Accuracy and Impact Assessments of Adding Errors to Simulated Radiance Data in Observing System Simulation Experiments

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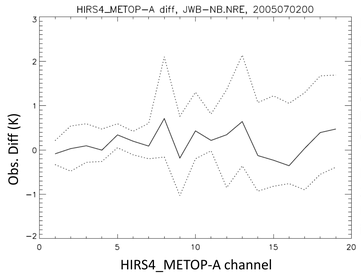
1. Motivation

Observing System Simulation Experiments (OSSEs) allow for assessment of new or moved instruments and their impacts on numerical weather prediction. However, there are questions about how representative simulated radiances can be, and how this will effect the conclusions on whether or not to build new instruments. Will the presence/absence of added biases or errors effect OSSE conclusions? How does this limit the type of OSSE that can be run?

2. Bias/Error Setup

This project accounts for two types of error:

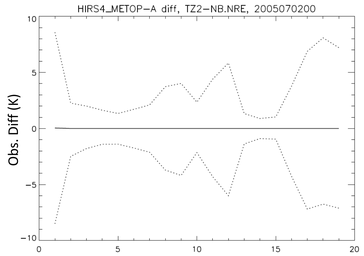
• Inherent instrument biases that can be identified by the GSI bias correction algorithm



Example of the effects of adding instrument bias to simulated HIRS4_METOP-A radiances. Black line shows mean departure from "perfect" observation, dashed curves show boundaries of full observation departure distribution.

Bias values obtained using July-August 2012 observations (courtesy E. Liu, EMC) for all operational radiance instruments.

• A random Gaussian distribution of errors

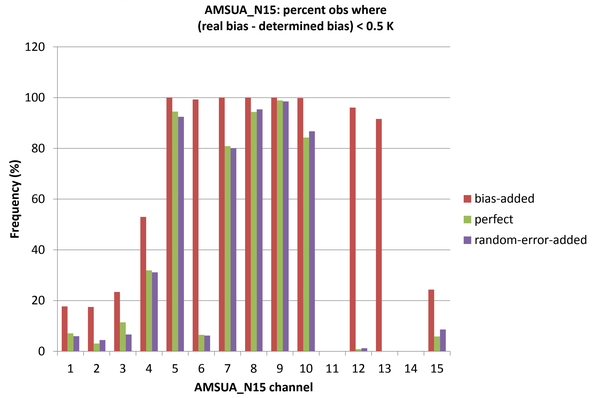


As with above figure, only showing the impacts of adding a random Gaussian distribution of errors to simulated "perfect" observations.

Random error distribution calculated from distribution of observation-background model counts, and added to simulated observations using a modified version of the random-error-addition code used in Errico et al. (2013), Prive et al. (2013a, b)

3. Real vs. Simulated Biases

If assimilating bias-added radiances, how well does GSI identify these bias magnitudes, compared to real observations?



Bias-added simulated radiances (red) more closely matched model-determined biases for real data than perfect or random-error-added observations. The best fit is in temperature sounding channels. Clear discrepancies exist in surface and water vapor channel biases; investigation is ongoing. (Other instruments, not shown here, reveal ozone channel discrepancies, a result of differing ozone concentrations between 2012 and the 2005 NR.)

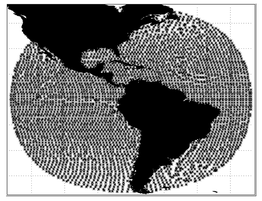
Matching real bias radiances is important for experiments testing instruments with greater accuracy than radiances (such as GPSRO). But what about an experimental radiance-measuring satellite?

A simulated new instrument may have a predicted random-error distribution, but condition-specific biases are instrument specific, and may not be known beforehand. As such, the following sections only test an experimental dataset with added random errors, not inherent biases.

4. Experimental Setup

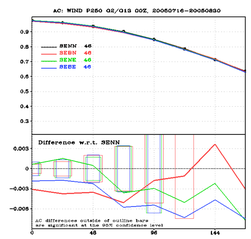
For the test instrument, this project uses a well-studied source of radiance observations [Atmospheric Infrared Sounder (AIRS)] in a new location/orbit (geostationary orbit at 75°W, current location of GOES-13). Two versions of airs_g13 are created, one with "perfect" observations and one with a distribution of random errors added. These are combined with four control datasets for a total of twelve experiments as described below:

Control observations:	No bias or random error	Bias added	Random error added	Bias and random error added
No airs_g13	Senn	Sebn	Sene	Sebe
Perfect airs_g13	Sennp	Sebnp	Senep	Sebep
Random-error-added airs_g13	Senne	Sebne	Senee	Sebee

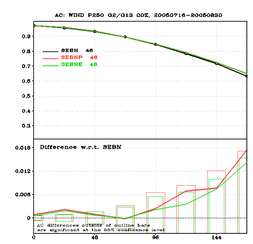


Range of simulated airs_g13 observations. Instrument impact comparisons calculated over this range: [55S, 55N]; [-130W, -20W]

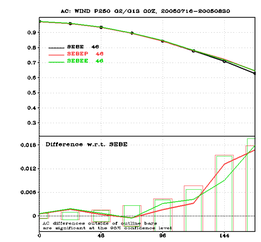
5. Bias/Random Error Impacts



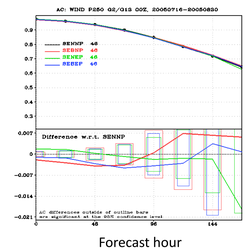
• Left: 250hPa vector wind anomaly correlation (AC) for no-airs_g13 cases
• Verification vs. Nature Run (over full grid)
• Colors:
  • Red: added biases
  • Green: added random error
  • Blue: added biases and random error
• Added biases degrade analysis, forecast through 72 hours
• Added random errors slightly IMPROVE forecast at 24 hours, neutral-to-degradation > 72 hours
• Adding both degrades through 72 hours



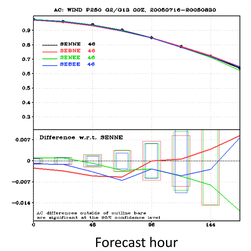
Above: Bias-added cases



Above: Bias- and Random-error-added cases



Above: Perfect airs_g13 cases

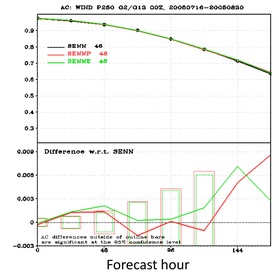


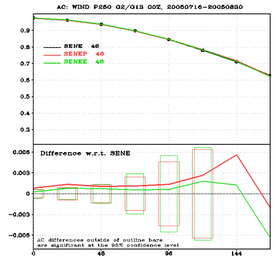
Above: Random-error-added airs_g13 cases

Similar features seen for cases with airs_g13:
• bias-added cases are significantly degraded (i.e., not all added biases are removed by the assimilation system)
• random-error-added case slightly improved for short-term forecasts; minimization process for analysis may be over-fitting where perfect obs are present, adding erroneous shortwave features and significantly degrading the analysis where no obs are present

6. Simulated AIRS_G13 Impacts

• Right: 250hPa vector wind AC for no bias, no random error cases
• Verification vs. Nature Run (over full grid)
• Colors:
  • Red: perfect airs_g13 *(ALL-PERFECT CASE)*
  • Green: random-error-added airs_g13
• Significant improvement in G13 region at 24, 48h forecasts from adding airs_g13





• Left: As before, only with random error added to all control radiances
• Significant improvement seen at 24 hours from adding airs_g13
• Smoother impact curves than no-random-error cases (especially all-perfect case, above, red)
• Greater impact from adding perfect airs_g13 (red), but adding a perfect test instrument to error-added control data would overstate skill of new instrument
• Impact of error-added airs_g13 *(ALL-ERROR CASE)* (green) small but positive, as expected from a single geostationary satellite

• As above, significant improvement seen at 24h forecast
• Though within 95% confidence interval error bounds (rectangles), 5-7-day impacts greatest of all experiments
• Bias impact curves (left) show large degradations for added biases; meanwhile, these cases add test data with no added inherent biases (unknown for test instruments)
• Adding inherent biases to the control dataset when they're unknown for the test data gives a clear *overestimate* of the impacts of a test radiance instrument

Conclusions

• Bias-added radiances more closely resemble real radiances in terms of expected accuracy
  • Best fit to real data in temperature sounding channels
  • Surface, water vapor, ozone channels still show large differences
• Addition of known bias to control radiance data degrades the forecast regardless of presence of geostationary hyperspectral IR data
• Addition of random error to control radiance data slightly improves the 24 hour forecast, degrades medium-range forecast; also regardless of presence of geo-hyper IR
• All experimental setups suggest adding airs_g13 yields a small but statistically significant impact on upper-level winds over G13 region
• Greatest impacts of airs_g13 for bias-added control cases; however, this likely provides an overestimate of the impact
• Adding random error creates smoother (potentially more reasonable) impact curves

Acknowledgments/References

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Cited References:
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• Prive et al. 2013b "The influence of observation errors on analysis error and forecast skill investigated with an observing system simulation experiment" JGR