Impact of assimilating AIRS cloud-cleared radiances on atmospheric dynamics at high latitudes

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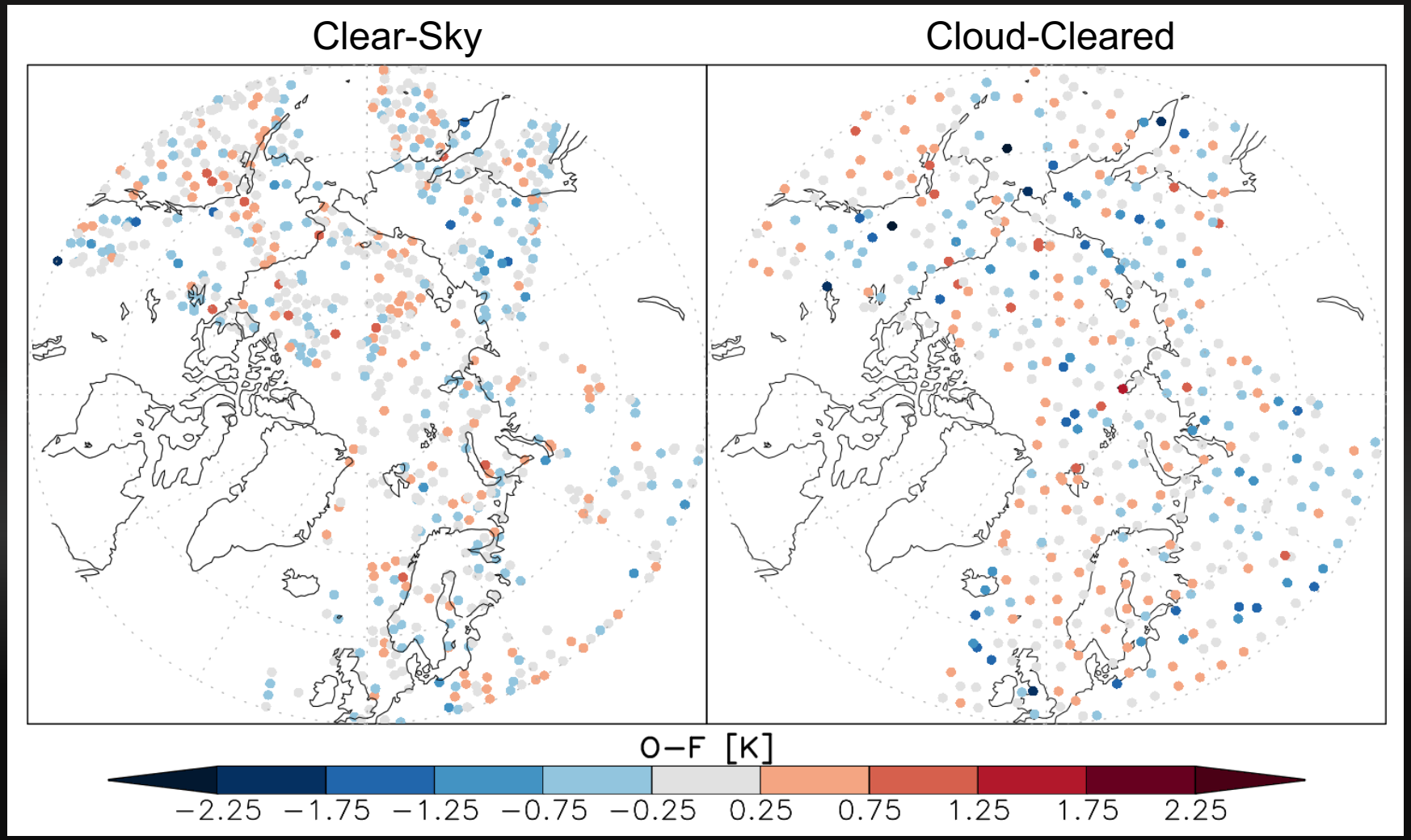
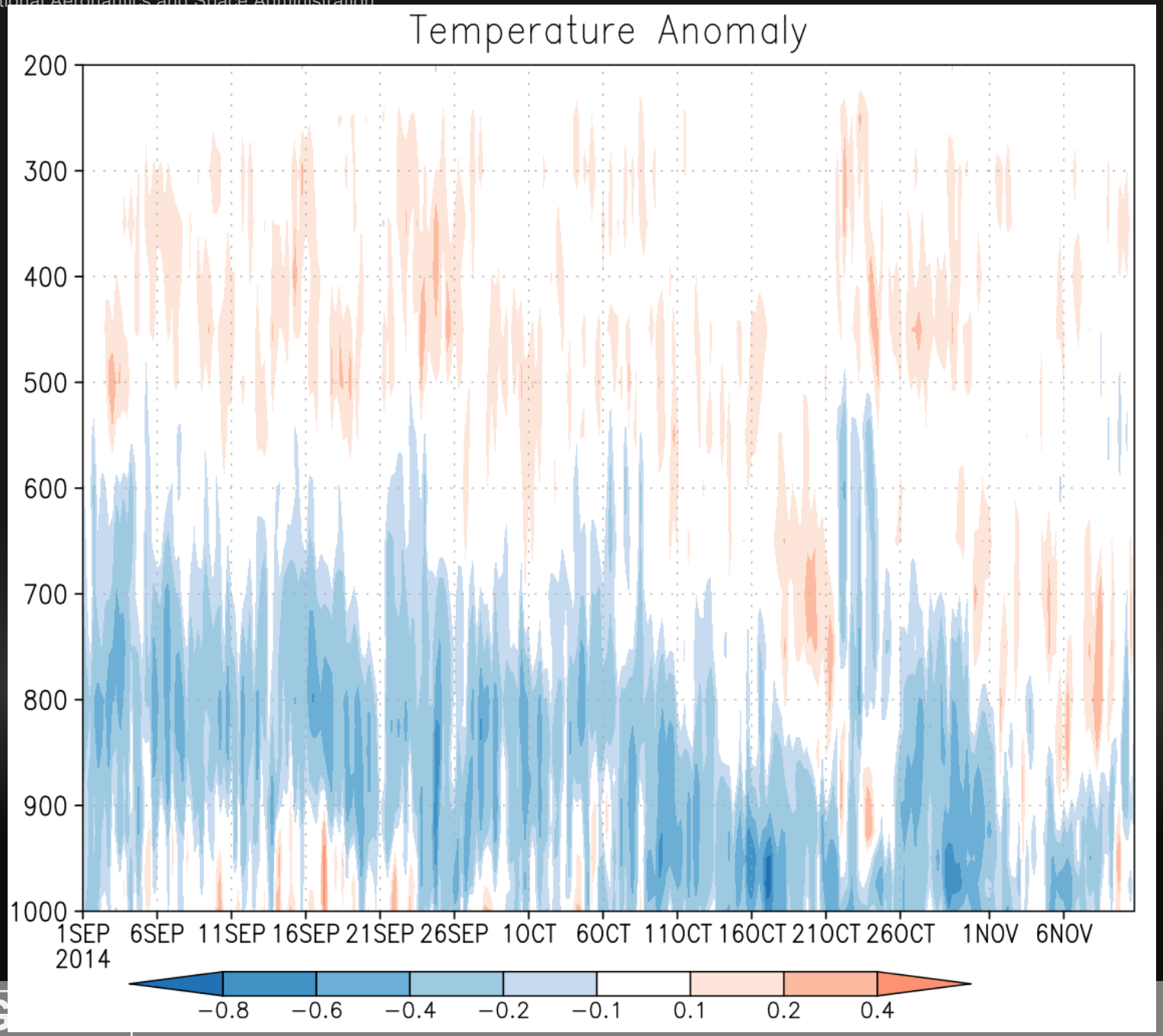
Introduction

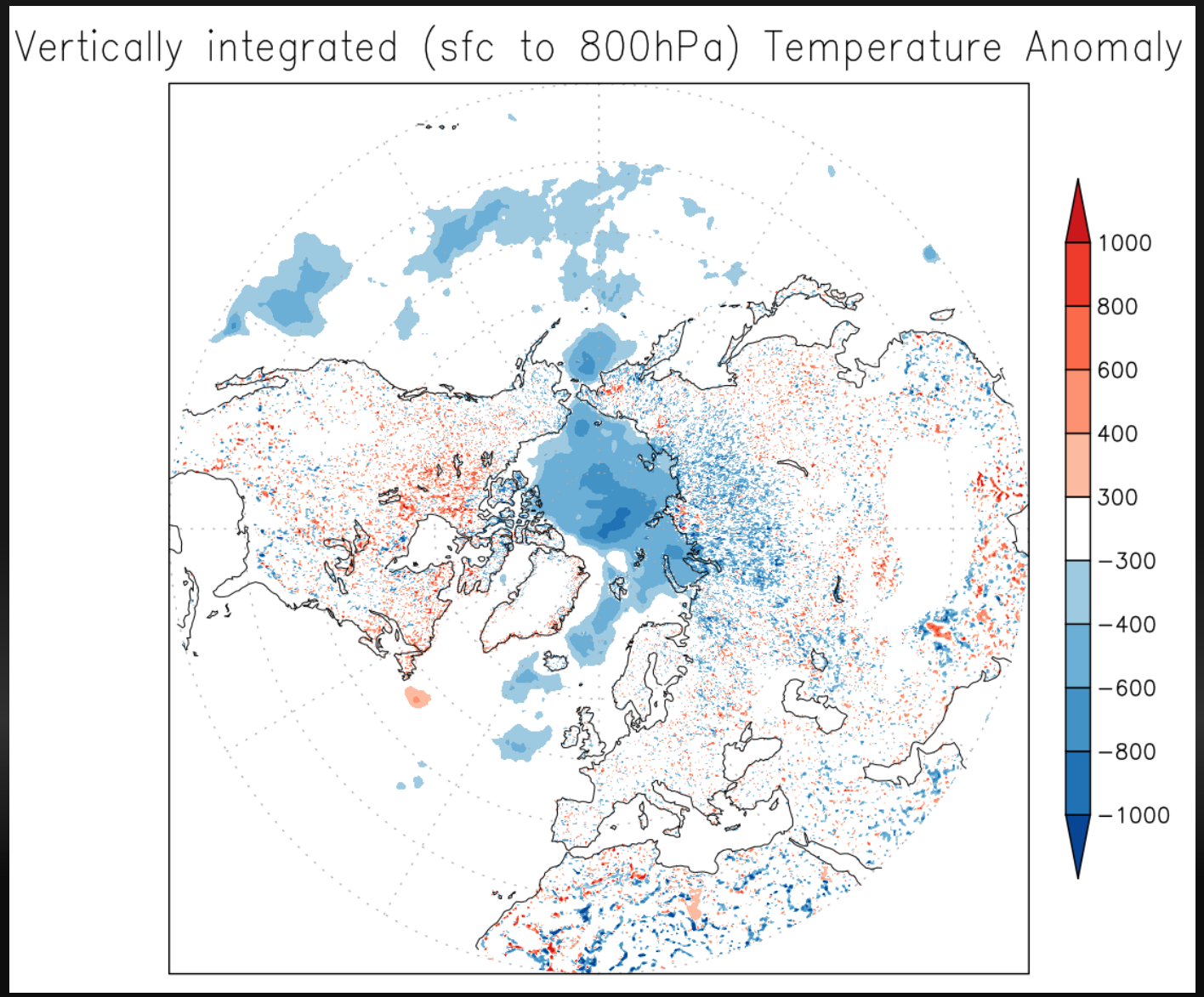
- Previous work focused on tropical systems, but assimilation of AIRS cloud-cleared radiances (CCRs) can also benefit the study of high latitudes
- Conventional observations are scarce in the high latitudes. Moreover, extended low-level stratus cloud cover limits assimilation of clear-sky infrared data
- In these regions, assimilation of CCRs can prove particularly beneficial
- Used Observing System Experiment (OSE) performed with Goddard Earth Observing System (GEOS, version 5) data assimilation and forecast system to study boreal fall 2014
- Experiment compares the impact of assimilating cloud-cleared AIRS radiances against clear-sky (without changing the rest of the observing system)

Clear-sky vs cloud-cleared coverage



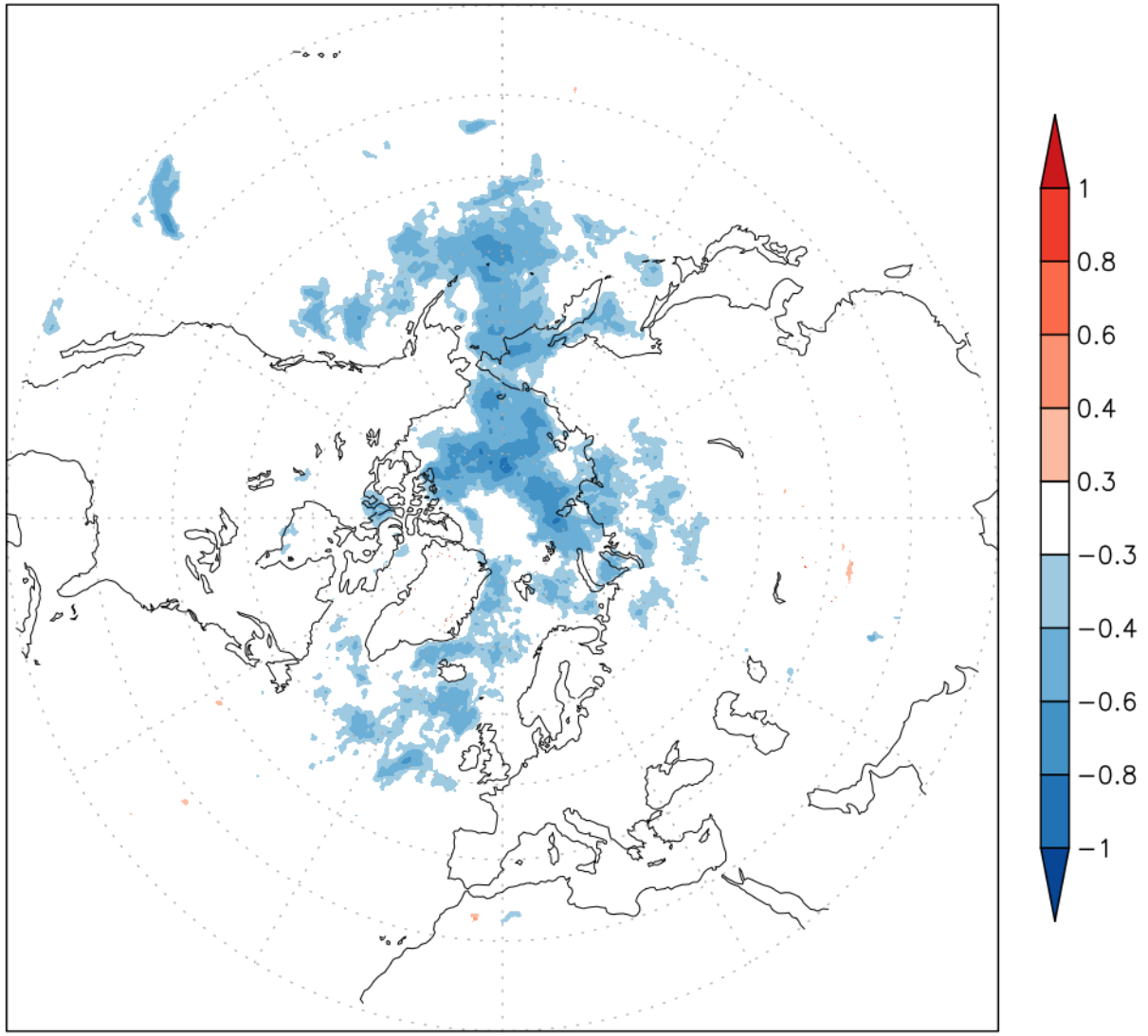


- *Cloud-cleared* minus *clear-sky* temperature anomaly averaged 70ºN – 90ºN
- Low-tropospheric temperatures (at the interface between boundary layer and free troposphere) decrease as a consequence of CCR assimilation
- The anomaly slopes downward, transitioning into the cold season

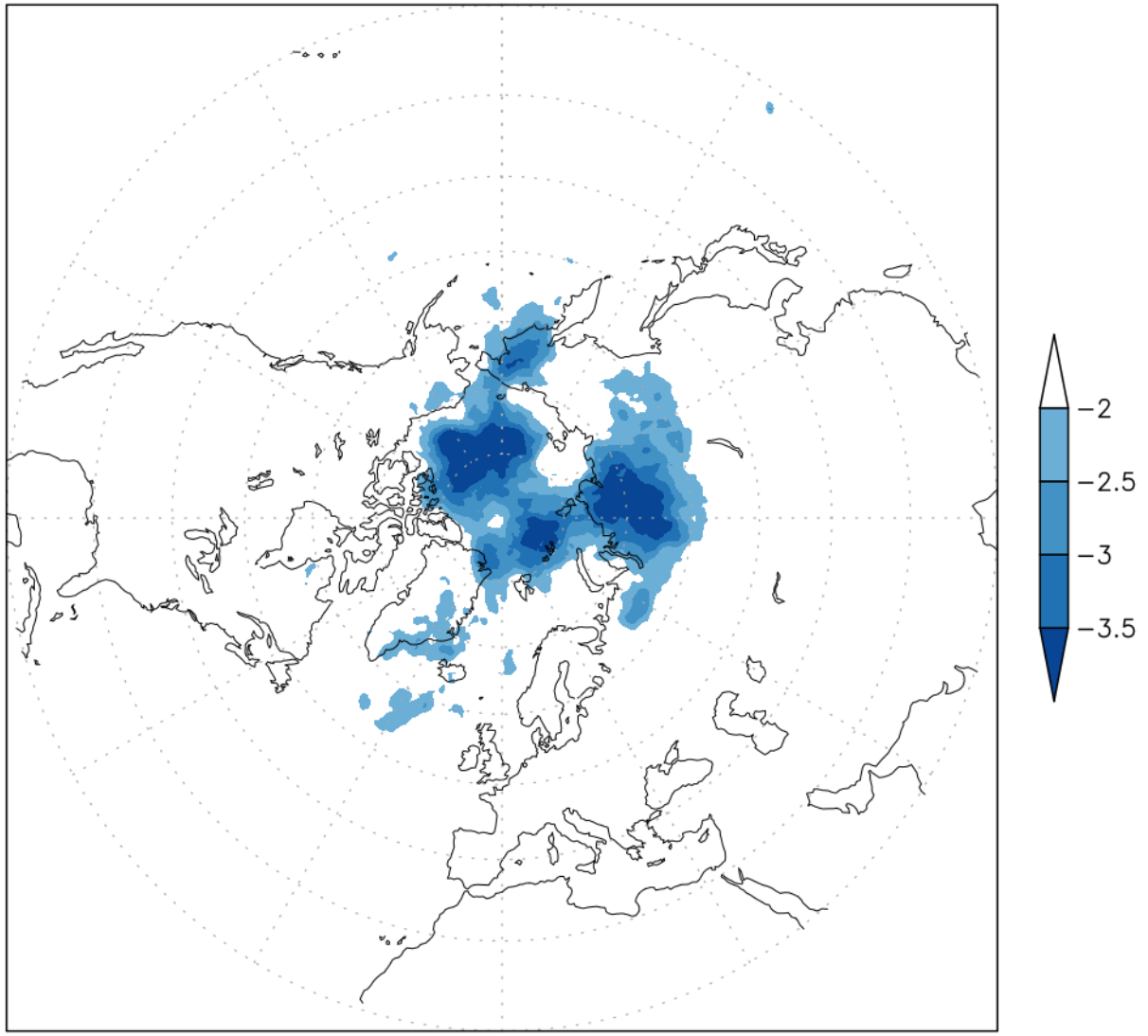


- Largest temperature anomaly over Arctic
- Colder low-tropospheric temperatures induce negative mid- and upper-tropospheric geopotential height anomalies due to hydrostatic adjustment

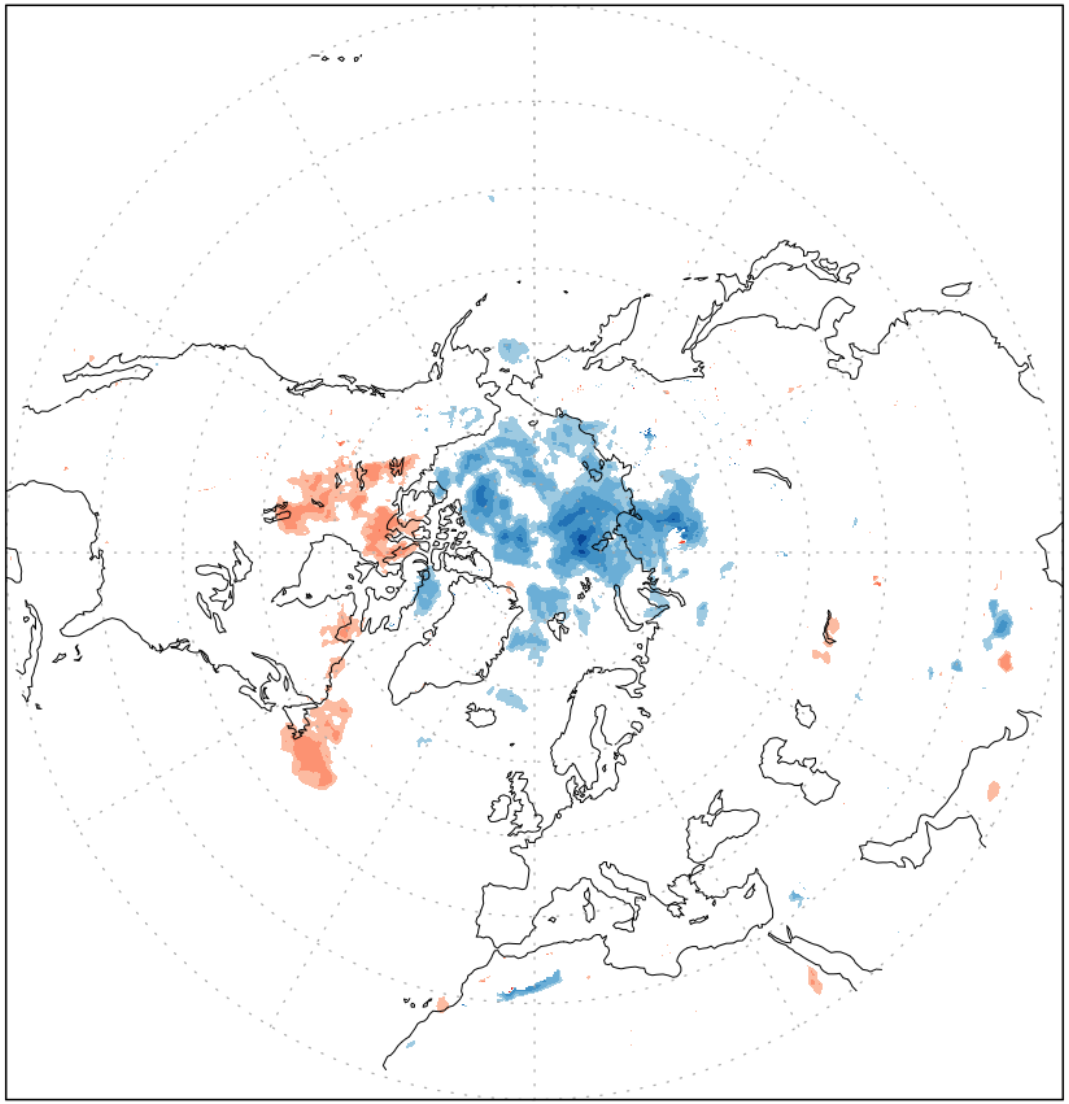
825hPa Temperature Anomaly (Sep)

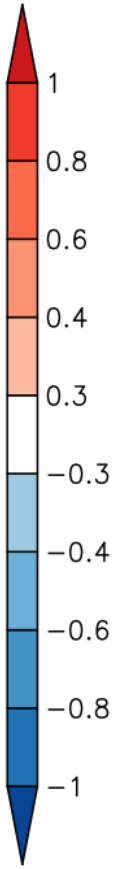


500hPa Geopotential Height Anomaly (Sep)

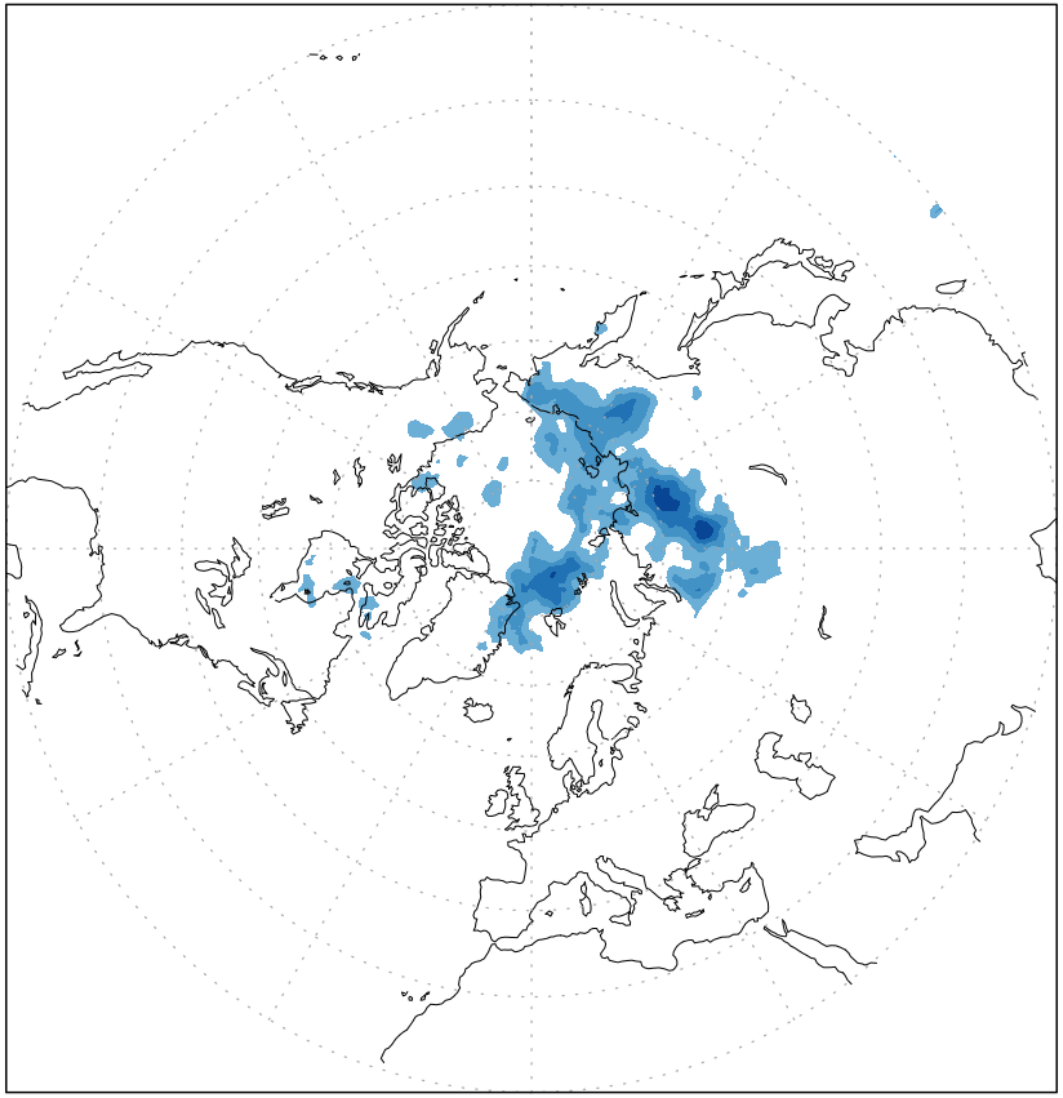


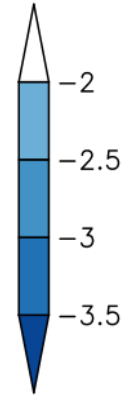
925hPa Temperature Anomaly (Oct)

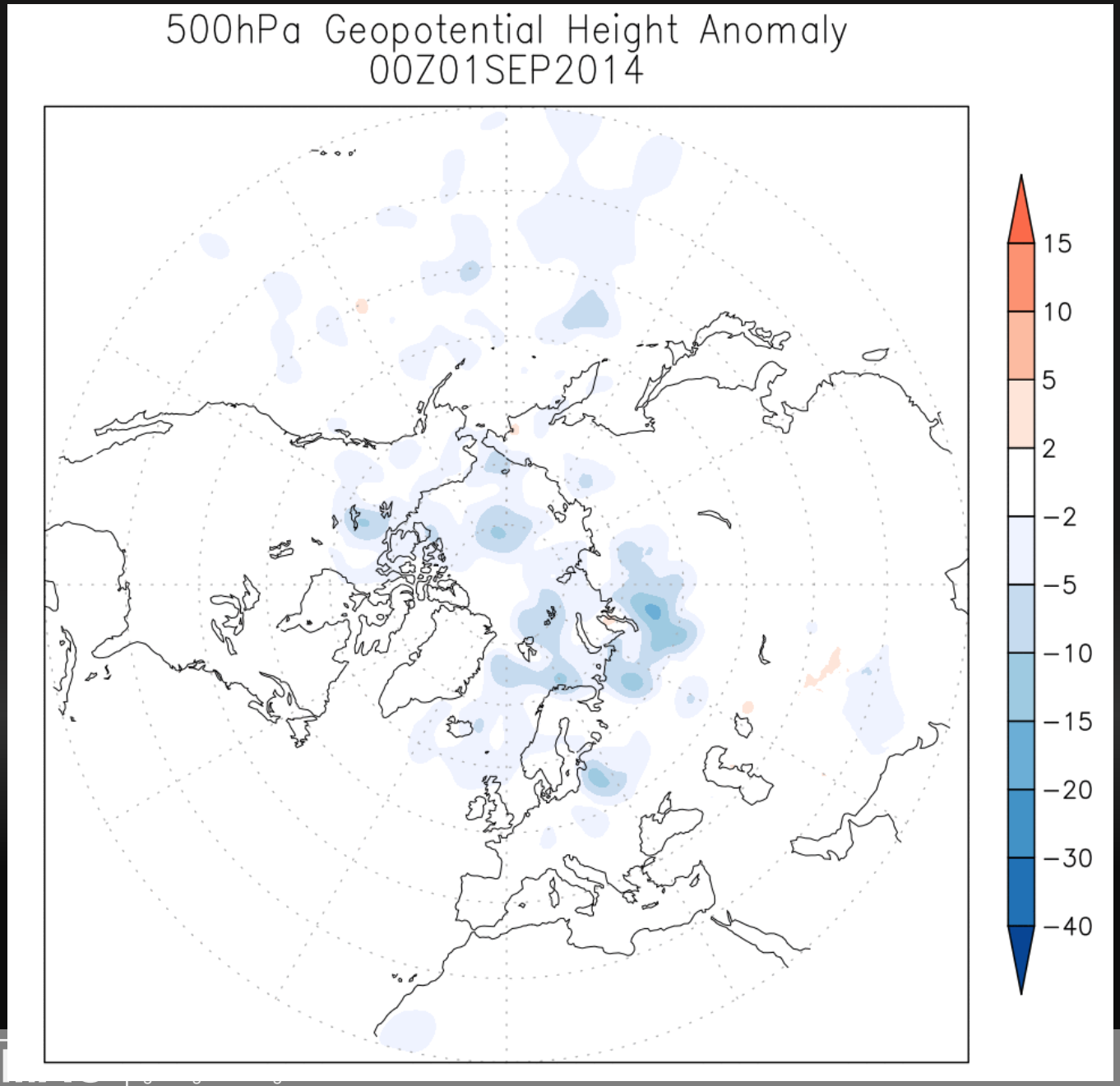




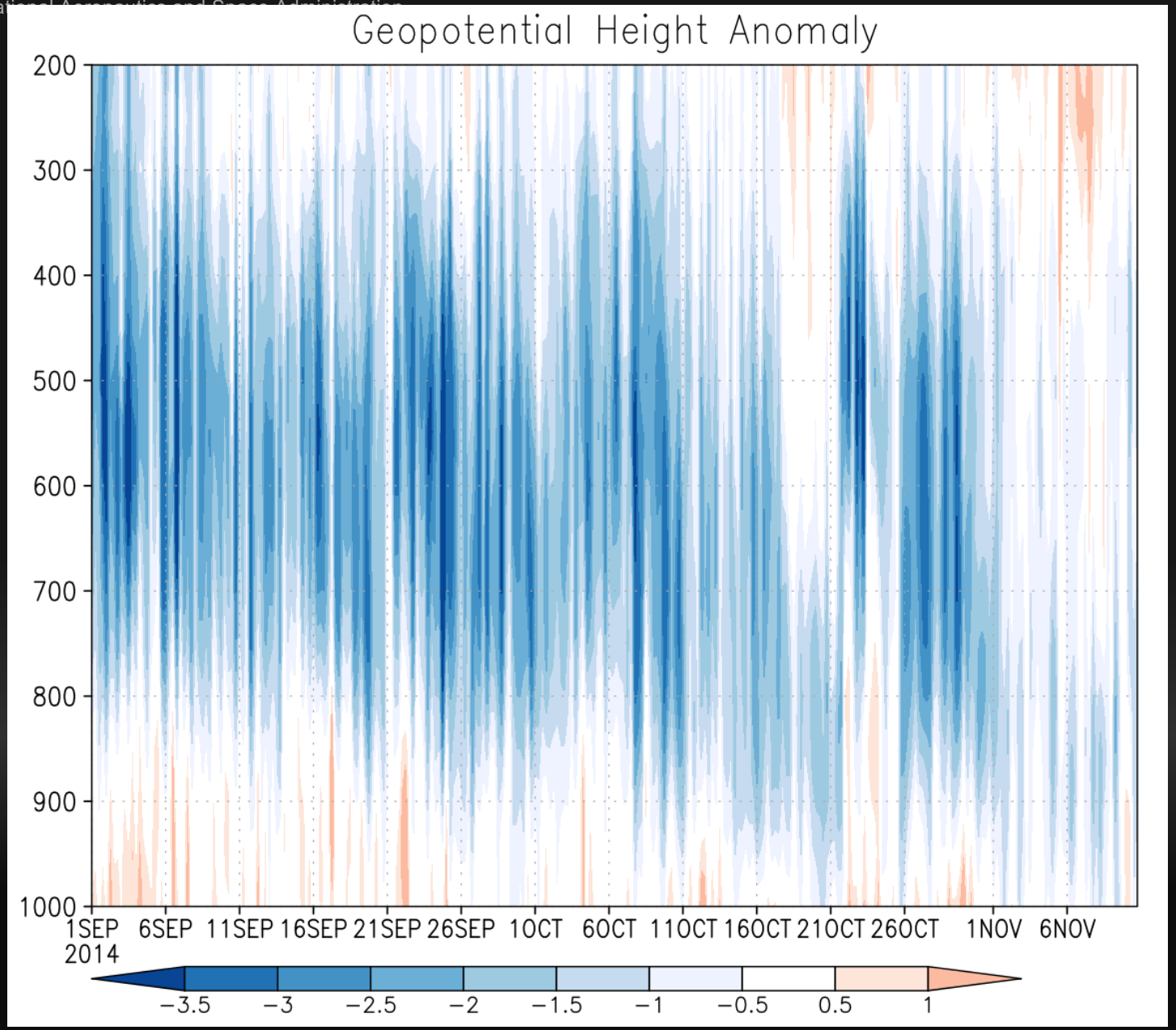
500hPa Geopotential Height Anomaly (Oct)



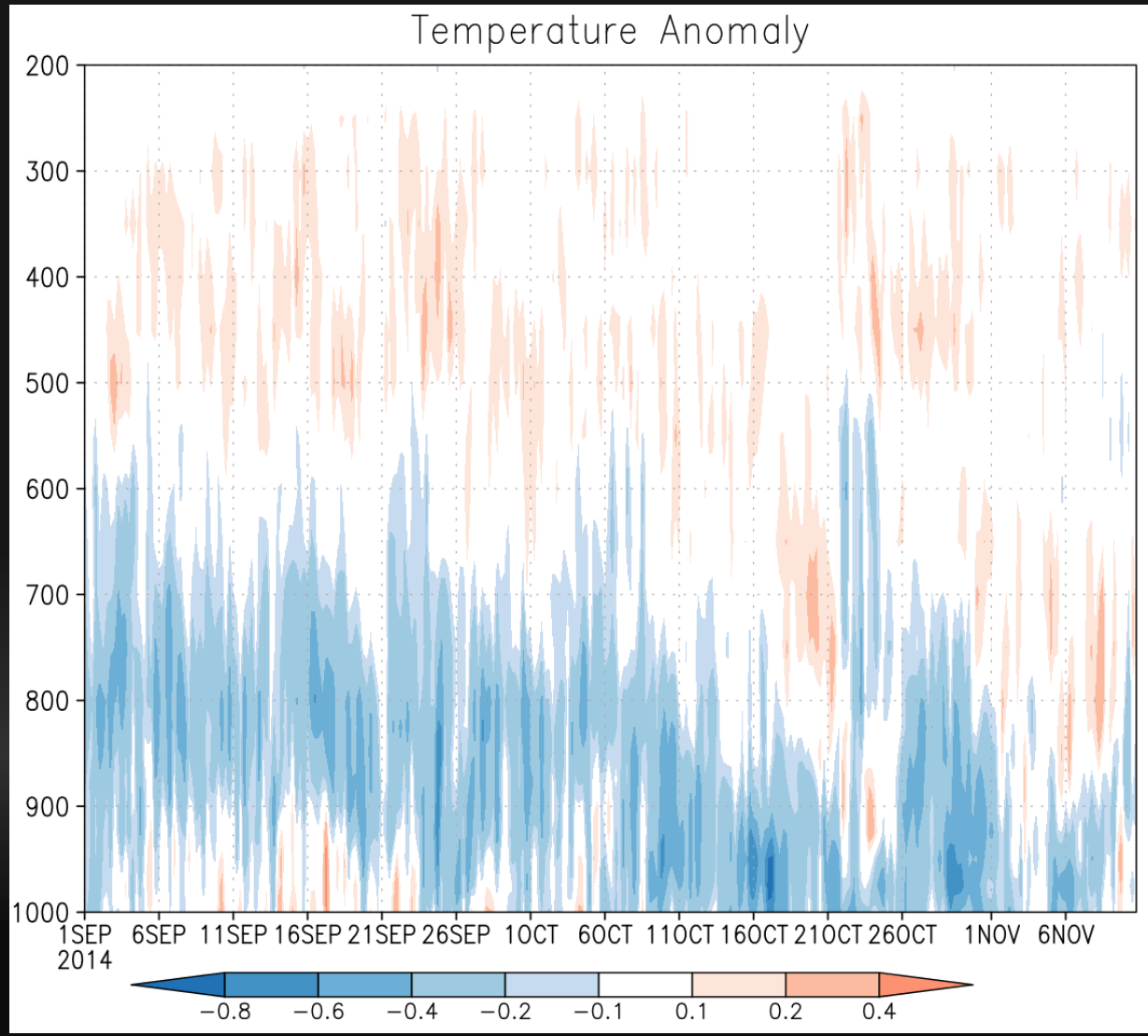


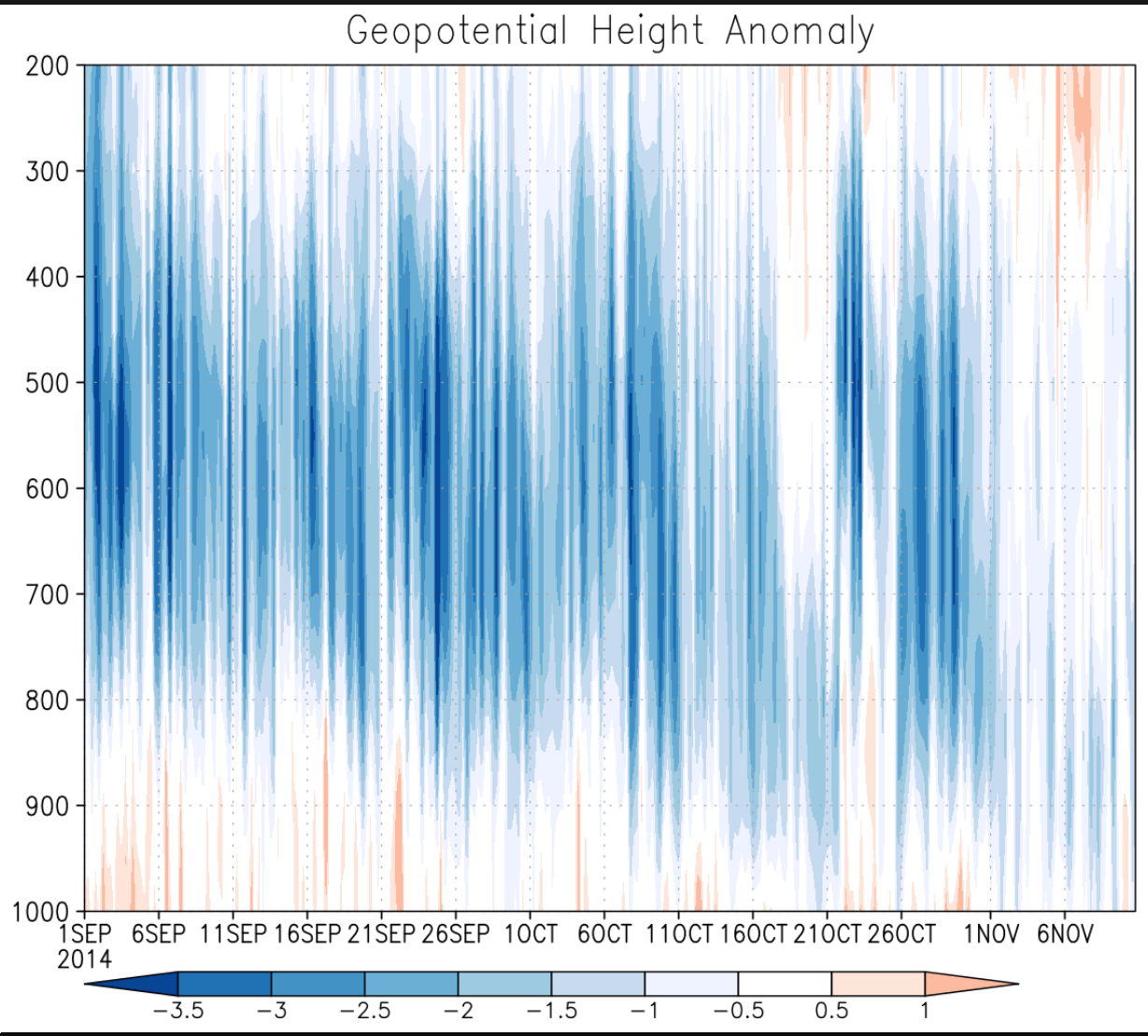


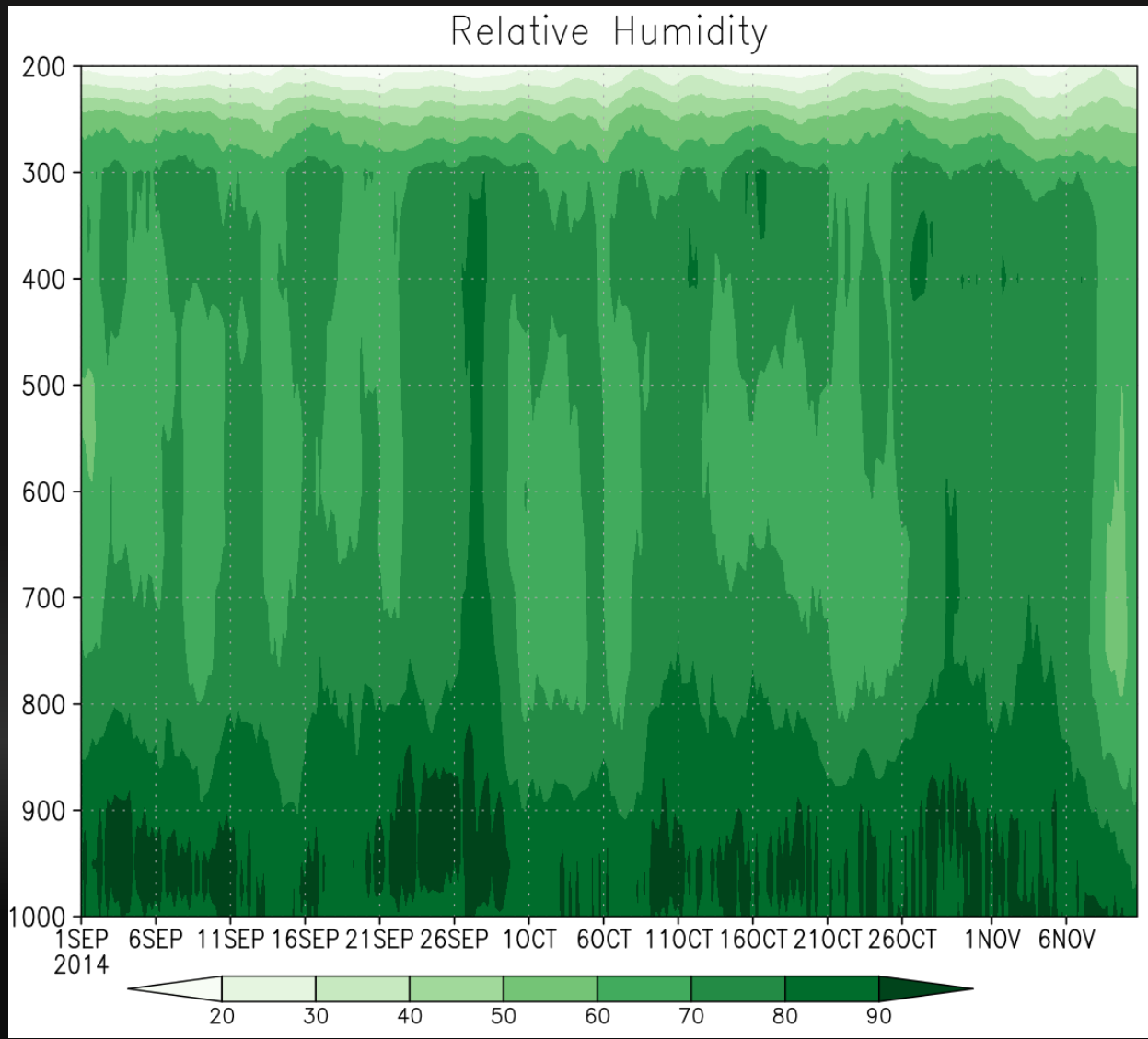
- *Cloud-cleared* minus *Clear-sky* analysis 500hPa geopotential height anomalies
- While average differences are small, large transient patterns exist due to variations in the representation of weather systems

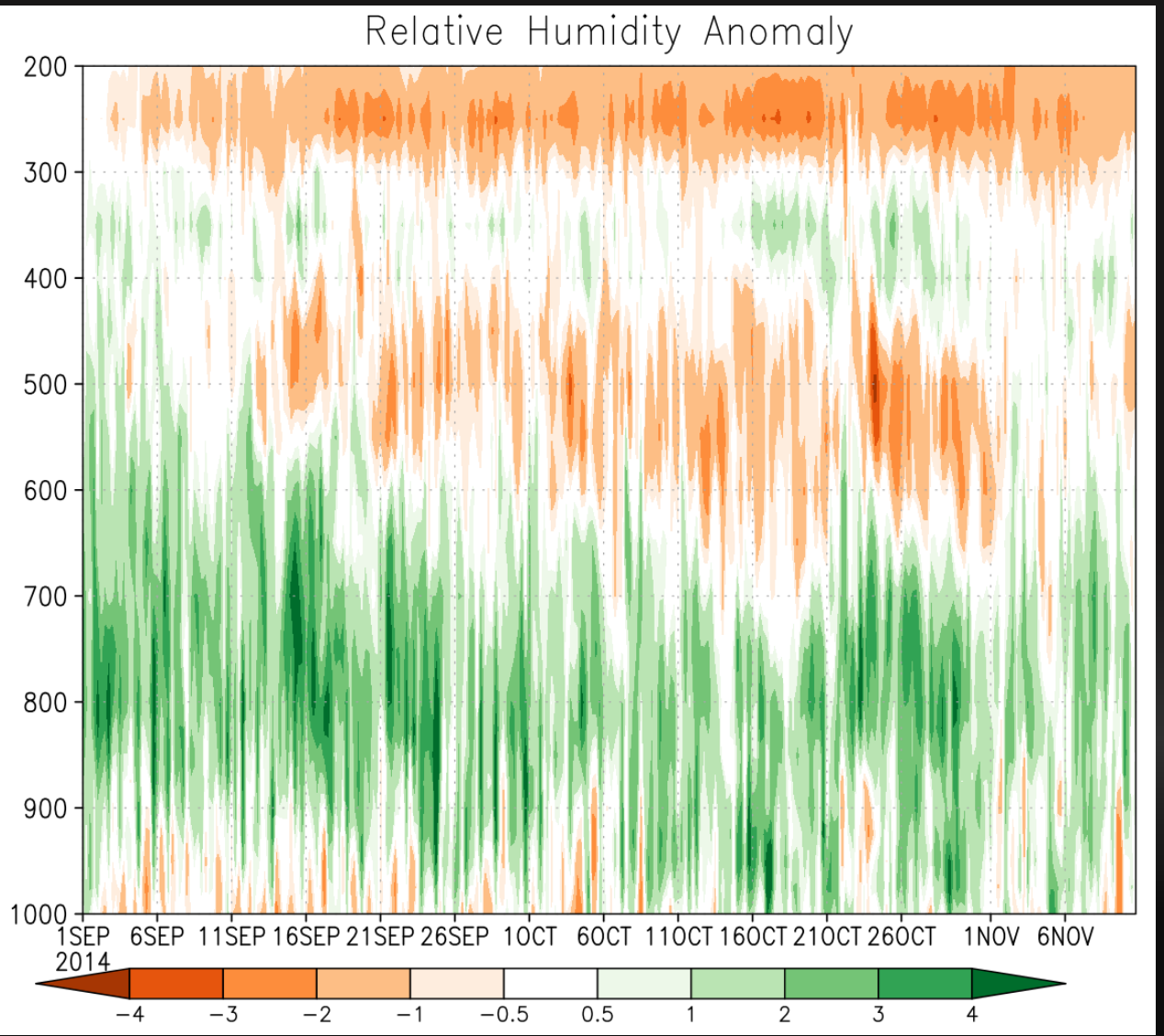


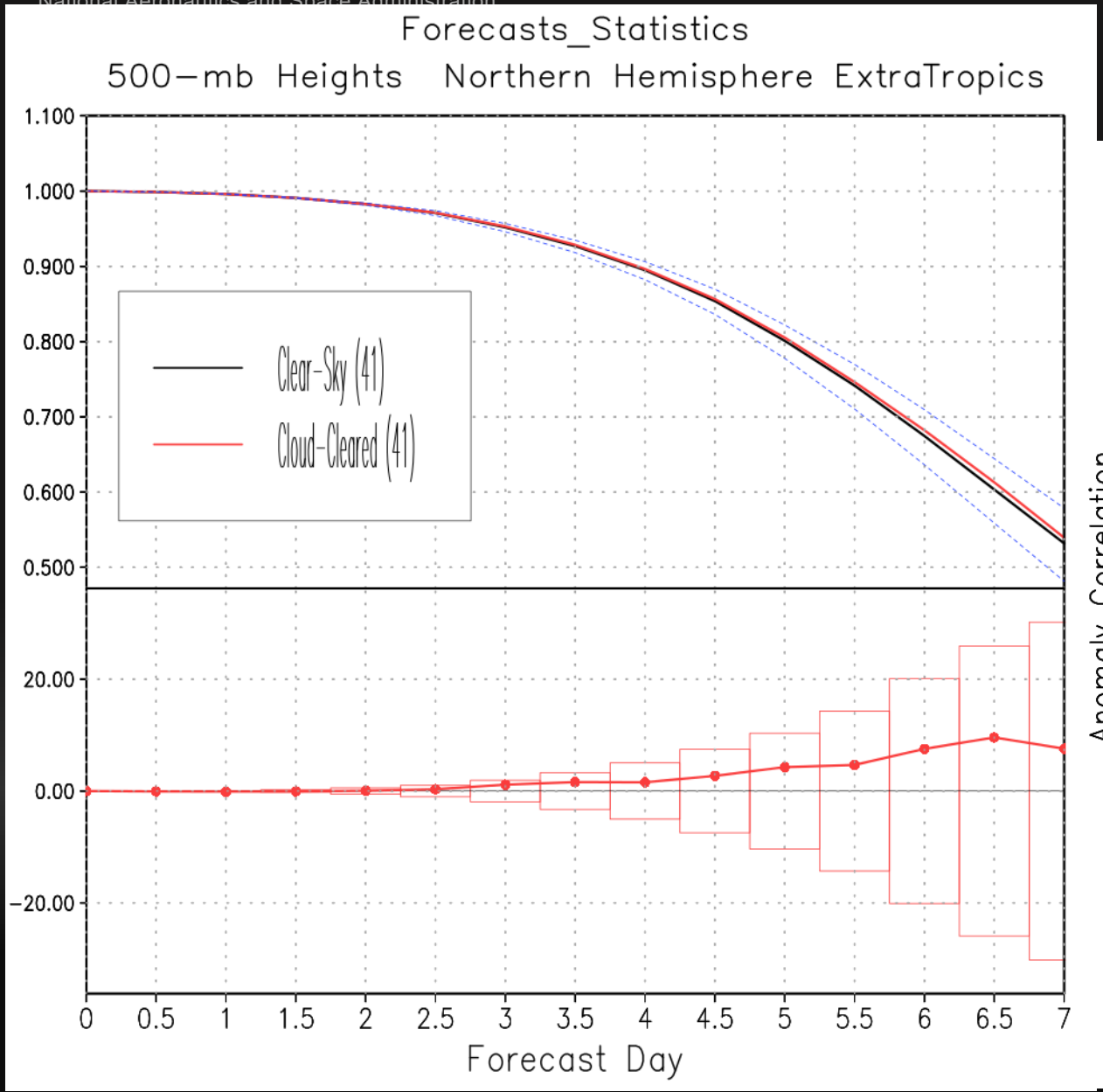
- *Cloud-cleared* minus *Clear-sky* geopotential height anomaly averaged 70ºN – 90ºN
- Negative height anomaly extends through mid to upper troposphere

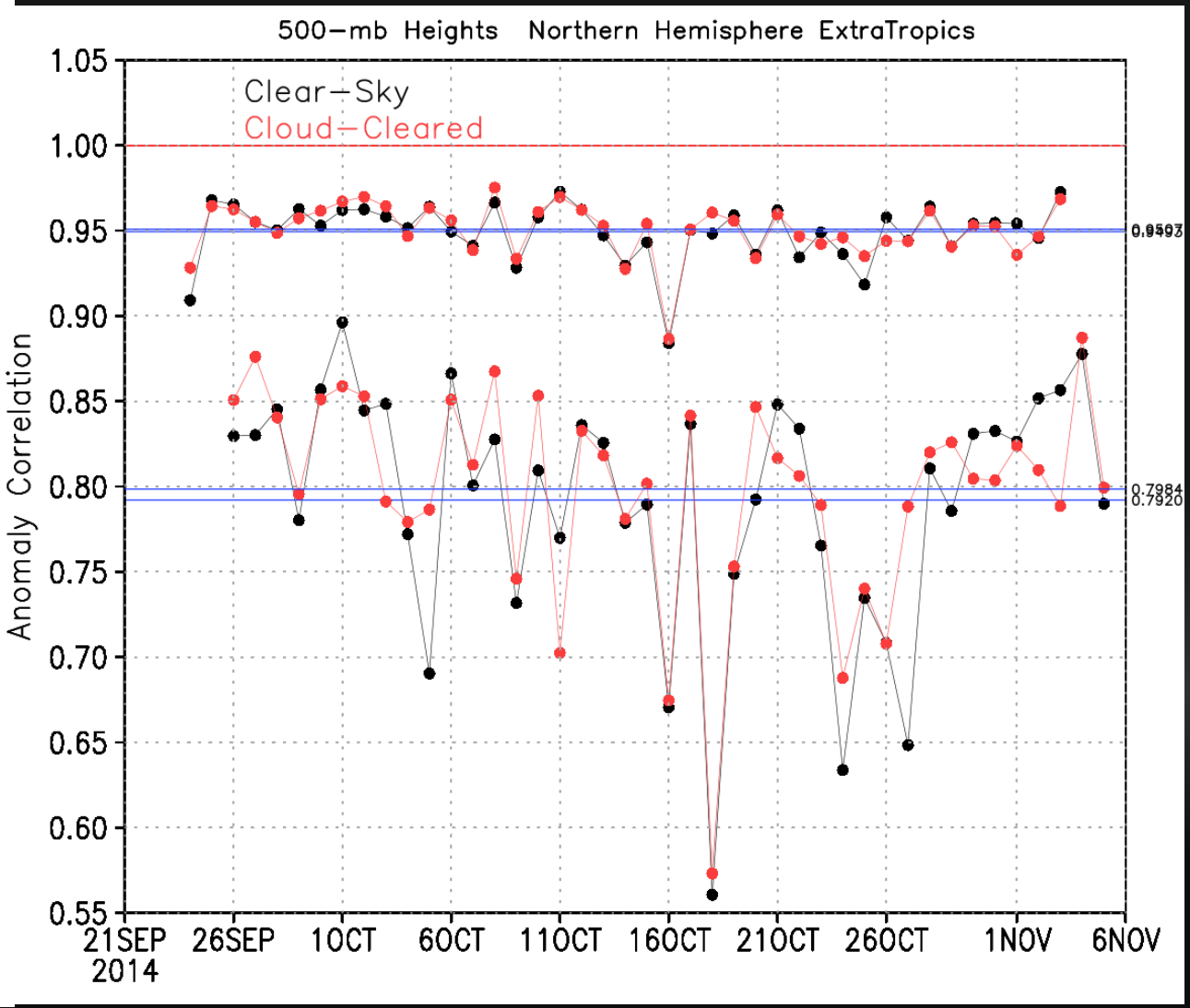

Temperature Anomaly
200
300
400
500
600
700
800
900
1000
1SEP 2014
6SEP
11SEP
16SEP
21SEP
26SEP
1OCT
6OCT
11OCT
16OCT
21OCT
26OCT
1NOV
6NOV
−0.8
−0.6
−0.4
−0.2
−0.1
0.1
0.2
0.4

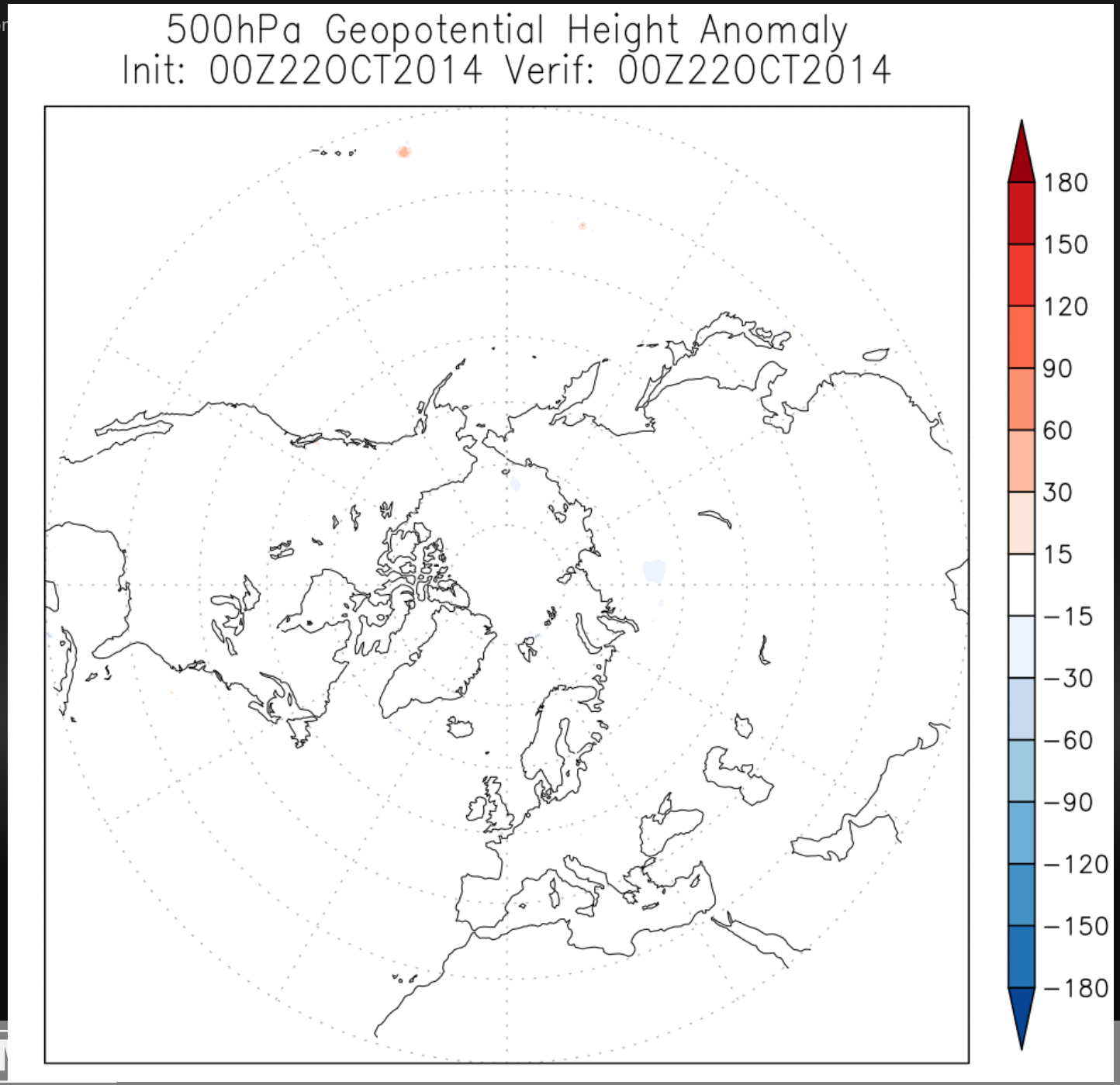

Geopotential Height Anomaly
200
300
400
500
600
700
800
900
1000
1SEP 2014
6SEP
11SEP
16SEP
21SEP
26SEP
1OCT
6OCT
11OCT
16OCT
21OCT
26OCT
1NOV
6NOV
−3.5
−3
−2.5
−2
−1.5
−1
−0.5
0.5
1


Relative Humidity
200
300
400
500
600
700
800
900
1000
1SEP 2014
6SEP
11SEP
16SEP
21SEP
26SEP
1OCT
6OCT
11OCT
16OCT
21OCT
26OCT
1NOV
6NOV
20
30
40
50
60
70
80
90

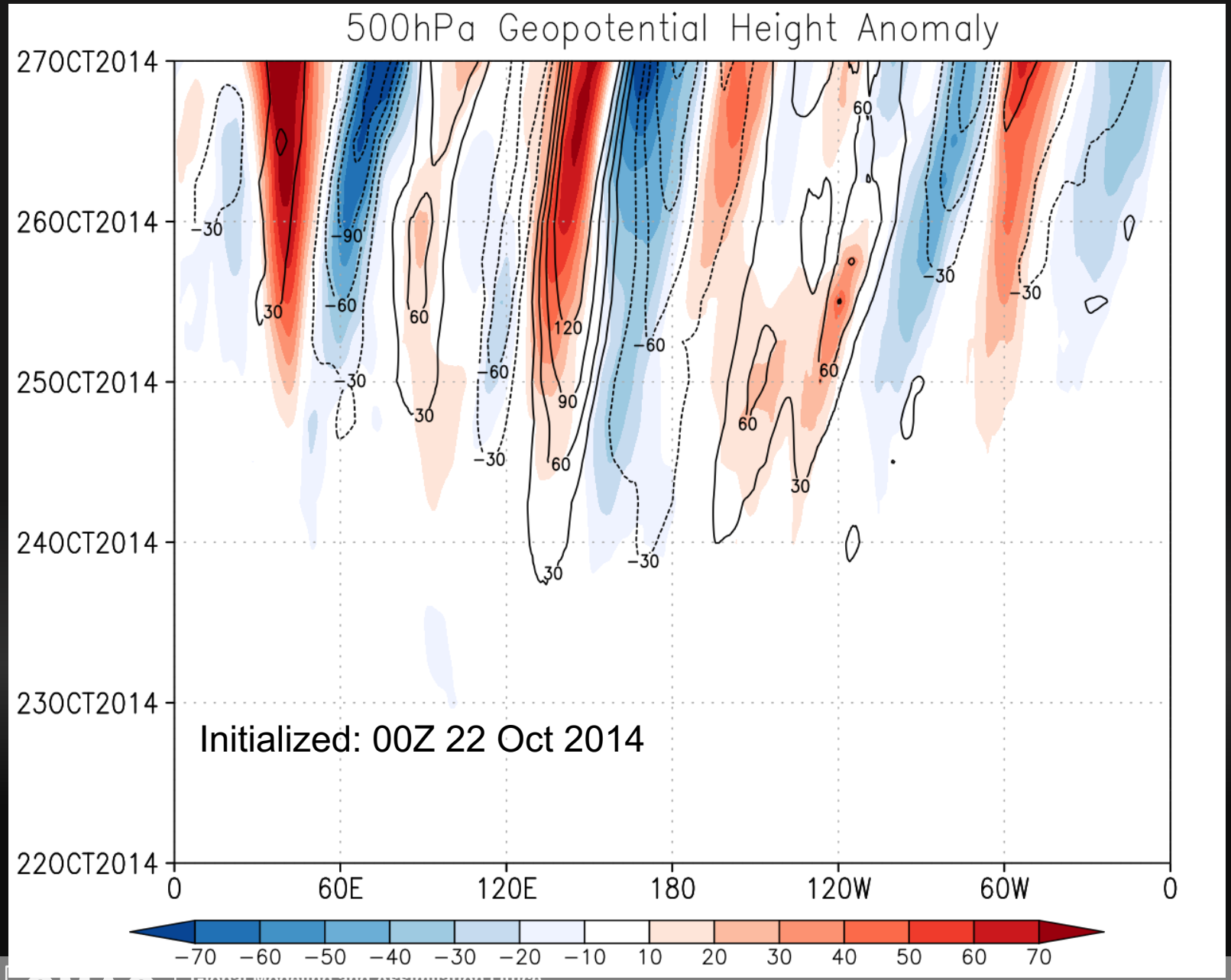

Relative Humidity Anomaly
200
300
400
500
600
700
800
900
1000
1SEP 2014
6SEP
11SEP
16SEP
21SEP
26SEP
1OCT
6OCT
11OCT
16OCT
21OCT
26OCT
1NOV
6NOV
−4
−3
−2
−1
−0.5
0.5
1
2
3
4


Forecasts_Statistics
500−mb Heights Northern Hemisphere ExtraTropics
Clear−Sky (41)
Cloud−Cleared (41)
Forecast Day

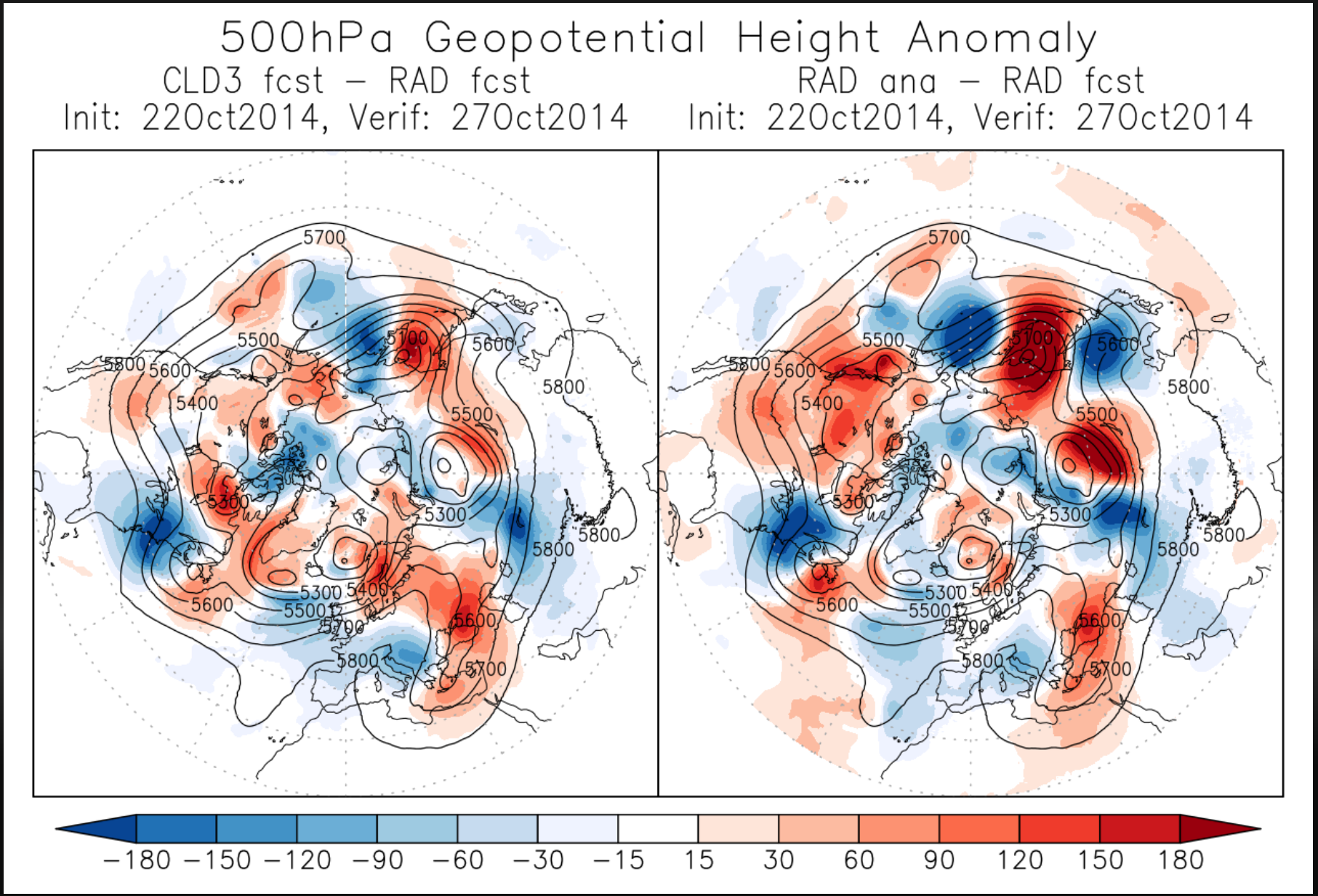

500−mb Heights Northern Hemisphere ExtraTropics
Clear−Sky
Cloud−Cleared
Anomaly Correlation
21SEP 2014
26SEP
1OCT
6OCT
11OCT
16OCT
21OCT
26OCT
1NOV
6NOV



- *Cloud-cleared* minus *clear-sky* forecast geopotential height anomalies
- Much larger differences than when comparing analyses
- Anomalies grow quickly, showing waves that propagate to the mid-latitudes
- Dipoles are created, associated with weather systems and fronts



- Hovmöller diagram with geopotential height anomaly averaged from 40ºN – 80ºN
- Shaded: *cloud-cleared forecast* minus *clear-sky forecast*
- Contour: *clear-sky analysis* minus *clear-sky forecast*
- Anomalies grow with time
- Changes induced by cloud-clearing attempt to correct the forecast in the direction of the analyses



- 5 day forecast geopotential height anomalies
- All valid 00Z 27 Oct. 2014
- Left: *Cloud-cleared forecast* minus *clear-sky forecast*
- Right: *Clear-sky analysis* minus *Clear-sky forecast*
- Assimilation of CCRs induce anomalies in the direction of the validating analysis

Summary

- Assimilation of cloud-cleared radiances provides information in cloudy regions, which can be very important in Arctic region where conventional observations are sparse and low-level stratus clouds are common
- Assimilation of CCR produces a strong negative lower tropospheric temperature anomaly
- As a consequence of the negative low-tropospheric temperature anomaly, mid-and upper-tropospheric geopotential is subjected to hydrostatic adjustment
- Height anomalies propagate to the mid-latitudes, amplifying in the forecasts of waves
- Due to information in cloudy regions, individual forecasts are benefitted when cloud-cleared radiances are assimilated, which leads to an overall improvement of forecast skill

- Next step is to examine the impact of cloud-cleared AIRS AND cloud-cleared CrIS data

Acknowledgements

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