Adaptive AIRS clear-sky radiance thinning to improve global forecast skill and tropical cyclone representation in the NASA GEOS-5

Oreste Reale, Erica McGrath-Spangler
(USRA/GESTAR and NASA/GMAO)
Will McCarty *(NASA/GMAO)*
Yaping Zhou *(MSU/GESTAR and NASA/ESD)*

Outline

Past work and Motivation:

Impact of assimilated version 5 and version 6 retrievals on:

- Midlatitude winter dynamics; Tropical cyclones (2006, 2008, 2010, 2012)
- Analyses and Forecasts of Extreme Precipitation associated with TCs
- Precipitation Analysis for the 2010 floods along the Indus river (Pakistan, 2010)
- All emphasized the importance of information in presence of clouds
- More recent experiments revealed contrasting impact (i.e. global scale vs. TC scale) of AIRS data density resulting from different THINNING

Current work:

Impact of clear-sky radiance adaptive (variable) thinning

- New GEOS-5 experiments focused on global skill and TC structure
- Focus on 2014 season.
- Results and implications
- Acknowledgements

Past work showed improvement in TC cloud/moisture distribution caused by AIRS v5 retrievals

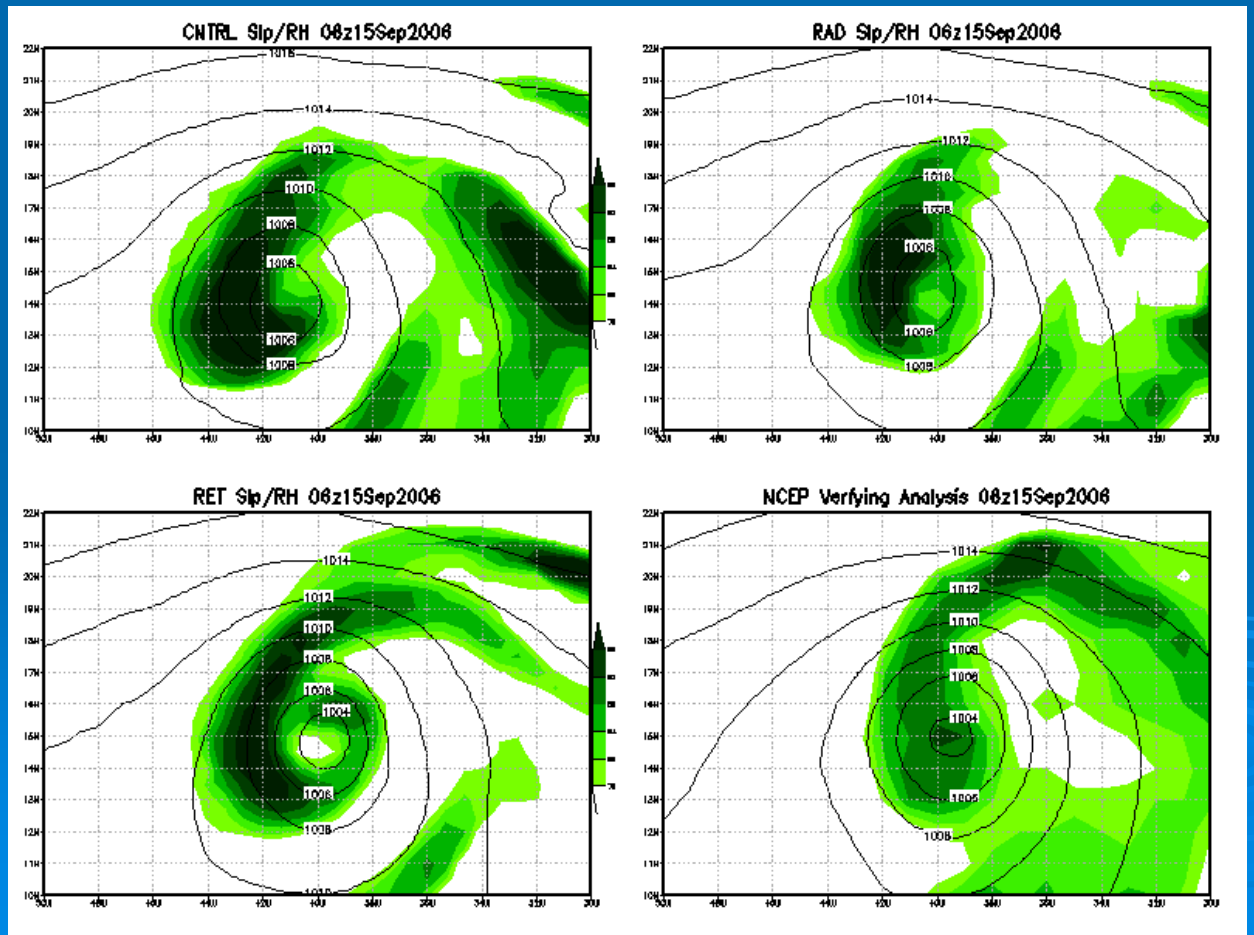
Example: **TS Helene Analysis at 06z 15Sep2006**

30 hours before becoming a hurricane

800 hpa relative humidity, sea level pressure (hPa)

CNTRL

RETRIEVALS
Produce an Eye-like feature



RADIANCES
Do NOT produce an Eye-like feature

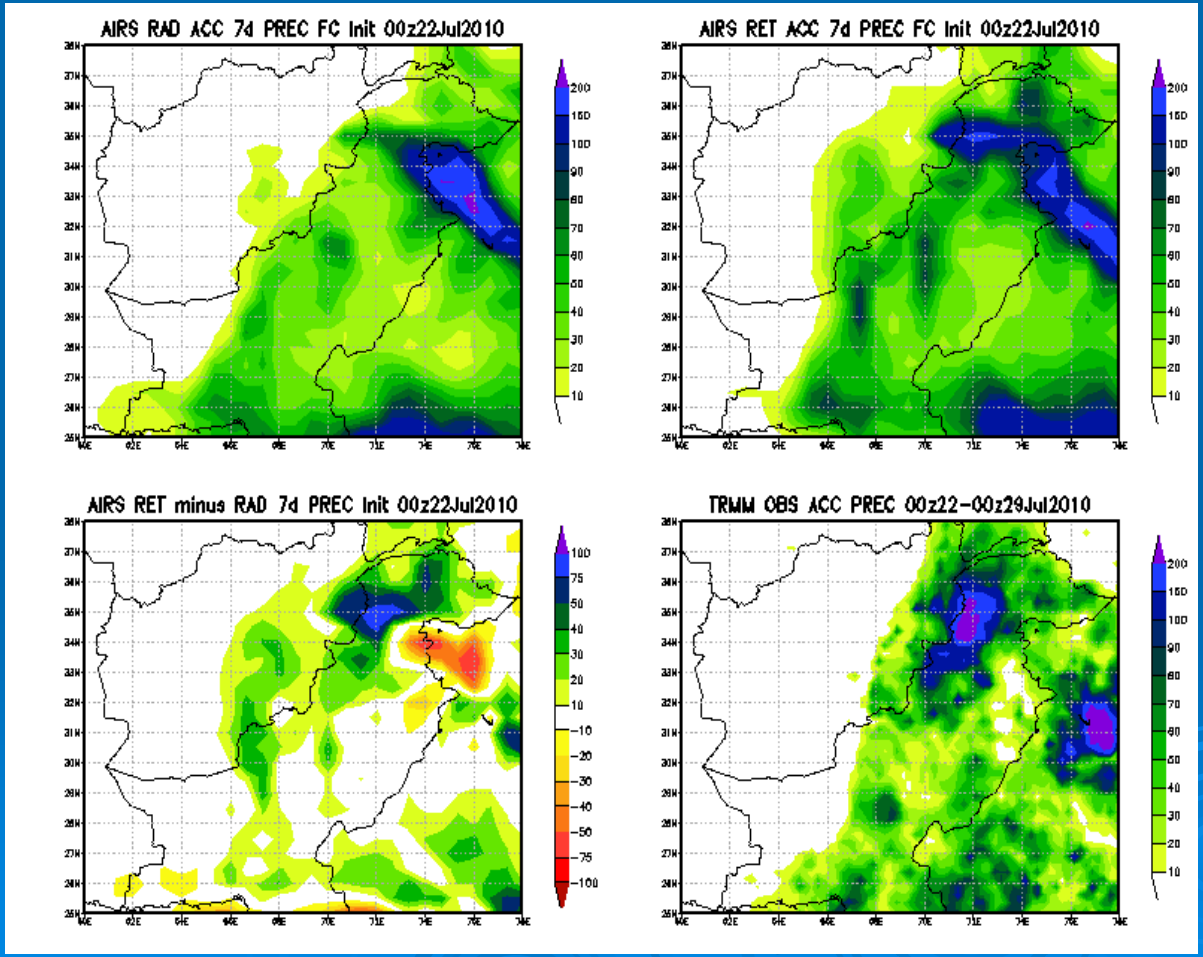
NCEP Operational Analyses, Very poor

- Past published AIRS impact study on precipitation associated with 3 tropical cyclones, selected in different seasons and basins, showed that Assimilation of AIRV v5 retrievals produced better precipitation forecast than the assimilation of clear-sky radiances, contrary to expectation
- Another published work on the impact of AIRS on PRECIPITATION focused on a set of catastrophic floods that affected the Indus River Valley (Pakistan) in 2010

Zhou, Y., W. K. Lau, O. Reale, R. Rosenberg, 2010: AIRS Impact on precipitation analysis and forecast of tropical cyclone in a global data assimilation and forecasting system. *Geophys. Res. Lett.*, **37,** L02806, doi.1029/2009GL041494

Reale, O., K. M. Lau, J. Susskind, and R. Rosenberg (2012), AIRS impact on analysis and forecast of an extreme rainfall event (Indus River Valley, Pakistan, 2010) with a global data assimilation and forecast system, J. Geophys. Res., 117, D08103, doi:10.1029/2011JD017093.

AIRS v5 retrievals improve the 7-day accumulated precipitation forecast with respect to AIRS radiances at the peak of the event



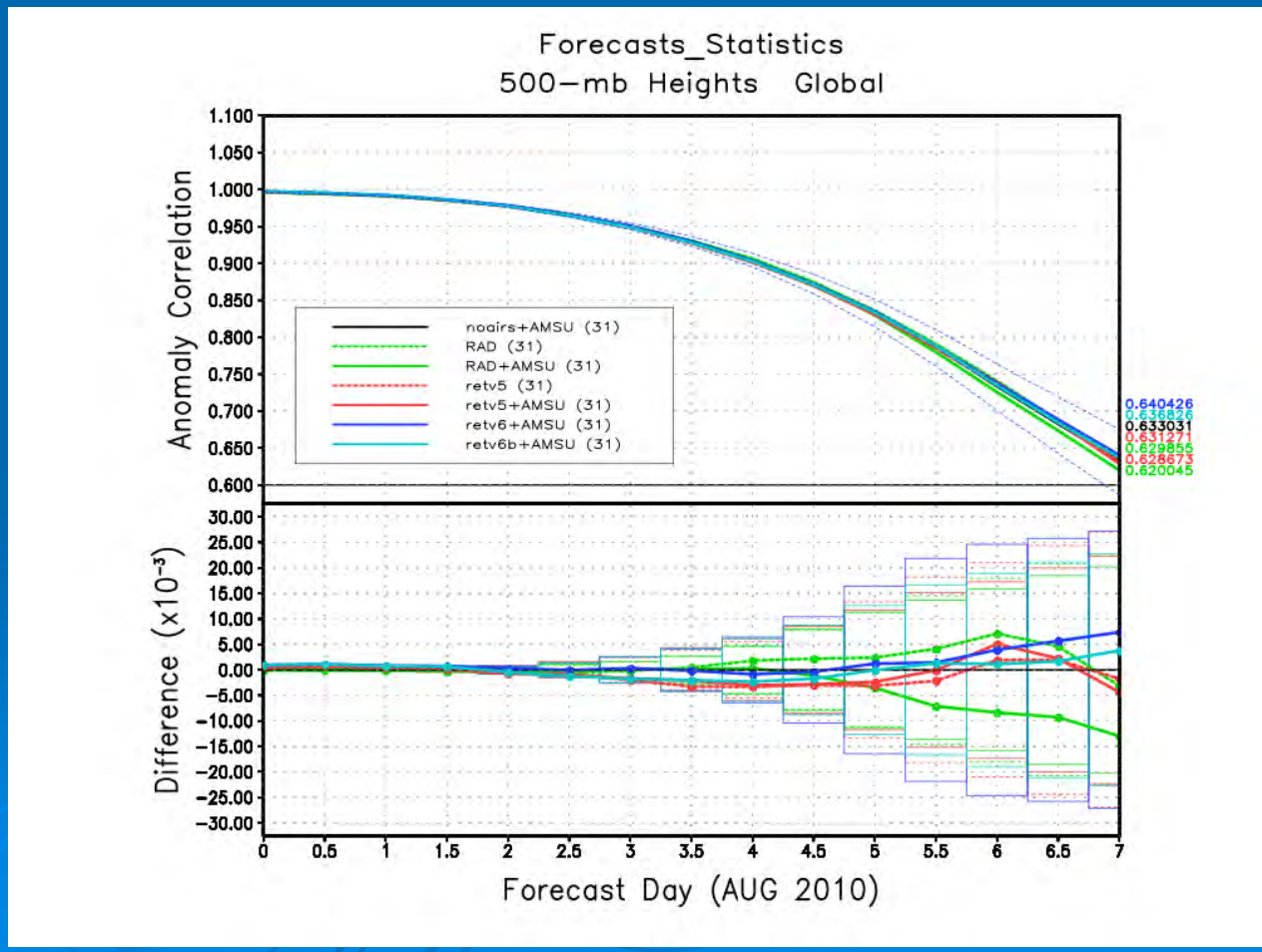
Comparison of AIRS v6 against v5 retrievals and clear-sky radiances assimilation

Seven experiments, forecasts to **7 days**
(retv6, retv6b, clear-sky radiances, retv5 with or without AMSU, AMSU alone).
retv6 and retv6b differ only because of the *thinning* applied
(retv6b ingesting more data)

August 2010

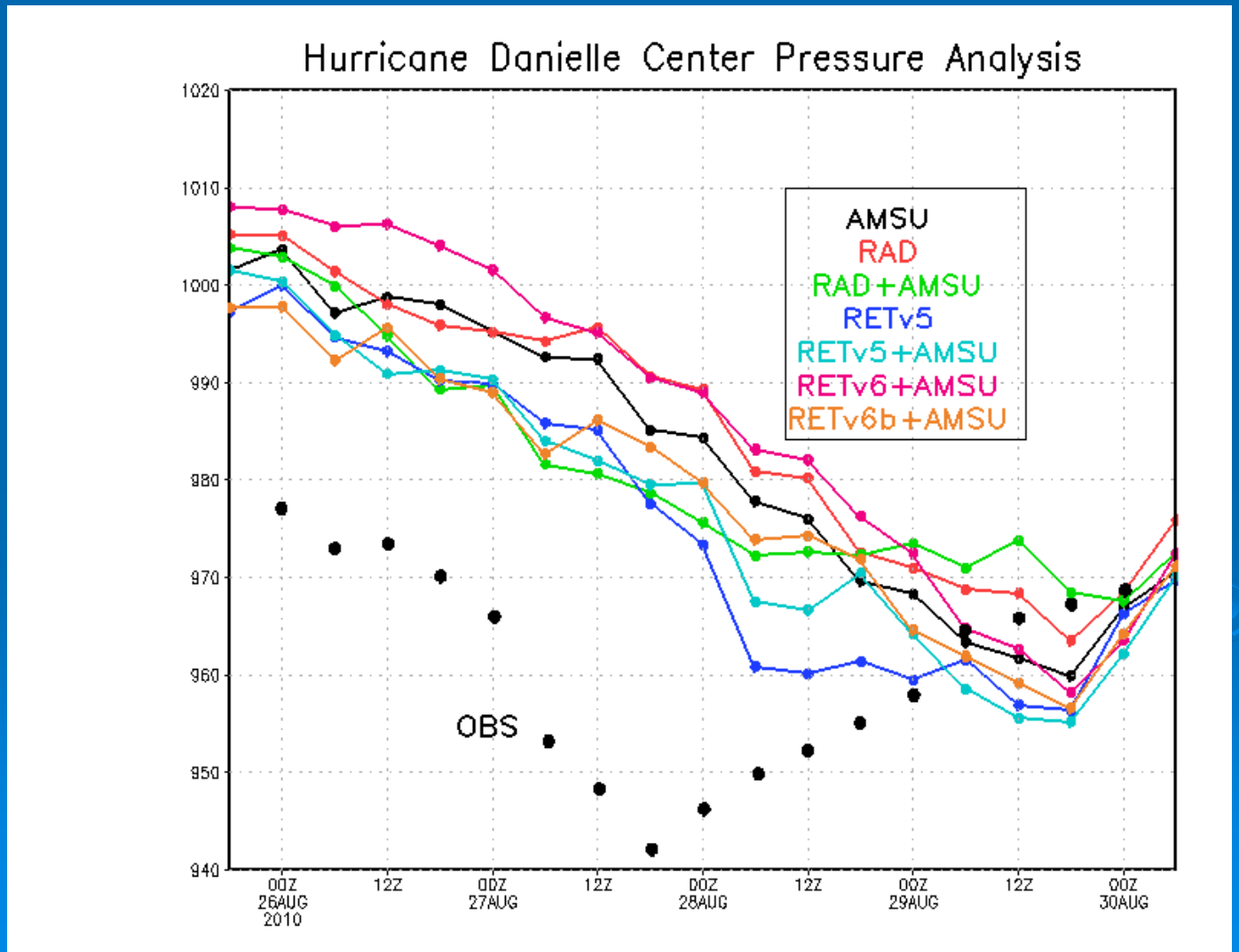
retv5 and retv6b are rigorously identical except for AIRS version

retv6 ingests slightly LESS data than retv6b, yet has slightly better global forecast skill!

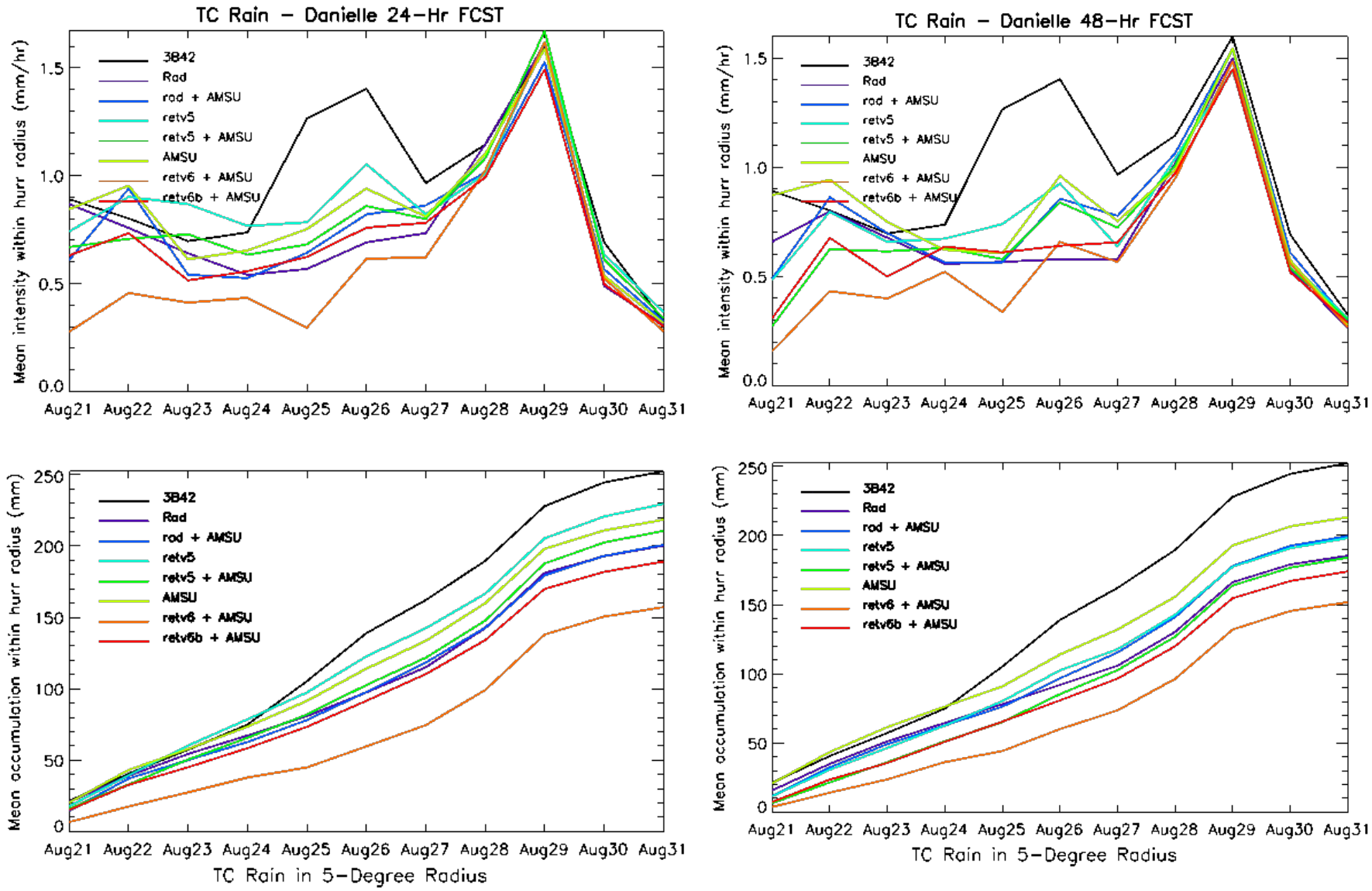


Comparison of assimilation of AIRS v6 against v5 and clear-sky radiances TC analysis: intensity, structure, precipitation produced.

Example: **Danielle** (2010) rapid intensification:
Comparison of GEOS-5 **Analyses** [vortex relocator is DISABLED], obtained from assimilation of AIRS version 5 retrievals, version 6 retrievals (with two different data distributions), and clear-sky radiances (with or without AMSU radiances)



retv6 ingests slightly LESS data than retv6b, and produces a slightly worse TC, (in contrast to effect on global skill) Both v6 exp are worse than v5.

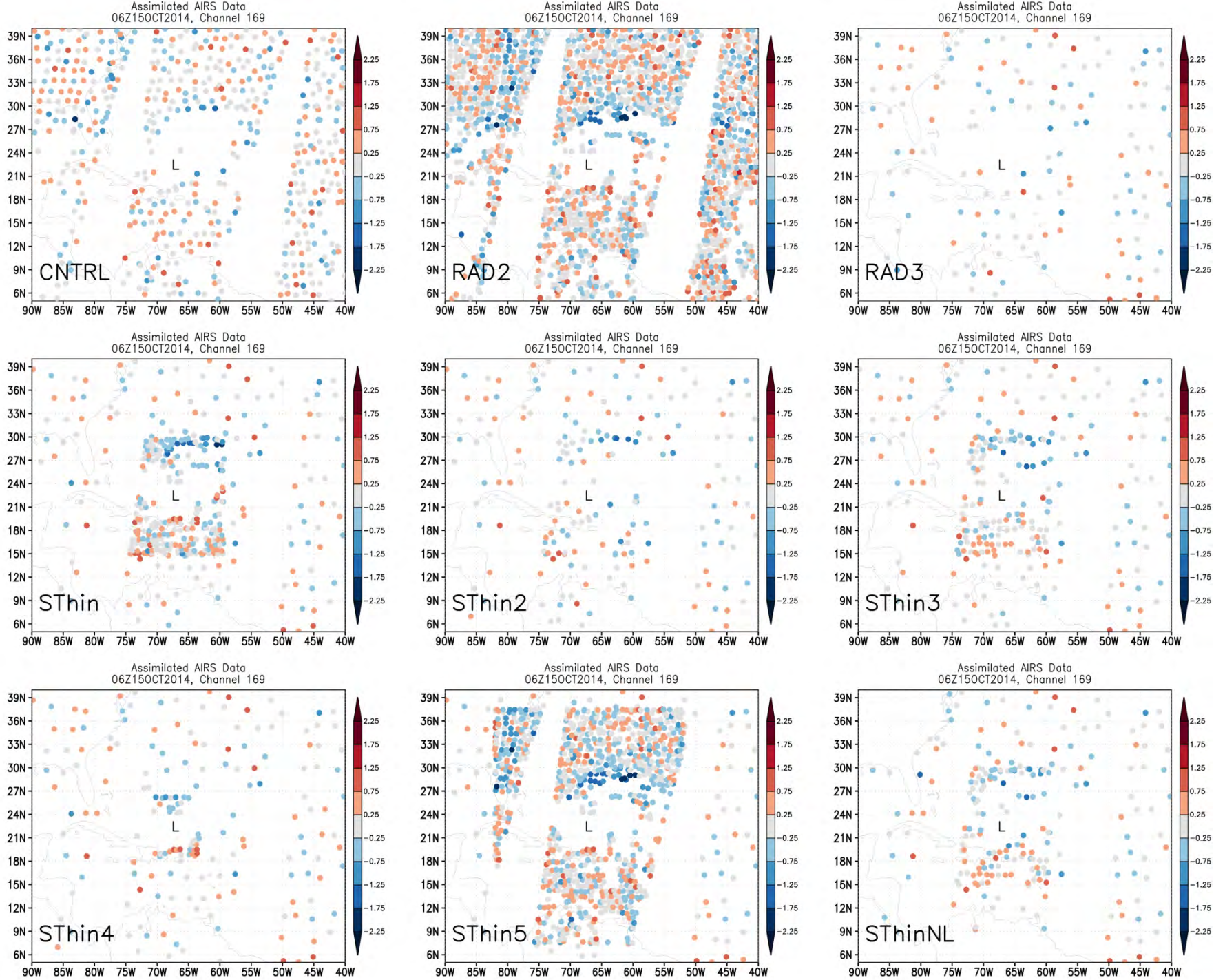

TC Rain – Danielle 24–Hr FCST
TC Rain – Danielle 48–Hr FCST
Mean intensity within hurr radius (mm/hr)
Mean accumulation within hurr radius (mm)
3B42
Rad
rad + AMSU
retv5
retv5 + AMSU
AMSU
retv6 + AMSU
retv6b + AMSU
Aug21 Aug22 Aug23 Aug24 Aug25 Aug26 Aug27 Aug28 Aug29 Aug30 Aug31
TC Rain in 5–Degree Radius

Past work conclusion

- Past work on data assimilation experiments without AIRS, with AIRS version 5 retrievals, AIRS clear-sky radiances were produced for boreal winter, spring, four summer-fall conditions, 5 different years.
- The overall impact on TC forecasts skill coming from v5 retrievals was higher than the corresponding impact of radiances in every season, every year and every basin, contrary to the well-established practice of assimilating clear-sky radiances (*four published articles 3GRL and 1 JGR*)
- Version 6 has been rigorously compared with version 5 in two different TC seasons (2010 and 2012) and with two different thinning strategies
- Version 6 retrievals produce some improvement in global skill compared to v5, but produce a negative impact on TC analysis or forecast. Metrics used: TC structure, TC intensity, TC-produced precipitation.
- AIRS v5 beats v6 on the TC scale, but v6 beats v5 on the global scale.
- Lessons learnt: contrasting impact of local versus global scale, importance of thinning.
- Global skill increases slightly when less data are ingested, BUT TC representation deteriorates.

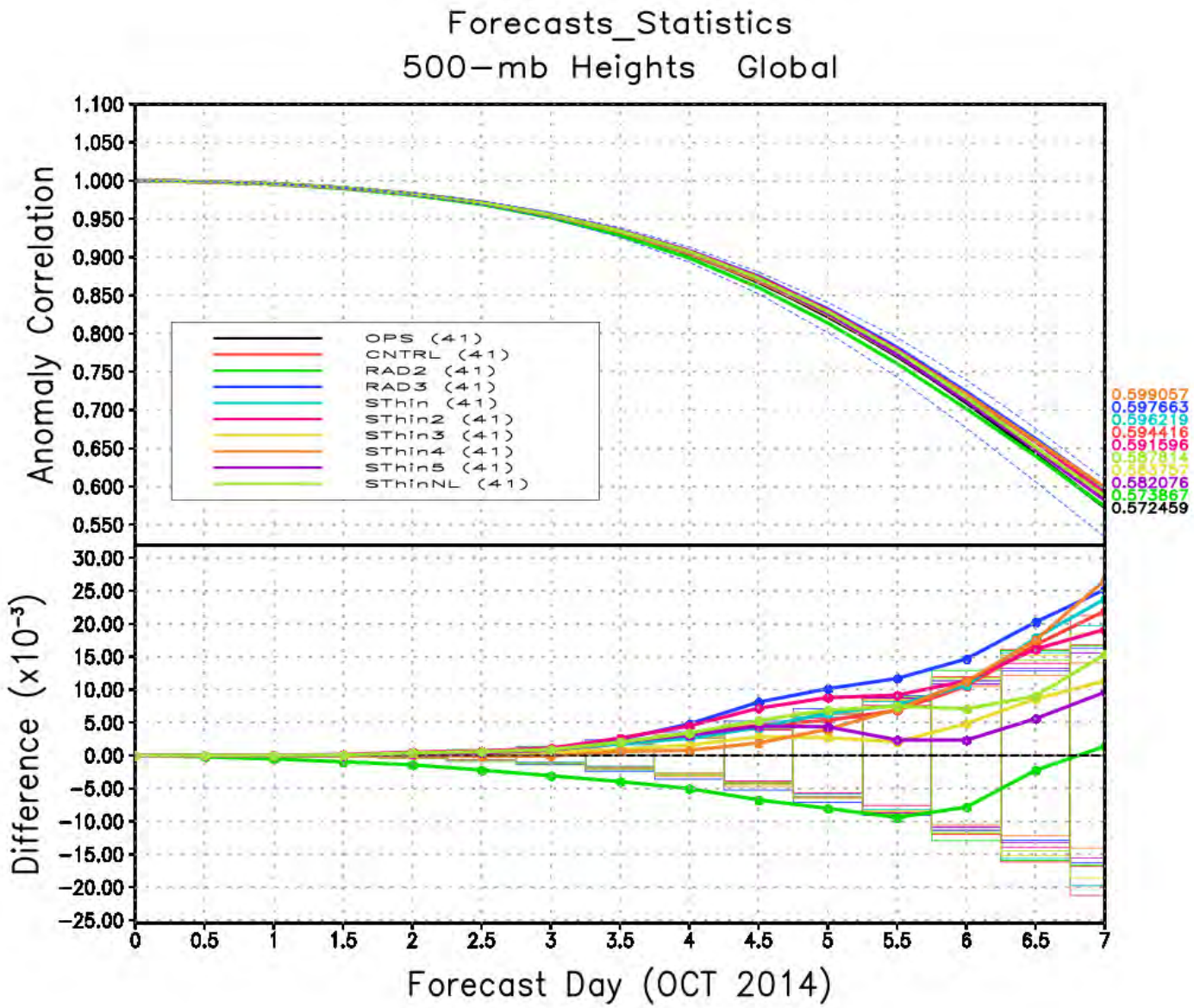
NEW: AIRS experiments settings

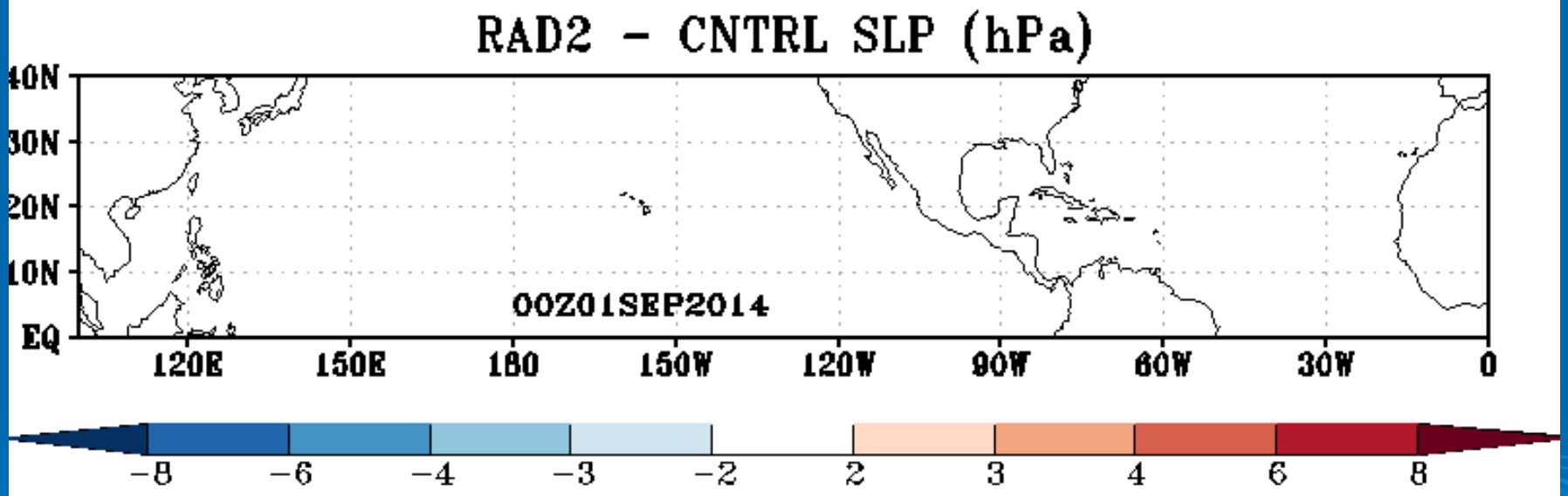
- GEOS-5 DAS: versions 5-13.0p1
- Periods chosen: Sep-Oct-Nov 2014
- CNTRL: assimilating all conventional and satellite obs, AIRS clear-sky radiances with standard thinning (145km box); no vortex relocator
- RAD2: As RAD but with 75km AIRS thinning box AIRS (~4 times more data)
- RAD3 As RAD but with 300km AIRS thinning box (~4 times less data)
- Sthin: As RAD2 within moving domain of 15x15 degrees, centered on, and following TCs, and as RAD3 outside the domain. TC-moving domain activated by NHC/JTWC warnings
- Sthin2: As CNTRL inside TC domain, as RAD3 outside
- Sthin3: Intermediate thinning (110 km thinning box) inside TC domain, as RAD3 outside
- Sthin4: As SThin, but with smaller TC domain (7.5°x7.5°)
- Sthin5: As SThin, but with larger TC domain (15°x15°)
- SthinNL: As SThin, but AIRS assimilated only over Ocean (NO-LAND AIRS)
- 60 ten-day Forecasts at 0.25 degrees initialized every day at 00z for each experiment, more than 700 ten-day forecasts.

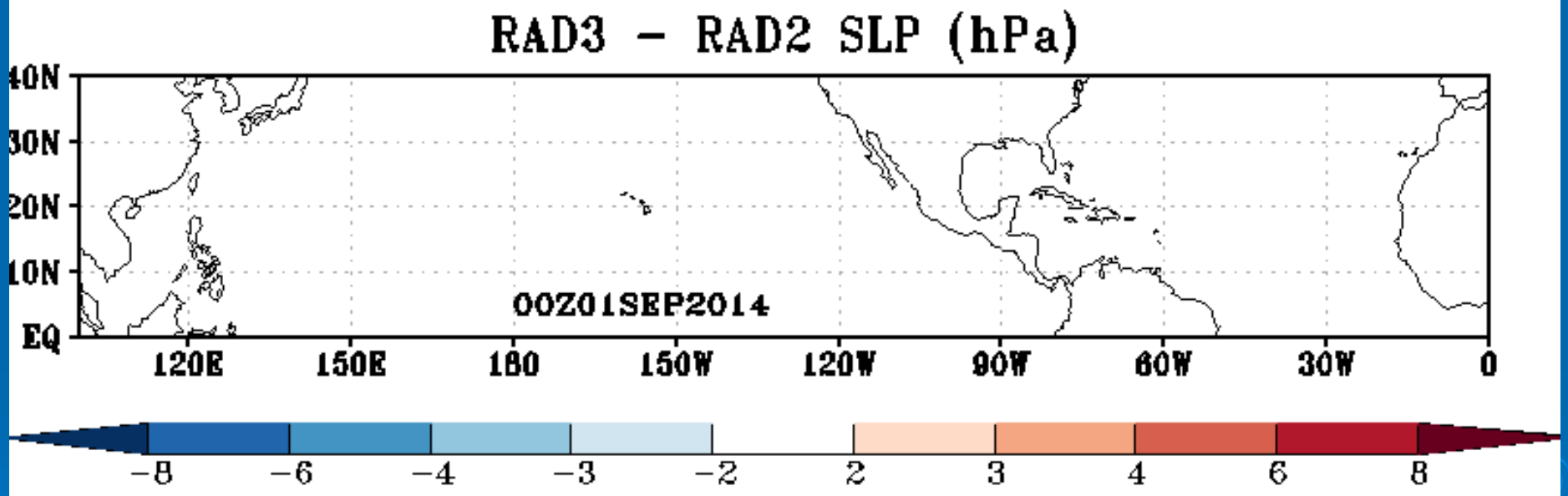

Assimilated AIRS Data
06Z15OCT2014, Channel 169
CNTRL
RAD2
RAD3
SThin
SThin2
SThin3
SThin4
SThin5
SThinNL
L
39N 36N 33N 30N 27N 24N 21N 18N 15N 12N 9N 6N
90W 85W 80W 75W 70W 65W 60W 55W 50W 45W 40W
2.25 1.75 1.25 0.75 0.25 -0.25 -0.75 -1.25 -1.75 -2.25

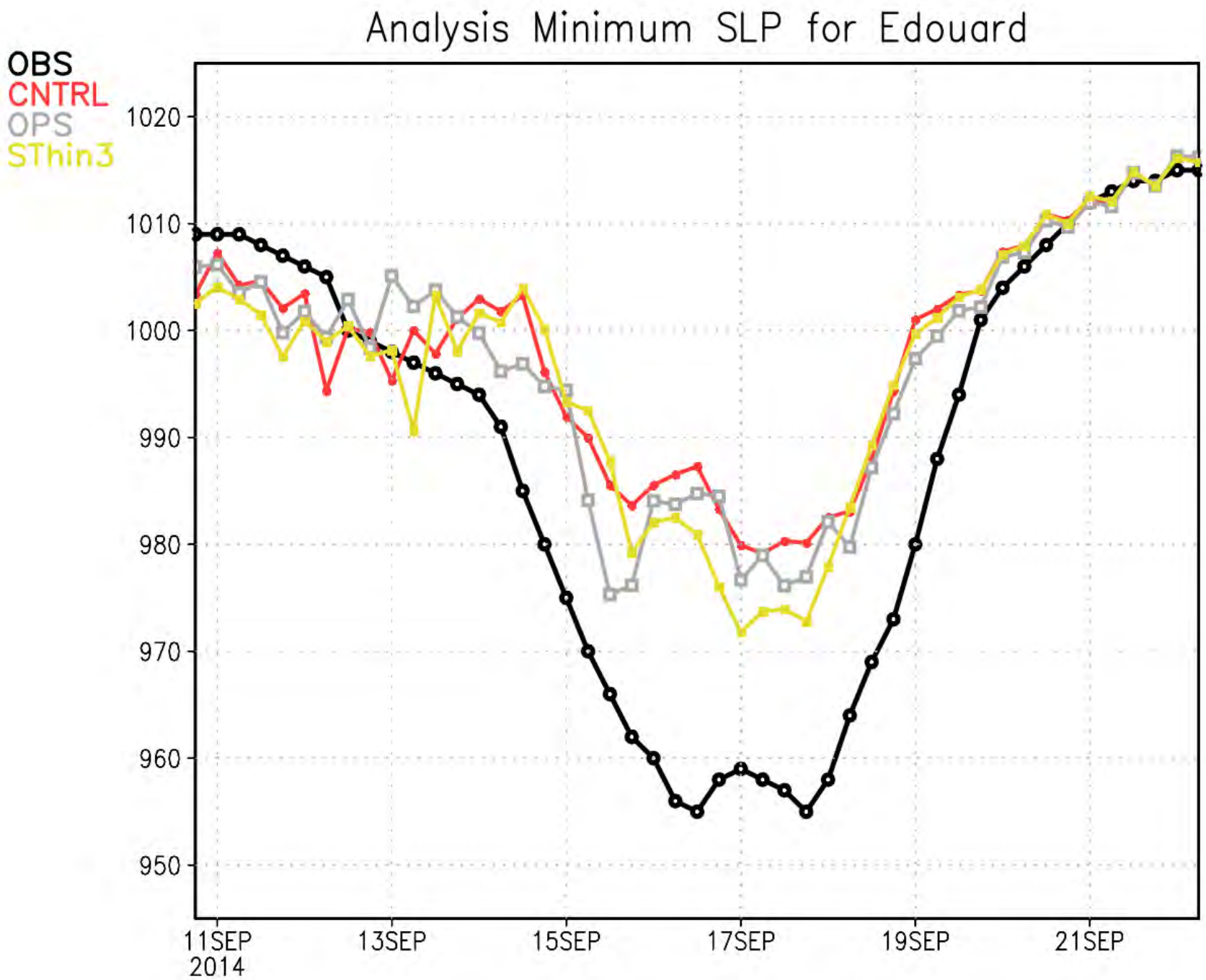
SKILL Computed for all exp against `OPS' which is the daily quasi-real time GEOS-5 forecasts produced by the GMAO (aka e5130_fp) in 2014

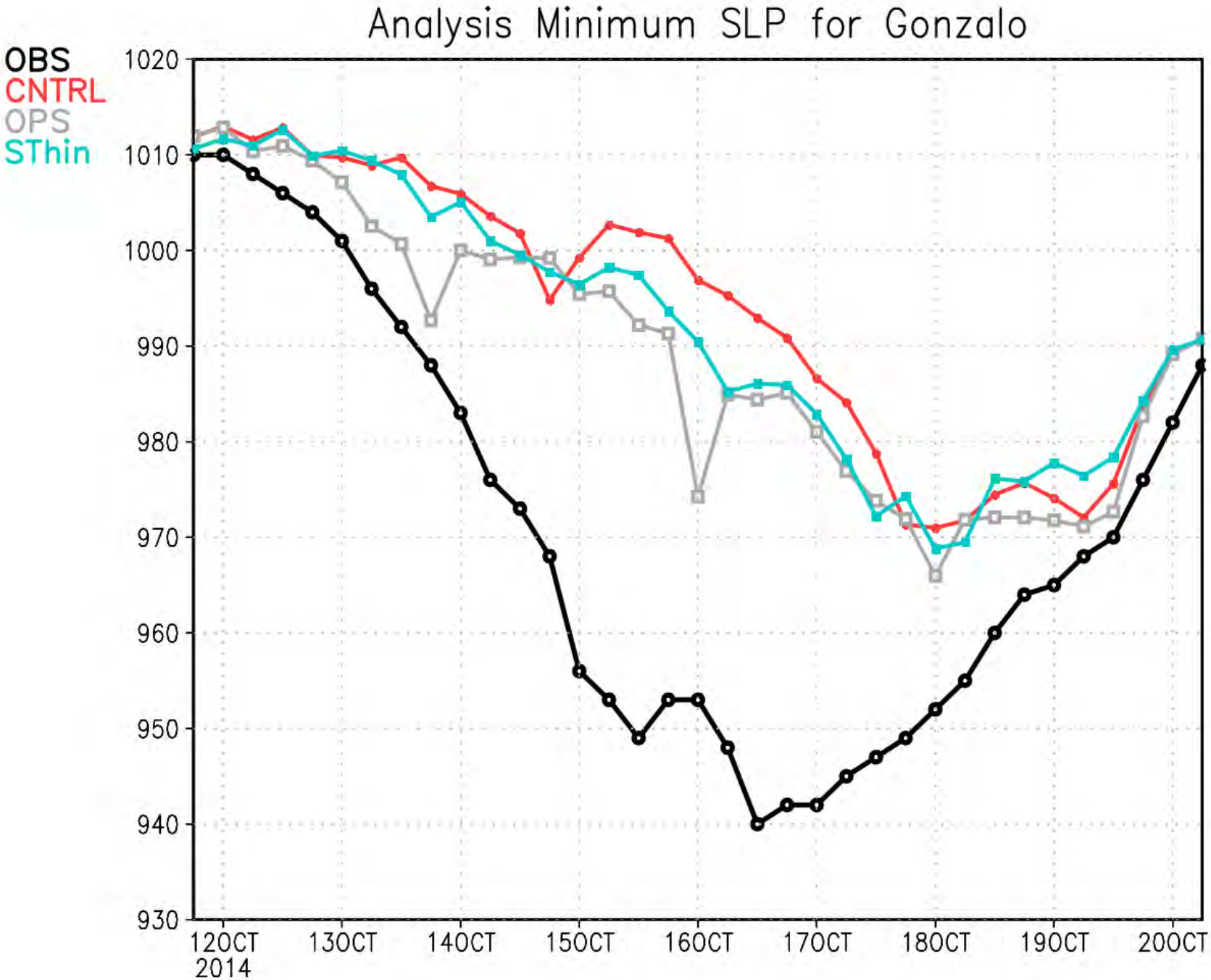
OPS is identical to CNTRL except for the vortex relocator (enabled)




RAD2 - CNTRL SLP (hPa)
40N
30N
20N
10N
EQ
00Z01SEP2014
120E
150E
180
150W
120W
90W
60W
30W
0
−8
−6
−4
−3
−2
2
3
4
6
8

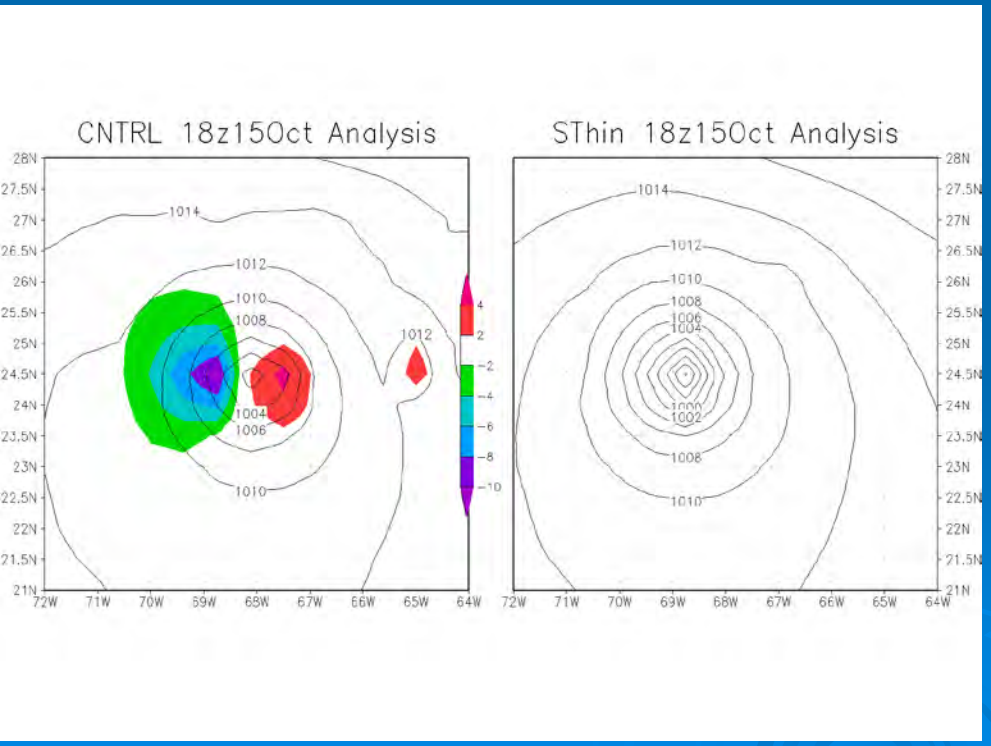

RAD3 - RAD2 SLP (hPa)
40N
30N
20N
10N
EQ
00Z01SEP2014
120E
150E
180
150W
120W
90W
60W
30W
0
-8
-6
-4
-3
-2
2
3
4
6
8


Analysis Minimum SLP for Edouard
OBS
CNTRL
OPS
SThin3
1020
1010
1000
990
980
970
960
950
11SEP
2014
13SEP
15SEP
17SEP
19SEP
21SEP

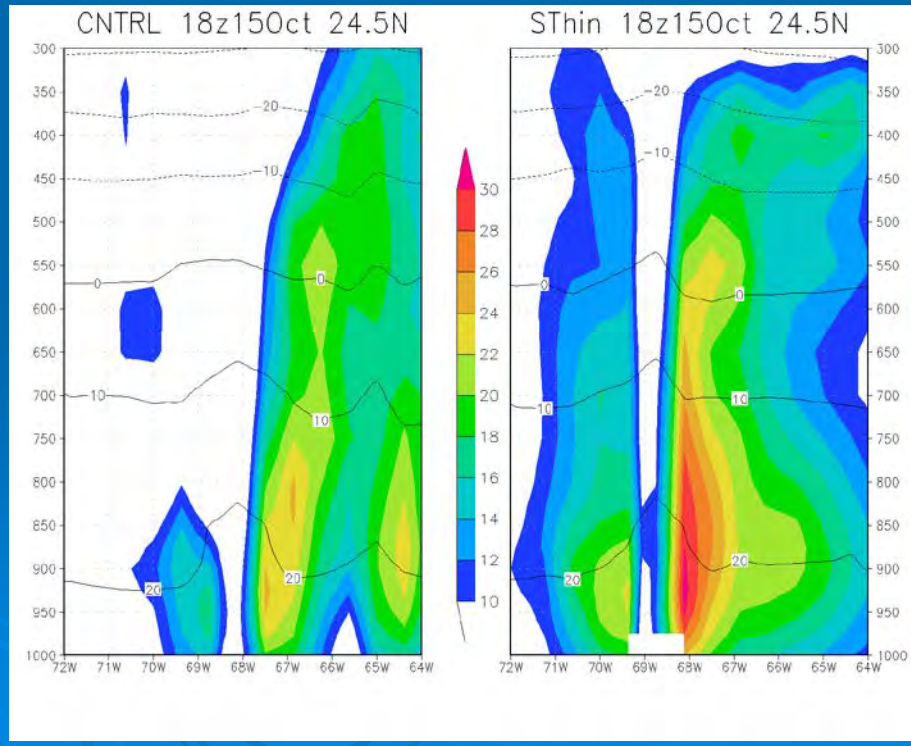

Analysis Minimum SLP for Gonzalo
OBS
CNTRL
OPS
SThin
1020
1010
1000
990
980
970
960
950
940
930
120CT
2014
130CT
140CT
150CT
160CT
170CT
180CT
190CT
200CT

Selective Thinning improves Hurricane Gonzalo in terms of intensity, position, and vertical structure

Sthin minus CNTRL slp (hPa, shaded)



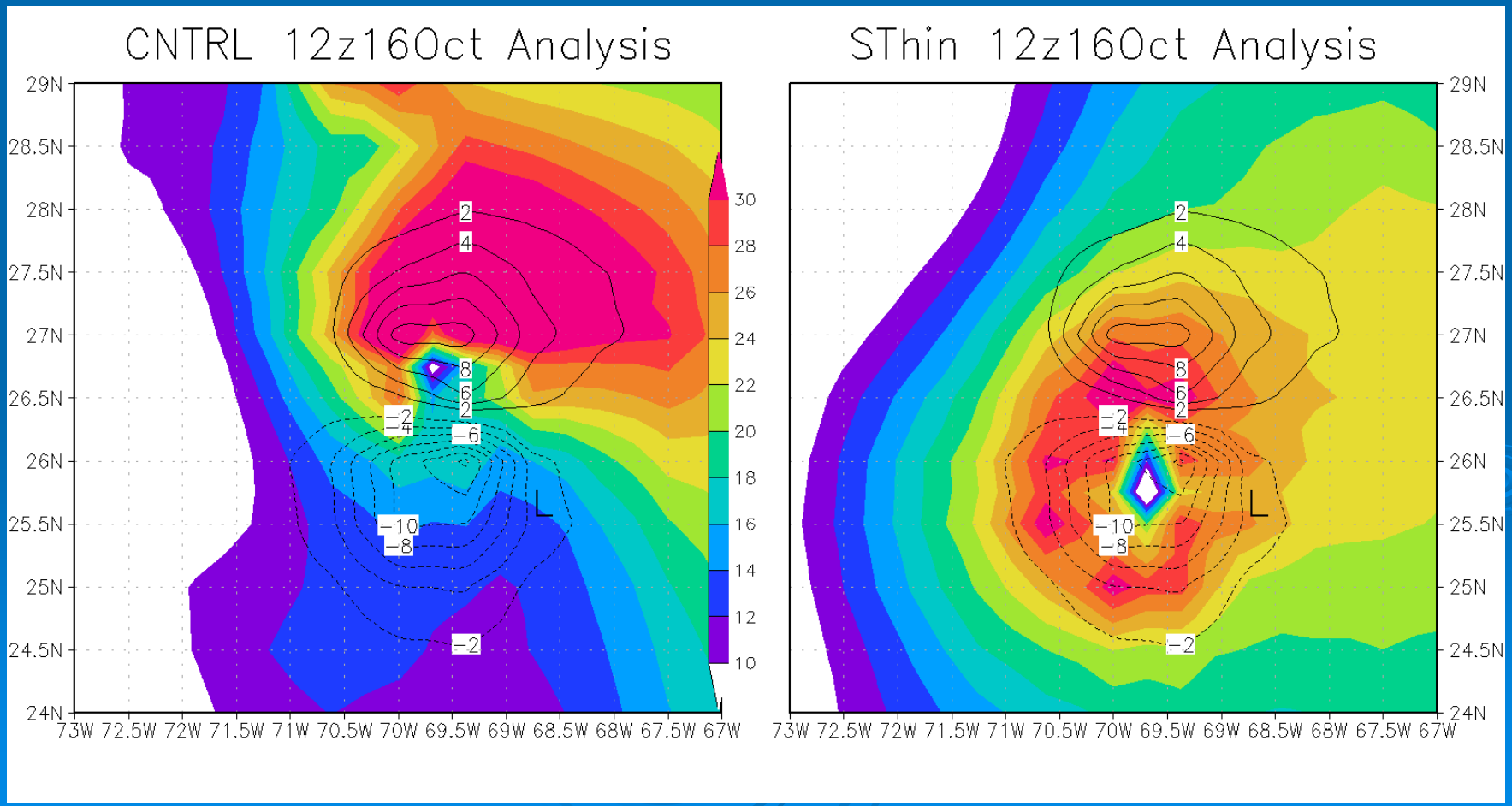
Gonzalo Vertical Cross Section

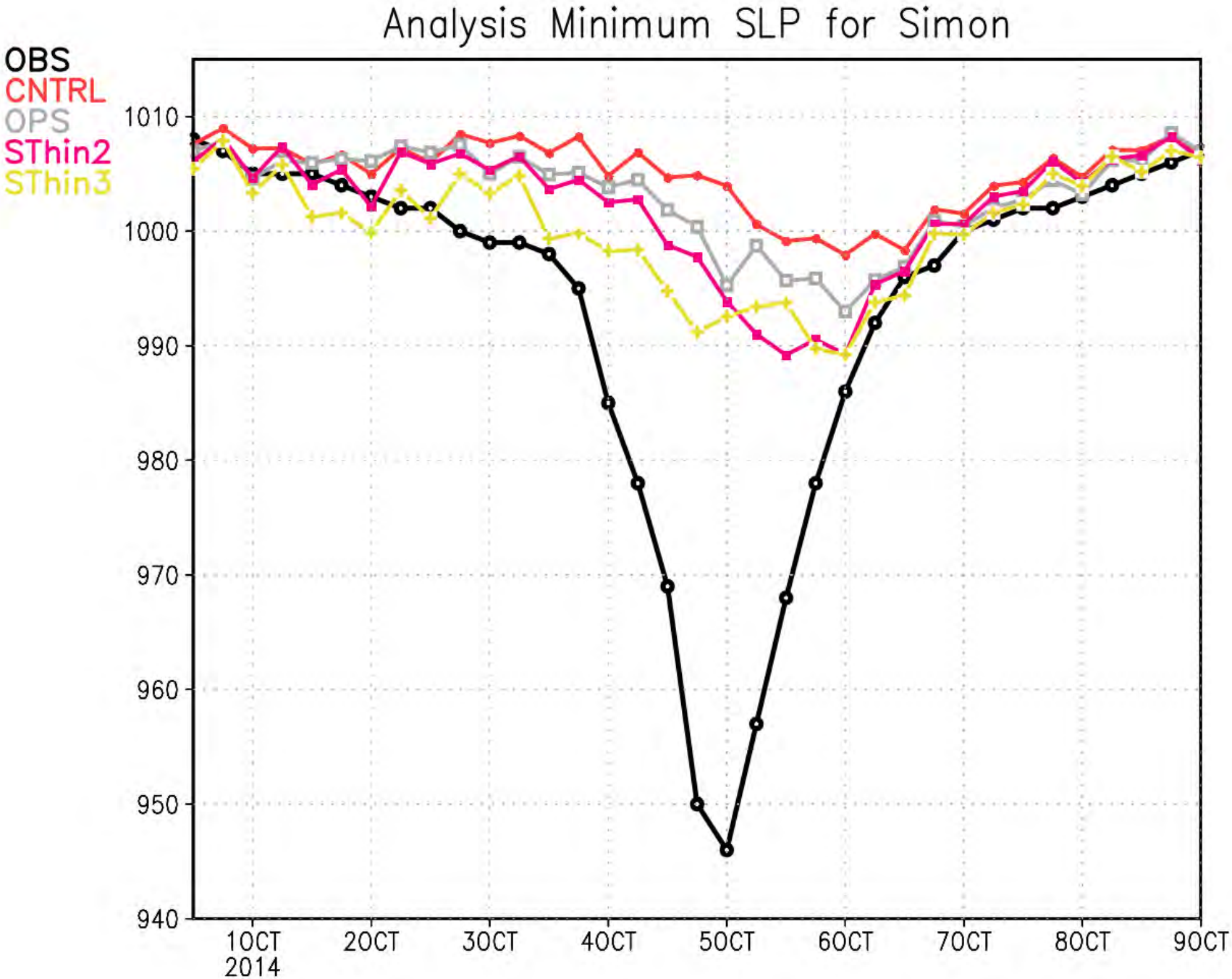


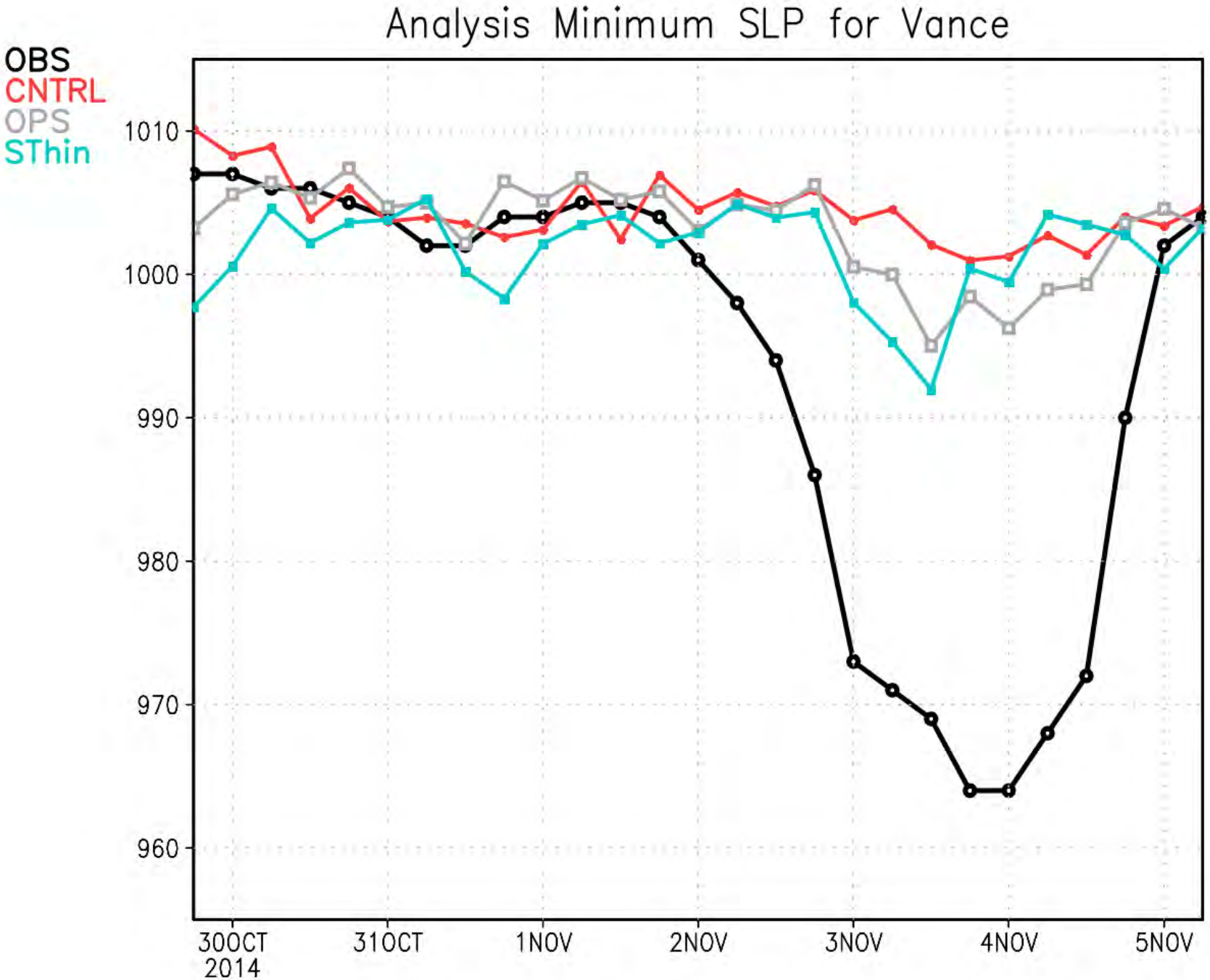
Gonzalo at peak intensity 12z16Oct2014

900 hPa wind (m/s, shaded)

Slp SThin Minus CNTRL anomaly (contours) .
Note the much better defined eye in the SThin analysis

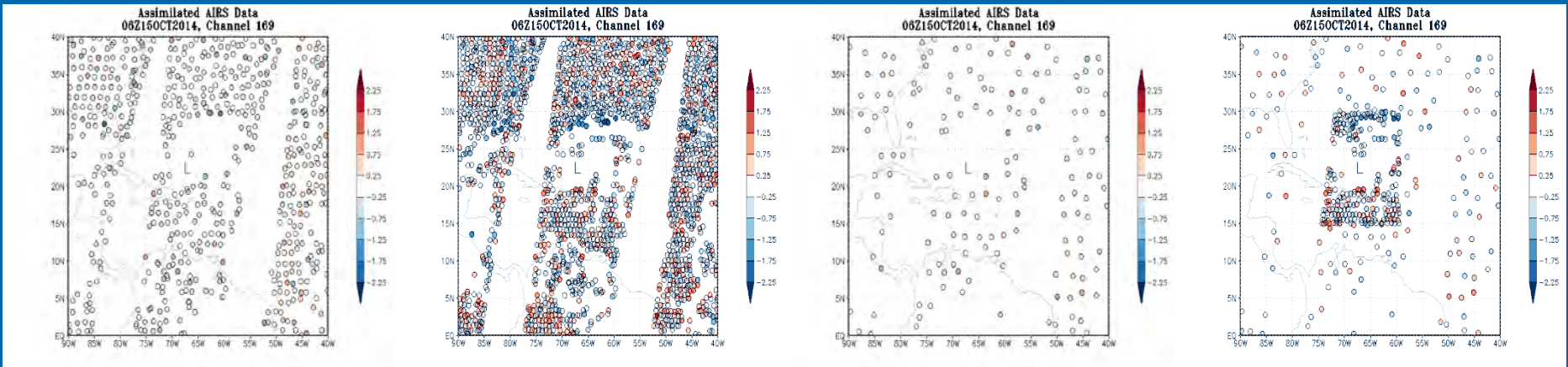


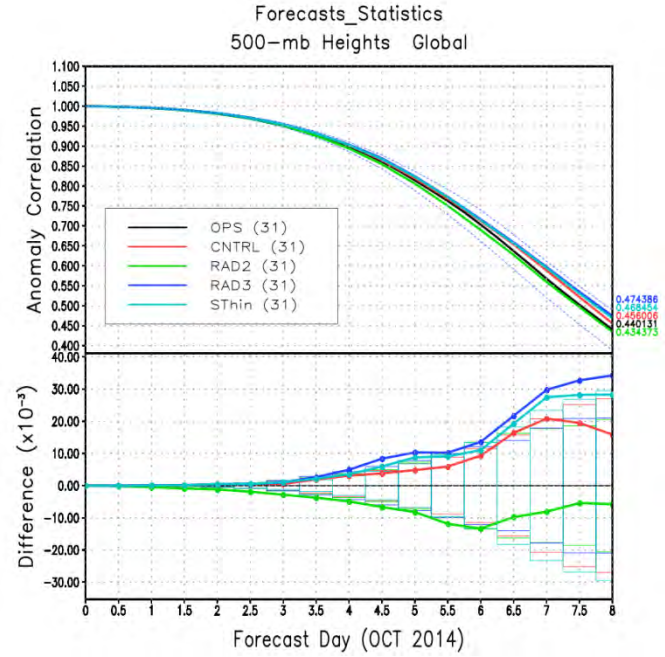

Analysis Minimum SLP for Simon
OBS
CNTRL
OPS
SThin2
SThin3
1010
1000
990
980
970
960
950
940
10CT
2014
20CT
30CT
40CT
50CT
60CT
70CT
80CT
90CT


Analysis Minimum SLP for Vance
OBS
CNTRL
OPS
SThin
1010
1000
990
980
970
960
30OCT
2014
31OCT
1NOV
2NOV
3NOV
4NOV
5NOV

Summary: global forecast skill and Tropical Cyclone structure both improve in response to variable `thinning' of AIRS clear-sky radiances in the GEOS-5

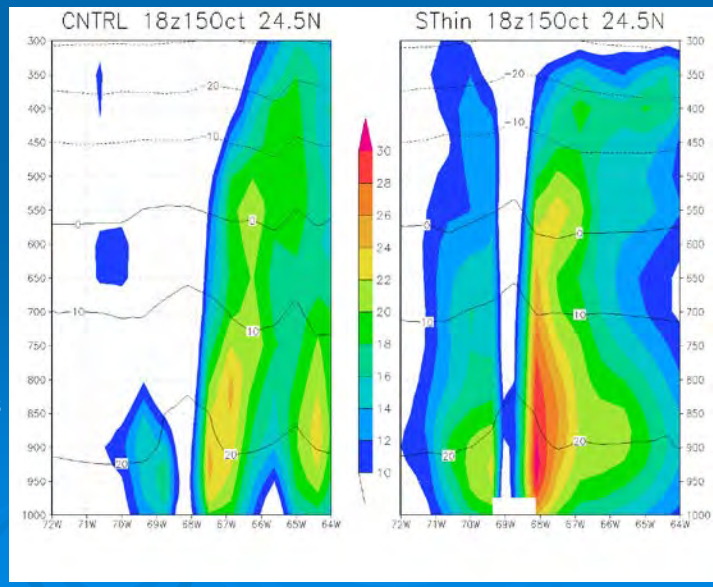
CNTRL RAD2 RAD3 SThin





Experiments in which the AIRS radiance coverage is perturbed with respect to the normal practice (CNTRL) are performed: RAD2 (RAD3), more (less) data globally; SThin (denser data coverage in a Moving domain around hurricanes, scarcer coverage elsewhere).

Results indicate that assimilation of AIRS radiances with variable density improves both the global skill of the model and the representation of Tropical Cyclone structure, compared to the operational version.
The TC scale affects the optimal size of the moving domain .



Hurricane Gonzalo: vertical structure

Conclusions

- Uniform thinning of clear-sky radiances is an established practice but it should be revisited
- With the current operational system, the density of AIRS data assimilated globally is excessive. In particular, large scale inactive features such as big anticyclones are negatively impacted by excessive data density. Global skill increases if the thinning box size is increased so that less data are assimilated.
- On the contrary, rapidly evolving features such as tropical cyclones are positively impacted by increased data density. TC representation improves when the thinning box size is decreased and more AIRS data are assimilated.
- A strategy of –adaptive- thinning which gets more data around TCs and less elsewhere produces both an increase in global skill and an improvement in the TC analysis.

Acknowledgments

- **Dr. Ramesh Kakar** *for support to previously funded proposal ``Relationships among precipitation characteristics, atmospheric water cycle, climate variability and change"* (PI: Dr. W. K. Lau)
- **Dr. Ramesh Kakar** *for support to previously funded proposal ``Using AIRS data to understand processes affecting Tropical Cyclone structure in a Global Data Assimilation and Forecasting Framework (2011-2014)"*
- **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 Computer resources
- **AIRS team** at JPL and the **Sounder Research Team** at NASA GSFC
- **Joel Susskind,** Lena Iredell, John Blaisdell, Louis Kouvaris
- **GES DISC** for their outstanding service to the community

National Aeronautics and Space Administration

AIRS-related articles published by this team

Reale, O., J. Susskind, R. Rosenberg, E. Brin, E. Liu, L. P. Riishojgaard, J. Terry, J. C. Jusem, 2008: Improving forecast skill by assimilation of quality-controlled AIRS temperature retrievals under partially cloudy conditions. Geophysical Research Letters, 35, L08809, doi:10.1029/2007GL033002.

Reale, O., W. K. Lau, J. Susskind, E. Brin, E. Liu, L. P. Riishojgaard, M. Fuentes, R. Rosenberg, 2009: AIRS Impact on the Analysis and Forecast Track of Tropical Cyclone Nargis in a global data assimilation and forecasting system. Geophysical Research Letters, 36, L06812, doi:10.1029/2008GL037122.

Reale, O., W. K. Lau, K.-M. Kim, E. Brin, 2009: Atlantic tropical cyclogenetic processes during SOP-3 NAMMA in the GEOS-5 global data assimilation and forecast system. Journal of the Atmospheric Sciences, 66, 3563-3578.

Zhou, Y., W. K. Lau, O. Reale, R. Rosenberg, 2010: AIRS Impact on precipitation analysis and forecast of tropical cyclones in a global data assimilation and forecasting system. Geophysical Research Letters, 37, L02806, doi.1029/2009GL041494.

Reale, O., K. M. Lau, J. Susskind, and R. Rosenberg, 2012: AIRS impact on analysis and forecast of an extreme rainfall event (Indus River Valley, Pakistan, 2010) with a global data assimilation and forecast system, J. Geophys. Res., 117, D08103, doi:10.1029/2011JD017093.