CICS Science Conference

November 29 – December 1, 2016

Impacts of AHI Radiance Assimilation on Quantitative Precipitation Forecasts over Eastern China

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Outline

- A Brief Description of Data Assimilation
- Infrared Only Cloud Detection
- Bias Estimate over Ocean and Land
- Impacts of AHI Data Assimilation on QPFs
- Summary and Conclusions
- Future Work

What are Important for Satellite Data Assimilation?

- Cloud Detection
- Bias Estimate

Clear Radiance

$$J(\mathbf{x}) = \frac{1}{2}(\mathbf{x}-\mathbf{x}_b)^T \mathbf{B}^{-1}(\mathbf{x}-\mathbf{x}_b) + \frac{1}{2}(H(\mathbf{x}) - \mathbf{y}^{obs} - \mu)^T (\mathbf{O}+\mathbf{F})^{-1}(H(\mathbf{x}) - \mathbf{y}^{obs} - \mu)$$

$$J(\mathbf{x}_a) = \min_{\mathbf{x}} J(\mathbf{x}) \quad \forall \mathbf{x} \text{ near } \mathbf{x}_b$$

$<$——— Maximum likelihood Estimate

$\mathbf{x}$ – analysis variable

$\mathbf{x}_a$ – final analysis

$\mathbf{x}_b$ – background

$\mathbf{B}$ – background error covariance

μ — bias

$\mathbf{y}^{obs}$ – observations

$\mathbf{O}$ – observation error covariance

H – observation operator

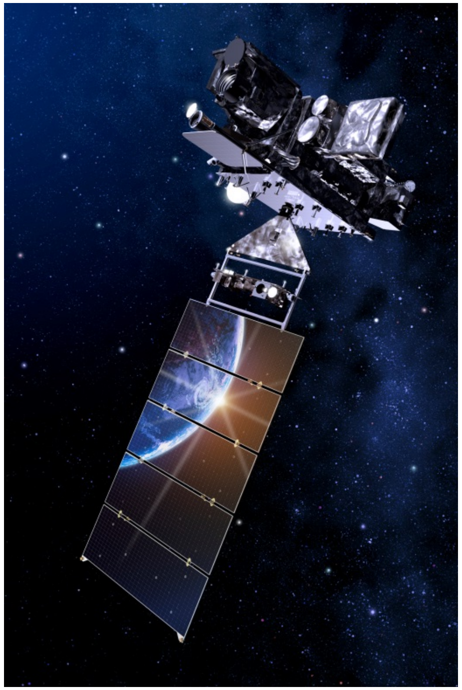
$\mathbf{F}$ – forward model error covariance

The success of satellite DA of any instruments requires the science of satellite data be effectively integrated into a DA system and the results from the DA system be carefully analyzed and interpreted.

GOES-13/15 Imager, GOES-R ABI and Himawari-8 AHI

GOES-13/15

GOES-R



Launched on November 19, 2016

Himawari-8/-9

Himawari-8: Launched on October 7, 2014
Himawari-9: Launched on November 2, 2016

5 channels:
- 1 visible channel
- 4 infrared channels

16 channels:
- 6 visible and NIR channels
- 10 infrared channels

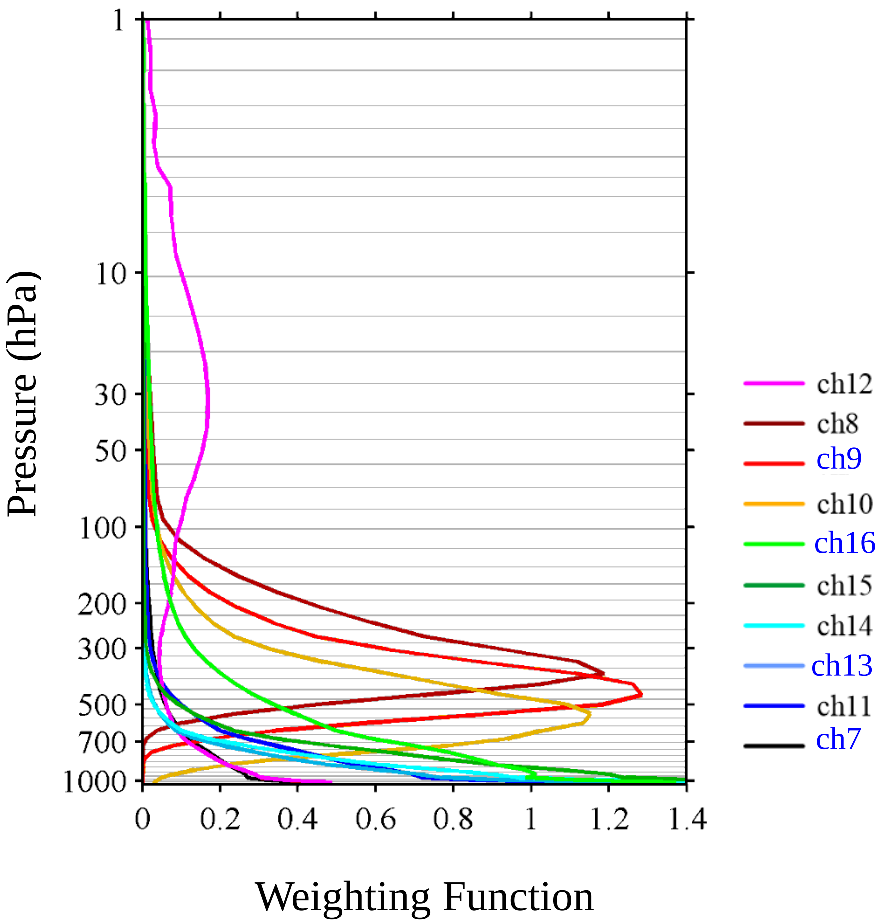
16 channels:
- 6 visible and NIR channels
- 10 infrared channels

ABI, AHI to Imager Channel Frequency Comparison

ABI #	ABI Freq. (μm)	AHI #	AHI Freq. (μm)	GOES #	GOES Freq. (μm)
1	0.47	1	0.47	1	0.65
2	0.64	2	0.51		
3	0.865	3	0.64		
4	1.378	4	0.86		
5	1.61	5	1.60		
6	2.25	6	2.30		
7	3.90	7	3.90	2	3.90
8	6.185	8	6.20		
9	6.95	9	6.90	3	6.55
10	7.34	10	7.30		
11	8.50	11	8.60		
12	9.61	12	9.60		
13	10.35	13	10.40		
14	11.20	14	11.20	4	10.70
15	12.30	15	12.40	5	12.0
16	13.30	16	13.30	6	13.35

Himawari-8 AHI Infrared Channels 7-16 for DA

Channel Number	Central Wavelength	Contribution
7	3.9 µm	Atmospheric windows
8	6.2 µm	Water Vapor
9	6.9 µm	
10	7.3 µm	
11	8.6 µm	SO_2
12	9.6 µm	O_3
13	10.4 µm	Atmospheric windows
14	11.2 µm	
15	12.4 µm	
16	13.3 µm	CO_2



AHI channels 7, 9, 13 and 16 are similar to GOES imager channels 2, 3, 4 and 6.

http://www.data.jma.go.jp/mscweb/en/himawari89/space_segment/spsg_ahi.html

A Modified Infrared Only ABI Cloud Mask Algorithm

Ten Cloud Mask (CM) Tests

1. Relative Thermal Contrast Test (RTCT)
2. Emissivity at Tropopause Test (ETROP)
3. Positive Fourteen Minus Fifteen Test (PFMFT)
4. Negative Fourteen Minus Fifteen Test (NFMFT)
5. Relative Fourteen Minus Fifteen Test (RFMFT)
6. Cirrus Water Vapor Test (CIRH2O)
7. Modified Uniform Low Stratus test (M-ULST)
8. Temporal Infrared Test (TEMPIR)

adopted from the ABI CM algorithm (*Heidinger and Straka III* 2013)

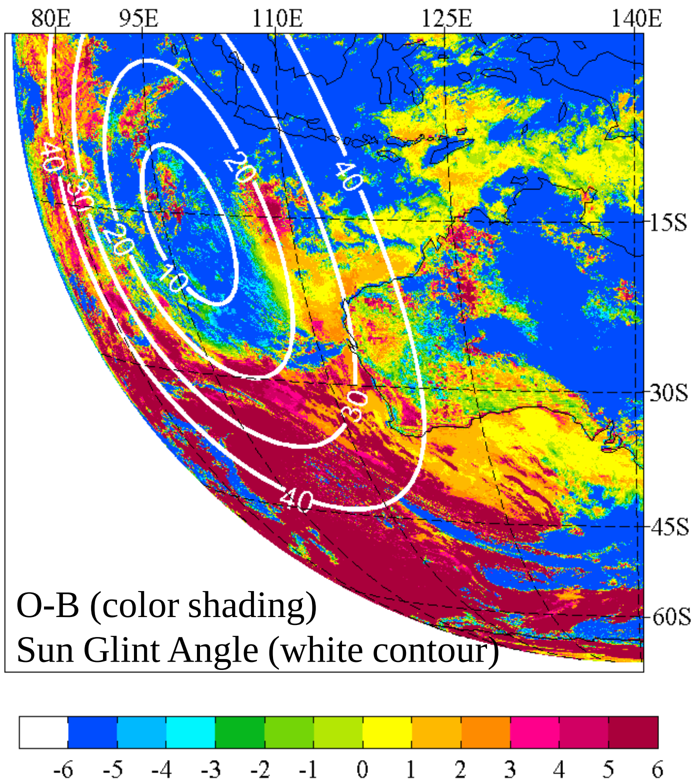
9. Modified 4 μm Emissivity Test (M-EMISS4)
10. New Optically Thin Cloud Test (N-OTC)

newly added CM

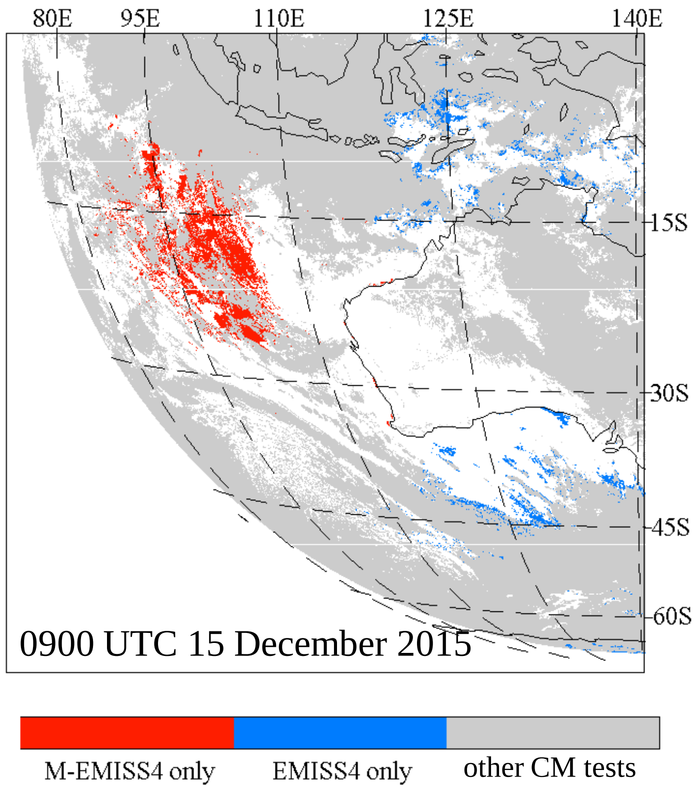
Zhuge, X. and X. Zou, 2016:Test of a modified infrared only ABI cloud mask algorithm for AHI radiance observations. *J. App. Meteor. Climatol.*, **55**, 2529-2546. doi: 10.1175/JAMC-D-16-0254.1.

Modified 4 μm Emissivity Test (M-EMISS4)

Channel 7



Cloudy Pixels

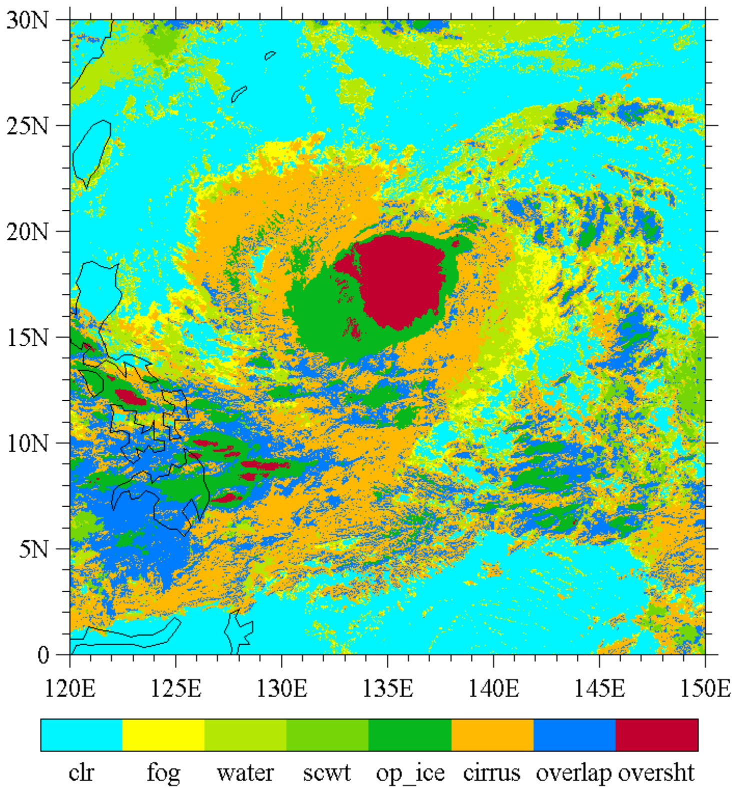


An area populated with cloudy pixels was successfully identified by M-EMISS4 over a sun-glint area located to the west of Australia at 0900 UTC 15 December 2015.

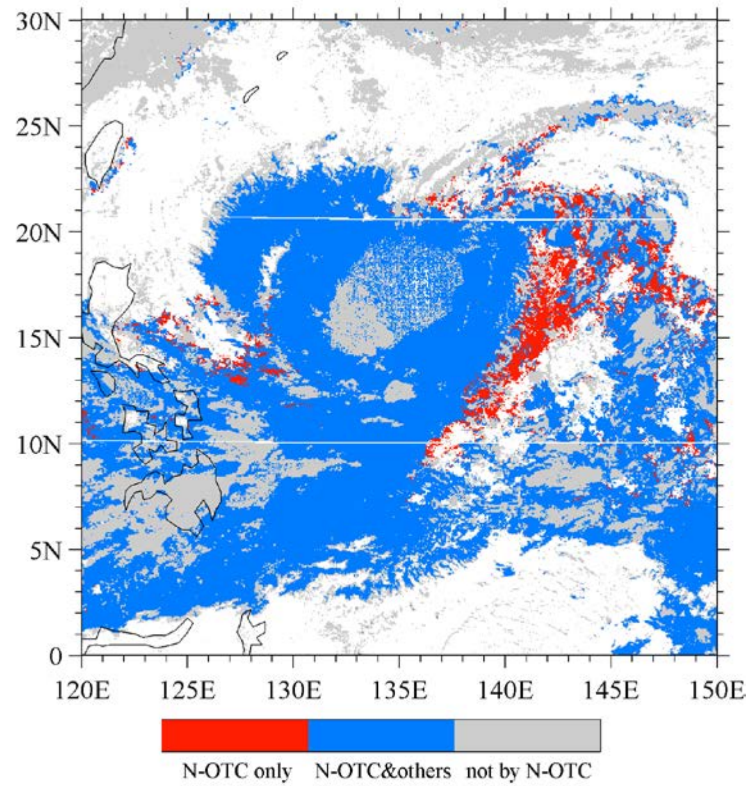
Modified 4 μm Emissivity Test (M-EMISS4)

Typhoon Dujuan (2015)

Cloud Types



The New N-OTC CM Test



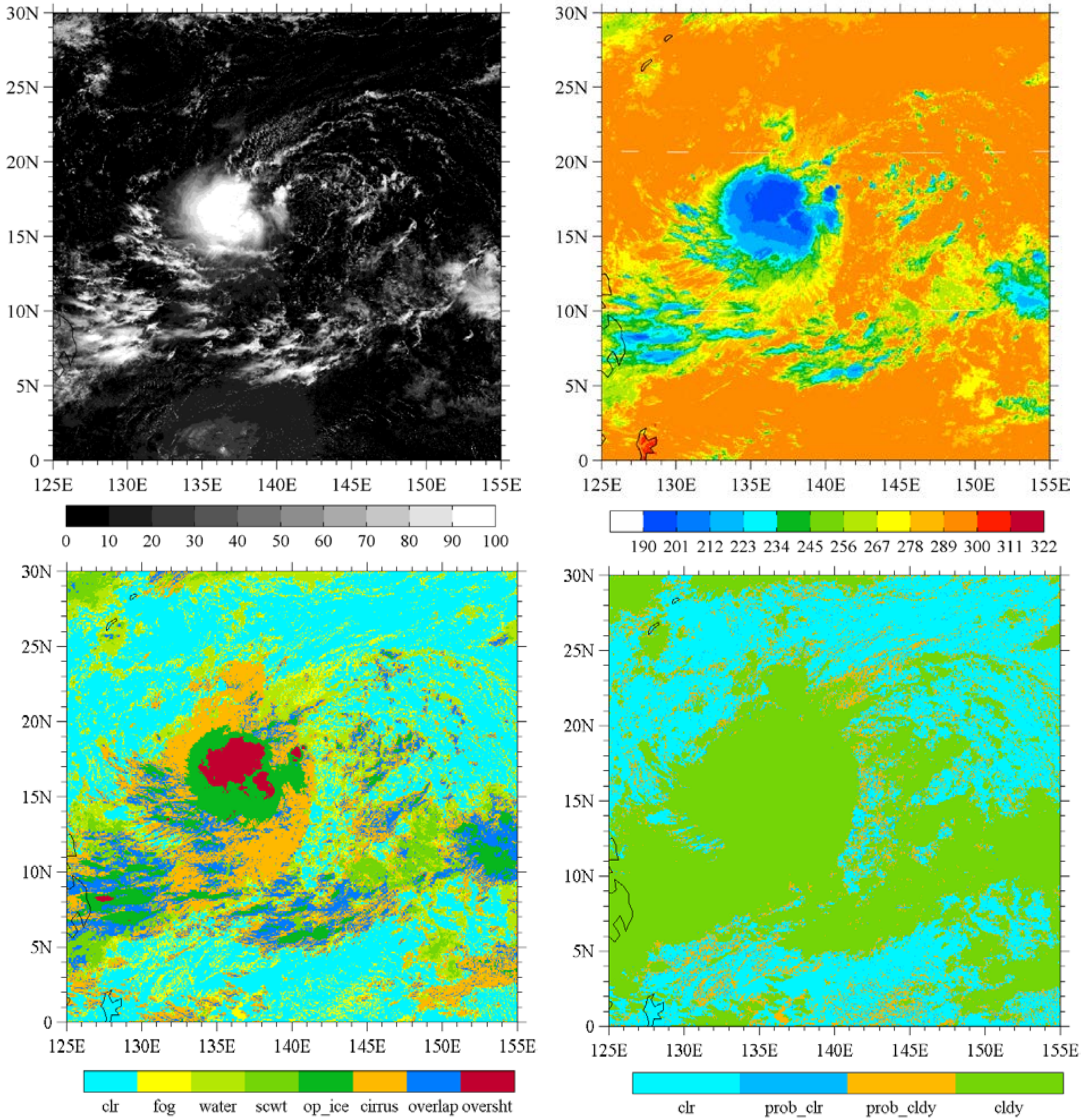
1500 UTC
22
September
2015

Optically thin clouds (cirrus, fog) are successfully flagged as cloudy by the newly added nighttime N-OTC CM test.

A Snapshot of AHI Observations at 0300 UTC 22 September 2015

Albedo$_{ch3}$ (0.64 μm)

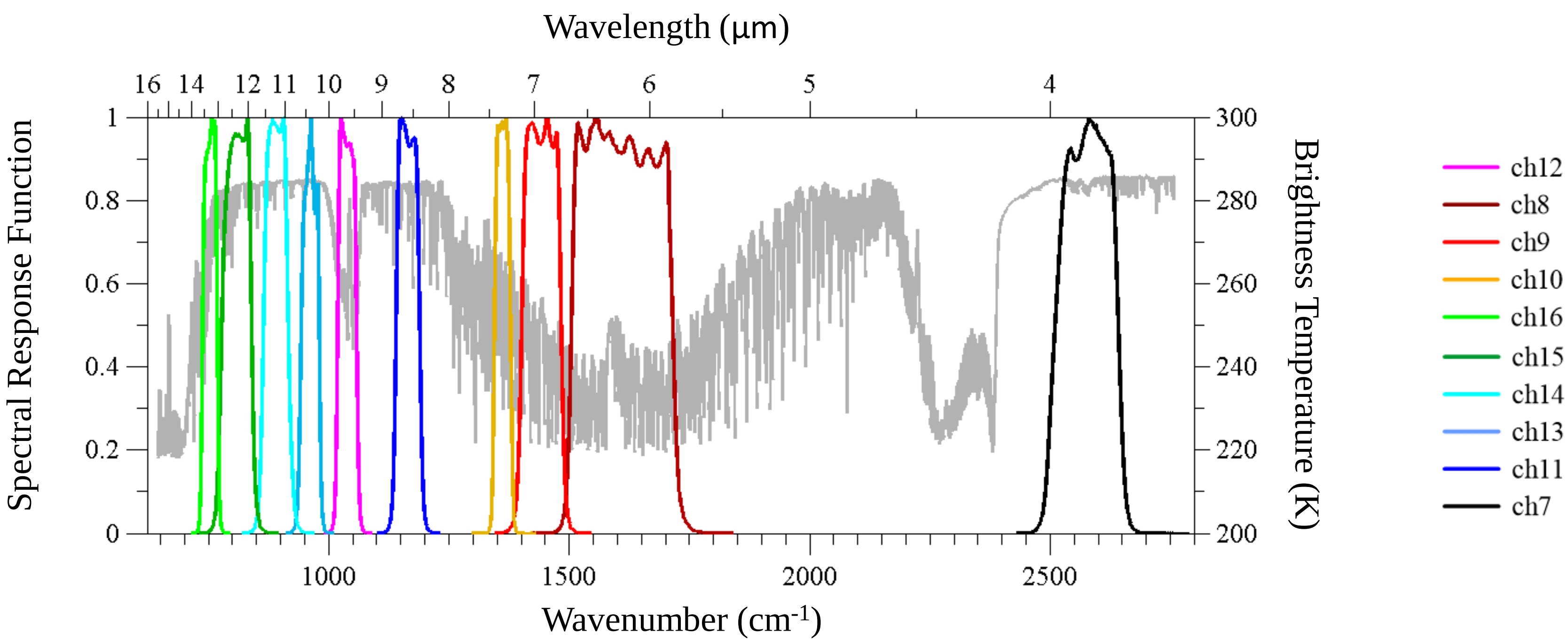
T$_{b,ch14}$ (11.2 μm)



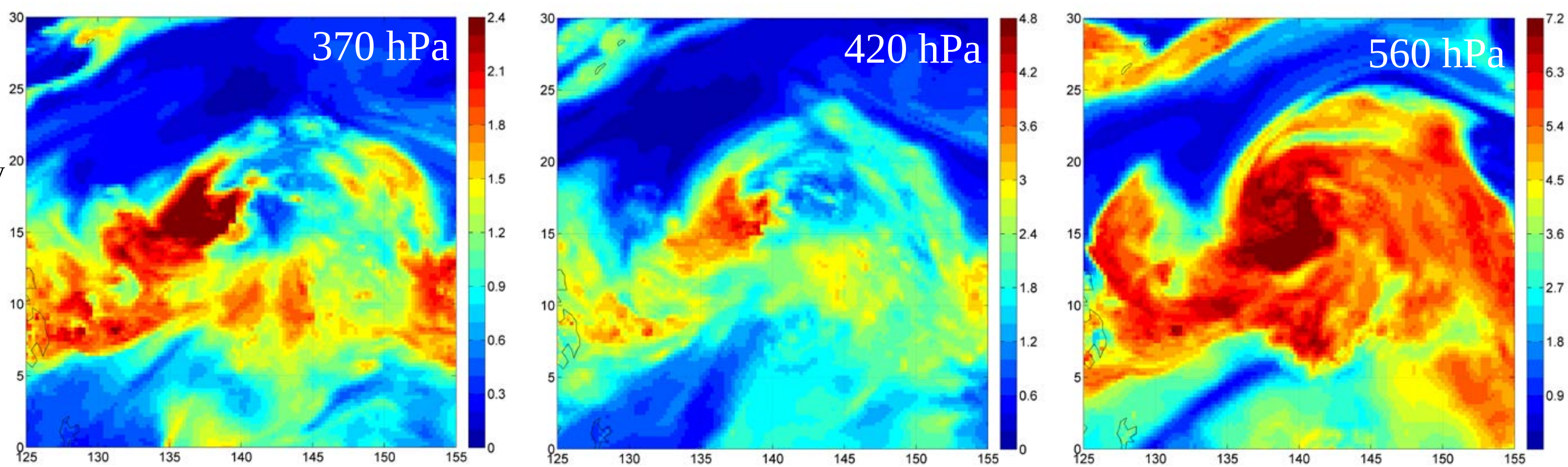
Cloud Types

Clear-sky AHI pixels

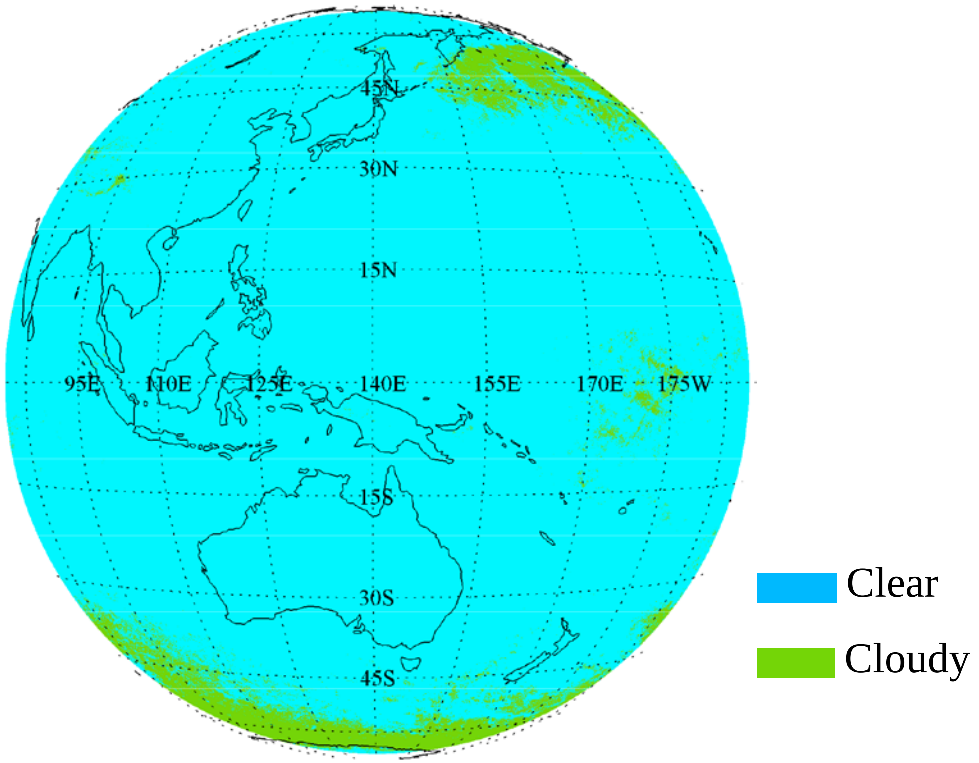
AHI Spectral Response Functions and ECMWF Specific Humidity



Specific humidity



Spatial Coverage of Clear-sky AHI Pixels and Biases



- ECMWF analysis

  Six hourly (0300, 0900, 1500, 2100 UTC)

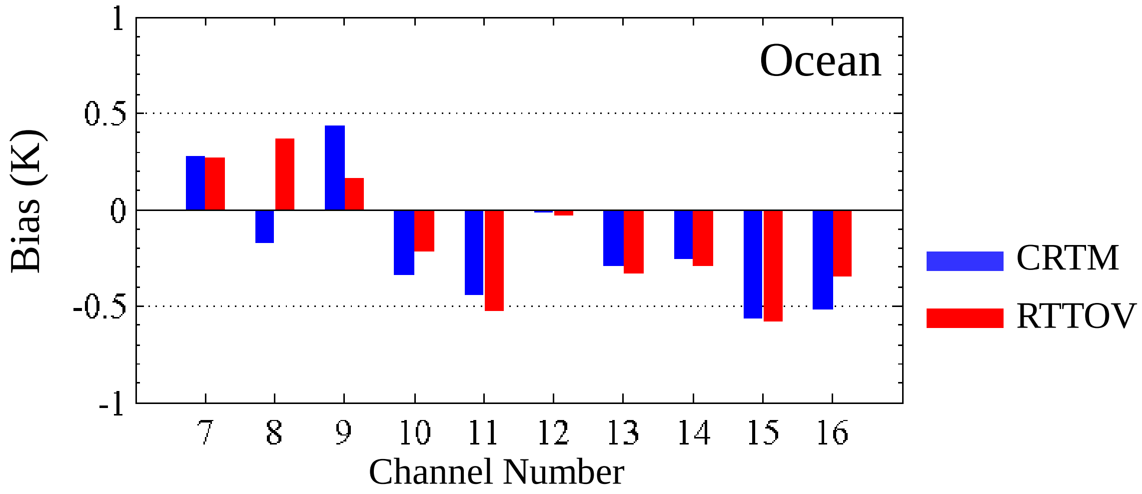
  Horizontal resolution: 0.25°x0.25°

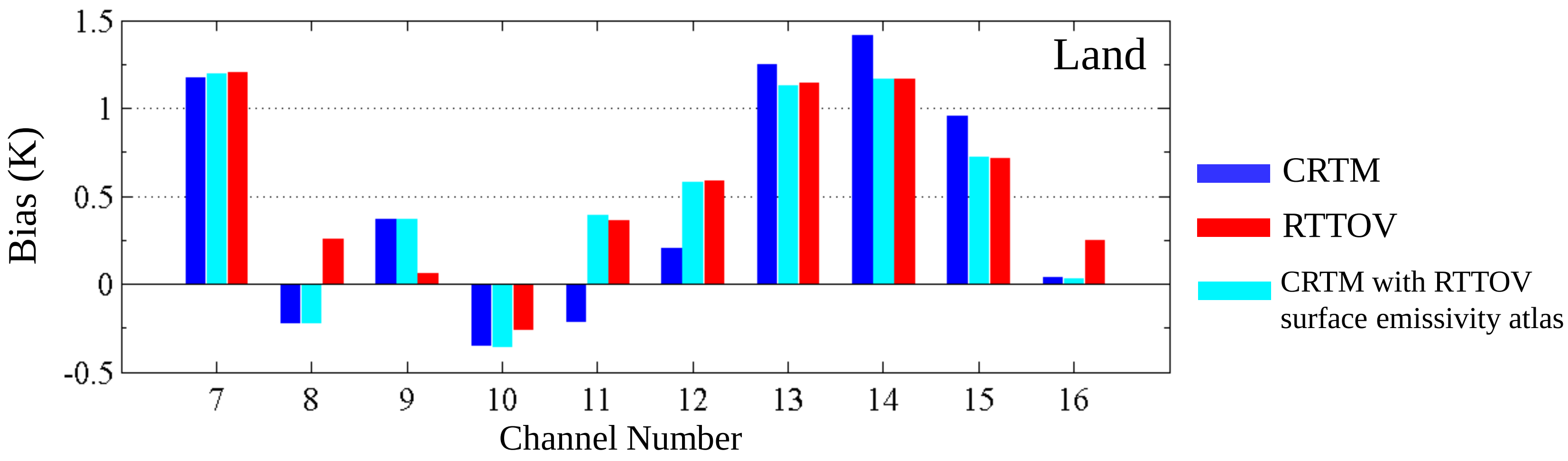
- AHI 10-minutes, 2-km data on

  22-24 September 2015 | 20-22 March 2016

  15-17 December 2015 | 5 - 7 June 2016

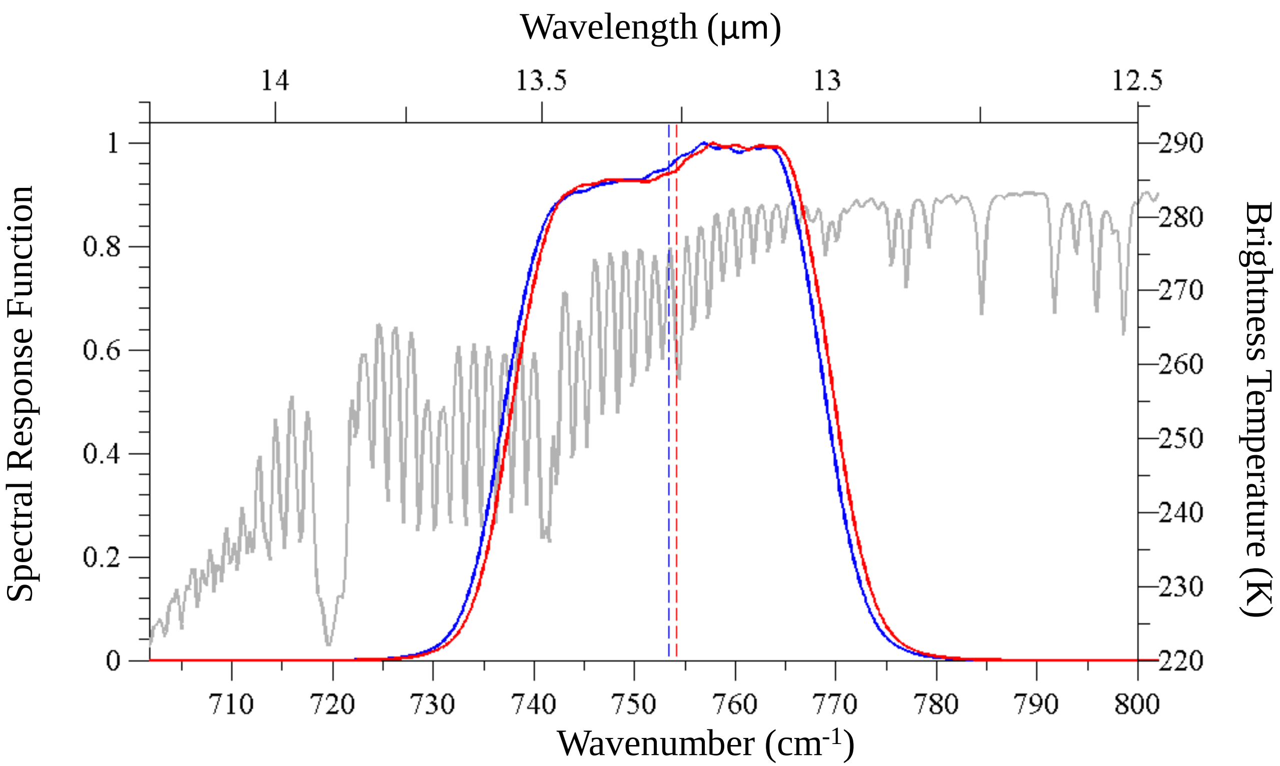
Spatial Coverage of Clear-sky AHI Pixels and Biases





Zou, X., X. Zhuge, and F. Weng, 2016: Characterization of bias of Advanced Himawari Imager infrared observations from NWP background simulations using CRTM and RTTOV. *J. Ocean Atmos. Tech.*, **33**, 2553-2567.

Impact of Spectral Response Function on Channel 16 Bias

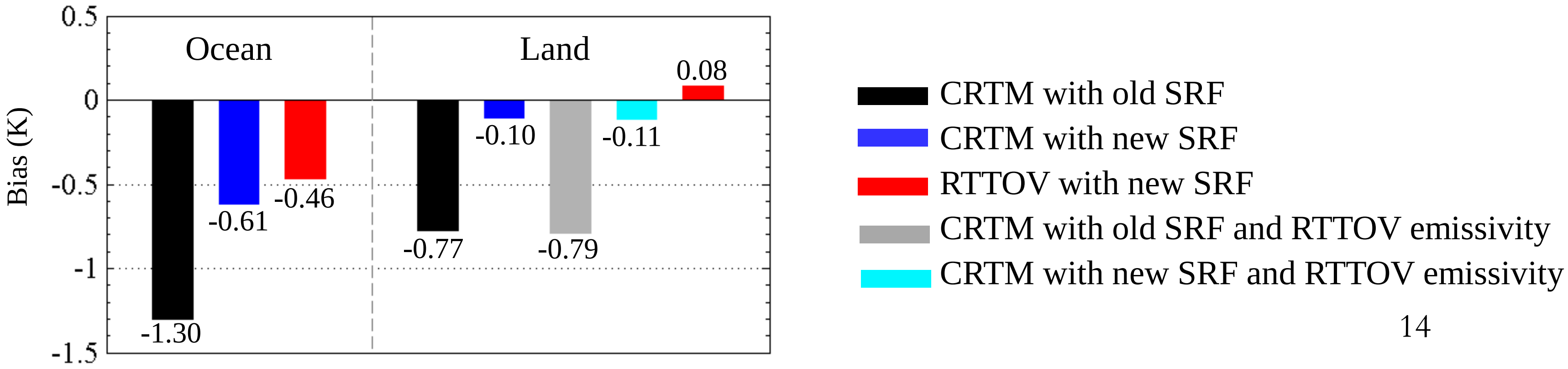


The center frequency of channel 16 was shifted after launch.

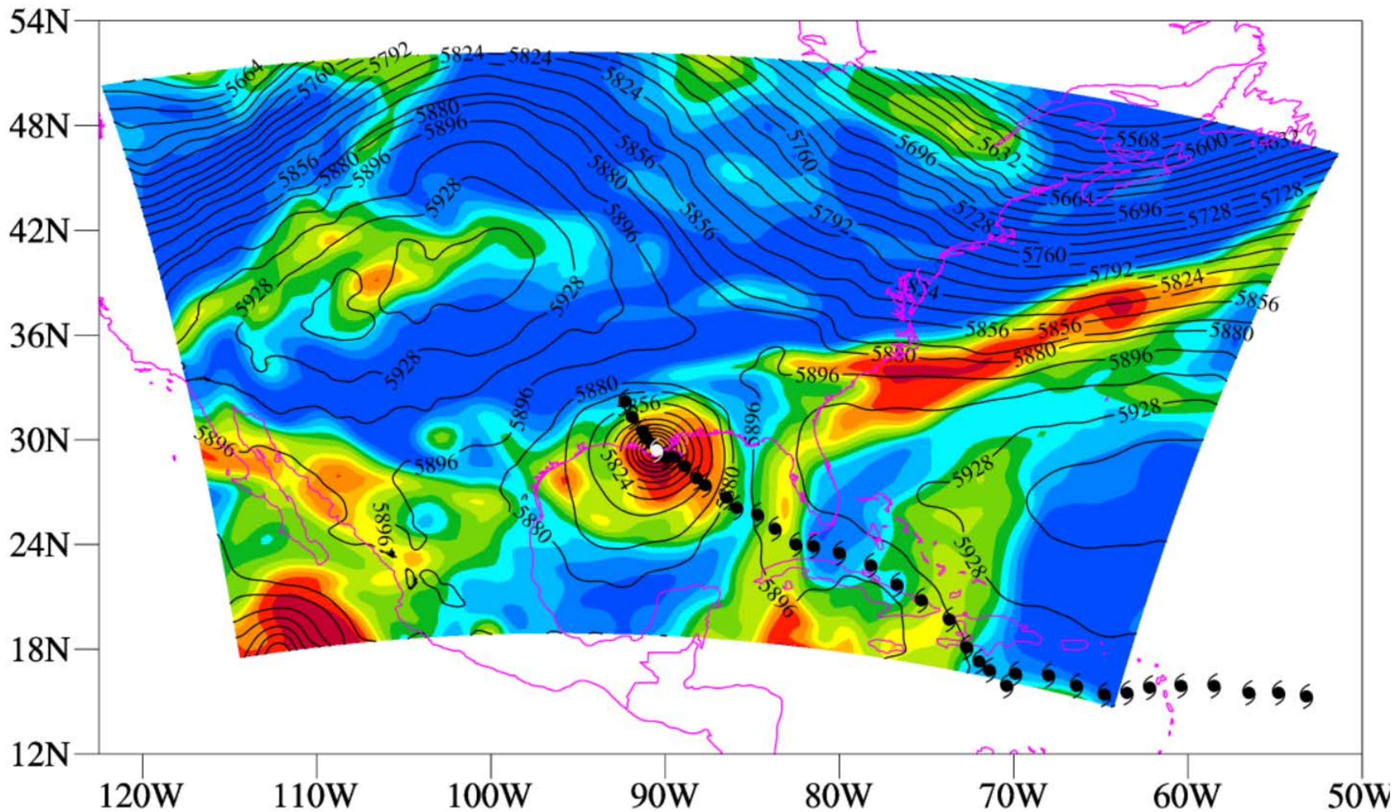
Old =754.13 cm^{-1}

New=753.37 cm^{-1}

New – Old = -0.72 cm^{-1}

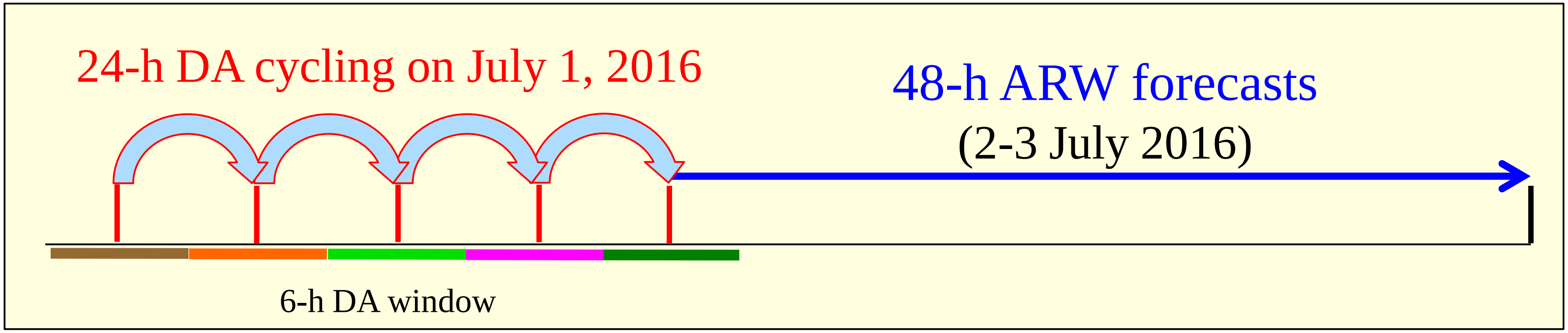


Model Domain and DA Cycling

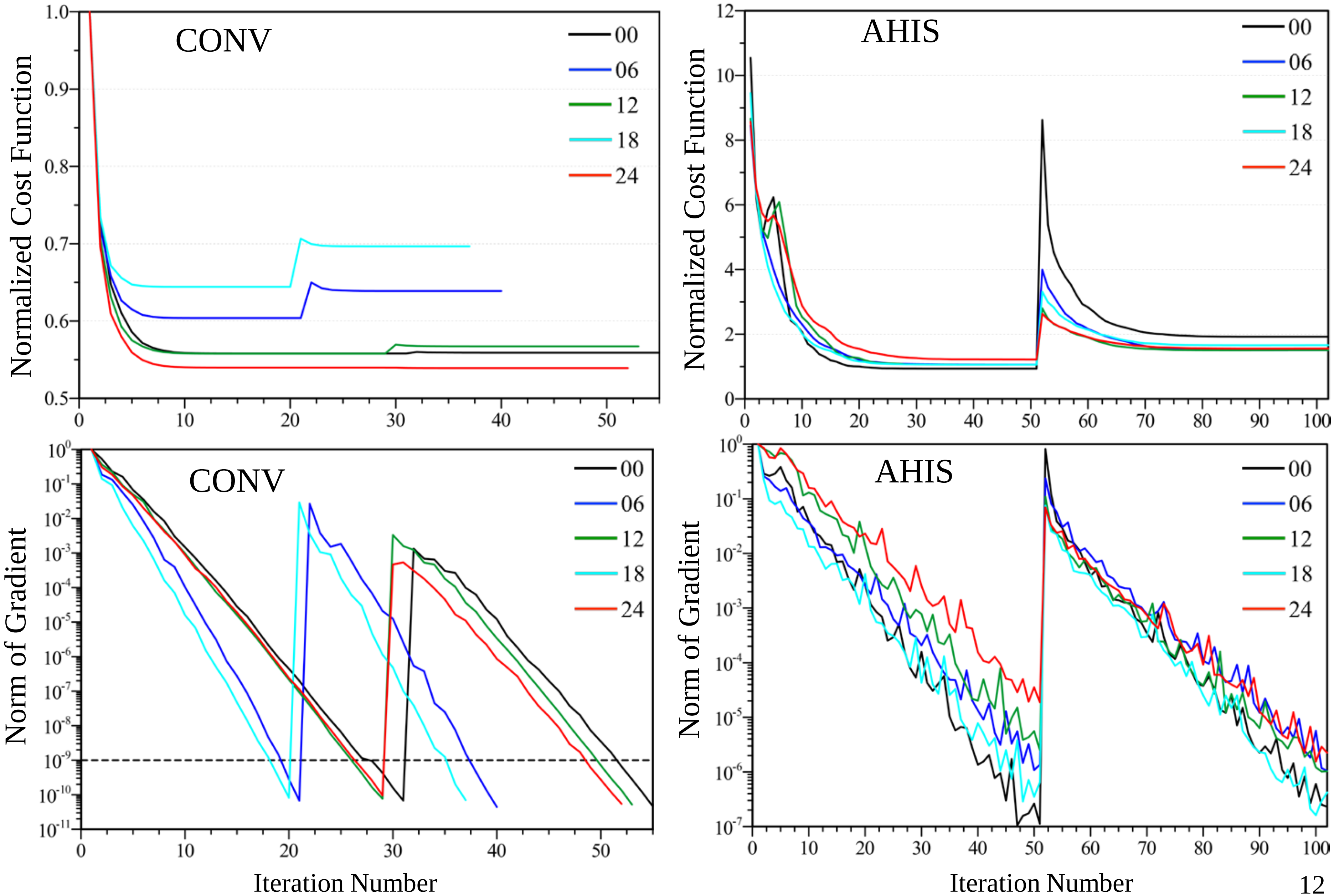


500 hPa
Geopotential
Relative humidity
0000 UTC 02/07/16

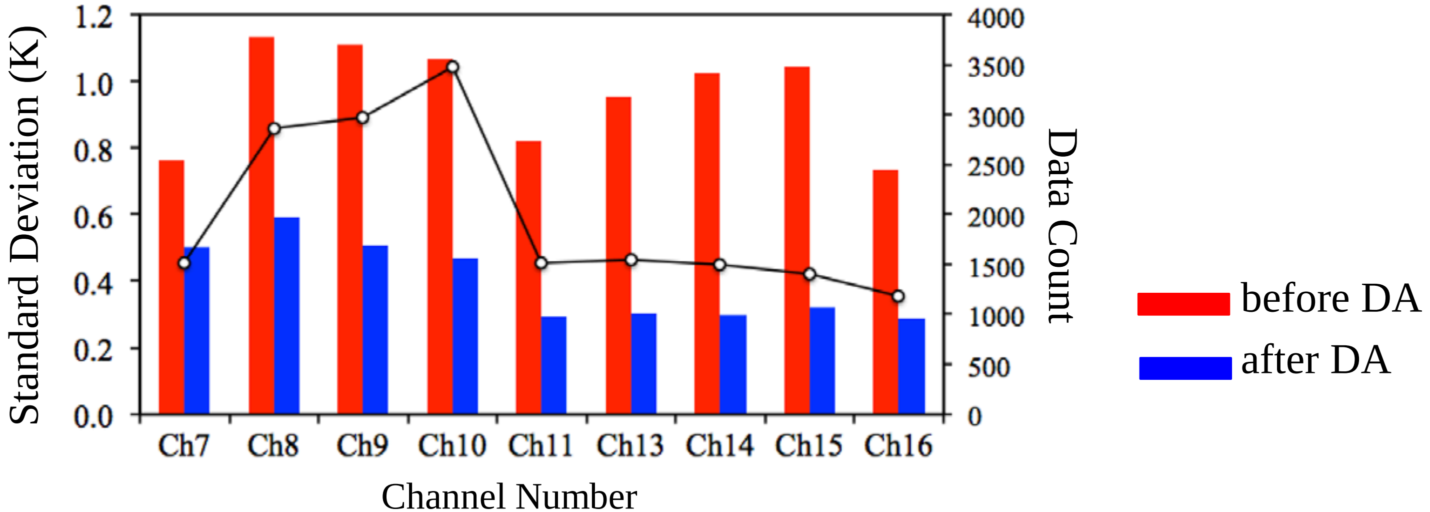
15 km resolution
Grid size: 400x250x43
Model top: 50 hPa
LBC: NCEP FNL
AHI thinning: 75 km

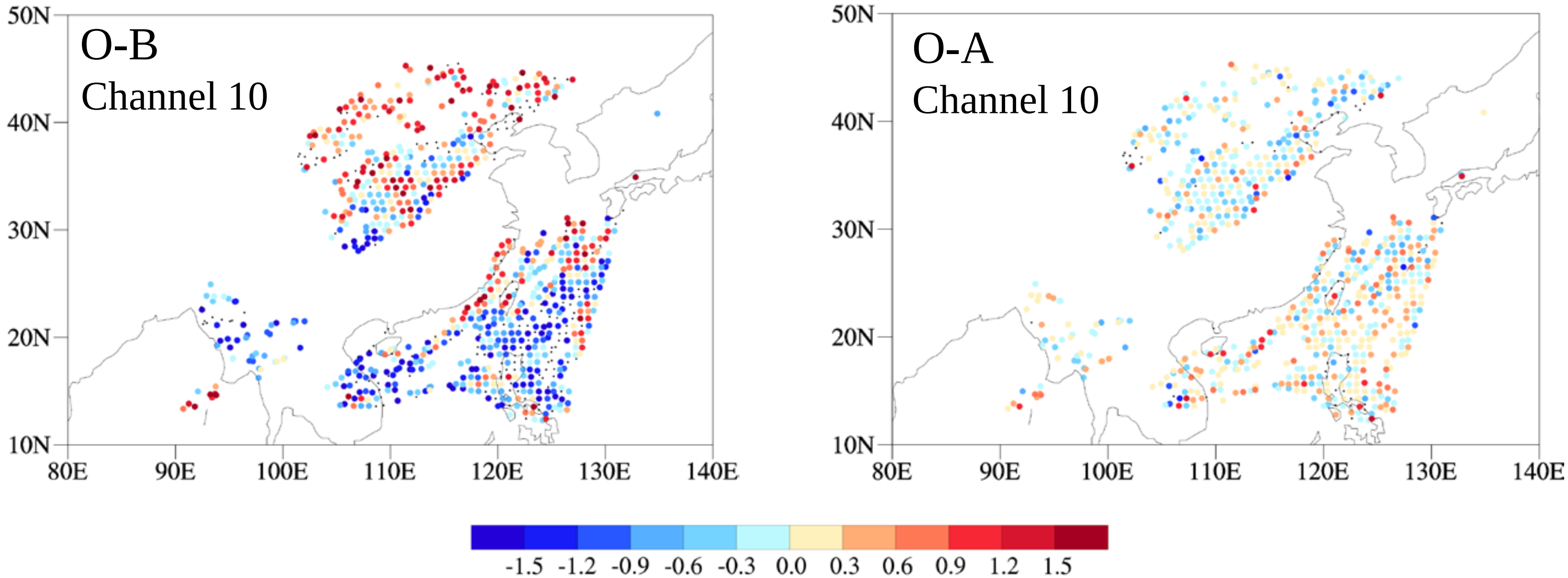


Convergence of AHI Data Assimilation Minimization



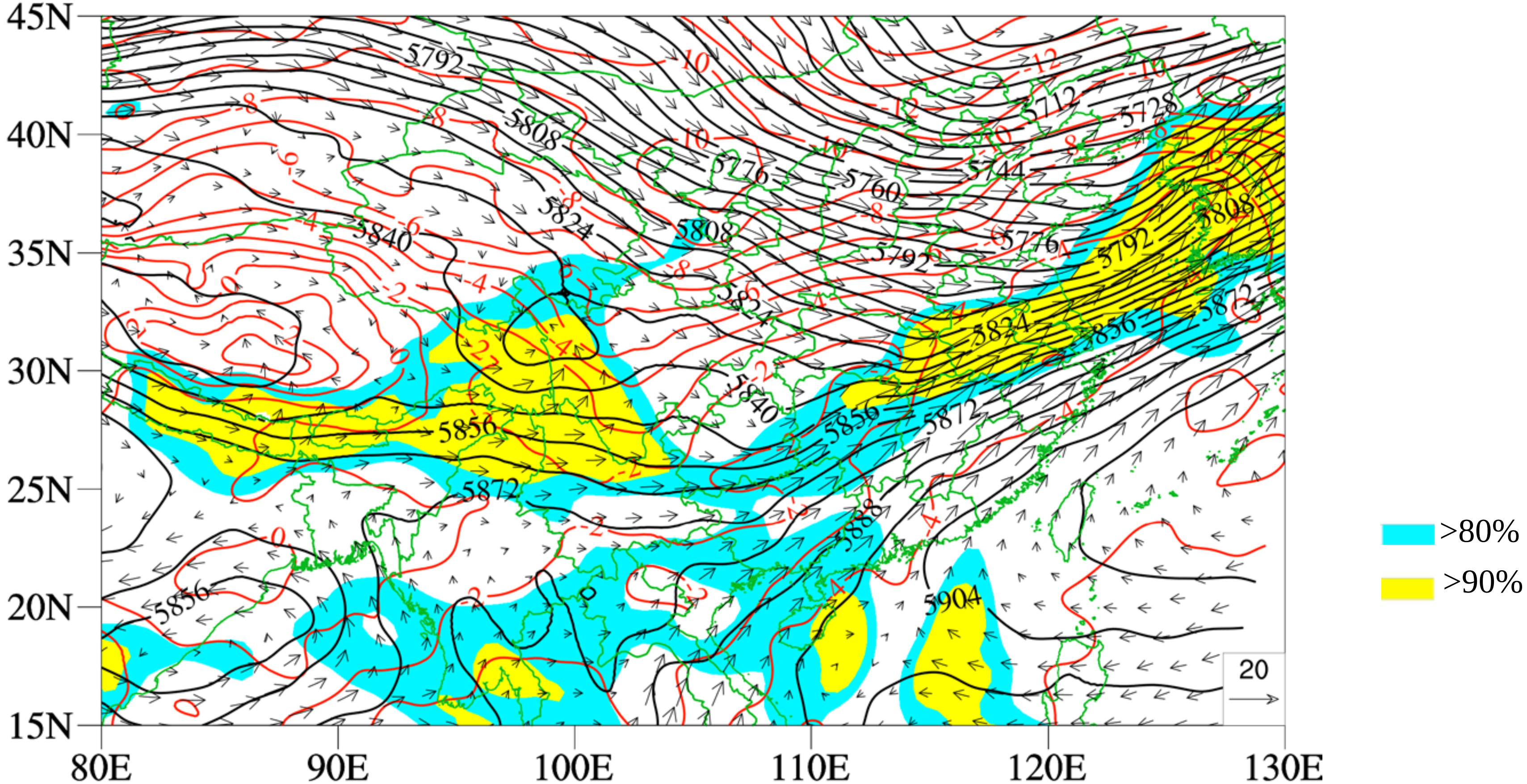
Convergence of Assimilating AHI Channels 7-16





500 hPa Temperature, Geopotential and Relative Humidity

0600 UTC 1 July 2016 (starting time of DA cycle)



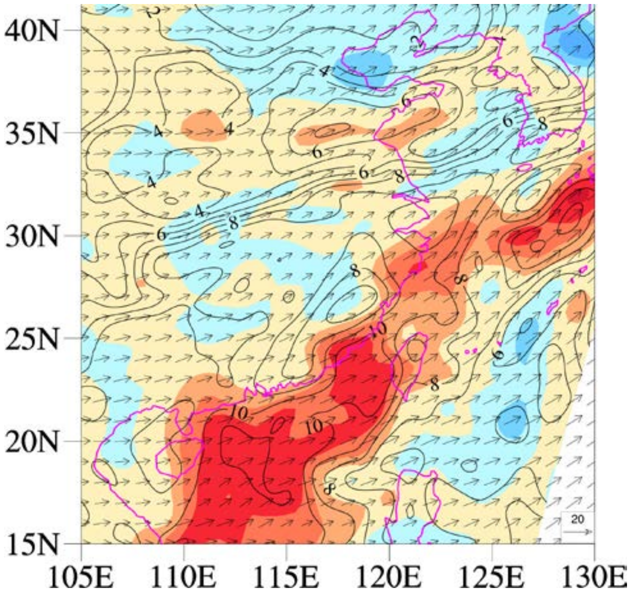
T (red curve)

Φ(black curve)

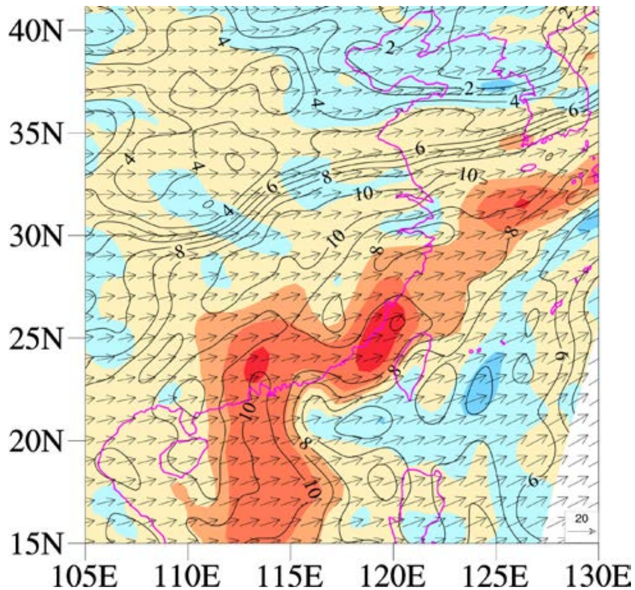
relative humidity (cyan and yellow shading)

Forecast Differences of Water Vapor Mixing Ratio at 750 hPa

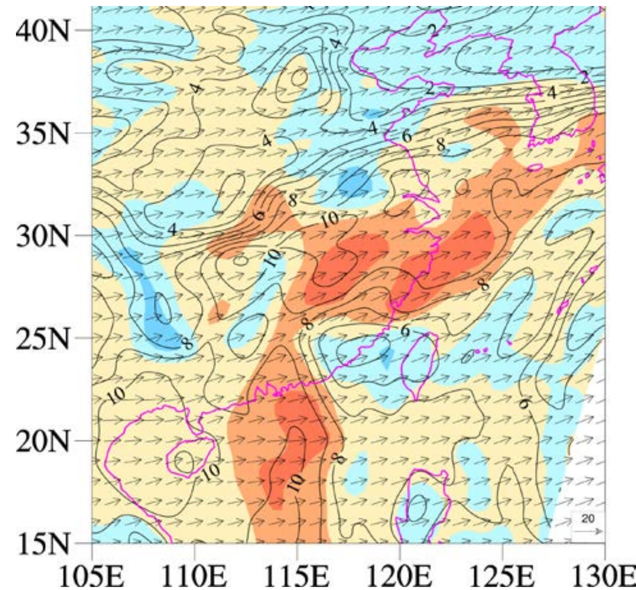
0000 UTC July 2



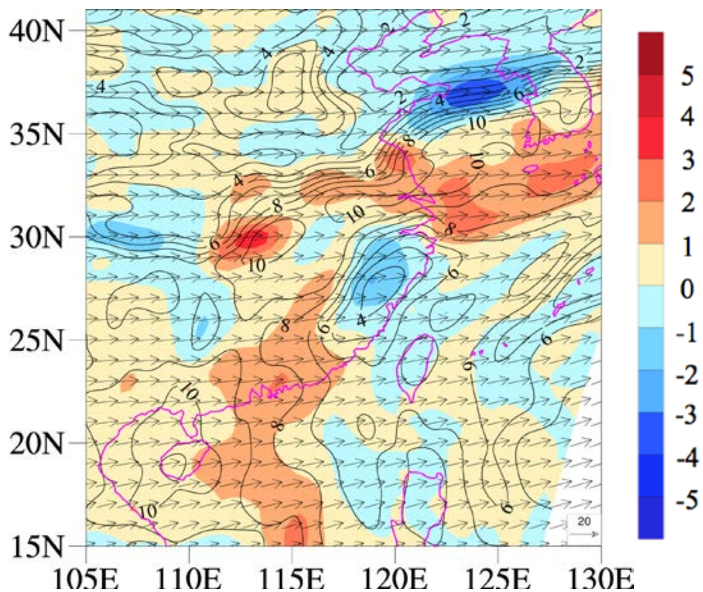
1200 UTC July 2



0000 UTC July 3



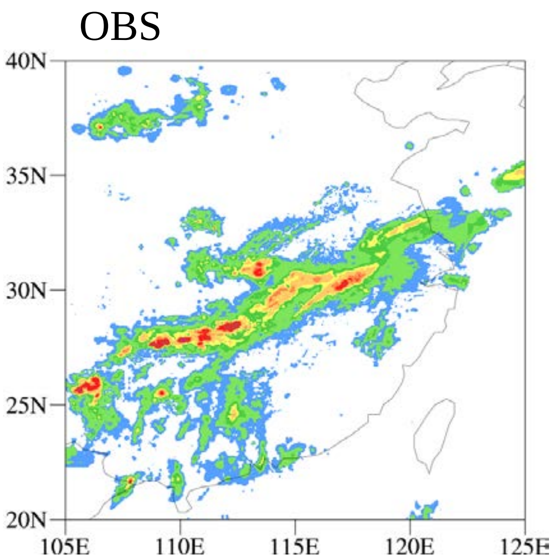
1200 UTC July 3



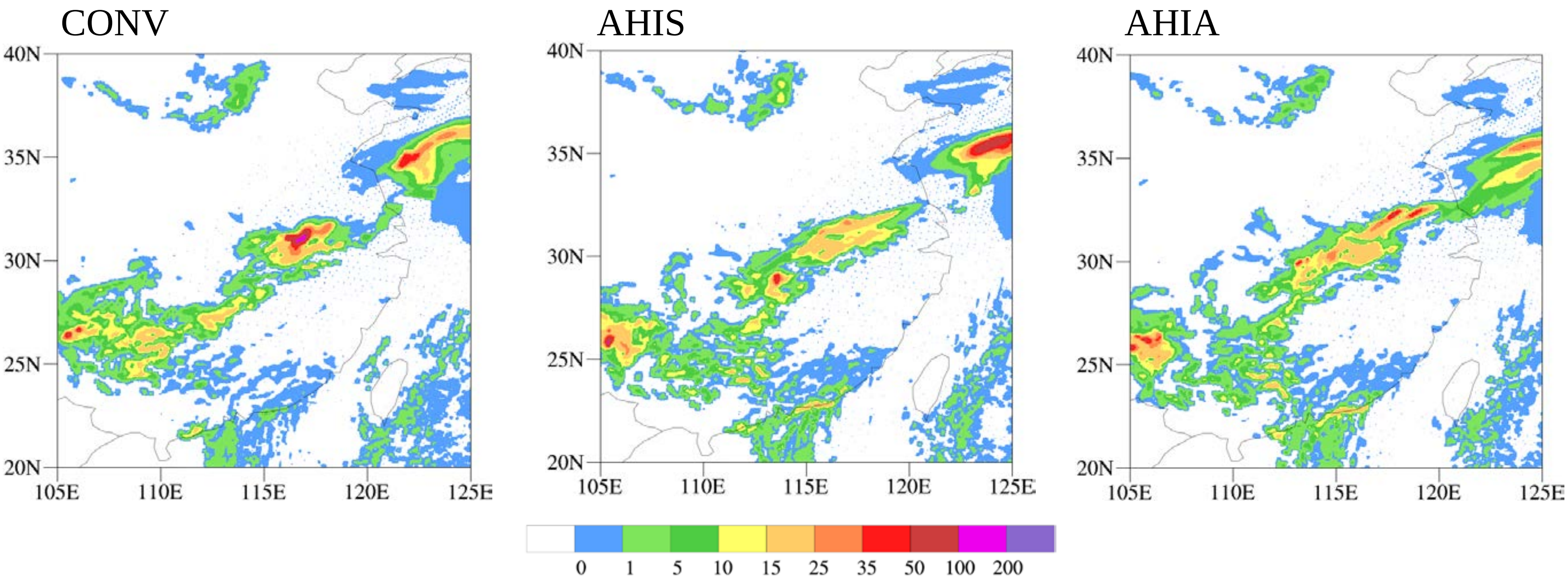
AHIA minus CONV

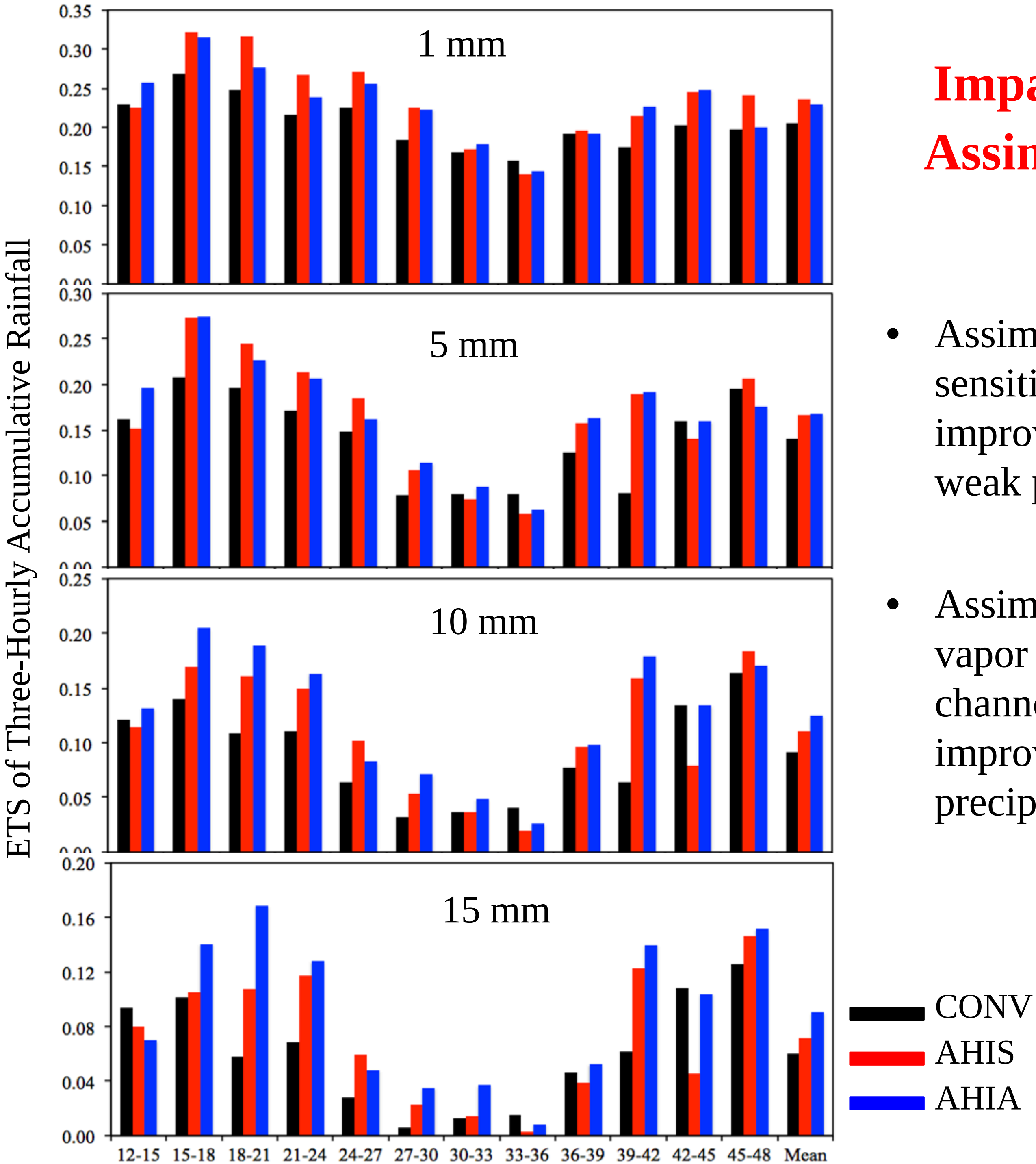
Impacts of AHI Data Assimilation on QPFs

39-42 hours forecasts



1500-1800 UTC
July 3, 2016



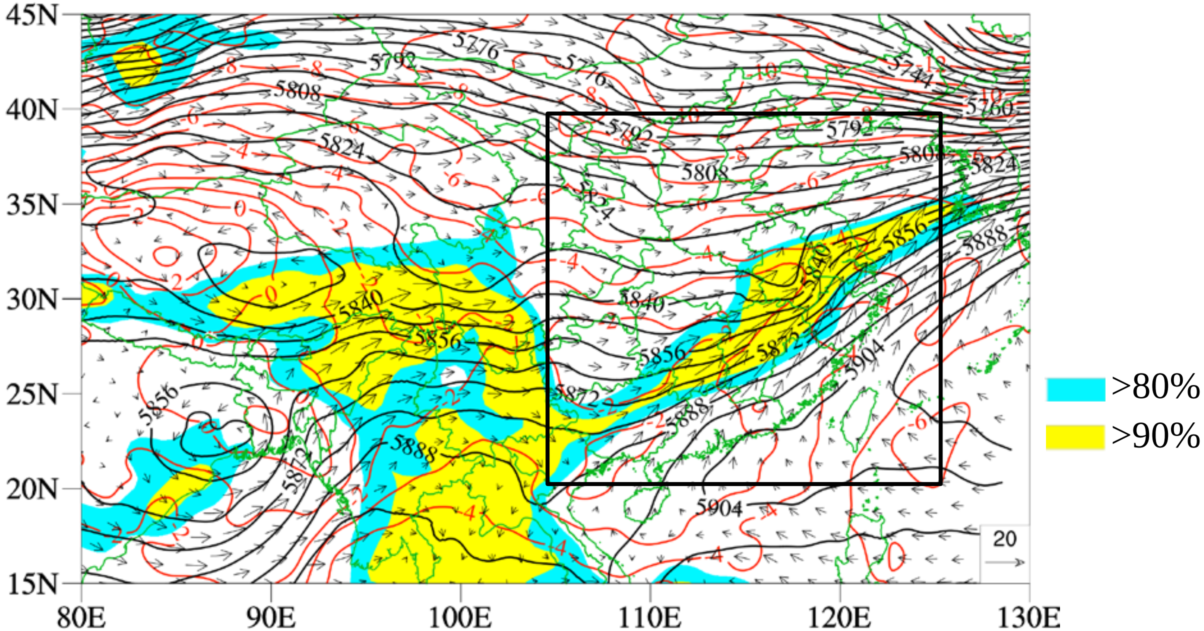


Impacts of AHI Data Assimilation on QPFs

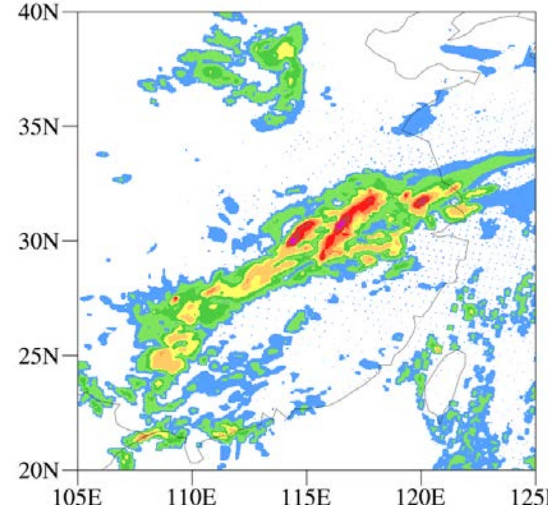
- Assimilation of AHI surface sensitive channels (AHIS) improves QPFs, especially the weak precipitation
- Assimilation of AHI water vapor and surface sensitive channels (AHIA) further improves QPFs of heavy precipitation

Three-hourly Accumulative Rainfall 1500-1800 UTC July 3, 2016

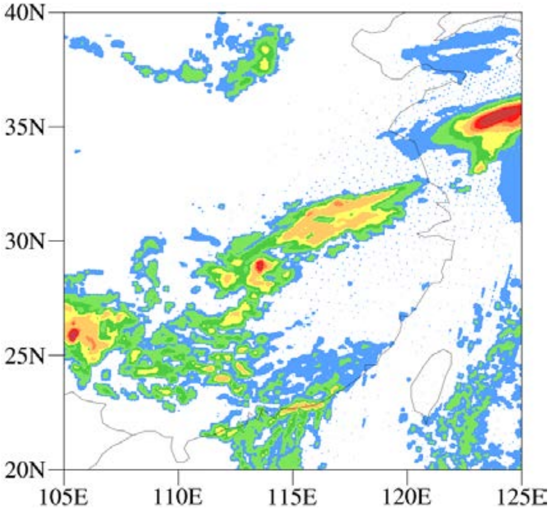
500 hPa T (red), Φ(black), relative humidity (shading)



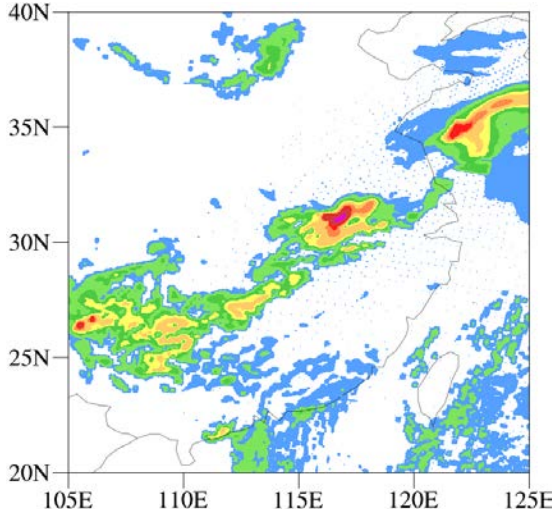
Observations



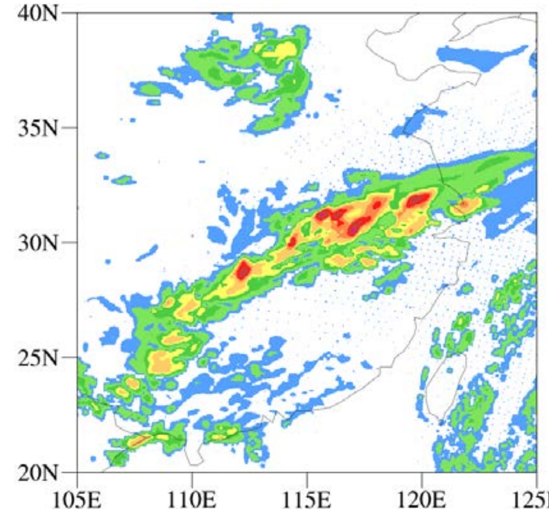
Without AHI



AHI Surface Channels Only

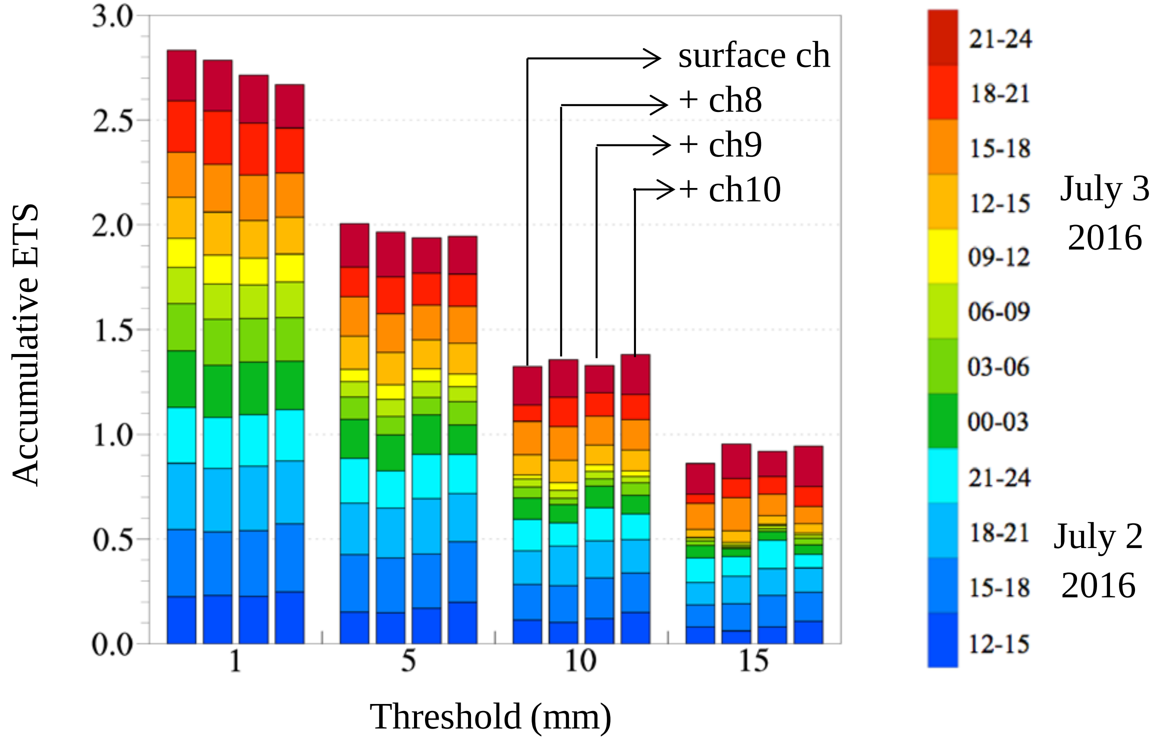


All AHI channels



Sensitivity of QPFs to AHI Water Vapor Channels

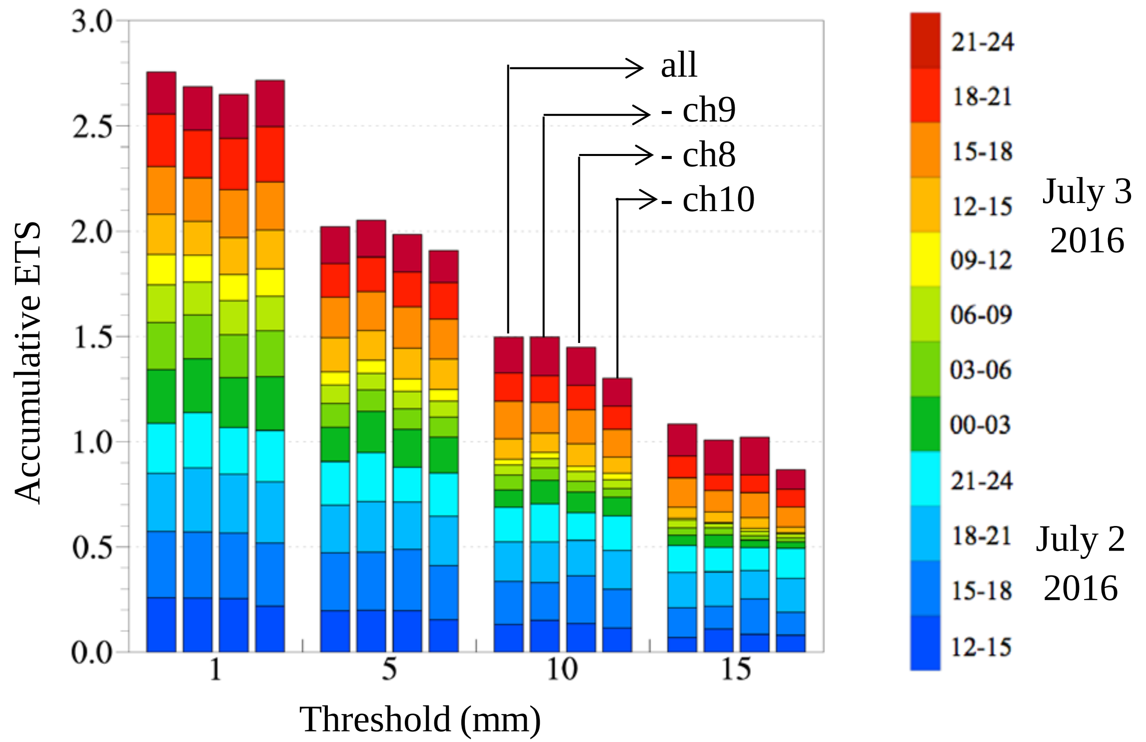
Adding a single water vapor channel to AHI surface channels DA



- Surface channels improve weak precipitation forecasts.
- Channels 8 and 10 improve further the forecasts of strong precipitation.

Sensitivity of QPFs to AHI Water Vapor Channels

Taking away a single water vapor channel from all AHI channels DA



- Channels 8 and 10 together contribute the most to QPFs especially during the first 24 h.
- Assimilating channels 8 and 9 together produces the least improvement to QPFs.

Summary and Conclusions

- AHI radiance data biases are estimated with respect to ECMWF analysis. AHI O-B biases are generally smaller than ± 0.5 K over ocean in clear-sky conditions
- Biases of channels 8-10, 12 and 16 with CRTM have a large jump when satellite zenith angle increases to more than 62^{o}
- A slight scene dependence of bias is found in all AHI channels
- CRTM and RTTOV perform equally well over ocean
- There exist large differences between CRTM and RTTOV for radiance simulations of surface channels over land
- AHI data assimilation improved significantly the 12-48 hours QPFs over China

Future Work

- Improve CRTM simulation for AHI surface channels by taking into account of the surface type, and quantify separately the O-B biases according to different surface conditions
- Complete the comparison between CRTM and RTTOV simulations
- Develop and implement an effective cloud detection algorithm for the assimilation of the new AHI channels for NWP models
- Assess impacts of AHI radiance data assimilation on hurricane track and intensity forecasts using HWRF

More details can be found in

Zou, X., X. Zhuge, and F. Weng, 2016: Characterization of bias of Advanced Himawari Imager infrared observations from NWP background simulations using CRTM and RTTOV**.** *J. Ocean Atmos. Tech.*, **33**, 2553-2567.

Zhuge, X. and X. Zou, 2016: Test of a modified infrared only ABI cloud mask algorithm for AHI radiance observations. *J. App. Meteor. Climatol.*, **55**, 2529-2546.

Qin, Z., X. Zou, and F. Weng, 2016: Impacts of AHI Radiance Assimilation on Quantitative Precipitation Forecasts over Eastern China. *J. App. Meteor. Climatol.*, (submitted)

Future Work

- An “Optimal” Data Thinning
- More Cases
- ABI Data Assimilation