Sensitivity to data density of assimilated cloud-cleared AIRS radiances in the new hybrid 4DEnVar GEOS

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

[1]NASA GSFC/GMAO
[2]GESTAR/USRA
[3]NASA GSFC/Climate and Radiation Lab

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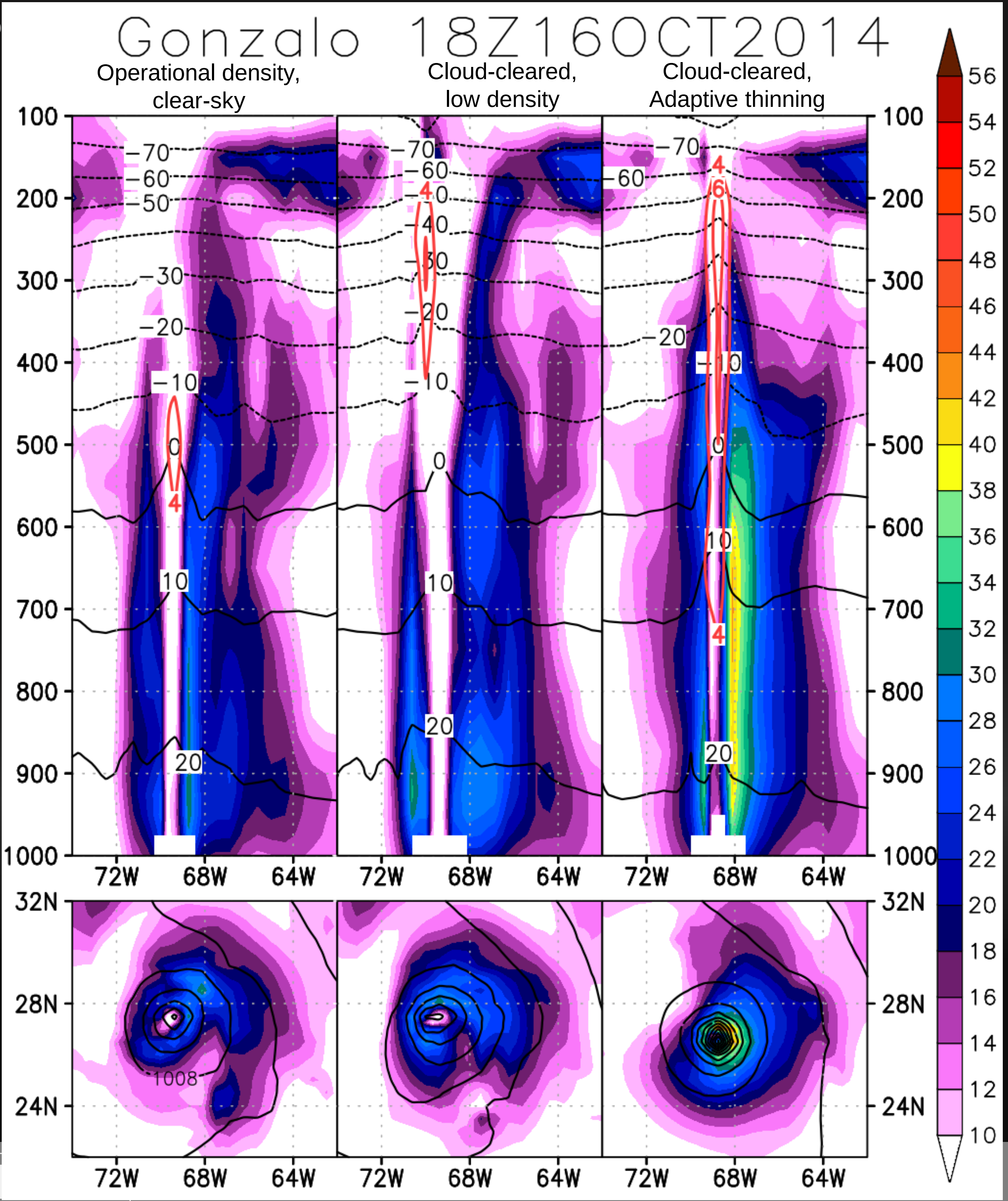
Outline

Background: assimilation of adaptively thinned AIRS cloud-cleared radiances (CCRs) on tropical cyclones (TCs) and global skill with GEOS 3DVar (2014 TC season, from Sep 1st to Nov 10th), published Aug. 2018

New experiments with the hybrid 4DEnVar GEOS system (2017 TC season, from July 31st to Oct 20th): Evaluate sensitivity of hybrid 4DEnVar to global CCR data density in preparation for adaptive thinning



Background: adaptively thinned AIRS CCRs

- H. Gonzalo (2014)
  - Vertical cross section: Wind magnitude (shaded), Temperature (°C, black), Temp. Anomaly (°C, red)
  - 850 hPa winds (shaded), slp (contours)

Homogenously thinned, low density, cloud-cleared radiances (CLD3) improve the global skill but not TC structure

Adaptively thinned, cloud-cleared radiances produce large improvements in vertical and horizontal TC structure, without degrading the global skill – COMPROMISE between global skill and TC representation

Specifically: more compact scale, stronger wind speeds, lower minimum pressure, stronger warm core

Transitioning from 3DVar to hybrid 4DEnVar

- For 3DVar, data are assimilated 4x per day, in 6 hour windows. Within the window, all observations are assimilated at the middle of the time period in imperfect correspondence to the time-dependent nature of the flow
- 4DVar assimilates observations at the time in which they are taken, reducing errors associated with observational temporal sampling
- Hybrid systems allow a weighted average of the static and the spatiotemporally-evolving background error covariance matrices
- Use of ensembles provides a way to get the time evolution of the covariances
- Hybrid 4DenVar allows increments that are consistent with the flow and the time of the observations
- Similar to system used operationally by NCEP

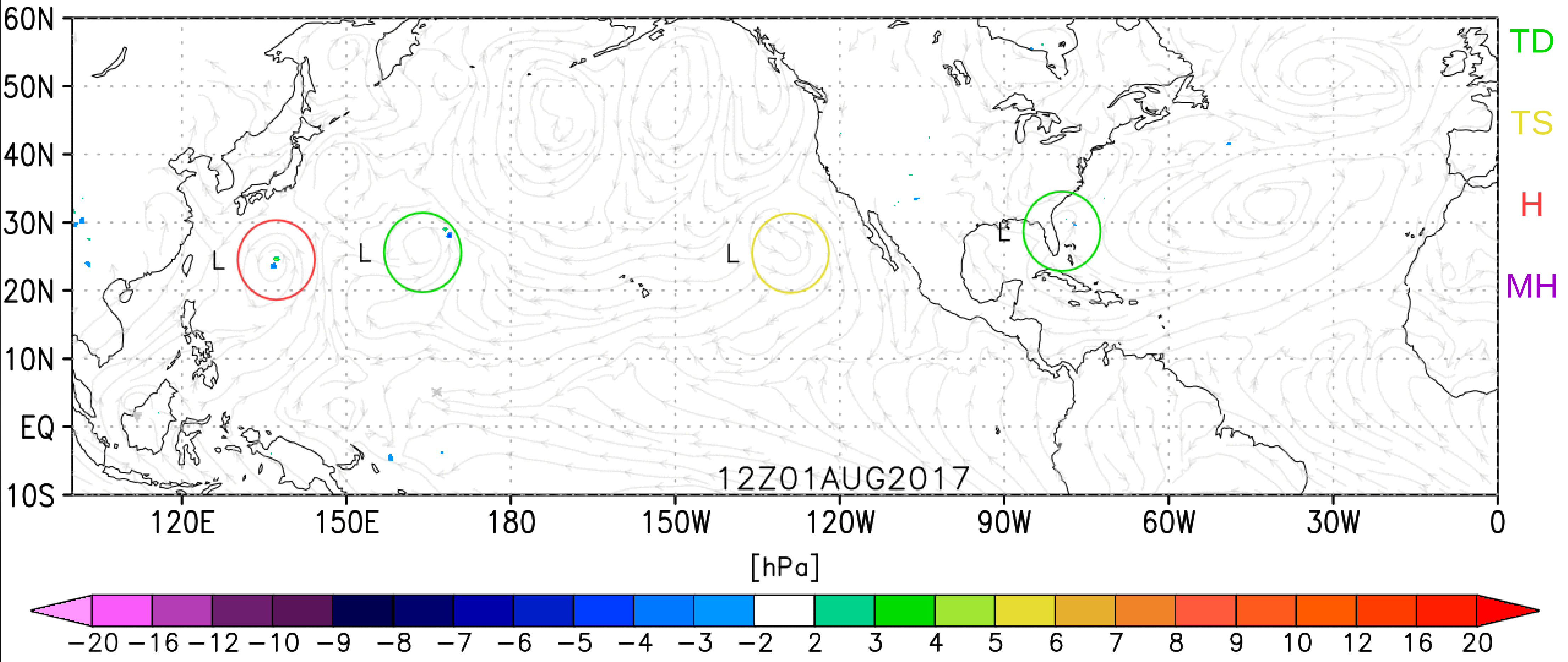
Inherent questions associated with the transition

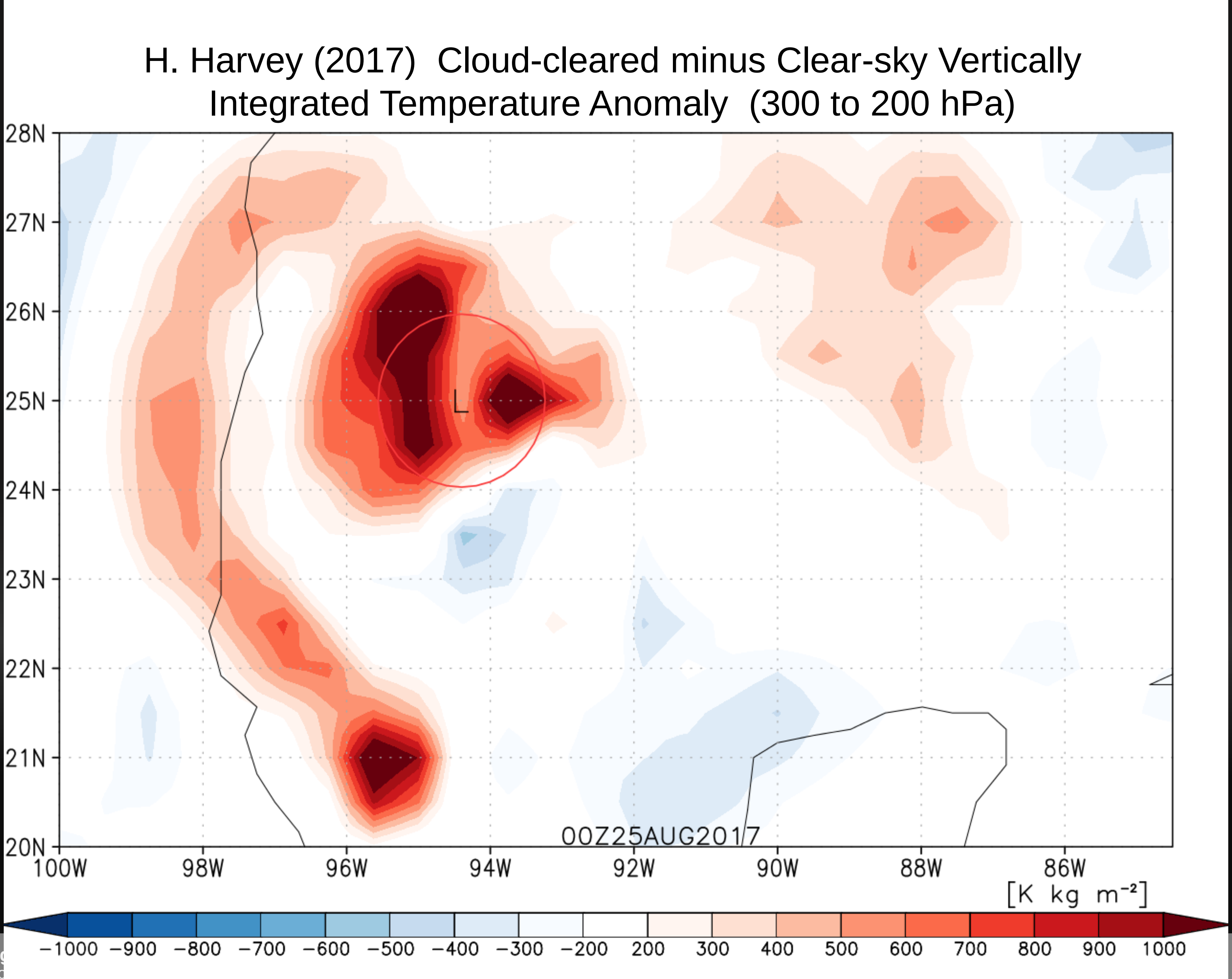
- Will the assimilation of cloud-cleared infrared radiances improve TC representation in a hybrid 4DEnVar framework as well?
- Will the impact on upper tropospheric TC temperature structure (which is the most important aspect of CCRs in the 3DVar system) still be so strong?
- Will the thinning levels used in the 3DVar environment be acceptable for the hybrid 4DEnVar?
- Will assimilation of CCRs produce comprehensive results as significant as in 3DVar, given that hybrid 4DEnVar uses the observations' distribution in time more efficiently and is less sensitive to impacts caused by individual data sets?

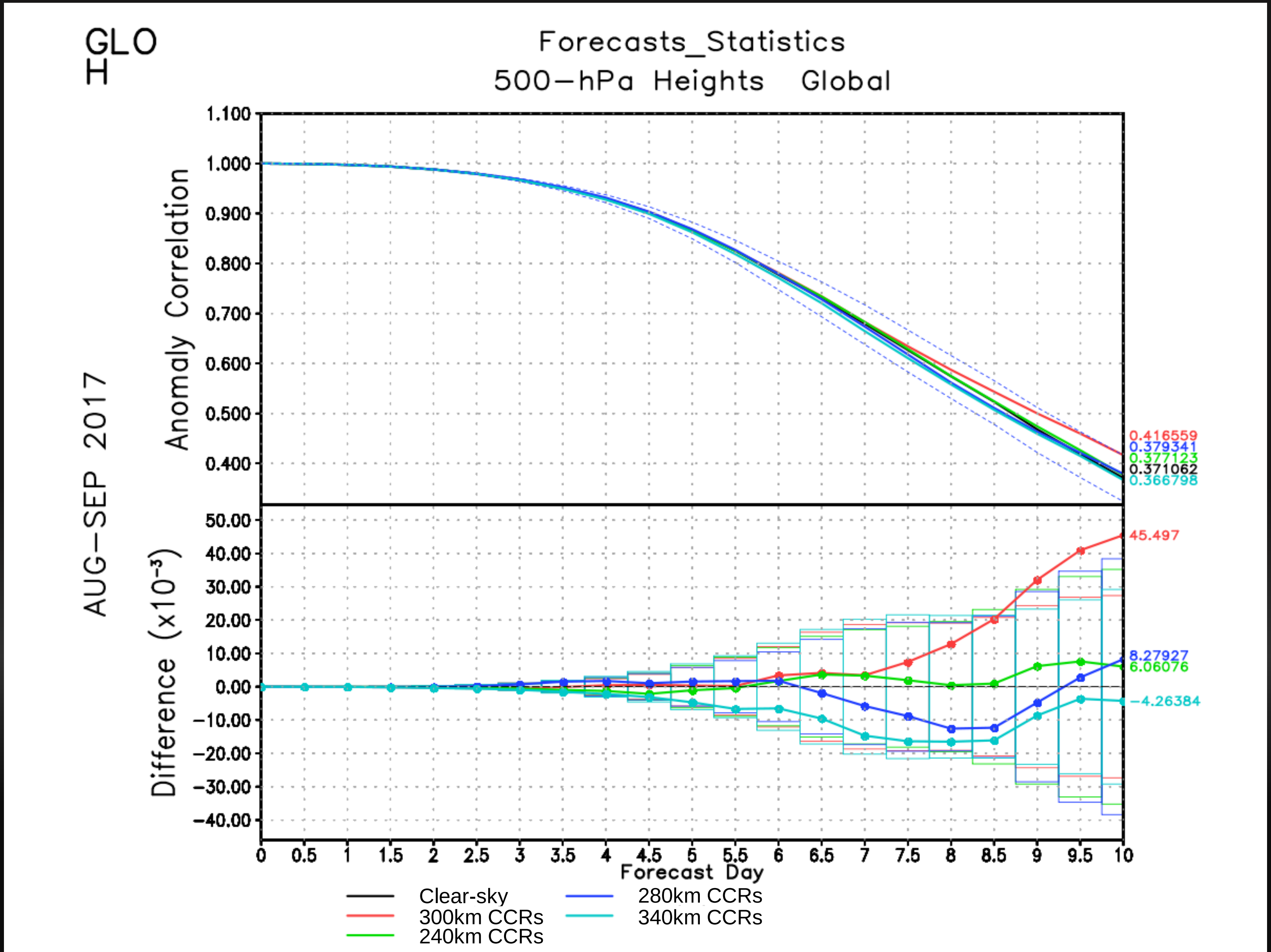
Exploring the sensitivity to thinning levels in the hybrid 4DEnVar: what is the optimal density of assimilated CCRs?

- GEOS, version 5.17 experiments, using hybrid 4DEnVar data assimilation, focused on boreal late summer – early fall 2017
- 80 daily, 10-day forecasts initialized at 00Z from July 31st to October 19th
- Clear-sky: Clear-sky AIRS radiances, as used operationally, globally assimilated at roughly every 180km (our reference)
- 300km CCRs: Cloud-cleared AIRS radiances, globally assimilated at roughly every 300km, about 1/3 of the clear-sky density
- 240km CCRs: Cloud-cleared AIRS radiances, density ~1/2 of Clear-sky
- 280km CCRs: Cloud-cleared AIRS radiances, density ~2/5 of Clear-sky
- 340km CCRs: Cloud-cleared AIRS radiances, density ~3/10 of Clear-sky

Impact of assimilating cloud-cleared against clear-sky radiances on the analyzed SLP




H. Harvey (2017) Cloud-cleared minus Clear-sky Vertically Integrated Temperature Anomaly (300 to 200 hPa)
28N
27N
26N
25N
24N
23N
22N
21N
20N
L
00Z25AUG2017
100W
98W
96W
94W
92W
90W
88W
86W
[K kg m⁻²]
−1000 −900 −800 −700 −600 −500 −400 −300 −200 200 300 400 500 600 700 800 900 1000


GLO
H
Forecasts_Statistics
500–hPa Heights Global
AUG–SEP 2017
Anomaly Correlation
Difference (x10⁻³)
Forecast Day
0.416559
0.379341
0.377123
0.371062
0.366798
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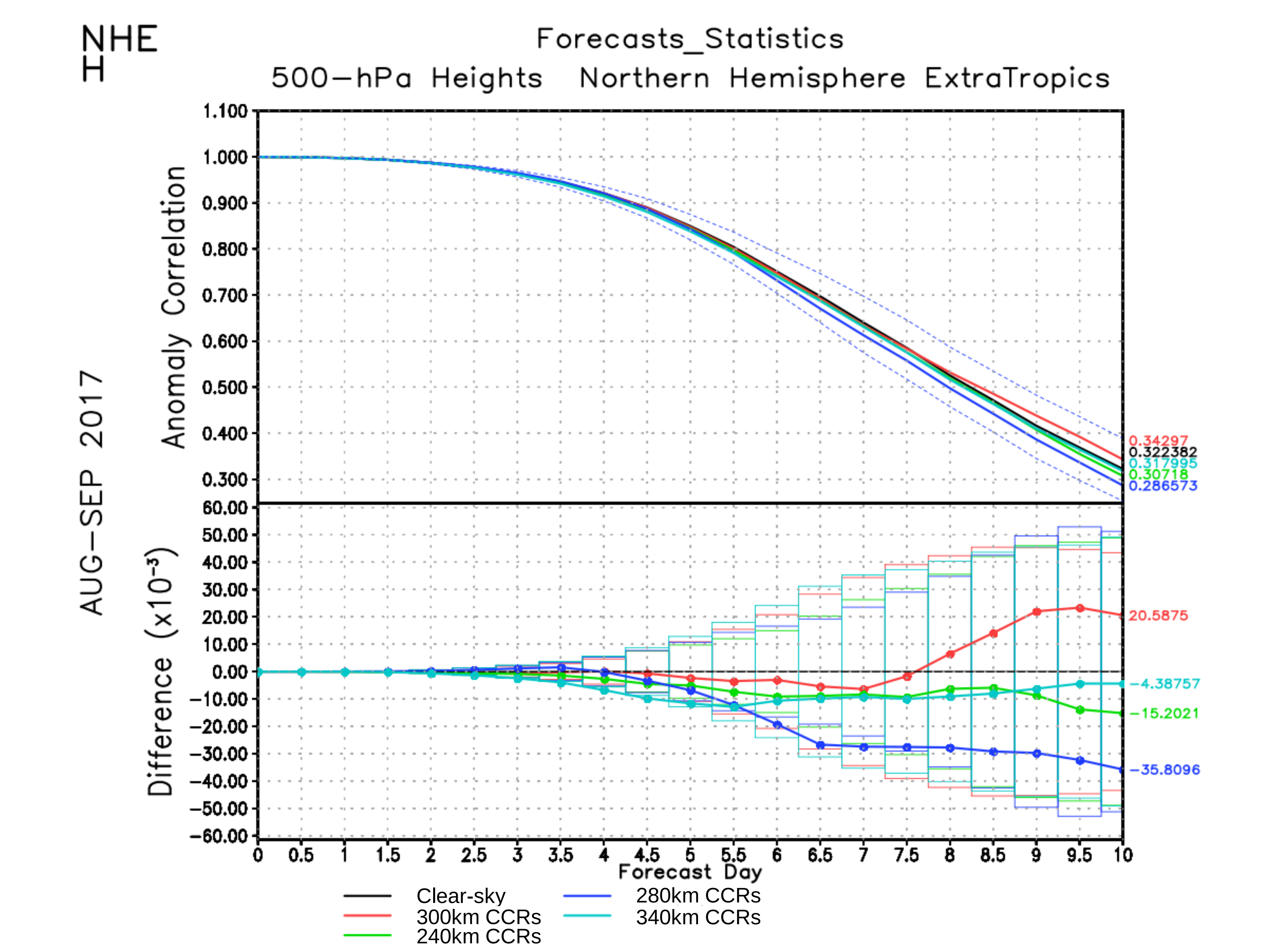
8.27927
6.06076
−4.26384
Clear-sky
300km CCRs
240km CCRs
280km CCRs
340km CCRs


NHE
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Forecasts_Statistics
500-hPa Heights Northern Hemisphere ExtraTropics
AUG-SEP 2017
Anomaly Correlation
Difference (x10⁻³)
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0.317995
0.30718
0.286573
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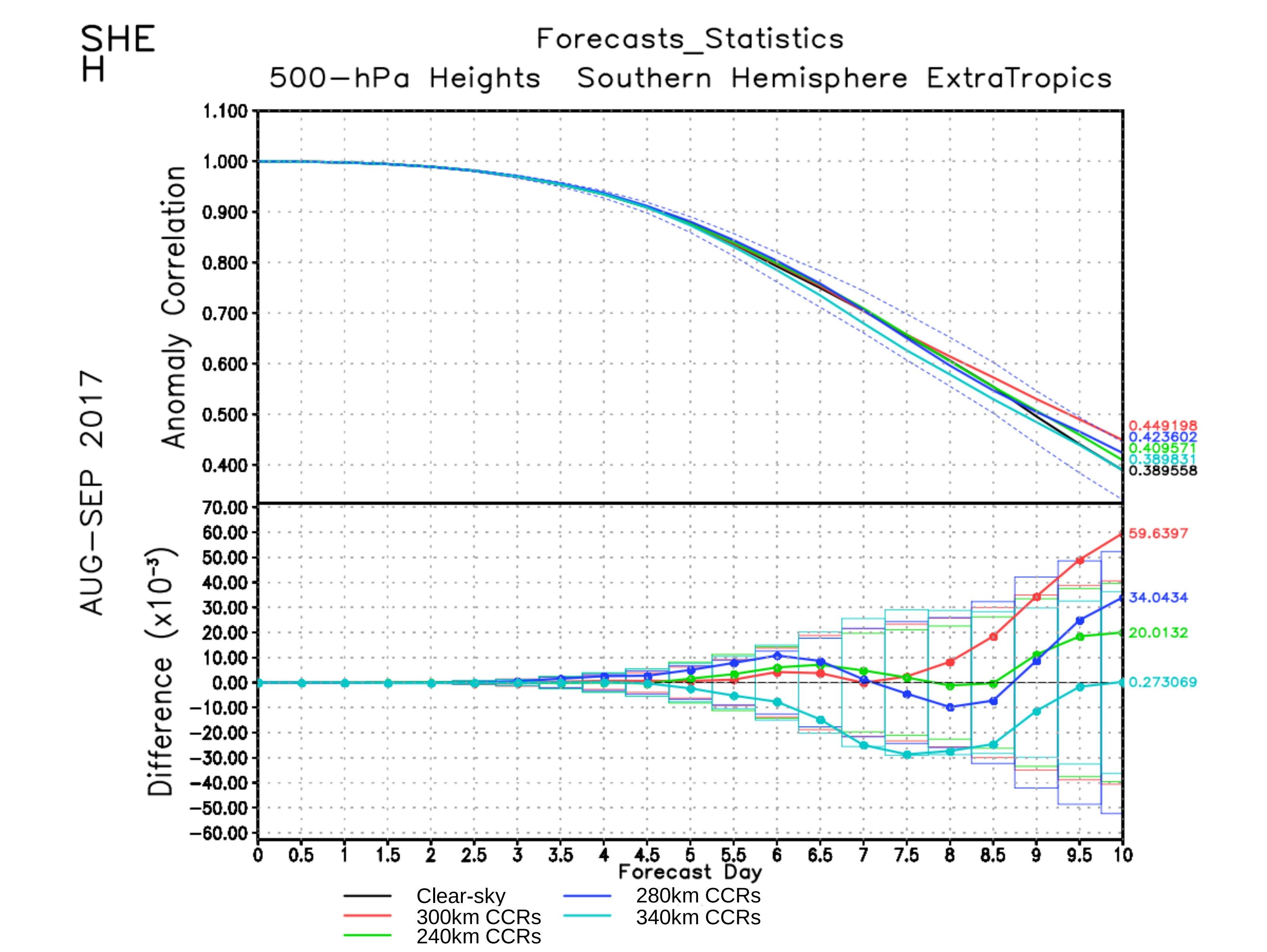
-4.38757
-15.2021
-35.8096
Forecast Day
Clear-sky
300km CCRs
240km CCRs
280km CCRs
340km CCRs



SHE
H
Forecasts_Statistics
500–hPa Heights Southern Hemisphere ExtraTropics
AUG–SEP 2017
Anomaly Correlation
Difference (x10⁻³)
Forecast Day
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0.423602
0.409571
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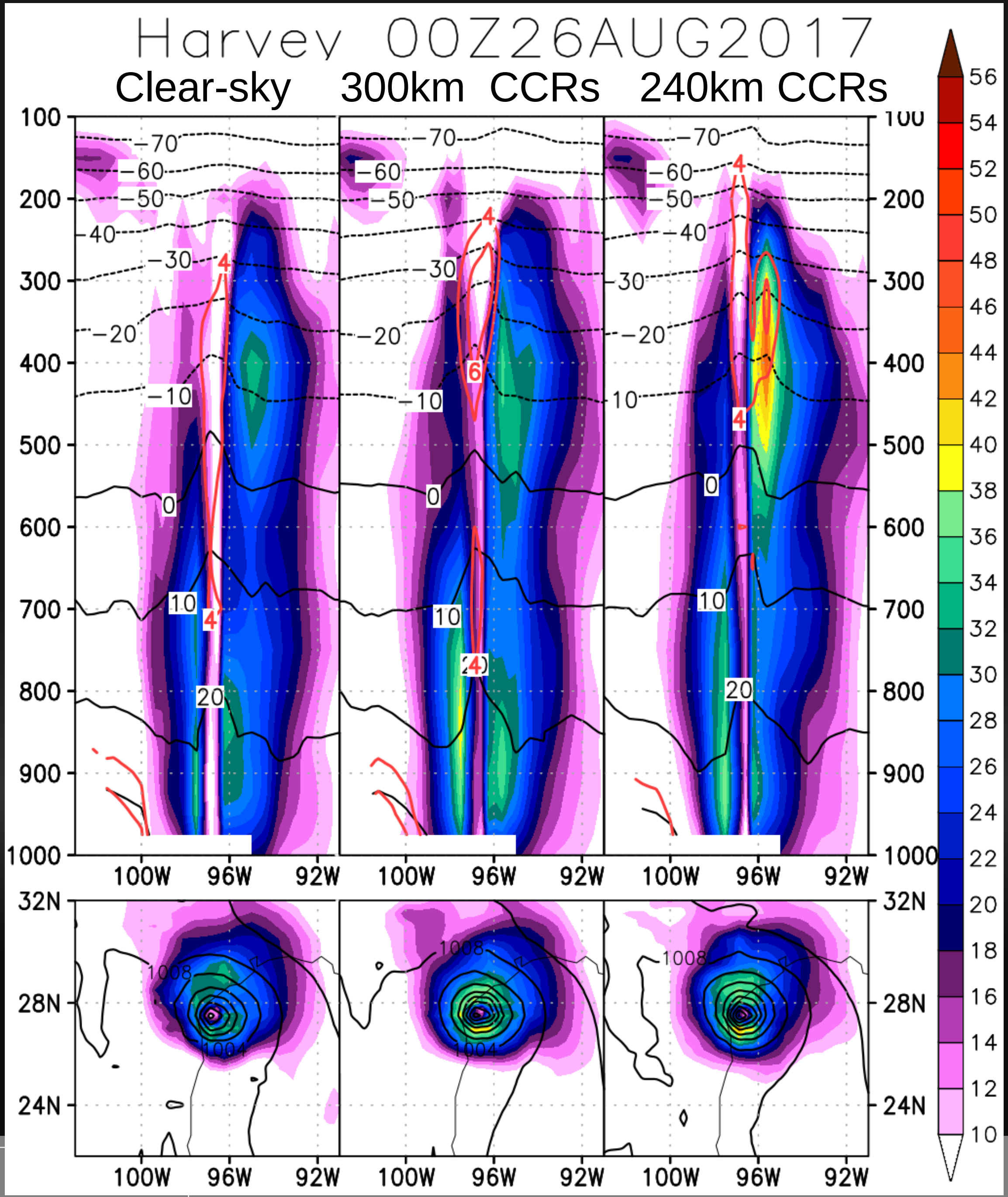
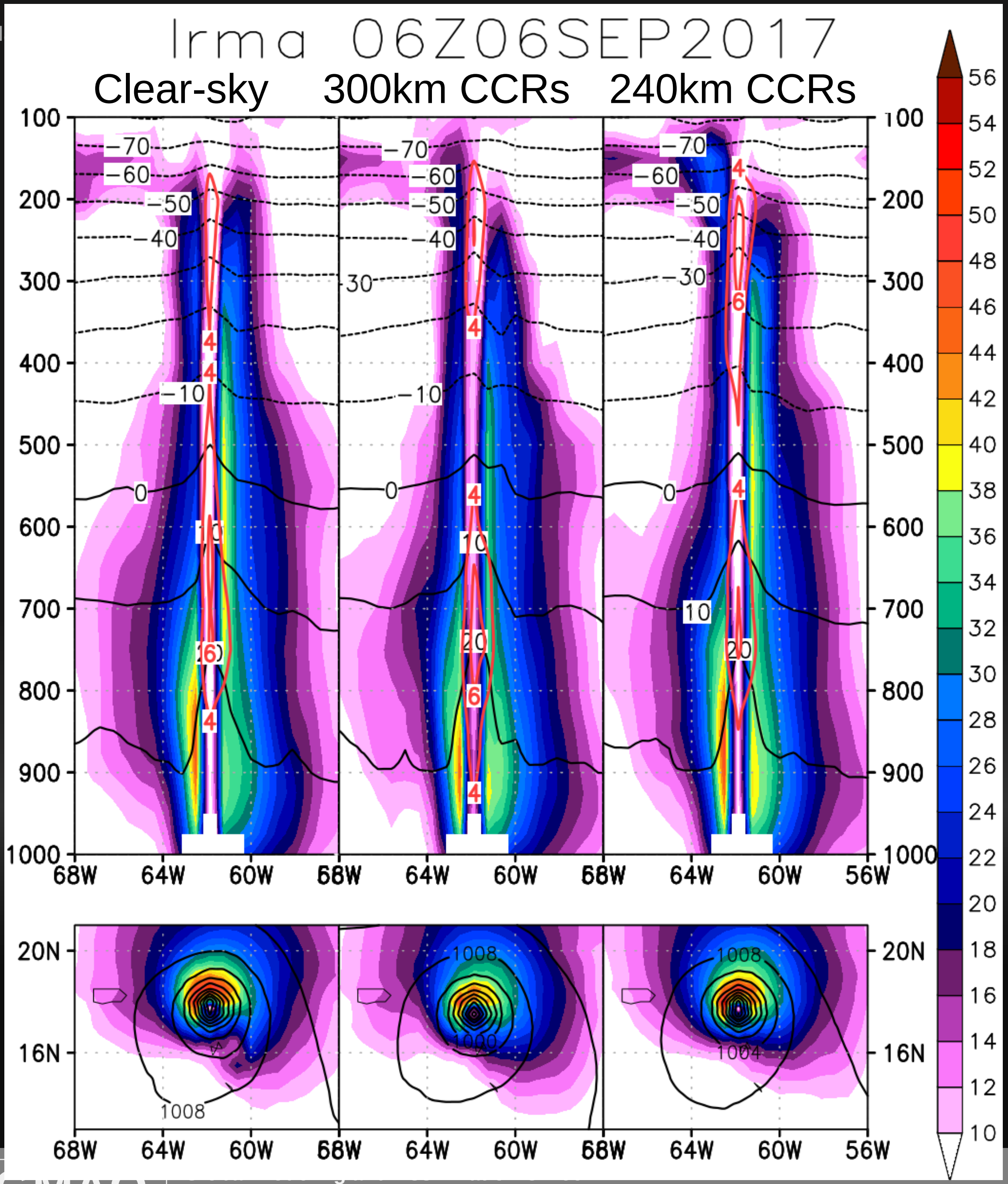
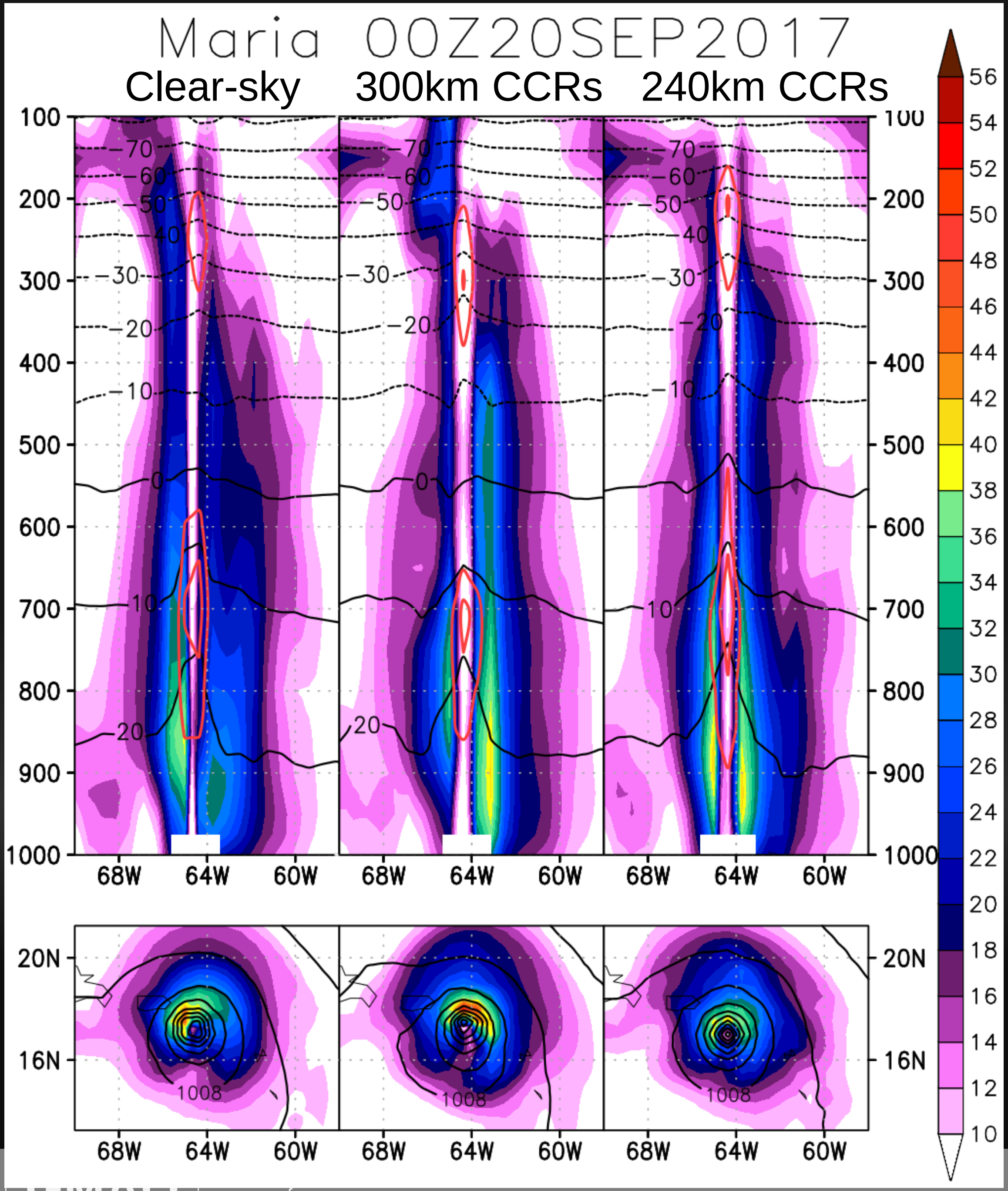
0.273069
Clear-sky
300km CCRs
240km CCRs
280km CCRs
340km CCRs



- H. Harvey (2017)
  - Vertical cross section: Wind magnitude (shaded), Temperature (°C, black), Temp. Anomaly (°C, red)
  - 850 hPa winds (shaded), slp (contours)
- Assimilation of CCRs at 300km density, in addition to increasing the global skill, slightly improves the TC structure (increased warm core structure, stronger wind speeds and lower sea level pressure).
- Sensitivity of TC structure to perturbations in global density of CCRs (240km-280km-300km-340km), caused by contrasting roles of large-scale and TC-scale processes, indicate that there is potential to implement an adaptive thinning methodology, similar to the one used in 3DVar



- H. Irma (2017)
  - Vertical cross section: Wind magnitude (shaded), Temperature (°C, black), Temp. Anomaly (°C, red)
  - 850 hPa winds (shaded), slp (contours)
- Strong warm core, more compact, and stronger winds when AIRS CCRs are assimilated, relative to clear-sky
- Increasing the observational density produces an even stronger response



- 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, assimilation of CCRs is capable of improving the vertical and horizontal structure of the storm relative to clear-sky. Moreover, TC representation sensitivity, consequent to different CCR density, indicates potential for adaptive thinning

Conclusions

- Previous work has shown the strong positive impact of assimilating adaptively thinned AIRS cloud-cleared radiances (CCRs) on TC representation, with no loss of global skill

New results

- CCRs can be ingested successfully in the hybrid 4DEnVar
- Exploring sensitivity of the radius of influence of the CCRs (compared to 300 km thinning density) has revealed that there is a loss of skill when perturbing the data density in both directions
- 4 experiments confirm that a thinning distance of 300km globally appears to be optimal for forecast skill
- Strong sensitivity in TC structure is noted when perturbing the CCR data density suggesting good potential for adaptive thinning

Future Work

- Assimilate CrIS CCRs and study impact on both global skill and TCs
- Investigate optimal density for CrIS CCRs in the hybrid 4DEnVar
- Implement comprehensive adaptive thinning on all hyperspectral IR sensors
- Investigate more efficient domain selections of denser data around TCs
- Continue exchanges with Joint Effort for Data assimilation Integration (JEDI) developers for possible use of TC-centered adaptive thinning methodologies

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GES DISC for their outstanding service to the community

AIRS-related articles published by this team

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