Bias correction of observations based on an analysis that uses only anchor observations

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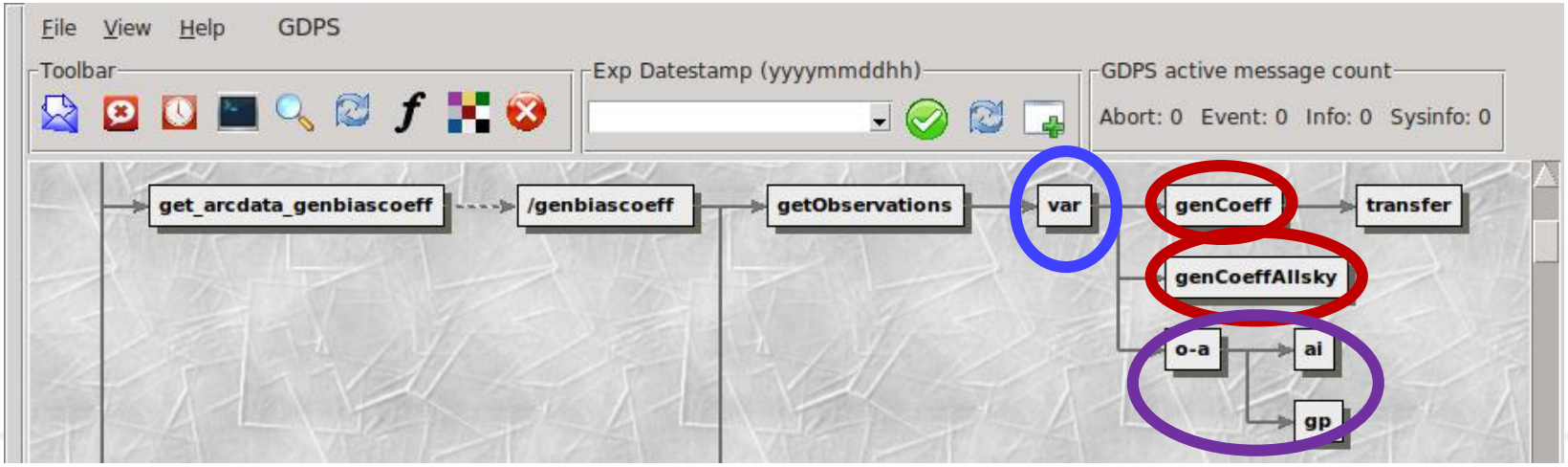
Introduction

- Until 2014, satellite radiance obs were bias corrected using dynamically computed bias model coefficients estimated by assuming the background state is unbiased
- Consequently, any forecast model bias would immediately be reflected in the satellite radiance observations, thus reinforcing this bias
- To allow other unbiased “anchor” obs to counteract the forecast model bias, a less-biased reference state is now produced by assimilating anchor obs with 3D-Var
- 3D-Var analysis only used for estimating obs bias with no direct impact on main 4D-EnVar, therefore it can be optimized for bias correction (e.g. different σ_b or obs)

Approach

- Perform 3D-Var analysis using background state of main 4D-EnVar cycle and only assimilate “anchor” observations:
  - GPS-RO, radiosonde, AMVs, surface obs
- Use regression to estimate bias model coefficients by fitting radiance obs to past 7 days of 3D-Var analyses
- Similar approach recently proposed for estimating obs error bias of aircraft and ground-based GPS obs

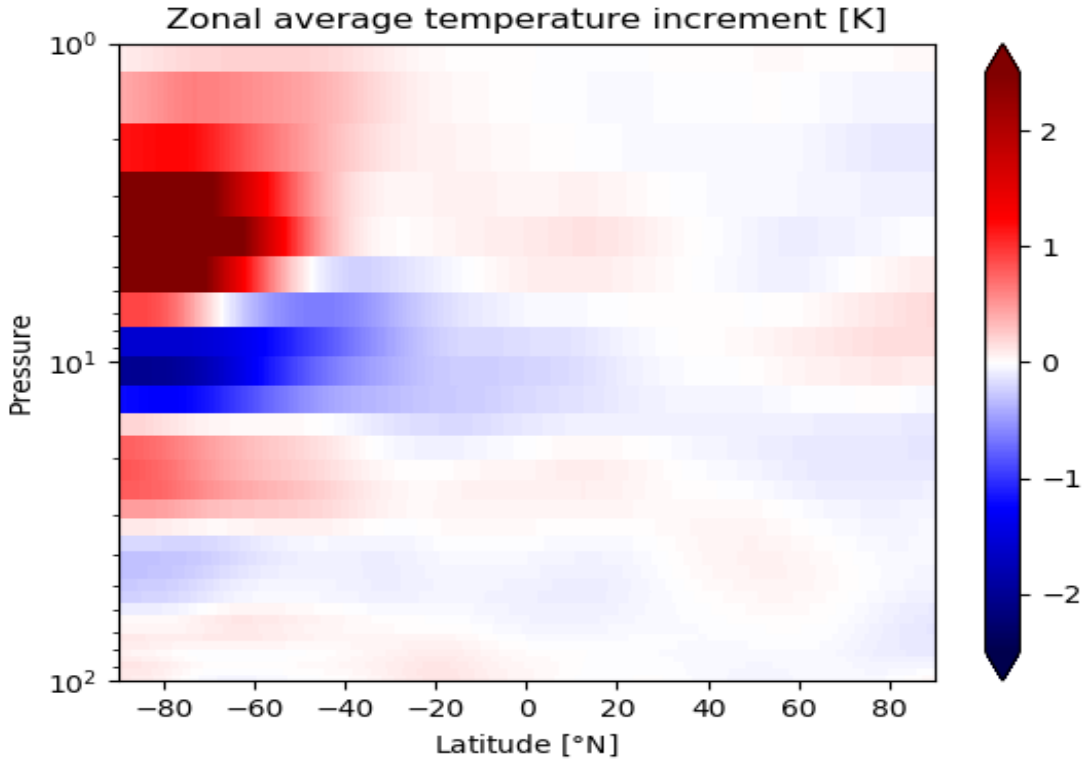


Results: Radiance Bias Correction

- Four-month experiment performed to evaluate impact of using the 3D-Var analysis assimilating only anchor observations as compared with using the background state for the bias coefficient estimation
- Applied to all satellite radiance observations, except AMSU-A ch13/14 and ATMS ch 14/15 which have fixed bias correction coefficients
- Bias model consists of a constant for each scan angle and a set of air mass predictors (thicknesses of troposphere and lower/upper stratosphere)
- Evaluated with comparisons against radiosonde, GPS-RO and ECMWF analyses (which uses Var-BC)

Results: Mean temperature increment

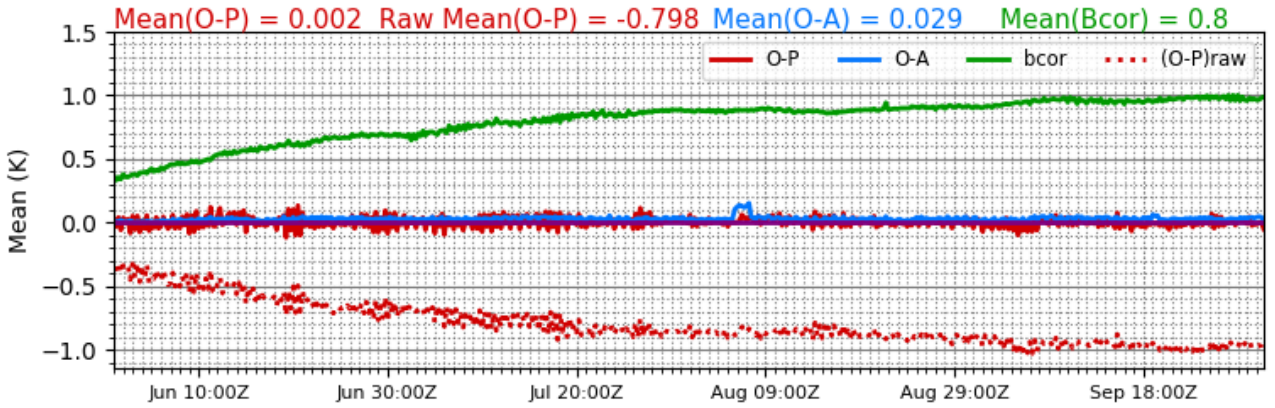
- Zonal and temporal average of temperature increment from 3D-Var analysis assimilating only the anchor obs: corrections made to counteract model bias within data assimilation cycle (plot only for July)



Results: Radiance Bias Correction

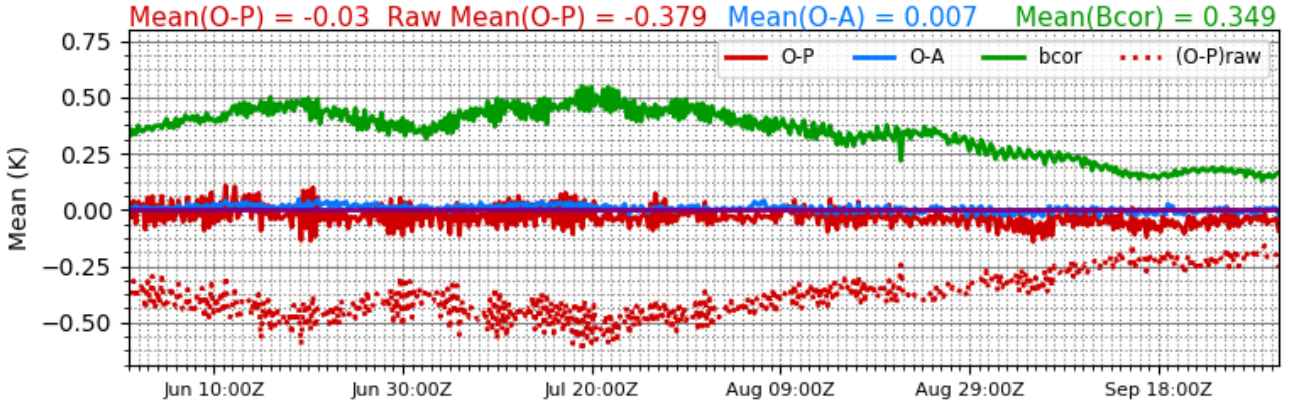
- **Mean bias correction** for AMSU-A ch12 differs by nearly 1K when using 3D-Var analysis vs. background state

Bias correction estimated using background state



+1.0K

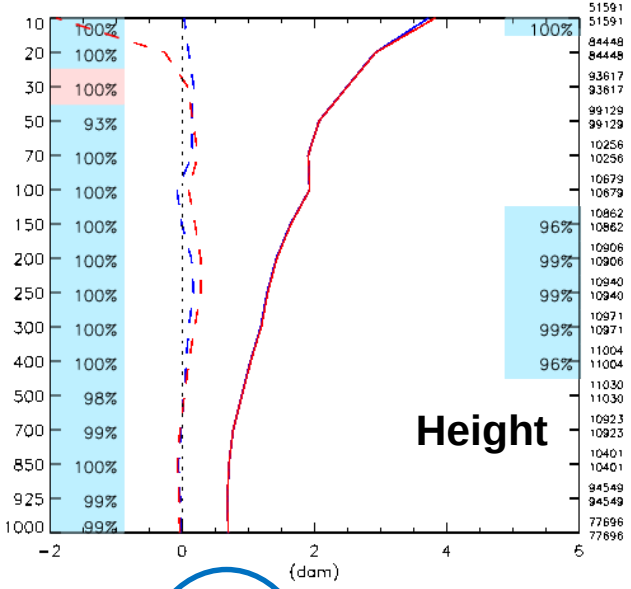
Bias correction estimated using 3D-Var with anchor obs

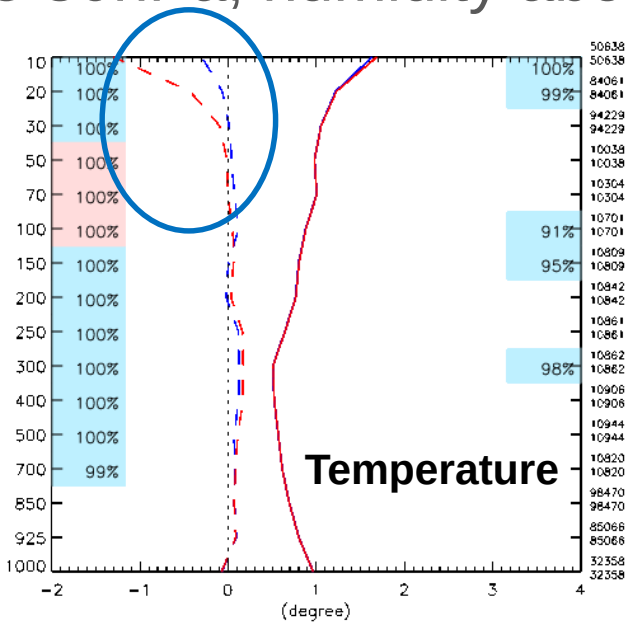


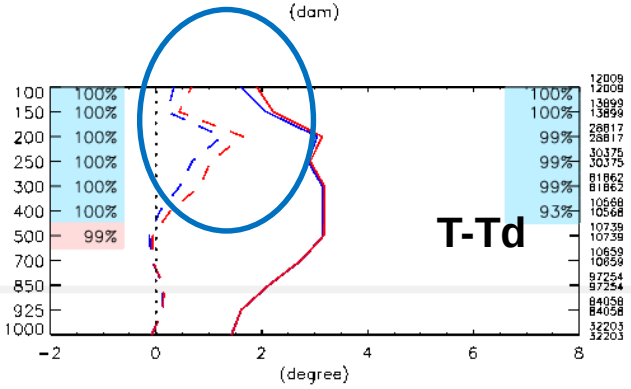
+0.15K

Results: Comparison with Radiosondes

- Mean and stddev of analysis differences relative to raobs significantly improved using 3D-Var analysis with anchor obs: temperature above 30hPa, humidity above 500hPa





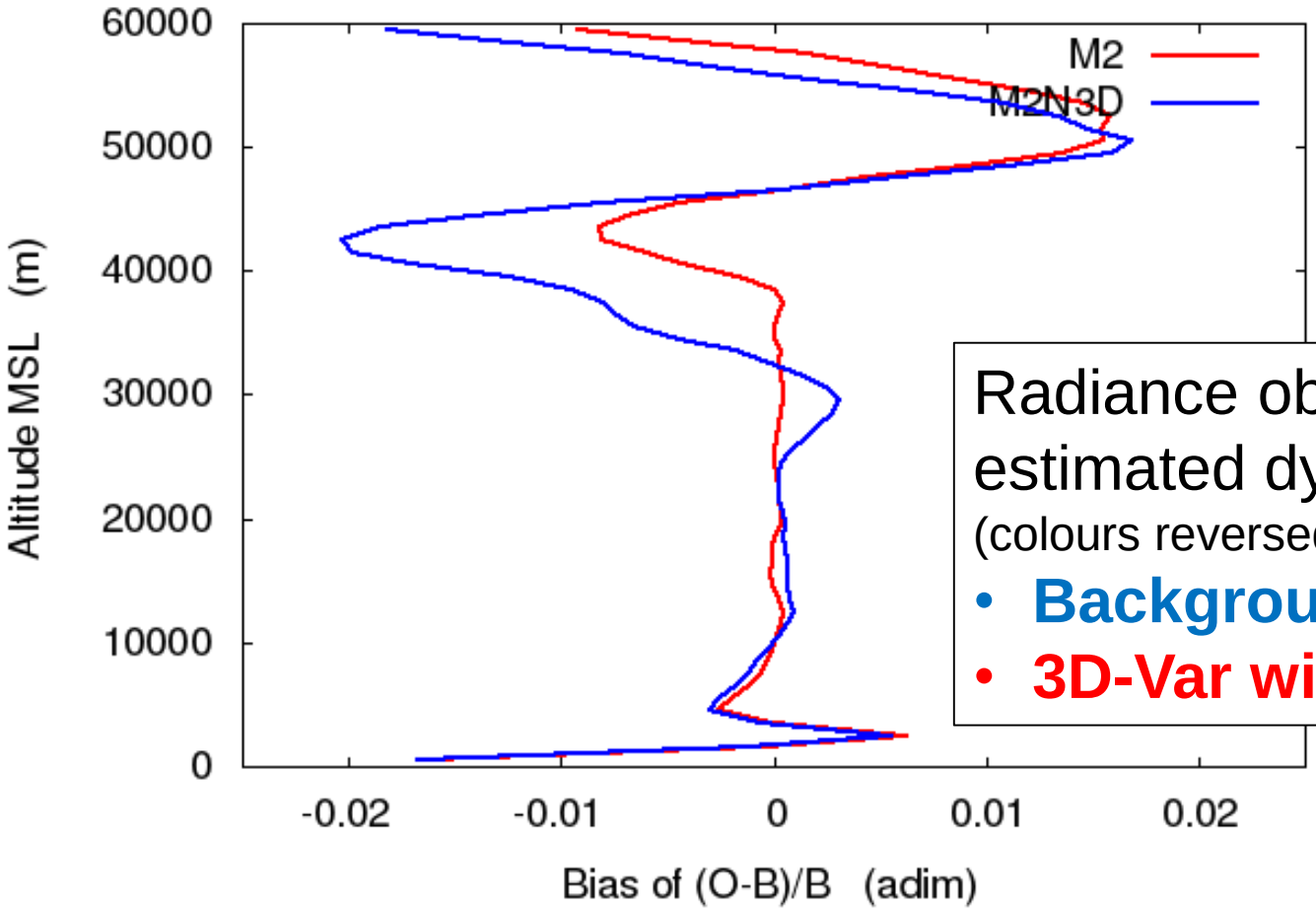


Radiance obs bias correction estimated dynamically using:

- **Background state**
- **3D-Var with anchor obs**

Results: Comparison with GPS-RO

- Mean of background state differences relative to GPS-RO refractivity improved in stratosphere over last month from using 3D-Var analysis with anchor obs (includes GPS-RO)

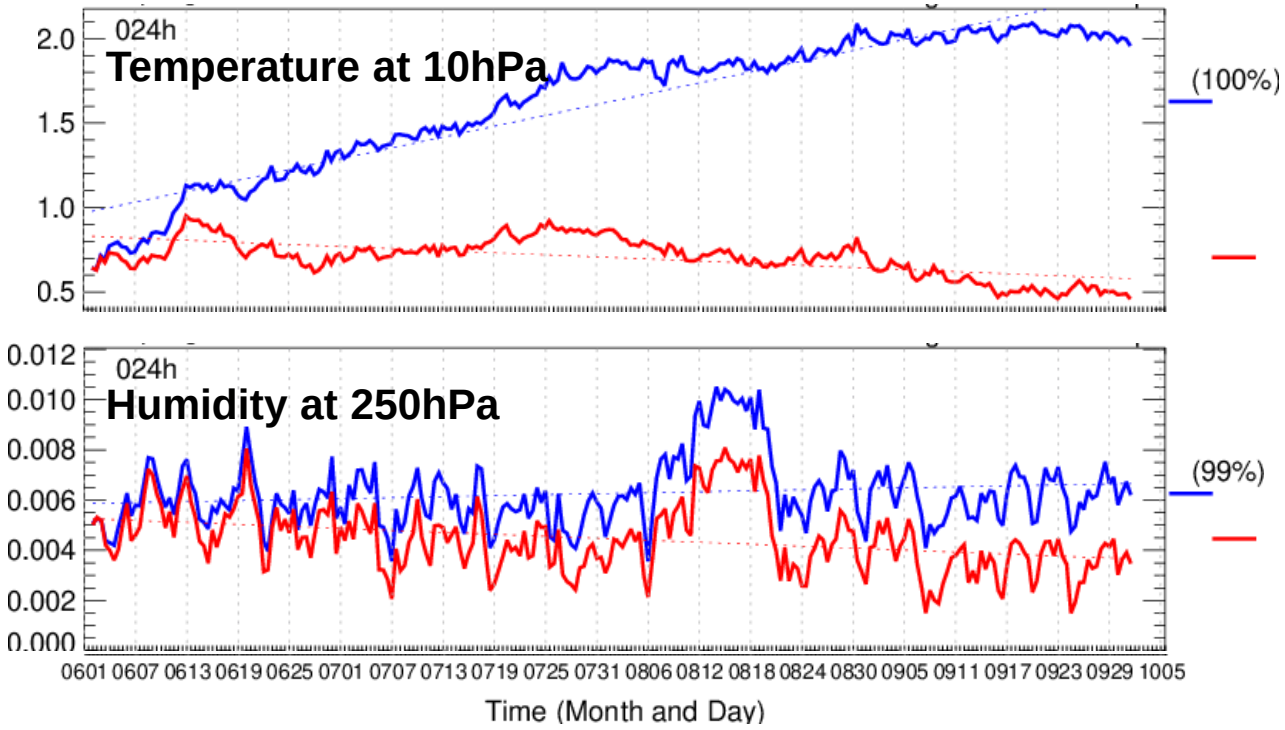


Radiance obs bias correction estimated dynamically using:
(colours reversed from previous slide!)

- **Background state**
- **3D-Var with anchor obs**

Results: Comparison with ECMWF Analyses

- Mean differences of 24h forecasts relative to ECMWF analyses significantly improved

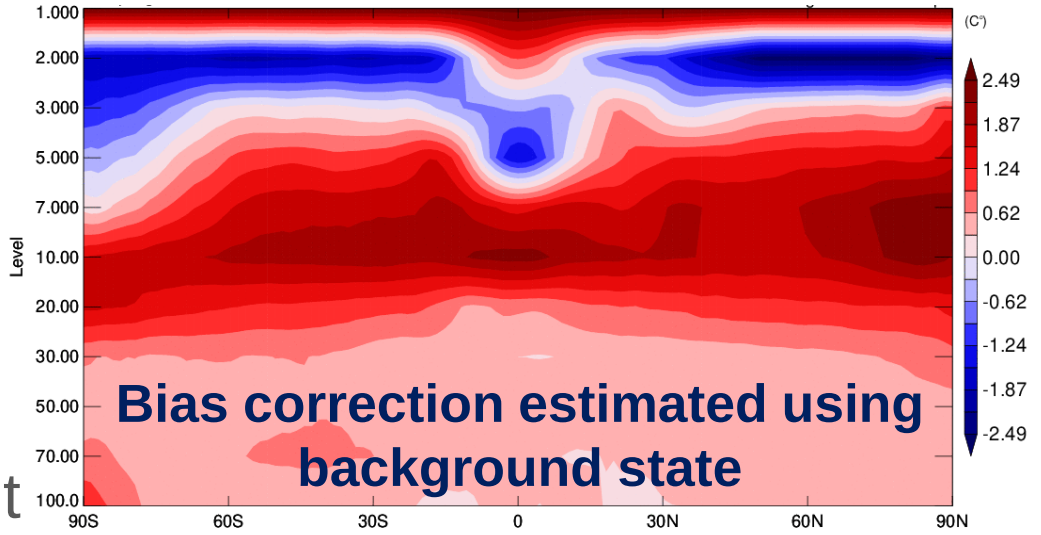


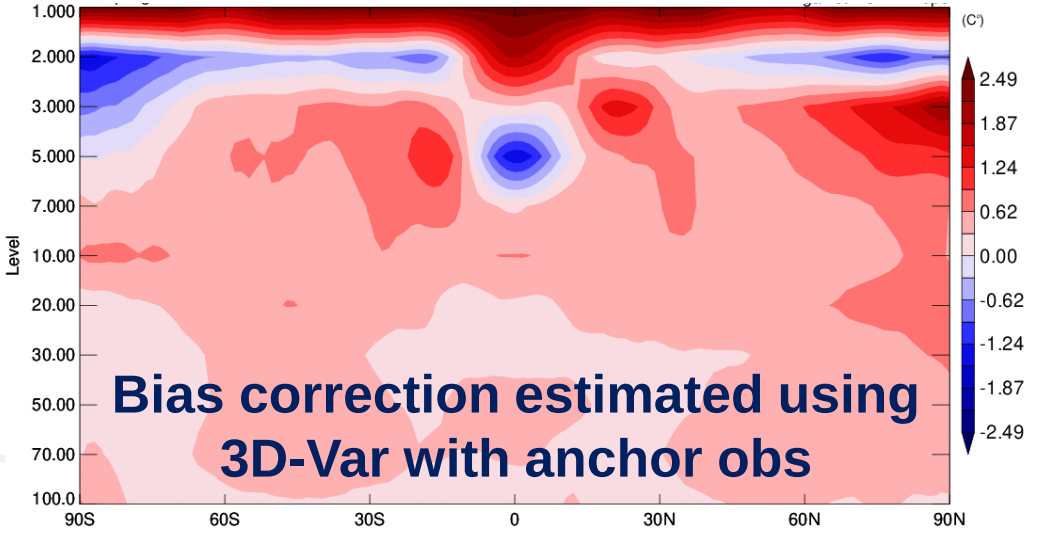
Radiance obs bias correction estimated dynamically using:

- **Background state**
- **3D-Var with anchor obs**

Results: Comparison with ECMWF Analyses

- Mean **temperature** differences of 24h forecasts relative to ECMWF analyses significantly improved
- Mean computed over last month of experiment

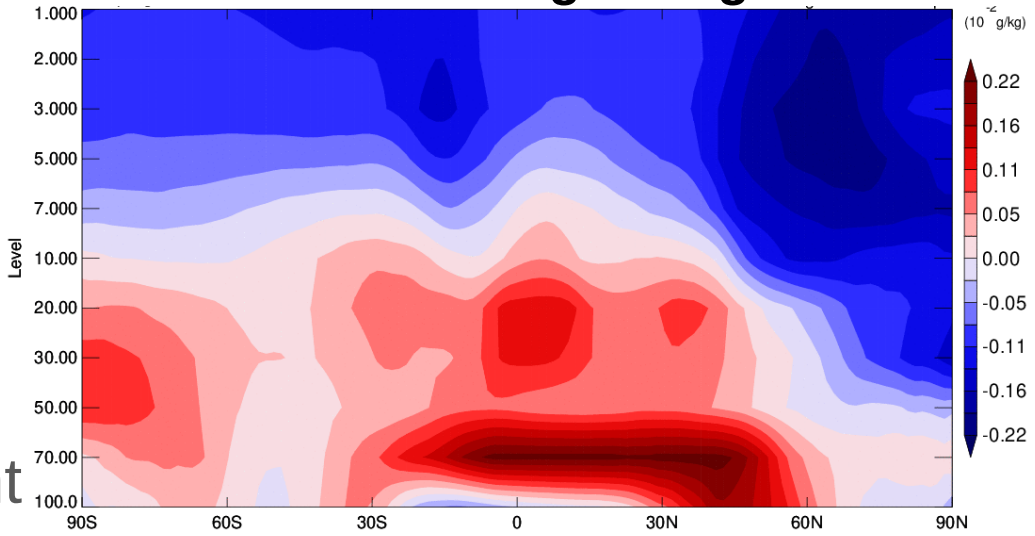




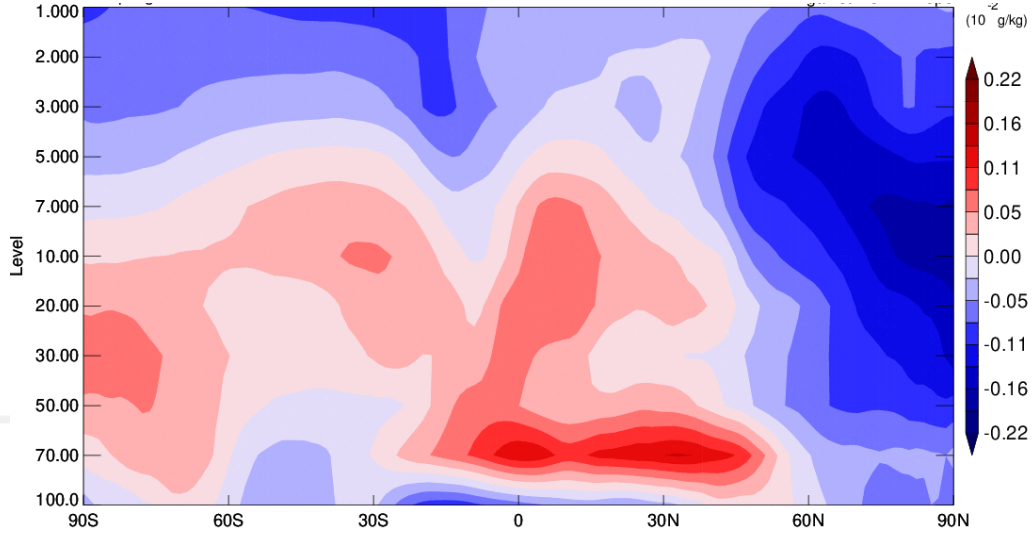
Results: Comparison with ECMWF Analyses

- Mean **humidity** differences of 24h forecasts relative to ECMWF analyses significantly improved
- Mean computed over last month of experiment

Bias estimated using background state



Bias estimated using 3D-Var analysis



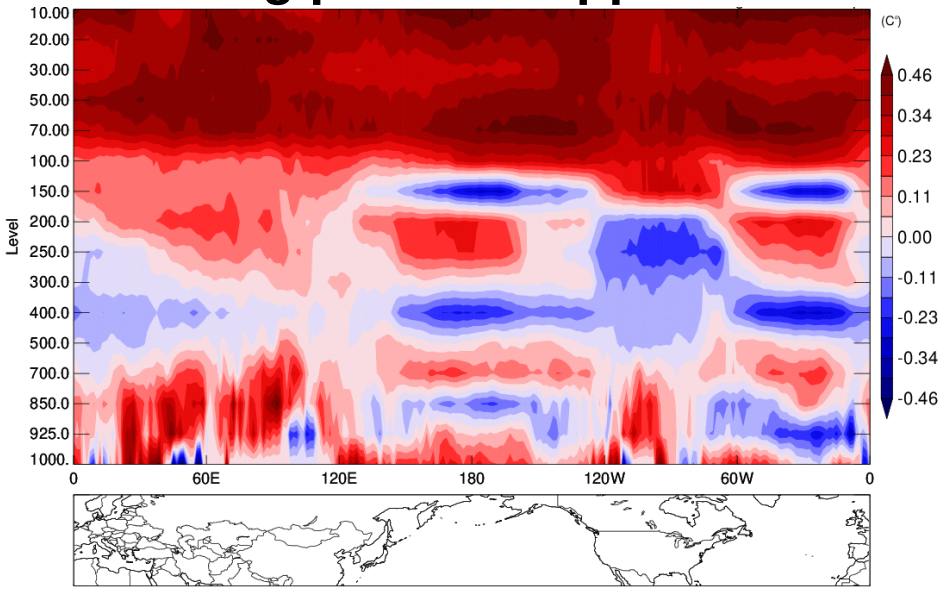
Results: Aircraft and Ground-based GPS Bias Correction

- 2.5-month experiment performed to evaluate impact of using 3D-Var analysis assimilating anchor obs for bias correction of **aircraft temperature** and **zenith total delay**
- Aircraft:
  - Previously, applied a fixed, level-dependent correction
  - New approach uses dynamic correction dependent on tail number, flight phase and pressure layer based on 3D-Var analyses over past period long enough to obtain robust estimate
- Ground-based GPS:
  - Previously, no correction was applied
  - New approach uses dynamic correction estimated separately for each station based on 3D-Var analyses over past 45 days

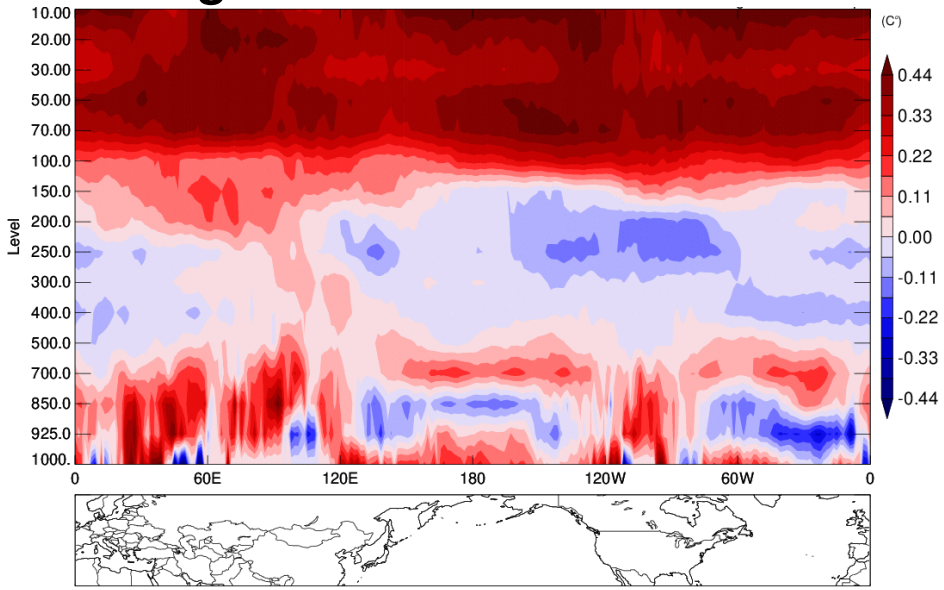
Results: Comparison with ECMWF Analyses

- Mean **temperature** differences of 0h forecasts relative to ECMWF analyses significantly reduced in northern extra-tropics between 100hPa and 500hPa

Bias correction estimated using previous approach

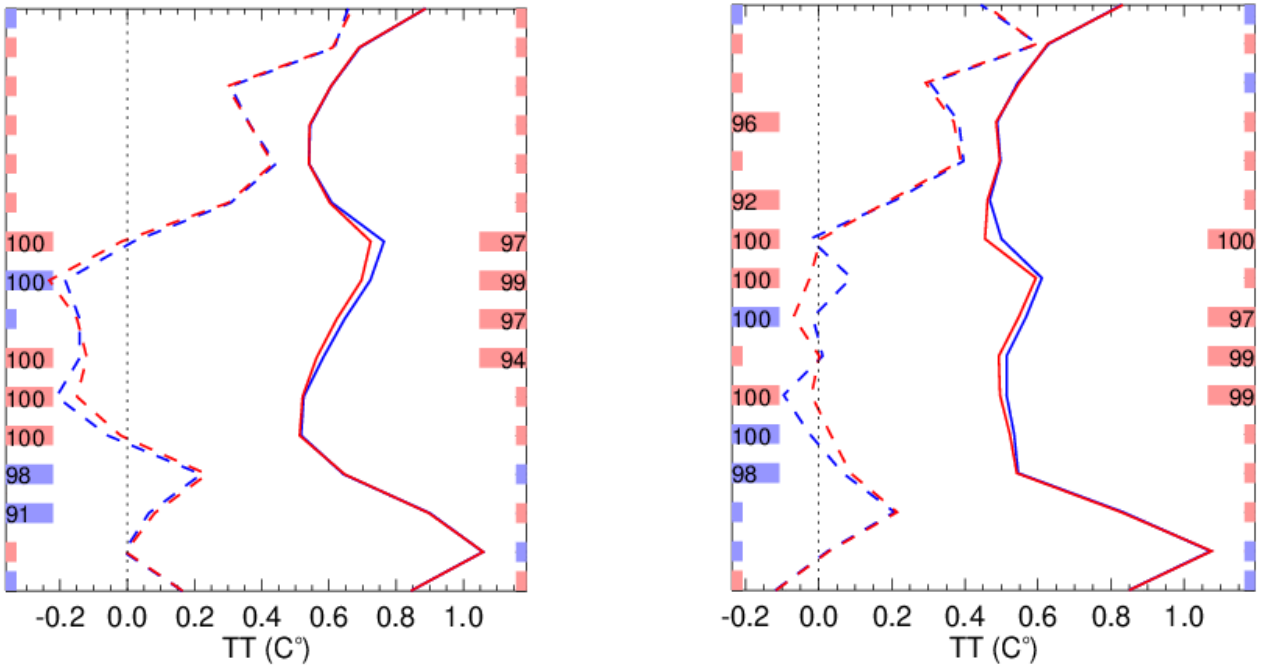


Bias correction estimated using 3D-Var with anchor obs



Results: Comparison with ECMWF Analyses

- Also significantly improves stddev of error for 24h forecasts over North America (left) and Europe (right)



Bias correction estimated:

- **Previous approach for aircraft and ZTD**
- **New approach based on 3D-Var with anchor obs**

Conclusions

- A simple 3D-Var analysis using only “anchor” observations reduces error bias in background state
- Compared with previous approach, dynamic estimation of bias model coefficients with 3D-Var analysis improves analyses and short-term forecasts
- So far, applied to all satellite radiances, aircraft temperature and ground-based GPS zenith total delay
- Use of separate 3D-Var analysis gives added flexibility to optimize for removal of model-induced bias without affecting main 4D-EnVar – preliminary tests with more GPS-RO data or more weight to obs gave mixed results