Improving the representation of tropical variability and its large-scale teleconnections in NOAA's Unified Forecast System

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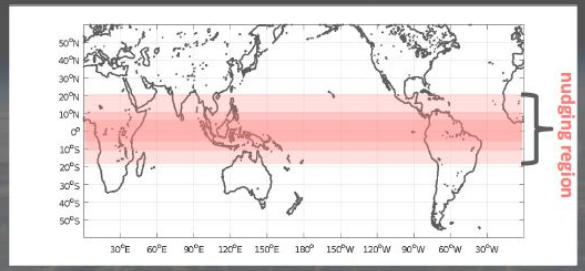
1) NOAA ESRL PSL
2) CIRES University of Colorado

Funding acknowledgement: California Department of Water Resources and NOAA ESRL PSL

Better forecasts of the tropics, improves forecasts world-wide

Nudge NOAA UFS Toward Reanalysis in the Tropics



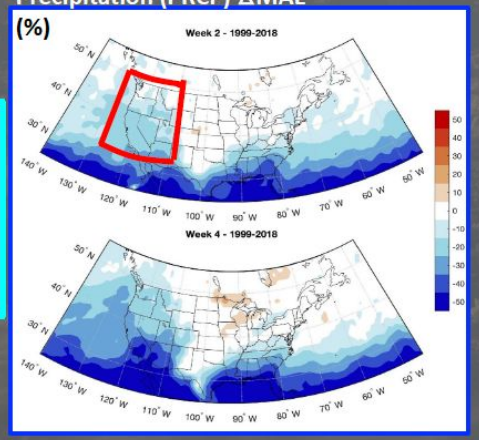
UFS (~GFSv15)

30 days reforecasts, initializations every 5 days (620 reforecasts)

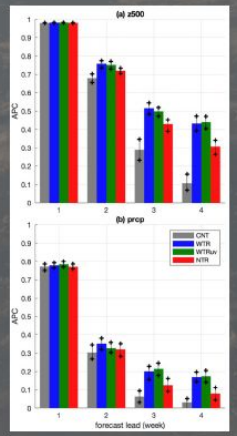
Nov-Mar 1999-2018

Nudged to ERAi reanalysis in Tropics

Precipitation (PRCP) ΔMAE



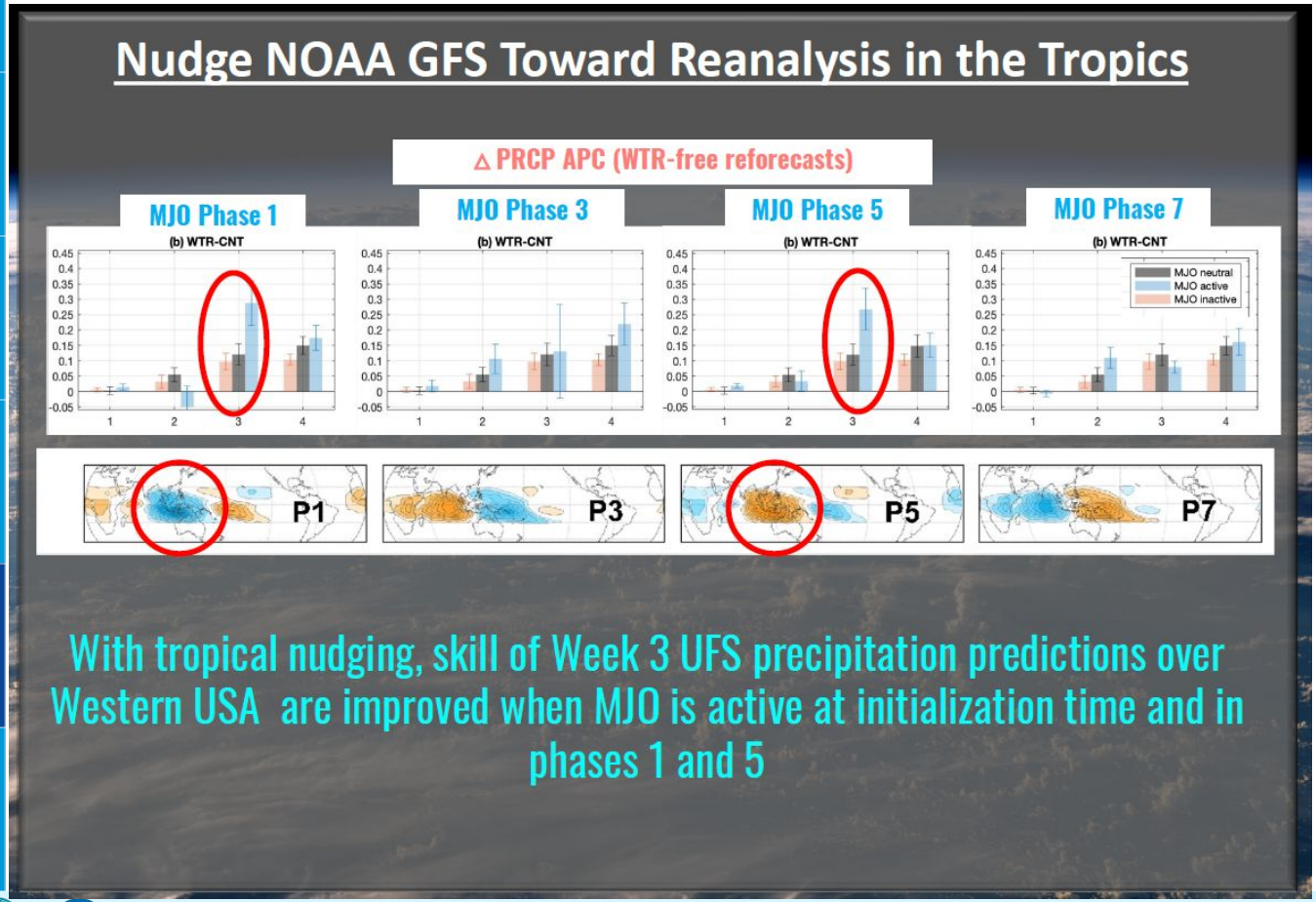
20-50% Reduction Week 2-4 Mean Average Error



Week 3 + 4 California Anomaly Pattern Correlation 2-4 X larger

From Juliana Dias, PSL

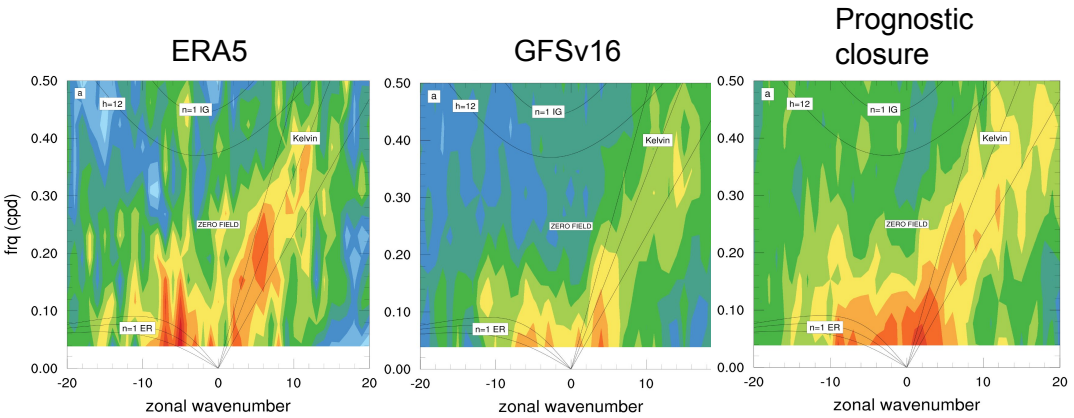
Better forecasts of the tropics, improves forecasts world-wide

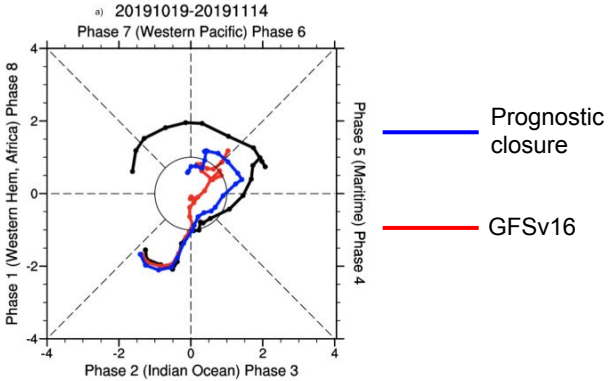


From Juliana Dias, PSL

Two recent developments to enhance convective organization in NOAA's Unified Forecast System

1) Use of stochastic self-organizing cellular automata (CA) for enhanced spatial (sub-grid and cross-grid) and temporal organization *(Bengtsson et al. 2011, 2013, 2016, 2019, 2022)*
2) Use of prognostic evolution of convective area fraction (closure) for temporal memory and orgnanization feedbacks. *(Bengtsson et al. 2022)*





Two recent developments to enhance convective organization in NOAA's Unified Forecast System

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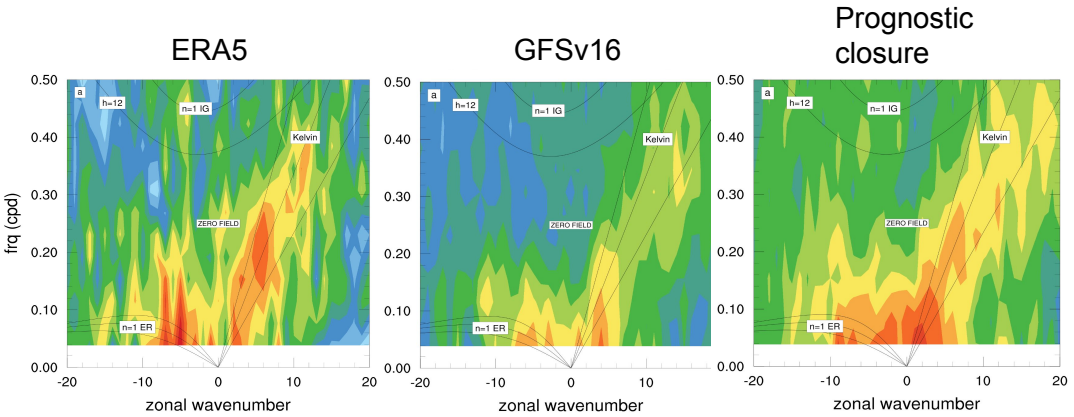
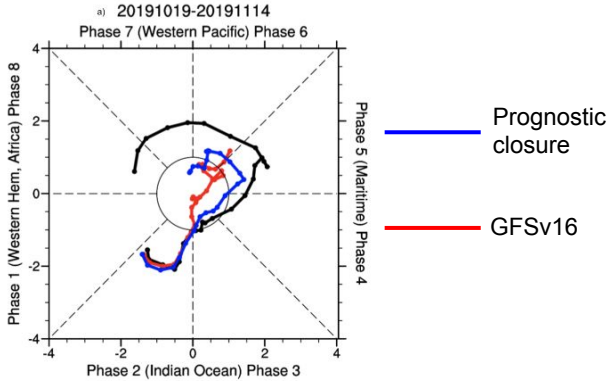
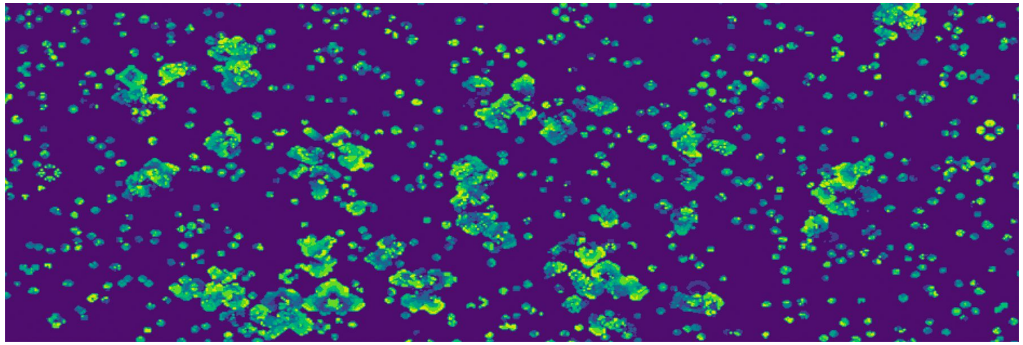


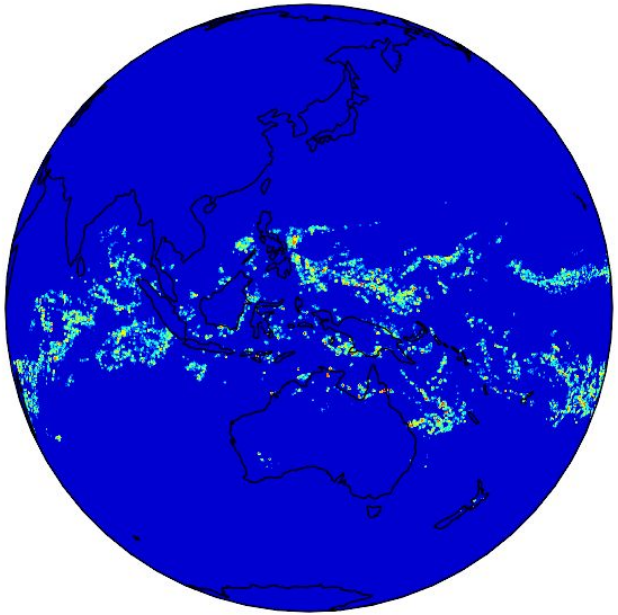


Cellular automaton convection organization scheme

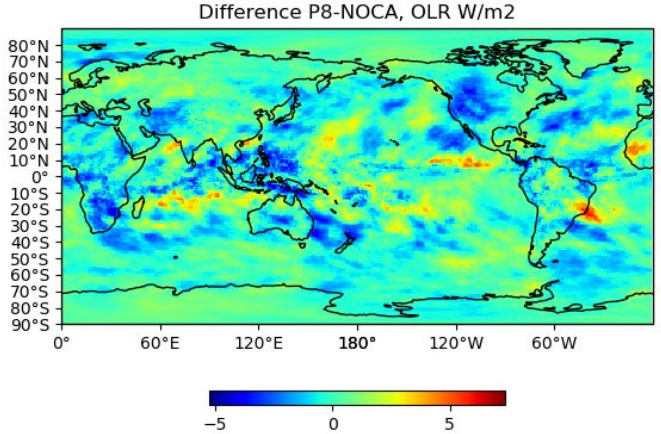
1. Self-organization and birth-death processes suitable for modeling of organized physical systems - such as atmospheric convection.
2. Introduce 3D physics of convection, which is generally modelled using a 1D plume model, by allowing the CA to inform on convective initiation in neighbouring grid-boxes.
3. It allows for a stochastic representation of deep convection *at the source of uncertainty* by addressing statistical fluctuations in cloud number or intensity on the sub-grid.
4. For seasonal/climate prediction, stochastic cumulus convection can be viewed as a noise induced forcing to modulate large scale predictors.



Impact in the UFS (GFSv17/GEFSv13) prototype (8), with/without CA



Snapshot of a flow-dependent cellular automaton in UFS GFSv17 prototype simulations coarse-grained onto GFS ~25km grid. (C384)



*Difference in **OLR bias** with and without CA in 24 MJO cases from the UFS coupled prototypes (all lead times (6 to 840 hours))*

Even though the CA is only active over the Tropics, we do see an imprint over the Western US.

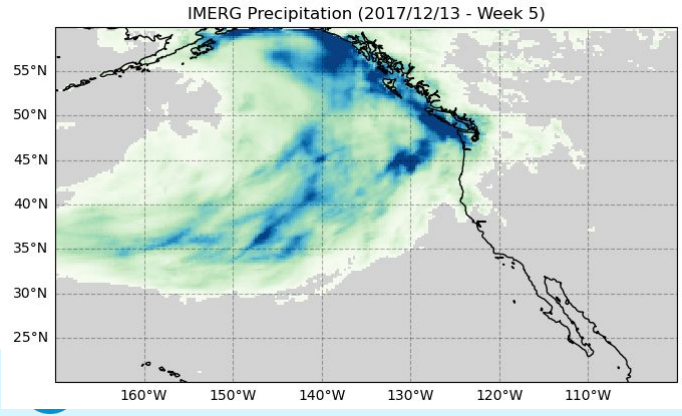
Figure acknowledgement: Lydia Stefanova, EMC

Forecast of opportunity?

The impact of the CA convective organization scheme is small compared to nudging the entire state of the tropics to an analysis.

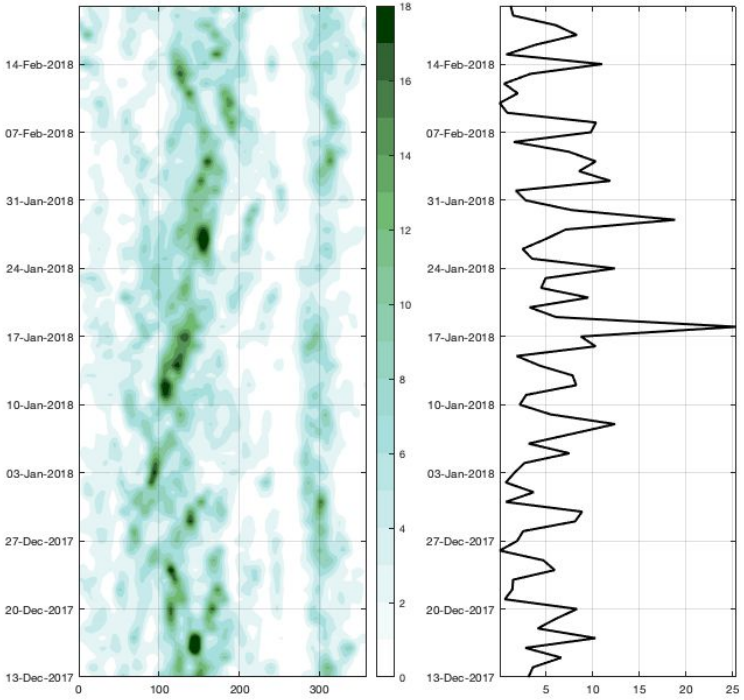
We approach the challenge in terms of "forecast of opportunity", in that when we have a case that has an active MJO over the Indian Ocean/MT continent, we see an atmospheric river event off the coast of the Western USA 2-5 weeks later.

Can the CA organization scheme, active only over the Tropics, improve such a case?



Observed (IMERG) tropical precipitation - MJO event

Observed precipitation over US/Canada West Coast



Precipitation, mm/day

Experiment design

UFS coupled prototype 8 (GFSv17/GEFSv13 pre-operational configuration)

Model git-hub tag: Prototype-P8 (**CA on/off**)

Workflow git-hub tag: prototype/8

Model components: FV3, MOM6, WW3, CICE6

Initial conditions (Acknowledgment, Bing Fu, EMC):

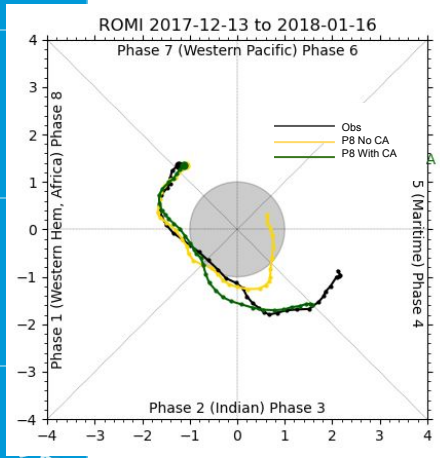
- ATM: GFSv16 with initial perturbation same as operations
- OCN: ORAS5 anl + perturbations
- ICE: CPC analysis
- WAV: GEFSv12 reanalysis forcing

Ensemble members: 10

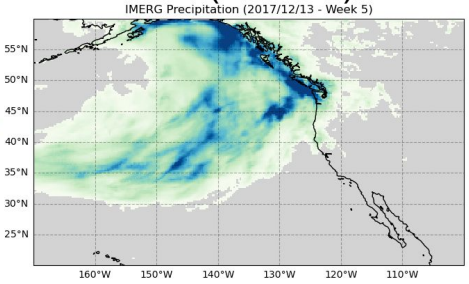
Resolution: C384 (~25km)

Forecast lead-time: 35 days

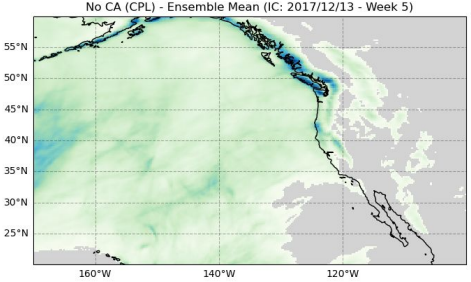
Impact on MJO, US West coast precip and vapour transport



OBS (IMERG)

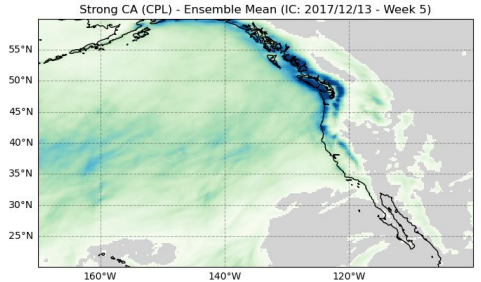


Without CA



Ensemble mean precip

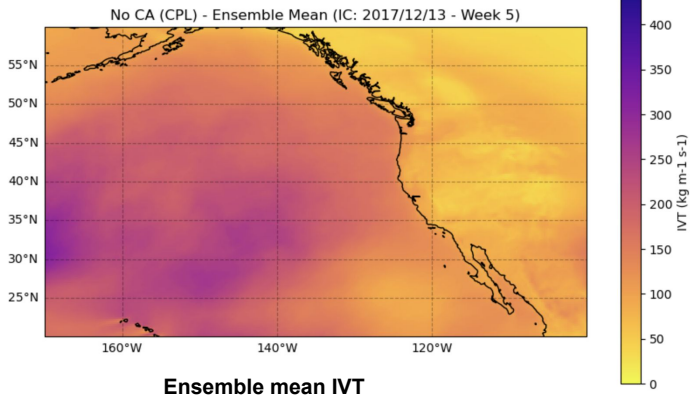
With CA



Ensemble mean precip

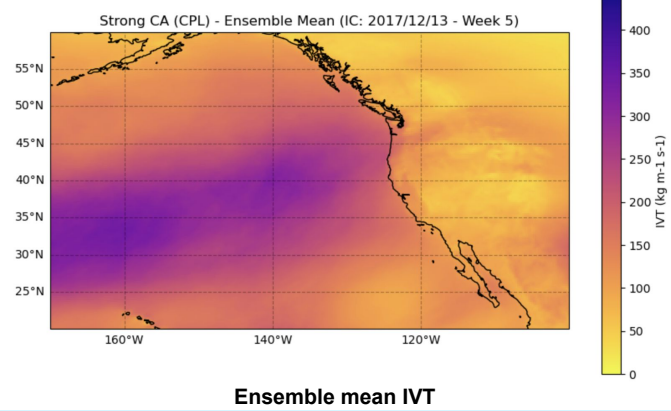
Initiated in phase 7, the ensemble mean **week 5** integrated vapour transport is enhanced, and precip is improved along the US/Canada west coast.

Without CA



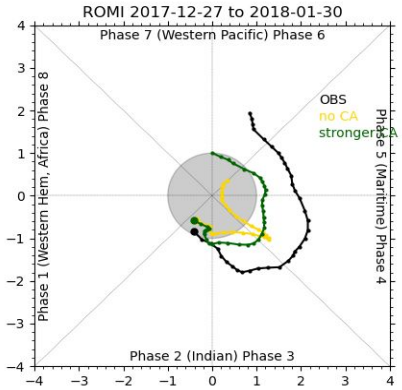
Ensemble mean IVT

With CA

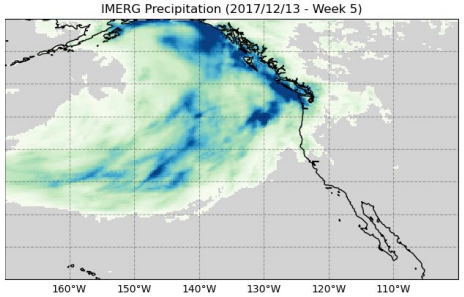


Ensemble mean IVT

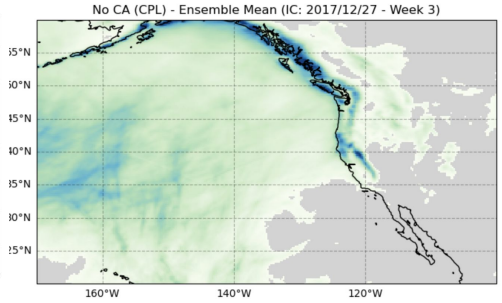
Impact on MJO, US West coast precip and vapour transport



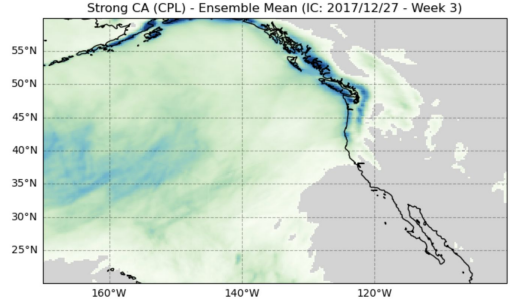
OBS (IMERG)



Without CA

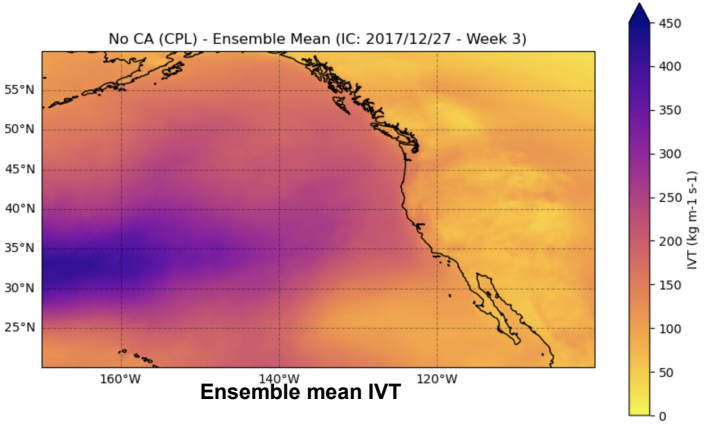


With CA

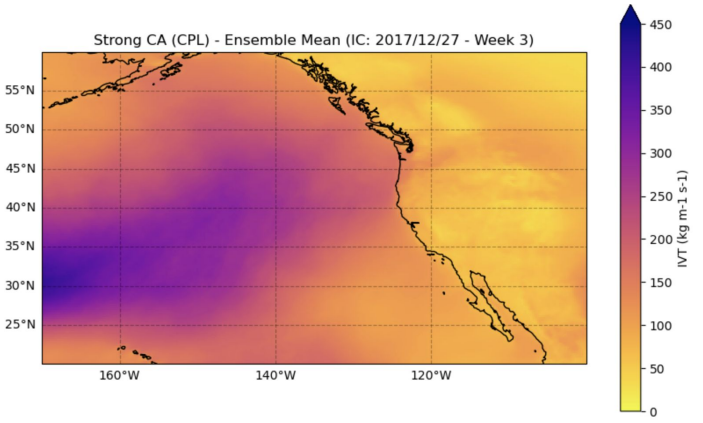


Initiated in phase 2, the ensemble mean **week 3** integrated vapour transport is brought further north in the runs with CA. The difference in precip is not as prominent as week 5. The model generally struggles to increase the amplitude of the MJO when initiated in a phase with weak initial amplitude.

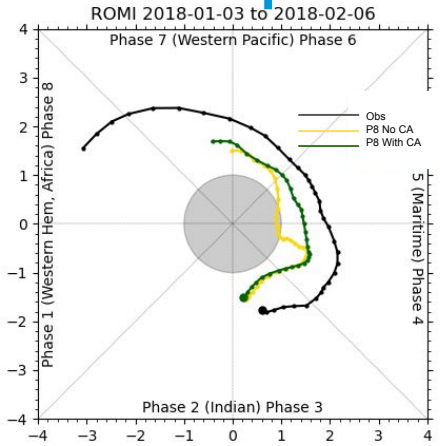
Without CA



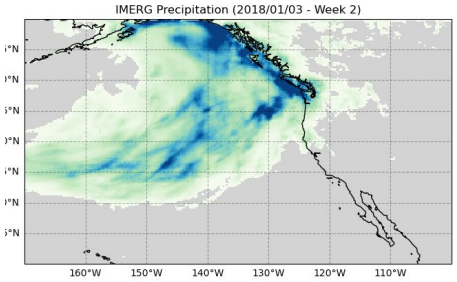
With CA



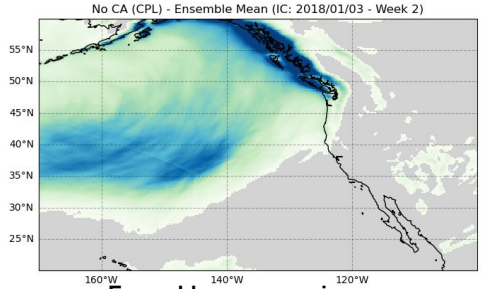
Impact on MJO, US West coast precip and vapour transport



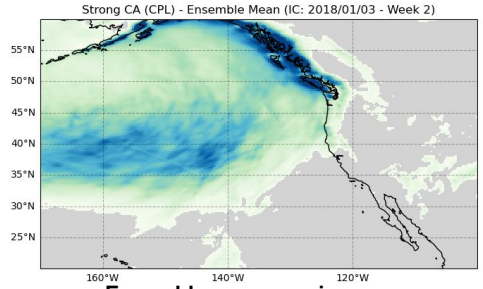
OBS (IMERG)



Without CA

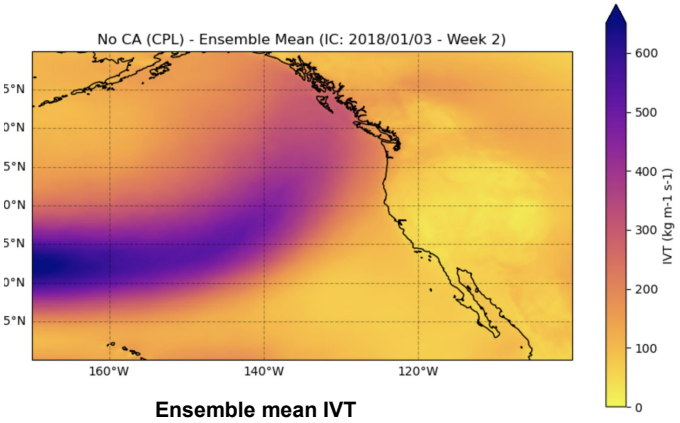


With CA



Initiated in phase 3, the impact on ensemble mean **week 2** integrated vapour transport and precip is quite neutral. Initial condition play a larger role. The ensemble mean forecast in both cases is really good

Without CA



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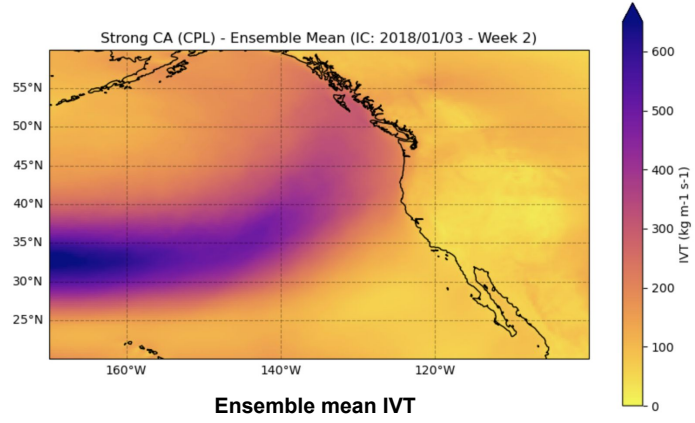
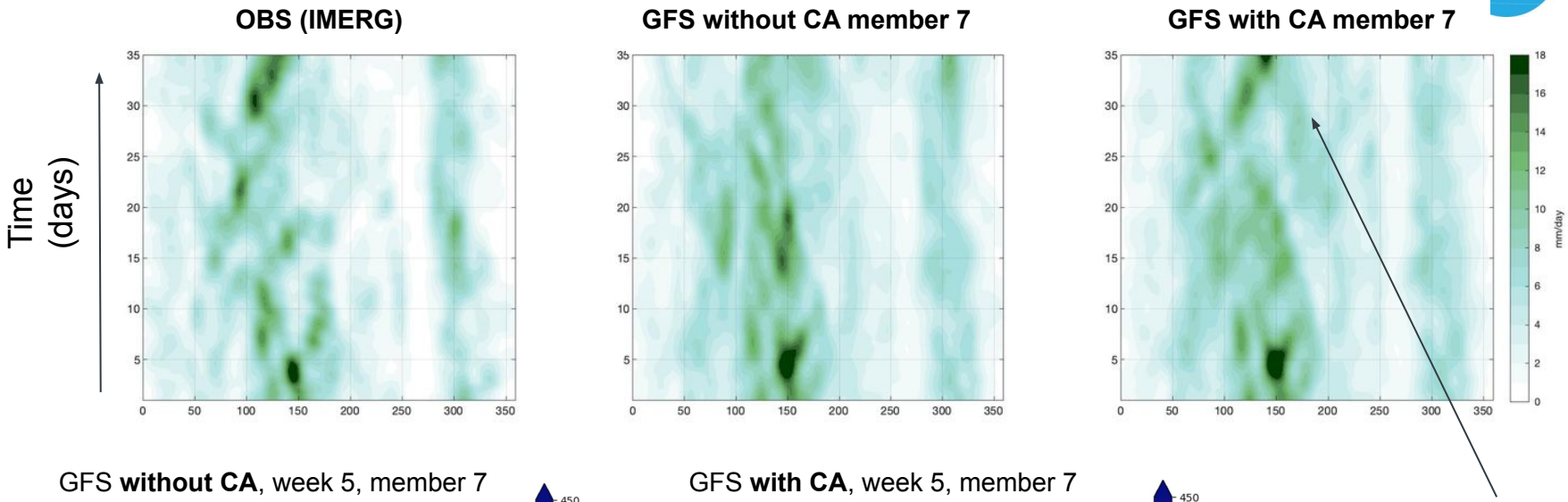
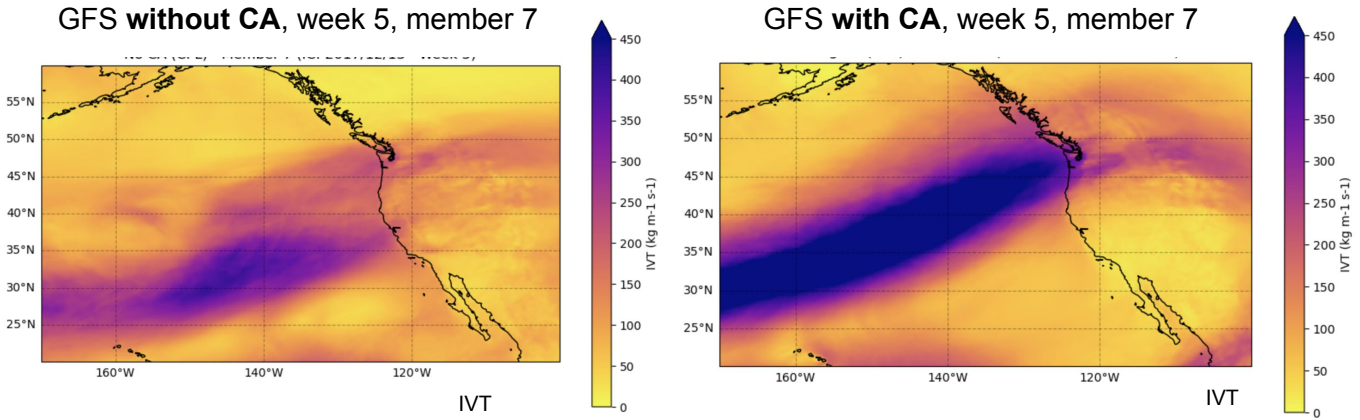


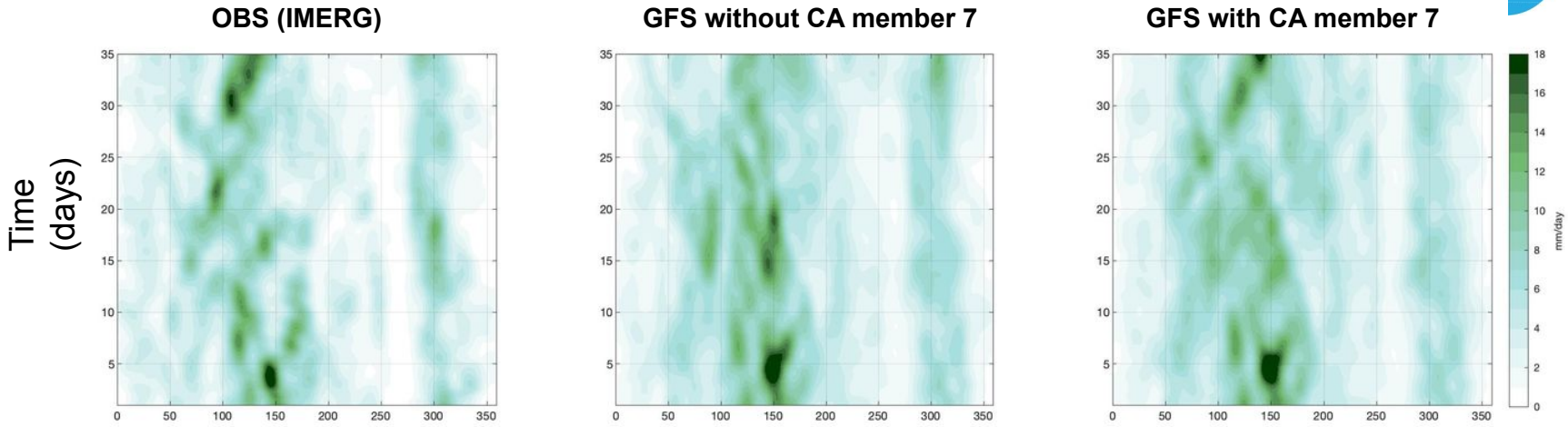
Best AR ensemble member in week 5, is associated with enhanced eastward propagation over the Tropics in week 5





The cellular automata convection organization scheme can organize disturbances, and generate eastward propagation far away from the initial state.

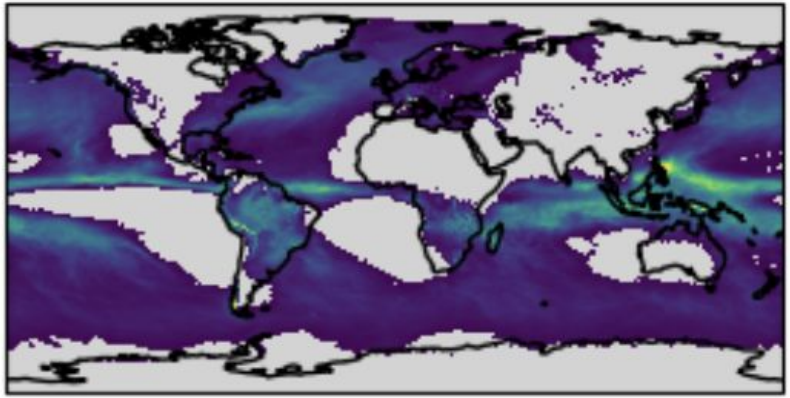
Impact on organization and propagation



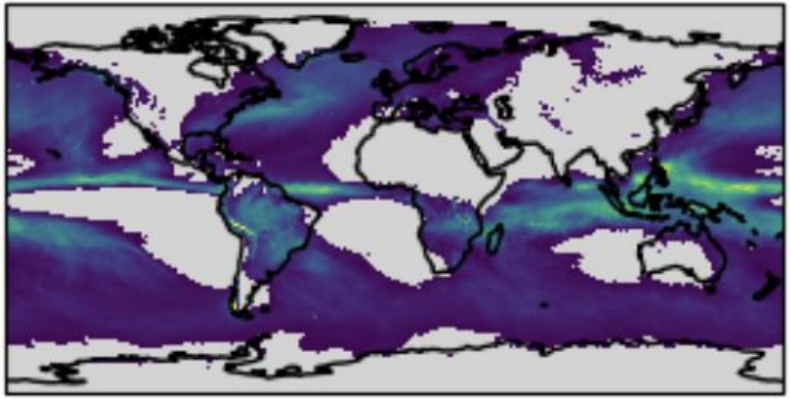
Precipitation variance is enhanced along phase speeds associated with MJO and Kelvin wave speeds. Shaded lines represent ensemble members.

Precipitation mean state

Without CA, 35 day mean, all cases, all members



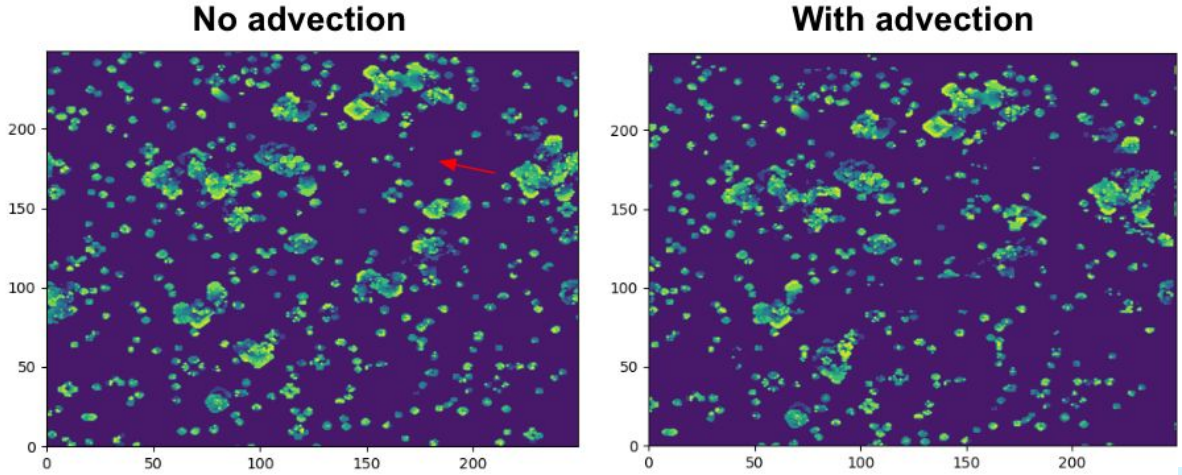
With CA, 35 day mean, all cases, all members



The enhancement of eastward propagation and organization seen with the CA convection organization scheme is not due to a change in the mean state in which disturbances are embedded in.

Future plans

- The cellular automaton convective organization scheme (and the new prognostic closure) has been included in the GFSv17/GEFSv13 coupled pre-operational prototypes.
- For the study presented here, we look to extend the number of cases and ensemble members to have more conclusive results.
- Currently exploring adding sub-grid 2D advection (or movement of cloud objects) of cellular automaton cells. Will explore impact for upcoming versions of the GFS/GEFS and SFS.
- Additional exploratory work on the CA in the UFS includes updating transition probabilities using a neural network.



Example of impact of advection in off-line toy model CA