Simulation of Nadir Longwave Spectral Radiance using PCRTM with MERRA Reanalysis Data sampled for a 90° CLARREO-like Polar Orbit

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INTRODUCTIONS

CLARREO

The focus of the CLARREO *climate* measurement is on the longer term (~annual), large spatial scale (~zonal) accuracy, not high resolution at low noise. One of the CLARREO instruments would be a highly calibrated SI traceable Infrared (FTS) Fourier transform spectrometer with accuracy to < 0.1K (k=3) with a spectral resolution of 0.5cm-1 over 200-2000cm-1, nadir pointing with a FOV size of 20-100Km. FTS calibration on orbit would be accomplished using a highly accurate blackbody with phase change cells to monitor temperature and quantum cascade lasers to monitor any changes to blackbody emissivity. The proposed orbit and sampling would allow complete global coverage on an annual basis resolving all times of the diurnal cycle multiple times per year. The 90deg orbit is selected to remove sampling bias as much as possible for the annual mean measurement. Besides direct measurement of the IR spectrum the CLARREO FTS could be used to calibrate existing instruments AIRS, IASI, CrIS, CERES, VIIRS and all geostationary instruments to near 0.1K accuracy.

PCRTM

The Principal Component Radiative Transfer Model (PCRTM) (Xu Liu et al. 2006) is used to simulate nadir longwave spectral radiances using MERRA data as input. Computations are made equivalent to the instantaneous 30sec FOV sampling that CLARREO would have. Spatial resolution for the simulated FOV is taken as a single MERRA (540x361) grid box.

OBJECTIVE

1) Show comparisons of anomalies of PCRTM computed radiance with that of ones from MERRA OLR to illustrate utility of the PCRTM computation using MERRA inputs.
2) Show examples of the benchmark spectral IR fingerprinting method and how it can be used to retrieve zonal anomalies of physical variables such as cloud fraction, temperature and humidity.

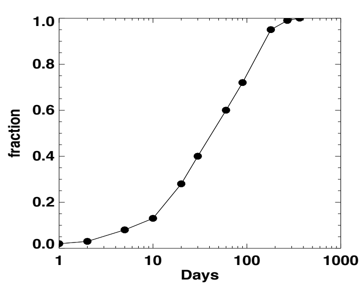


Fig 1) Simulation of the sampling coverage of the global MEARRA (540x361) grid for a 90 degree polar 'CLARREO-like" orbit of the Extended Pre-PhaseA NASA CLARREO Mission assuming a 30sec sampling interval covering a single MERRRA grid box.

Reference
Detection of Atmospheric Changes in Spatially and Temporally Averaged Infrared Spectra Observed from Space. Seiji Kato, Bruce A. Wielicki, Fred G. Rose, Xu Liu, Patrick C. Taylor, David P. Kratz, Martin G. Mlynczak, David F. Young, Nipa Phojanamongkolkij, Sunny Sun-Mack, Walter F. Miller, Yan Chen Journal of Climate Volume 24, Issue 24 (December 2011) pp. 6392-6407 doi: http://dx.doi.org/10.1175/JCLI-D-10-05005.1

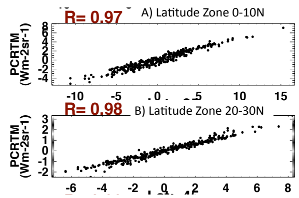


Fig 2) Zonal Mean at a) 0-10N and b) 20-30N of our PCRTM (merra) monthly broadband radiance anomaly(Wm^{-2} sr^{-1}) at nadir *versus* broadband OLR anomaly (Wm^{-2}) from GMAO model output. Shows robust reproduction by PCRTM spectral radiance model of radiation anomalies given in the MERRA dataset with correlations greater than 0.97.

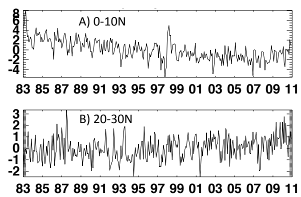


Fig 3) Zonal Mean at a) 0-10N and b) 20-30N of PCRTM using MERRA inputs monthly **broadband** radiance anomaly (Wm^{-2} sr^{-1}) at nadir *versus* time for 28yr(336month) computation. These zones show evidence of secular trends in computed radiance.

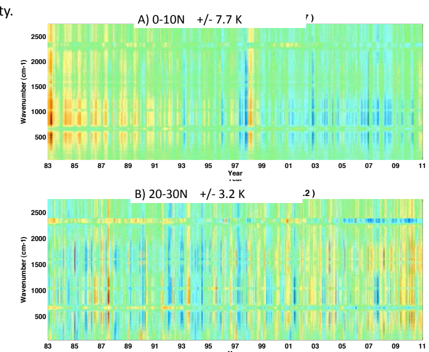


Fig 4) Zonal mean a) 0-10N and b) 20-30N Color contour of LW spectral brightness temperature anomalies [Tb(K)] *versus* Time (month) scaled to Min/Max anomaly for respective zone a) +/- 7.7 K b) +/- 3.2 K Latitude zone 0-10N shows secular anomalies in the window region representing near surface and atmosphere temperature. While zone 20-30N show trends in H_2O absorption bands and in stratosphere temperature in CO_2 absorption bands.

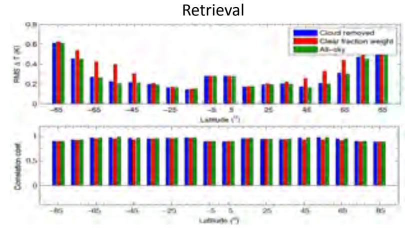
Benchmark Fingerprint Method

The benchmark fingerprinting method requires the pre-computation of a set of partial derivatives the Jacobian (A) with respect to all of the anticipated inputs that are likely to change over time and that have a measureable impact on TOA spectral radiances. The observed change in spectral radiance Y between two times is input. The solution to a linear regression is used to give the scaling vector C to the set of input variables used to generate the Jacobian (ie. matrix A). Jacobian is computed using monthly means of MERRA inputs. Retrievals made on annual anomalies.

$$C = (A^T A + \lambda H)^{-1} A^T Y$$

A is an m wavenumber by n input parameter matrix
Y is the m wavenumber vector of the observed spectral change
C is the n parameter scaling vector to the input variable.
H is the identity 'smoothing' matrix , λ is 1E-7

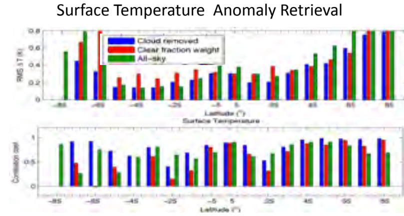
Stratospheric (10-100hPa) Temperature Anomaly Retrieval



Clear-sky only sampling does not affect retrieval
All-sky and clear-sky with cloud removed has similar RMS and correlation coef.

Fig 7) Summary plot of stratosphere temperature annual mean anomaly retrieval by latitude zone and sky condition {Cloud Removed, Clear fraction weighted ,All-Sky}. Reduced sampling for clear fraction weighted (ie. obs. clear) increase error RMS.
•Top) RMS error between MERRA truth and retrieval.
•Bottom) Correlation coefficient of MERRA truth and retrieval.

Surface Temperature Anomaly Retrieval



SH ocean ~60°S is mostly cloudy: All-sky had a larger RMS
Tropics and mid-latitude (NH): all-sky has slightly larger RMS and smaller correlation coef.
Compared with cloud removed

Fig 8) Summary plot of surface temperature annual mean anomaly retrieval by latitude zone and sky condition {Cloud Removed, Clear fraction weighted ,All-Sky}.
•Top) RMS error between MERRA truth and retrieval.
•Bottom) Correlation coefficient of MERRA truth and retrieval.

Cloud Fraction anomaly retrieval

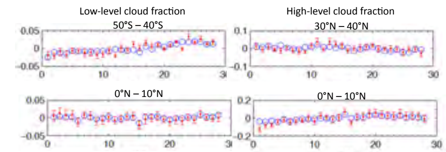


Fig 5) Time series of (Red Retrieval), (Blue MERRA Truth): Zonal annual anomalies cloud fraction for selected zonal bands. Anomalies are defined as deviation from 28yr mean. •Left) Low Cloud •Right) High Cloud

Cloud Fraction Anomaly Retrieval

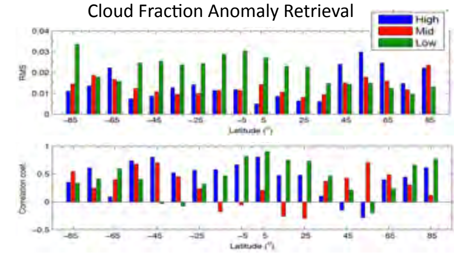


Fig 6) Summary plot of cloud fraction annual mean anomaly retrieval by latitude zone and cloud height category {High, Mid ,Low}.
•Top) RMS error between MERRA truth and retrieval.
•Bottom) Correlation coefficient of MERRA truth and retrieval.

Upper Troposphere (200-500 hPa) RH Anomaly Retrieval

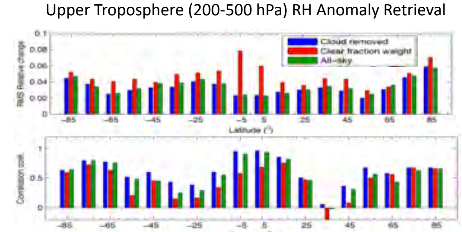


Fig 9) Summary plot of upper troposphere RH% annual mean anomaly retrieval by latitude zone and sky condition {Cloud Removed, Clear fraction weighted ,All-Sky}.
•Top) RMS error between MERRA truth and retrieval.
•Bottom) Correlation coefficient of MERRA truth and retrieval.

SUMMARY

The benchmark fingerprinting method using highly spatially temporally averaged spectral longwave radiance has shown utility in retrieval of zonal annual mean anomalies of temperature and humidity, especially above the typical cloud height for a region, as we expected. However retrieval of cloud property anomalies remains difficult, even under an ideal closed model simulated environment, as we have shown here. Retrievable cloud property anomalies are some kind of means (e.g. emissivity, cloud fraction, or some other cloud property weighted mean). We need to understand how cloud properties are averaged in order to understand cloud information that can be extracted from highly averaged spectral radiances. The combination of forward modeling and simulation of retrieval is, therefore, necessary to improve cloud property retrieval.