Evaluation of different ensemble configurations for the analysis and prediction of high-impact mesoscale convective systems

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INTRODUCTION

- As ensembles of numerical models at convection-allowing grid spacing become used more frequently for research and operations, it is important to understand the strengths and weaknesses of different ensemble configurations
- Storm-scale ensembles can provide useful probabilistic forecast information about high-impact mesoscale convective systems (MCSs), and they can also be used to understand the key processes in those MCSs
- In this work, we focus on a multi-day period of heavy rainfall in the southern United States in June 2010 (Fig. 1). A series of MCSs associated with a long-lived mesoscale convective vortex (MCV) led to three days of extreme precipitation and flash flooding in Texas and Arkansas.

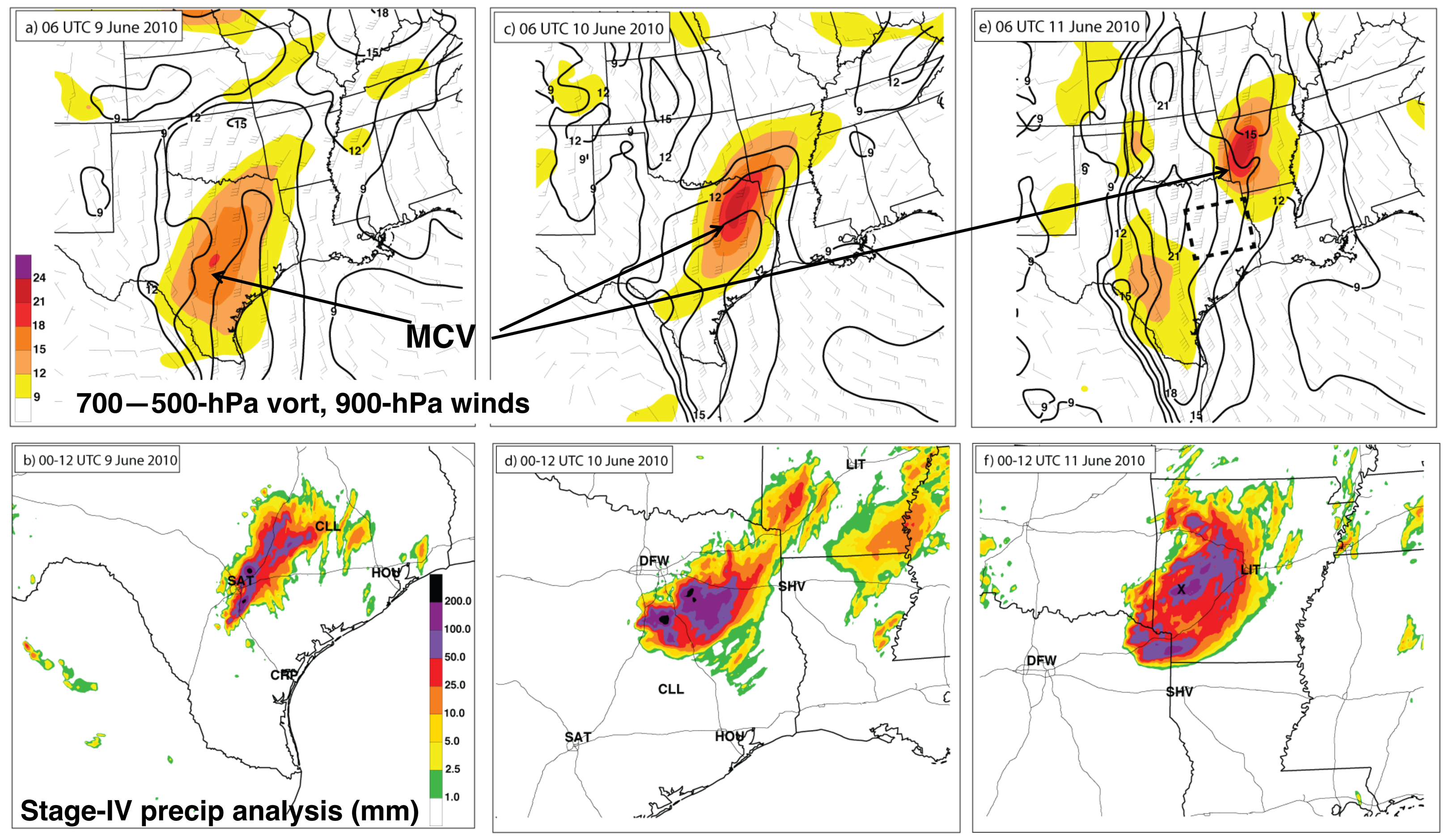

Fig. 1: *(left column) NARR analyzed 700—500-hPa layer-average absolute vorticity (colors); 900-hPa winds and isotachs (solid contours) (right column) NCEP Stage IV precipitation analysis (mm)*

Questions to address:

- What is the predictive skill of this type of high-impact MCS/MCV with a storm-scale ensemble?
  - How does the configuration of the ensemble impact the answer to this question?
- What atmospheric features and processes are both necessary and sufficient for this type of event to occur? (and how can ensembles help us answer this question?)

THE ENSEMBLE SYSTEMS

Ensemble	CAPS storm-scale ensemble system (SSEF)	WRF-DART single physics	WRF-DART mixed physics
Number of members	26	24	24
Models	WRF-ARW, ARPS, WRF-NMM all at dx=4 km	WRF-ARW at dx=4 km	WRF-ARW at dx=4 km
Initial/boundary conditions	NAM-based, perturbations from SREF, radar assimilation for most members (see Xue et al. 2010 and Clark et al. 2012a,b)	36-member WRF-DART EnKF assimilation/forecast system cycled for 96 with standard obs assimilated, perturbed 18Z GFS forecast for LBCs	Same as WRF-DART single physics, except mixed physics used during assimilation cycle (as in, e.g., Wheatley et al. 2010)
Physics parameterizations	Varied microphysics, boundary layer, and land-surface schemes	Thompson microphysics, YSU boundary layer	Varied microphysics, boundary layer, and land-surface schemes
Forecast info	0000 UTC 10 June for 30 h	0000 UTC 10 June for 36 h	0000 UTC 10 June for 36 h

RESULTS – PRECIP FORECASTS

- Here we focus on the forecast initialized 0000 UTC 10 June. Early in the forecast (6-12 h) all of the ensemble systems show high probabilities of heavy precipitation in northeast Texas, consistent with the observed event (Fig. 2). All give some probability of heavy rain in Nebraska as well

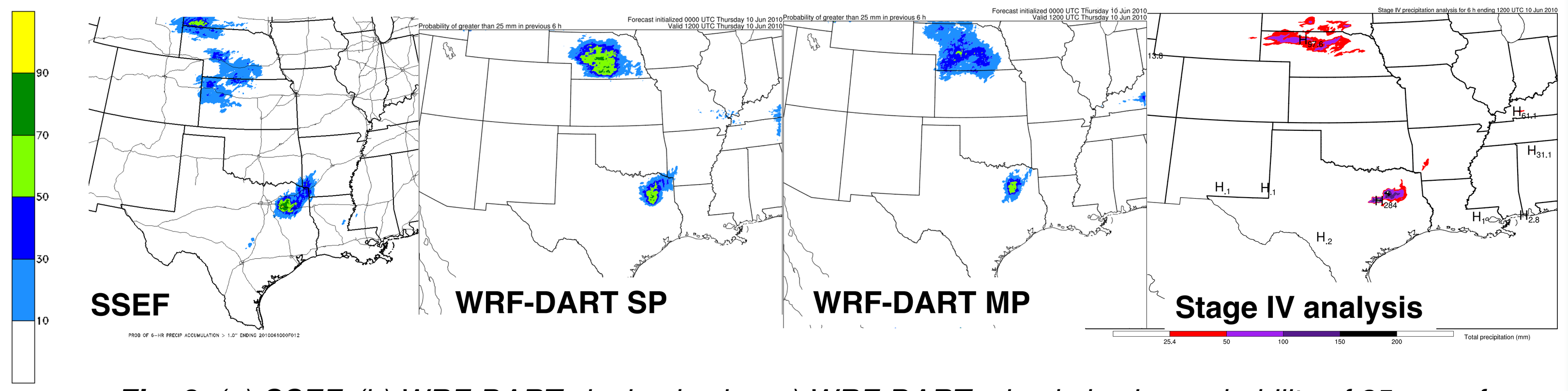

Fig. 2: *(a) SSEF, (b) WRF-DART single physics, c) WRF-DART mixed physics probability of 25 mm of rainfall in 6—12-h forecast period ending 1200 UTC 10 June 2010. (d) Stage IV precipitation analysis, showing only locations receiving 25.4 mm or more.*

- By the 24-30-hour forecasts, however, the ensemble predictions start to diverge somewhat in the vicinity of the MCV (Fig. 3). The SSEF has its highest probabilities displaced somewhat, the SP moves the MCV too quickly, and the MP correctly locates the highest probabilities

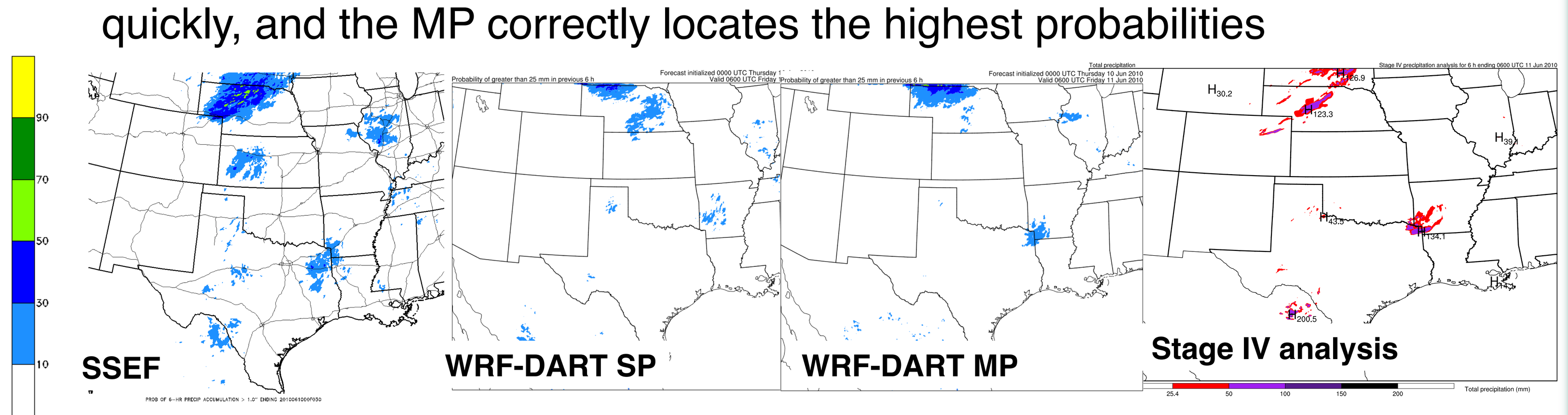

Fig. 3: *As in Fig. 2, except for forecast hours 24-30 (0000-0600 UTC 11 June 2010).*

- The SSEF moves the MCV through more slowly, indicating heavier rainfall in east Texas, whereas the WRF-DART ensembles move the MCV faster to the east along with the rainfall (Fig. 4)

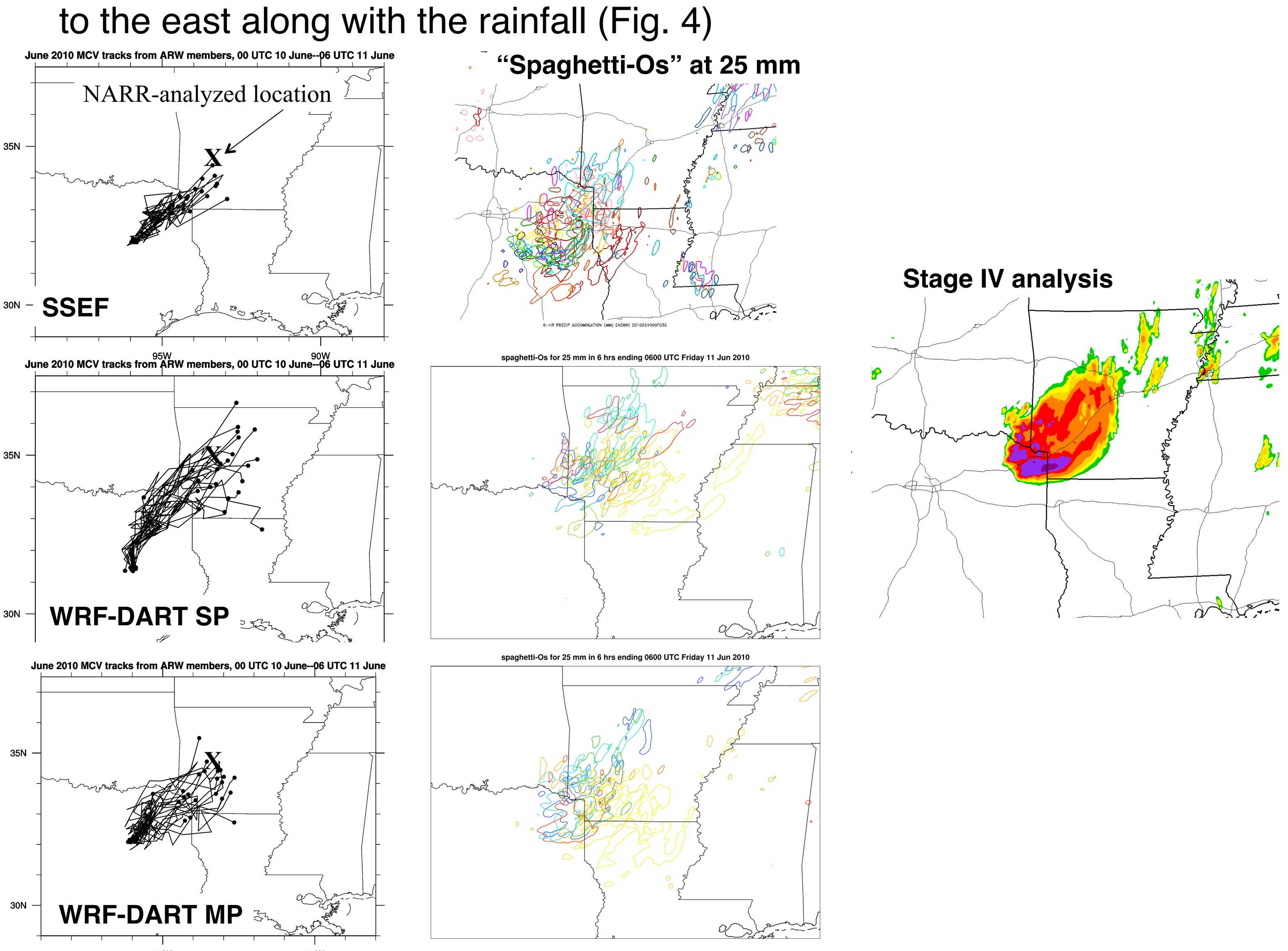

Fig. 4: *(Left) Predicted MCV tracks from the SSEF and WRF-DART ensembles. (Middle) Maps showing the 25-mm contour from each ensemble member. (Right) Stage IV precipitation analysis*

ACKNOWLEDGMENTS

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RESULTS -- PROCESSES

- We now exploit differences between ensemble members with "good" and "bad" forecasts to understand what was favorable or detrimental for the MCS
- SSEF results shown here; WRF-DART analysis ongoing
- The strength of the remnant cold dome from the previous night's convection, along with the strength of the MCV, were key to the development of the nocturnal heavy-rain-producing MCS (Fig. 5)

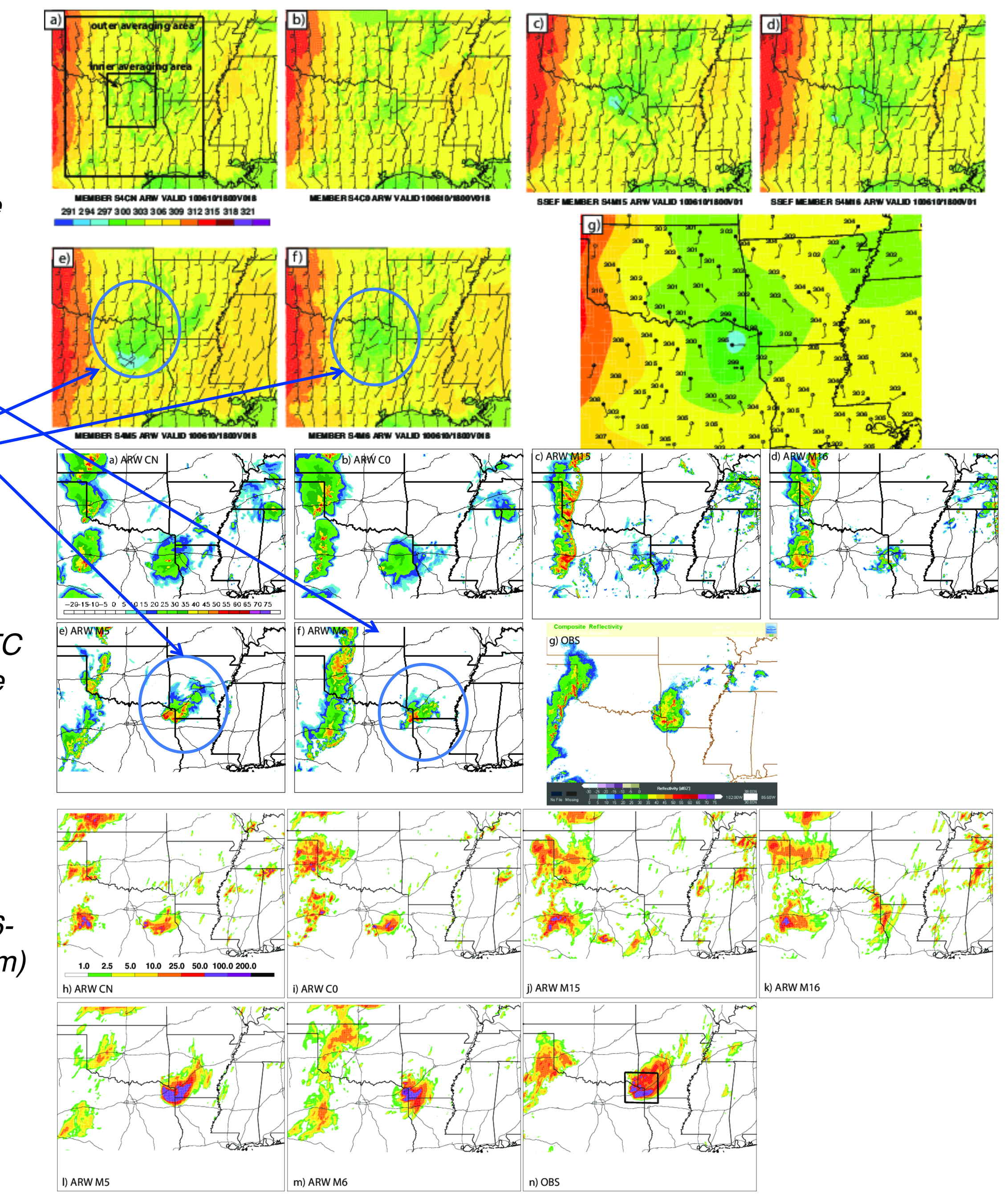

Fig. 5: *Surface potential temperature from selected members of the Storm-Scale Ensemble Forecast (SSEF) system; a 26-member ensemble at 4-km grid spacing. The time shown is 1800 UTC 10 June 2010. Objectively analyzed observations are in (g).*

Members with accurate representation of afternoon surface cold dome also correctly predict the overnight MCS

As in the top panels, but for simulated reflectivity at 0300 UTC 11 June (9 hours after the above images).

As in the above panels, but for 6-hr accumulated precipitation (mm) from 0000-0600 UTC 11 June 2010.

- Only a couple members have afternoon cold pools and MCVs similar to observations; these are the members that correctly predict the nocturnal MCS

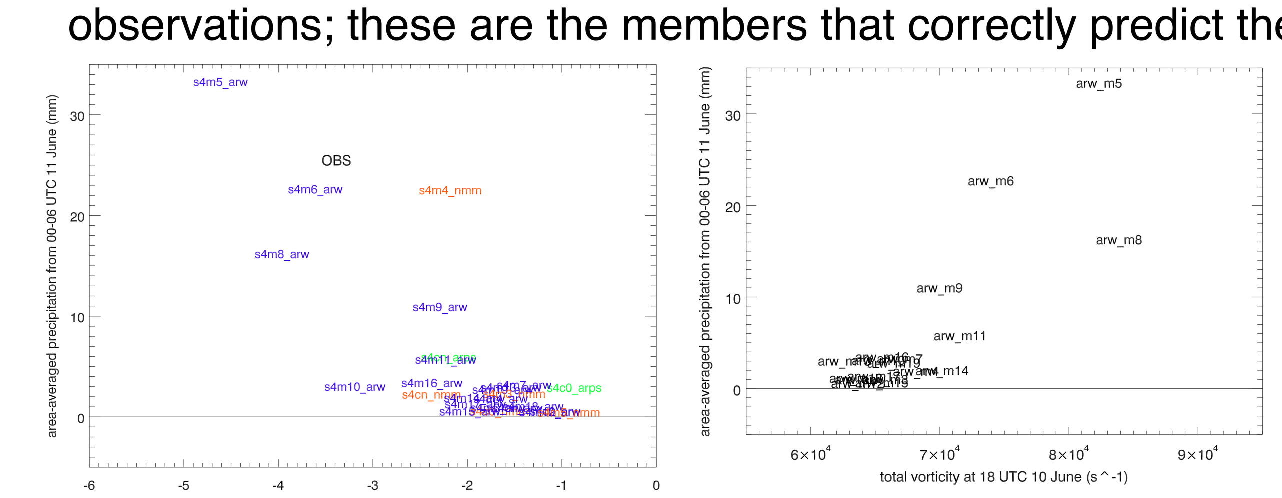

Fig. 6: *(Left) Scatterplot showing area-averaged cold-dome strength at 18 UTC 10 June on the x-axis, and area-averaged precip from 00-06 UTC 11 June on the y-axis. (Right) As in the left panel, but the x-axis shows area-integrated midlevel vorticity*

SUMMARY