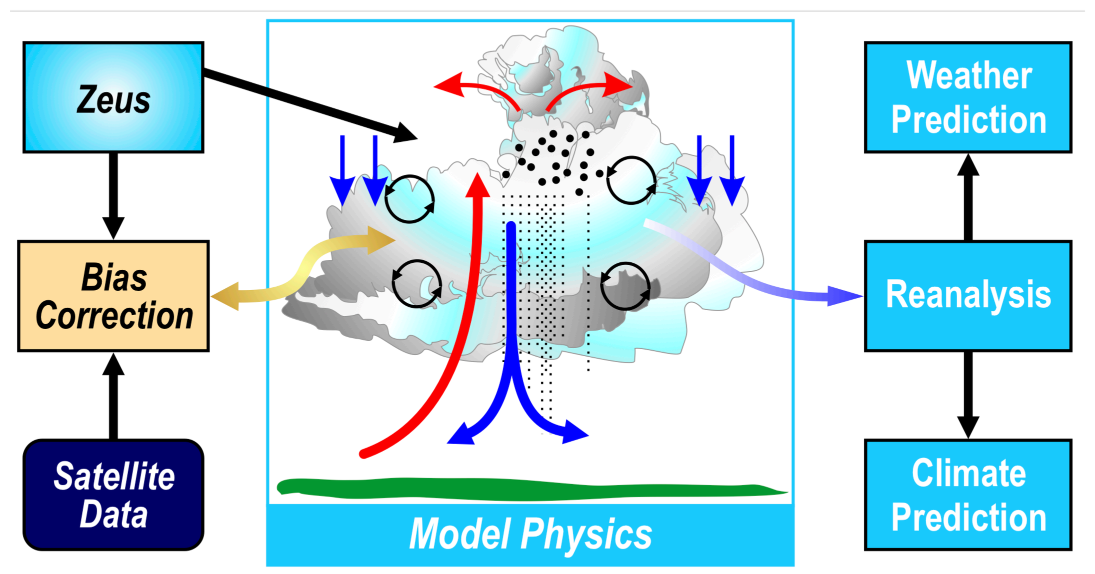
Poster 455

AMS, January 7-11, 2013

Toward Anchoring Reanalysis with Absolute Data

Stephen S. Leroy[1], Mark J. Rodwell[2]

[1]Harvard School of Engineering and Applied Science, [2]European Centre for Medium-range Weather Forecasts



Abstract

We investigate the potential of assimilating spectral infrared data without bias correction into a four-dimensional variational assimilation system. Our investigation has two motivations: (1) the need to "anchor" data assimilation—and especially reanalysis—with data of trusted accuracy without bias correction, and (2) the possibility of developing a seamless weather-climate prediction system by tuning model physics to reduce data assimilation diagnostics. Modern atmospheric reanalysis systems have incorporated variational bias correction in order to deliver timeseries of atmospheric analyses that are unaffected by heterogeneity and bias in remote sensing instrumentation, yet the climate trends they produce disagree at the level of ~0.2 K per decade over the satellite era. Furthermore, improving a core model in numerical weather prediction may well be hindered by the presence of variational bias correction, resulting in the possible confusion of inaccuracy in data for error in model physics. To address both, we performed a numerical experiment using the four-dimensional variational assimilation system of ECMWF.

Anticipating the assimilation of satellite spectral infrared data without bias correction in the future, we compare first guess departures of a system run with perturbed radiative transfer in the forward model for HIRS channel 12 and another with perturbed vertical diffusion to a control run of the same system. The system absorbs the perturbation in radiative transfer for HIRS channel 12 into the bias correction for that channel, as it is designed to do, but it also absorbs the perturbation of vertical diffusion into the bias correction of all bias-corrected data types. The first guess departures of GPS radio occultation, though, do show a weak signature of the perturbation of vertical diffusion, but the forward model for GPS radio occultation is only marginally accurate enough to detect it. We conclude that, in order to better anchor reanalysis and diagnose errors in model physics, it is necessary to assimilate a complementary and redundant suite of trusted accurate data without bias correction and improve the accuracy of the radiative transfer forward models for the data.

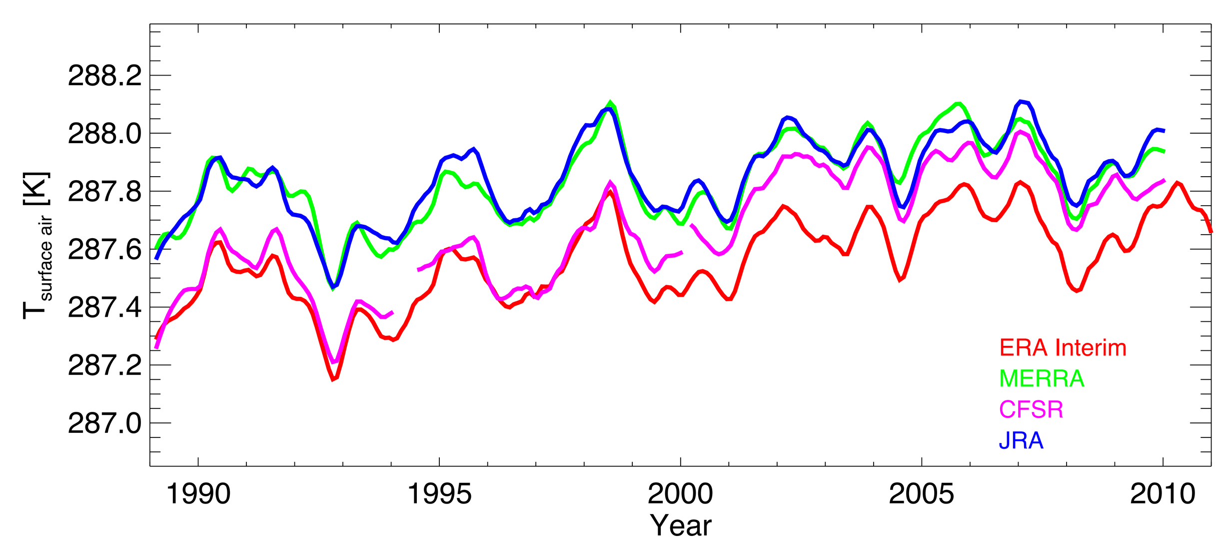


Figure 1: Global surface air temperature trends produced by four modern reanalyses, with 6-month smoothing. All four reanalyses implemented bias correction to account for heterogeneity in assimilated data.

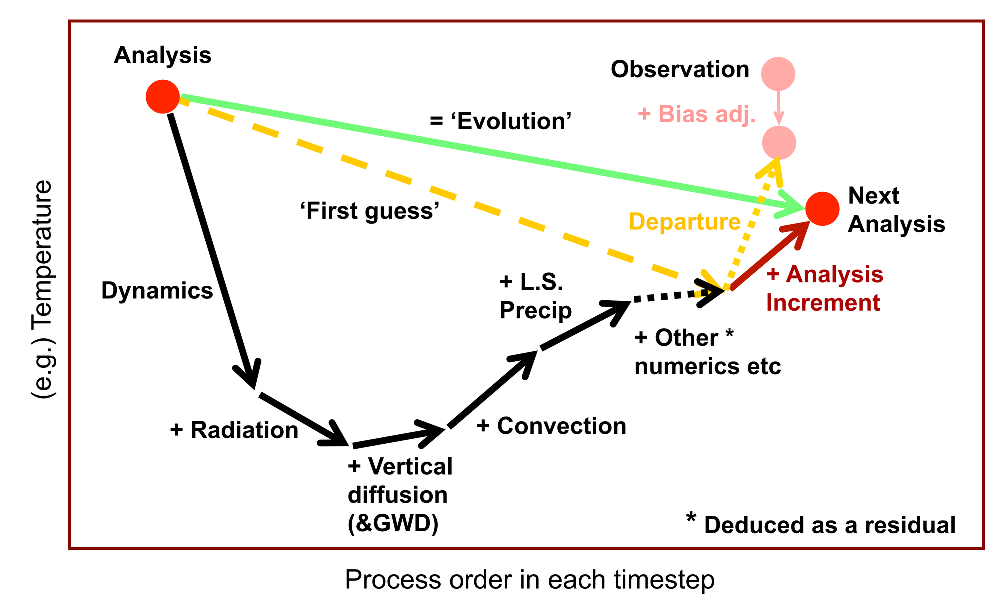


Figure 2: The steps in data assimilation, including bias correction. Perturbing model physics should yield fingerprints in the diagnostics of data assimilation: the first guess *departures*, the analysis *increments*, and the *bias* adjustments.

Experiment

- ECMWF four-dimensional variational data assimilation (4DVar) system with variational bias correction (VarBC)
- April 4–May 31, 2011
- Three runs:
  - Control run
  - Perturbed vertical diffusion, expected to redistribute water vapor in the vertical
  - Perturbed radiative transfer of HIRS channel 12, a water vapor sounder at 350 hPa
- Fingerprints in departures and bias are determined by differencing the control run from the perturbed runs for a variety of water vapor sounders

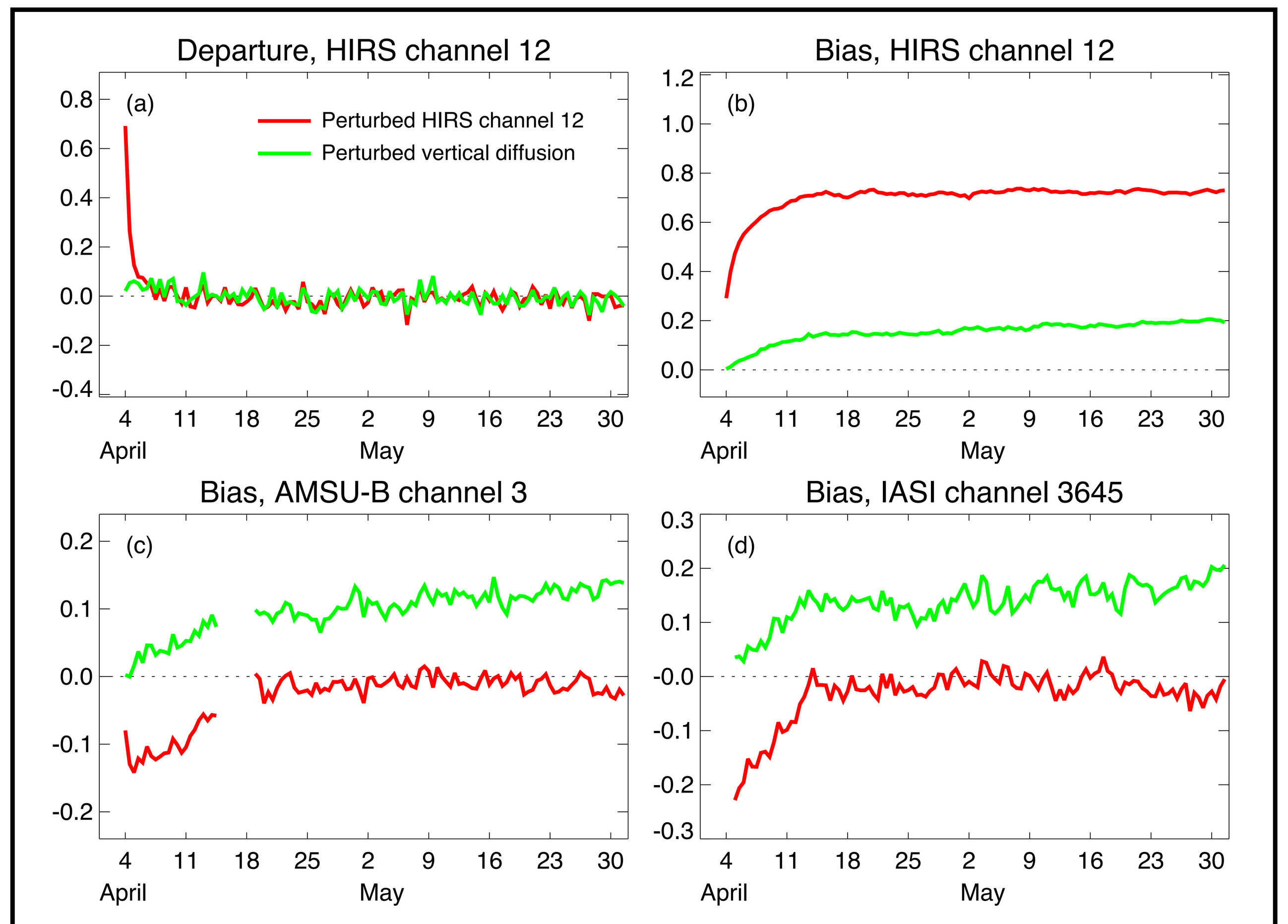


Figure 3: Timeseries of the diagnostics of data assimilation in the tropics in K: (a) first guess departures for HIRS channel 12, (b) bias correction for HIRS channel 12, (c) for AMSU-B channel 3, and (d) for IASI channel 3645. All three data types are sounders of water vapor near 300 hPa. Both perturbed runs are plotted after subtracting the control run. These are the only non-zero fingerprints of the diagnostics.

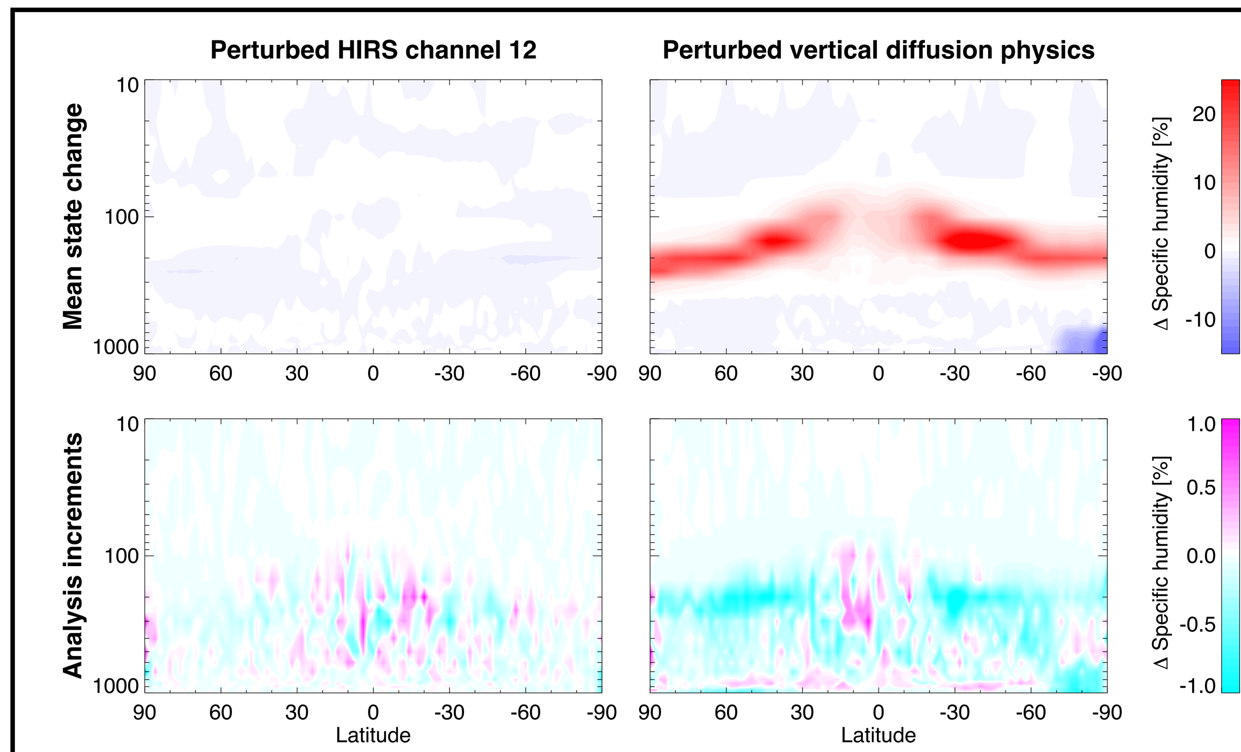


Figure 4: Top row: change in mean analysis; bottom row: fingerprint in analysis increments. Left: perturbed HIRS channel 12 radiative transfer; right: perturbed vertical diffusion physics. Analysis increments represent the overall influence of data, as opposed to model, on the atmospheric analysis.

Perturbing HIRS channel 12 radiative transfer is fully compensated by bias correction, and the mean state of the atmosphere is unchanged. Perturbed vertical diffusion is also, but wrongly, compensated by bias correction, and an enormous perturbation to upper tropospheric humidity results. The data still tends to pull the analysis closer to the truth, but it is outweighed by the (erroneous) model.

Get poster here:
http://fugue.arp.harvard.edu/leroy/AMS-2013-Poster

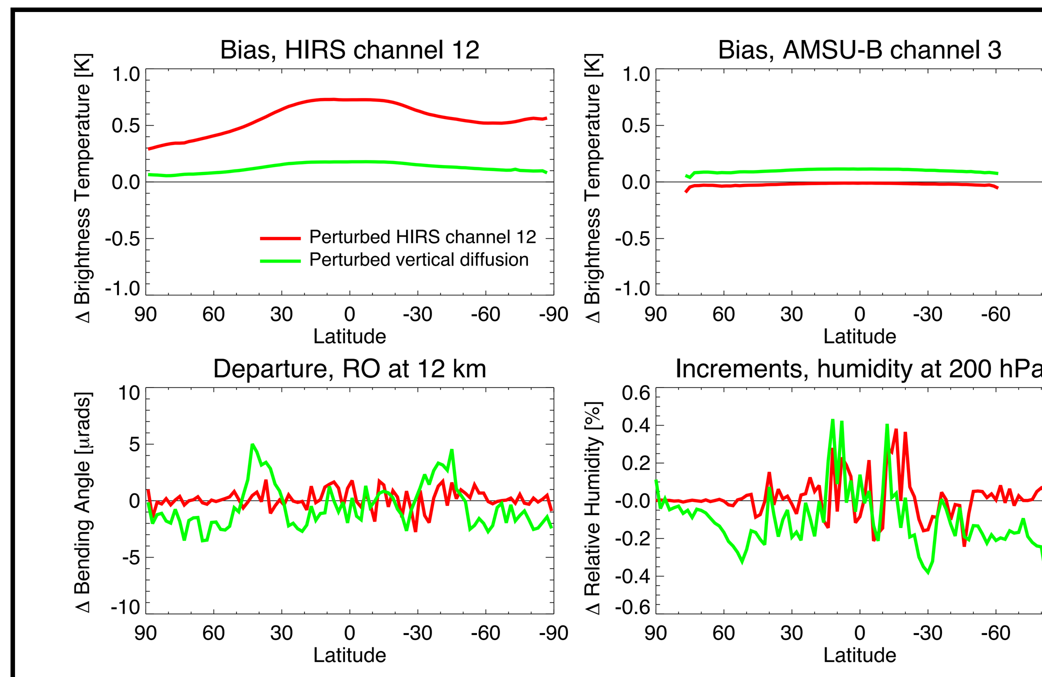


Figure 5: Time-average zonal average fingerprints in diagnostics: bias in HIRS channel 12, bias in AMSU-B channel 3, first guess departure in radio occultation bending angle at 12 km, and analysis increments in specific humidity at 200 hPa.

Even though perturbed vertical diffusion physics is interpreted as a radiative transfer error in nadir radiance water vapor sounders, it is visible in first guess departures in radio occultation (RO) bending angle at 12 km. RO, which obeys very different radiative physics than radiance sounders, is assimilated at ECMWF without bias correction.

Conclusions

- The redistribution of water vapor in the vertical is easily confused for erroneous radiative transfer in nadir radiance sounders of water vapor.
- The alternative physics of radio occultation sounding makes it useful for detecting the signature of erroneous physics in its first guess departures where nadir radiance sounders have difficulty.
- Three recommendations:
  1) *Deploy more anchor data types. They should have the property of on-orbit traceability to international standards.*
  2) *Make radiative transfer calculations at least as accurate as the data that anchors analyses.*
  3) *Implement anchor data types that have similar sensitivity but orthogonal radiation physics.*

References

Rodwell, M.J., and T.N. Palmer, 2007: Using numerical weather prediction to assess climate models. *Q. J. R. Met. Soc.*, **133**, 129–146.

Dee, D.P., and S. Uppala, 2009: Variational bias correction of satellite radiance data in the ERA-Interim reanalysis. *Q. J. R. Met. Soc.*, **135**, 1830–1841.