Assimilation of precipitation-related observations into global NWP models

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Ways to use observations

Precipitation observations

- Rain gauges
- Ground and space radar (retrievals or reflectivities)
- Cloud- and precipitation-affected radiances (IR/MW)

Rain products - now

Retrievals

Nowcasting – 0h to 3h ahead

Blend rain products with model wind fields

Regional modelling – to 24h

Data assimilation into forecast models

Global NWP – day 2 onwards

Data assimilation into forecast models

Retrievals and models

IPWG intercomparisons in 2003-2005

“**Satellite-derived estimates of precipitation** … are most accurate during the warm season and at lower latitudes, where the rainfall is primarily convective in nature.

NWP models perform better than the satellite estimates during the cool season when nonconvective precipitation is dominant.”

Comparison of Near-Real-Time Precipitation Estimates from Satellite Observations and Numerical Models.
Elizabeth E. Ebert, John E. Janowiak, and Chris Kidd, 2007, Bull. Amer. Meteor. Soc., 88, 47–64.

None of the models assimilated rain observations back then – we don’t need to assimilate rain to predict rain.

Precipitation-related assimilation at ECMWF

	Operational	Next few years
Ground-based rain radar	NEXRAD stage IV radar/gauge composites	European OPERA radar
Rain gauges	-	Global SYNOP rain-gauge measurements
All-sky microwave imager radiances	19 – 90 GHz channels from SSMIS and TMI	10 GHz for convective precipitation
All-sky microwave humidity radiances	183 GHz channels on SSMIS and MHS (MHS early next year)	Extend to all sensors (e.g. ATMS humidity channels)
All-sky infrared humidity radiances	-	HIRS or IASI 6.7μm
Space radar		EarthCARE

Ground-based radar/gauge assimilation

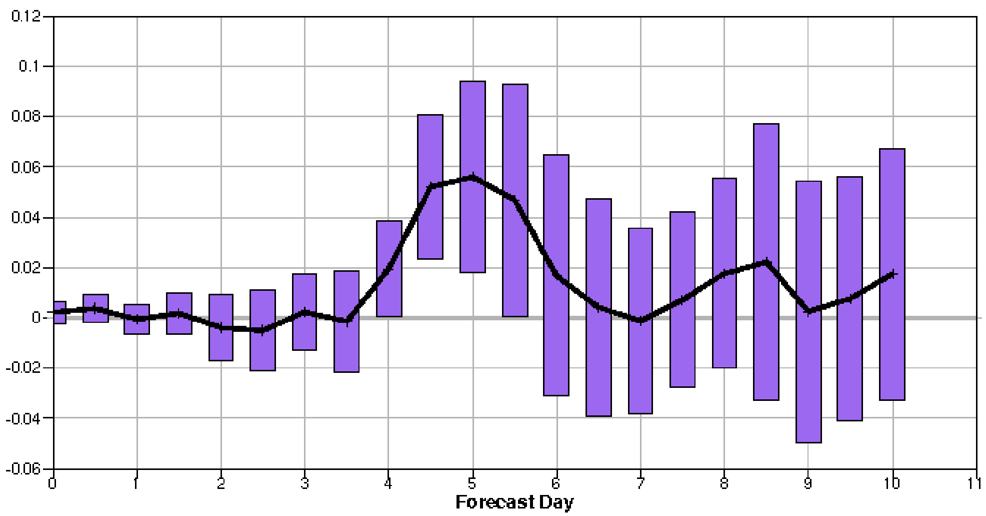
NEXRAD stage IV radar-gauge composites

- Method:
  - Radar-gauge composites over the US
  - Surface rain rate assimilated as 6h accumulations
- Results:
  - Improved short-range precipitation forecasts over US
  - Positive impact of US data on Europe forecast scores 4-5 days later

Change in RMS error in European 500hPa geopotential

Improvement

Degradation



Relative change in root-mean-square forecast error (against own analysis)

From test experiment:
1 April – 6 June 2010, T1279 (~15 km) L91

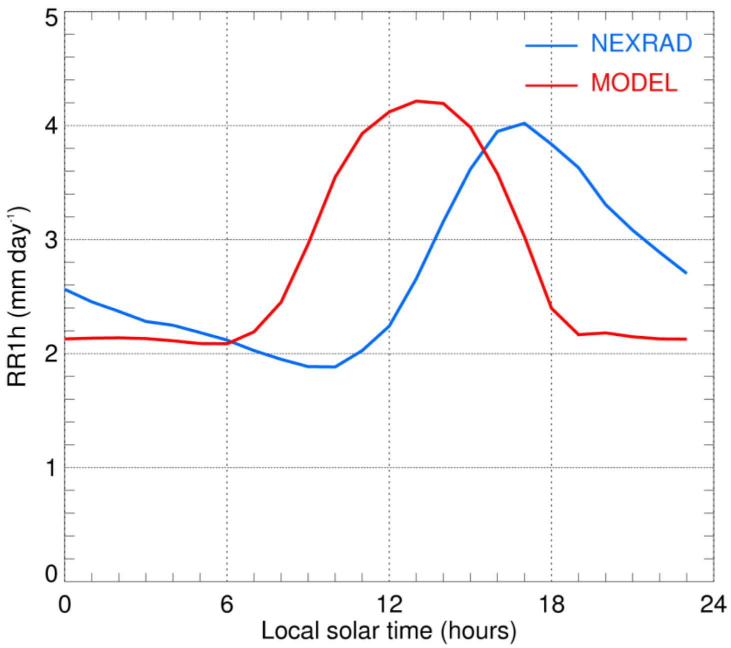
(Lopez, 2011, MWR)

ECMWF

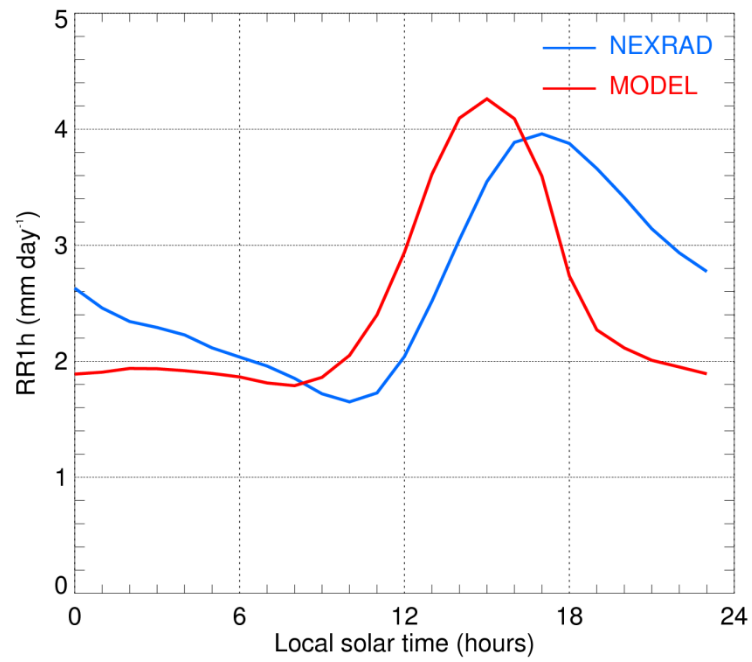
Short-range forecast precipitation validation with NEXRAD rain rates

1st May – 31st July, continental USA

2013



2014



Comparison: Lopez (2014, ECMWF tech memo 728)
Improved diurnal cycle of modelled convection: Bechtold et al. (2014, JAS)

ECMWF

Passive microwave assimilation

All-sky observations in 4D-Var assimilation

Observation minus first-guess* departures in clear, cloudy and precipitating conditions

*FG, T+12, background…

Observation operator including cloud and precipitation (RTTOV) - TL/Adjoint

Rest of the global observing system

Moist physics - TL/Adjoint

Forecast model - TL/Adjoint

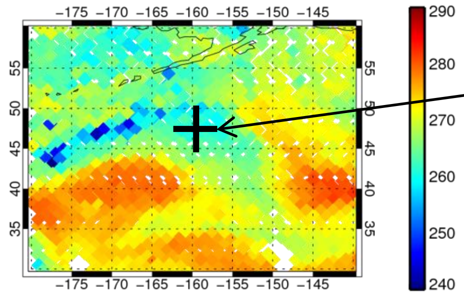
Background constraint

Control variables (winds, mass and humidity at start of assimilation window) optimised by 4D-Var

Single observation of frontal cloud and precipitation

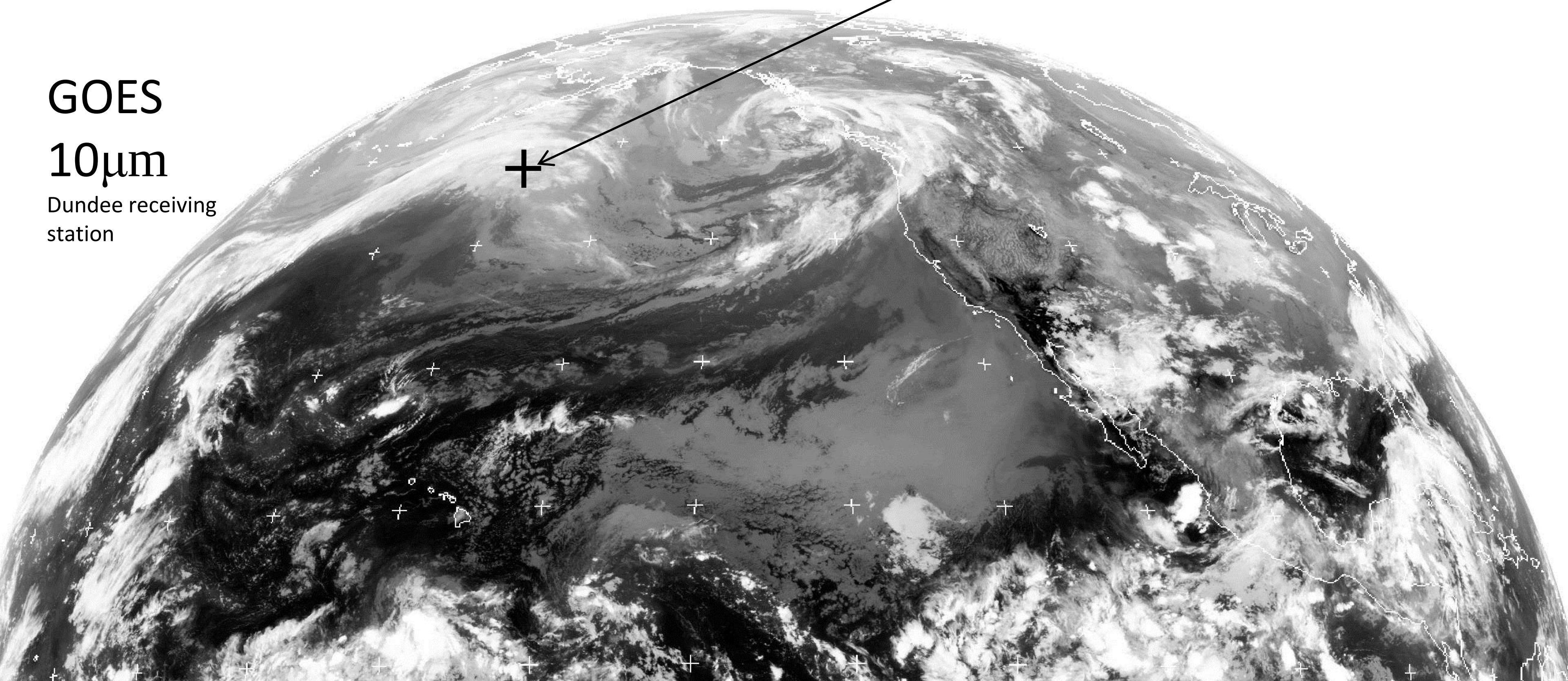
at 190 GHz

Metop-B MHS
190 GHz

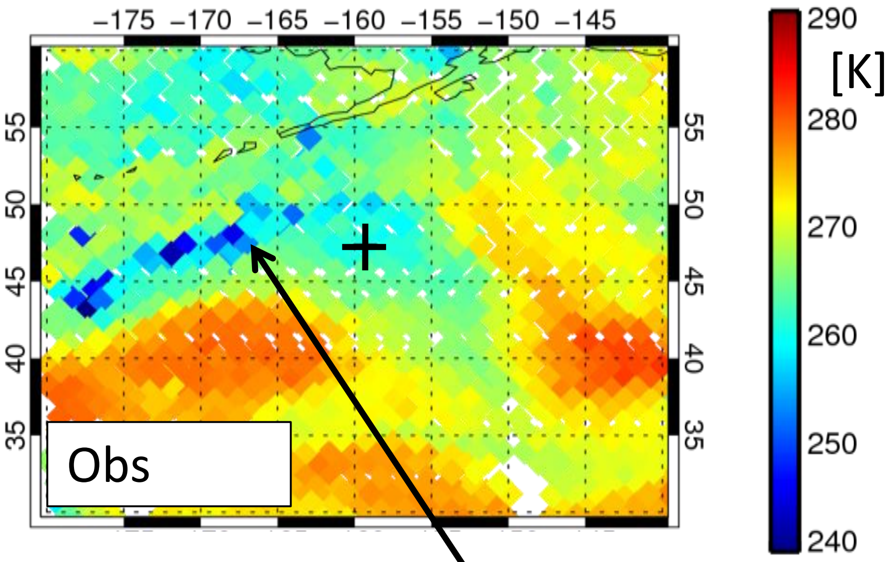


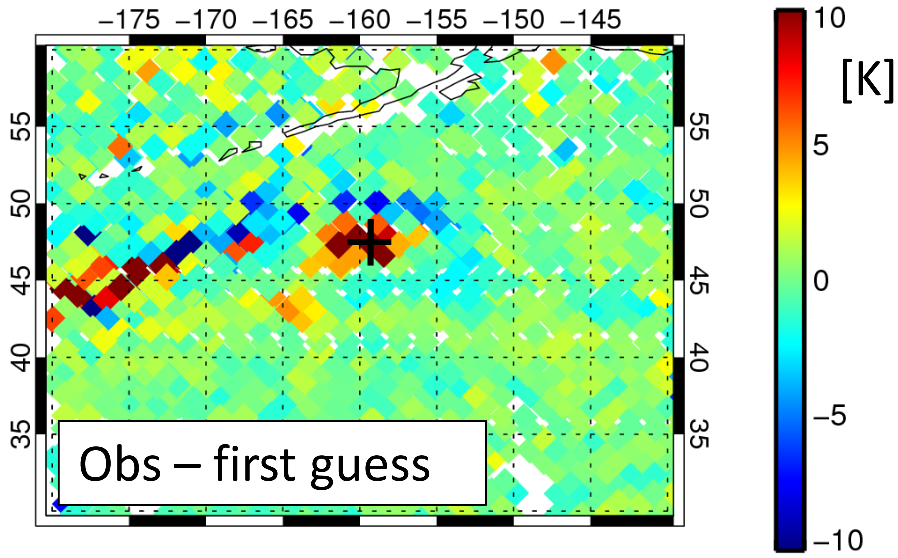
08Z, 15 Aug 2013
47°N 159°W

GOES
10µm
Dundee receiving station

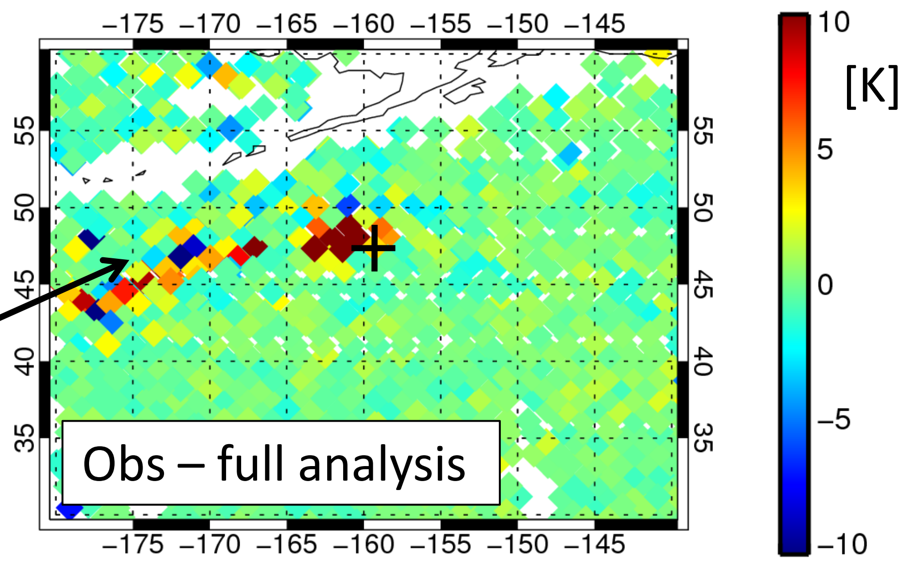


Context of the single observation: full system results



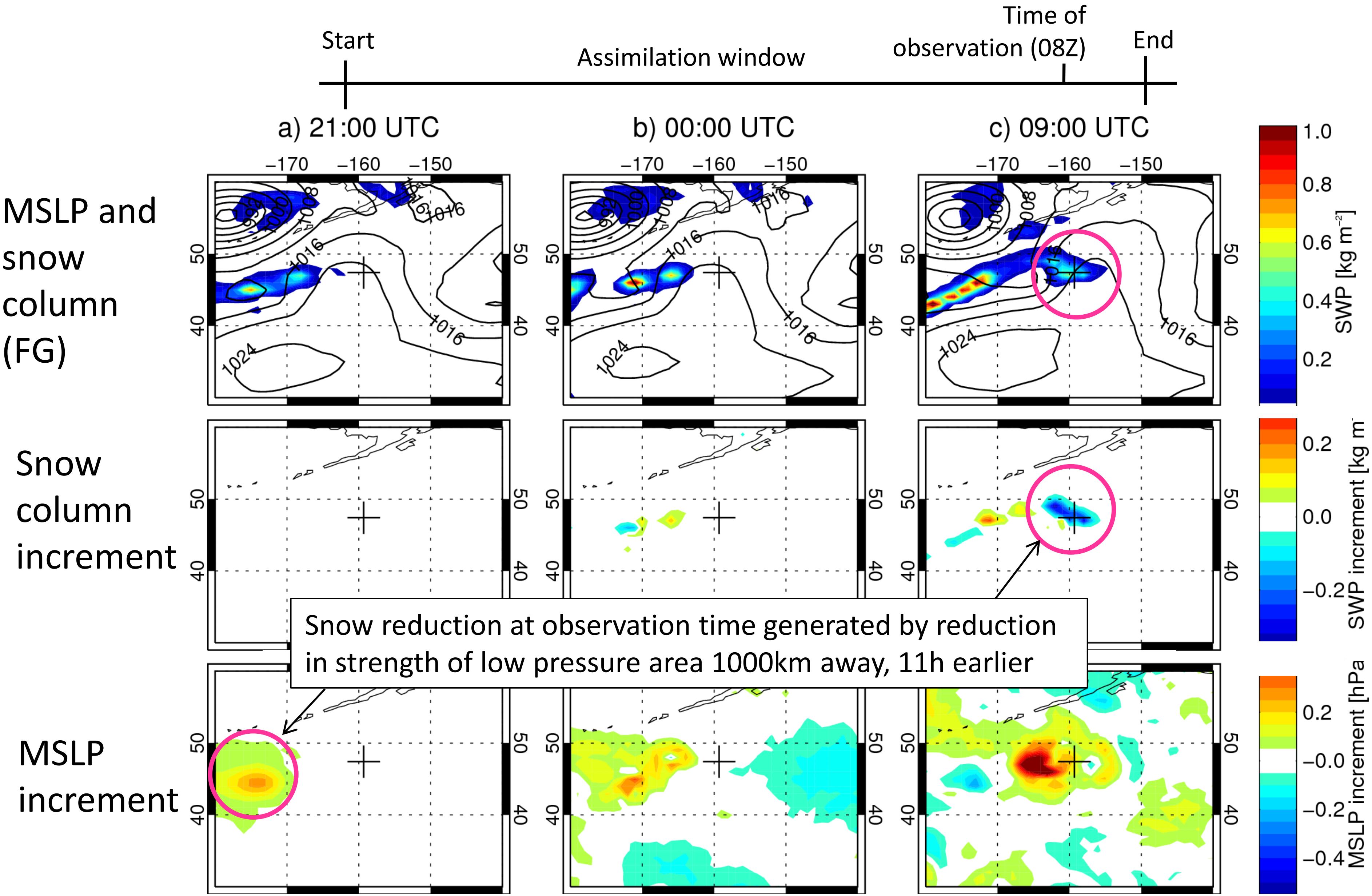


Scattering from snow hydrometeors along front



Analysis of frontal precipitation is not perfect

Single observation results



A reason to assimilate precipitation in global models

- Precipitation (along with cloud and humidity) is generally driven by synoptic-scale weather patterns
- In a data assimilation system, humidity/cloud/precipitation radiances are essentially observations of the synoptic structure of the atmosphere
- Better dynamical initial conditions (wind, temperature) lead to better forecasts later…

Impact of all-sky microwave humidity sounders – on top of the otherwise full observing system

Around 1% impact on day 4 and 5 dynamical forecasts

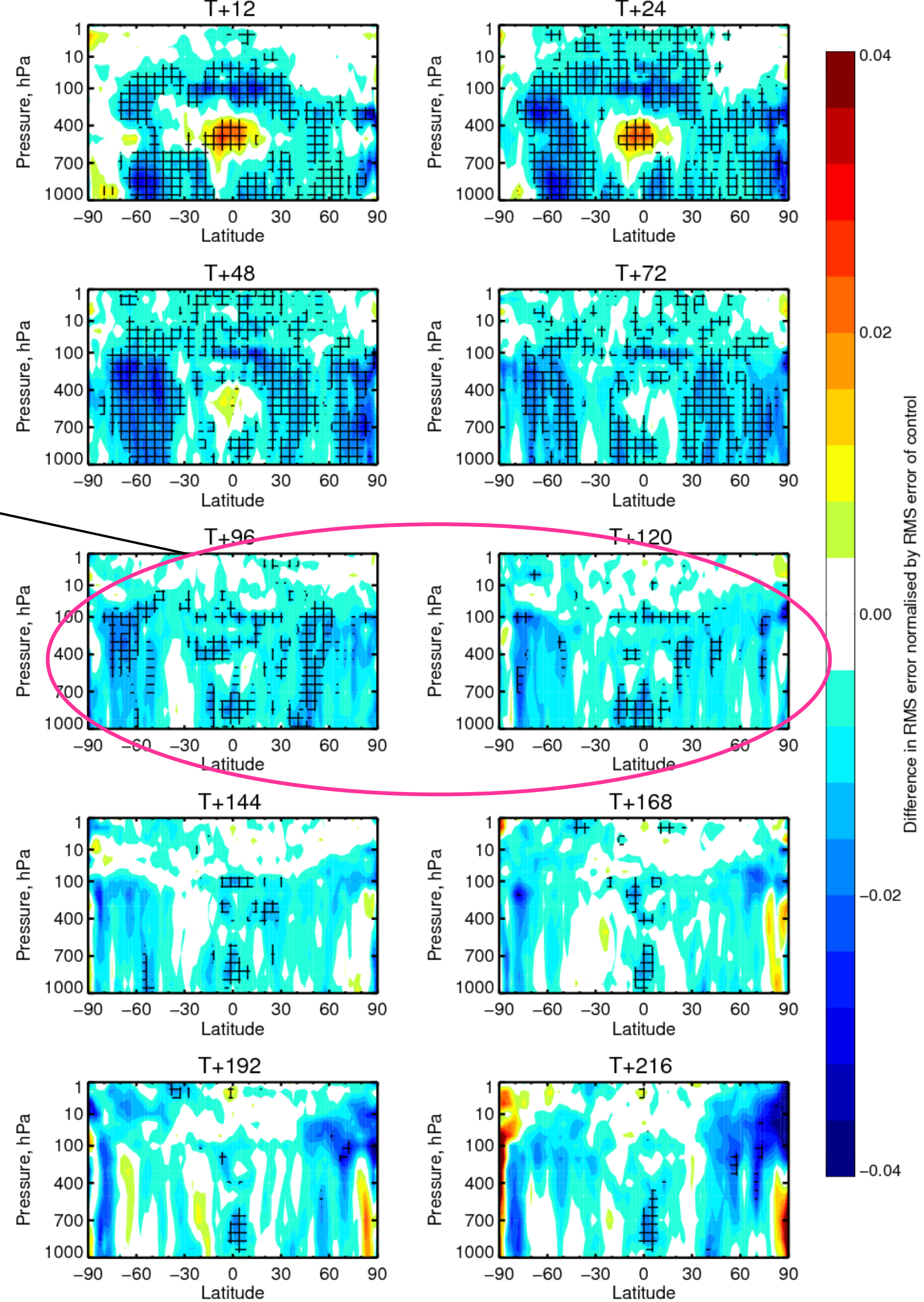
Change in RMS error of vector wind

Verified against own analysis

Blue = error reduction (good)

Based on 164 to 202 forecasts

Cross hatching indicates 95% confidence



Impact of all-sky microwave humidity sounders **and imagers**

-on top of the otherwise full observing system

2-3% impact on day 4 and 5 dynamical forecasts

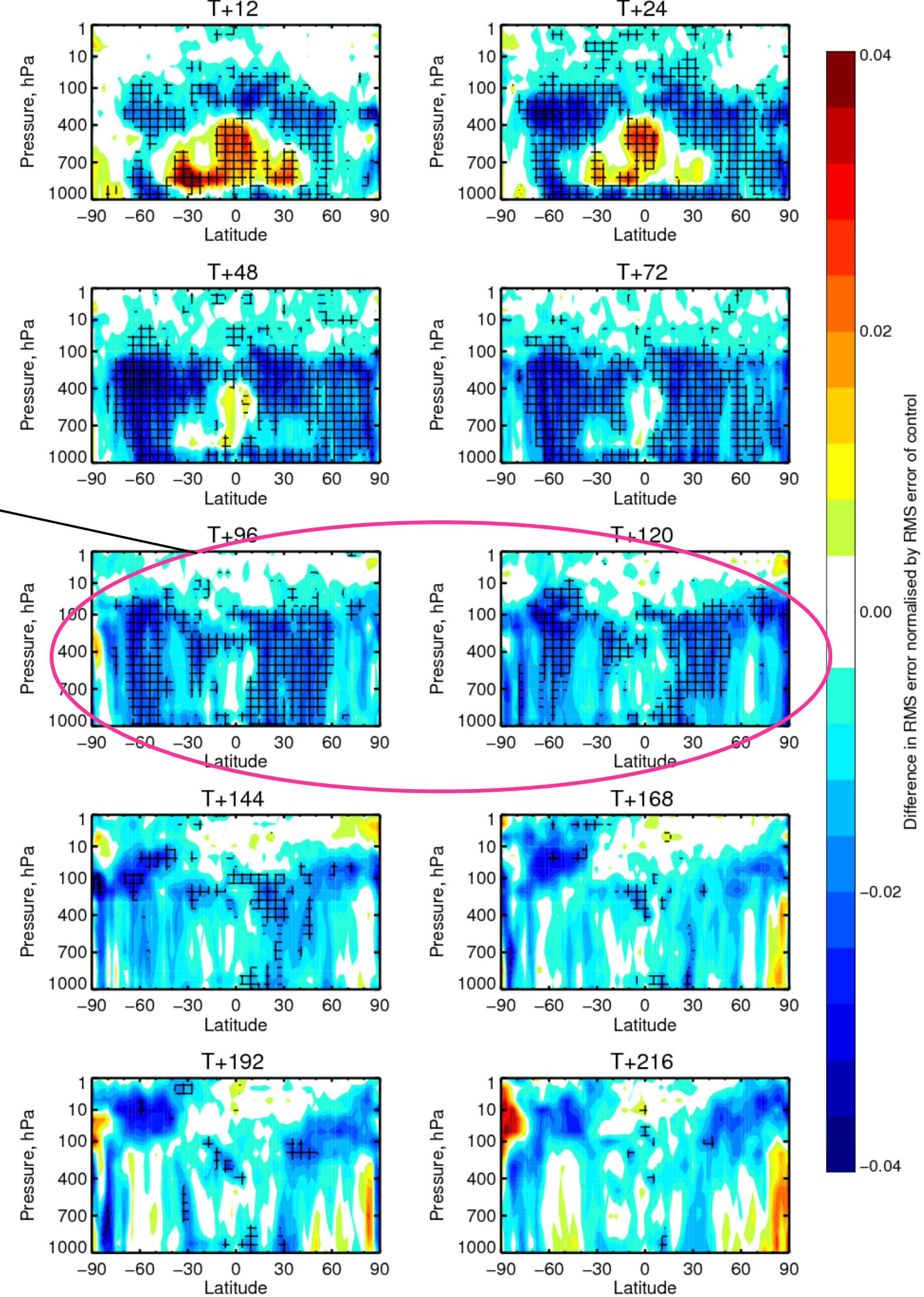
Change in RMS error of vector wind

Verified against own analysis

Blue = error reduction (good)

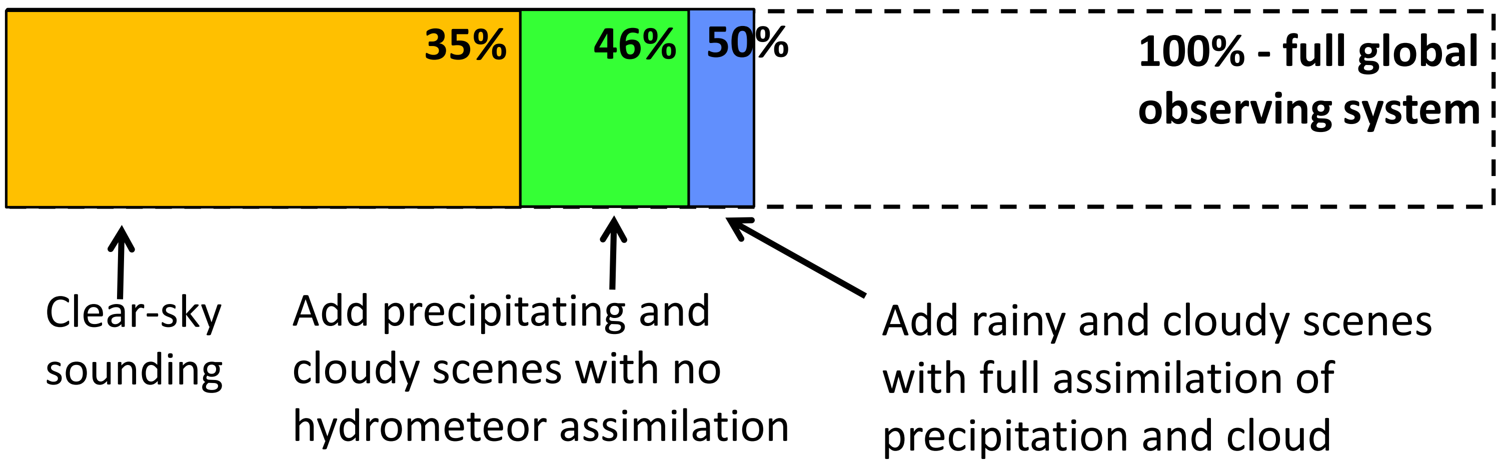
Based on 322 to 360 forecasts

Cross hatching indicates 95% confidence



What is the impact of rain and cloud-affected scenes in the 183 GHz channels?

- T+12 wind impact of all-sky MHS and SSMIS humidity channels in the southern hemisphere (single observing system experiment):



- Primary effect: Dynamical information from water vapour features in the presence of cloud
- Secondary effect: direct use of heavy cloud and precipitation signals (e.g. midlatitude frontal precipitation) to infer dynamical information

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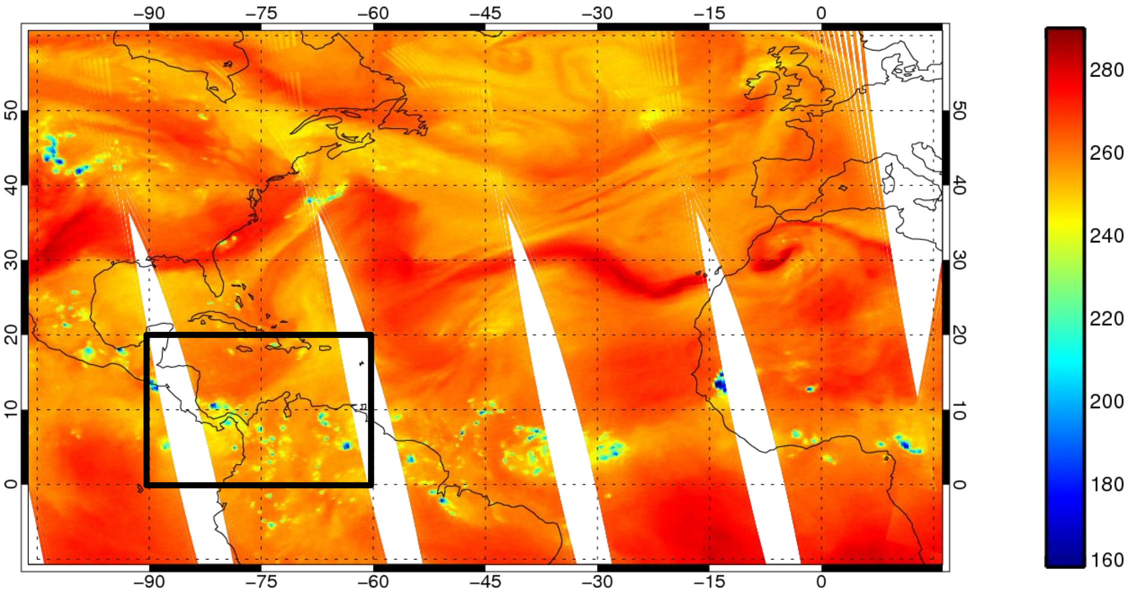
Issues: representivity and convection

Representing convective precipitation in models

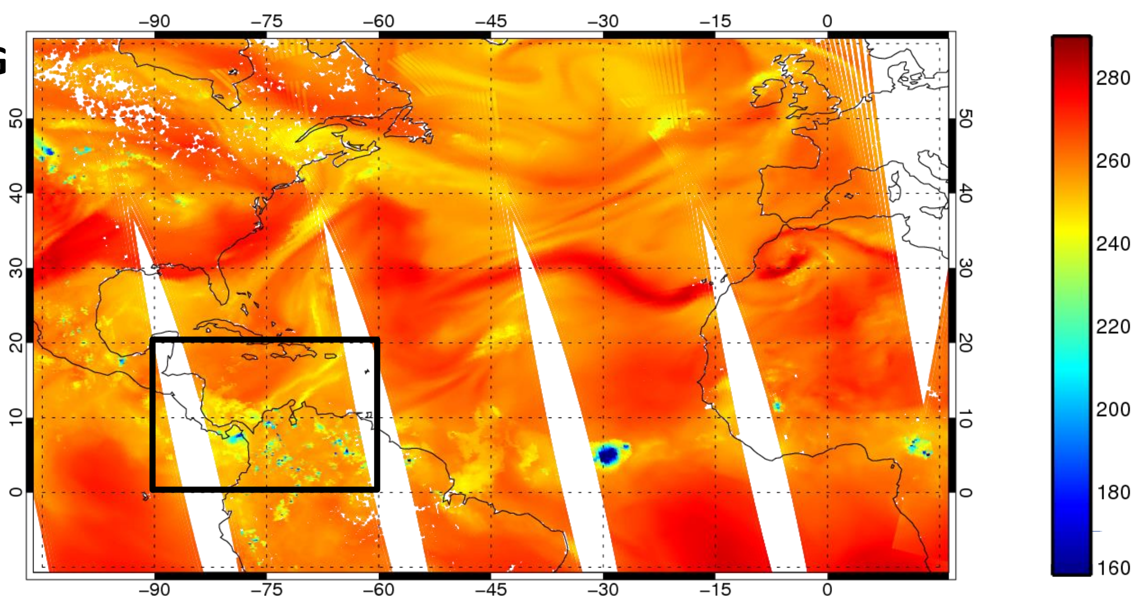
Observations



TB [K]

MHS 183±3 GHz
June 12th 2013

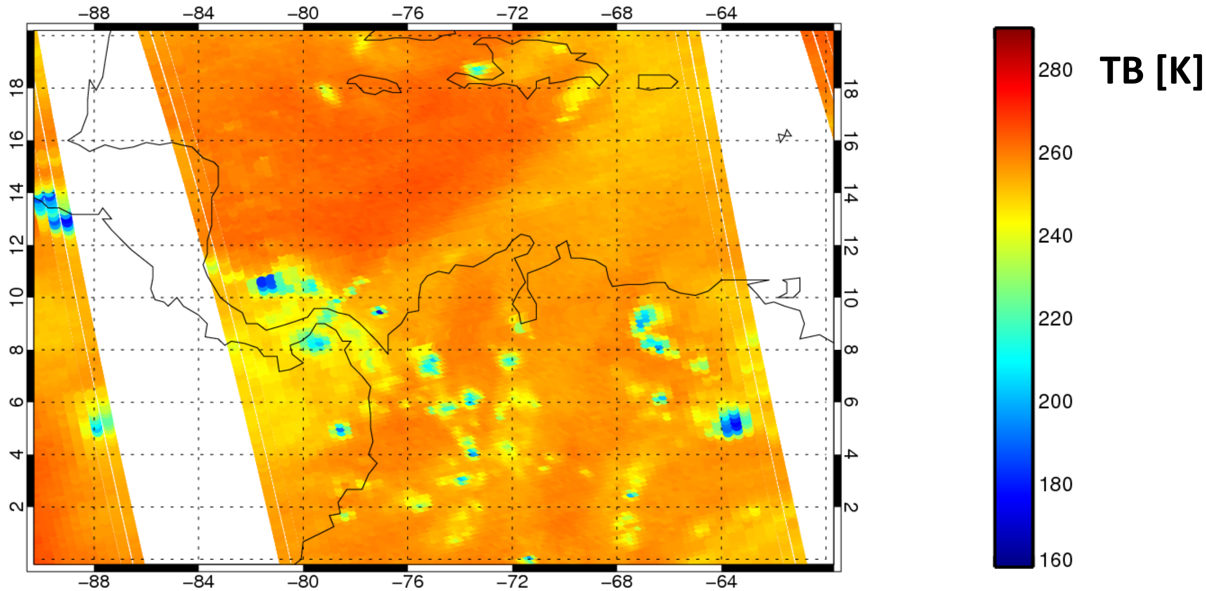
ECMWF FG



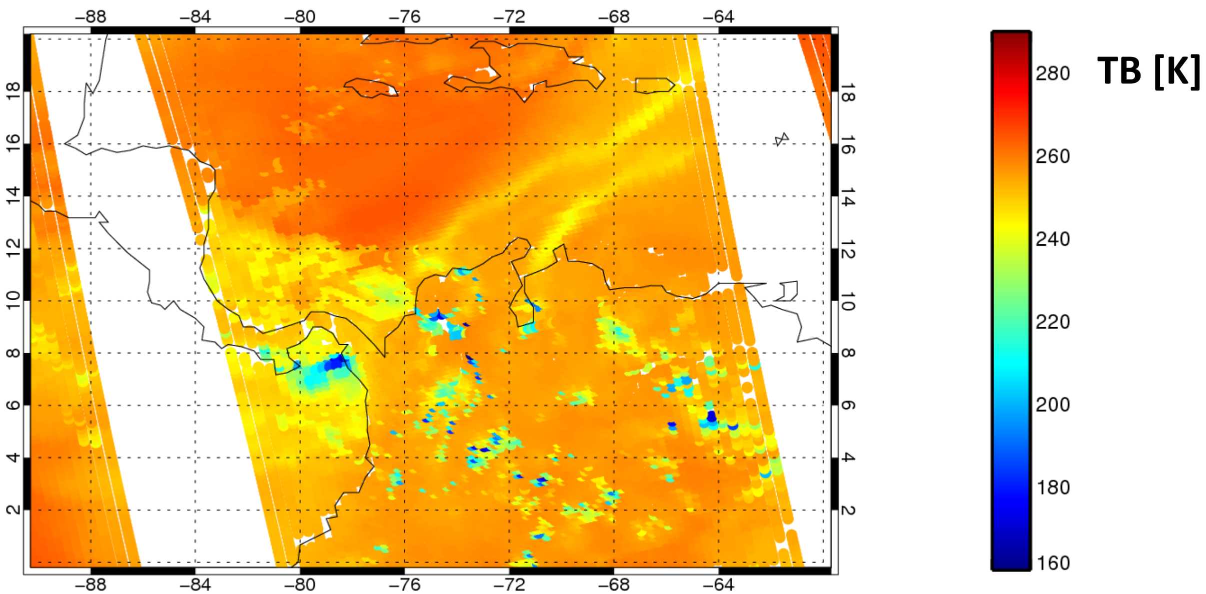
TB [K]

Representing convective precipitation in models

Observations



ECMWF FG



Solutions to the representivity issue

- NEXRAD rain rates
  - Temporal averaging: assimilated as 6h accumulated precipitation

- Passive microwave:
  - Spatial superobbing of microwave imager radiances to 80km by 80km
  - Observation errors are boosted in cloudy and precipitation situations

- Experimental and not used at ECMWF:
  - Discard situations where model and observation disagree
  - Spatial displacements included in assimilation (grid warping)

Can we put more weight on precipitation-affected radiance observations?

- Not at the moment
  - we should not force the model to fit convective features that it cannot accurately predict. It results in:
    - degraded winds and temperatures in the analysis
    - degraded medium-range forecasts
  - (alternative hypothesis: our assimilation system is still suboptimal for precipitation)

- We are a long way from making the precipitation in the analysis look exactly like the precipitation in the observations.
  - Data assimilation is about making small corrections to a reasonable forecast
  - Ebert et al. (2007) still applies

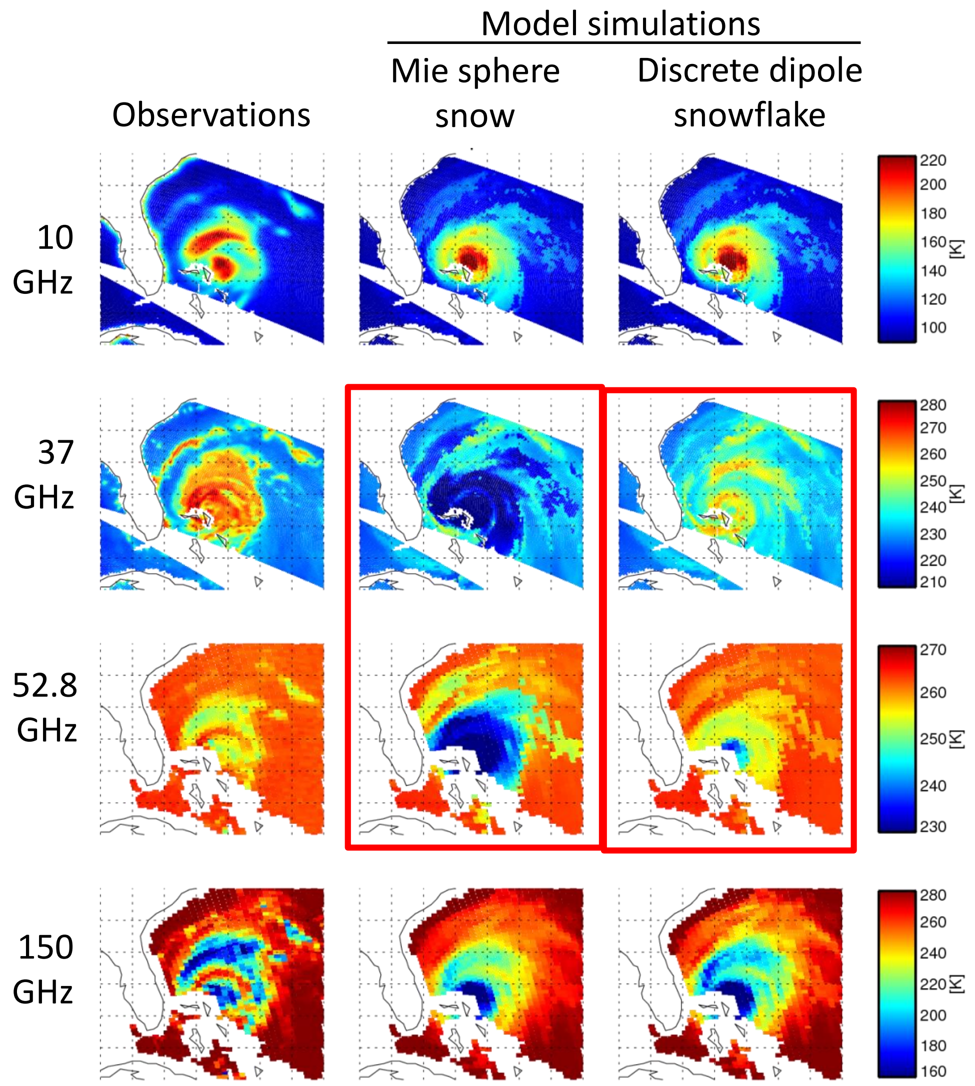
ECMWF

Issues: scattering radiative transfer

Improving the radiative transfer model: Hurricane Irene

Better knowledge of microphysical influences on scattering properties of rain and snow is needed

- Particle shapes
- Particle size distributions



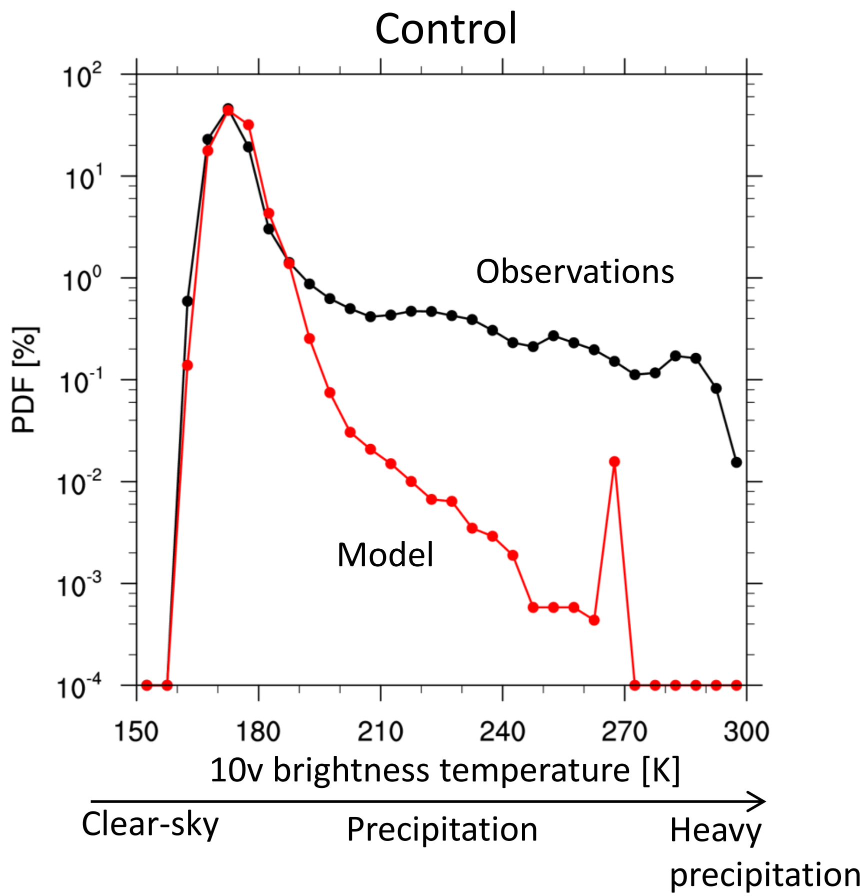
Geer and Baordo (2014, AMT)

Issues: radiative transfer and model physics at 10 GHz

looking to heavy rain assimilation over ocean

10 GHz: Model precipitation or observation operator?

1 month ocean sample from TMI



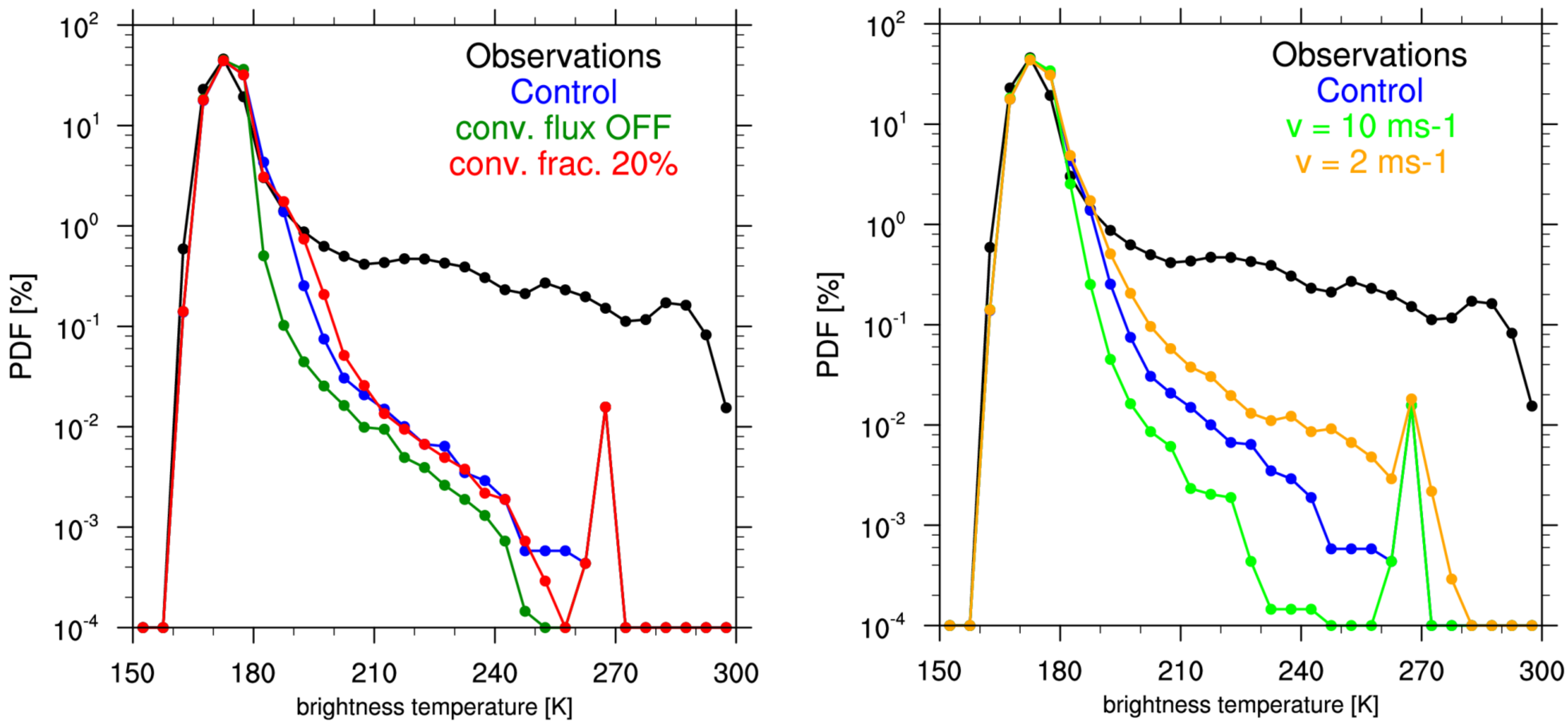
Thanks to Katrin Lonitz

10 GHz: Model precipitation or observation operator?

1 month ocean sample from TMI

Convection and/or sub-grid variability?

Fall speed in conversion from precipitation flux to mixing ratio?



Thanks to Katrin Lonitz

ECMWF

Summary (1/2)

Why assimilate precipitation-related data into global NWP models?

1. Adjust large-scale weather patterns to better fit observed precipitation

→ **Improve synoptic forecasts in the medium range**

2. Identify and fix systematic errors in the forecast model and observation operator

Improvements in the exact location of convective precipitation in analyses and short-range forecasts will be the work of many years

- Rain assimilation is not a "quick fix"
- Will benefit from improvements in forecast model, moist physics, observation operators and data assimilation

Summary (2/2)

What commonality with H-SAF?

- ECMWF currently assimilates radar rain retrievals
  - Future interest: European OPERA network, GPM space radar
  - Ideally in the future, we want to assimilate reflectivities
- For passive microwave and infrared, we assimilate radiances
- Common interest:
  - Better forward operators for radar, microwave and infrared
    - Community radar operator (following RTTOV)
  - Better knowledge of microphysics i.e. particle shapes and sizes
  - Forecast model validation