ROMEX: Attempts to understand model and observation biases

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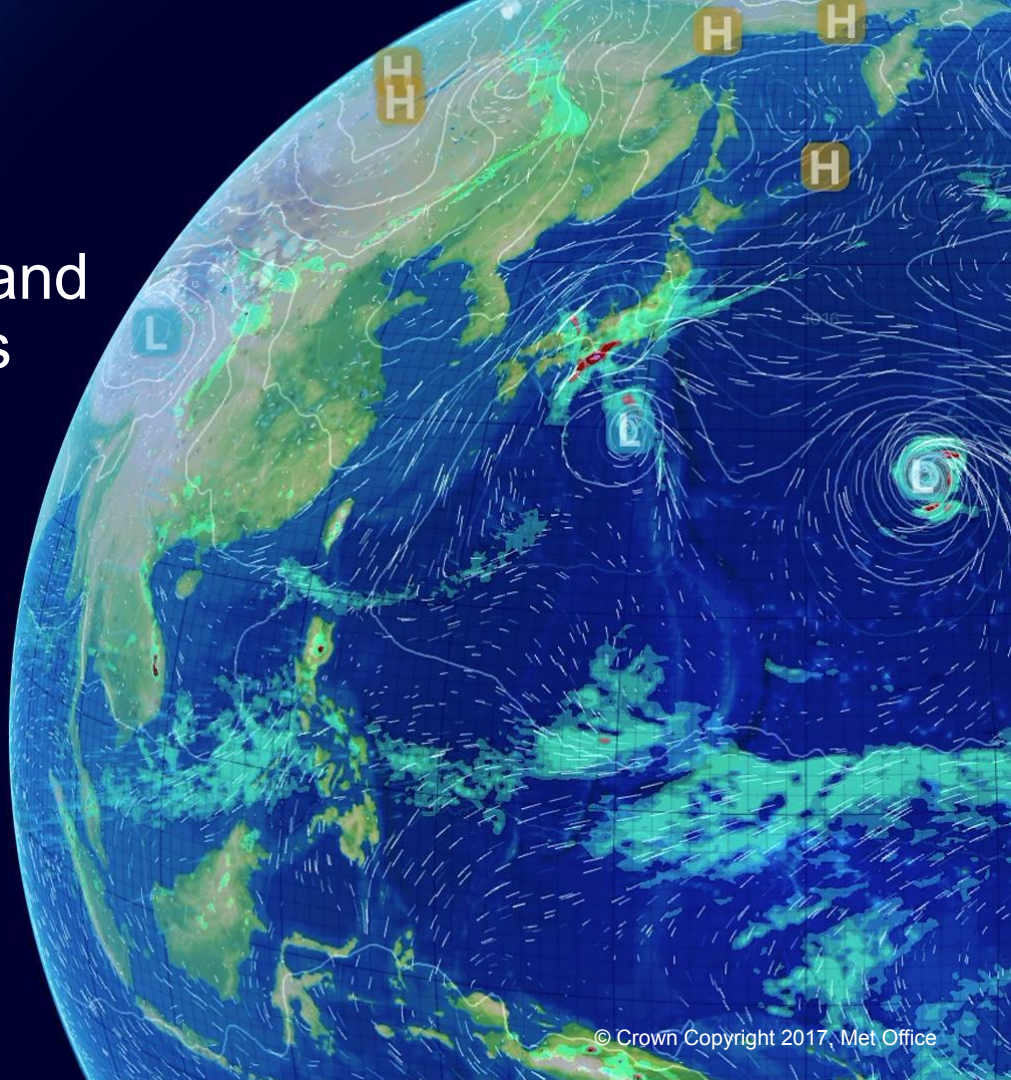

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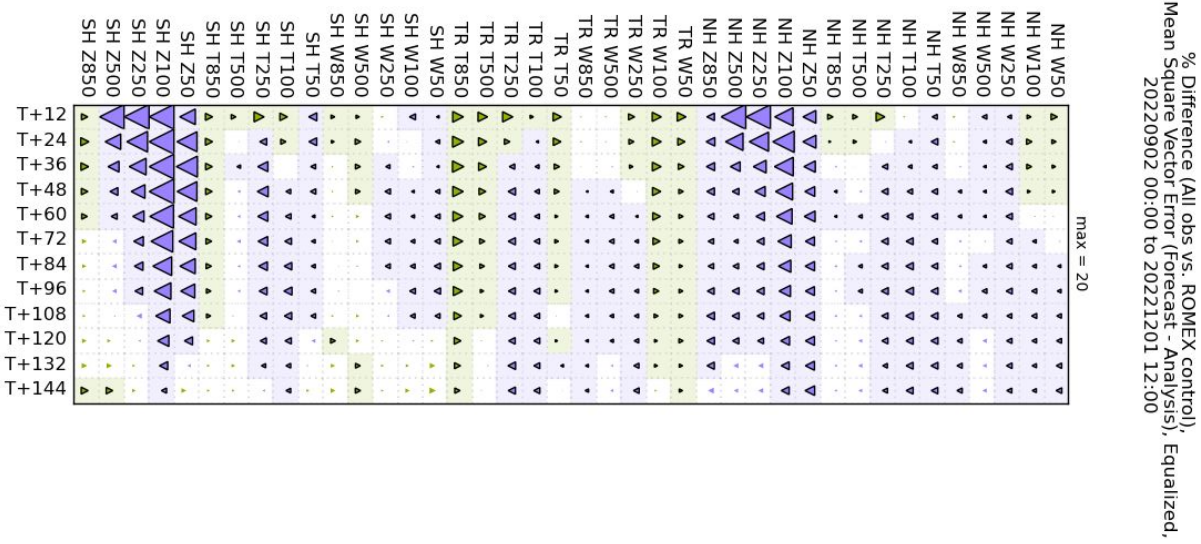
Background

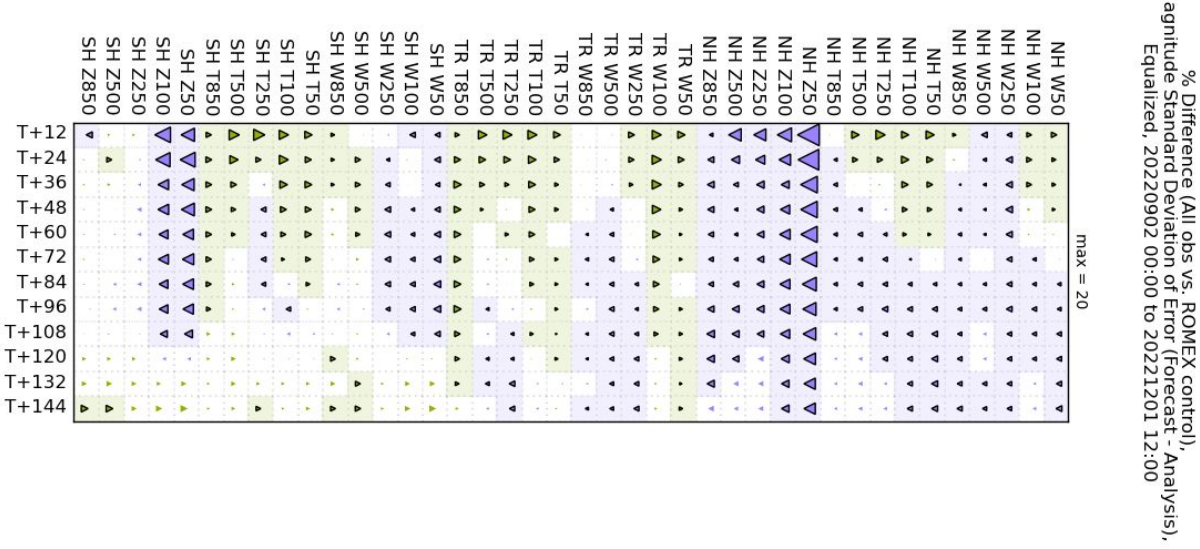
- ROMEX – lots of observations
  - It'll be easy, right?
- Initial impacts appeared negative (verified using RMSE against ECMWF analyses)
- Let's have more of a look at those biases

Adding all ROMEX observations (RMSE)



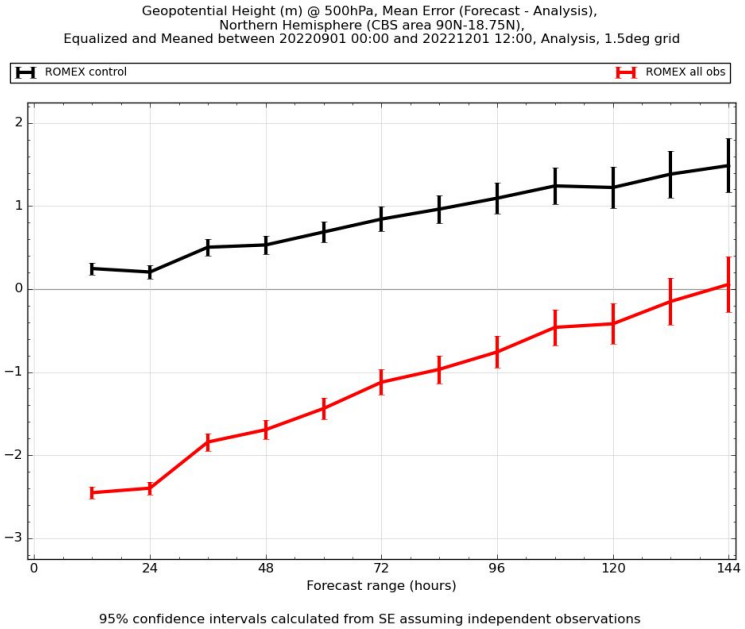
- Change in RMSE, verified against ECMWF analyses
- Area of triangle shows percentage improvement (degradation) in green (blue)
- Various lead times and forecast quantities

Adding all ROMEX observations (std dev)



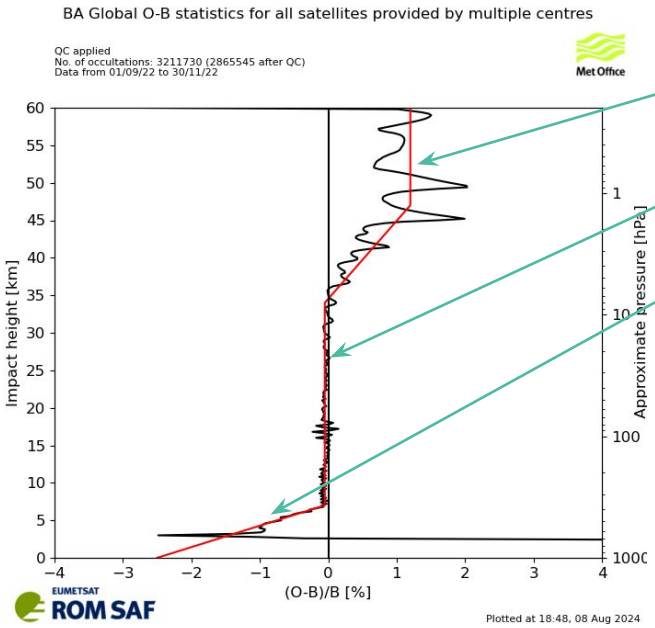
- Change in standard deviation of error, verified against ECMWF analyses
- Area of triangle shows percentage improvement (degradation) in green (blue)
- Various lead times and forecast quantities

Z500 forecast bias



- 2.5m negative bias in Z500 forecasts induced by adding extra observations

Biases (O-B)/B



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

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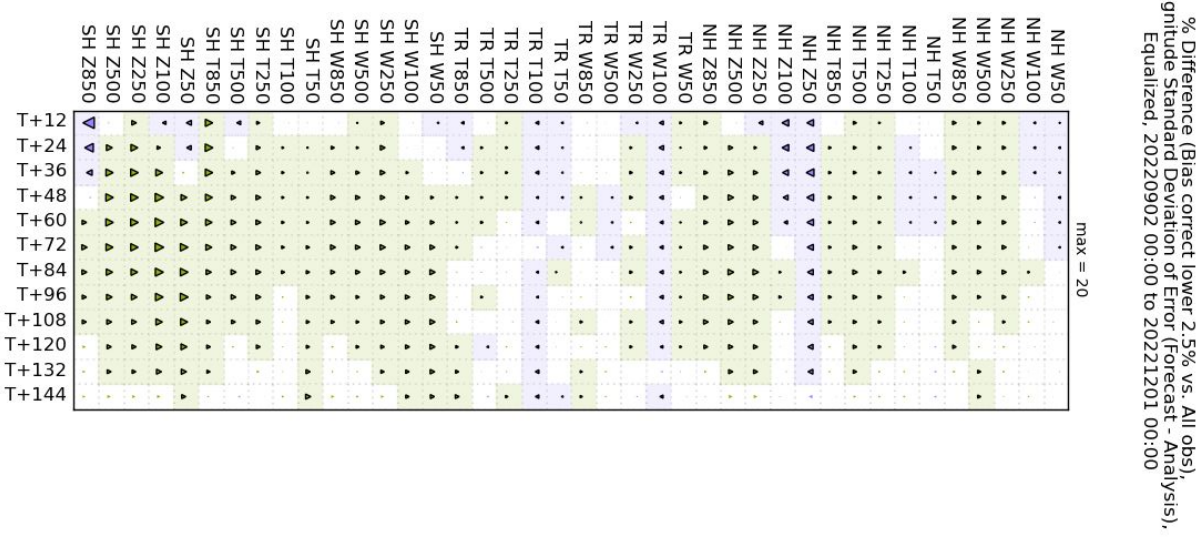
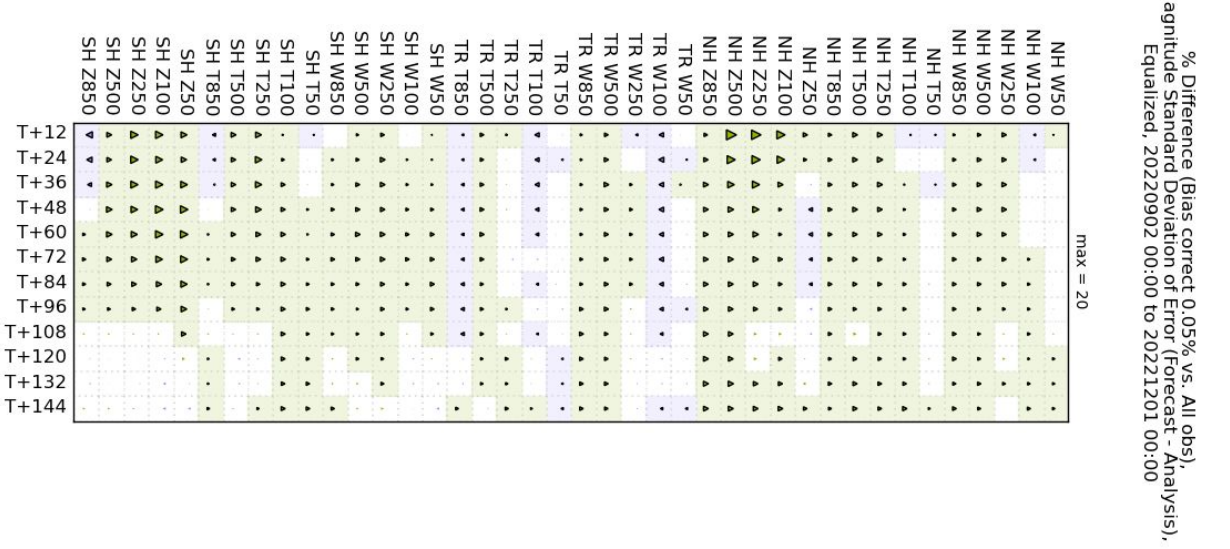
Increasing banding angles in lower troposphere



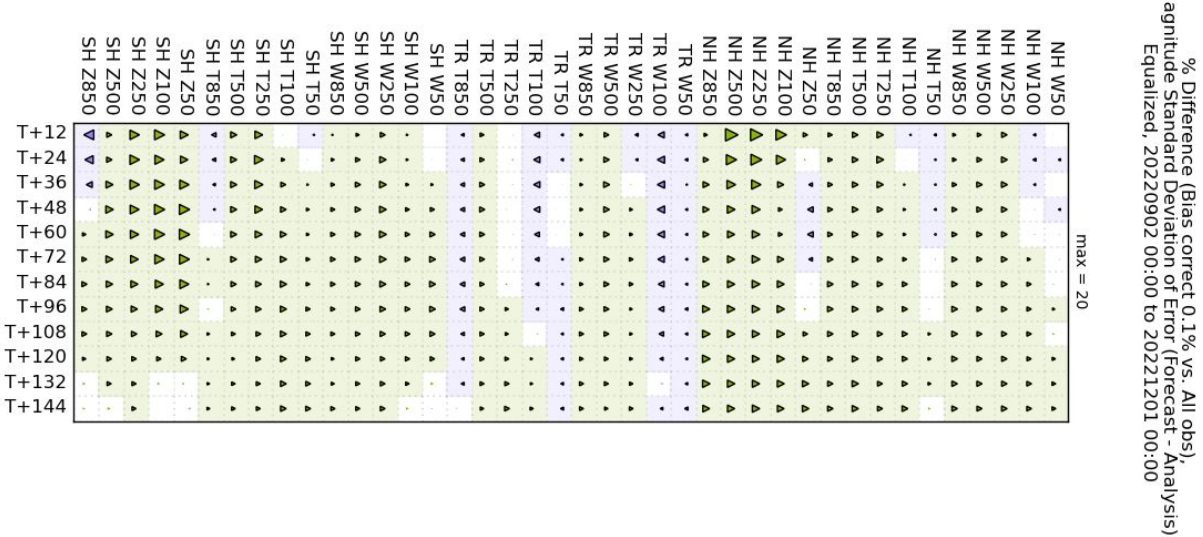
- Adjusting bias improves many quantities
- But doesn't help the bias for Z500!

Increasing all bending angles by 0.05%



- Smaller degradations in geopotential heights
- Large improvements relative to run without bias correction

Increasing all bending angles by 0.1%



- Most degradations in geopotential heights eliminated
- Large improvements relative to run without bias correction
- Degradations in Z50

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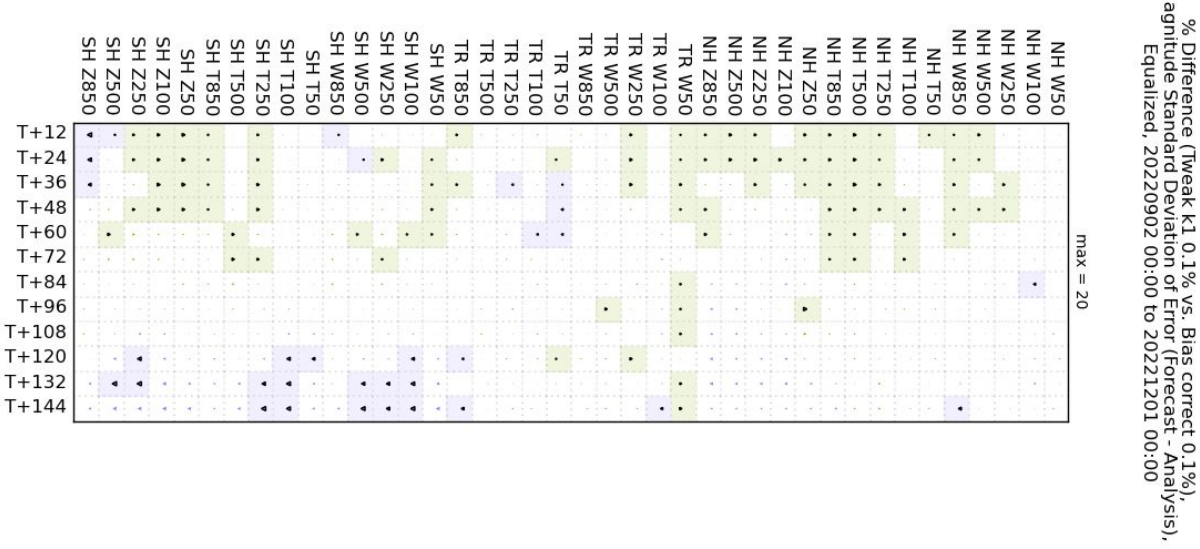
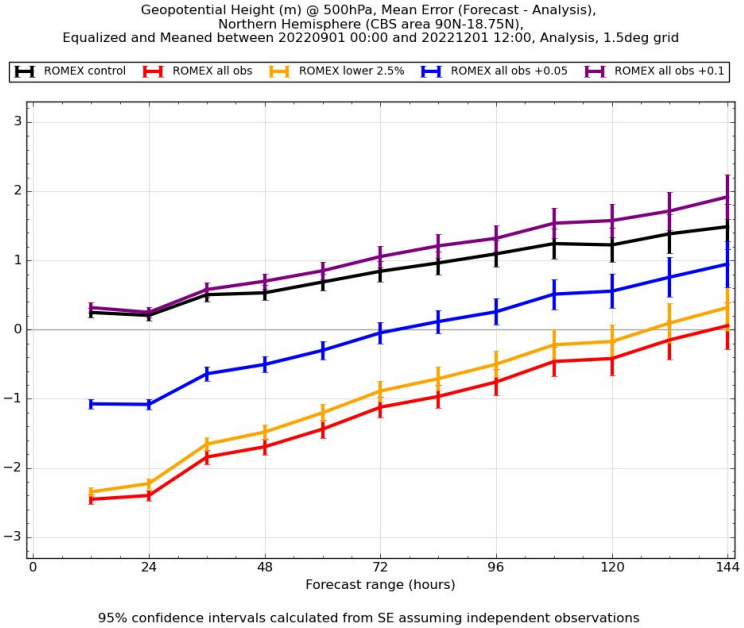
Changing k1



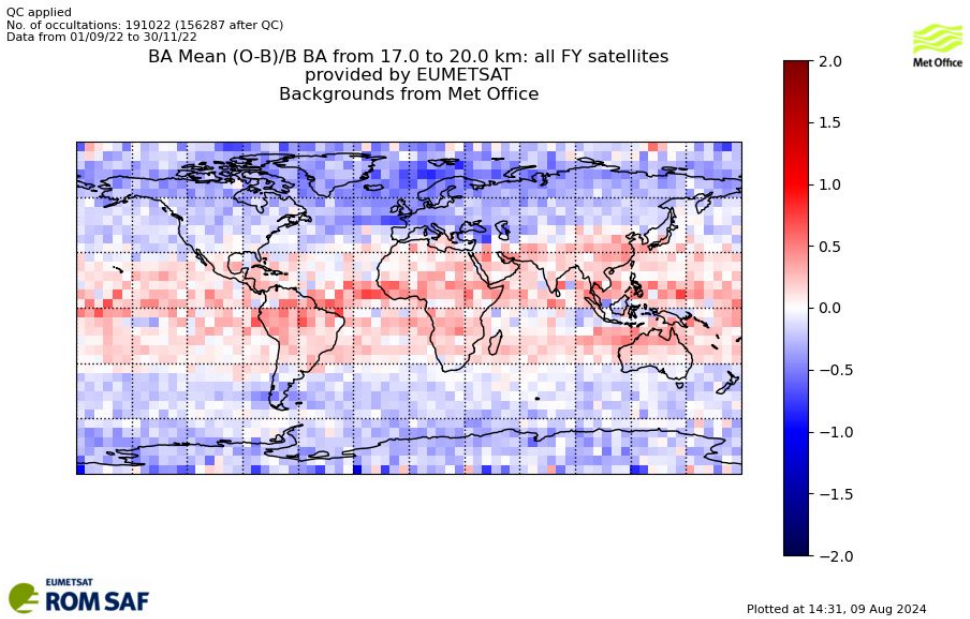
- We use Smith & Weintraub (1953) for refractivity
- $N = \frac{77.6\ P}{T} + \frac{3.73\ 10^5\ P_e}{T^2}$
- Can get nearly same effect by changing
  - 77.6 → 77.5224

Z500 forecast bias



- Bias correcting all obs (in particular lower stratosphere) changes Z500 bias
- Bias correcting by 0.1% “fixes” bias

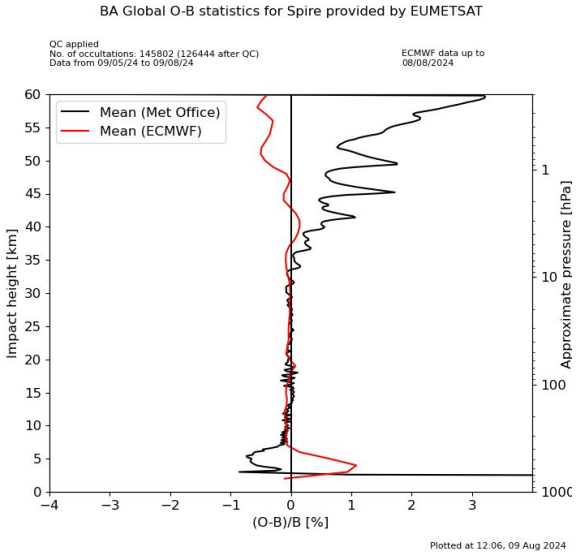
Spatially-varying biases



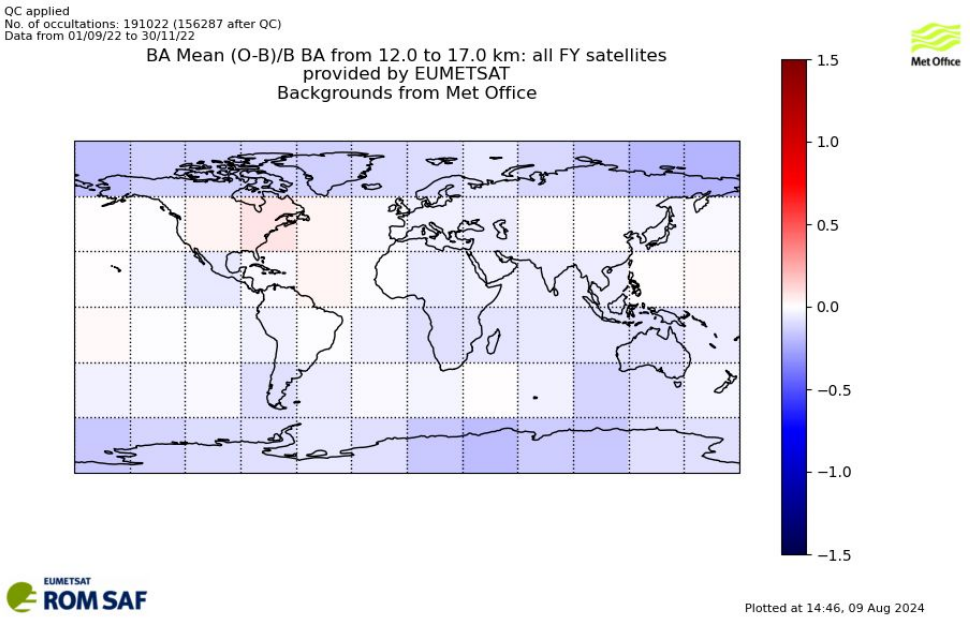
- Most satellites have similar pattern
  - Negative in extra-tropics
  - Positive in tropics
- COSMIC-2 positive in 30-45 N/S
- Spire less positive in tropics
- Other satellites stand out at different heights

The heresy

- GNSS-RO observations are known to be (largely) unbiased
- Applying a bias correction to the observations (or altering refractivity coefficients) improves the forecasts
  - The bias in the troposphere is largely modulated by the observations in the stratosphere
- Should we apply bias correction to upper-stratosphere to correct model biases?



Spatially-varying biases



- Calculate (O-B)/B on 30 degree grid for satellite groups
- For each observation, interpolate “bias” to observation location (in 3D)
- Apply “bias” correction to observation

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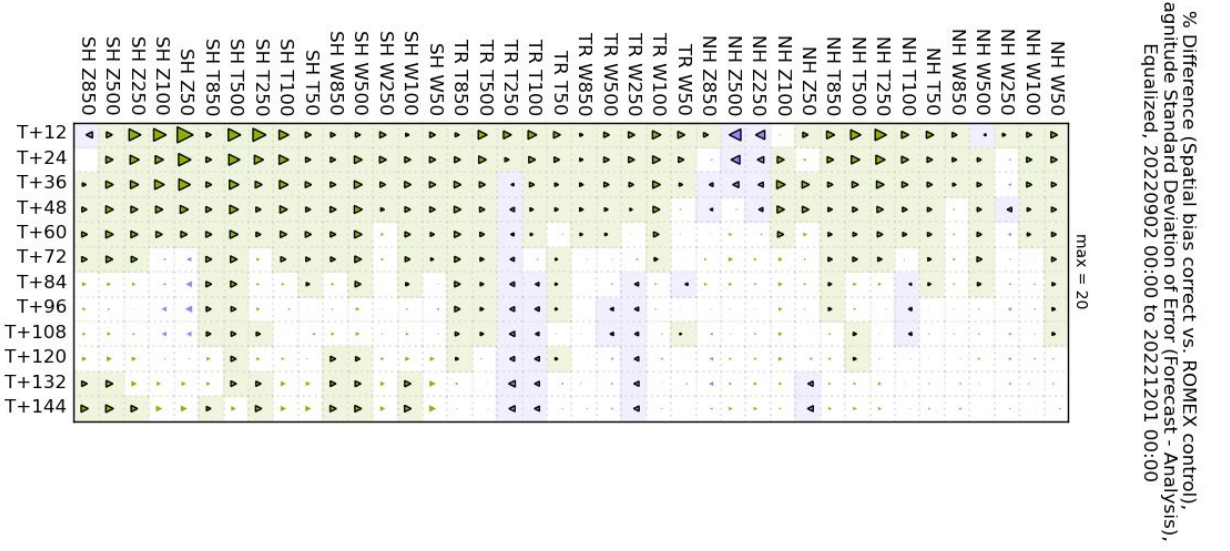
Spatially varying bias correction (std dev)



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

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Conclusion

- Adding all ROMEX observations did not yield better forecasts
  - For geopotential heights this is largely bias issue
- There are apparent biases between the observations and the background forecast
  - Most are due to the model, some coming from the observations
  - Increasing all bending angles by 0.1% helps in troposphere
  - Correcting the observations for these (spatially-varying) biases gives further improvements
- The forecast biases at a given height are (largely) controlled by the observations above it

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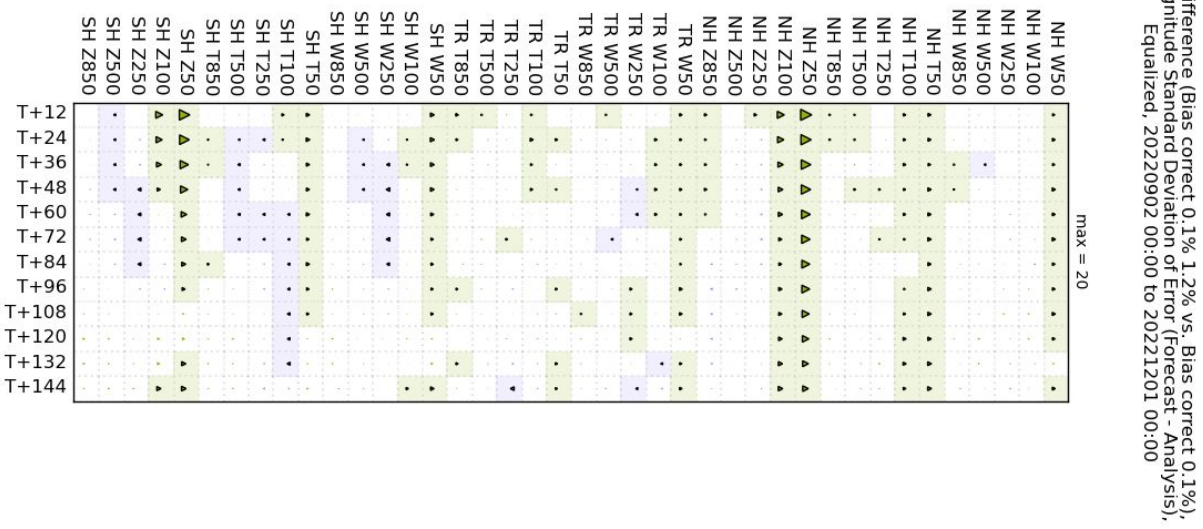
However…

- With this extra work we are able to see clear benefits of the additional ROMEX data
  - *It's just that the model biases made this hard to see*

Spare slides

Adding bias correction above 34km



- Reduces errors for Z50
- Mixed results in SH
- Does not fully improve RMSE

Bias correcting observations

- Applying a bias correction to the observations (for a model bias) takes the analysis further from the truth
  - Leads to the bias saturating more quickly
- We are bias correcting obs at high levels to effect a bias change at low levels

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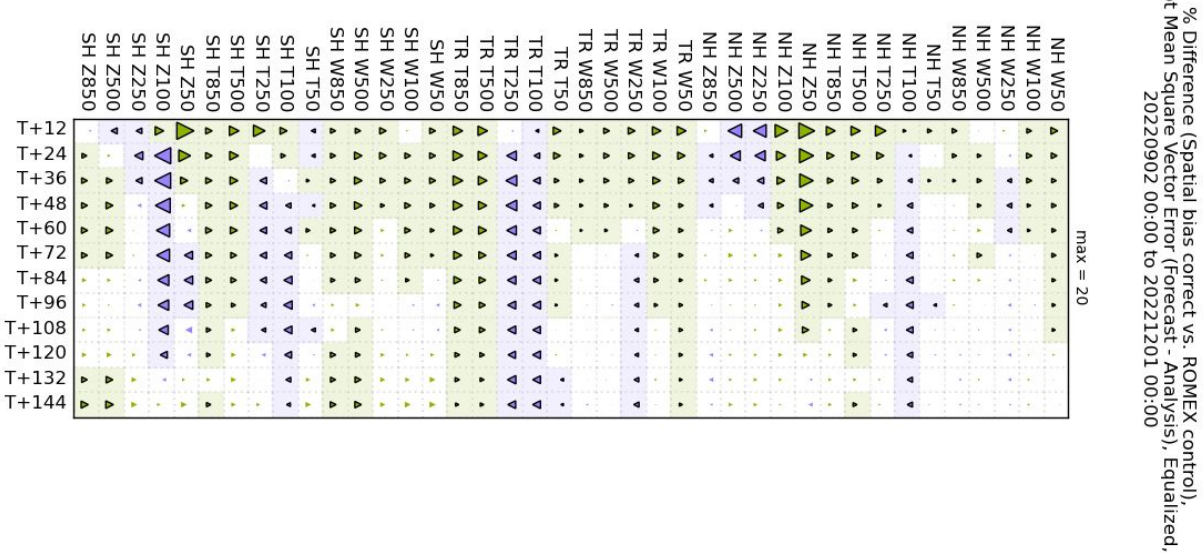
Spatially varying bias correction (RMSE)



- Generally positive results
- Negative for some upper-troposphere temperatures and geopotential heights