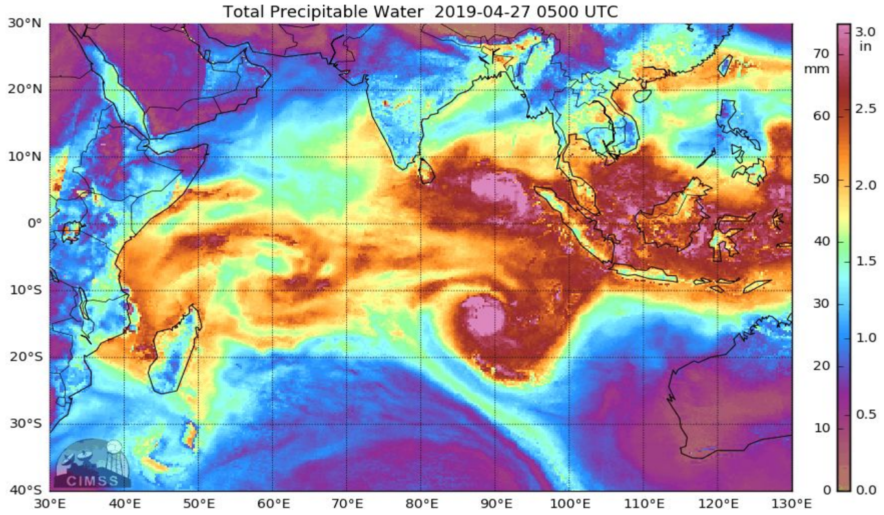
Use of Analysis Increments to Advance MJO Prediction in the NOAA UFS



Stefan Tulich[1,2], J.-W. Bao[2], I-K. Hu[1,2], P. Pegion[2], L. Bengtsson[2]

Affiliations: 1) CU/CIRES and 2) NOAA/PSL

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The difficult problem of numerical MJO prediction needs no introduction

As discussed in Frederic Vitart's talk – a common problem in operational NWP models is their inability to maintain the amplitude of the disturbance, as well as its eastward propagation (which tends to be too slow), particularly over the Maritime Continent

Objective of this project

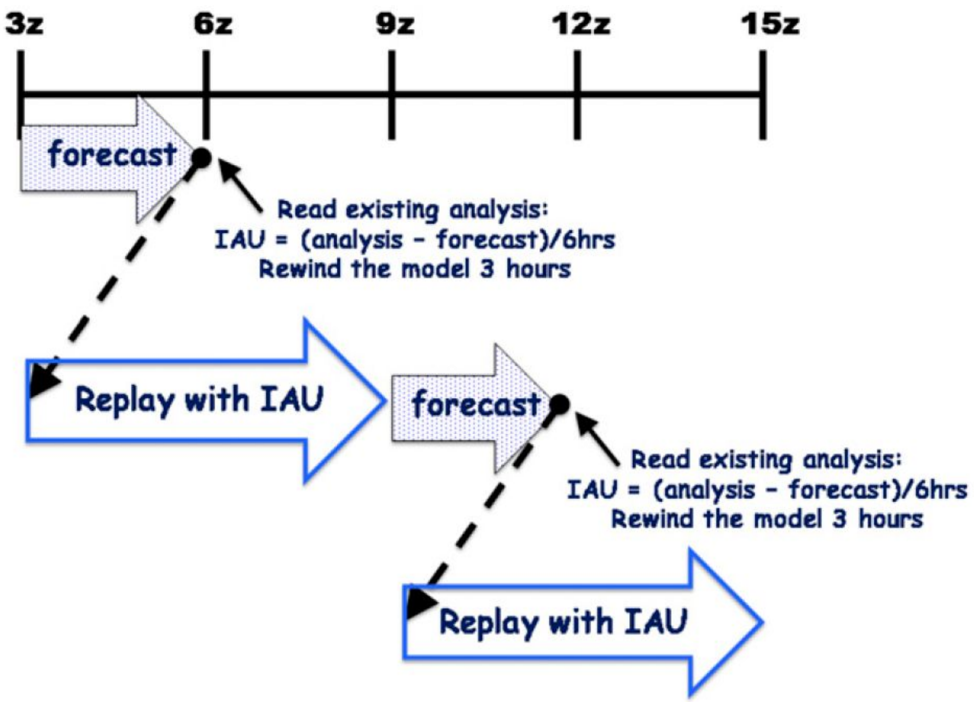
- Use a relatively inexpensive form of data assimilation (namely “replay”) to help steer refinements in the coupled UFS prototype’s moist physics parameterization to improve its MJO prediction skill

- Basic approach: look at the model’s composite “first-guess” (3-hr) MJO re-forecast errors and then iteratively make refinements to the model physics to reduce these errors (inspired by the work of Mapes and Bacmeister 2012)

- A key benefit is that it is much less expensive than the traditional method of iterating on the basis of large numbers of S2S re-forecasts, offering the potential for more rapid advances

What is “replay” and why do we use it?

A form of cycled data assimilation (first developed at NASA/GMAO) in which the corrector step involves taking the difference between the model’s first-guess forecast and an existing reanalysis product and then applying this difference as a forcing (called ”incremental analysis update” or IAU)

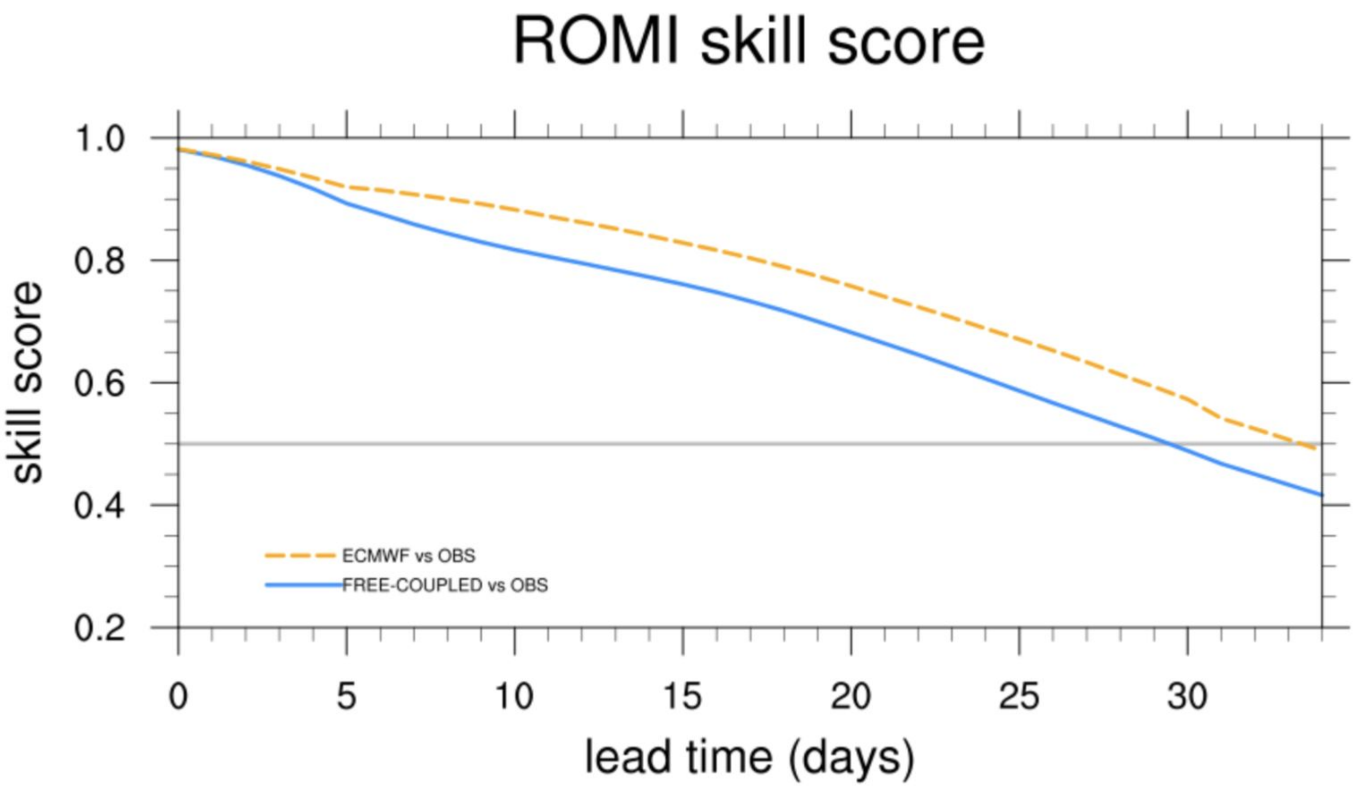


Two 30-yr coupled replay datasets are leveraged in this project

1) “High-resolution” product which use the “HR1” prototype (tagged in January 2023) with roughly 25-km grid-spacing in both the atmosphere (driven to ERA5) and ocean (driven to ORAS5) - purpose was to generate a set of initial condition files for NOAA/EMC to generate an associated S2S (35-day) re-forecast dataset for the next-generation GEFSv13 (which is currently ongoing)

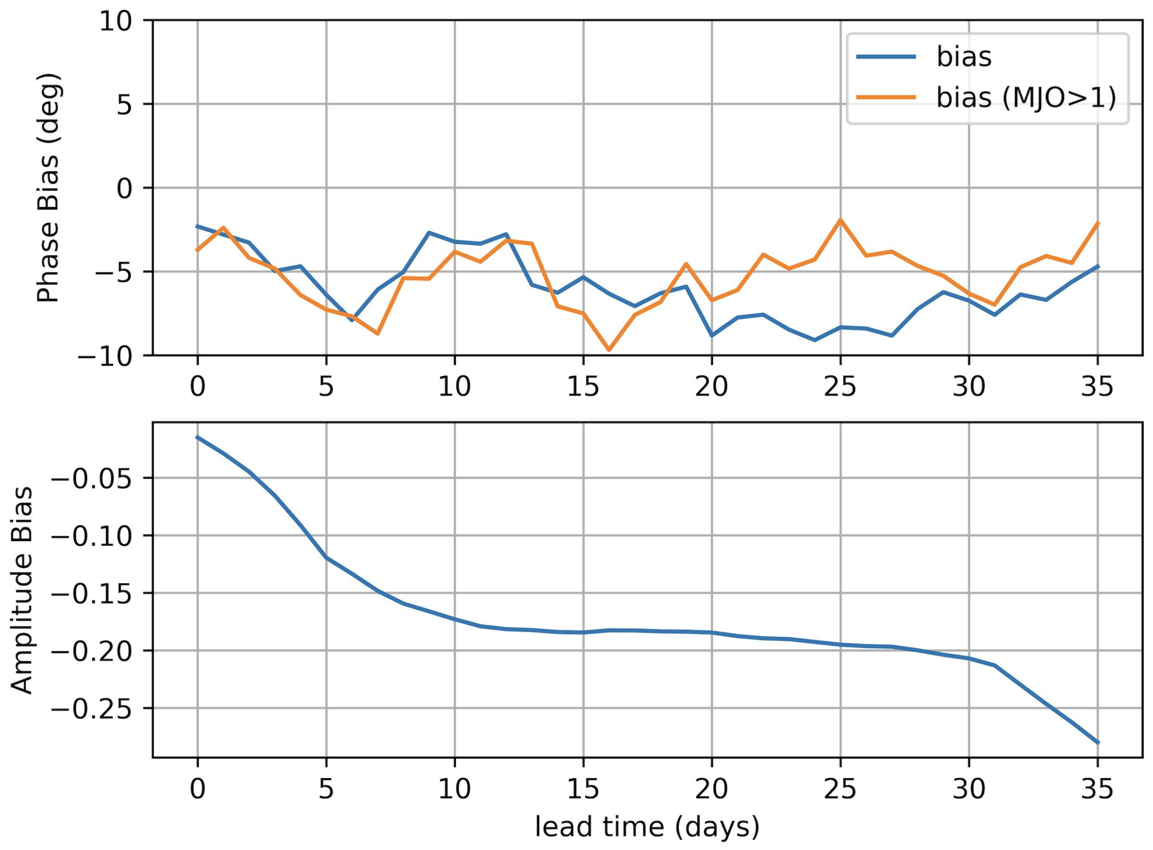
2) “Low-resolution” product identical to the first, but where the grid-spacing is coarser (roughly 100 km in both the atmosphere and ocean; no tuning!) – purpose was to have a less-expensive option for in-house tinkering, along with a 35-day ensemble reforecast dataset that is already in hand

The MJO prediction skill of the low-resolution UFS is not terrible

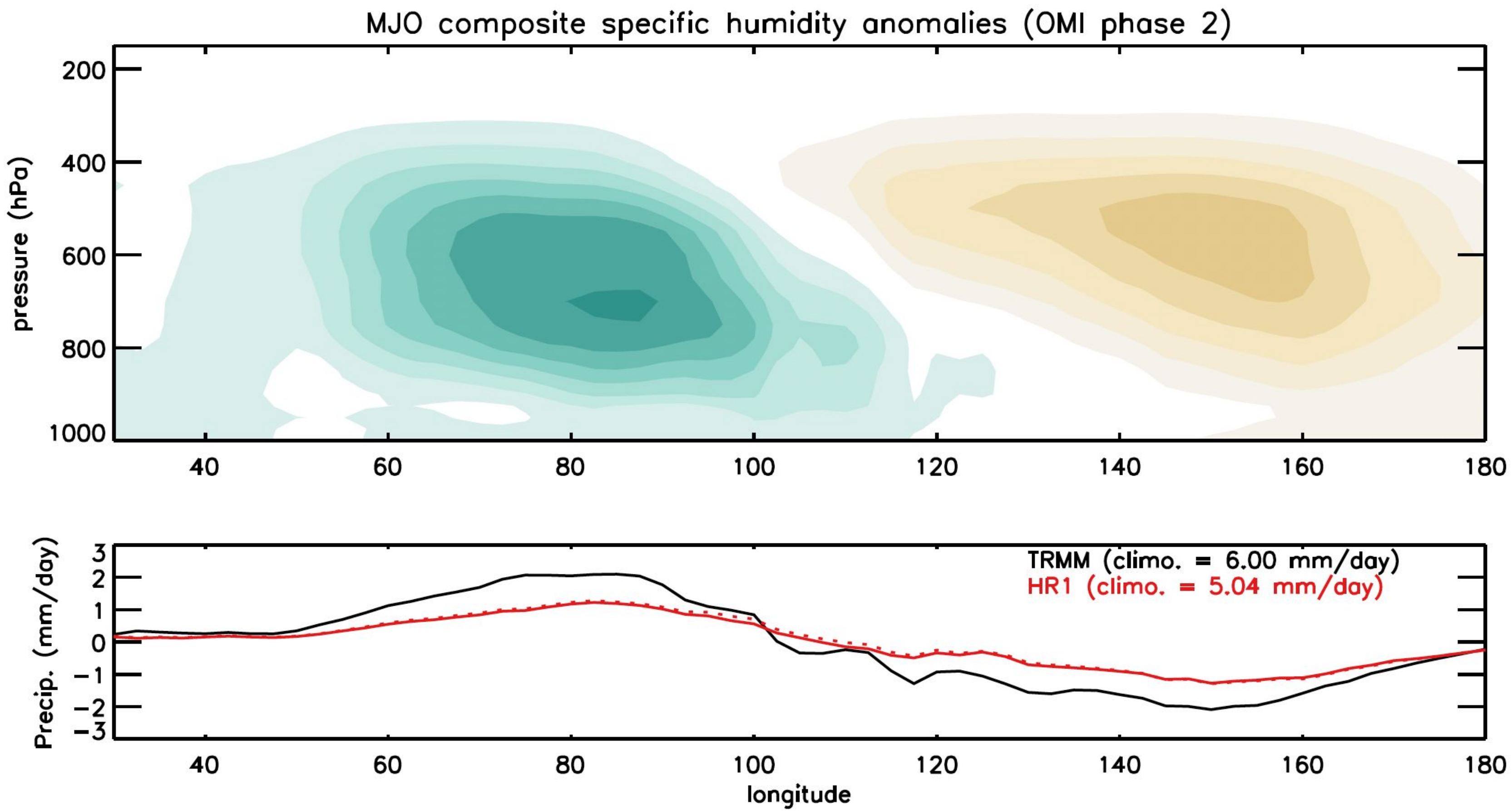


Results based on 5-member ensemble 35-day reforecasts initialized twice weekly (2002-2021); Figure courtesy of M. Gehne

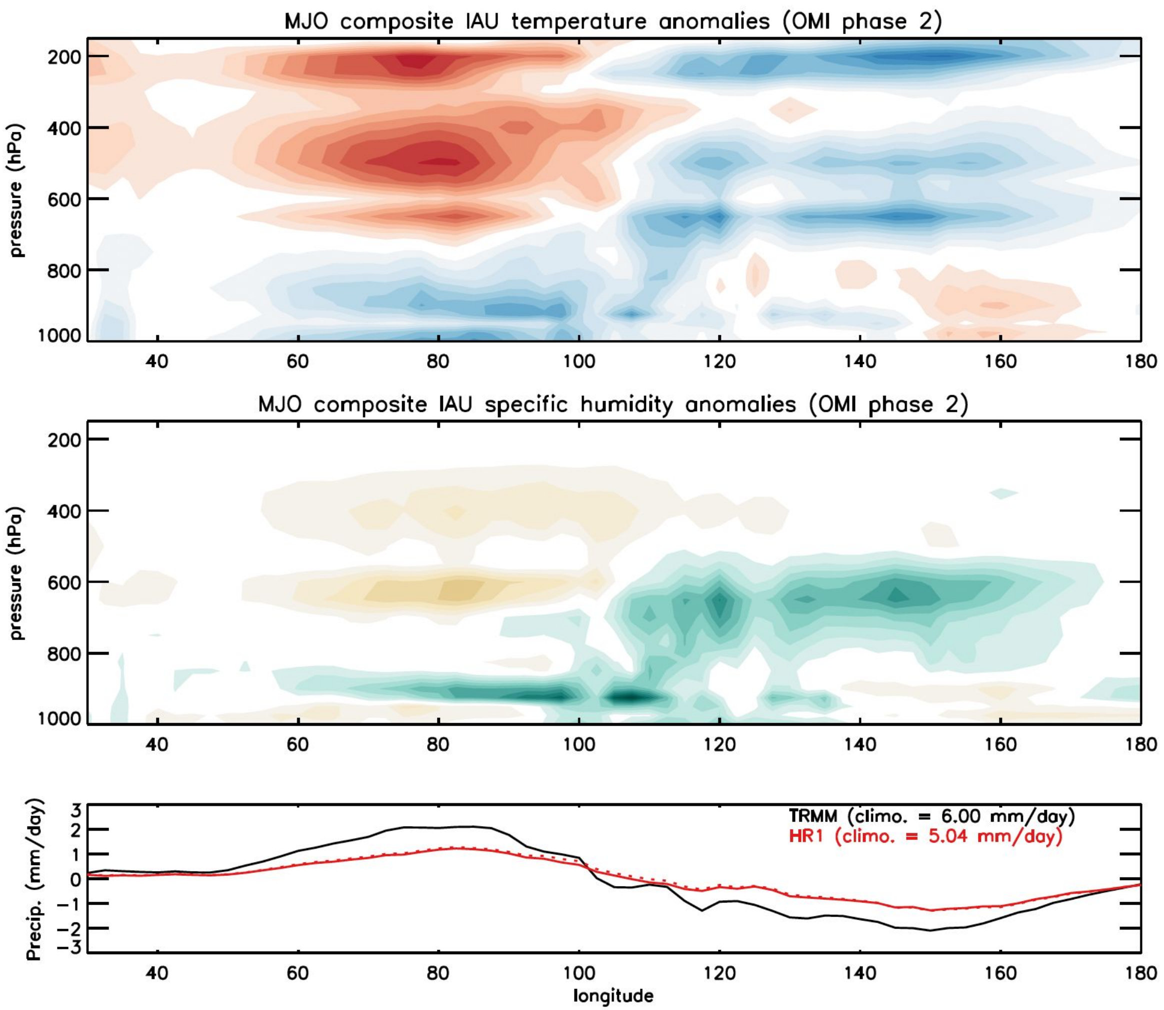
Amplitude and phase biases are consistent with expectations



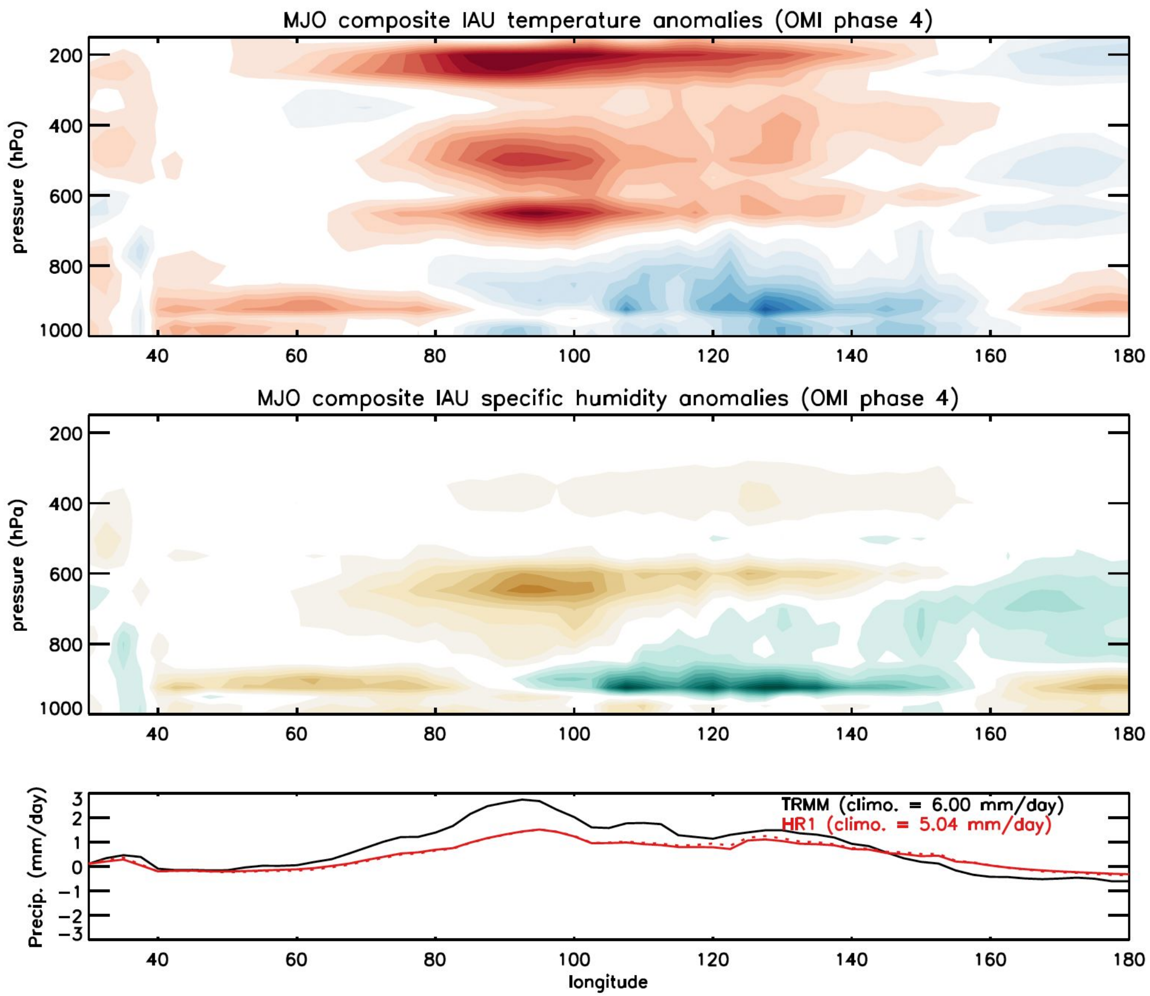
Underprediction of MJO convection amplitude is seen even in the first-guess



Associated IAU anomalies are suggestive of missing MCS-type Q1 and Q2 sources

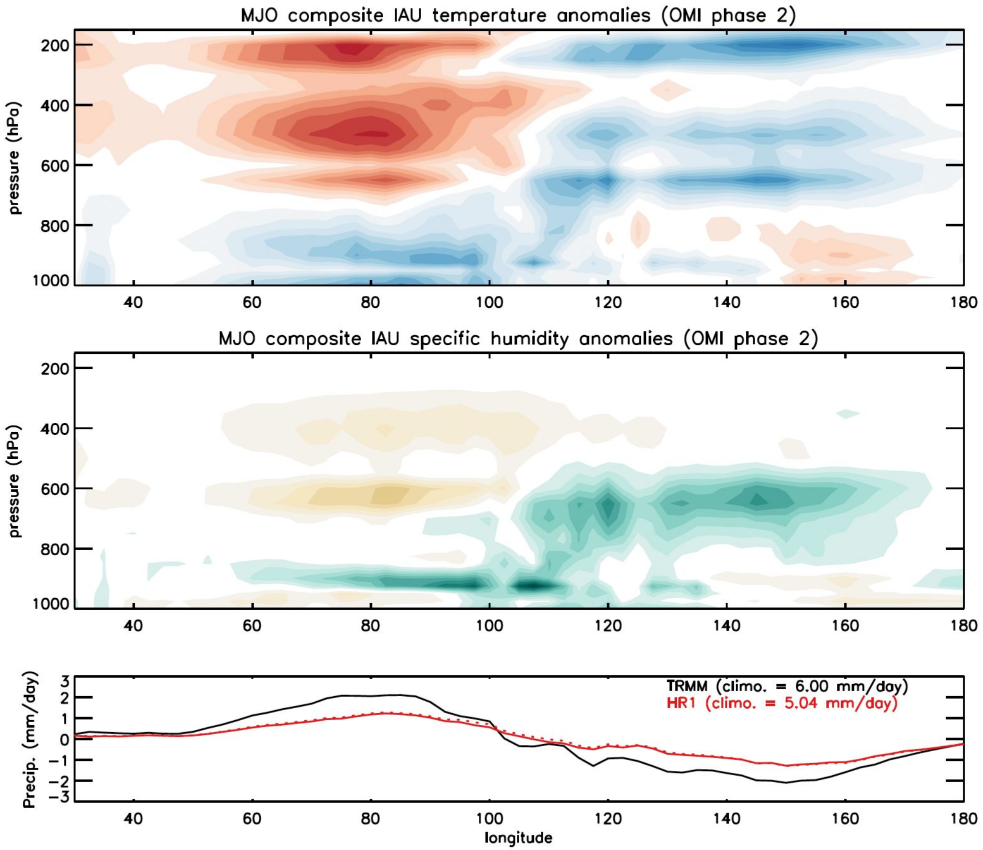


The picture is similar when looking at other MJO phases

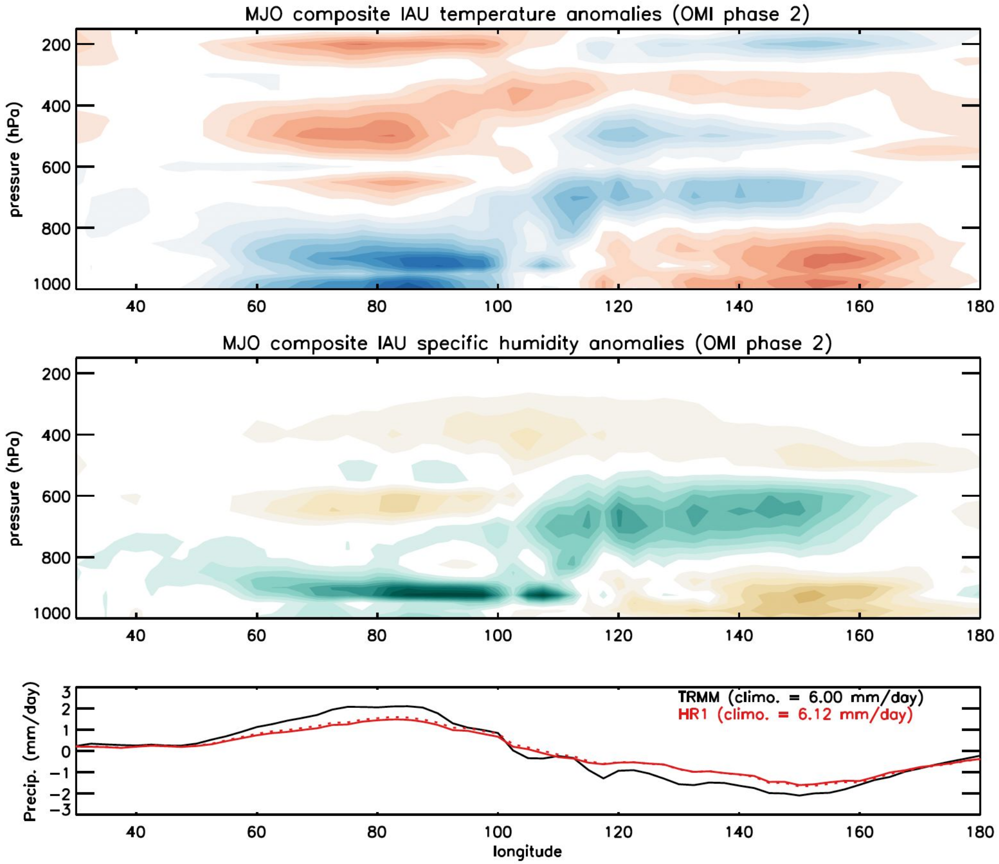


The high-resolution UFS shows a similar but less-severe problem

1-deg. UFS



0.25-deg. UFS



What is the reason for this problem?

- Our working hypothesis is that convection in the model is too insensitive to fluctuations in free-tropospheric moisture, due to deficiencies in the treatment of entrainment

- To explore this idea, we simply compared this treatment to what is used in the IFS (whose MJO prediction skill was reported in the literature to be greatly enhanced when adopting a formulation that includes an explicit dependence on environmental relative humidity; RH)

- This comparison showed that the treatment is structurally quite similar but where:

    1) The parameterized strength of the entrainment is roughly an order of magnitude smaller than in the IFS

    2) The RH dependence of the scheme is rendered negligible due to differing parameter choices

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Summary and next steps

- The coupled UFS prototype HR1 (both at 1-deg. and 0.25 resolution) suffers from a tendency to underpredict the intensity of MJO rain anomalies (even in the first guess)

- This underprediction leads to missing MCS-type Q1 and Q2 sources

- The reason for these errors is thought to be due to parameter choices controlling the strength and RH depedence of entrainment, which ultimately leads to convection being insufficiently sensitive to free-tropospheric moisture fluctuations

- Currently, we are exploring the impact of adopting parametric choices similar to what is used in the IFS