The Potential Impact of RFI on the Assimilation of Microwave Radiances at NCEP

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NATIONAL WEATHER SERVICE

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Outline

- Use of Microwave Data in the NCEP Global Model
- The importance of 23GHz on cloud detection / characterization
- The potential impact of RFI
- Discussion

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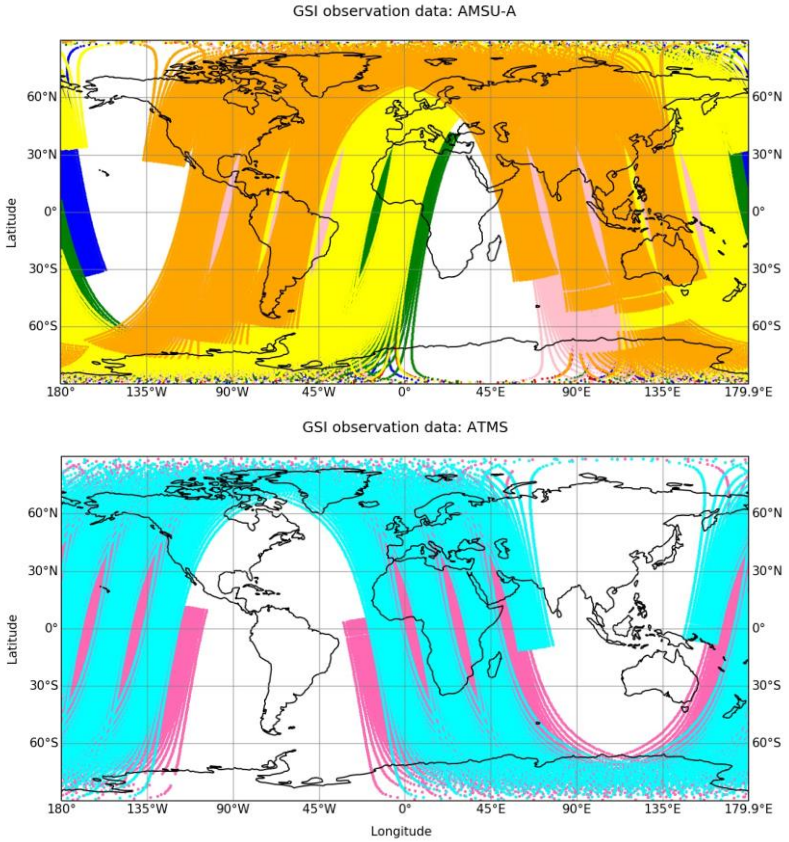
MW Sounder Radiances used in GFS

Sensor	Platform	Orbit	Channels
AMSU-A	NOAA-15	AM; Drifting	1-5,6,7-10,11,12-13,14,15
	NOAA-18	PM; Drifting	1-4,5,6-7,8-9,10-15
	NOAA-19	PM; Drifting	1-6,7-8,9-15
	MetOp-A	Mid AM	1-6,7-8,9-15
	MetOp-B	Mid AM	1-7,8-14,15
	MetOp-C	Mid AM	1-15

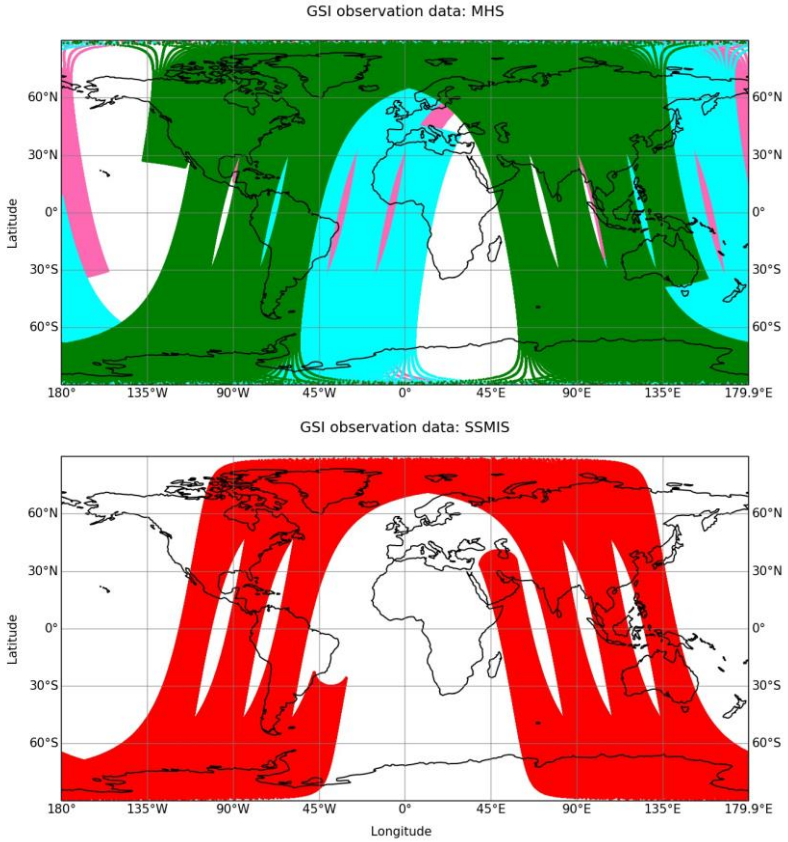
Sensor	Platform	Orbit	Channels
ATMS	S-NPP	PM	1-16,17-22
	NOAA-20	PM	1-16,17-22



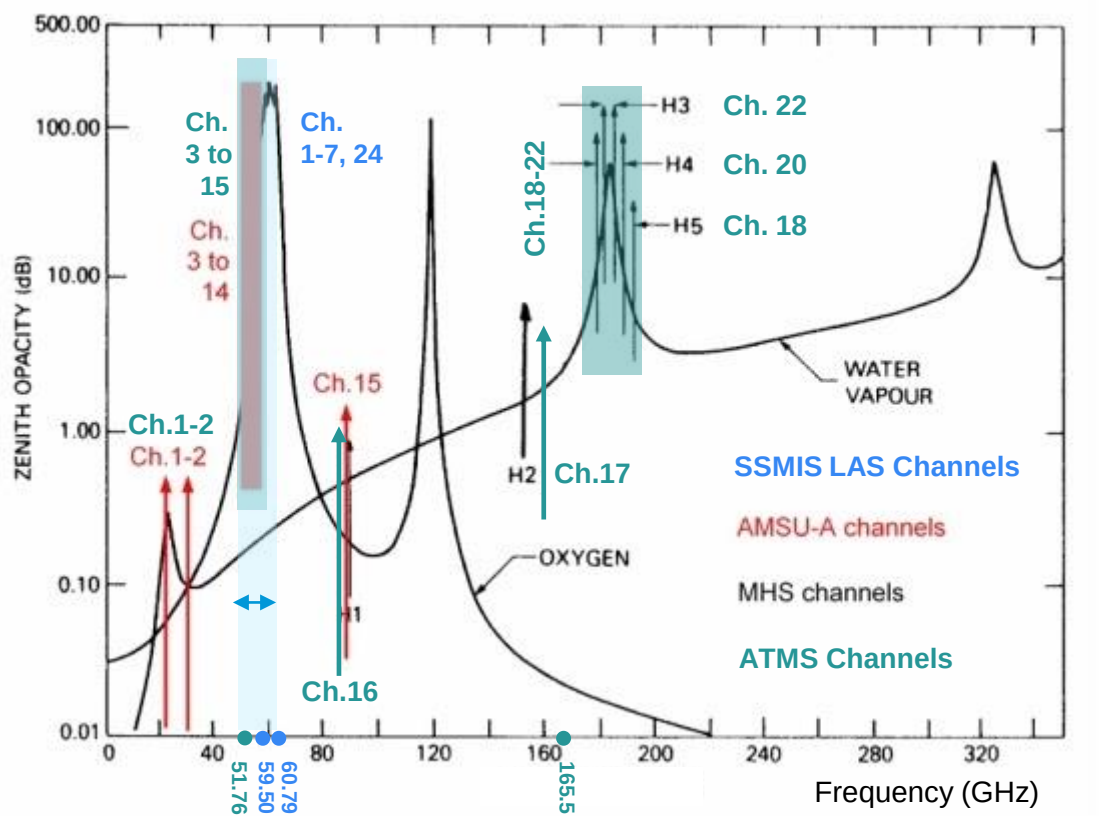
MW Sounder Radiances used in GFS

Sensor	Platform	Orbit	Channels
MHS	NOAA-18	PM; Drifting	1,2,3,4,5
	NOAA-19	PM; Drifting	1,2,3,4,5
	MetOp-A	Mid AM	1,2,3,4,5
	MetOp-B	Mid AM	1,2,3,4,5
	MetOp-C	Mid AM	1,2,3,4,5

Sensor	Platform	Orbit	Channels
SSMIS	DMSP-F17	Early AM	1,2-4,5-7,8-23,24



MW Sounder Data Spectral Range in GFS



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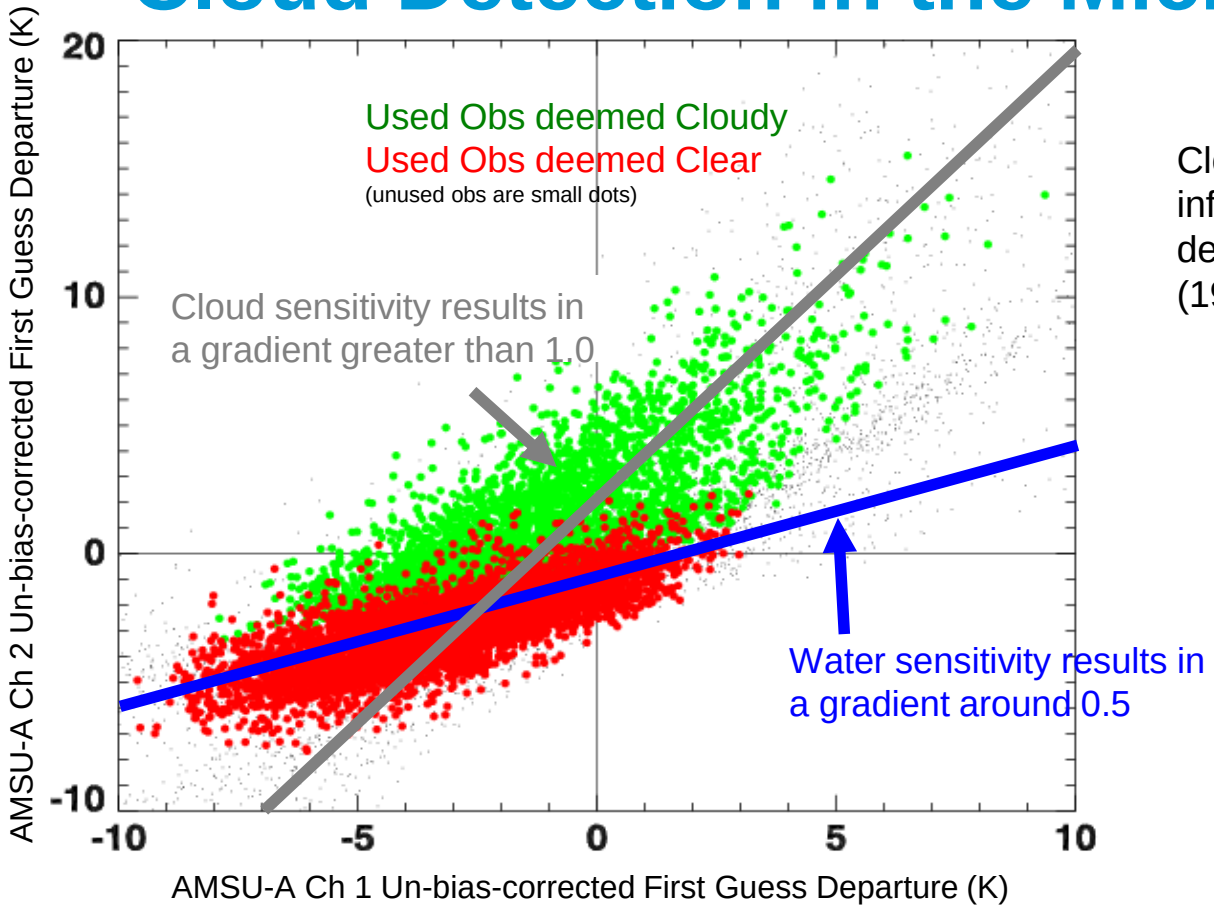
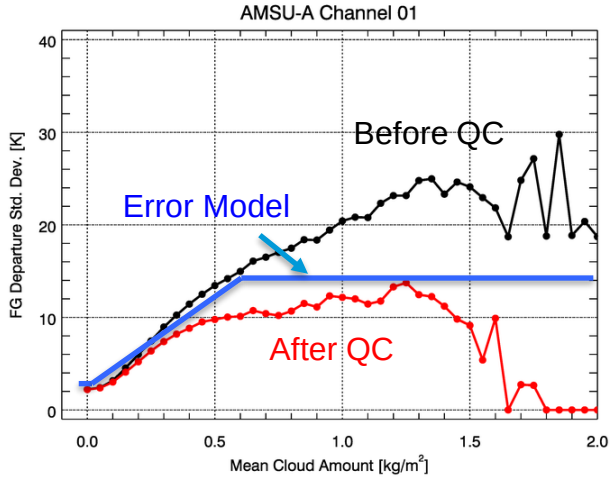
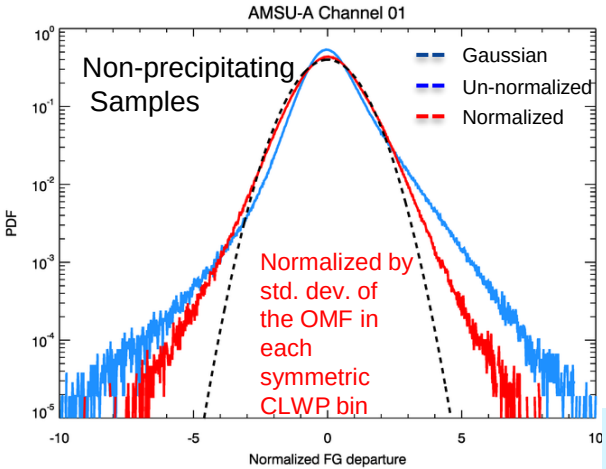
Cloud Detection in the Microwave

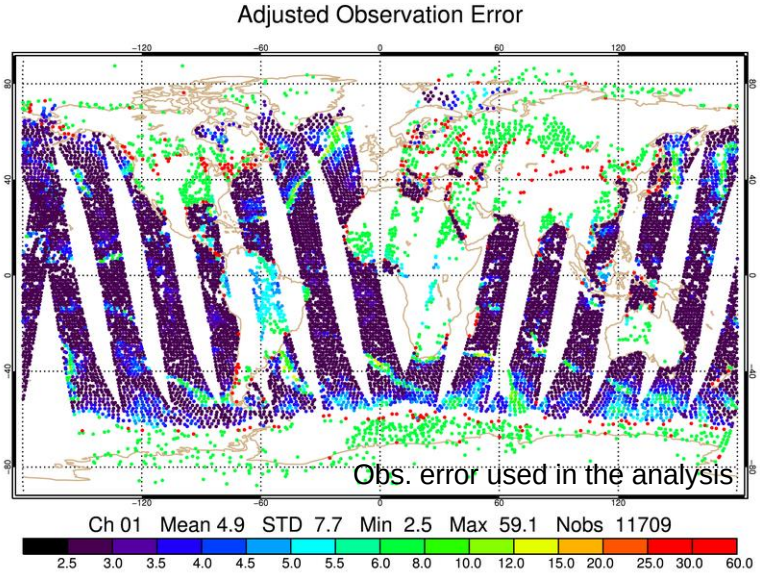


Cloud Liquid Water Column is inferred using the empirical derivation of Weng and Grody (1994)

Observation Error for AMSU-A under Cloudy Conditions







This error model is used over sea only for:

AMSU-A Chans 1-6 & 15
ATMS Chans 1-7 & 16-22

Yanqiu Zhu.
Method originally suggested by Geer

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Use of 23GHz Band in NCEP Global Model

- The 23GHz water vapor line corresponds to channel 1 of ATMS and AMSU-A.
- In NWP this channels may be directly assimilated …
- … and are also used to infer the amount of cloud in the observation so that other channels may be screened for cloud or (for cloudy radiance assimilation) the assumed observation error may be adjusted.
- For AMSU-A, channels 1-6 and 15 rely on this information. For ATMS it is channels 1-7 and 16-22. This is only the case over water.

Denial Experiments

- Low resolution (C384) experiments are run to test various scenarios:
  1. All channels that rely on Ch.1 for cloud characterization are not assimilated.
  2. Channel 1 only is not assimilated (so assuming that an alternative cloud QC algorithm could be developed)
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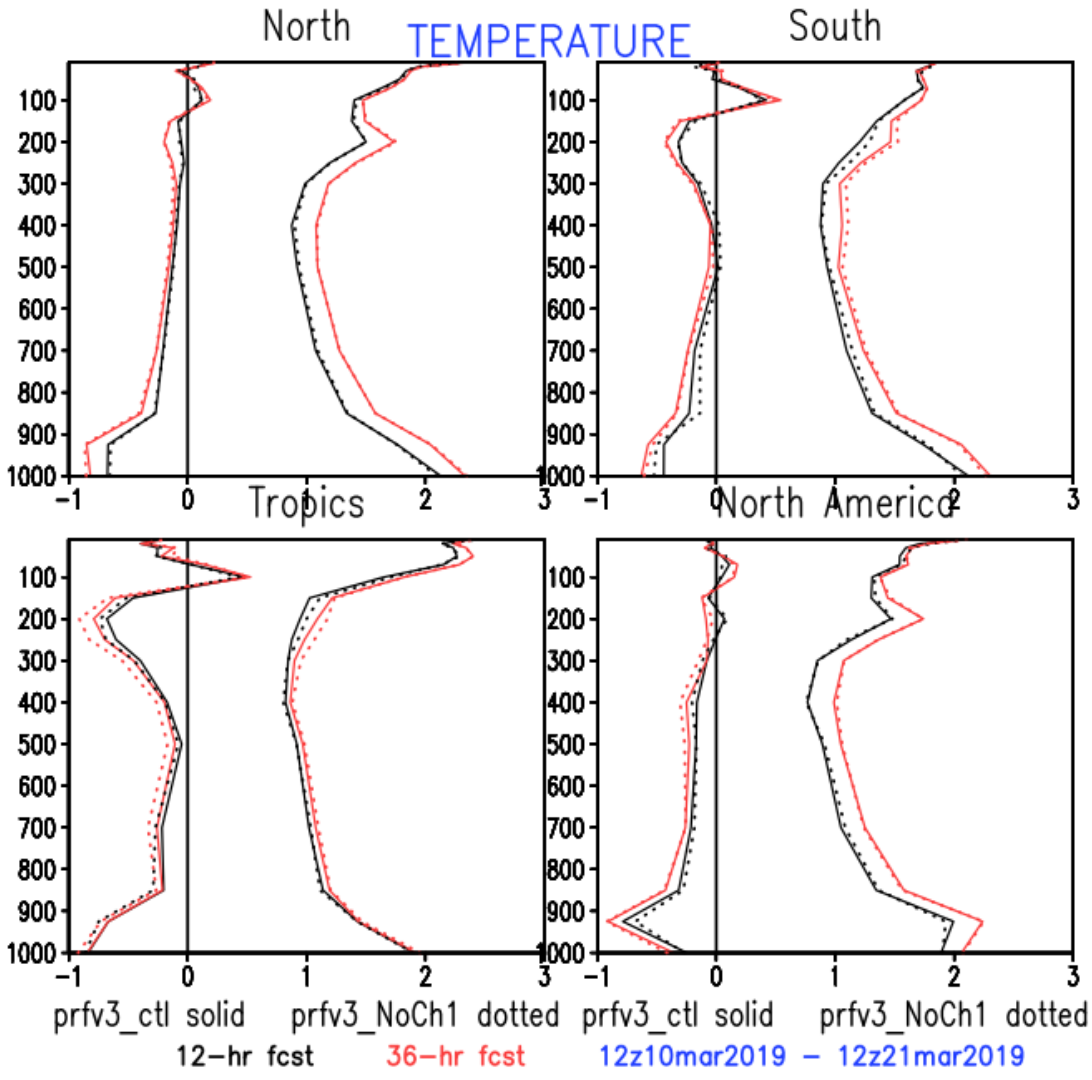
Temperature Fits to Radiosondes at 24 and 48hrs

24hour is in black
48hour is in red

Control is solid
Experiment is dotted



Humidity Fits to Radiosondes at 24 and 48hrs

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48hour is in red

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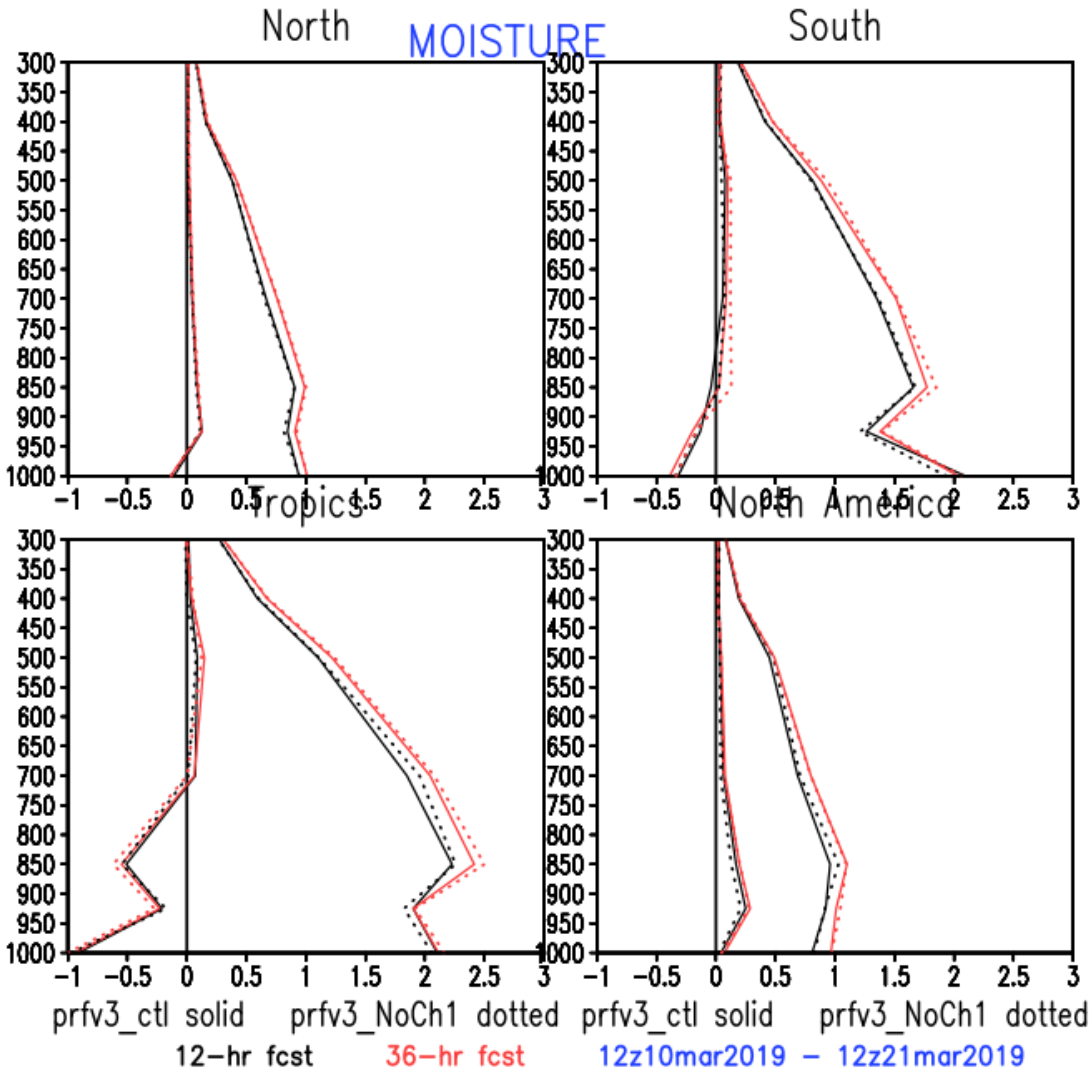

Vector Wind Fits to Radiosondes at 24 and 48hrs

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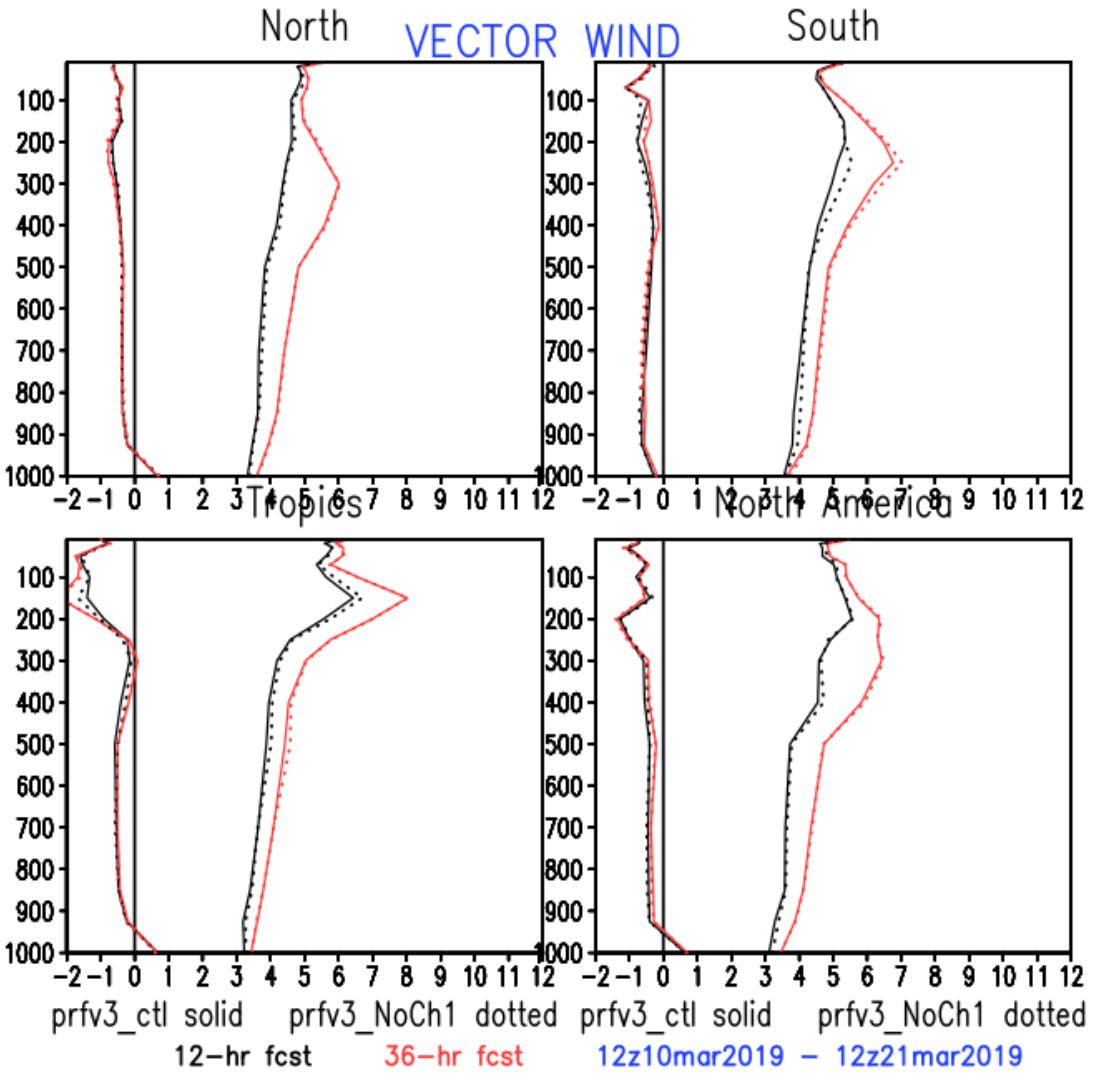
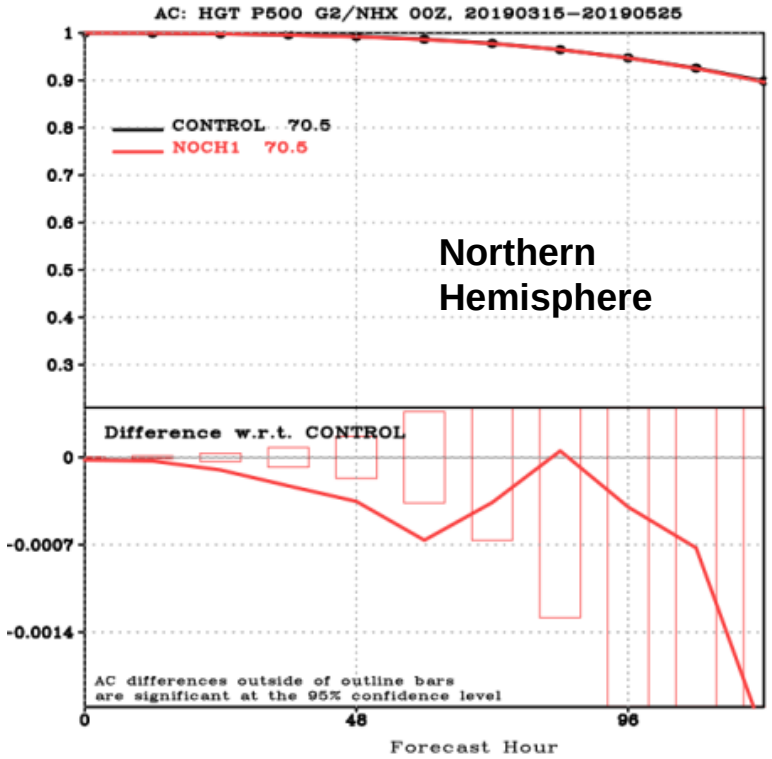
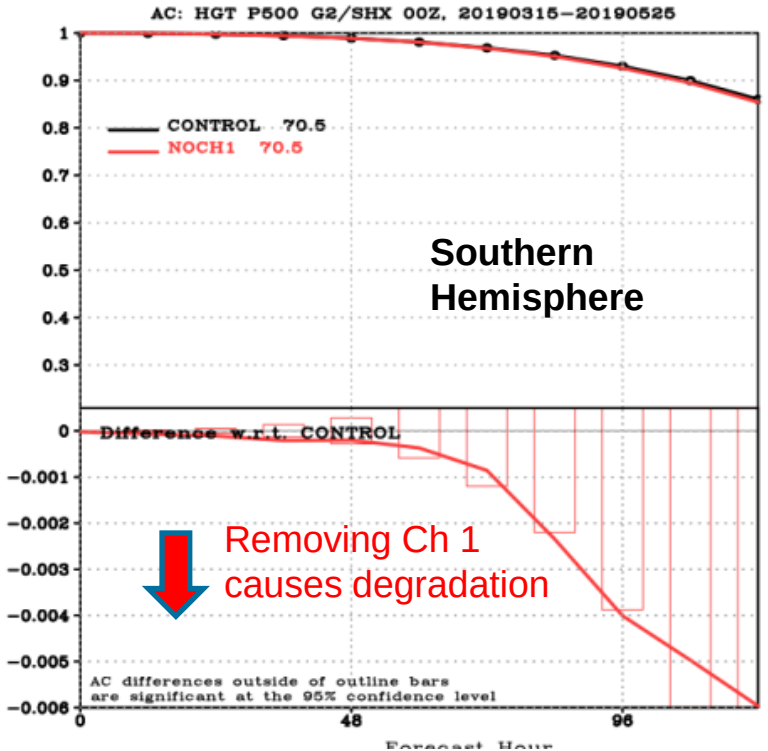
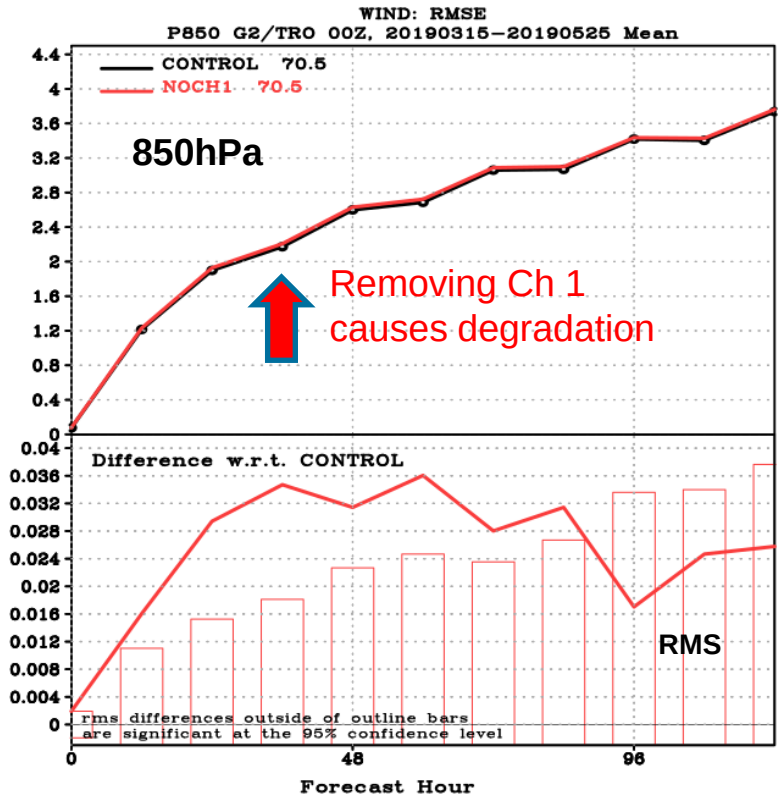


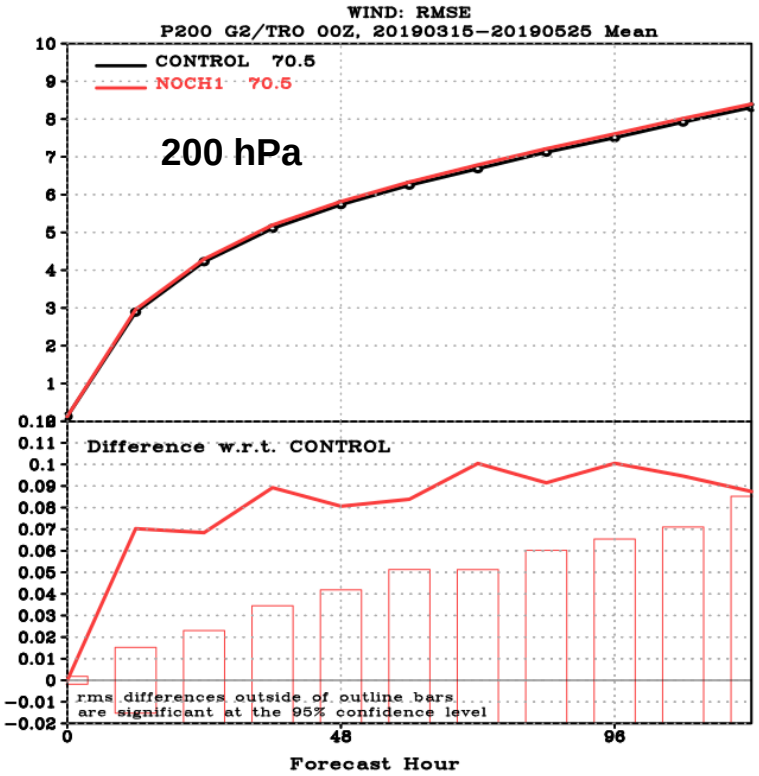
500hPa Geopotential Height Forecast Scores



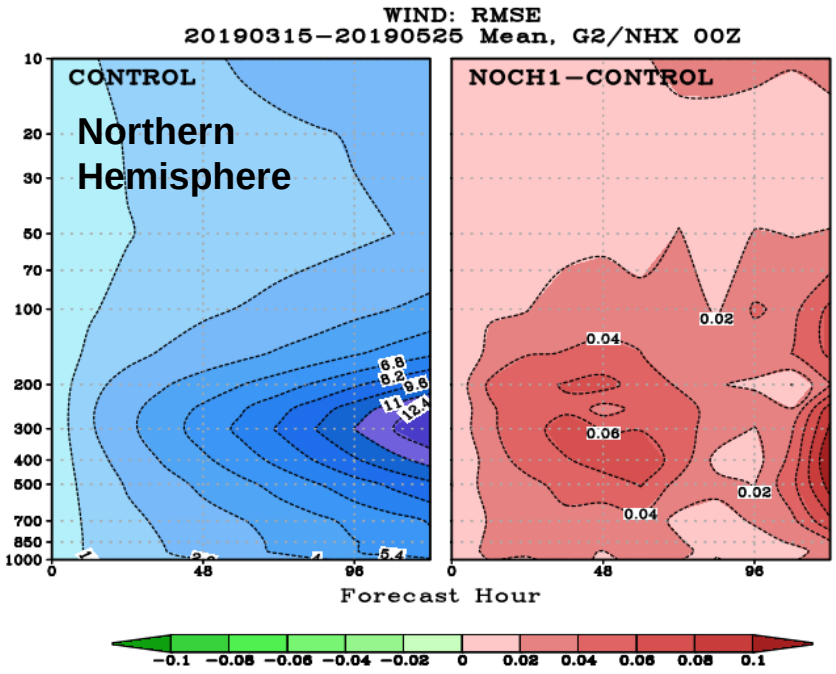


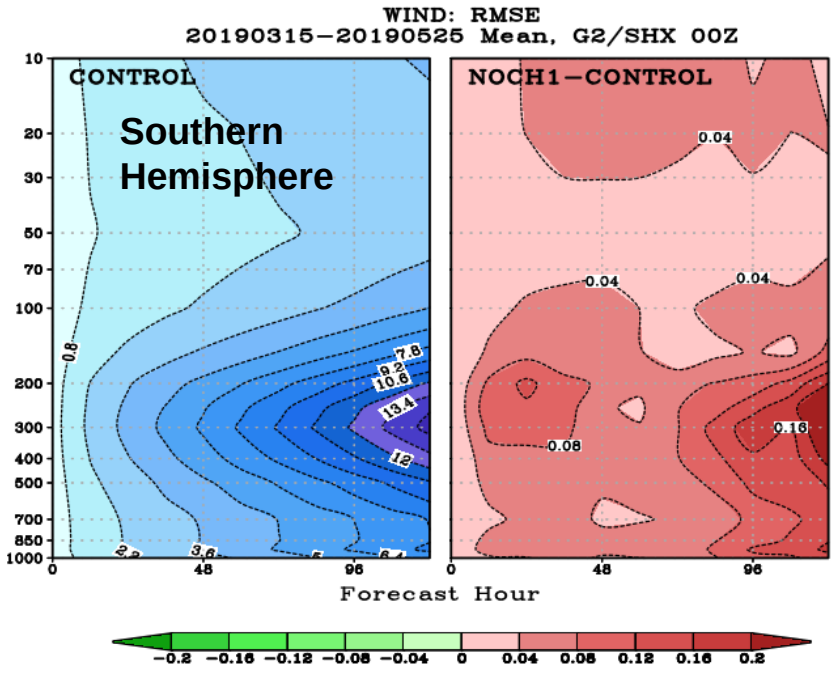
Tropical Wind Forecast Scores





Extra-Tropical Wind Forecast Scores





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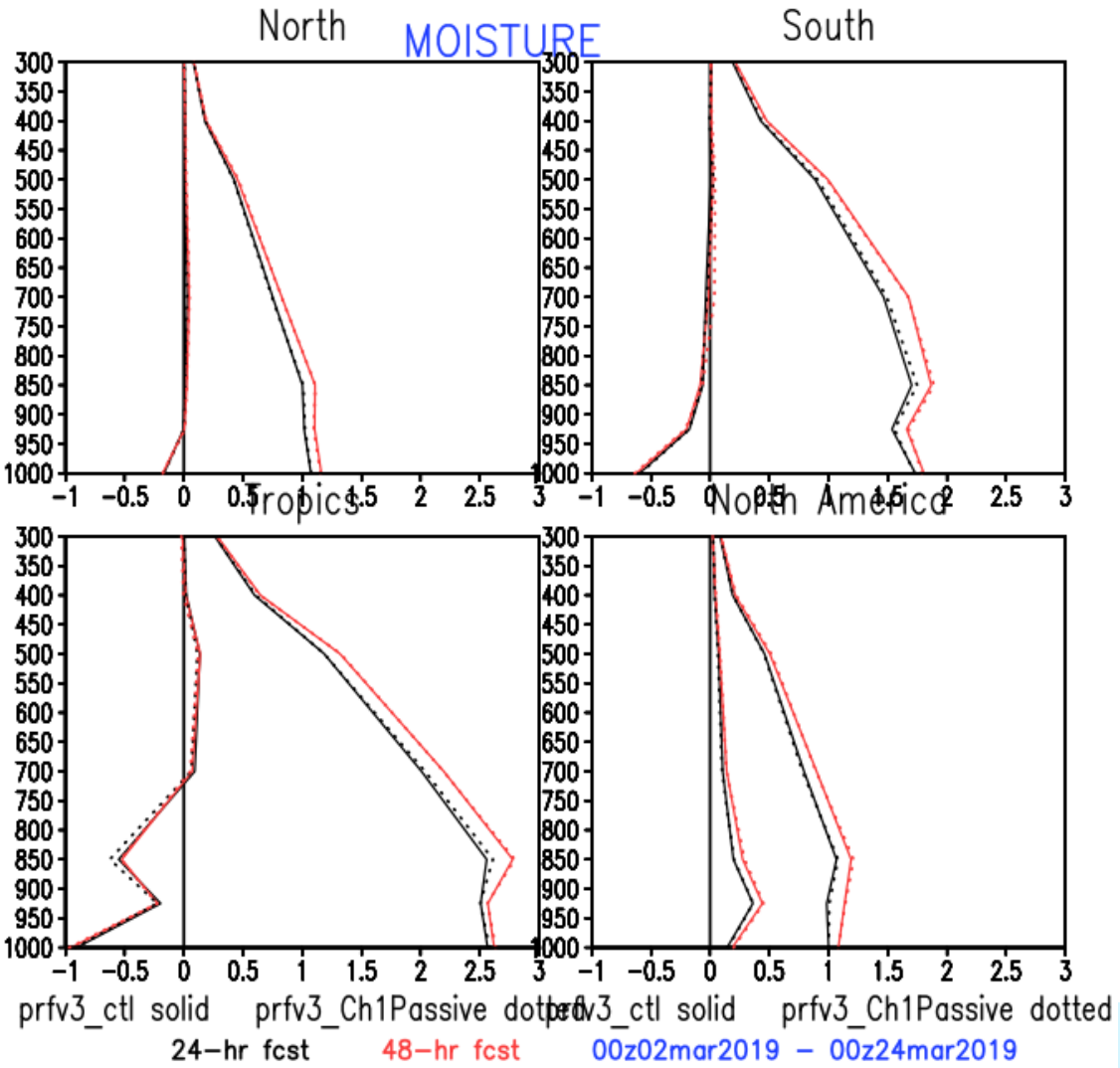

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The other experiment

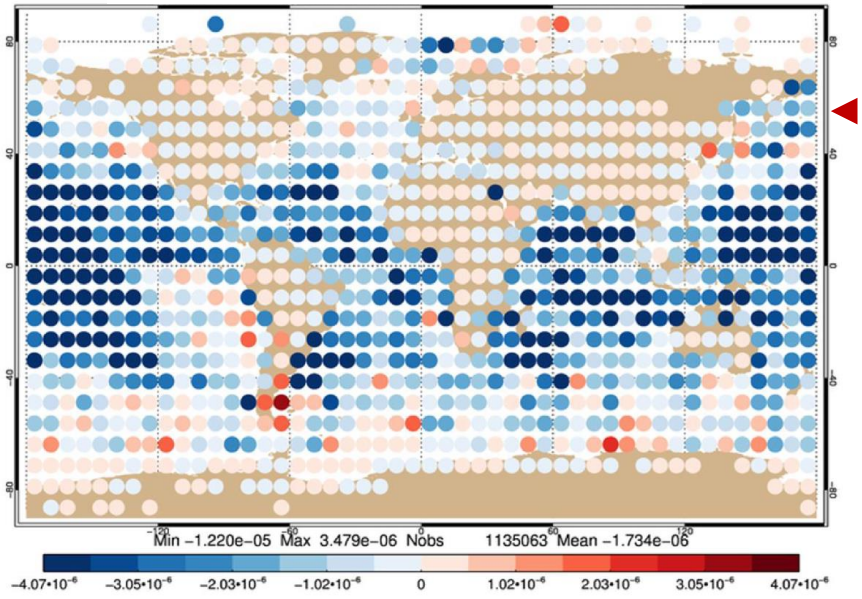
- Turning off channel 1 over land shows no noticeable degradation.

EFSIO

$\Delta e_t < 0$ Observation is beneficial

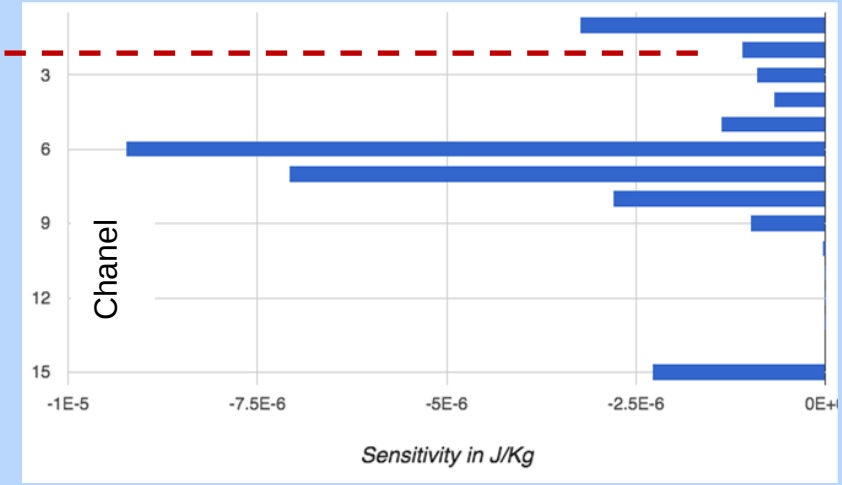
$\Delta e_t > 0$ Observation is detrimental

AMSU-A Channel 2 (7.5º x 7.5º)



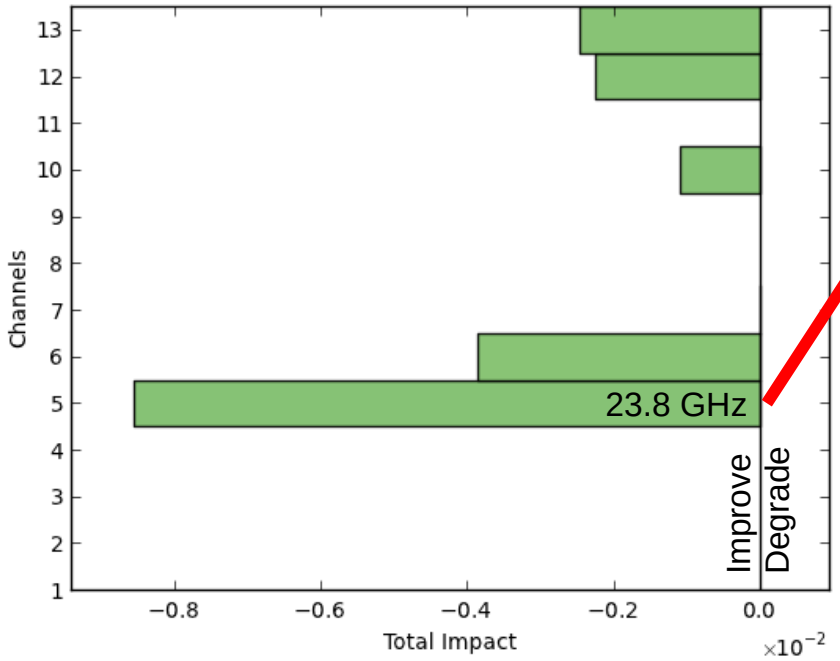
24-hr Forecast Error Reduction

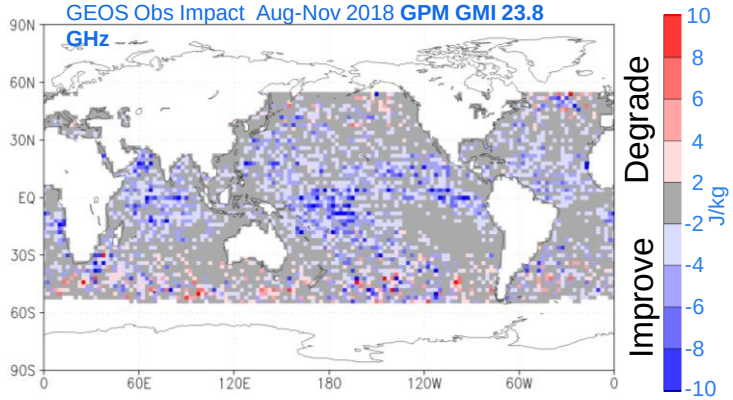
due to AMSU-A MetOp-B



The Impact of 23.8 GHz on 24 Hour Forecasts at GMAO

GPM Microwave Imager FSOI by Band
1 Aug – 30 Nov 2018





The spatial distribution of the impact shows the importance of 23.8 GHz to forecasting the tropics, as denoted by the broad blue regions

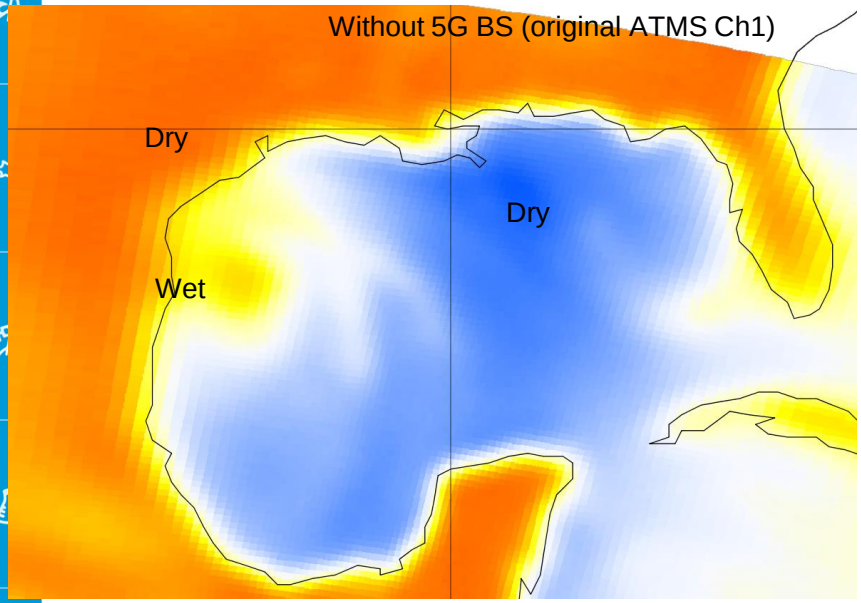
Will McCarty

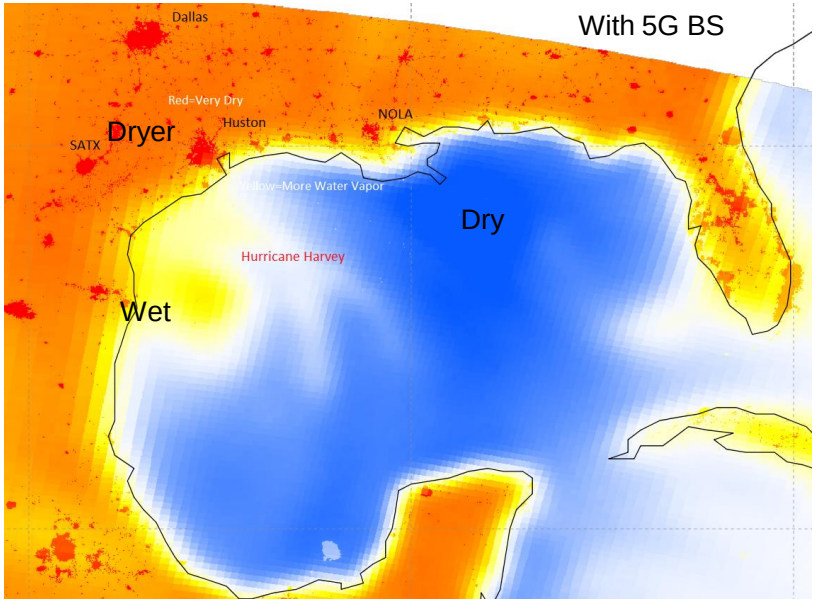
MiRS Retrievals

- NOAA/NESDIS operates the Microwave Integrated Retrieval System (MiRS), a one-stop shop for microwave products from various satellites with different instrumental configurations.
- MiRS makes use of 23GHz observations over land for various products.

ATMS Ch1 with and without 5G BS

-Simulation for the Hurricane Harvey Case





Over land: red=dryer; yellow=wet; Over ocean: blue=dry; yellow=wet

Cikanek and Cao

Water vapor in metropolitan areas will be significantly under-estimated due to unwanted 5G signals. As a result, ATMS Ch1 may show dry conditions in metropolitan areas (such as Houston), where in reality, there is a large amount of water vapor during a hurricane.

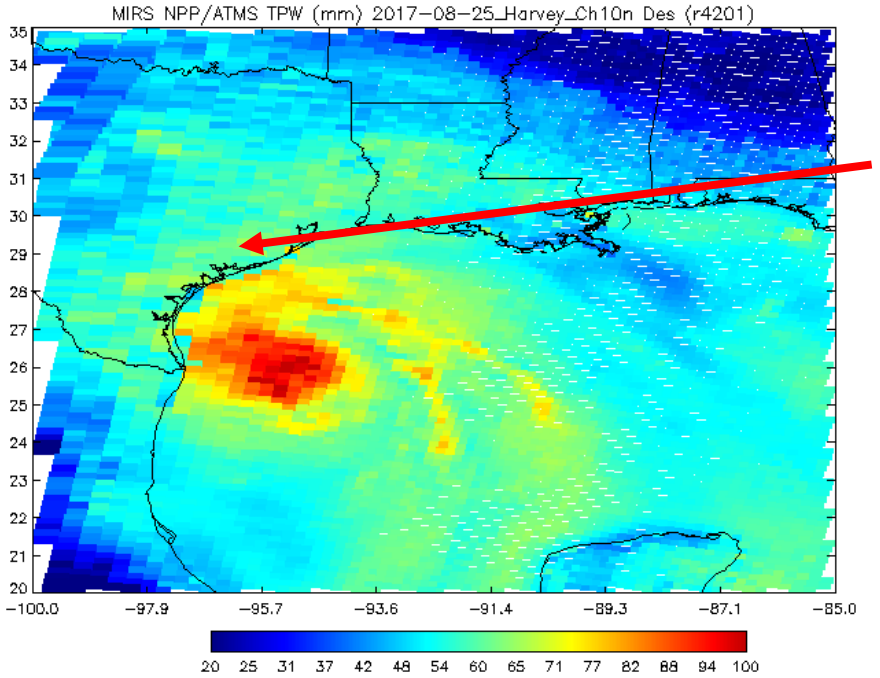
Impact of Losing ATMS Ch1

Hurricane Harvey MiRS TPW

August 25, 2017, Descending (Nighttime)

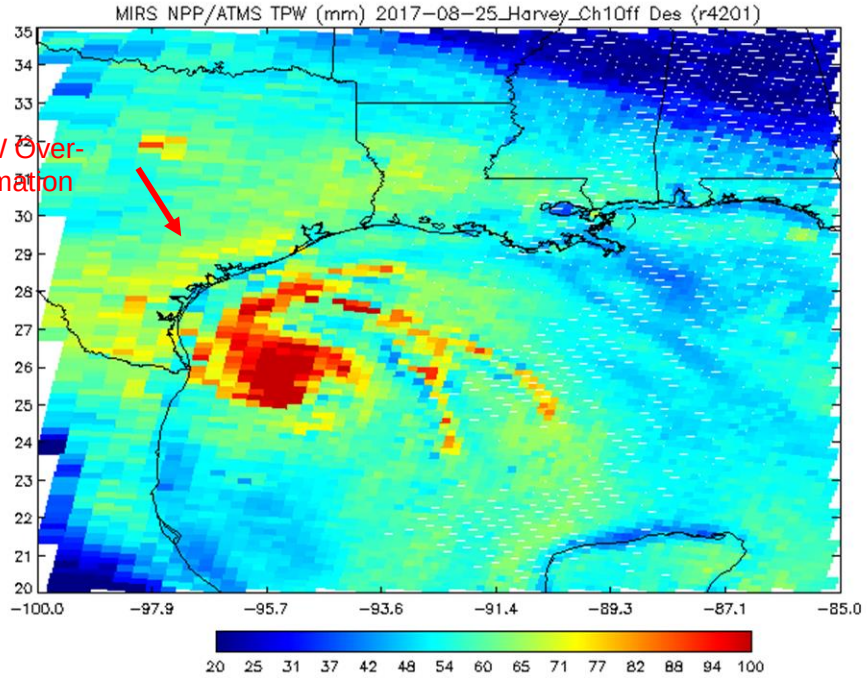
Cikanek and Cao

With ATMS ch 1



TPW Over-estimation

Without ATMS ch 1



Retrievals without ATMS Ch1 will lead to over-estimation of TPW over land

Impact of Losing ATMS Ch1

Hurricane Harvey MiRS TPW

August 25, 2017, Ascending (Daytime)

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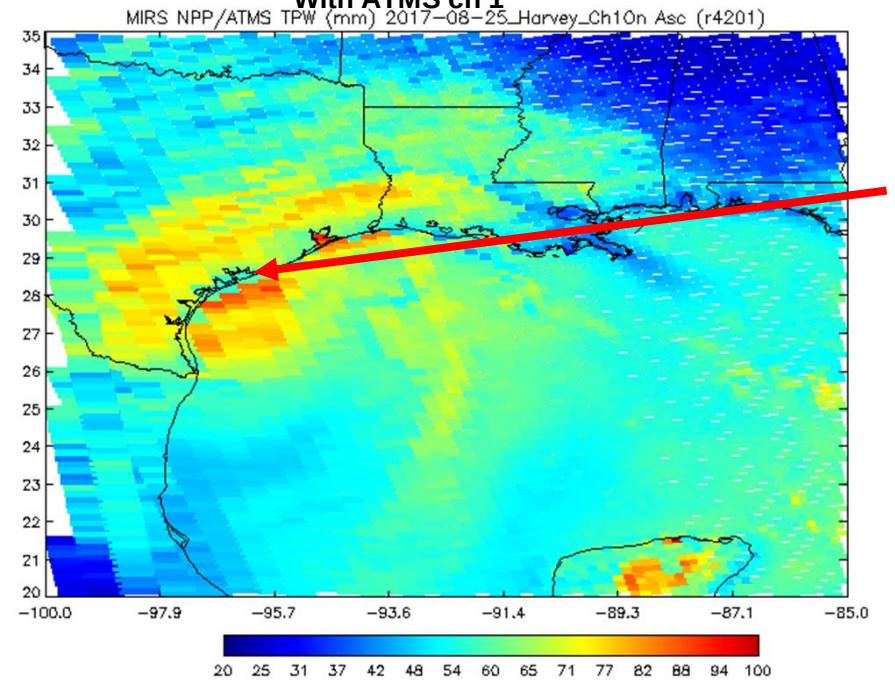
With ATMS ch 1



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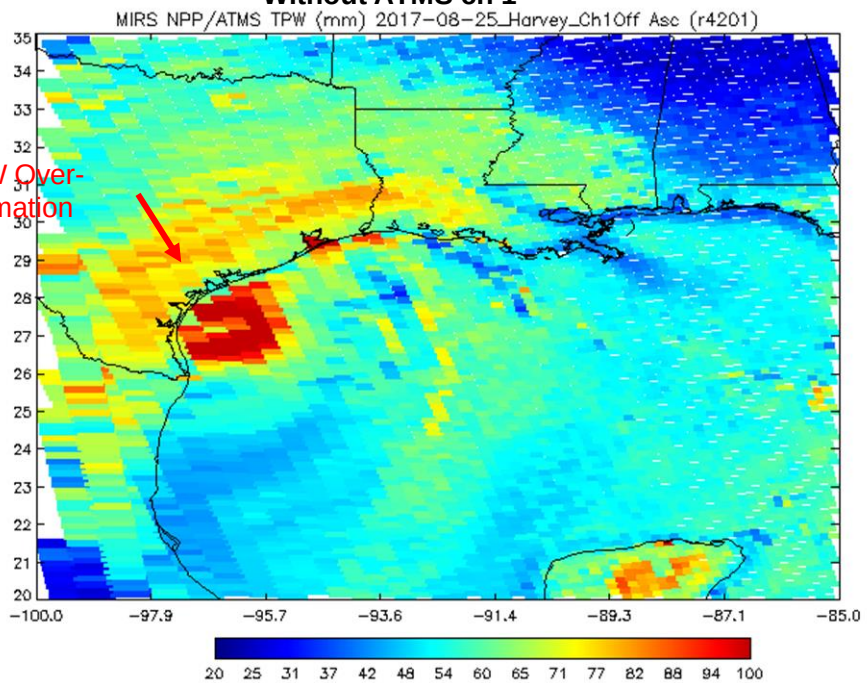
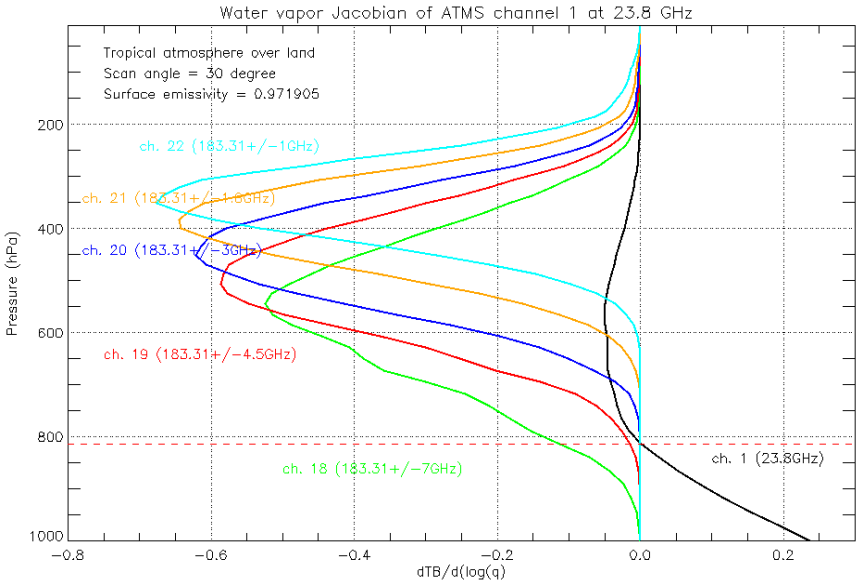


Retrievals without ATMS Ch1 will lead to over-estimation of TPW over land, with complex effect over ocean because this "window" channel is also used to detect ocean from land.

How Can Microwave Observations at 23.8 GHz Help in Acquiring Water Vapor in the Atmosphere over Land?

- The “nearly zero sensitivity” of the microwave 23.8 GHz channel to total precipitable water (TPW) over land could be misleading, because its “positive” sensitivity to the boundary layer and “negative” sensitivity to the layer above are canceled (see black line). 183 GHz channels have negative sensitivities to TPW
- The 23.8 GHz channel provides unique information to the moisture in the boundary layer.
- Together with temperature and other moisture sounding channels, this channel allows us to accurately retrieve water vapor profile, where TPW is just the integration of the water vapor profile.



Reference: Liu, Q.; Cao, C.; Grassotti, C.; Lee, Y.-K. How Can Microwave Observations at 23.8 GHz Help in Acquiring Water Vapor in the Atmosphere over Land? Remote Sens. 2021, 13, 489. https://doi.org/10.3390/rs13030489

NOAA-20 MiRS (Channel 1 turnoff) experiments for 26 April 2019 TPW CONUS compared to ECMWF

Ascending orbit

	Full channels				Chan1 missing			
	Clear		Cloudy		Clear		Cloudy	
	Land	Sea	Land	Sea	Land	Sea	Land	Sea
Bias (mm)	1.81	1.71	1.82	1.18	2.32	2.34	3.05	1.10
Std (mm)	3.57	2.20	3.40	2.75	4.12 (15.4%)	2.67 (21.4%)	4.47 (31.5%)	4.16 (51.3%)

Descending orbit

	Full channels				Chan1 missing			
	Clear		Cloudy		Clear		Cloudy	
	Land	Sea	Land	Sea	Land	Sea	Land	Sea
Bias (mm)	0.32	1.67	1.94	0.38	0.69	2.42	3.88	0.55
Std (mm)	3.09	2.25	2.94	2.07	3.54 (14.6%)	2.74 (21.8%)	4.10 (39.5%)	3.07 (48.3%)

Without channel 1 at 23.8 GHz, TPW retrieval will be degraded by 14% to 51%.

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Impact of Potential RFI on our system

- The 23GHz channels is currently used primarily over the ocean in NWP systems
- FSOI studies indicate that this is an important channel, especially for low-level humidity.
- Data denial experiments show a small degradation in low-level humidity when removing this channel over all surfaces for AMSU-A/ATMS.
- There is no measurable impact when it is only removed over land.
- Larger impact when removing channels requiring channel 1 for QC/obs error assignment are removed.
- But…

Our use of microwave radiances is constantly improving

- The importance of microwave radiances continues to increase
- A decade ago microwave radiances affected by cloud were not used.
- Now most NWP centers have all-sky capability, but often limited to the ocean.
- The move towards coupled modelling and ever-improved radiative transfer will dramatically improve the use of these observations over non-oceanic surfaces.

Thank You!