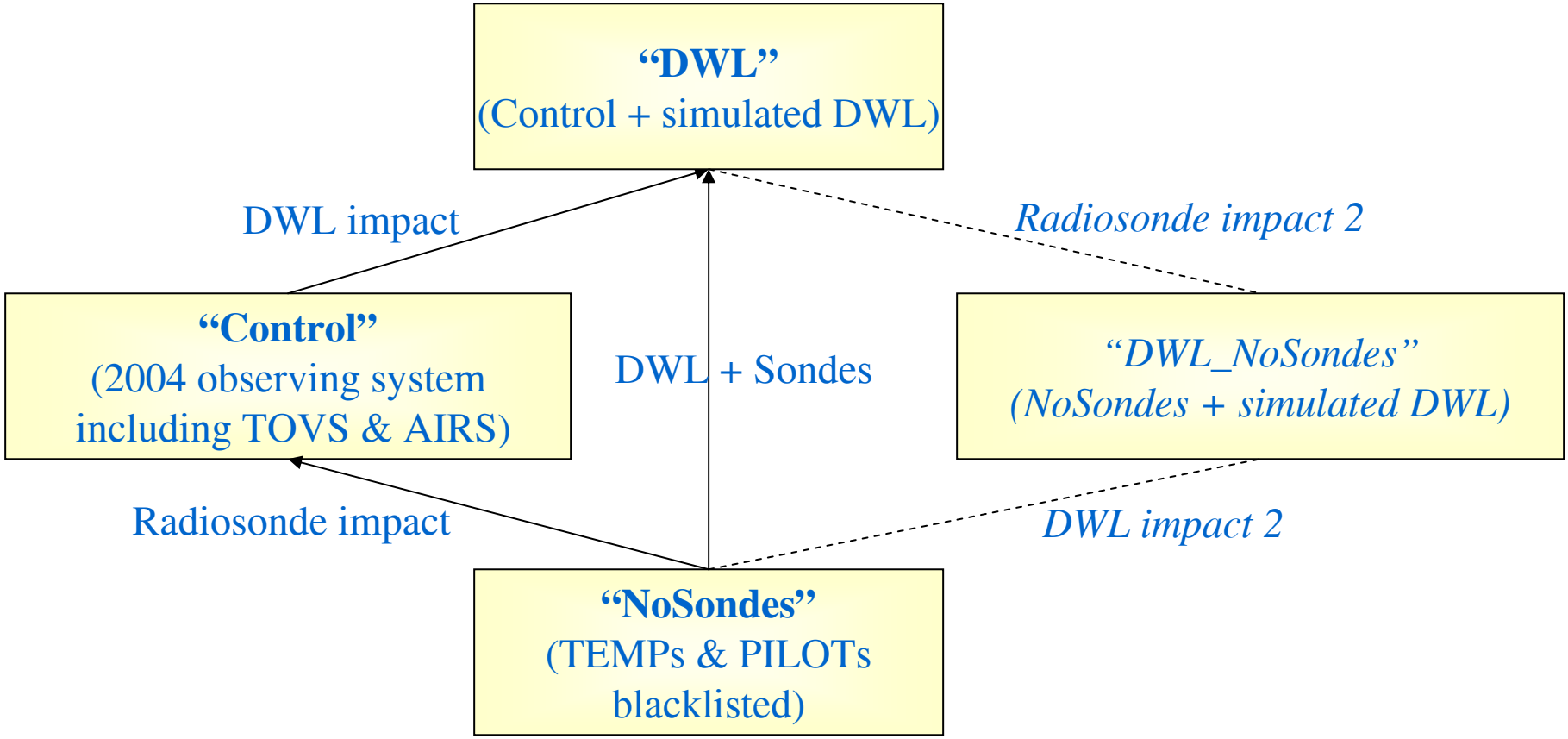
	TEMP/PILOT	Simulated DWL
Data considered	u,v to 55 hPa	HLOS
Entropy_Reduction ("Info bits")	4830	3123
Deg_Free_Sig	3707	2743
N_Obs	90688	50278
Info bits per obs	0.053	0.062
N_Obs/Deg_Free_Sig	24.5	18.3
Redundancy		2 — 3 %

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)

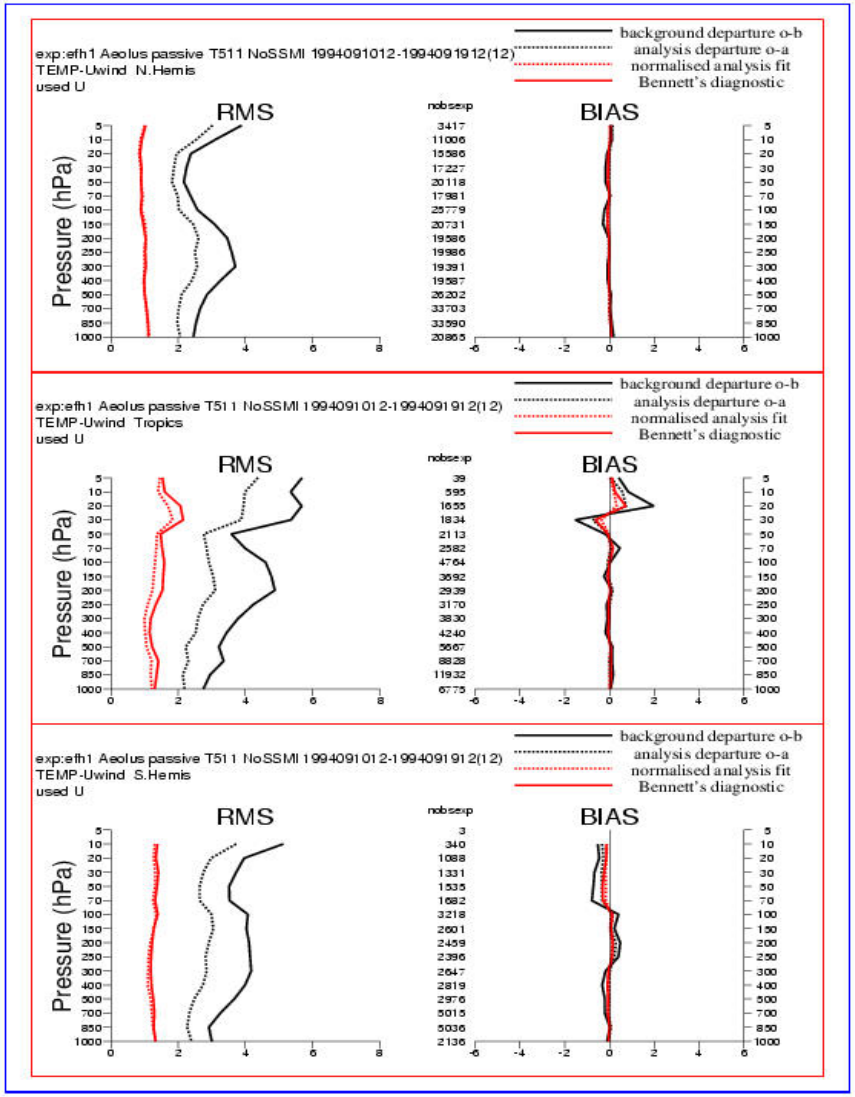
- **Impact = Spread(Ensemble-1) – Spread(Ensemble-2)**
  - *A reduction in spread (negative values) should indicate data benefits*

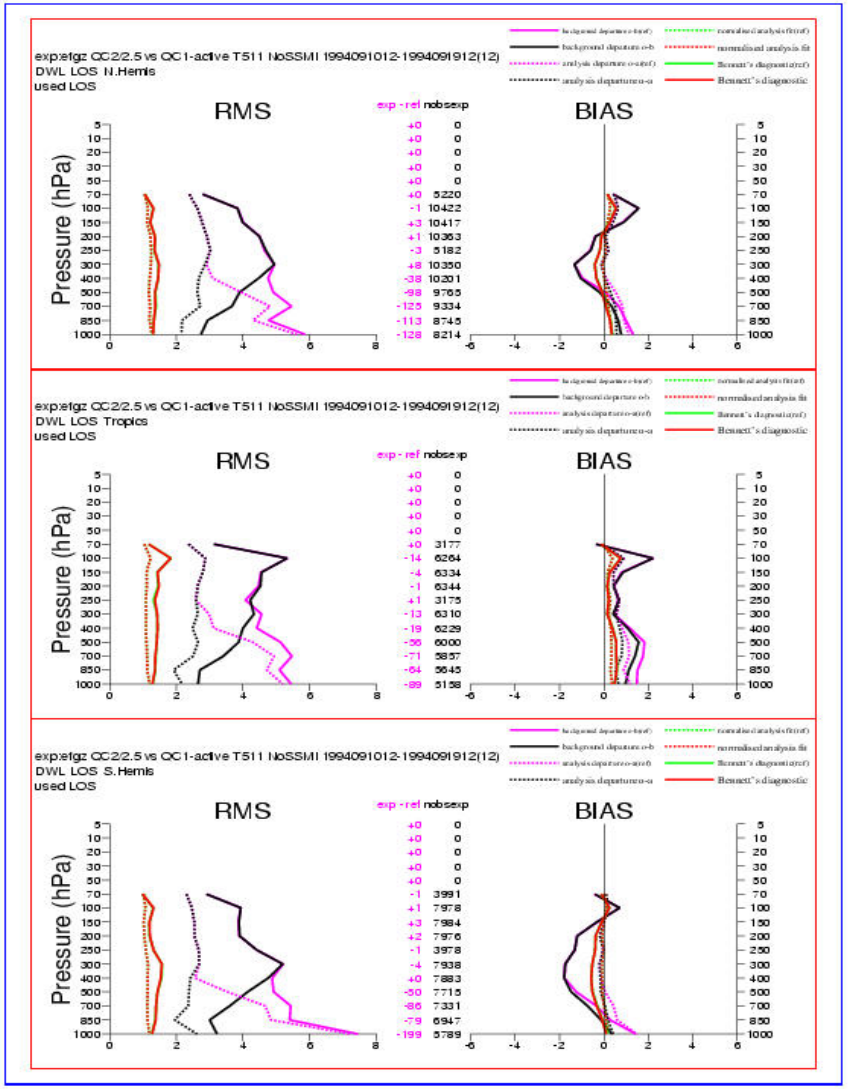


Quality Control Examples: Std + Aeolus-optional QC for DWL -- *active*

Radiosonde U-wind

Option improves departure statistics





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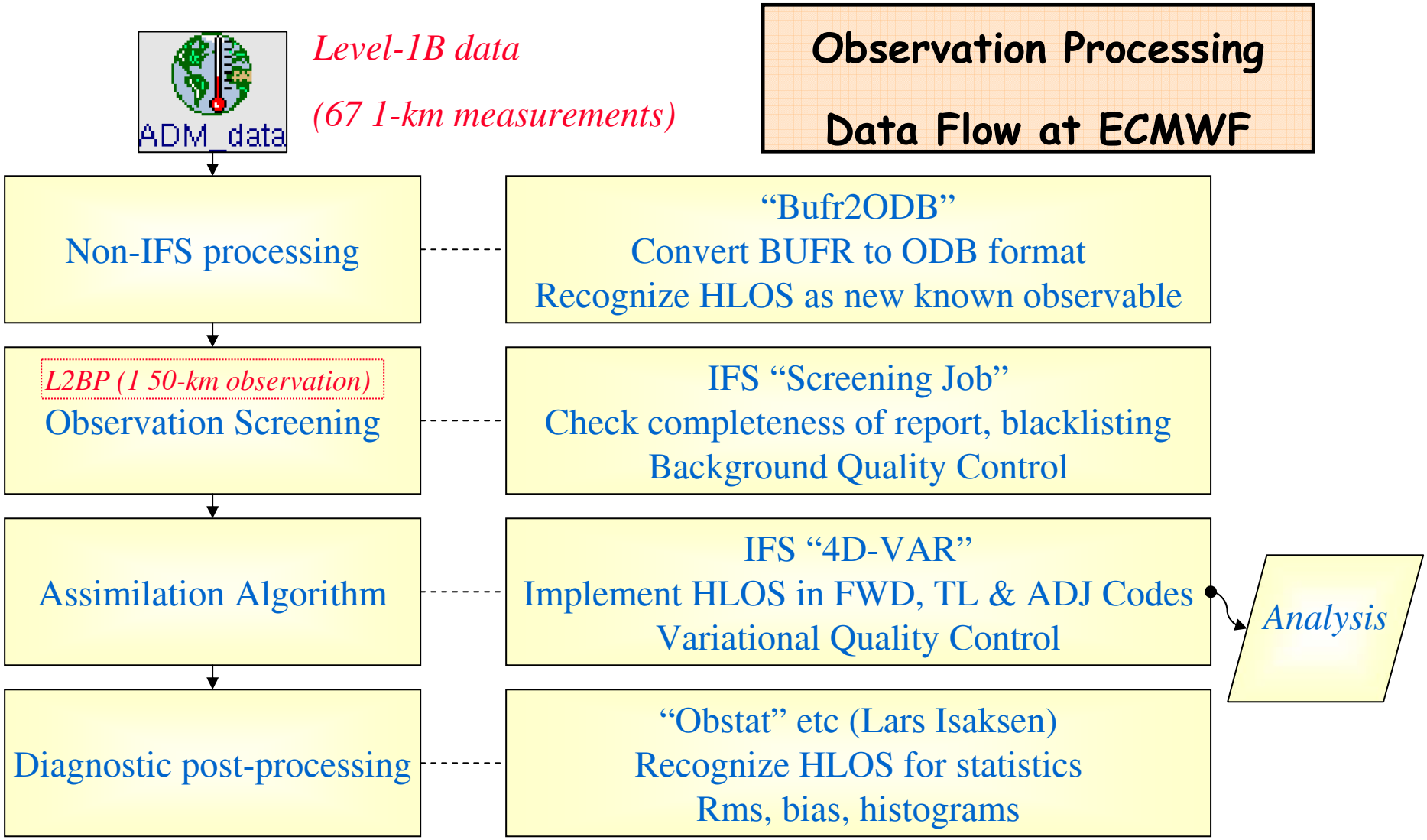
Assimilation of prototype ADM-Aeolus data

Reception of L1B data and L2B processing at NWP centres



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Facts and figures for ADM-Aeolus

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

Orbit	Sun-synchronous	Dawn-dusk
- inclination & altitude	97 °	408 km
Mass - total & "ALADIN" lidar component	1100 kg	450 kg
Transmitter - laser type & pulse energy	Nd:YAG, frequency tripled to 355 nm	150 mJ
- pulse repetition freq. & duty cycle	100 Hz	10 s every 28 s
Receiver - telescope diameter		1.5 m
- spectrometers	Fizeau (Mie)	Dual edge etalon (Rayleigh)
Average power demand	1400 W	
Launch date & mission lifetime	2008	3 years

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 = (obs-bg) / ES(obs-bg), accept obs iff 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 $s_o = \min(\sigma_o, 2.5\ \mathrm{ms}^{-1})$

- 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