All Sky Radiance Assimilation Overview

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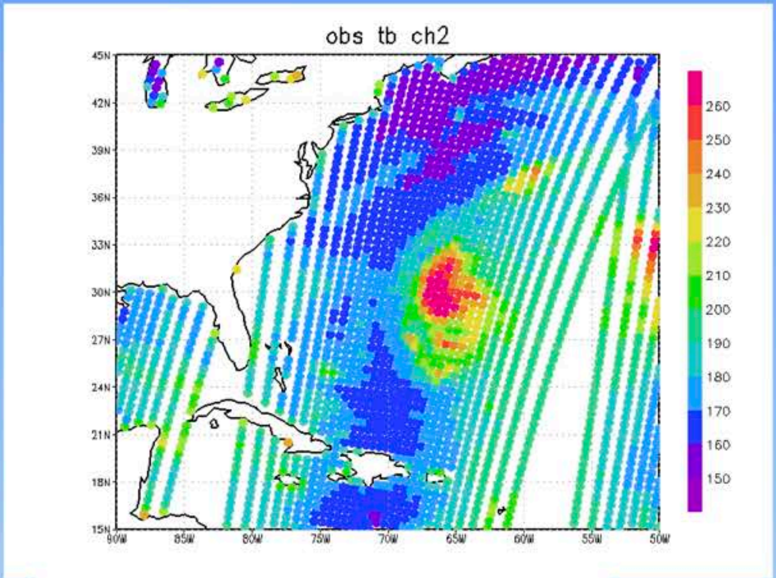
All-Sky Radiance DA challenges

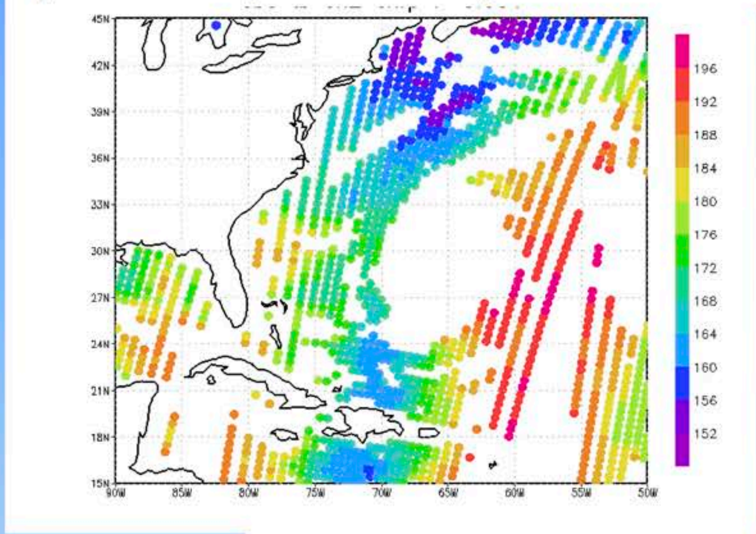
- Clouds are spatially and radiatively complex, and reflect highly nonlinear processes.
- Forward operator may depend on very uncertain parameters from model microphysics (e.g. drop size distributions, ice habits).
- Forward operator can be quite nonlinear.
- Non-gaussian, correlated errors.
- Background-error covariances between microphysical species and state variables needed to ensure balanced T,q perturbations.
- BUT – potential payoff is large, since 75% of radiance data is discarded now due to cloud contamination and unknown surface conditions.

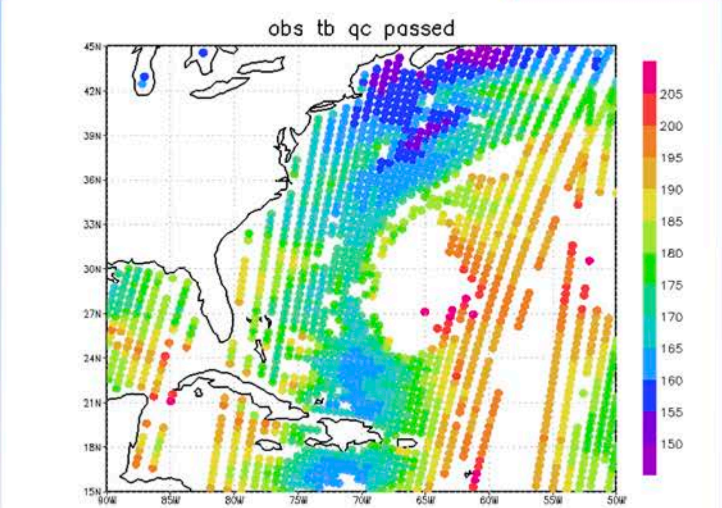
Microwave Obs of Hurricane Igor (9/19/2010)



All Obs

(cloud liquid water path < 0.001 kg/m^2)





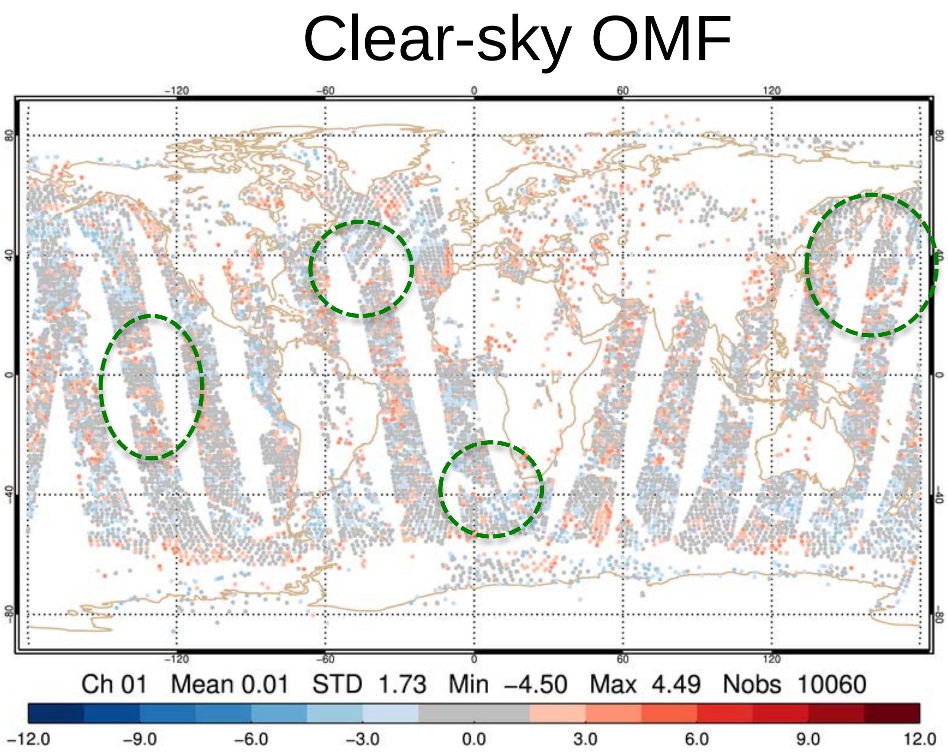
Passed QC in GSI

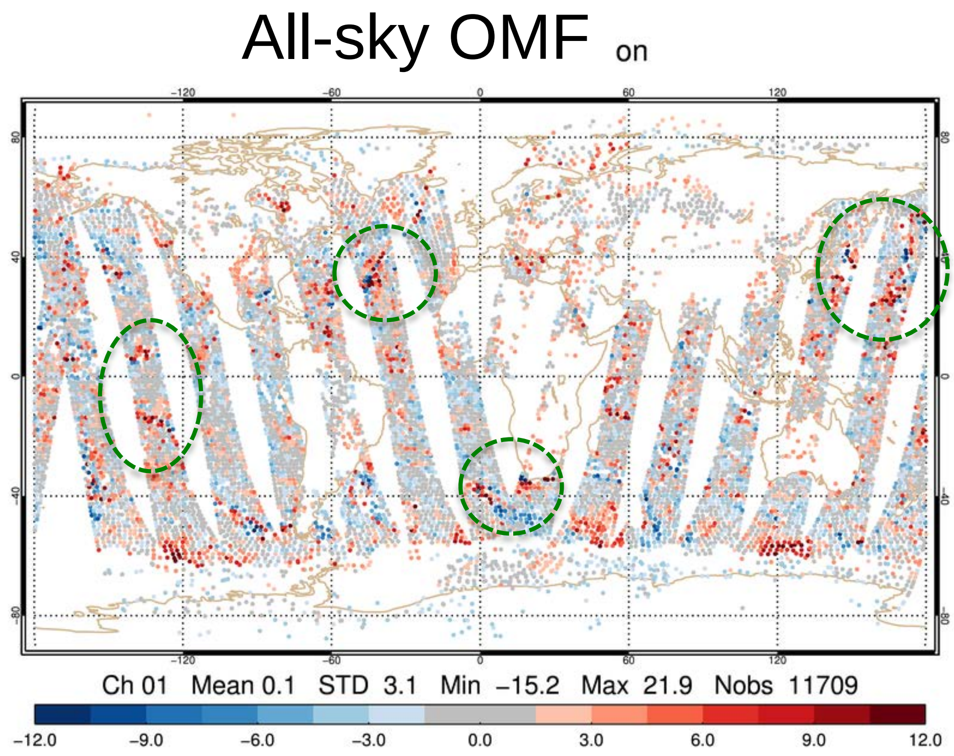
Cloud or precipitation indicates that some dynamically important weather is occurring. Subsequent forecasts are often sensitive to initial conditions in regions with cloud and precipitation.

NCEP: include AMSUA microwave radiance in cloudy areas.

- Radiative transfer not that much more complicated.
  - Need to add hydrometeors to control vector (and background-error covariance model), pass to RTM.
  - Revisions to QC, observation errors, bias correction.
  - Still filter out rainy areas.
- ECWMF tried this, but did not implement. GFS in parallel testing now.

Clear-sky vs. All-sky

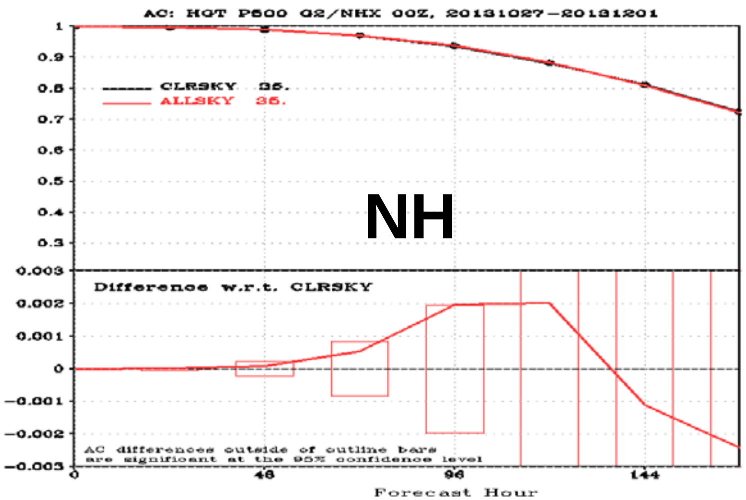


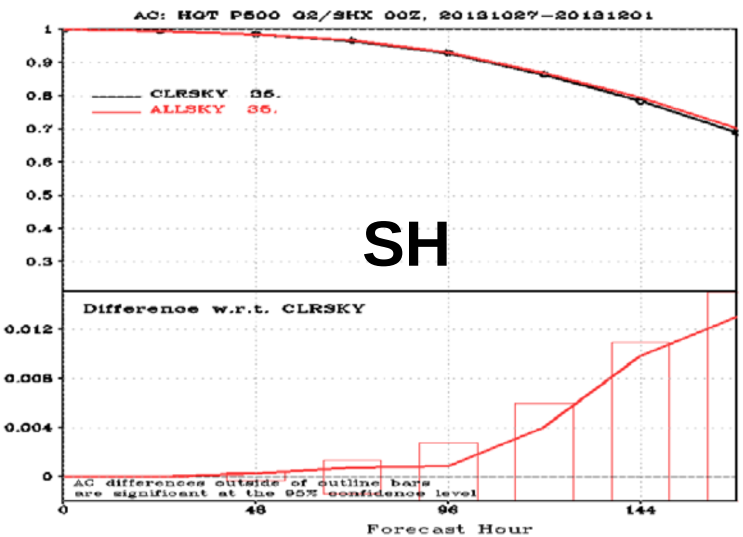


- Thick clouds that are excluded from clear-sky assimilation are now assimilated under all-sky condition
- Rainy spots are excluded from both conditions
- Cloud-affected, non-precipitating clouds are assimilated.

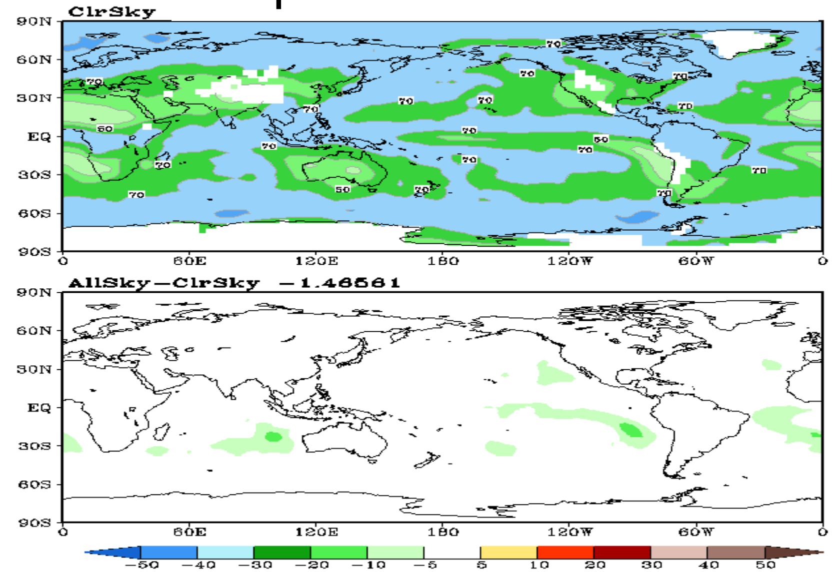
Experiment on All-sky Microwave Radiance Assimilation in 3D EnsVar T670/T254

Anomaly Correlation at 500 hPa

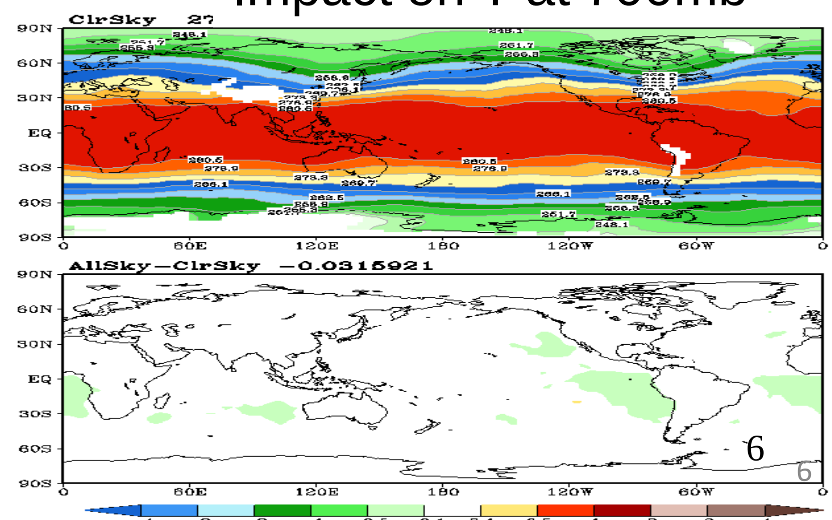




Impact on RH at 850mb



Impact on T at 700mb



ECMWF: ‘simplified’ assimilation of IR from HIRS/AIRS/IASI in cloudy areas.

- extend the 4D-Var analysis control vector to include parameters which describe the cloud conditions and simultaneously estimate these parameters together with temperature and humidity inside the main analysis (a ‘sink’ variable).
- the extra cloud variables are decoupled from the model physics and only cloudy data in completely overcast (but no rainy) conditions are used.
- Operational since 2009, adds about 5% more data.

Status of tropospheric microwave at ECMWF: Operations at 41r2 configuration for early 2016

	Instrument	Ocean	Sea-ice	Land	Snowy land	High land
Imager channels 19-90 GHz	SSMIS-F17 imager	☼ 💧				
	GMI	☼ 💧				
	AMSR2	☼ 💧				
183 GHz WV	SSMIS-F17 sounder	☼ 💧	☼ 💧	☼ 💧	☼ 💧	
	SSMIS-F18 sounder	☼ 💧				
	MHS on Metop-A/B and NOAA-18/19	☼ 💧	☼ 💧	☼ 💧	☼ 💧	
	MWHS	☼				
	MWHS-2	☼ 💧	☼ 💧	☼ 💧	☼ 💧	
	ATMS	☼	☼	☼	☼	
50 GHz temperature	AMSU-A on Metop-A/B and NOAA-15/18/19	☼	☼	☼	☼	☼

☼=clear-sky 💧=cloud and precipitation

ECMWF Plans

- We are in the process of developing the **advanced cloudy assimilation system** (drawing on experience from a similar scheme for rain affected microwave radiances)

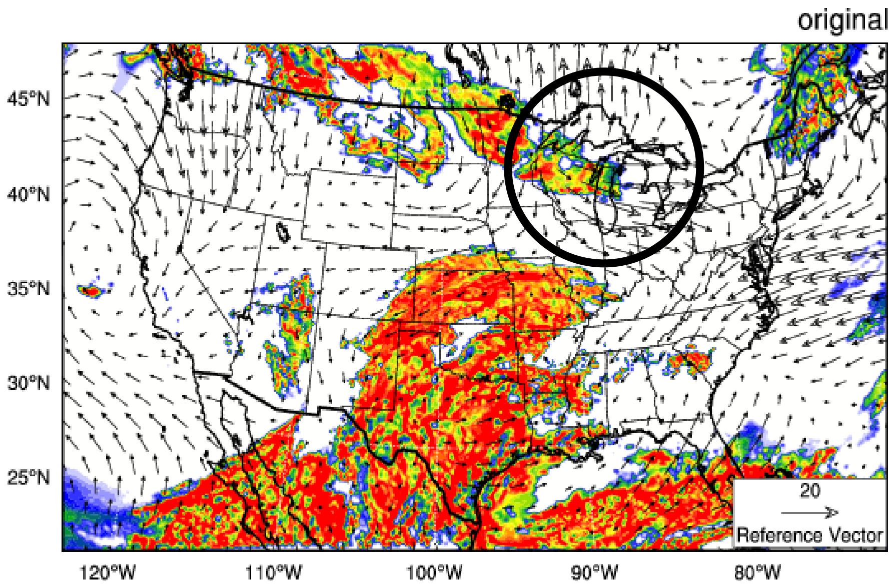
- Initially, cloud parameters (clw,ciw,cc) will be **diagnostic** and driven by the **model physics** via adjustments in the analysis control vector variables (T,Q and V).

- Later the cloud parameters will be tested as full variables in the **analysis control vector** (but this will require accurate background error covariances)

NCAR/JCSDA approach

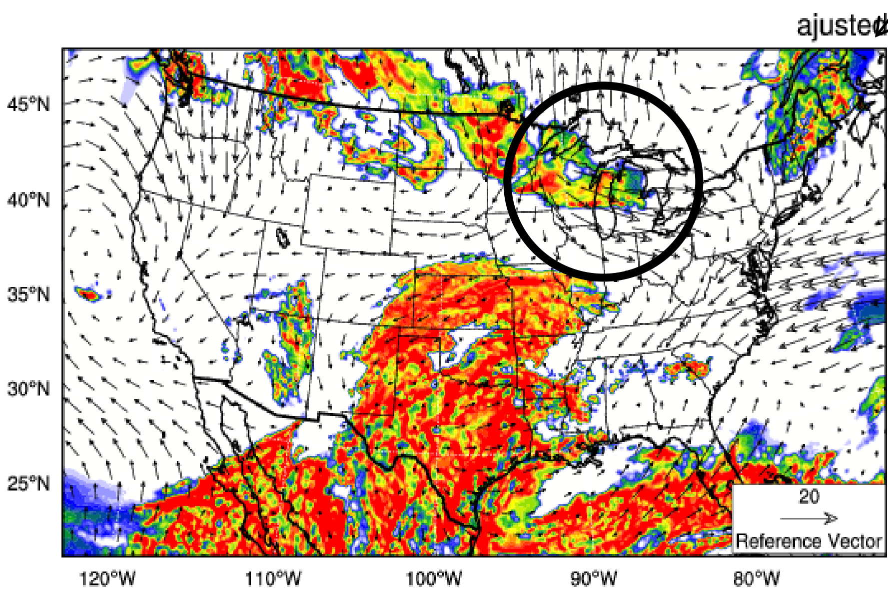
- the analysis control variable is limited to 3D cloud fraction and the model is reduced to dynamical advection (the physics being switched off).
  - Useful for nowcasting
  - Adaptive Advection Adjustment via Realigned Grid mesH (AAARGH).

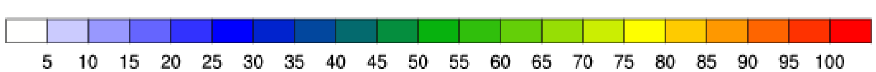
The following cycle:



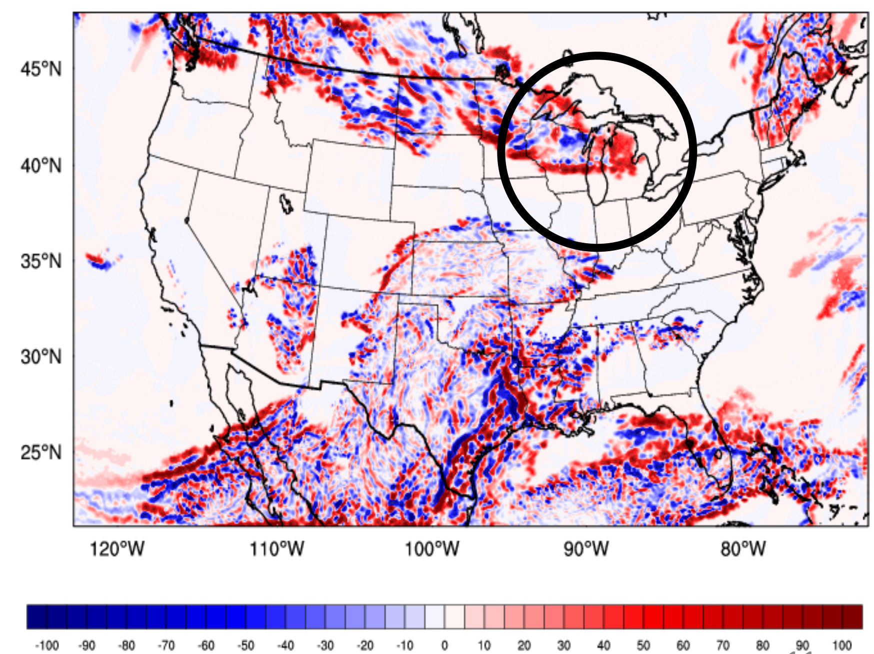
WRF

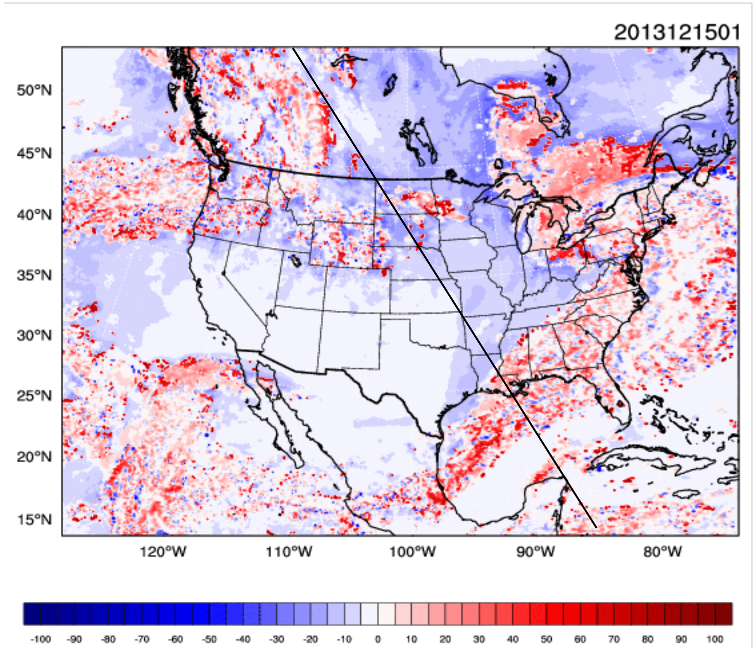
WRF + AAARGH



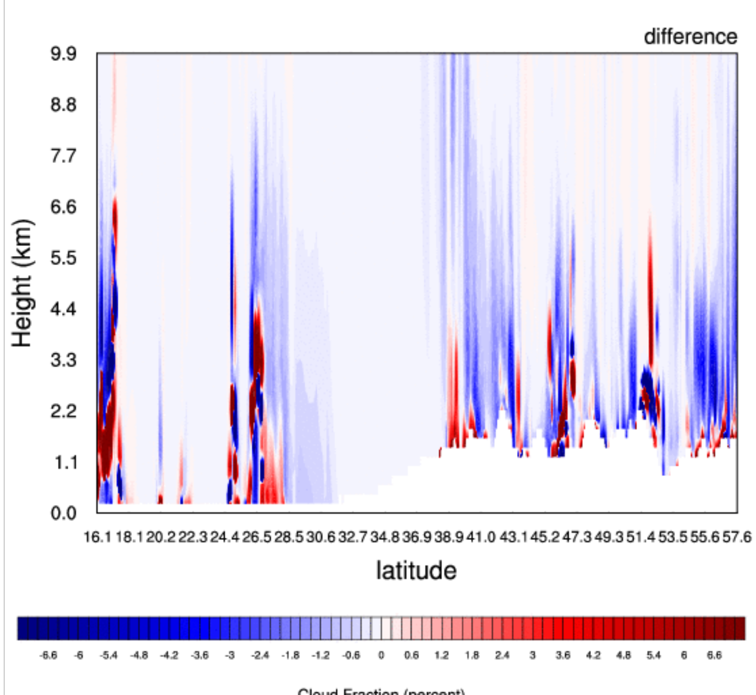


Difference

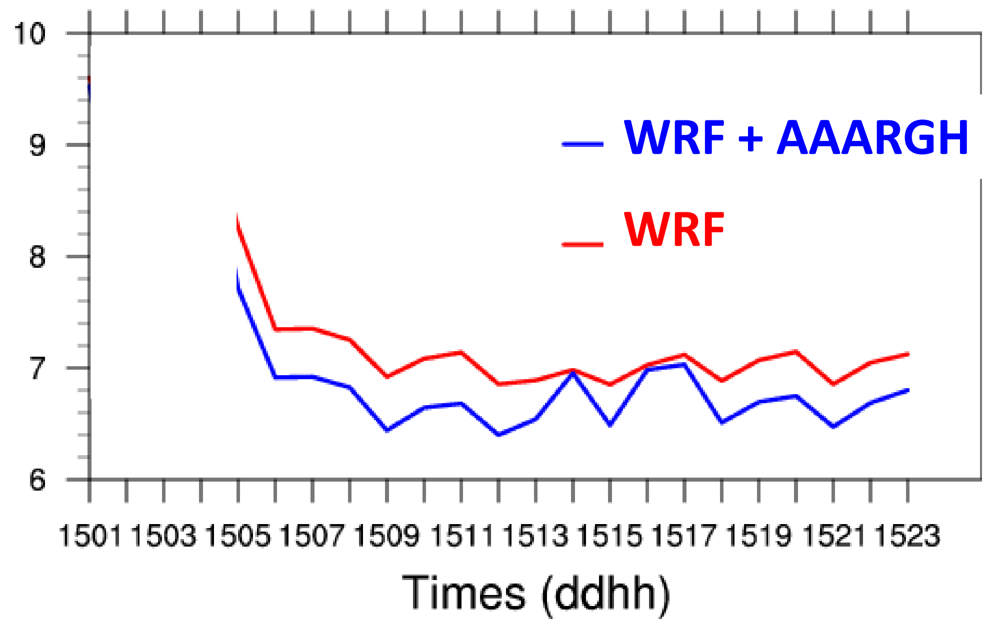




Difference



RMSE of forecast vs. GOES radiances

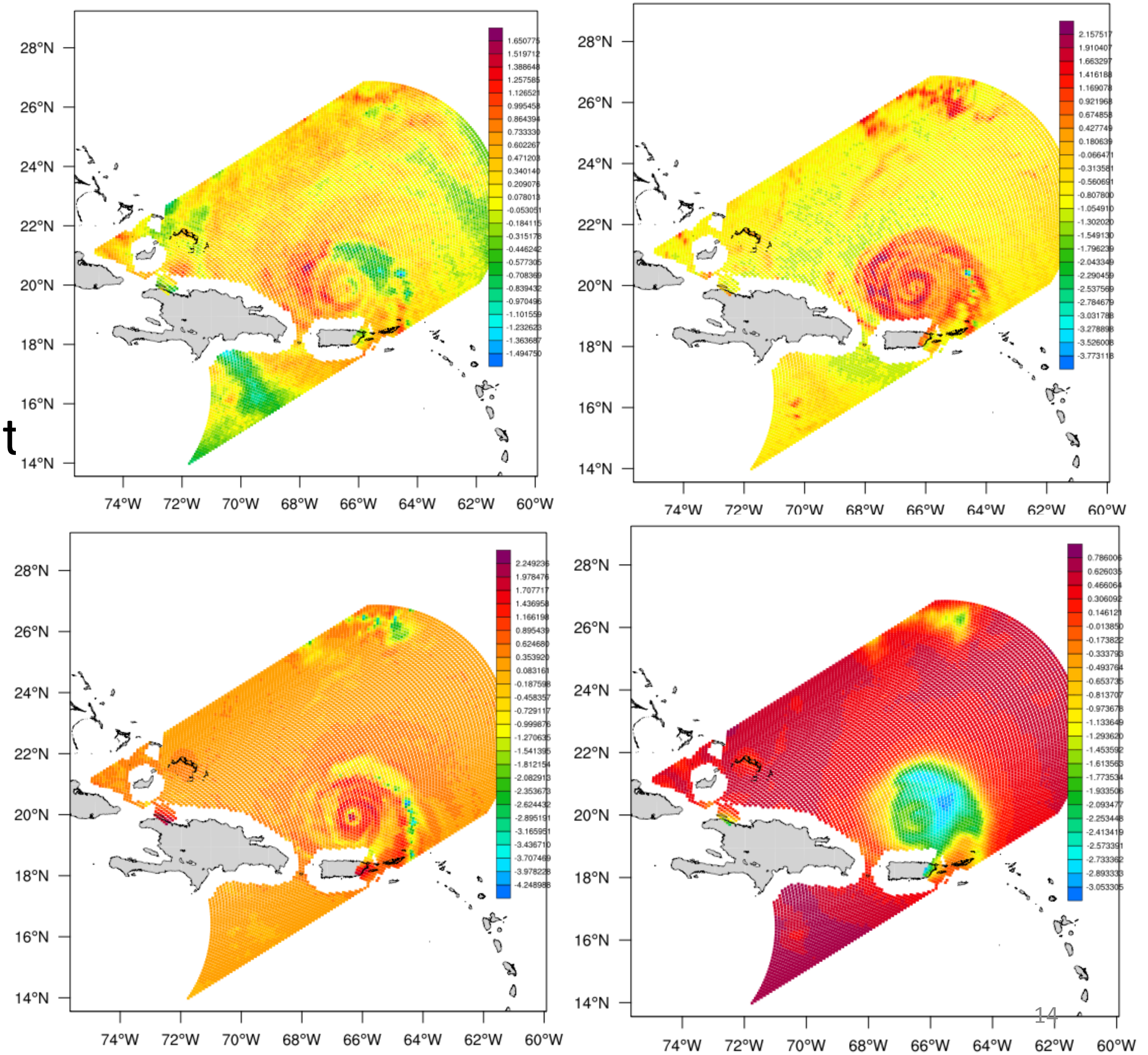


Statistical Forward Operator (J. Steward, JPL)

- Trained from dataset of model forecast/RTM, observation pairs.
- Canonical correlation analysis (CCA) used to predict observations given model – this becomes the forward operator.
  - Truncated to include only vectors with strong correlation (regularizes + bias corrects, neglects uncertain relationships).

HEDAS Example: 1st 4 CCV "obs" for TRMM/TMI

1st 3 represent "maximally certain information"



Needs for hurricane application

- Need to use radiances in rain-affected regions.
- Need high temporal and spatial resolution, low latency
  - Geostationary radiances crucial.
- A simplified and/or statistical approach may be required to extract the useful information
  - Filter out model biases and reduce nonlinearities
- Assimilation of images?
  - Through retrieved velocities, lagrangian information.
  - Through assimilation of 'objects', image 'warping' techniques (like AARGH).