Impact of assimilating multi-instrument hyperspectral infrared cloud-cleared radiances on hurricanes Harvey, Irma and Maria during the 2017 Atlantic season

Oreste Reale[1,2], Erica McGrath-Spangler[1,2], Manisha Ganeshan[1,2], Niama Boukachaba[1,2], Will McCarty[2], Chris Barnet[3], Ron Gelaro[2]

[1]USRA/GESTAR

[2]NASA GSFC

[3]STC

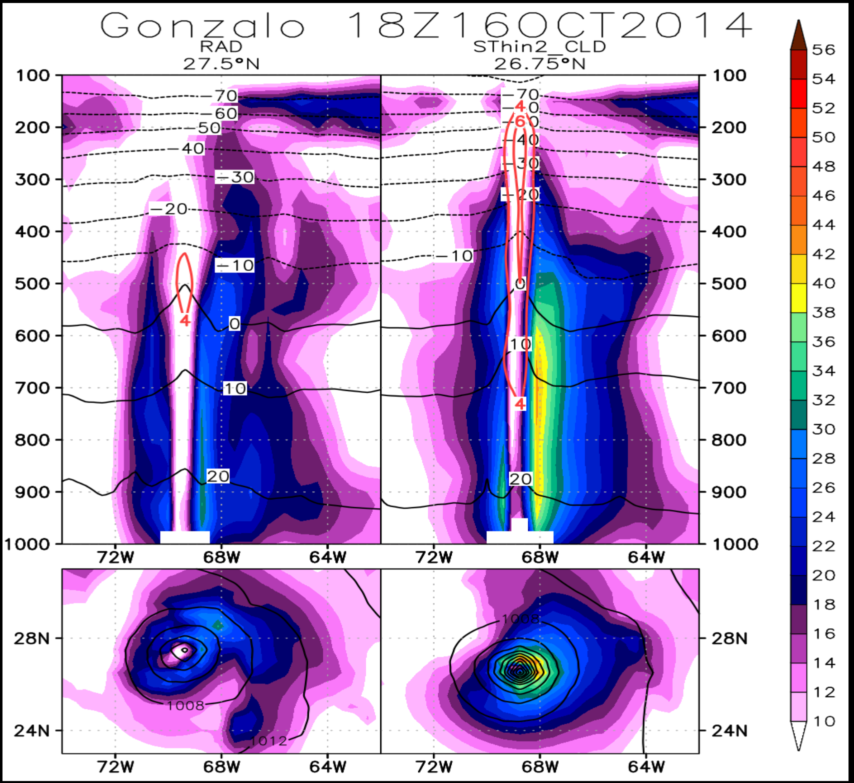
Outline

- Past work – Demonstrated that the operational use of AIRS clear-sky radiances was suboptimal –cloud-cleared radiances are superior
- Ported and customized the AIRS cloud-clearing algorithm on NCCS **New: exploring the sensitivity to data density changes for the internally-produced CCRs**
- **Assimilating cloud-cleared CrIS (taken from the NOAA CLASS)**
- **Experiments investigating the 2017 Boreal TC Season**
- Future work: work on a customizable version of the CrIS cloud-clearing algorithm

Ten years (2007-2017) of work by this team with assimilation of cloud-cleared retrievals showed a very strong impact on the representation of tropical cyclones

In 2018, this team demonstrated the positive impact of assimilating cloud-cleared AIRS radiances in a global 3DVAR framework on tropical cyclone representation.

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.*



Major Findings: Cloud-cleared AIRS radiances are superior compared to clear-sky radiances, but need to be thinned more aggressively on the global scale

In 2019, we improved the cloud clearing algorithm to facilitate an operational use of CCRs

- Latency and external dependencies in the original algorithm were seen as limitations by operational centers as not controllable
- The cloud-clearing algorithm developed by Joel Susskind and his team was ported to NCCS and a first attempt was made to customize it (thanks to Lena Iredell, Lou Kouvaris and John Blaisdell) and free it from external dependencies (using the model own fields as first guess, instead of ECMWF neural network)
- During 2019, the algorithm was fully parallelized with a **75 gain factor** in speed
- Produced AIRS CCRs to cover the entire boreal 2017 TC season
- Vast set of experiments assimilating these CCRs in the new hybrid 4DEnVAR GEOS for the entire period

New :

1) Exploring the sensitivity to internally produced AIRS CCR global density; 2) Assimilating cloud-cleared radiances from CrIS

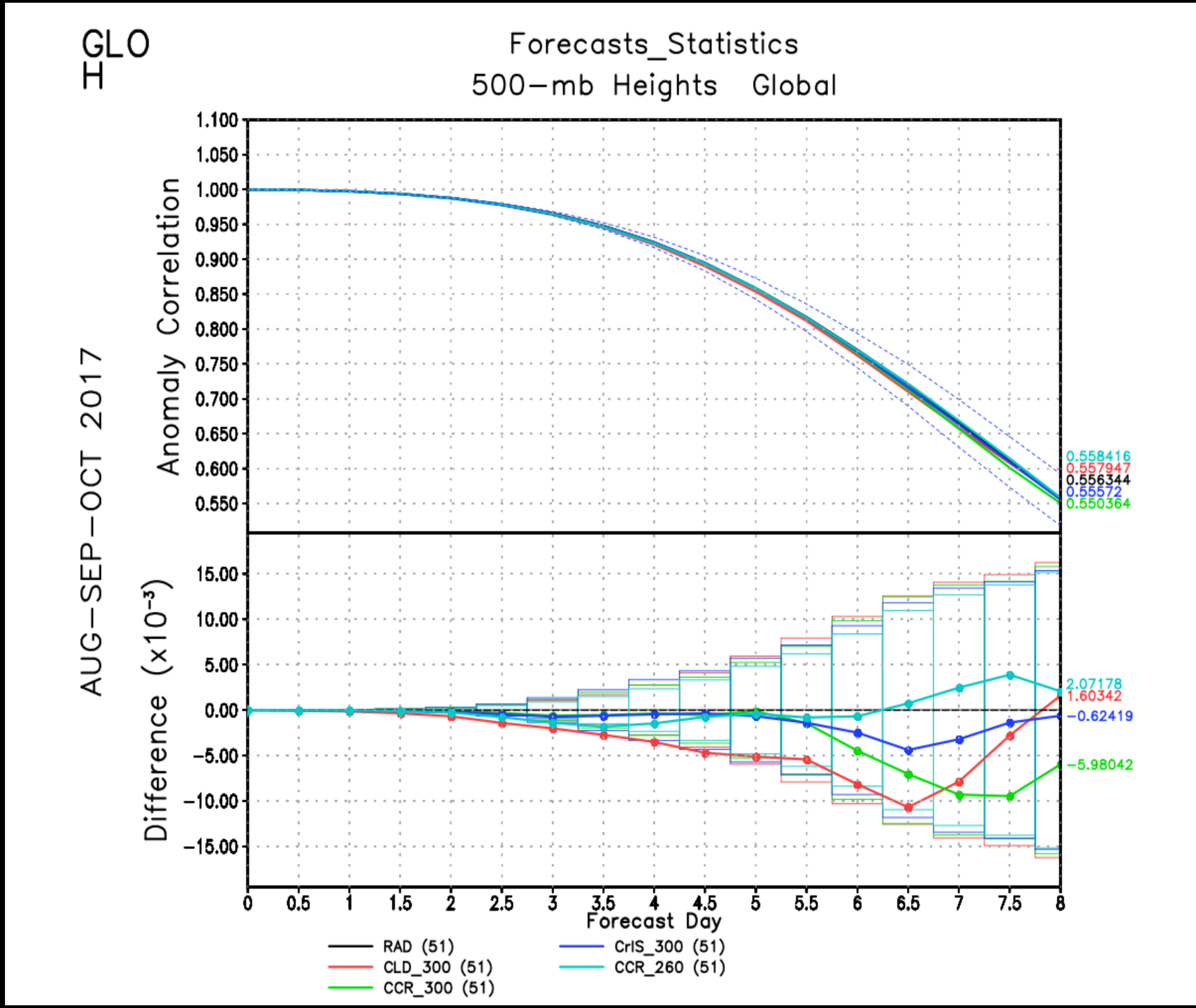
GEOS-5 DAS hybrid 4DEnVar version 5.17

Assimilation from 31 Jul – 20 Oct 2017 of *all observations* assimilated operationally

10 day forecasts from the following experiments:

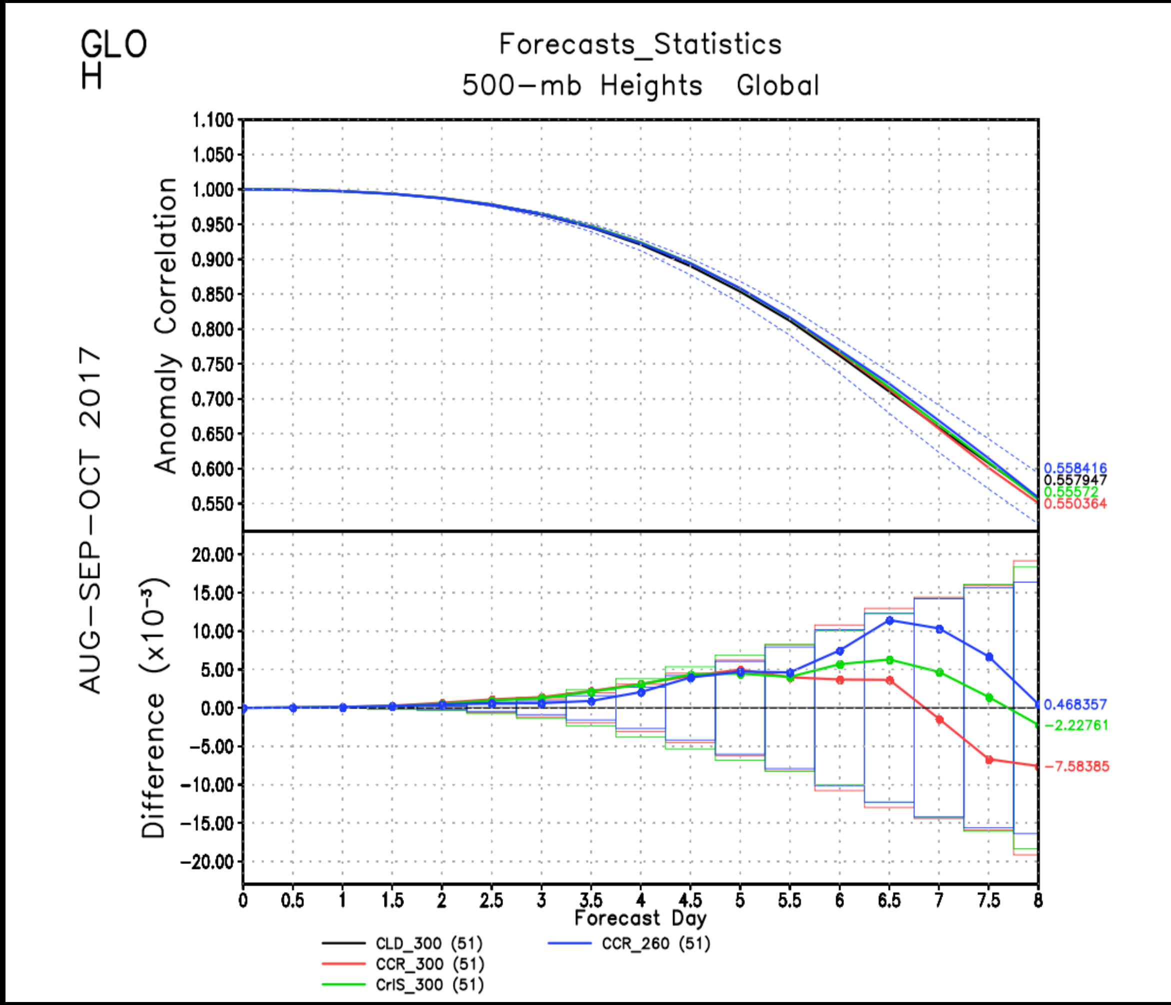
- RAD: AIRS and CrIS clear-sky radiances, regularly-spaced thinning (180km)
- CLD_300: AIRS cloud-cleared radiances from the GES DISC, regularly-spaced thinning (300km)
- CCR_300: *internally-produced AIRS cloud-cleared radiances,* same thinning as CLD3
- CCR_260: *internally-produced AIRS cloud-cleared radiances, thinned at 260 km*
- CrIS_300*: cloud-cleared CrIS radiances, from NOAA CLASS, thinned at 300km*

Verification of global skill



None of the new experiments degrade the global skill compared to the RAD (that mimics the ``operational” approach), except the assimilation of cloud-cleared radiances taken from the DAAC

All the new experiments improve the global skill compared to the assimilation of cloud-cleared radiances from the DAAC



Increasing density of internally produced CCRs (to 260 km instead of 300) improves the skill up to day 7

Assimilation of cloud-cleared CrIS radiances from NOAA CLASS also produce some increase in global skill

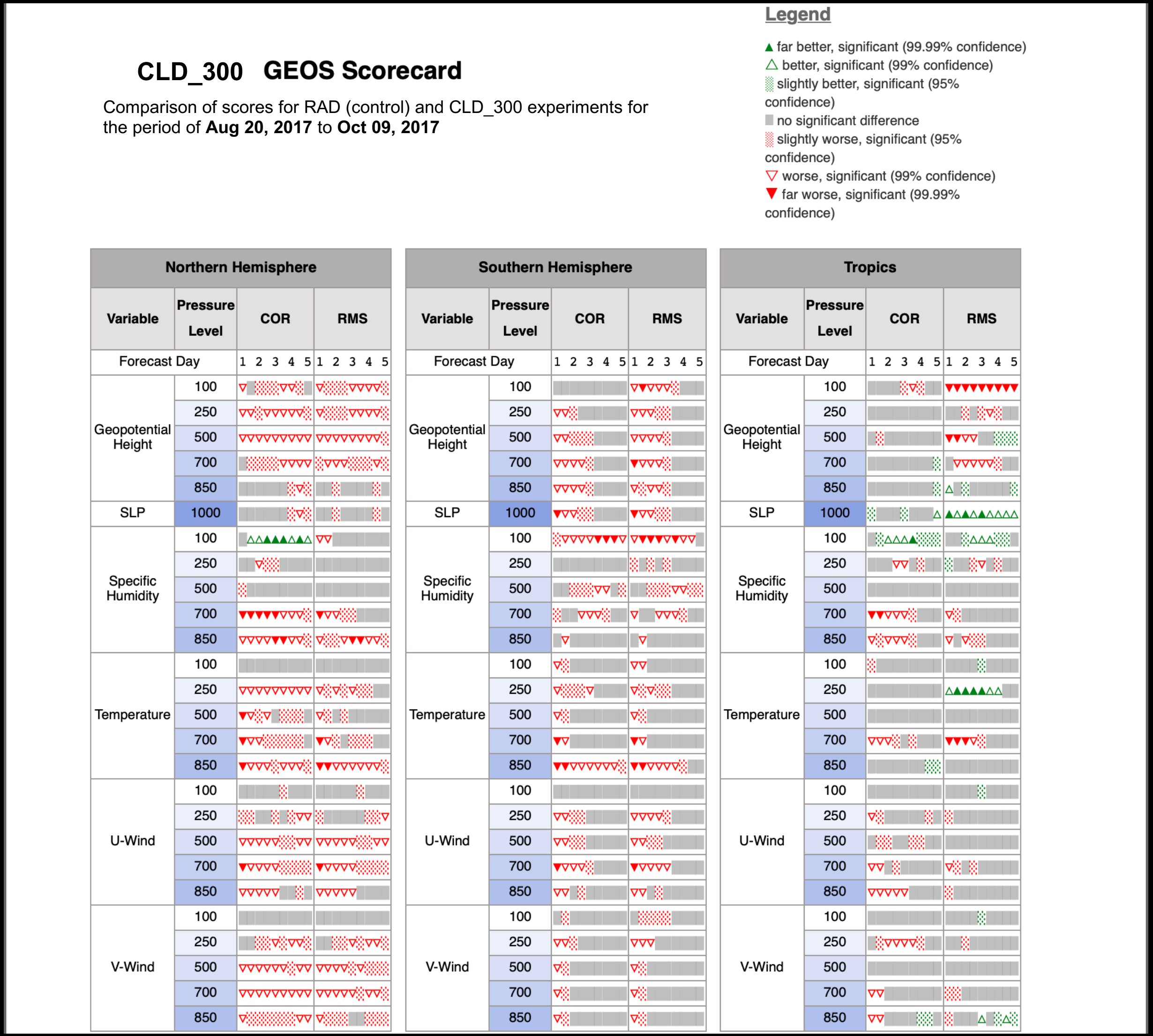
However global skill is just a safety check: more diagnostics are needed

Comparisons of cloud-cleared AIRS from DAAC against RAD

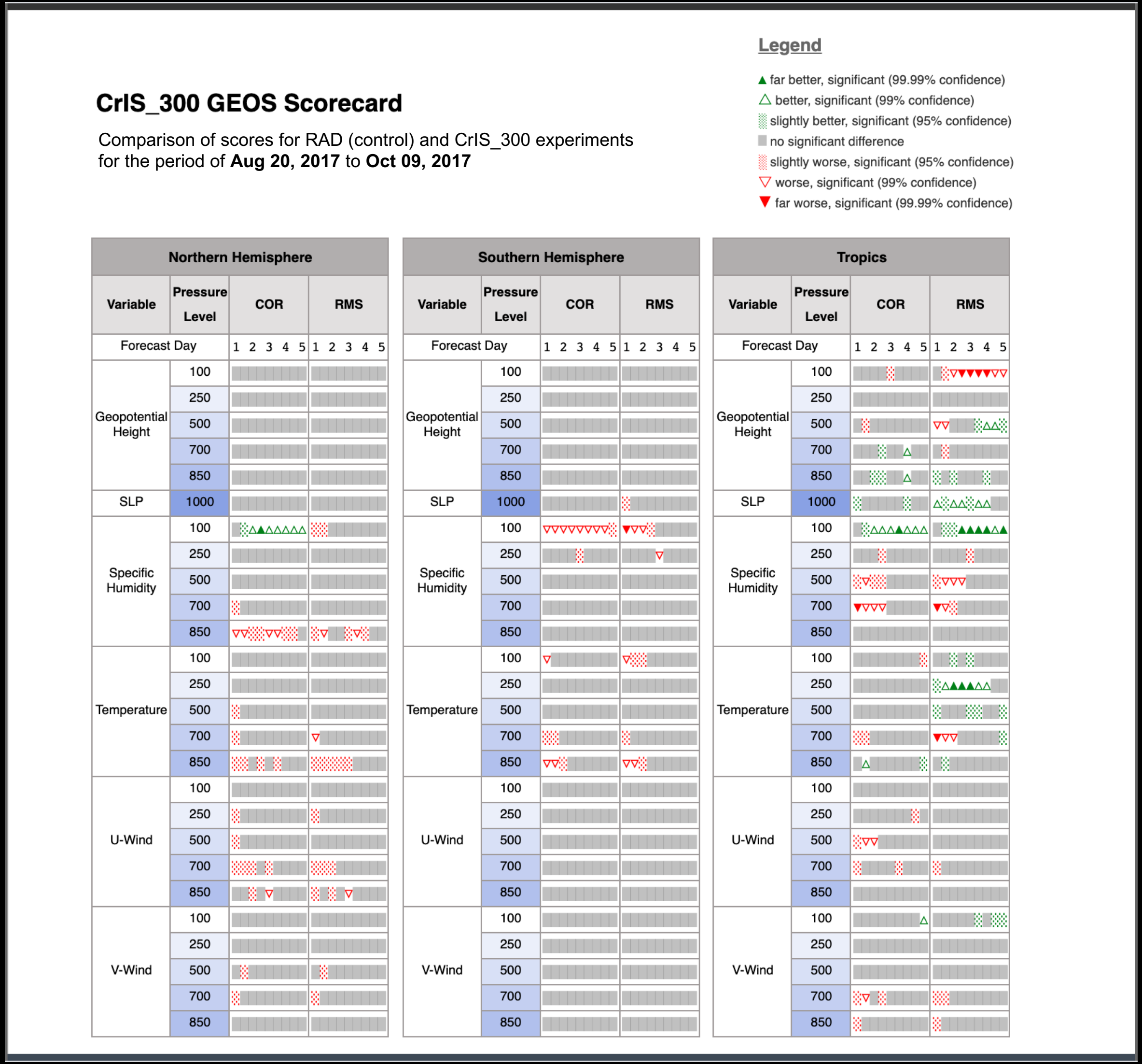
The scorecard is a much more robust diagnostics.

Two experiments are compared at a time, verifying improvement of h, q, t, u, v at in the midlatitudes, tropics at all levels

The result shows that assimilation of cloud-cleared AIRS radiances from the DAAC in the GEOS has some negative impacts, compared to the assimilation of clear-sky radiances, which would be the "operational" practice



Comparisons against RAD

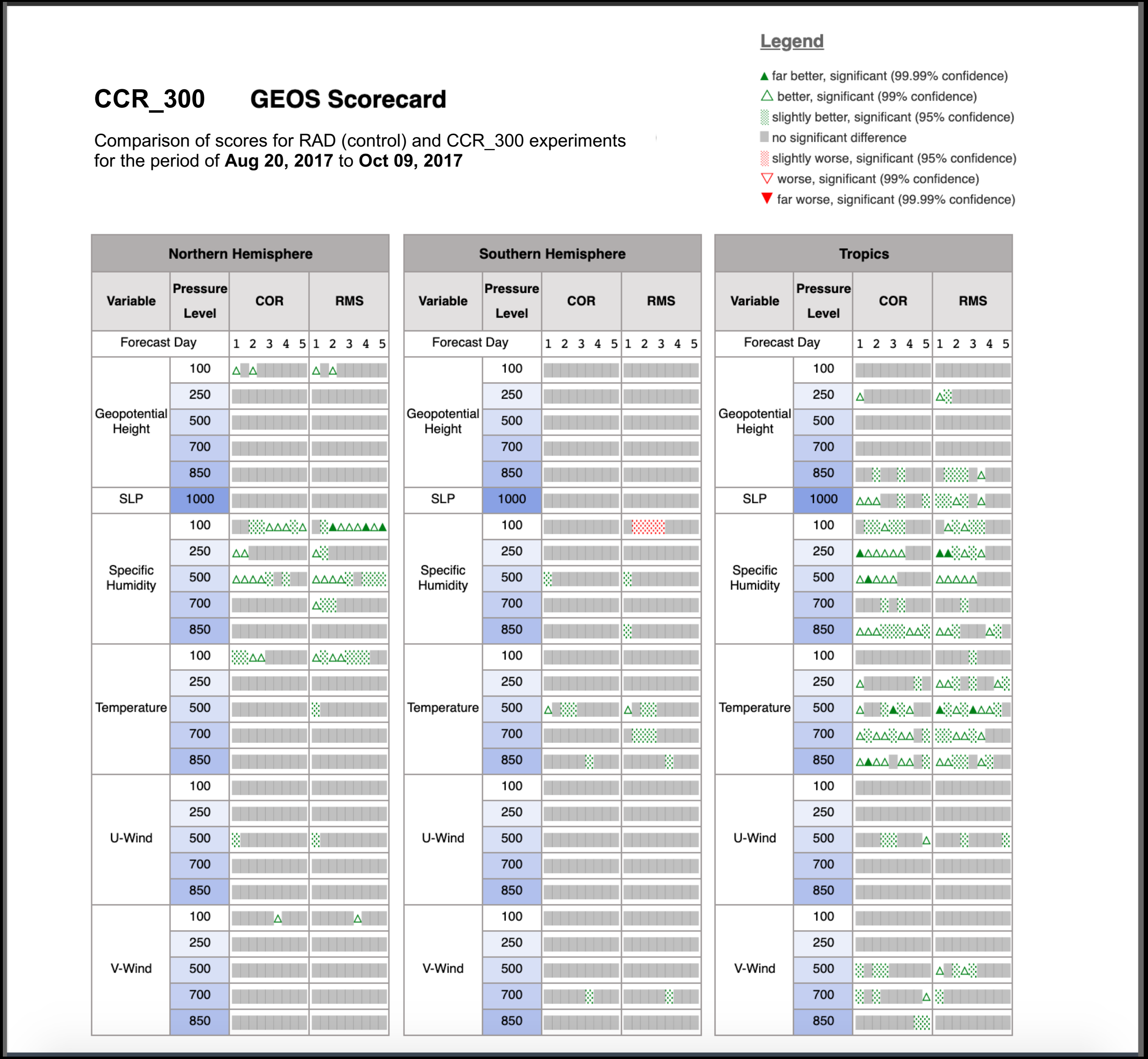


The result shows that assimilation of cloud-cleared CrIS radiances from NOAA CLASS in the GEOS is essentially neutral compared the assimilation of CrIS clear-sky radiances

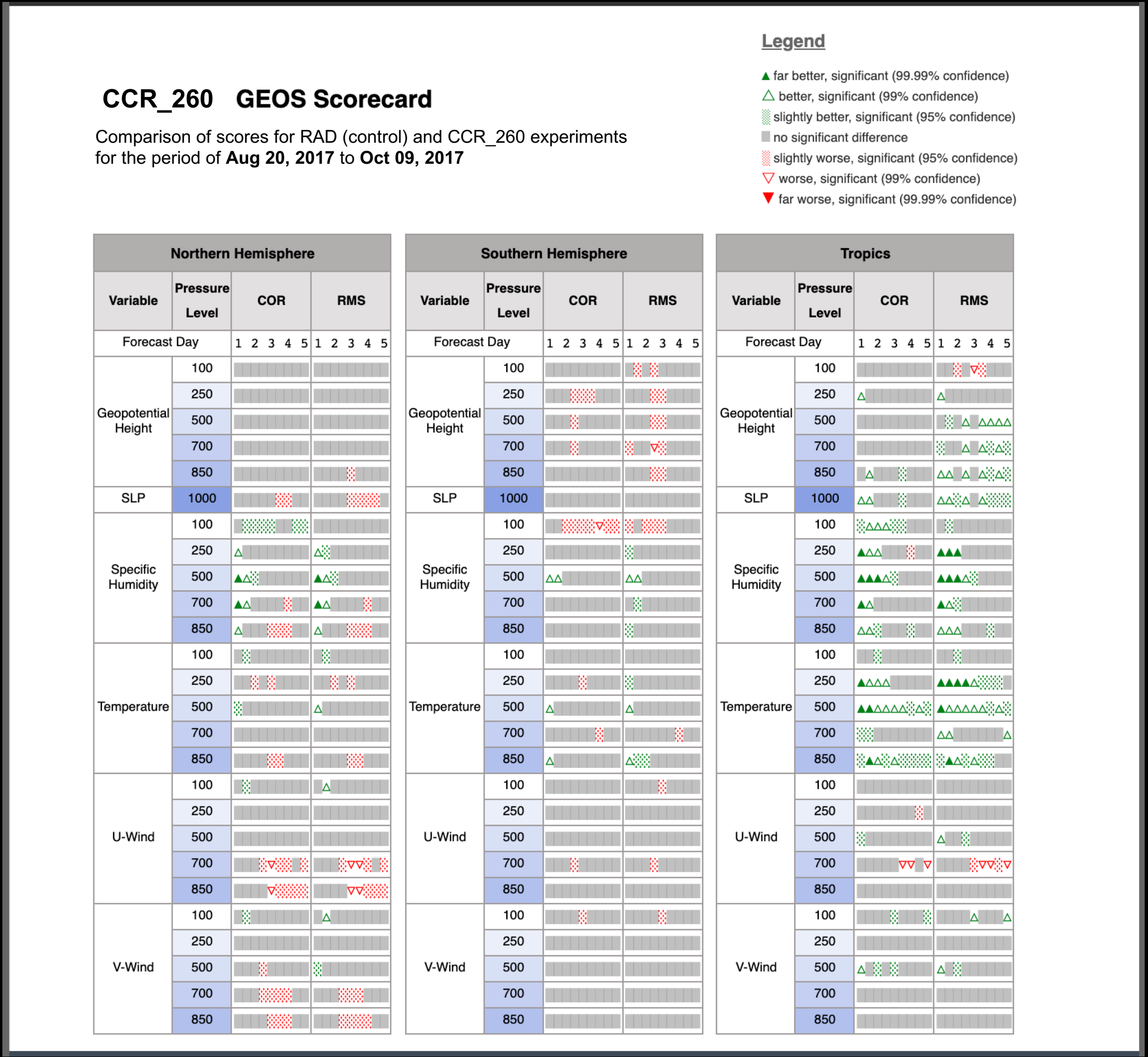
Comparisons of internally-produced cloud-cleared AIRS radiances against RAD (the operational approach)

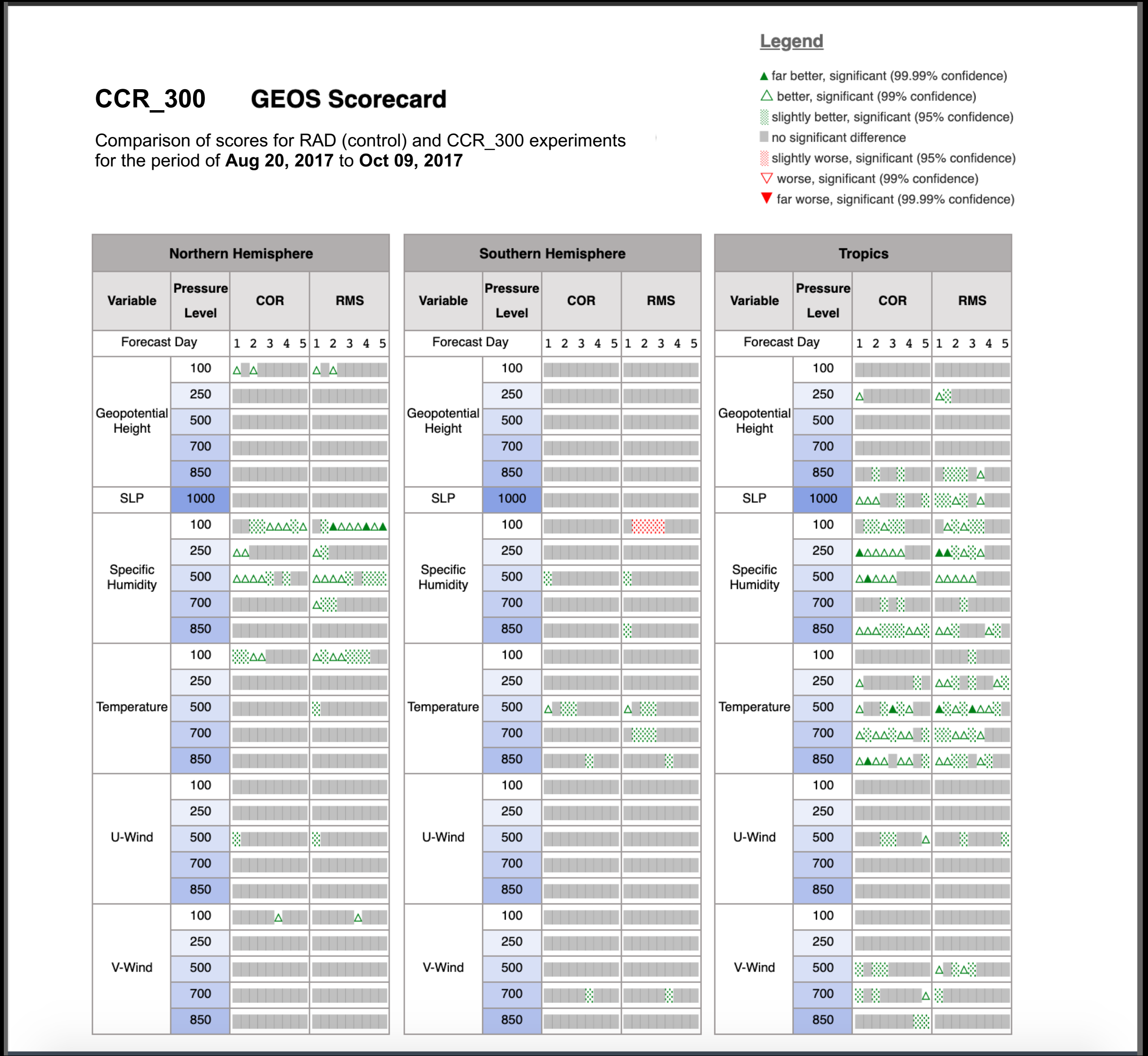
However, the assimilation of internally-produced cloud-cleared radiances thinned at 300 km, against the clear-sky radiances used operationally, show slight improvements in the mid-latitudes and strong improvements in the tropics.

This is a robust diagnostics that indicates the validity of tailoring the cloud-clearing algorithm towards a specific forecast framework

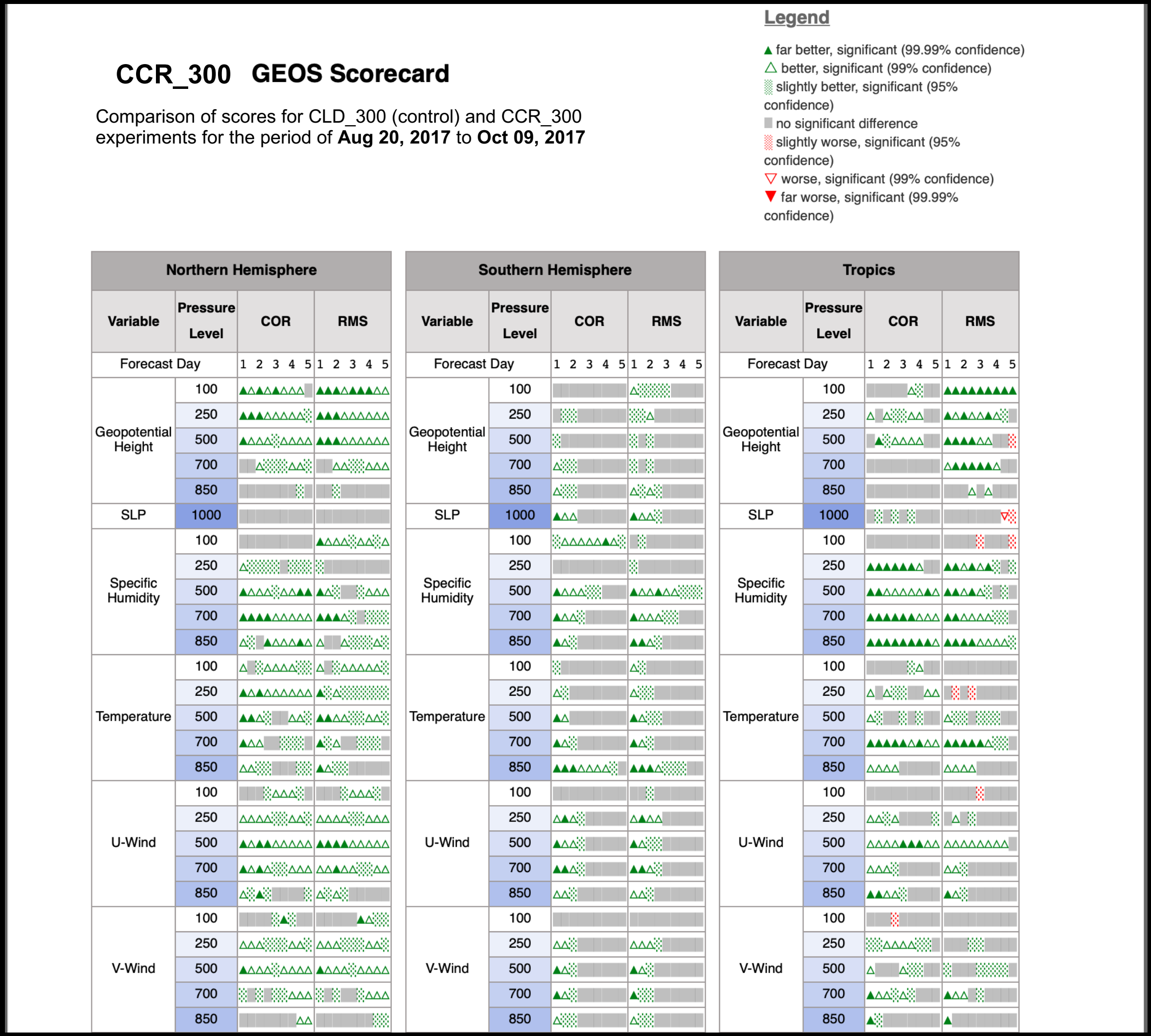


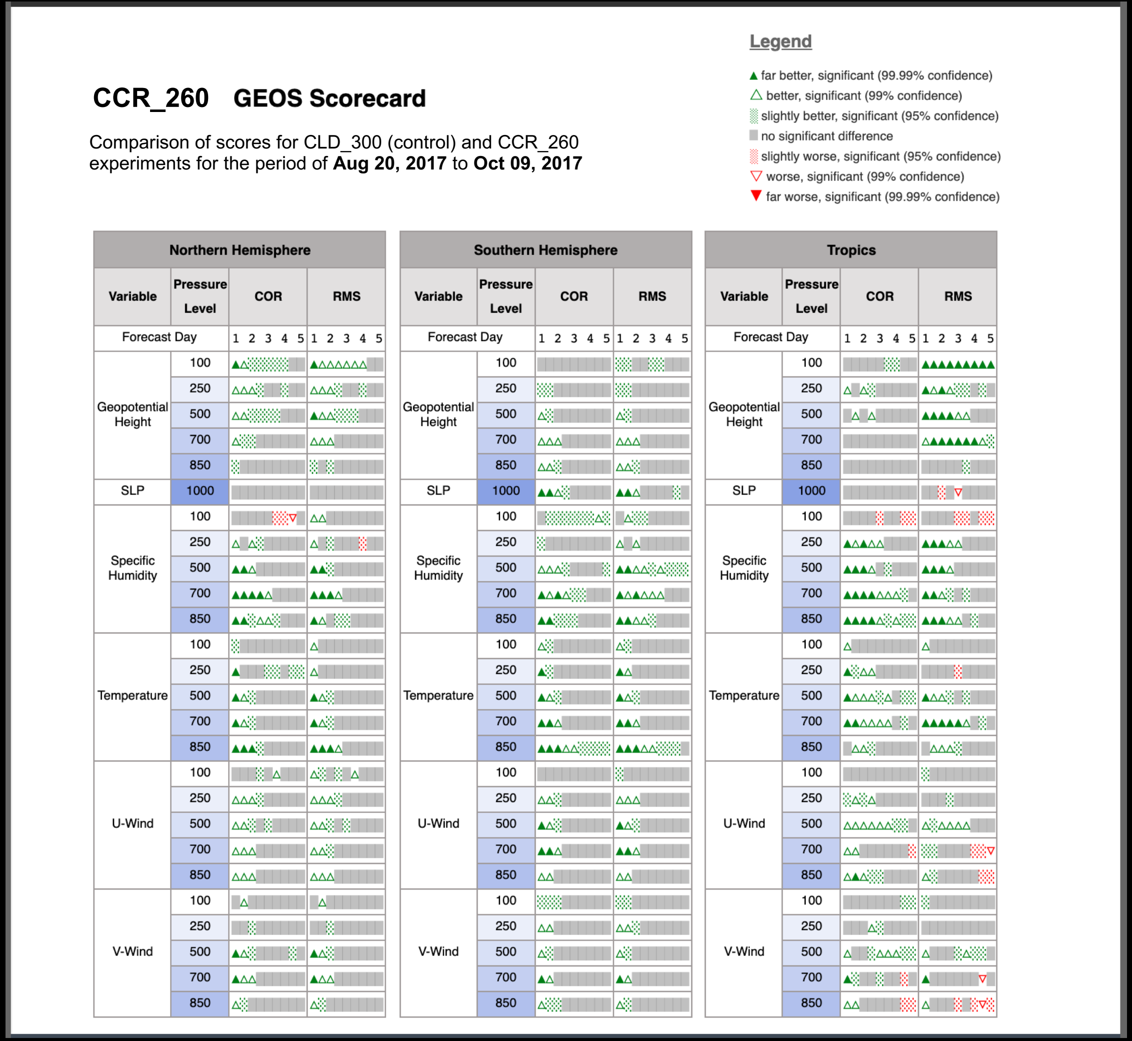
Comparisons of internally produced AIRS cloud-cleared radiances against RAD (at 2 different thinning levels): always an improvement



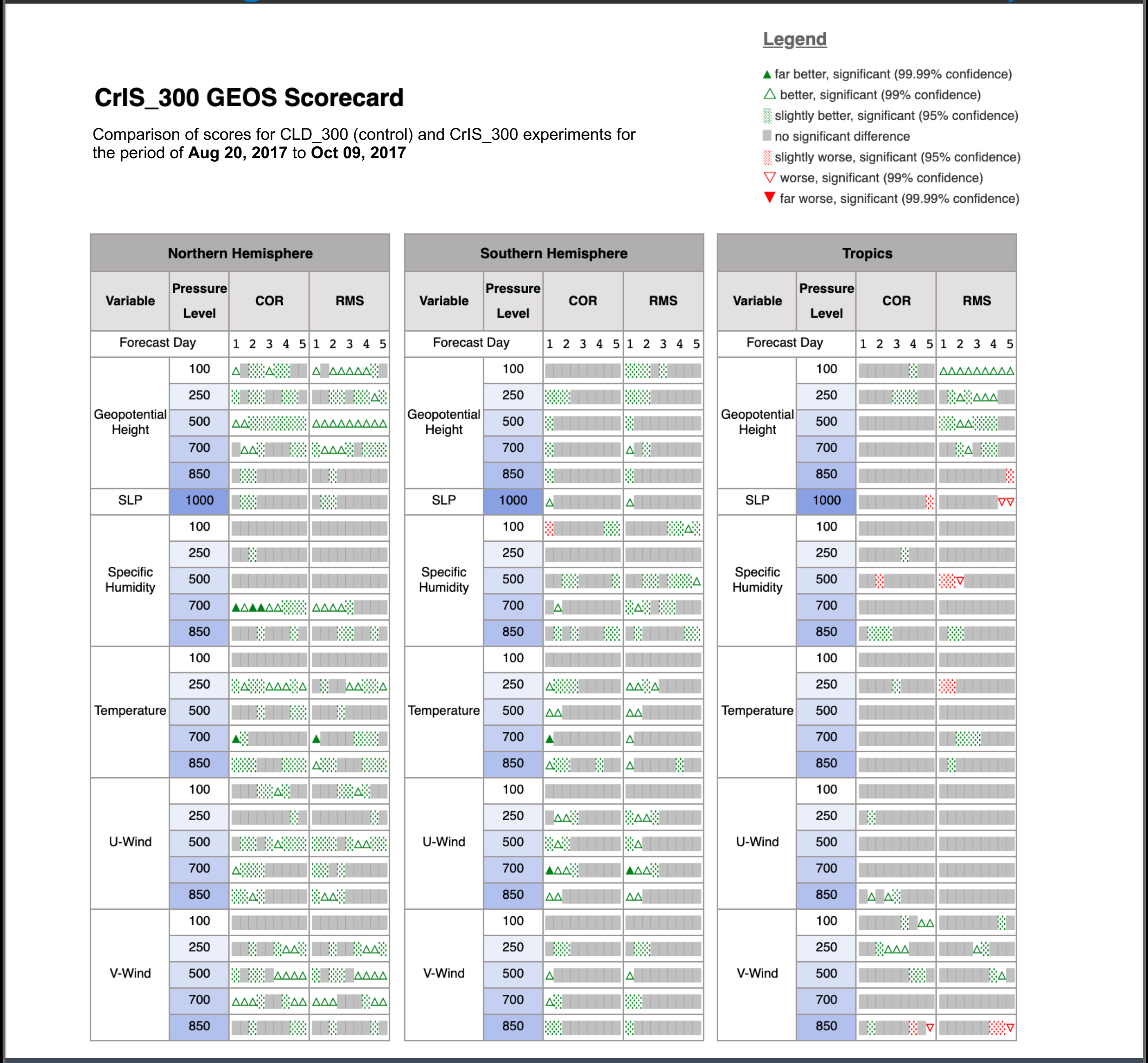


Comparisons of internally produced cloud-cleared radiances against cloud-cleared radiances obtained from the DAAC: always an improvement





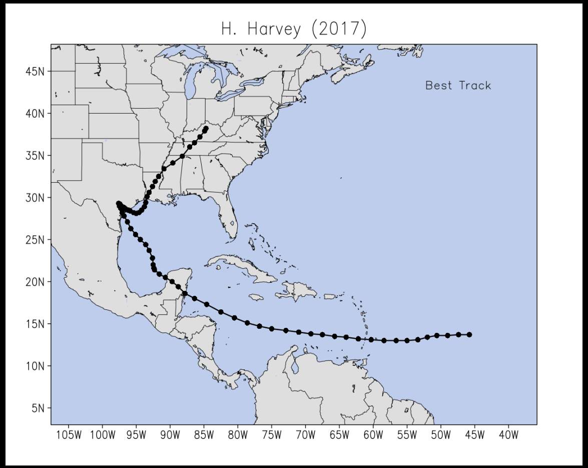
Comparisons of cloud-cleared CrIS (from CLASS) against cloud-cleared AIRS from DAAC)

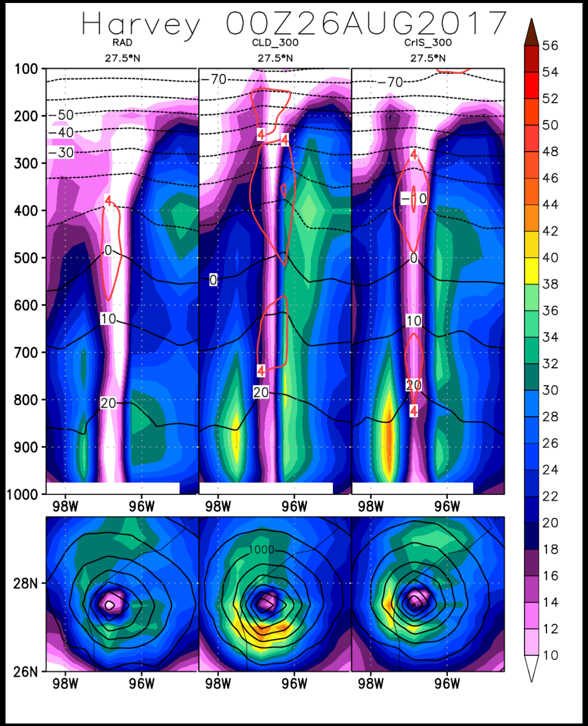


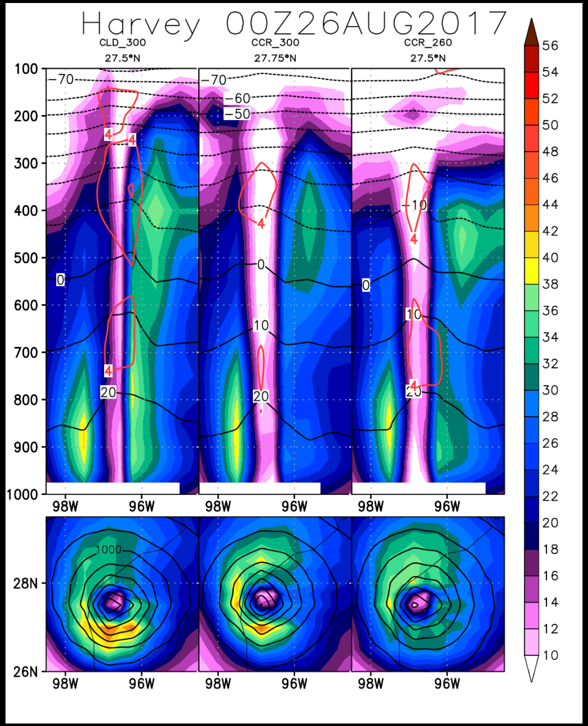
This diagnostics indicates the great potential of CrIS cloud-cleared radiances. When not yet tailored, the impact is positive and stronger than AIRS.

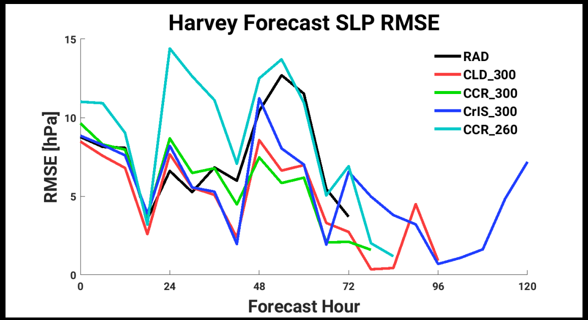
We expect larger improvements when the CCR algorithm for CrIS will be tailored to the GEOS

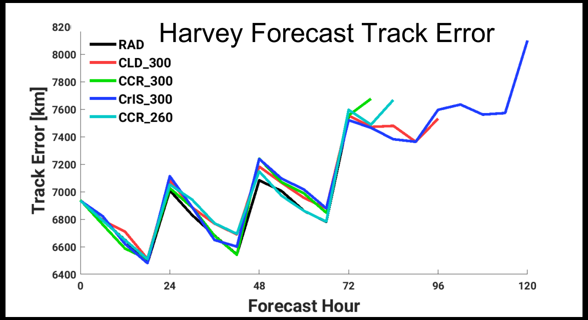
Hurricane Harvey

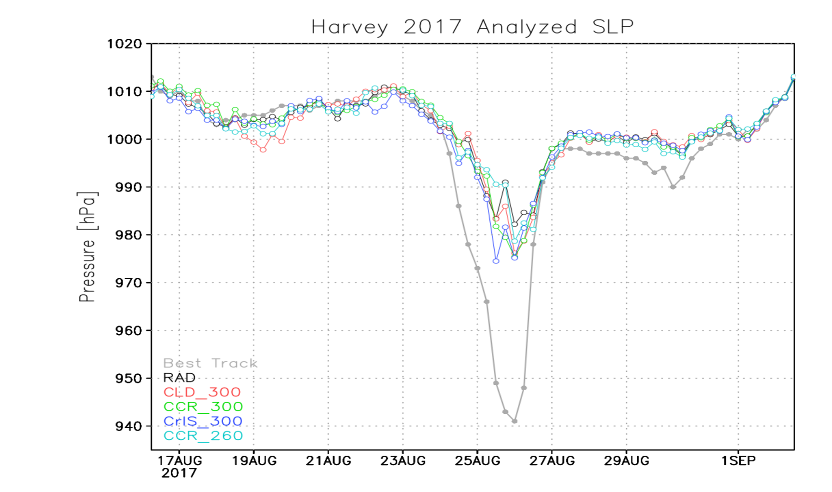






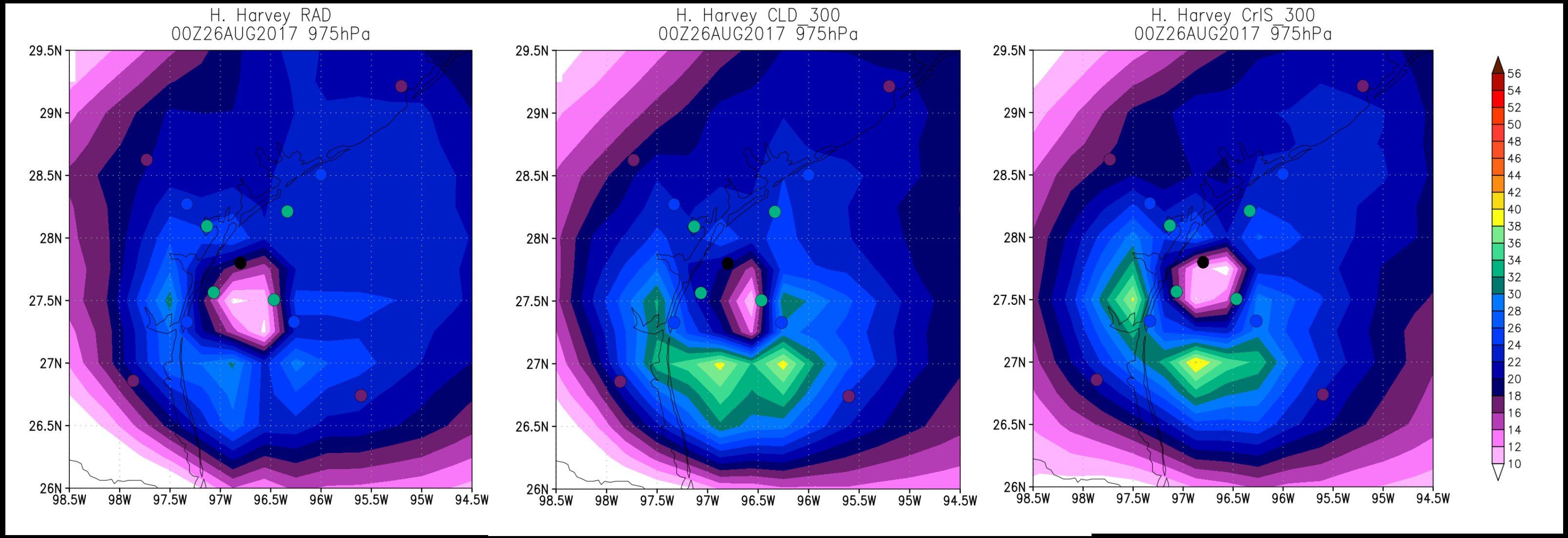




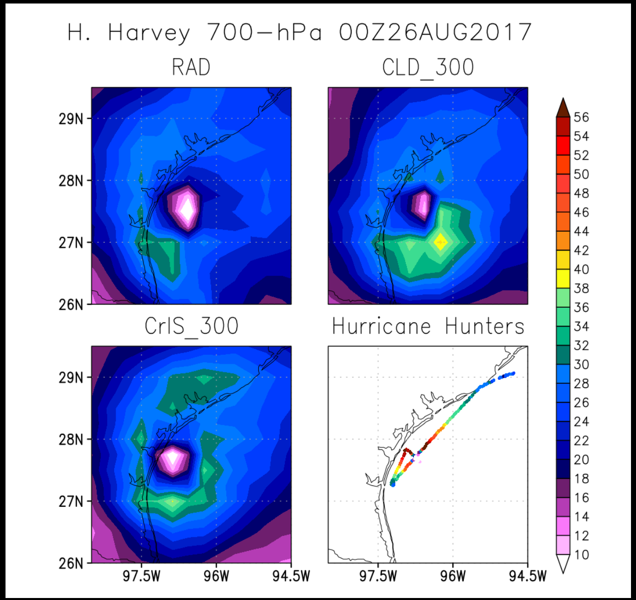


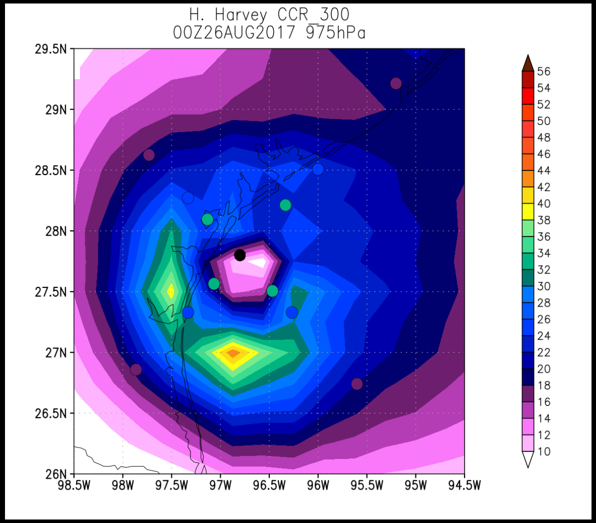
Regardless of slight differences in global skill, all assimilation strategies of cloud-cleared radiances produce an improvement in hurricane structure against assimilation of clear-sky radiances

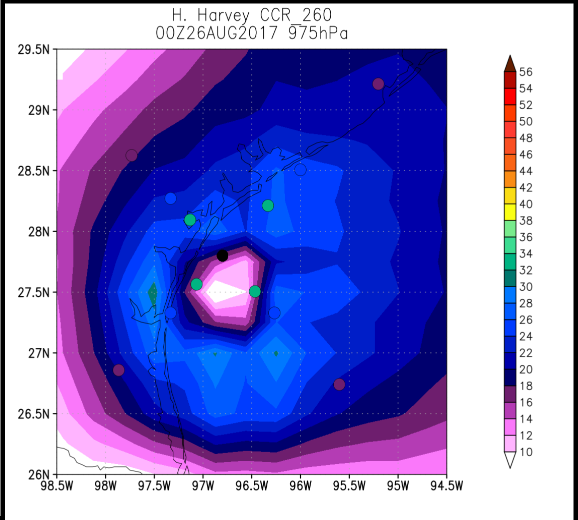
Hurricane Harvey



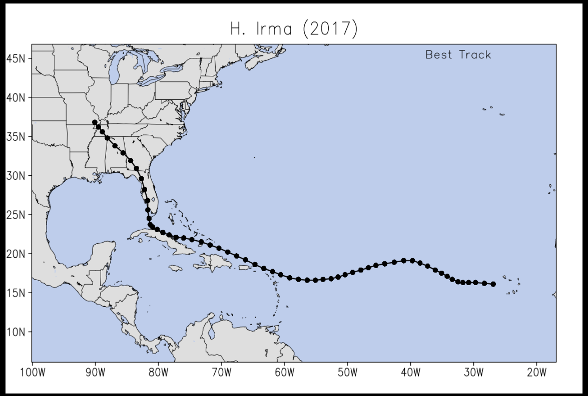
A close-up reveals the success of assimilating Different versions and densities of cloud-cleared radiances from AIRS, and from CrIS, against the assimilation of clear-sky which is done operationally

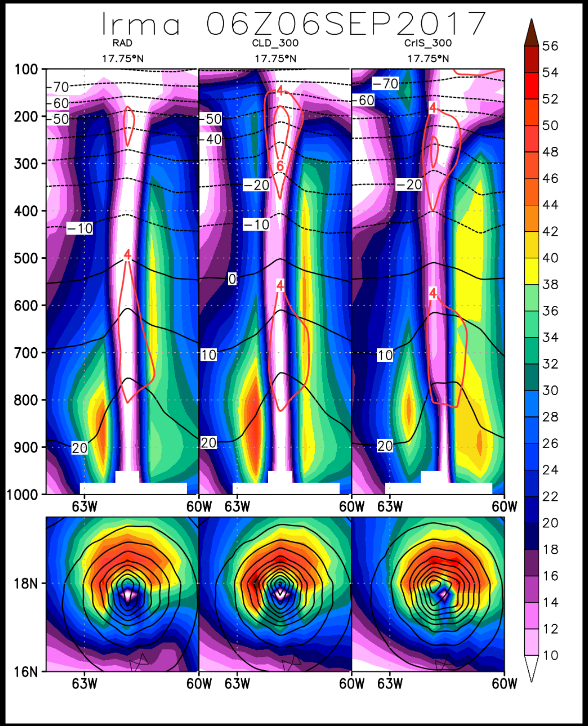


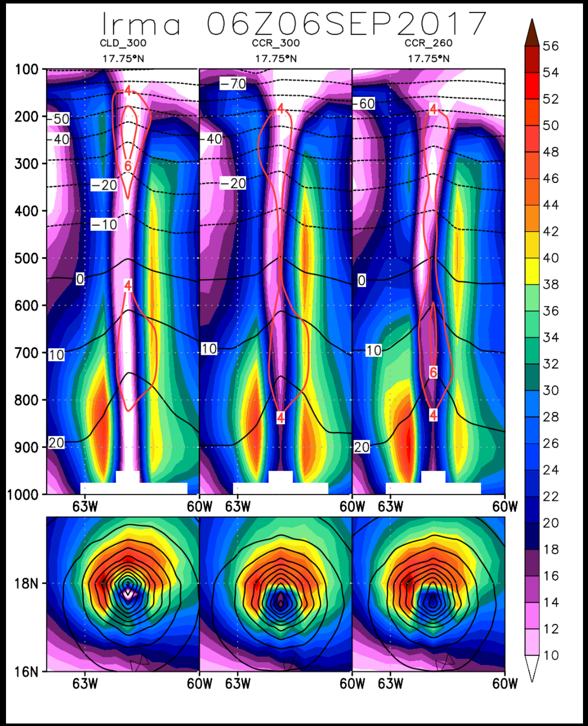


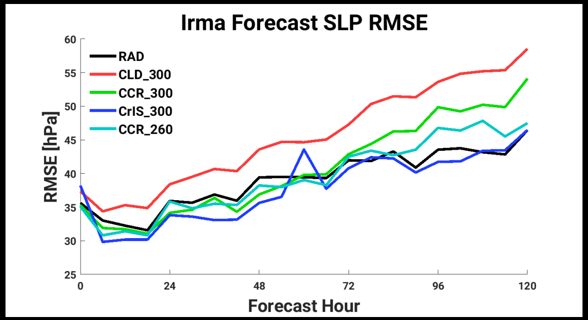


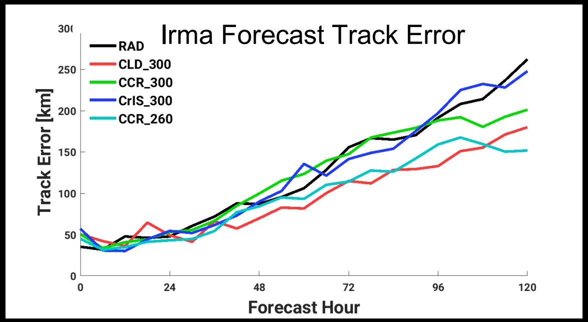
Hurricane Irma

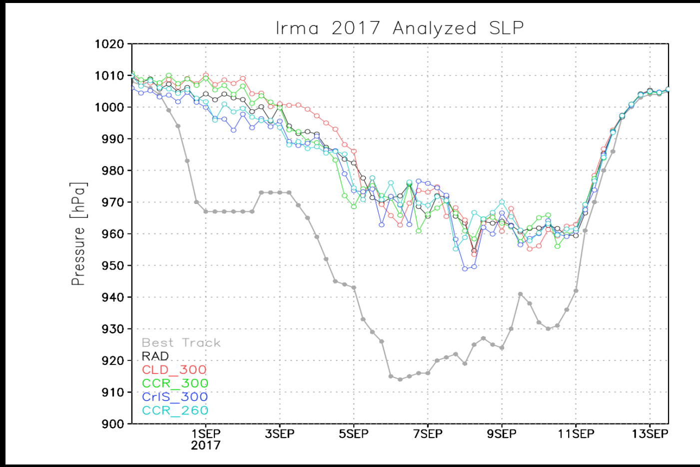




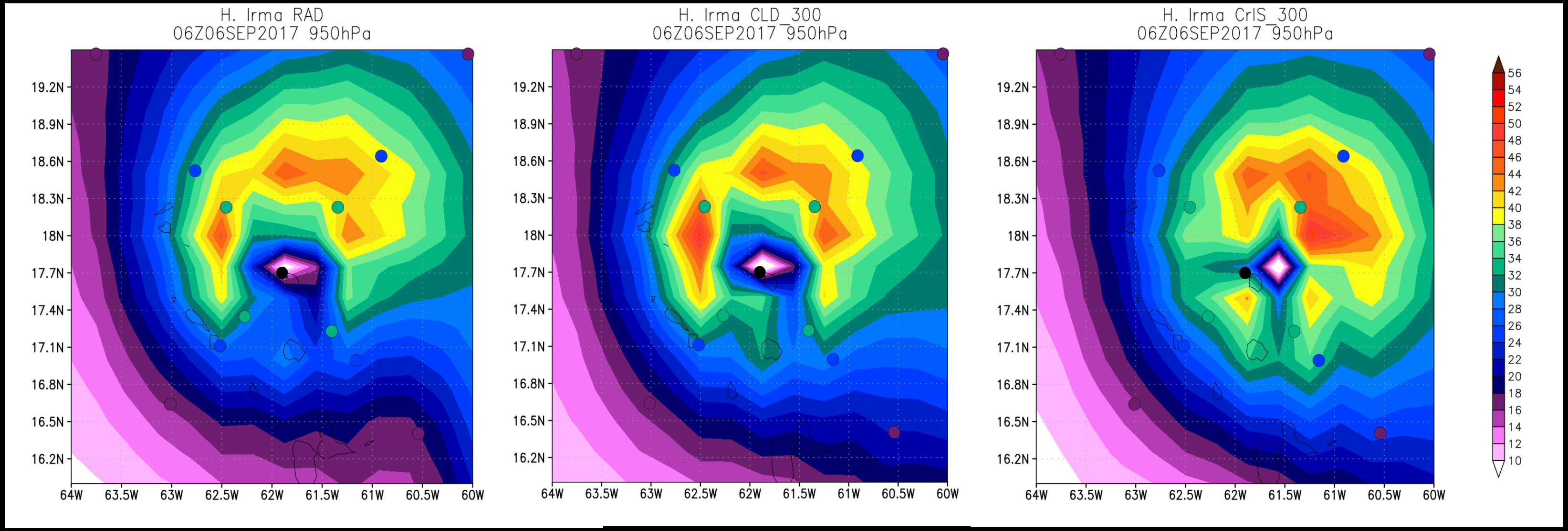


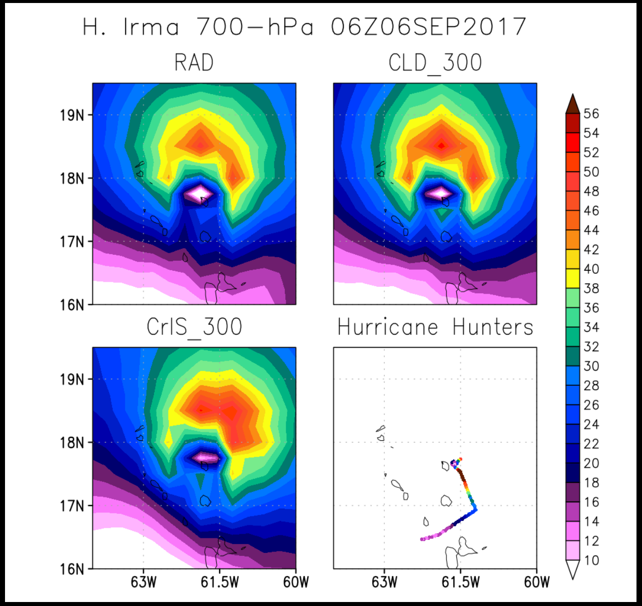


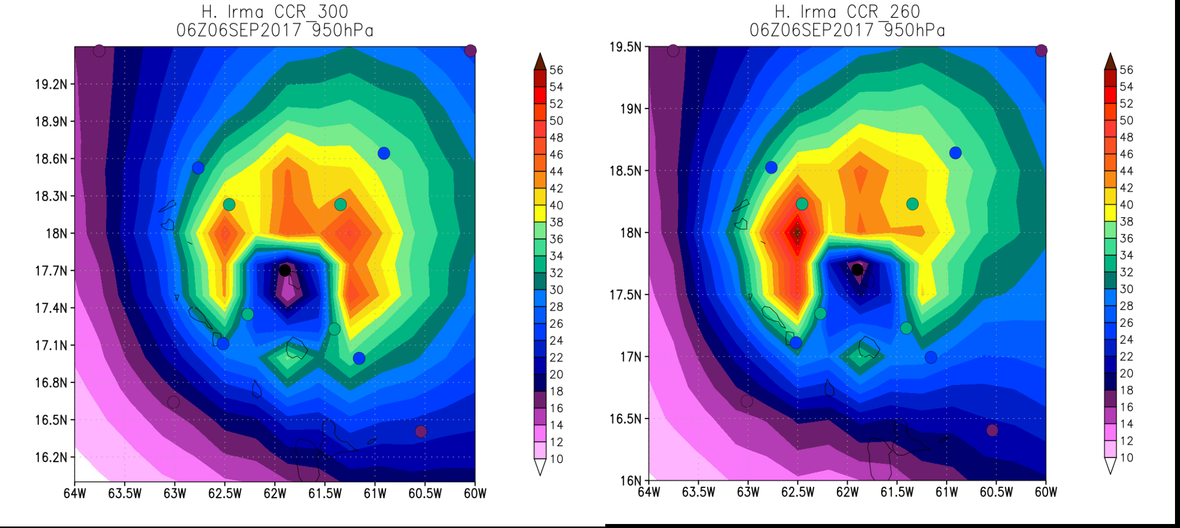




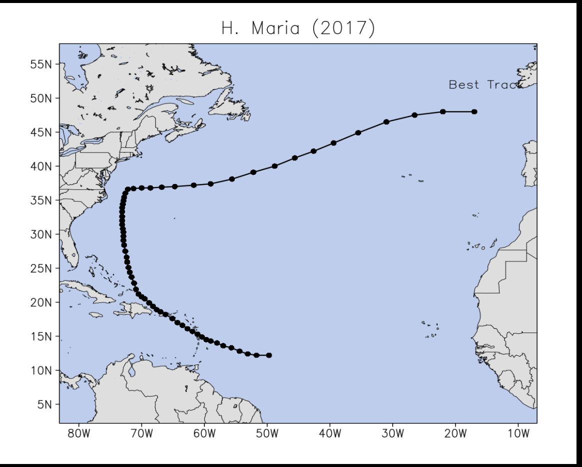
Hurricane Irma

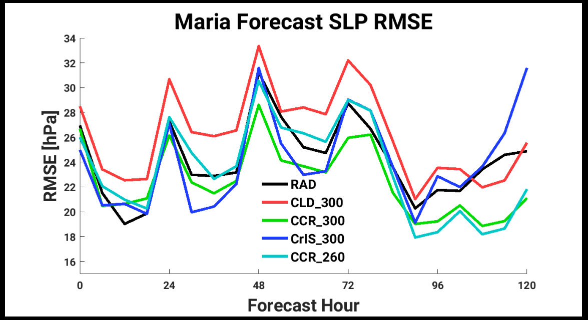


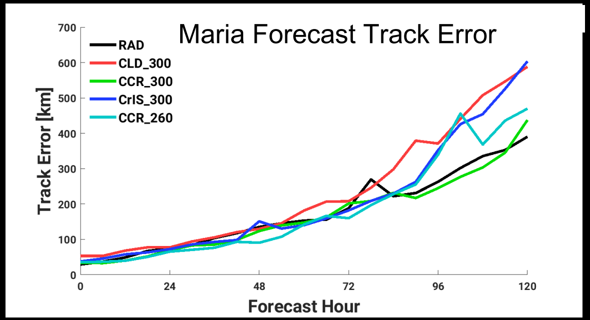


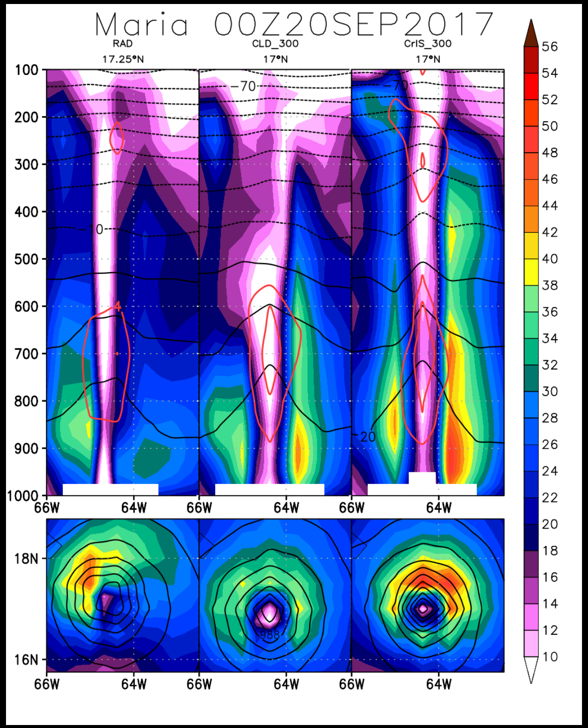


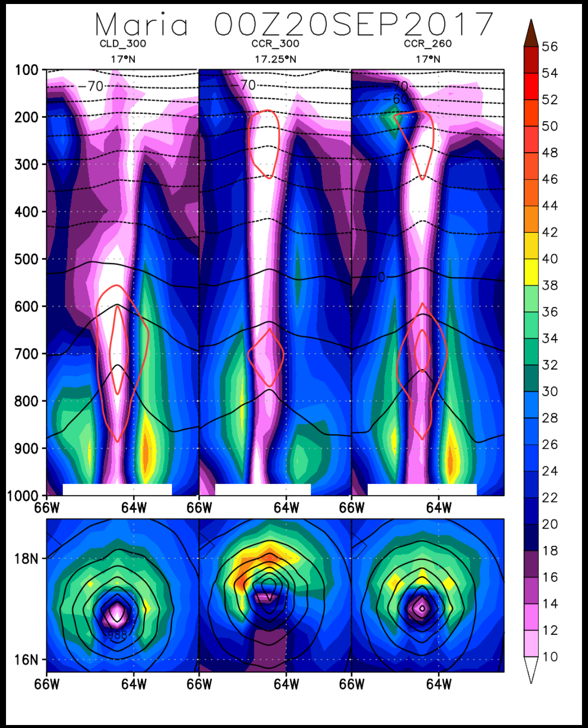
Hurricane Maria

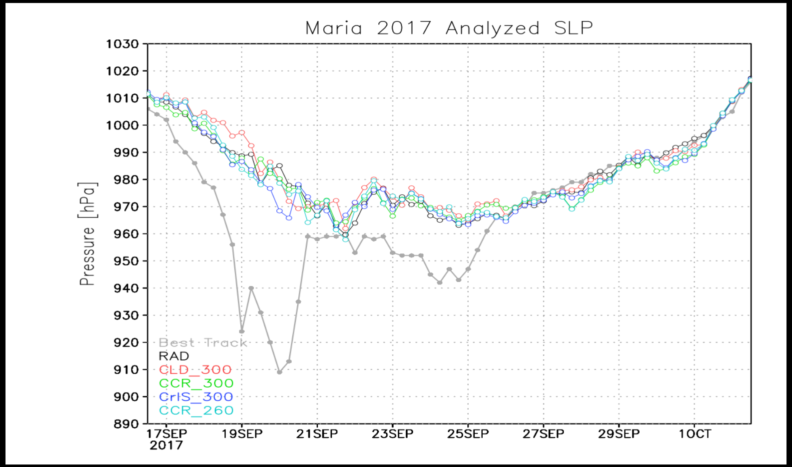




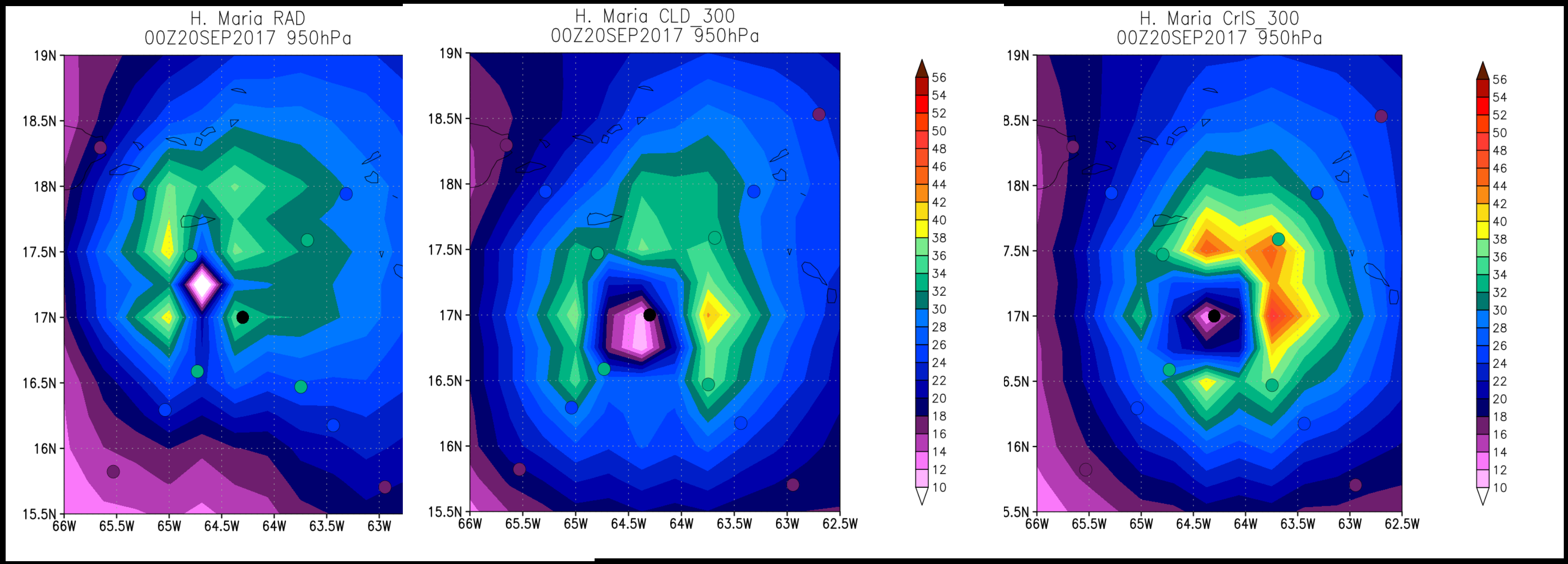


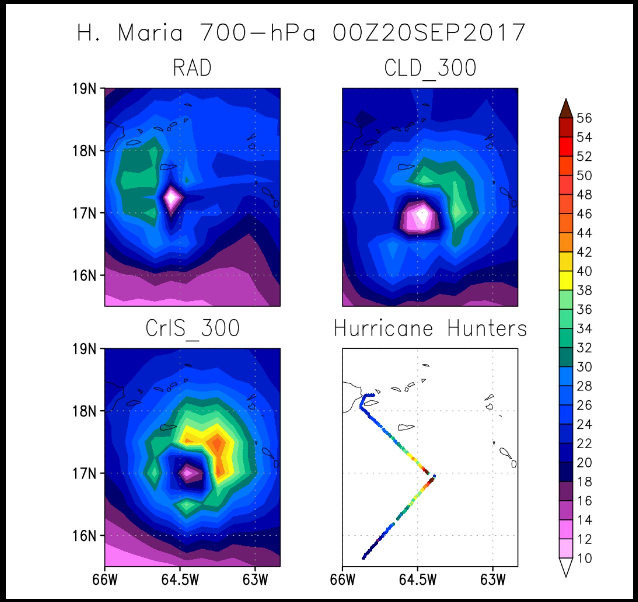


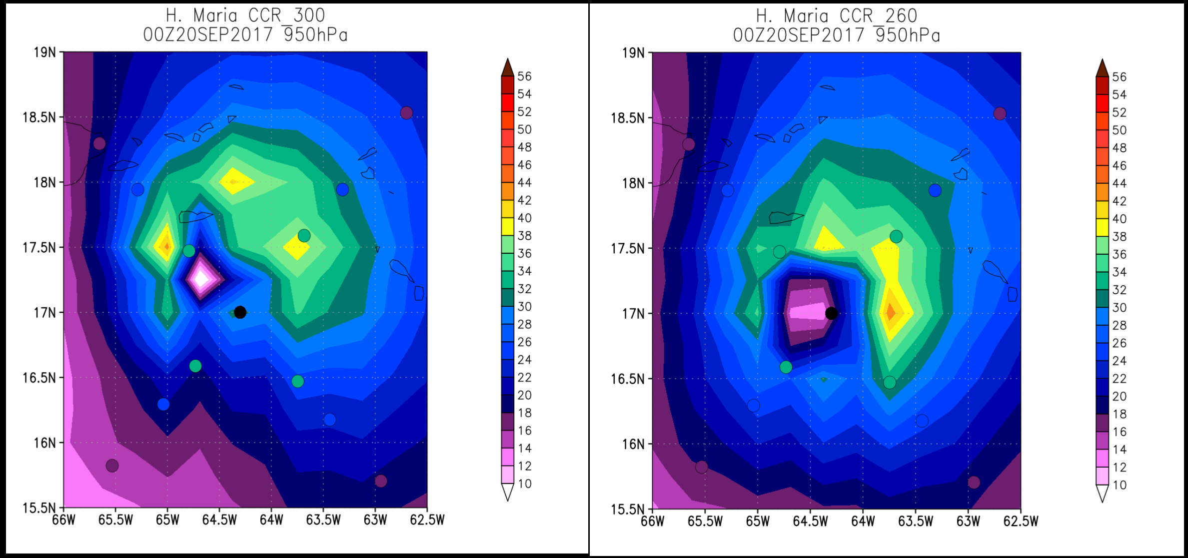




Hurricane Maria







Conclusions and future work

- In 2018 demonstrated value of assimilating AIRS cloud-cleared radiances
- In 2019 we ported the AST algorithm on NCCS, deprived if of neural network, ECMWF, allowed for customized selection of channels; parallelized it; demonstrated that the assimilation of these customized radiances produced better results than assimilation of radiances from the DAAC
- New set of experiments focused on exploring the sensitivity to the optimal density of internally-produced cloud-cleared AIRS radiances; confirming the need of adaptive thinning possibly regionally and feature based – **consistent large improvement of TC structure**
- First assimilation of cloud-cleared CrIS radiances obtained from NOAA CLASS gives promising result particularly on **TC intensity forecast and TC structure**
- We expect further improvements with the planned internal production of GEOS-tailored CrIS radiances
- Next step: IASI; continuing work on the Polar Regions

Acknowledgements

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Bryan Karpowicz, and NCCS team for help with CrIS cloud cleared radiances.

NASA DAAC

NOAA CLASS

AIRS-related peer-reviewed 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.