# Sensitivity of the North Indian tropical cyclone analysis to AIRS data assimilation strategy

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AIRS Science Team Meeting

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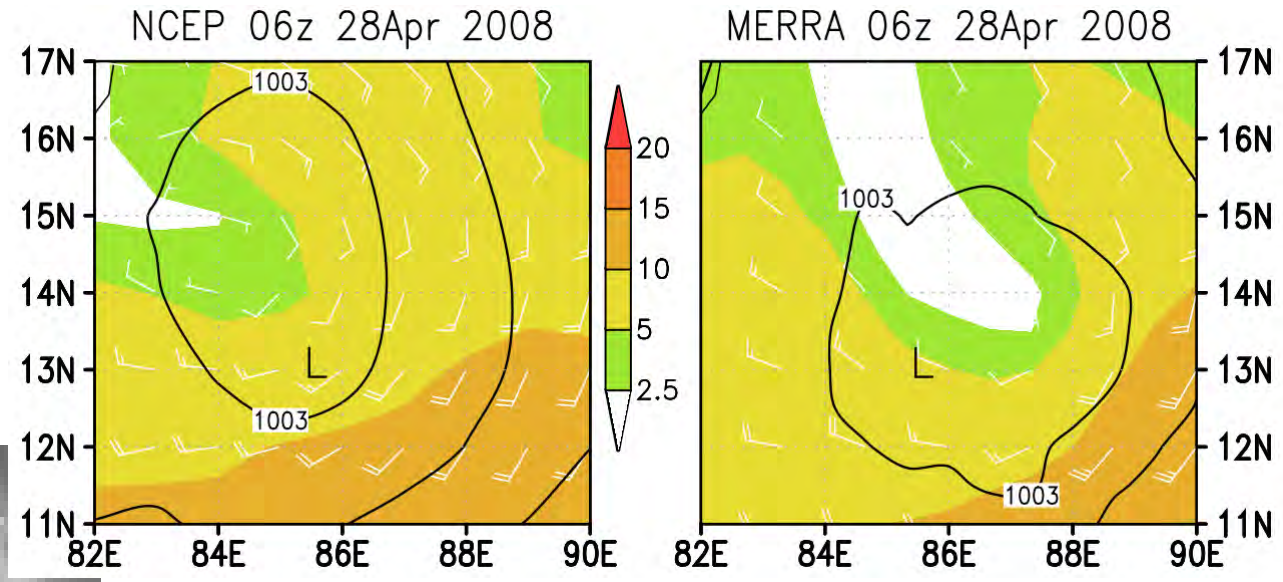
Thanks to Will McCarty (GMAO)

# Outline

- Motivation
  - N. Indian TCs are difficult to analyze yet significant for human life and property
  - Large uncertainty associated even with “best track” estimates
- Global analyses are sensitive to density of AIRS data assimilated
  - Data density impacts global forecast skill and ability to simulate regional events
  - Minimum sea level pressure, vertical structure, and track of TCs are impacted
- Conclusions

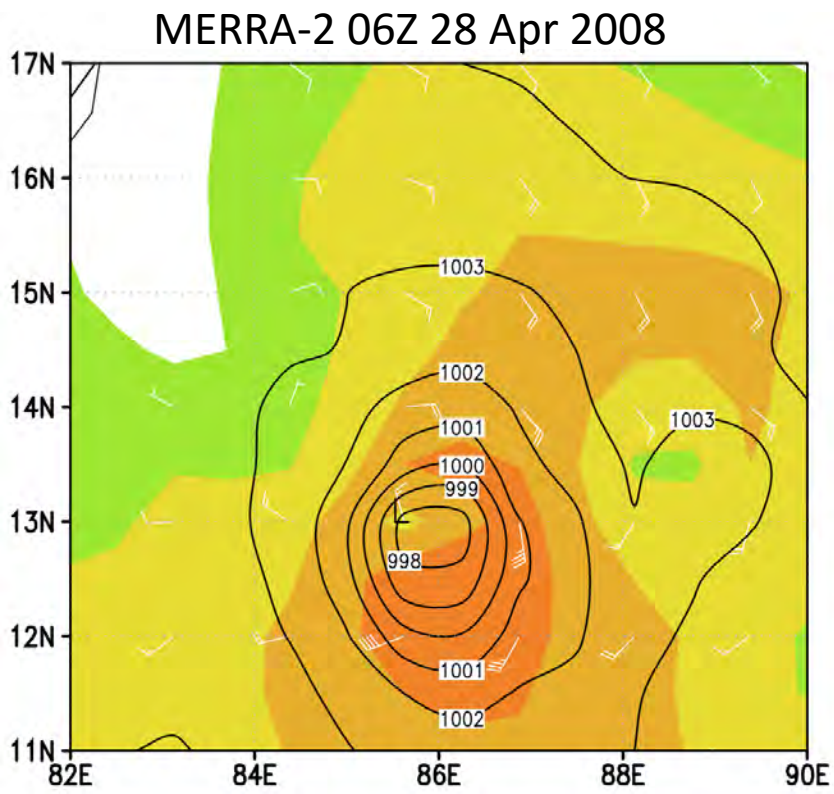
# TC Nargis in the N. Indian Ocean was missed in operational analyses and reanalyses at the time. As a consequence, forecasts for the storm were extremely poor

Wind magnitude (shaded) and slp (contours)

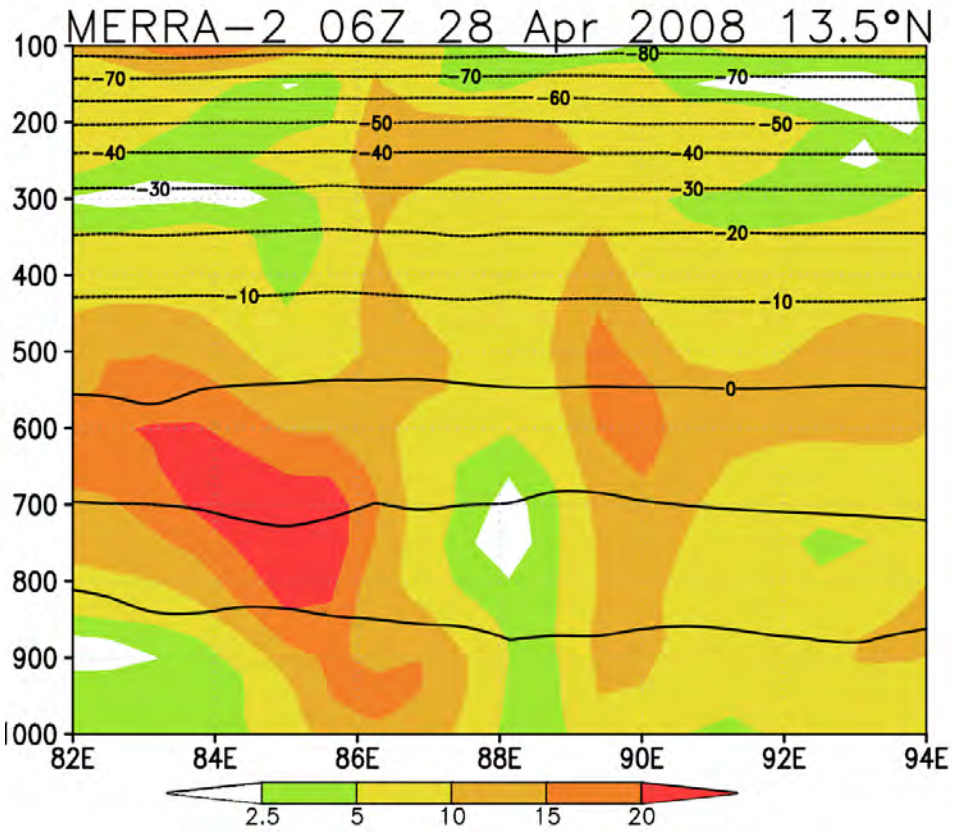



Infrared satellite image at 6Z 28 April 2008 from Meteosat 7 shows hurricane strength storm

# Modern systems perform better than those in 2008, but there is still a lot of room for improvement

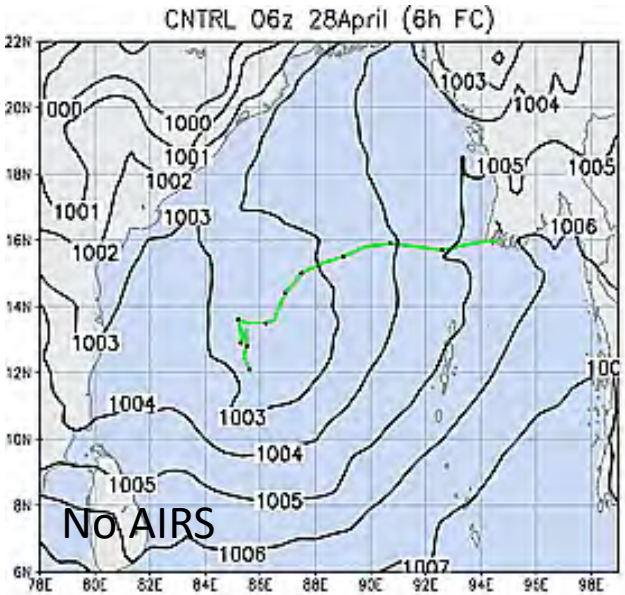


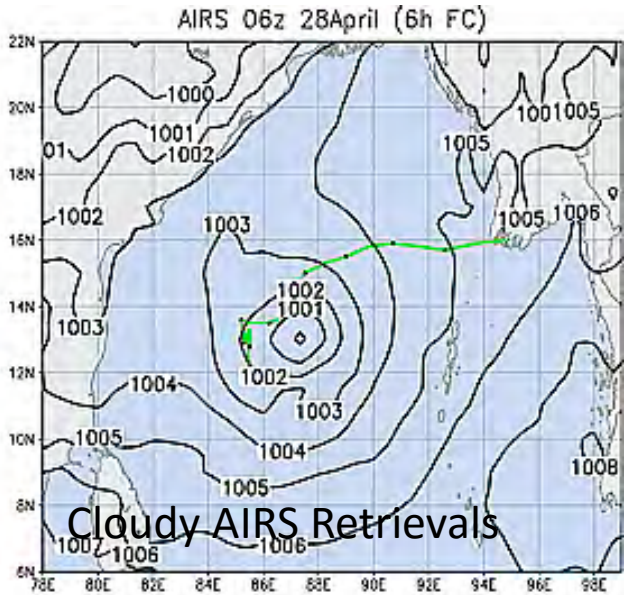

Wind magnitude (shaded) and slp (contours)



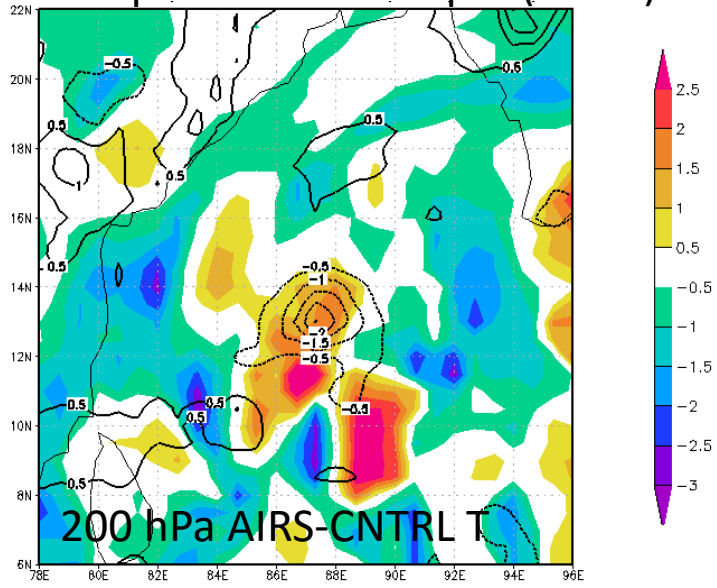

Wind magnitude (shaded) and temperature (contours)

# Reale et al., 2009 showed that TC Nargis could be captured with addition of AIRS cloudy retrievals




AIRS impact at 06Z 28 April (6h FC)



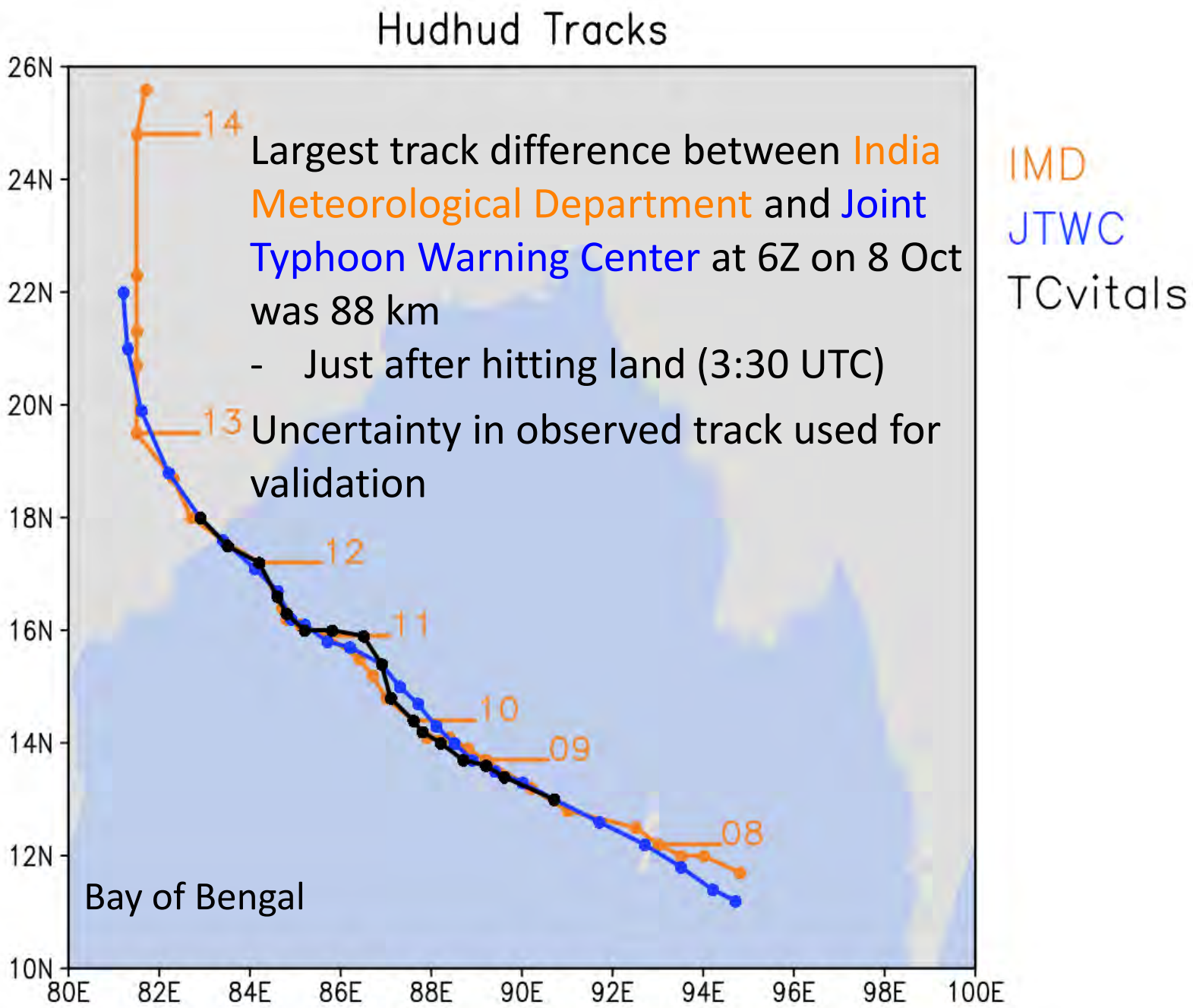


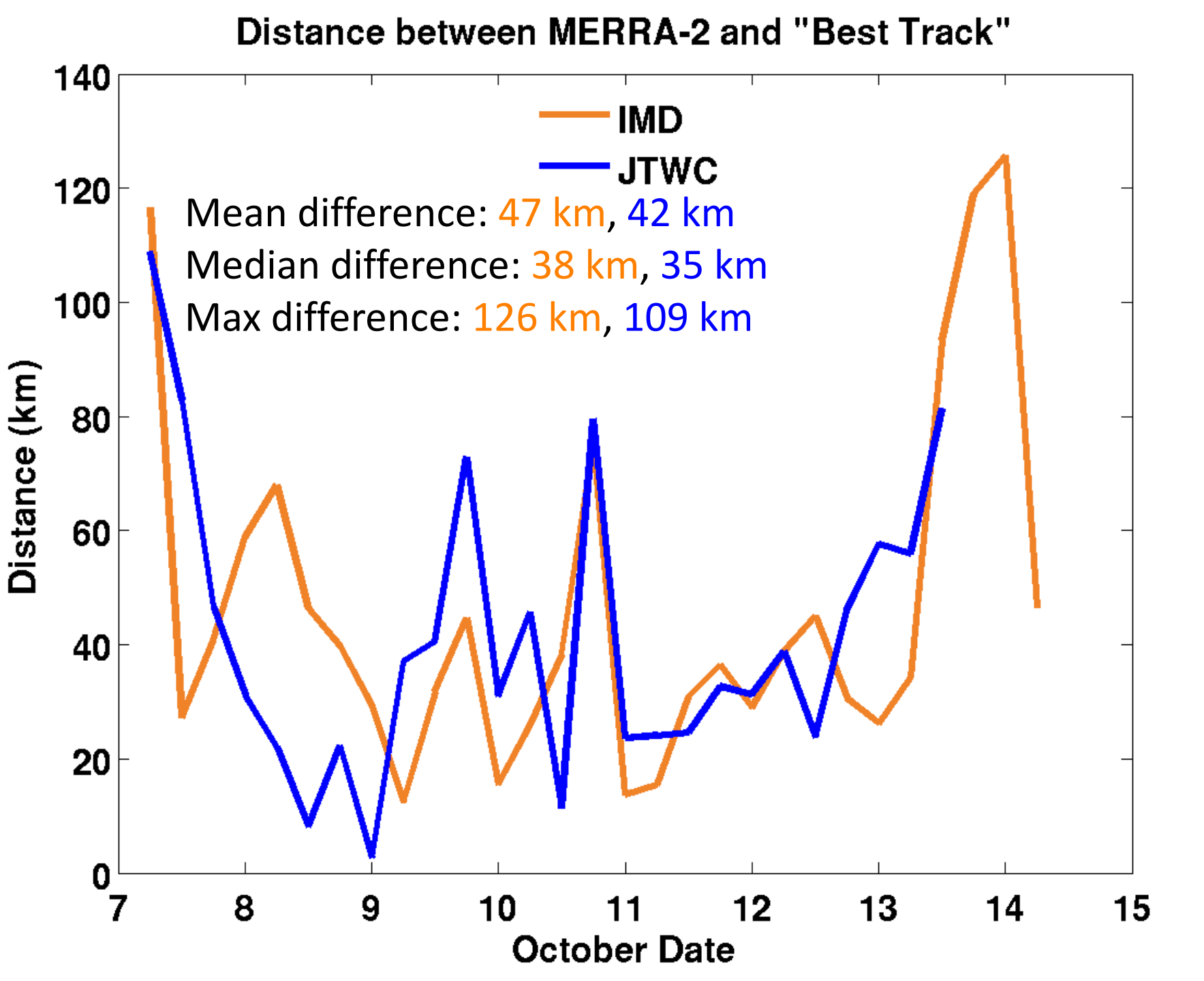


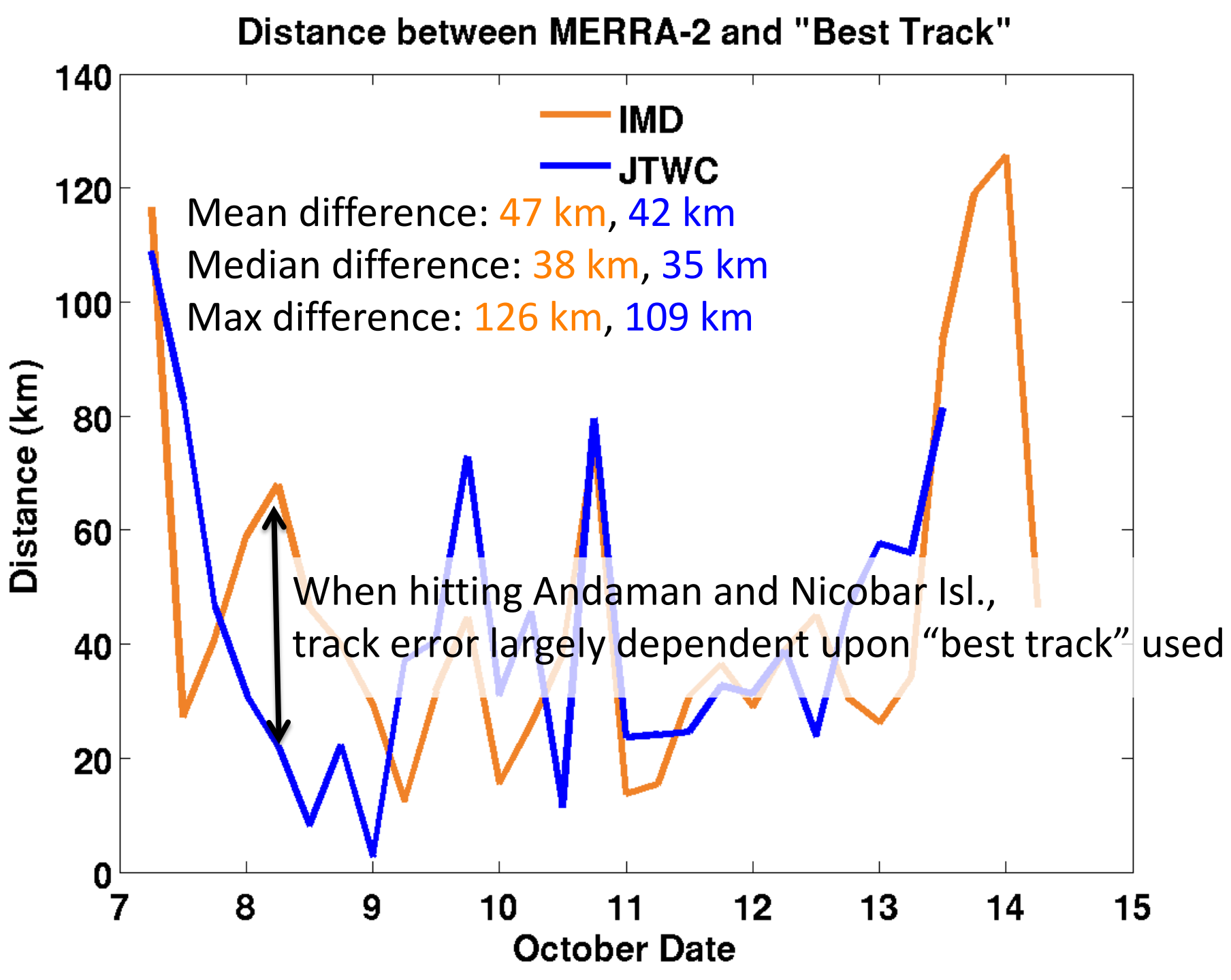
Cloudy AIRS retrievals produced warmer temperatures aloft, leading to lower slp

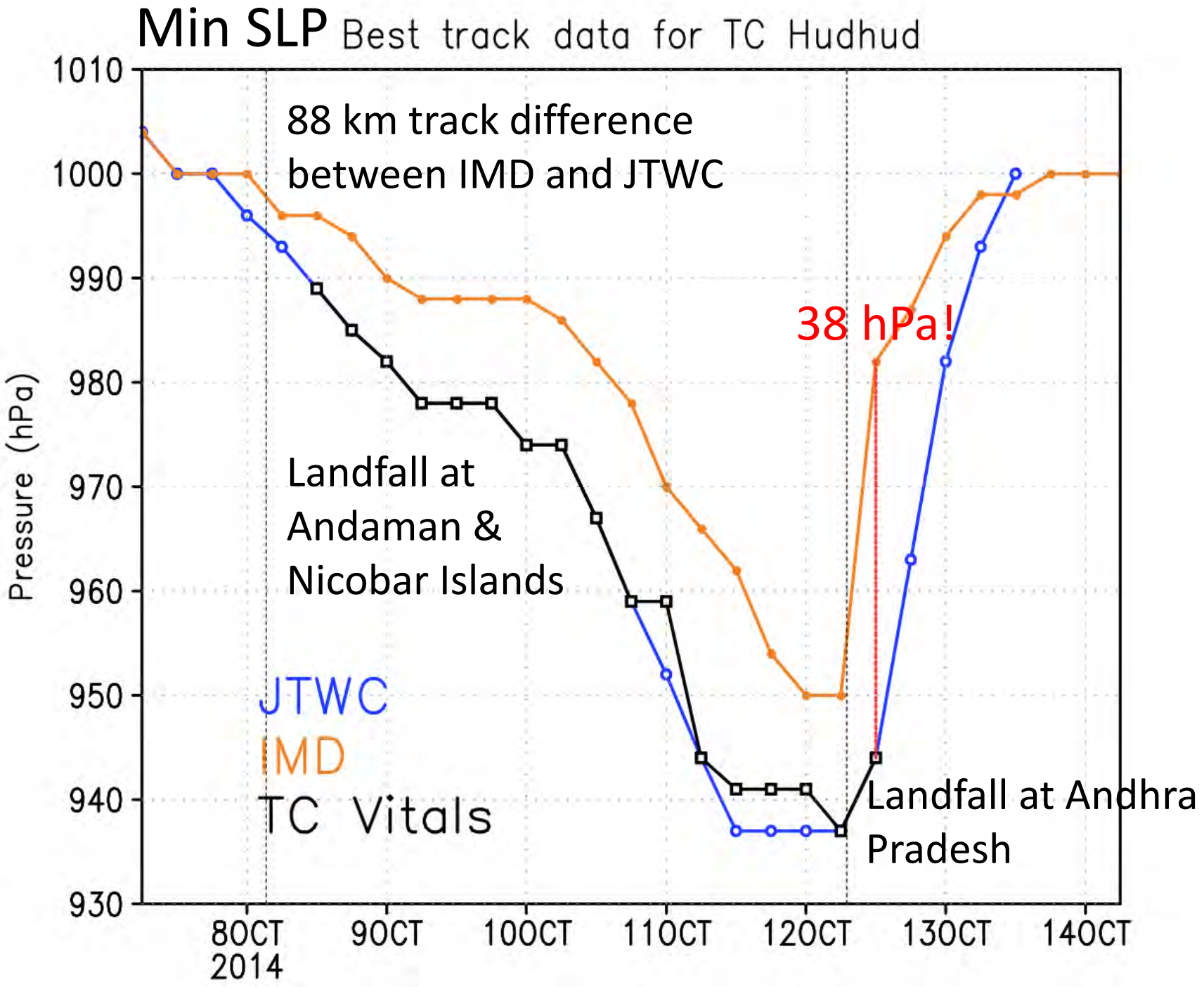
# TC Hudhud

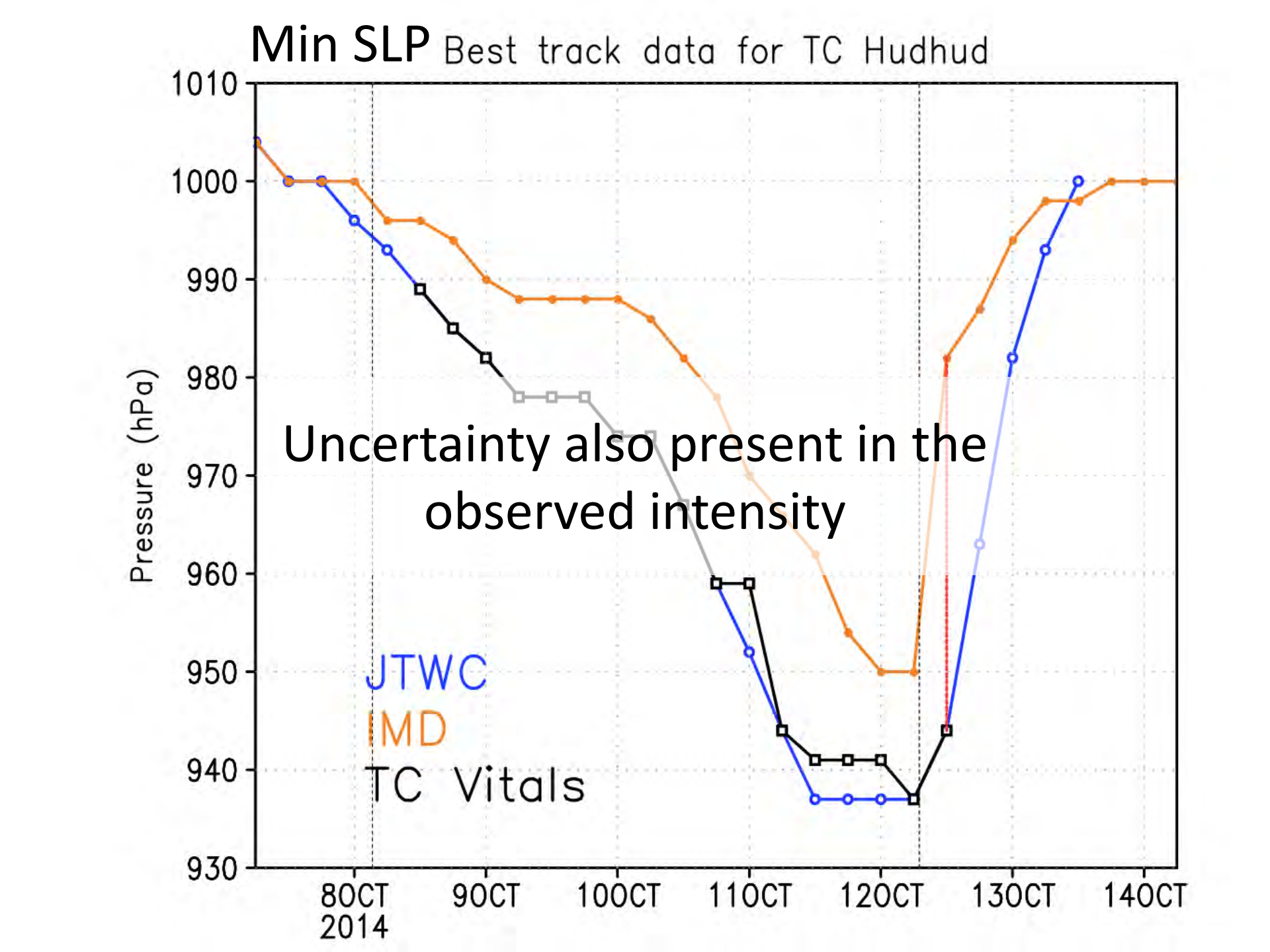
- Storm similar to Nargis formed in 2014: Can modern data assimilation systems capture this event?
- Hudhud formed in the Bay of Bengal in the North Indian Ocean in Oct. 2014
- Crossed the Andaman and Nicobar Islands on 8 October and hit Andhra Pradesh, India on 12 October
- Produced a blizzard and avalanches in Nepal

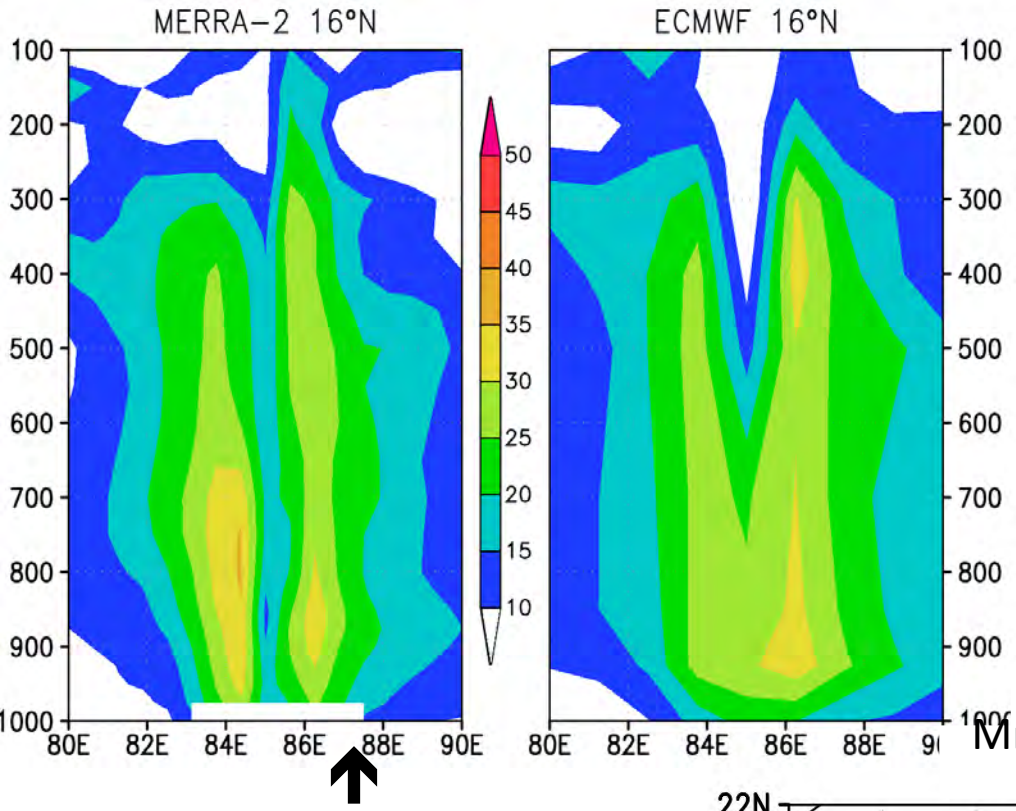

Hudhud Tracks
26N
24N
22N
20N
18N
16N
14N
12N
10N
80E
82E
84E
86E
88E
90E
92E
94E
96E
98E
100E
14
13
12
11
10
09
08
Largest track difference between India Meteorological Department and Joint Typhoon Warning Center at 6Z on 8 Oct was 88 km
- Just after hitting land (3:30 UTC)
Uncertainty in observed track used for validation
Bay of Bengal
IMD
JTWC
TCvitals


Distance between MERRA-2 and "Best Track"
IMD
JTWC
Mean difference: 47 km, 42 km
Median difference: 38 km, 35 km
Max difference: 126 km, 109 km
Distance (km)
October Date
0
20
40
60
80
100
120
140
7
8
9
10
11
12
13
14
15


Distance between MERRA-2 and "Best Track"
IMD
JTWC
Mean difference: 47 km, 42 km
Median difference: 38 km, 35 km
Max difference: 126 km, 109 km
When hitting Andaman and Nicobar Isl.,
track error largely dependent upon “best track” used
Distance (km)
October Date
0
20
40
60
80
100
120
140
7
8
9
10
11
12
13
14
15


Min SLP Best track data for TC Hudhud
88 km track difference
between IMD and JTWC
38 hPa!
Landfall at
Andaman &
Nicobar Islands
JTWC
IMD
TC Vitals
Landfall at Andhra
Pradesh
Pressure (hPa)
1010
1000
990
980
970
960
950
940
930
80CT
2014
90CT
100CT
110CT
120CT
130CT
140CT

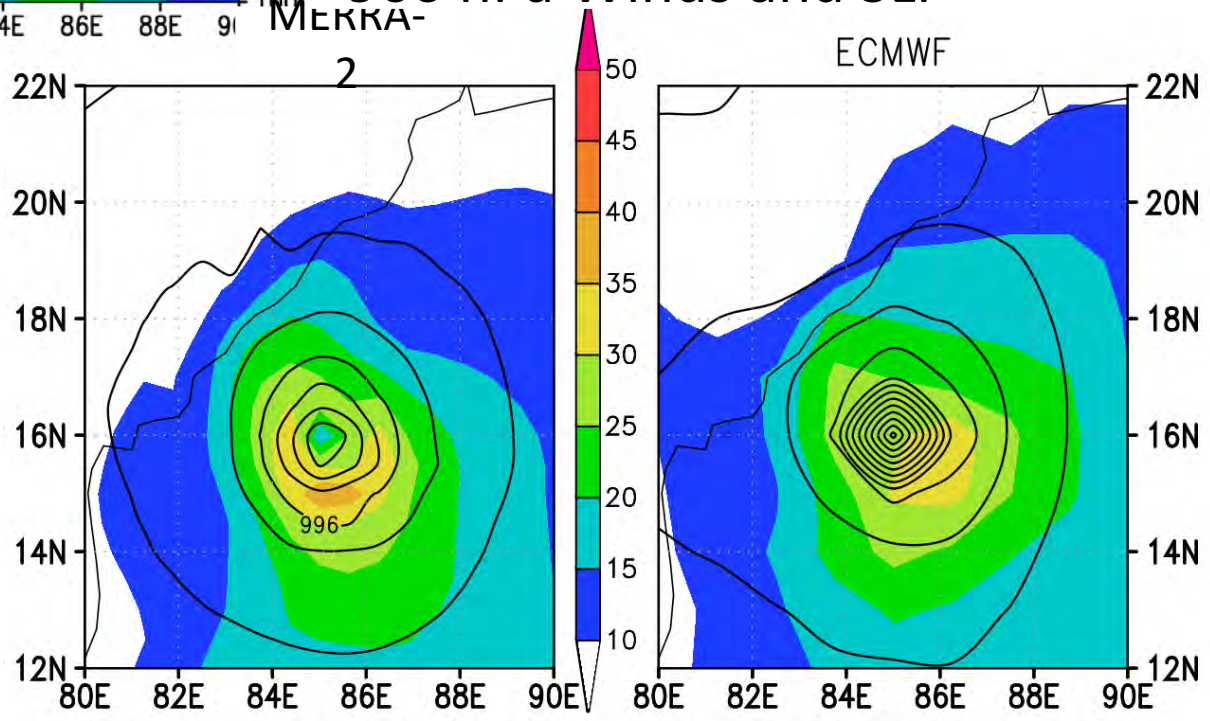

Min SLP Best track data for TC Hudhud
1010
1000
990
980
970
960
950
940
930
Pressure (hPa)
Uncertainty also present in the observed intensity
JTWC
IMD
TC Vitals
80CT
2014
90CT
100CT
110CT
120CT
130CT
140CT




Vertical Structure of Wind magnitude

Modern reanalysis and operational analysis give very different representations so while there is an improvement over the past, there is still ambiguity present

900 hPa Winds and SLP




# 06Z 11 Oct 2014

MERRA-2: 980.7 hPa

ECMWF: 958.3 hPa

JTWC: 944 hPa

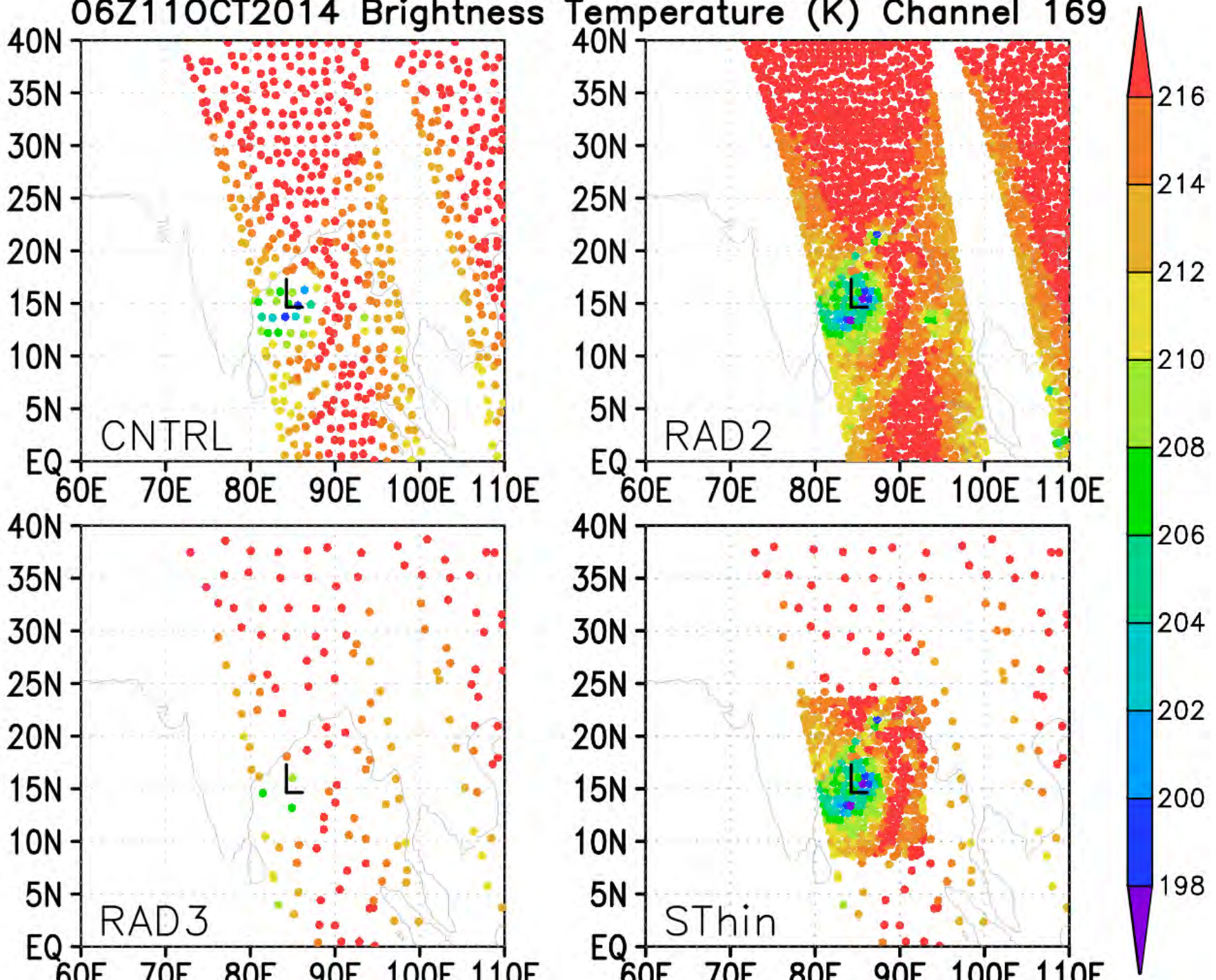
- Large uncertainties present in different analyses provide an opportunity for AIRS data to constrain the thermodynamic structure of the atmosphere over tropical cyclones

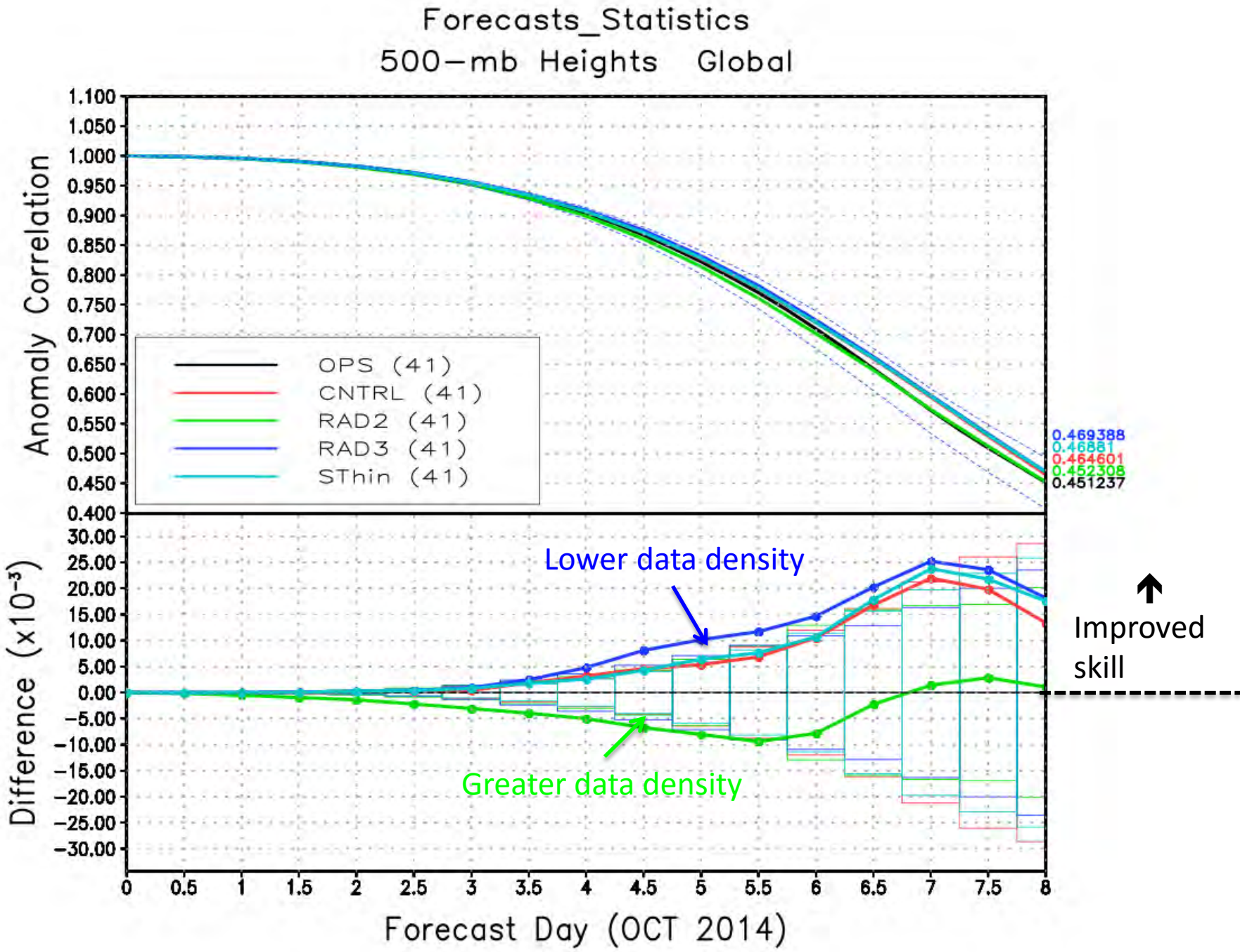
- GEOS-5 DAS version 5.13.0
  - Operational version at time of the storm
- 4 experiments all with Vortex Relocator turned off
  - Resolution C360 (~1/4°)

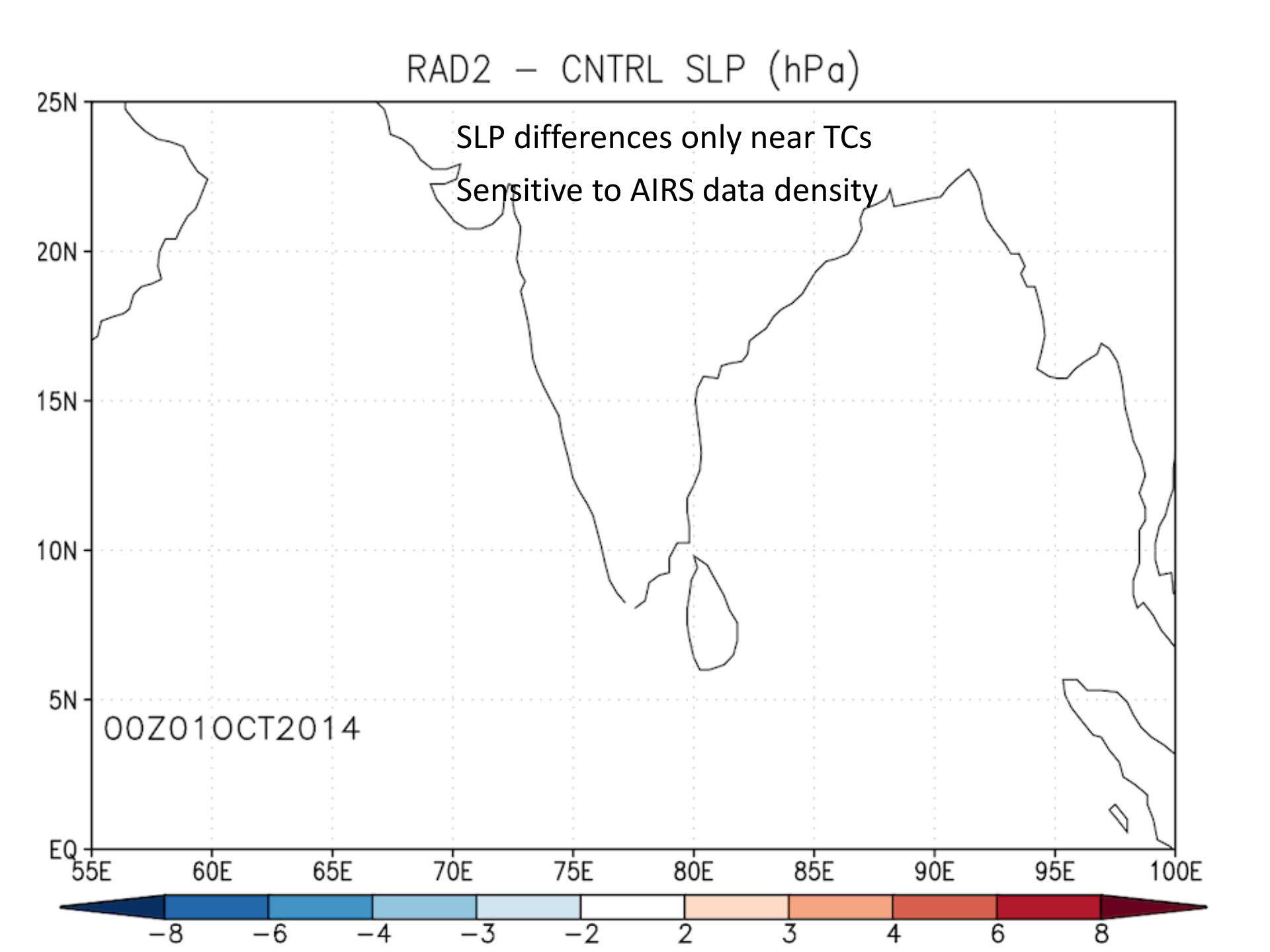
# 4 experiments

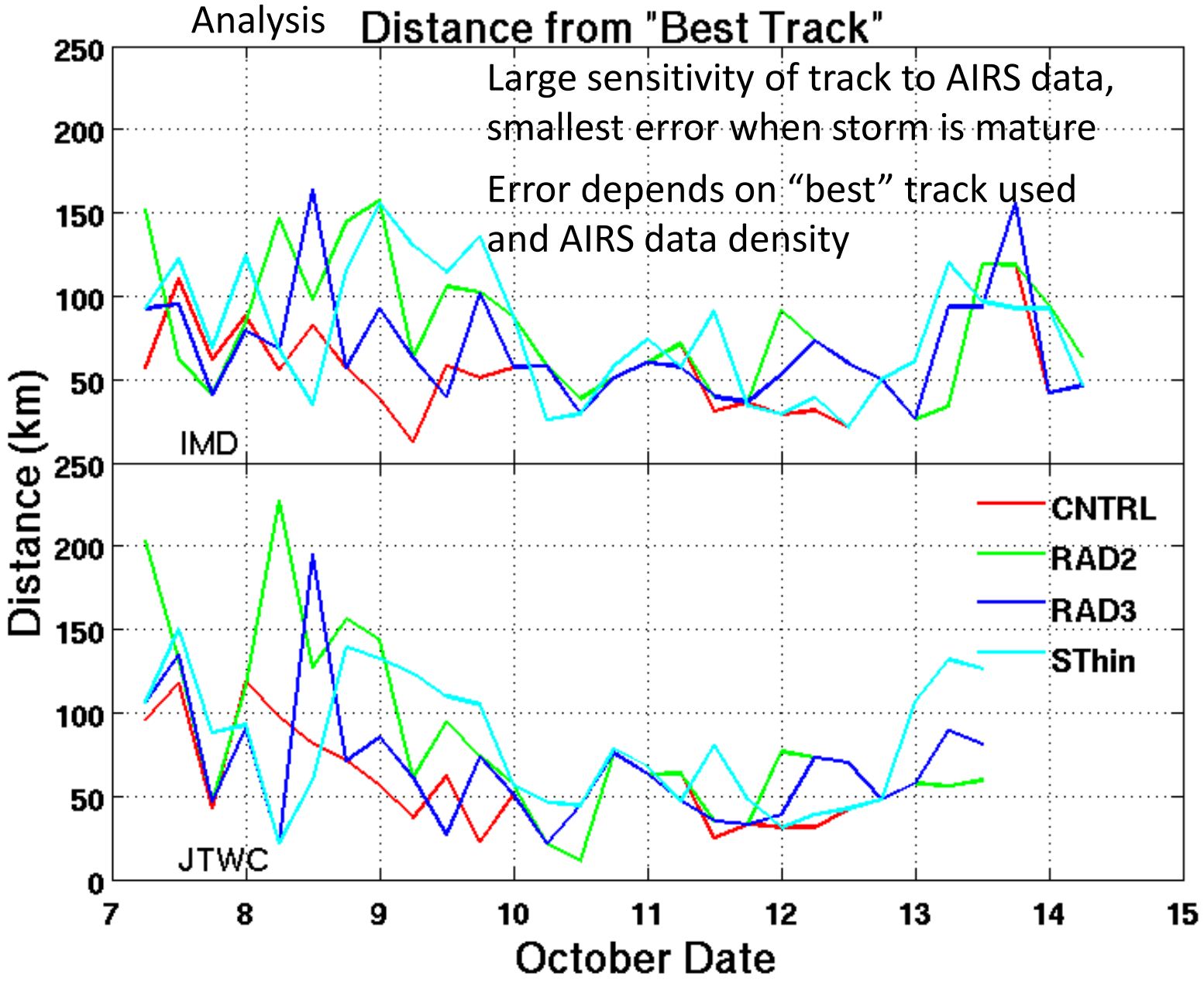
- CNTRL – operational AIRS data density
- RAD2 – 4x operational AIRS data density
- RAD3 – 1/4x operational AIRS data density
- SThin – Adaptive thinning with increased data density within a TC domain, but decreased data elsewhere

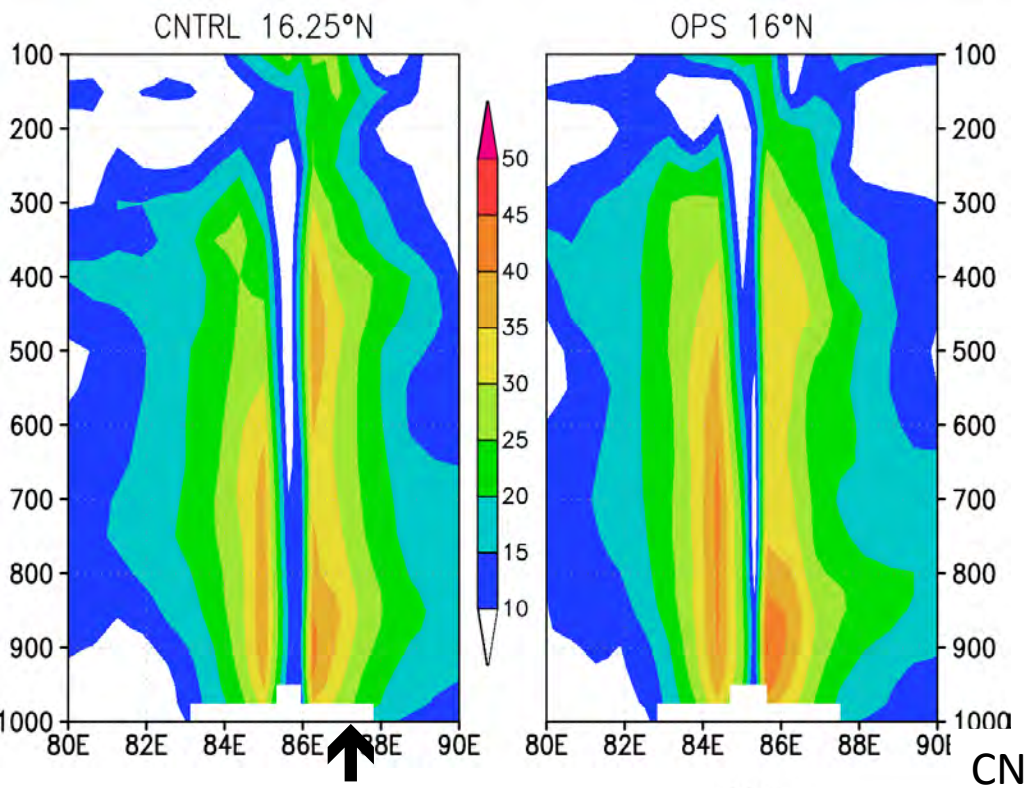
(See previous talk on adaptive thinning)


06Z11OCT2014 Brightness Temperature (K) Channel 169
CNTRL
RAD2
RAD3
SThin
40N
35N
30N
25N
20N
15N
10N
5N
EQ
60E
70E
80E
90E
100E
110E
216
214
212
210
208
206
204
202
200
198


Forecasts_Statistics
500–mb Heights Global
Anomaly Correlation
1.100
1.050
1.000
0.950
0.900
0.850
0.800
0.750
0.700
0.650
0.600
0.550
0.500
0.450
0.400
OPS (41)
CNTRL (41)
RAD2 (41)
RAD3 (41)
SThin (41)
0.469388
0.46881
0.464601
0.452308
0.451237
Difference (x10⁻³)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
−5.00
−10.00
−15.00
−20.00
−25.00
−30.00
Lower data density
Greater data density
Improved skill
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
Forecast Day (OCT 2014)


RAD2 – CNTRL SLP (hPa)
SLP differences only near TCs
Sensitive to AIRS data density
00Z01OCT2014
25N
20N
15N
10N
5N
EQ
55E
60E
65E
70E
75E
80E
85E
90E
95E
100E
−8
−6
−4
−3
−2
2
3
4
6
8


Analysis
Distance from "Best Track"
Large sensitivity of track to AIRS data, smallest error when storm is mature
Error depends on “best” track used and AIRS data density
IMD
JTWC
CNTRL
RAD2
RAD3
SThin
Distance (km)
October Date
250
200
150
100
50
0
7
8
9
10
11
12
13
14
15




Vertical Structure of Wind magnitude

OPS includes vortex relocator and produces a similar representation to the CNTRL.

Can we do better using only data?

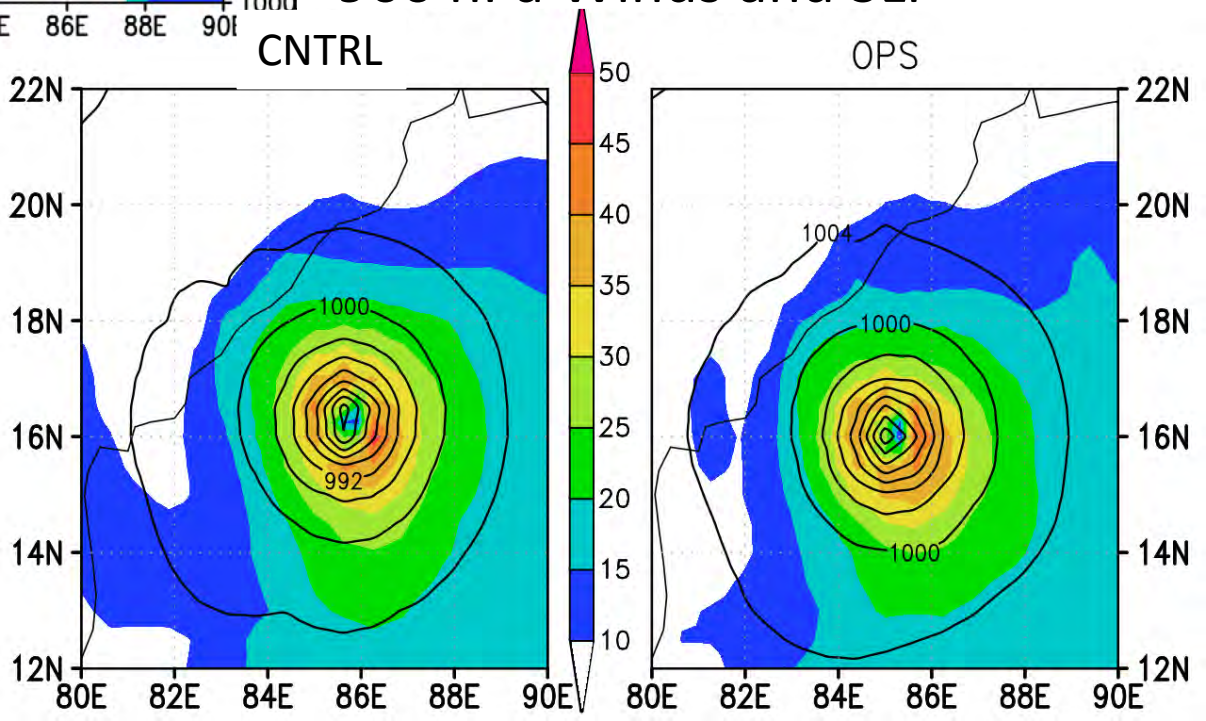
# 06Z 11 Oct 2014

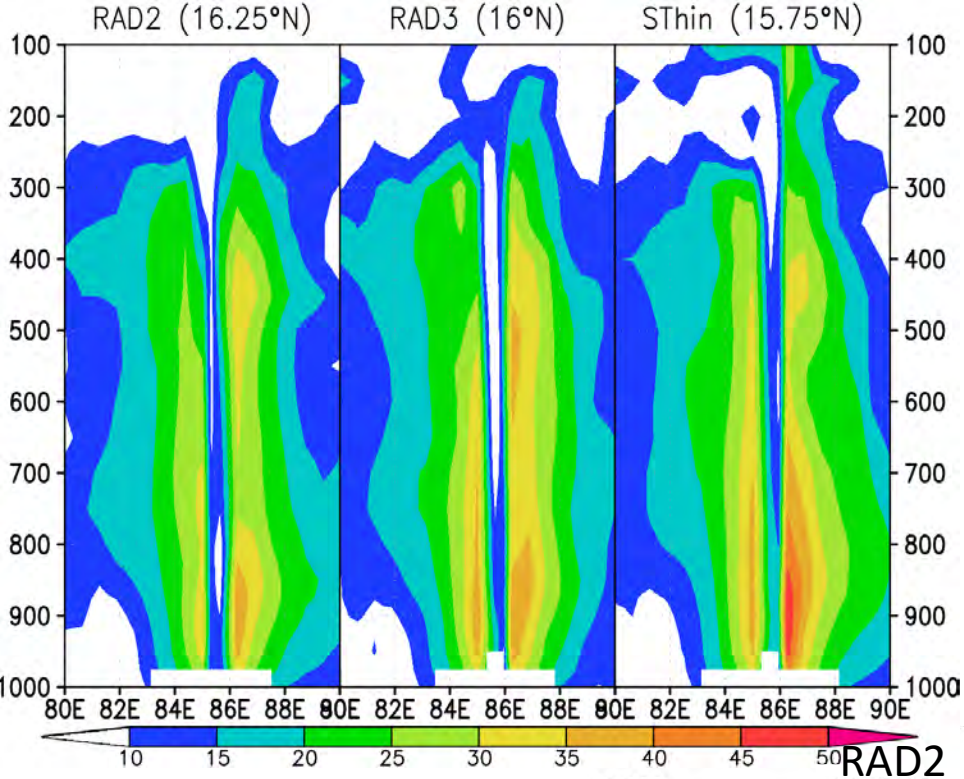
CNTRL: 970.4 hPa

OPS: 969.3 hPa

JTWC: 944 hPa

## 900 hPa Winds and SLP






Vertical Structure of Wind magnitude

06Z 11 Oct 2014

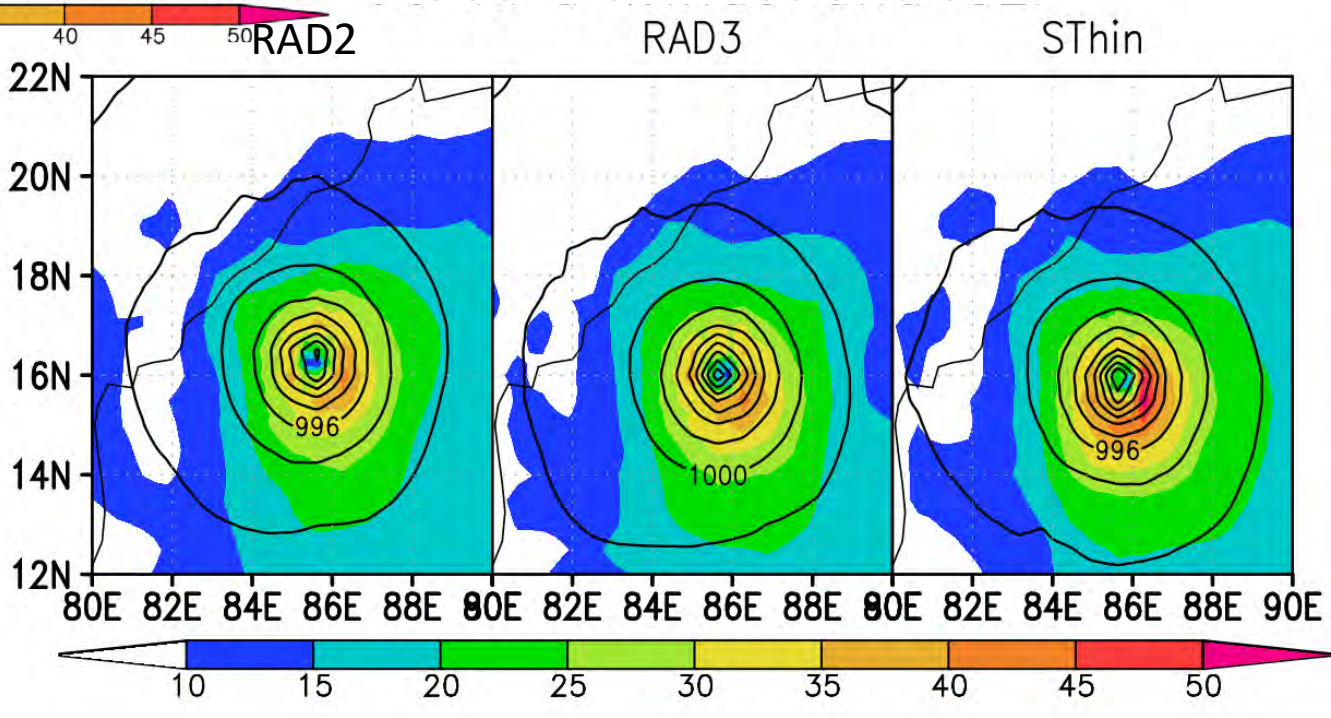
RAD2: 975.4 hPa

RAD3: 969.3 hPa

SThin: 967.8 hPa

JTWC: 944 hPa

900 hPa Winds and SLP




SThin uses a combination of RAD2 and RAD3 data thinning strategies, but performs better than both!

06Z 11 Oct 2014

SThin – CNTRL temperature (K, shaded)

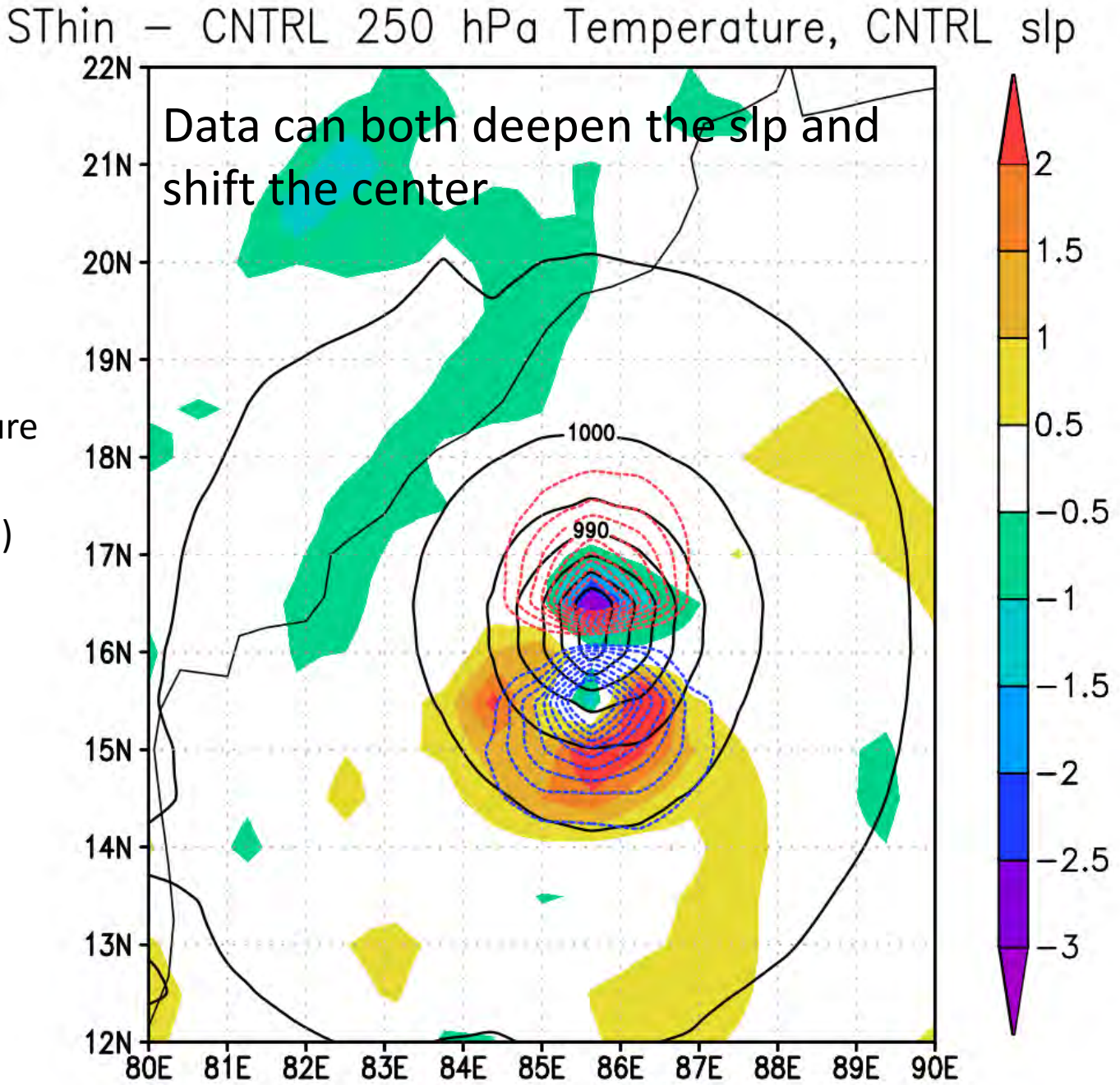
CNTRL slp (solid contours)

SThin-CNTRL slp (dashed contours)

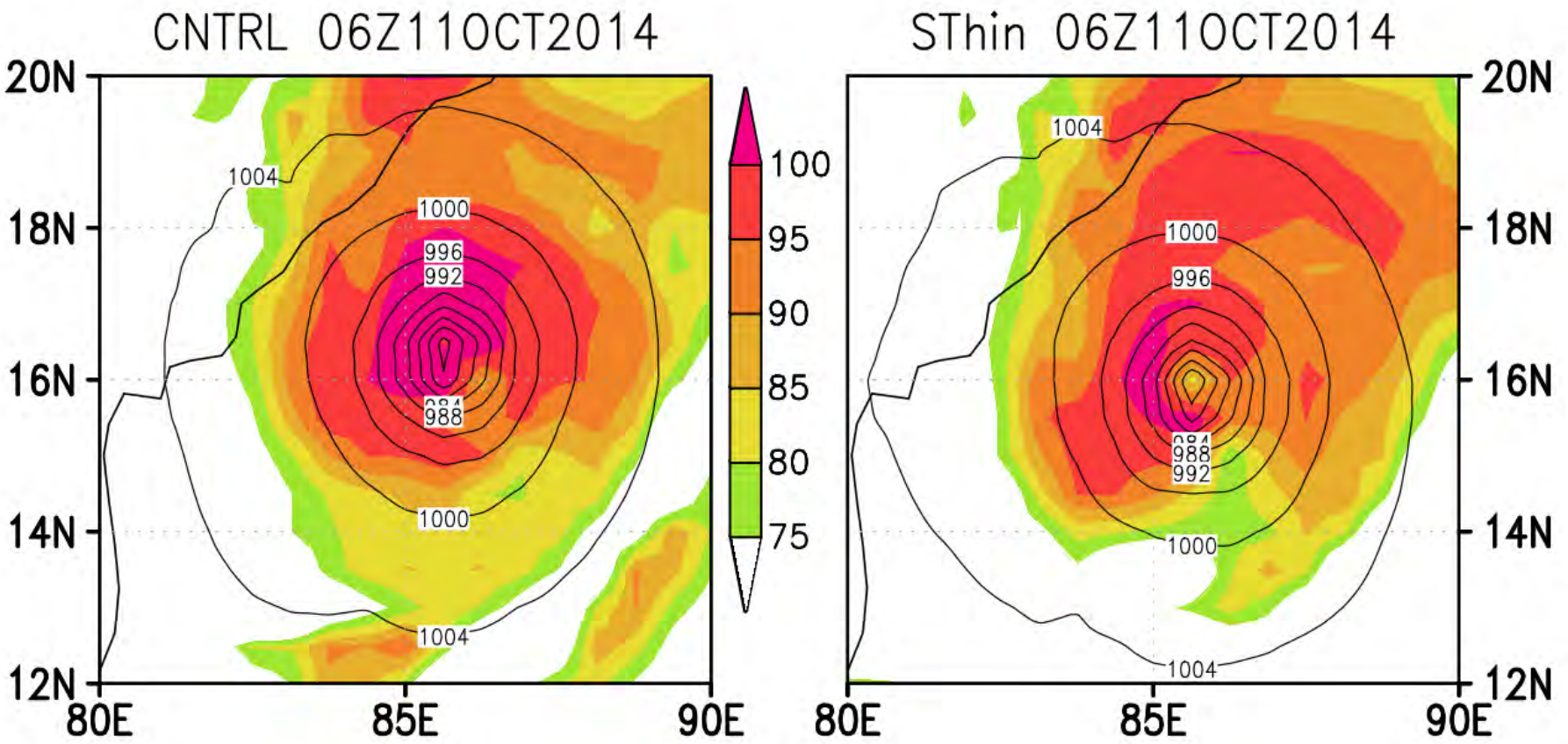
CNTRL: 970.4 hPa

SThin: 967.8 hPa

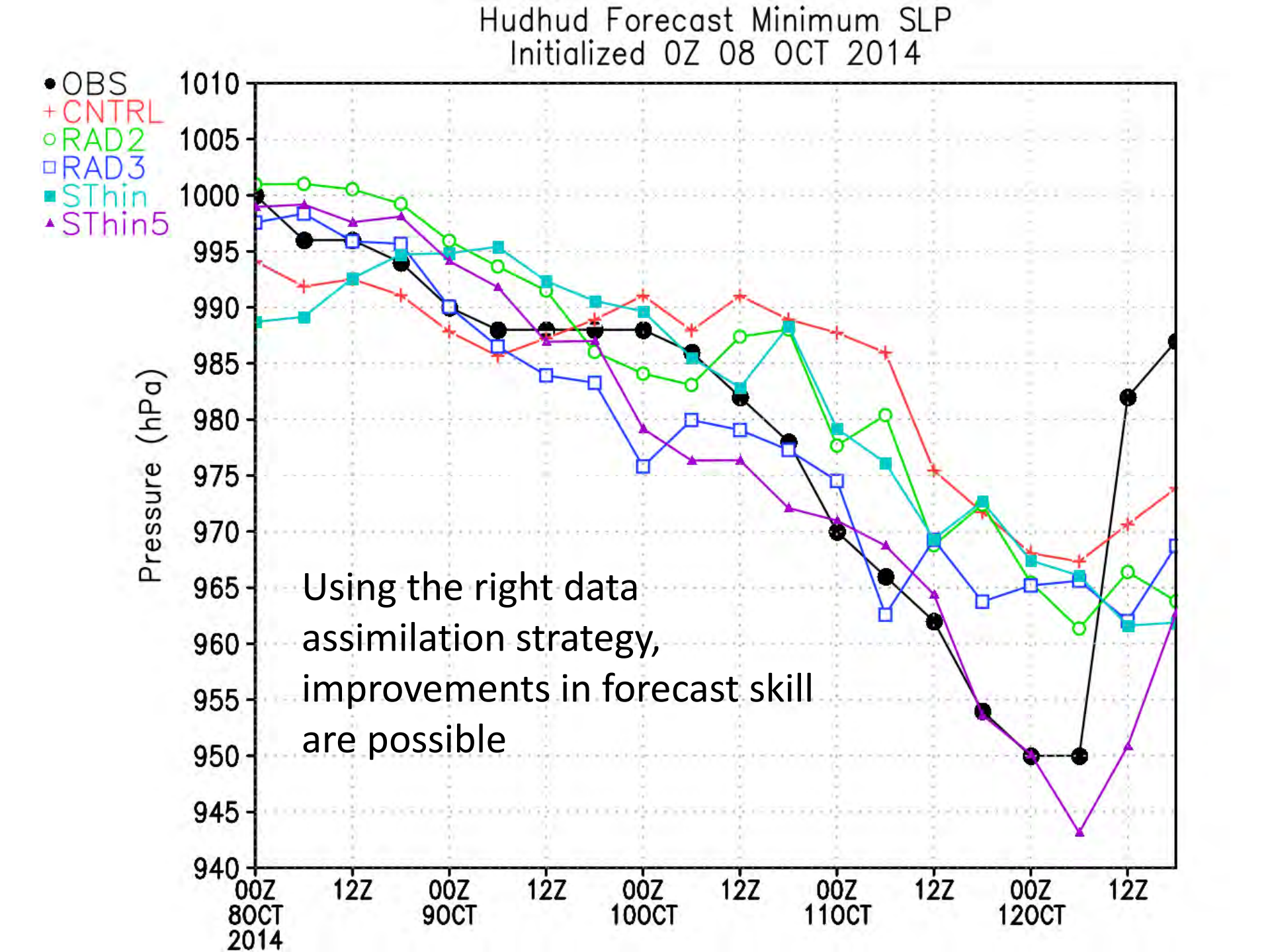
JTWC: 944 hPa



# 800 hPa RH (shaded) and slp (contours)




- SThin is able to simulate an eye in the relative humidity fields
- Variables not affected by the vortex relocator can improve with addition of targeted high density AIRS data


Hudhud Forecast Minimum SLP
Initialized 0Z 08 OCT 2014
OBS
CNTRL
RAD2
RAD3
SThin
SThin5
Pressure (hPa)
1010
1005
1000
995
990
985
980
975
970
965
960
955
950
945
940
00Z 8OCT 2014
12Z
00Z 9OCT
12Z
00Z 10OCT
12Z
00Z 11OCT
12Z
00Z 12OCT
12Z
Using the right data assimilation strategy, improvements in forecast skill are possible

# Conclusions

- North Indian tropical cyclones are still difficult to analyze in data assimilation systems and are particularly sensitive to AIRS data assimilation strategy
- Different AIRS thinning affects global skill and tropical cyclones in contrasting ways
  - 5 assimilation strategies tested
- There is a strong potential to use AIRS data in lieu of the vortex relocator to observationally constrain tropical cyclones and improve analysis and forecast

# Acknowledgements


- Dr. Ramesh Kakar for support to current proposal "Using AIRS data to understand processes affecting TC structure and extreme precipitation in a Global Data Assimilation and Forecasting Framework" (2014-2017, PI: Dr. O. Reale)
- Dr. Tsengdar Lee for generous allocations of NASA High End Computing resources
- AIRS team at JPL and the Sounder Research Team at NASA GSFC
- GES DISC for their outstanding service to the community