Impact of assimilating cloud-cleared and adaptively thinned infrared hyperspectral radiances on Tropical Cyclones in a global data assimilation and forecast framework

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(NASA/GMAO)

Recent past work: Three major findings

A new article published in August 2018 summarizes the work done by this team on the assimilation of *adaptively thinned AIRS cloud-cleared radiances* against *homogenously thinned clear-sky radiances.*

Reale, O., E. McGrath-Spangler, W. McCarty, D. Holdaway, R, Gelaro, 2018: Impact of adaptively thinned AIRS cloud-cleared radiances on tropical cyclone representation in a global data assimilation and forecast system. *Weather and Forecasting, 33, 908-931.*

1) Global data density of radiances operationaly assimilated globally is excessive, except around tropical cyclones

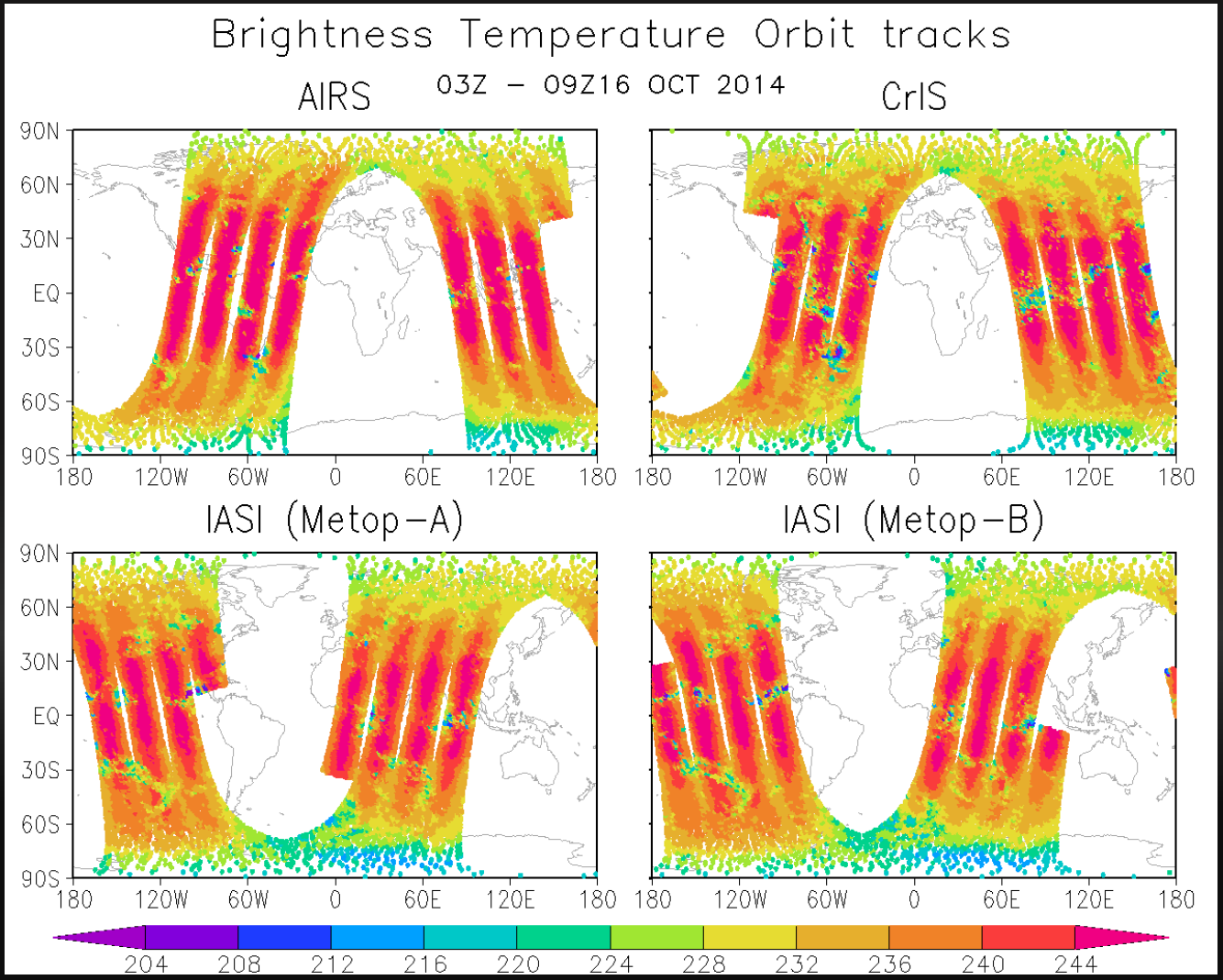
2) Cloud-cleared AIRS radiances are substantially superior compared to clear-sky radiances, as long as they are more aggressively thinned

3) An adaptive strategy that assimilates *more data around TCs*, and *less globally*, improves TC structure and intensity forecast, without damaging global skill.

Caveats: limited by AIRS coverage; no impact on TC track forecast.

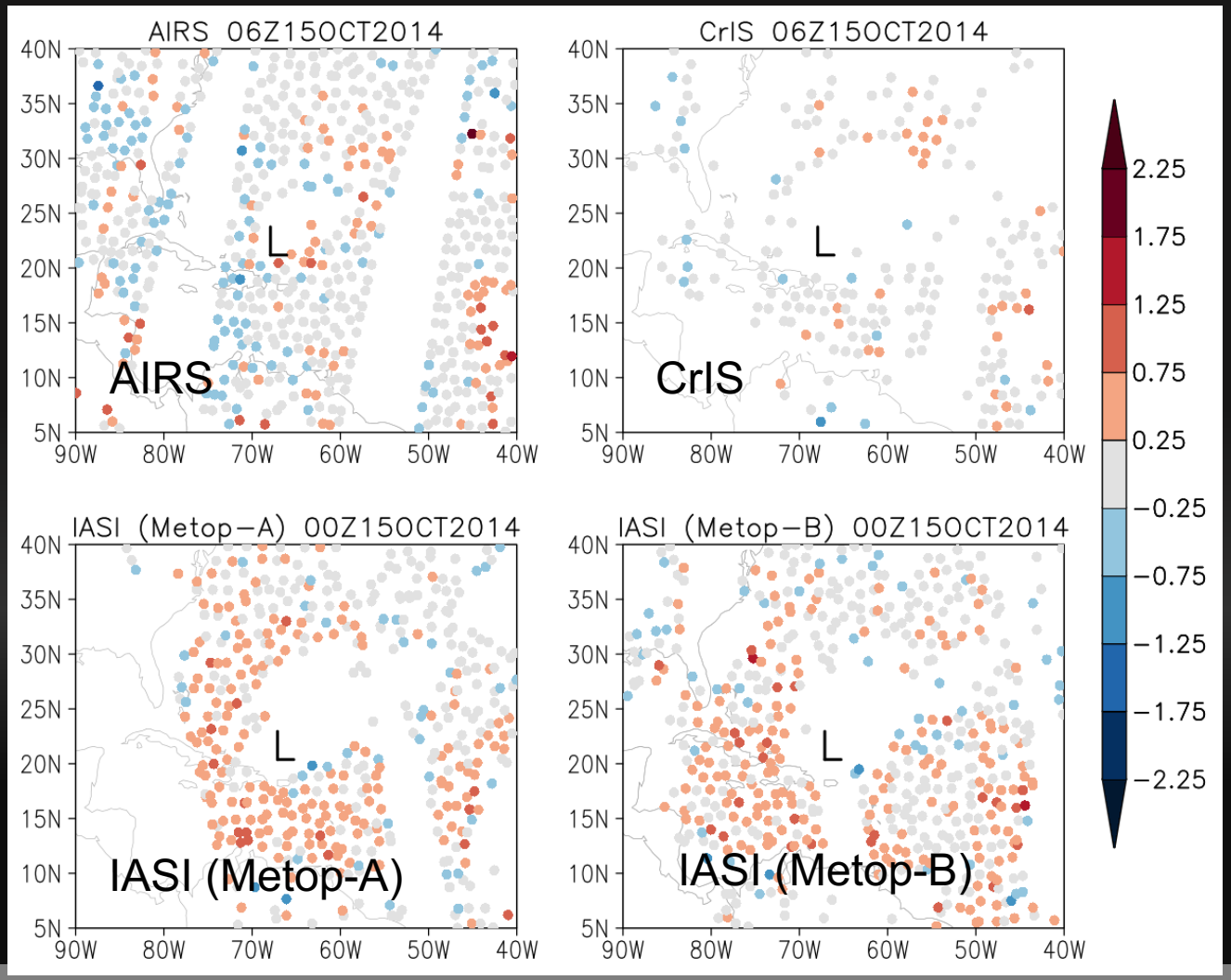
Question: What is the impact of this adaptive methodology if it is simultaneously applied to *all* hyperspectral sensors?

Hyperspectral instruments orbit tracks



Hyperspectral observations around Hurricane Gonzalo

- Different type of coverage around TCs
- Clear-sky radiances have large gaps corresponding to TCs circulations



New Experiment to evaluate the adaptively thinned procedure extended to all hyperspectral sensors

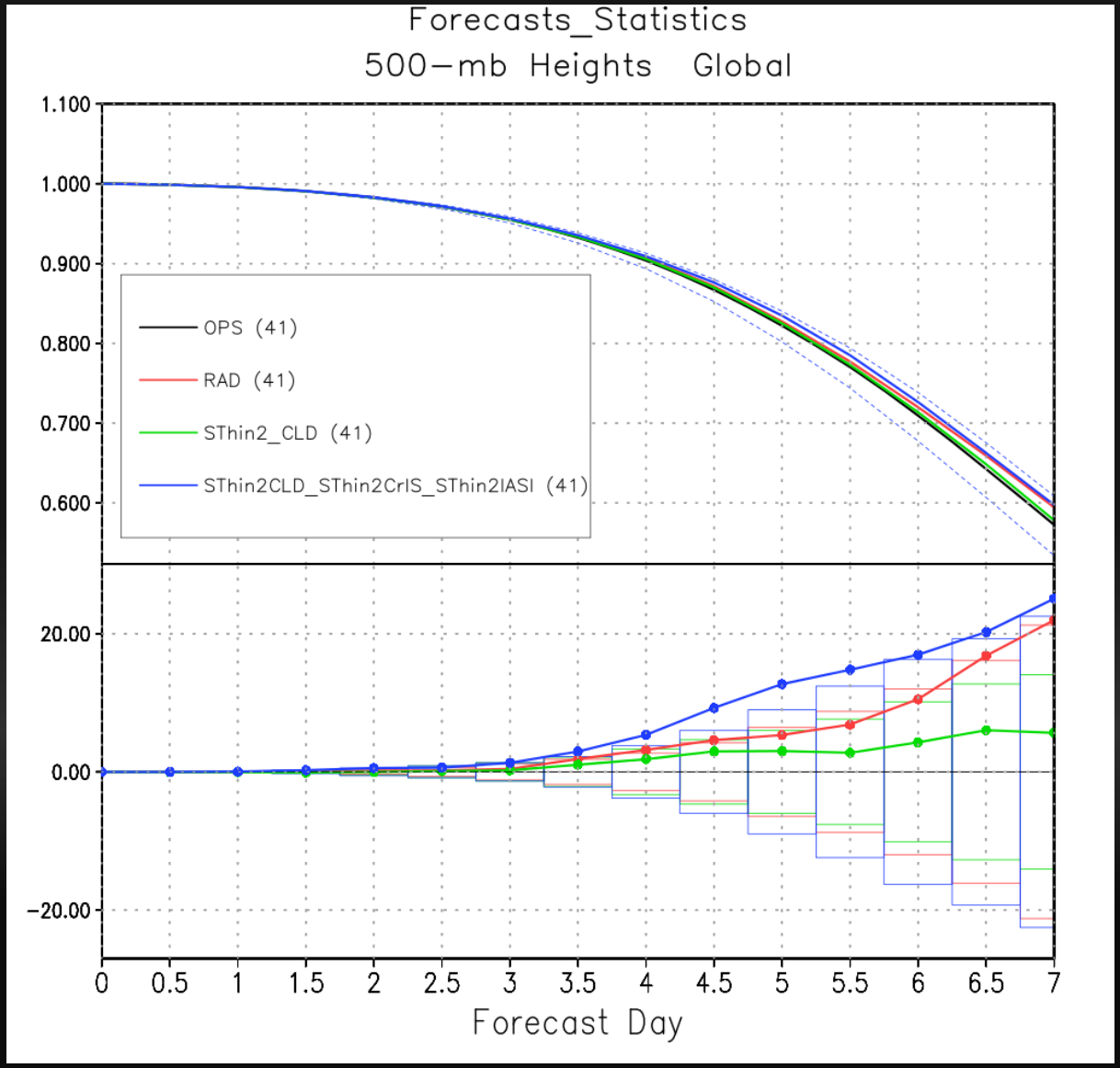
GEOS-5 DAS version 5-13.0p1

Assimilation from 1 Sep – 10 Nov 2014 of *all observations* assimilated operationally

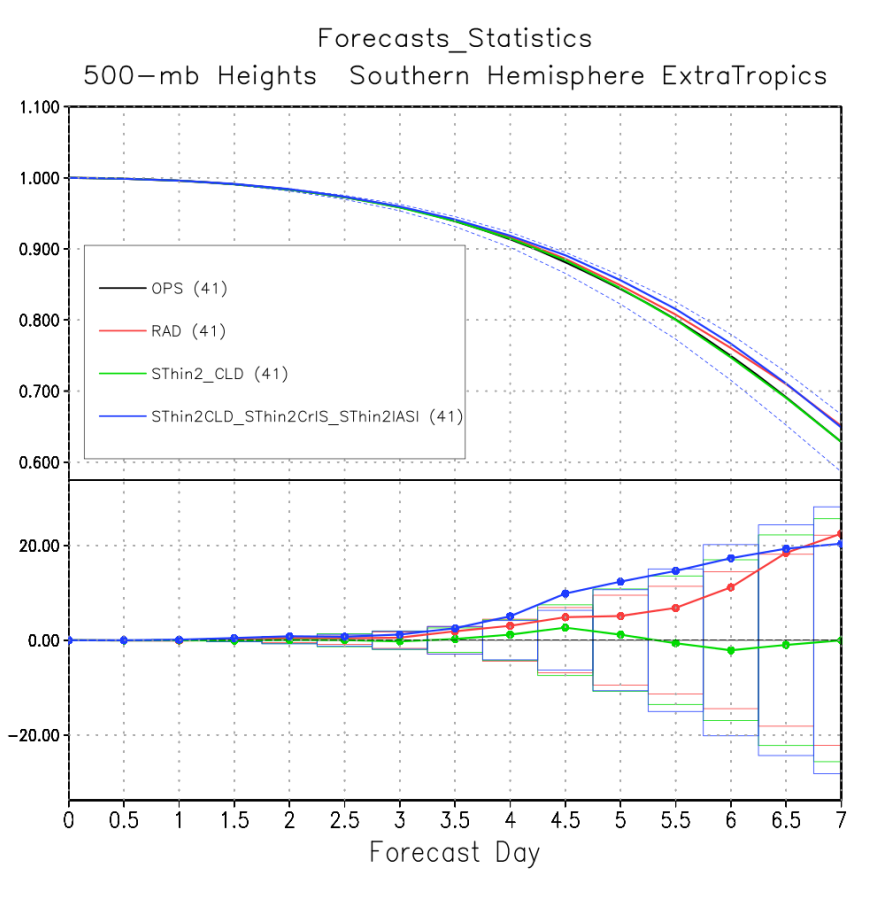
10 day forecasts from 21 Sep – 31 Oct 2014

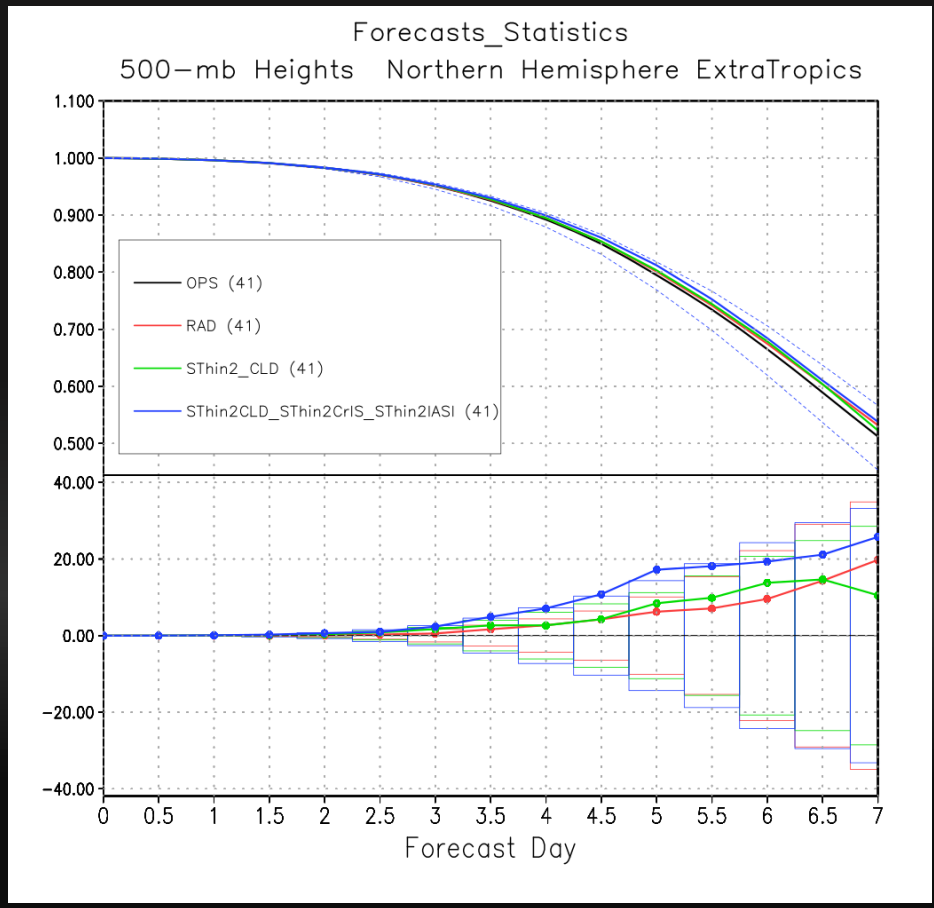
- OPS: AIRS clear-sky radiances, regularly-spaced thinning
- RAD: AIRS clear-sky radiances, regularly-spaced thinning, no vortex relocator
- SThin2_CLD: Adaptively thinned AIRS cloud-cleared radiances (the best of the configurations resulting from our published work), no vortex relocator
- SThin2_CLD_SThin2CriS_Sthin2IASI: *adaptively thinned AIRS cloud-cleared radiances* plus *adaptively thinned clear-sky CrIS and IASI, no vortex relocator*

Global 500 hPa height anomaly correlation



Global 500 hPa height anomaly correlation



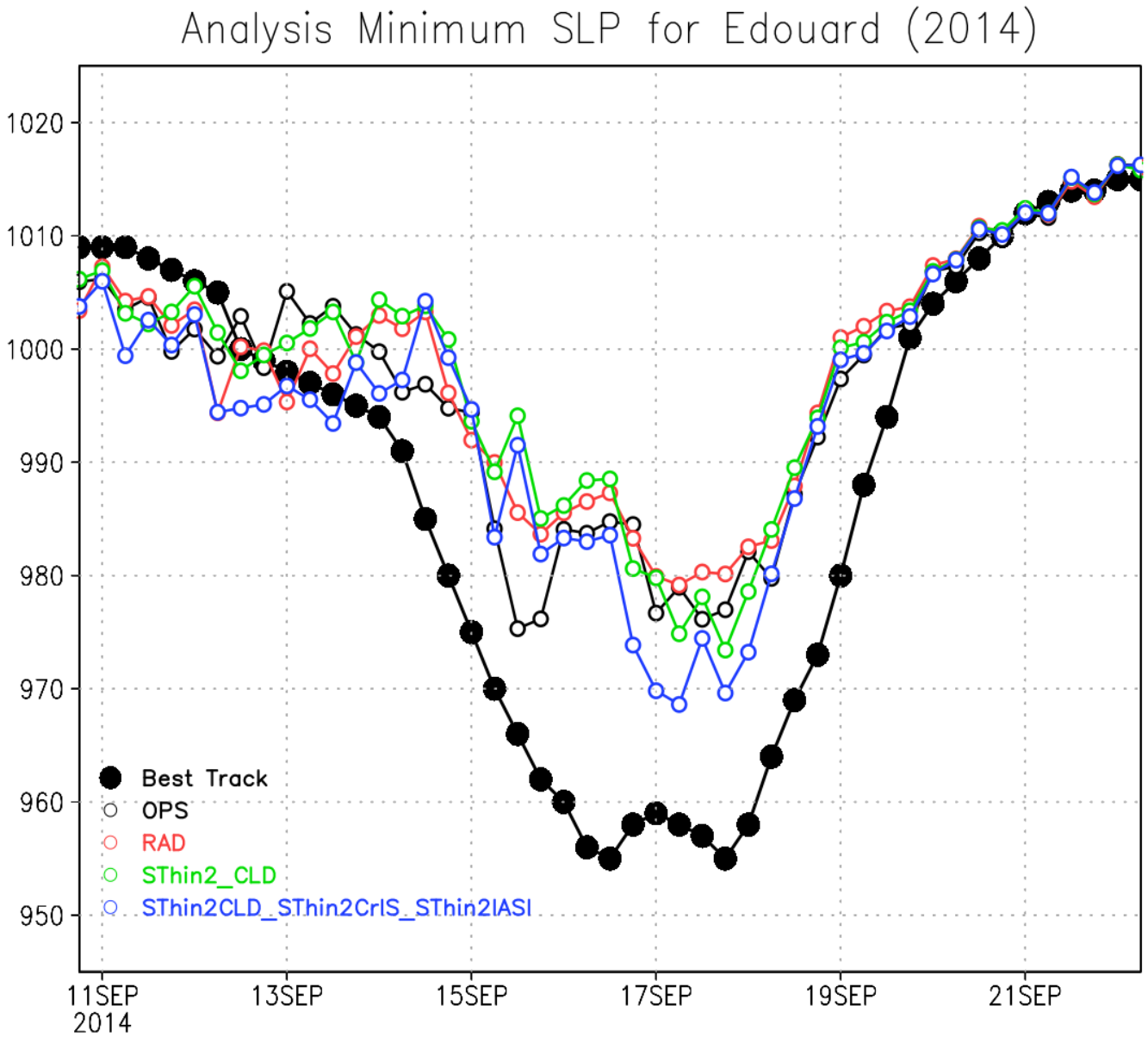


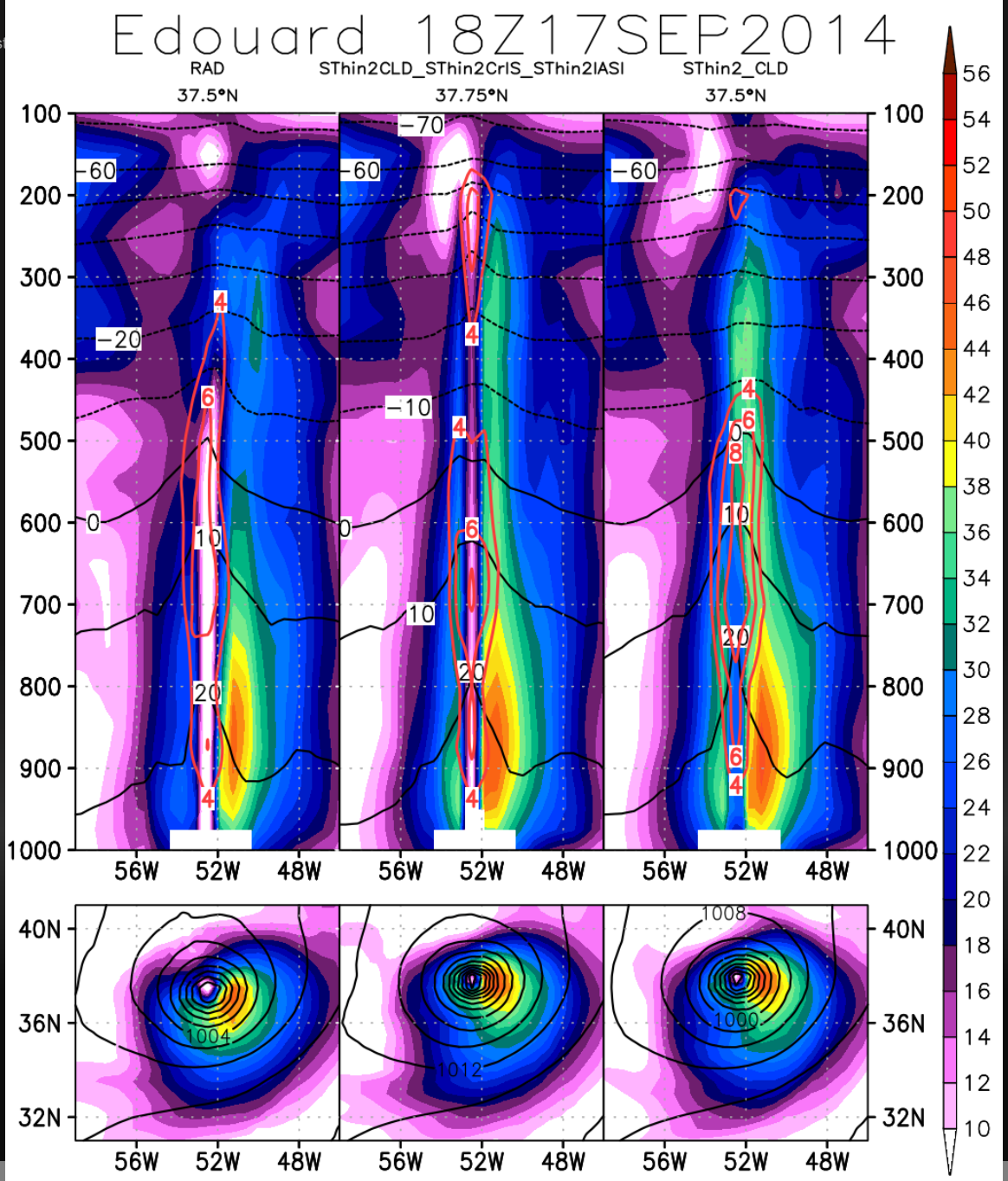
New Experiment's evaluation: what is the impact of a comprehensive adaptive strategy on TCs?

5 Tropical Cyclones selected: Edouard, Gonzalo (ATL); Simon, Vance (EPAC); Hudhud (North Indian Ocean); Vonfong (Northwestern Pacific)

Evaluation of:

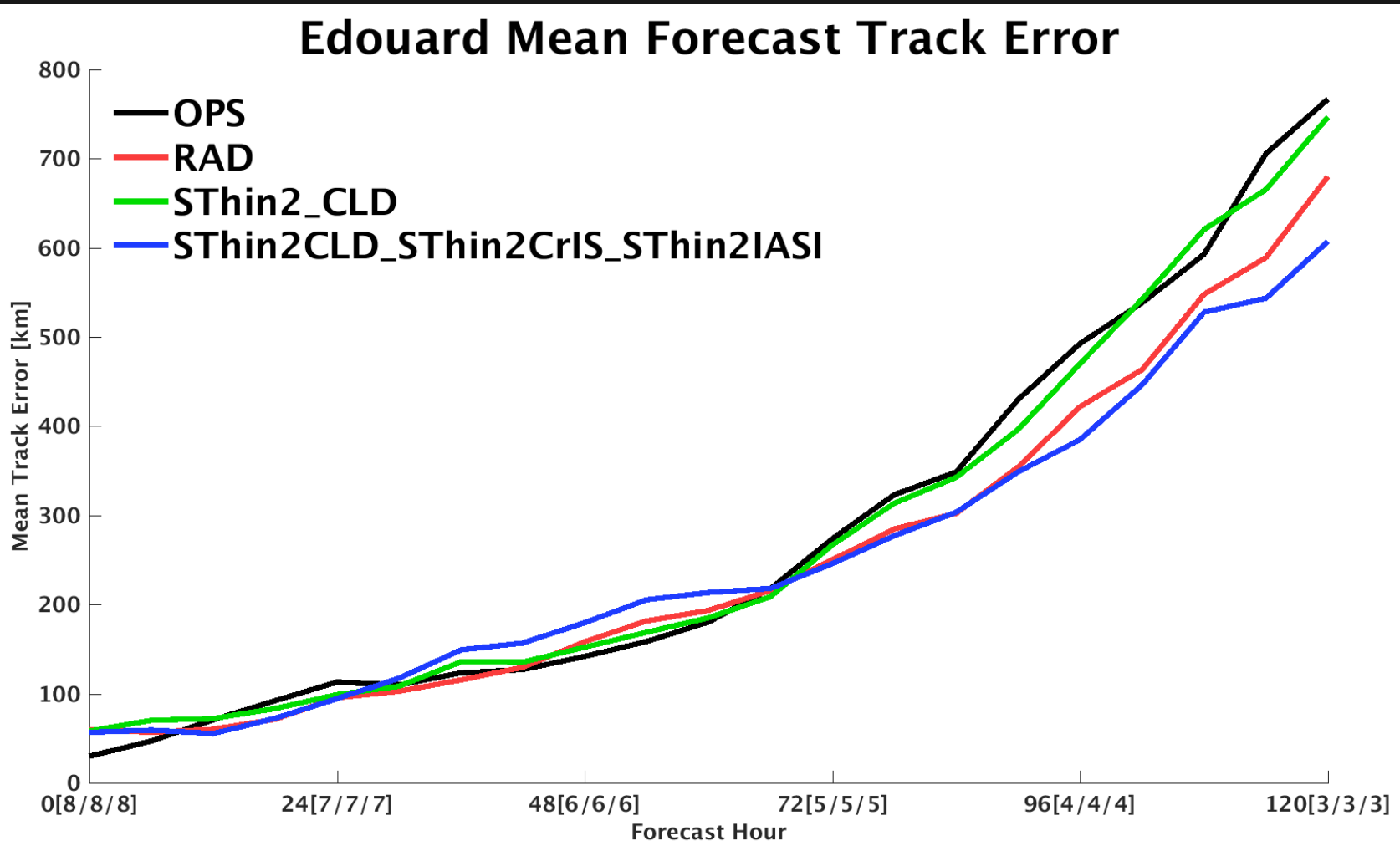
- Impact on center depth in the analysis
- Impact on vertical structure in the analysis
- Impact on track forecast
- Impact on intensity forecast


Analysis Minimum SLP for Edouard (2014)
1020
1010
1000
990
980
970
960
950
11SEP
2014
13SEP
15SEP
17SEP
19SEP
21SEP
Best Track
OPS
RAD
SThin2_CLD
SThin2CLD_SThin2CrIS_SThin2IASI



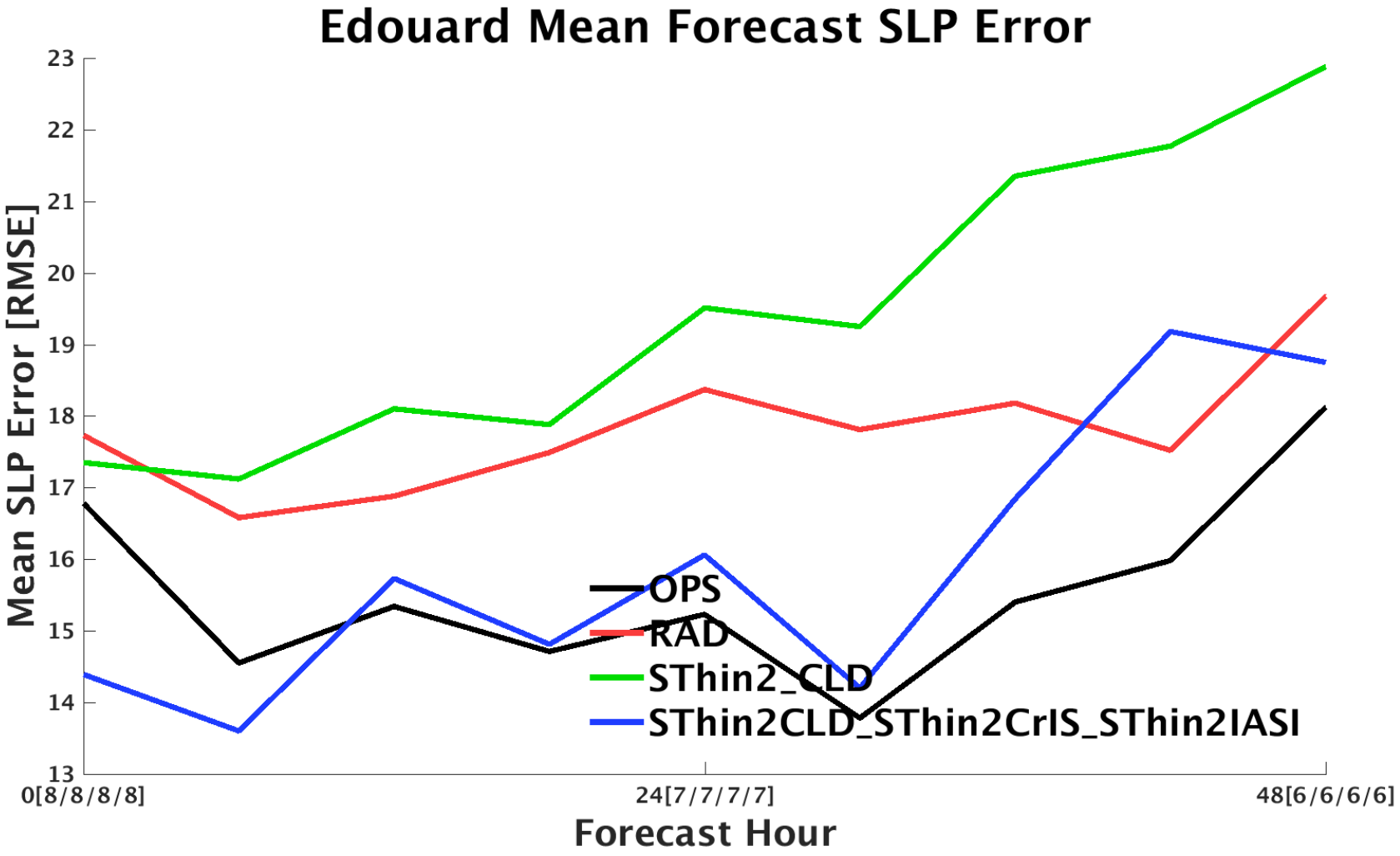
Vertical cross section
Wind magnitude (shaded)
Temperature (°C, black)
Temp. Anomaly (°C, red)

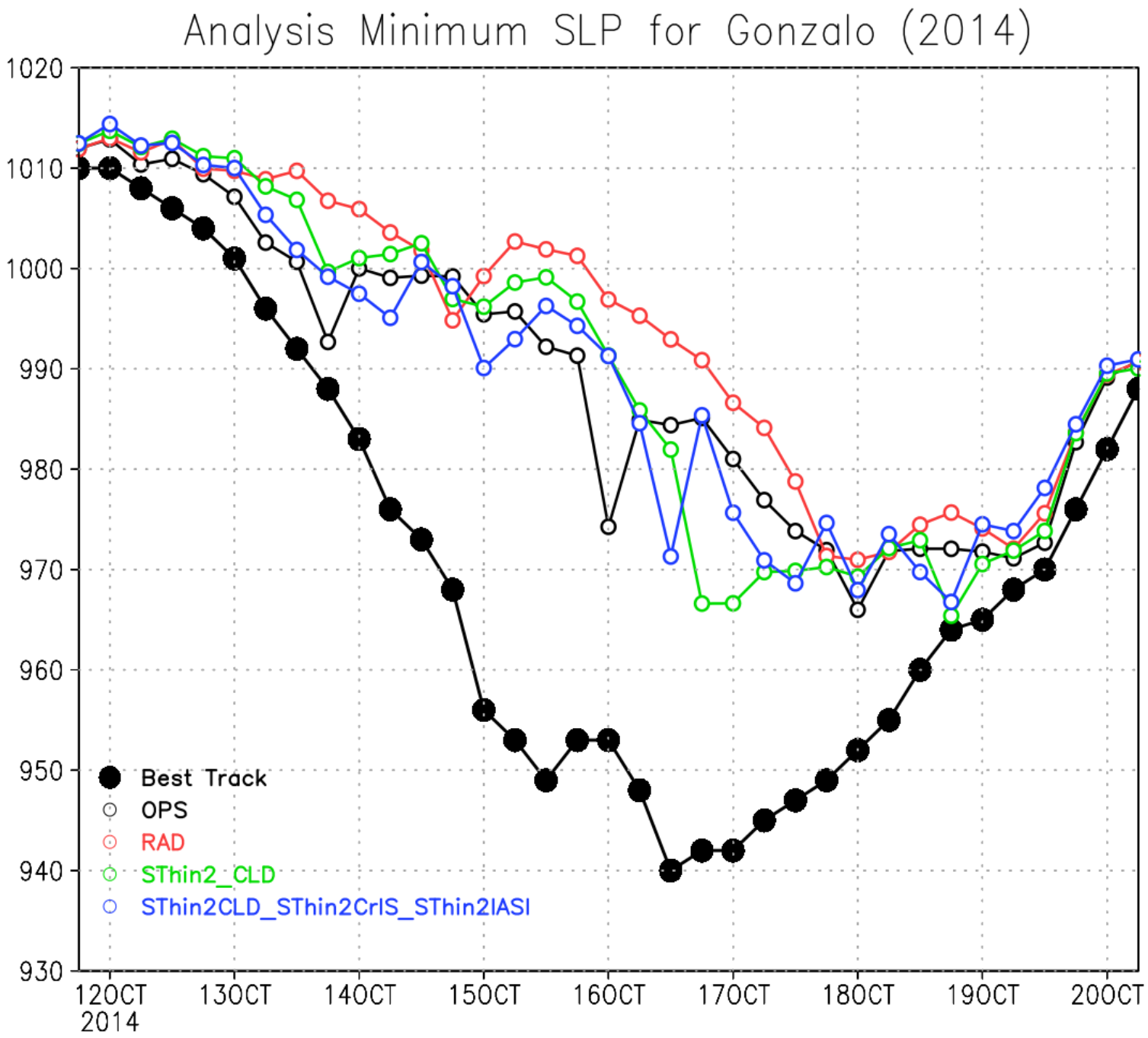
850 hPa winds (shaded)
slp(contours)

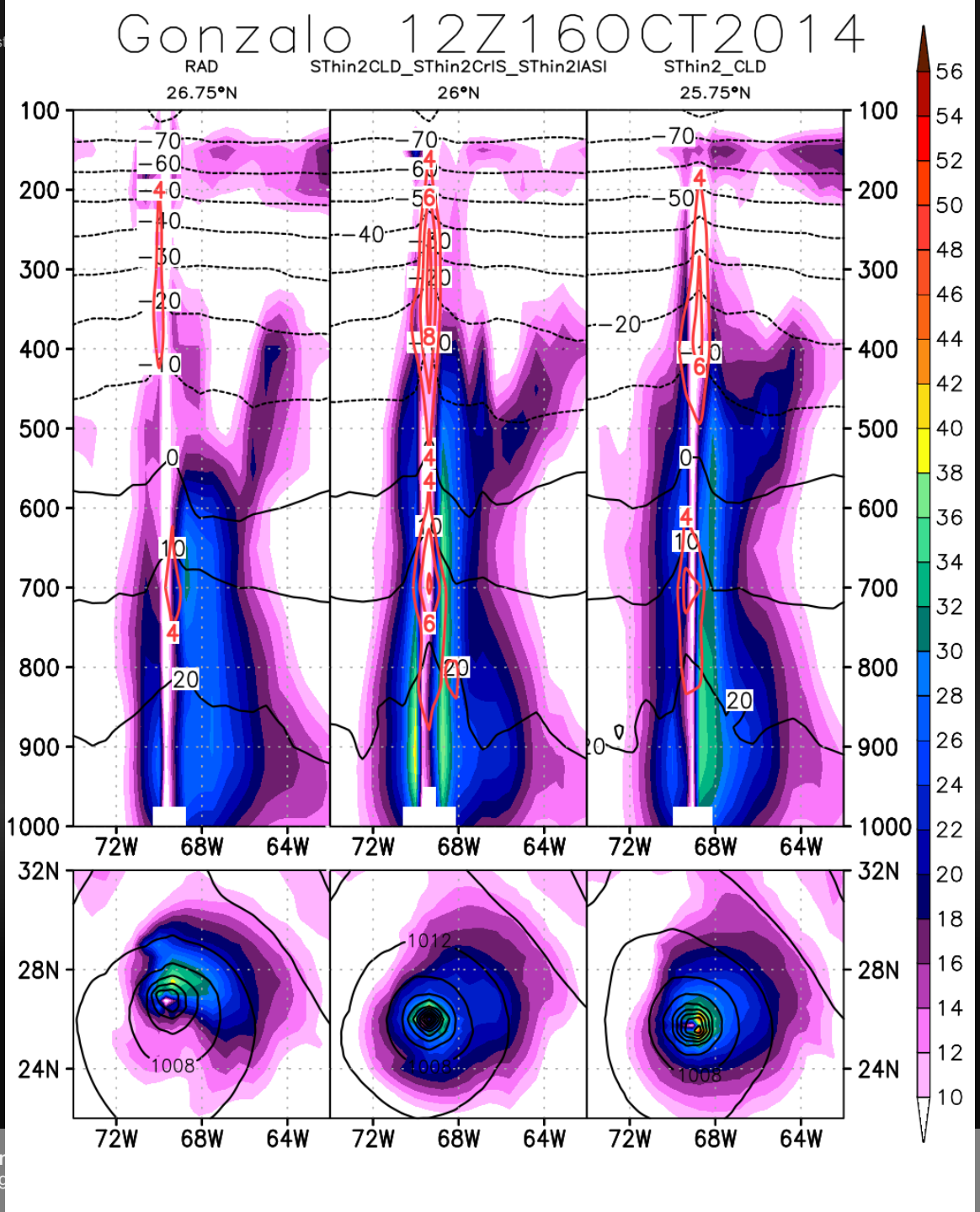


Improvement in analyzed structure improve track forecast skill

H. Edouard intensity forecast




Analysis Minimum SLP for Gonzalo (2014)
1020
1010
1000
990
980
970
960
950
940
930
120CT
2014
130CT
140CT
150CT
160CT
170CT
180CT
190CT
200CT
Best Track
OPS
RAD
SThin2_CLD
SThin2CLD_SThin2CrIS_SThin2IASI



Vertical cross section
Wind magnitude (shaded)
Temperature (°C, black)
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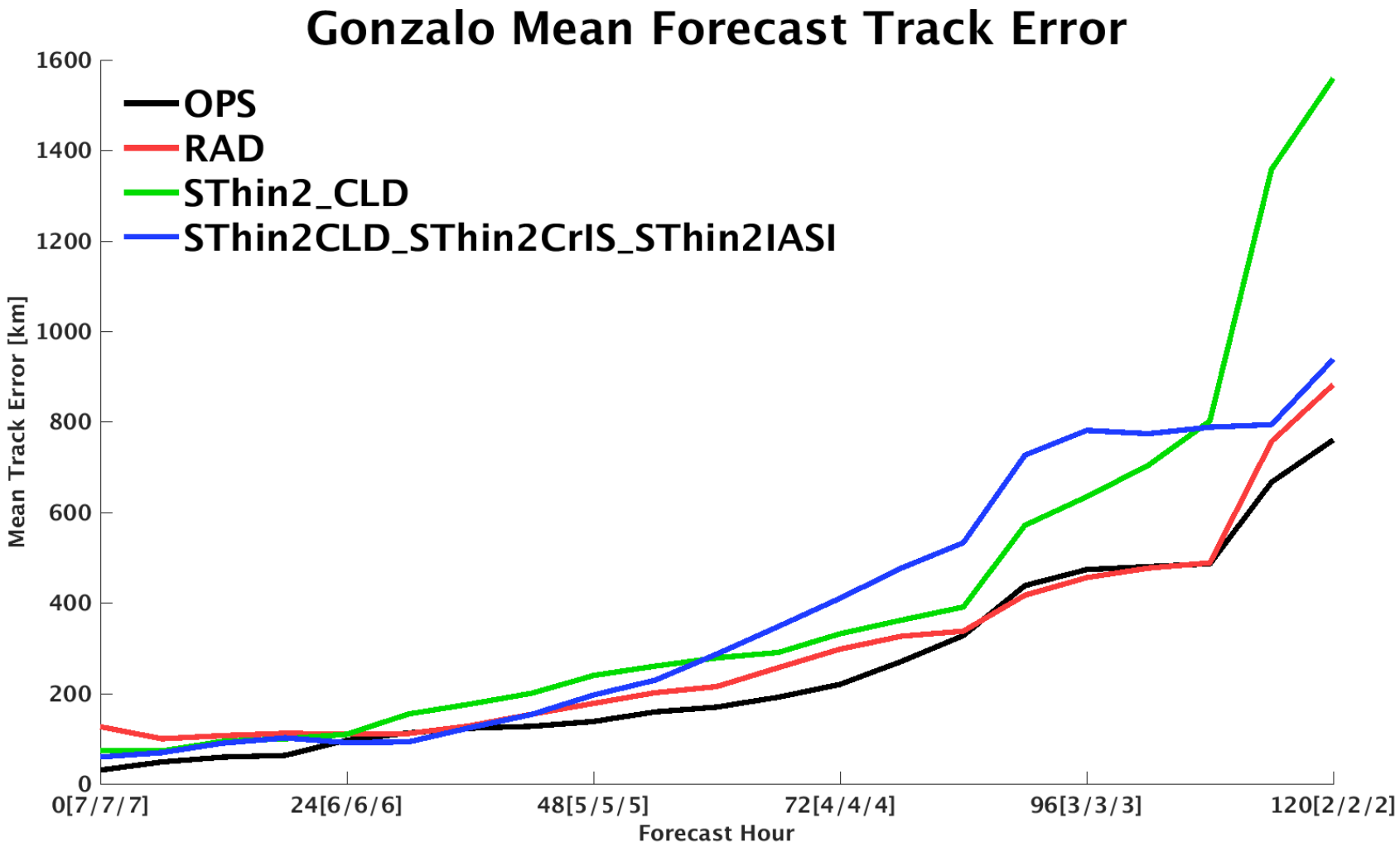
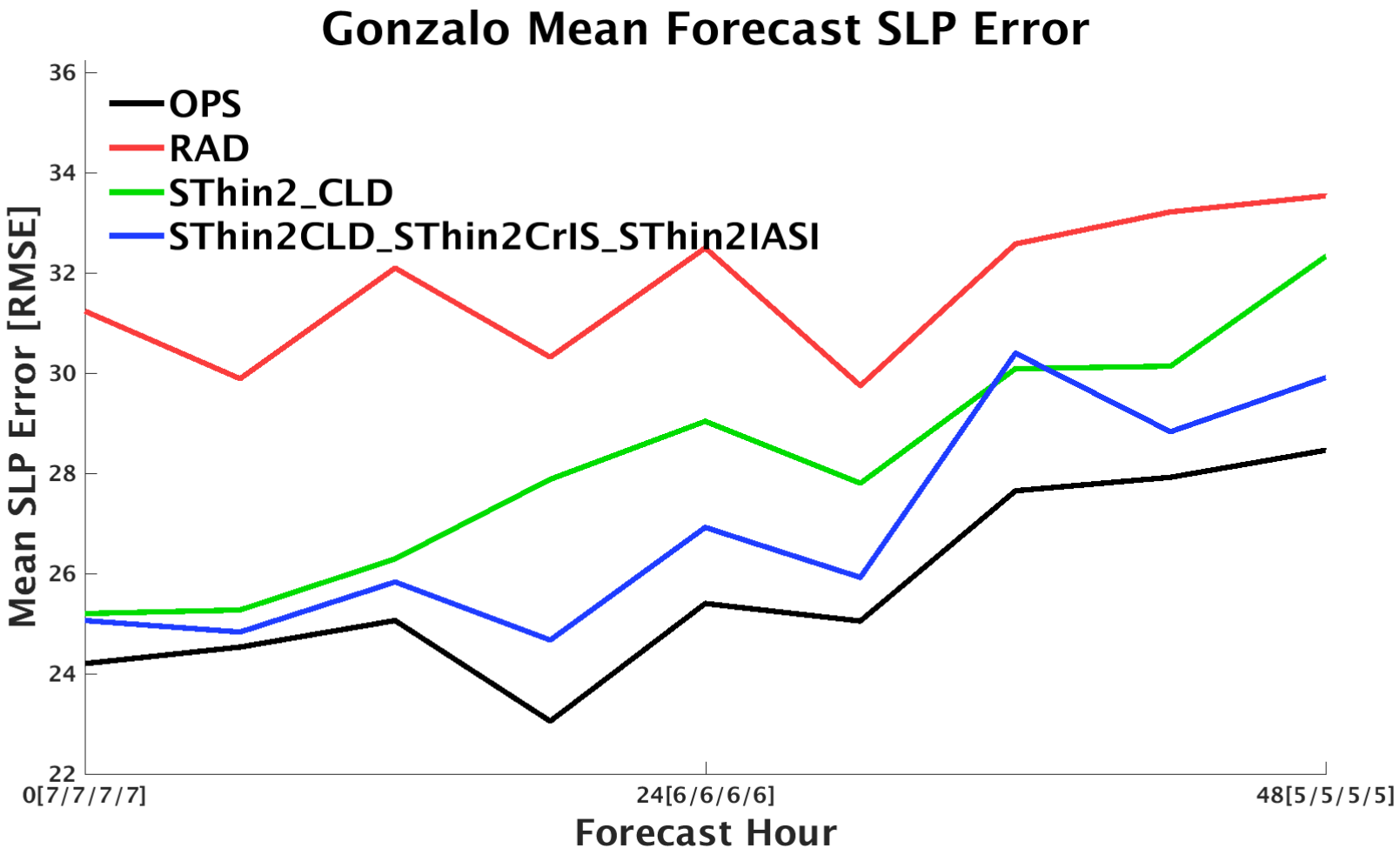
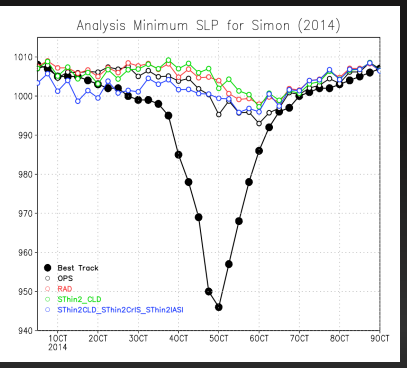
slp(contours)


Gonzalo Mean Forecast Track Error
OPS
RAD
SThin2_CLD
SThin2CLD_SThin2CrIS_SThin2IASI
Mean Track Error [km]
1600
1400
1200
1000
800
600
400
200
0
0[7/7/7]
24[6/6/6]
48[5/5/5]
72[4/4/4]
96[3/3/3]
120[2/2/2]
Forecast Hour

H. Gonzalo intensity forecast



comprehensive and more aggressive



Impossibly difficult TC: rapid deepening and rapid dissipation

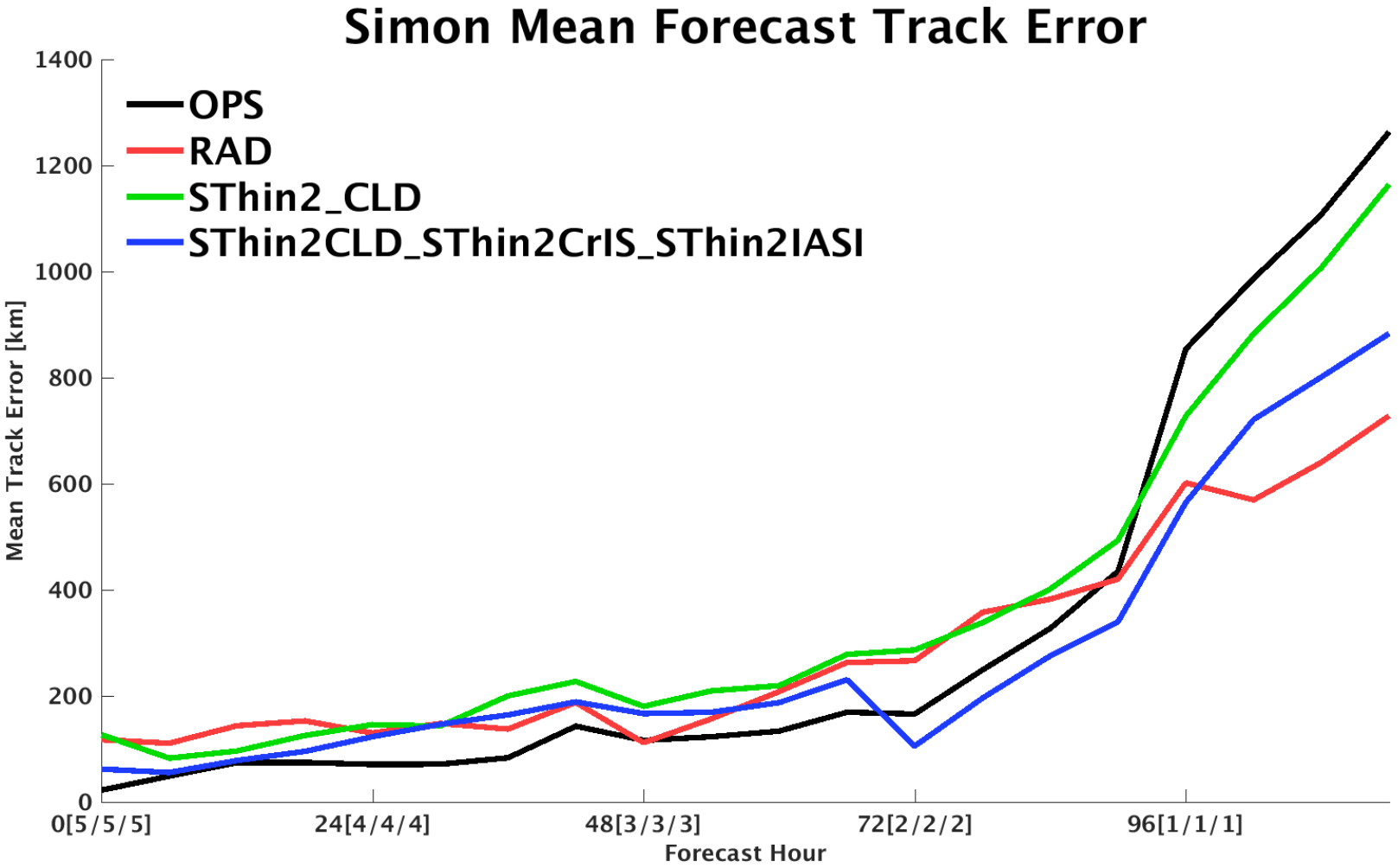
Simon 00Z05OCT2014

RAD SThin2CLD_SThin2CrIS_SThin2IASI SThin2_CLD

20°N 20.75°N 19.5°N

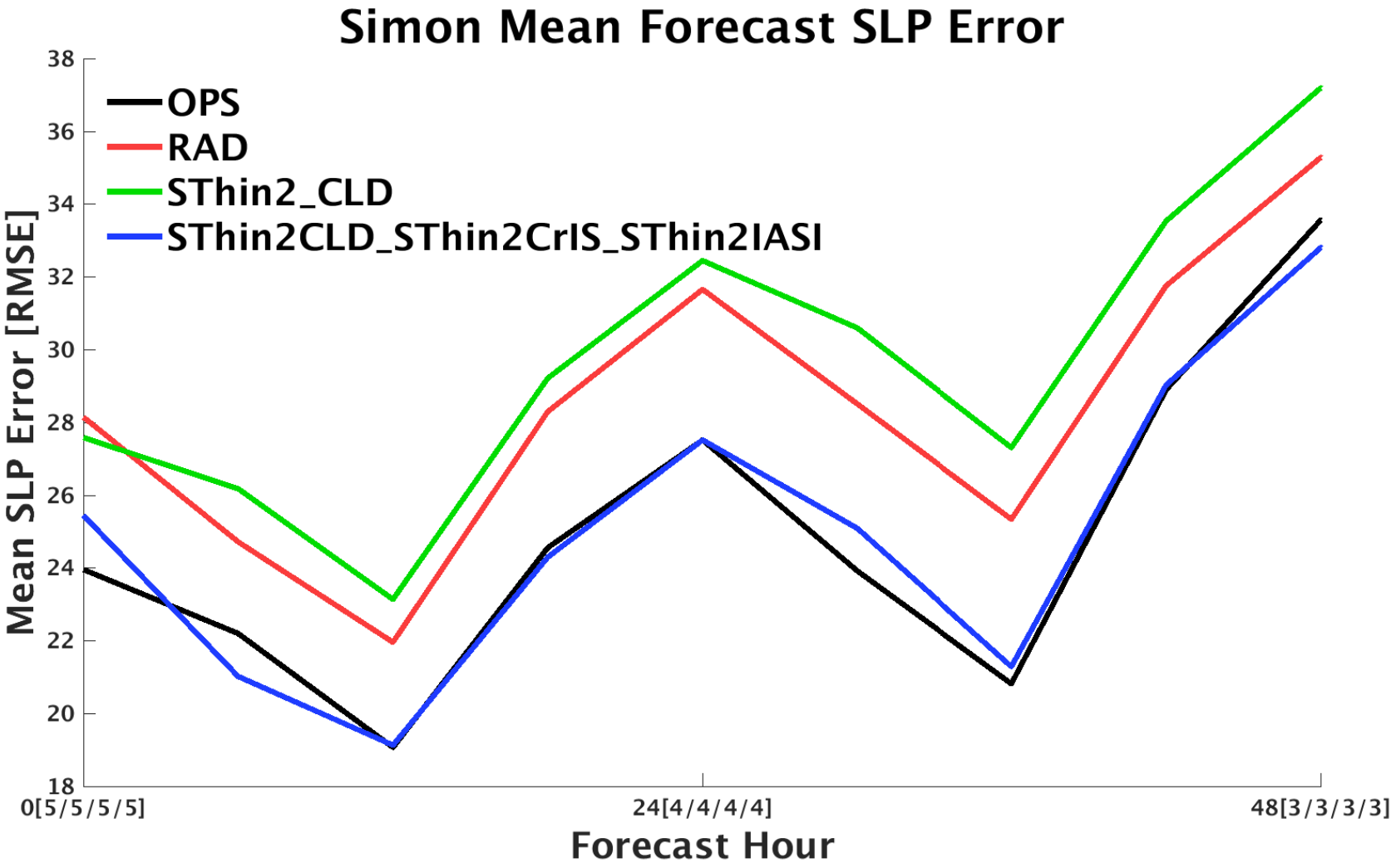
Vertical cross section
Wind magnitude (shaded)
Temperature (°C, black)
Temp. Anomaly (°C, red)

850 hPa winds (shaded)
slp(contours)

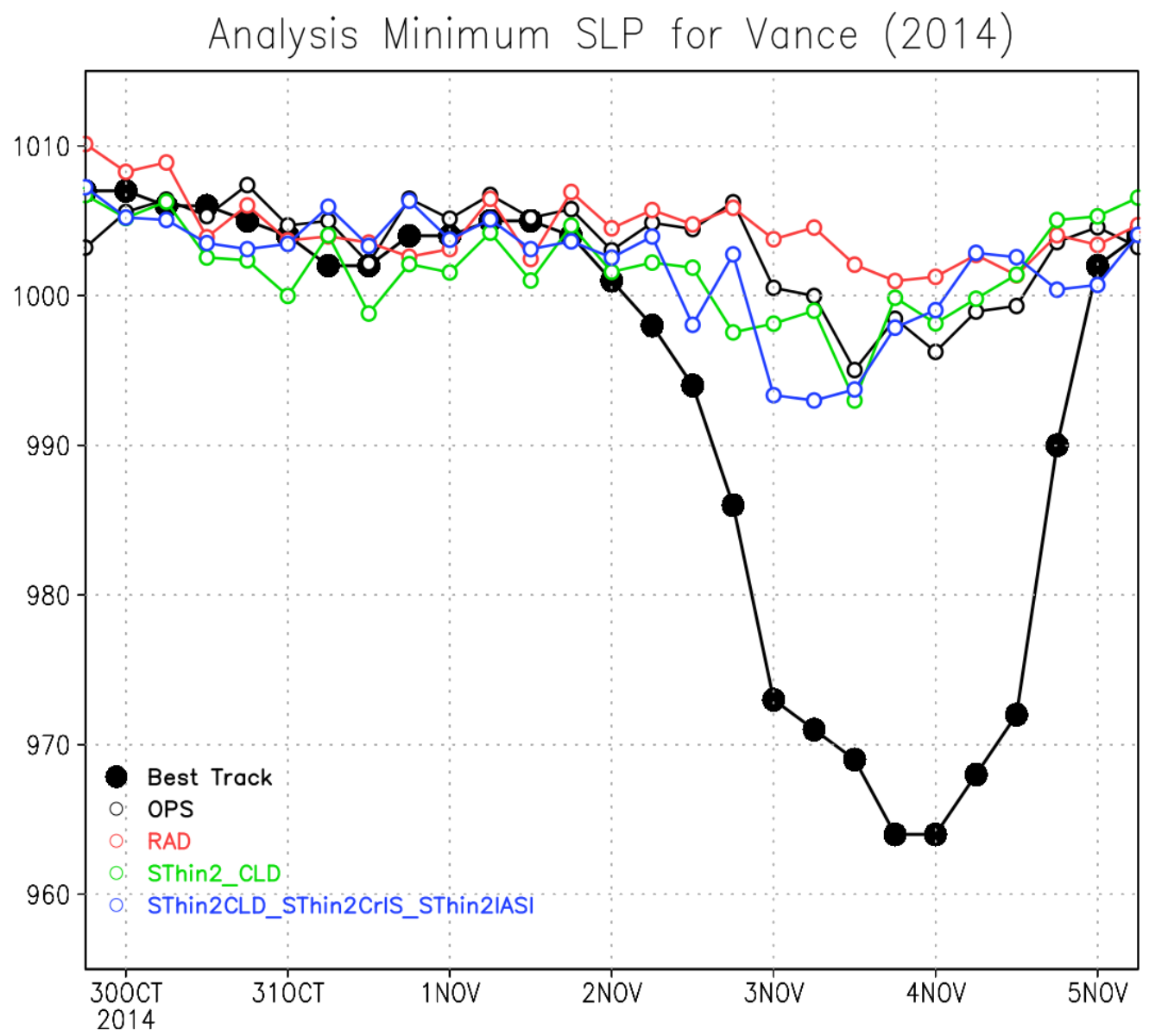


Substantial improvement in forecast track for this difficult storm

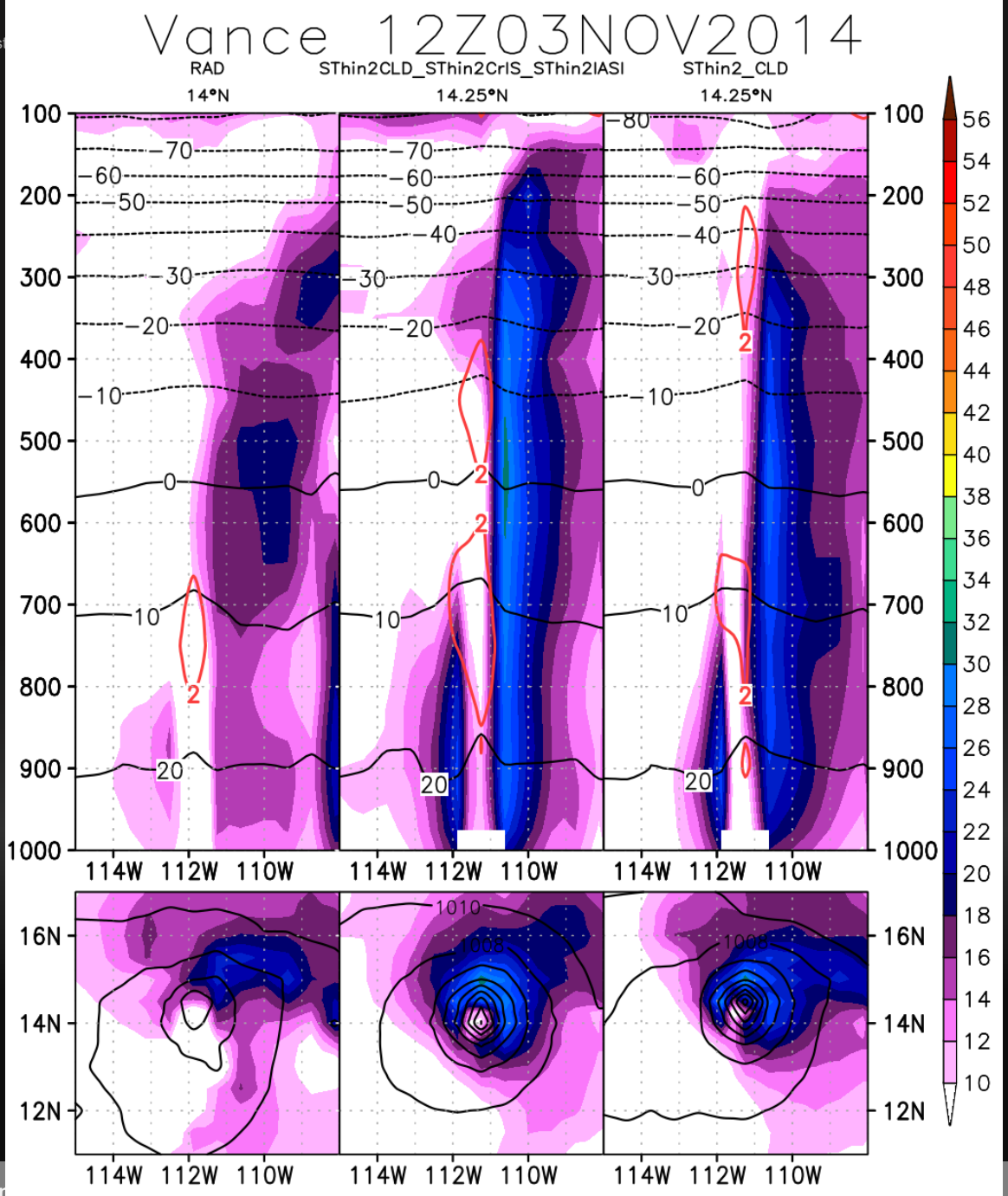
H. Simon intensity forecast



Substantial improvement in intensity forecast for this difficult storm



Another short-lived TC, very difficult to represent in global analyses



Vertical cross section
Wind magnitude (shaded)
Temperature (°C, black)
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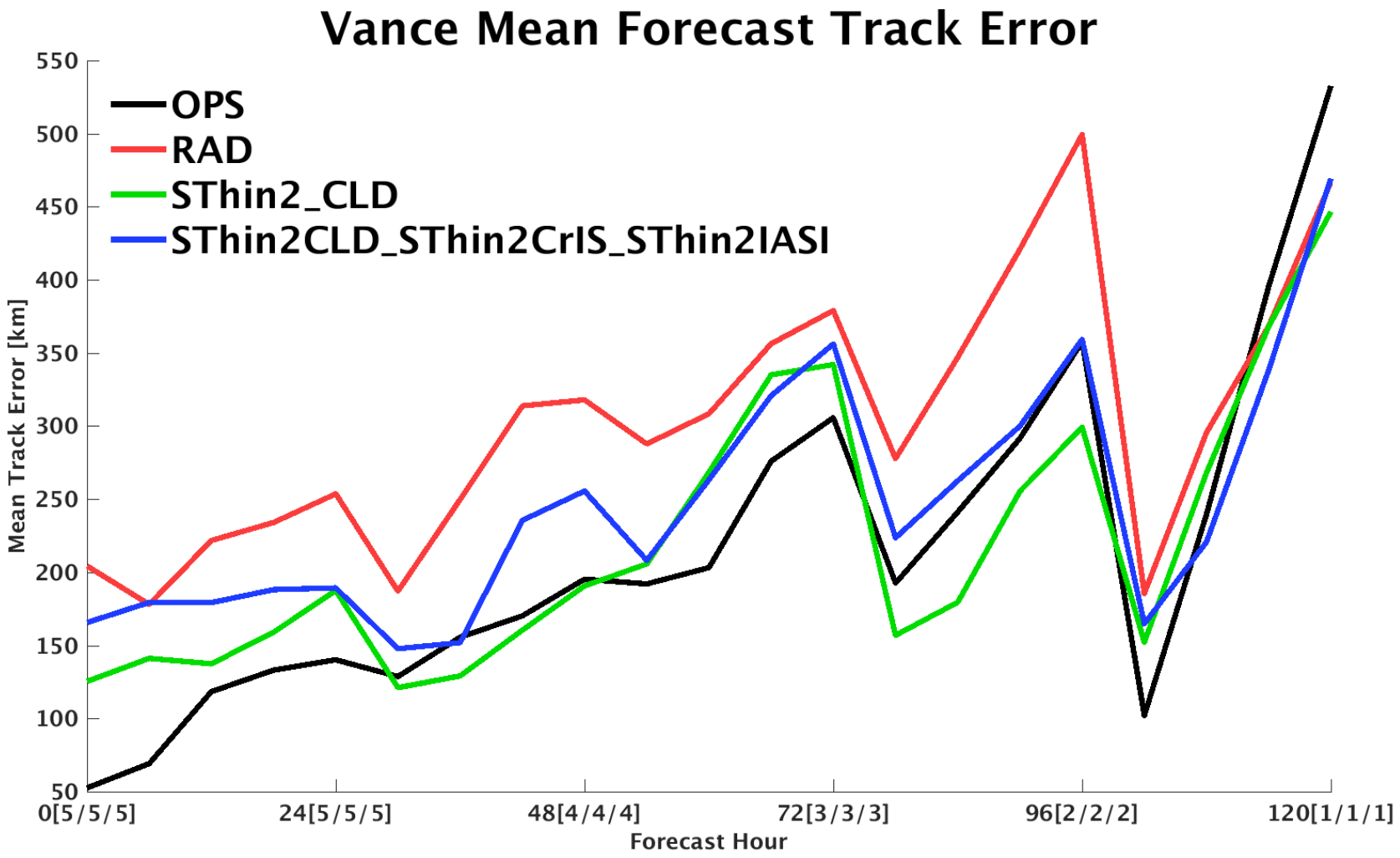
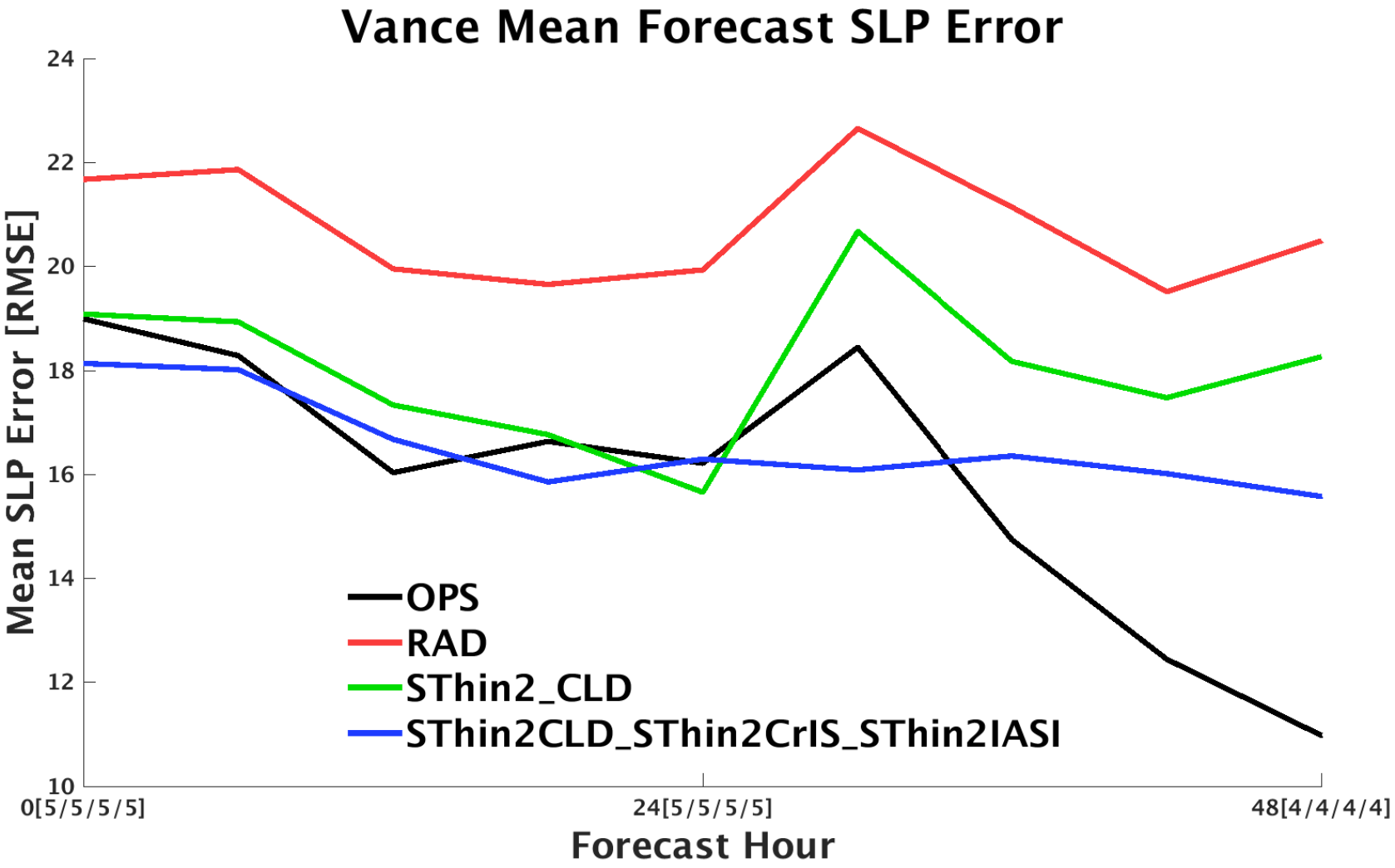
850 hPa winds (shaded)
slp(contours)

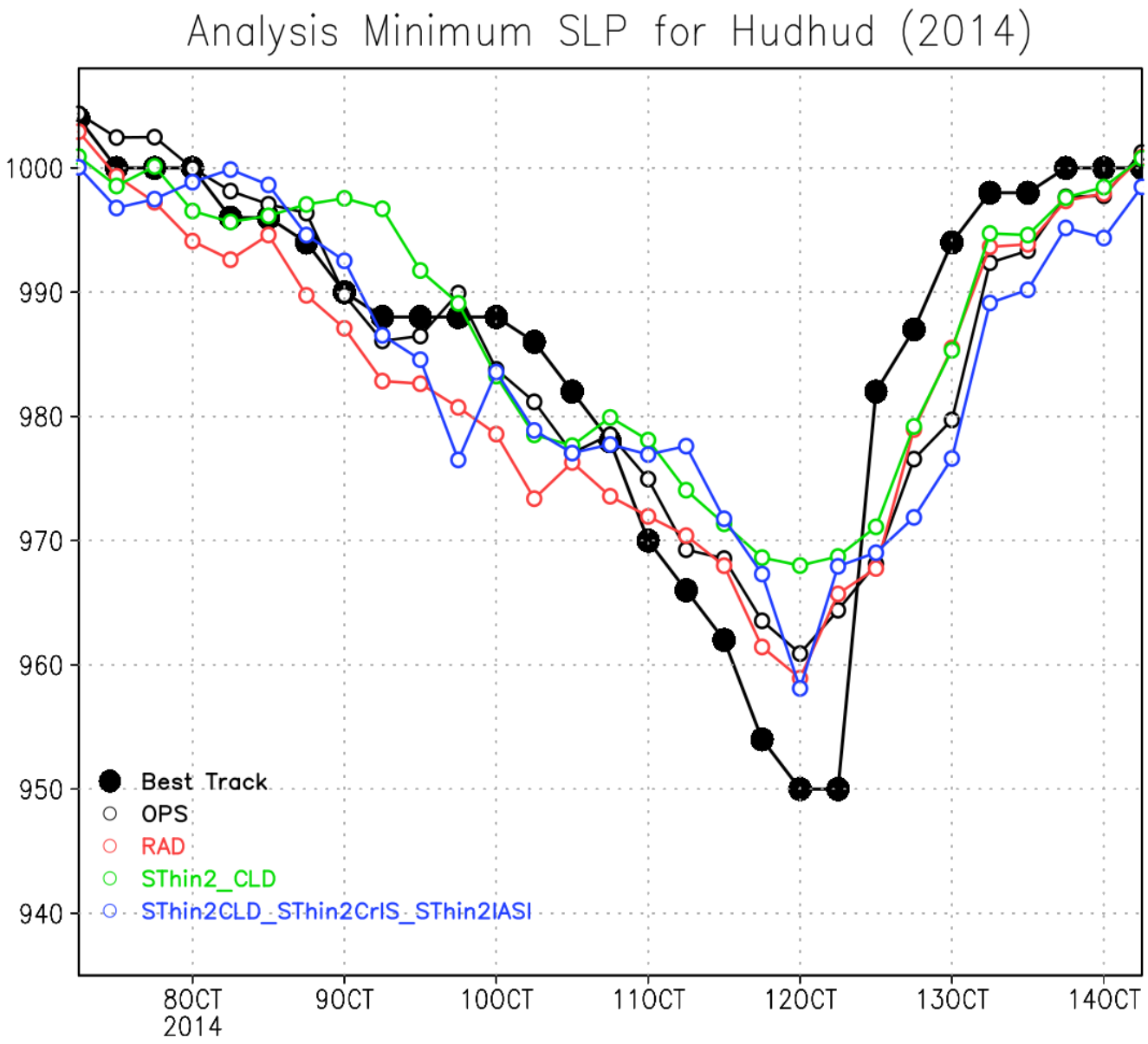


Substantial improvement in forecast track for this difficult storm

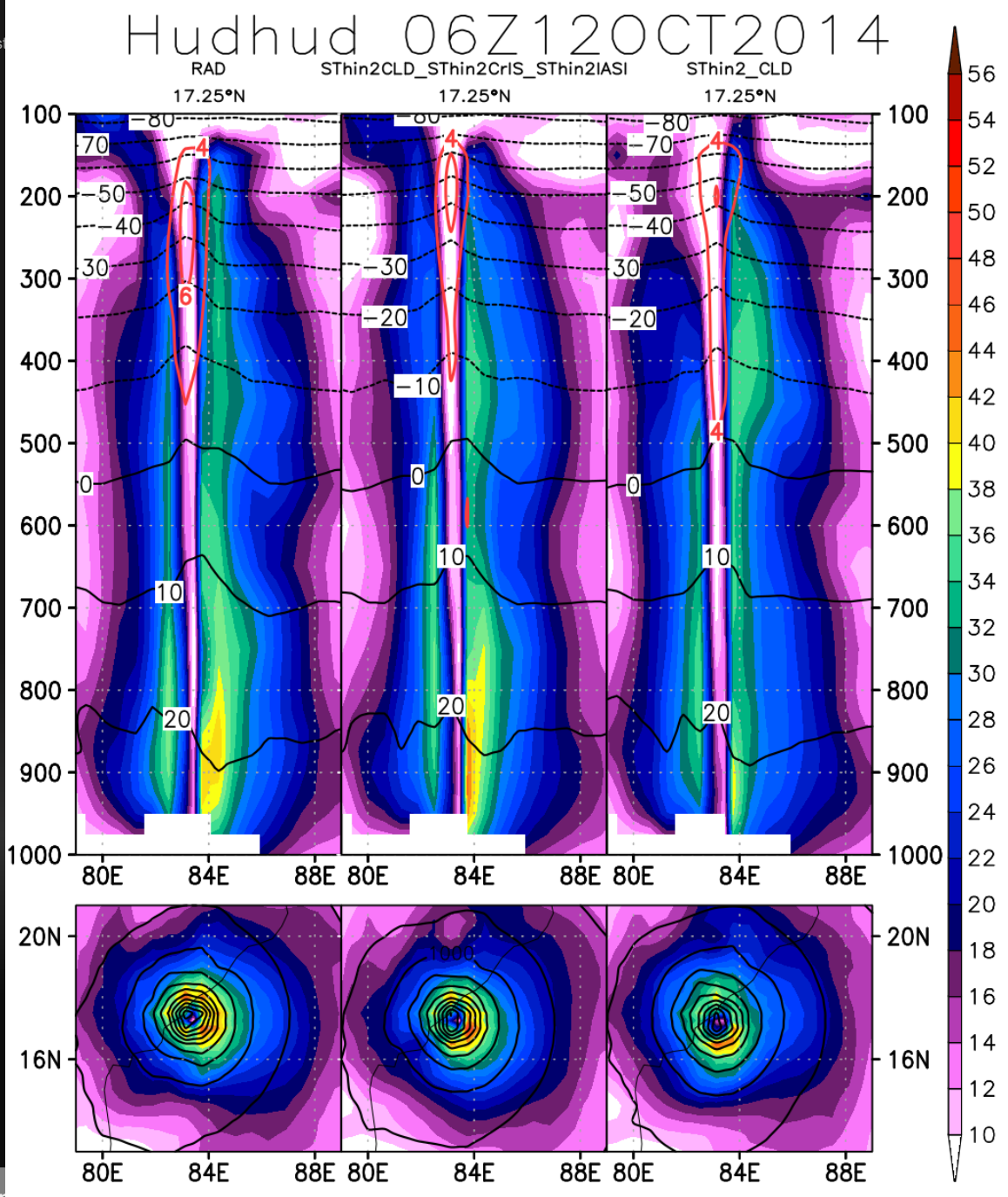
Hurricane Vance Intensity Forecast



Improvement in intensity forecast for this difficult, short-lived TC



N Indian Ocean TCs are the most difficult to represent in global analyses



Vertical cross section
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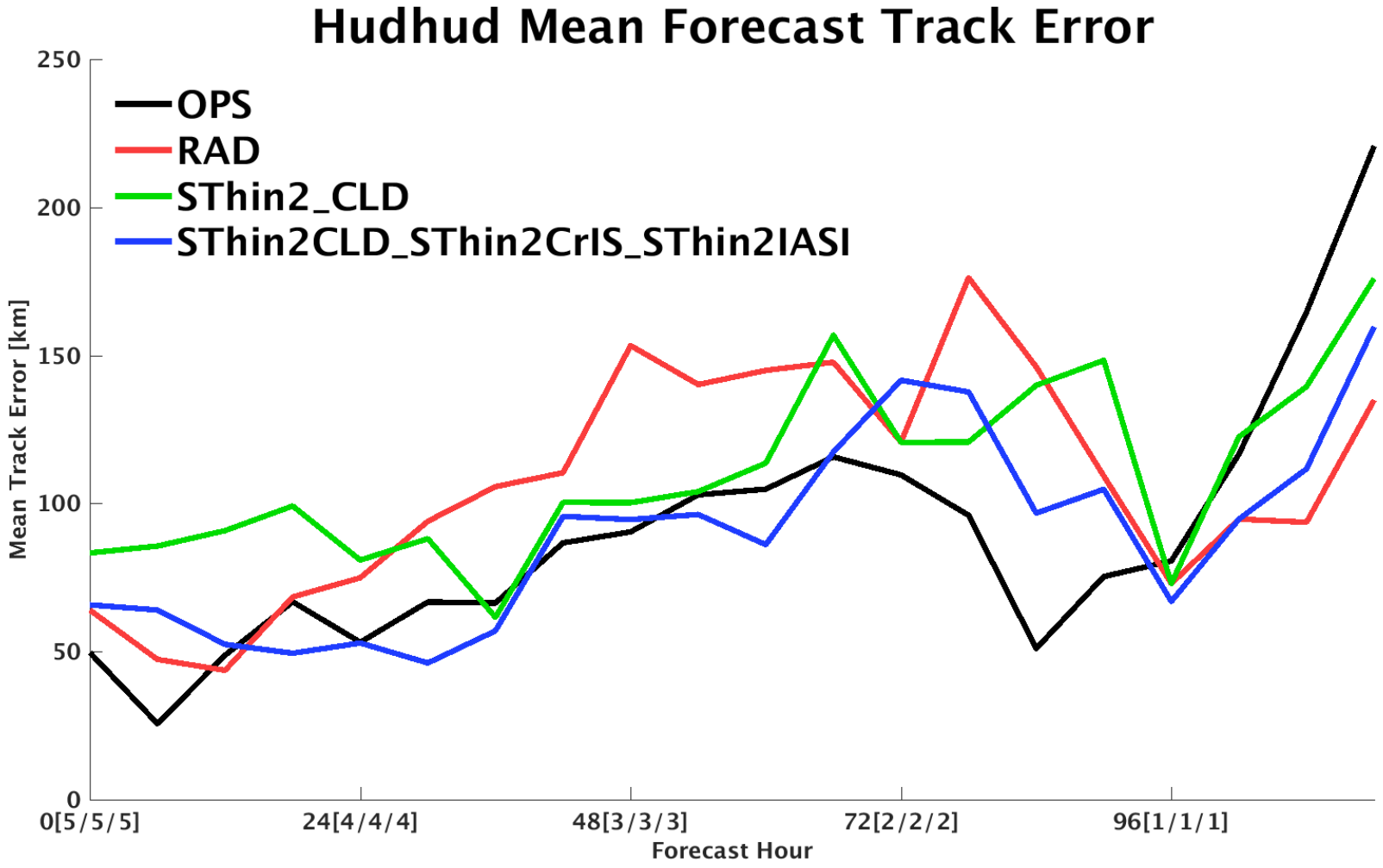
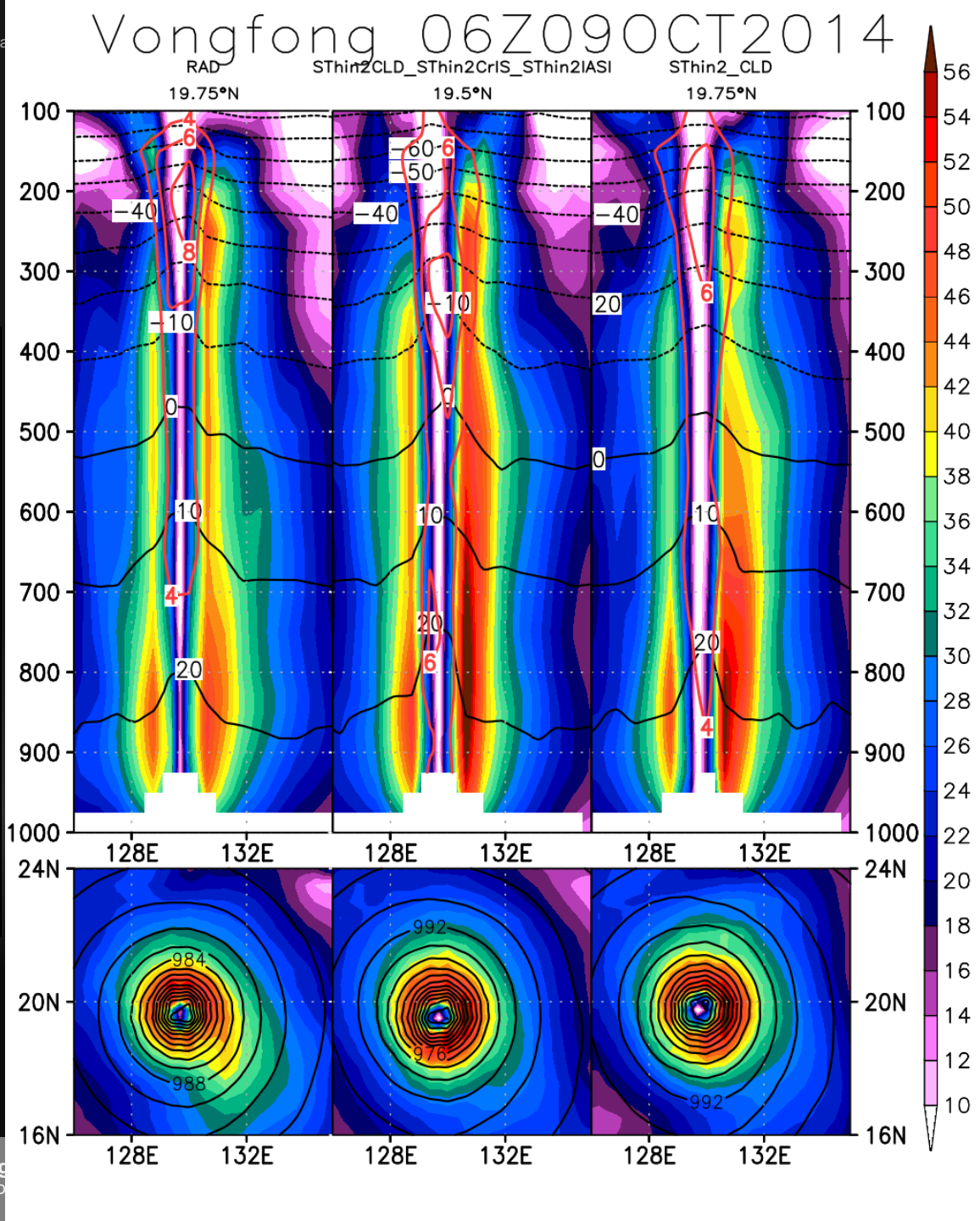
850 hPa winds (shaded)
slp(contours)



Improvement in forecast track



Extreme large typhoon, previously insensitive to changes in AIRS DA strategy, now positively impacted by combined adaptive thinning.

Conclusions

- Comprehensive adaptive thinning strategy that consistently modifies the density of assimilated radiances for *all hyperspectral instruments together* (combining Cloud-clear AIRS, with clear-sky CrIS and IASI) proves to be very promising:
  - Improvement in global skill
  - Improvement in analyzed TC structure
  - Improvement in TC error track
  - Improvement in TC intensity forecast
  - Improvement occurring also on TCs for which the impact of changes in AIRS data assimilation strategy was minimal because of a) poor coverage (Simon) or b) scale exceeding the swath (Vonfong) or c) intrinsically difficult (North Indian Ocean, Hudhud).

Future work: we need cloud-cleared CrIS and IASI radiances

Acknowledgements

Thanks to:

Dr. Tsengdar Lee for current support through grant 80NSSC18K0927 “Using AIRS data to understand processes affecting TC structure in a Global Data Assimilation and Forecasting Framework (2018-2021)” (PI: O. Reale)

Dr. Ramesh Kakar for past support through previous grants NNX11AK05G and NNX14AK19G “Using AIRS data to understand processes affecting Tropical Cyclone structure in a Global Data Assimilation and Forecasting Framework”(2011-2014, 2014-2018), PI: 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

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.

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.

Reale, O., E. McGrath-Spangler, W. McCarty, D. Holdaway, R, Gelaro, 2018: Impact of adaptively thinned AIRS cloud-cleared radiances on tropical cyclone representation in a global data assimilation and forecast system. Weather and Forecasting, 33, 908-931.