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Understanding the impact of additional observations in the Met Office system

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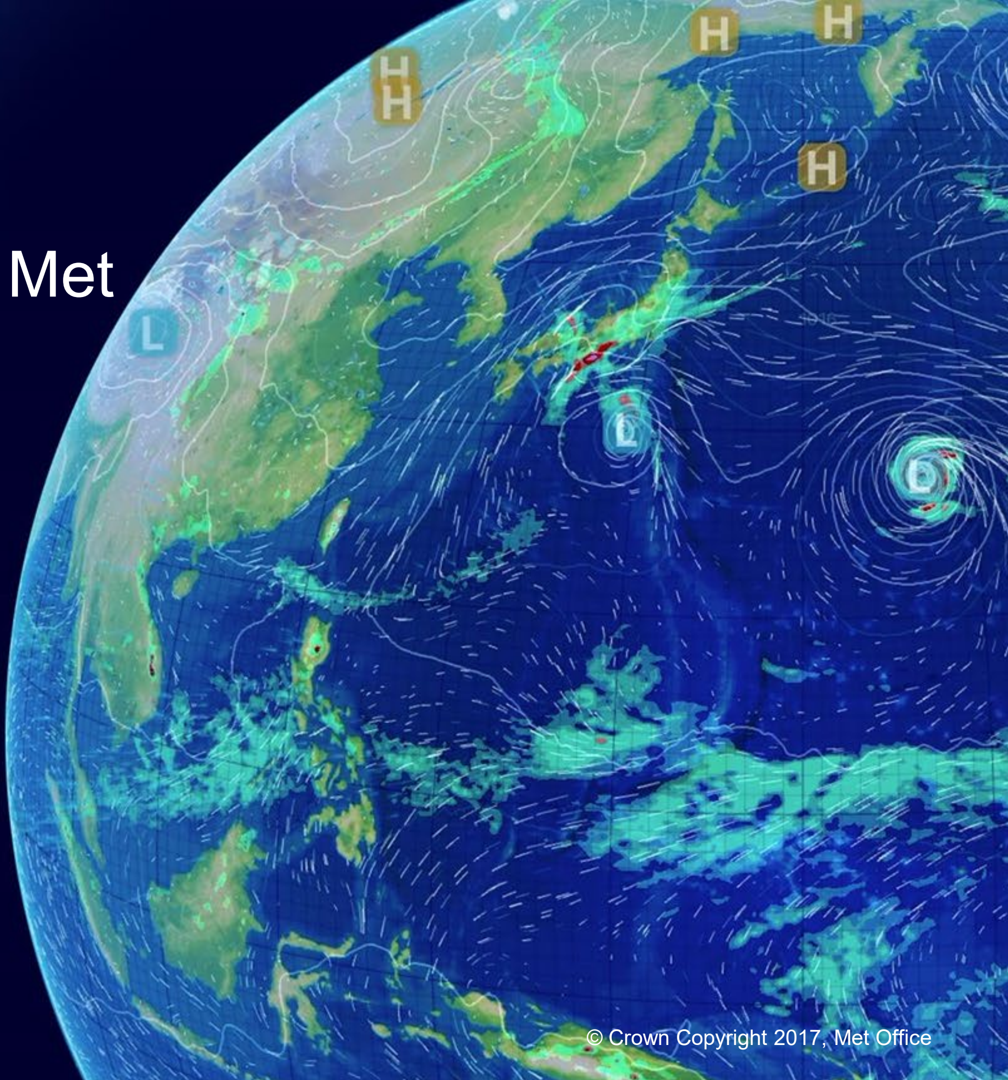


Outline

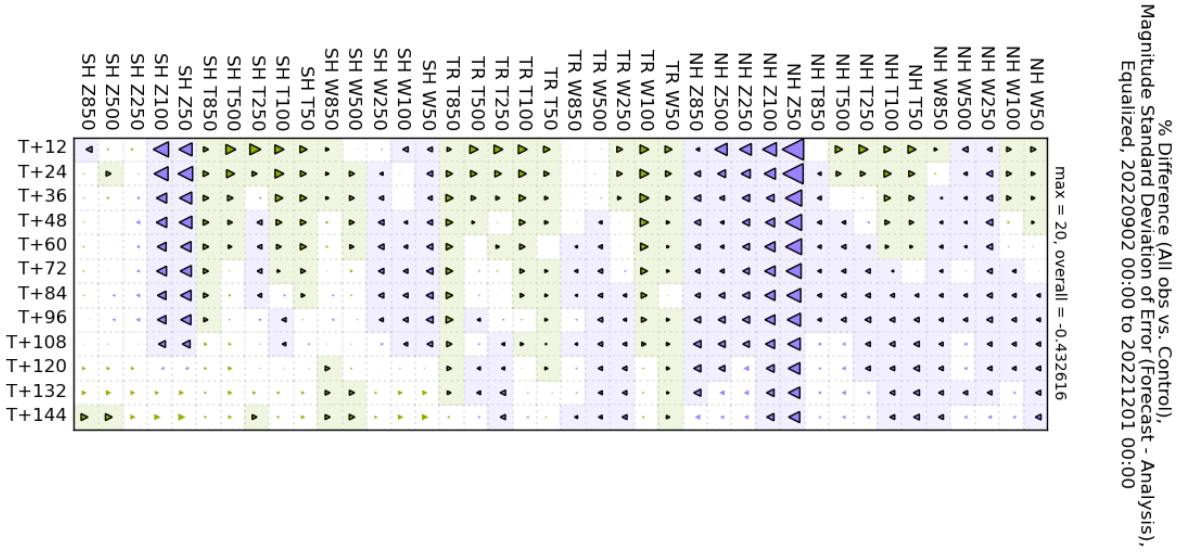
- Overview of experiments run
- Demonstrate the additional benefit of the extra observations
- Biases change depending on the number of observations assimilated
- Verification complications
- Conclusion

Experimental setup

- Experiments were run for ROMEX period:

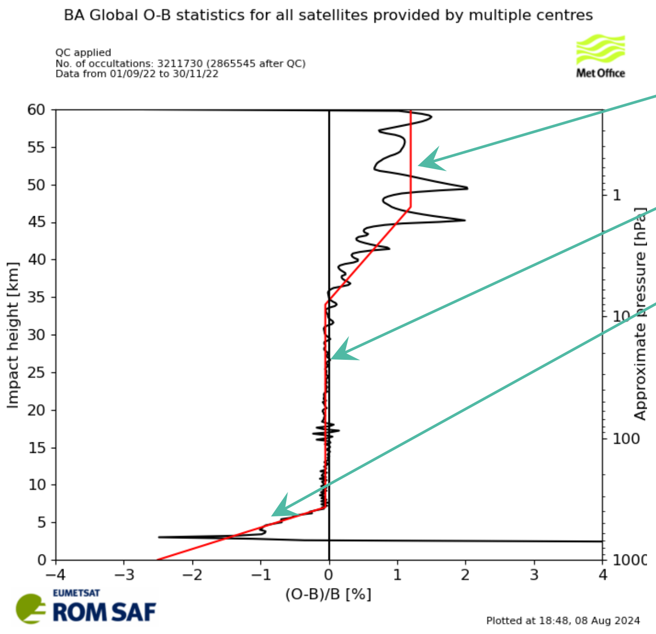
  1st September 2022 – 1st December 2022
- The first week was excluded from verification statistics, verification at 0000 and 1200 UTC
- Using a Met Office standard trial setup
  - Atmosphere only hybrid 4D-Var global low resolution
  - UM resolution: N320 (~40 km at mid-latitudes)
  - VAR resolution: low N108 (~130 km) / high N216 (~60 km)
  - Error modes from archived operational ensemble forecasts
  - 70 levels up to 80 km

Adding additional observations – vanilla



- Change in standard deviation for forecast error
- Verification against ECMWF analyses
- Negative for geopotential height
- Negative for medium-range in NH

Biases (O-B)/B



- 1.2% above 47km
- -0.05% between 7km and 34km
- Linear ramp to -2.5% at 0km

- Refractivity calculated using Smith & Weintraub (1953)

$$N = \kappa_1 \frac{P}{T} + \kappa_2 \frac{e}{T^2}$$

$$\kappa_1 = 0.776 \qquad \kappa_2 = 3.73\ 10^3$$

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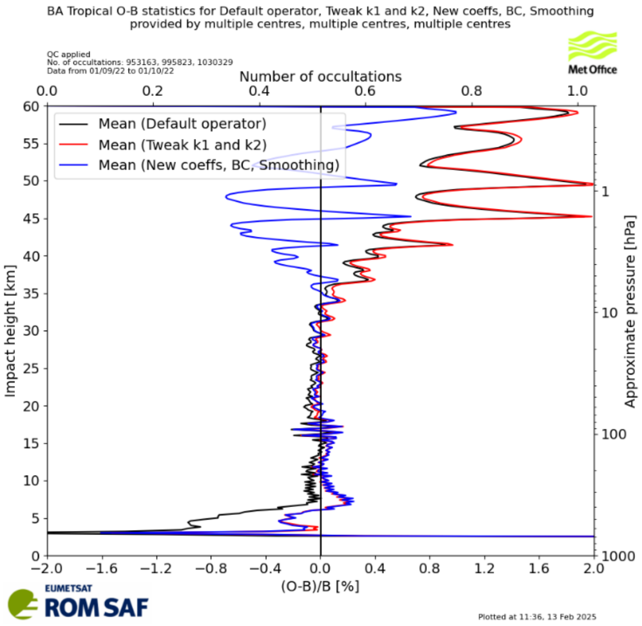
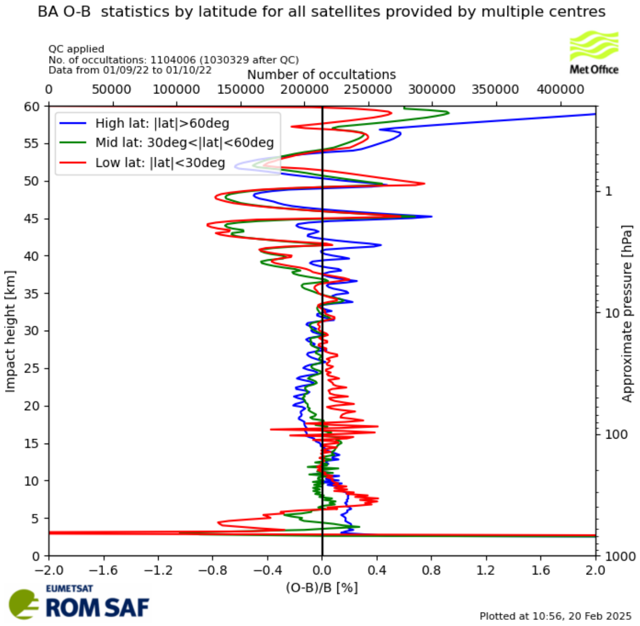
Biases (O-B)/B



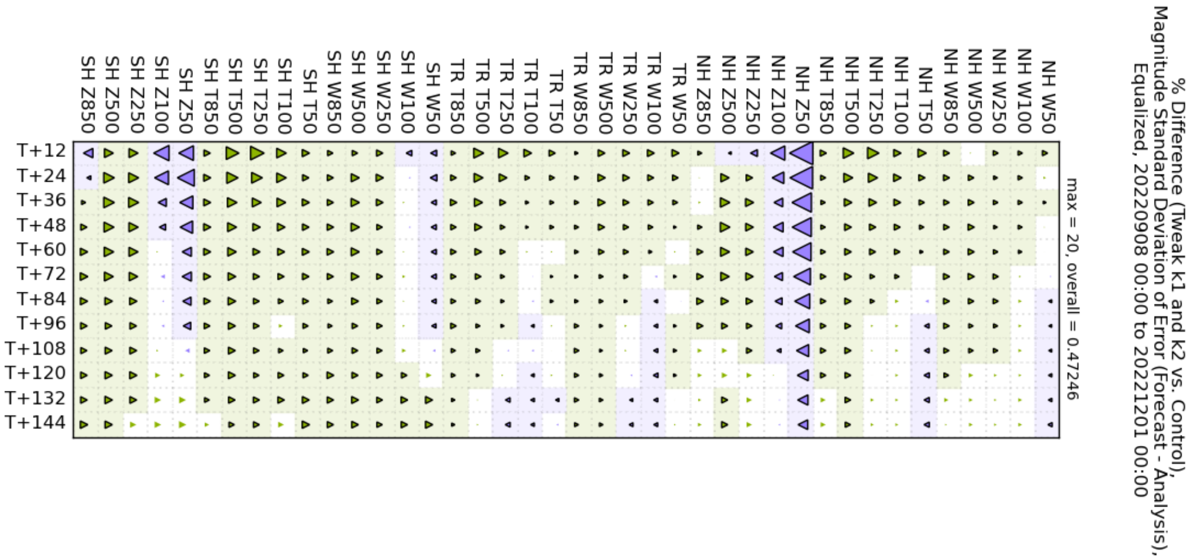
- Testing changes to refractivity coefficients
  - κ_1: 0.776 → 0.775612 (0.05% change)
  - κ_2: 3.73 10^3 → 3.6 10^3 (3.5% change)
- Biases above 35km are due to model, apply direct bias correction to observations

Biases (O-B)/B



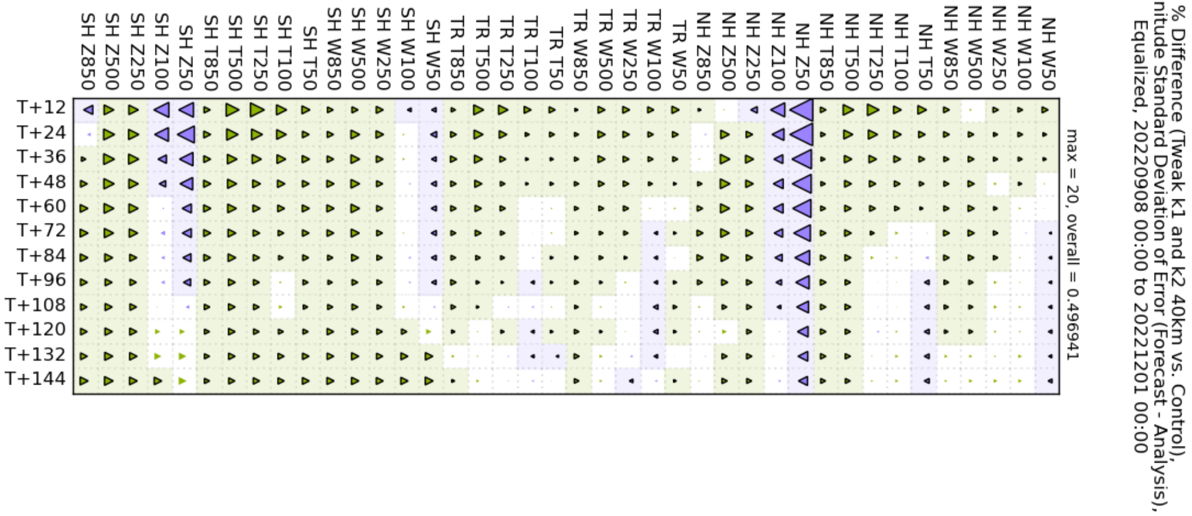
- Around 20km: negative biases in extra-tropics, positive biases in tropics
  - Not experimented with RoC correction for wide-angle occultations
- Rather different behaviour in troposphere

– k1 & k2



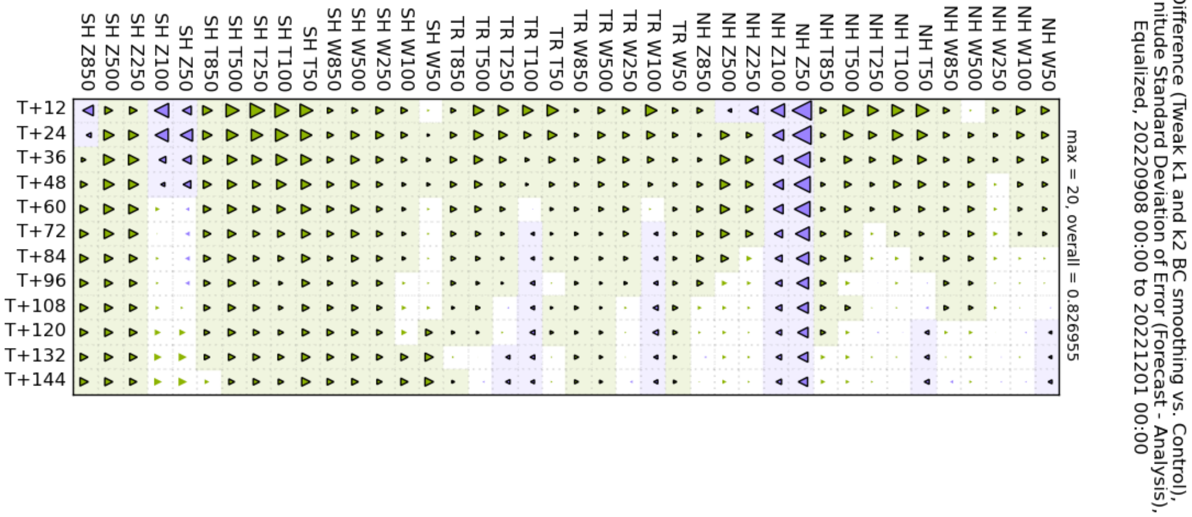
- Change in standard deviation for forecast error
- Verification against ECMWF analyses
- Generally positive
    - Still negative for geopotential height at 50 & 100 hPa

bove 40km



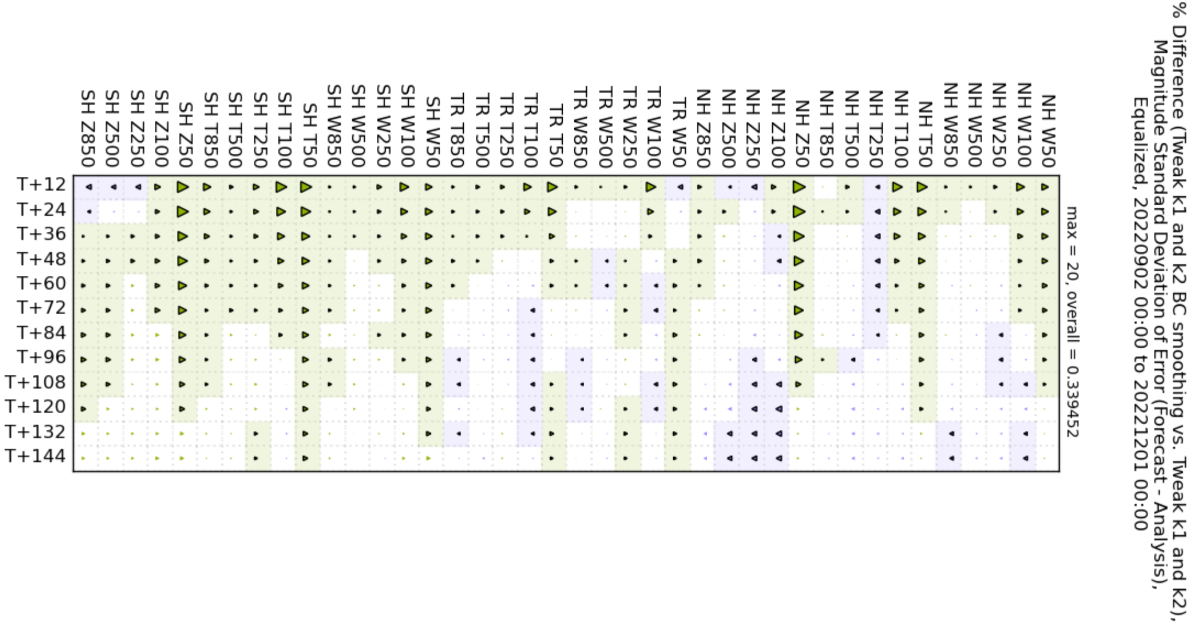
- Additional observations above 40km have (nearly) zero impact

oothing



- The best configuration
  - Adjusting the refractivity coefficients
  - Apply bias correction to the observation above ~40km
  - Vertical smoothing of bending angles

oothing



- The best configuration
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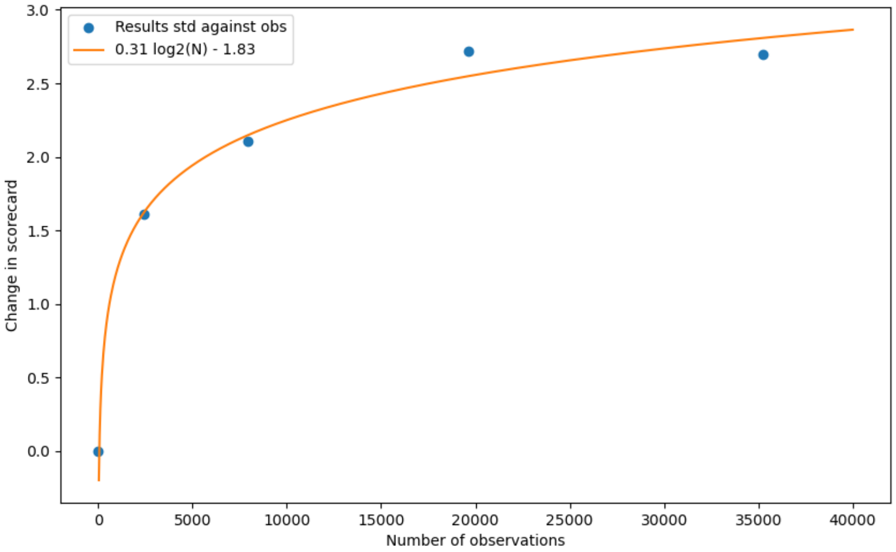
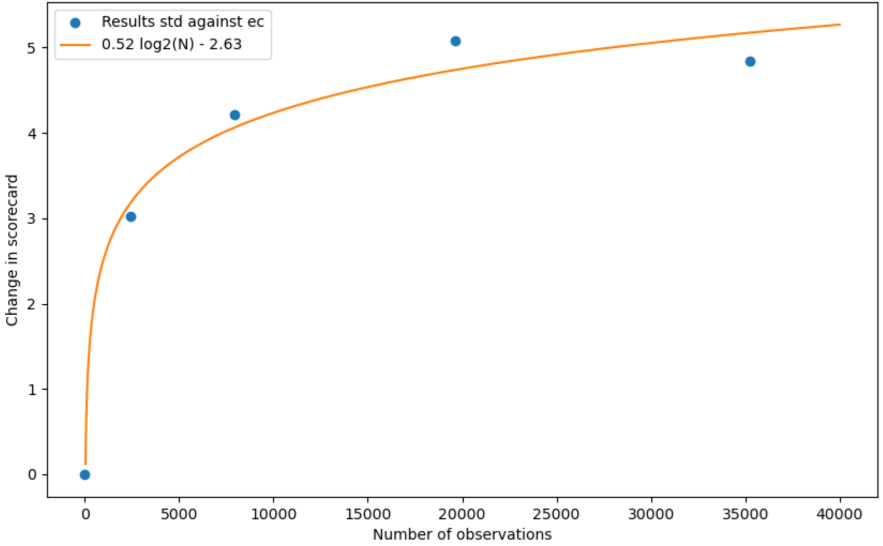
Standard deviation(obs)



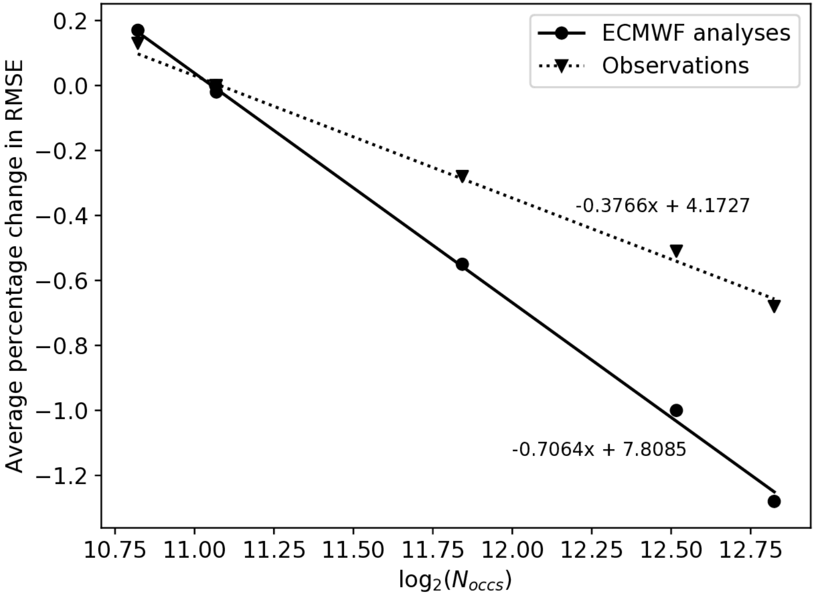
- Doubling number of observations gives 0.31% reduction in standard deviation
- Note 20k results better than all-obs results

Standard deviation(ECMWF)



- Doubling number of observations gives 0.52% reduction in standard deviation

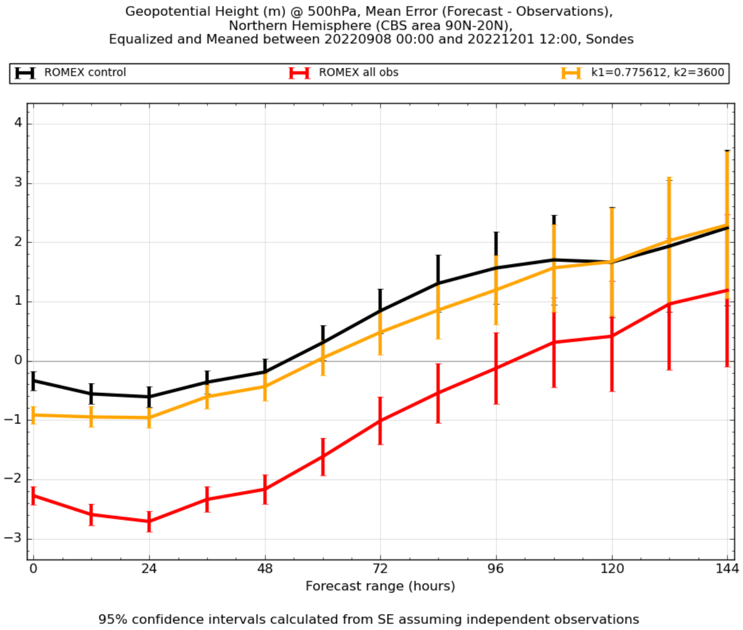
Previous results with Spire



- Doubling number of observations gives 0.38% or 0.71% decrease in RMSE
- Used Spire-processed observations (which had compensating biases)
- Didn't reach as high number of observations

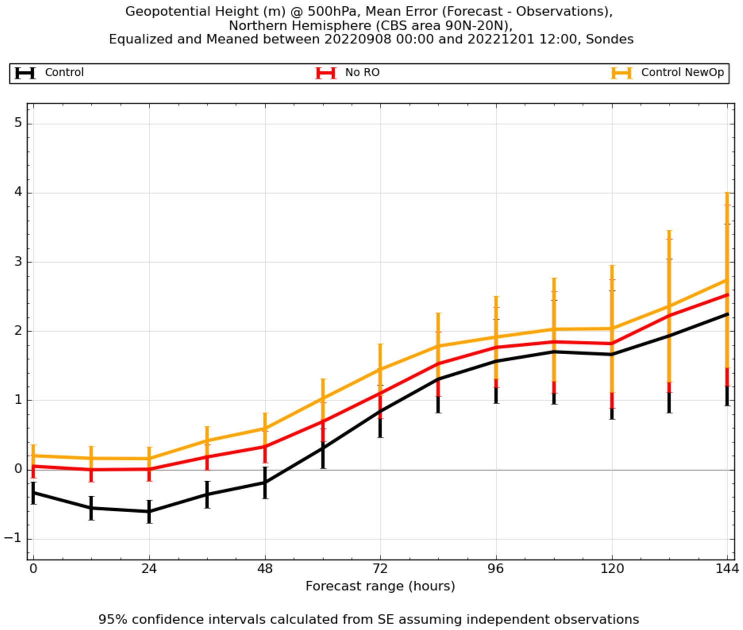
Bias changes

Bias 500 hPa geopotential height



- Verified against sondes
- Control biases small at short lead time
- Adding all ROMEX observations gives large cooling
- Changing refractivity coefficients greatly reduces cooling

Bias 500 hPa geopotential height



- Verified against sondes
- Experiment with no RO: little bias
- Changing refractivity coefficients with control: little or positive bias

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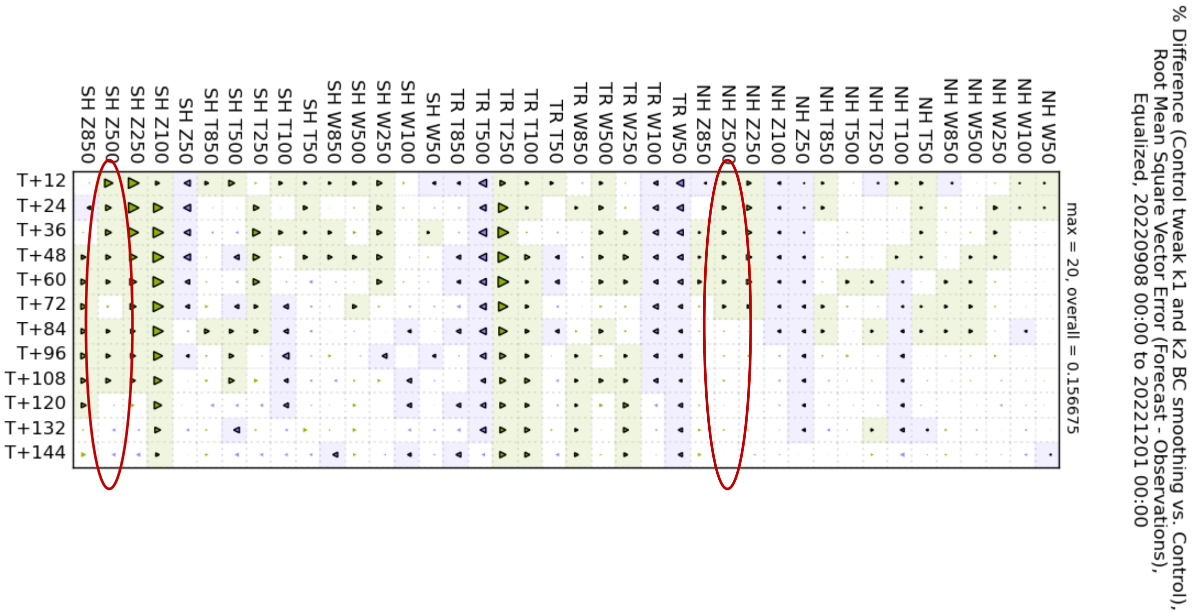

- RMSE against sondes for operator changes (using control observations)
- Z500 forecasts improved

Verification complications

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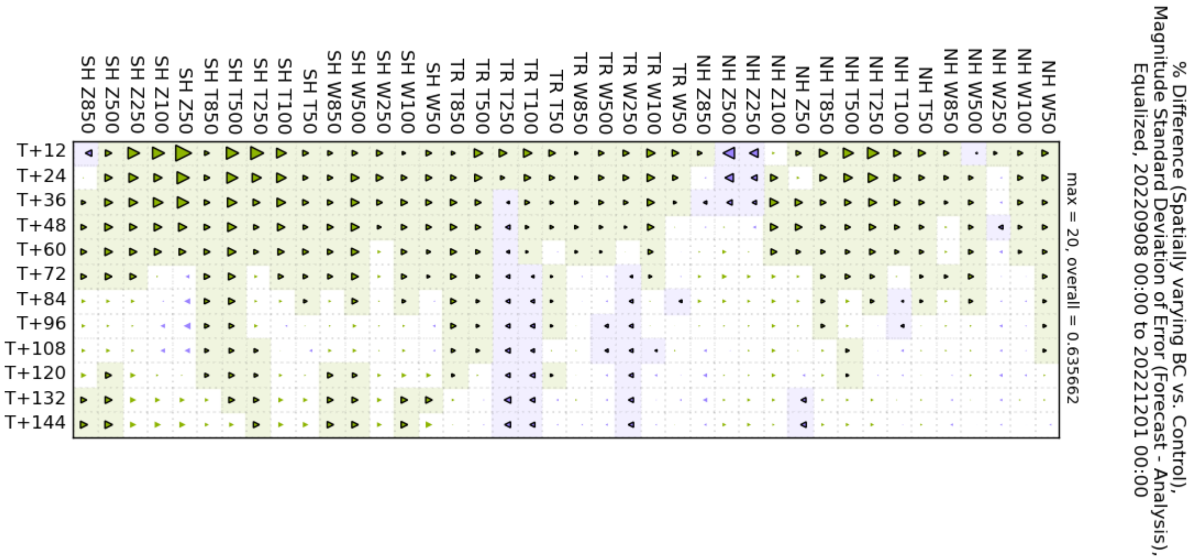
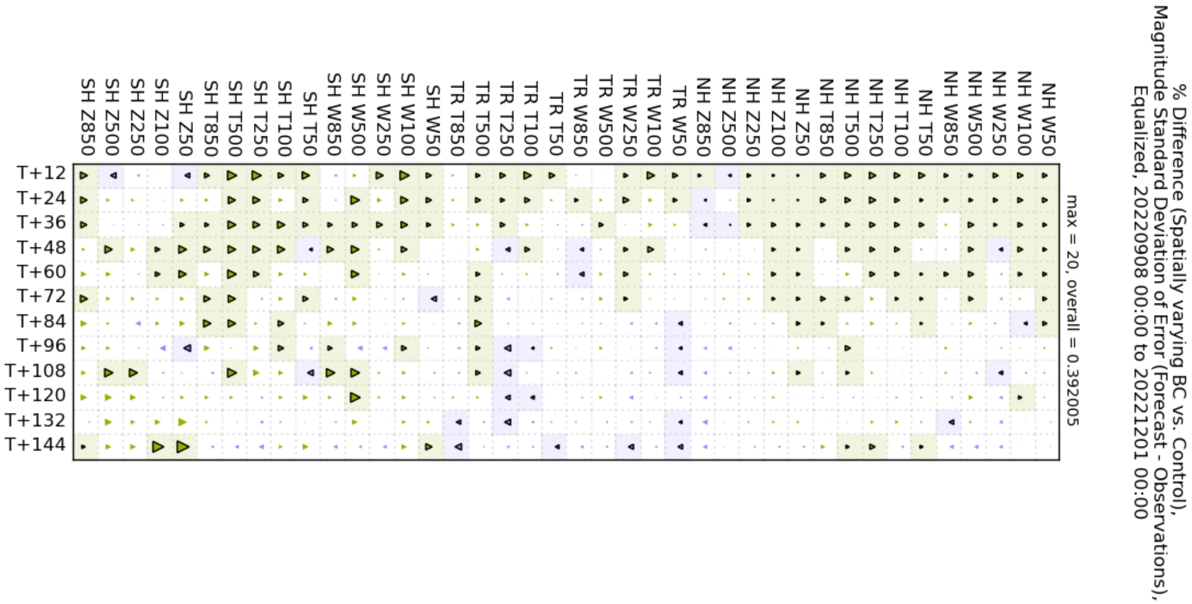
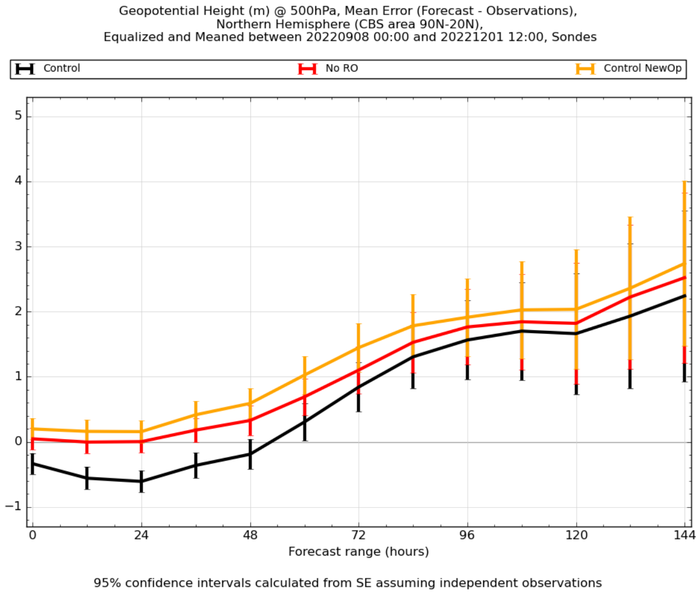


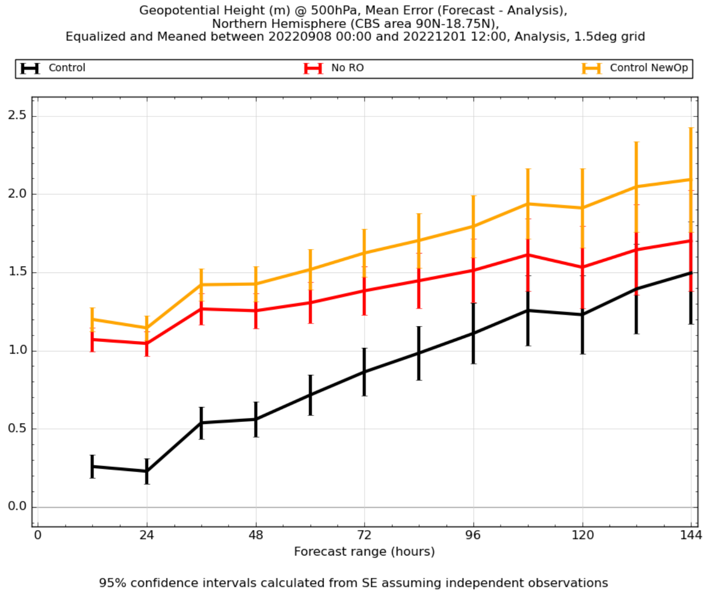
- Verification against ECMWF analyses using standard deviation of error
- Addition of observations beneficial in first three days



- Verification against sondes using standard deviation of error
- Addition of observations beneficial in first three days

Comparison 500 hPa geopotential height bias





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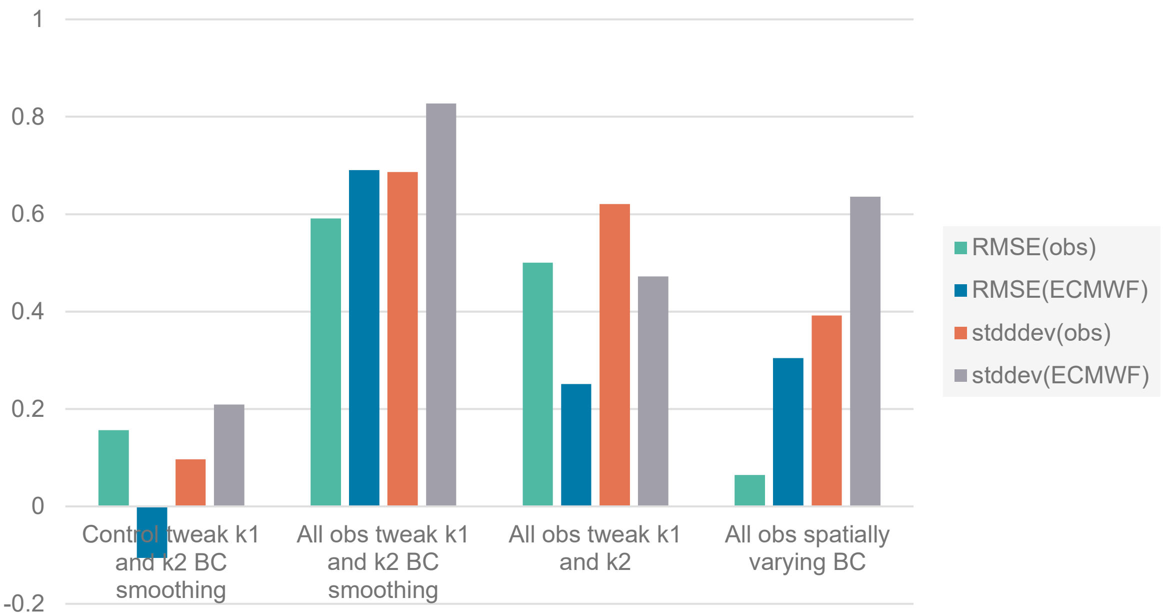
Comparing results across verification



- Spatially-varying BC good against ECMWF analyses
- Changing k1 and k2 better against sondes
- Adding high-altitude BC improves ECMWF verification
- Vertical smoothing gives small improvements for all

Conclusion

- See benefit from additional observations in Met Office system
  - Benefit maximised in 20k experiment
- Adjusting κ_1 by 0.05% and κ_2 by 3.5% minimises difference to observations (in a global sense)
  - Additional bias correction at high altitudes due to model biases
- Even with operator changes, tropospheric biases depend on the number of GNSS-RO observations
  - What's the best unbiased estimate of tropospheric temperatures / heights?
- Results depend on what is used in verification