Impact of CYGNSS Data Assimilation on Tropical Cyclone Forecasts in August 2017

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Research goals

1. Conduct preliminary attempt to assimilate CYGNSS data in global data assimilation and forecasting system

2. Assess the output of a month-long Observing System Experiment
   - Assimilation statistics
   - Impact on tropical cyclone track and maximum wind speed forecasts
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Why use CYGNSS to observe tropical cyclones?

**Cyclone Global Navigation Satellite System**

- Derives surface wind speed over oceans using reflected GPS signals – signal penetrates clouds and precipitation

- Offers access to poorly observed near-TC environment

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Hurricane Michael – Mexico Beach, FL  
Courtesy: NY Times

Hurricane Harvey – Port Arthur, TX  
Courtesy: US Air National Guard
CYGNSS Impact Experiment

- Month-long global experiment 1-31 August 2017
  - 1-14 August spin-up; 15-31 August for impact study
  - week-long forecast at 00Z during impact study
  - Analysis cycling 4x per day

- GDAS/GFS experimental system (version FY17q3)
  - Global Data Assimilation System (T254)
  - Hybrid 4D-EnVar Gridpoint Statistical Interpolation (GSI) – 6 hr assimilation window
  - Global Forecast System (T670)

- Two tests: CTL and CYG

- Best track databases: HURDAT-2 (Atl/E. Pac.) and JTWC (W. Pac.)

- 9 tropical cyclones (Gert, Harvey, Irma, Kenneth, Lidia, Banyan, Hato, Pakhar, Sanyu)
  - 38 TC forecast initializations
How to prepare CYGNSS data for assimilation?

Data Thinning

• A LOT of CYGNSS data in close proximity and want to avoid overfitting to one observation type, thus data thinning

• Ideal to thin through GSI, but initial test acted unexpectedly

• Preprocess the data: 100km specular point thinning

GSI Data Type Processing

• No data processing subroutine specifically for CYGNSS

• Use subroutine for a type of ship wind speed data – assimilated at 20-m (type 283 “spd”)

Observation Errors

• CYGNSS gross error parameters modelled after those of ASCAT (allows o-b of 7-10 m s⁻¹)
**CYGNSS prepbufr files**

- **Young Seas Limited Fetch** near TC
- **Fully Developed Seas** away from TC

FDS

YSLF

\[ r = \text{larger of 111km or } 3x \text{ radius of maximum surface wind} \]

- FDS inside radius and YSLF outside radius “turned off” through qc mark = 10
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![Map showing CYGNSS sampling near Gert](image)

- FDS inside radius and YSLF outside radius “turned off” through qc mark = 10

**Legend**

- FDS
- YSLF

**Equation**

\[ r = \text{larger of 111km or } 3\times \text{radius of maximum surface wind} \]
Young Seas Limited Fetch near TC
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YCNGNSS prepbufr files

r = larger of 111km or 3x radius of maximum surface wind

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**CYGNSS sampling near Gert (16 AUG 12z)**
CYGNSS Assimilation Statistics
CYGNSS Assimilation Statistics

- CYGNSS observations 6K – 10K per cycle
- Rejection rate below 2% for all cycles
- Bias greatly reduced during assim
- Perhaps too much – overfitting?
- RMS reduced from 1.8-2.0 m s$^{-1}$ to 1.2-1.5m s$^{-1}$ during assim
CYGNSS Impact on Tropical Cyclone Forecasts

1. Global
2. Harvey
Global Impacts on Tropical Cyclones (15-31 August 2017)

- Minimal impact on averaged track errors first 108 hr
- Improved track errors after 108 hr
- Significant improvement only at 168 hr (NOTE: only 8 forecasts)

- Minimal impact on averaged wind speed errors at all lead times (+/- 1 kt)
- Small improvements at 48-72 hr, only significant at 66 hr (NOTE: 29 forecasts)
- Small degradations otherwise, only significant at 30 hr (NOTE: 35 forecasts)
Global Impacts on Tropical Cyclones (15-31 August 2017)

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Hurricane Harvey (track & duration)
Hurricane Harvey (track & wind errors)

**Track errors**

- **CTL**
- **CYG**

**Wind errors**

- **CTL**
- **CYG**
Hurricane Harvey Track Maps

24 August 2017 00z

24 AUG

- CYG forecast on 24 AUG slightly closer to Best Tracks on approach to SE Texas
- Both show stall and loop in track

25 August 2017 00z

25 AUG

- Both forecasts much better approaching coastline
- Both loop to the southwest
- Major improvement in CYG track after storm re-emerges into Gulf of Mexico
Hurricane Harvey Forecasts

24 August 2017 00z

Track error (km)
- CTL
- CYG

Wind error (kt)
- CTL
- CYG

25 August 2017 00z

Track error (km)
- CTL
- CYG

Wind error (kt)
- CTL
- CYG
Hurricane Harvey Forecasts

24 August 2017 00z

- Track error (km)
  - CTL:
  - CYG

- Wind error (kt)
  - CTL:
  - CYG

25 August 2017 00z

- Track error (km)
  - CTL:
  - CYG

- Wind error (kt)
  - CTL:
  - CYG
Conclusions and Next Steps

• Successful month-long experiment assimilating CYGNSS data into global modeling system
  • Rejection rate low (<2% for all cycles)
  • Bias (O-A) reduces to very small number at analysis

• Overall globally-averaged impact on TCs neutral

• Hurricane Harvey track notably improved, intensity neutral impact

Next Steps

• Need new subroutine to handle CYGNSS data in GSI (assimilating at 20-m not ideal)

• User-provided error parameters may need updating
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Questions?

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