Cloudy 1DVAR

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NOAA/NESDIS/STAR

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Contents

Challenges in Satellite Data Assimilation
(From JCSDA)

- Difficult to ingest all hyperspectral sounding data due to a lack of computational resources and fast radiative transfer schemes

- Difficult to use satellite measurements that are affected by surface

- Difficult to assimilate satellite radiances that are affected by aerosols and clouds

Cloudy Radiance Assimilation

- Community Radiative Transfer Model (CRTM) is now applicable from visible, IR and microwave wavelengths
- CRTM is fully integrated into NCEP Gridded Statistical Interpolation System (GSI) which is similar to 3DVAR
- CRTM is also integrated into Microwave Integrated Retrieval System (MIRS) which is a new generation NESDIS product system for atmospheric sounding under all weather conditions
- Hybrid variational scheme: 1DVAR retrieved profiles assimilated through 4DVAR system

Cloudy Radiances Assimilation

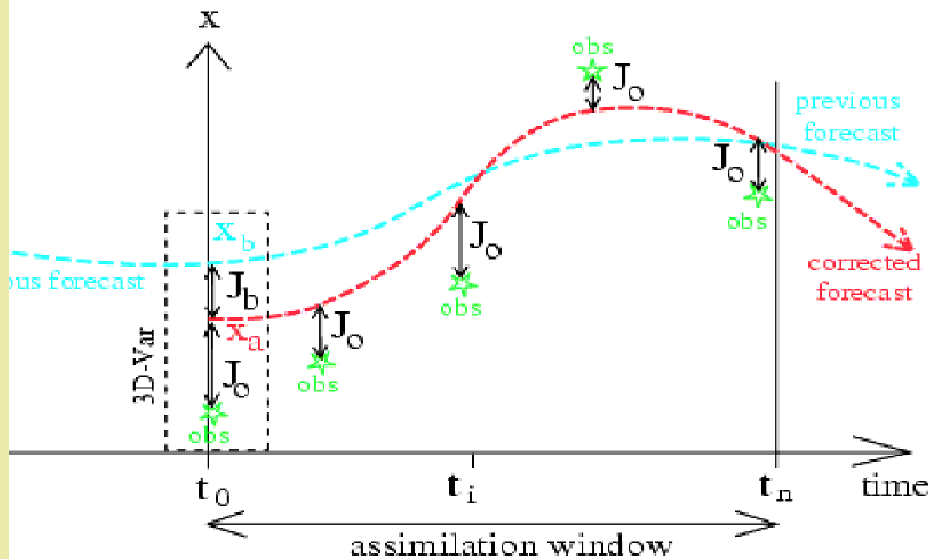
- CRTM plays a key role by modeling the full effects of clouds, precipitation, etc as well as providing the Jacobians

- 1DVAR approach is used either in a standalone mode (i.e. MIRS) or as a front-end to the Hybrid method (1DVAR+4DVAR), to account for the high-nonlinearities introduced by cloud.

Consistent with ECMWF approach (Bauer et al.)

Four Dimension Variational Analysis (4DVAR)

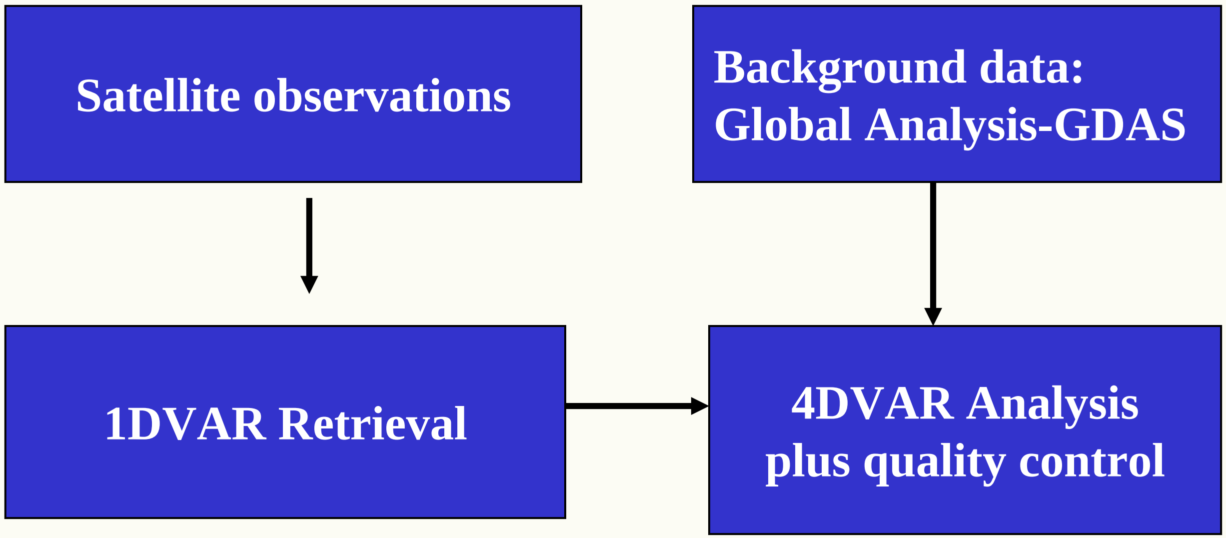
- Within an assimilation window, recent measurements are accounted for to reduce the time-dependent cost-function and produce a new trajectory for subsequent forecast.



- Difficulties:
  - Adjoint in temporal domain can be non-linear
  - Huge computational requirements and storage

$$J(x) = \frac{1}{2}(x - x_b)^T B^{-1}(x - x_b) + \frac{1}{2}\sum_i^n [y_i - H_i(x_i)]^T R_i^{-1}[y_i - H_i(x_i)]$$

Hybrid Variational Scheme
(1DVAR+4DVAR)



Weng et al, JAS, 2007

How to 1DVAR ?

Method#1: Use of Cloud Resolving Models

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Method#2: Radiometric Signal Only

Advantages:

-Simple and fast: Jacobians used from CRTM. No need for a cloud resolving model and for additional Jacobians.
-Physical constraints through the covariance matrix, just like the Temperature and humidity.

Disadvantages:

- **Null-space and local minima a problem.**
- **Strong dependence on first guess used**

1DVAR Algorithm Description

- 1DVAR Algorithm used: MIRS
- Currently applied to POES, METOP and DMSP microwave systems
- Uses CRTM as the forward operator
- Performs both Sounding and/or Imaging
- Integrates the cloud and precip parameters as part of the retrieved state vector
- EOF decomposition used for the vectors (emiss, atmospheric profiles)
- Regression-based algorithms serve as first guess to the 1DVAR

Assumptions Made in Solution Derivation

- Local linearity
- Gaussian Distribution of the Instrument/Model Errors
- Gaussian Distribution of the Background Error
- Independence between Instrument/Model errors and Background Errors

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Could be assumed satisfied for microwave retrieval of surface and atmospheric parameters, including hydrometeors

Currently Retrievable Parameters

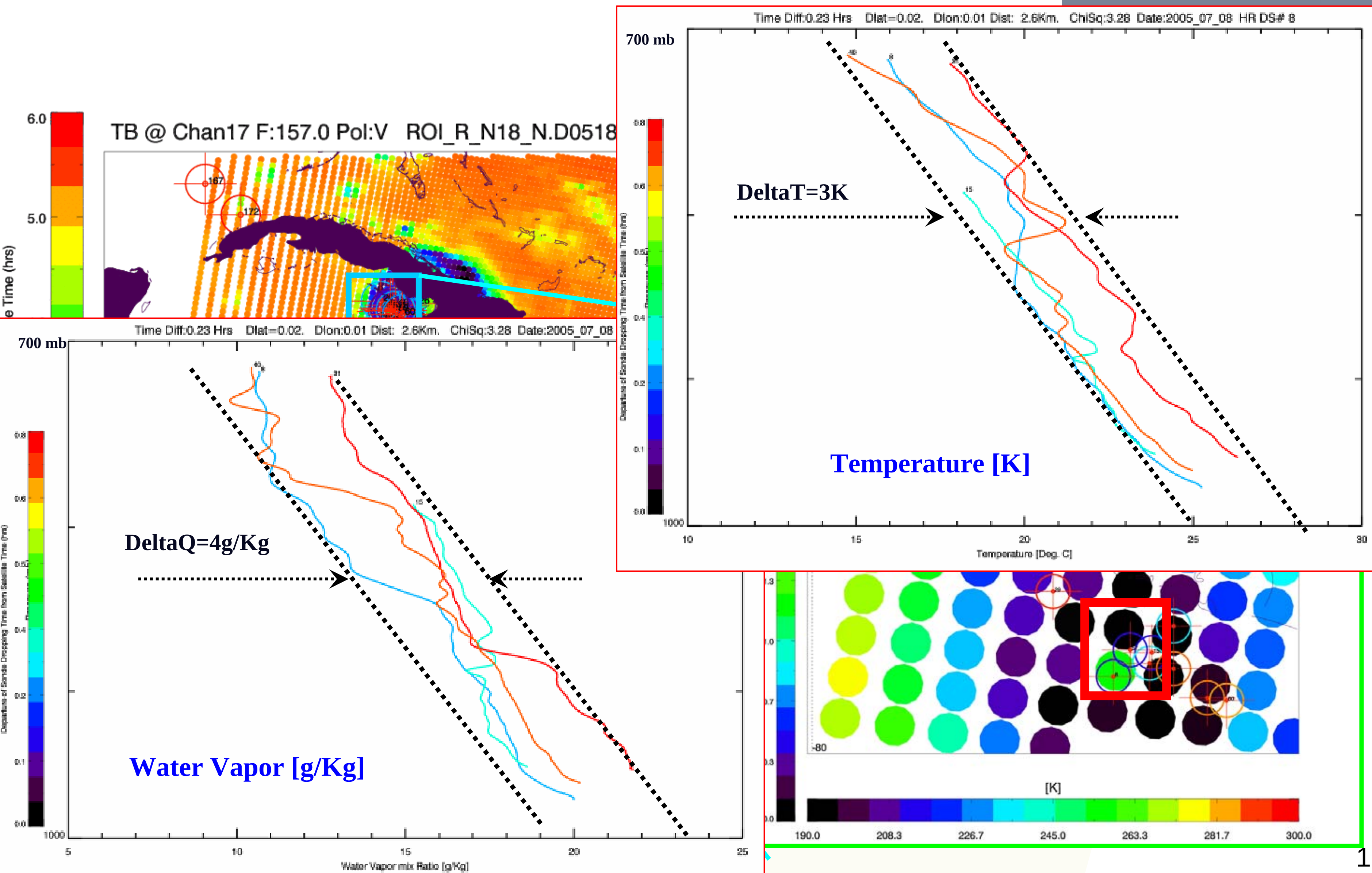
- Temperature & Water vapor profiles @ 100 layers
- Skin Temperature
- Surface Emissivity Spectrum
- Non-precipitating cloud amount vertical profile
- Rain, Ice, Snow and Graupel vertical profiles

Retrieval is done in reduced space (EOF) for profiles and spectra, so fine structures are not retrieved. But system allows for an accurate retrieval if information content present (more channels)

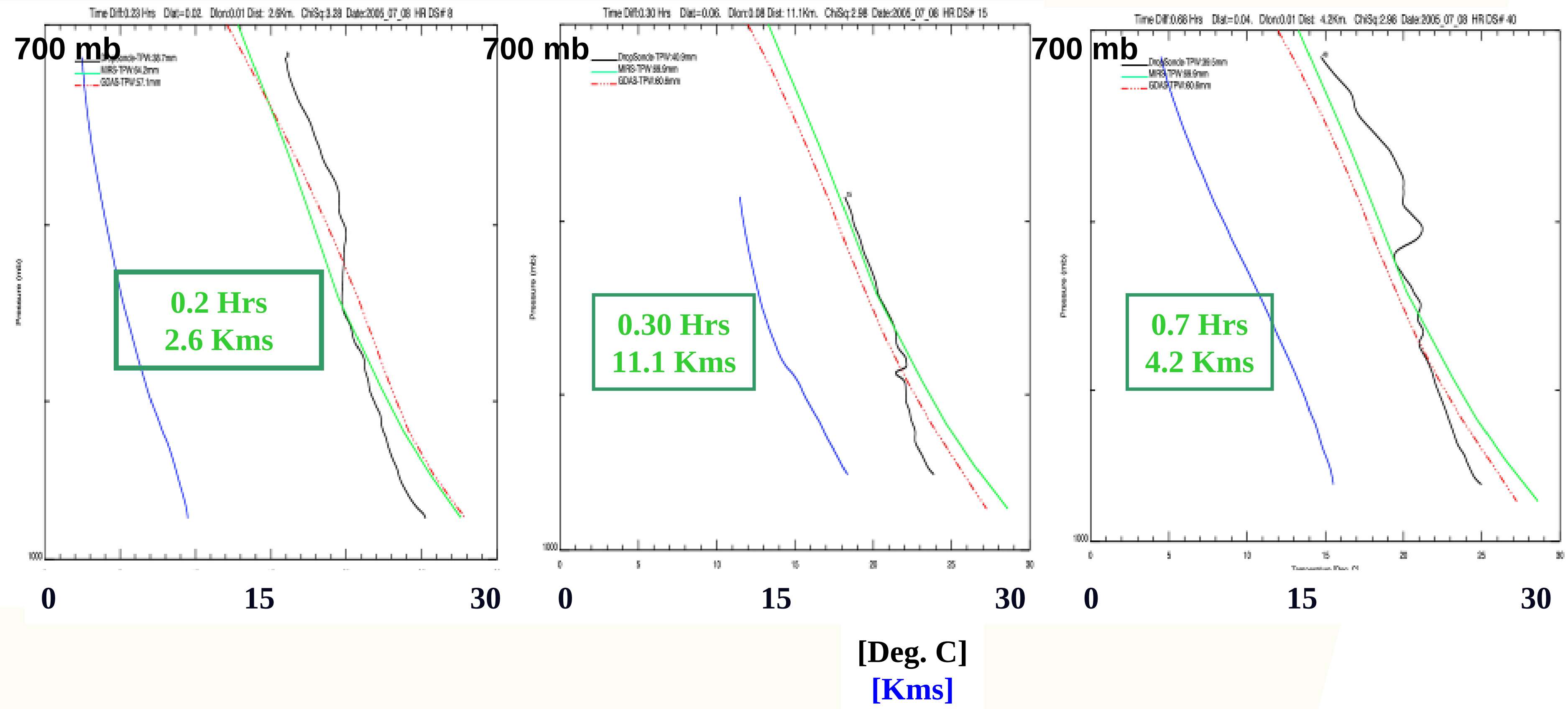
1DVAR Validation

- When used in Standalone Mode (in Hurricane)
  - Based on individual comparisons between NOAA-18 AMSU/MHS and GPS-dropsondes
  - Temperature and humidity profiles retrieved using 1DVAR and NOAA-18 brightness temperatures
  - Main challenge is the fast moving atmospheric features: Very strict collocation criteria must be used
  - Dropsondes themselves have uncertainty as well
- When used as front-end to Hybrid variational approach (1DVAR+4DVAR)
  - Qualitative validation of the storm warm core

Challenges of Profiling in Active Areas



N-18 Profiling In Active Areas

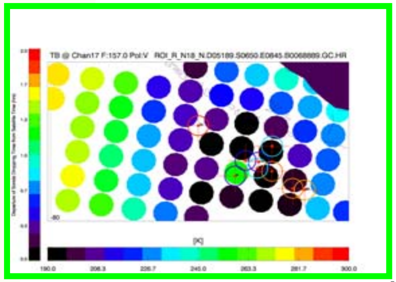


Retrieval

GDAS

DropSonde

Profile of DS Distance Departure

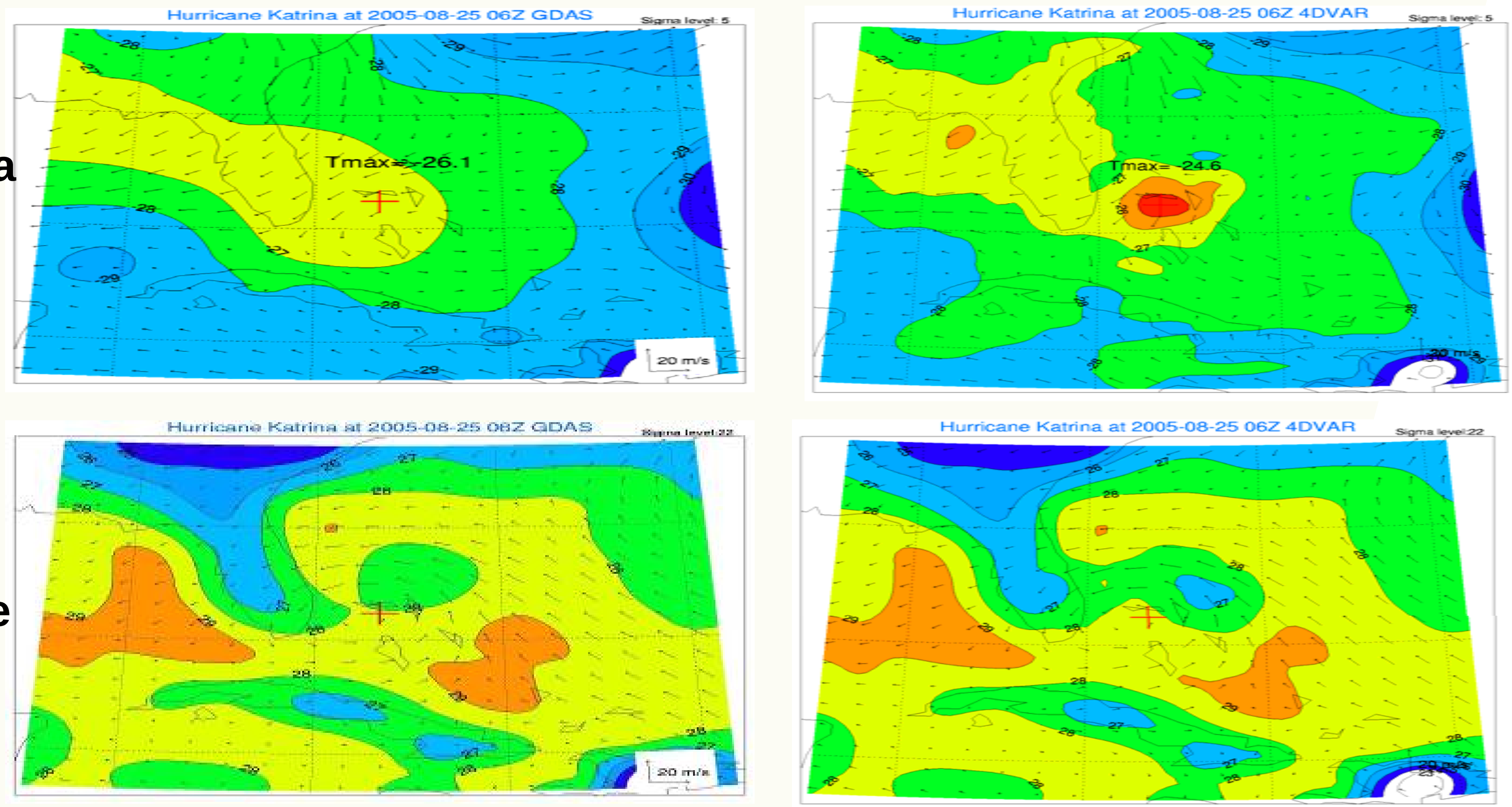


1DVAR+4DVAR: Katrina Analysis

GDAS | 4DVAR

250 hPa

Surface



Above figures compare GDAS analysis temperature fields near 250 hPa and surface with 1DVAR retrievals and 4DVAR analysis. The temperature field from analysis shows hurricane warm core is about 2 degree warmer than GDAS analysis. Uses of cloudy radiances under storm conditions dramatically improve warm core structure. At 0600 UTC August 25, 2005, Katrina was at tropical storm intensity, with the minimum central pressure of 1000 hPa.

Summary

- 1DVAR Algorithm coupled with CRTM integrates imaging and sounding capabilities in all-weather conditions
- Challenging task to undertake validation in active areas: Case-by-case comparison preferred to statistical assessment. GPS-Dropsondes helpful.
- Hybrid Approach (1DVAR+4DVAR) leads to better analyses of hurricane vortex structures and allows a smooth start for forecast runs.

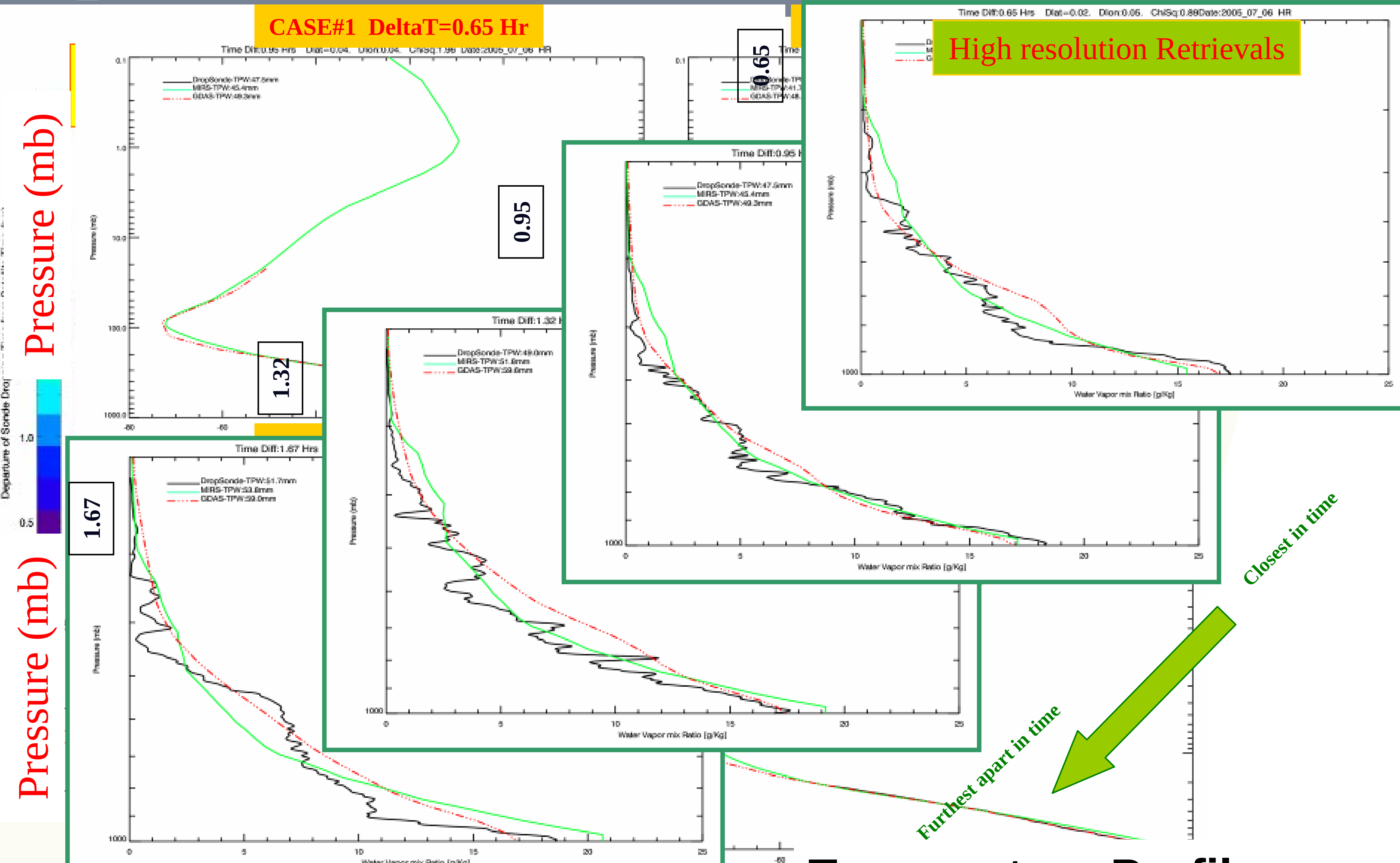
Thank You !

Questions?

BACKUP SLIDES

N-18 AMSU/MHS Clear Sky Profiling

(Comparison to GPS-Dropsondes)



Temperature Profiles s