Radiance Bias Correction from an Alternative Analysis
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?
• 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**

- 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

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

**Radiosondes**: 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
• 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?