Variational Bias Correction in the NCEP Data Assimilation System

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OUTLINE

- **The enhanced radiance bias correction scheme**
- **All-sky microwave radiance bias correction**
- **Variational aircraft temperature bias correction**

Studies on Radiance Bias Correction

- The first variational air-mass bias component implemented in GSI (Derber and Wu, 1998)
- The scheme developed by Harris and Kelly (2001) at ECMWF
- The Met Office (Hilton et al., 2009) used the scheme of Harris and Kelly (2001)
- Dee (2004) replaced ECMWF's scheme by a variational scheme including both scan-angle and air-mass bias components; etc.

Original Radiance Bias Correction Scheme

A two-step procedure
- **Variational air-mass component**
- **Separate scan-angle component**

$$\tilde{h} = h(x) + b^{air}(x,\beta) + b^{angle},$$

where

$h(x)$ is radiative transfer model

$$b^{air}(x,\beta) = \sum_{i=1}^{N} \beta_i [\alpha_i p_i(x)]$$

The control variables x and β are estimated by minimizing (Derber et al., 1991, Derber and Wu, 1998)

$$J(x,\beta) = \frac{1}{2}(x - x_b)^T B_x^{-1}(x - x_b) + \frac{1}{2}(\beta - \beta_b)^T B_\beta^{-1}(\beta - \beta_b) + \frac{1}{2}\left[y - \tilde{h}(x,\beta)\right]^T R^{-1}\left[y - \tilde{h}(x,\beta)\right]$$

Enhancements to the Radiance Bias Correction Scheme

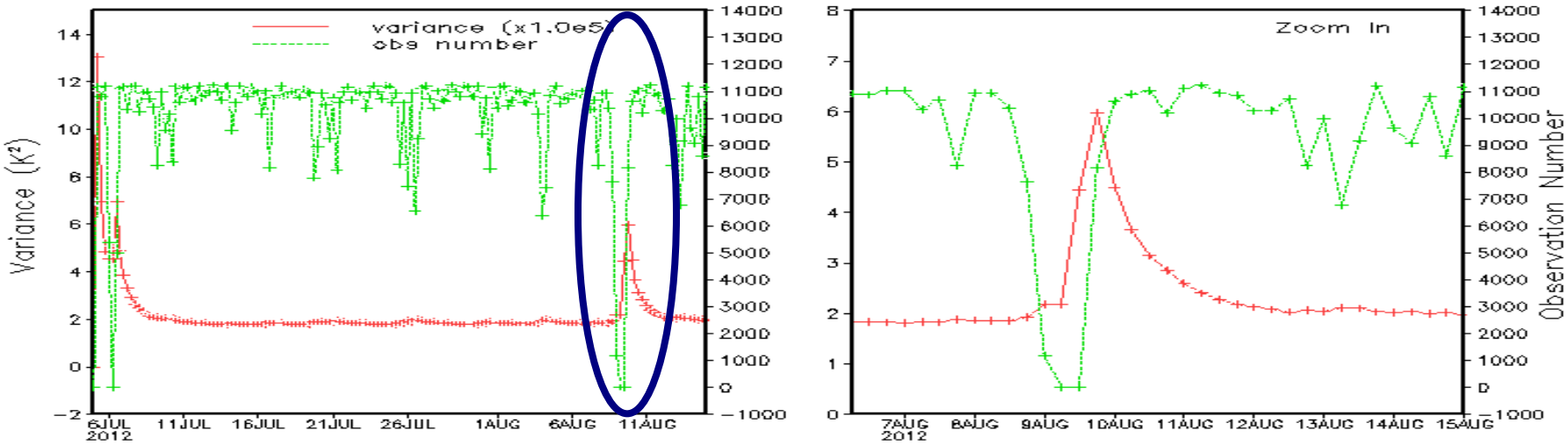
- Combine the scan angle and air-mass bias components inside the GSI variational framework, simplify the operational job suite
- With the modified pre-conditioning, the pre-specified parameter for each predictor is removed
- Add new emissivity sensitivity bias predictor to handle large land-sea differences
- Automatically initialize the bias of any new radiance data
- Automatically detect any new/missing/recovery of radiance data
- Quickly capture any changes in the data and the data assimilation system, preferred scheme for re-analysis projects
- Faster GSI minimization convergence

Enhancements to the Radiance Bias Correction Scheme (cont.)

- **Adaptive background error variance for bias predictor coef.:** set to be the estimate of analysis error variance of the coef. from previous analysis cycle.

More & higher quality data ⟹ smaller variance

Variance vs. Observation number



A big drop of obs number prompts a jump of variance

Enhancements to the Radiance Bias Correction Scheme (cont.)

- Provide a convenient and efficient way, via the newly added passive channel bias correction capability, to obtain the bias of any new satellite data that are not used but monitored for preparation for future use, such as the radiance data from NPP satellite

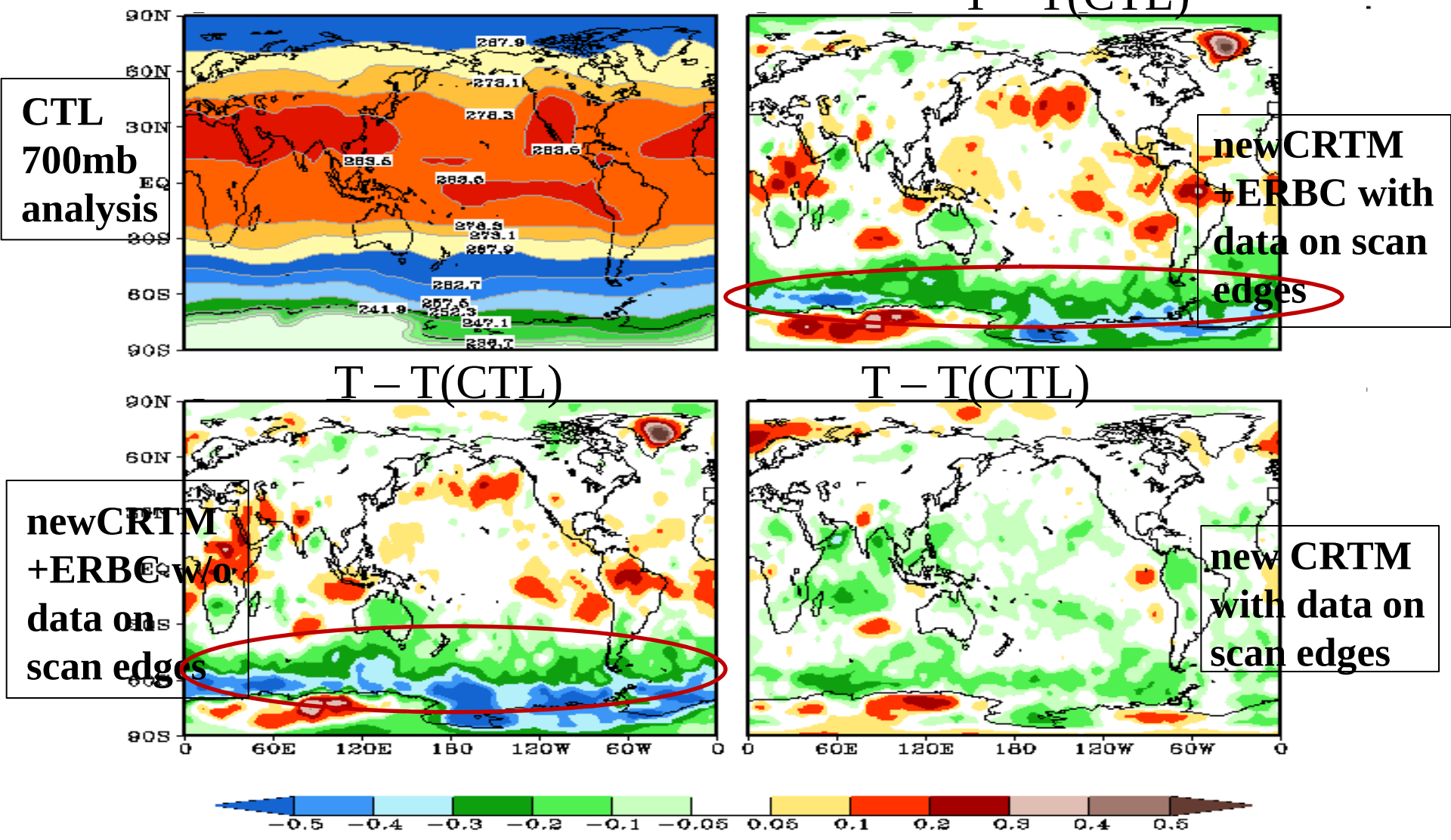
Passive channel bias correction: at the end of analysis minimizing the functional

$$F(\beta) = \frac{1}{2}(\beta - \beta_b)^T B_\beta^{-1}(\beta - \beta_b) + \frac{1}{2}\left[y - \tilde{h}(x_a, \beta)\right]^T R^{-1}\left[y - \tilde{h}(x_a, \beta)\right]$$

where

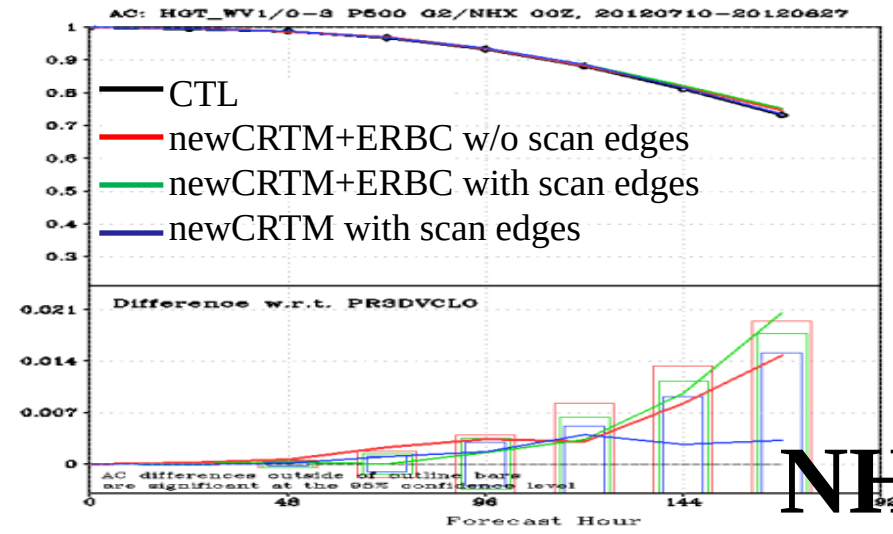
$$\tilde{h}(x_a, \beta) = h(x_a) + \sum_{i=1}^{N+K} \beta_i p_i(x_a)$$

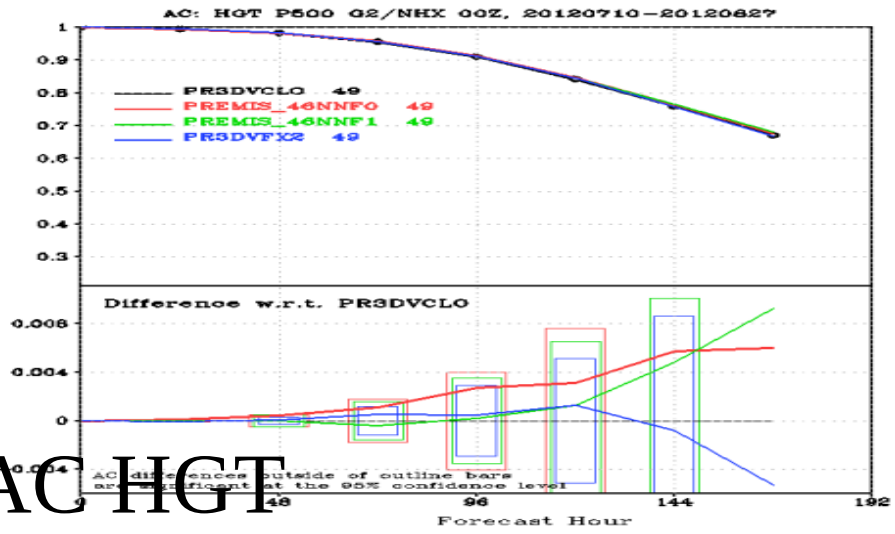
Both enhanced radiance bias correction (ERBC) and CRTM v2.1.3 are in the T1534 implementation -- test combined performance



Both enhanced radiance bias correction (ERBC) and CRTM v2.1.3 are in the T1534 implementation

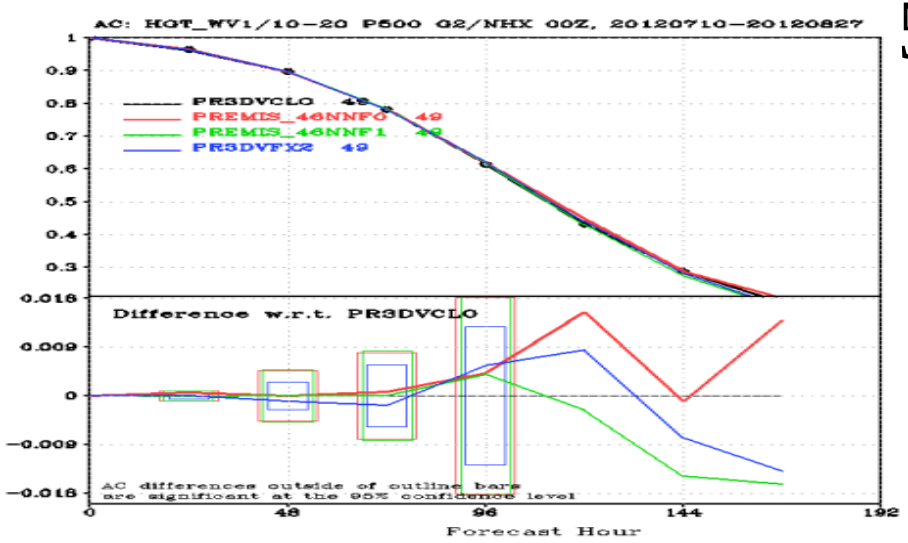
-- test combined performance (cont.)

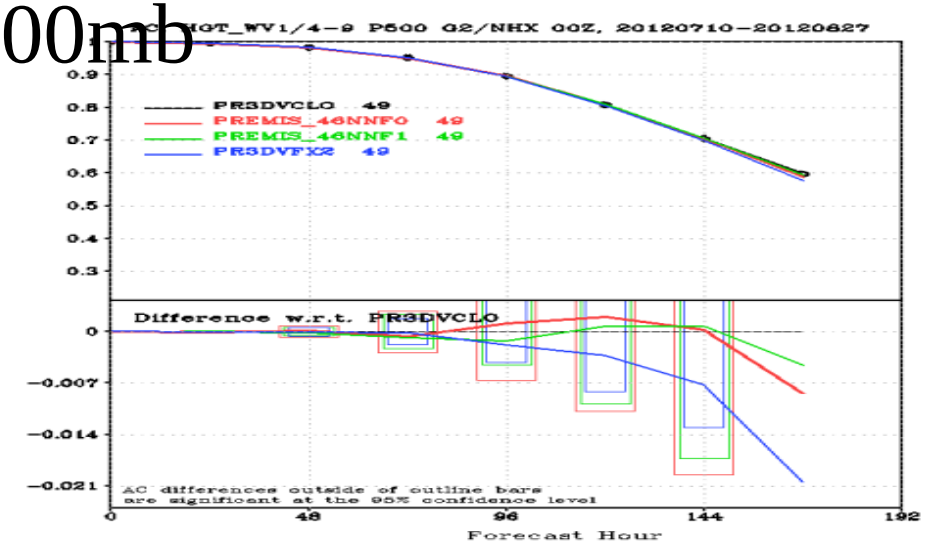




NH AC HGT

500mb





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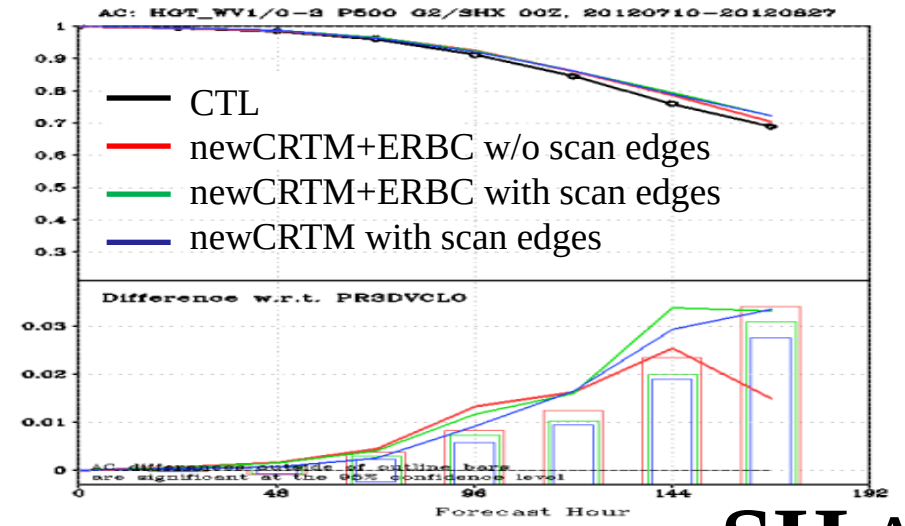

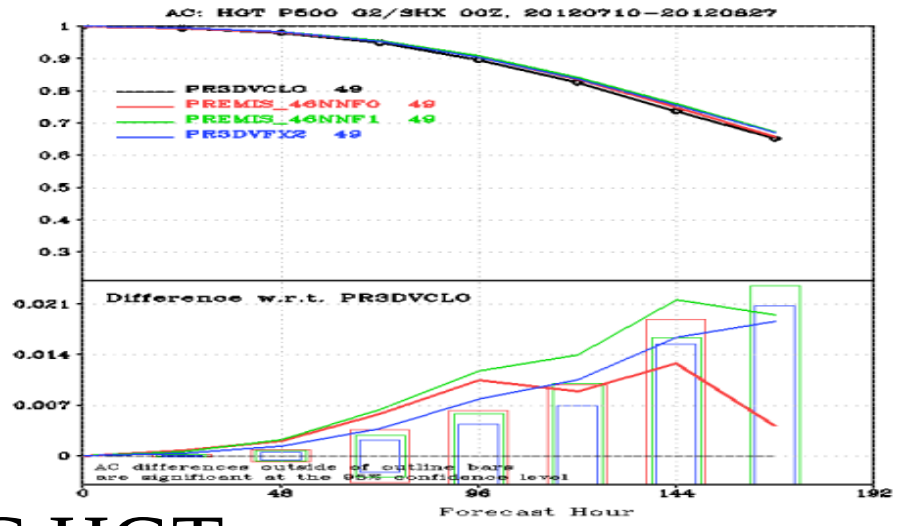

SH AC HGT

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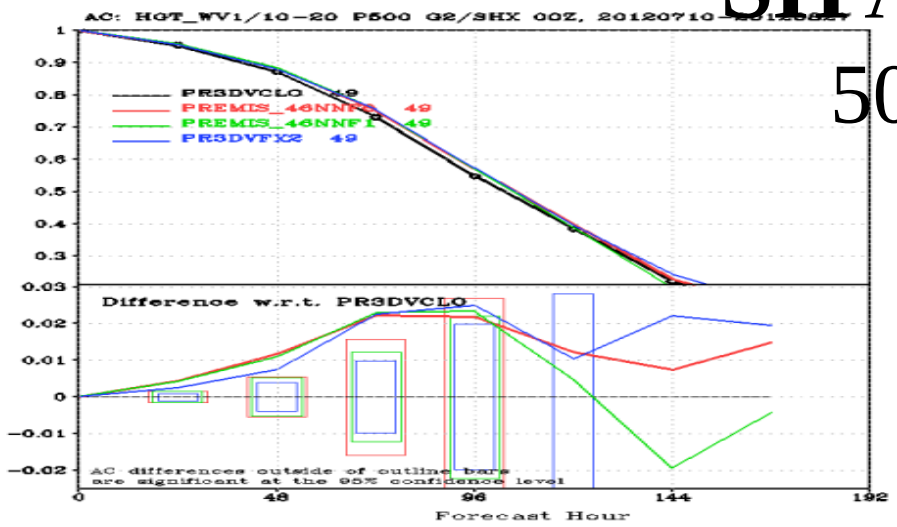

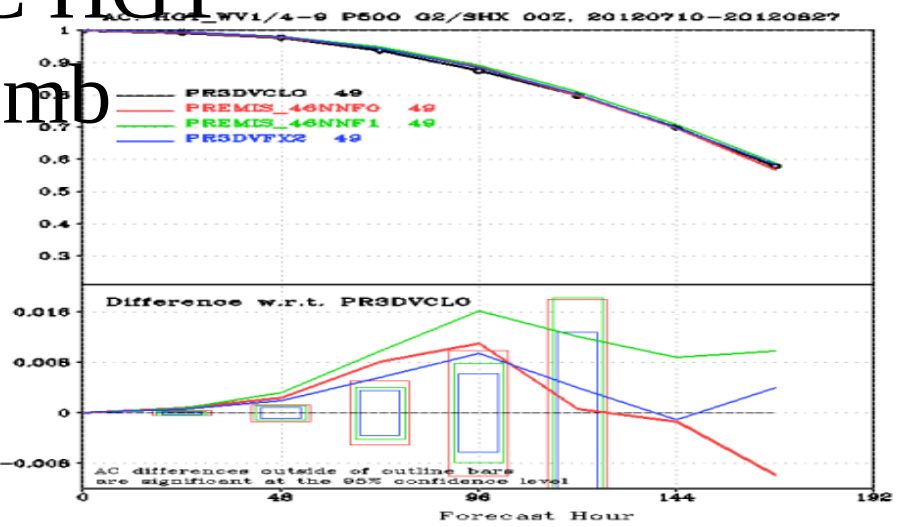

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Modifications to Assimilate Cloudy Microwave Radiance

- Control variable for clouds: total cloud water (cw)
- State variables for hydrometeors: ql, qi, (qr, qs, qg, qh)
- Background error covariance for cw from static and ensemble: stochastic physics (Whitaker et al., 2012)
- Observation error model based on averaged CLW from observation and first guess (Geer and Bauer, 2011)

  CLW over ocean (Grody et al. 2001; Weng et al. 2003):

  $$CLW = \cos\theta * \{c_0 + c_1 \ln[285 - T_B(23.8)] + c_2 \ln[285 - T_B(31.4)]\}$$

- Quality control: remove cloud filtering
- Radiance bias correction strategy
  - Remove cloud liquid water predictor
  - Bias correction based on the radiance data with matched cloud information
  - Test scattering index predictor

All-sky Radiance Bias Correction

- Based on CLW calculated from radiance observation (O) and first guess (F), different cloud information:

  1) O:clear vs. F:clear

  2) O:clear vs. F:cloudy → eliminate cloud

  3) O:cloudy vs. F:clear → generate cloud

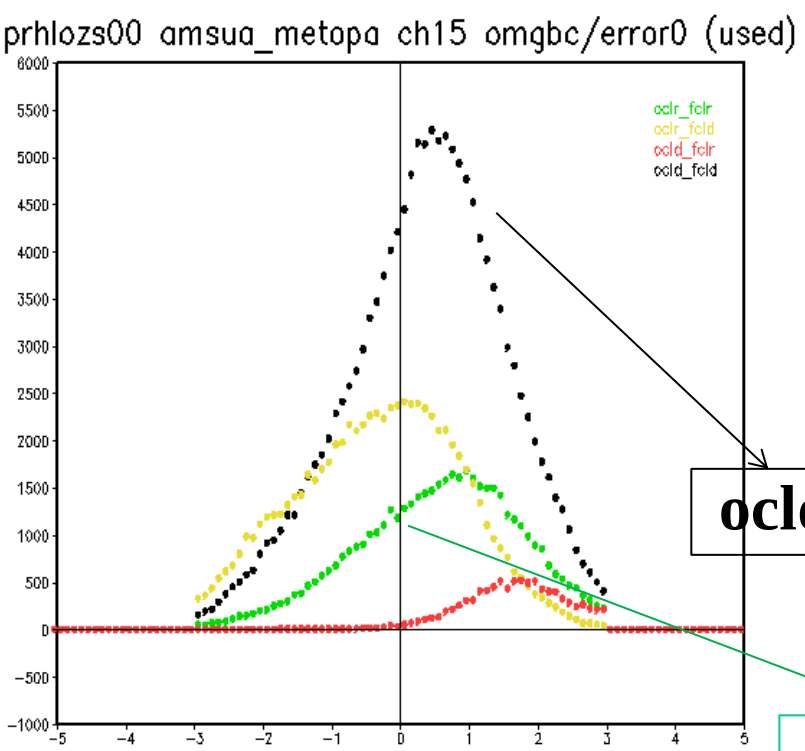
  4) O:cloudy vs. F:cloudy

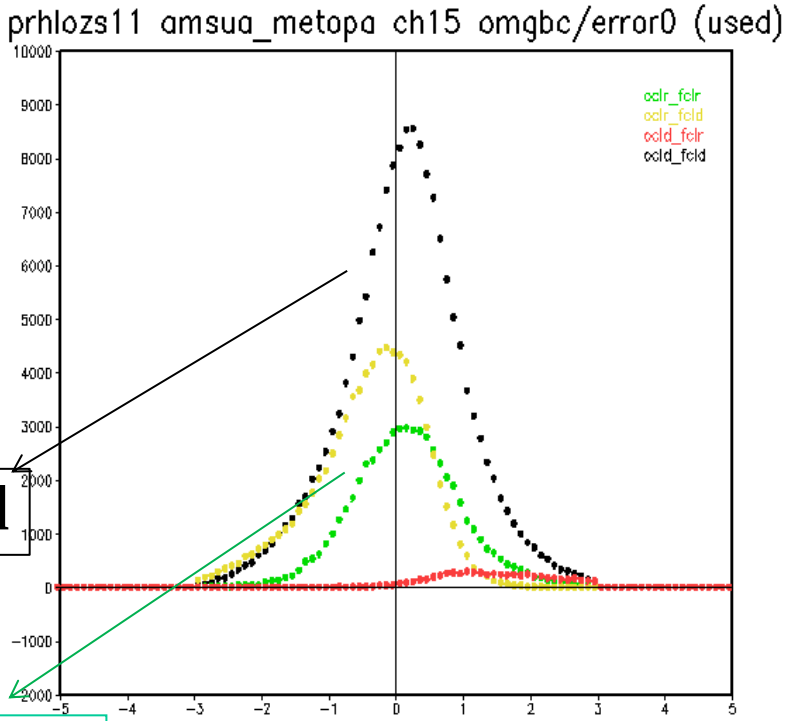
- Remove the bias while preserve the useful cloud information from the OmF with mis-matched cloud info
- Ideally, Gaussian distributed (O:clr,F:clr) & (O:cld,F:cld), with one hump (O:clr,F:cld) / (O:cld,F:clr) on each side
- Bias correction coefficients are retrieved only using the radiance data with cloud info matched with the first guess
- Use latest bias coef. available to bias correct the radiance data with mis-matched cloud info

Histogram of OmF with Bias correction

CTL

Test





ocld_fcld

oclr_fclr

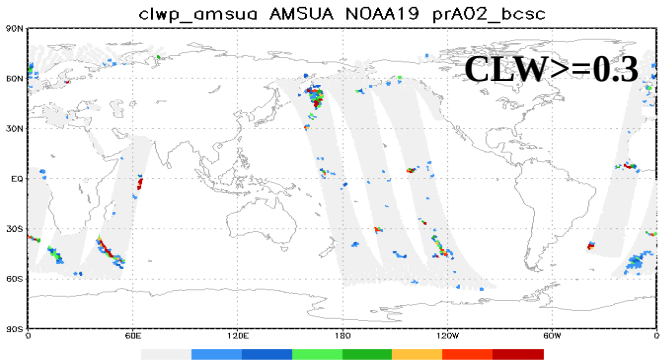
Scattering Index Bias Predictor Test

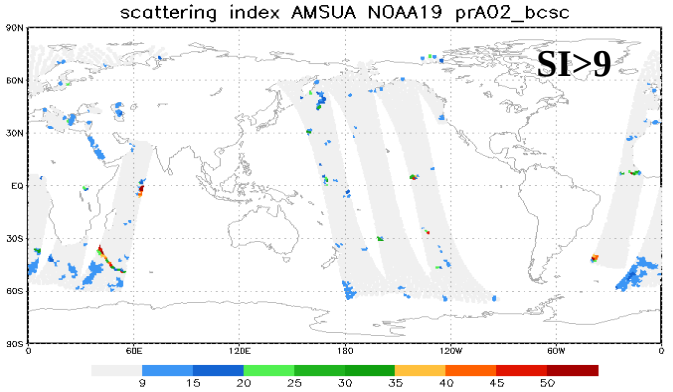
(when precipitation info of FG is not available)

SI bias predictor = { SI (clw>0.3 or SI>9)
0 (everywhere else)

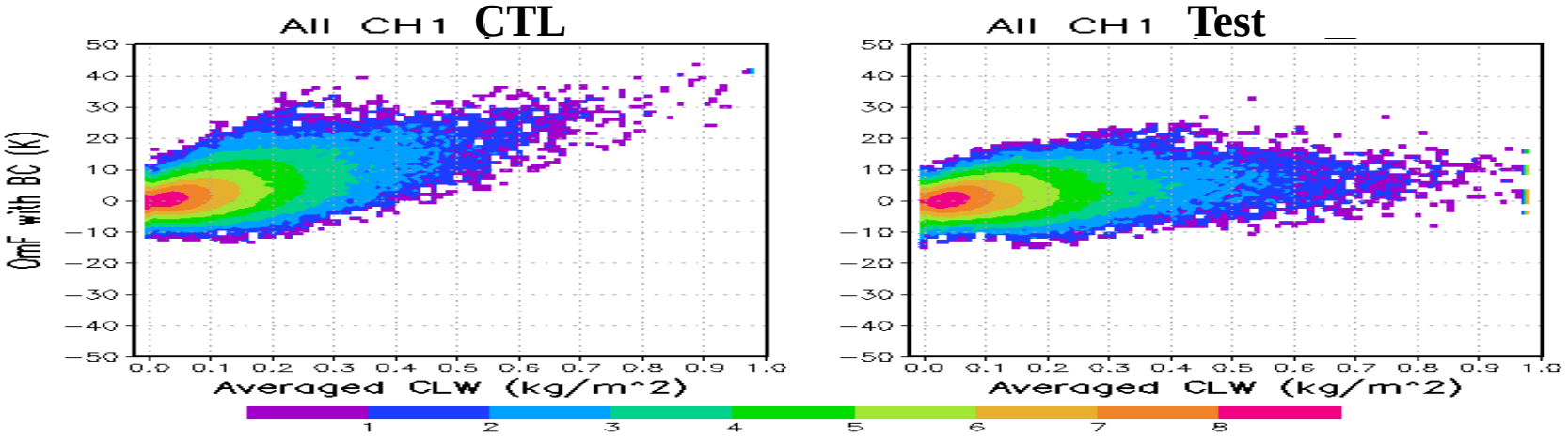
where

SI=-113.2+(2.41-0.0049*tb(1))*tb(1)
+0.454*tb(2)-tb(15) (Weng et al. 2003)





Averaged CLW vs. OmF with Bias correction



Future Work

- Our data assimilation system (model & ensemble parts) is still evolving, need to re-evaluate the previous work when the system is ready for next implementation, and focus on non-precipitating clouds first
- Examine the background error covariance from the ensemble with stochastic physics
- Examine possible further quality control criteria for cloudy radiance, e.g., cloud effect > 0.5K for channel 5 (Geer et al. 2012)
- Assess the multivariable balance of the analysis