Utilizing CYGNSS Near Surface Winds to Improve Surface Sensible and Latent Heat Flux Estimates

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Introduction

Extratropical Cyclones (ETCs) play a vital role in Earth's general climate as they transport moisture and energy from the tropical regions poleward, as well as providing a majority of the precipitation observed in the midlatitudes.

While we have a well-defined understanding of ETCs at the synoptic scale, there is still much to learn at the mesoscale, especially surface processes for marine based ETCs. Recent work has highlighted a case study of a marine ETC that exhibited a stratiform-to-convective transition within its warm front (Crespo & Posselt 2016 (hereinafter CP16)|Fig. 1).

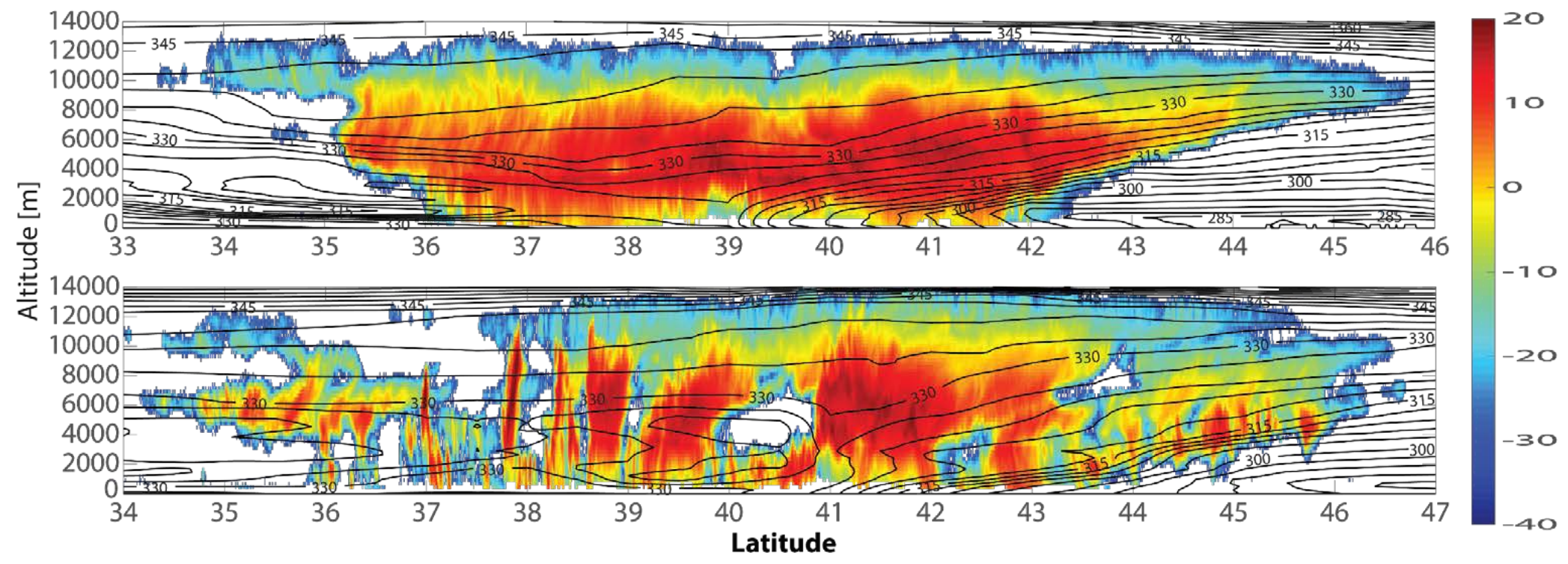

Fig. 1: *CloudSat* Radar Reflectivity (dBZe | colored contours) and Equivalent Potential Temperature (K | lined contours) from ECMWF-AUX at 22 November 2006 around 1800 UTC (top) and 24 November 2006 around 0600 UTC (bottom).

Source: Crespo & Posselt 2016

It was hypothesized that surface processes and surface heat fluxes led to the observed stratiform-to-convective transition seen in Fig. 1. This has motivated our current work and how we could better observe these surface processes with the recently launched CYGNSS satellite constellation.

While CYGNSS's core mission is to better observe and estimate surface winds within tropical cyclones, it will have the ability to observe ETCs developing over the oceans in the lower mid-latitudes. We aim to show that CYGNSS will not only be able to observe ETCs frequently in the lower midlatitudes, but also provide data that is currently not available for ETC analysis.

Data & Methods

MERRA-2 Reanalysis Data

- Use storms in the MAP Climatology of Mid-latitude Storminess (MCMS) database. Fronts are automatically detected in MERRA-2 (Naud et al. 2012) using the periods of 2007-2009 and 2014-2015 (Fig. 2).
- Latent and sensible heat flux analysis (equations below)
  - Hourly, two dimensional diagnostics.
  - 0.625°x0.5° resolution
  - 2006 Nov. 20-25 case study (same days as in CP16) and 2007-2009/2014-2015

QuikSCAT SeaWinds

- Active Microwave Instrument (13.4 GHz)

Simulated CYGNSS Orbits

- End-to-End Simulator (E2ES) for 6-day CP16 case study
- Spacecraft Orbital Characterization Kit (SpOCK) for 1-year orbits

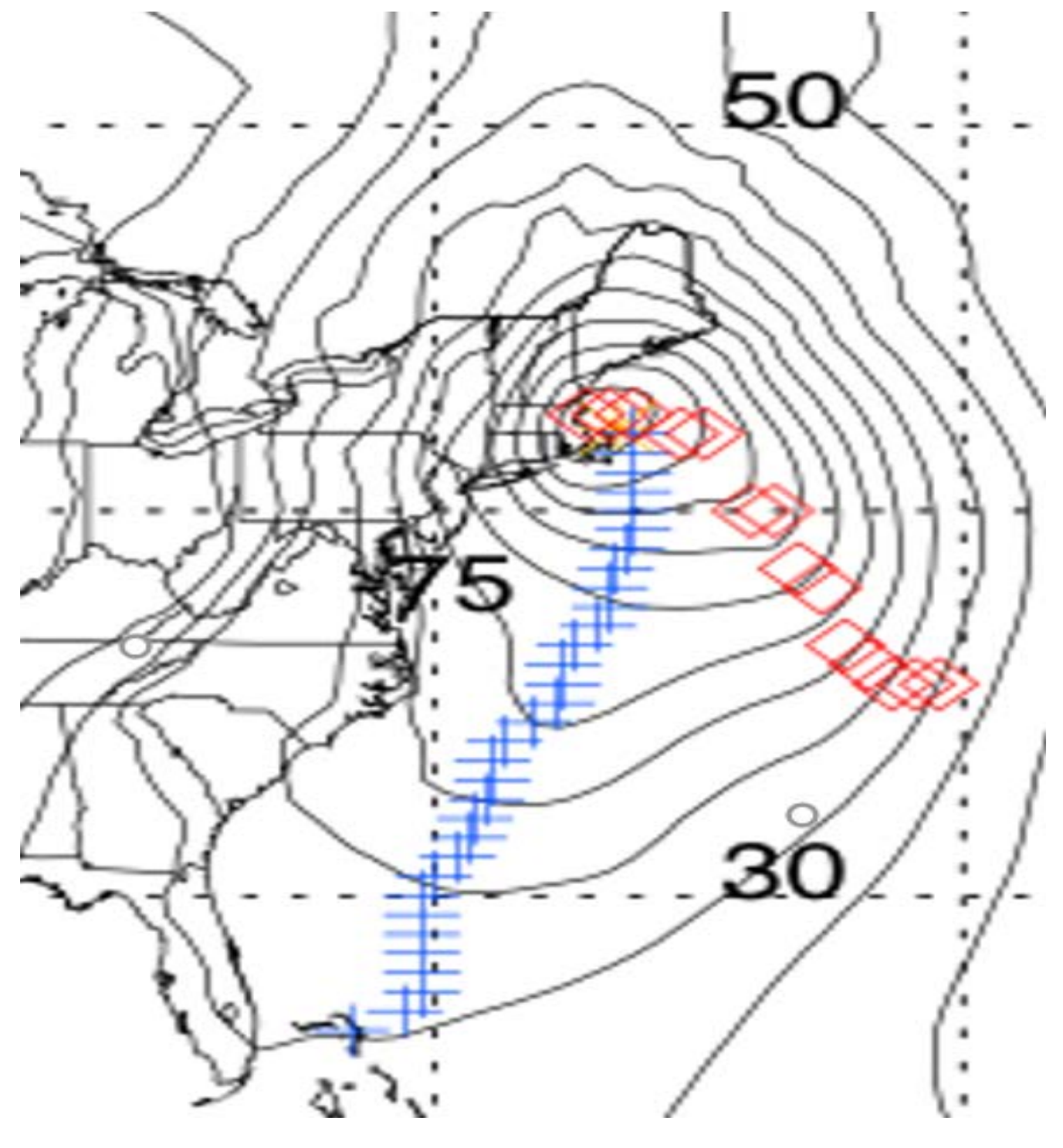

Fig. 2: Illustration of automated cold (blue) and warm (red) front detection.

$$Latent\ Heat\ Flux\ (LHF) = L\rho C_{DE}U(q_s - q_a)$$
$$Sensible\ Heat\ Flux\ (SHF) = c_P\rho C_{DH}U(T_s - T_a)$$

Acknowledgements

We would like to thank Dr. C. Bussy-Virat for providing 1-year simulated CYGNSS orbits from SpOCK and Dr. J. Edson for his assistance and information regarding the COARE 3.5 Algorithm and Surface Heat Flux Calculations.

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Latent and Sensible Heat Fluxes around Extratropical Cyclones

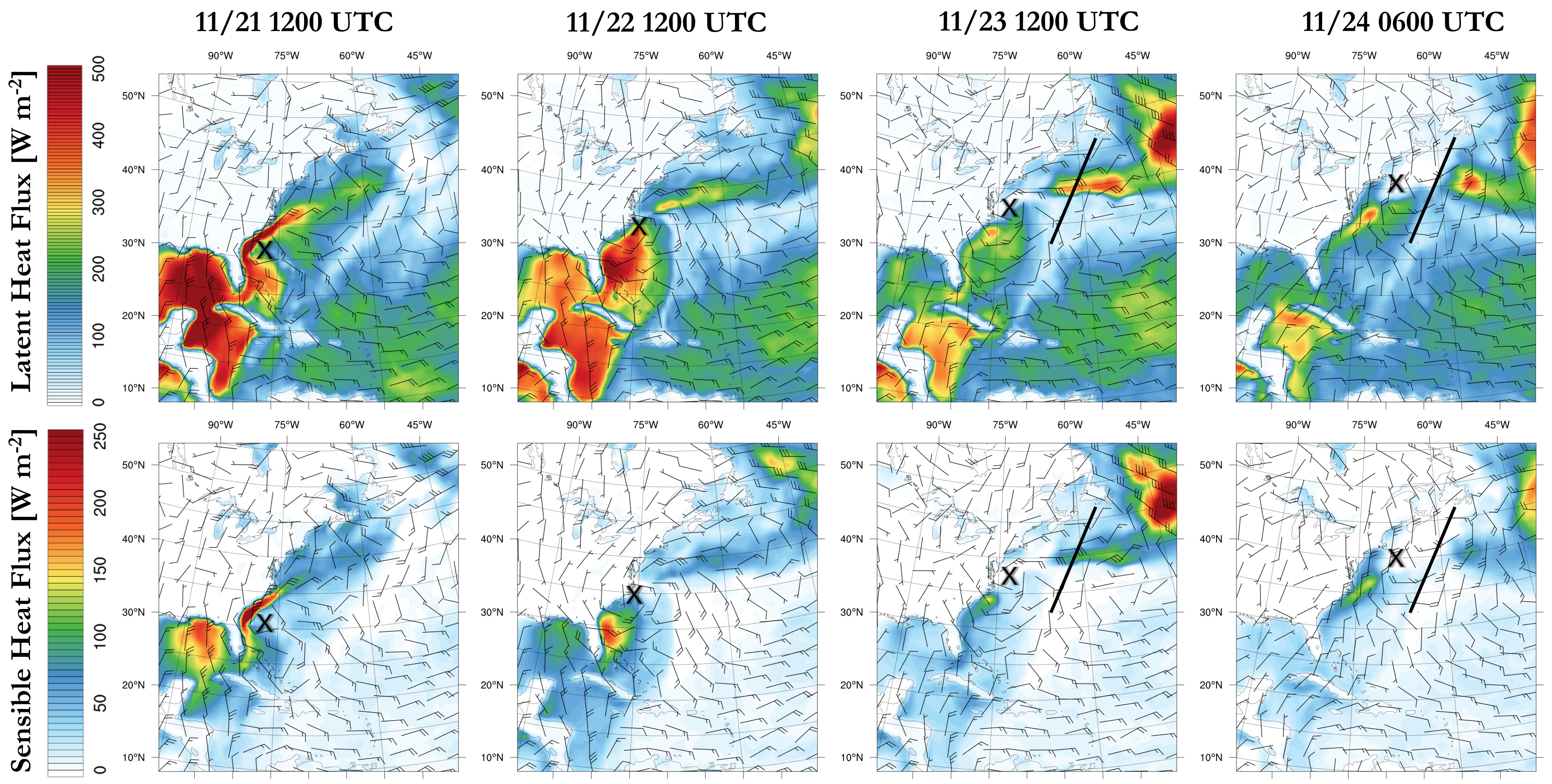

Fig. 3: Latent (top) & sensible (bottom) surface heat fluxes [W m^{-2}] from 21-24 November estimated by MERRA-2. X marks the approximate location of the cyclone center The black line represents the approximate location of the CloudSat observation shown in bottom of Fig. 1.

Large latent and sensible heat fluxes observed immediately off the coast on 21-22 November

- Corresponding to large air-sea differences in temperature and humidity, along with an increase in surface winds
- Values decreased significantly as cyclone center moved poleward on 23 November

Increase in surface latent and sensible heat fluxes on 23 November around 40°N, 60°W

- Increase in surface winds in area contributed to increase in surface fluxes
- Same area where the warm front was observed on 24 November (Fig. 1)
- Possible increase in instability shortly before warm front passage

CYGNSS Sampling of Extratropical Cyclones

November 2006 Case Study (Fig 4):

- CYGNSS simulated specular points cover large portions of the storm, including areas missed by QuikSCAT due to its orbit and attenuation from precipitation
- CYGNSS specular points extend to ~ 43° latitude

One-Year Orbits (Fig. 5):

- Higher frequency of fronts and cyclone observations in W. Atlantic and W. Pacific Oceans
  - Influence of the warm western boundary currents (Kurishio and Gulf Stream) on ETC development
  - ~14,000 specular points/year within 25 km of fronts along Kurishio Current
- Smaller longitudinal variability in S. Hemisphere.
  - Observation frequency maximum ~ 35°-40°

CYGNSS realistically samples winds and surface fluxes across fronts (Fig. 6)

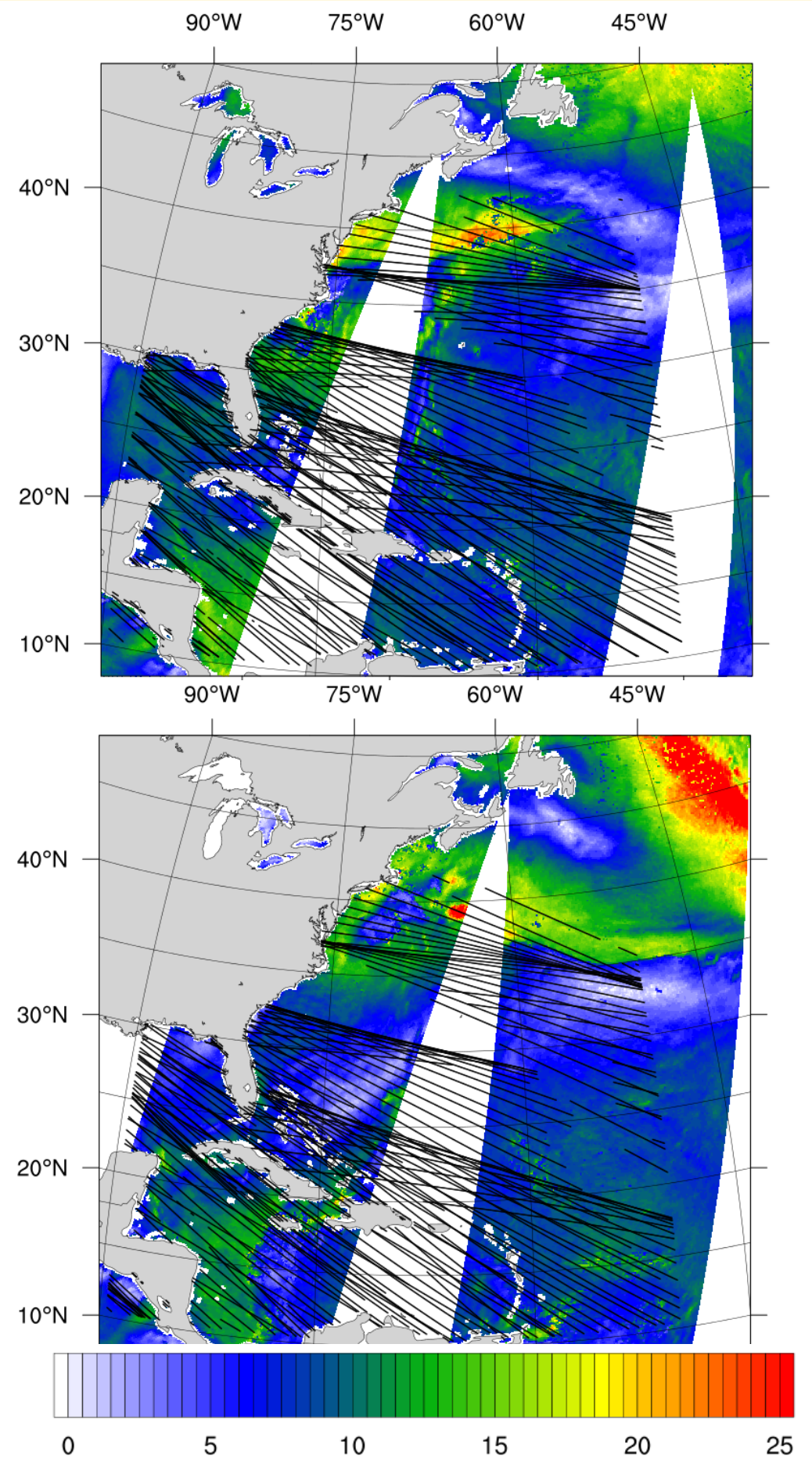

Fig. 4: QuikSCAT surface winds [m s^{-1}] at 2100 UTC on 22 (top) and 23 (bottom) Nov. 2006, overlaid with simulated CYGNSS orbits ±3 hours for respective days and times.

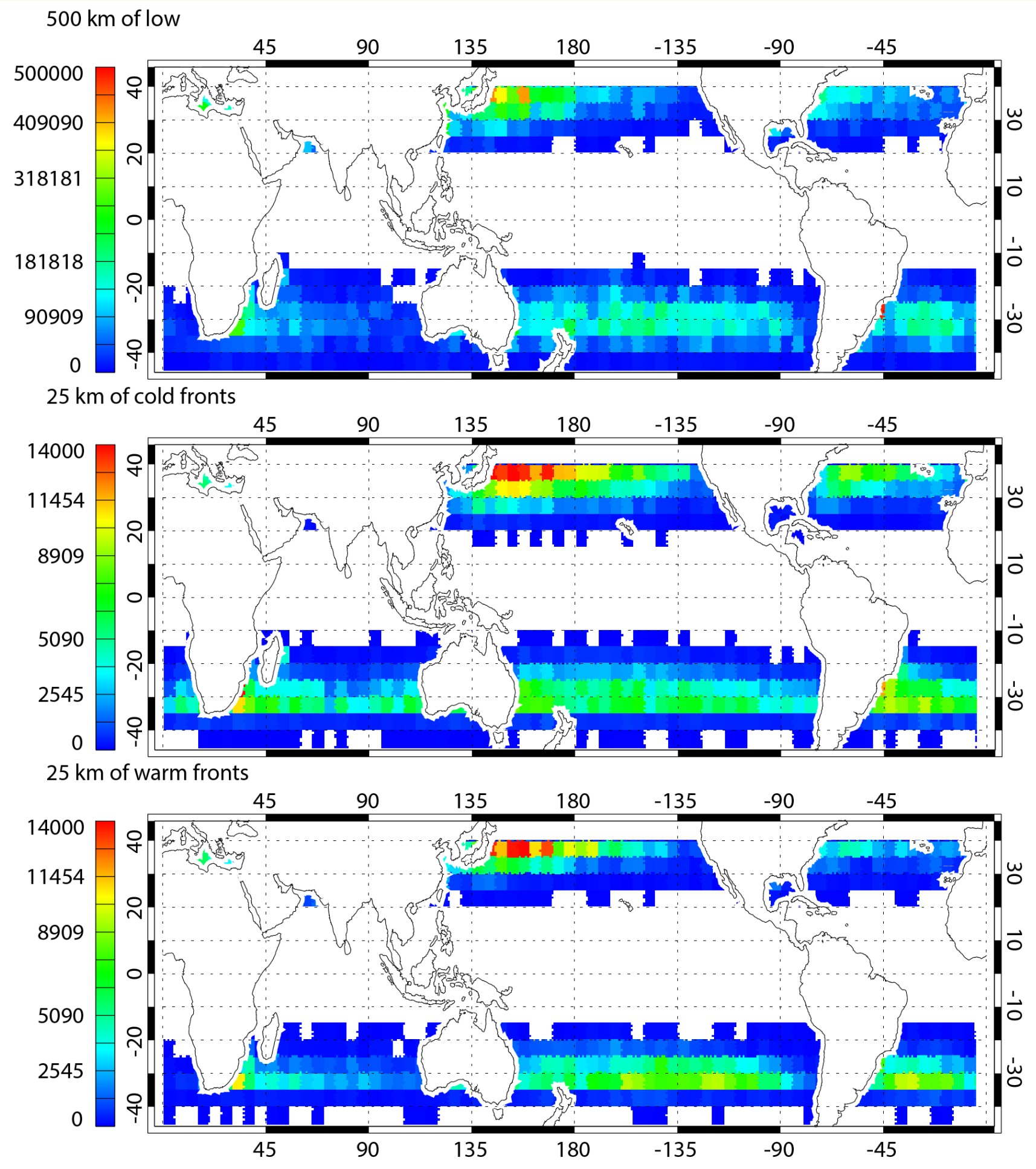

Fig. 5: Frequency of number of simulated specular points within 500 km of a cyclone center (top), and within 25 km of a cold front (middle) and warm front (bottom) expected within a year of CYGNSS's orbit.

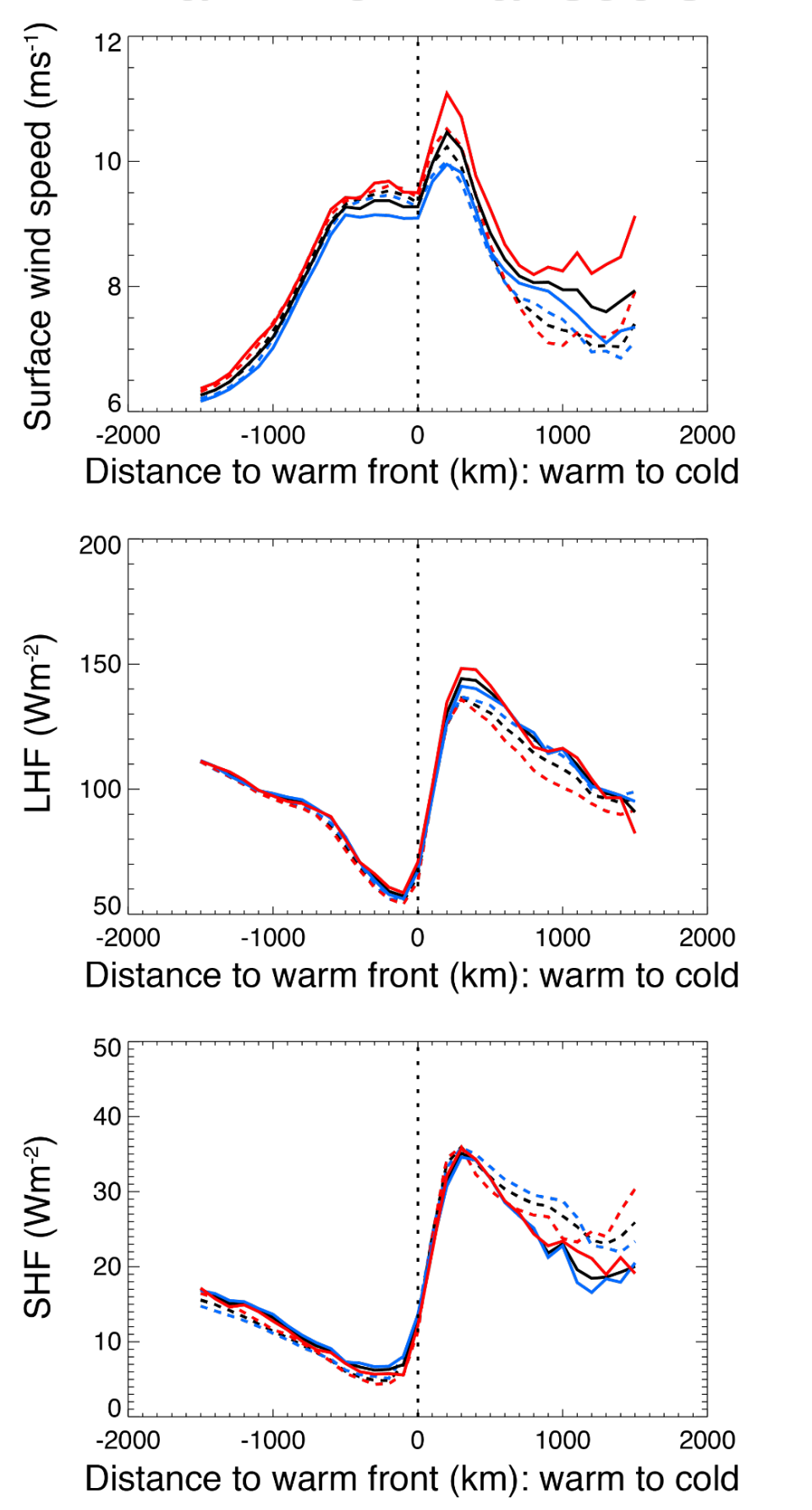

Fig. 6: MERRA-2 (solid) and CYGNSS (dashed) mean wind (top), and latent (middle) and sensible (bottom) heat fluxes for 2014 (blue), 2015 (red), and both (black).

CYGNSS Surface Flux Algorithm and Product

We will utilize the *Coupled Ocean-Atmosphere Response Experiment (COARE) 3.5* Algorithm for future CYGNSS surface flux estimates and eventual product.

- Designed to produce and calculate surface heat flux estimates in turbulent flow over surface waves
- Current COARE 3.5 algorithm validated up to ~25 m/s
- Input thermodynamic variables from GFS and Level-2 Winds from CYGNSS
- Calibration/Validating using buoy data along with clear air satellite measurements from IR and Microwave instruments

Conclusions

Latent and sensible heat fluxes can play a critical role in ETC genesis and evolution, which was highlighted by the CP16 case study.

While we do not know how many ETCs CYGNSS will observe every year, we have shown that, despite its tropical orbit and mission, CYGNSS has the ability to make multiple observations of ETCs forming in the lower midlatitudes in both hemispheres.

With CYGNSS's ability to better estimate surface winds, especially in the presence of precipitation, we can use these estimates to offer better estimates of latent and sensible heat fluxes over the oceans.