Suggesting a 1DVAR System for NWP Assimilation Pre-Processing

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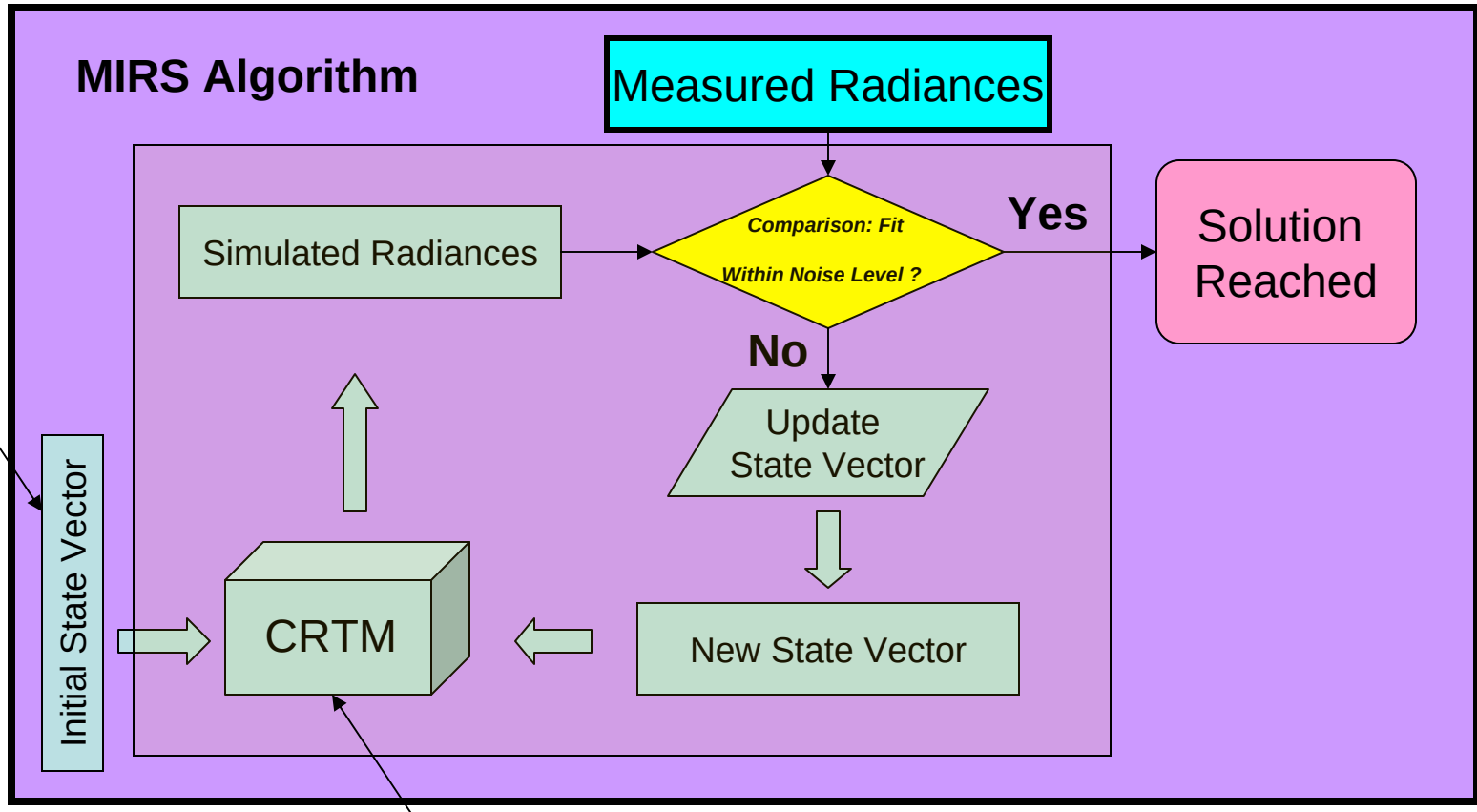
Layout

- Scope/Agenda of the presentation
  - Present a 1DVAR system to pre-process radiances
  - Show the applicability in non-conventional areas (over land, sea ice, etc. and in cloudy/rainy conditions)
  - Promote it as a pre-processor to NWP assimilation models
- The Microwave Integrated Retrieval System
  - System Design & Mathematical Basis
  - Assimilation/Retrieval
- Potential Benefits to NWP Assimilation
  - QC & Precipitation/Ice Detection
  - Suggested sounding in Precipitating Conditions
  - Emissivity Spectrum & Surface Type Information
  - Expanded coverage

The MIRS System

System Design & Architecture



Could be from:
-Climatology,
-Regression
-NWP

Community Radiative Transfer Model
(validity: in clear, cloudy, precip)

The MIRS System

- Mathematical Basis: *Minimization of Cost Function*

$$J(X)=\left[\frac{1}{2}\left(X-X_0\right)^T\times B^{-1}\times\left(X-X_0\right)\right]+\left[\frac{1}{2}\left(Y^m-Y(X)\right)^T\times E^{-1}\times\left(Y^m-Y(X)\right)\right]$$

- State Vector X comprises:
  - Temperature & Moisture profiles
  - Non-precipitating cloud **profile**
  - **Hydrometeors profiles (liquid & frozen phases)**
  - Skin Temperature
  - Surface Emissivity spectrum

Atmosphere

Surface

- EOF Decomposition *to balance X with information content of radiances Y*

$$\Theta = L^T \times B \times L$$

Diagonal Matrix *(used in reduced space inversion)*

Transf. Matrx *(computed offline)*

Covariance matrix *(geophysical space)*

Assumptions in the Assimilation with MIRS *(Usual suspects…)*

- The PDF of X is assumed Gaussian

A variable transformation is needed for Q, Hydr

- Operator Y able to simulate measurements-like radiances

Rely on CRTM

- Errors of the model and the instrumental noise combined are assumed (1) non-biased and (2) Normally distributed.

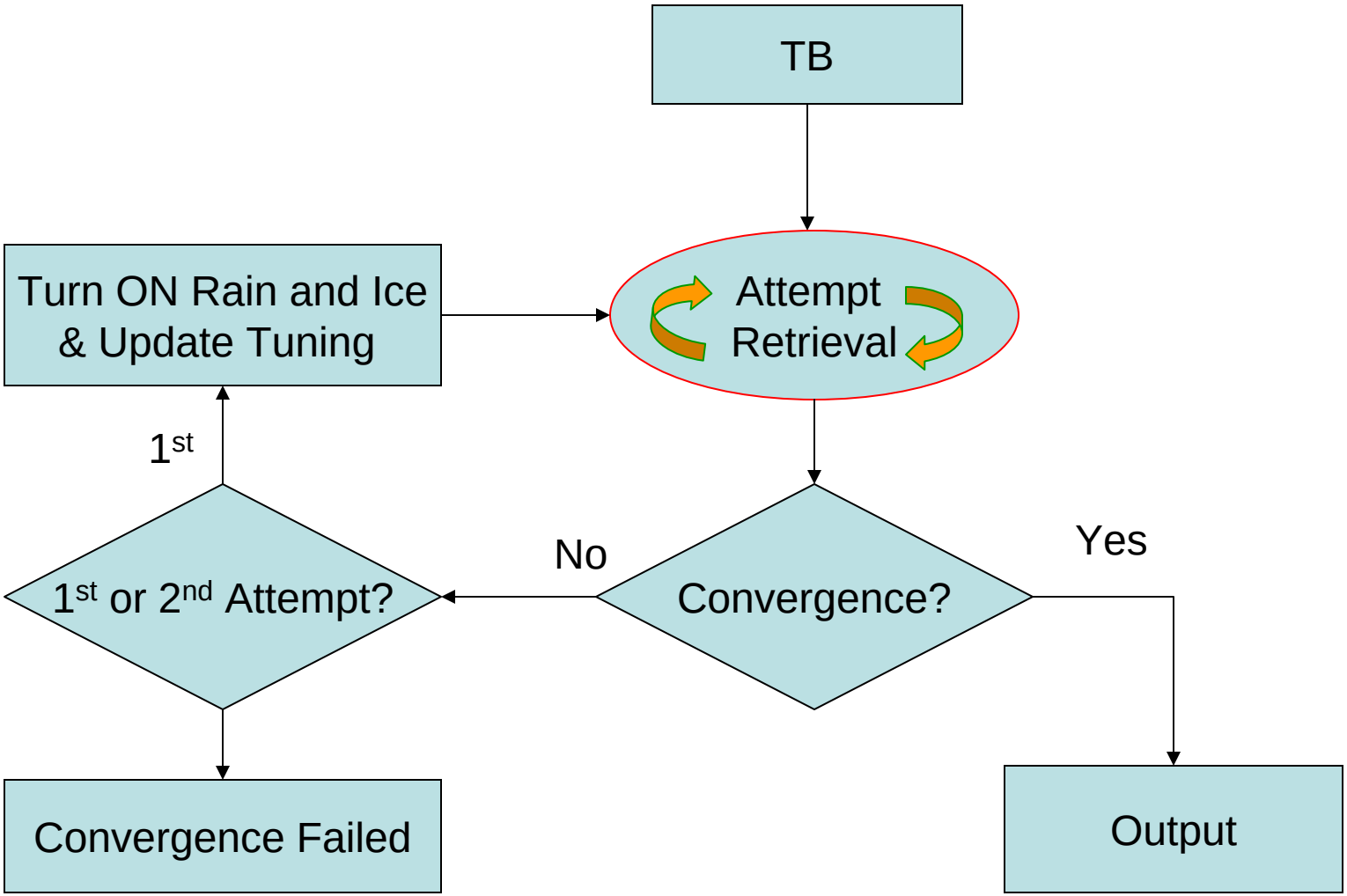
Usually valid

- Forward model assumed locally linear at each iteration.

Valid assumption. Reminder: This is just the RTM FWD model. No cloud model coupled with the RTM

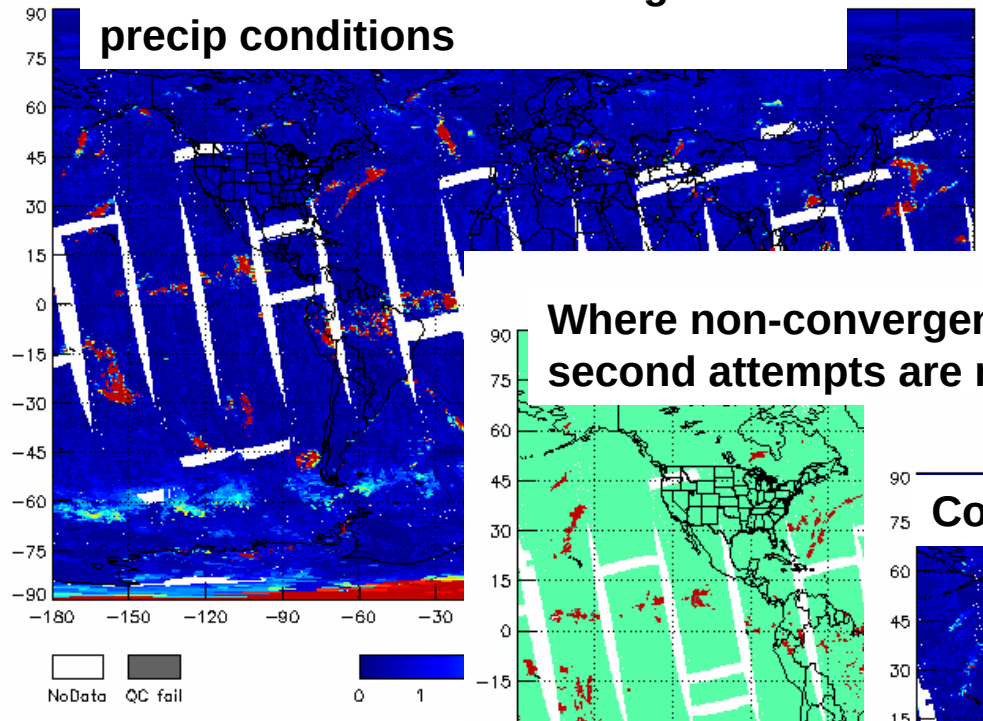
CRTM used in MIRS to provide:
(1) Simulation of Radiances and
(2) Jacobians for all parameters

How Does MIRS work in Precipitating Conditions ?



Example of convergence

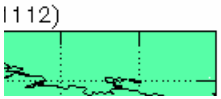
First Retrieval: non-convergence in precip conditions

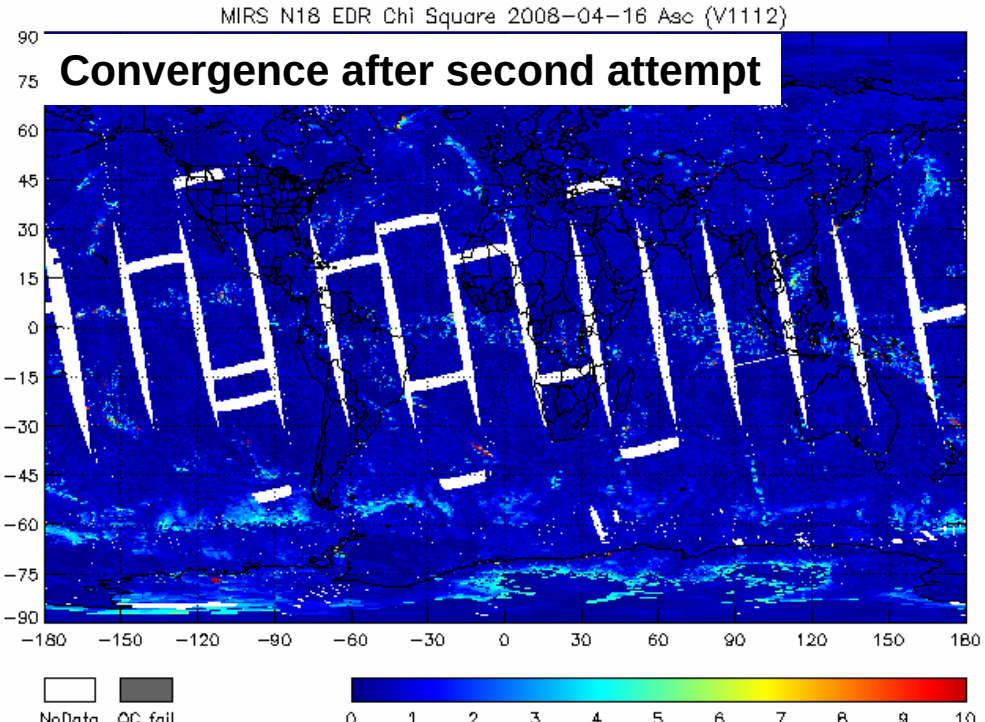


Convergence Metric:

$$\varphi^2 = \left[\left(Y^m - Y(X)\right)^T \times E^{-1} \times \left(Y^m - Y(X)\right)\right]$$

Where non-convergence occurs, second attempts are made





How is Assimilation done in Cloudy/Precipitating Conditions?

- X includes clouds and Hydrometeors Parameters
- Rely on CRTM to provide radiances that account for scattering and absorption due to cloud/rain/ice
- Rely on CRTM to provide Jacobians of Radiances wrt cloud/rain/ice parameters
- Constraints provided in the Covariance Matrix

Cloud and Hydrometeors parameters are treated in a similar way as the traditional temperature and moisture parameters

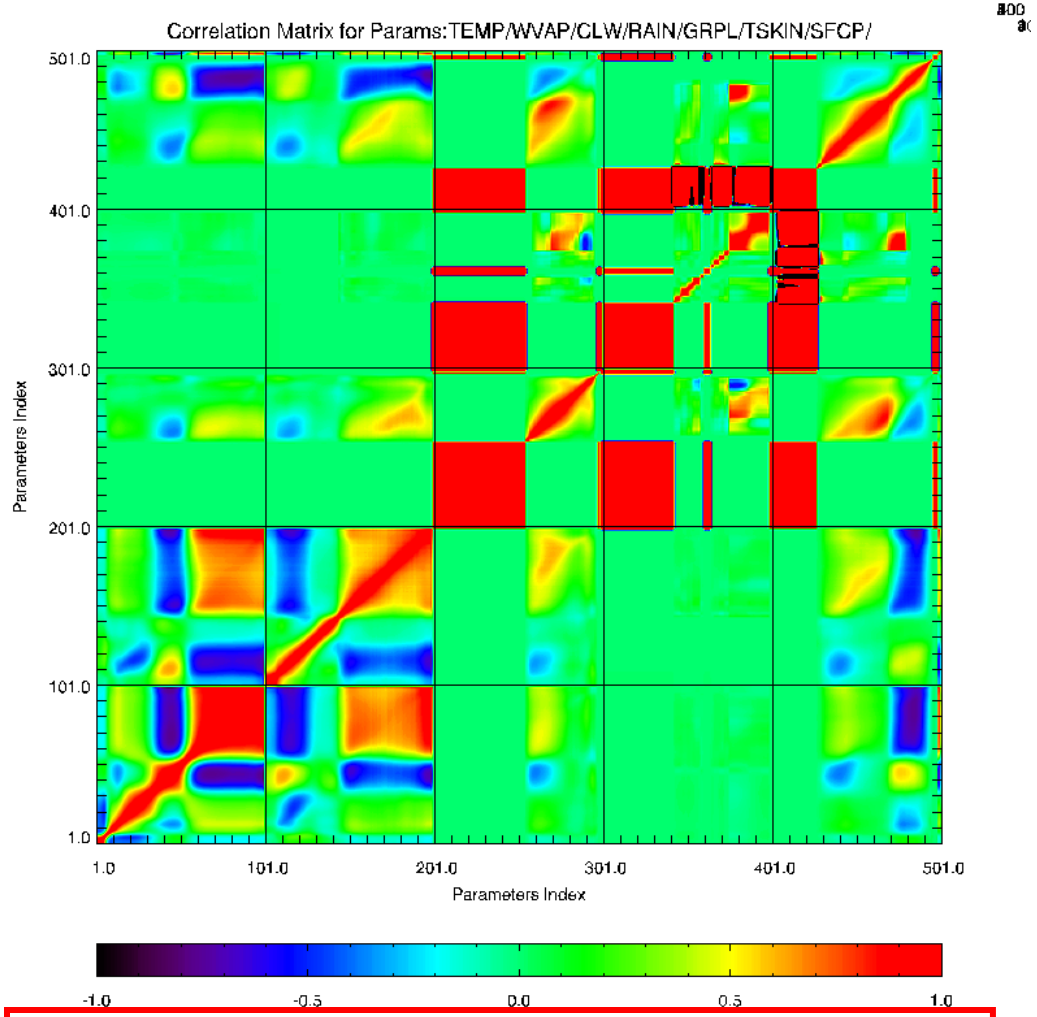
No cloud resolving model is used in the forward operator

Covariance Matrix Used in MIRS

Obtained by combining ECMWF-based covariance with WRF-based correlations for rain (correlations with Ice, Temperature, Humidity, etc)

This assures that T, Q, CLW, Rain and Ice Retrievals are physically consistent, **on average**.

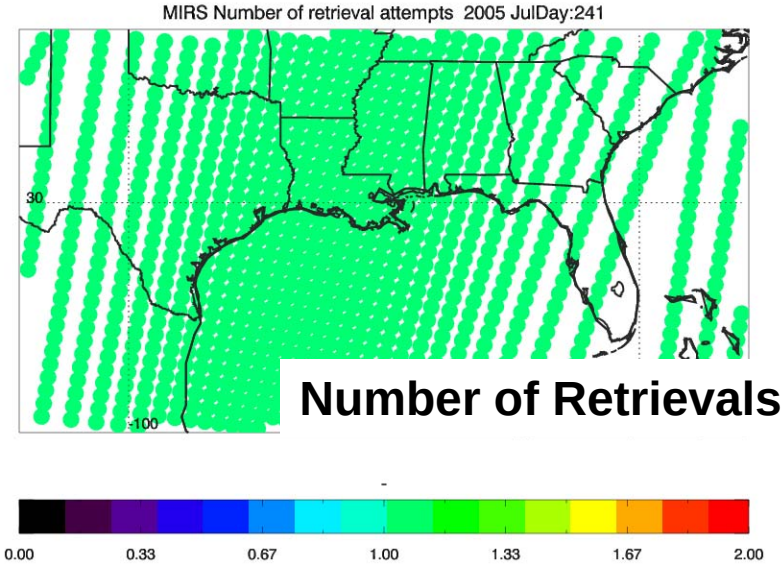
No cloud resolving model is used in the forward operator



Makes the covariance matrix very important

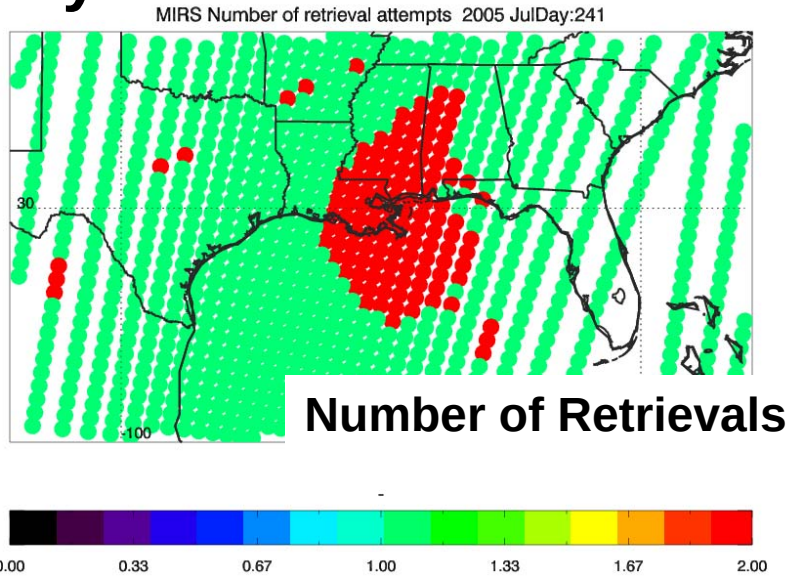
Results of MIRS (Convergence)

Absorption Only (no rain, no ice)



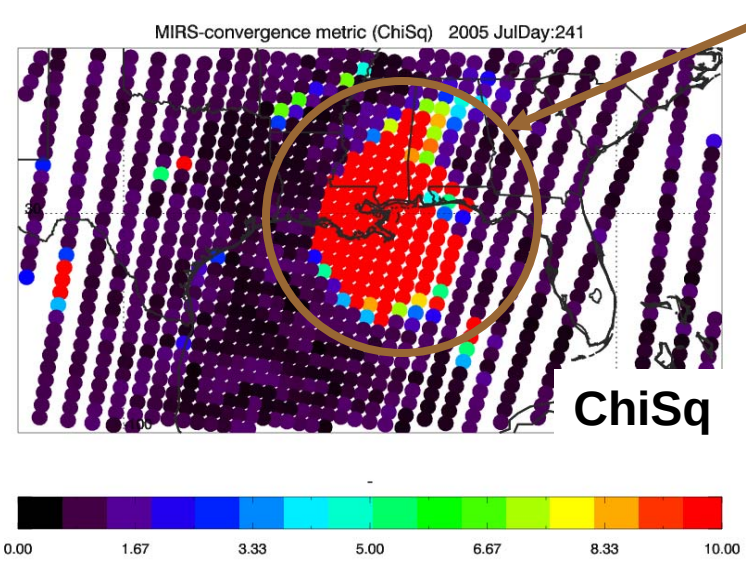
Number of Retrievals

Hydrometeors turned ON

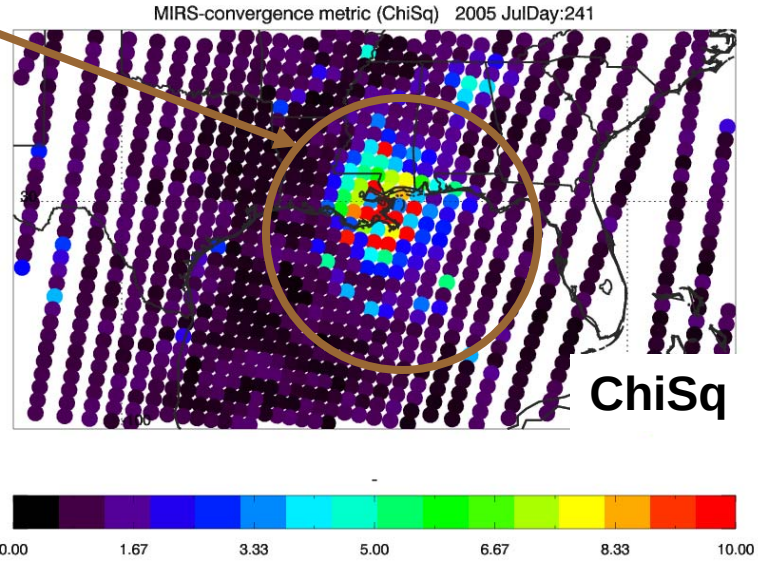


Number of Retrievals

Significant improvement in convergence



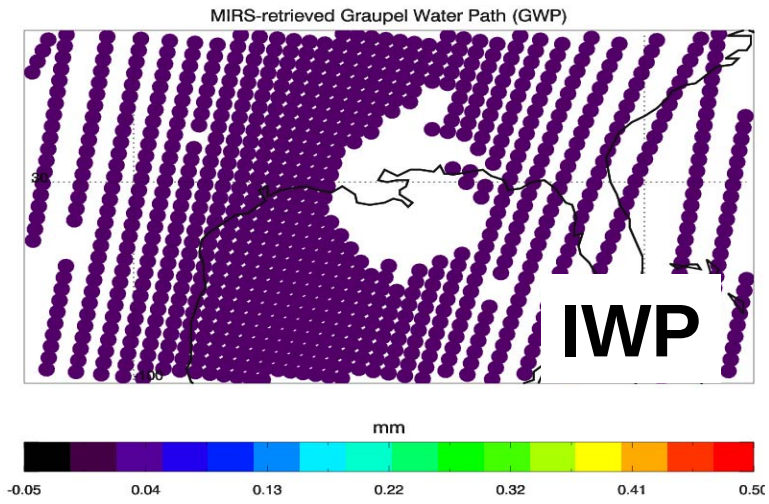
ChiSq

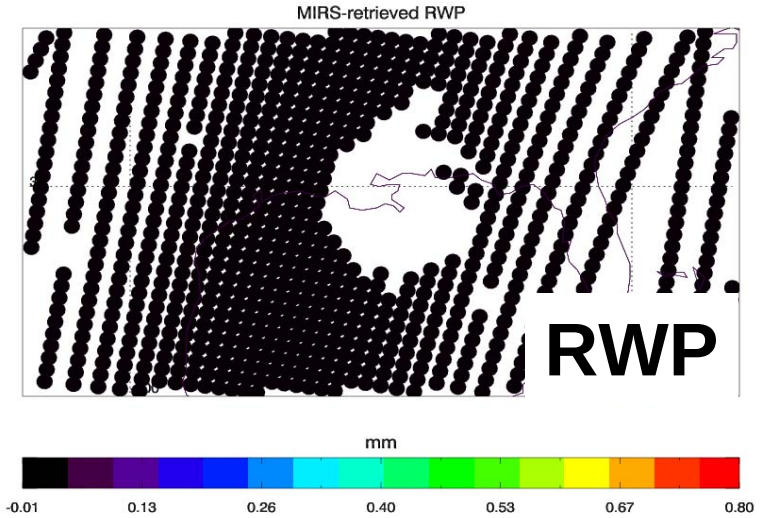


ChiSq

Results of MIRS (Hydrometeors retrieval -GWP)

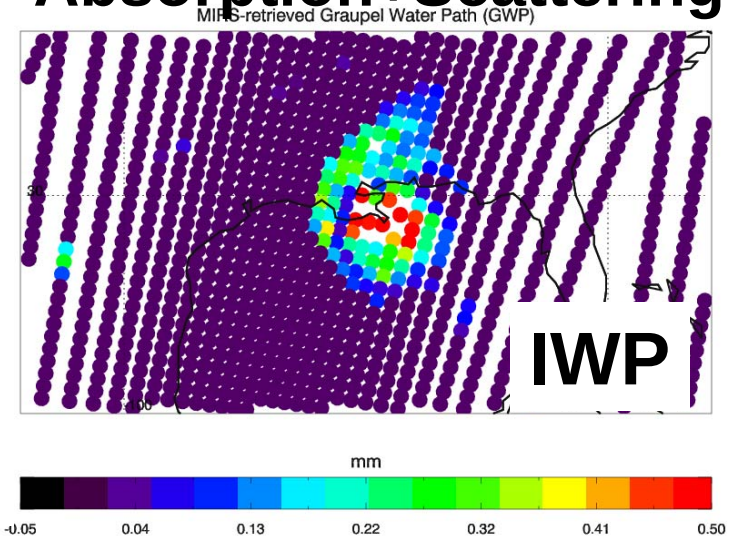
Absorption Only

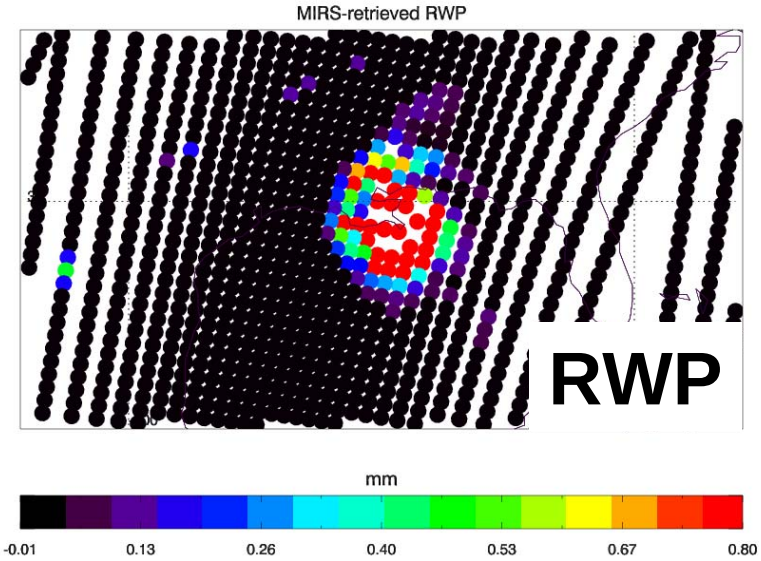




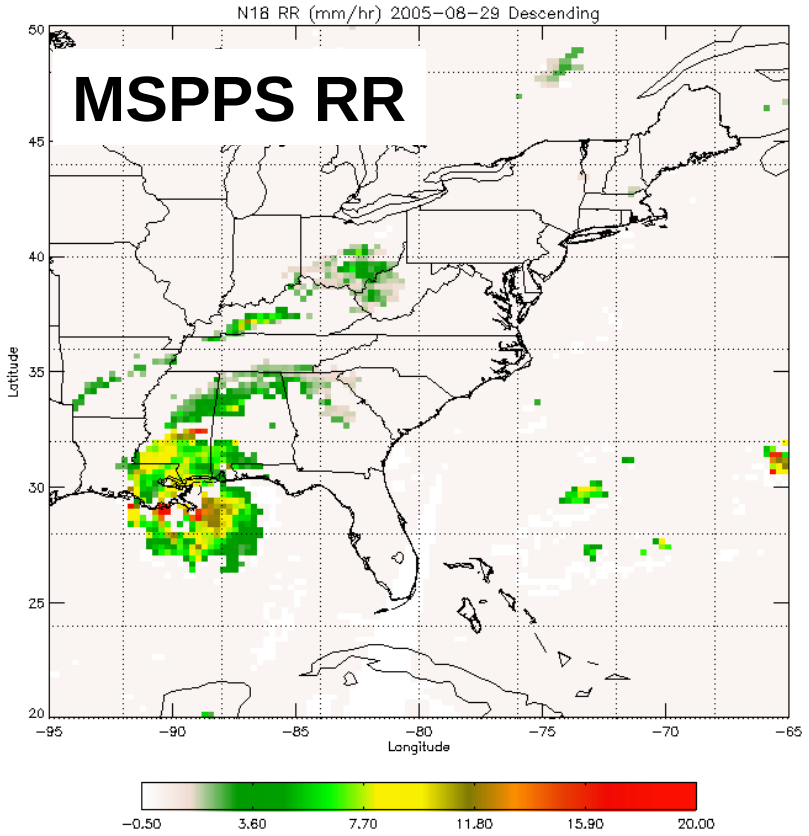
No convergence was reached before

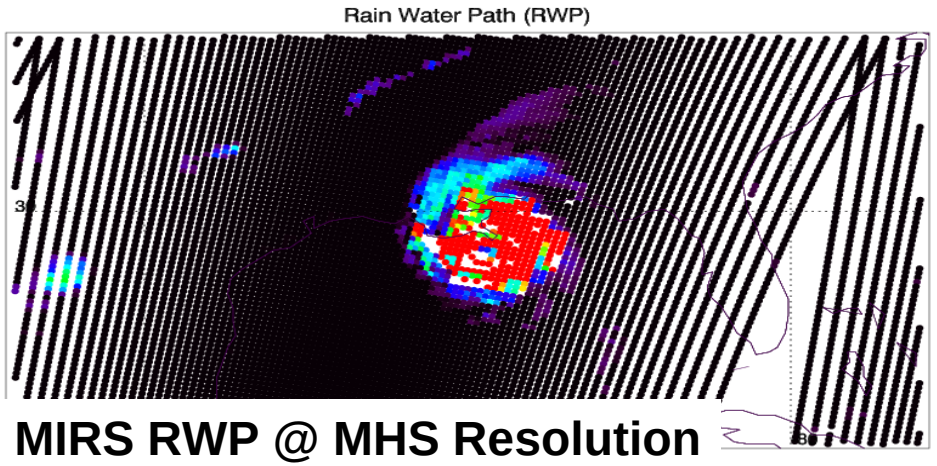
Absorption+Scattering

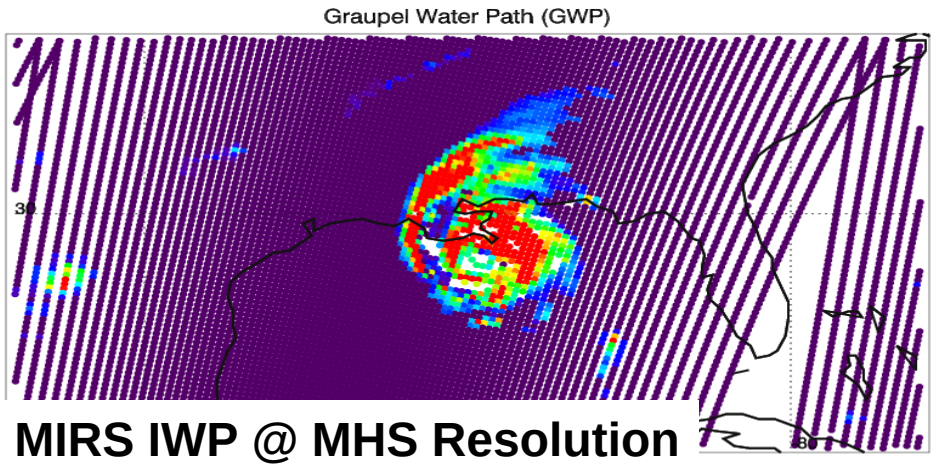




Comparison at MHS Resolution







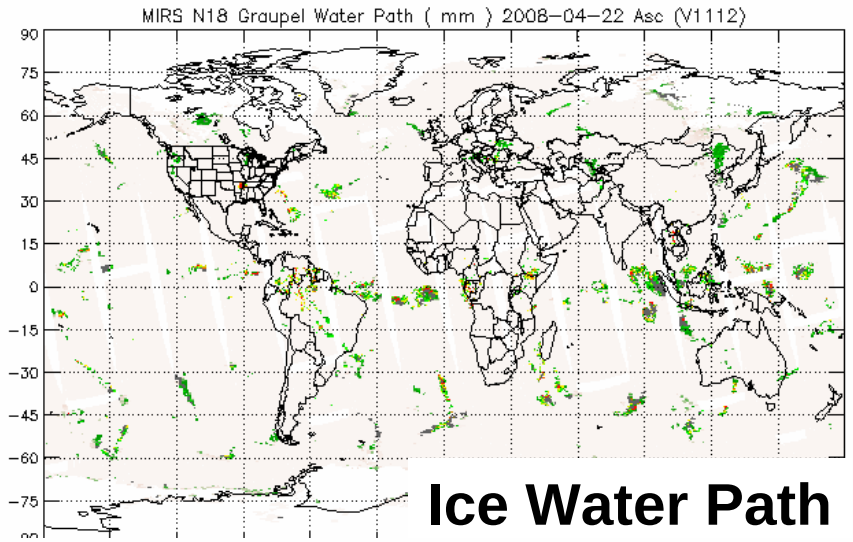
High spatial correlation MSPPS / MIRS

Coastal transition smooth

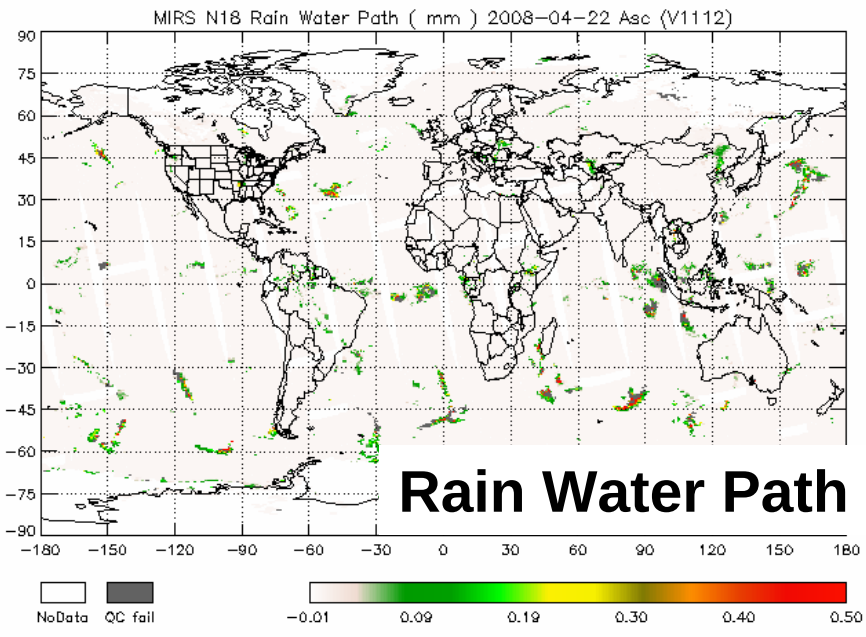
Potential Benefits to NWP Assimilation

Detecting Cloud/Precip/Ice

Ice and Rain could be retrieved at the same time or one without the other, depending on the signal in the radiances and the Jacobians from CRTM.

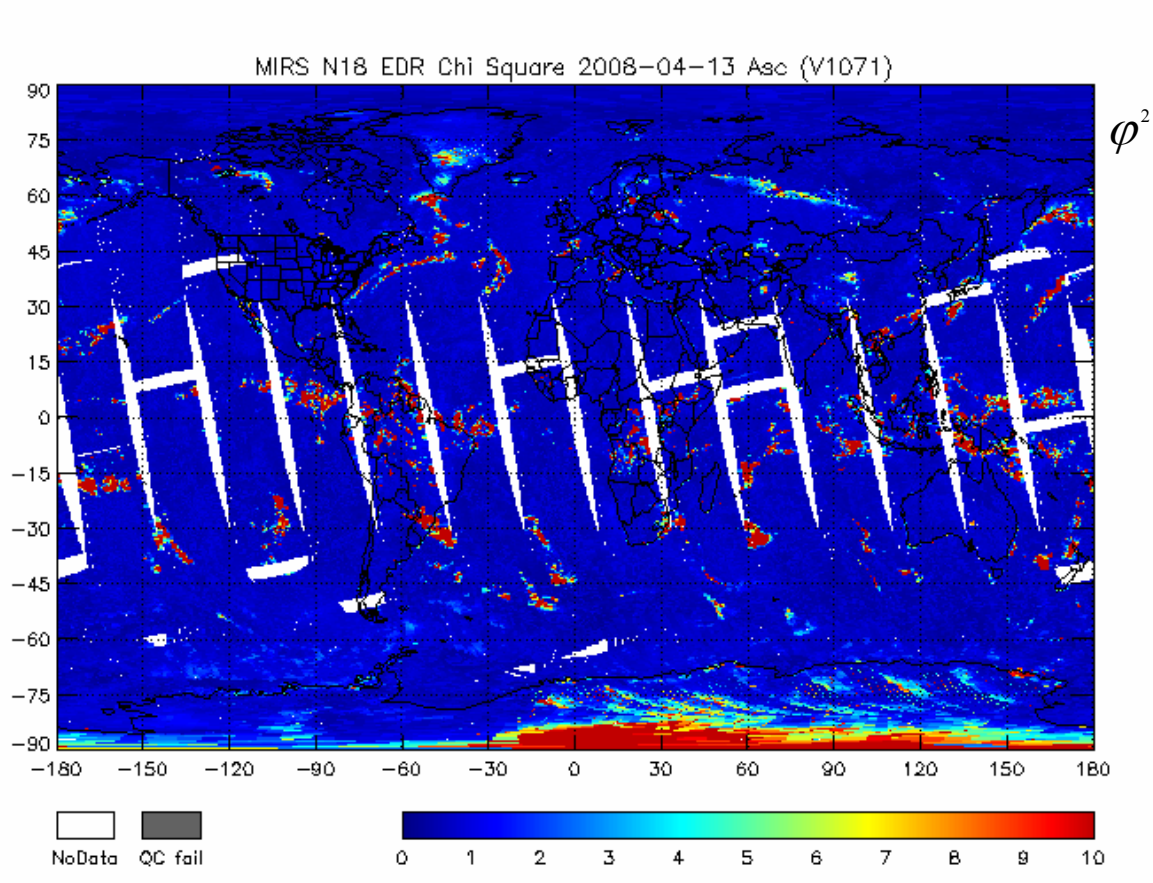


Ice Water Path



Rain Water Path

Providing NWP with QC



Convergence Metric:

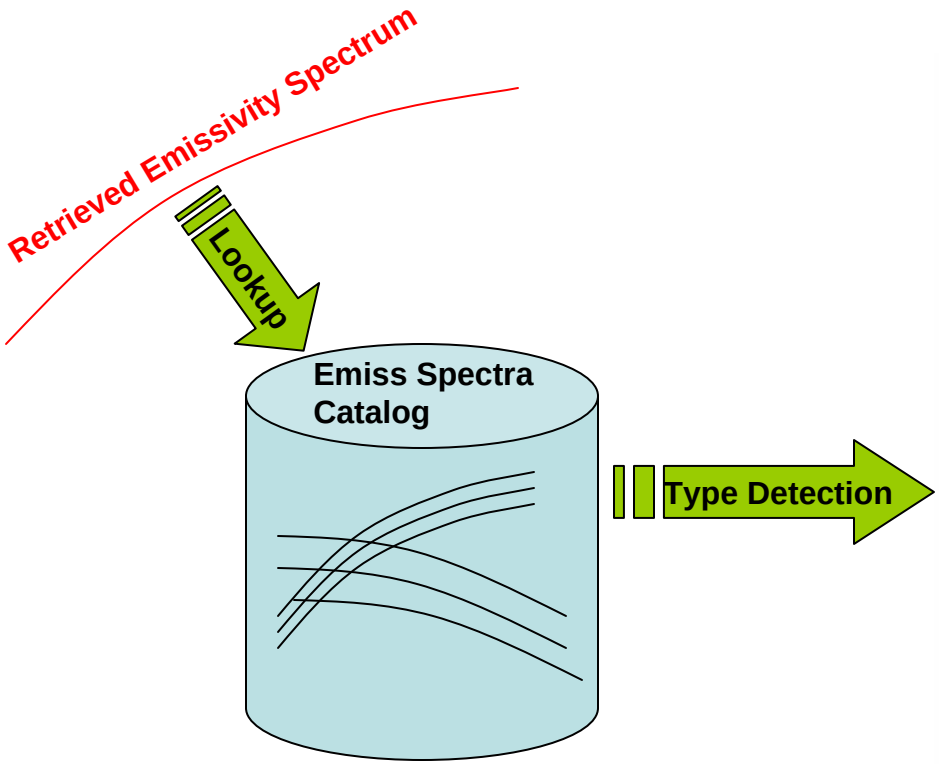
$$\varphi^2 = \left[\left(Y^m - Y(X)\right)^T \times E^{-1} \times \left(Y^m - Y(X)\right)\right]$$

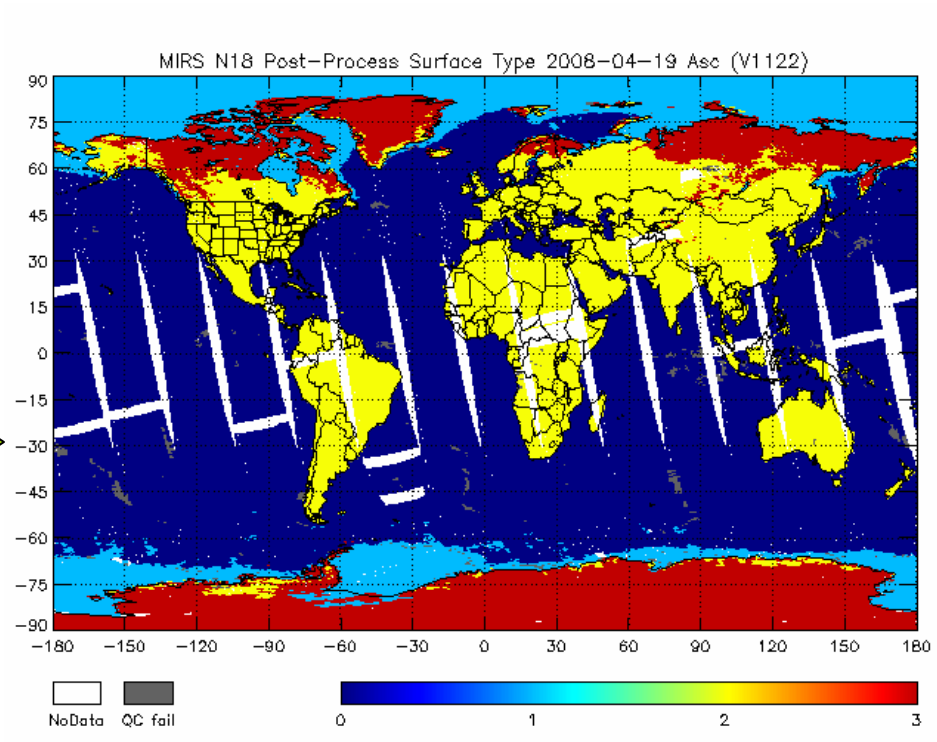
Non-convergence is a powerful QC tool for NWP assimilation.

It could signal a contamination, a surface mixture that is hard to model or anything that might be inconsistent with the forward operator

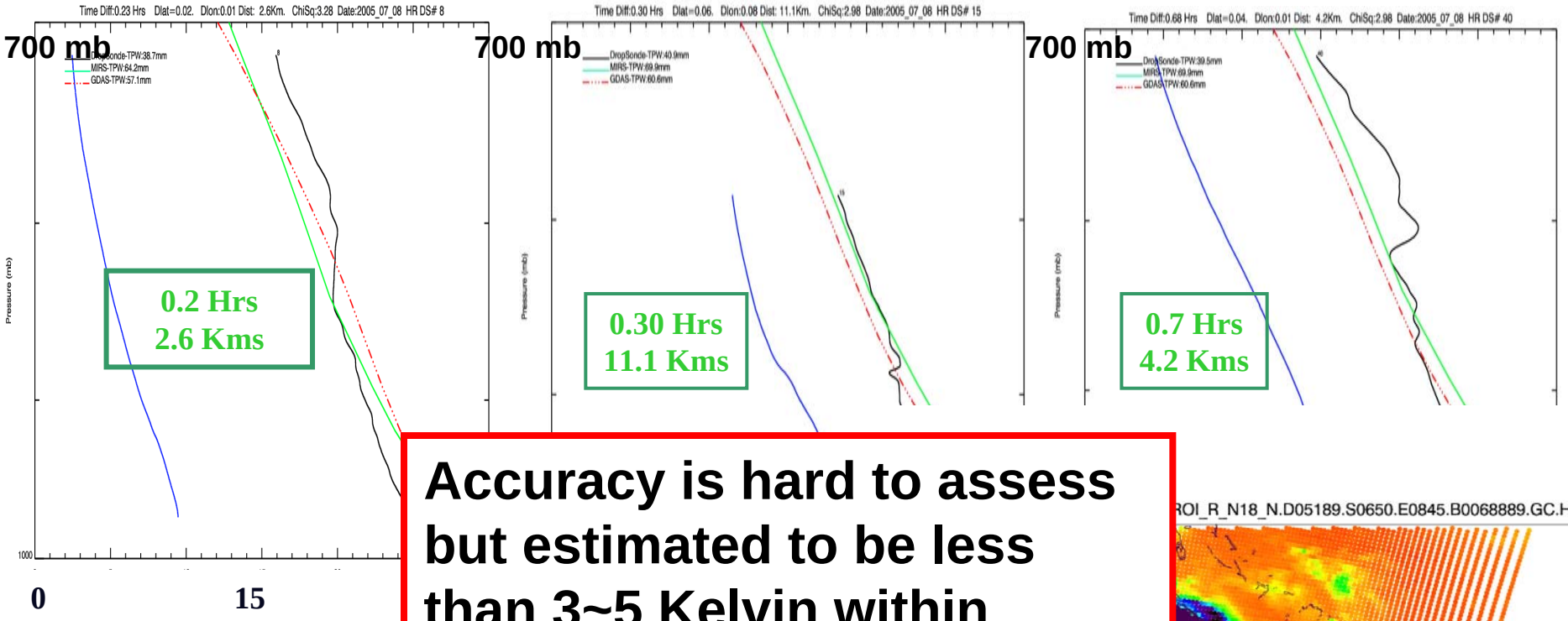
Detecting Surface Type

- Thanks to retrieved Emissivity spectrum:
  - Sea Ice detected over water
  - Snow detected over land

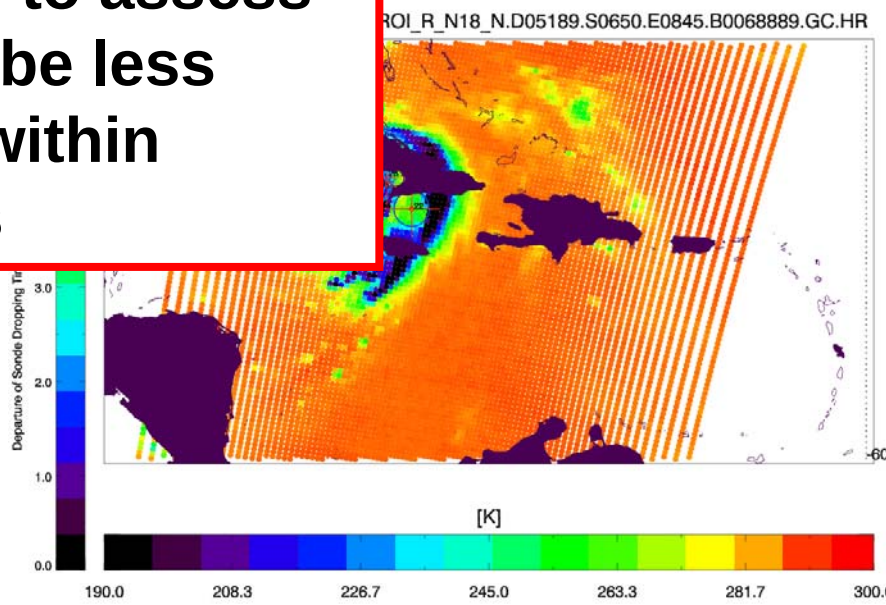




Provide an Estimate of the State Vector, Including in Precip Conditions



Accuracy is hard to assess but estimated to be less than 3~5 Kelvin within convective areas



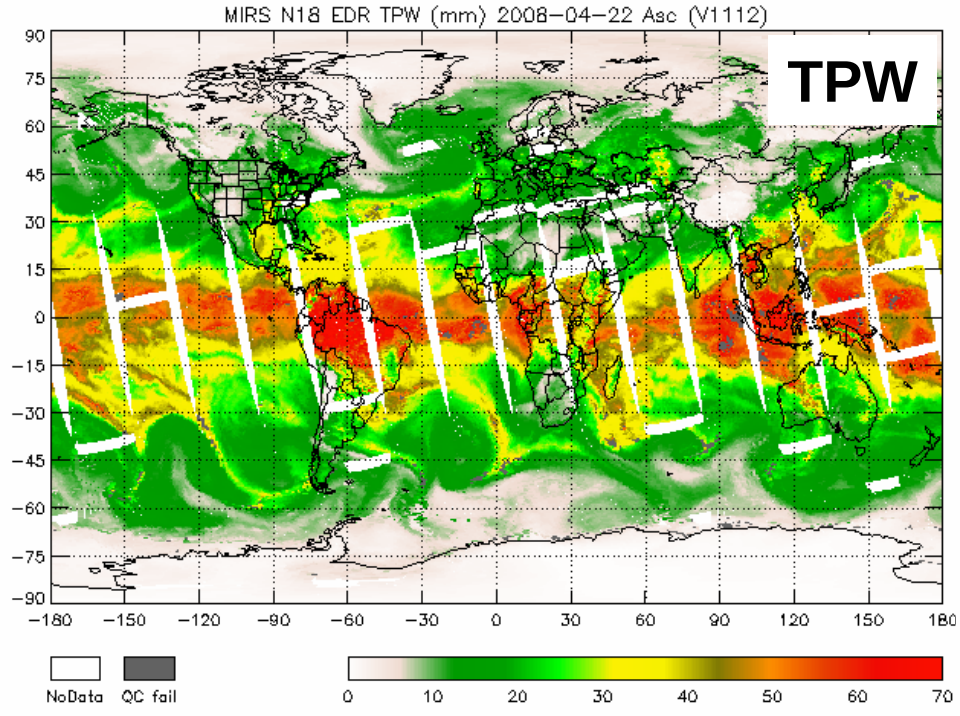
Retrieval

GDAS

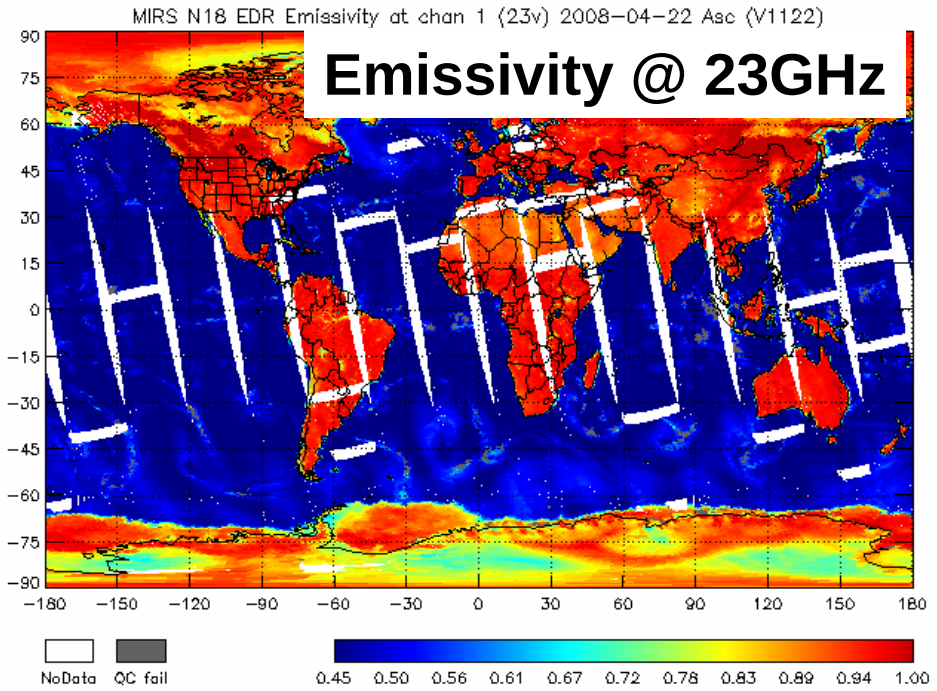
DropSonde

Profile of DS Distance

Expanded (Global) Coverage



Most parameters are retrieved globally (over land/ocean/sea ice/desert/snow/coast/etc)



Conclusions

- No difference between a variational Retrieval and 1DVAR radiance assimilation
- Algorithm estimates sounding, cloud, precipitation and surface parameters in non-traditional areas (could be used as 1st Guess to NWP assimilation models)
- MIRS also offers powerful QC indicators for NWP assimilation
- MIRS could be considered a rapid pre-processing tool that could help the full 3D or 4D VAR NWP assimilation
- MIRS is generic (for all MW sensors), so treatment of sensors data is consistent (used routinely for AMSU, MHS, SSMIS)
- MIRS is freely available to scientific community.