IMPACT OF ASSIMILATING COSMIC REFRACTIVITY PROFILES ON POLAR WRF FORECASTS OF SYNOPTIC-Scale CYCLONES OVER WEST ANTARCTICA

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Outline

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- Assimilation strategy for case study
- WRFDA and GPS RO in Polar WRF
- GPS RO Statistics over Antarctica
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INTRODUCTION

- Polar WRF is used in real-time numerical weather prediction in Antarctica in support of USAP
- Applications of Polar WRF in Antarctica faces significant challenges. Data needed for accurate initial and lateral boundary conditions are limited.
- Data from the FORMOSAT-3/COSMIC (F3C) project can provide high vertical resolution measurements of the Antarctic atmosphere.
- WRFDA v3.1.1 from NCAR allows the assimilation of RO refractivity profiles in the initial fields and lateral boundaries for Polar WRF forecasts
- We use WRFDA together with Polar WRF to assess the impact of using GPS RO data in simulations of synoptic cyclones over WAIS
SYNOPTIC CYCLONES IN THE DOMAIN

Synoptic-scale cyclones which penetrate low-lying areas of the West Antarctic Ice Sheet (WAIS) significantly impact the ice-sheet mass balance.

Strong winds associated with these cyclones affect the safety of aircraft taking part in USAP operations.

Improving the ability of Polar WRF to predict such cyclogenesis events is a major objective of this NASA funded project.

The causal mechanisms are not fully understood because of lack of data.
On October 4, 2007, a synoptic scale cyclone (shown here after 2 days) moved into the Ross Ice Shelf and crossed West Antarctic Ice Sheet (WAIS).

As it crossed WAIS, cyclogenesis occurred near the main hub of USAP operations at McMurdo on October 8, 2007.

This case is used in this study to test the ability of Polar WRF to simulate cyclogenesis and also assess the potential benefit of using GPS RO data in West Antarctica.
The station distribution over Antarctica is very uneven and not all stations report continuously; Most are coastal, along steep terrain (top left)

No observations in the Southern Ocean in areas of cyclogenesis; GPS RO most valuable in such areas

Choice of physics and other settings represent a well tested configuration
GPS RO ASSIMILATION STRATEGY

- Specify sea ice using National Snow Ice data Center data from the bootstrap algorithm (SMMR and SMM/I)

- Specify elevation using Radarsat Antarctic Mapping Project Digital Elevation Model (RAMP-DEM; Lui et al. 2001) at 1 km

- Specify SST using real-time, global, sea surface temperature analyses from NCEP

- Use National Centers for Environmental Prediction Global Forecast System (Final) global gridded analysis archive as first guess

- Use the WRF Data Assimilation (WRFDA) System with 3DVAR to assimilate GPS RO data to update the first guess fields above in cycling runs (the first forecast provides input for the following run) every three hours.

- Use the a case study to perform simulations in which the initial conditions and lateral boundaries are updated with (a) Conventional synoptic data alone (b) GPS RO alone and (c) GPS RO plus Conventional synoptic data

- Compare statistics from the three simulations
ASSIMILATION STATISTICS

- There are at least 20 Observation types that can be assimilated using WRFDA.
- Less than 2000 out of a global total >7000 measurements fall within the Antarctic domain in any given assimilation cycle.
- There are time periods with no GPS refractivity within the domain.
- SSMI retrievals are used in all runs.
- The impact of Conventional data dominates the GPS RO; Extra experiments with cycling for longer periods are necessary to bracket the contribution of GPS ALONE.

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Number of GPS RO measurements

Time (Hours: Since Oct 1 0000 UTC)
Averaged (Oct. 3 to Oct. 10, 2007) surface air (2m) temperature differences—(GPS RO + CONV. data in PREPBURF) minus CONV only

The impact of GPS RO is much smaller on the 2m air temperature when the PREPBURF data is included; This suggests that the contribution from GPS data is small.

Assimilation of GPS RO results in colder (up to 3 K) surface air temperatures compared to conventional synoptic data alone in parts of west Antarctica.

Warmer air temperatures occur elsewhere

The area of colder temperatures coincides with location of the synoptic-scale cyclone and stations on the Ross Ice Shelf.

The differences in temperatures are most likely due to assimilation of synoptic data from stations on/or near the Ross Ice Shelf.
Using GPS RO data alone in the WRFDA assimilation results in slightly lower surface pressure average over WAIS (approx. by orange box –right panel); Consistent with temperature assimilating GPS RO results in lower surface pressure.

Both simulations show very similar locations (right panel; instantaneous example for the cyclones at 700 hPa.
Differences averaged over duration of cyclone (Oct. 3-Oct. 10, 2007) in 700 hPa height are generally negative. (Blank – 700 hPa below sfc)

Heights simulated with assimilation of both GPS and Conventional data are lower than Conventional data alone

The lower heights are consistent with the surface pressure; may deepen the synoptic cyclone
GPS RO data can be assimilated in Polar WRF using WRFDA.

The preliminary results show that use of GPS RO has modest impacts on the synoptic cyclone simulated in this case study. However, the cycling period needs to be substantially extended.

Surface pressures (and 700hPa heights) resulting from assimilation of GPS refractivity have large spatial variability but are generally lower.

These results are very preliminary, and lots more research is needed.
Assimilation of COSMIC GPS RO Data for An Explosive Cyclone over the Antarctic: Some Preliminary Results

Bill Kuo and Na Liu, UCAR
Dave Bromwich, OSU
An explosive cyclone (1 mb per hour deepening for at least 24h) took place over Southern Ocean on 10-12 December 2007.

The prediction of the storm is sensitive to initial conditions. WRF experiments with different initialization times produced different forecasts.

This study examines the impact of COSMIC GPS RO data on the prediction of this explosive cyclone.
Comparison of the track between FNL and WRF simulations (three different initial times)

Initialized at 00 UTC 9 Dec.

Significant different track predictions for WRF experiments started at different initial times.
Central Pressure Varies with time

Red symbols denote the deepening rate are greater than 1 Bergeron

00 Z 9 Dec initialization
FNL Forecast 0900
FNL Forecast 1000
3DVAR – GPS ONLY
Data assimilation for 1 day with 6hr cycling
3DVAR – GPS ONLY Cycle
COSMIC GPS Data
Distribution From Dec 9 to Dec 16

COSMIC GPS Data
Distribution over 6-h, from 21Z 9 – 03 Z10 Dec 2007

COSMIC GPS Data
Distribution over one day, from 00 UTC 9 – 10 Dec 2007
Comparison of the track between FNL, WRF simulations and WRF 3DVAR

Red symbols denote the deepening rate are greater than 1 Bergeron

Central Pressure Varies with time
Assimilation of GPS RO data helps improve the forecast (initialized at 00 Z 9 December 2007).
Different assimilation strategies (cycling or not) have significant influence on the results.
The more data are assimilated, the more impact GPS RO has on the cyclone prediction.
Additional experiments and further studies are needed to fully explore the impact of GPS RO data on Antarctic weather prediction.
FUTURE STUDIES

- Use ensemble Kalman filter data assimilation (EnKF) system for assimilation of GPS RO data.
- Examine the modification to temperature, moisture, and wind fields due to assimilation of GPS RO data.
- Study how GPS RO data improve the prediction of cyclogenesis over the Antarctic.