



Novel Application of NASA's GEOS-CF CO₂ Forecasting System to ACT-America Airborne Campaign

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Why do we need a real-time CO₂ forecasting product?

- Forecasting CO₂ for field campaigns.
- Given enough observations, forecasts allow for a quick real-time evaluation of known CO₂ sources.
- In theory, CO₂ forecasting products could assimilate CO₂ observations and perform inversions in near real-time. If we want to monitor CO₂ emissions at a policy level, such a step would be imperative.

The Atmospheric Carbon and Transport-America (ACT-America) NASA Campaign



C-130 aircraft.



B-200 aircraft.

- 2 aircraft (C-130 and B-200).
- 3 different regions in the Eastern United States: Gulf, Midwest, and Mid-Atlantic.
- 5 seasonal campaigns (2 summer campaigns) over 2016-2019 time period.
- Main mission goals are:
 1. Quantify and reduce atmospheric transport uncertainties.
 2. Quantify and reduce uncertainties in prior CO₂ and CH₄ flux estimates.

The CO₂ Forecasting Model Used: GEOS-CF

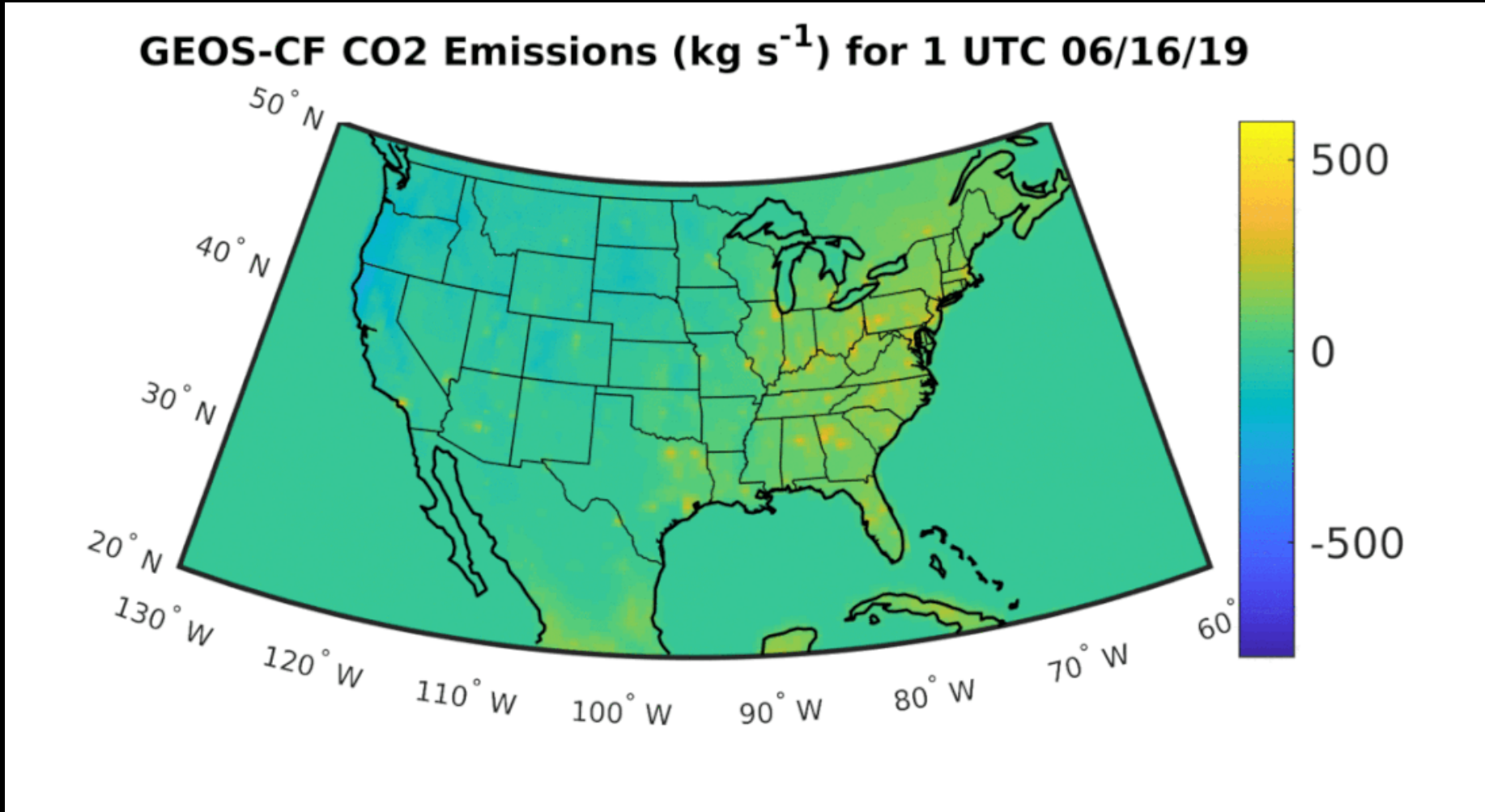
- The model used for ACT-America forecasting operated in two modes: GEOS-Chem and “GOCART”.
- GEOS-Chem operated in online mode providing CO and C₂H₆.
- “GOCART” simplified processes to generate CO and CO₂ forecasts.
- Meteorology was simulated with GEOS FP-IT.
- Resolution was 0.25 x 0.25 (~25 km).

CO₂ from "GOCART"

- Near real-time CO₂ from GOCART (LoFi – Low-order Flux Inversion) is derived from several retrospective flux components.
- LoFi flux package adjusts land and ocean sinks to match global observed CO₂ growth rates.

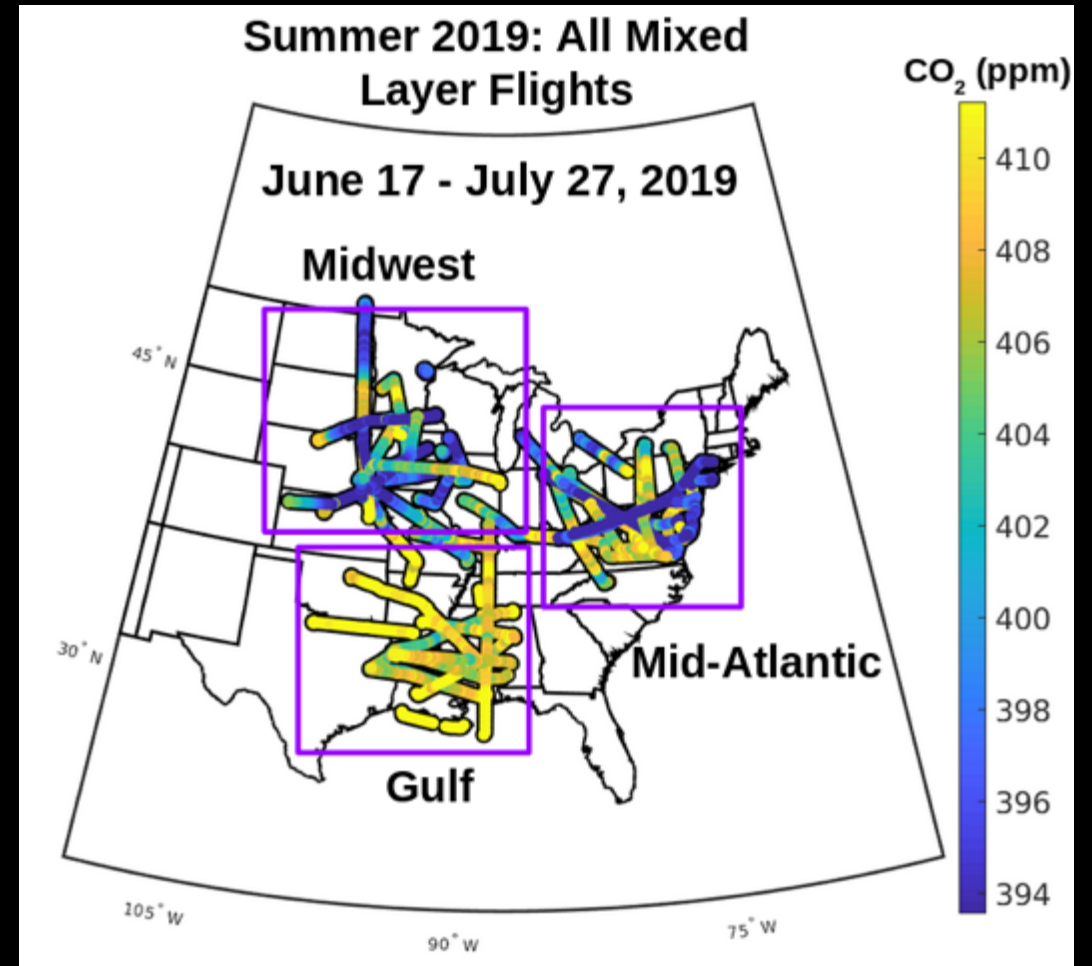
Flux Type	Method
NEE (Net Ecosystem Exchange) & Biofuel	LoFi CASA
Biomass Burning	QFED
Fossil Fuel	ODIAC
Ocean	LoFi Extension to Takahashi Climatology

Simulated CO₂ Flux



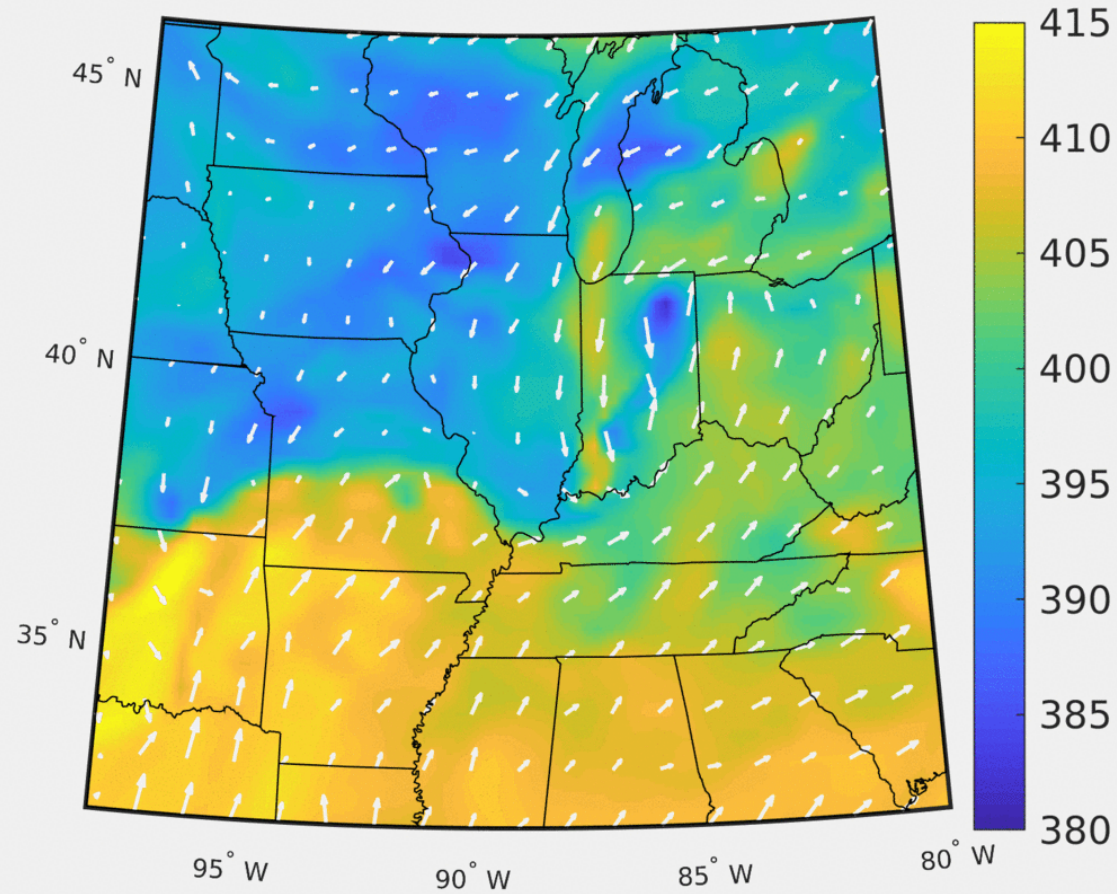
Forecasting for ACT-America Summer 2019 Campaign

- CO₂ forecasting was experimented with extensively only in 2019 summer campaign.
- The main goal was to help plan research flights.
- Forecasts were used to point out areas of CO₂ gradients.
- Studying these gradients with specific model studies could help better understand the uncertainty of modeled CO₂ due to errors in transport.



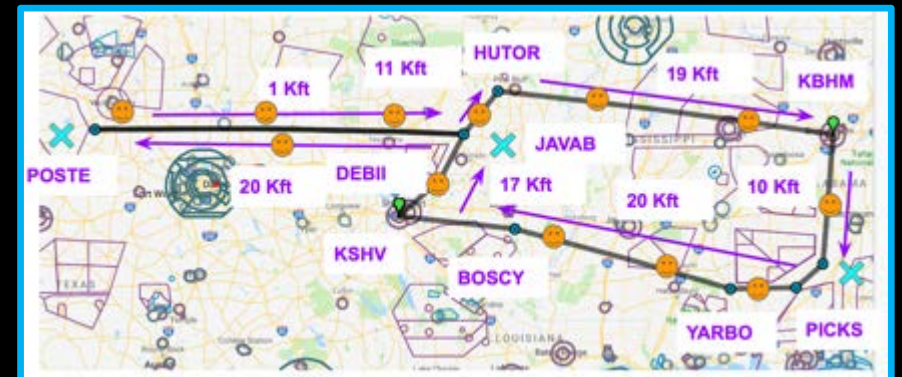
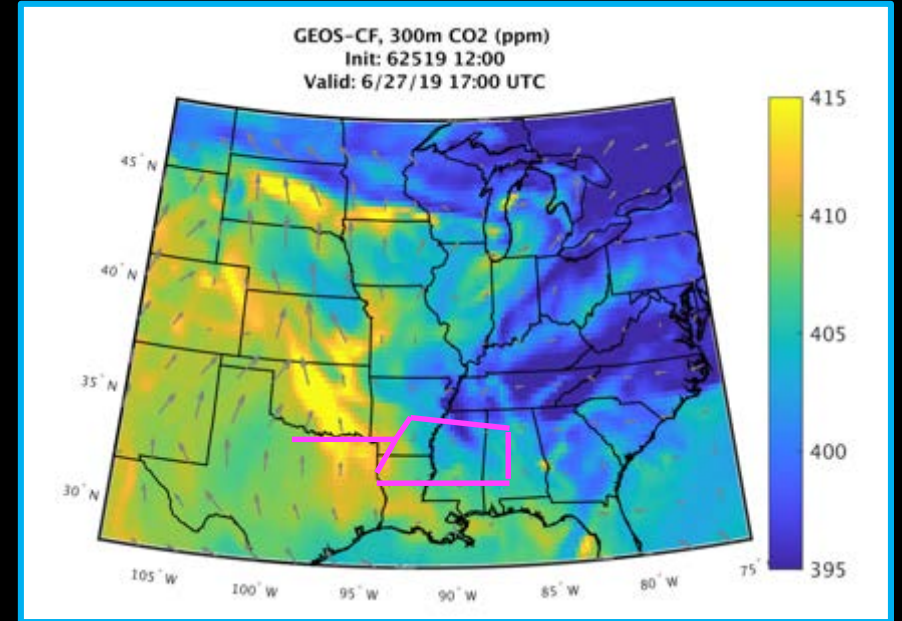
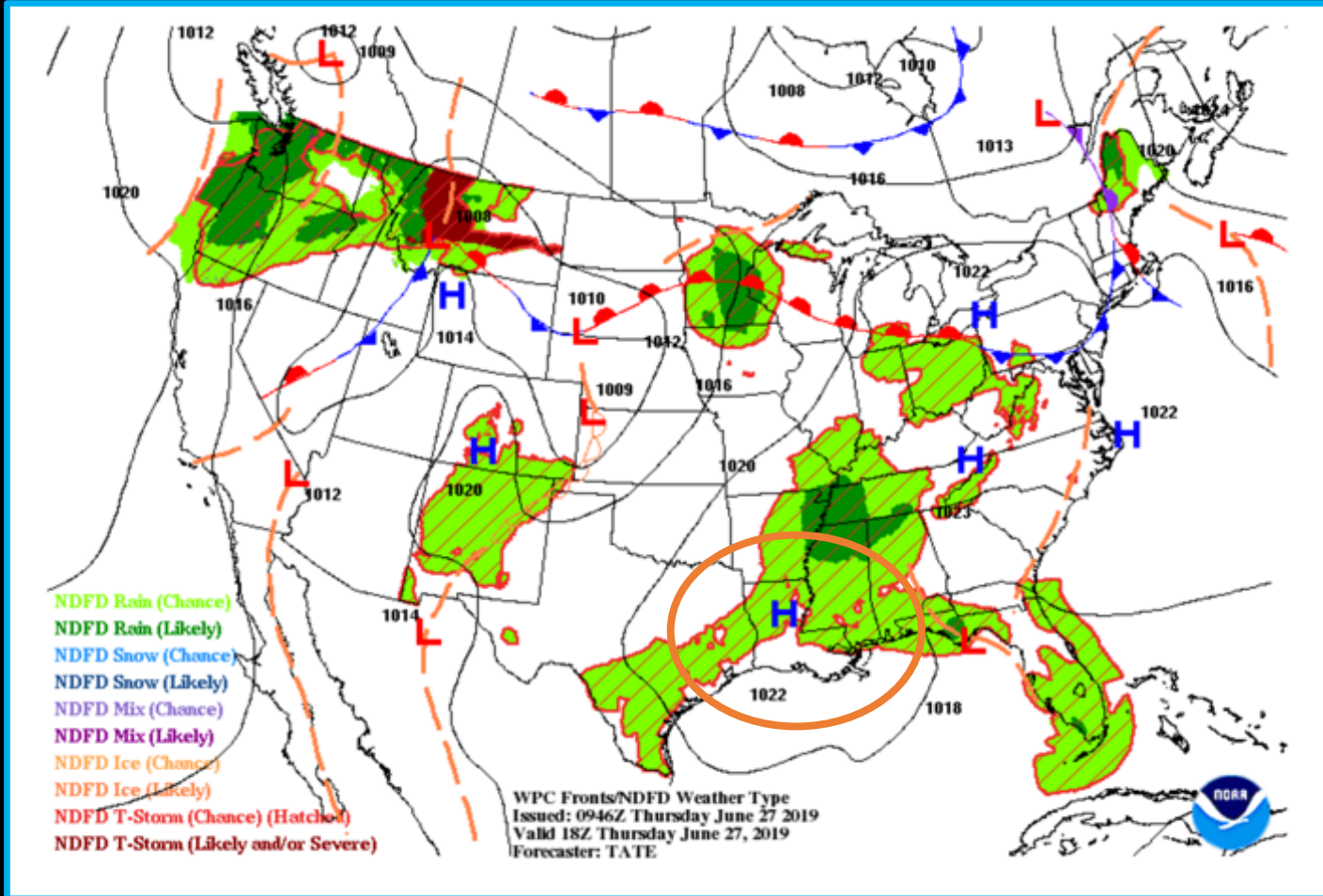
Sample of 2-Day Forecast

GEOS-CF CO2 (ppm) 2 Day Forecast for 1 UTC 06/20/19



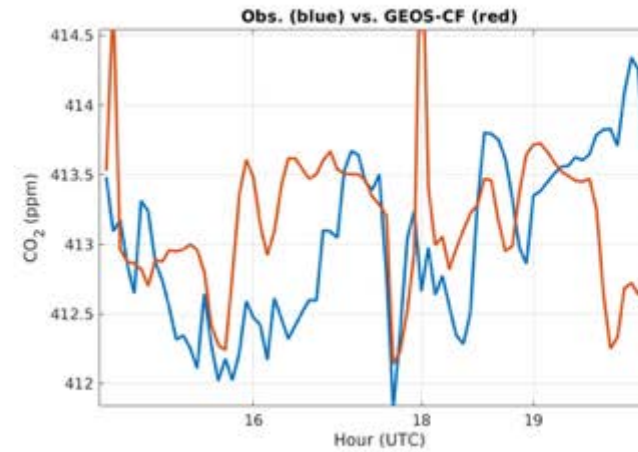
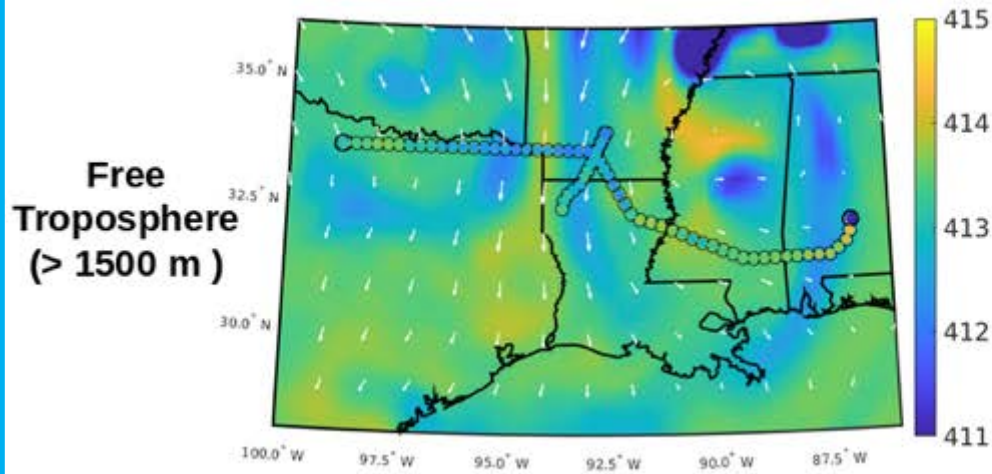
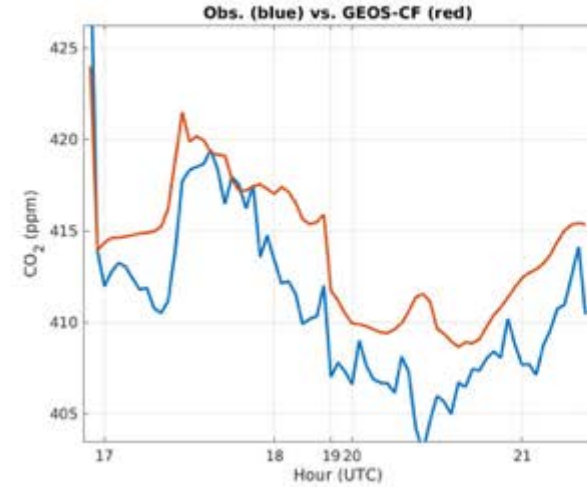
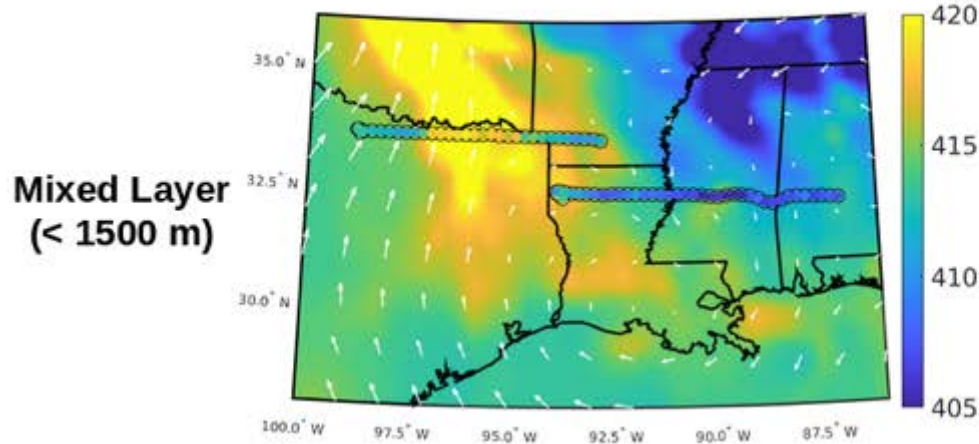
Forecasting Example 1

NWS Fronts for 18Z Thursday 06/27/19

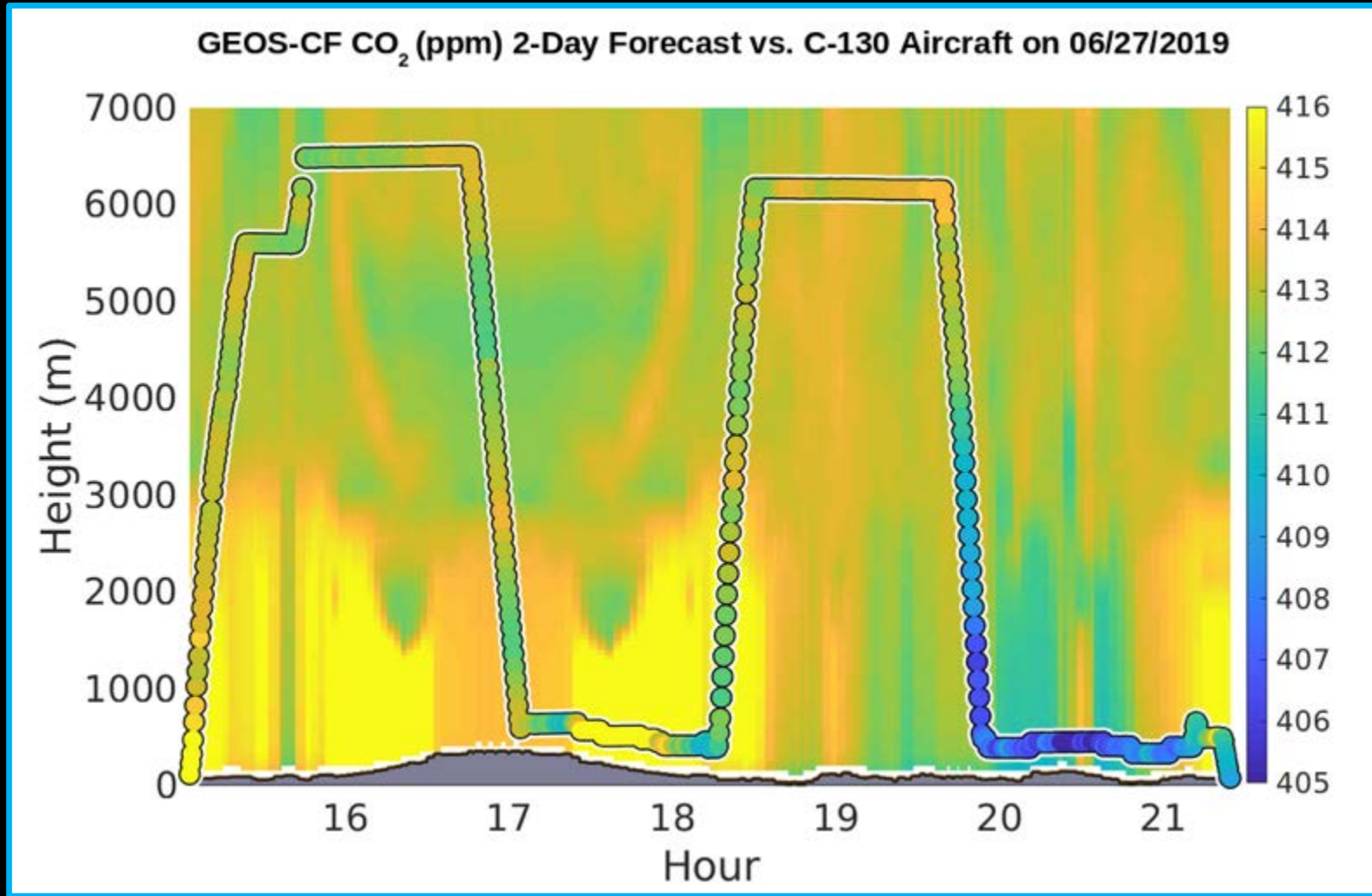


Forecasting Example 1 (cont.)

GEOS-CF CO₂ (ppm) 2-Day Forecast vs. C-130 Aircraft on 06/27/2019

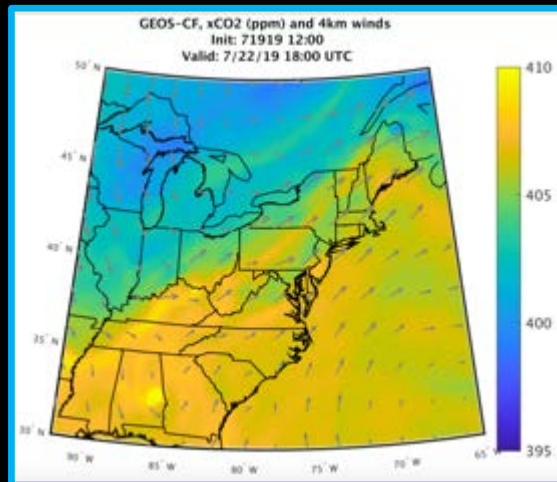
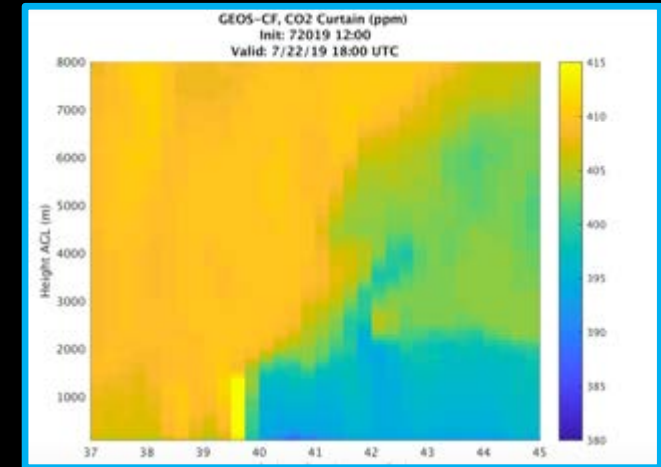
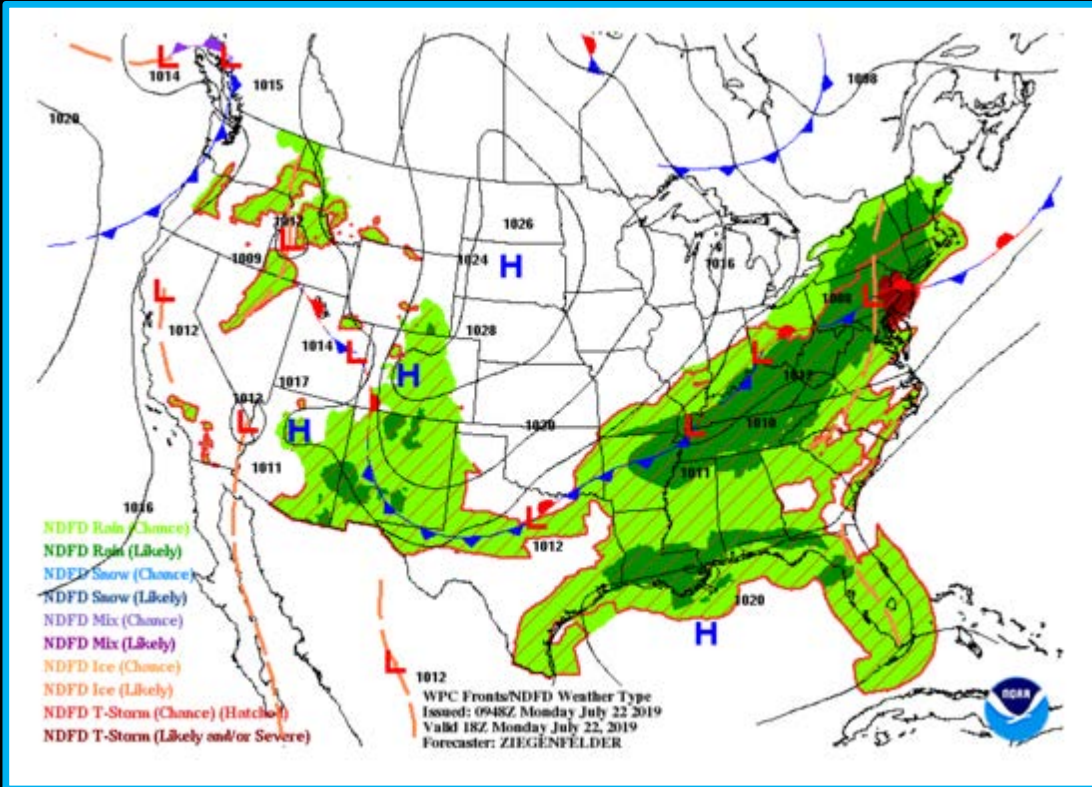


Forecasting Example 1 (cont.)



Forecasting Example 2 (cont.)

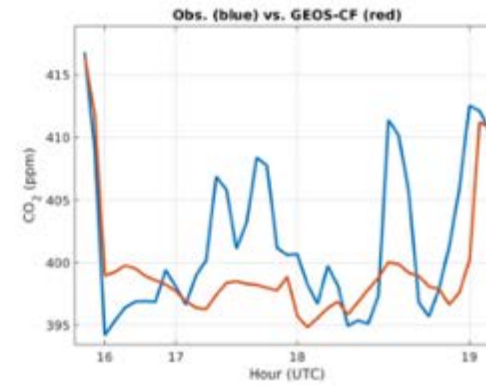
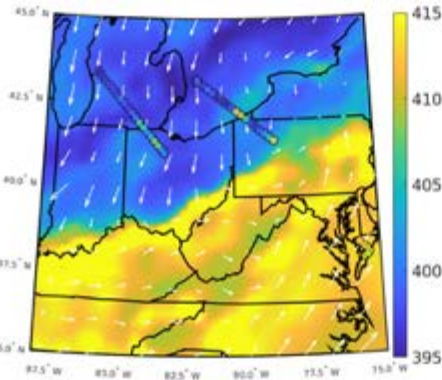
NWS Fronts for 18Z Monday 07/22/19



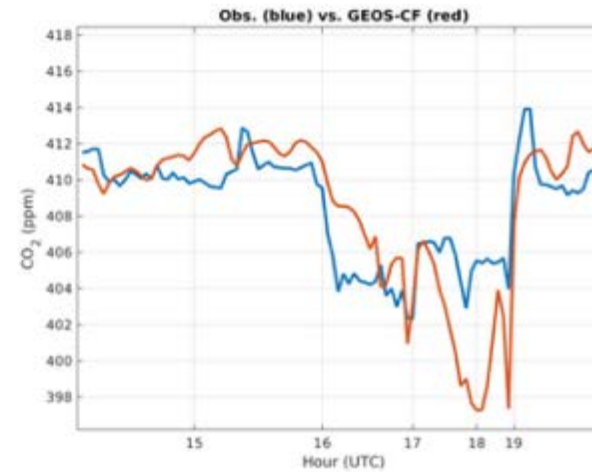
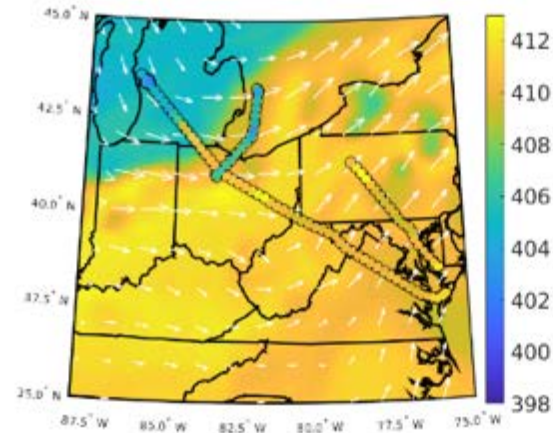
Forecasting Example 2 (cont.)

GEOS-CF CO₂ (ppm) 2-Day Forecast vs. C-130 Aircraft on 07/22/2019

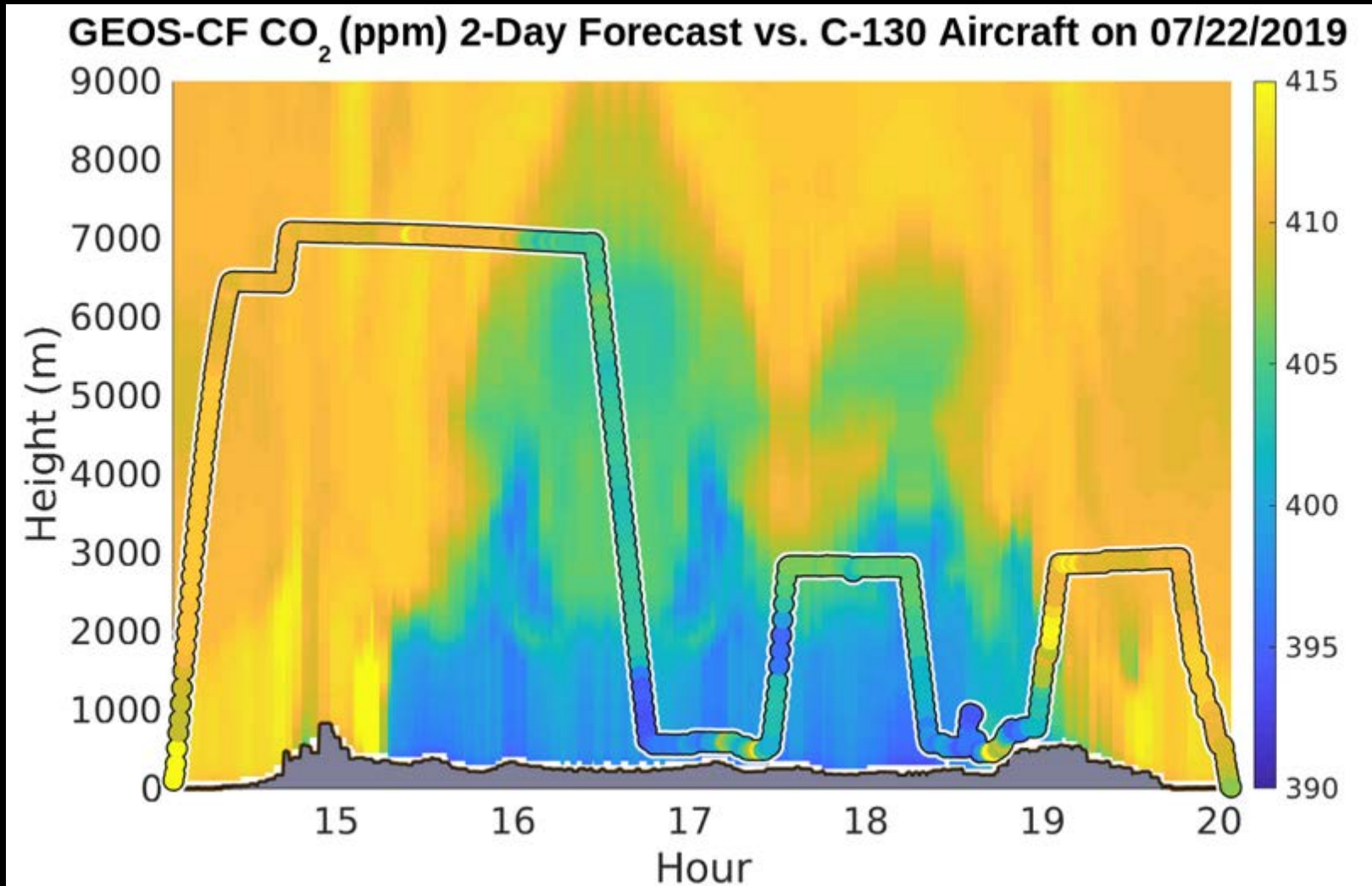
Mixed Layer
(< 1500 m)



Free
Troposphere
(> 1500 m)



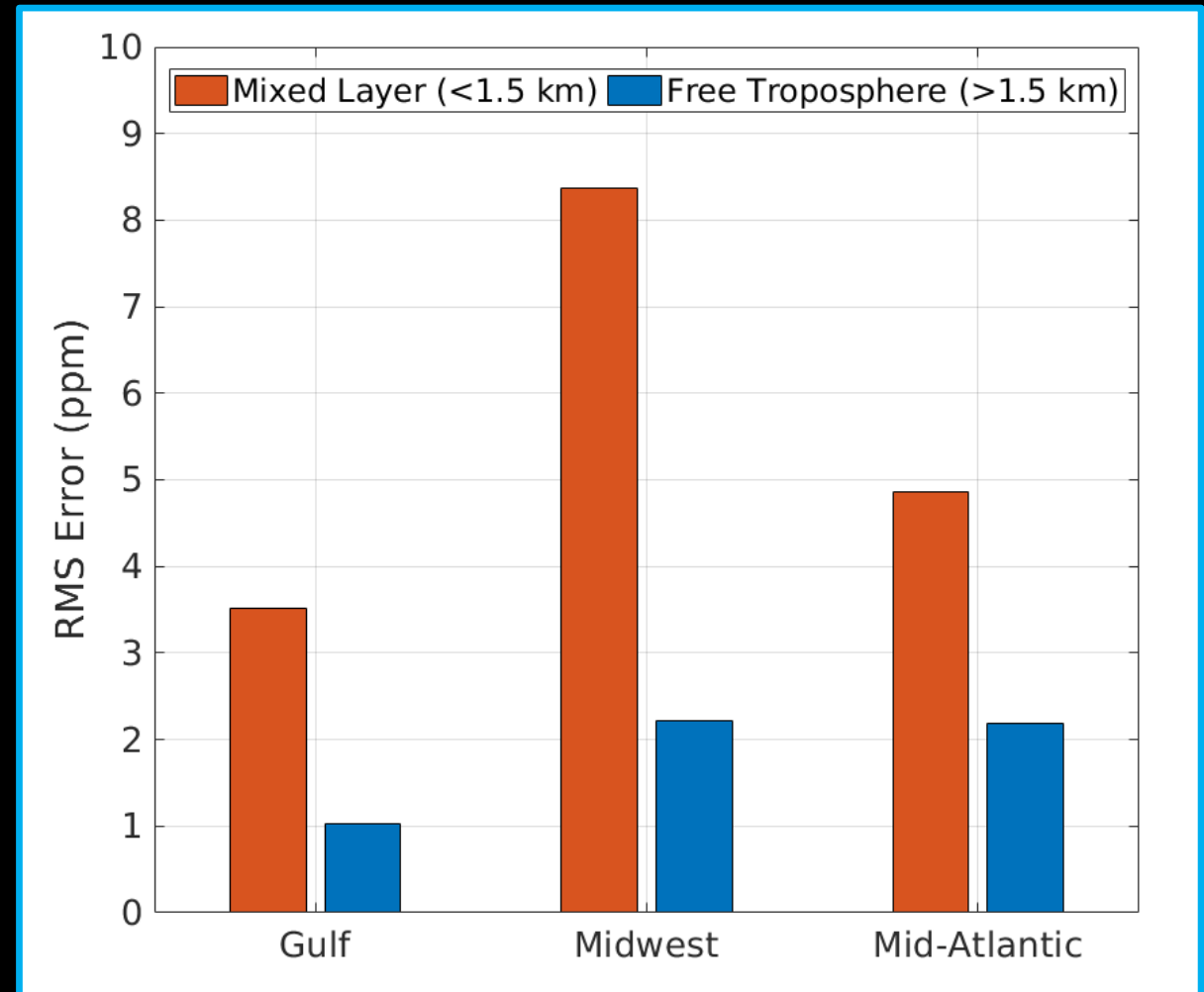
Forecasting Example 2 (cont.)



Results 1

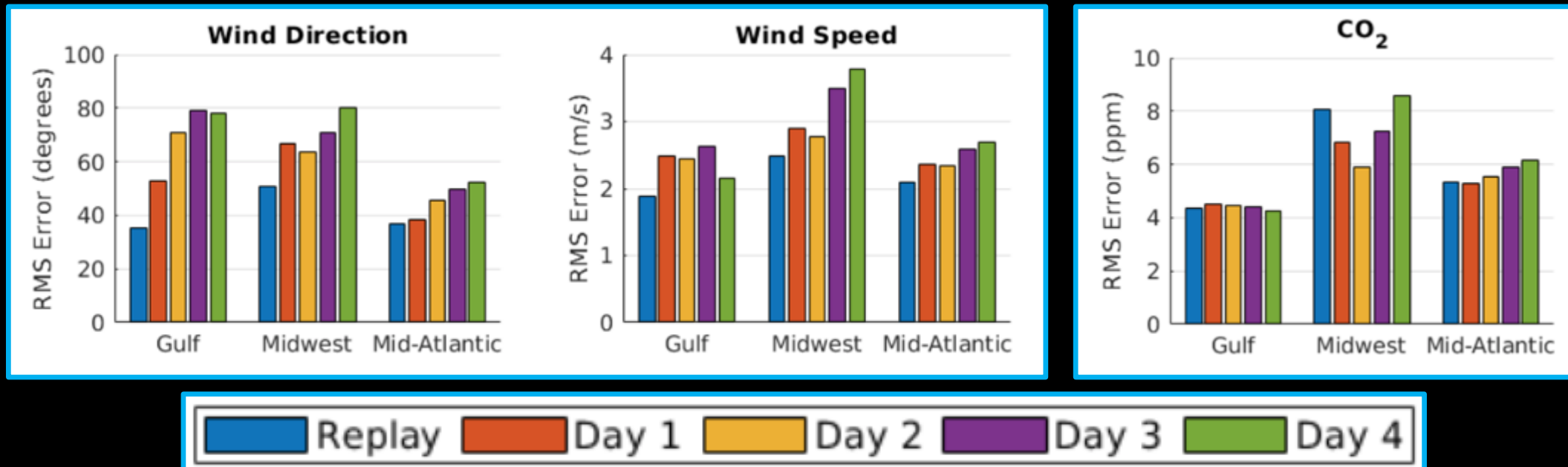
- The model performs much better in the free troposphere than in mixed layer.
- This implies that flux errors are larger than transport errors.
- Extreme flooding of 2019 in the Midwest significantly affected CO₂ sink for the duration of the ACT-America campaign.

RMS Error for Model vs. Aircraft Observations

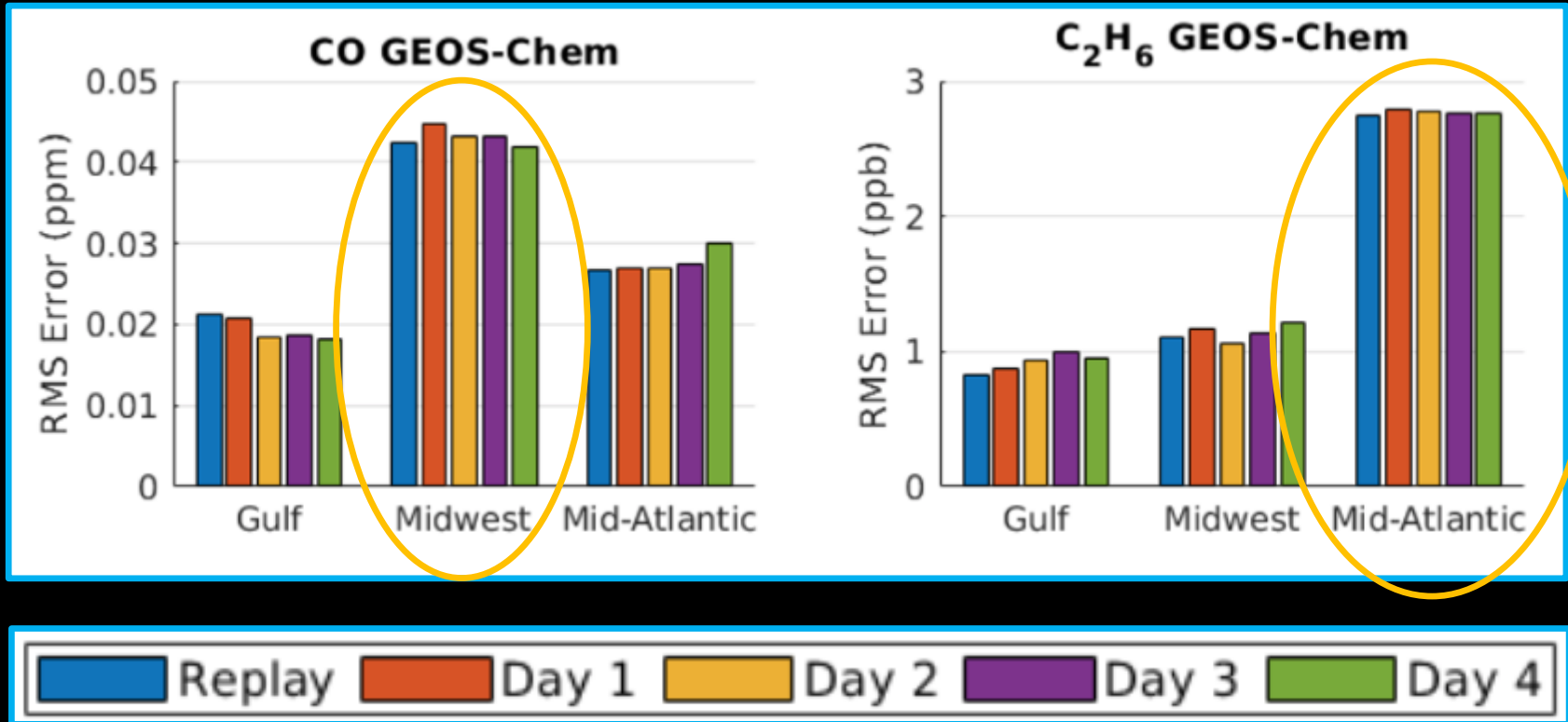


Results 2

- Forecasts from different lead times indicate that skill in transport prediction is decreasing, while CO₂ forecast skill is relatively consistent.
- This implies that the main source of error in the CO₂ stems from the emissions input (flux) of the CO₂ (at least in Gulf and Mid-Atlantic).



Results 2 (cont.)



Conclusions

- The forecasting of CO₂ is useful when planning flight missions (such as ACT-America) by helping to identify interesting CO₂ features such as gradients.
- The model is much more accurate in the free troposphere than in mixed layer.
- The NASA GEOS-CF model's skill of predicting CO₂ remains relatively similar when considering lead times of 1 to 4 days for Gulf and Mid-Atlantic regions.
- Given current analysis, emissions seem to contribute more to CO₂ modeling errors than transport.



Acknowledgments

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- Everybody who is part of NASA's ACT-America campaign!