Extreme Weather Initiative

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Program: Strategic

Project Objective:

Strengthen JPL's capabilities to develop and conduct breakthrough scientific advances in extreme weather, focusing on Observing System Simulation Experiments (OSSEs) for improved mission formulation capabilities.

Motivation:

- OSSEs were recommended in the NASA HQ 2015 Weather Focus Area workshop report and 2017 Decadal Survey for quantitative mission trade studies.
- JPL possesses a suite of robust OSSE tools applicable to extreme weather, but these tools have not yet been used to quantify measurement uncertainty or identify and assess weather science applications.
- Coalescing internal weather OSSE capabilities will lead to more effective mission formulation.

Approach: OSSE Spectrum for Mission Formulation

Sampling OSSE	Retrieval OSSE	Process OSSE	Forecast OSSE
Database of Features ➔ Orbit Simulator ➔ *Quantify Feasibility*: Are Features of Interest Sufficiently Sampled?	Nature Run ➔ Instrument and Retrieval Simulators ➔ *Quantify Uncertainty*: Does observation provide enough information?	Collection of Events ➔ Statistical Sampling ➔ *Quantify Information*: Does mission improve process understanding?	Nature Run ➔ Simulate Current and Future Obs ➔ Data Assimilation Experiments ➔ *Quantify Impact*: Do obs improve a forecast?

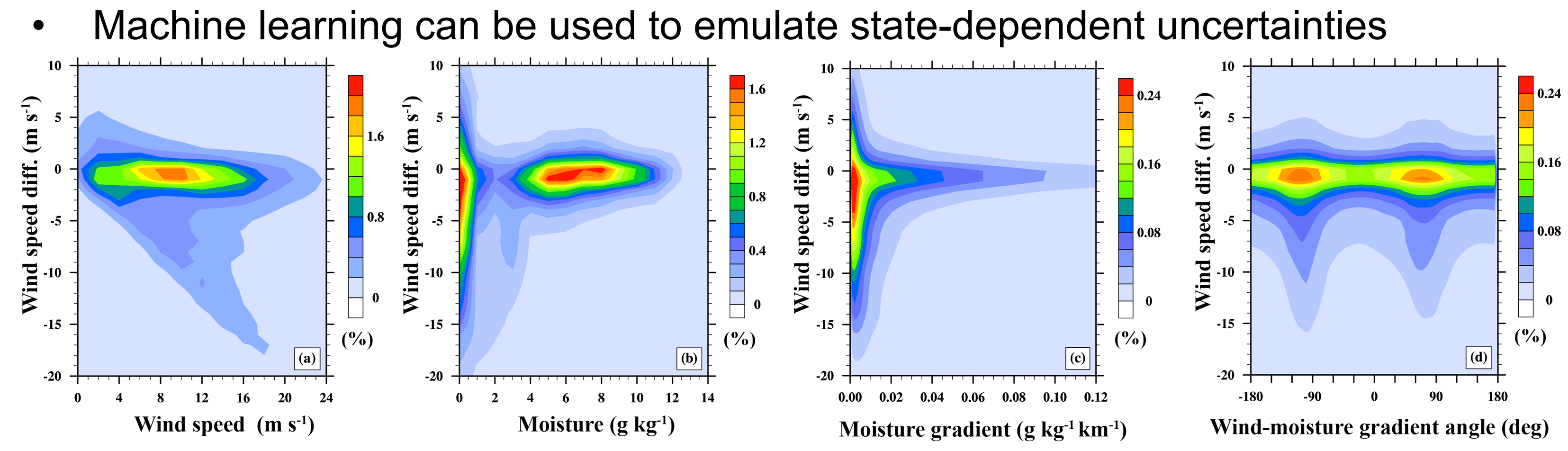
FY19 Highlights:

1. Published papers on AMV uncertainties and convection-environment interactions
2. Ran an IR AMV forecast OSSE
3. Implemented an EnKF convective-scale data assimilation system
4. Conducted DA experiments for tropical convection

Atmospheric Motion Vector OSSE

1. Characterize Uncertainty

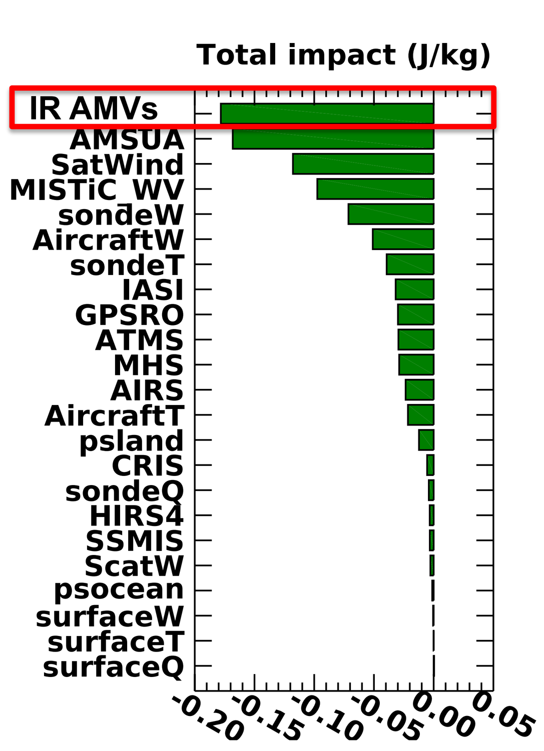
- High resolution simulation (nature run) used as a reference to quantify uncertainty
- Uncertainty in feature tracked winds is state-dependent
- Machine learning can be used to emulate state-dependent uncertainties



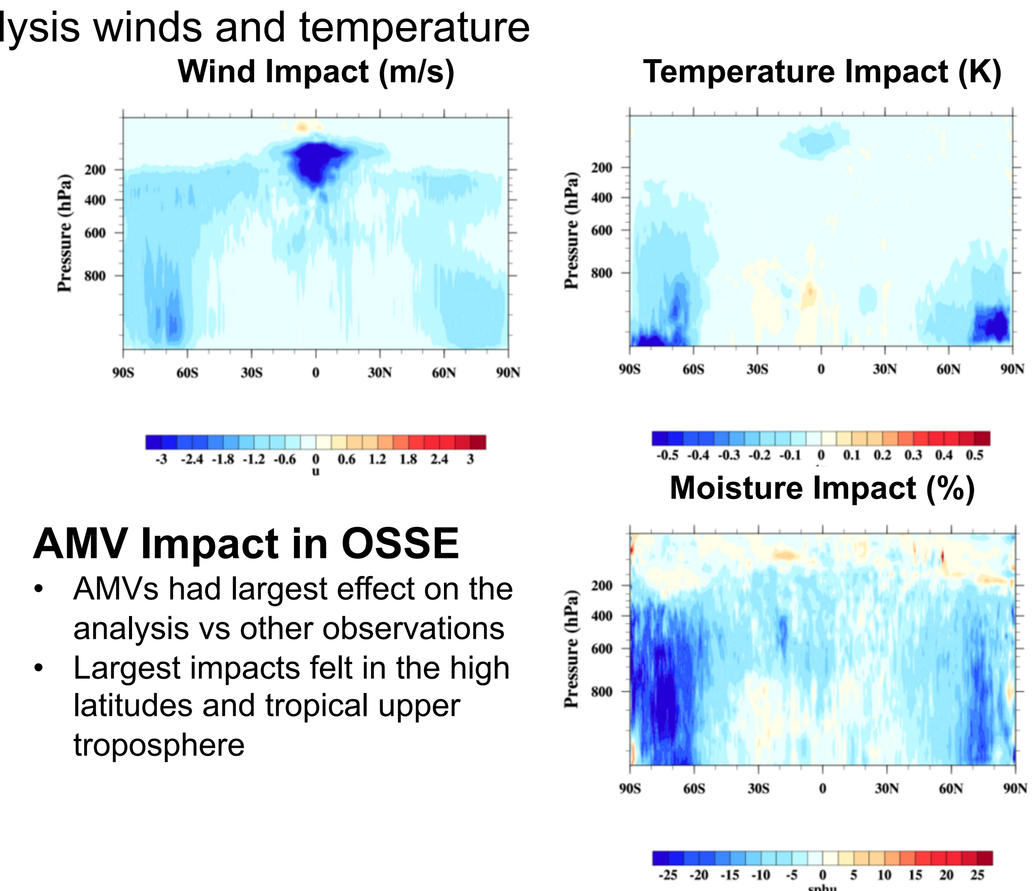
True – tracked wind speed difference vs (a) wind speed, (b) water vapor content, (c) water vapor gradient, and (d) angle between wind and water vapor

2. Assess Impact on NASA Reanalysis

- Assimilated AMVs from a constellation of IR sounders in the GMAO system
- Implemented JPL state-dependent errors
- Assessed impact on analysis winds and temperature



Observation impact in units of energy



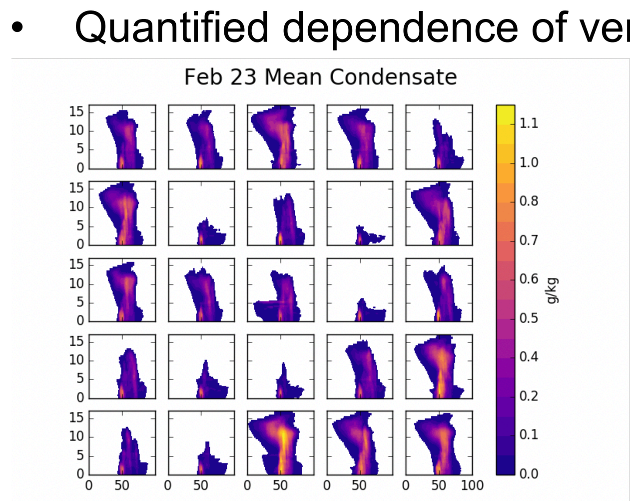
AMV Impact in OSSE

- AMVs had largest effect on the analysis vs other observations
- Largest impacts felt in the high latitudes and tropical upper troposphere

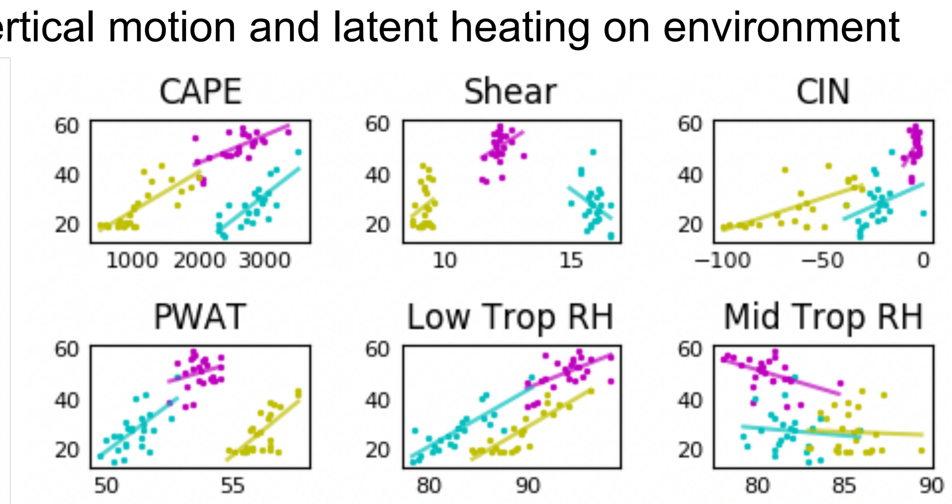
Convective Vertical Velocity OSSE

1. Quantify Sensitivity of Convection to Environment

- Ran an ensemble of convection-resolving simulations in differing environments
- Quantified dependence of vertical motion and latent heating on environment



North-south averaged condensate at 110 minutes of simulation time.



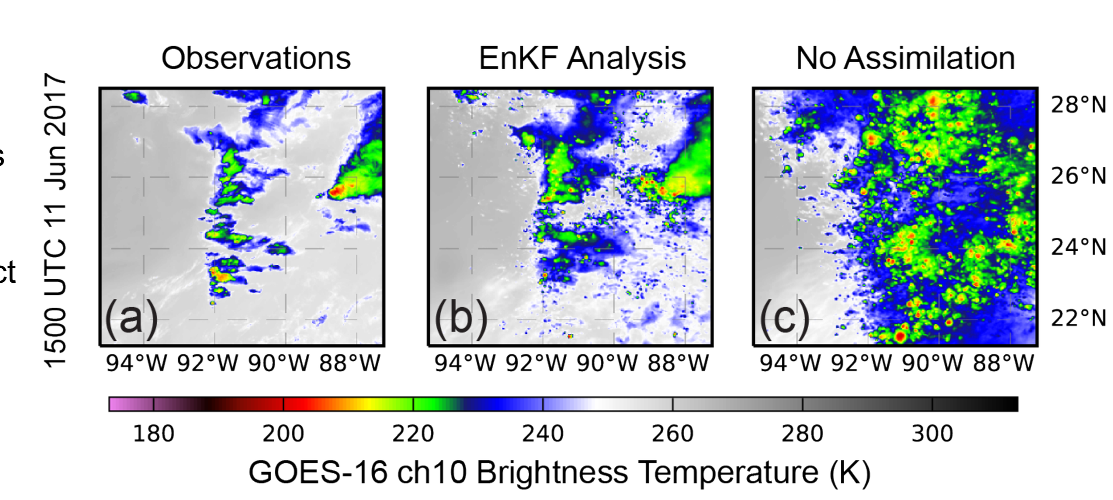
Simulation maximum vertical velocity as a function of CAPE, shear, CIN, precipitable water vapor, and low and mid-tropospheric relative humidity.

2. Conduct Convection-Resolving Data Assimilation Experiments

- Assimilated high resolution IR water vapor channel brightness temperature
- Analyzed covariance between water vapor and vertical motion using ensembles generated by EnKF

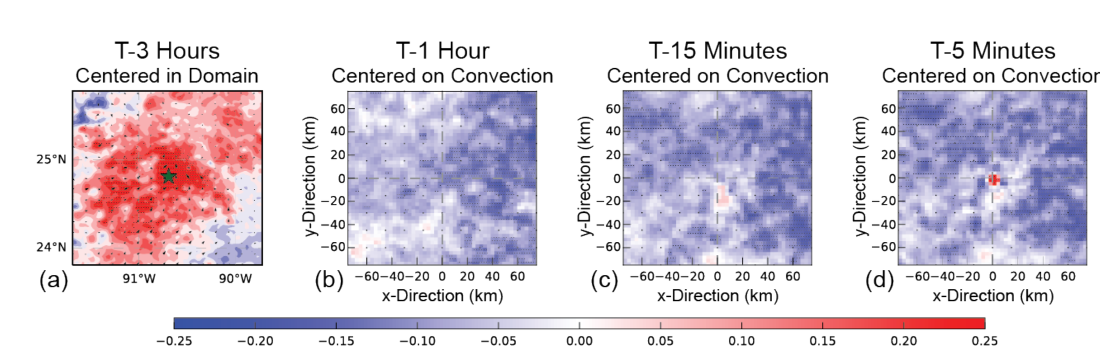
Water Vapor Assimilation

- Without assimilation, convection is too widespread
- With assimilation, convection occurs at approximately the correct place and time



Effect on Vertical Motion

- 3 hours prior to convection, moistening positively correlated with vertical motion
- < 1 hour prior to convection
  - Drying suppresses convection where it does not occur
  - Local scale moistening influences location of updraft



Benefits to NASA and JPL, and Significance of Results:

- We have coalesced in-house capabilities in extreme weather research, including: instrument simulators, satellite retrievals, and cloud models, and have engaged the JPL UQ team in weather-related research and mission design.
- The 3D AMV retrieval uncertainty study has led to more realistic assessment of errors in wind measurements, and is guiding the formulation of future wind missions.
- The convective ensemble experiments have directly aided an EV-I mission design (the D-Train), and are contributing toward the Clouds, Convection, and Precipitation (CCP) Decadal Survey Mission.
- Posselt is the OSSE lead for the CCP Designated Observable study team
- The interactions with external partners (especially NOAA, NRL and CIMSS/UW) have laid solid foundation for further practical collaborations.

Publications:

Posselt, D. J., F. He, J. Bukowski, and J.S. Reid, 2019: On the Relative Sensitivity of a Tropical Deep Convective Storm to Changes in Environment and Cloud Microphysical Parameters. J. Atmos. Sci., 76, 1163–1185, https://doi.org/10.1175/JAS-D-18-0181.1

Posselt, D. J., L. Wu, K. Mueller, L. Huang, F. W. Irion, S. Brown, H. Su, D. Santek, and C. S. Velden, 2020: Quantitative Assessment of State-Dependent Atmospheric Motion Vector Uncertainties. J. Appl. Meteor. Clim., Conditionally Accepted.

Storer, R. L., and D. J. Posselt, 2020: Environmental Impacts on the Flux of Mass Through Deep Convection. Q. J. Roy. Meteor. Soc., In Press.

Zeng, X., R. Atlas, R. J. Birk, F. H. Carr, M. J. Carrier, L. Cucurull, W. H. Hooke, E. Kalnay, R. Murtugudde, D. J. Posselt, J. L. Russell, D. P. Tyndall, R. A. Weller, and F. Zhang, 2019: Use of Observing System Simulation Experiments in the U.S. Bull. Amer. Meteor. Soc., Submitted.

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