Comparison among three CrIS Cloud-Clearing Radiance (CCR) products & All-Sky SEVIRI Radiance Assimilation at NCEP

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Part 1: Comparison among three CrIS Cloud-Clearing Radiance (CCR) products

Cloud-Clearing Methodology: The observed radiance at channel i in field of view (FOV) j with K cloud types can be expressed as

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

If we assume R_{clr}^i and $R_{cld}^{i,k}$ are the same in all the FOVs in a single CrIS field of regard (FOR), after eliminating $R_{cld}^{i,k}$, the cloud-cleared radiance R_{ccr}^i can be written as,

$R_{ccr}^i = R_1^i + \boldsymbol{\eta}_1 \times (R_1^i - R_2^i) + \boldsymbol{\eta}_2 \times (R_1^i - \times R_3^i) + \ldots\ldots + \boldsymbol{\eta}_k\,(R_1^i - R_{k+1}^i)$, $\boldsymbol{\eta}_k$ are the cloud-clearing parameters which depend on cloud fraction only (Chahine (1977) and Joiner and Rokke (2000)). $\boldsymbol{\eta}_k$ can be estimated using a set of cloud sounding channels to solve an over-estimated problem in a least-square sense. There have generally been three cloud-clearing methods developed for CrIS, which are being compared here.

NCEP/EMC CCR (CCR_GSI)

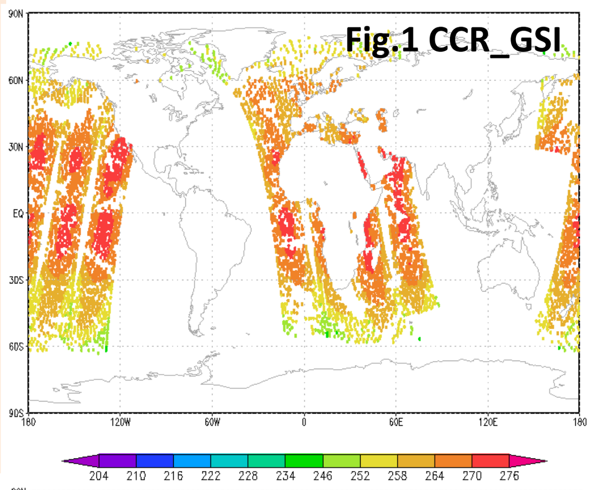
- NCEP has developed an inline cloud-clearing algorithm in their global data assimilation system (GDAS) and the CCRs are estimated together with all other observations, so they are constrained by all the observations being actively used in the data assimilation system.
- Rclr at pivot pixel is estimated using CRTM and the GFS model field. This cloud-clearing is conducted over seas only.

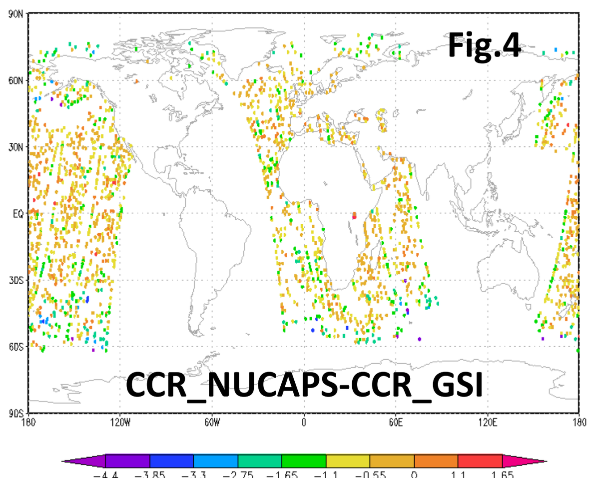
NUCAPS CCR

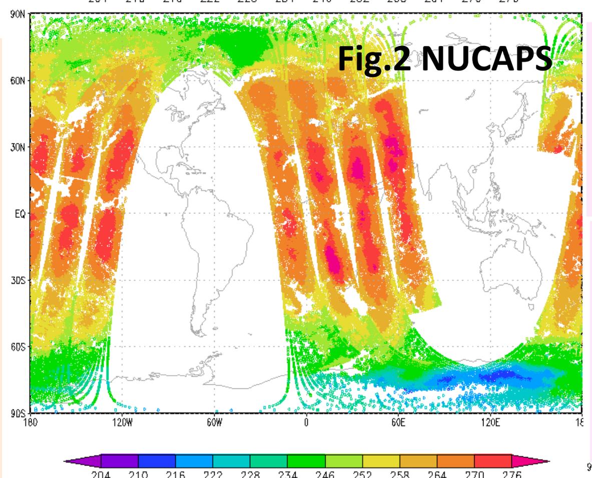
- The NOAA-Unique CrIS/ATMS Processing System (NUCAPS) is a heritage algorithm based upon the Atmospheric Infrared Sounder (AIRS) Science Team algorithm (Barnet et al, 2005). The same retrieval algorithm is currently used to process the CrIS/ATMS suite operational at NESDIS.
- Rclr at pivot pixel is estimated using the atmospheric state derived with Rosenkranz's retrieval method from ATMS data and the fast eigenvector regression (Goldberg et al. 2003).

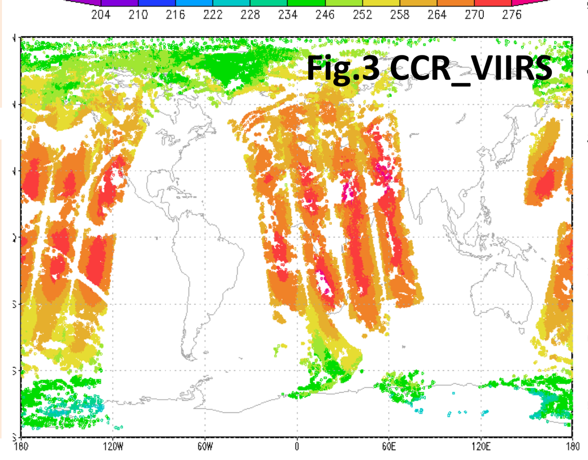
VIIRS_based CCR

- This algorithm is developed by Li et al (2005) using collocated high spatial resolution imager measurements.
- Rclr at pivot pixel is the weighted average of the radiances from the confident clear VIIRS pixels within one CrIS footprint.



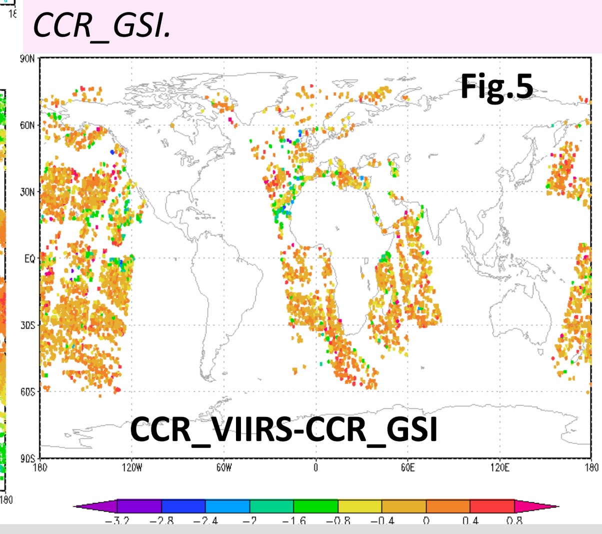


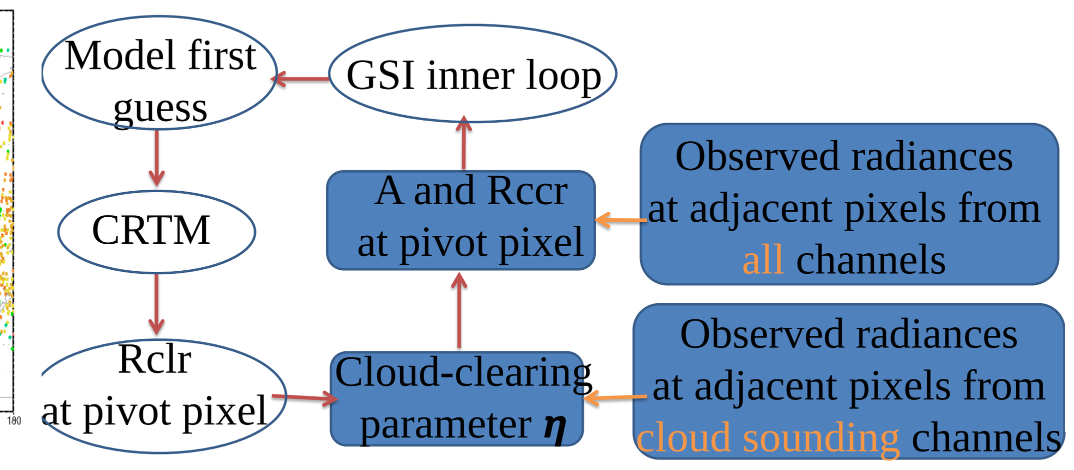


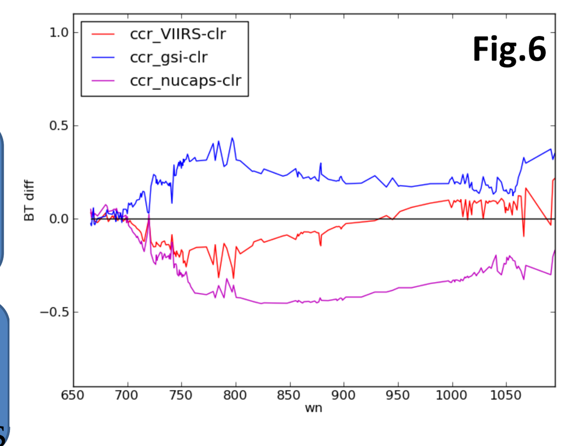


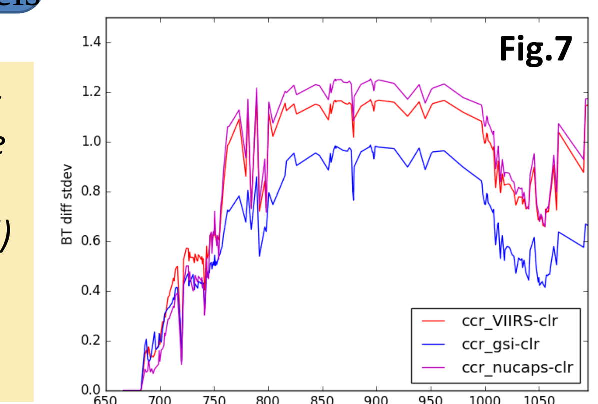
Figs.1-3 are at the CrIS channel with wave number=743.125cm^{-1} . Note Fig.2 includes both CCR and clear-sky data.

Figs. 4-5 are the CCR differences for the matched FORs only. Fig.4 is between CCR_NUCAPS and CCR_GSI and Fig.5 between CCR_VIIRS and CCR_GSI.





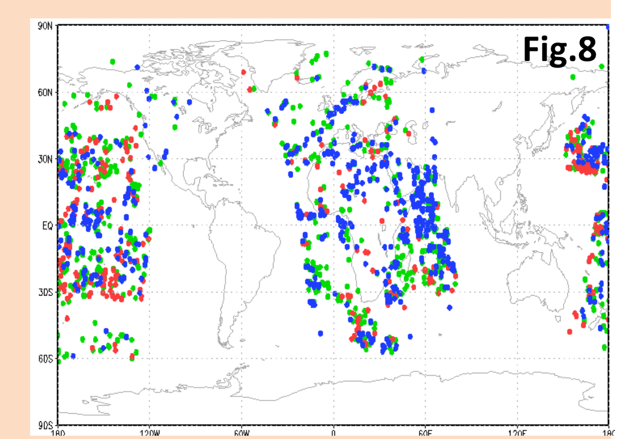


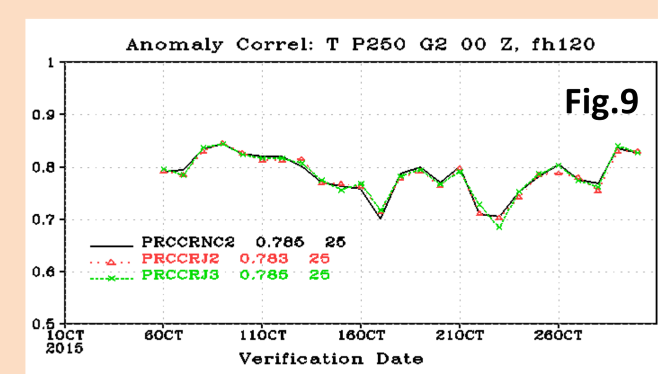


In Figs. 6-7, the "clr" represents the BT averaged over all clear-sky FOVs within one FOR identified by the VIIRS cloud mask. The three curves are respectively the BT differences between the "CCR_GSI" and "clr" (blue), between "CCR_VIIRS" and "clr" (red) and between "CCR_NUCAPS" and "clr" (magenta). They are all in terms of wave number and averaged globally. Fig.7 shows standard deviations of the above-mentioned BT differences.

CCR_VIIRS Data Parallel Experiments

- A set of parallel experiments were conducted to evaluate the CCR_VIIRS data impact on the GFS global forecast scores.
- prccrnc2 assimilates all the data currently used in operation, including the CrIS clear-sky data (blue dots in Fig. 8).
- prccrj2 assimilates all the data in prccrnc2 + CCR_VIIRS (red dots in Fig. 8)
- prccrj3: as prccrj2 but modifying the data thinning method, giving preference to the CrIS clear-sky data over CCR_VIIRS (green dots indicating more data passing quality control in Fig. 8).





Summary

- The three CCRs are comparable in quality compared to the clear-sky data identified by VIIRS cloud mask.
- The impact of the CCR_VIIRS on the global forecast score is neutral so far.

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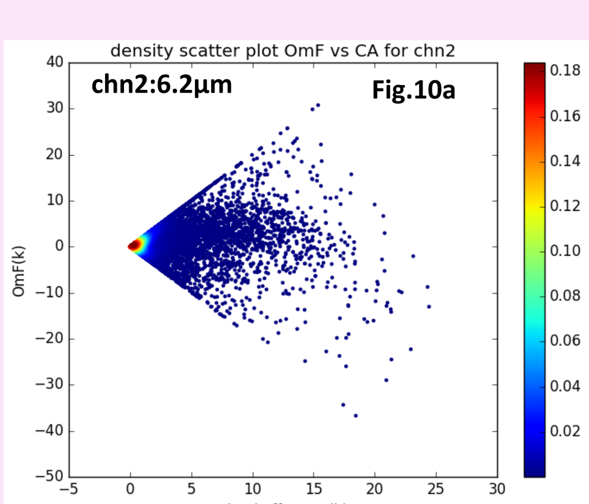
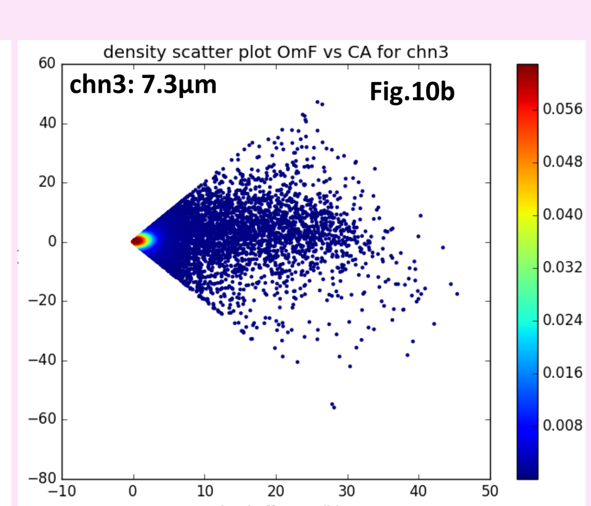
Part 2: All-sky SEVIRI radiance assimilation at NCEP

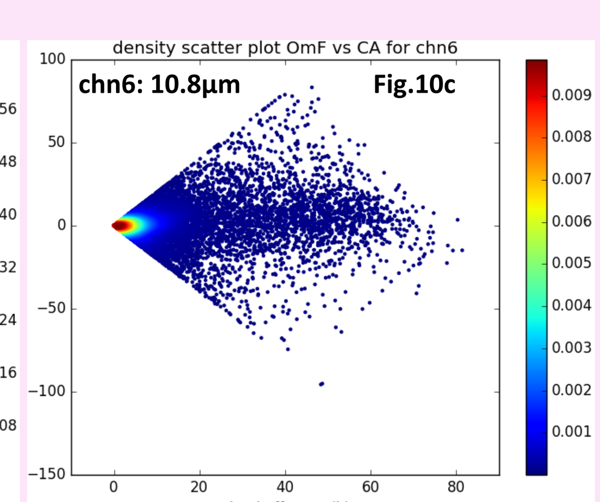
Introduction: This work is to extend the IASI all-sky radiance assimilation at NCEP/EMC (5p.03) to geostationary IR imagers such as SEVIRI or GOES-16 in the future in the NCEP global data assimilation system. Cloudy radiance simulation is conducted with Community Radiative Transfer Model (CRTM) that includes profiles for liquid-water content and ice-water content from the GFS model. Statistical analysis of observation minus background departures (OmF) are evaluated for all 8 SEVIRI channels using data samples collected over oceans from 17 days in August, 2017.

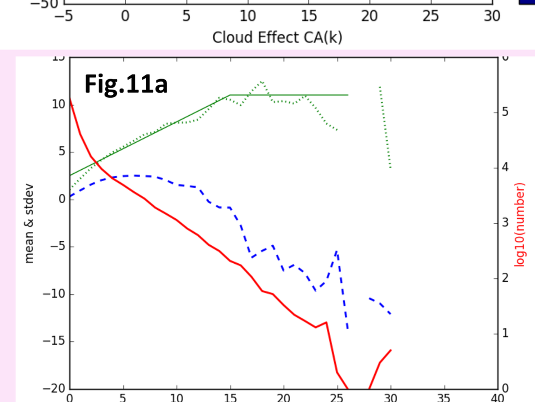
OmF Evaluation

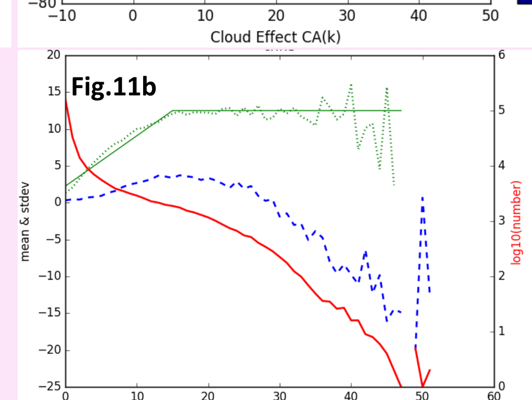
The cloud effect (CA) is defined as the average of the absolute departures of the observed and background BTs from the clear-sky BT (Okamoto *et al*., 2014). Fig. 10a-c show density scatter plots of the OmF vs CA, Fig. 11a-c are the OmF mean (bias) and standard deviation (stdev, or SD) vs CA and Fig. 12a-c show PDFs of normalized OmF. They are at the channels with wave lengths of 6.2μm (chn2 in the left column), 7.3μm (chn3 in the middle column) and 10.8μm (chn6 in the right column) which are sensitive to upper, middle-tropospheric humidity and surface temperature, respectively.

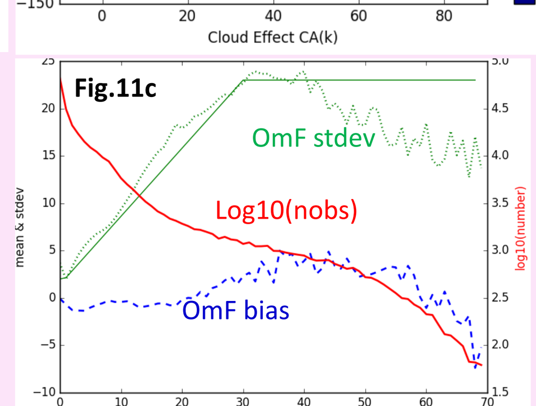


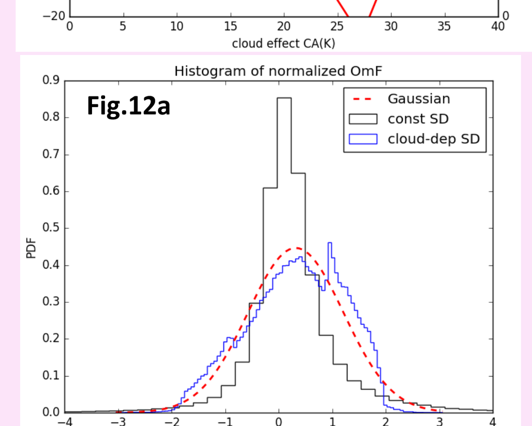


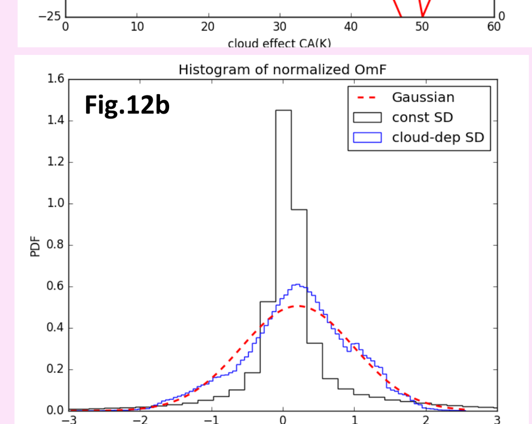


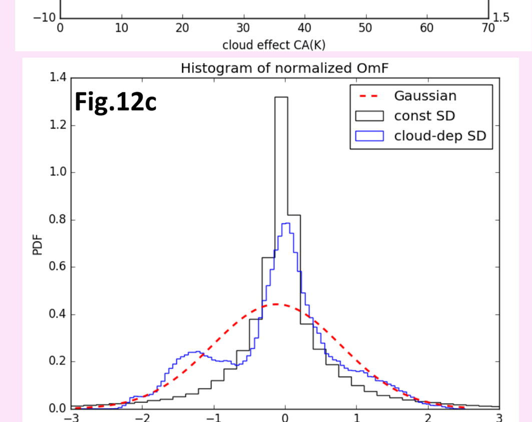






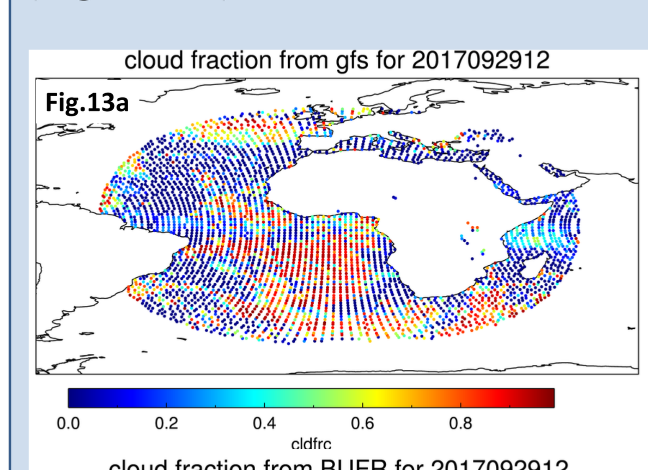


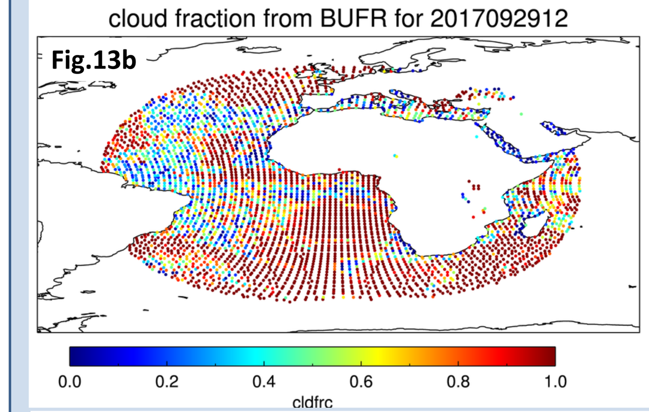


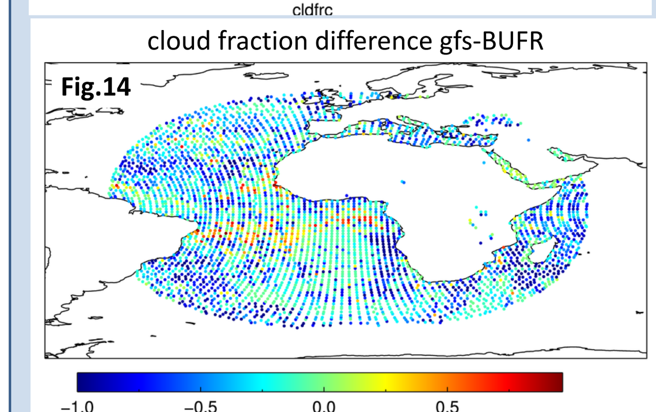


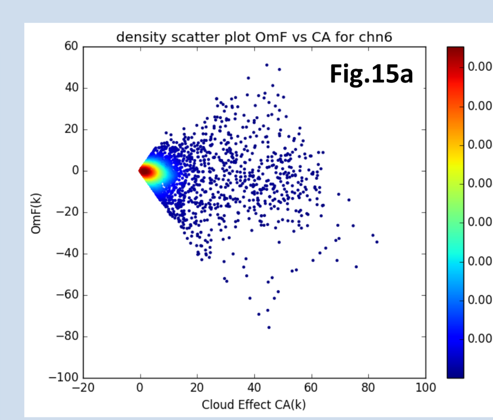
Cloud Cover from GFS or BUFR

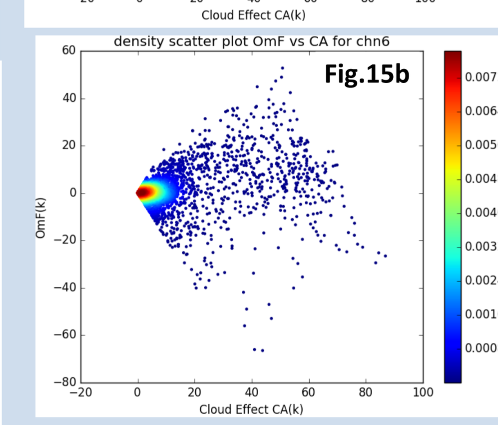
Cloud fraction profile is required by the CRTM to simulate all-sky cloudy radiances. It is diagnosed from the GFS model then the averaging overlapping method is used to compute the cloud cover(Fig.13a). The SEVASR BUFR product contains cloud cover (Fig.13b). The difference between the two cloud covers (Fig.14) causes important differences in the OmF statistics (Fig.15a-d).

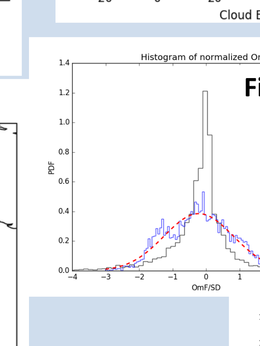


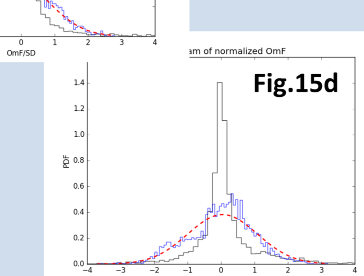






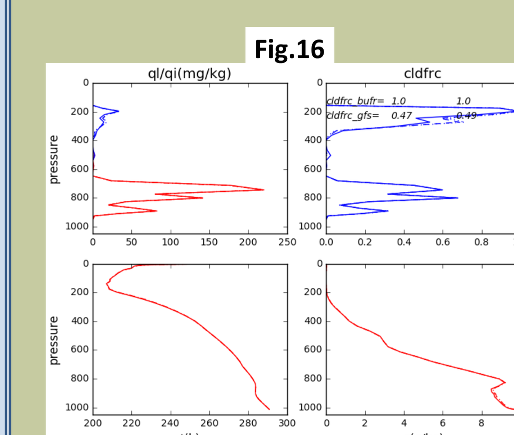


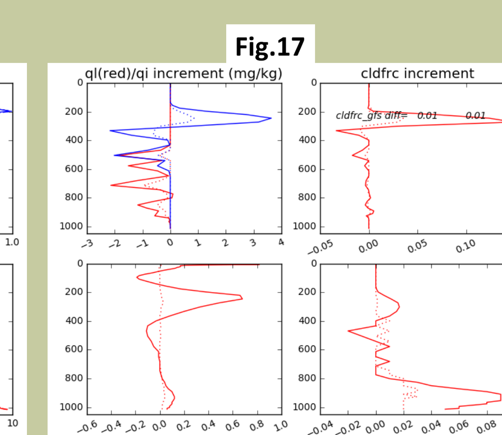




Single Observation Analysis

An analysis with a single cloudy radiance observation over sea is conducted to demonstrate how the cloudy radiance affects the temperature (t), humidity (q) and cloud liquid (ql) and cloud ice (qi) fields. Fig. 16 shows the ql/qi, t, q and diagnosed cloud fraction (cldfrc) backgrounds (solid) and analyses (dashed). Fig.17 are their analysis increments from the 1st (solid) and 2nd (dashed) outer loops. Fig. 18-19 are their Jacobians for the chn2 and chn6.





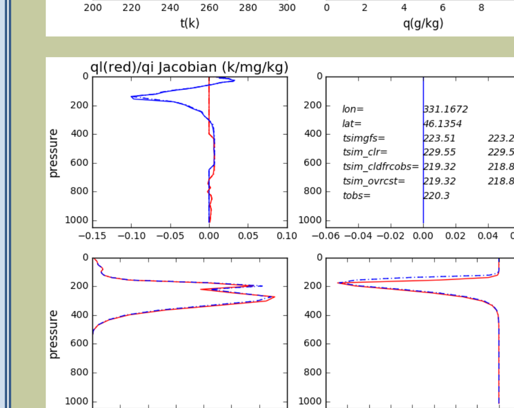


Fig.18

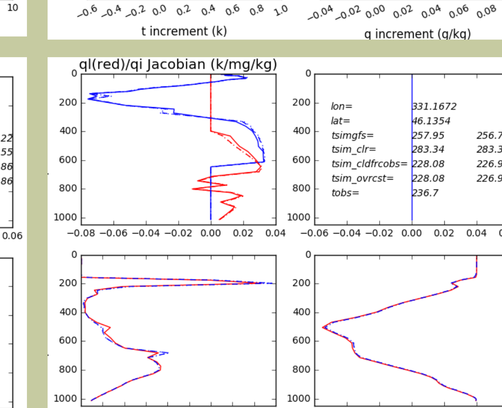


Fig.19

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