Practical and Intrinsic Predictability of Multiscale Weather and Convectively Coupled Equatorial Waves during the Active Phase of an MJO

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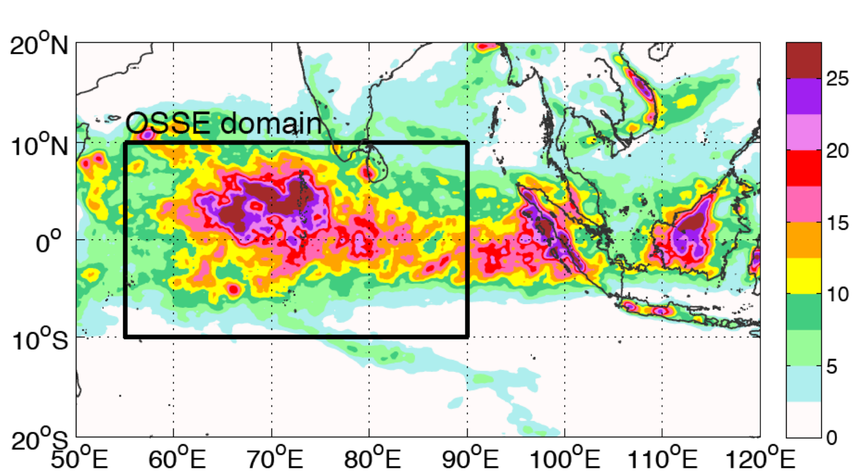
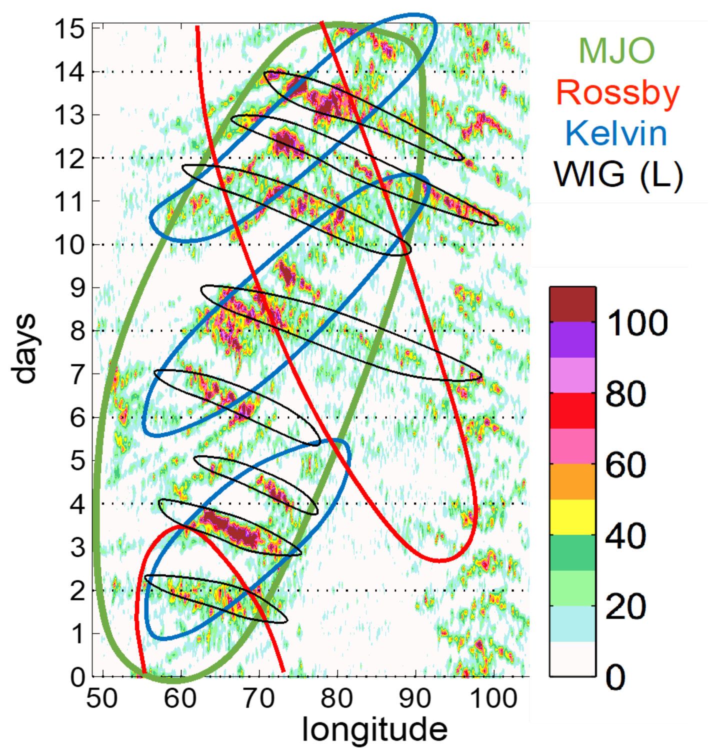
Introduction

Tropical weather systems are important components of the global circulation that span a wide range of spatial and temporal scales. In this project, we study the predictability of convectively coupled equatorial waves using Weather Research and Forecasting (WRF) model ensemble simulations at convection-permitting (9-km) resolution.

The computational domain (left) covers Indian Ocean and part of Maritime Continent. An active phase of MJO (Oct 18 - Nov 2, 2011) is simulated. The averaged daily precipitation (mm) during the simulation is shown in the domain. Hovmöller diagram (right) shows evolution of precipitation averaged over 0-5°N. Contours show wave modes extracted with space-time filtering: the equatorial Rossby wave, Kelvin wave, and westward inertia-gravity (WIG) wave.



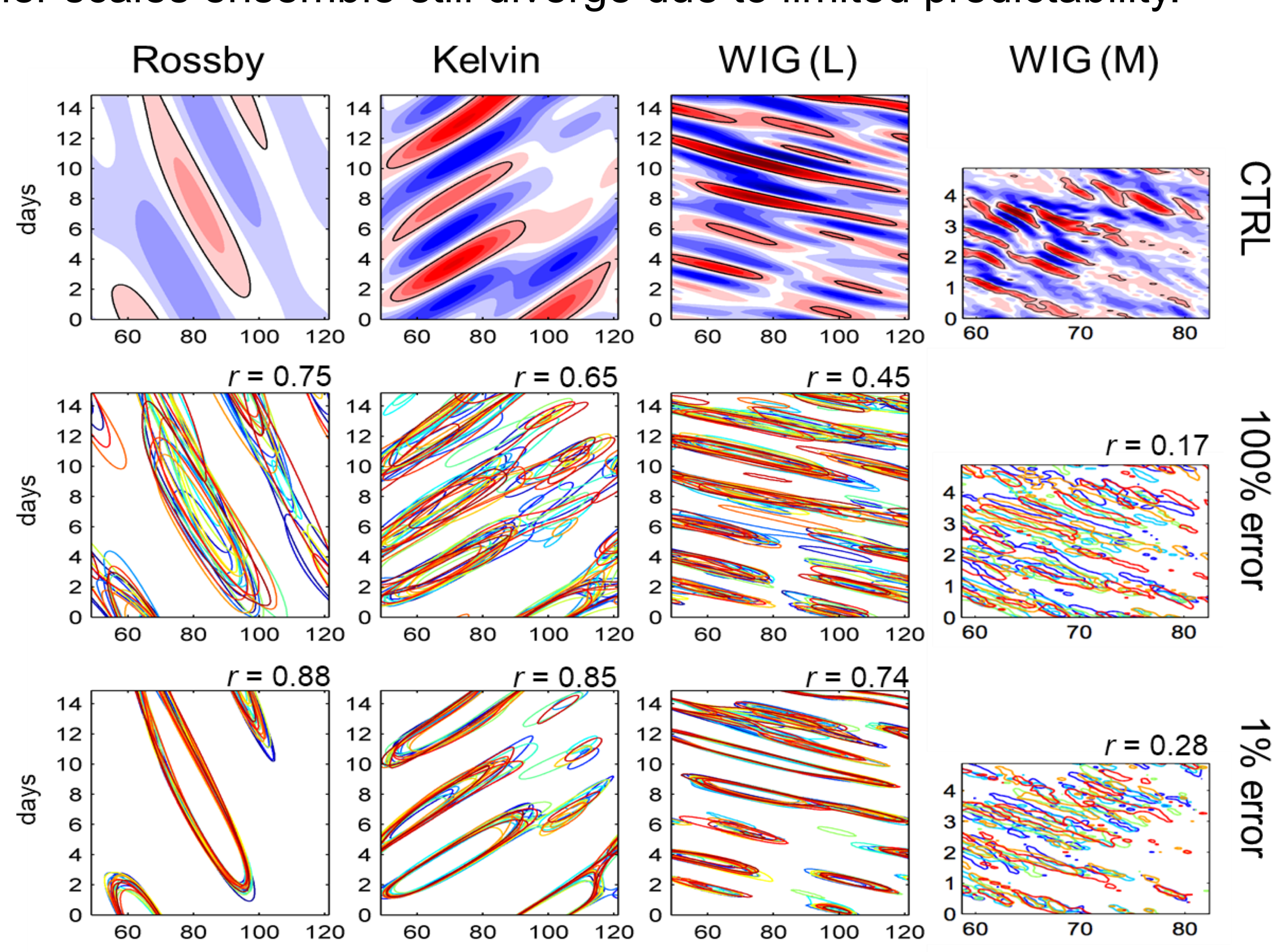


Ensemble simulations

A control simulation initialized with ERA-Interim is run. Hovmöller diagrams of precipitation are shown for each wave modes (top row).

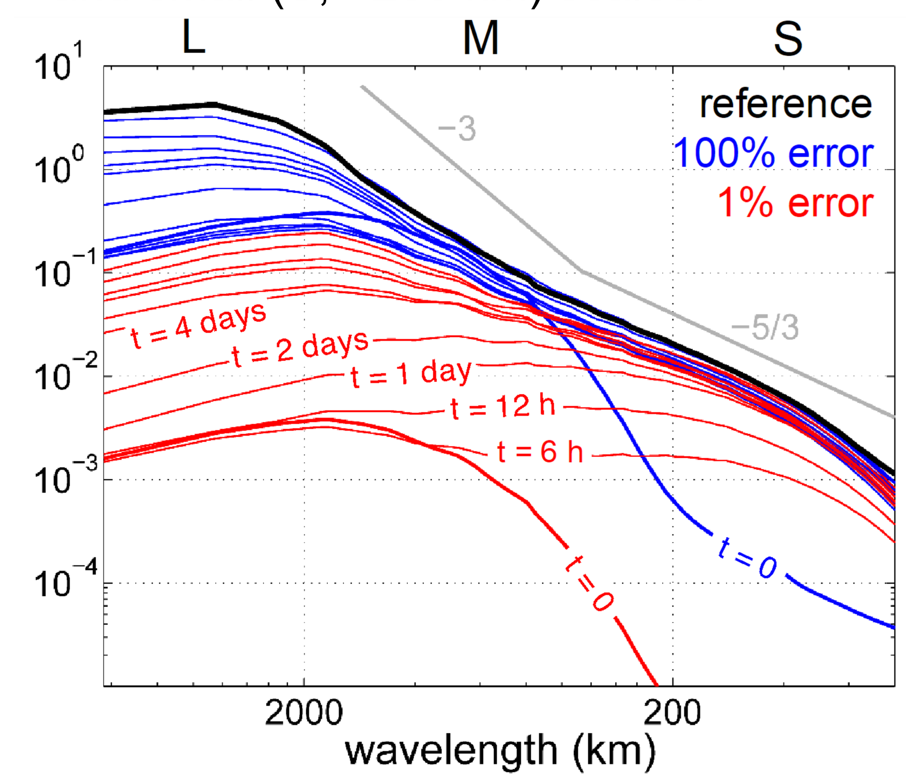
Then, a 20-member ensemble forecast is run with perturbed initial and boundary conditions. The perturbations are realistic forecast errors sampled from ECWMF global model. Spaghetti plots (middle row) of a precipitation contour show disagreement among the members. r is the averaged pattern correlation between member and control.

Another ensemble with error variance reduced to 1% (bottom row) is run. The ensemble is in much better agreement for large-scale waves, while at smaller scales ensemble still diverge due to limited predictability.



Estimation of predictability limits

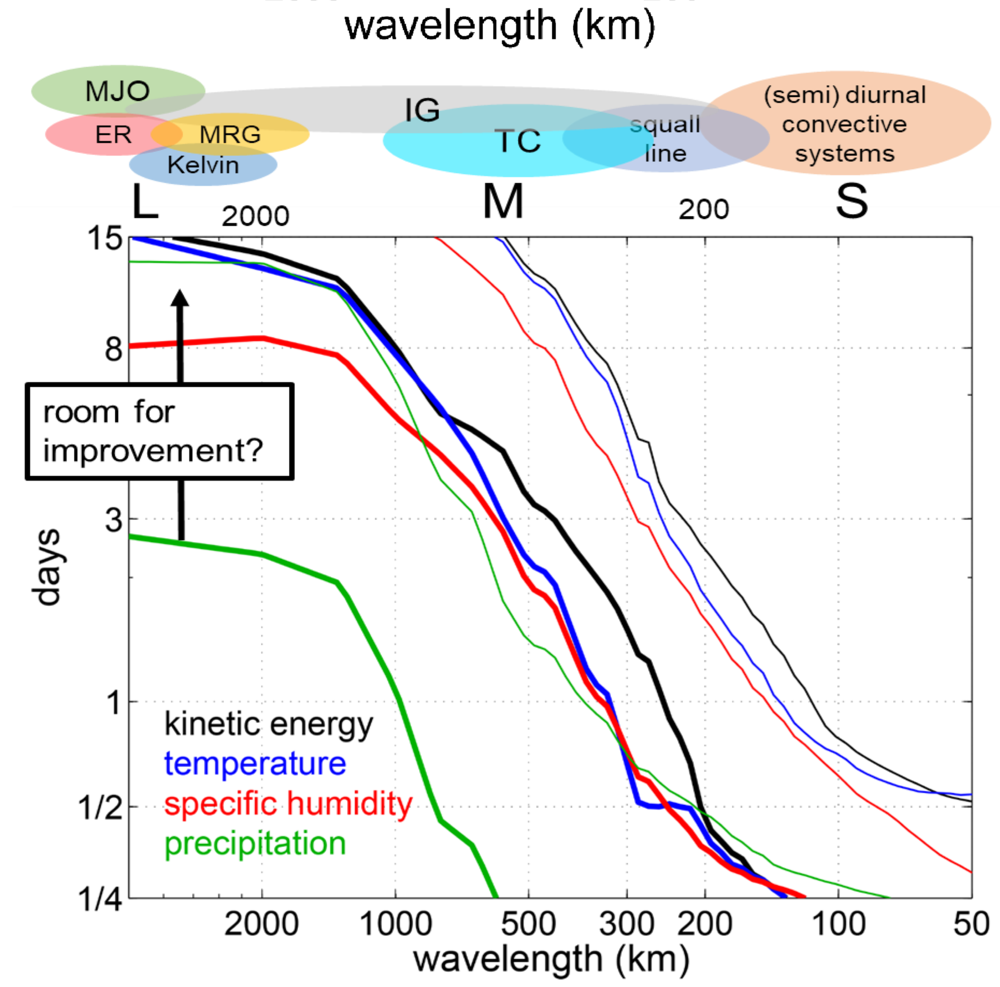
Predictability limit is reached when errors (ensemble spread) grow to the level of the signal itself (reference). Practical predictability limit is estimated from the 100% error ensemble, while intrinsic predictability limit is estimated from the 1% error ensemble. Error spectrum is calculated to evaluate the predictability limits at large (L; >2000 km), intermediate (M; 200-2000 km), and small (S; <200 km) scales.



Time sequences of error kinetic energy spectra are plotted (left).

At L scale, reducing error extends the predictability limit.

At S scale, error growth rate is much higher and reduced error does not extend predictability limit too much.



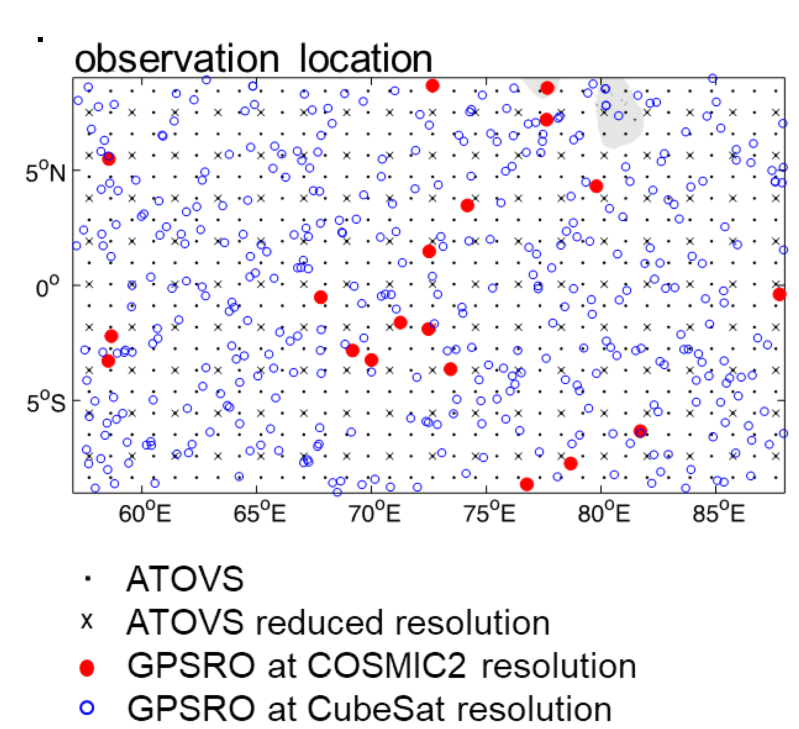
Intrinsic predictability limits (thin) and practical predictability limits (thick) plotted as a function of horizontal wavelength (left).

The predictability decreases rapidly across the intermediate scale (near 500 km).

Precipitation is less predictable than other variables.

Tropical satellite observing networks

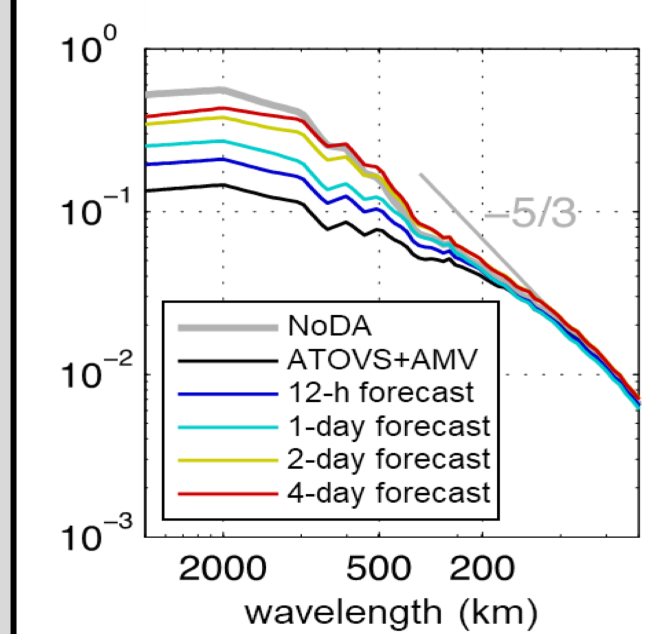
Observing System Simulation Experiment (OSSE) is performed on a smaller domain to test the potentials in satellite observations in improving the predictability. Synthetic observations are generated by adding random errors to the truth. These observations are assimilated using a 60-member ensemble Kalman filter (EnKF) every 3 h during a 15-day period.



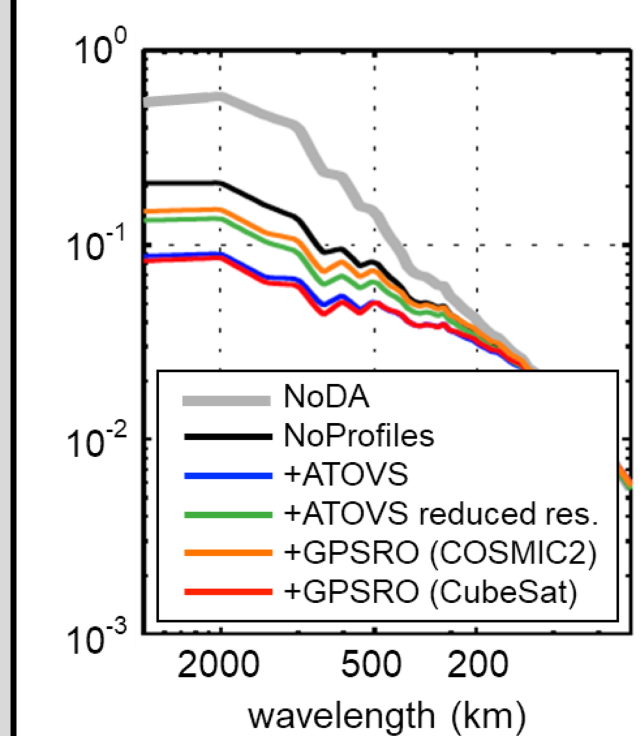
Observing networks investigated in this study include atmospheric motion vectors (AMV), CYGNSS surface wind speed, and temperature and humidity retrieved profiles from ATOVS radiances and GPS radio occultation (GPSRO).

A snapshot of observation distribution in the OSSE domain is shown (left).

Potentials in improving predictability



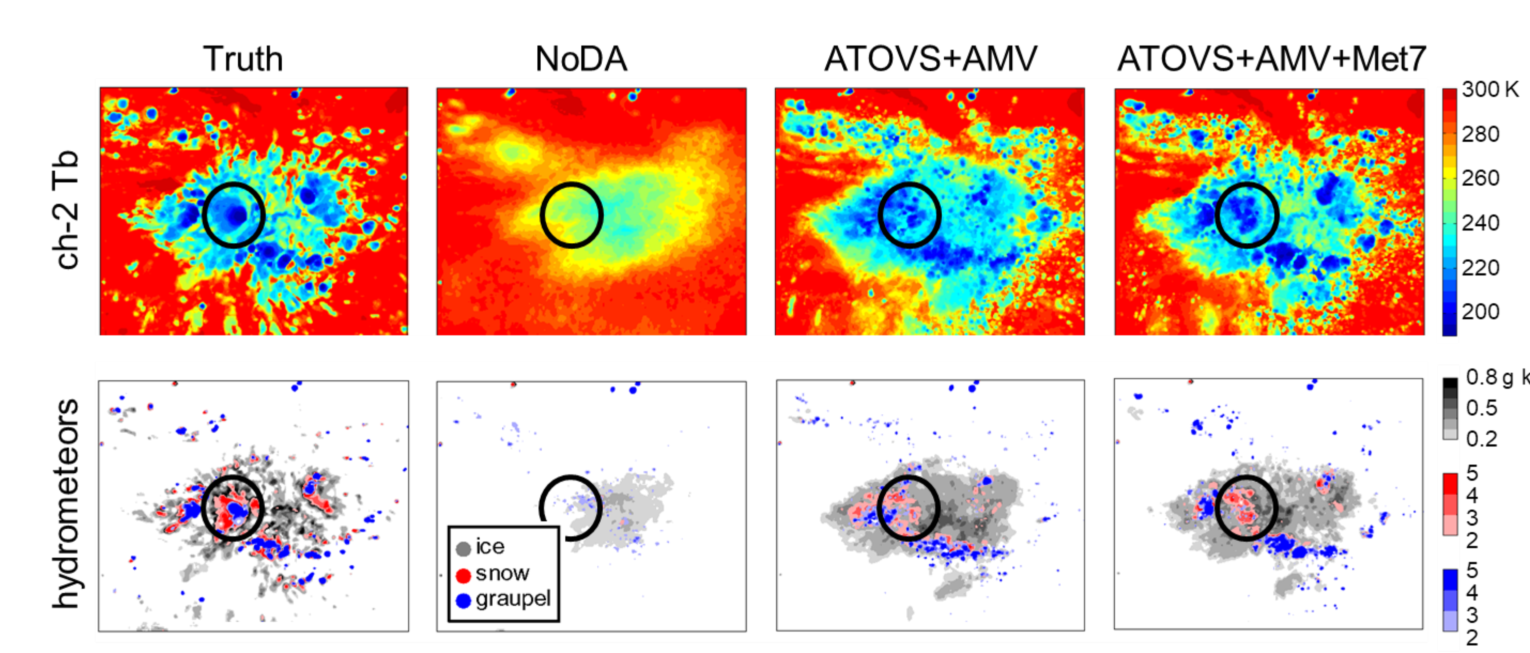
Assimilating ATOVS retrieved profiles and AMV improves L and M scales, as shown by the error kinetic energy spectra (left). Forecast from the analyses show that predictability limit is extended by >4 days at L scale, and 2-4 days at M scale. Not much improvement is found at S scale.



Error kinetic energy spectra (left) show that reduced-resolution ATOVS profiles produce less accurate analysis than the full-resolution one. High spatial resolution is essential for intermediate scales.

Current COSMIC2 GPSRO profiles are approaching the performance of ATOVS profiles at reduced resolution.

Direct assimilation of Meteosat-7 (Met7) radiance is tested, and resulting analysis are compared below. The Met7 radiance has higher resolution than ATOVS, which helps further constrain smaller scales. However, challenges remain in handling nonlinearity and spreading information in the vertical.



Conclusions

- Practical predictability limit of tropical weather is ~2 weeks at L scale, and decreases rapidly to <1 day at S scale.
- Intrinsic predictability limit is achievable beyond 2 weeks at L scale, but likely still <3 days at S scale.
- Assimilating satellite observations can potentially improve the predictability at L and M scales.

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For more details, see Ying and Zhang, 2017; 2018, JAS