Variational Cloud-Clearing with CrIS Data at NCEP

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Motivations

- Most of the global domain is affected by clouds
  - IR is used in current NCEP operation only over clear areas or the channels that peak well above cloud tops
- Efforts on using IR cloudy radiances
  - Explicitly describe clouds
    - Simplified clouds with the assumption of single-layer clouds
    - Sophisticated cloud profiles are estimated.
  - Cloud-clearing: is a method to remove the cloud radiative effect by comparing adjacent pixels within one field of regard (FOR). It aims at using partially cloudy data.

Cloud-Clearing Methodology

$FOV1: R_1 = (1 - \alpha 1) \times R_{clr} + \alpha 1 \times R_{cld}$

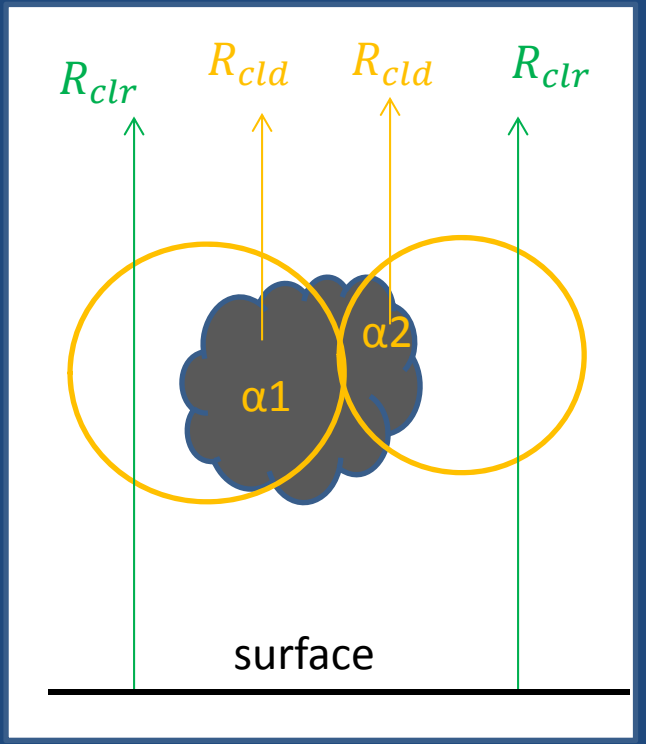
$FOV2: R_2 = (1 - \alpha 2) \times R_{clr} + \alpha 2 \times R_{cld}$

Assume: R_{clr} and R_{cld} in the 2 adjacent FOVs are same

After eliminating the R_{cld} from above 2 equations, we can get:

$R_{clr} = R_1 + \boldsymbol{\eta} \times (R_1 - R_2)$,

where $\boldsymbol{\eta} = \alpha 1/(\alpha 2 - \alpha 1)$ and $\alpha 1 \neq \alpha 2$

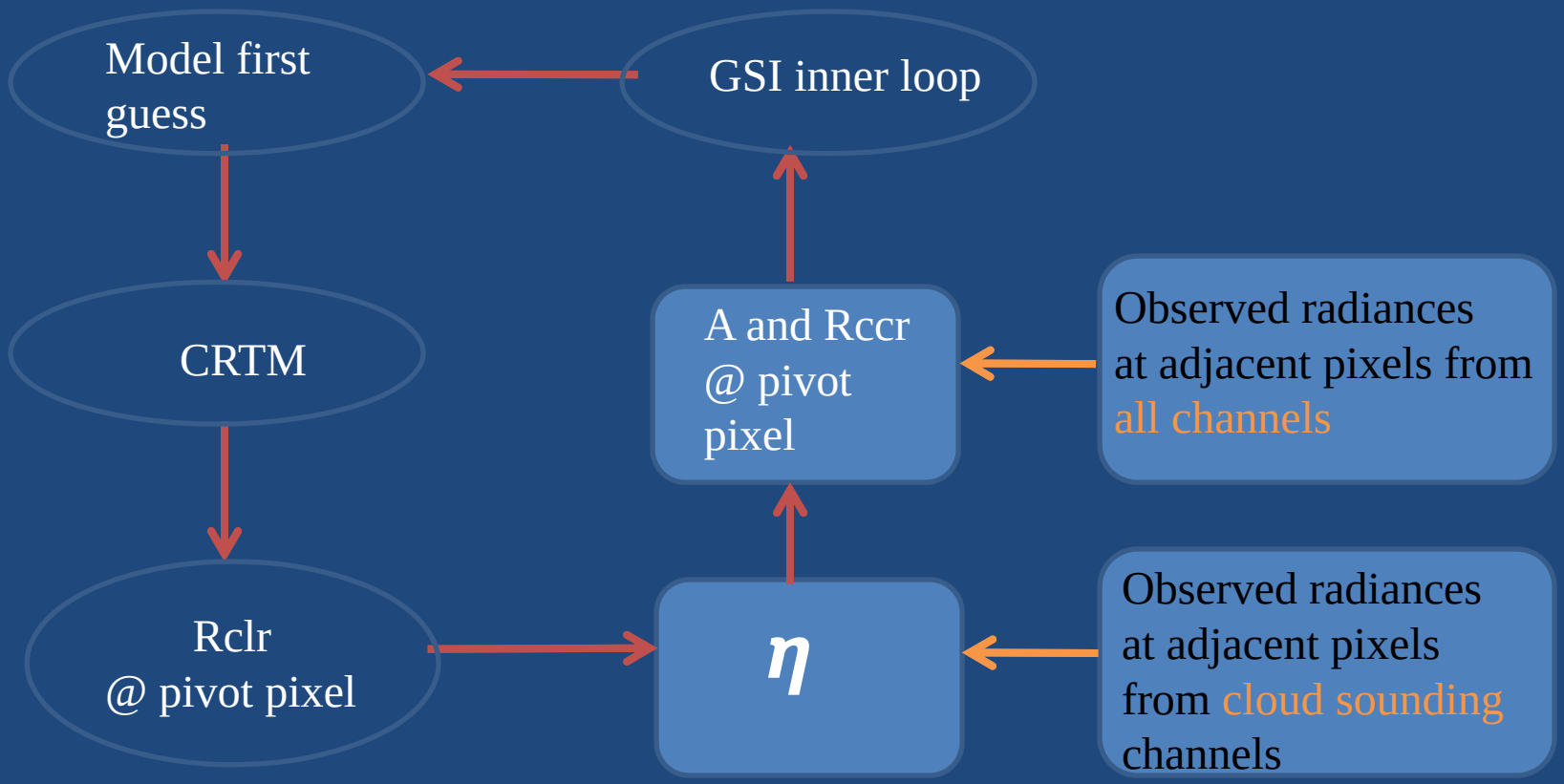


Extend to multiple cloud layers and more adjacent pixels:

$R_{ccr} = R_1 + \boldsymbol{\eta}_1 \times (R_1 - R_2) + \boldsymbol{\eta}_2 \times (R_1 - \times R_3) + \ldots\ldots + \boldsymbol{\eta}_k (R_1 - R_{k+1})$,

$\boldsymbol{\eta}_1, \boldsymbol{\eta}_2$ … are cloud-clearing parameters which depend on α only. They can be estimated using a set of cloud sounding channels to solve an over-estimated problem in a least-square sense.

Flow Chart of Variational Cloud-Clearing



The cloud-clearing parameters are estimated inline together with other meteorological variables within the variational framework and reconstructed Rccr is assimilated with all other available observations.

Pre-Processing

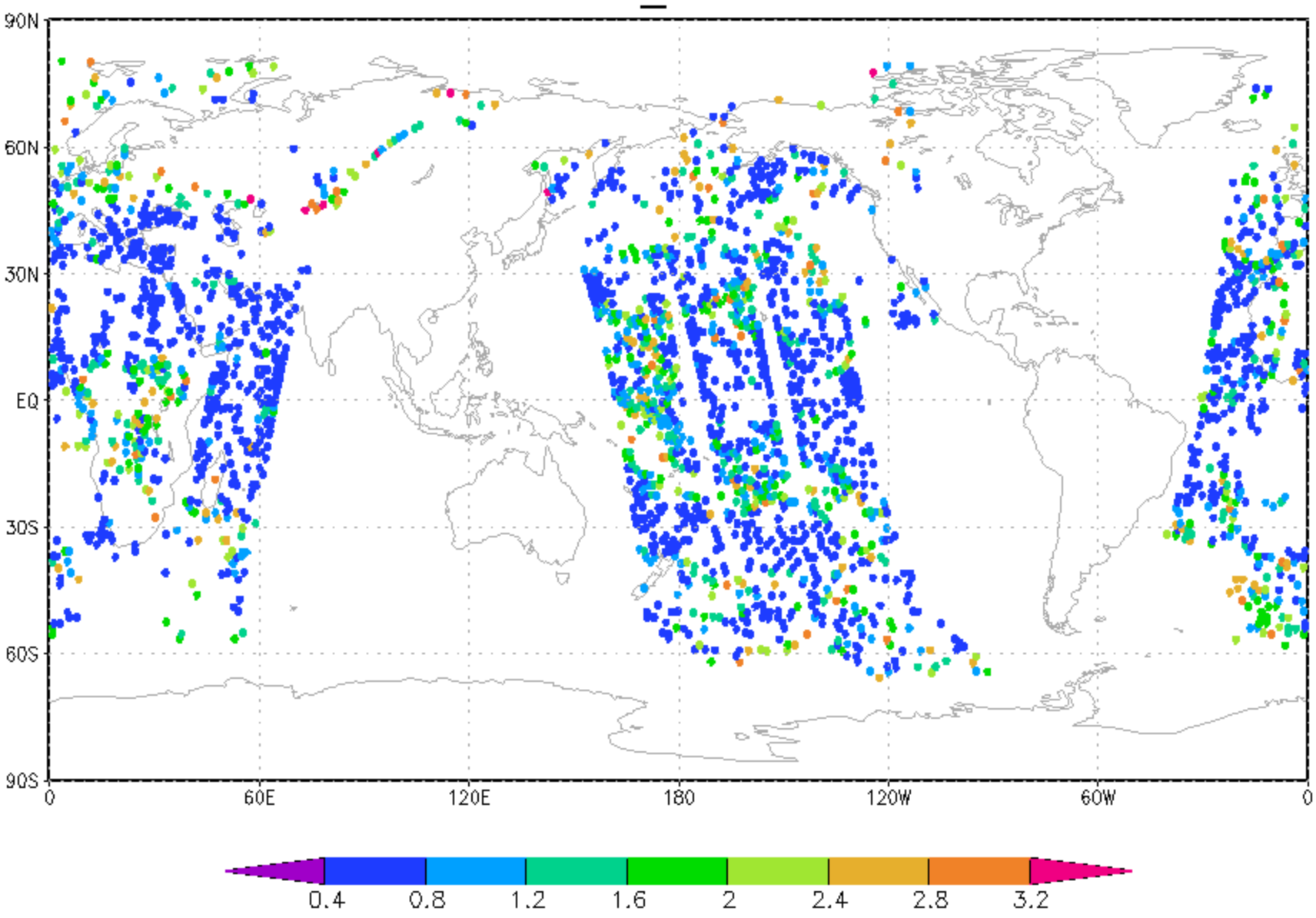
- No change to the thinning. Clear-sky has privilege to the cloudy data
- Channel selection: stays the same as the clear-sky data.
- Bias correction: applied to partial cloudy pixels before cloud-clearing is done.
- Obs error: amplification factor A is applied for the CCR data.
- QC: additional check A < threshold

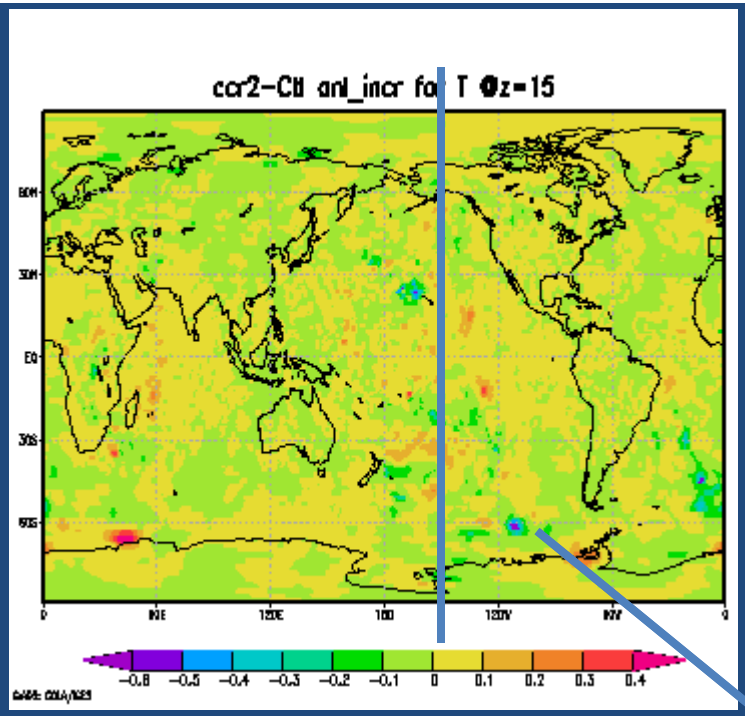
$$A = \sqrt{(1+\sum_{k=1}^{K}\boldsymbol{\eta}_k)^2+\sum_{k=1}^{K}\boldsymbol{\eta}_k^2}$$

Experiment Configuration

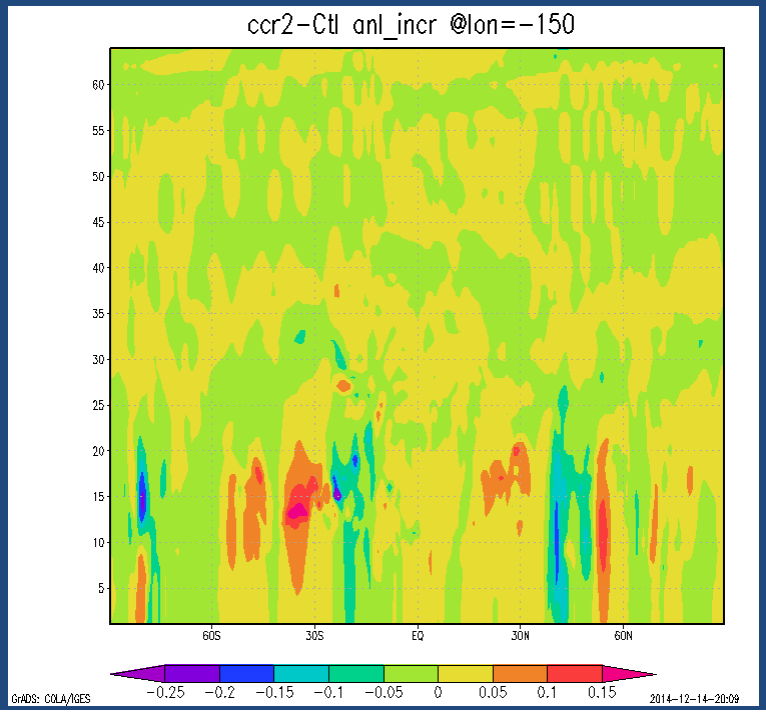
- CNTL :
  - Period: 2013102118-2013122200. The first month completed so far.
  - 3D-hybrid GSI
  - Resolution T670-T254, L64
  - All data used in operation
- CCR :
  - CrIS cloud-cleared radiance (CCR) data turned on. 1st trial to perform inline cloud-clearing with CrIS and then variationally assimilate the CCRs data. The impact of CCRs on global analysis and forecast scores will be evaluated.

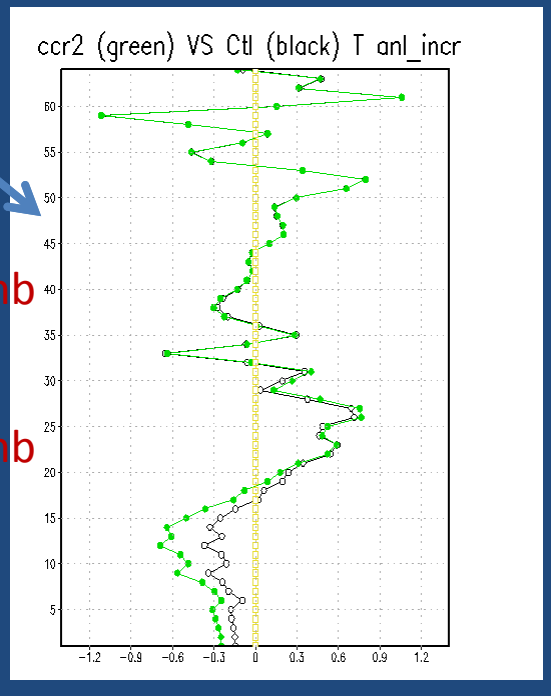
Observation Error for SNPP-CrIS Channel 154



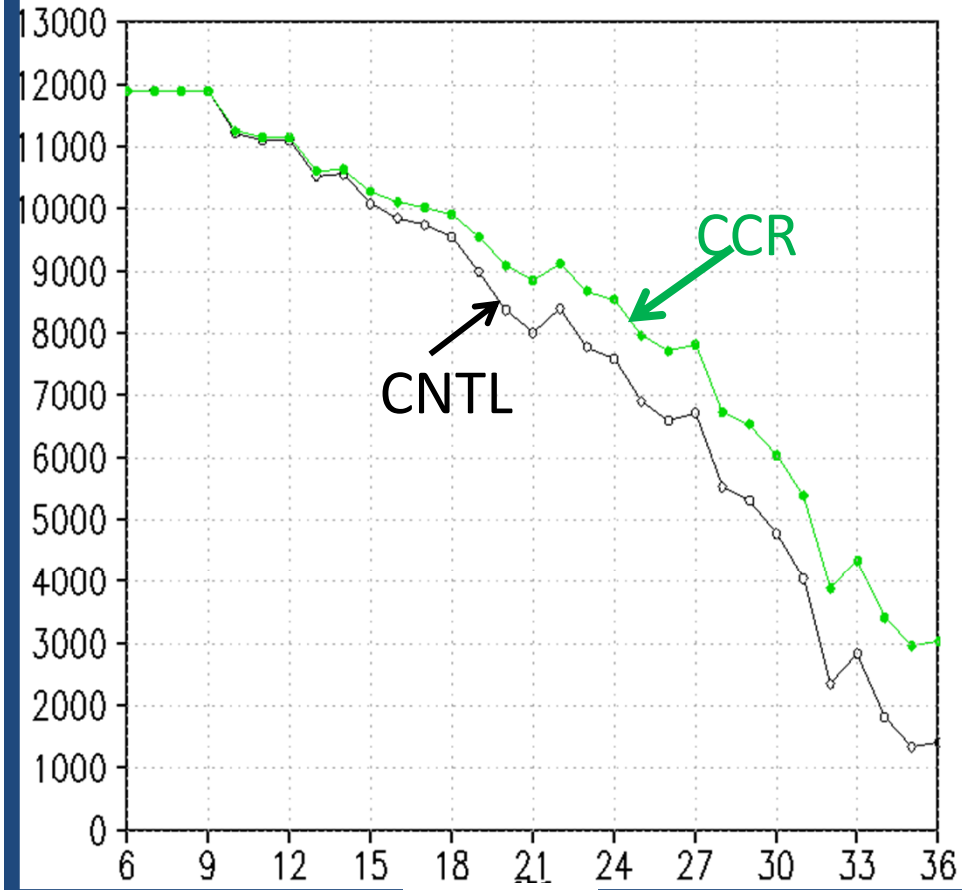


Analysis differences are shown below 100mb and mainly at middle and lower troposphere

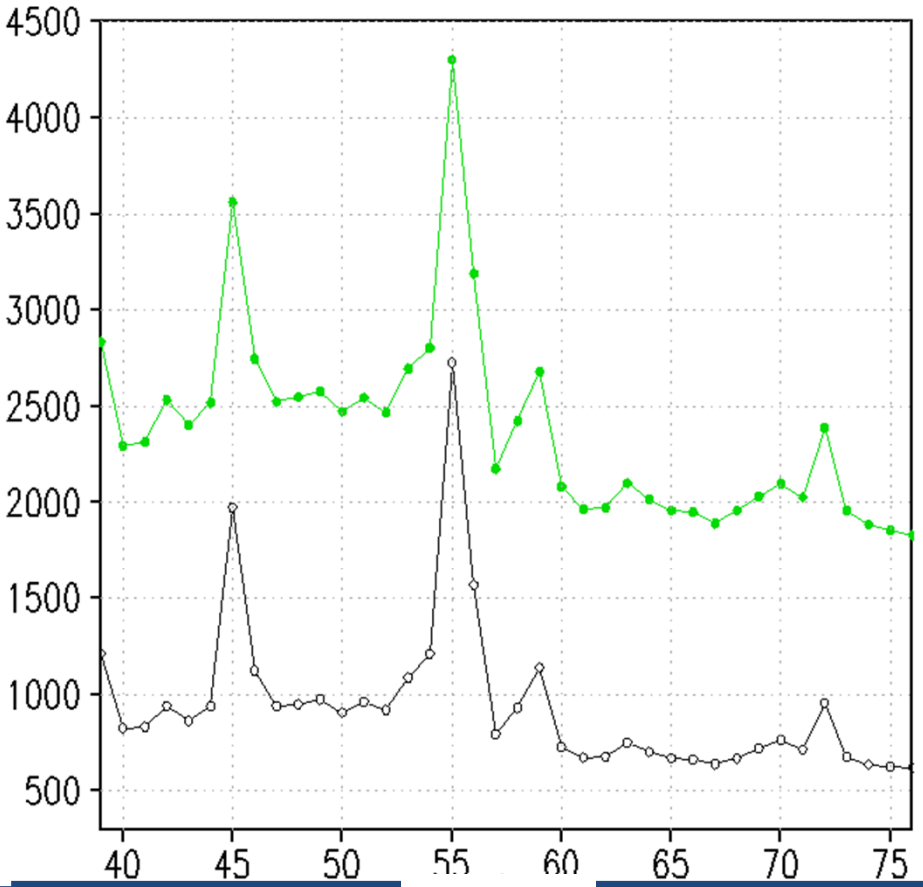




Data Count of CrIS_NPP



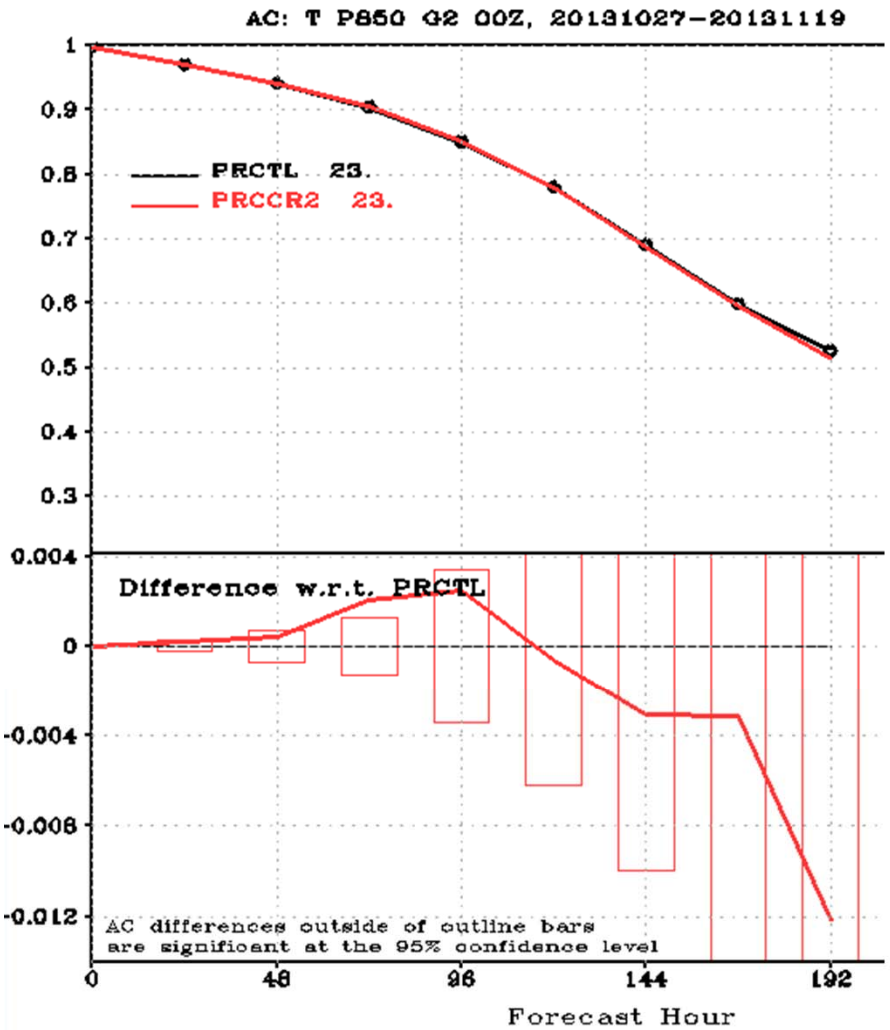
channel



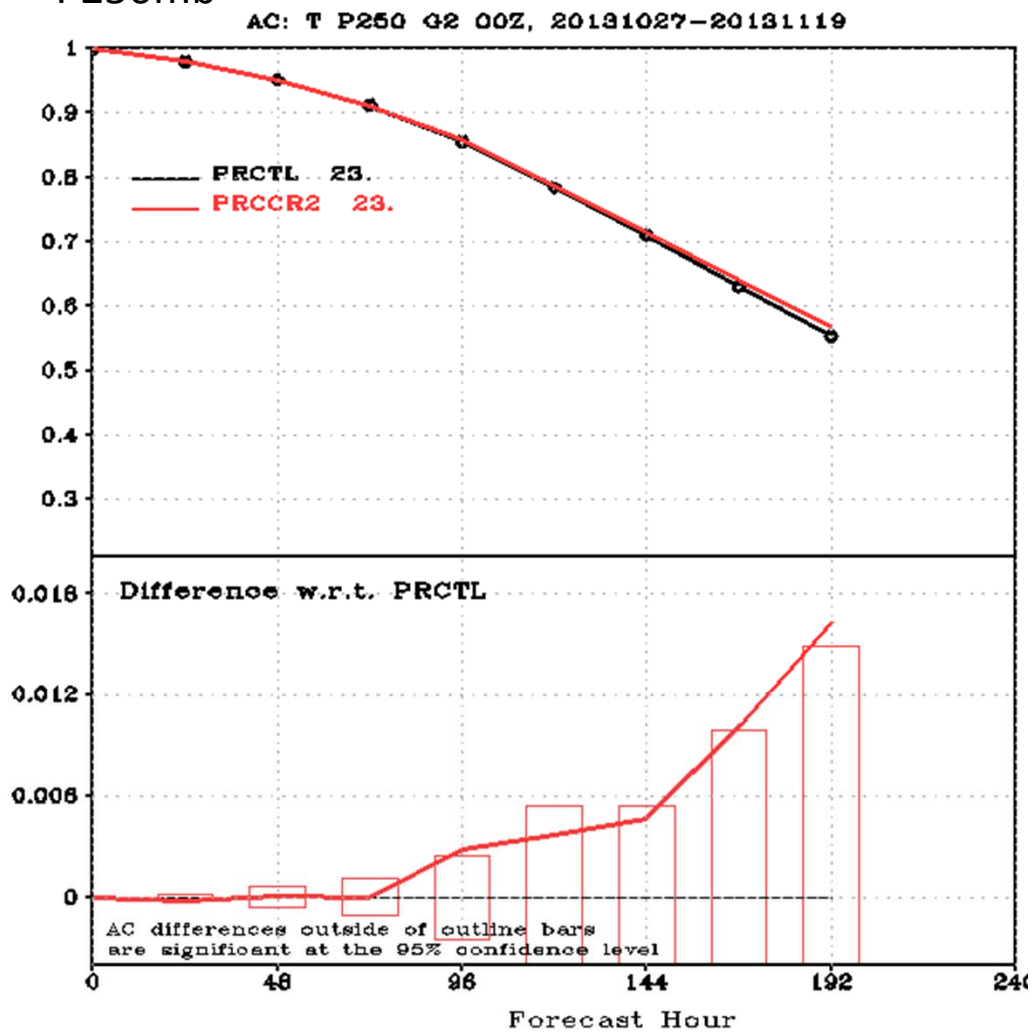
channel

Anomaly Correlation: T

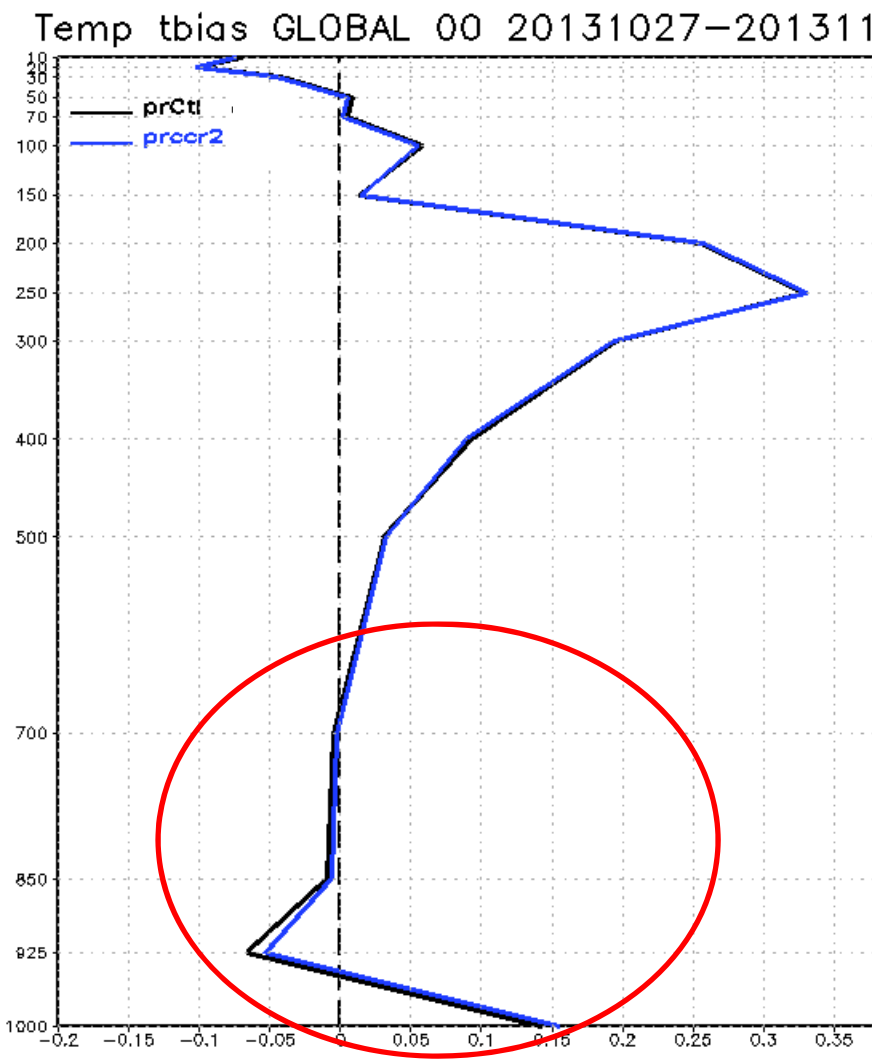
P850mb

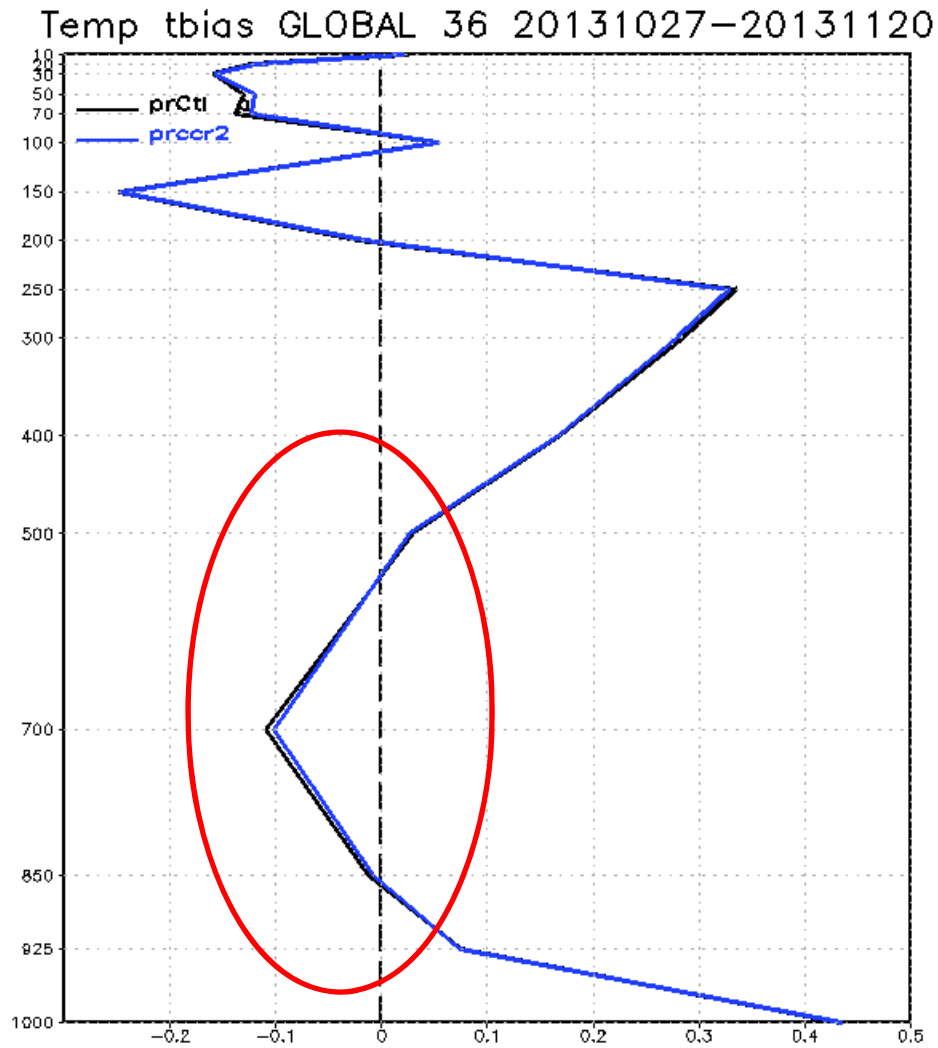


P250mb



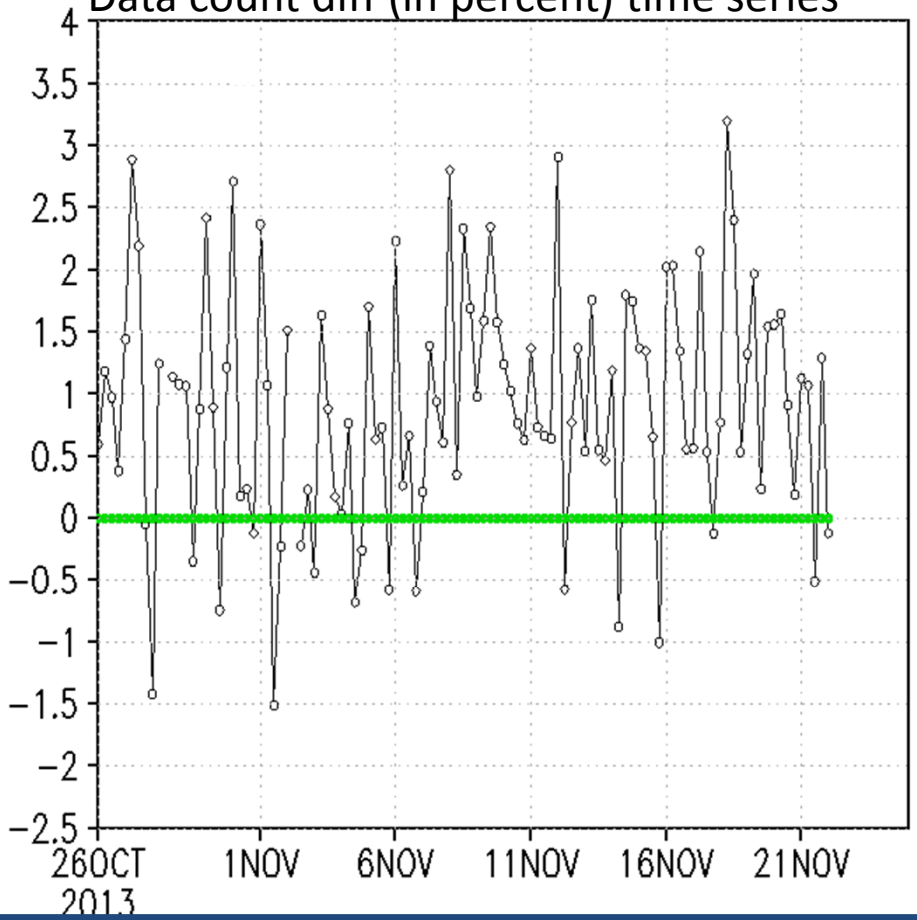
Fit-to-Obs: T bias



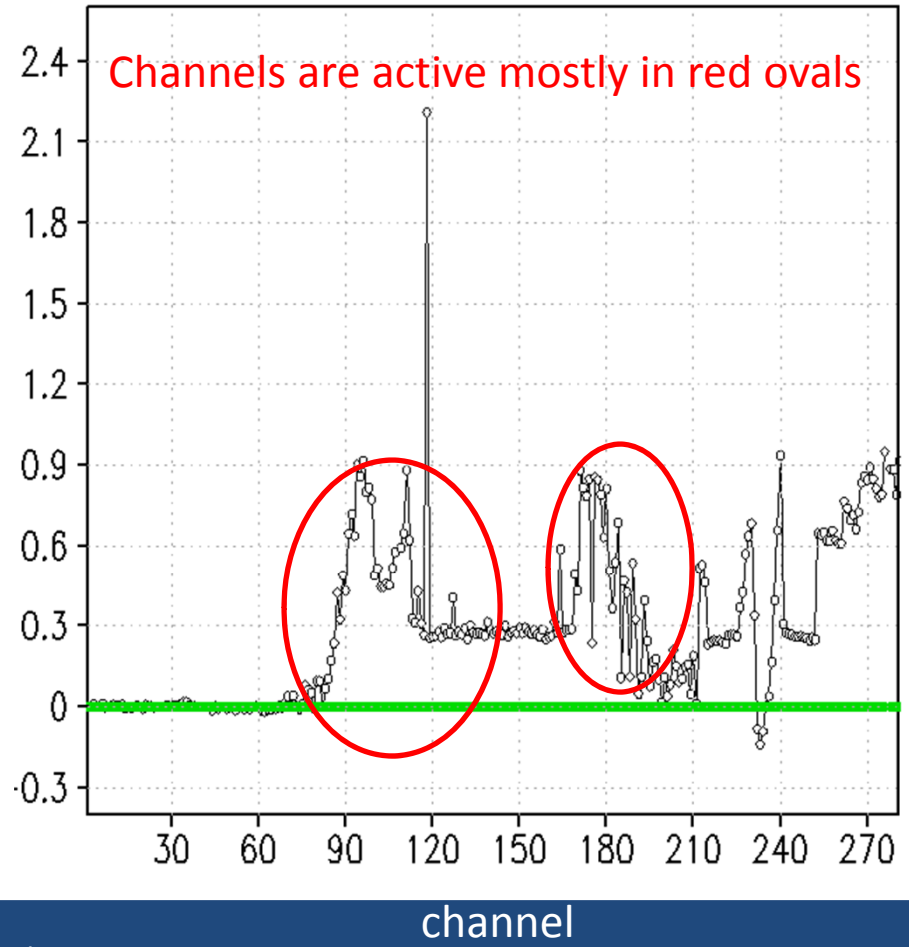


Impact on Data Count of AIRS_AQUA

Data count diff (in percent) time series



Time averaged over 2013102600-2013112200



Summary and Future Plan

- The preliminary results are encouraging.
- Evaluate the impact over a longer period.
- The GSI surface temperature and emissivity check to CrIS data should be revisited. It is expected that more CCR data can be used.
- The cloud-clearing relies on the cloud detection in GSI which will be revised.
- Investigate how the a priori impacts on the cloud-clearing and the subsequent analysis.

Backup slides

Cloud Clearing Methodology

$$R_j^i = \left(1 - \sum_{k=1}^{K} \alpha_{j,k}\right) \times R_{clr}^i + \sum_{k=1}^{K} \alpha_{j,k} \times R_{cld}^{i,k}$$

(Joiner and Rokke, 2000)

$$R_{ccr}^i = R_1^i + \boldsymbol{\eta}_1 \times (R_1^i - R_2^i) + \boldsymbol{\eta}_2 \times (R_1^i - \times R_3^i) + \ldots\ldots + \boldsymbol{\eta}_k\,(R_1^i - R_{k+1}^i),$$

$$\begin{pmatrix} \widehat{R_{clr}^1} - R_1^1 \\ \widehat{R_{clr}^2} - R_1^2 \\ \ldots\ldots \\ \widehat{R_{clr}^{ich}} - R_1^{ich} \\ \ldots\ldots \\ \widehat{R_{clr}^n} - R_1^n \end{pmatrix} = \begin{pmatrix} R_1^1 - R_2^1 & R_1^1 - R_3^1 & \ldots\ldots & R_1^1 - R_{k+1}^1 \\ R_1^2 - R_2^2 & R_1^2 - R_3^2 & \ldots\ldots & R_1^2 - R_{k+1}^2 \\ & \ldots\ldots\ldots\ldots & & \\ R_1^i - R_2^i & R_1^i - R_3^i & \ldots\ldots & R_1^i - R_{k+1}^i \\ & \ldots\ldots\ldots\ldots & & \\ R_1^n - R_2^n & R_1^n - R_3^n & \ldots\ldots & R_1^n - R_{k+1}^n \end{pmatrix} \begin{pmatrix} \boldsymbol{\eta}_1 \\ \boldsymbol{\eta}_2 \\ \ldots\ldots \\ \boldsymbol{\eta}_k \end{pmatrix}$$

Implemented the cloud-clearing method into the GSI outer loop. The cloud detection inside of the GSI (minimum residual method Eyre and Menzel 1989) is used to detect cloudy pixels and only inhomogeneous FORs are chosen for cloud-clearing. Focus on CrIS only.