Advances towards ingestion of multi-instrument cloud-cleared infrared radiances in a global data assimilation and forecast framework

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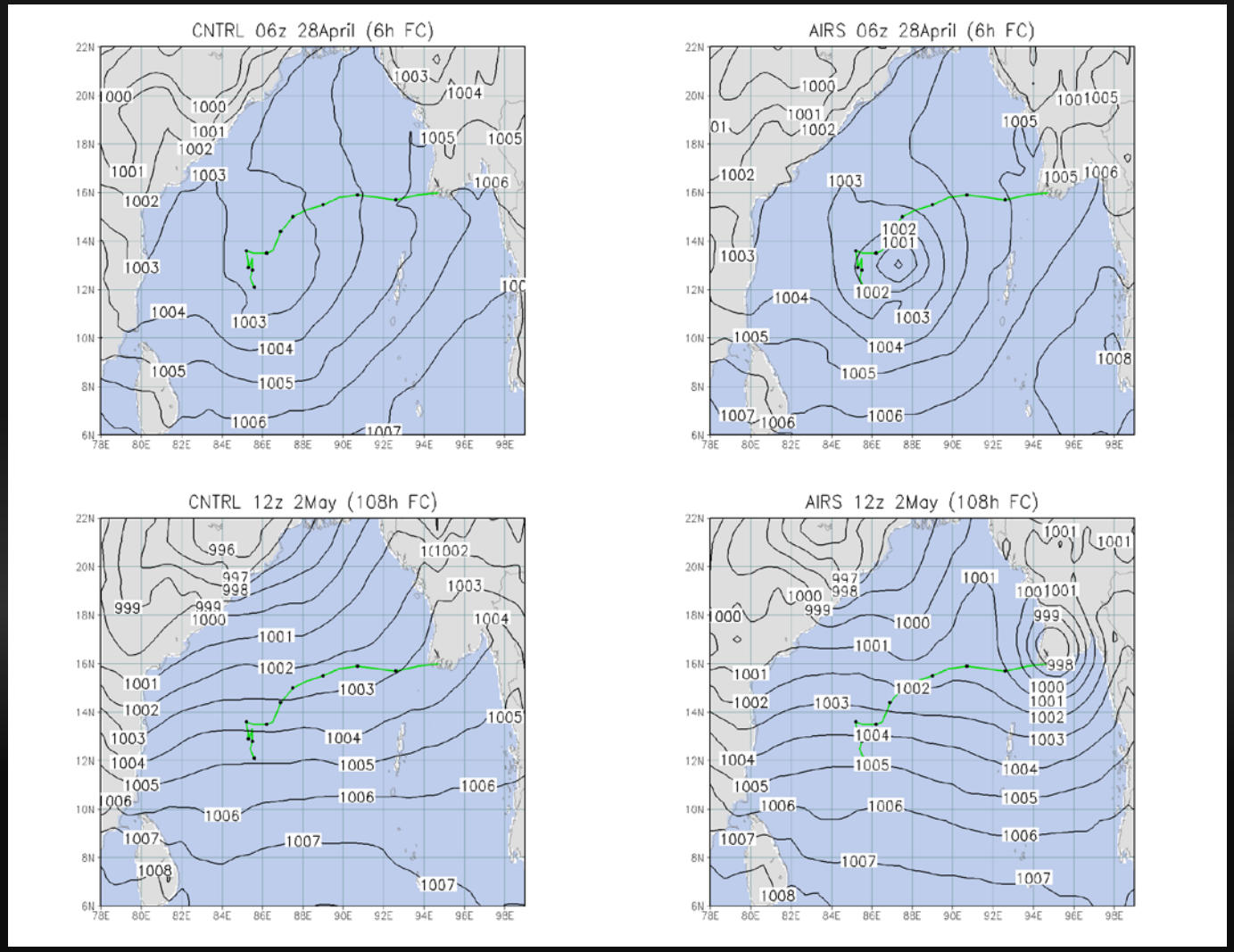
More than ten years ago (2008): first attempt to improve the representation of a tropical cyclone in a global data assimilation system using AIRS cloud-cleared retrievals



Catastrophic Tropical Cyclone Nargis (2008)
Missed in all operational analyses
when it was already at hurricane intensity level.
Assimilation of v5 AIRS cloud-cleared retrievals produced a well-defined low from which successful 5-day forecasts could be initialized. Horizontal resolution of the state-of-the-art GEOS was half a degree!

Unfortunately, in spite of subsequent studies by this team demonstrating the superiority of cloud-cleared retrievals against clear-sky radiances, operational centers did not consider the real-time assimilation of retrievals possible because of latency and external dependencies

Green: Observed Track

Reale, O., W. K. Lau, J. Susskind, R. Rosenberg, 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. Geophys. Res. Lett., 36, L06812, doi: 10.1029/2008GL037122

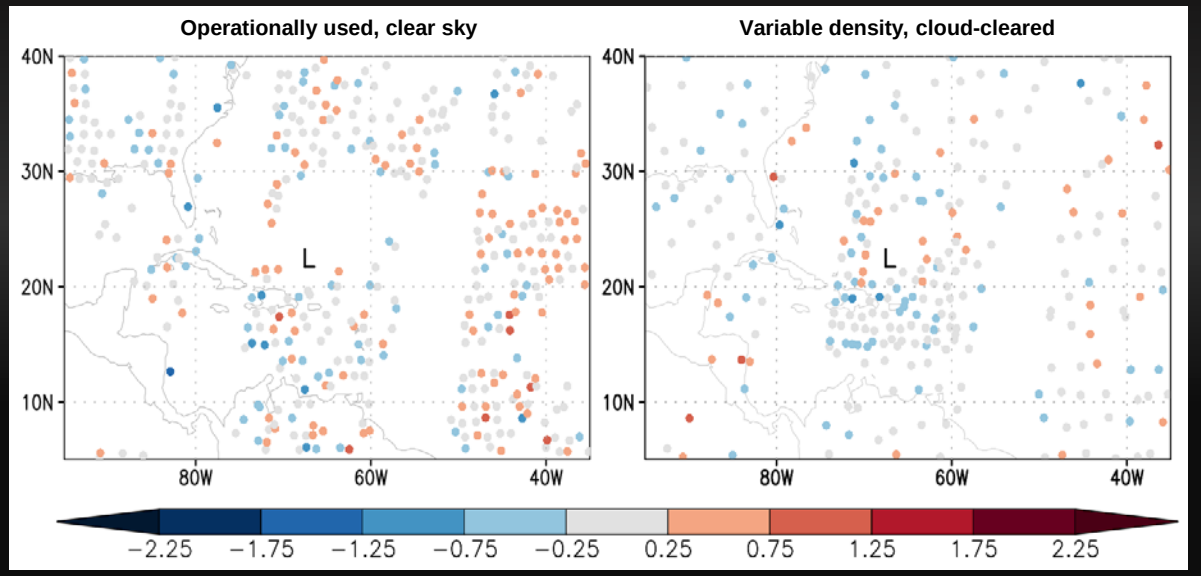
Ten years later (2018): major findings in the assimilation of AIRS radiances

Article published in August 2018 summarizes the work done by this team on the assimilation of *adaptively thinned AIRS cloud-cleared radiances* against *homogeneously 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.*

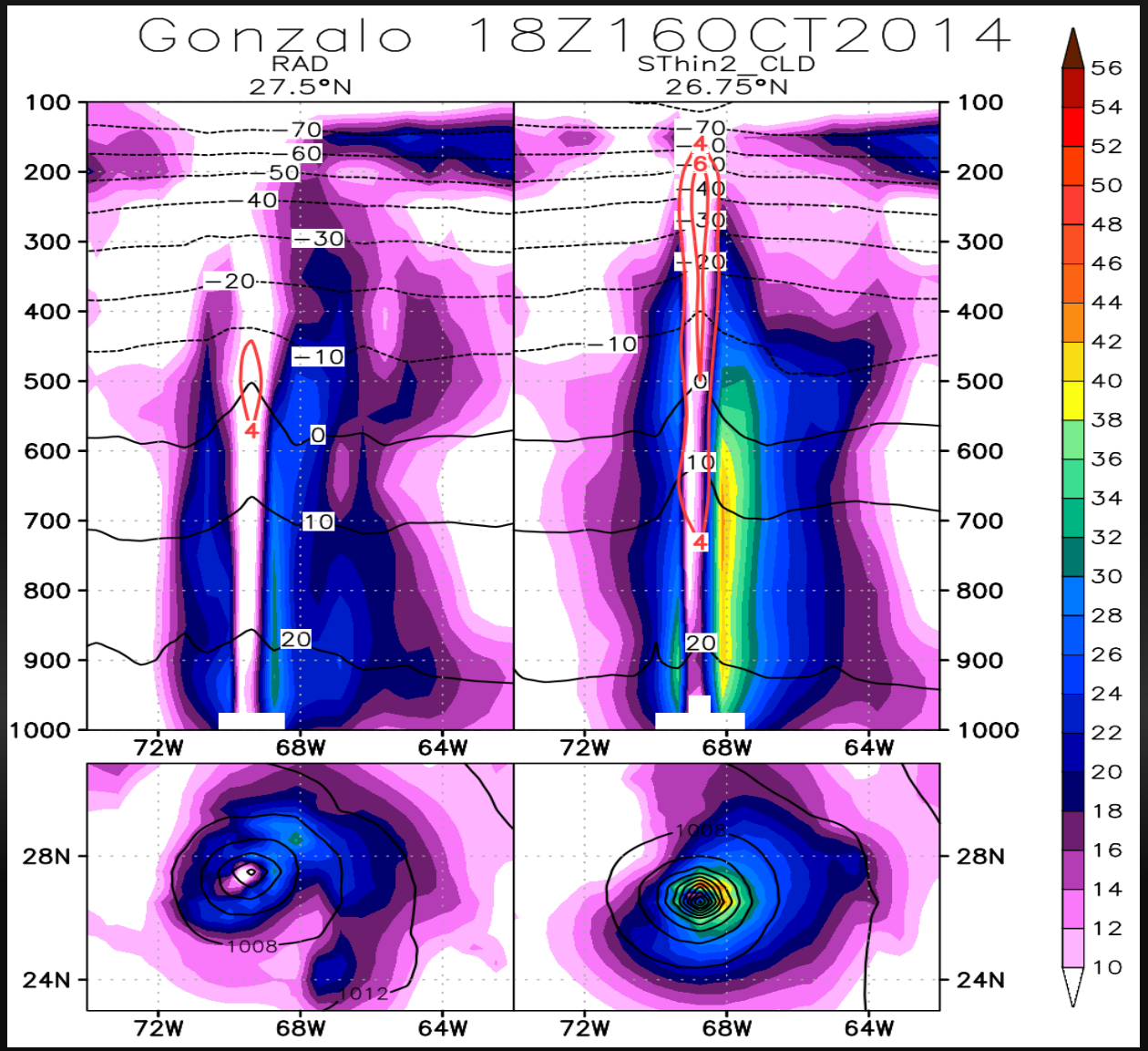
1) Cloud-cleared AIRS radiances are substantially superior compared to clear-sky radiances, as long as they are more aggressively thinned

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



Operational, clear-sky

Variable density, cloud-cleared



Shading: wind speed
Black contours: temperature (top), sea level pressure (bottom)
Red contours: temperature anomaly

Reale et al (2018) shows that cloud-cleared radiances are a substantially better product than clear-sky radiances when assimilated with a global density of about 300 km.

An increased density only around TCs improves TC structure dramatically.

Caveats: limited by AIRS coverage; negligible impact on very small or very large TCs and on TC track forecast.

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

Next step: test an adaptive strategy on CrIS and IASI

New Experiments 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 initialized daily at 00Z from 10th Sep – 9th Nov 2014

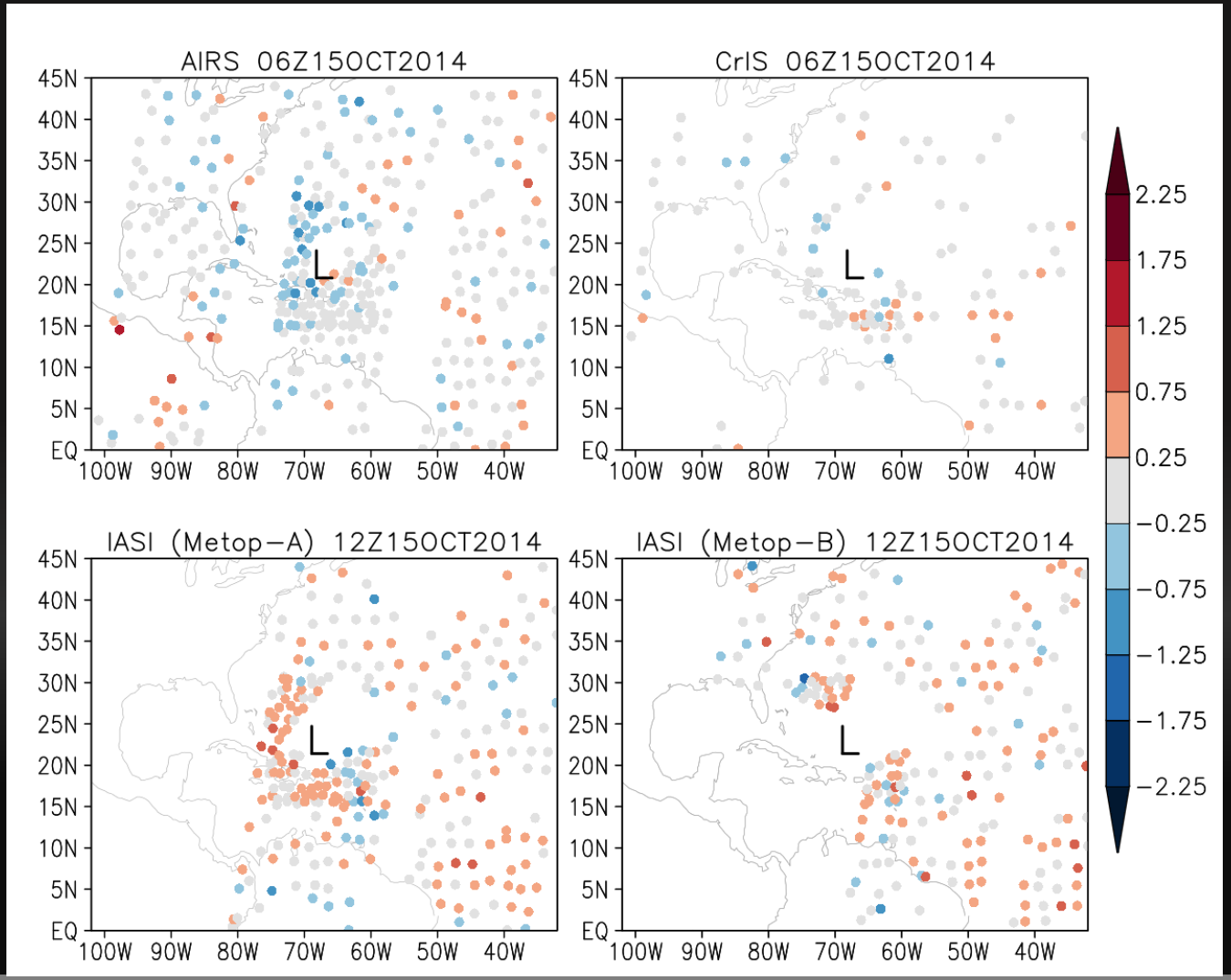
- OPS: AIRS clear-sky radiances, regularly-spaced thinning
- RAD: AIRS clear-sky radiances, regularly-spaced thinning, no vortex relocator
- SThin2_CLD: Adaptively thinned AIRS cloud-cleared radiances (the best of the configurations resulting from our published work), no vortex relocator
- SThin2_CLD_SThin2CriS_Sthin2IASI: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

Hyperspectral observations around Hurricane Gonzalo

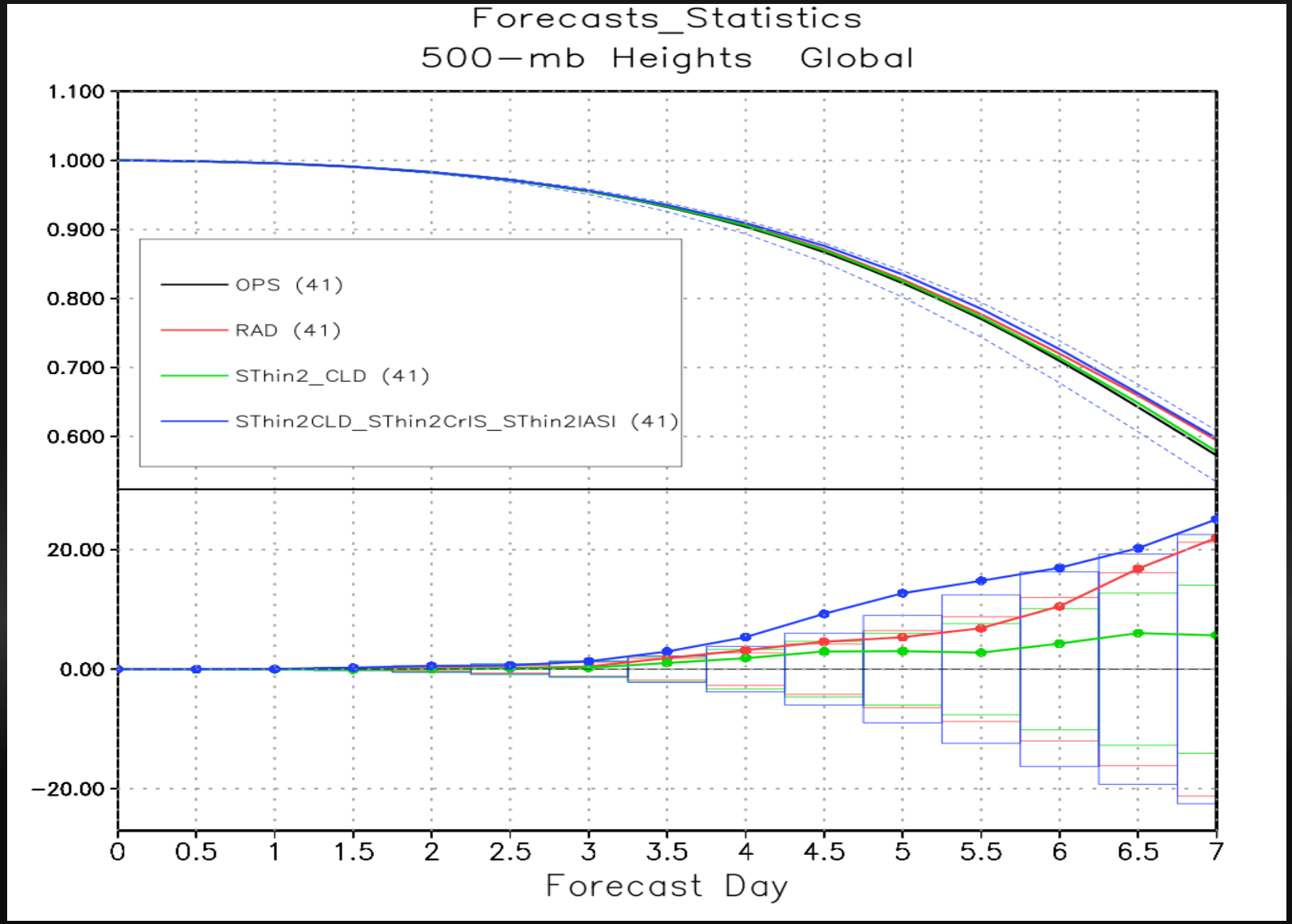
Different coverages around TCs

Cloud-cleared radiances available only for AIRS

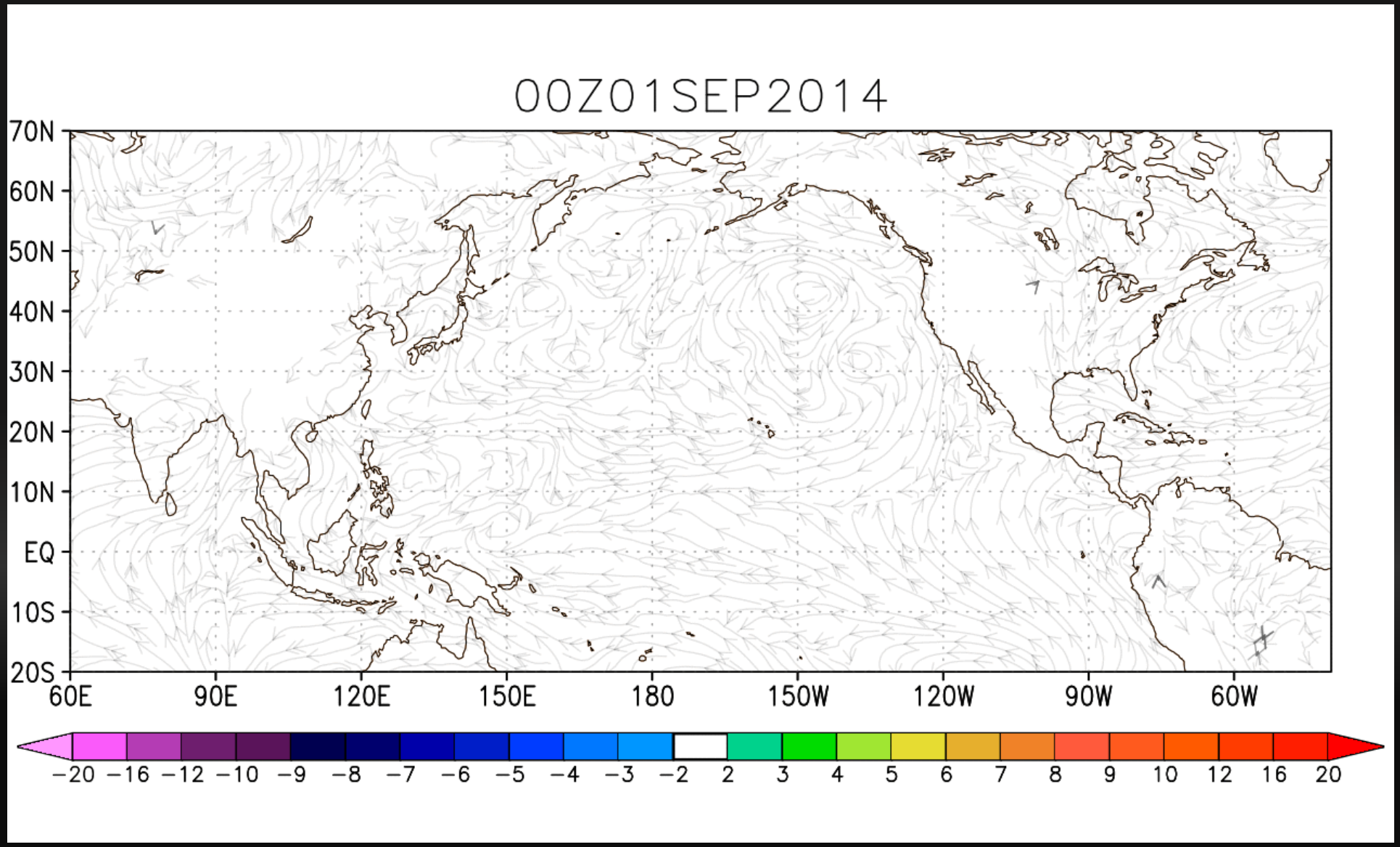
Clear-sky radiances have large data void areas corresponding to TCs circulations



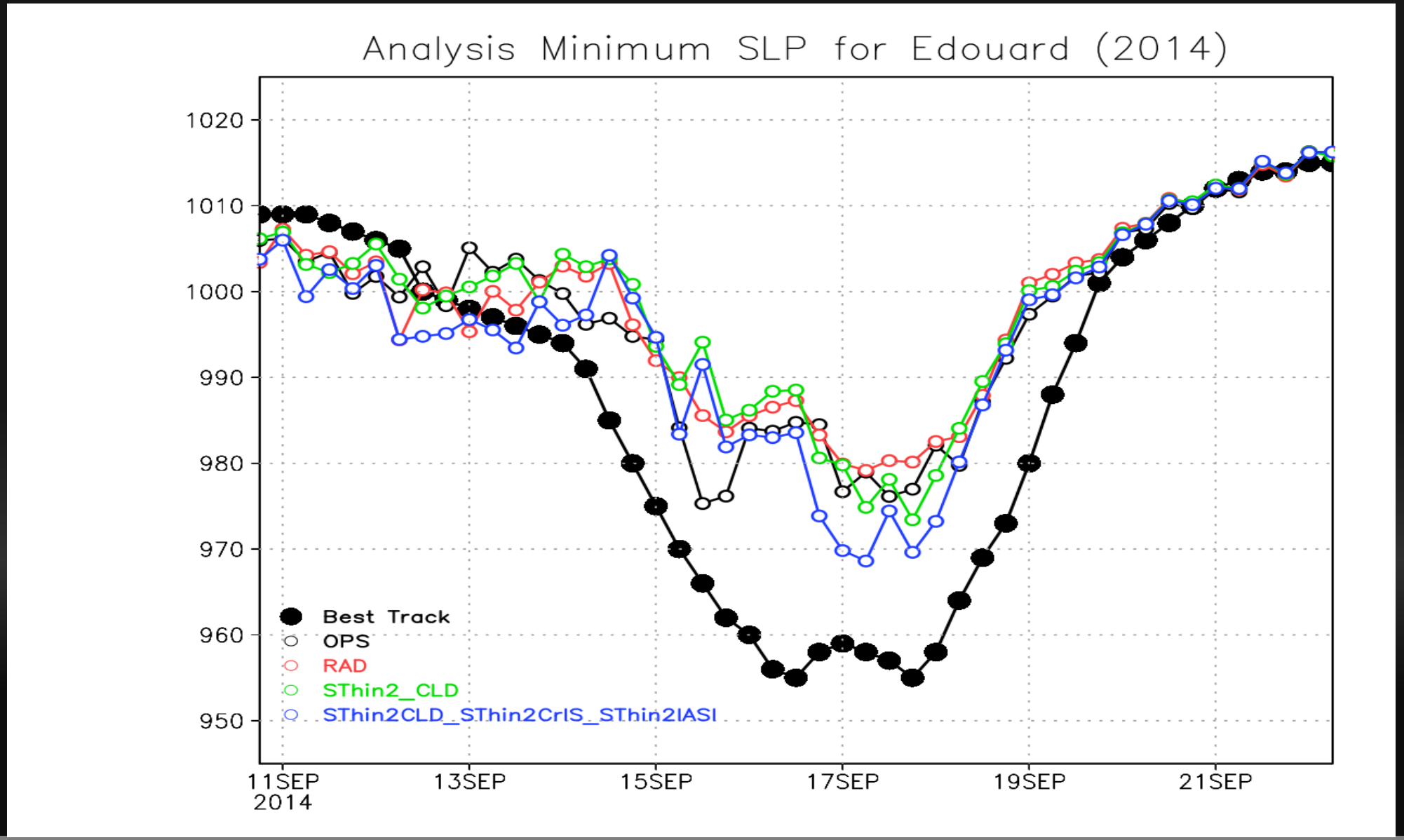
Global 500 hPa height anomaly correlation

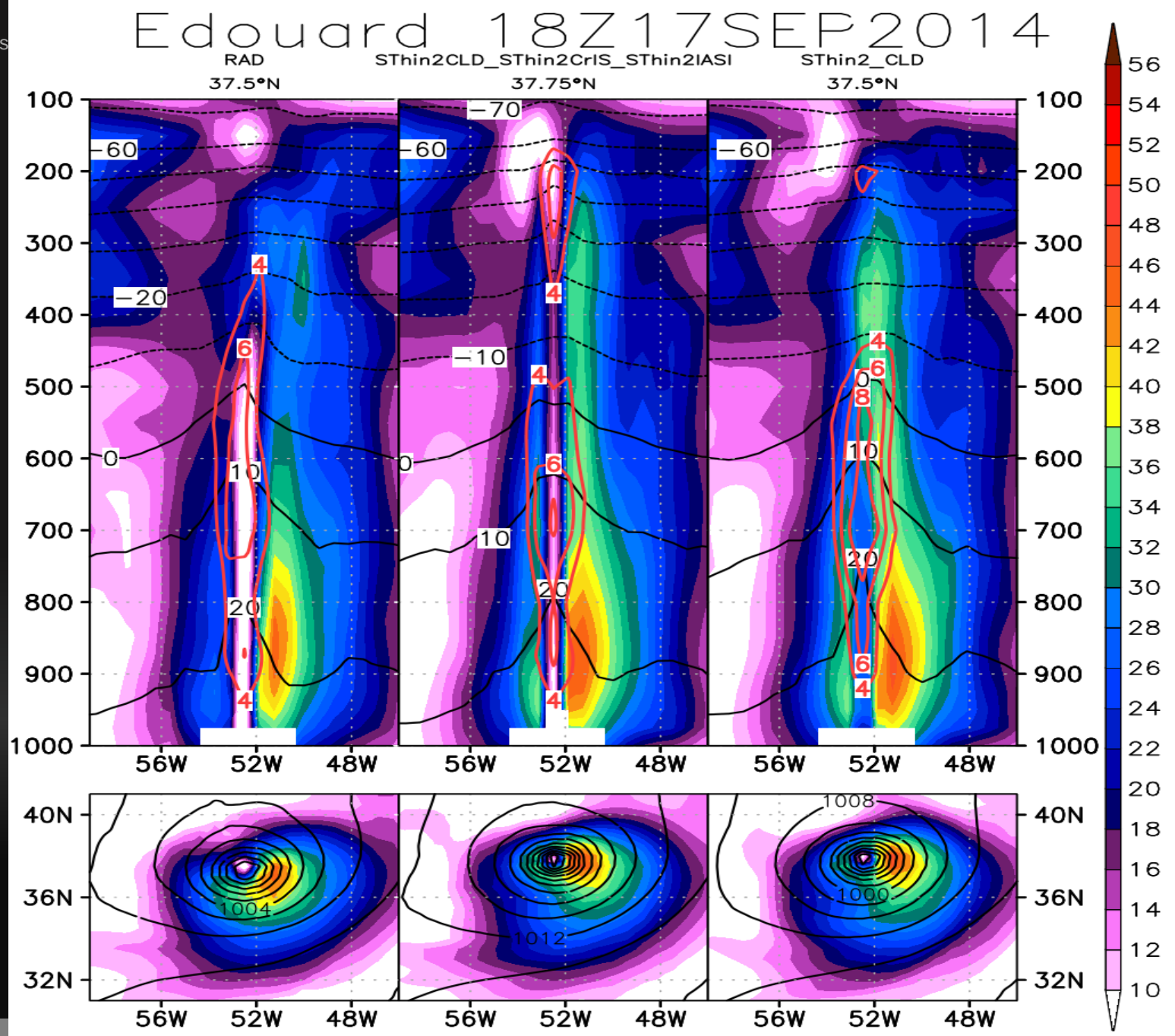


Impact of assimilating adaptively AIRS CCRs + CrIS and IASI on slp: TCs worldwide are affected



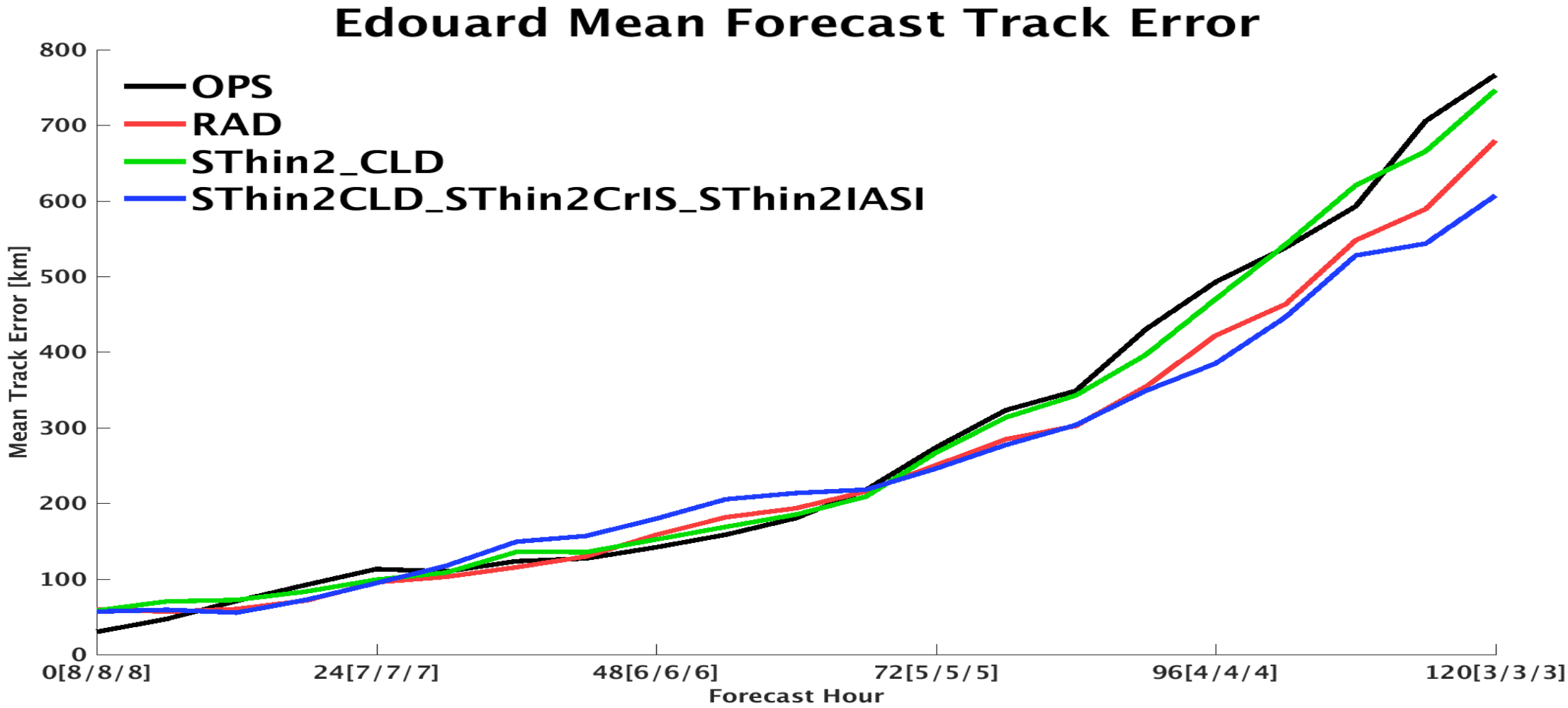
Hurricane Edouard center pressure analysis





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

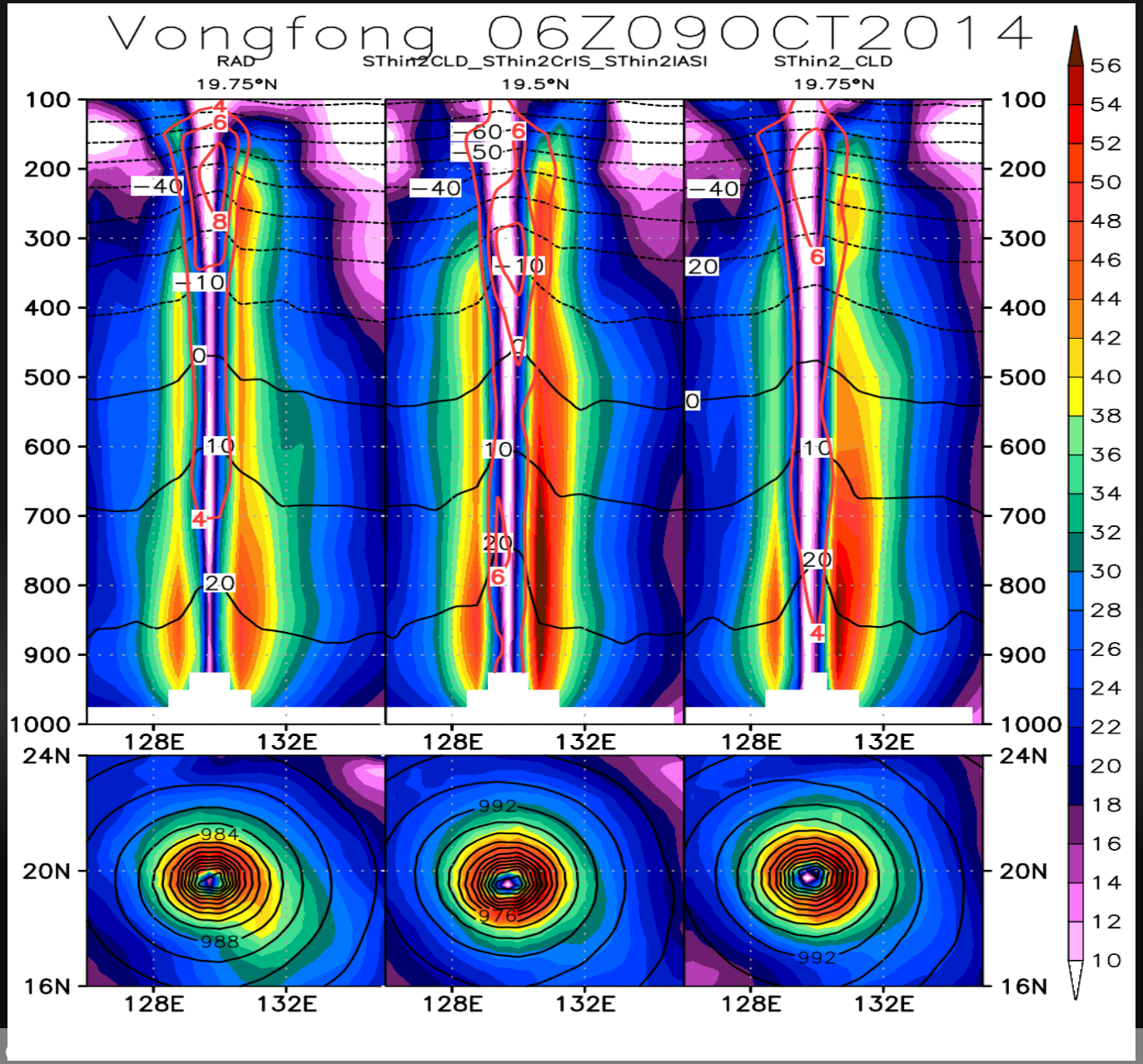
850 hPa winds (shaded)
slp(contours)



Comprehensive adaptive thinning improves track forecast skill (unlike when applied to AIRS alone)

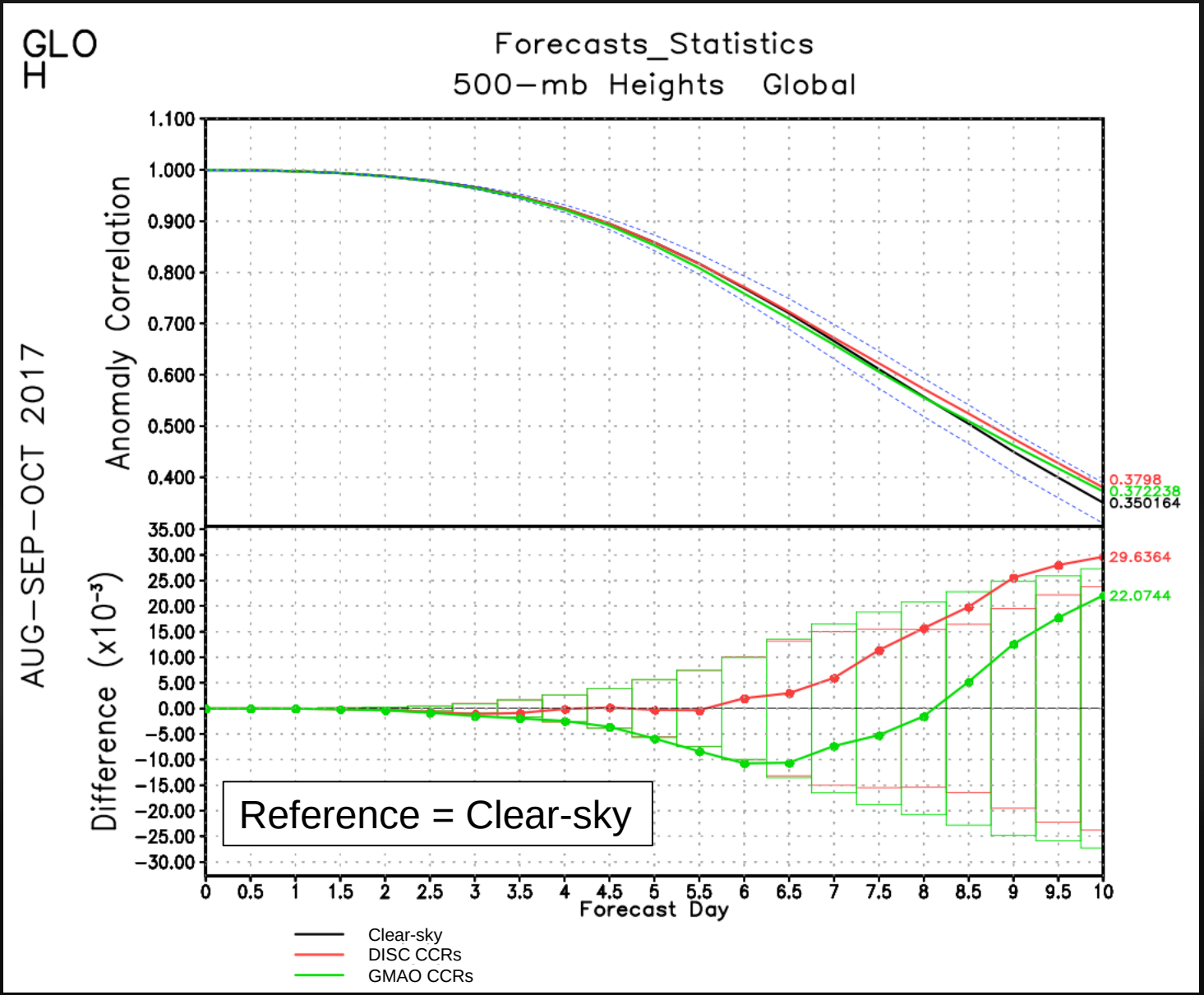
Improvement in structure also for very large TCs

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

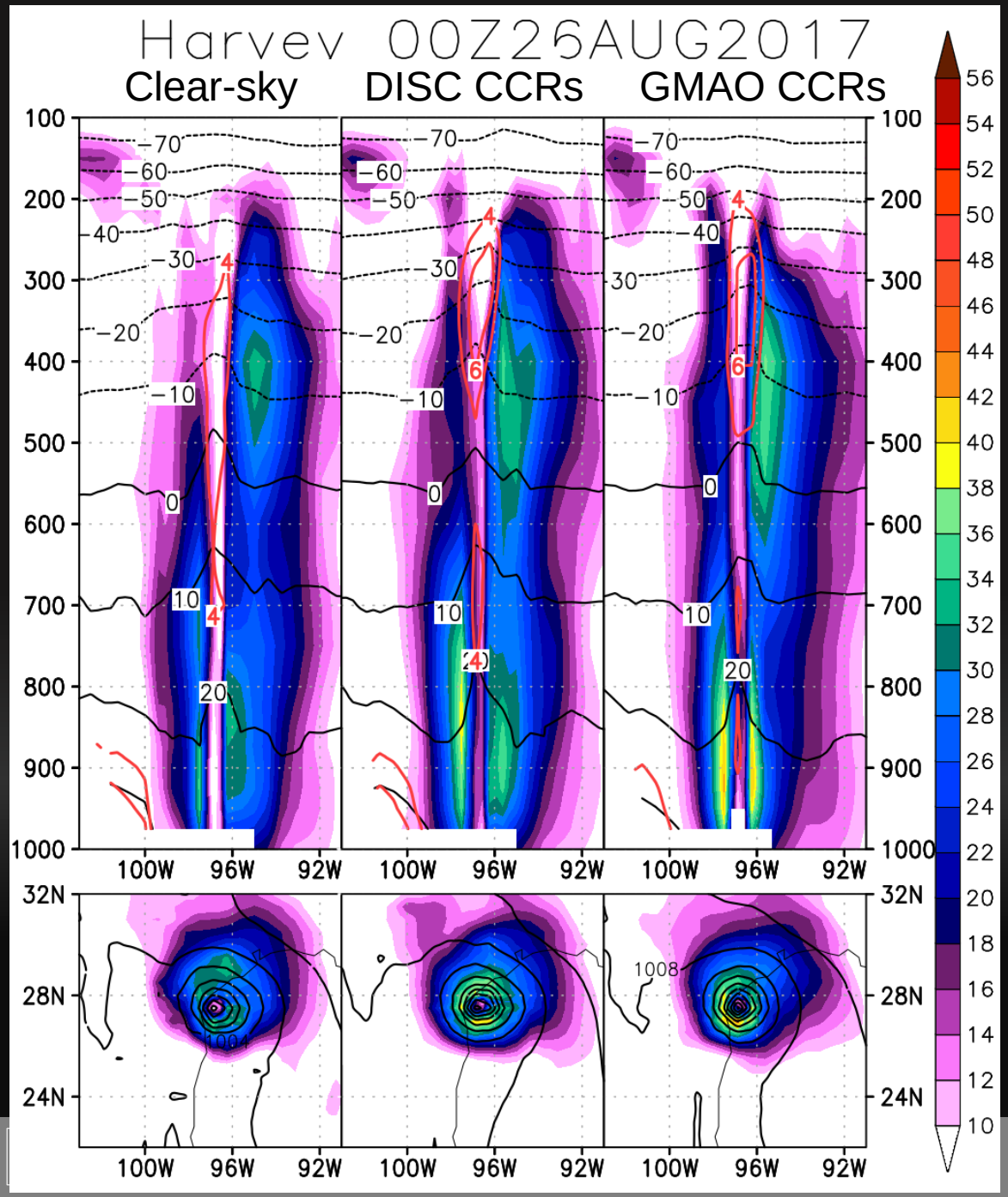


Roadmap towards an operational use of CCRs

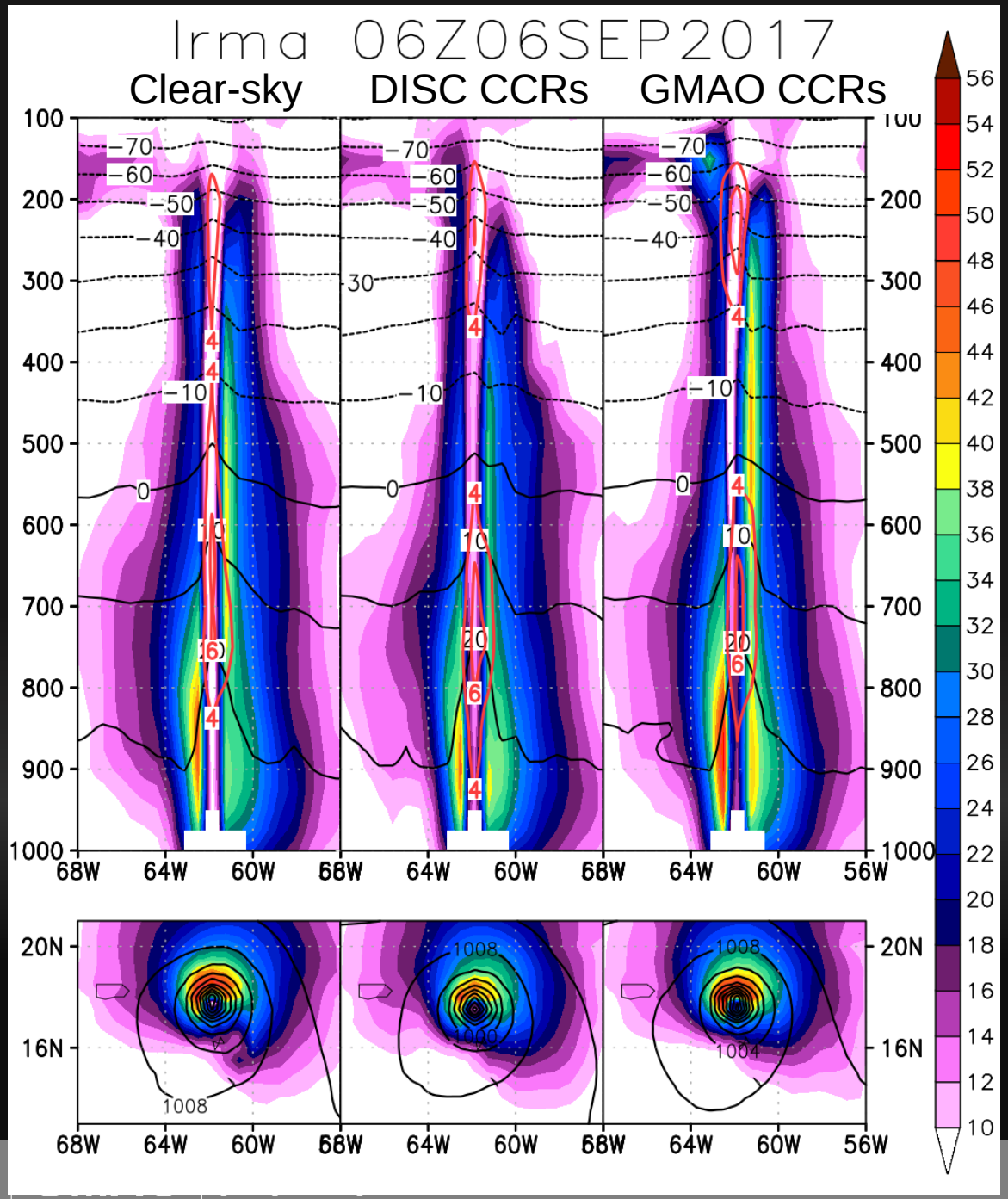
- In spite of the overwhelming evidence that cloud-cleared products are an immensely superior data type compared to clear-sky, cloud-cleared infrared radiances have not been operationally used because of: 1) lack of awareness that CCRs need to be much more aggressively thinned; 2) latency; and 3) external dependencies (ECMWF data; neural network) which are perceived by operational centers as not controllable
- As part of this plan, with the goal of raising awareness and interest towards cloud-cleared AIRS products, the cloud-clearing algorithm developed by Joel Susskind and his team was analyzed in the attempt of making it customizable (thanks to Lena Iredell, Lou Kouvaris and John Blaisdell)
- Selection of channels changed to match the one used by the GMAO
- GEOS-originated fields replace the neural network training against ECMWF
- Revised algorithm ported to NCCS
- Produced CCRs from July to October 2017
- Customized CCRs have been successfully assimilated in the new hybrid 4DEnVAR GEOS for the entire period



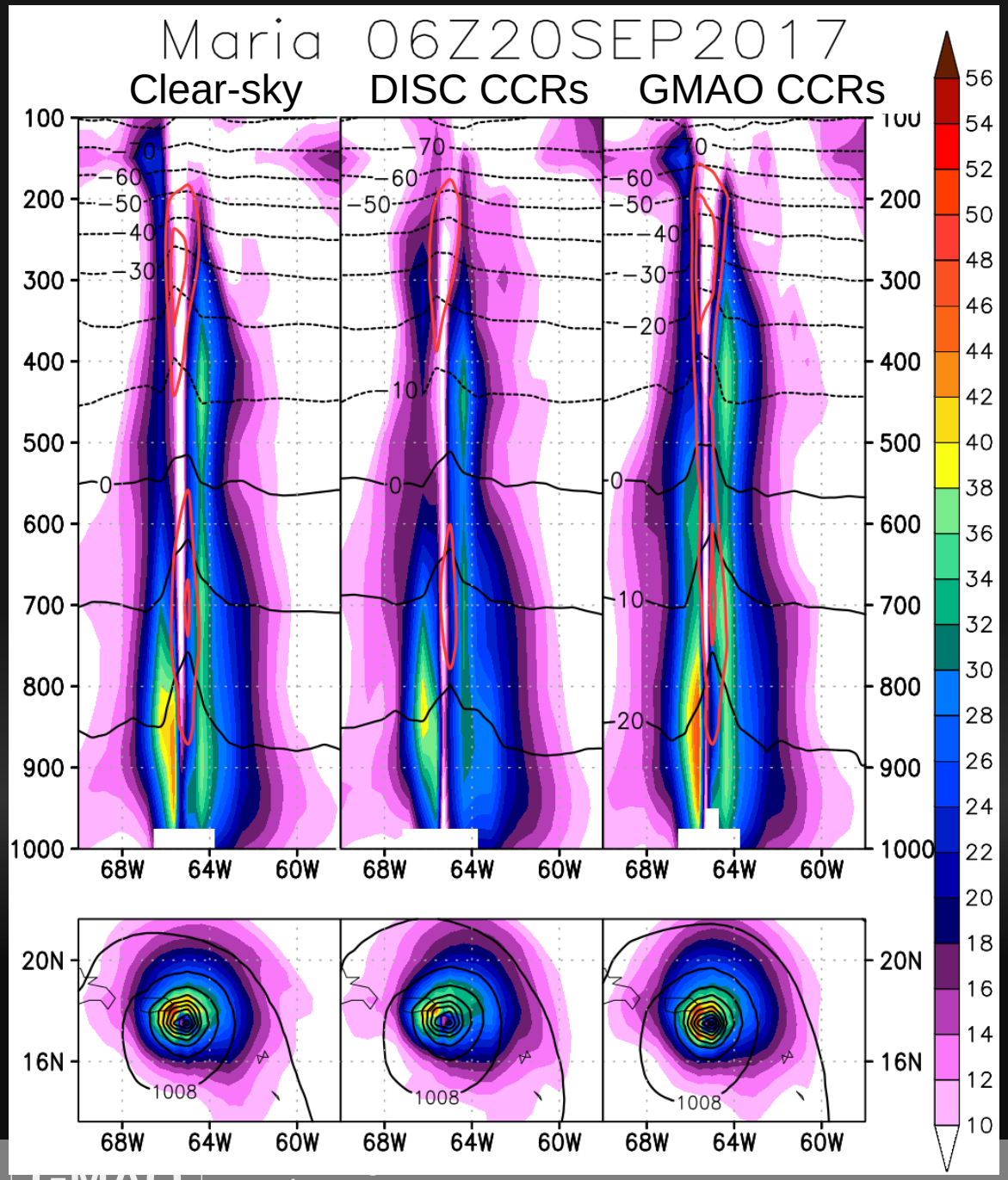
- The comparison of two AIRS CCR products (the one produced by the DAAC and the experimental one generated within the GMAO), reveals no significant difference
- This is the first attempt ever to create a GMAO-customized CCR product on NCCS and successfully assimilate it in the GEOS
- These preliminary results are very encouraging because they indicate the feasibility of producing CCRS internally without any external dependency and controlling latency



- # H. Harvey (2017)
  - Vertical cross section: Wind magnitude (shaded), Temperature (°C, black), Temp. Anomaly (°C, red)
  - 850 hPa winds (shaded), slp (contours)
- Increased warm core structure, stronger wind speeds and lower sea level pressure and an overall improvement in vertical and horizontal structure result from assimilation of cloud-cleared AIRS radiances against clear-sky radiances
- The customized AIRS CCRs, tailored to the GMAO system, produce even better results



- # H. Irma (2017)
  - Vertical cross section: Wind magnitude (shaded), Temperature (°C, black), Temp. Anomaly (°C, red)
  - 850 hPa winds (shaded), slp (contours)
- The assimilation of customized CCRs brings improvements in Irma's structure: stronger low-level winds and more compact eye



- H. Maria (2017)
  - Vertical cross section: Wind magnitude (shaded), Temperature (°C, black), Temp. Anomaly (°C, red)
  - 850 hPa winds (shaded), slp (contours)
- Similar result with Maria, the customized cloud-clearing adapted to the GEOS is capable of improving the vertical and horizontal structure of the storm

Conclusions and future work

- Long progress since first experiments with retrievals more than a decade ago
- Demonstrated value of adaptively thinned AIRS cloud-cleared radiances
- Expanding the concept towards other sensors
- Comprehensive adaptive thinning strategy that consistently modifies the density of assimilated radiances for *all hyperspectral instruments together* (combining Cloud-clear AIRS, with clear-sky adaptively thinned CrIS and IASI) proves to be very promising
- Demonstrated customizability of cloud-cleared radiances
- Next 2 talks: hybrid 4DEnVAR (Erica), Polar lows (Manisha)

Future work: CrIS and IASI cloud-cleared radiances

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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.

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