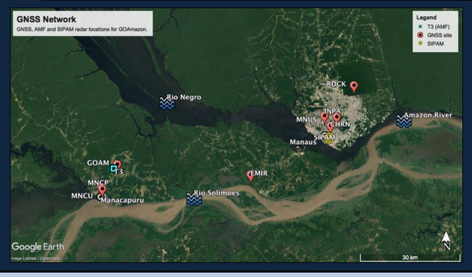
Investigating the impacts of Kelvin wave activity on convection in the Amazon through observations and model experiments

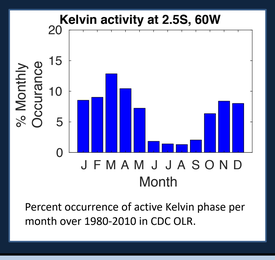
Yolande Serra[1,2], Angela Rowe[1], Samson Hagos[3], and Zhe Feng[3]

[1]University of Washington, Seattle, WA, [2]JISAO, Seattle, WA; [3]PNNL, Richland, WA

1. Motivation

In our previous work we linked GOAmazon derived cloud products with GPS-Met integrated column water vapor measurements to investigate the shallow-to-deep transition in the context of both local and large-scale moisture variability, including the observed role of Kelvin waves. Ground-based data was composited with respect to wave activity through use of space-time filtered geostationary satellite data for identifying active, suppressed, and neutral Kelvin and westward inertial gravity (WIG) wave periods. Our analysis showed that Kelvin and WIG waves significantly modulate surface rainfall, mid-level moisture, low- and upper-level divergence, MCS fraction, and precipitable water vapor at the GOAmazon ARM site and across the broader region captured by the SIPAM radar and GPS-Met network. We found that Kelvin waves interrupt the moisture transport from the Amazon to mid-latitudes during their active phase through a weakening of the South American low-level jet. A weakening of the jet is reinforced through impacts on surface pressure via surface heat flux anomalies (Serra et al. 2019, in prep.). Regional model simulations at convective resolving scales offer the opportunity to further evaluate the importance of these waves on local convective development in this region.





Percent occurrence of active Kelvin phase per month over 1980-2010 in CDC OLR.

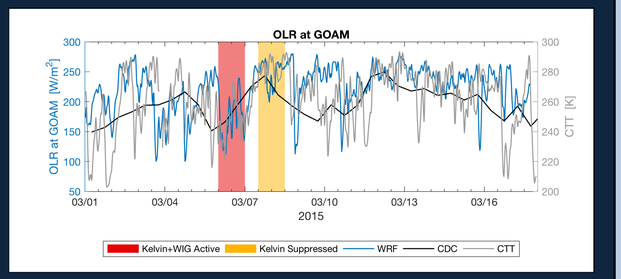
2. Research Questions

- Does WRF capture the mean characteristics of the environment over the Central Amazon in March 2015?
- Does WRF maintain the large-scale Kelvin wave characteristics across the domain?
- Does WRF capture the diurnal development of convection over T3?
- Does WRF develop MCSs in the domain with characteristics similar to those seen in GOAmazon?

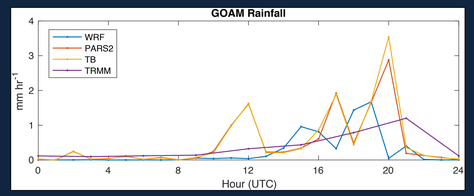
4. Model Kelvin waves

- During the model simulation a Kelvin and WIG active phase passed over T3 around 3/6, followed by a suppressed Kelvin envelope on 3/7-3/8.
- Overall, the WRF deep convection responds to the Kelvin and WIG forcing, with low OLR during the active period and high OLR during the suppressed period.

- On shorter time scales WRF deep convection is seen to be out of phase with observed OLR and CTT (e.g., 3/5, 3/11, 3/13, 3/16). We will investigate the links between the large-scale forcing and skill in WRF to capture MCSs.



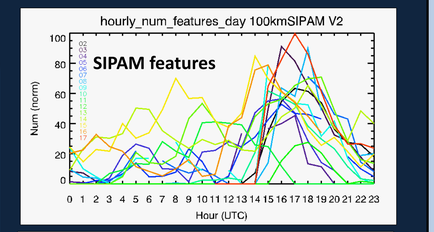
5. Model at GOAM

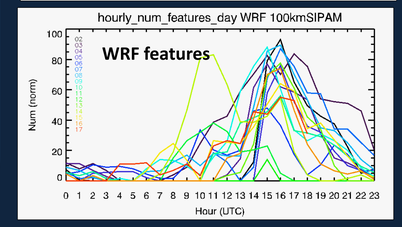


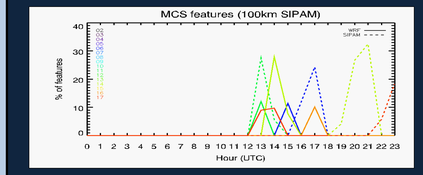
- WRF diurnal cycle in rainfall at GOAM shows late afternoon rainfall but misses rain events before local noon (UTC-4).
- The synoptic variability of PWV at GOAM is well captured by the WRF model when compared to the GPS and MWR at the site.
- The offset in PWV between WRF and the MWR is likely due to the fact that the forcing data was drier than what is indicated by the MWR. Note that the short GPS time series is also lower than the MWR. (Including February cases will permit more validation times with GPS PWV.)

6. Model Convection

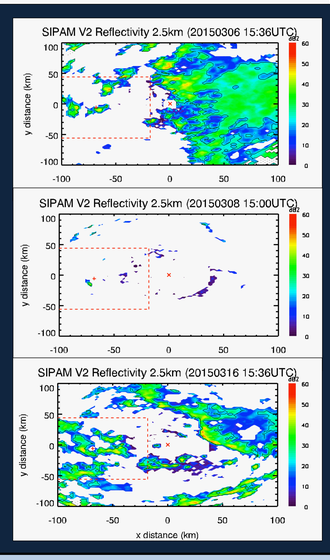
- The operational S-band radar (SIPAM) provides the broader context for ARM column measurements at T3. A feature-based algorithm with a 20-dBZ threshold is applied to both SIPAM and WRF reflectivity to identify MCSs using a 100-km major axis threshold. SIPAM analysis is restricted to within 100 km radius of the radar. WRF reflectivity output is restricted to a similar domain for comparison.
- WRF captures afternoon features, but peaks somewhat earlier and misses cases where features occur overnight into the morning hours (e.g., 3/13, 3/15, 3/16)
- When looking at percent of features meeting MCS threshold, see similar dates captured (3/6, 3/11, 3/14, 3/17), but differences in timing (concentrated in afternoon in WRF).

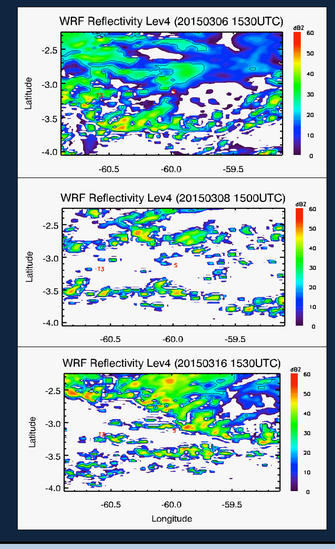






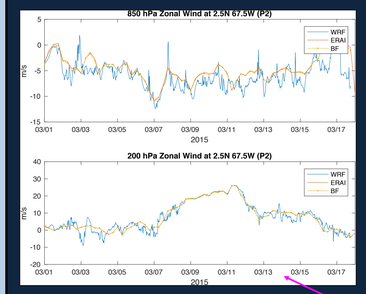
Examples of reflectivity and feature IDs from SIPAM (left) and WRF (right) show discrepancies in timing and strong tendency in model to produce afternoon convection (3/16 & 3/8), but also promise in capturing incoming MCSs during the late afternoon (3/16).

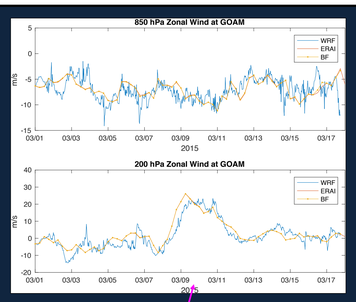


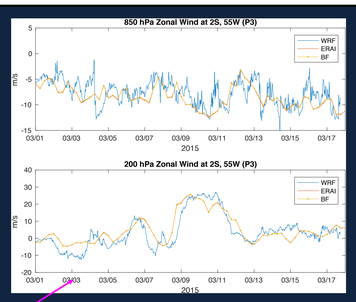


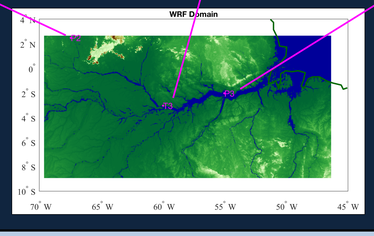
3. Model Setup

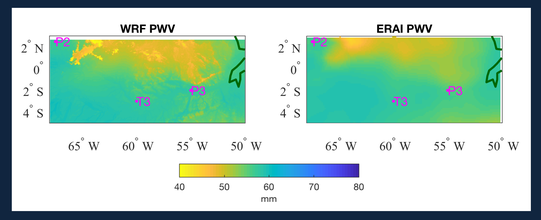
The impact of Kelvin waves on localized convection over the Amazon during GOAmazon will be assessed by comparing convective development for WRF simulations with and without Kelvin wave forcing at the boundaries. This presentation shows results from a 2-km WRF control simulation for 2015-03-01 to 2015-03-17 using ERA Interim reanalyses at 0.7 deg as initial and boundary forcing (BF). Version 3.9 of the WRF model was run at convective-resolving scale using Thompson microphysics, RRTMG radiation and MYNN2 boundary layer parameterizations. The control simulation shows generally good agreement with the forcing data average winds and column water vapor across the domain (right panels). There is also good agreement in both upper and lower level zonal wind time series over the GOAM site throughout the simulation period, as well as at two other locations at the boundary of the WRF simulation and further east. These three sites demonstrate that lower frequency variations in the winds on the order of 10 days or so can dominate the entire region, particularly at upper levels, while higher frequency variations differ at these sites. (ERA Interim at native resolution (0.125 deg) is also shown to be indistinguishable from the 0.7 deg BF used for the simulation.)

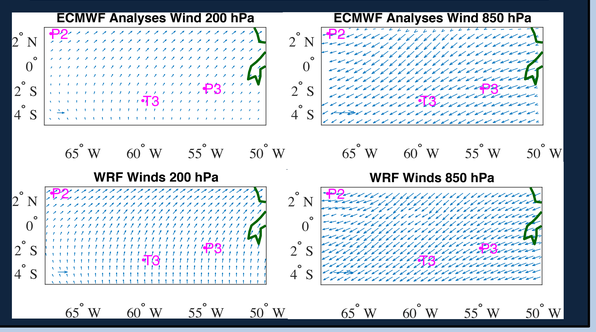












7. Next Steps

- Extend control simulation through end of March 2015 to capture Kelvin active wave period later in the month and include shorter simulations (~5 days) of Kelvin cases in February 2015.
- Repeat control simulations but with no Kelvin wave forcing at the boundary.
- Compare convective characteristics (e.g., features, MCSs) across the domain for the control run including the Kelvin waves and for the run with no Kelvin waves.
- Investigate the relationship between MCS occurrence and domain-scale synoptic variability in moisture convergence and surface heat and moisture fluxes in both simulations.

E-mail: yserra@uw.edu

Funded by DOE ASR Grant DE-SC0016222
Joint ARM User Facility and ASR PI Meeting, June2019, Rockville, MD