Justification for high ascent attainment from NWP perspective

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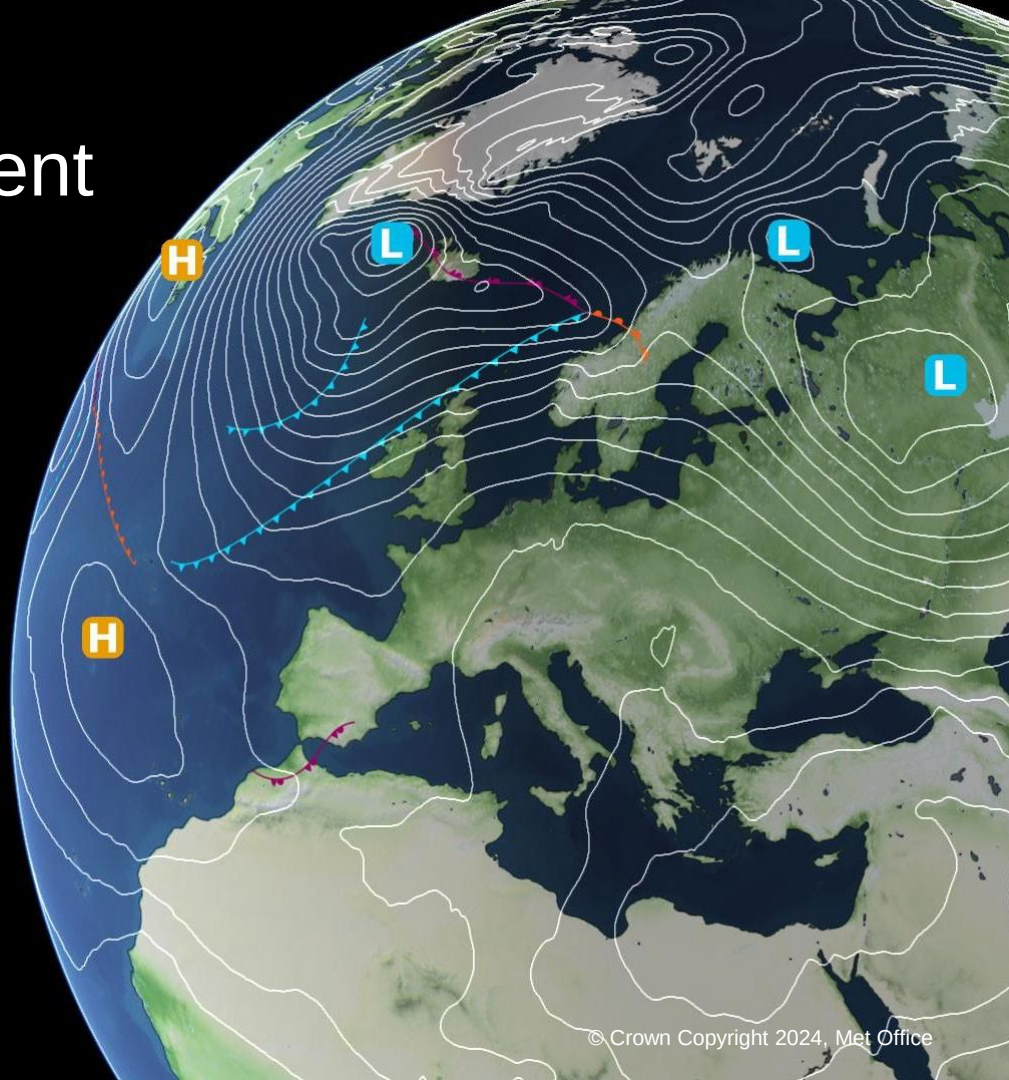


Key questions we are trying to answer:

- Where the radiosonde are most useful and offers unique capability?
  - E.g. tropospheric temperature, humidity and wind?
  - Stratospheric wind, temperature?
  - Bias corrections?

- How high should radiosondes go?
  - Are radiosonde reaching pressure ≤ 30hPa any useful to NWP systems?

WMO workshop on observing system experiments

Piggy backed Met Office effort for the WMO workshop to look at five denial experiments:

- Reject all sondes
- Reject all sondes above 30hPa
- *Plus a few others not presented for the sake of time*

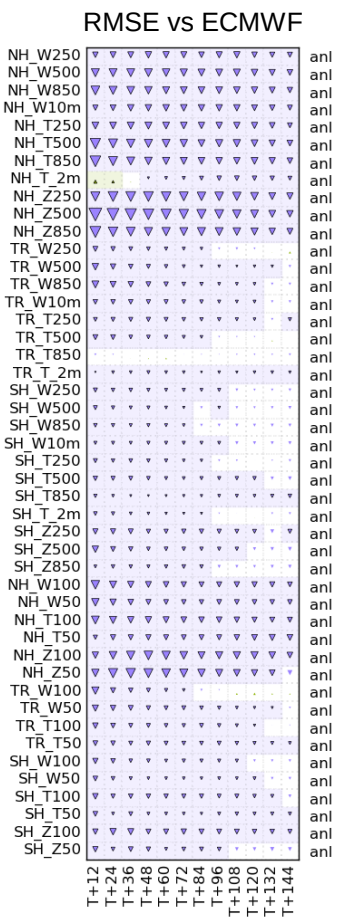
Control & experiments reflect the operational system from 15th December 2022 to 15th March 2023 but at lower resolution and decoupled from the ocean model.

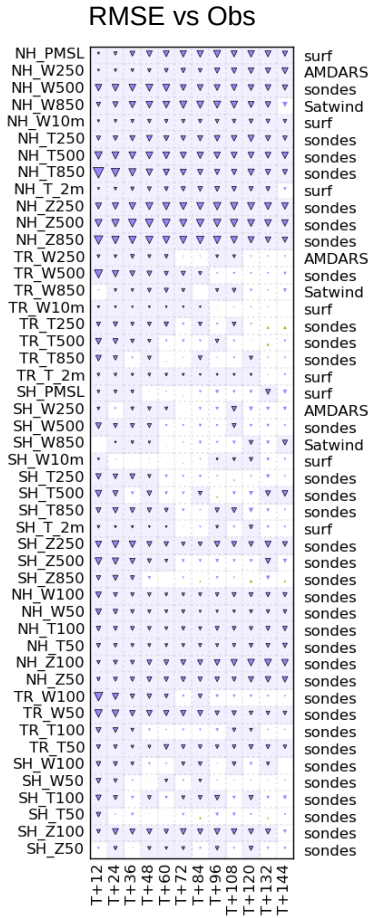
What happens when all the radiosondes are removed?

First Evaluation Metric

Change in root-mean-square error (RMSE) calculated against independent data sources for key forecast variables and pressures at lead times up to 7 days:

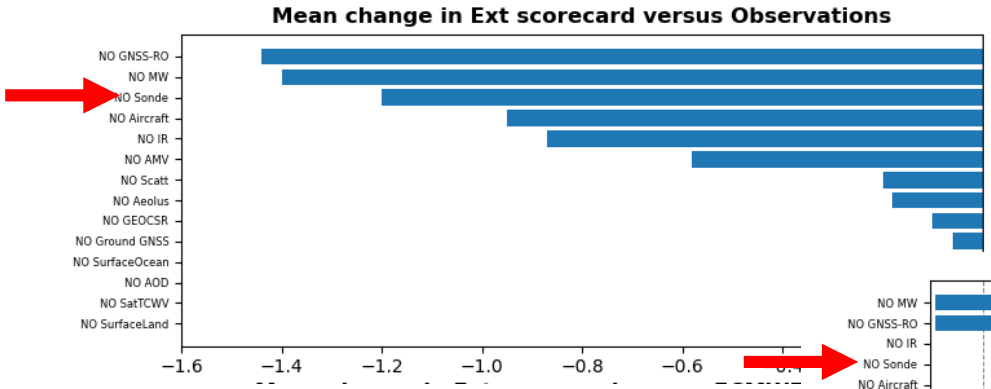
- Overall degradation of 1.66% against ECMWF analyses (left).
- Overall degradation of 1.34% against observations (right).

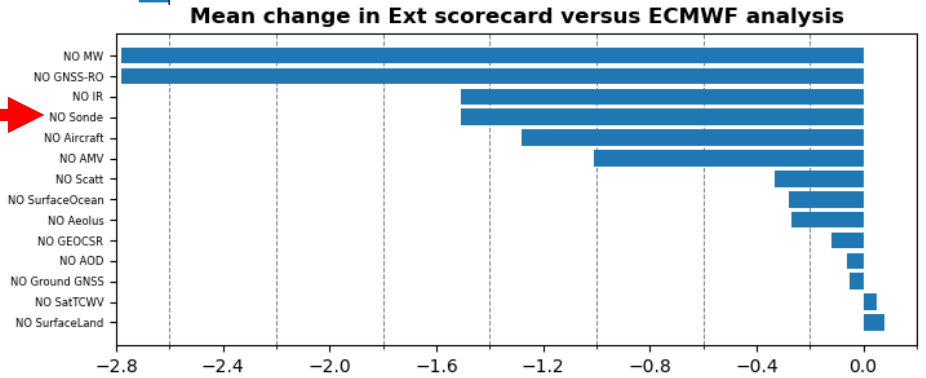




e.g., NH_T250 = Northen Hemisphere Temperature at 250hPa; blue=degradation; green=improvement

Top 4 most important observation family according to this metric when compared to other denial experiments



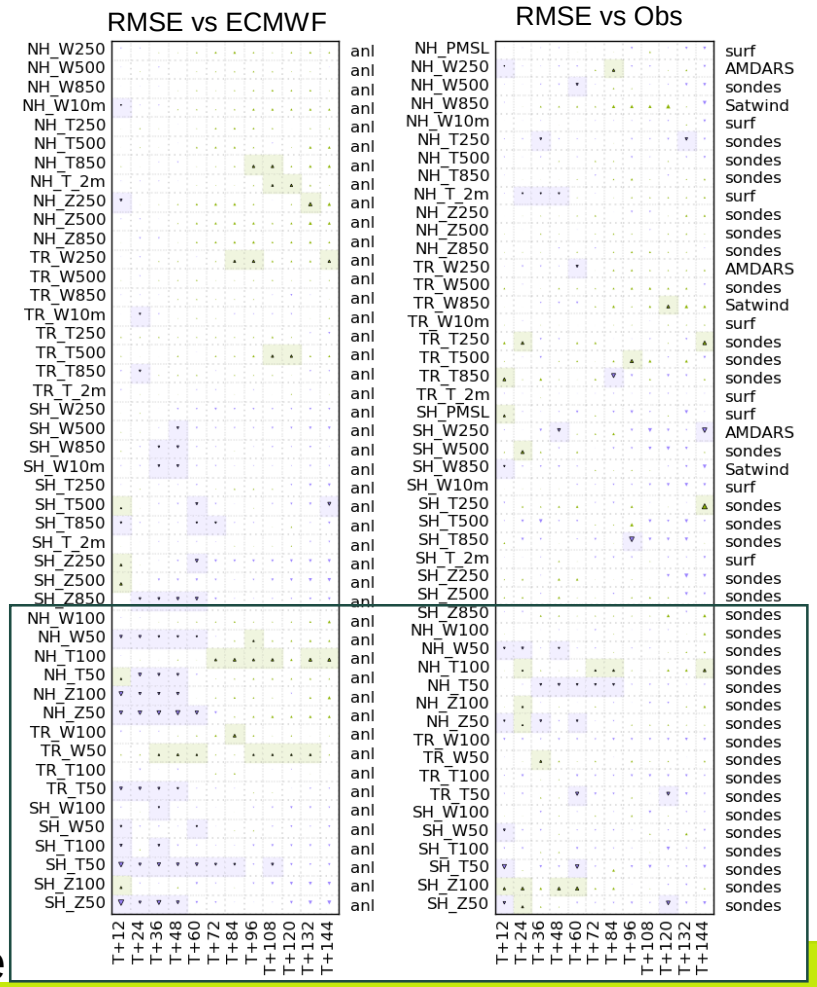


What happens when profiles are cut at 30hPa ?

First Evaluation Metric

Change in RMSE calculated against independent data sources:

- No significant change of against ECMWF analyses (left, -0.02%).
- No significant change of against observations (right, -0.04%).



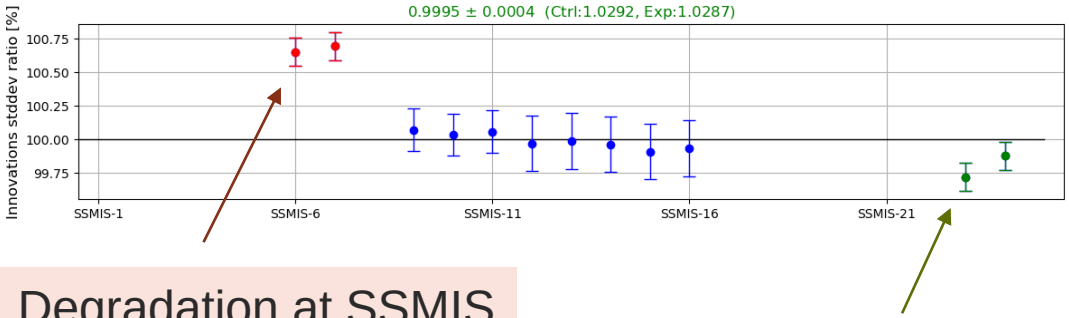
What happens when profiles are cut at 30hPa ?

Second Evaluation Metric

Fit between independent observations and the model background (6-hr forecast), expressed as the variation of the standard deviation in background departure:

$$\sigma\left(\frac{|O - B_{denial}|}{|O - B_{control}|}\right)$$

F17 SSMIS



Degradation at SSMIS temperature sounding channel 6 ~60hPa and 7 ~35hPa

Improvement at SSMIS temperature sounding channel 23 ~5hPa and 24 ~15hPa

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‘Anchoring’ the bias correction

Because data assimilation systems work with the assumption that the assimilated observation are represented by Gaussian PDF free from systematic error, variational bias correction schemes are used to correct systematic errors in satellite observations.

A correction term, *c*, for k^{th} observation is estimated during the variational analysis:

$$c_k = \mathrm{s_k} + \sum_{i=1}^{r_k} \beta_{k,i} p_{k,i}(x)$$

with *s* a constant offset
p the predictors
β coefficients that are updated at each cycle
x the NWP model state

‘Anchoring’ the bias correction

Problems arise when the model biases are not negligible and cannot be disentangled from biases in the observations: **the correction will drift in time to unrealistic values and propagate biases in the analysis**.

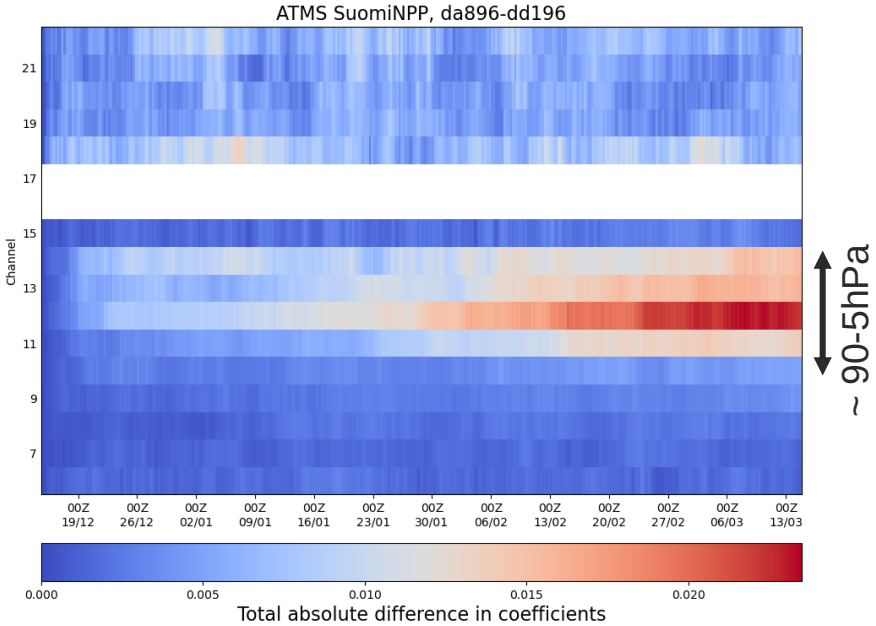
Observations with bias much smaller than that of the model state being observed are used uncorrected (in the variational analysis) to “anchor” the bias correction.

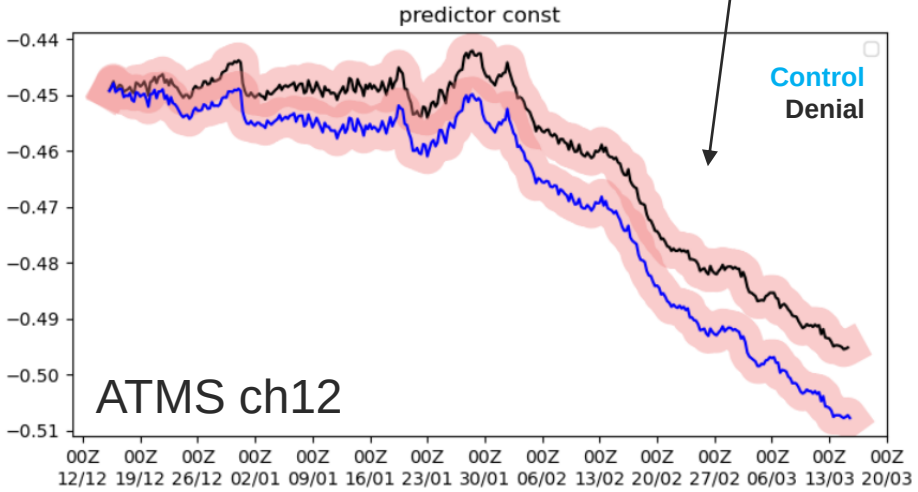
- The uncertainty associated with the anchor observations can be used to establish the weight given to the observations.
- The weighting given to the anchor observations can be increased by using more anchor observations.

Francis et al., 2023 https://doi.org/10.1002/qj.4482

‘Anchoring’ the bias correction

$$c_k = s_k + \sum_{i=1}^{r_k} \beta_{k,i} p_{k,i}(x)$$





Predictors are drifting over time, i.e., the bias correction is gradually degrading

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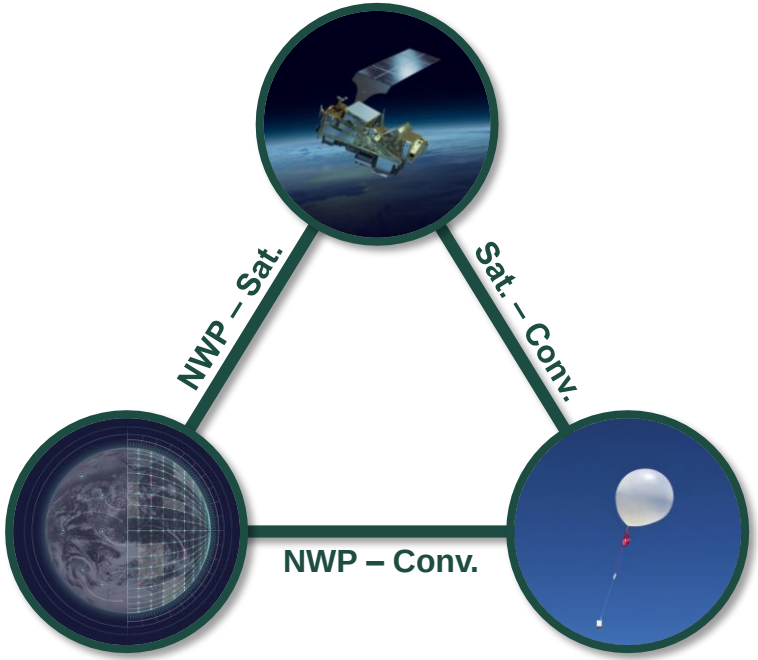
Conclusion

- Sondes are highly beneficial to the forecast in the troposphere.
- Impact on forecasts is marginal in the stratosphere, but …
- Sondes act as anchors to the variational bias correction scheme.
  - Removing the anchoring results in drifting bias correction.
  - Overtime, the bias correction will wrongly propagate model biases in the analysis leading to increasing degradation of the forecasts.
- NWP systems need plenty of these high quality – low uncertainty anchor data, in particular where model biases are large and model states under observed.

Conclusion

NWP systems are commonly used – along conventional observations – to assess, calibrate and validate satellite missions.

The link between NWP and high-quality observations is fundamental to make the most of the 2 other sides of the triangle (e.g., VICIRS) and should not be disregarded, in particular at funding levels.



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Thank you

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