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Radiance Bias Correction from an Alternative Analysis

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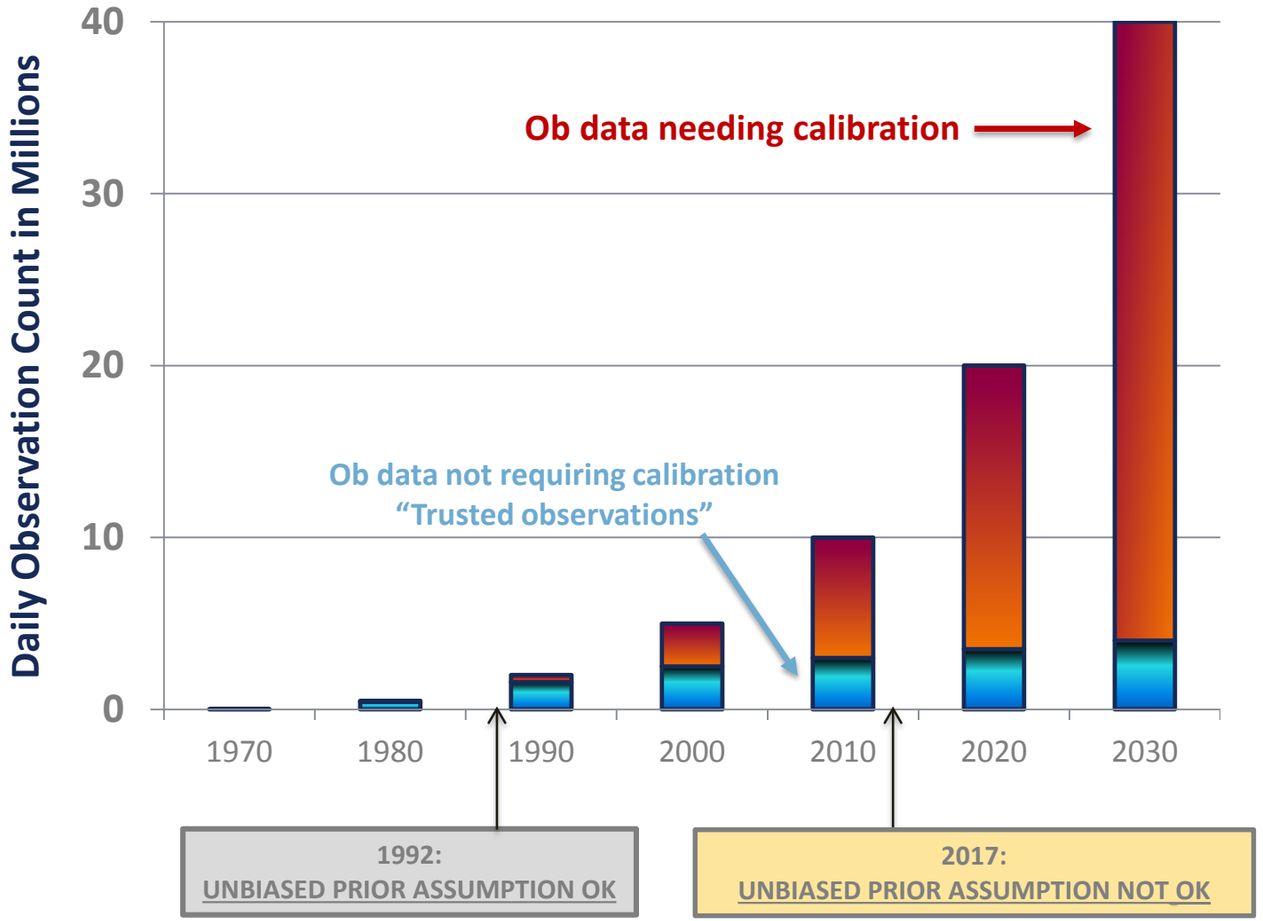
Outline

Forecast Model Bias Interaction with Radiance Bias Correction

- Radiance bias correction has become integral for use of satellite radiances.
- Does radiance bias correction reinforce forecast model bias?
- If so, can we design a radiance bias correction scheme that mitigates some of this behavior?

Use of Satellite Radiance Data

- In 1992: 50% or less of observation data required bias corrections
- By 2017, 80% of total observations are from satellites and require bias correction
- The “unbiased prior assumption” is an **obvious deficiency** in current DA methodology



Bias-Drift

- A significant problem called **bias-drift** occurs when systematic error and bias from model forecast **contaminate** observation data.
- Bias-drift causes system to “drift” towards systematic errors and biases in the forecast
- Loss of accuracy and reduced reliability of analyses and forecasts.
- Bias-drift caused by **invalid assumption** in current method for satellite calibration:
  assumption: model prior contains no bias

Numerical forecasts contain bias.
These arise from imperfect representations of atmospheric dynamics and physical processes

Bias-drift is a problem which has been **created** by the current practice in atmospheric data assimilation

Bias Correction Methodologies

- Radiance Bias Correction
  - Eyre (1992) “A bias correction scheme for simulated TOVS brightness temperature” ECMWF Tech Memo 186.
  - Harris and Kelly (2001), “A satellite radiance-bias correction scheme for data assimilation.” Q.J.R. Meteorol. Soc., 127: 1453–1468.
  - Auligne, McNally and Dee (2007). “Adaptive bias correction for satellite data in a numerical weather prediction system.” Q.J.R. Meteorol. Soc., 133: 631–642.
- Radiance assimilation needs bias correction
  - Families of sensors are brought into alignment
  - Physical reasons for scan asymmetries can be handled
- Recent examinations of bias correction:
  - Buehner et al (2015) Implementation of a Deterministic Weather … Part I: The Global System. Monthly Weather Review, 143, 2532-2559.
  - Han and Bormann (2016) Constrained adaptive bias correction for satellite radiance assimilation in the ECMWF 4D-Var system. * EUMETSAT NWP-SAF report: NWPSAF-EC-VS-028, 31pp.
  - Eyre (2016) “Observation bias correction schemes in data assimilation systems: a theoretical study of some of their properties.” Q.J.R. Meteorol Soc., 142, 2284-2291.

*uncertainty estimation useful in limiting size of bias correction

“systematic errors in the brightness temperature simulated from forecast model profiles … unless these biases are corrected … it is difficult to use measured radiances to positive effect in NWP” – Eyre 1992

Residual variance after bias correction is a sum of errors from:
- Measurements
- Radiative transfer calculation
- Forecast model

Predictor selection (there have been many tried):
- Air mass
- Zenith angle
- Radiative transfer model (gamma)
- Lapse rate
- …
- ¿¿¿What to do for regional models???

“effect of model bias … will increase as more observations are bias corrected and a smaller proportion are used as ‘anchor’ observations” – Eyre 2016

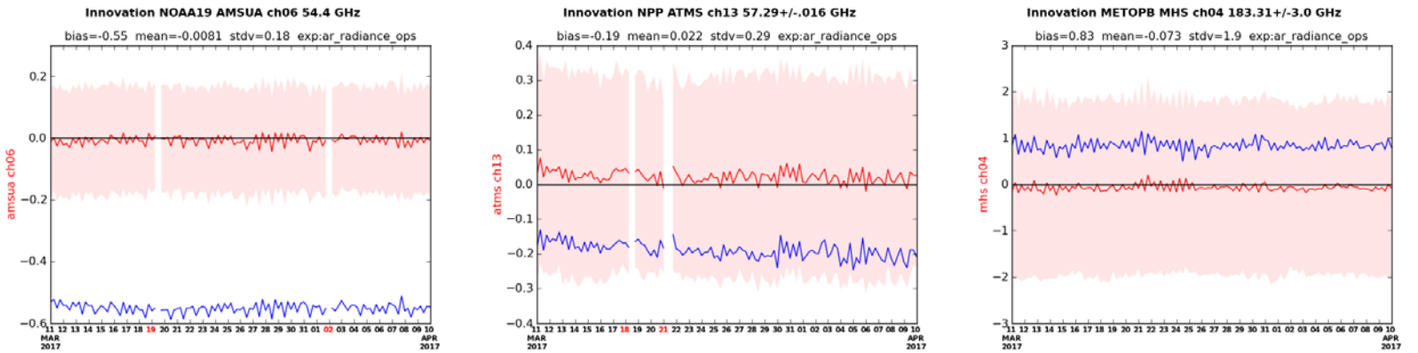
Evidence of a Problem with Bias Correction

- Global bias correction
  - **The Good:** Produces low standard deviation
  - **The Bad:** Maps of residual show persistent bias with magnitudes much larger than global standard deviation; and, size of global bias correction often larger than global standard deviation.

Should we correct for the residuals spatially, or are these signal pointing to model bias?

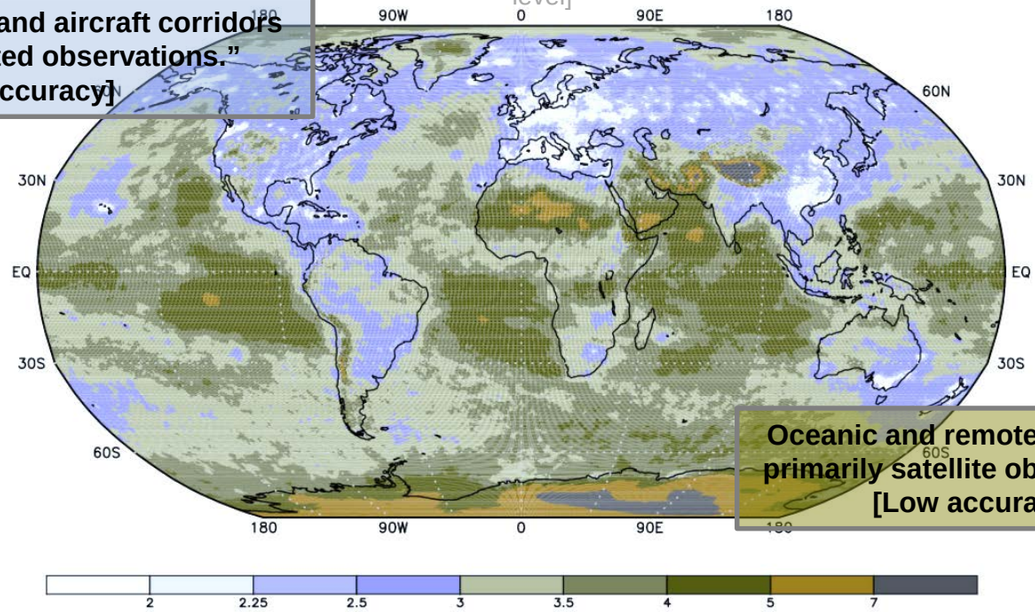
- Does Bias Correction Reinforce Model Tendencies?
  - Model may have a tendency towards developing certain biases
  - How to diagnose these and communicate

- Can we remove some of these biases reinforced by radiance bias correction?
  - Parallel update cycle run without radiances
    - Use resulting background for bias coefficients



Accuracy of Atmospheric Temperature Analyses

NAVGEM-ECMWF-GFS RMS difference June-Aug 2017 [500hPa pressure level]

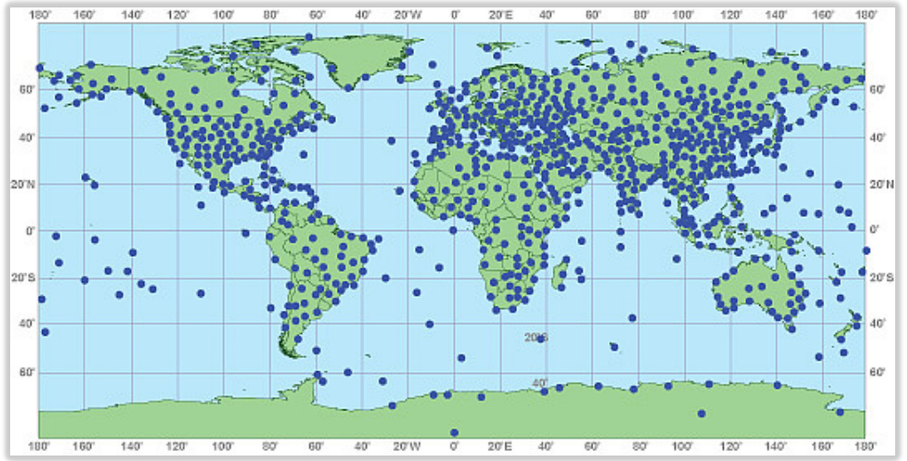


Accurate analyses ➔ Less-accurate analyses [BIAS DRIFT]

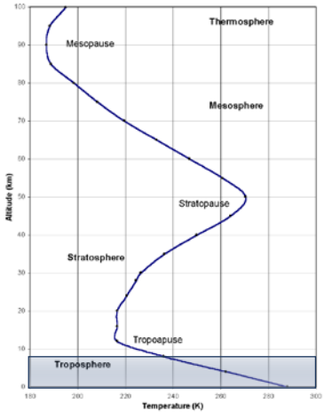
Using other Observations for Bias Correction

Trusted observations with high-accuracy are used to calibrate data provided from space-based sensors

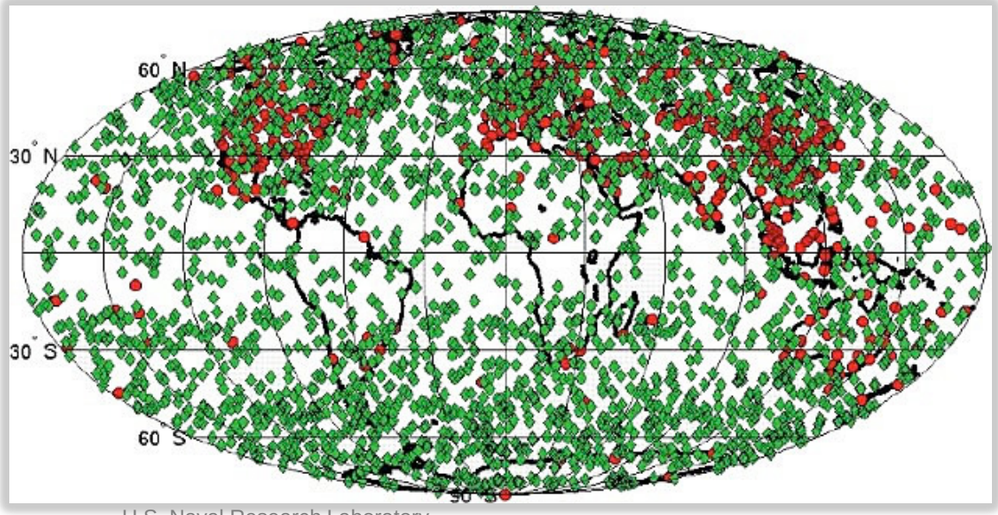
Radiosondes: T, u, v, q, surface to 10hPa



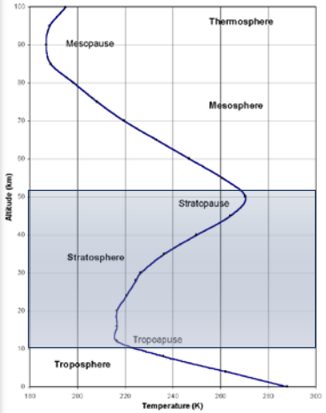
High-accuracy Region



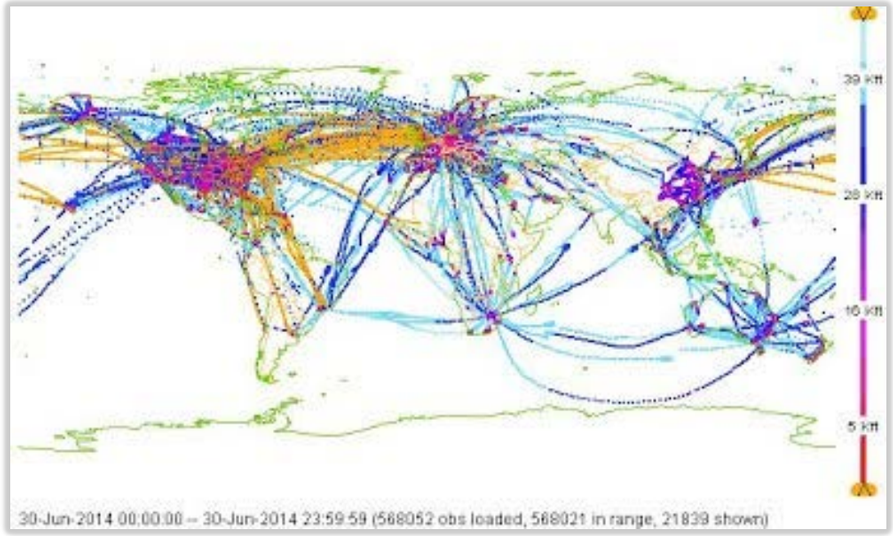
GPS-MET: bending angle through troposphere



High-accuracy Region



Aircraft: T, u, v, q, flight-level, ascent, descent



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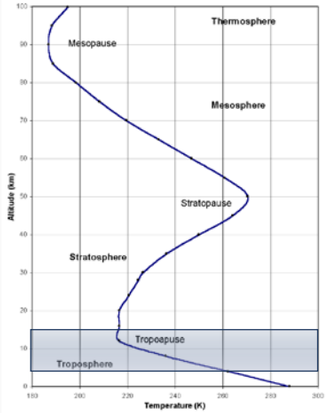


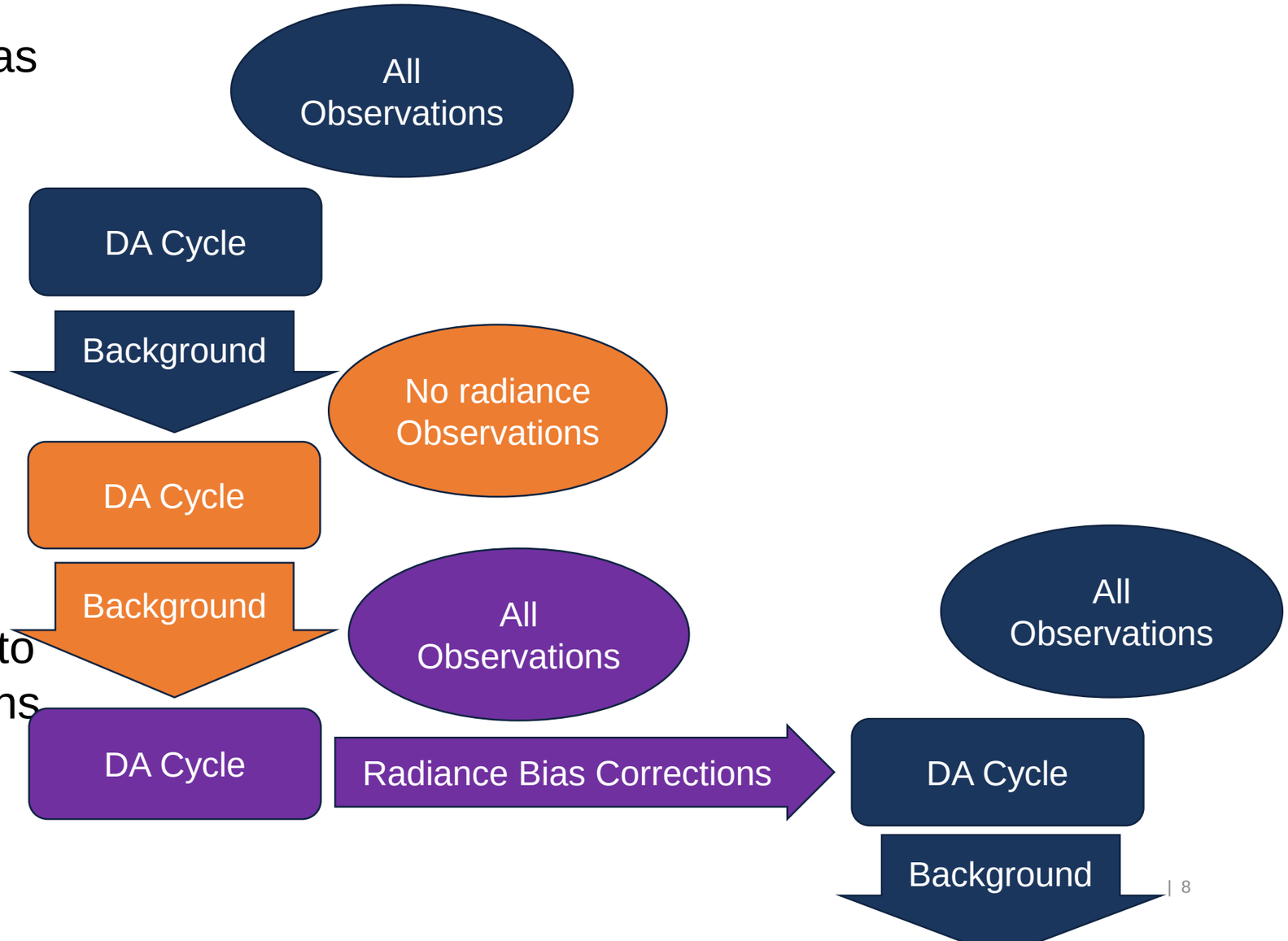
Bias Correction Alternate Cycle

- Attempt to reduce radiance bias corrections contribution from model bias

- Assume non-radiance observations are un-biased
  - Trying to draw model to “truth”

- Background from “no-radiance” DA cycle will have smaller mode bias
  - Use this to produce bias corrections for radiances

- Not practical but a proof-of-concept to determine changes in bias corrections and model bias relative to other models and observations



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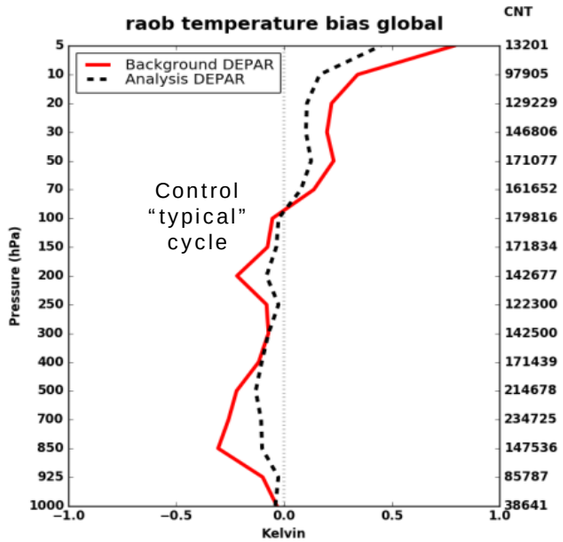
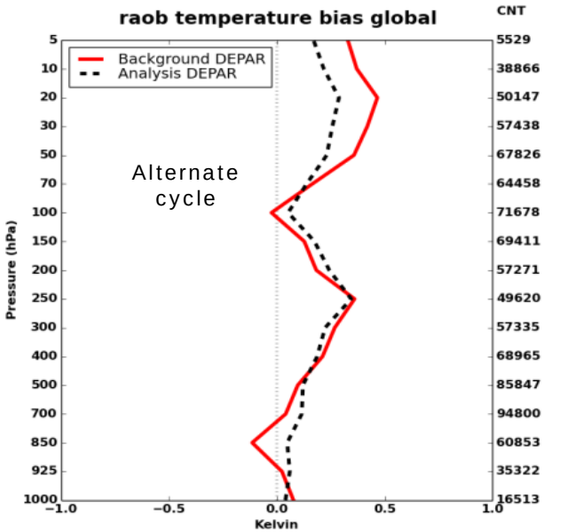
Prototype of Alternate Cycle

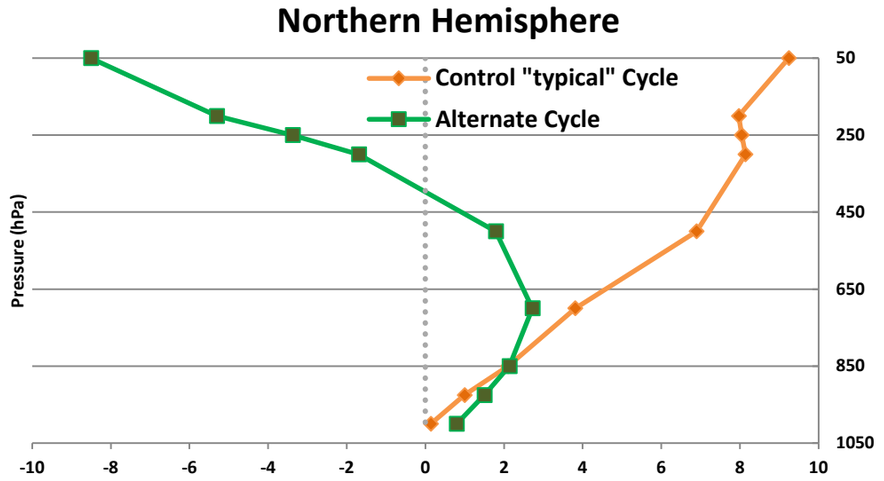
NAVGEM fit to Radiosonde 18Dec2015

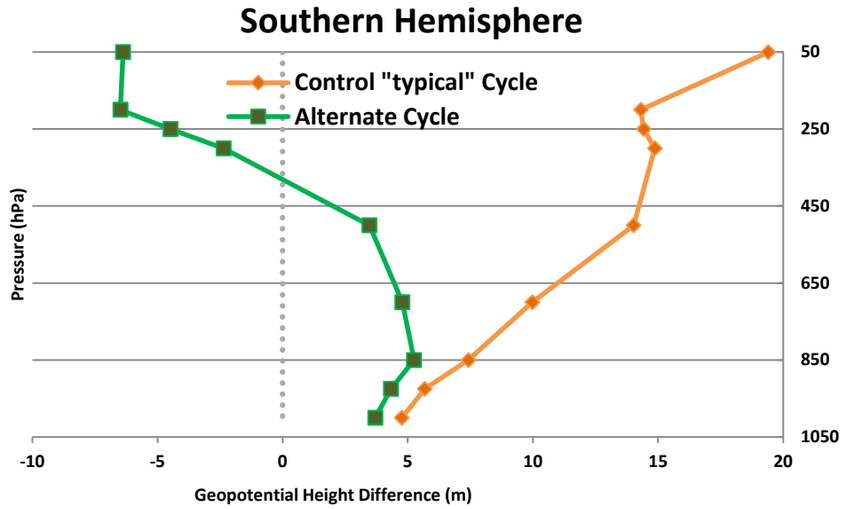




- Prototype shows a **dramatic shift** in behavior of system.
- Proves that **bias-drift** toward the model tendency can be **altered incrementally** by the cycling DA
- Just a prototype investigate:
  - **Long window DA**
  - **Observation weighting**
  - **DA control vector**

NAVGEM – ECMWF ANALYSIS
00UTC 18Dec 2015
Difference Geopotential Height (m) vs Pressure (hPa)





Other Bias Correction Investigation

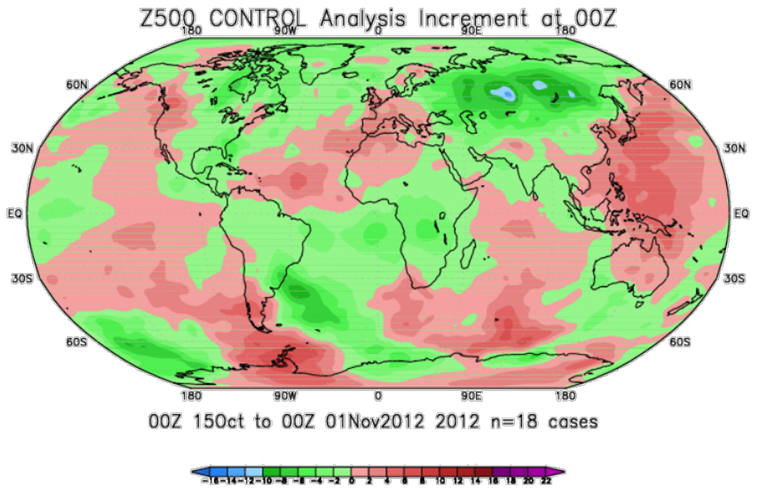
- Typically bias correction adjusts quickly
  - Spinup from zero bias correction typically stabilizes after 5 days in the U.S. Navy global system.

- Evolution of bias corrections
  - Model tendencies may change seasonal timescales
  - Method need to allow adaptation to these changes

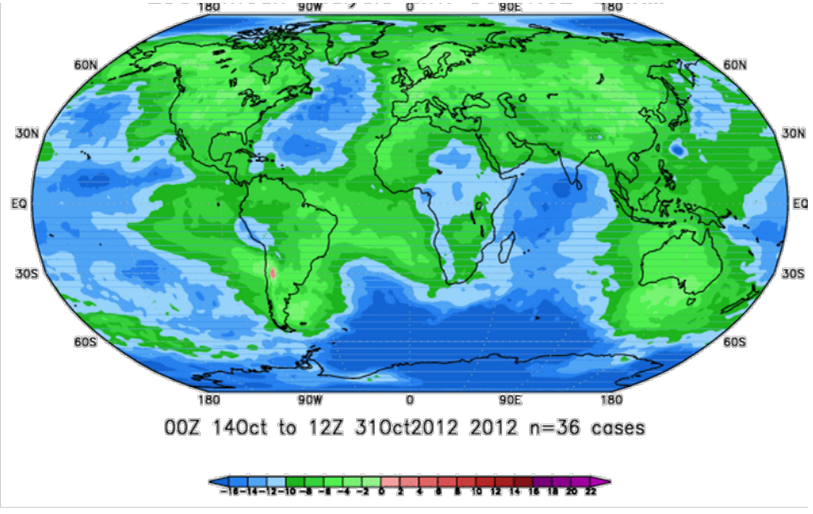
- How to best separate components of bias
  - Radiative transfer biases will likely have different characteristics than systematic NWP model biases

- Pitfalls of autonomous systems
  - Drifts over time:
    - Sensor degradation
    - Buildup of NWP bias (moisture in stratosphere, incorrect Ozone, …)

500 hPa Analysis Increment



500 hPa Analysis Increment (using ECMWF psuedo-obs)



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Summary

- Remember assumptions made by the system, and reinvestigate often
  - Things work well but a lot depends on very gross assumptions
  - Re-examinations are worthwhile, often the simplest approach can apply more broadly

- Bias corrections required for radiances to get beneficial impact in NWP
  - Do the bias corrections reinforce the NWP model bias?
  - Can a background using observations without bias-corrections be used to reduce model bias component in the radiance bias corrections?
  - How can the resulting residuals be used to better inform and diagnose NWP model bias or radiative transfer model bias?
  - How can we accurately determine the analysis error in a routine manner?