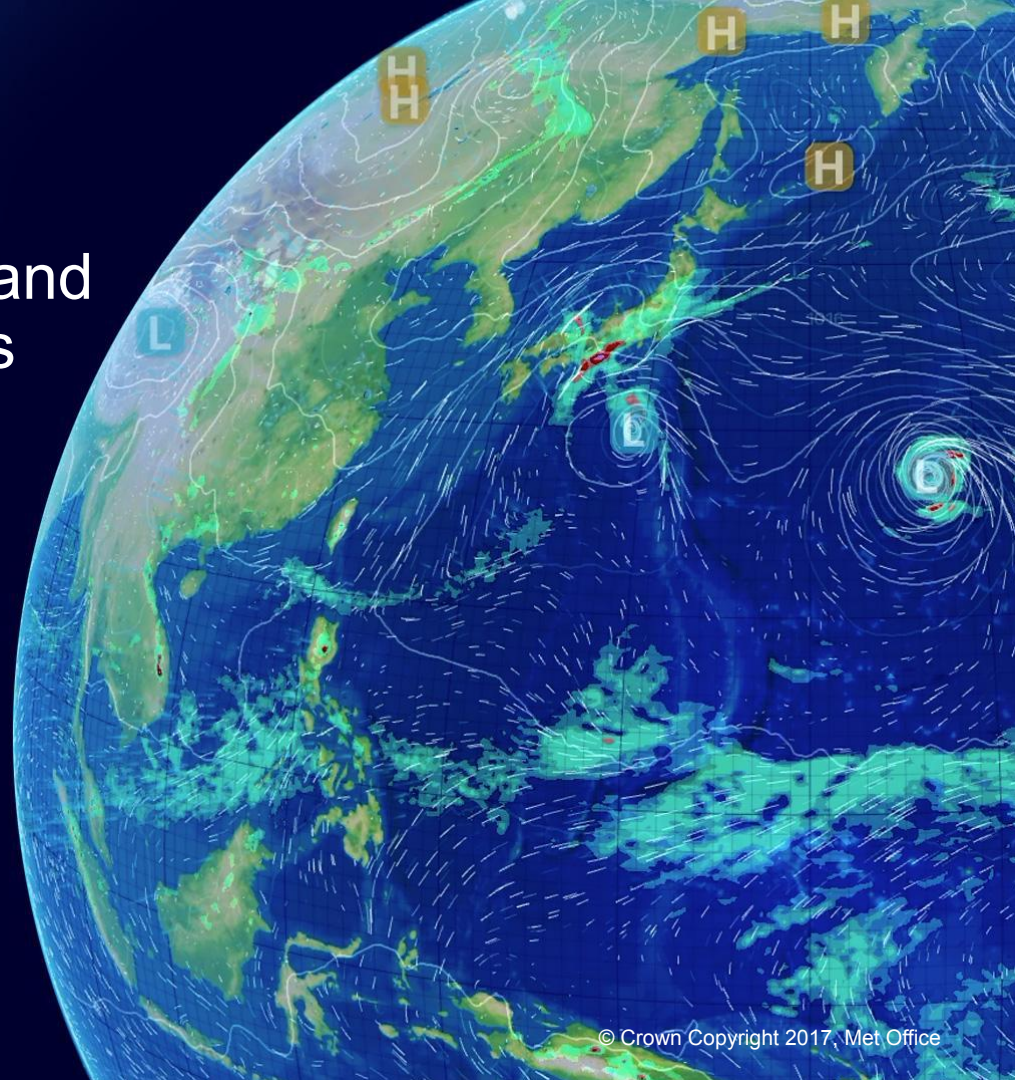


ROMEX: Attempts to understand model and observation biases

Neill Bowler

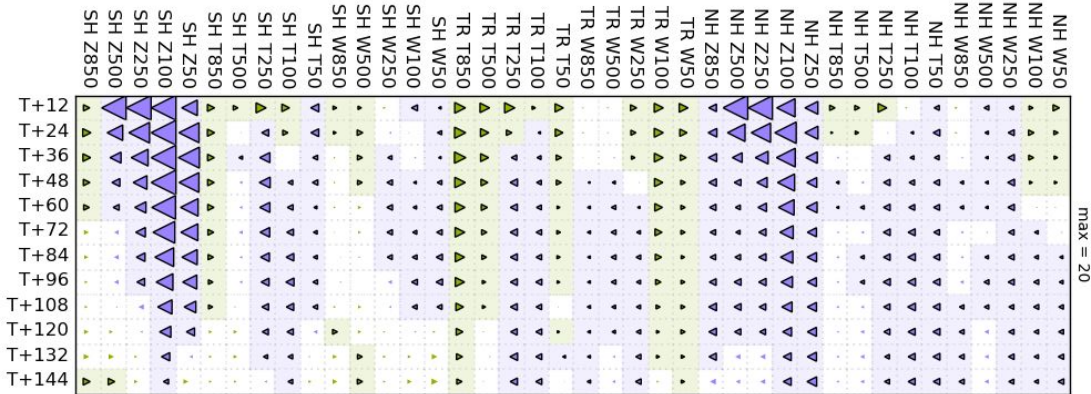
Owen Lewis



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

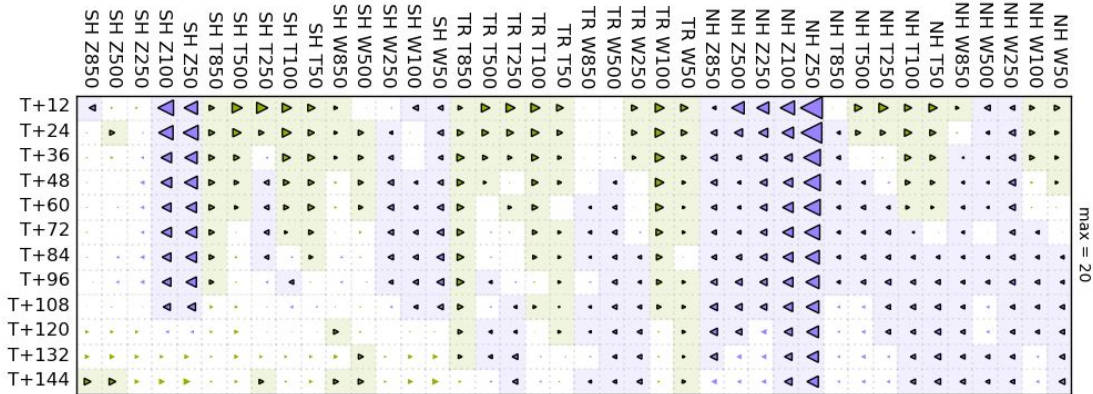
Adding all DOMEV observations (RMSE)



% Difference (All obs vs. ROMEX control),
 Root Mean Square Vector Error (Forecast - Analysis), Equalized,
 20220902 00:00 to 20221201 12:00

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

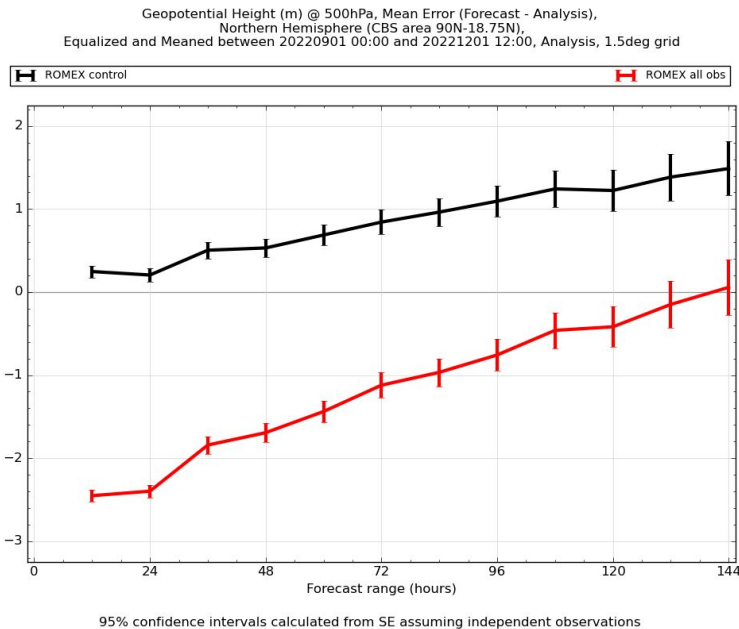
Adding all DOMEV observations (std dev)



% Difference (All obs vs. ROMEX control),
Magnitude: Standard Deviation of Error (Forecast - Analysis),
Equalized, 20220902 00:00 to 20221201 12:00

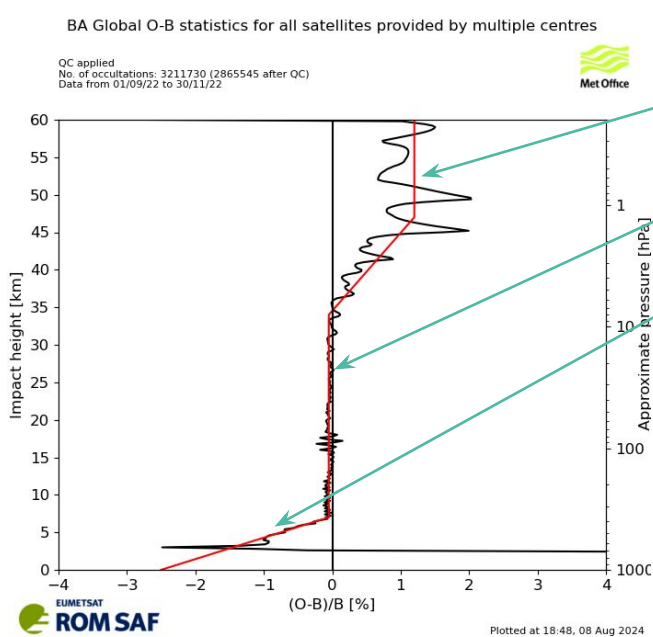
- Change in standard deviation of error, verified against ECMWF analyses
- Area of triangle shows percentage improvement (degradation) in green (blue)
- Various lead times and forecast quantities

Z500 forecast bias



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

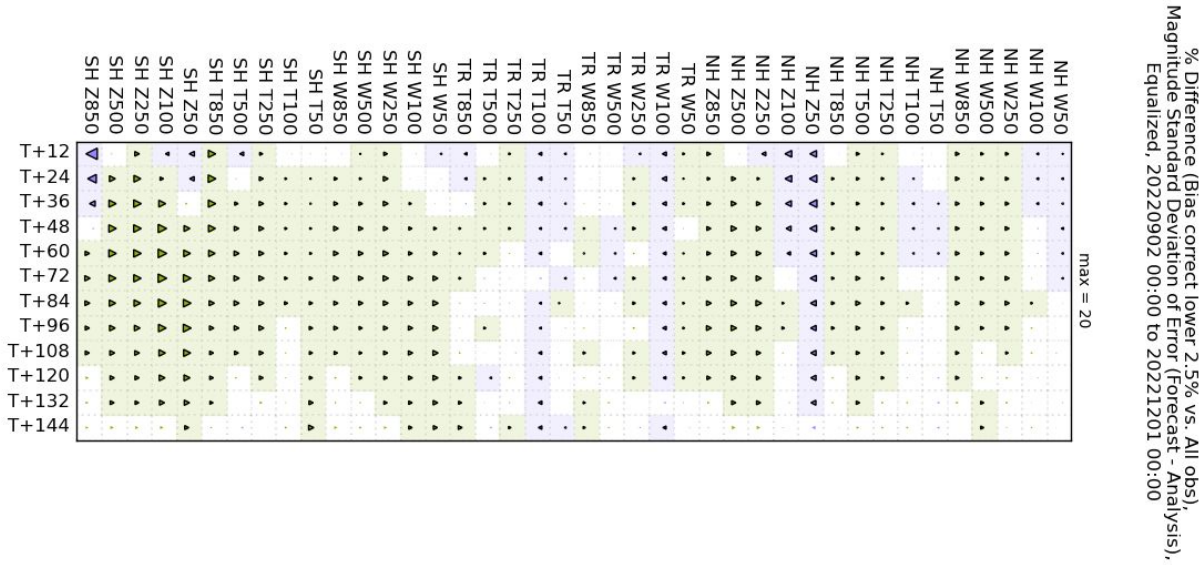
Biases (O-B)/B



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

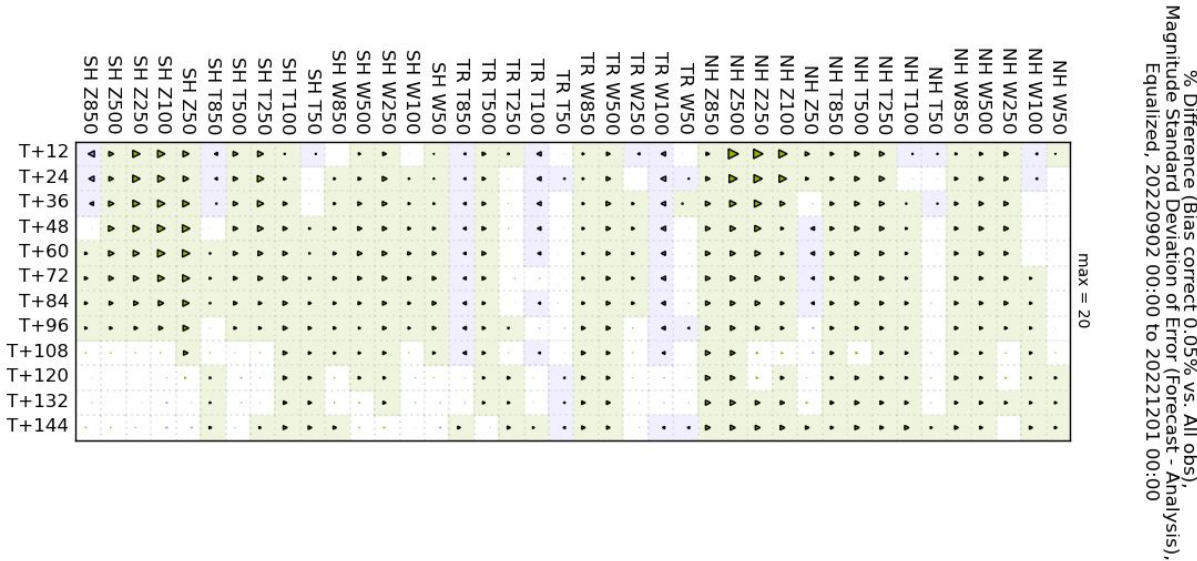
Improving landing cycles in lower troposphere

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

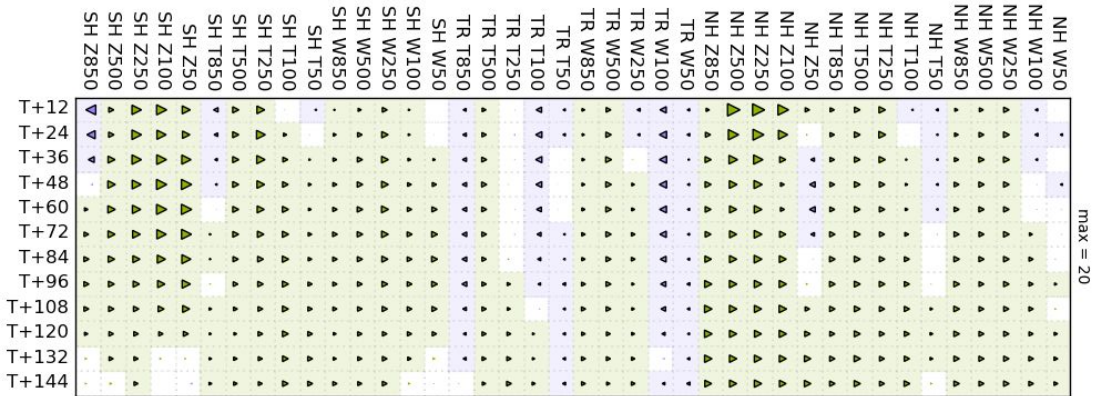


Increasing all bending angles by 0.05%

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



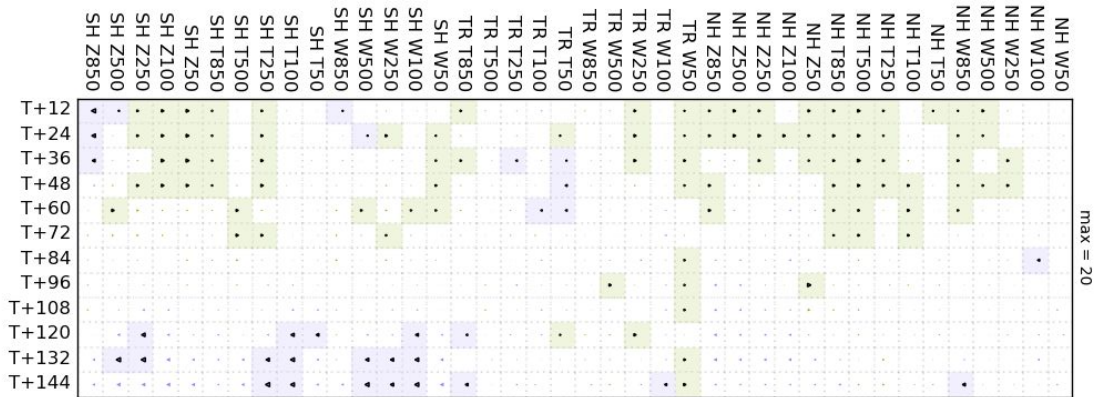
Increasing all bonding angles by 0.1%



% Difference (Bias correct 0.1% vs. All obs), Magnitude Standard Deviation of Error (Forecast - Analysis), Equalized, 20220902 00:00 to 20221201 00:00

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

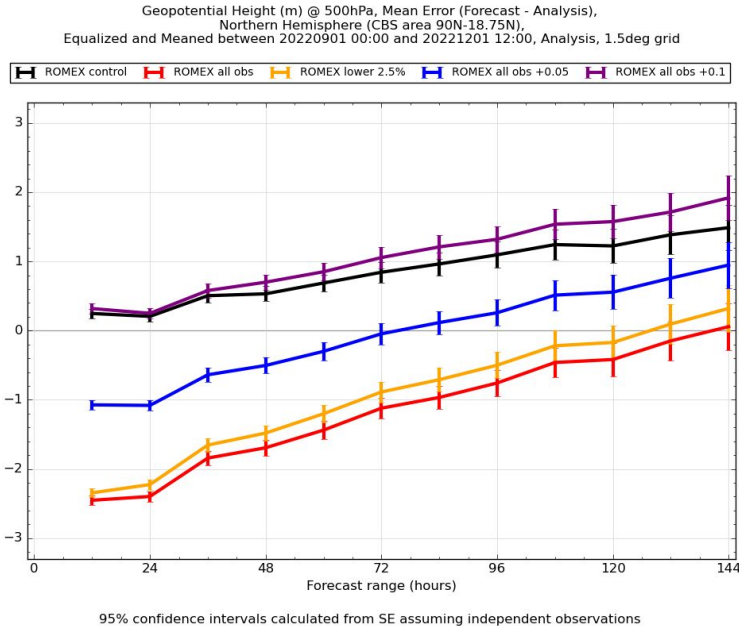
Changing k1



% Difference (Tweak k1 0.1% vs. Bias correct 0.1%),
 Magnitude Standard Deviation of Error (Forecast - Analysis),
 Equalized, 20220902 00:00 to 20221201 00:00

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

Z500 forecast bias

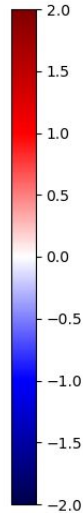
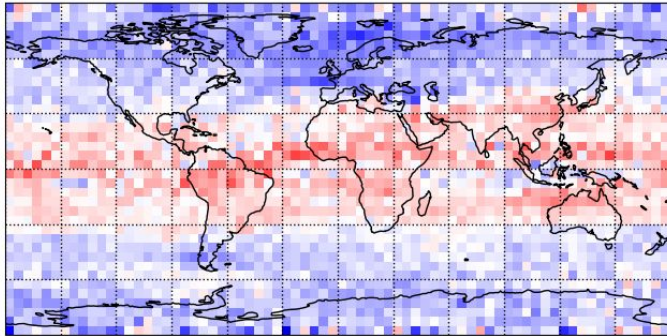


- Bias correcting all obs (in particular lower stratosphere) changes Z500 bias
- Bias correcting by 0.1% “fixes” bias

Spatially-varying biases

QC applied
No. of occultations: 191022 (156287 after QC)
Data from 01/09/22 to 30/11/22

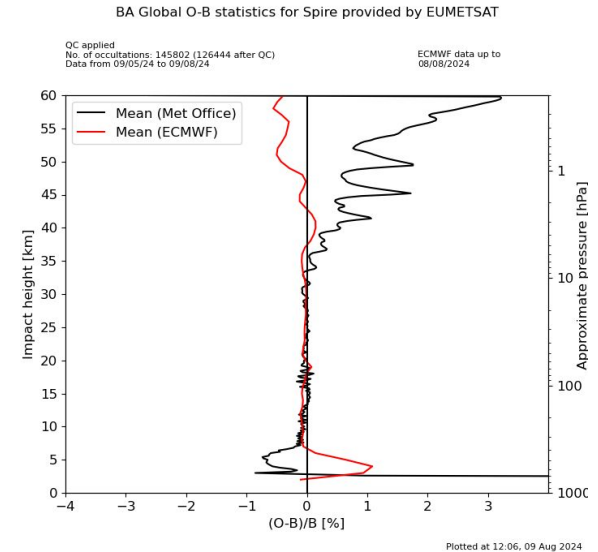
BA Mean (O-B)/B BA from 17.0 to 20.0 km: all FY satellites
provided by EUMETSAT
Backgrounds from Met Office



- 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

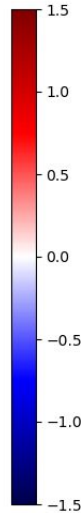
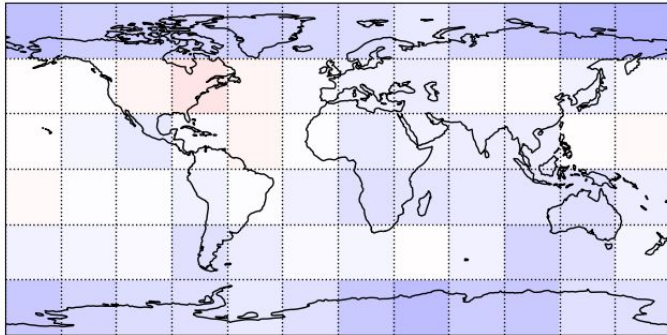
- GNSS-RO observations are known to be (largely) unbiased
- Applying a bias correction to the observations (or altering refractivity coefficients) improves the forecasts
 - The bias in the troposphere is largely modulated by the observations in the stratosphere
- Should we apply bias correction to upper-stratosphere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



Spatially-varying biases

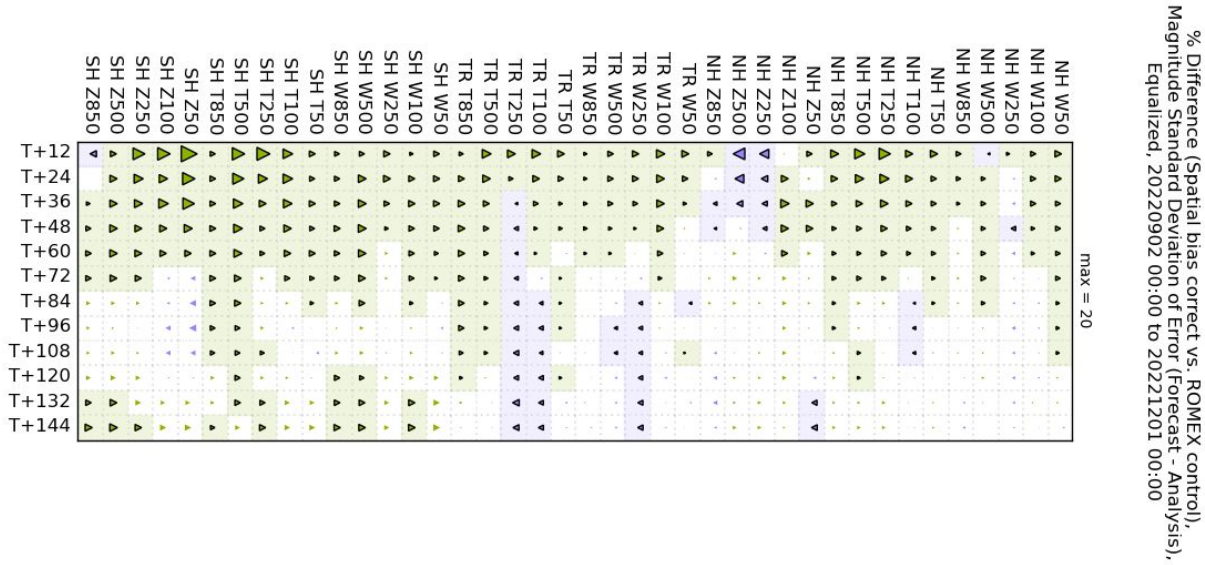
QC applied
No. of occultations: 191022 (156287 after QC)
Data from 01/09/22 to 30/11/22

BA Mean (O-B)/B BA from 12.0 to 17.0 km: all FY satellites
provided by EUMETSAT
Backgrounds from Met Office



- 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

Spatially varying bias correction (std dev)



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

Conclusion

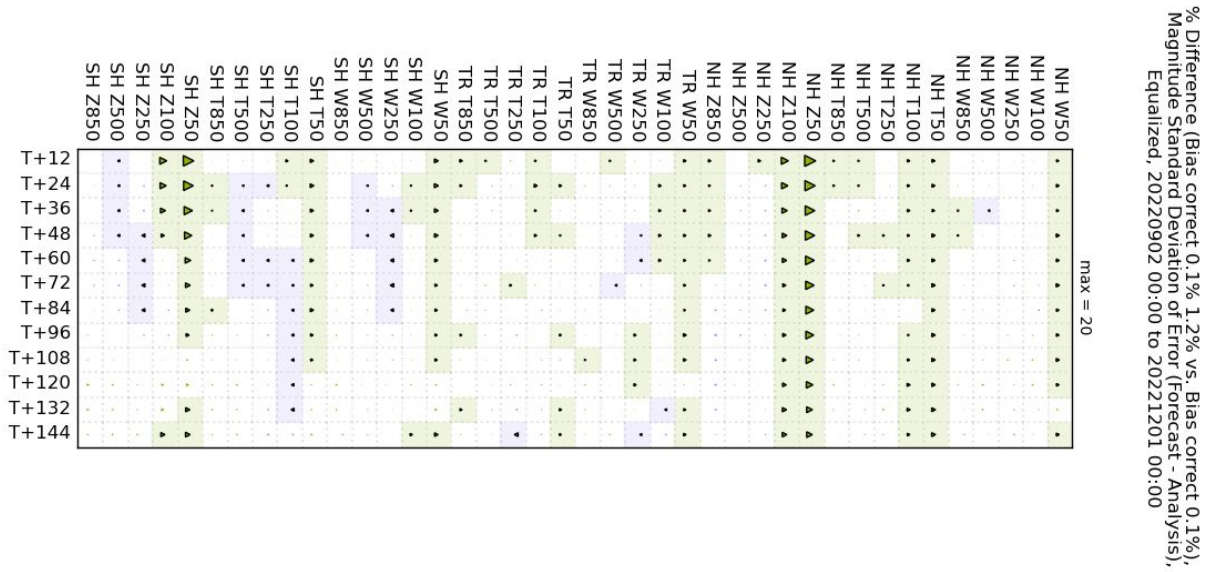
- Adding all ROMEX observations did not yield better forecasts
 - For geopotential heights this is largely bias issue
- There are apparent biases between the observations and the background forecast
 - Most are due to the model, some coming from the observations
 - Increasing all bending angles by 0.1% 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

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*

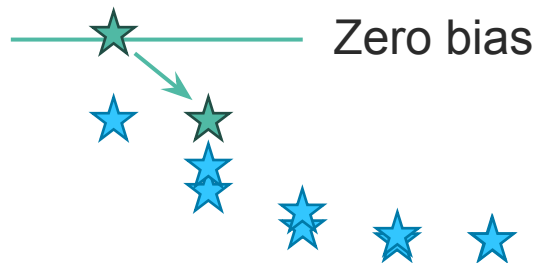
Spare slides

Adding bias correction above 24km



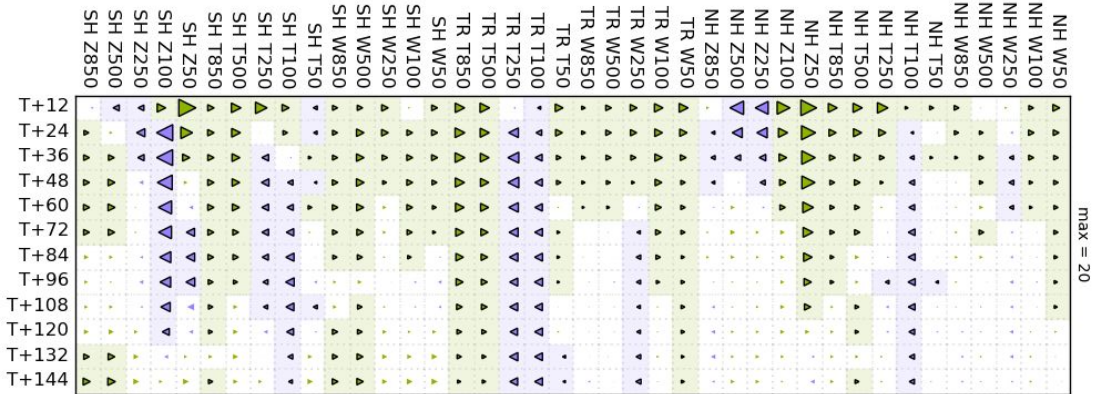
- Reduces errors for Z50
- Mixed results in SH
- Does not fully improve RMSE

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

Spatially varying bias correction (RMSE)



% Difference (Spatial bias correct vs. ROMEX control),
 Root Mean Square Vector Error (Forecast - Analysis), Equalized,
 20220902 00:00 to 20221201 00:00

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