Assimilation of GPS radio occultation measurements at the Met Office

Chris Burrows

Thanks to Richard Marriott, Sangwon Joo, Ian Culverwell, Sean Healy and Mike Rennie.

Assimilation of RO at the Met Office

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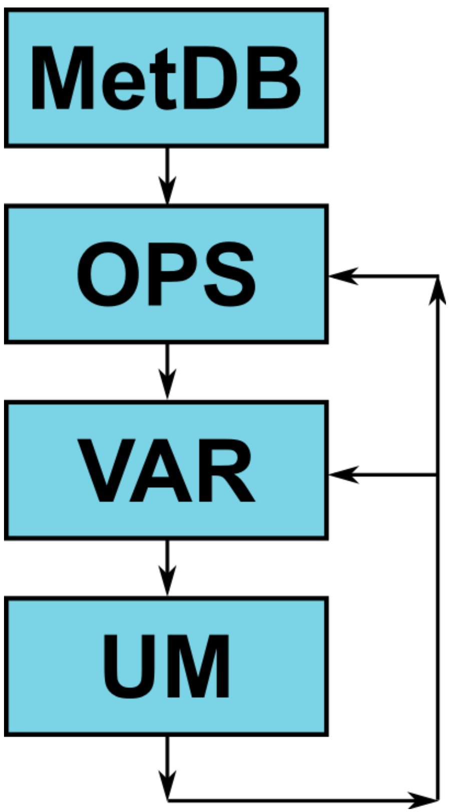
The EUMETSAT Network of Satellite Application Facilities

ROM SAF
Radio-Occultation Meteorology

Met Office assimilation system



- All observations are stored in the MetDB database.
- Initially, observations undergo QC in the OPS system.
- Good observations are then passed to an incremental 4D-Var system (VAR).
- The resulting increments are applied to the background which is used as an initial point for the Unified Model (UM).
- The UM is run for a number of areas/resolutions. RO is used in the global and North Atlantic/European models.
- There are “update runs” which use late-arriving data.

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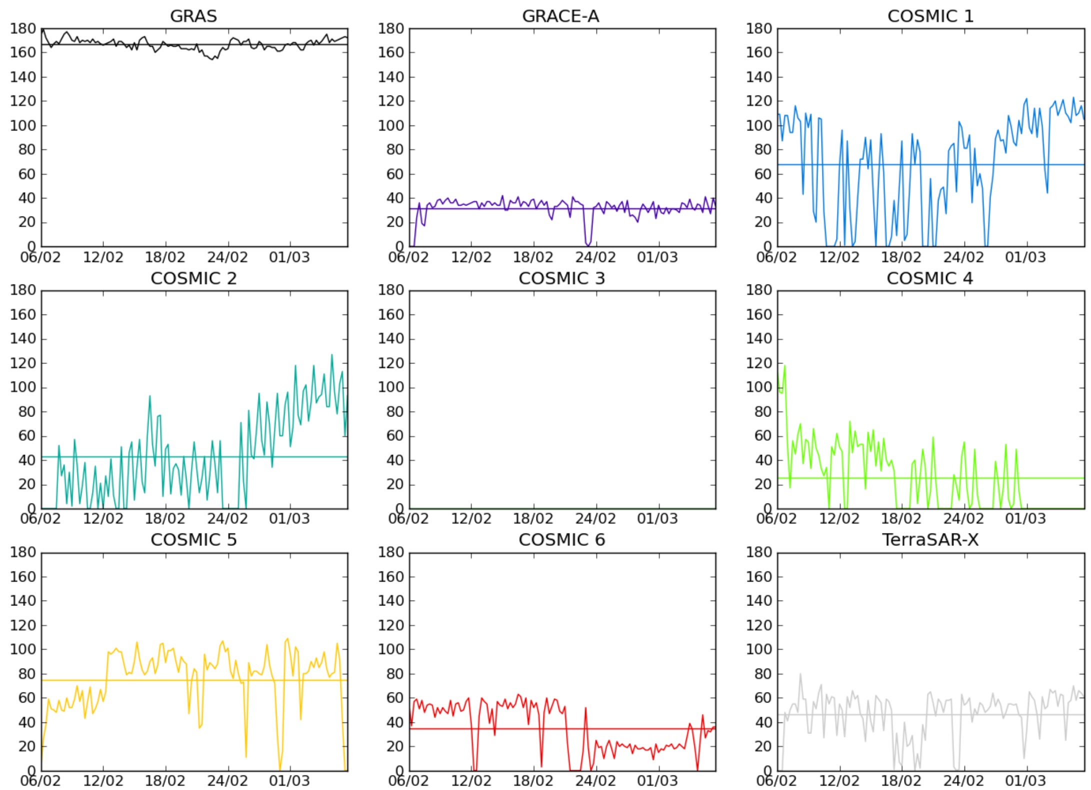
GPSRO – data used (number of occultations per 6 hours)

Met Office

All plots on same scale



We are also monitoring the quality of C/NOFS prior to assimilating it operationally.

In each 6-hourly cycle, we usually receive around 500 timely RO profiles.

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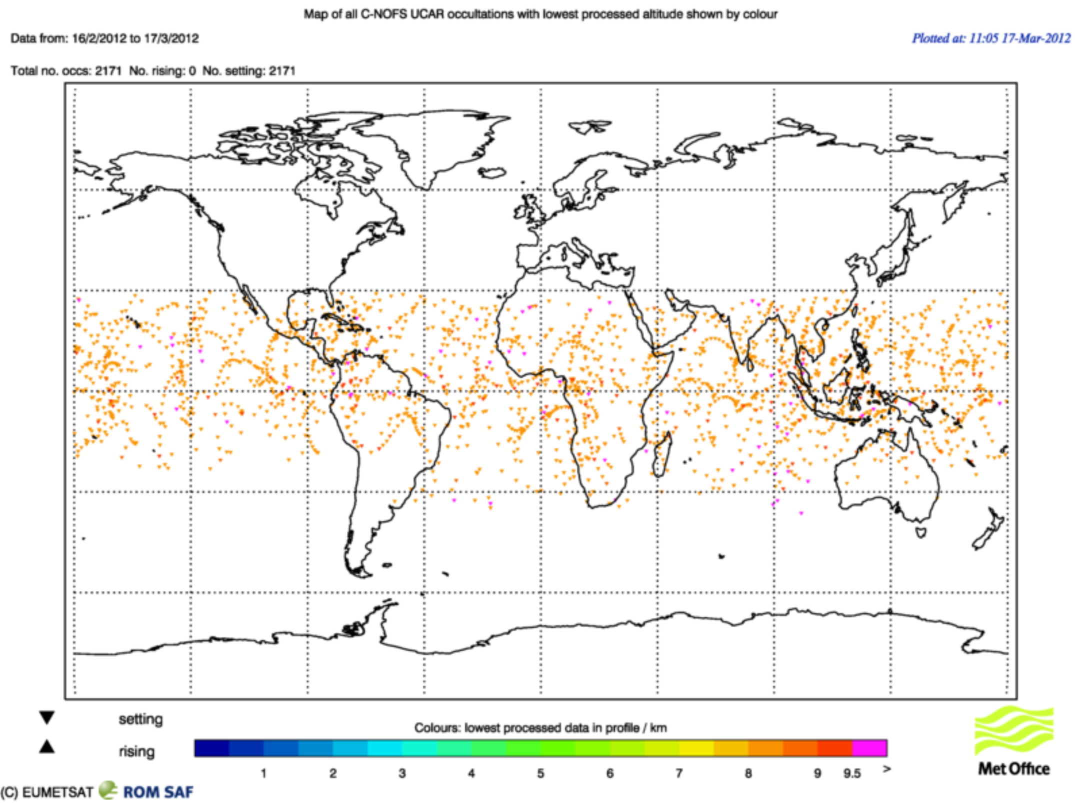
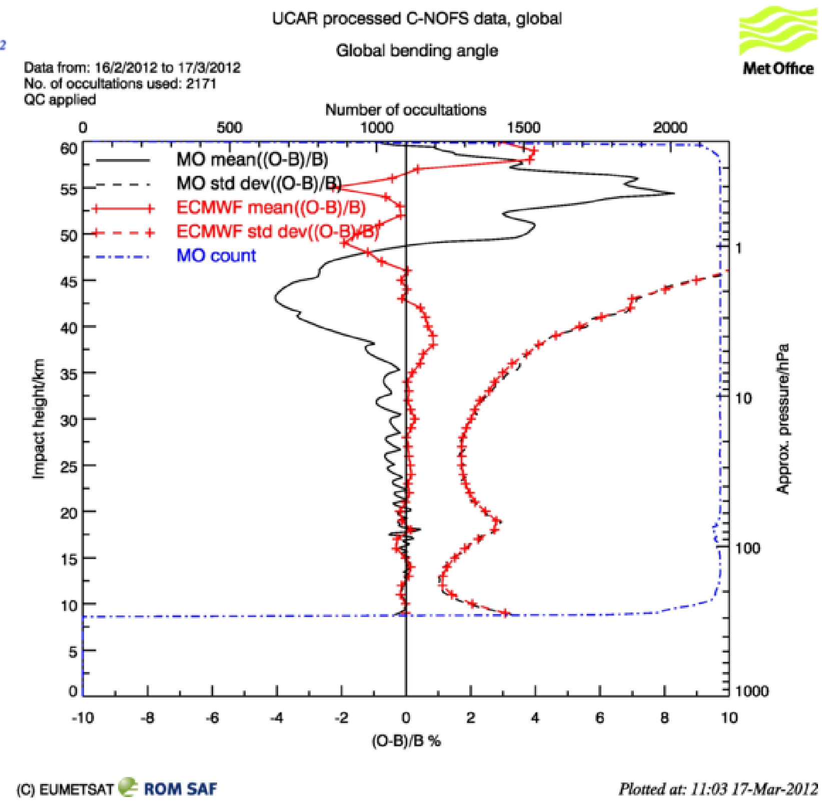
C/NOFS quality





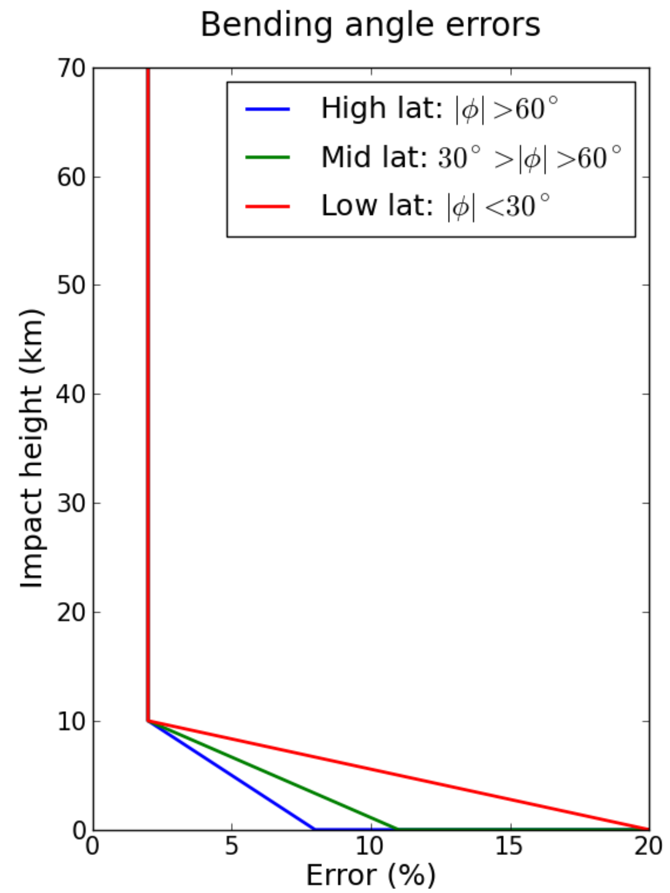
Coverage is confined to tropics, though existing data are sparse in this region.

O-B stats look worse than other satellites, globally but are comparable in the tropics.

Met Office

GPSRO assimilation

- As of 2010 we have been assimilating bending angles [Mike Rennie].
- We still have the refractivity capability for research/monitoring.
- Our error model is based on that used at ECMWF, but the errors are slightly larger (2% instead of 1.5% above 10km). The minimum absolute error is 6μrads. No correlations.
- A 1D-Var is carried out on each profile for QC, and then the good observations are passed to the incremental 4D-Var system.
- These obs are assimilated at the *nominal lat-lons*.



Rennie, M. P.: Q. J. Roy. Meteor. Soc., 136, 116–131

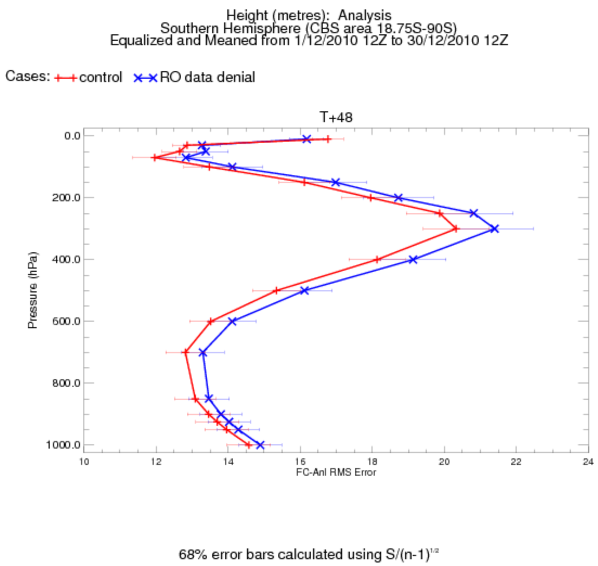
ROM SAF

Impact – data denial experiment

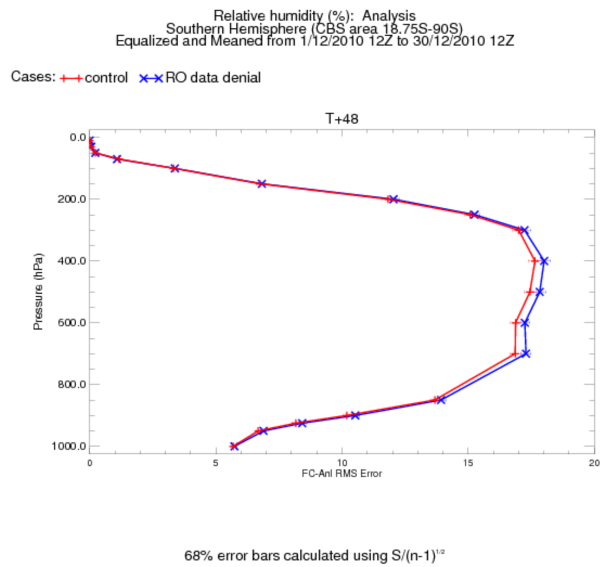
Met Office

- The impact of RO is largest in the southern hemisphere.
- In the southern hemisphere, the height-profiles of RMS error increase when RO is removed from the assimilation system.
- Impact is a lot smaller in the NH.

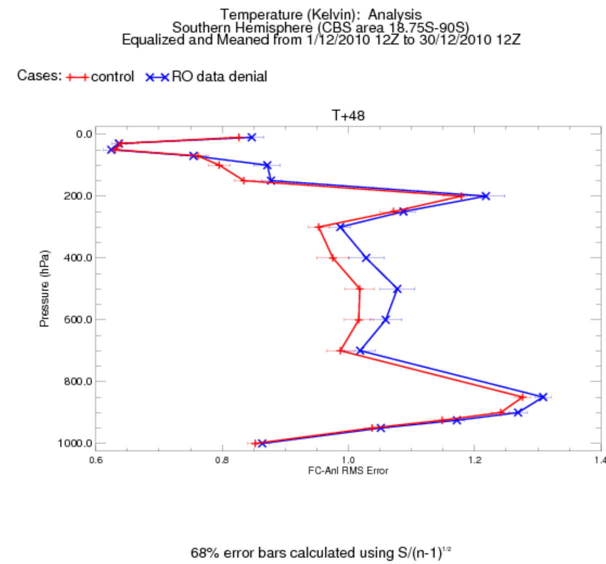
Height



RH



Temp.



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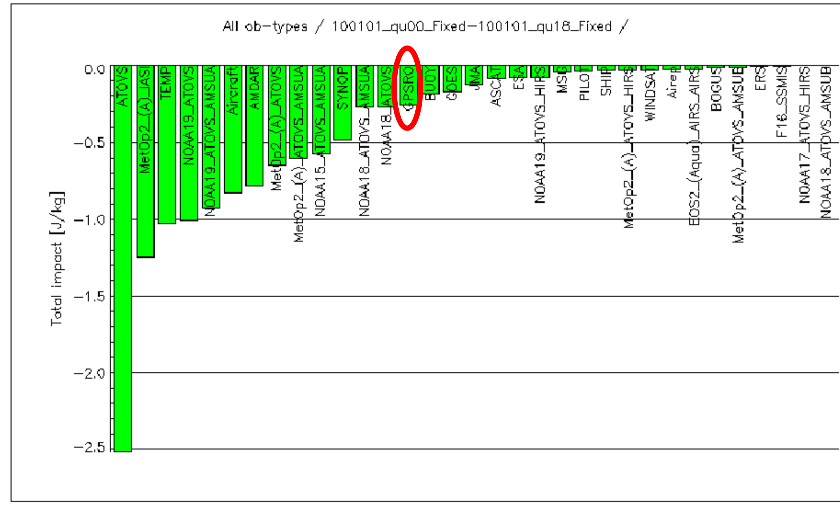
Adjoint sensitivity studies (by Sangwon Joo*)



Total impact – moist energy norm (up to 150hPa).

cf. ECMWF.

* KMA, on secondment to the Met Office

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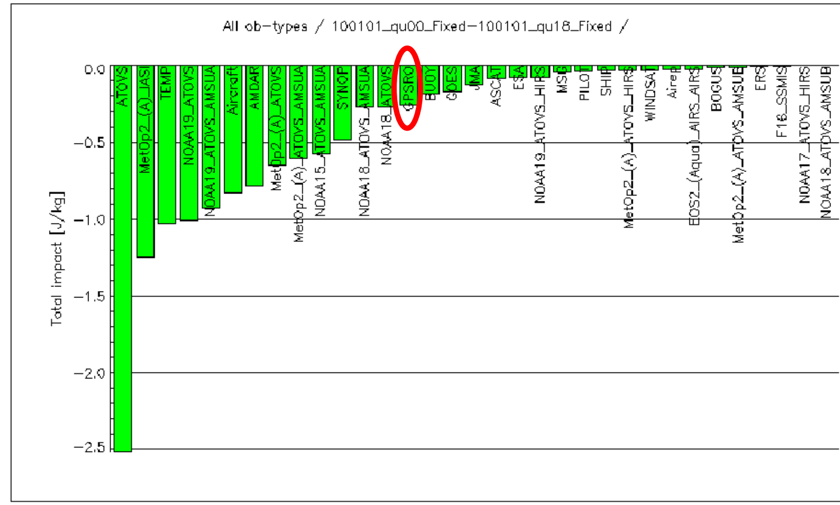
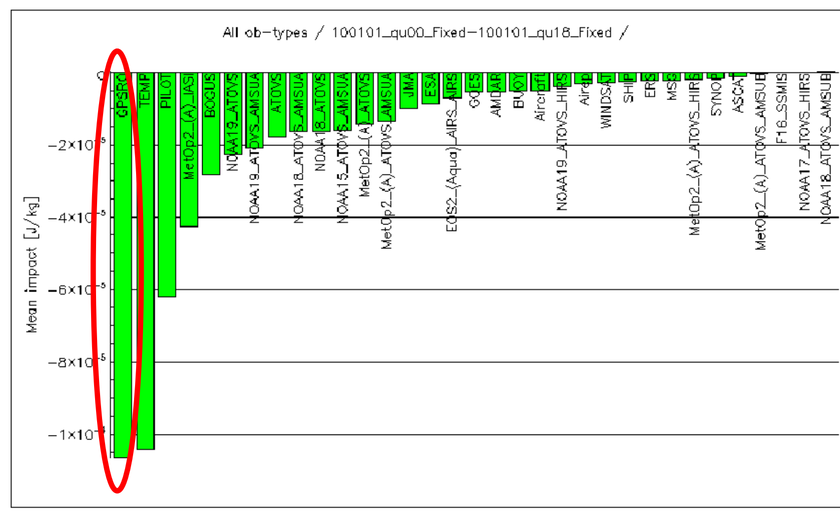


Impact per observation (up to 150hPa).



* KMA, on secondment to the Met Office

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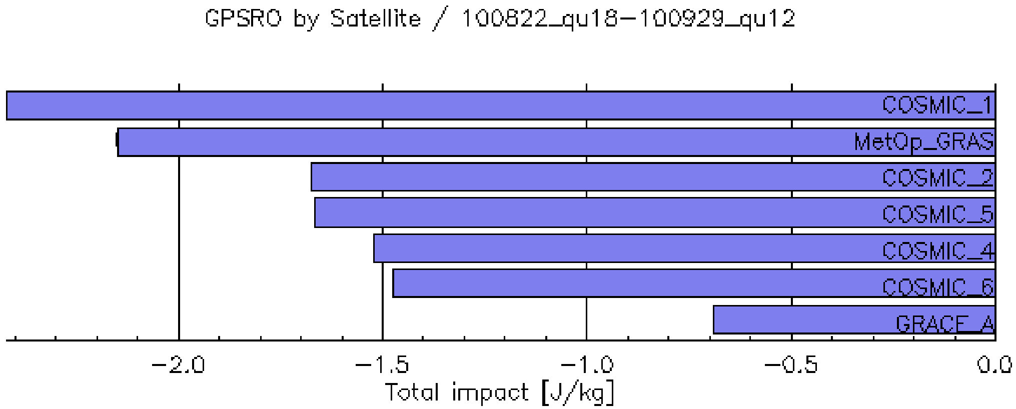
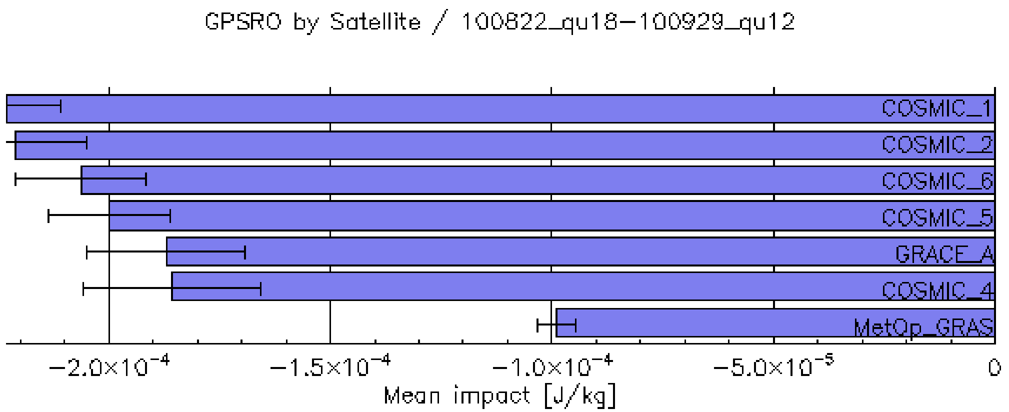
Adjoint studies (Richard Marriott)



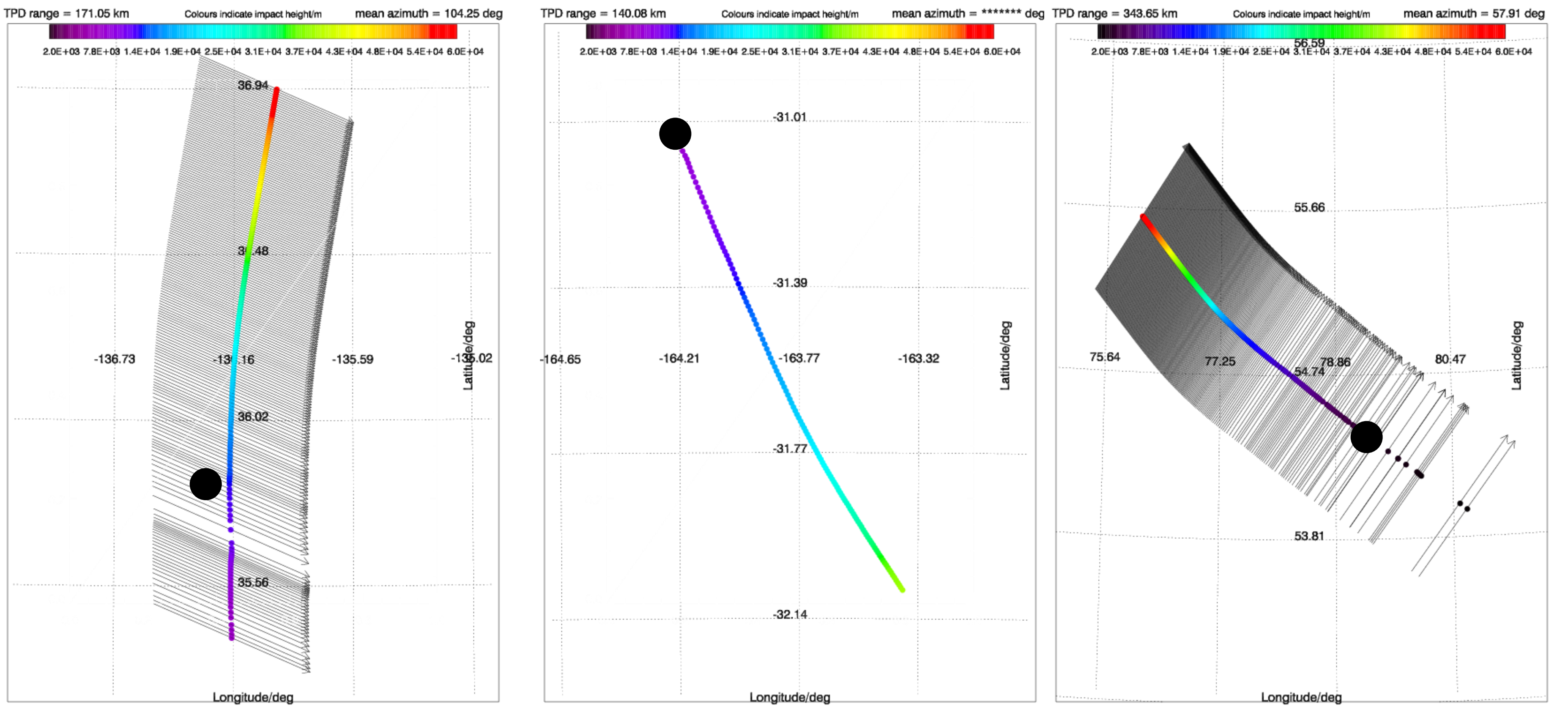
Total impact – moist energy norm (up to 150hPa).



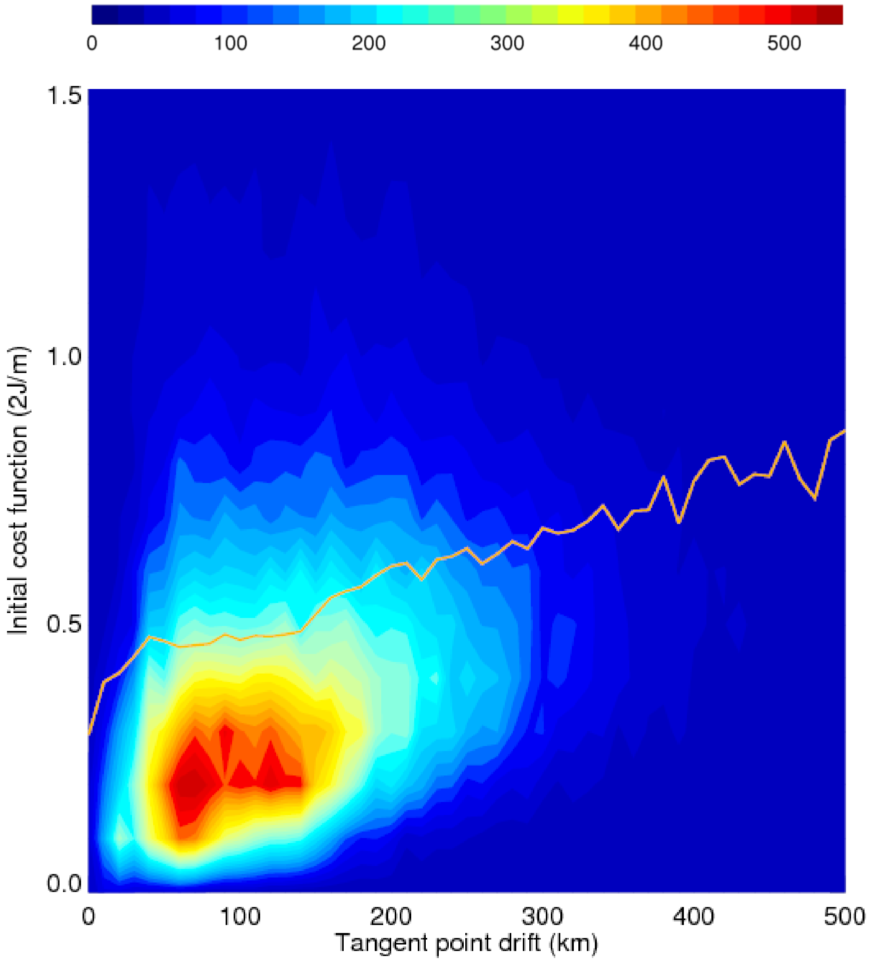
Impact per observation (up to 150hPa).

Tangent point drift – different definitions

GRAS TerraSAR-X COSMIC-FM2



Bending angle 1D-Var initial cost function



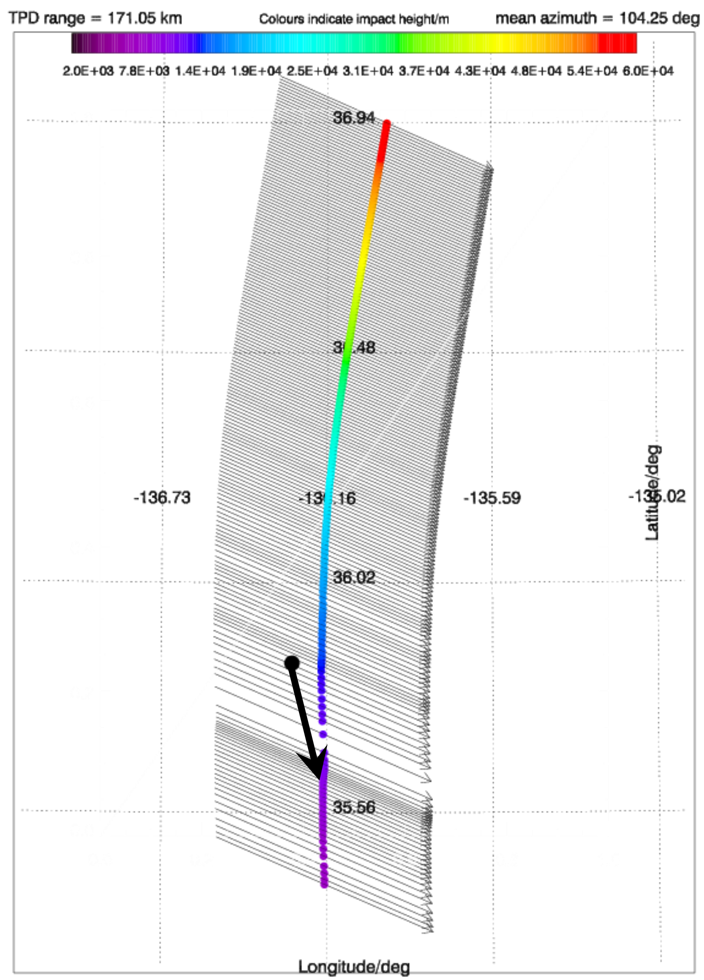
- The colour scale shows the number of occultations in December 2011.
- The orange line shows the mean initial cost function for each value of tangent point drift.
- Dependence is roughly linear with some offset.

Tangent point drift – different approaches

- Ignore – what we currently do. Drift is comparable to horizontal resolution. Spherical symmetry is assumed in pre-processing. Current global model resolution is 25km at mid-latitudes.
- Reassign nominal lat-lon (like DWD).
- Account for the drift fully (improvement in impact operationally at ECMWF and in experiments at NCEP).
- Map drifted positions back to the nominal point with a suitable transform (?).

Reassignment of lat-lons

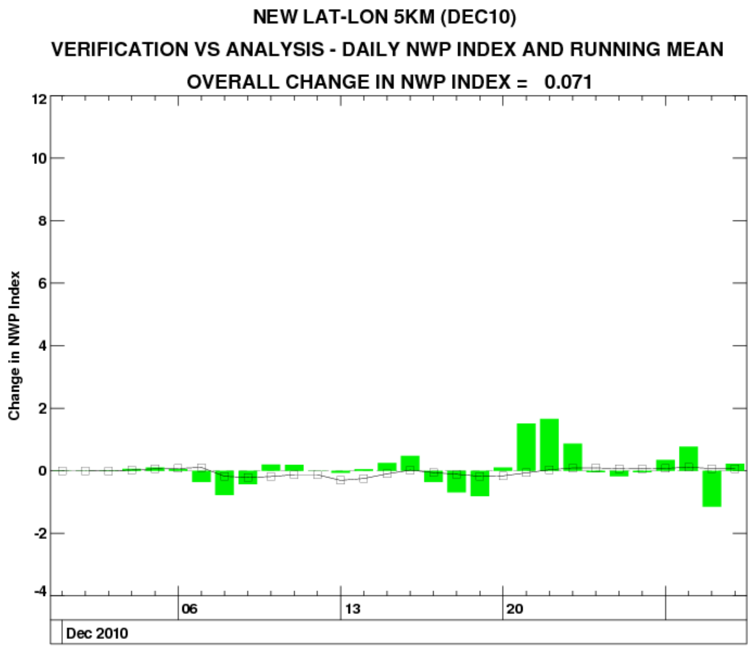
- New scheme (similar to DWD) – the user selects an impact height, and the lat-lon associated with the observation level closest to this value becomes the new occultation point.
- Improves consistency between data from different processing centres, though it will tend to favour the level set by the user.
- This could become an option in ROPP (Radio Occultation Processing Package developed by the ROM SAF).



Impact of lat-lon reassignment

- Initial studies show that this implementation produces a broadly neutral impact.
- Not too surprising – occultation point isn't shifted very far.
- Trial period was 1 month – not long enough to see a clear signal in any of the parameters (changes much smaller than error bars).
- This approach offers flexibility for the occultation point height to be chosen by the user, but these results suggest it could be more beneficial to include the tangent point drift in full.

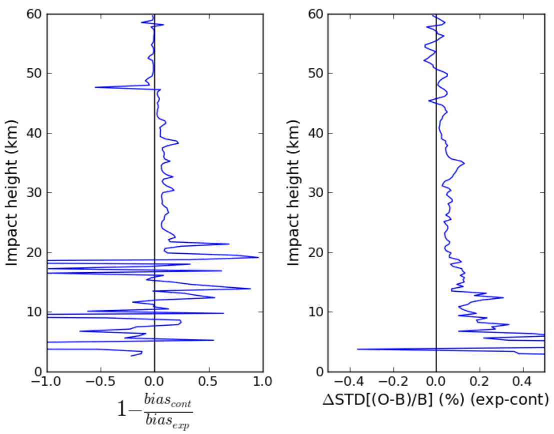
Change in skill



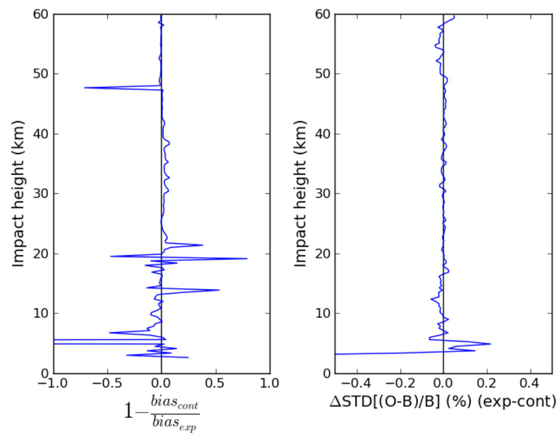
Impact of lat-lon reassignment

- In observation space – some very quick results (523 occultations – all satellites in a 6 hour period).
- Plotted fractional change in bending angle bias (-ve good) and percentage change in standard deviation (-ve also good)
- Noisy data, but a trend is apparent: at 5km, there is little change (to be expected based on existing definitions of the occ pt. At 0km the bias and stdev are worse, and at 15km they are better.

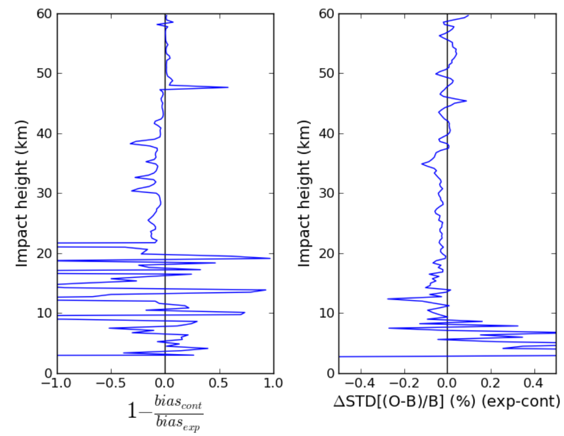
0km



5km

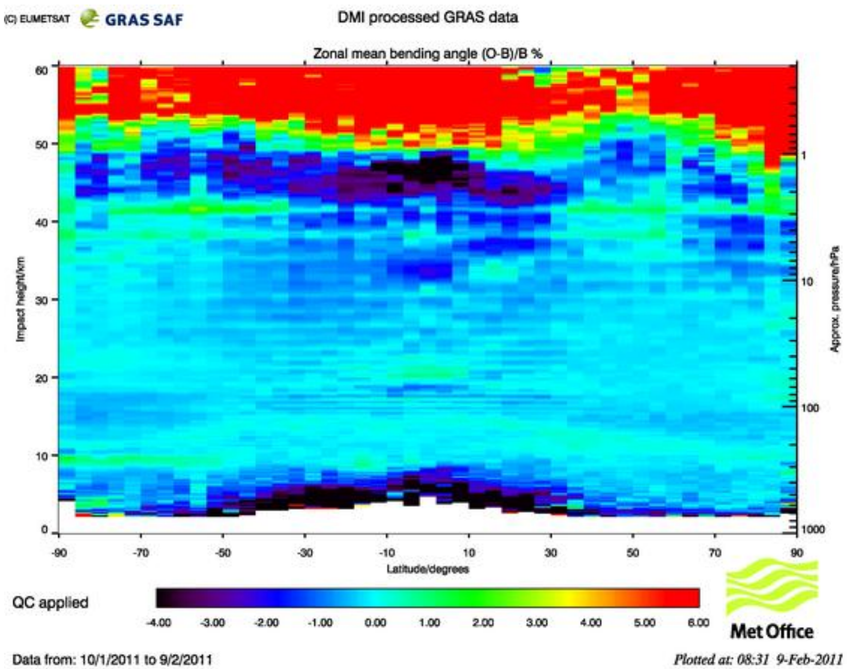


15km

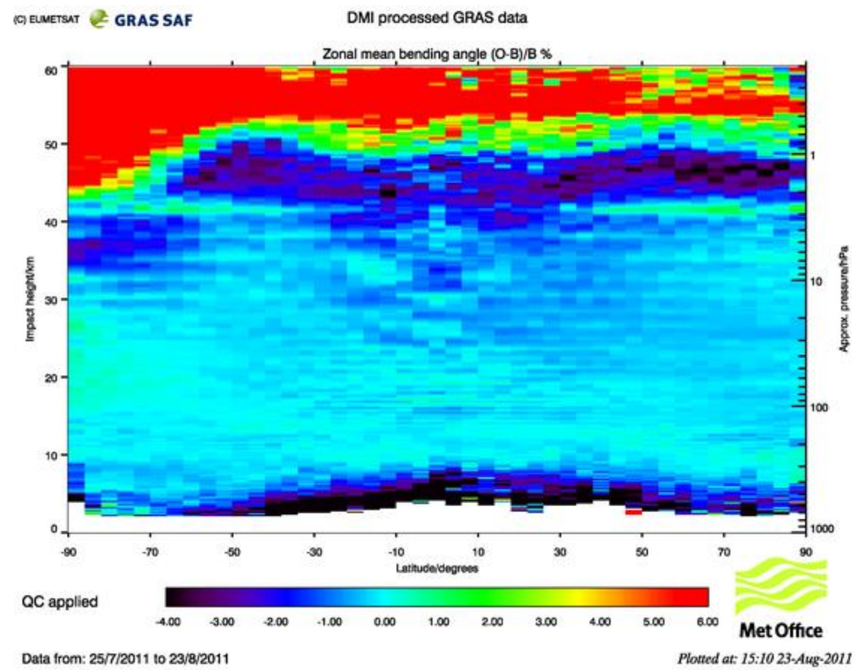


Seasonal observation errors (BA)

Feb



Aug

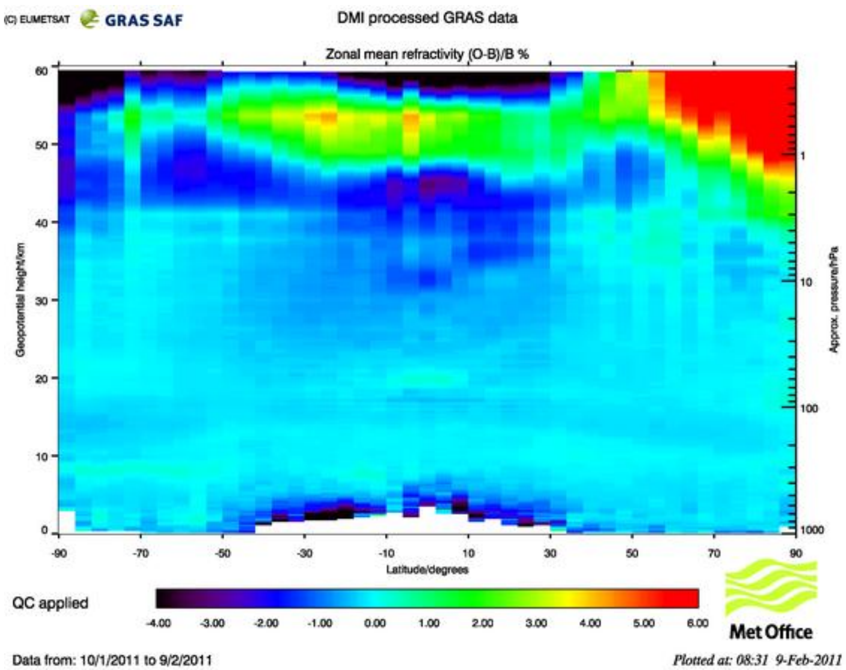


- The O-Bs in bending angle space show strong seasonal dependence at high levels. The winter hemisphere has a much larger bias. It is unclear how much of this is model or observation.
- We may consider implementing a Scherllin-Pirscher error model.
- Fully accounting for tangent point drift may help?

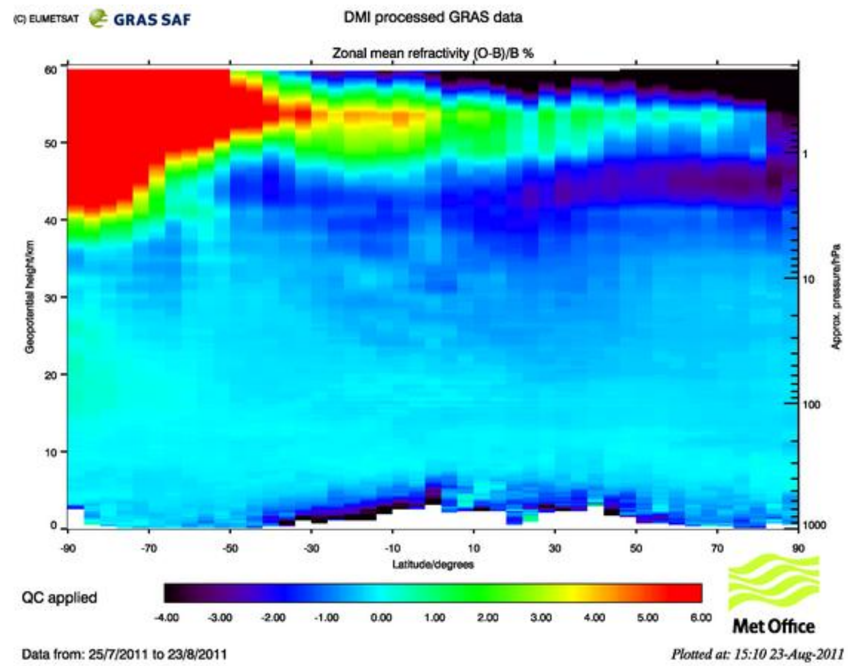
Scherllin-Pirscher, B., et al. 2011: Atmos. Meas. Tech., 4(9), 1875-1890

Seasonal observation errors (Ref.)

Feb



Aug



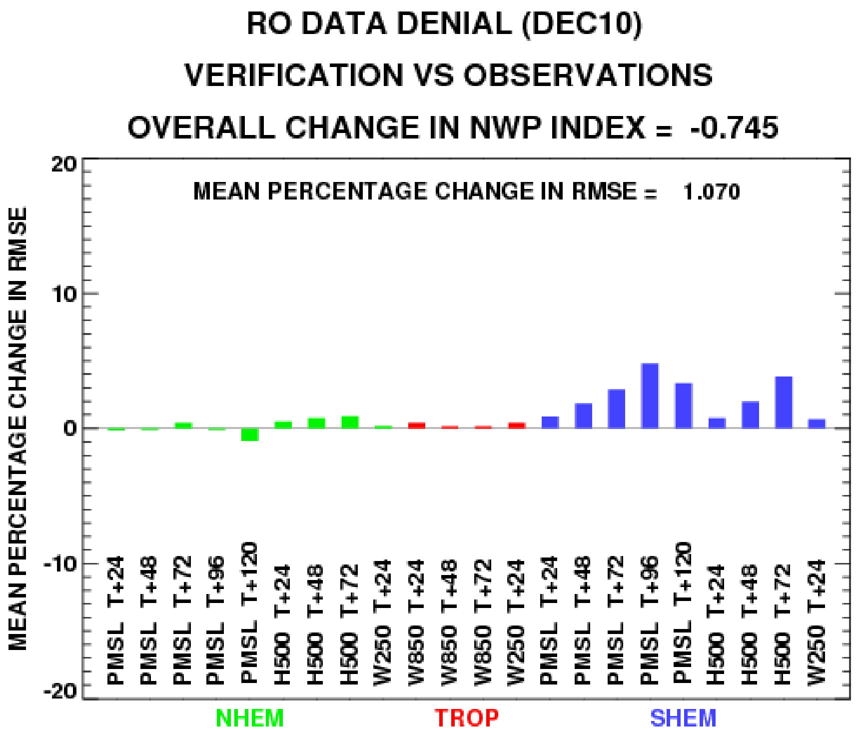
- Also present in refractivity statistics, so the problem isn't due to the bending angle forward model.

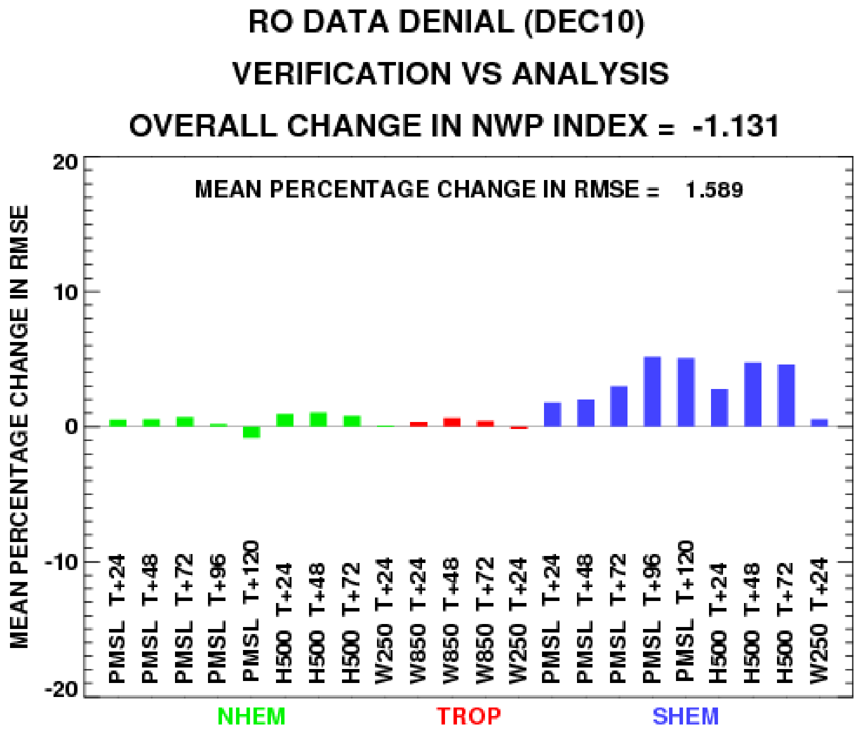
Other future work

- Assimilate new satellites (esp. MetOp-B).
- Use GRAS bending angles processed with wave-optics – better in the troposphere due to multipath effects.
- Investigate dynamic error allocation.
- Consider using non-ideal-gas compressibility factors in refractivity forward model.
- Use adjoint sensitivity results to help improve selection of good profiles.

Questions and answers

Impact – data denial experiment

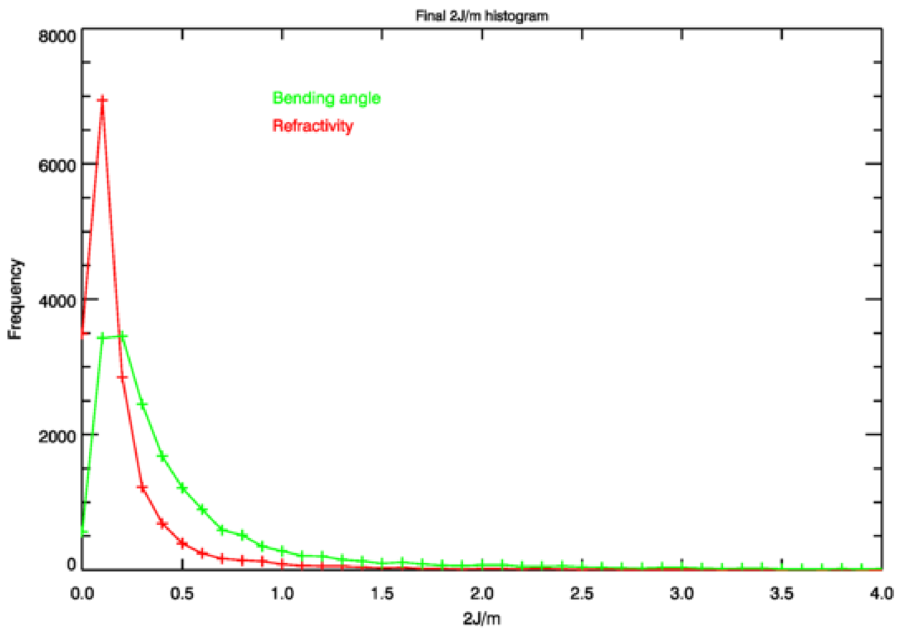




- The impact of RO is largest in the southern hemisphere.
- RO provides up to a 5% improvement in RMS error in PMSL.

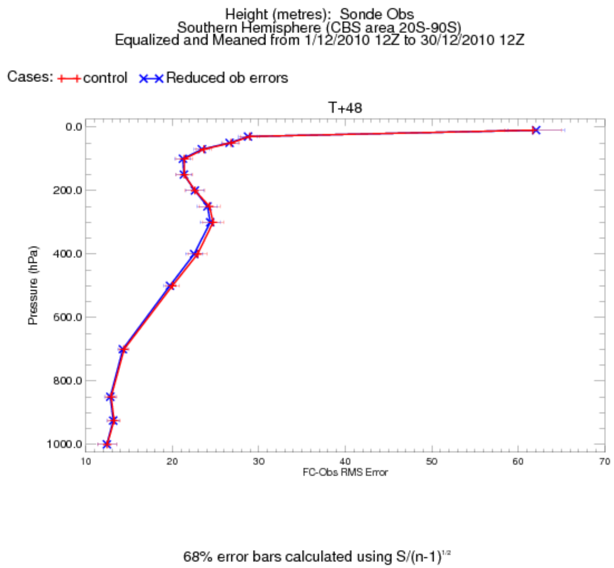
Observation errors (bending angle)

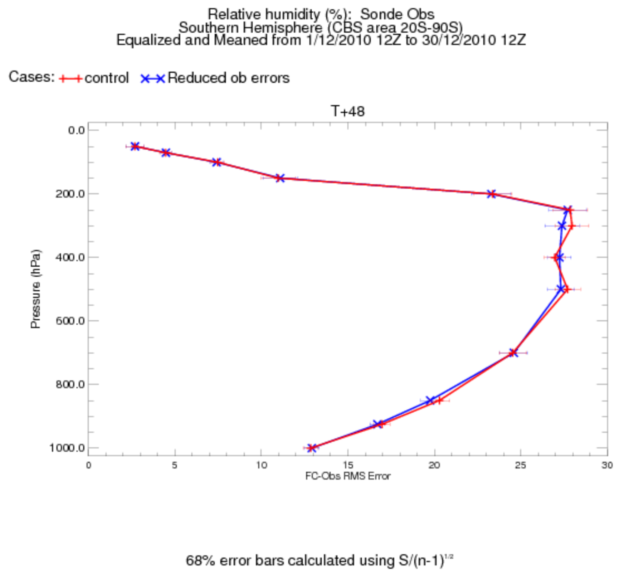
- 1D-Var studies show that the final cost function (2J/m) tends to be ~0.2 suggesting that the observation or background errors are too large.
- A trial was carried out to see the effect of reducing the observation errors to more closely match those at ECMWF (1.5% above 0km, and a 3 μrad minimum absolute error).

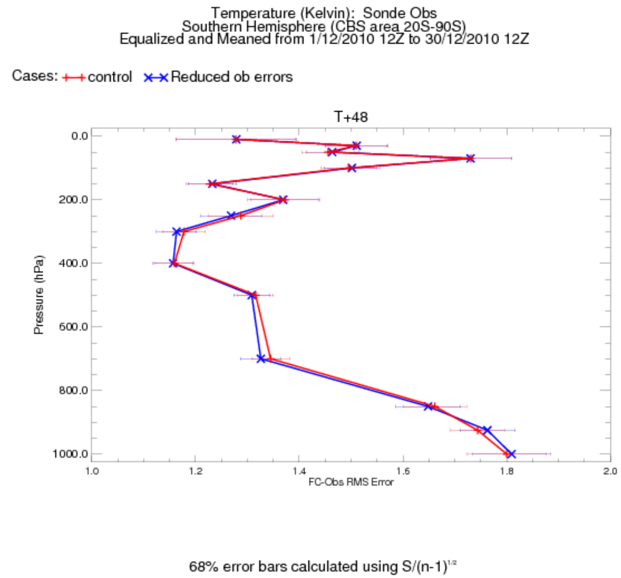


Observation errors (bending angle)

- Results show a small positive impact against observations: change in RMS forecast errors are shown below.
- Against analyses, the impact is neutral (slightly negative).
- These small improvements suggest that the error characteristics are fairly well optimised. Further optimisation should then involve variable errors with height (e.g. by a Desroziers analysis).







Adjoint studies (Richard Marriott)