# Impact of assimilating AIRS cloud-cleared radiances on atmospheric dynamics and boundary layer height at high latitudes

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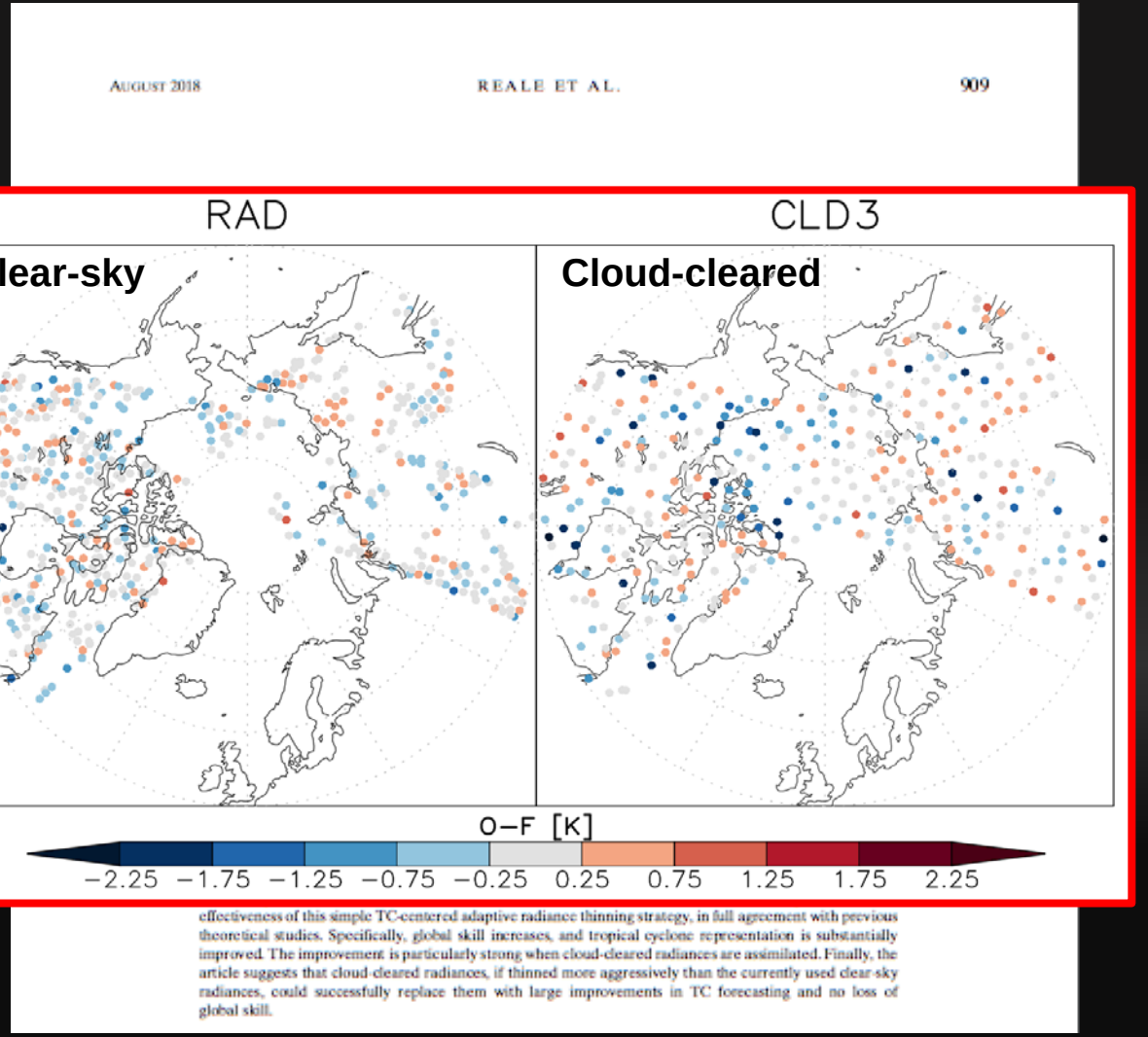
# Introduction

Recent work by this team (Reale et al. 2018) has found the assimilation of cloud-cleared and adaptively thinned AIRS radiances to be beneficial for the representation of tropical cyclones. Due to better representativeness, cloud-cleared radiances (CCRs) are substantially superior to the current operational clear-sky infrared radiances as long *as they are thinned more aggressively*.

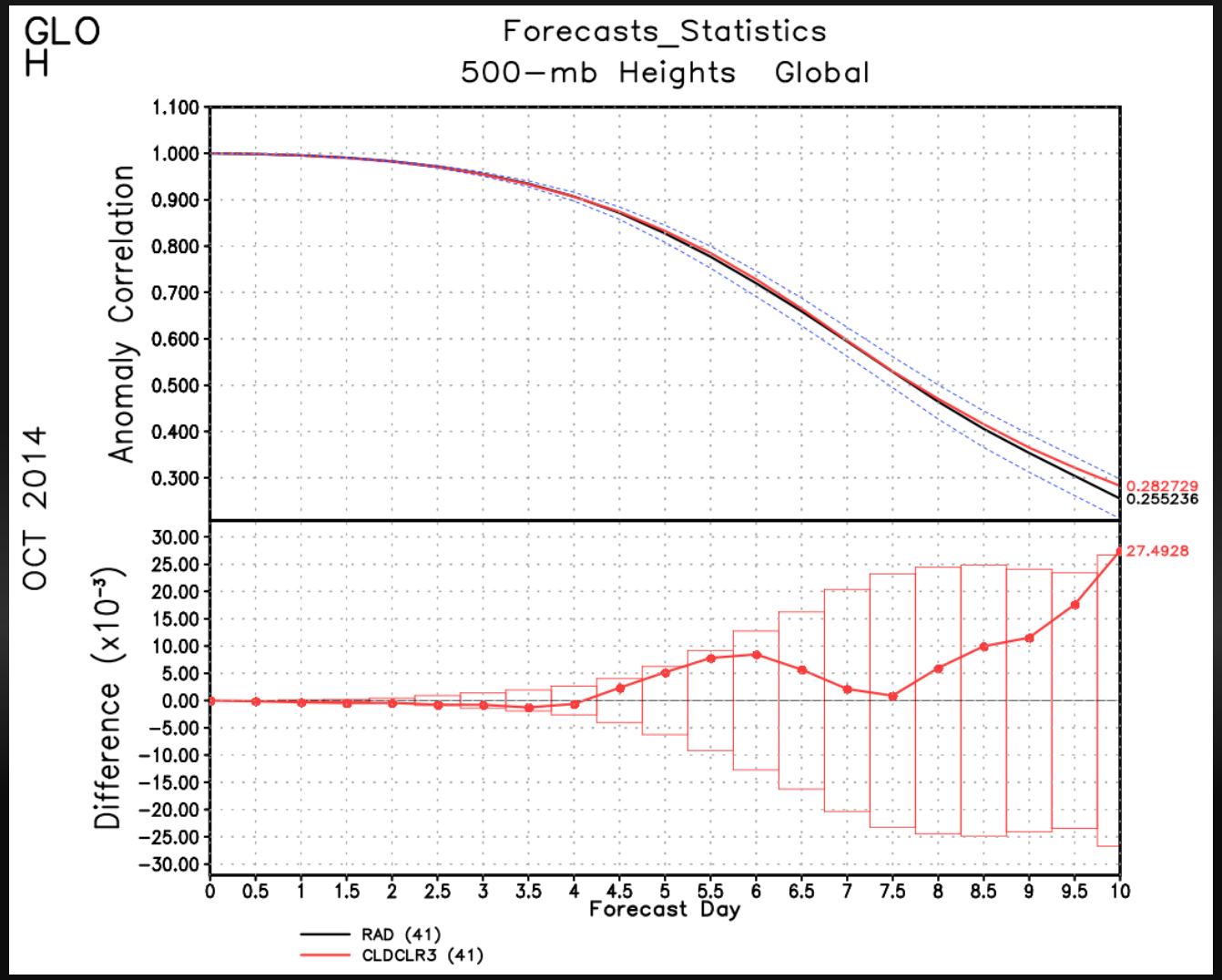
In this follow-up study, we investigate the high latitude impacts of assimilating AIRS cloud-cleared radiances, focusing in the Arctic region where persistent low-level cloud cover might limit the ingestion of clear-sky infrared data.

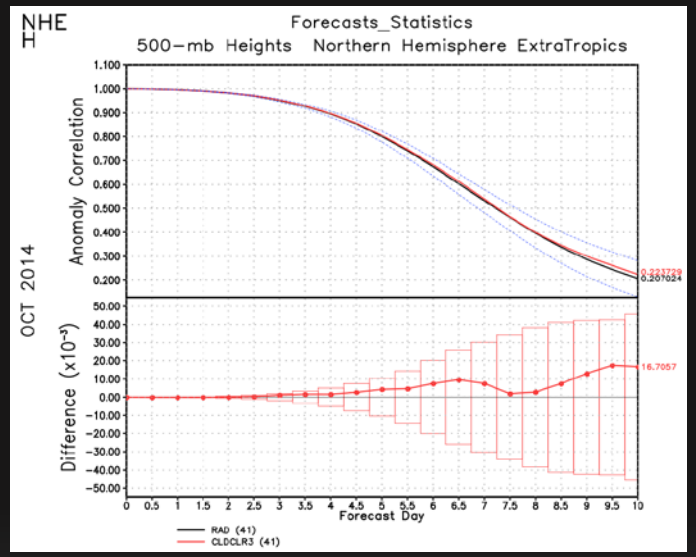
NASA's Goddard Earth Observing System, version 5 data assimilation and forecast system (GEOS DAS version 5, 3Dvar data assimilation and forecast system) is used at approximately quarter degree resolution to study boreal fall 2014.

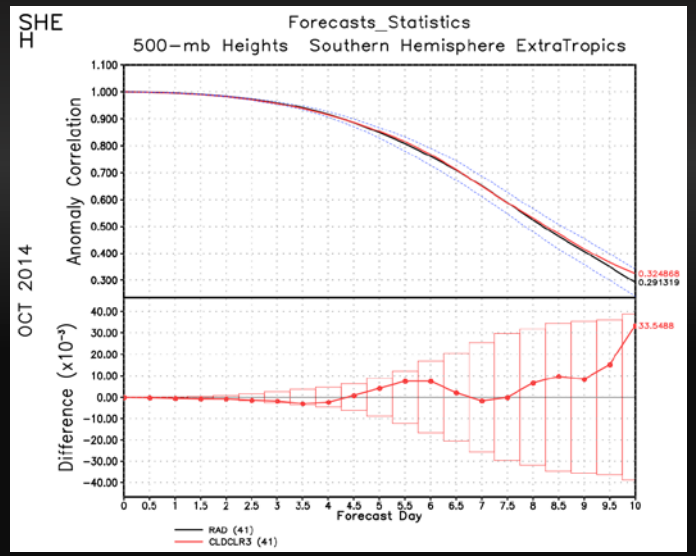
Control experiment (named RAD) uses AIRS clear-sky radiances at the current operational density and OSE (named CLD3) uses AIRS cloud-cleared radiances at roughly one quarter density, in addition to other operationally assimilated observations.



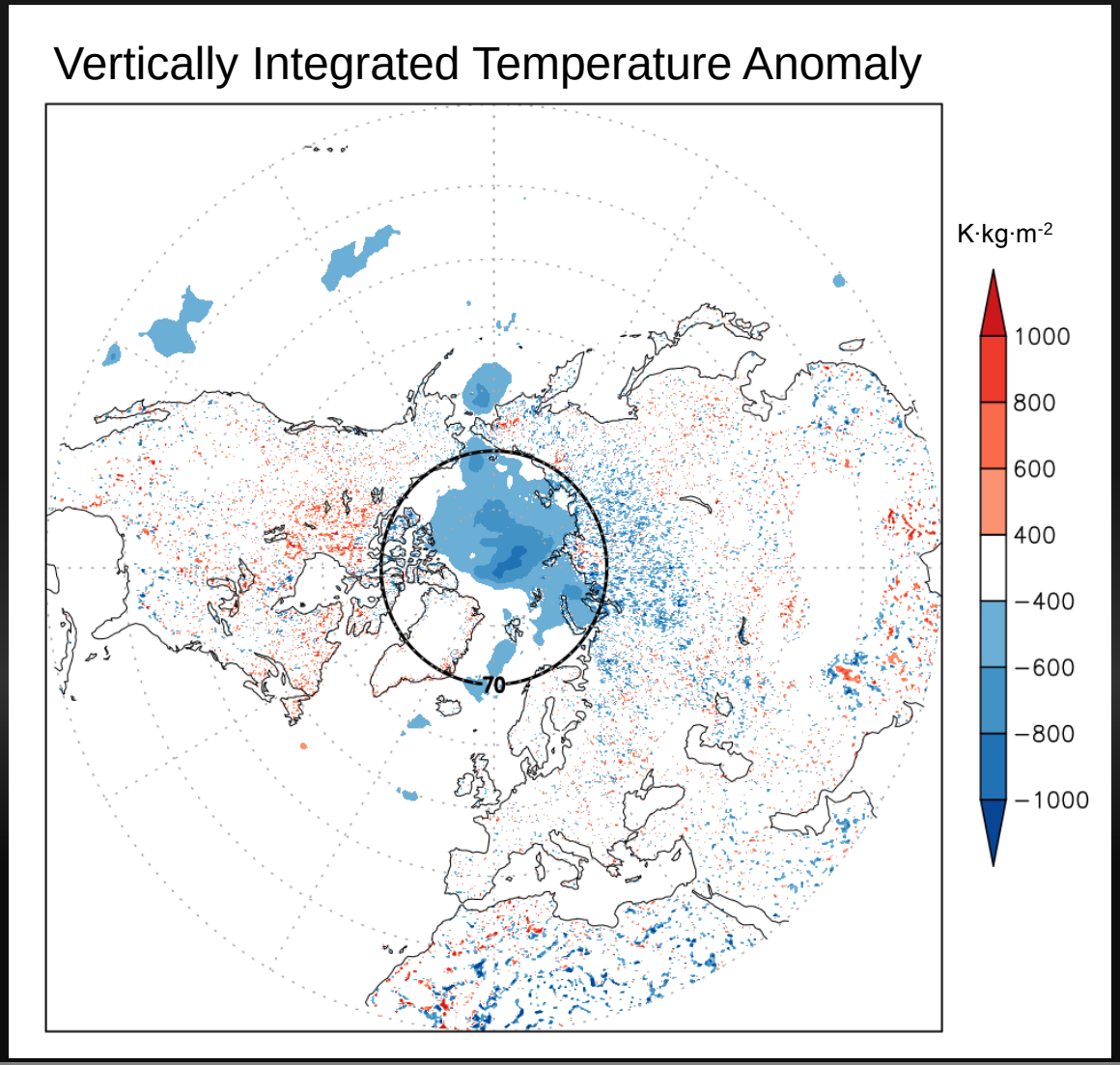
# Improvements in global skill due to assimilation of CCRs in CLD3



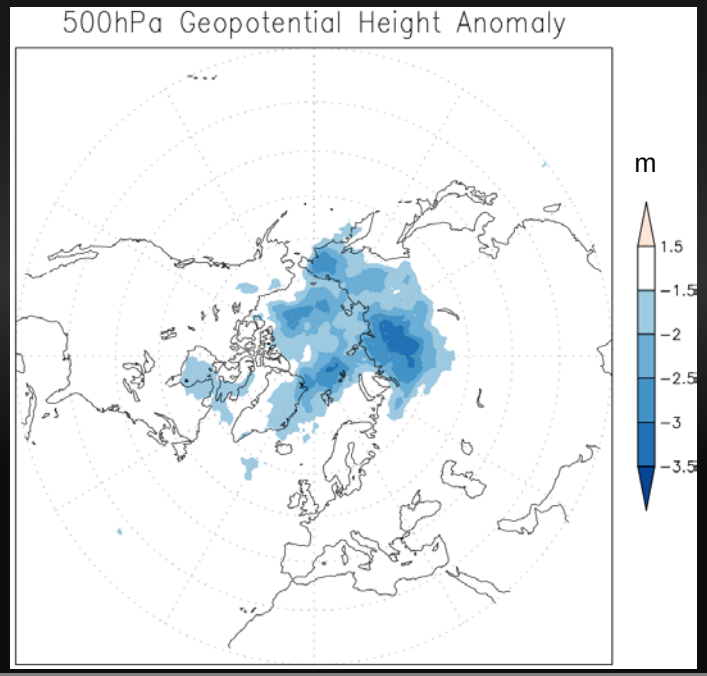



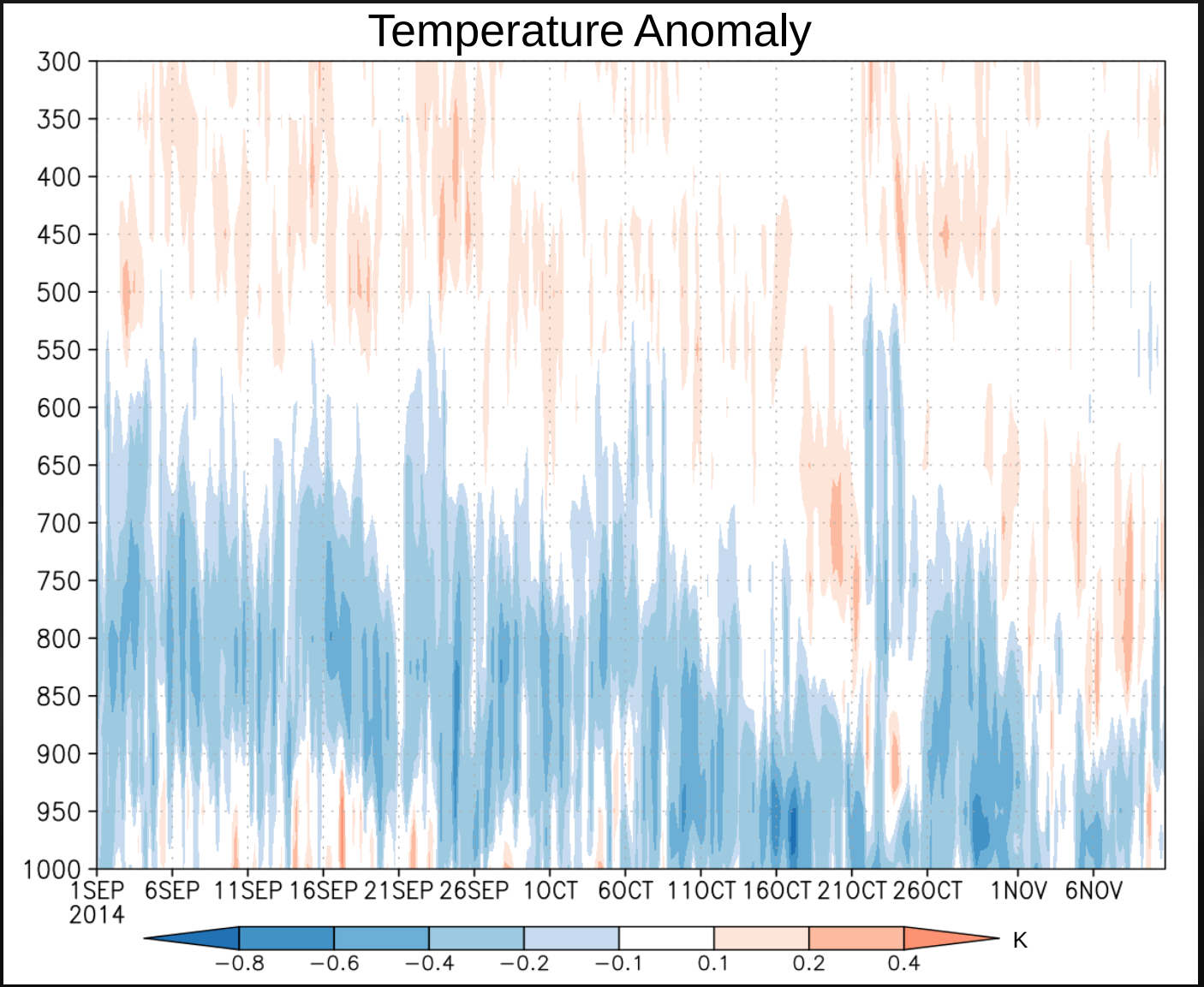



# CLD3 shows significant lower tropospheric cooling over Arctic



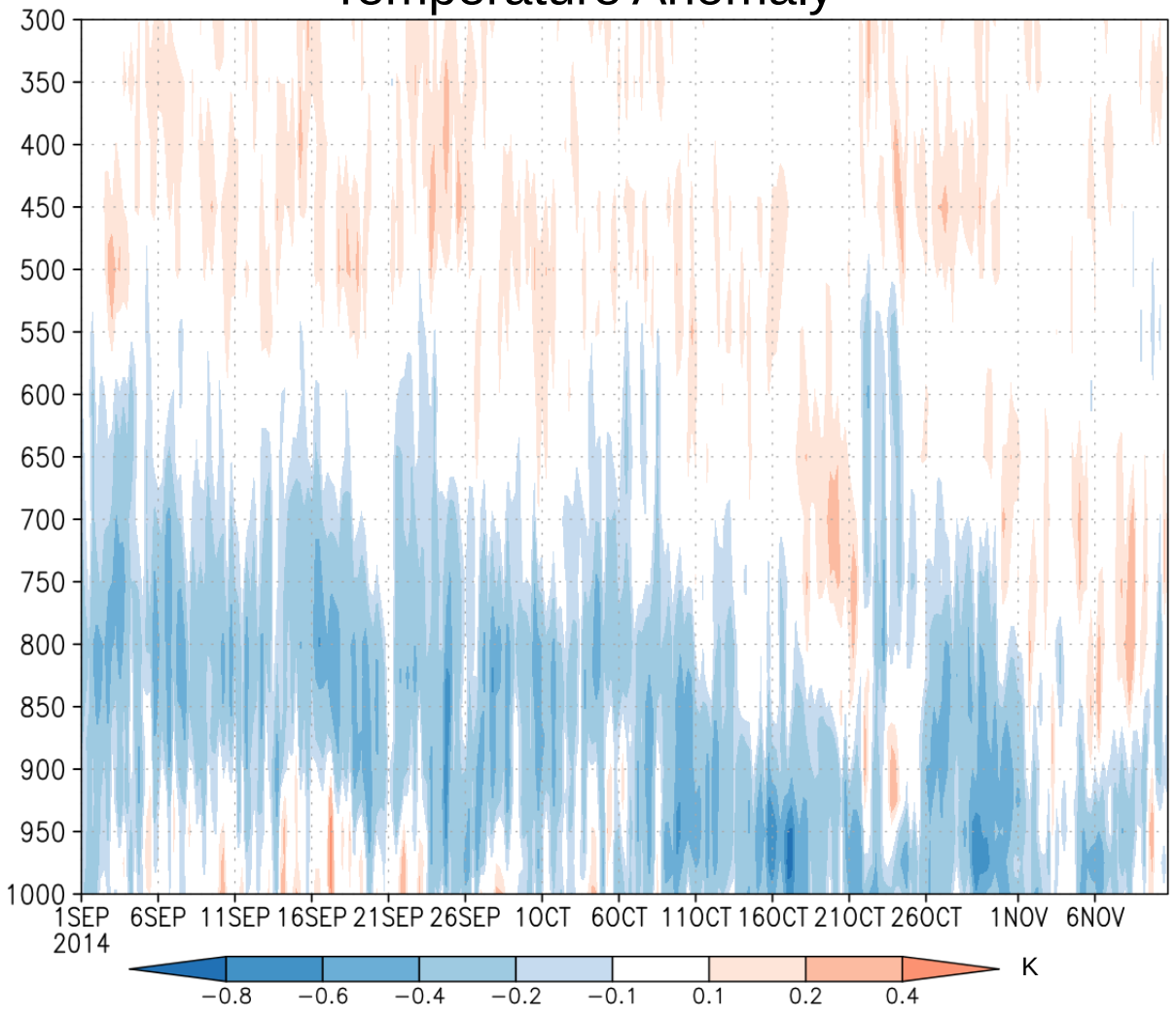

- *Cloud-cleared* minus *clear-sky* vertically integrated temperature anomaly from surface to 800hPa averaged from 01 Sep to 10 Nov 2014.
- Colder low-tropospheric temperatures induce negative mid- and upper-tropospheric geopotential height anomalies due to hydrostatic adjustment



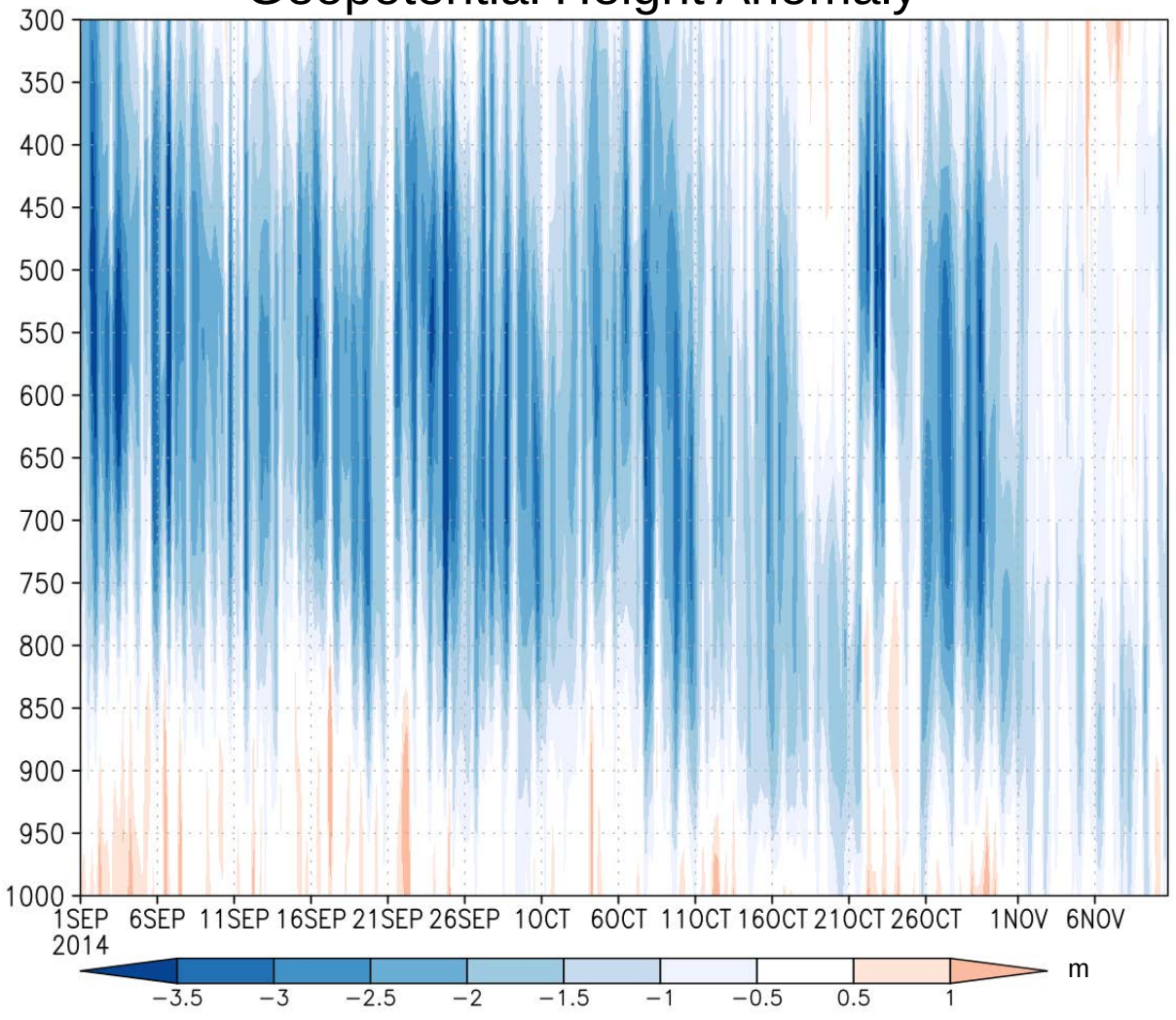



- *Cloud-cleared* minus *clear-sky* temperature anomaly averaged 70ºN – 90ºN
- Persistent cooling over large area (over 15 million sq. km) and over 2 month time period
- Low-tropospheric temperatures (at the interface between boundary layer and free troposphere) decrease as a consequence of CCR assimilation
- The anomaly slopes downward, transitioning into the cold season

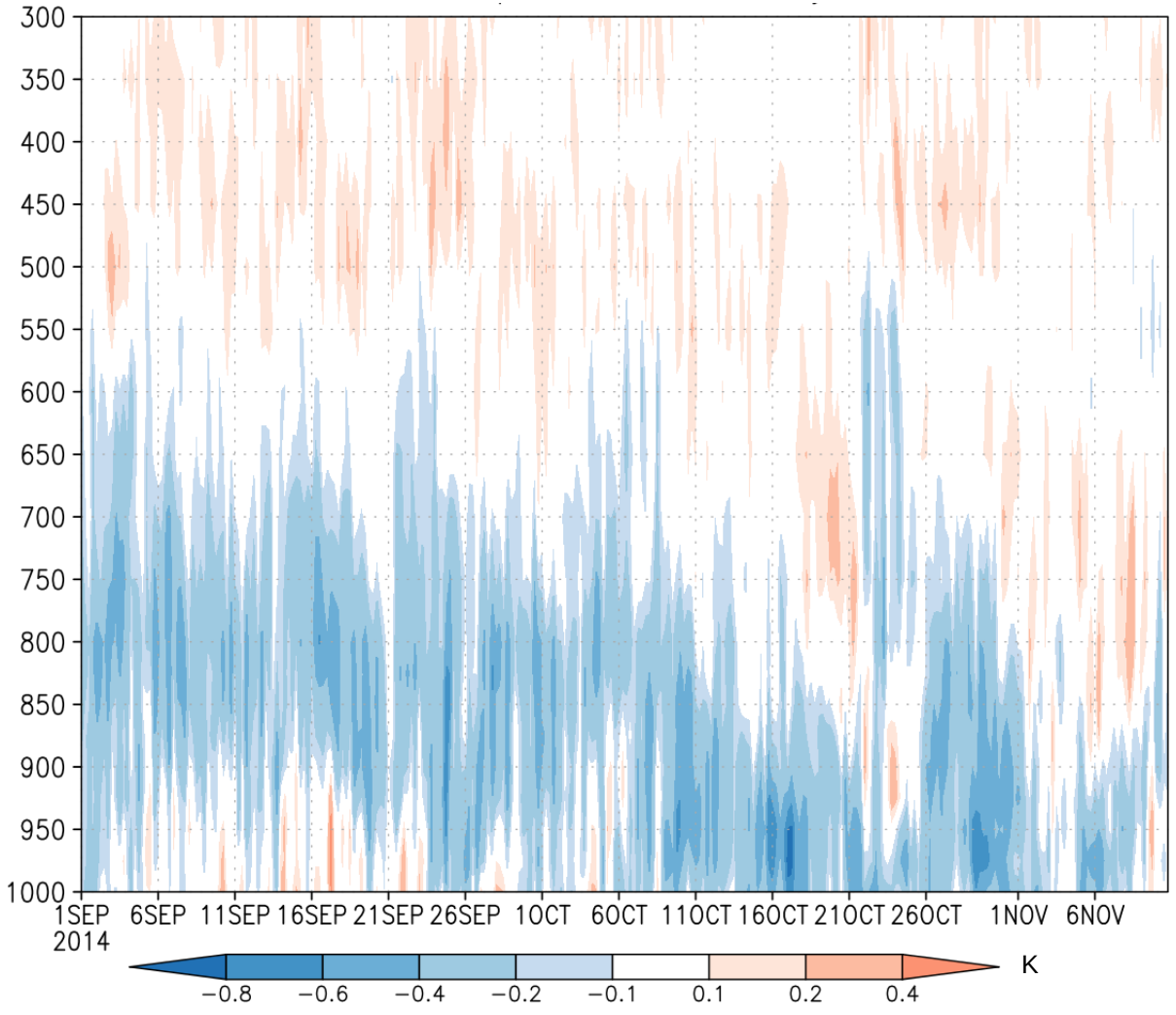
## Temperature Anomaly



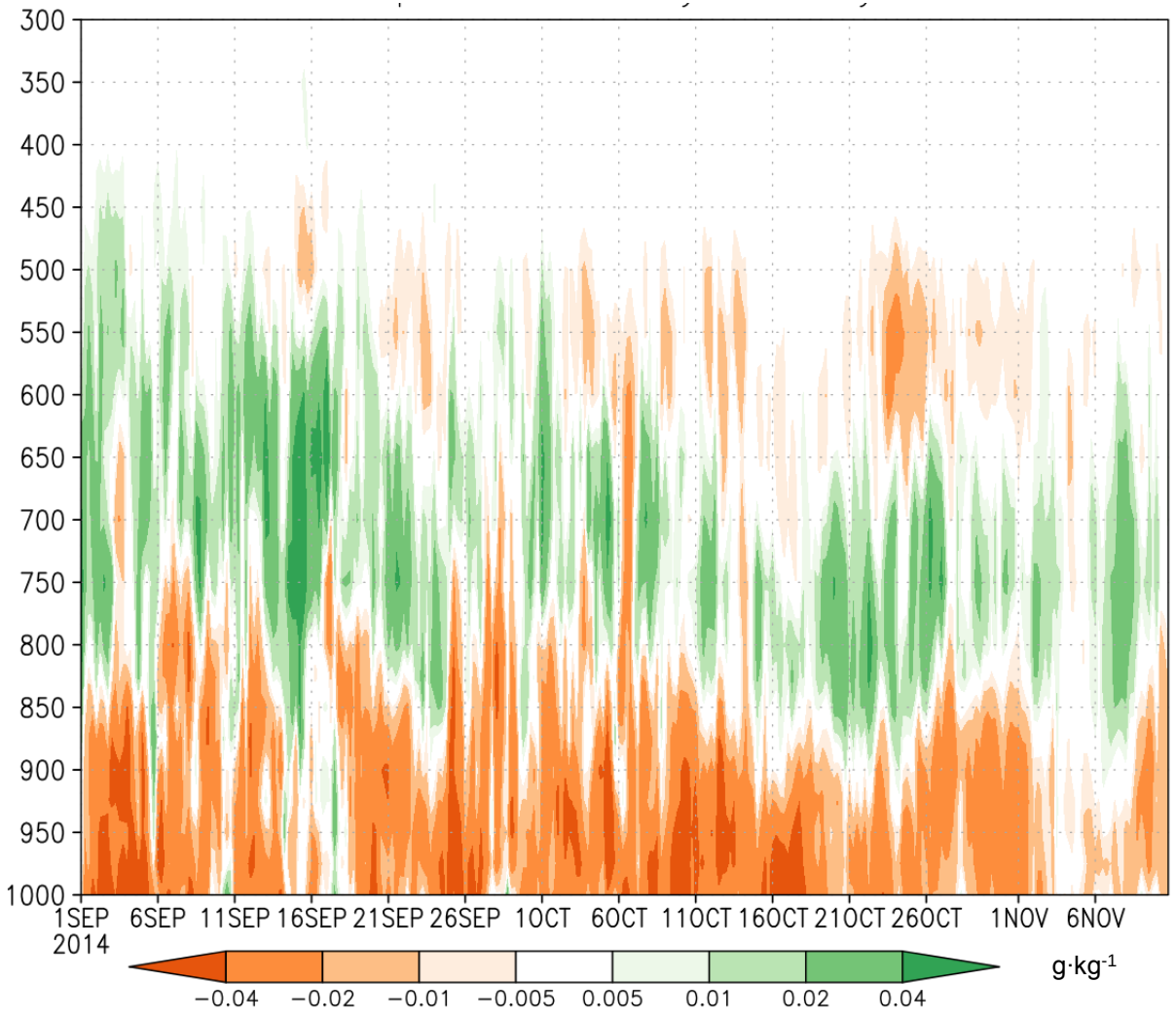

## Geopotential Height Anomaly



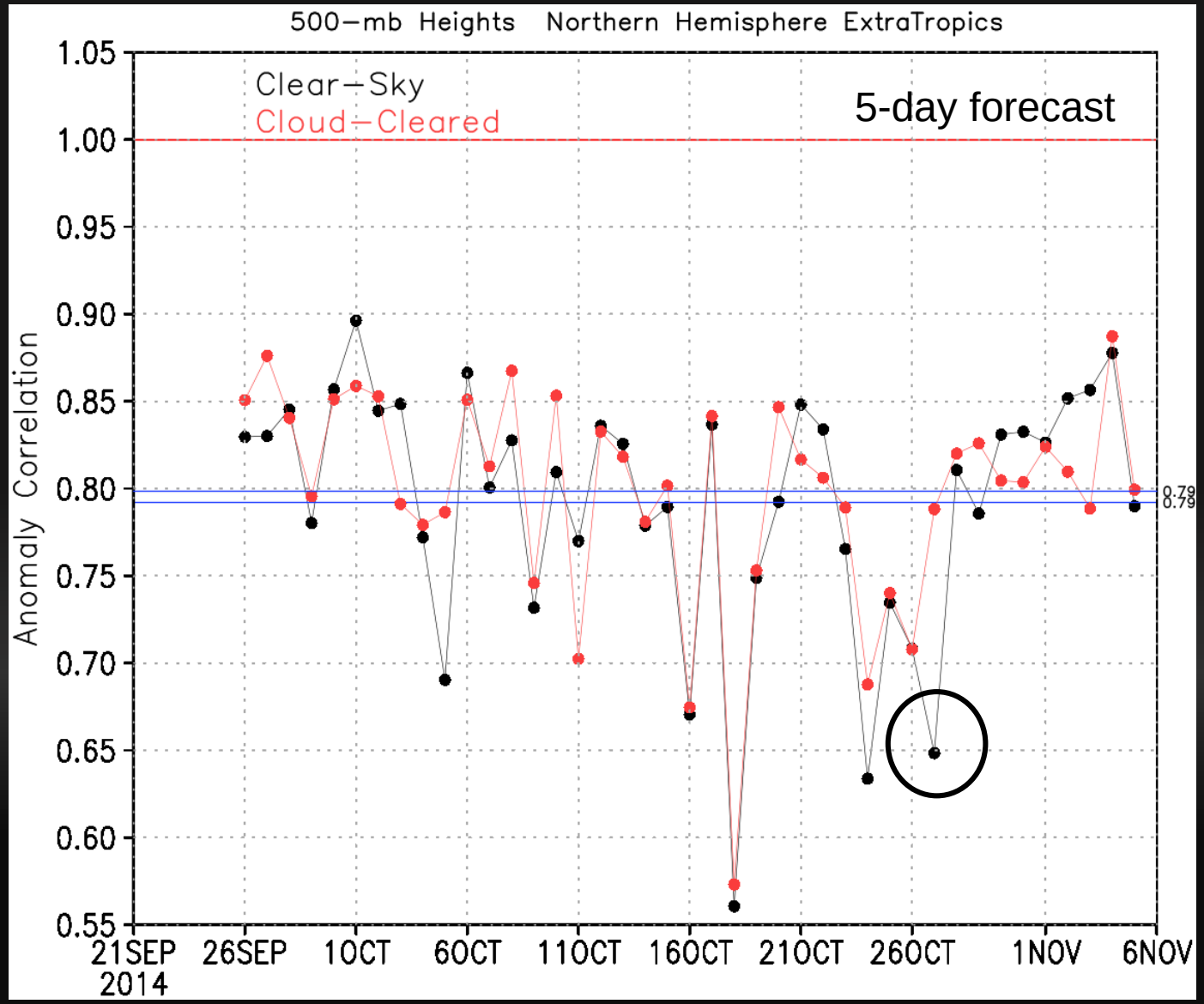
## Temperature Anomaly



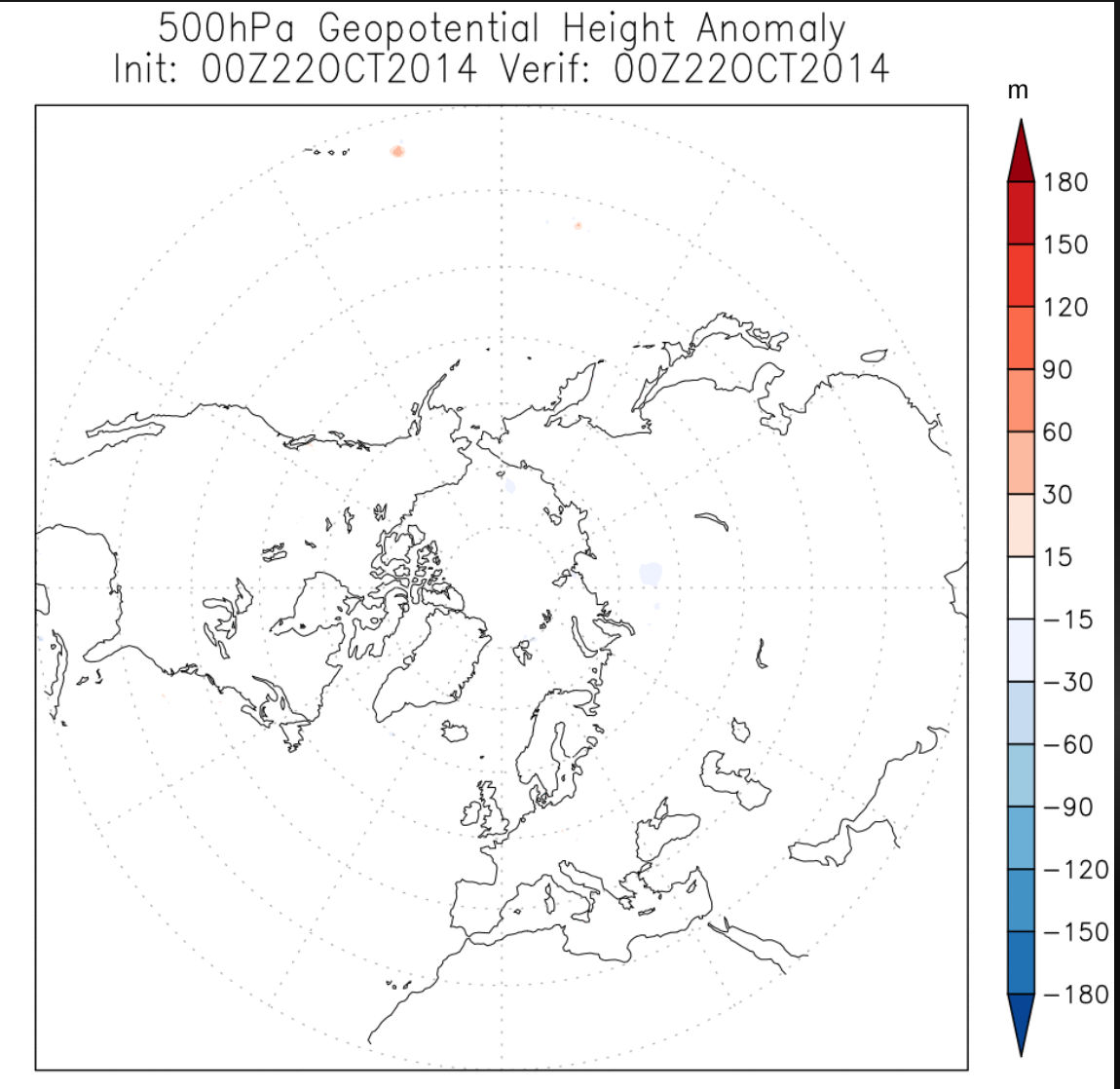

## Specific Humidity Anomaly



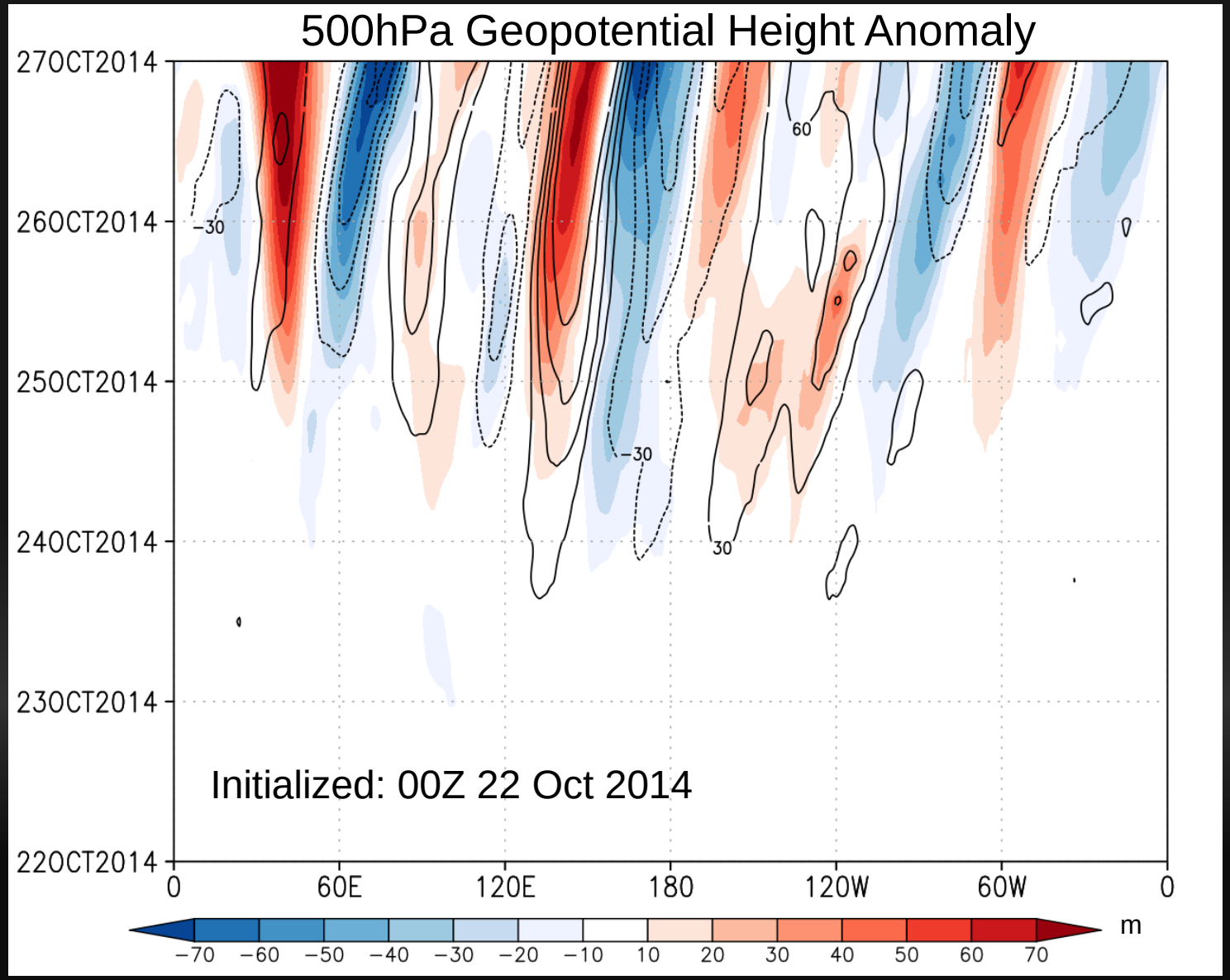
# Impact on forecasts



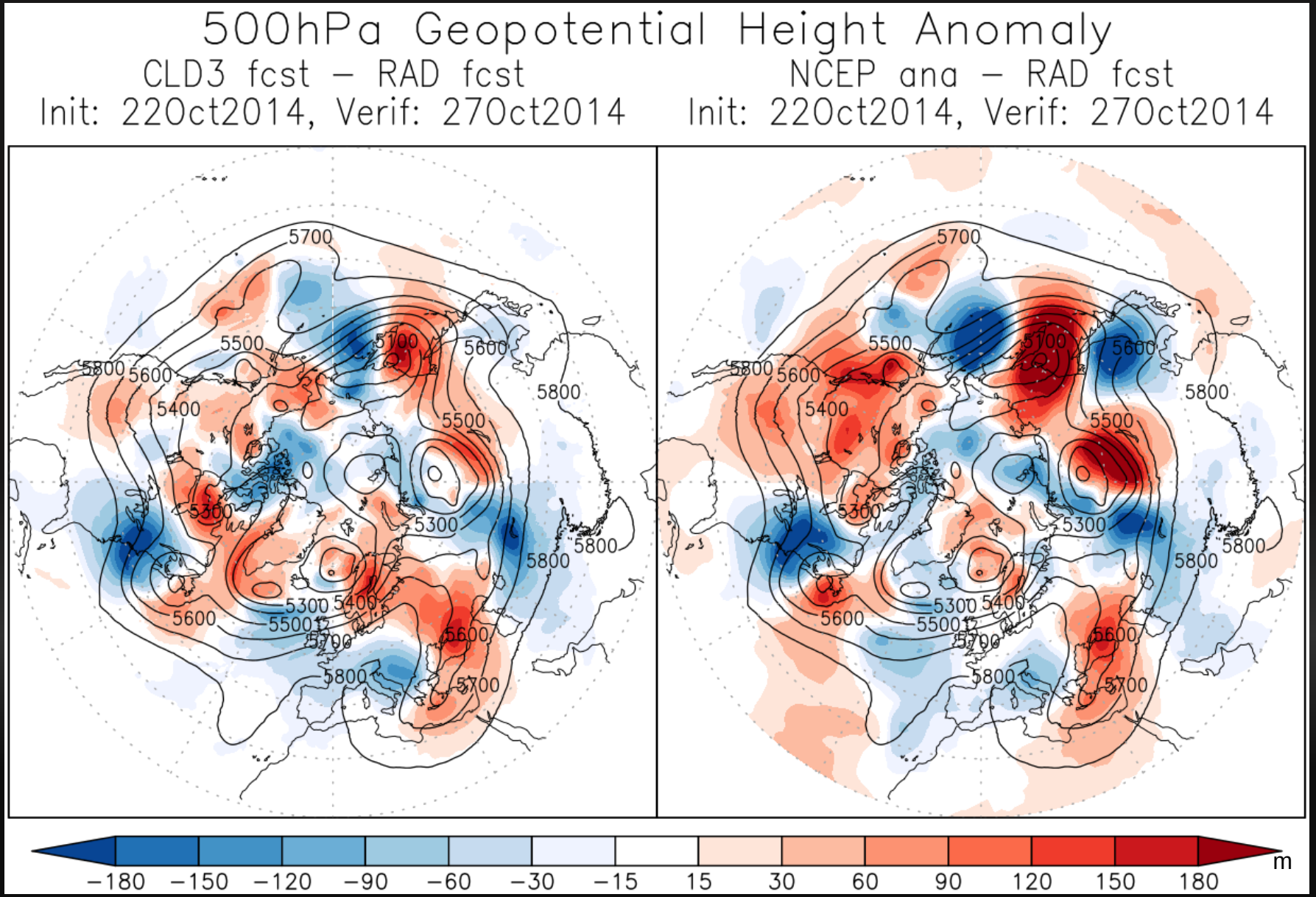
# Impact on individual forecasts




- Cloud-cleared forecast – clear-sky forecast geopotential height anomalies for forecast initialized 00z22Oct.
- Anomalies grow quickly, showing waves that propagate to the midlatitudes.
- Localized anomaly over the Arctic can propagate to the midlatitudes in the forecast of waves.
- Wave dynamics over the entire NH appears to be very sensitive to the temperature information that appears in the initialization over the Arctic region.




- Hovmöller diagram with forecast geopotential height anomaly averaged from 40ºN – 80ºN as a function of longitude vs. forecast time
- Shaded: *cloud-cleared forecast* minus *clear-sky forecast*
- Contour: *NCEP operational verifying analysis* minus *clear-sky forecast*
- Anomaly amplitudes grow with forecast time, propagating eastward with midlatitude waves.
- Changes induced by cloud-clearing attempt to correct the forecast in the direction of the NCEP verifying analysis.




- 5 day forecast geopotential height anomalies
- Forecast initialized: 00z 22 Oct 2014, valid 00Z 27 Oct. 2014.
- Left: *Cloud-cleared forecast* minus *clear-sky forecast*
- Right: *NCEP operational verifying analysis minus clear-sky forecast*
- Similar to Hovmöller, shows assimilation of cloud-cleared radiances corrects errors in the forecast.

# Summary

- The Arctic region has extensive low level stratus cloud coverage, and conventional observations are sparse. Assimilation of AIRS cloud-cleared radiances can improve the representation of low level clouds compared to that of clear-sky only radiances.
- In the experiment assimilating cloud-cleared radiances, forecast skill is improved in both hemispheres compared to the current, operational clear-sky approach. The strongest, most consistent thermodynamic signal resulting from the assimilation of cloud-cleared radiances is observed as lower tropospheric cooling over the Arctic associated with low level stratus clouds.
- The lower tropospheric cooling produces negative mid- and upper-tropospheric geopotential height anomaly due to hydrostatic adjustment. Height anomalies propagate to the mid-latitudes, amplifying in the forecasts of waves, which leads to an improvement in individual forecasts and an overall improvement in forecast skill
- Future work will explore the use of cloud-cleared radiances from other infrared hyperspectral instruments (IASI, CrIS) in a hybrid ensemble 4dvar data assimilation framework.

# Acknowledgements

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