Radiance Bias Correction from an Alternative Analysis

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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?

The most dangerous phrase in the language is ‘We’ve always done it this way.’

– Grace Hopper
Rear Admiral U.S. Navy
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
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

• 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:

  *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]**

- Developed nations and aircraft corridors with many “trusted observations.” [High accuracy]
- Oceanic and remote areas with primarily satellite observations. [Low accuracy]
Using other Observations for Bias Correction

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

**GPS-MET**: bending angle through troposphere

**Radio sondes**: $T, u, v, q$, surface to 10hPa

**Aircraft**: $T, u, v, q$, flight-level, ascent, descent
• 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
Prototype of Alternate Cycle

**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
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, … )
• 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?