Single Field of View IASI/AMSU Retrieval Under All Sky Condition

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Introduction

An ultra fast Physical retrieval algorithm has been developed to carry out combined Infrared/Microwave (IR/MW) retrieval for collocated IASI/AMSU measurements. The retrieval algorithm uses Principal Component Based Radiative Transfer Model (PCRTM) for the IR forward simulation and Community Radiative Transfer Model (CRTM) for the MW part. PCRTM has been developed to effectively perform cloud radiative transfer calculations using pre-computed cloud transmittance and reflectance, enabling the retrieval algorithm to obtain cloud properties along with atmospheric variables and surface properties simultaneously from single field of view (FOV) measurements. While fully utilizing IR instrument's higher spatial and vertical resolution, the combined IASI/AMSU retrieval takes advantage of the MW instrument's ability to penetrate cloud so that accurate information for under the cloud atmosphere profiles and surface parameters can be retrieved from top-of-atmosphere (TOA) radiation measurement with high yield rate.

Physical retrieval algorithm

I. Forward Model:

PCRTM is designed for hyperspectral IR forward simulation with useful features including

- multiple scattering in clouds
- 15 variable trace gases
- short wave solar radiation and Non-LTE
- radiative kernel/Jacobian

PCRTM can be used for hyperspectral forward simulation for instruments on satellite – IASI, CRIS, AIRS, CLARREO or airborne – NASTI, S-HIS

Cloud is simulated as one indefinitely thin and homogeneously distributed plane parallel layer (or multiple layers) in the forward model. For a single layer forward model, integrated contribution to radiance from the real cloud with vertical structures is approximated as the contribution from the single effective layer

$$\int_0^{\tau} B\left(T(\tau')\right)e^{\tau'}d\tau' \approx B(\hat{T})$$

where τ is the optical thickness of the real cloud and τ' is the optical path for a point along the optical path. B is the Planck function at temperature T. $\hat{T}$ is defined here as the effective cloud temperature.

II Inversion

The physical retrieval process follows a standard maximum likelihood estimation procedure, i.e., mathematical inversion for a radiative transfer system which can be briefed using a linear form,

$$Y = F(X)+\varepsilon$$

Y - the radiance measurement. F - the forward model. X - the input parameter of the forward model. ε - the deviation of the forward model from the real measurement. By minimizing the cost function defined within *a posteriori* framework,

$$J(X)=(Y-F(X))^T S_y^{-1} (Y-F(X))+ (X-X_a)^T S_a^{-1} (X-X_a)$$

the solution is given as

$$X_{n+1}-X_n=\left(K^TS_y^{-1}K+S_a^{-1}\right)^{-1}\left(K^TS_y^{-1}\left(Y-Y_n\right)-S_a^{-1}(X_n-X_a)\right)$$

S_y is the measurement error covariance matrix, X_a is the background vector (*a priori*) and S_a is the associated covariance matrix, K is the Jacobian.

Technical Highlights

I. Be ultra fast, suitable for application on data of massive volume

II. utilize all the channels, keeping fine scale spectral information

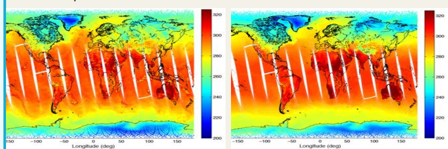
III. retrieve cloud properties along with atmospheric and surface properties using single FOV observations.

IV. Can incorporate two forward model (PCRTM + CRTM) to do IR/MW combined retrieval. Application examples: CrIS/ATMS , IASI/AMSU

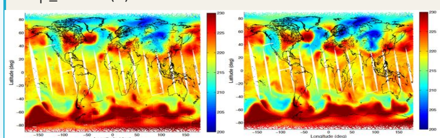
Applications on CRIS/ATMS Data

PCRMT+CRTM retrieval results VS collocated ECMWF value 02/17/2015

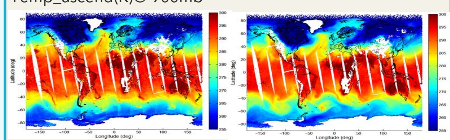
Skin temperature



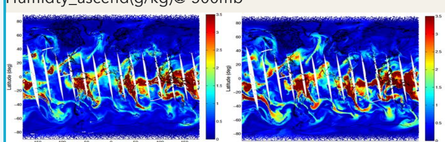
Temp_ascend(K) @ 200 mb



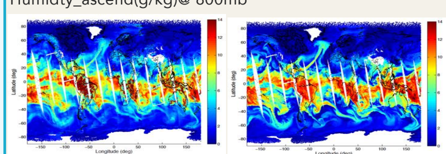
Temp_ascend(K)@ 900mb



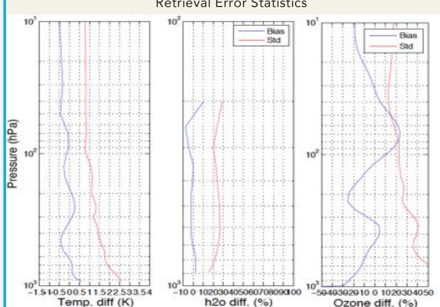
Humidty_ascend(g/kg)@ 500mb



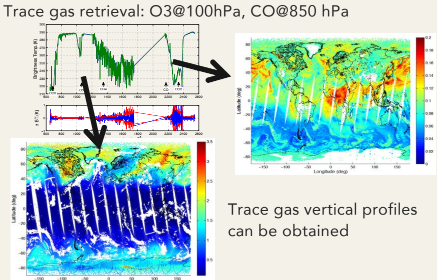
Humidty_ascend(g/kg)@ 800mb



Retrieval Error Statistics

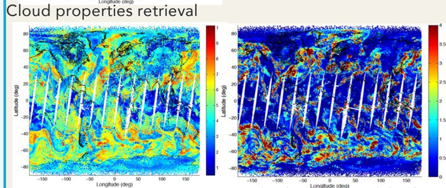


Trace gas retrieval: O3@100hPa, CO@850 hPa



Trace gas vertical profiles can be obtained

Cloud properties retrieval

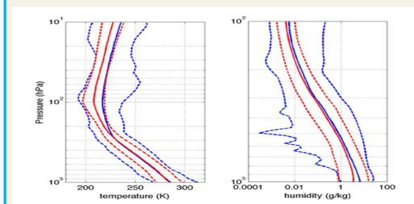


Cloud top pressure (hPa) Cloud visual optical depth

IASI/AMSU retrieval Study

I End-to-end simulation experiment

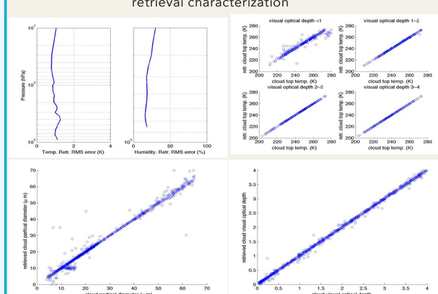
Simulate radiances for 1500 selected profiles from a globally distributed radiosonde/ECMWF data set that includes atmospheric profiles for temperature, humidity, ozone, and carbon monoxide. Other trace gas data are generated using Model for OZone And Related chemical Tracers (*MOZART*). Add randomly distributed IASI instrument noise to the radiances to generate synthetic IASI spectra.



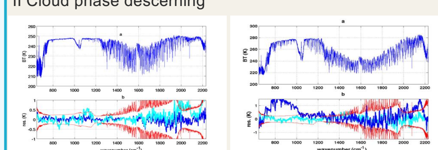
Dashed blue lines: minimum and maximum for the simulation set for temperature (left) and water vapor (right) profiles as a function of pressure. Solid blue lines show the mean values of the simulation set. Red lines: background (initial guess) profiles (solid lines) and variance (dashed line).

Retrieve the temperature, humidity, cloud and trace gas properties from the synthetic spectra, using climatology background as the first guess, standard statistical estimates of ensemble background as the *a prior* constrain, and instrument noise defined radiance error covariance matrix.

Temperature, humidity and cloud properties retrieval characterization

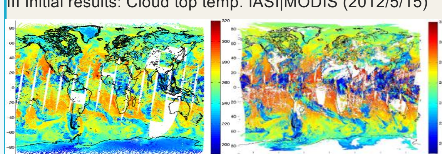


II Cloud phase descerning



(a) Example of observed single FOV IASI cloudy spectrum in brightness temperature (b) Spectra showing the difference between the observed and the best fitting by PCRTM modeled spectra under two types of single layer cloud (blue curve- ice cloud, cyan curve – water cloud). Left: an ice cloud with visual optical depth of 0.93, particle diameter of 88.2 μm, and effective cloud top pressure around 255.8 hPa enables a better fitting. Right: a water cloud with optical depth of 0.45, particle diameter of 52.7 μm, and effective cloud height around 239.5 hPa enables a better fitting. The IASI instrument noise converted to brightness temperature is plotted (red curves) for comparison purpose.

III Initial results: Cloud top temp. IASI|MODIS (2012/5/15)



Conclusion and future work

The application of the PCRTM based, nonlinear physical retrieval algorithm for all sky IASI observations has been demonstrated and validated. Our results indicates that single FOV observations provided by hyperspectral infrared sensors like IASI can be used to locate the cloud height, extract cloud micro-physical characteristics and thermal-dynamic parameters of the atmosphere simultaneously.

We are currently working on the IASI/AMSU data aggregation and colocation, and started to prepare collocated ECMWF data to be used as in-situ truth for the validation. MODIS, CLIPSO/CLOUDSAT cloud products will be used to validate cloud properties.