Impact of CYGNSS Data on Tropical Cyclone Analyses and Forecasts in a Regional OSSE Framework

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Motivation

• *Inform* the design of orbit and data collection strategies prior to launch of new instrument

• *Prepare* data assimilation systems to handle real data after launch in an optimal way

• CYGNSS is a new and unique platform well-suited for observing the surface wind field of tropical cyclones
What is CYGNSS?

- The Cyclone Global Navigation Satellite System is a constellation of 8 micro-satellites scheduled for launch in October 2016... a NASA Earth Venture Mission
- Utilize signals from existing GPS satellites to measure ocean surface wind speeds (surface roughness affects forward-scattered signal)
What is CYGNSS?

- Capable of retrieving usable data over a large range of wind speeds (0-70 m/s) in all precipitating conditions throughout the tropics and subtropics with frequent revisit times (~2-6 hours)

A hurricane over the western Atlantic Ocean is well-sampled in this simulation of orbits during a 6-hour time window. Colors indicate wind speed.
Osse Framework

- Regional Hurricane OSSE (Observing System Simulation Experiment) framework developed at NOAA/AOML
- A robust, realistic, vetted nature run is the foundation and “truth”
  - High-resolution regional nature run (1-km inner domain) embedded within lower-resolution global nature run.
- Simulated observations from a variety of instruments/platforms are generated and provided to a data assimilation scheme which provides an analysis to a regional forecast model.
Hurricane OSSE Framework Details

- **Nature Runs**
  - **Global**
    - ECMWF: low-resolution (~40km) “Joint OSSE Nature Run”
  - **Regional (North Atlantic)**
    - WRF-ARW: high-resolution (27-km) regional domain, 9/3/1-km nests (v3.2.1)
- **Data Assimilation Scheme**
  - **GSI**: Gridpoint Statistical Interpolation… a standard 3D variational assimilation scheme (v3.3). Analyses performed on 9-km grid.
- **Forecast Model**
  - **HWRF**: the 2014 ‘operational’ Hurricane-WRF model (v3.5). Parent domain has 9-km resolution, single storm-following nest has 3-km resolution.

- For results shown here, DA cycling performed every 6/3/1 hours, forecast model run every 6 hours (each run producing a 5-day forecast)
- There are a total of 16 runs, but first 4 model runs omitted from verification to allow for model spin-up (12 total cases)
Overview of Experiments

• Nominal CYGNSS wind speeds
• Direction information added to CYGNSS wind speeds using 2D Variational Analysis Method (VAM)
  • VAM creates gridded wind analysis by minimizing an objective function which measures the misfit of the analysis to the background, the data, and a priori constraints… the analyzed dynamical balance must be close to that of the background (GFS global model in our case)
  • Used for 30+ years to create high-quality ocean surface wind datasets
• Vary data assimilation cycling frequency
• Results shown include: 0-5 day average error of minimum central pressure, maximum surface wind, and track from a single tropical cyclone in the nature run
Experiments

- **CONTROL**: conventional satellite/surface/sounding data, no CYGNSS
- **CYG SPD**: C + CYGNSS wind speeds, no direction; nominal CYGNSS product
- **VAM VEC**: C + VAM wind vectors at CYGNSS retrieval coordinates
6-hourly DA Cycling

MIN PRESSURE (Average Error)

MAX WIND (Average Error)

TRACK (Average Error)

- **CONTROL 6HR**
- **CYG_SPD 6HR**
- **VAM_VEC 6HR**
3-hourly DA Cycling

MIN PRESSURE (Average Error)

MAX WIND (Average Error)

TRACK (Average Error)

- **CONTROL 3HR**
- **CYG_SPD 3HR**
- **VAM_VEC 3HR**
1-hourly DA Cycling

MIN PRESSURE (Average Error)

MAX WIND (Average Error)

TRACK (Average Error)

- **CONTROL 1HR**
- **CYG_SPD 1HR**
- **VAM_VEC 1HR**

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6 HOURLY: observations binned into 6-hour windows (cycle time +/- 3 hours), DA performed every 6 hours, 5-day forecasts produced every 6 hours

3 HOURLY: observations binned into 3-hour windows (cycle time +/- 1.5 hours), DA performed every 3 hours, 5-day forecasts produced every 6 hours

1 HOURLY: observations binned into 1-hour windows (cycle time +/- 0.5 hours), DA performed every hour, 5-day forecasts produced every 6 hours
CONTROL

MIN PRESSURE (Average Error)

MAX WIND (Average Error)

TRACK (Average Error)

- CONTROL 6HRL
- CONTROL 3HRL
- CONTROL HRL

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MIN PRESSURE (Average Error)

Error (hPa)

0 10 20 30

0 12 24 36 48 60 72 84 96 108 120

Forecast Hour

CYG SPD 6HRL
CYG SPD 3HRL
CYG SPD HRL

MAX WIND (Average Error)

Error (kt)

0 10 20 30

0 12 24 36 48 60 72 84 96 108 120

Forecast Hour

TRACK (Average Error)

Error (km)

0 100 200 300 400 500 600

0 12 24 36 48 60 72 84 96 108 120

Forecast Hour
Results

- **Analysis of TC intensity** (pressure, wind) improved with addition of CYGNSS data at any cycling frequency
  - greatest improvement from 3-hourly cycling with VAM_VEC data

- **Forecasts of TC intensity** improved, though lead time varies with DA cycling frequency
  - 6-hourly cycling benefits extend ~0-24 hr, 1-hourly cycling benefits extend ~0-36 hr, 3-hourly cycling benefits extend out to 5 days in many cases
  - 3-hourly seems optimal… data too washed out in time with 6-hourly?, insufficient volume of data or model “spin-up” time with 1-hourly?

- **Track at 0-24 hr** very slightly improved with addition of CYGNSS data
  - CYGNSS impacts on track forecasts are small and typically gone by ~24h… they are only surface winds, and a small fraction of all assimilated observations
General Conclusions

• Assimilation of CYGNSS data with GSI almost always improves hurricane intensity and track analyses and short-range forecasts

• Processing retrieved CYGNSS wind speed data with VAM to get vectors generally produces better analyses and forecasts

• DA cycling frequency affects quality of analyses (1hr too short, 6hr too long, 3hr just right?)

• We have relatively few samples from one storm, so error statistics are not robust, but provide guidance
Questions?

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- Upcoming CYGNSS presentations:
  - Maria-Paola Clarizia, Wednesday 11:15am
  - Chris Ruf, Thursday 1:45pm

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