GESTAR

Impact of assimilating AIRS cloud-cleared radiances on the analysis and forecast of Polar Lows

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Introduction

Previous work by this team (Reale et al. 2018) has found that the current assimilation of AIRS radiances on a regularly spaced thinning grid is suboptimal, probably because of horizontal error correlation over meteorologically inactive areas. Moreover, cloud-cleared radiances appear to be a better product than clear-sky radiances, but need to be assimilated at a much lower density globally, because of the higher information content. Specifically:

1. Assimilation of AIRS cloud-cleared radiances at a density of about one quarter of the clear-sky radiances improves global forecast skill
2. An adaptive thinning strategy assimilating cloud-cleared radiances at reduced density globally except around tropical cyclones (TCs), leads to substantial improvement in the structure and intensity forecast of TCs without damaging global skill.

Model and Experiment Setup

All experiments are performed with the NASA Goddard Earth Observing System data assimilation & forecast system, version 5 (GEOS-5 DAS version 5-13.0p1) at approximately quarter degree resolution.

RAD: Control experiment with all observations assimilated operationally, without vortex relocator. Assimilation of AIRS **clear-sky radiances at 145km** thinning density, as done operationally at NCEP.

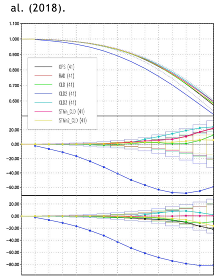
OPS: as RAD, but with vortex relocated (operational GMAO version in 2014)

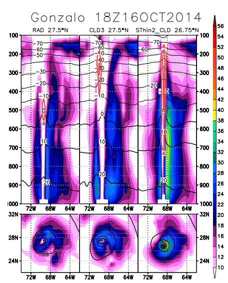
CLD: OSE with assimilation of AIRS **cloud-cleared radiances** at **145km** thinning density (same as RAD).

CLD3: OSE with assimilation of AIRS **cloud-cleared radiances** at **300km** thinning density (one-quarter coverage as RAD).

SThin2_CLD: OSE with adaptive thinning, assimilating AIRS cloud-cleared radiances at 145km inside a 15°x15° box centered around TCs, and at 300km globally.

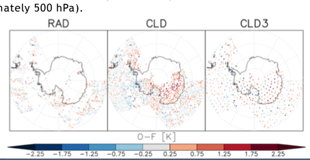
Plot: Global anomaly correlation and forecast skill as a function of time, showing improved global skill for CLD3 experiment. Forecasts initialized from 21 Sep to 31 Oct 2014 (41 7-day forecasts, 500hPa height). Figure from Reale et al. (2018).
Cross-section: Zonal cross-section of analyzed windspeed (m.s^{-1}, shaded), temperature (°C, black), and temperature anomaly (°C, red) showing improved structure of Hurricane Gonzalo (1800 UTC 16 Oct 2014) in SThin2_CLD experiment .
Map: 850hPa windspeed (m.s^{-1}, shaded) and SLP (hPa, black). Figures from Reale et al. (2018).



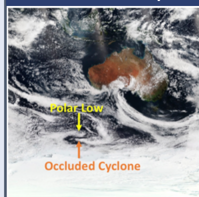


In this study, we investigate the impact of assimilating AIRS cloud-cleared radiances on the analysis and forecast of high-latitude convective systems, viz. polar lows. Polar lows are warm core mesocyclones that form in a cold environment within a large-scale occluded system, occurring poleward of the jet stream and over open ocean. Here, we compare the representation of two polar lows in RAD, CLD, and CLD3 experiments.

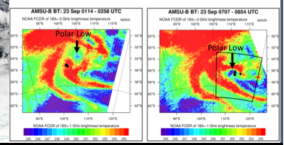
Map: Coverage of AIRS radiances for each experiment showing locations of observations at the time of assimilation (06z 23 Sep 2014). Shading represents "Observation minus Forecast" brightness temperature differences (K) for channel 215 (approximately 500 hPa).



23 Sep 2014 Antarctic Polar Low

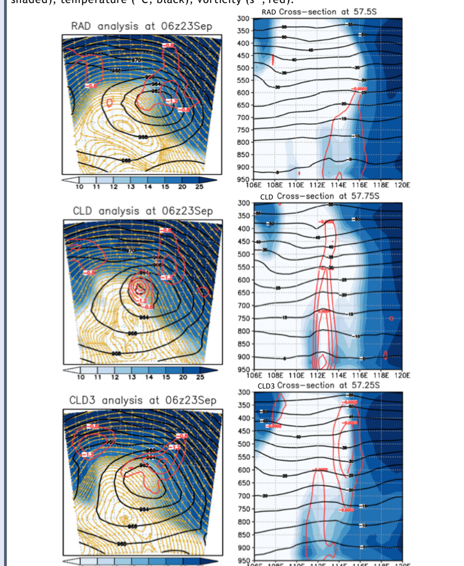


Map: Polar Low identified by brightness temperature depression in an occluded cyclone. Domain for model analyses (black polygon).



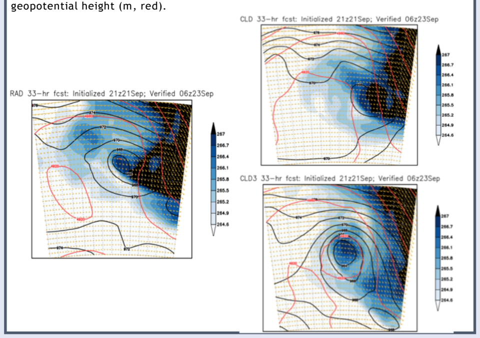
Representation in GEOS5 analysis

Map: 300 hPa windspeed (m.s^{-1},shaded), streamlines (yellow), SLP (hPa,black), vertically integrated vorticity (kg.m^{-2}.s^{-1},red). **Cross-section:** Windspeed (m.s^{-1}, shaded), temperature (°C, black), vorticity (s^{-1}, red).

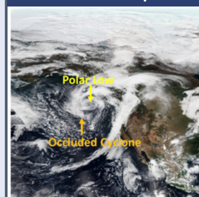


Representation in GEOS5 forecasts

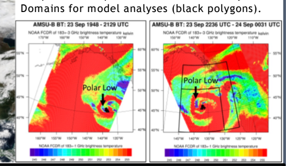
Map: 850mb temperature (K, shaded), wind vectors (yellow), SLP (hPa, black),500mb geopotential height (m, red).



24 Sep 2014 Gulf of Alaska Polar Low

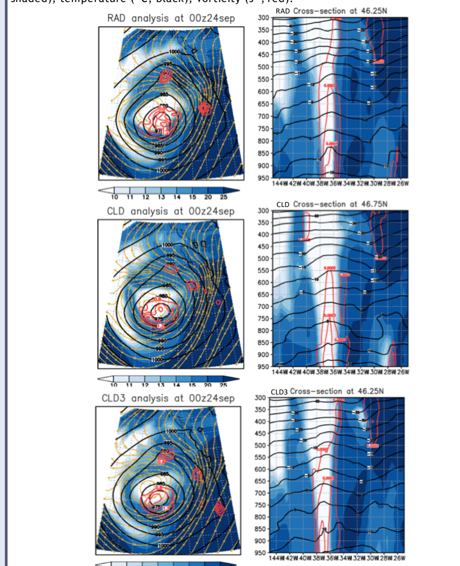


Map: Polar Low identified by brightness temperature depression in an occluded cyclone. Domains for model analyses (black polygons).



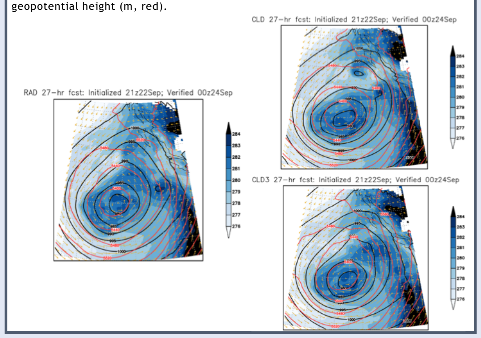
Representation in GEOS5 analysis

Map: 300 hPa windspeed (m.s^{-1},shaded), streamlines (yellow), SLP (hPa,black), vertically integrated vorticity (kg.m^{-2}.s^{-1},red). **Cross-section:** Windspeed (m.s^{-1}, shaded), temperature (°C, black), vorticity (s^{-1}, red).



Representation in GEOS5 forecasts

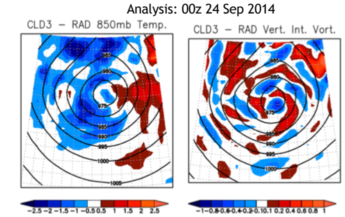
Map: 850mb temperature (K, shaded), wind vectors (yellow), SLP (hPa, black),500mb geopotential height (m, red).



Differences between CLD3 and RAD

Map (L):CLD3 minus RAD 850mb analyzed temperature anomalies (K, shaded) and SLP (hPa, black) showing cold anomalies over the occluded front and polar low, and warm anomalies in the clear region (see inner domain in corresponding satellite image).
MAP (R): CLD3 minus RAD vertically integrated vorticity anomalies (kg.m^{-2}.s^{-1}, shaded) and SLP (hPa, black) showing banded structure around the polar low.

Analysis: 00z 24 Sep 2014



Results and Discussions

- **Representation of Antarctic Polar Low (06z 23 Sep 2014):**
Assimilation of cloud-cleared radiances produces a more sophisticated analyzed structure and intensity of the polar low improving the realism of warm core representation, windspeed, and vorticity structure, and center pressure depth. The CLD experiment produces the best analyzed representation of the polar low. The occluded cold front is more clearly represented in the 33-hr forecast of CLD3, compared to RAD and CLD.

- **Representation of Gulf of Alaska Polar Low (00z 24 Sep 2014):**
The structure (vorticity, warm core) and intensity (min. SLP) of the polar low are better represented in RAD and CLD3, compared to CLD. Significant CLD3 minus RAD 850mb temperature anomalies are observed in the form of cold (warm) anomalies in cloudy (clear) regions. The CLD3 minus RAD vertically integrated vorticity anomalies reveal a banded structure confirmed by satellite imagery.

Conclusions and Future Work

- Previous work by this team has found that the assimilation of cloud-cleared infrared radiances that are adaptively thinned (with higher density around TCs) can benefit the forecast of tropical cyclones. Following these results, we expect to see similar improvements for polar lows.
- An adaptive thinning methodology for polar lows is being developed, and the use of brightness temperatures is being considered for obtaining Best Track information (analogous to TC vitals) that can allow denser assimilation of cloud-cleared radiances around polar lows.
- We find that assimilating AIRS cloud-cleared radiances already improves effectively the analyses of polar lows, but there is work to be done in order to improve the forecasts.
- Apart from developing a suitable adaptive thinning framework, future work will also investigate the impact of assimilating cloud-cleared radiances from additional hyperspectral instruments (IASI, CrIS) on the forecast of polar lows.

Acknowledgements

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- Dr. Ramesh Kakar for past support through previous grants NNX11AK05G and NNX14AK19G "Using AIRS data to understand processes affecting Tropical Cyclone structure in a Global Data Assimilation and Forecasting Framework"(2011-2014, 2014-2018), (PI: O. Reale).

Reference

Reale, O., McGrath-Spangler, E. L., McCarty, W., Holdaway, D., & Gelaro, R. (2018). Impact of adaptively thinned AIRS cloud-cleared radiances on tropical cyclone representation in a global data assimilation and forecast system. *Weather and Forecasting*, (2018).