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Revised observation uncertainties for bending angle assimilation

Neill Bowler

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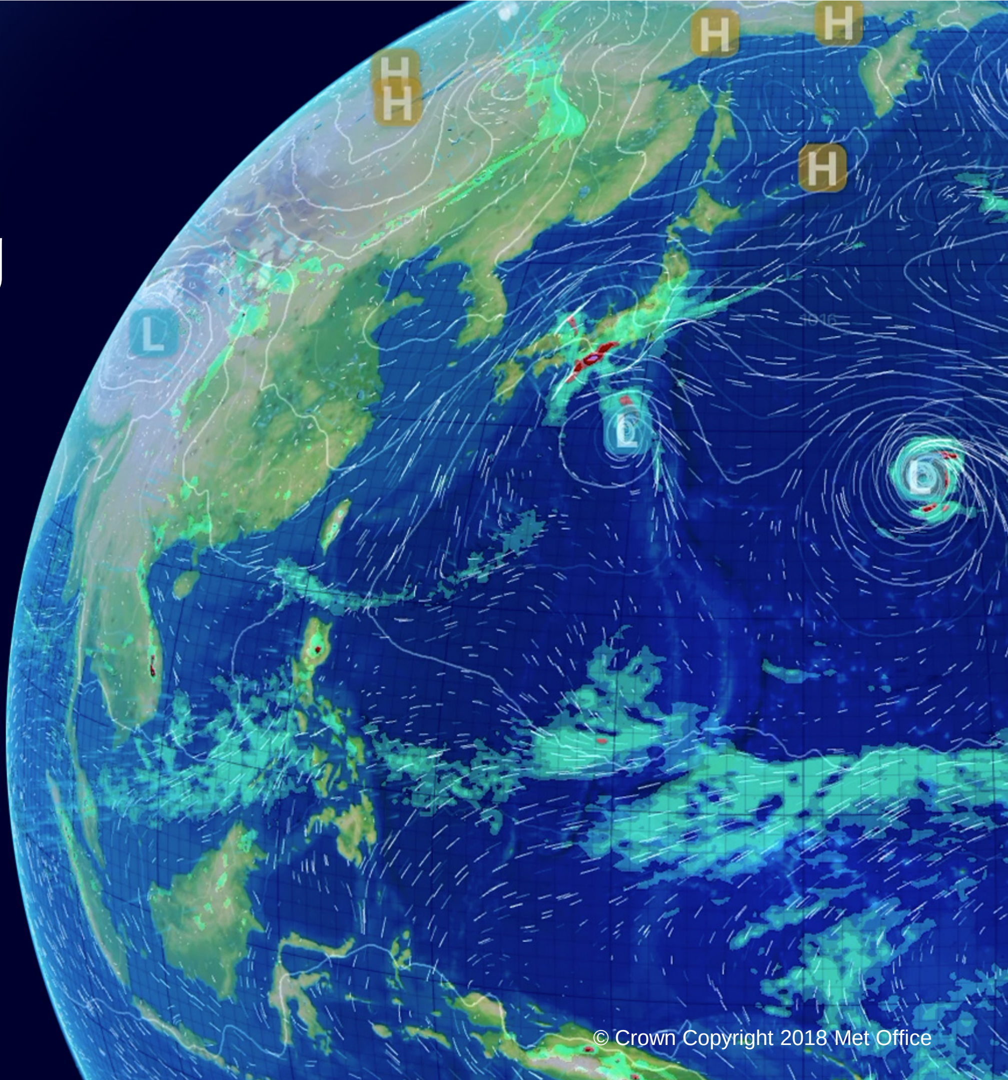

Desroziers' method

- If **H**, **R** and **B** are correctly specified, then:

$$E(\mathbf{d}_a^o(\mathbf{d}_b^o)^T) = \mathbf{R}$$

- If they are not correctly specified, then:

$$E(\mathbf{d}_a^o(\mathbf{d}_b^o)^T) = \mathbf{R}(\mathbf{HBH}^T + \mathbf{R})^{-\mathbf{1}}E(\mathbf{d}_b^o(\mathbf{d}_b^o)^T)$$

$$\mathbf{d}_b^o = \mathbf{y} - H\big(M(\mathbf{x}_b)\big)$$

$$\mathbf{d}_a^o = \mathbf{y} - H\big(M(\mathbf{x}_a)\big)$$

Correction term – would apply to background errors as well

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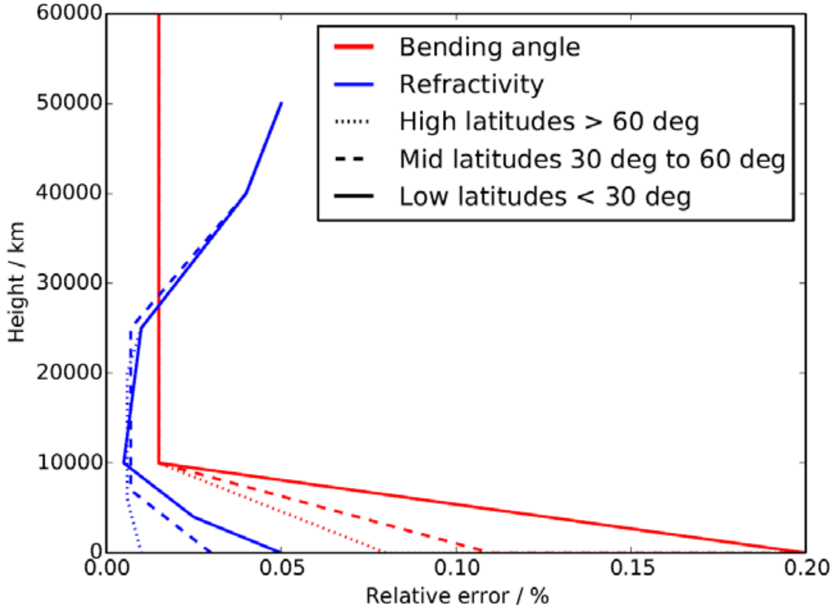
Reminder

- Desroziers' method uses innovations and residuals to determine the observation and background uncertainties
- It can only provide a correction to the input covariances
- Calculated using 1m trialing (16th Dec 2017 – 16th Jan 2018)
- Assimilating all normal satellites + FY-3C and COSMIC-6

- Not using Hollingsworth and Llonberg, or the three-cornered hat method

Current observation uncertainties



- Errors relative to observed bending angle
- Minimum of 3 μrad (applies above 40km)
- No dependence on satellite ID
- All 1.5% above 10km

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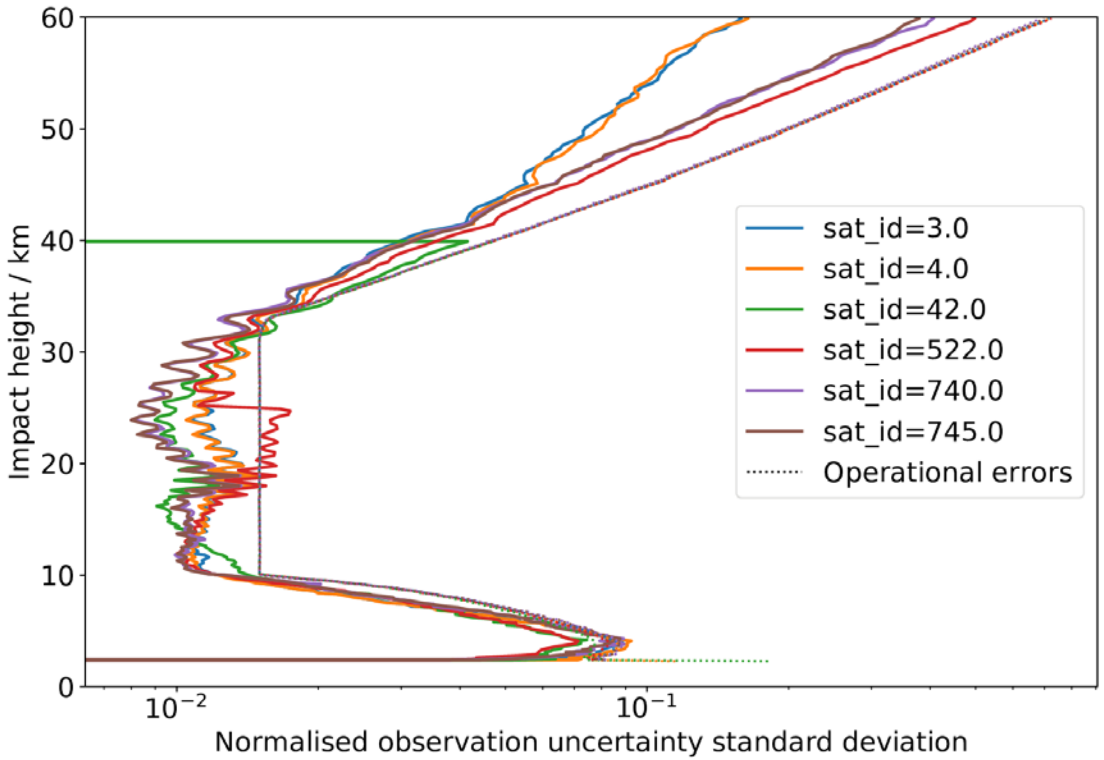
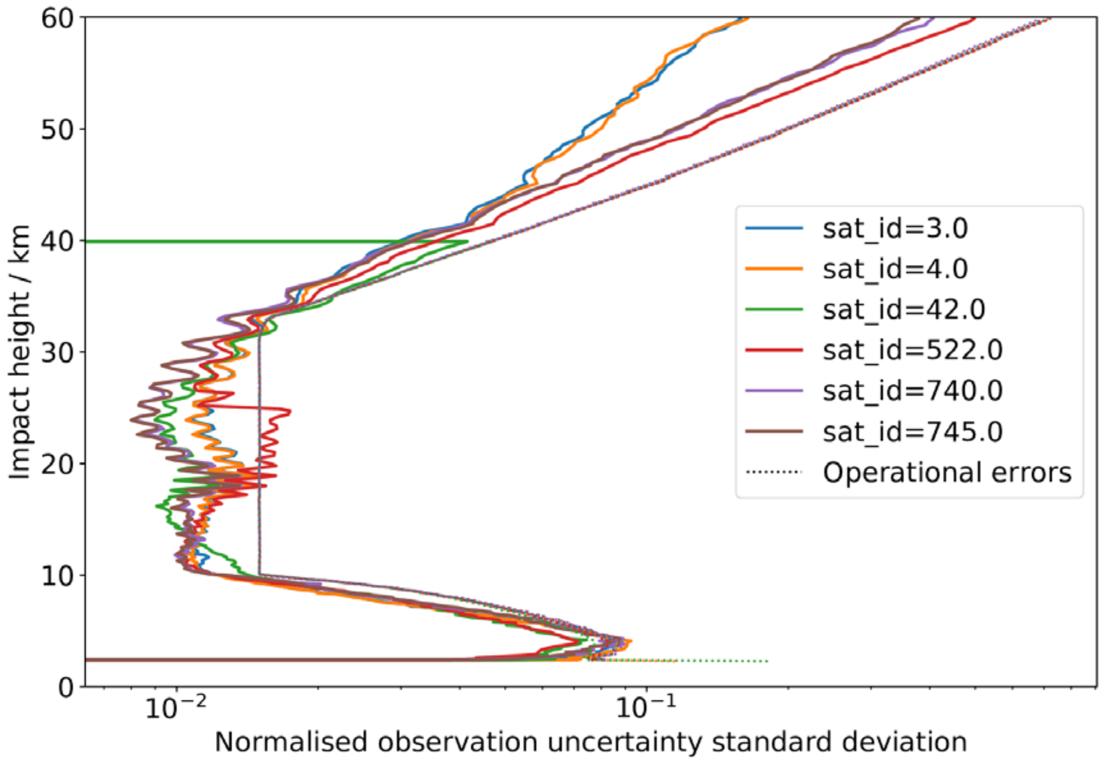
Variation with satellite



- Note: oscillations above 15km due to interpolation between model levels

Variation with satellite – Above 35km



- Metop A/B: Smaller standard deviations above 45km
- FY-3C: Slightly larger standard deviations
- TerraSAR-X: Not assimilated above 40km
- All uncertainties smaller than operational (3μ rad assumed minimum)

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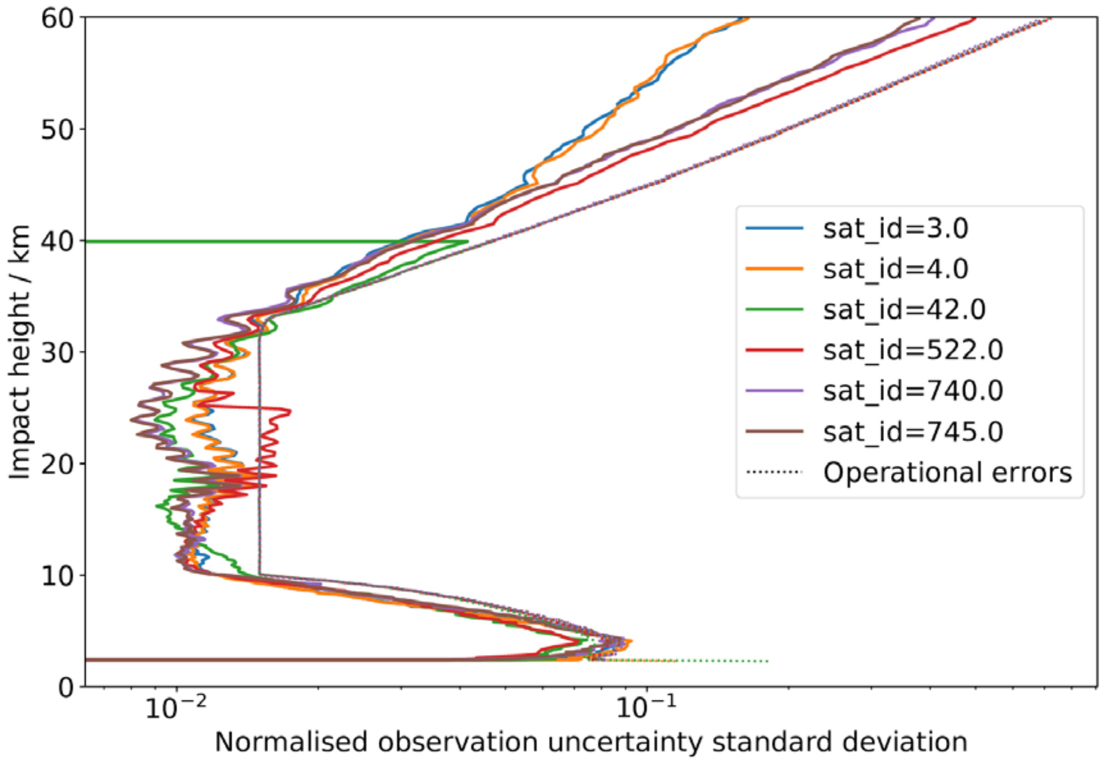
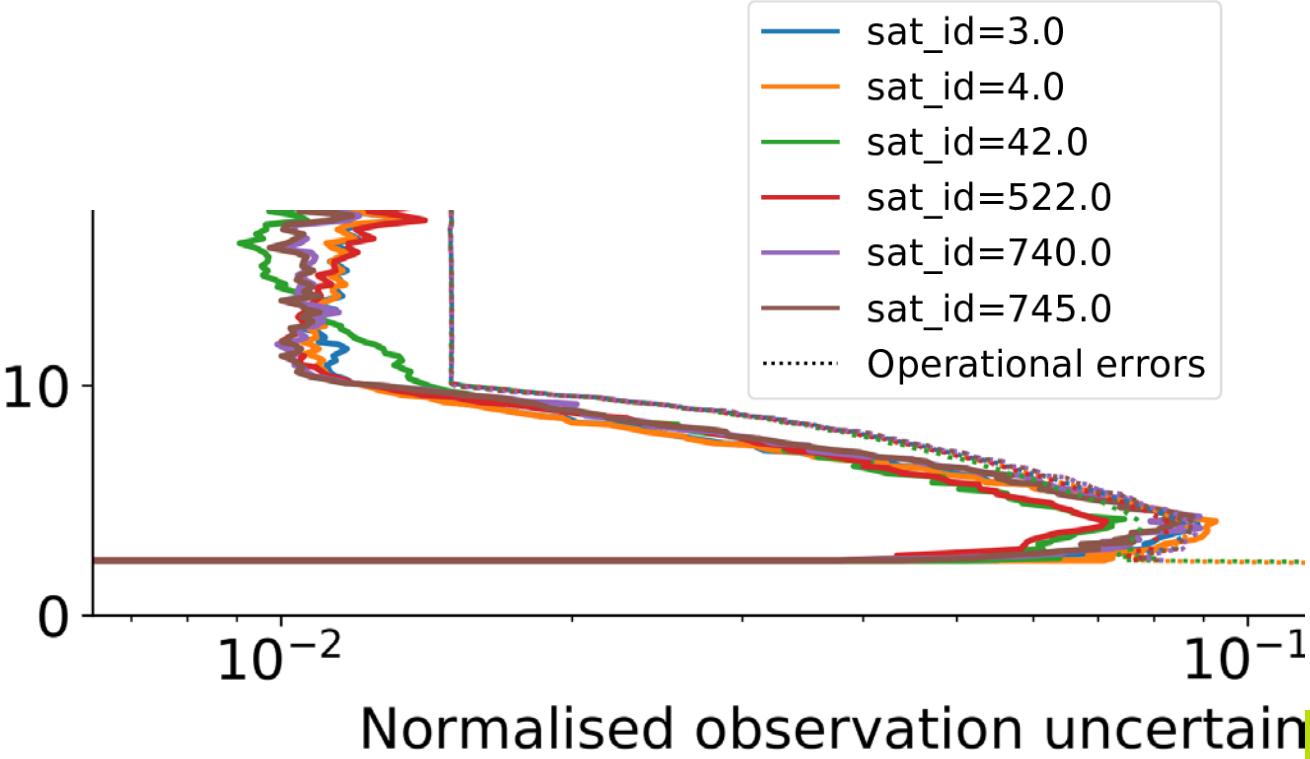
Variation with satellite – Core region



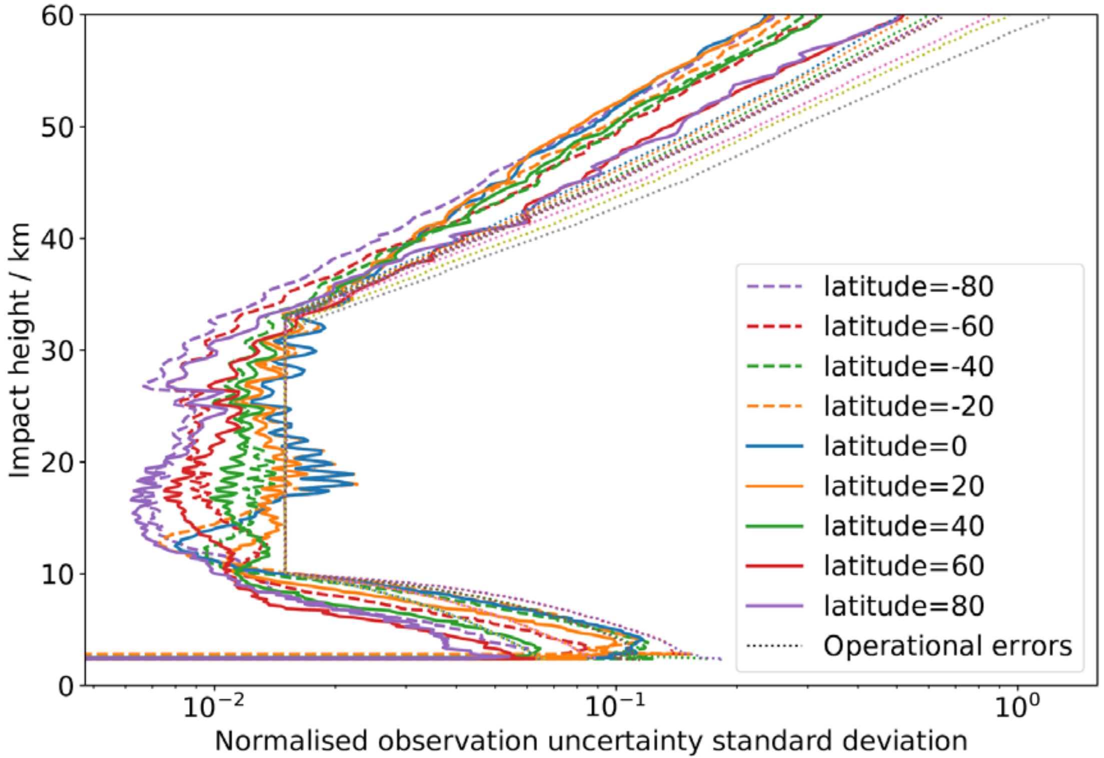
- FY-3C: Large jump in standard deviations below 25km – smoothing
- Metop A/B: Larger standard deviations than others – smoothing!
- Operational uncertainties generally too large

Variation with satellite – Troposphere



- Metop A/B: Smaller standard deviations in upper troposphere
- TerraSAR-X + FY-3C: Smaller standard deviations in the lower troposphere
- Operational uncertainties closer to diagnosed

Variation with latitude



- Complicated!

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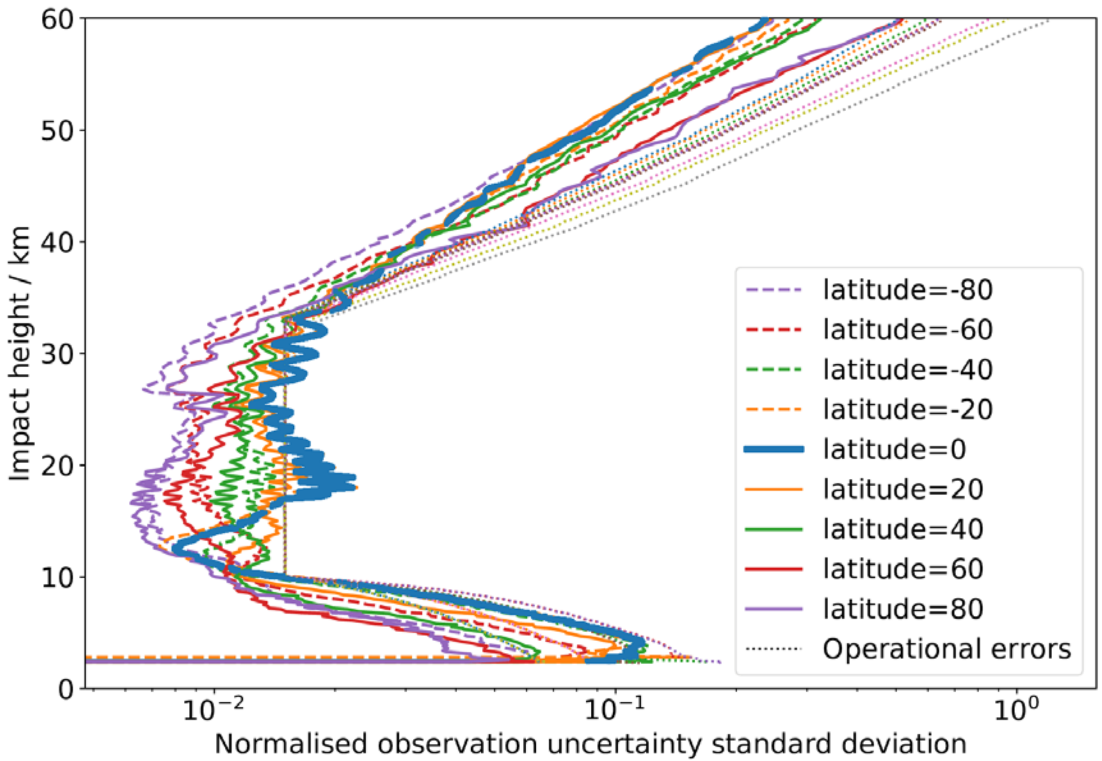
Variation with latitude



- Large uncertainties in troposphere
  - Small uncertainties in upper troposphere
- Large uncertainties in lower stratosphere
- Small (relative) uncertainties above 40km

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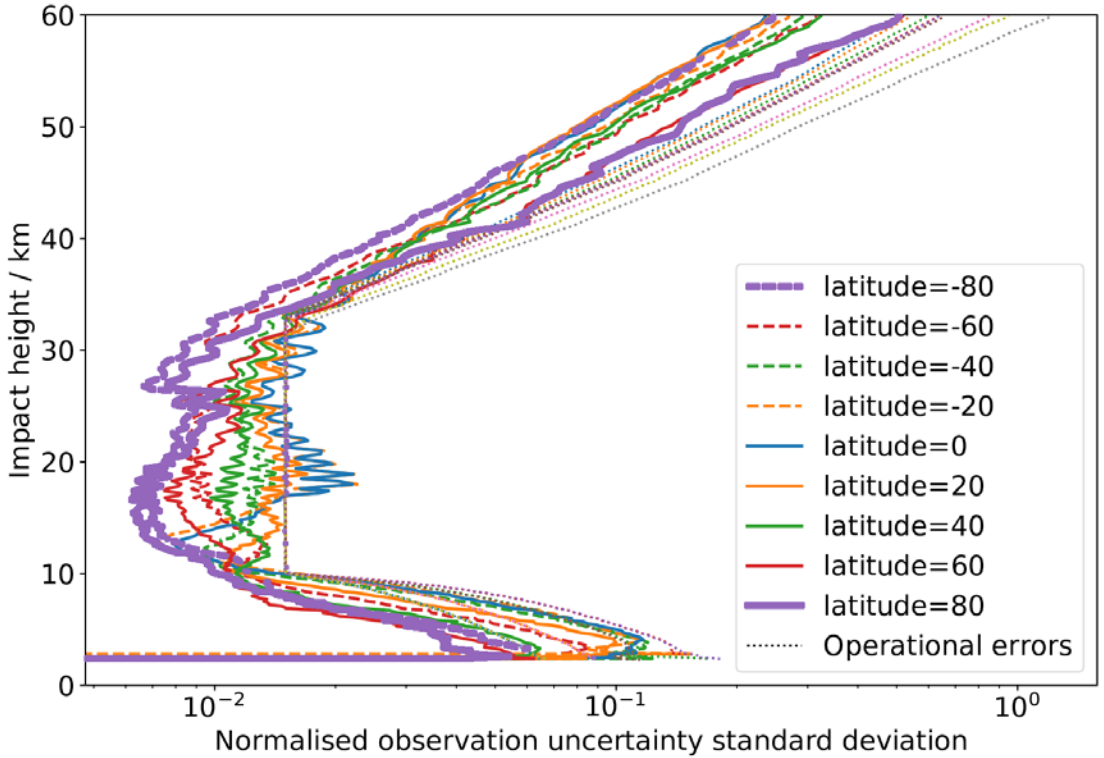
Variation with latitude



- Small uncertainties in troposphere
- Small uncertainties throughout stratosphere
- Differences in relative errors above 40km – climatology of observed bending angles

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Early trial results

Trial setup

- Obs uncertainties used in two steps
  - Quality control
  - Data assimilation
- Initially keep old uncertainties for QC
- Low-resolution mimic of operational NWP system (Forecast model: 640x480)
- Winter: Dec 2017 – Feb 2018
- Summer: 15 Jul 2018 – 15 Oct 2018

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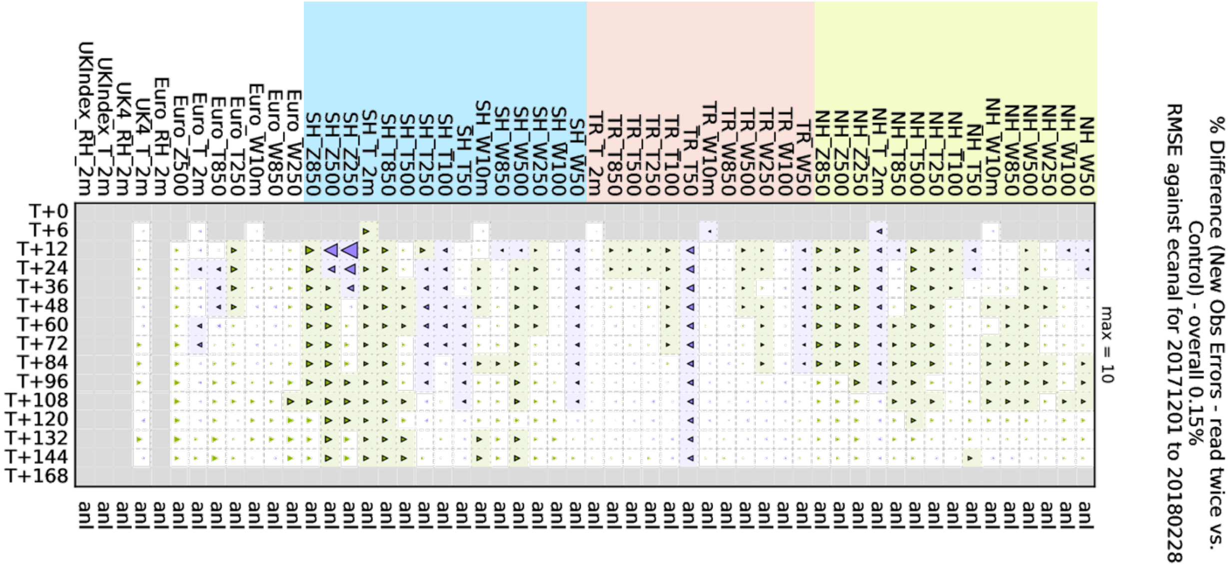
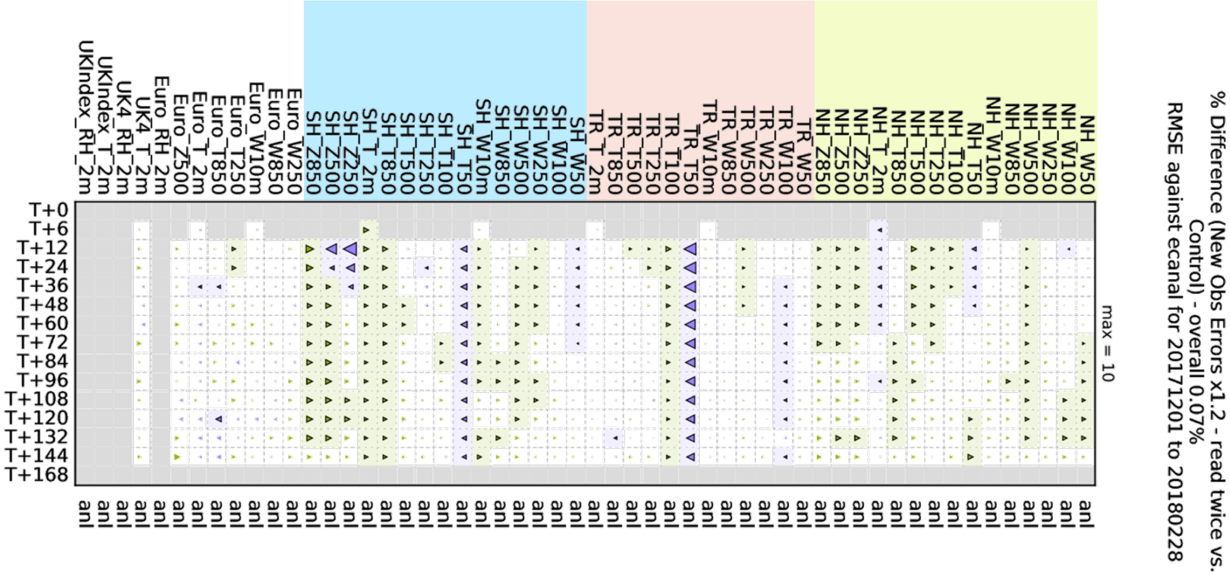
First trial



- General benefit from new observation uncertainties
- Largest changes in SH
- Negatives in temperature at 50hPa

Inflated observation uncertainties



- Observation uncertainty standard deviation inflated by 1.2
- Tropical temperatures at 50hPa more negative

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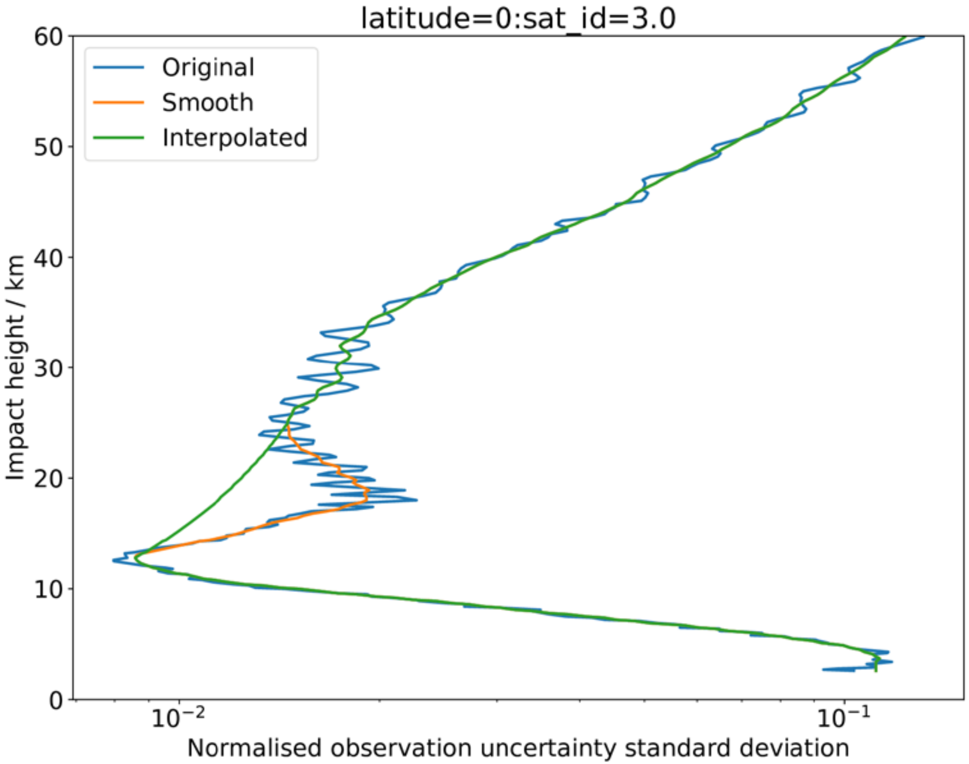
Bump removal



- UTLS increase in diagnosed uncertainties
  - Cause of negative results?
- Interpolate between nearest minima

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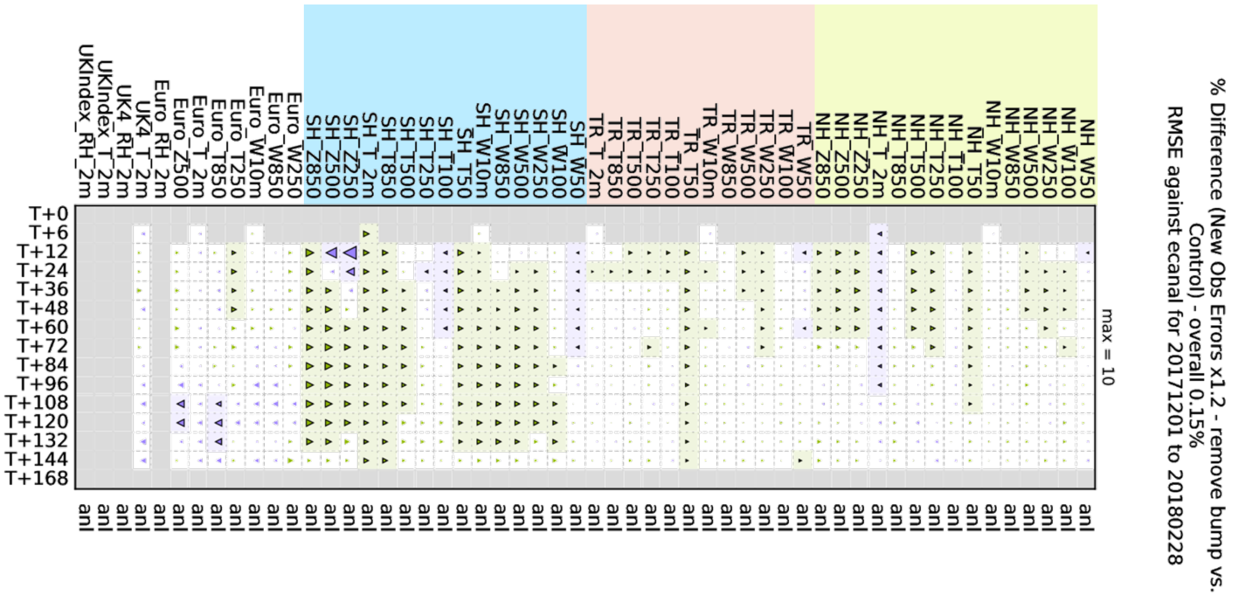
Inflated uncertainties – remove bump



- Much better performance at 50hPa
  - Maximum in UTLS is model error

Alternatives to latitude

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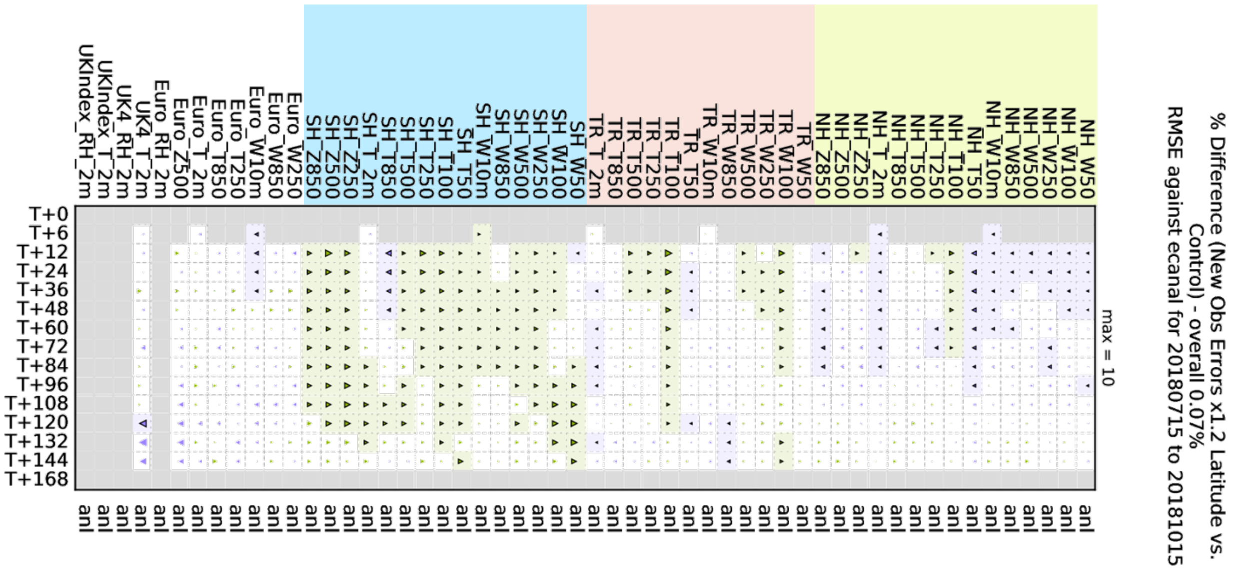
Summer season results



- Obs uncertainties diagnosed in winter
- Less good results in summer (e.g. Scherllin-Pirscher et al., 2011)
- Latitude not an atmospheric quantity

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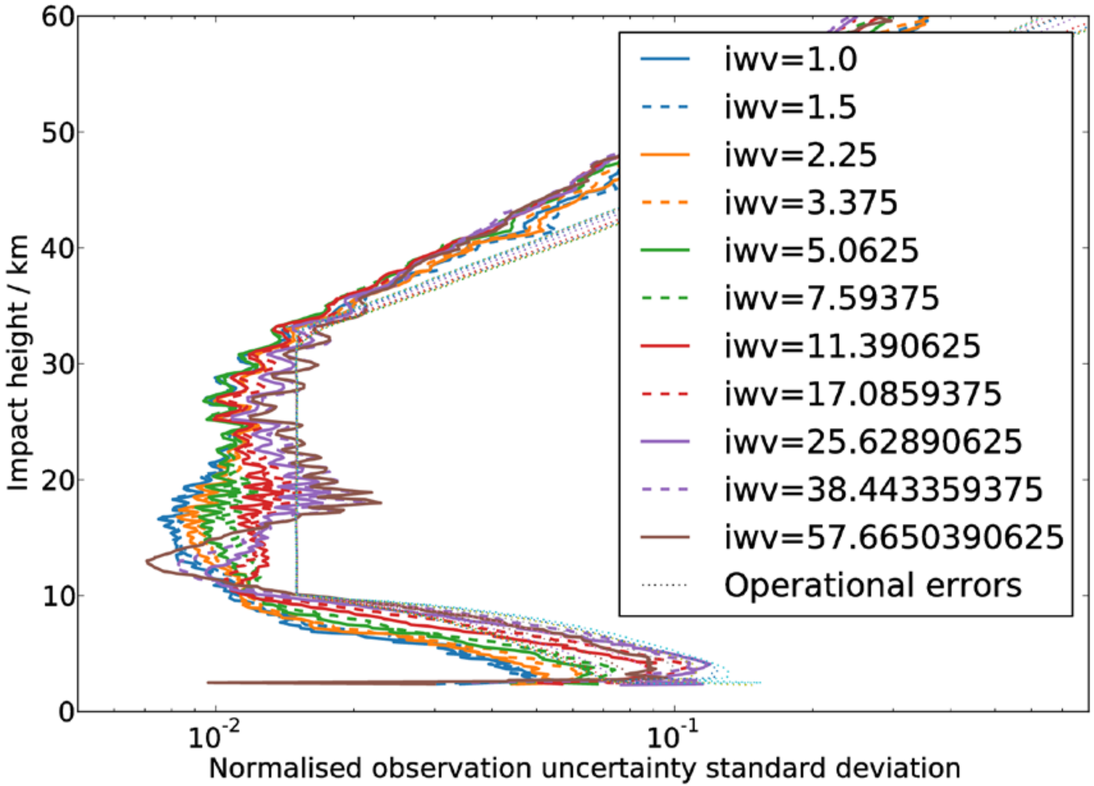
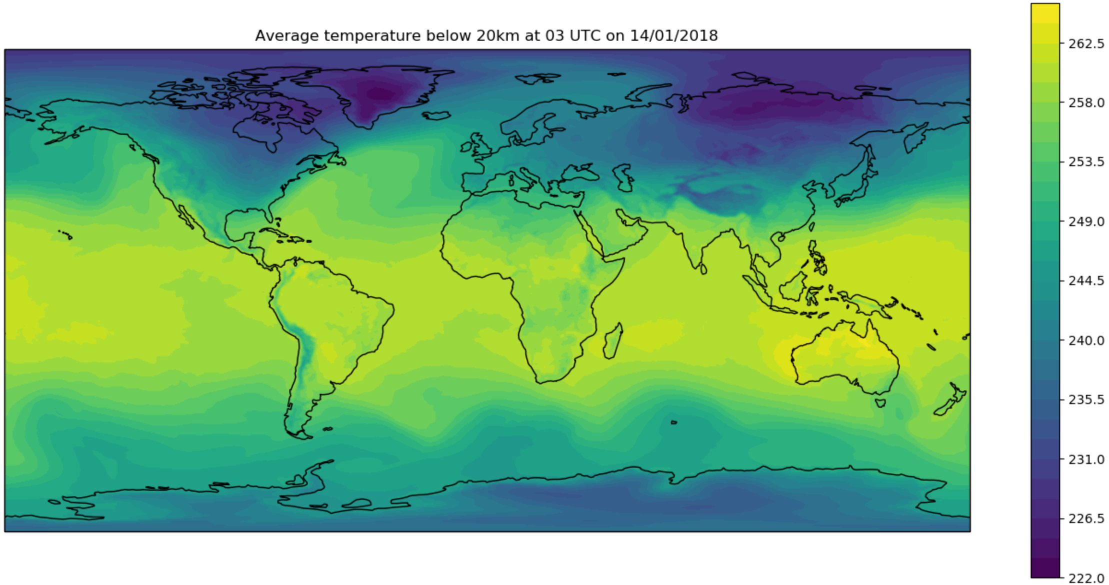
Variation with Vertically Integrated WV



- Some variation with IWV
- Not as good separation as latitude

Average temperature diagnosis



- Average model temperature surface – 20km
- Smooth variation with latitude
  - Somewhat affected by orography

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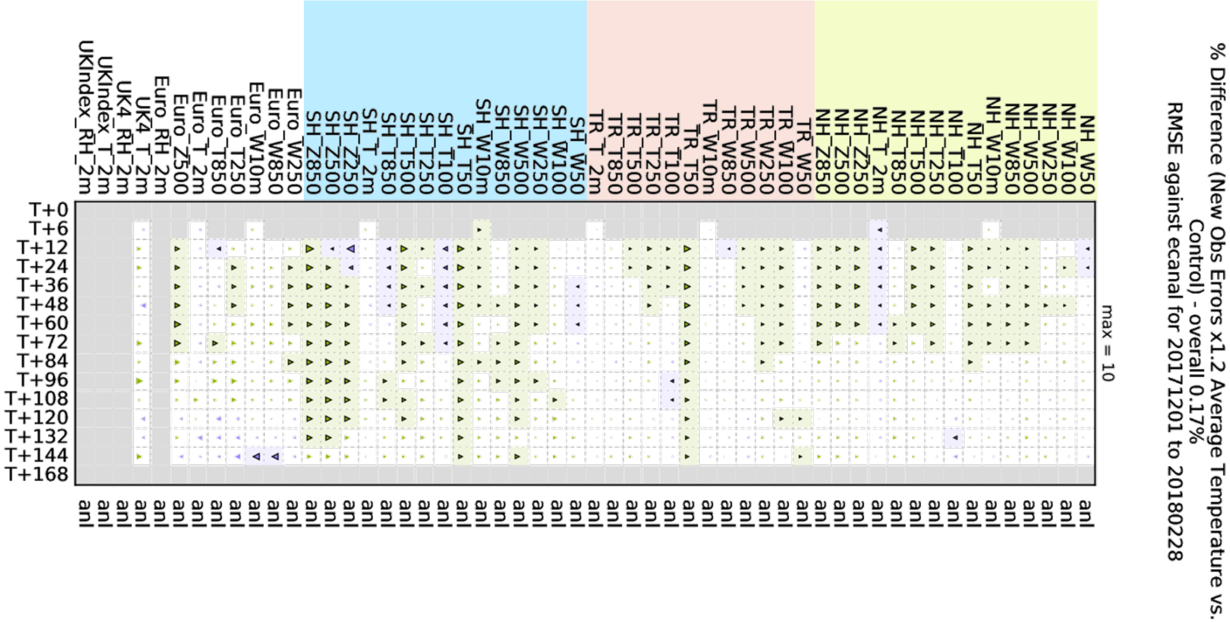
Average temperature trial



- Good performance for most variables
  - Replicated for second season
- Will be implemented next year

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Conclusion

- New observation uncertainties calculated using the method of Desroziers et al. (2005)
- Improvement in forecast performance
- Allow uncertainties to depend on average temperature below 20km

- Diagnosed increase in UTLS area degrades forecast – removed
- Benefits related to smoother variation (with latitude) and variation with satellite

Extra slides

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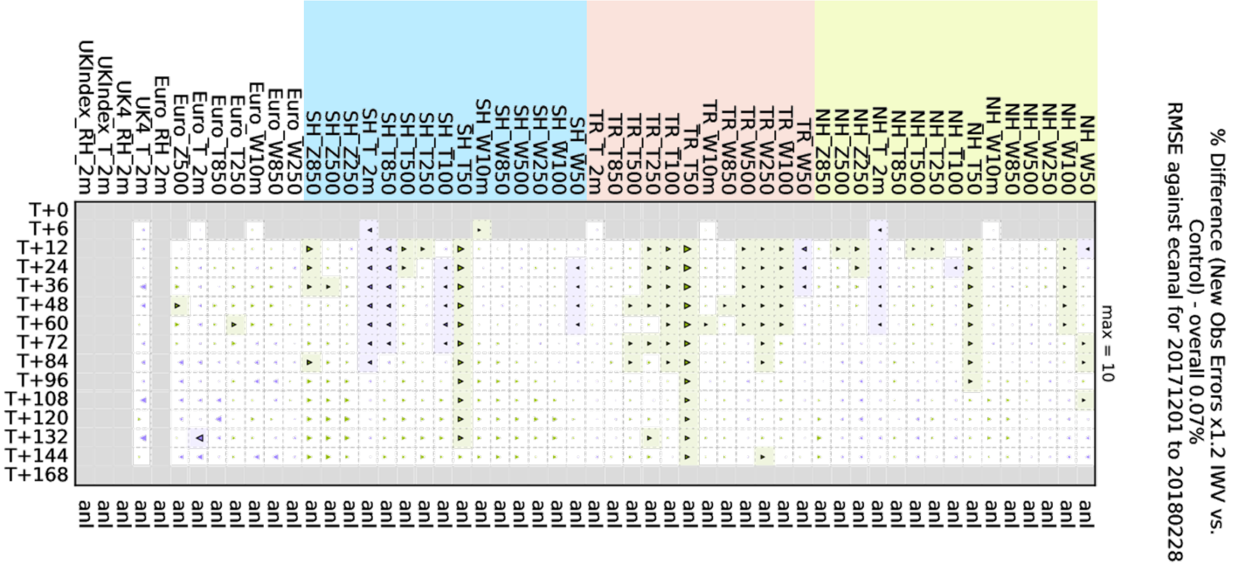
Integrated Water Vapour



- Small benefits for some variables – no big degradations

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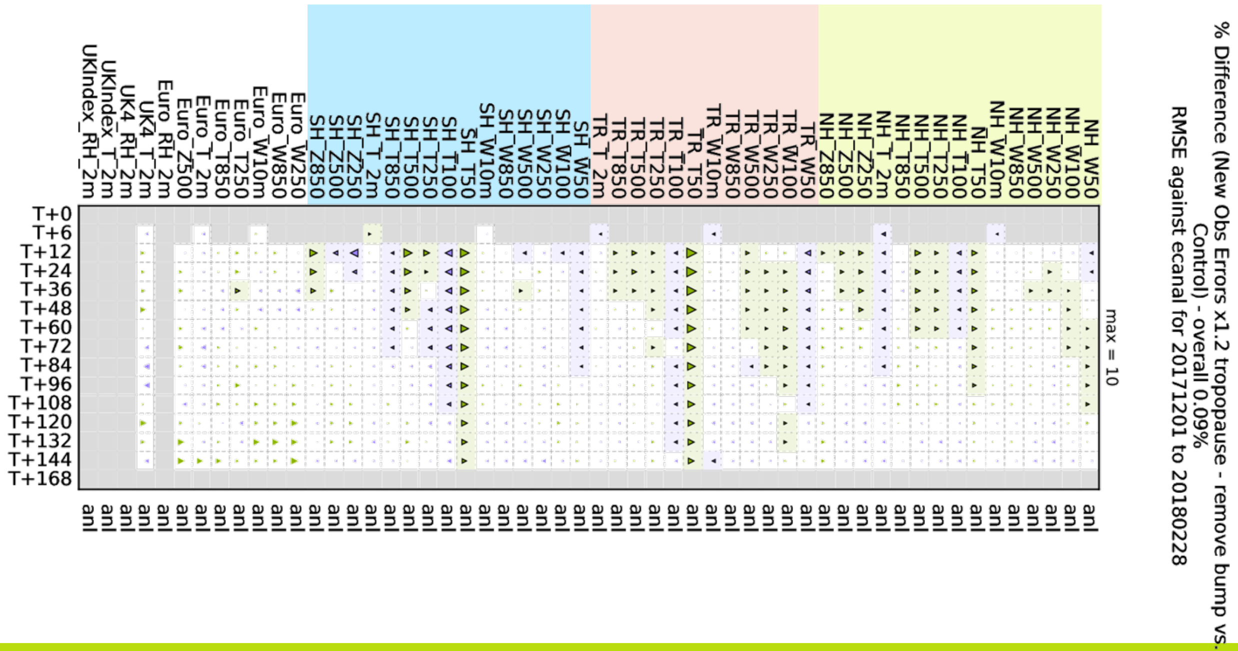
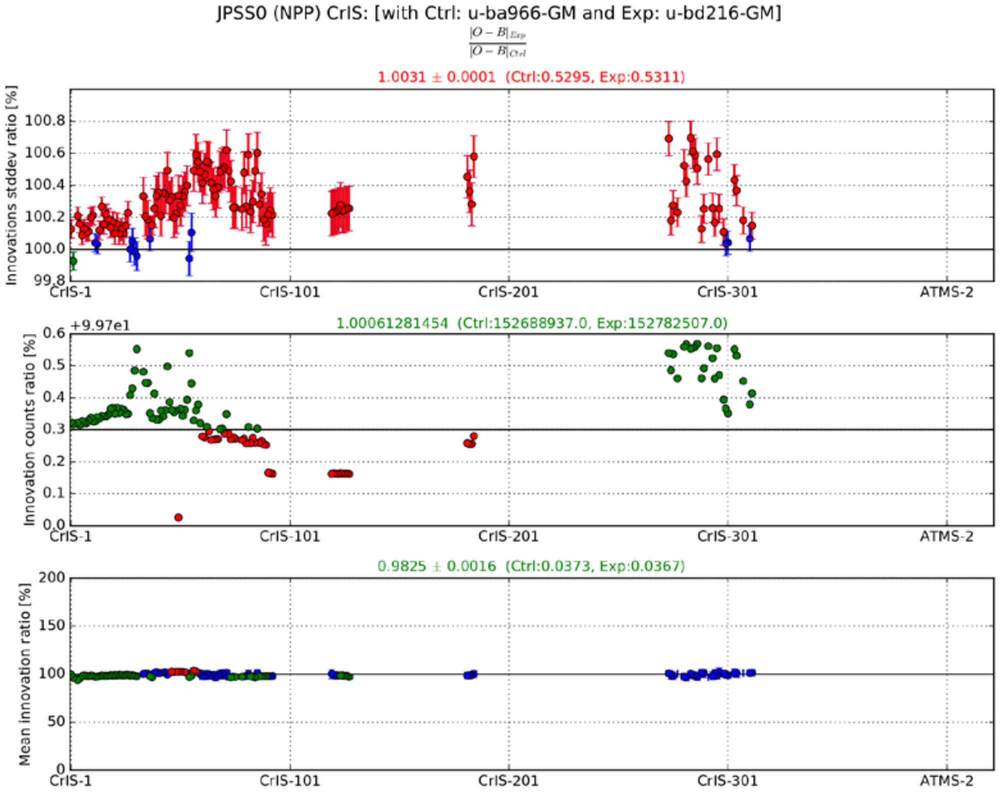
Tropopause height



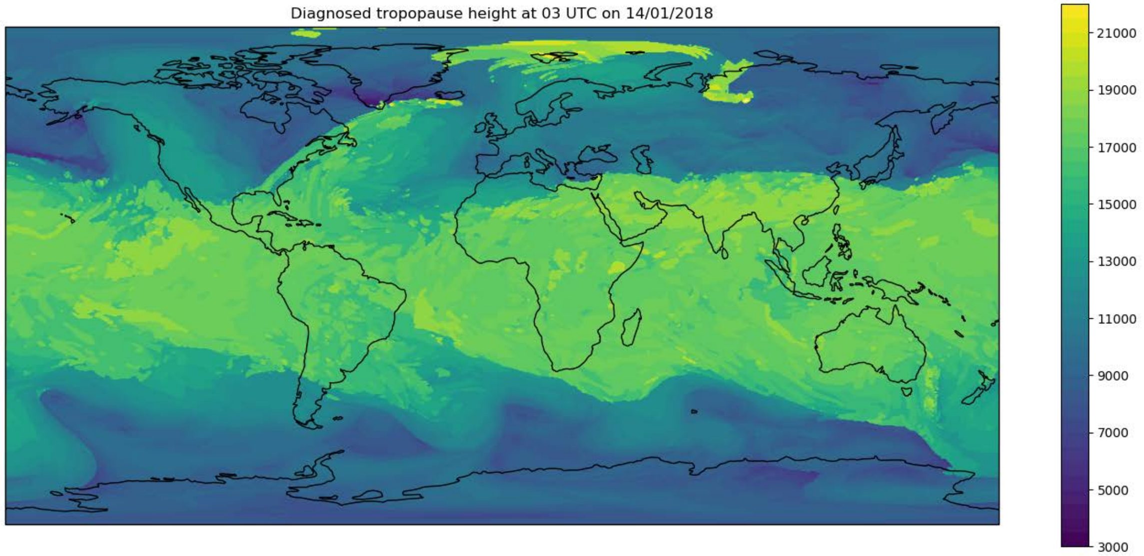
- General benefit, but with some negative for temperature at 100 hPa

Tropopause height – data assimilation stats



- Check assimilation stats to confirm forecast performance
- Increase in RMS innovations point to problems with obs uncertainties based on tropopause height

Tropopause height



- Tropopause height as diagnosed from a short-range forecast
- Shows interesting variation with weather system
- Sharp gradients are seen

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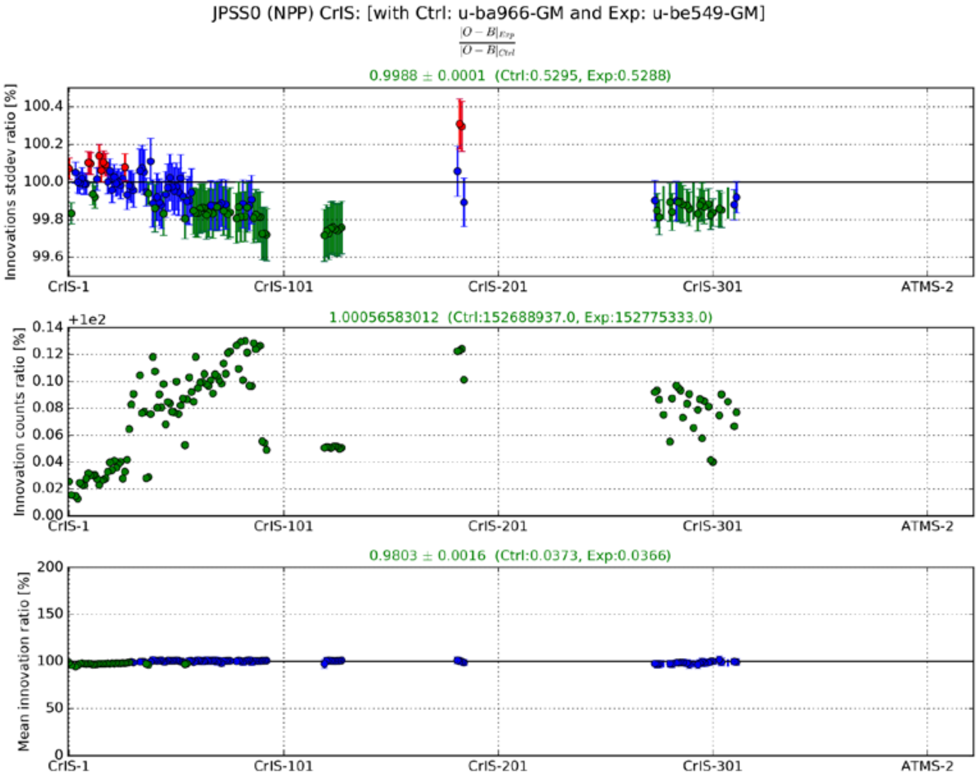
Average temperature – data assimilation stats



- Check assimilation stats to confirm forecast performance
- Reductions in RMS innovations point to benefits of new uncertainties

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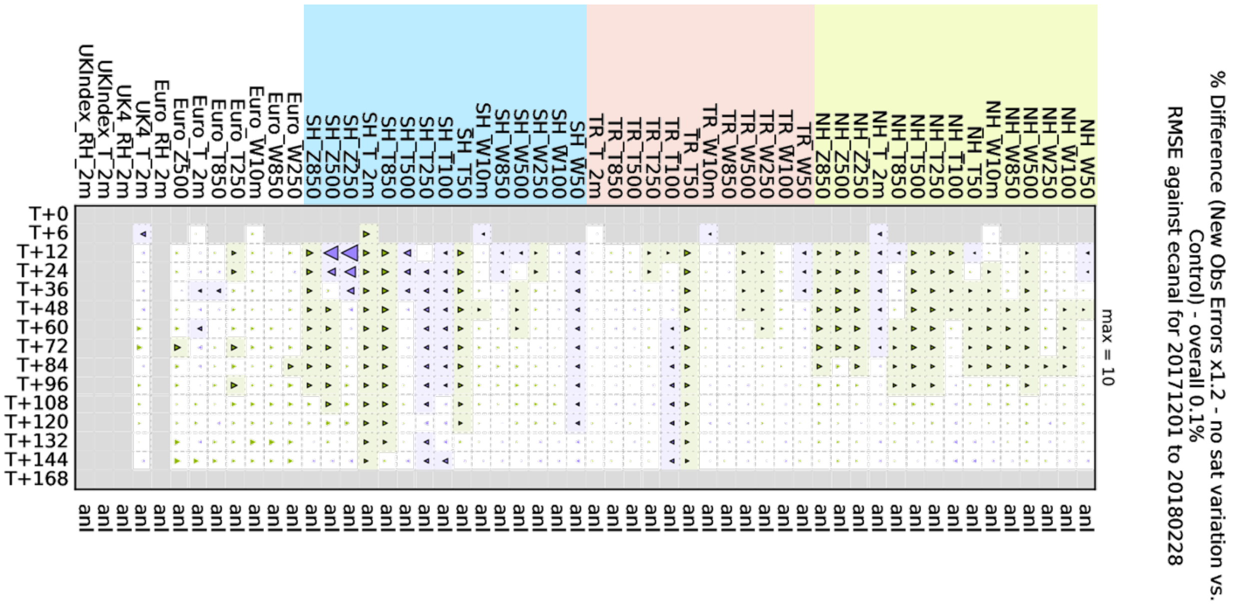
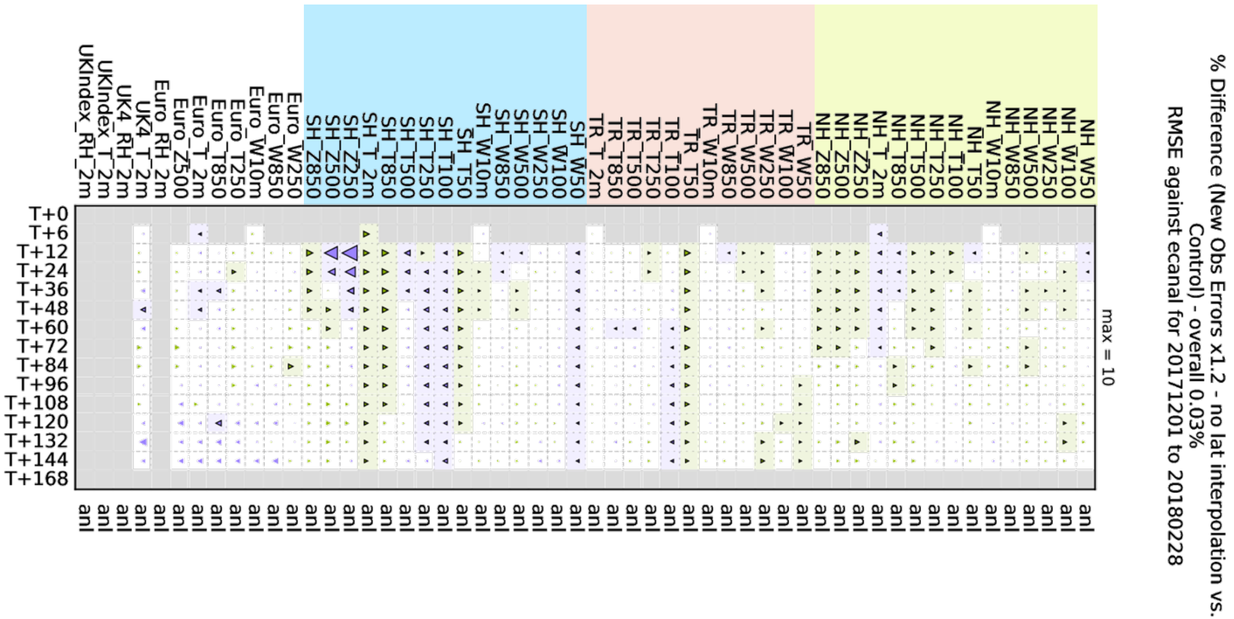
No variation with satellite



- Large reductions in benefit in SH-ET
- Small increase in benefit in NH-ET

Crude variation with latitude (and no sat)



- As current model, observation uncertainties in 30 degree bands
  - No interpolation
- Further reductions in benefit across all regions