NARCCAP Regional Climate Model Simulations of the North American Monsoon

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Introduction

This poster displays simulations from the North American Regional Climate Change Assessment Program (NARCCAP) and their ability to reproduce average near-surface conditions from June-September (JJAS) during the North American Monsoon (NAM). This analysis covers major precipitation features, wind and moisture flux fields, the monsoon-related seasonal change in wind direction, specific humidity, and temperature. Simulations drvien by the NCEP-DOE global reanalysis II (NCEP) are the focus of this evaluation. Because the North American Regional Reanalysis (NARR) is used in this model comparison where observations are not available, a comparison of its winds with those observed during the 2004 North American Monsoon Experiment (NAME) is also included.

Models & Methods

NARCCAP is producing 50-km horizontal resolution climate simulations over North America by dynamically downscaling 4 different global climate model (GCM) simulations and one reanalysis (NCEP) using 6 different regional climate models (RCMs). All models are shown at their original resolution with their original projections.

Major characteristics of the NARCCAP RCMs:

	CRCM	ECP2	HRM3	MM5I	RCM3	WRFG
Dynamics	Nonhydrostatic, Compressible	Hydrostatic, Incompressible	Hydrostatic, Compressible	Nonhydrostatic, Compressible	Hydrostatic, Compressible	Nonhydrostatic, Compressible
Lateral Boundary Treatment	9 points (Davies 1976); spectral nudging of horizontal wind.	Perturbations relaxed at boundaries; spectral filter	4 points (Davies and Turner 1977)	4 points (linear relaxation)	12 points (exponential relaxation)	15 grid points (exponential relaxation)
Land Surface	CLASS	NOAH	MOSES	NOAH	BATS	NOAH
Thermal/Water Layers	3/3	4/4	4/4	4/4	1/3	4/4
Vegetation Types	21 vegetation classes	13 classes	53 classes (Wilson and Henderson- Sellers 1985)	16 classes from USGS SiB model	19 classes	24 classes from USGS
Boundary Layer	Local K, gradient Richardson number formulation	Hong-Pan non-local K	First order turbulent mixing	Hong-Pan (MRF) countergradient, non-local K	Non-local K, countergradient flux	Yonsei Univ. (explicit entrainment)
Explicit Moist Physics	Removal of supersaturation	Removal of supersaturation	Prognostic cloud liquid and ice; liquid potential temperature	Dudhia simple ice	SUBEX, prognostic cloud water	Prognostic cloud liquid and ice, rain, snow
Cumulus Parameterization	Mass Flux	Simplified Arakawa-Schubert	Mass Flux, including downdraft	Kain-Fritsch 2	Grell with Fritsch-Chappell closure	Grell
Number of Vertical Levels	29	28	19	23	18	35
Type of Vertical Coordinate	Gal-Chen scaled-height	Normalized pressure	Hybrid terrain following & pressure	Sigma	Terrain following	Terrain following
Original Grid Size	160 x 135	161 x 136	171 x 146		160 x 130	155 x 130
Sponge Zone Depth (# grid pts.)	10	14/20 (x/y)	8		13	10.5
Length of Timestep	900 Seconds	100 seconds	300 Seconds	120 seconds	150 Seconds	150 seconds
Spectral Nudging	Yes	Yes	No	No	No	No

For more information on NARCCAP and these regional models visit: **www.narccap.ucar.edu**

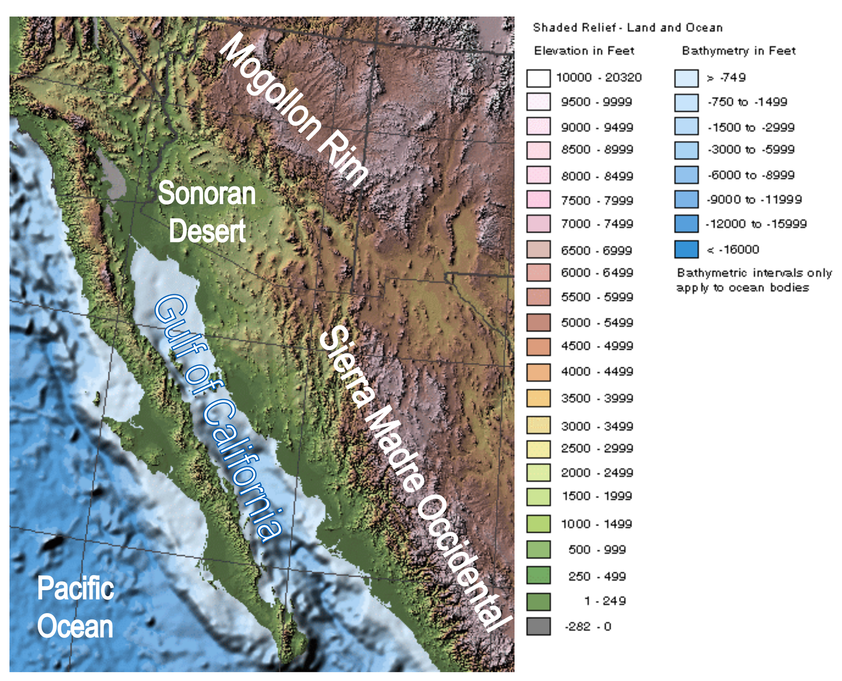
Observation based datasets and reanalyses:

NARR: North American Regional Reanalysis. 32-km horizontal resolution, 45 layers.

UDEL: University of Delaware air temperature and precipitation analysis. 1/2° resolution, global. (http://www.esrl.noaa.gov/psd/)

NAME: CSU-NAME upper-air and surface gridded analyses version 3.1c. 1° resolution, analysis of data collected during NAME. Uses NARR reanalysis data over data-sparse oceanic regions, but not the Gulf of California. http://tornado.atmos.colostate.edu/name/products/gridded/index.html

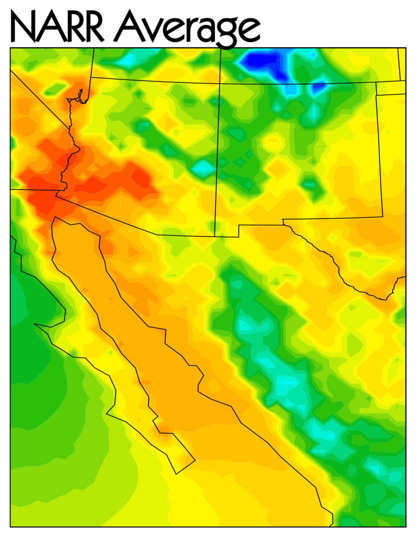
North American Monsoon Highlights



Onshore moisture flow develops during the monsoon season due to a shift in the subtropical high and the development of a thermal low over lowland desert areas. Flux of onshore moisture feeds precipitation along the Mogollon Rim and Sierra Madres. Precipitation occurs in "bursts and breaks" regulated by the passage of tropical easterly waves, which force moisture up the Gulf of California, and shifts in the upper-level ridge.

1980-2004 JJAS Average 2-m Temperature

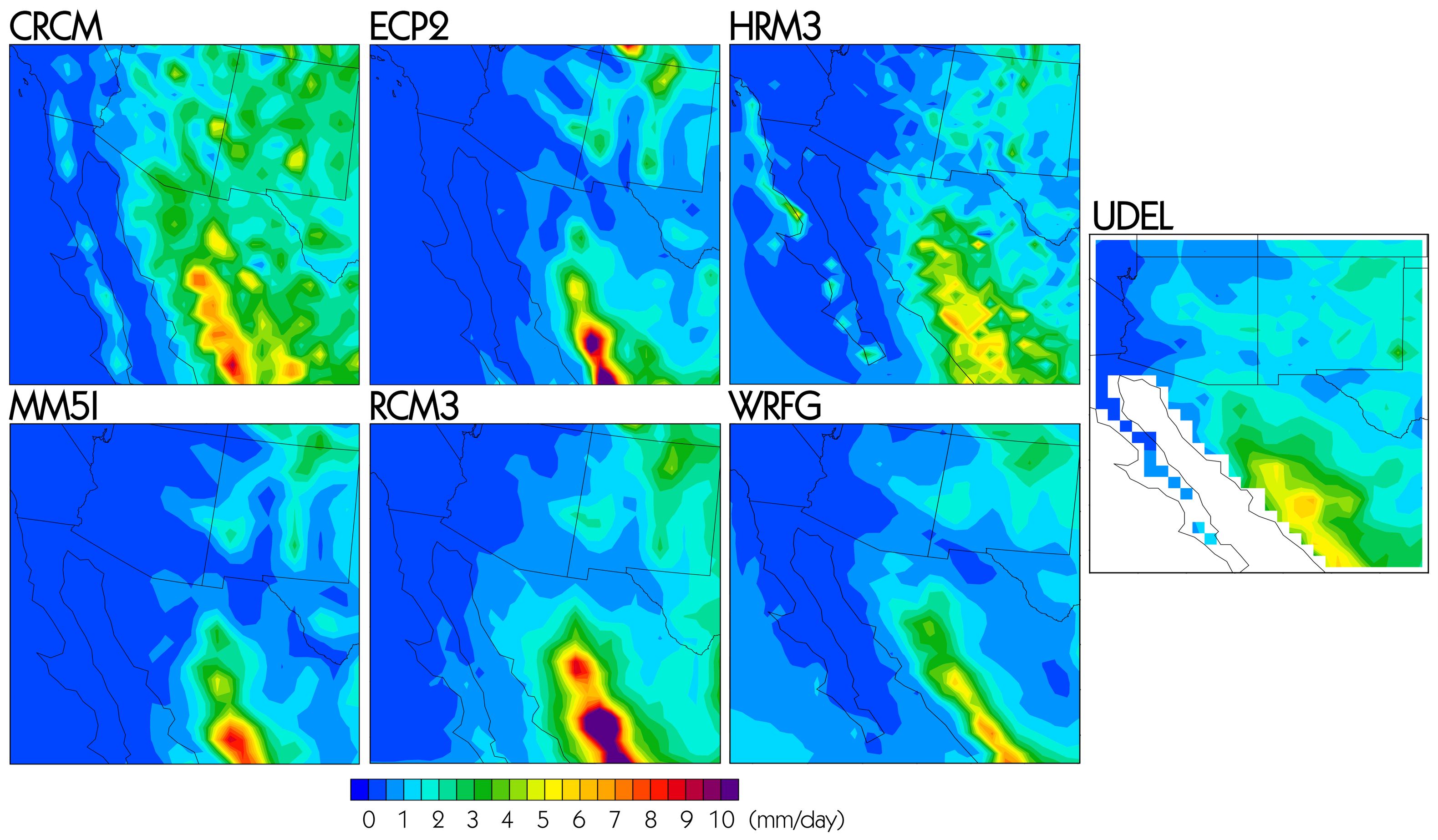
NARR Average



Area Avg Temperatures (region shown at left):

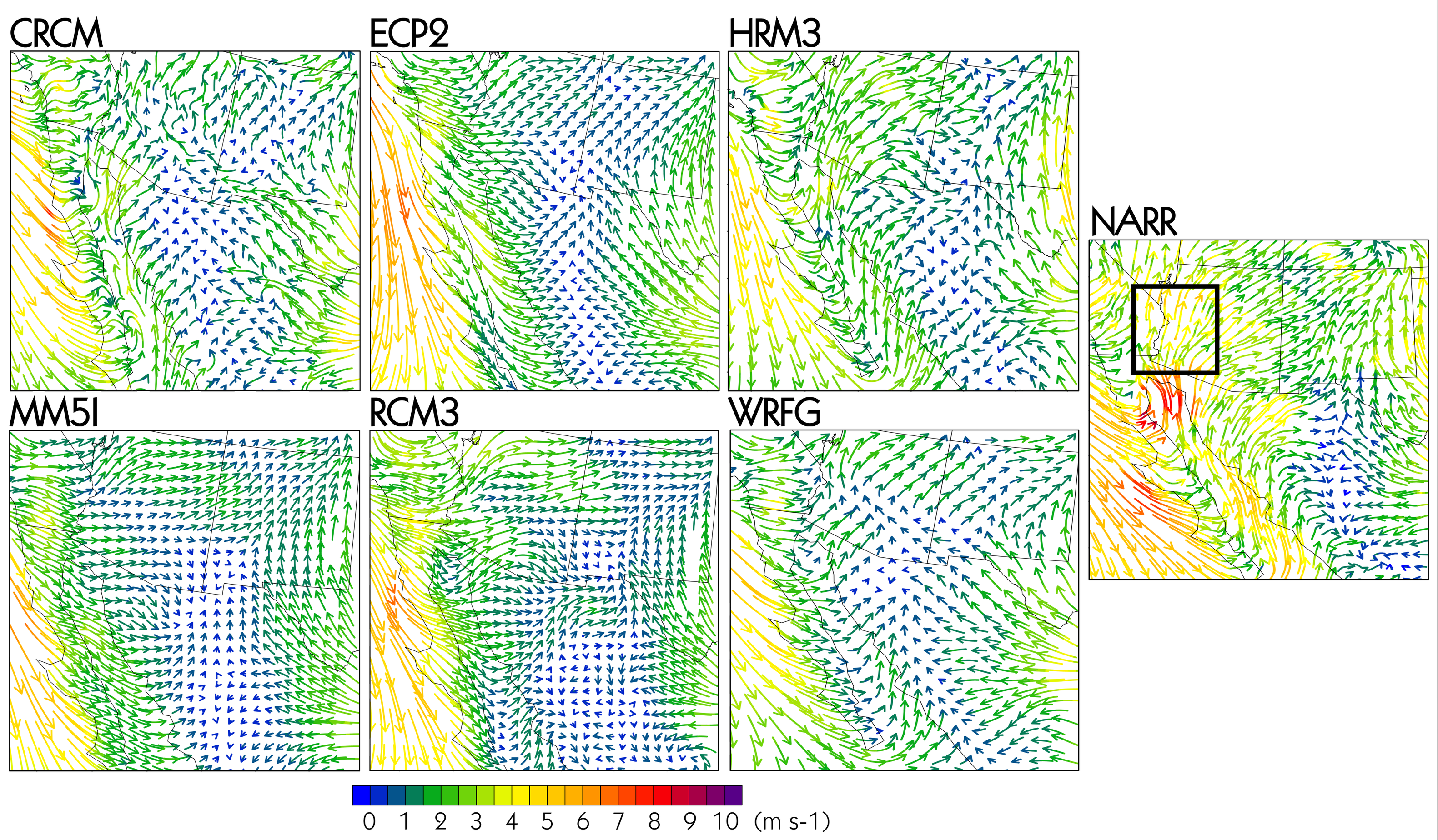
NARR: 24.61 °C
CRCM: 23.36
ECP2: 24.61
HRM3: 25.64
MM5I: 24.70
RCM3: 24.29
WRFG: 23.12

NARCCAP simulations of 2-m temperature are similar and realistic in most models in terms of their magnitude and spatial distribution. The HRM3 is the acception. Its warm bias is present here, particularly over the Sonoran Desert, though it is not as strong throughout the region as it is elsewhere in North America.

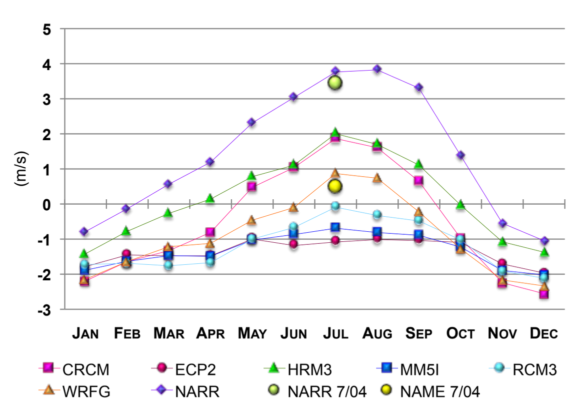


1980-2004 JJAS Average Precipitation Rate

Precipitation should be present along the Mogollon Rim in AZ and the Sierra Madre Occidental in Mexico. Both are simulated in all of the RCMs, but with errors in magnitude and spatial coverage in most of the models. Precipitation in the CRCM is noisy, several models have a dry bias in AZ, and the RCM3 and ECP2 have high biases along the Sierra Madres compared to UDEL precipitation. Precipitation is dependent on many other processes, so it is important to examine other driving fields in order to gain a better understanding of the models and their simulations of precipitation.



1980-2004 JJAS Average 10-m Wind

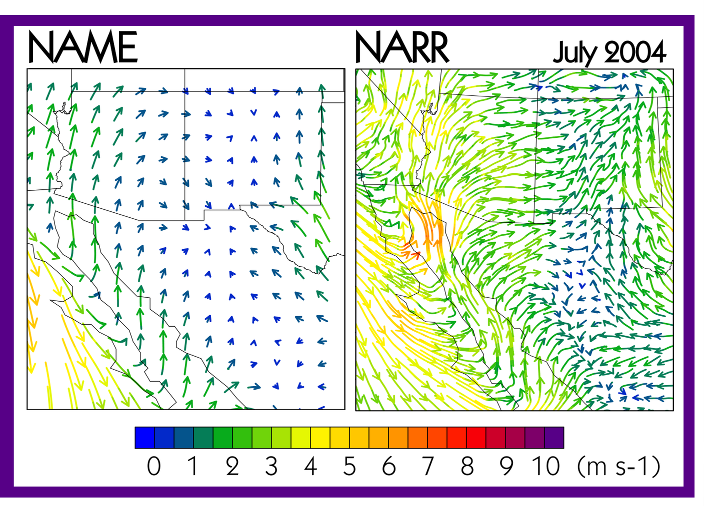


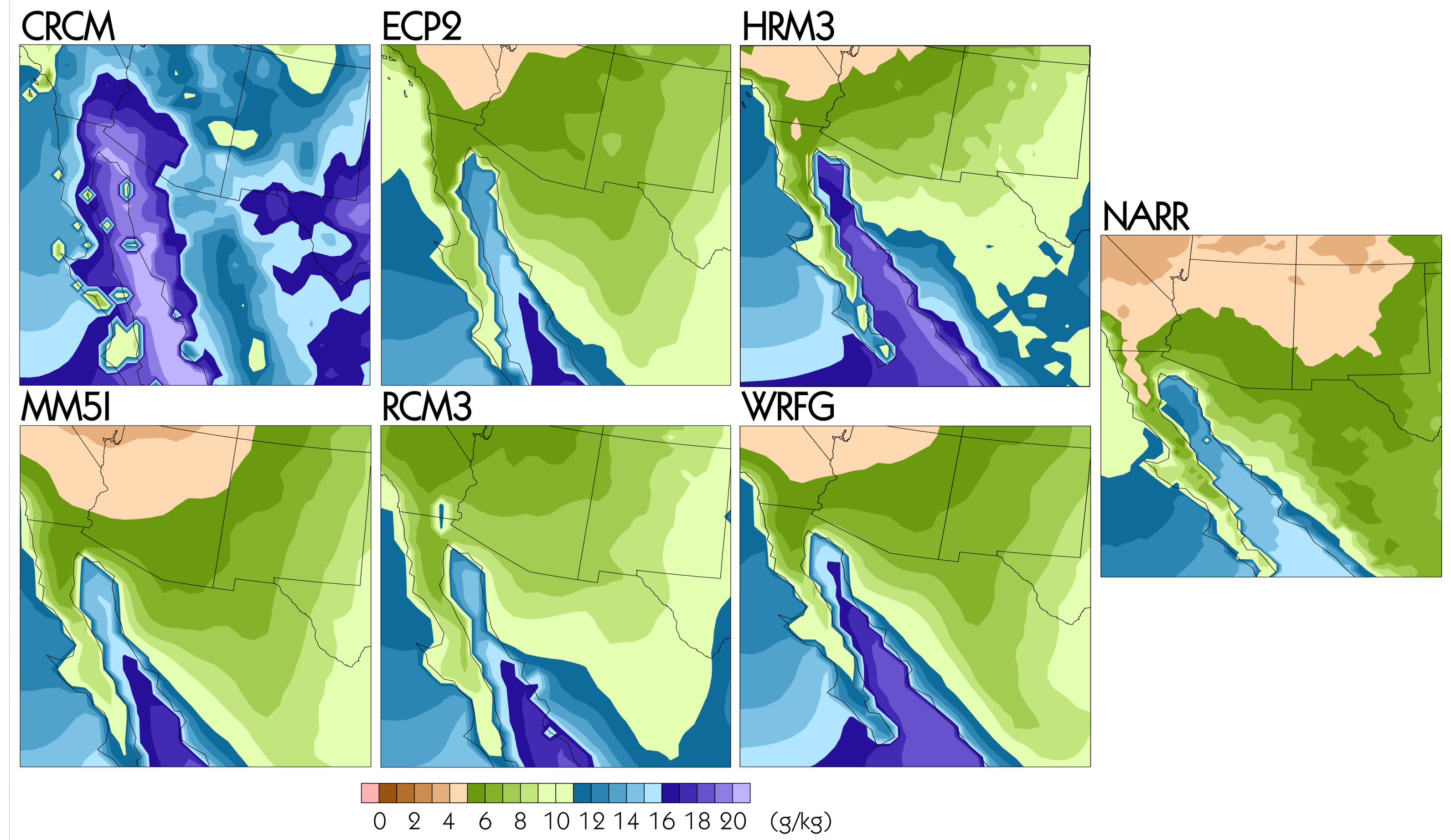
While most of the models capture the onshore flow into Mexico, several models have difficulty simulating the onshore, northward wind component in the northern Gulf of California up into AZ. This is particularly apparent in the MM5I and the ECP2. The onshore flow in the HRM3 into AZ may be aided by its warm bias over the Sonoran Desert.

The seasonal cycle of the meridional wind component averaged over the box shown in the NARR panel above is shown directly above/left. While the switch to a dominant northward average wind component during monsoon season is overdone in the NARR (see below), it should still be present in this region. The models that do not capture this on average, do form a sea-breeze during the peak in the diurnal cycle, allowing moisture flux into and precipitation in AZ.

NOTE: NARR Wind Bias

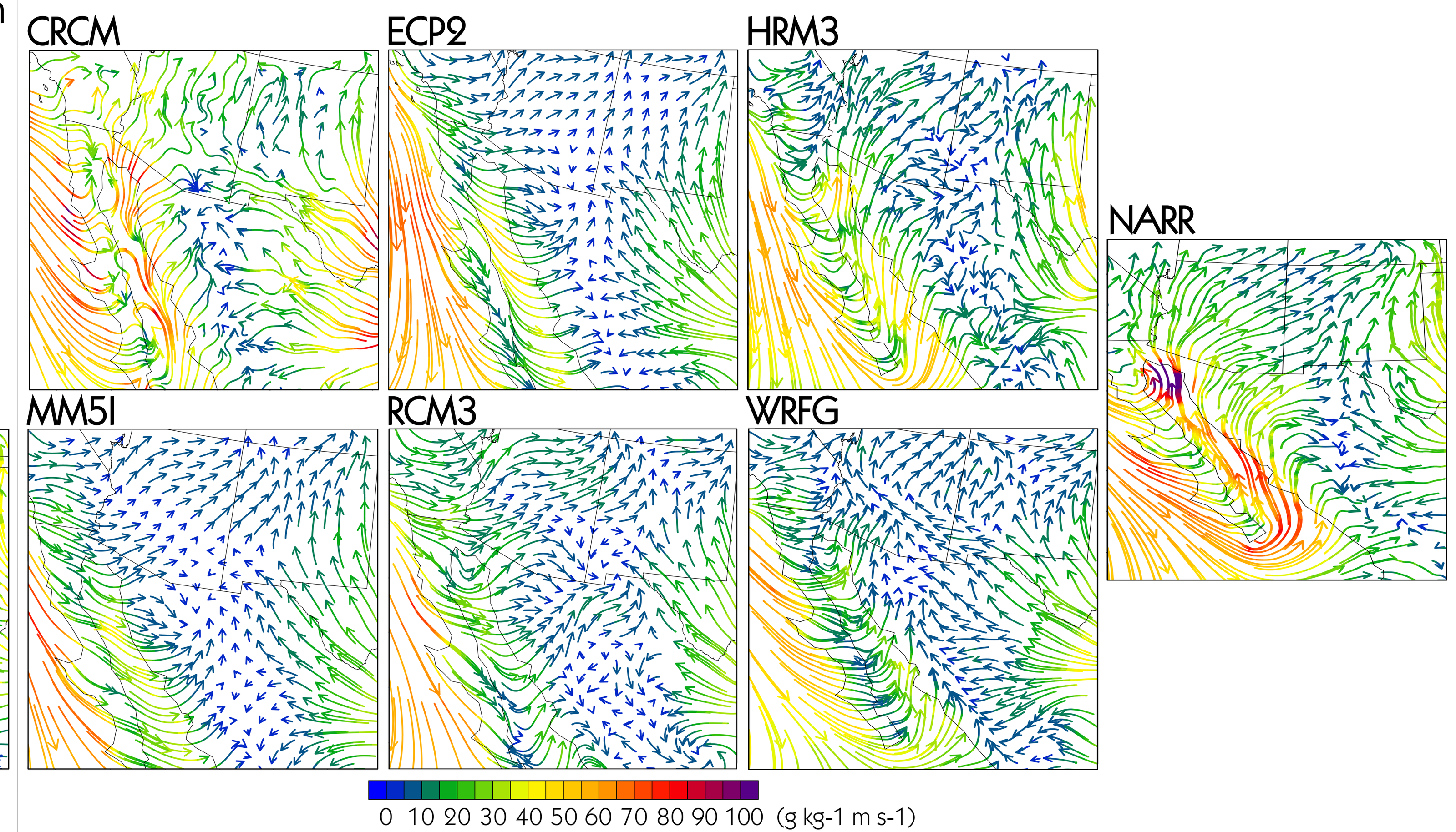
A word of caution... the NARR wind field is used here for this model comparison because no better dataset seems to exist for this 25-year period over this region. However, the NARR has a strong wind bias over the Gulf of California into AZ relative to the 2004 July average gridded NAME observations (shown right and in above chart), particularly in the northern Gulf. A version of NARR run for July of 2004 enhanced with more of the NAME observations contains a nearly identical error (not shown here; Ciesielski and Johnson, J. Climate, 2008), implying that this is a systematic problem in the NARR. This bias is most likely not limited to this one season.





1980-2004 JJAS Average Specific Humidity

All RCMs perform reasonably, except the CRCM. The cause of its unusual high bias in 2-m specific humidity in this area is still unknown.



1980-2004 JJAS Average Moisture Flux

Performance in simulating moisture flux mirrors that of the wind field. Note that the NARR moisture flux is likely too high over the northern part of the Gulf into AZ, as the wind field is too strong here. The magnitude of the CRCM moisture flux appears reasonable, but with inherent error because of the specific humidity bias.

Discussion

When determining the credibility of a model's simulation, more should be taken into account than just its average precipitation and temperature. While the NARCCAP simulations shown here perform well, for the most part, with these 2 measures, most of them have problems with other fields that indicate how well they are simulating the processes behind the NAM system precipitation. The HRM3 has a warm bias over the Sonoran Desert, which could strengthen its onshore flow and moisture flux into AZ. The CRCM has an obvious bias in specific humidity in this region. The MM5I and ECP2 do not properly simulate the average monsoon flow in the northern Gulf of California into AZ. The RCM3 has the same problem, but not to the same extent. The only model with no substatial bias in these fields is the WRFG.

This is not to say that this model will not have strong biases in variables/processes in other regions (i.e. do not assume you could get by using just this model for your analysis). These results also do not indicate how any of the models will perform when forced with any of the 4 GCMs being used in NARCCAP. Similarly, they do not yet indicate that any one NARCCAP model simulation of future climate in this region is more credible than another. A process-based analysis of the GCM-driven simulations of current climate and an analysis of the processes driving their projections of future climate will need to be completed first.

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