Regional Climate Model Projections for the North American Monsoon

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NCAR/IMAGe
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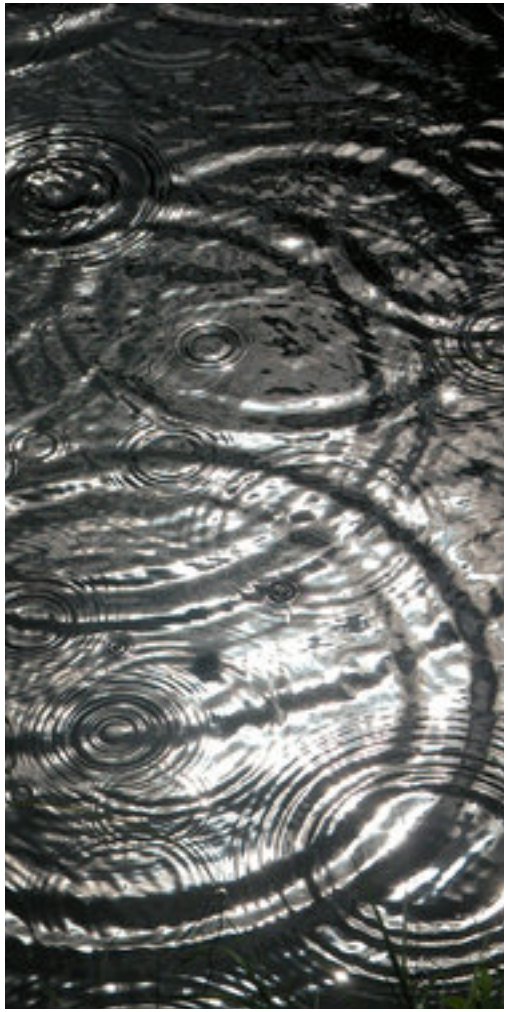
NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Project Goals

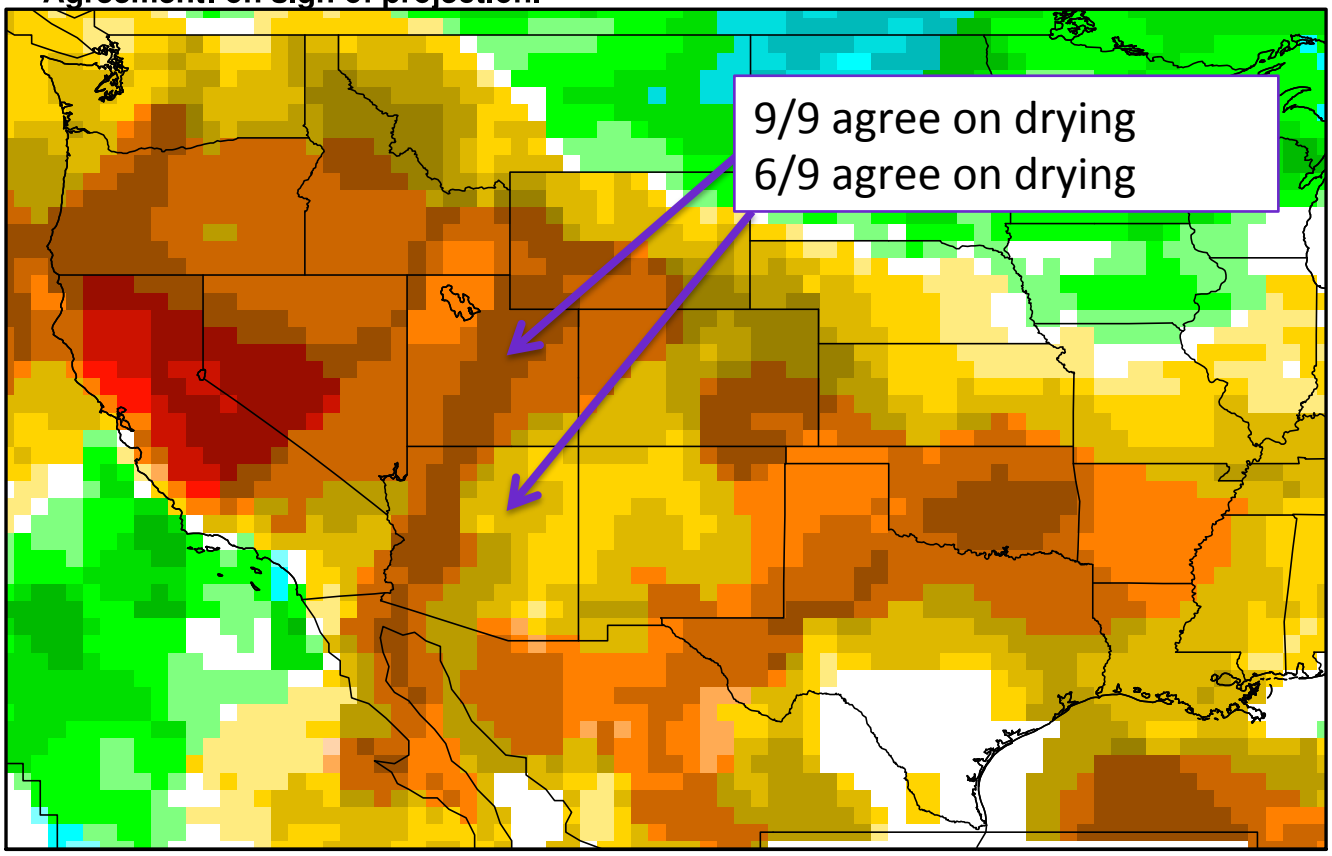


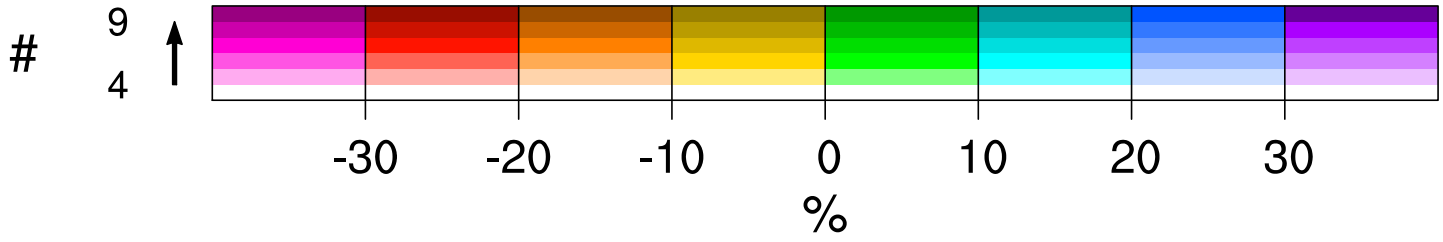
- Examine credibility of an ensemble of RCM simulations and their projections for the North American Monsoon System (among others).
- Establish the *differential* credibility of the RCM/ GCM combinations.
- Extend analysis beyond temperature and precipitation and the use of basic metrics.
  - Establish whether or not the *processes* that make up the monsoon system are credibly simulated.
- Identify bias in monsoon processes and establish the potential impact of that bias on projections.

ENSEMBLE MEAN CHANGE: Precipitation

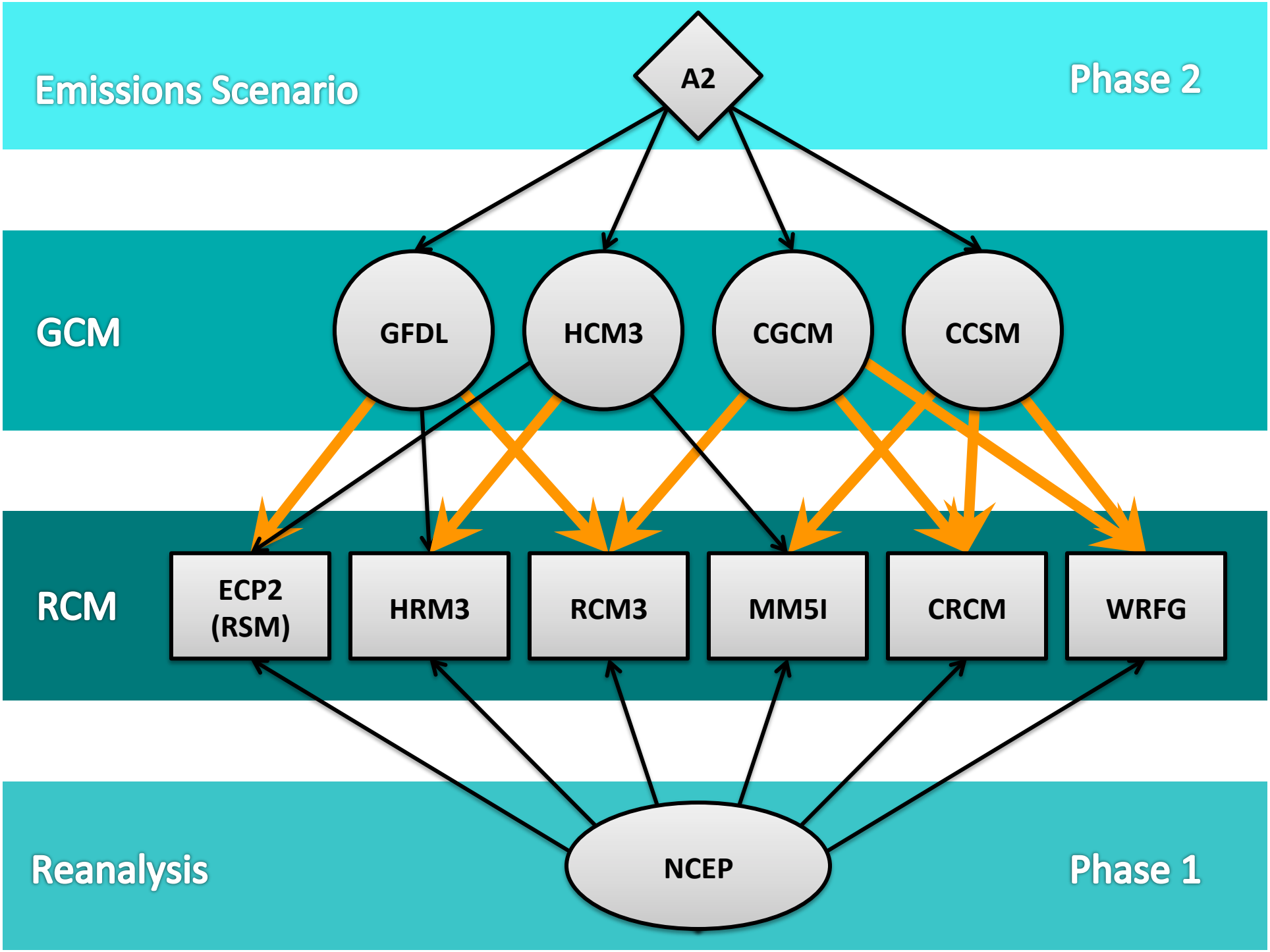
1971-1999 vs. 2041-2069 Months: 06,07,08,09

Agreement: on sign of projection.





9 RCM JJAS Mean Change


Emissions Scenario
A2
Phase 2
GCM
GFDL
HCM3
CGCM
CCSM
RCM
ECP2 (RSM)
HRM3
RCM3
MM5I
CRCM
WRFG
Reanalysis
NCEP
Phase 1

Other Datasets

- For comparison:
  - **NARR** (North American Regional Reanalysis), **32-km** horizontal resolution.
  - **UDEL** (University of Delaware), **½ degree** resolution, gridded observations, for land only.
  - **NAME** (North American Monsoon Experiment), **1 degree** resolution, gridded observations from a special observing period during July 2004
  - **TRMM** (Tropical Rainfall Measuring Mission) satellite derived precipitation. **¼ degree** resolution, available Dec. 1997 – present.

NAM 101

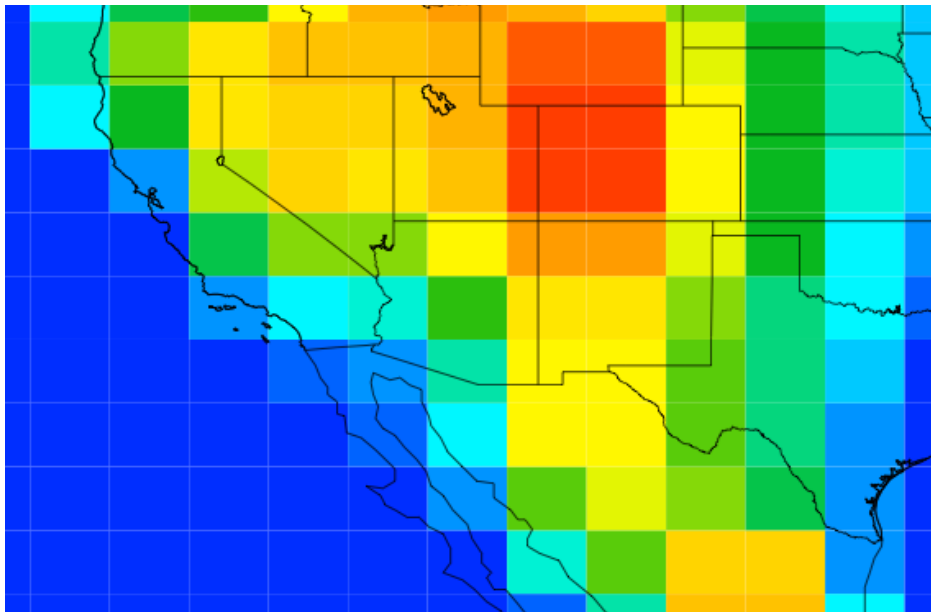
THE NORTH AMERICAN MONSOON SYSTEM

Shaded Relief - Land and Ocean
Source: U.S. Geological Survey

Shaded Relief - Land and Ocean

Elevation in Feet	Bathymetry in Feet
10000 - 20320	> -749
9500 - 9999	-750 to -1499
9000 - 9499	-1500 to -2999
8500 - 8999	-3000 to -5999
8000 - 8499	-6000 to -8999
7500 - 7999	-9000 to -11999
7000 - 7499	-12000 to -15999
6500 - 6999	< -16000
6000 - 6499	
5500 - 5999	
5000 - 5499	
4500 - 4999	
4000 - 4499	
3500 - 3999	
3000 - 3499	
2500 - 2999	
2000 - 2499	
1500 - 1999	
1000 - 1499	
500 - 999	
250 - 499	
1 - 249	
-282 - 0	

Bathymetric intervals only apply to ocean bodies

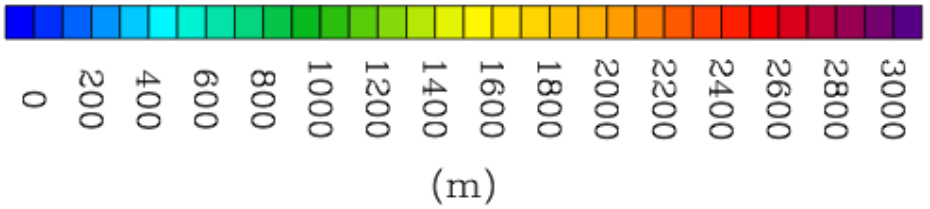


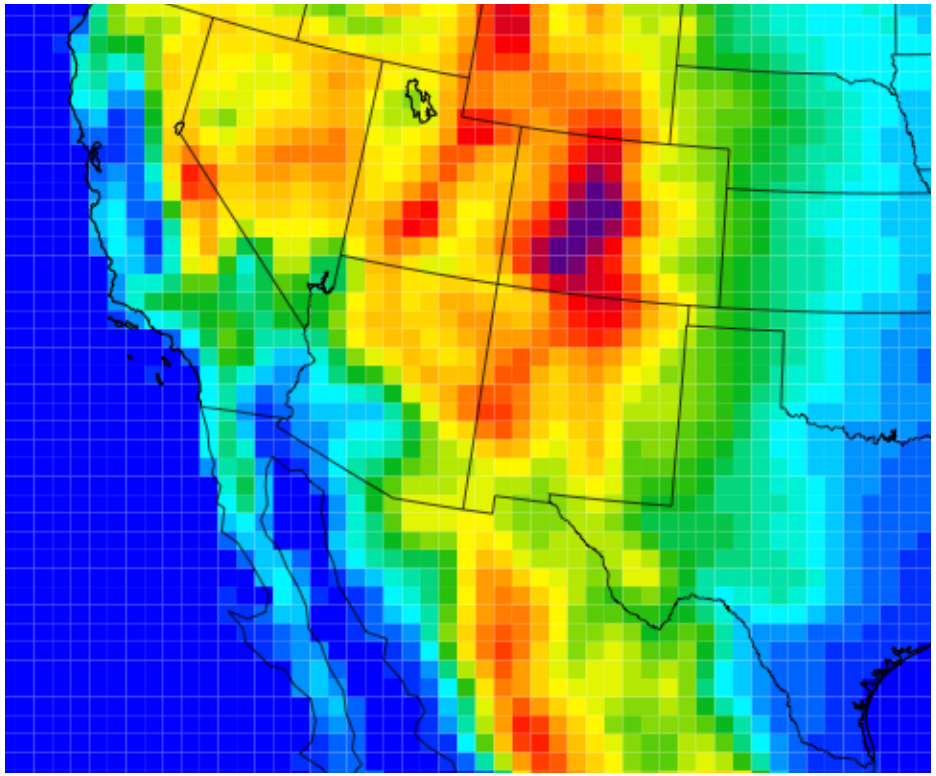
SOUTHWEST OROGRAPHY

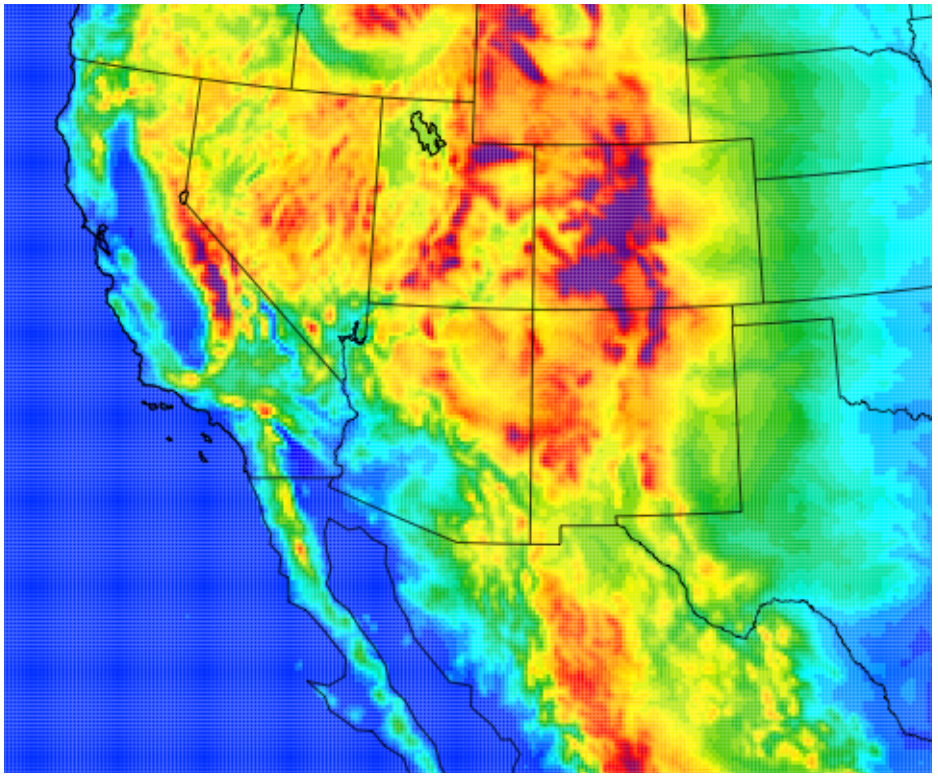
Left: 2.0°x 2.5°

Bottom Left: 50km

Bottom Right: 10km







Mogollon Rim east of Pine, AZ (Wikipedia)

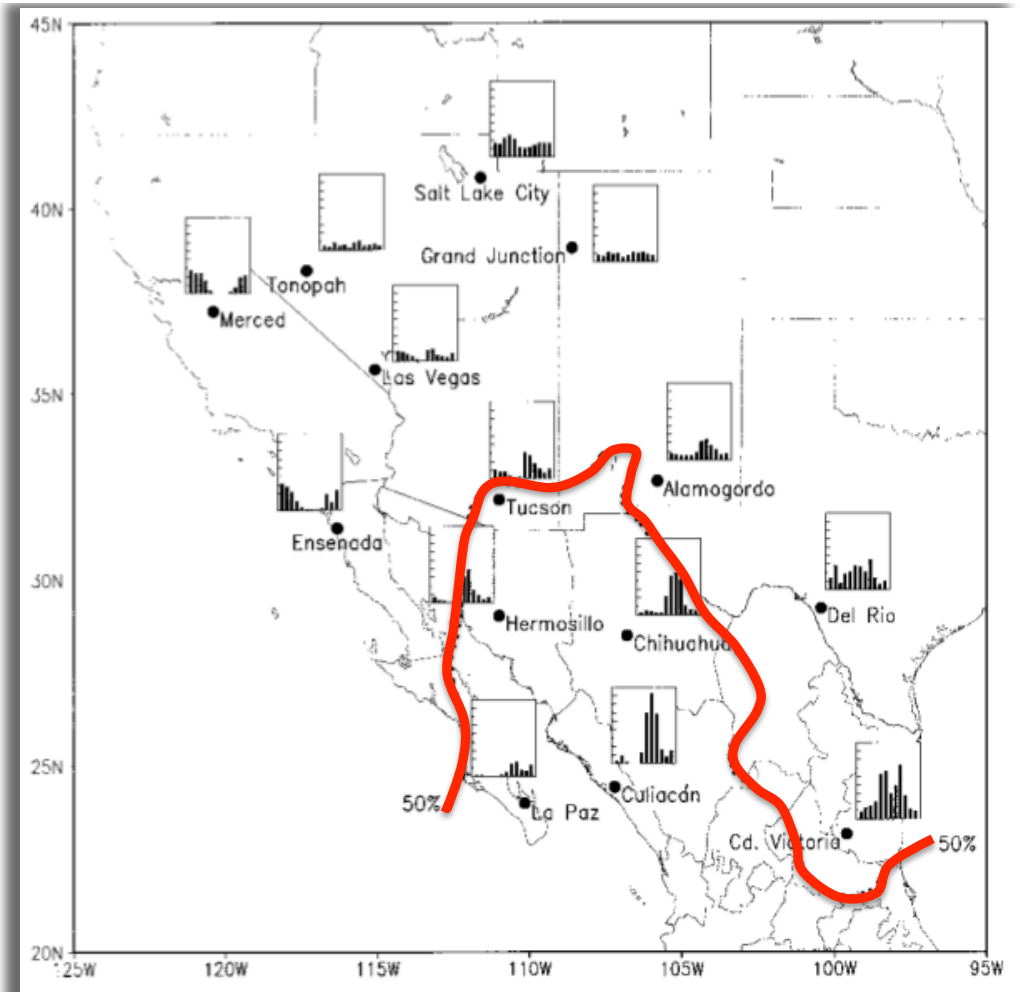
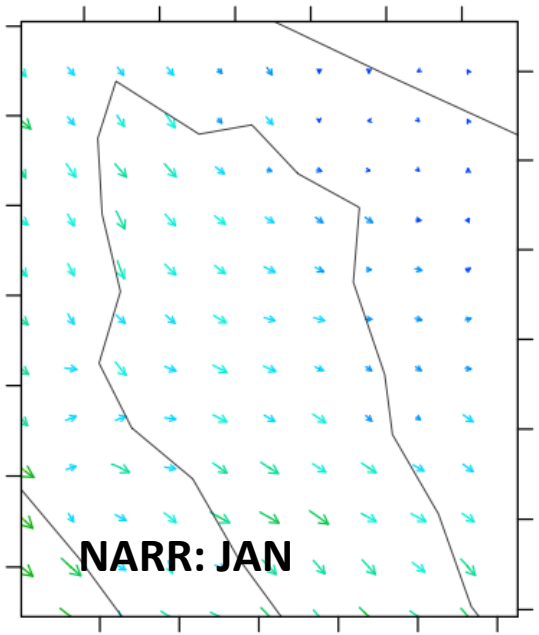


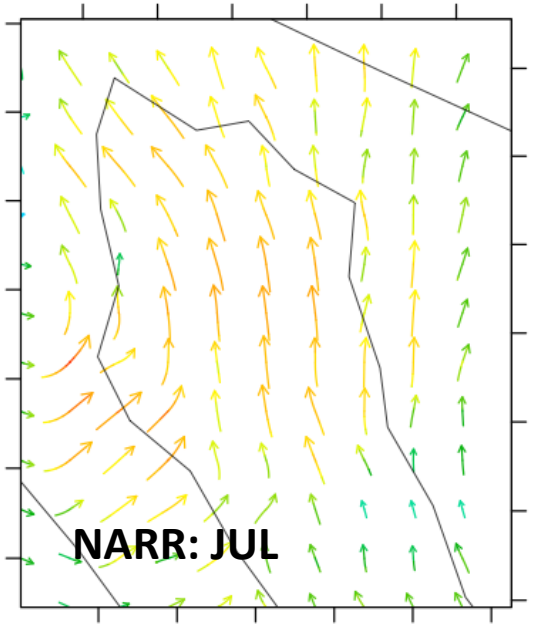
FIG. 2. Seasonal distribution of precipitation across southwestern North America. Note that northwestern Mexico shows the strongest monsoon signal, which diminishes through Arizona, New Mexico, and Nevada. Northeastern Mexico and Texas display early summer–late fall precipitation peaks, while the West Coast has a dry summer Mediterranean distribution (vertical axis of all graphs represents 180 mm with 20 mm increments). Areas south of the broken line receive greater than 50% of their annual rainfall in July, August, and September (after Douglas et al. 1993).

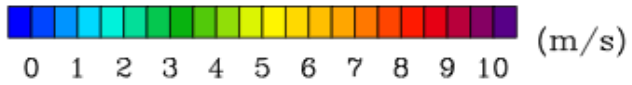
Verification Part 1

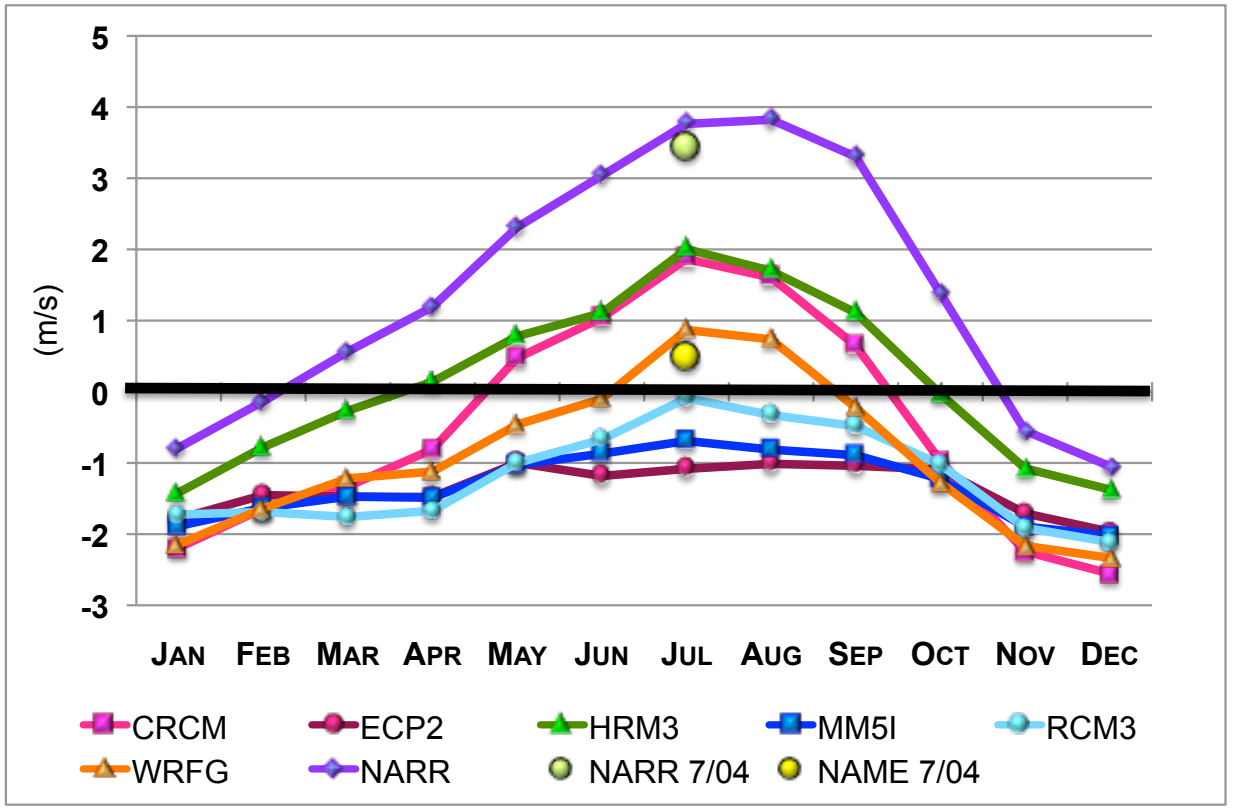
REANALYSIS DRIVEN SIMULATIONS

10m Wind: Annual Cycle









N

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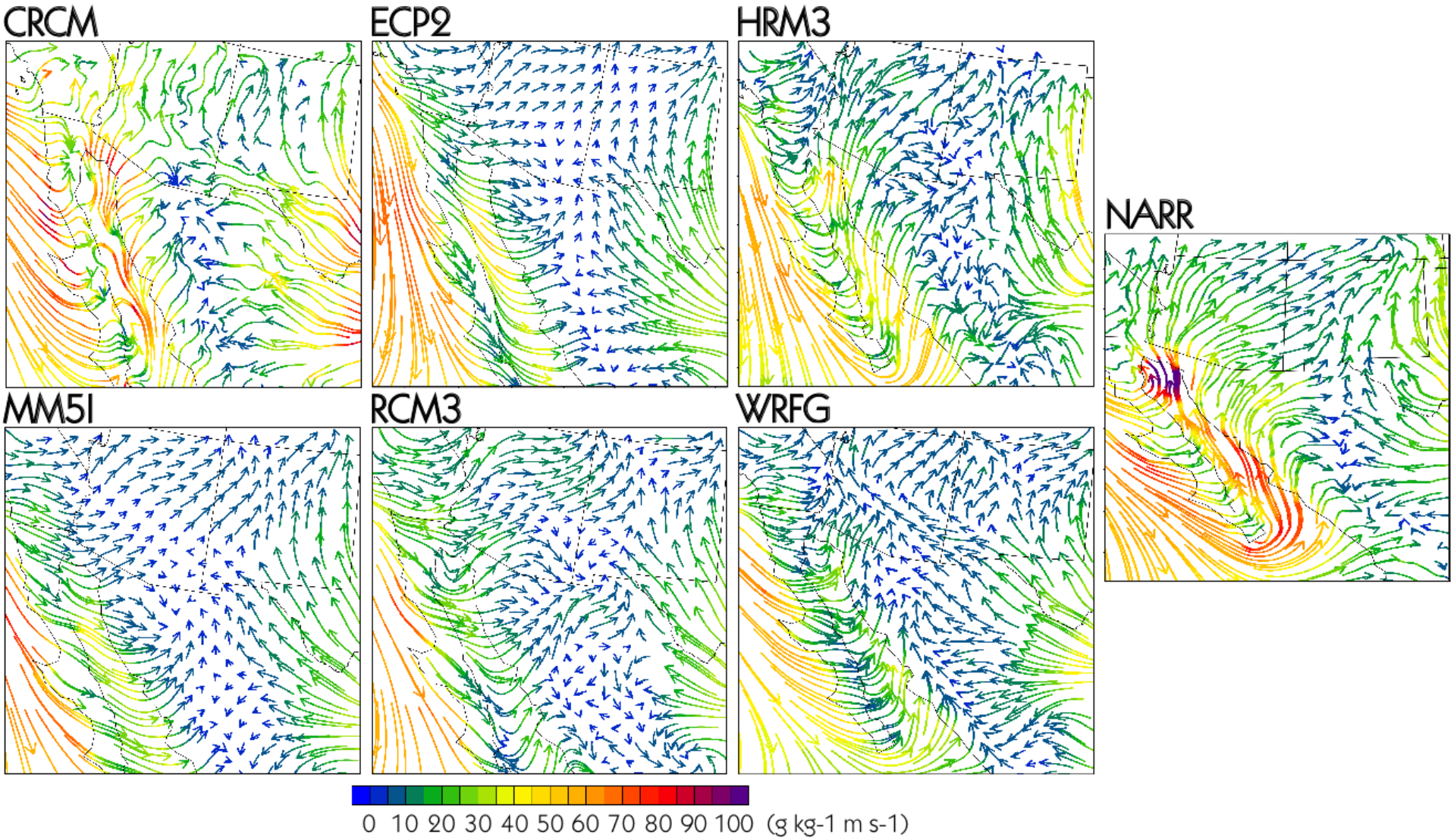
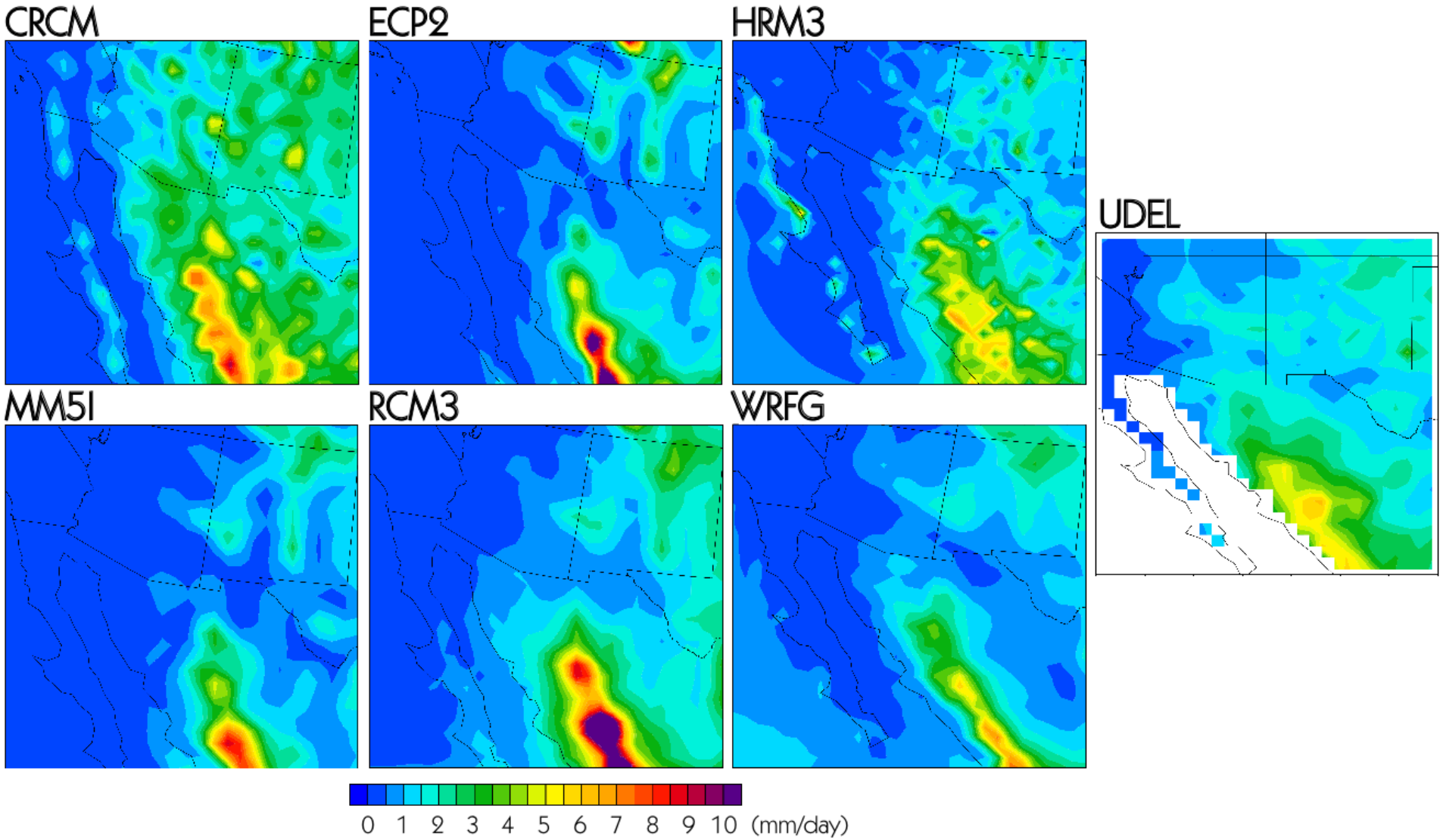
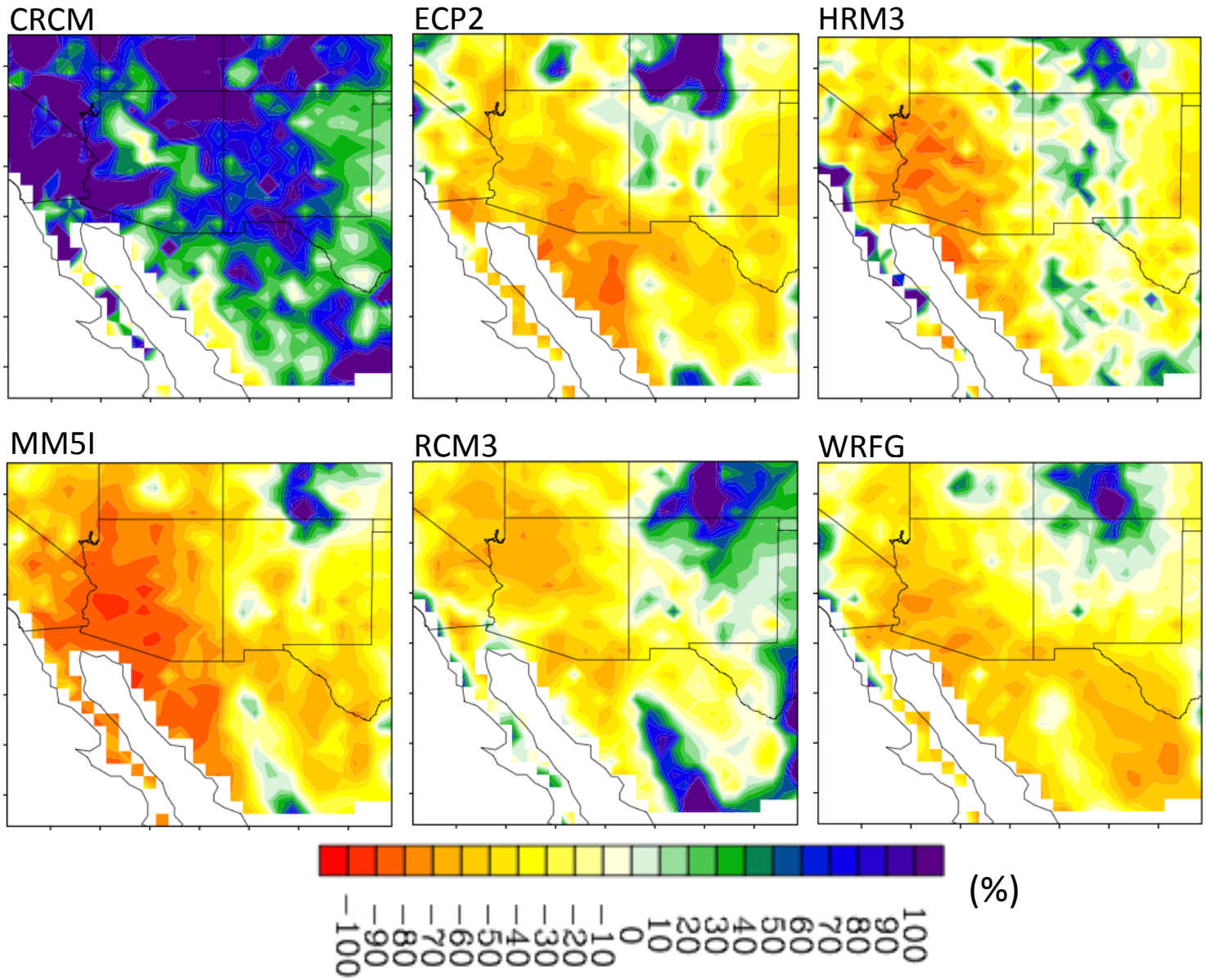
1980-2004 JJAS Average Near-Surface Moisture Flux



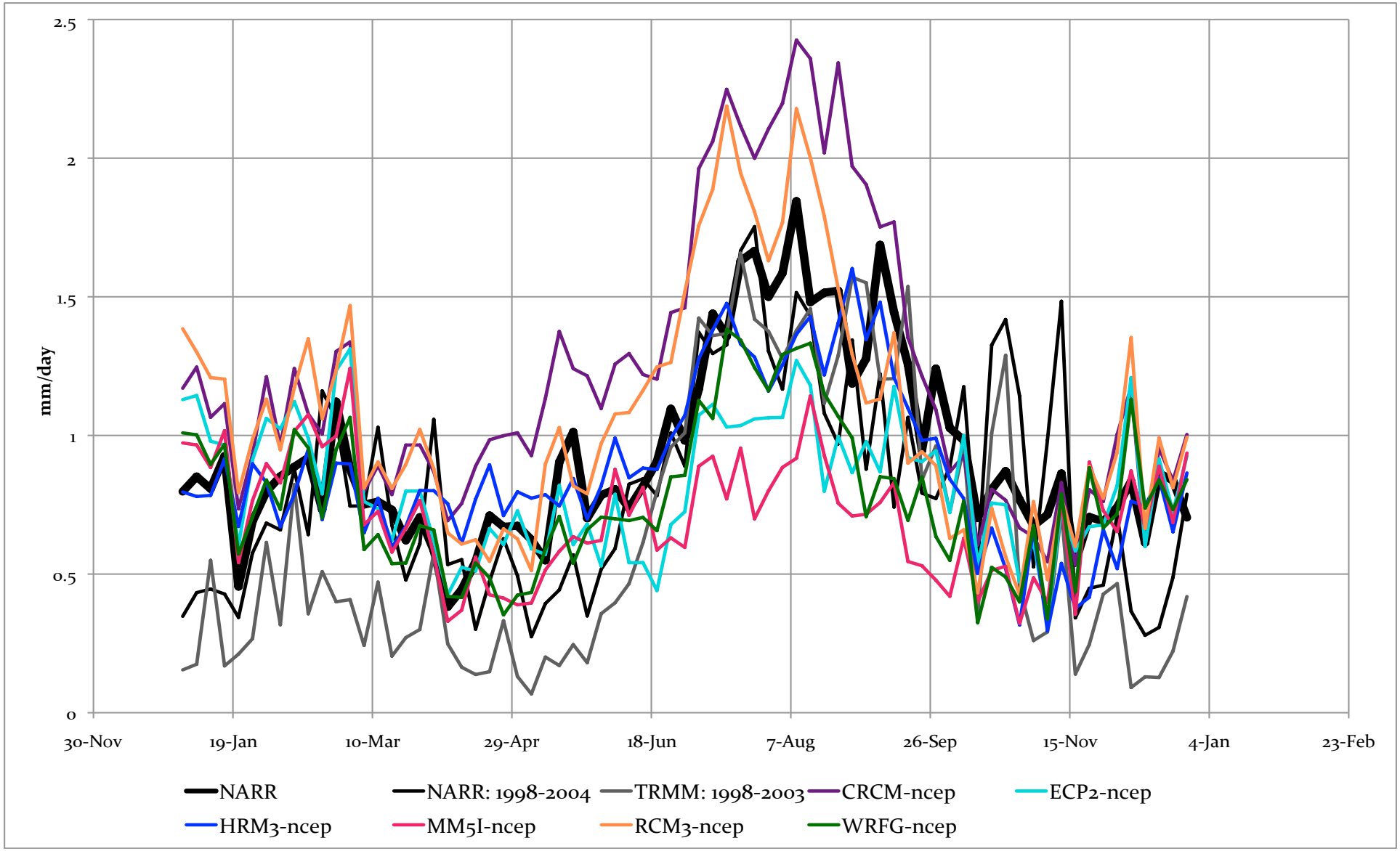
1980-2004 JJAS Average Precipitation Rate



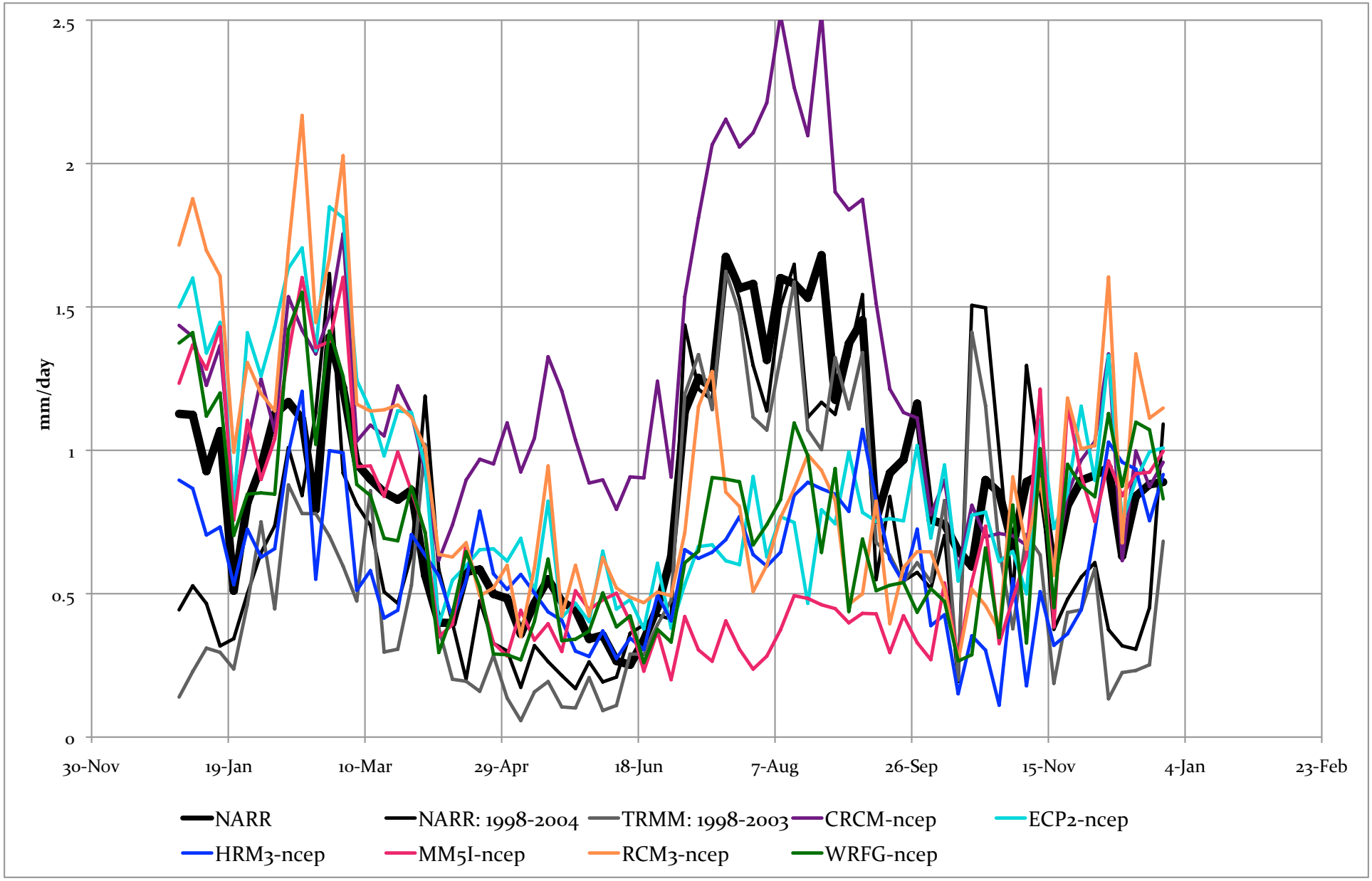
Precipitation Bias (vs. UDEL): 1980-2004 JJAS



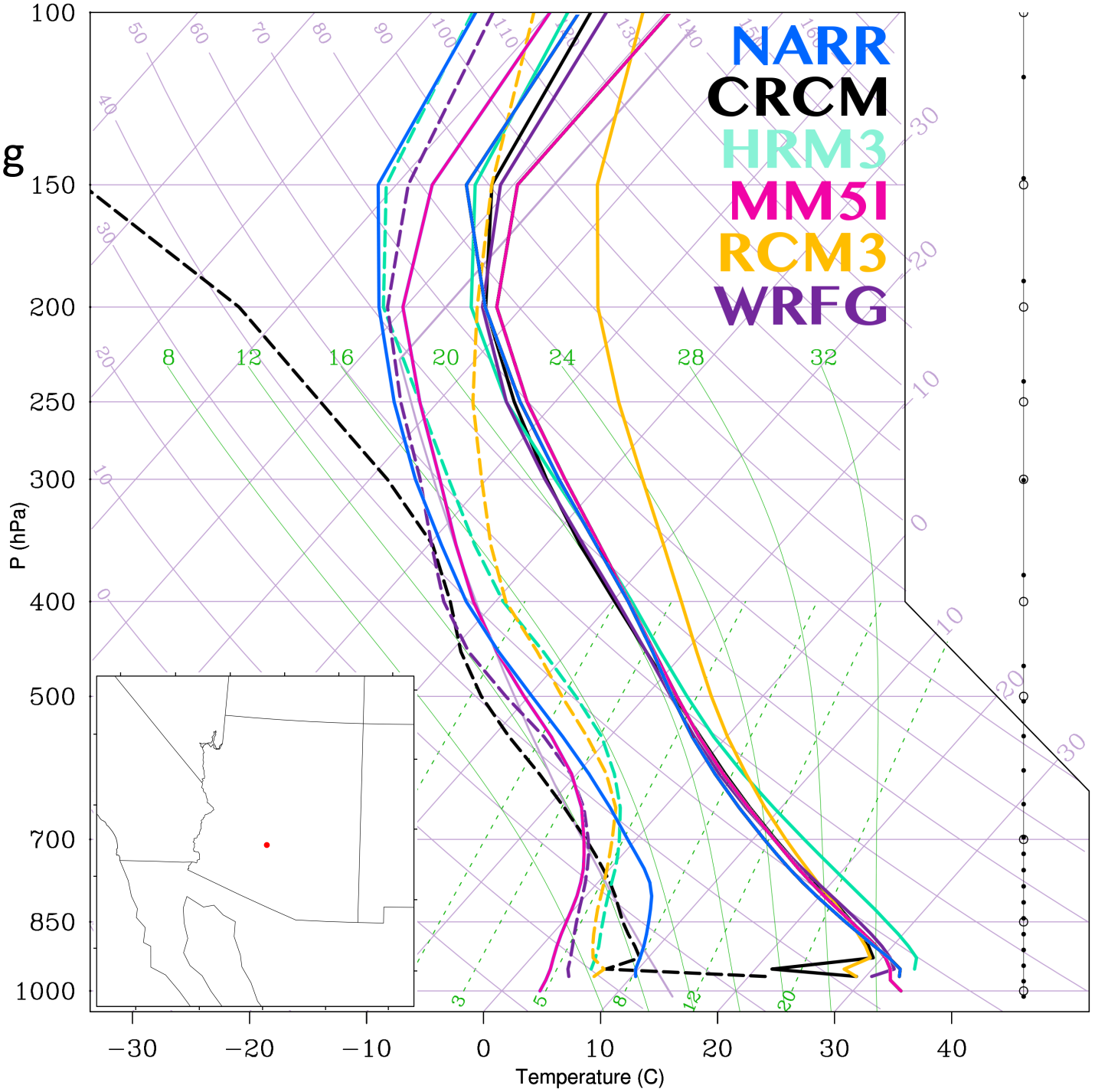
1980-2004 5-day Average Precipitation Climatology
NCEP-Driven Simulations



1980-2004 5-day Average Precipitation Climatologies: AZ Only

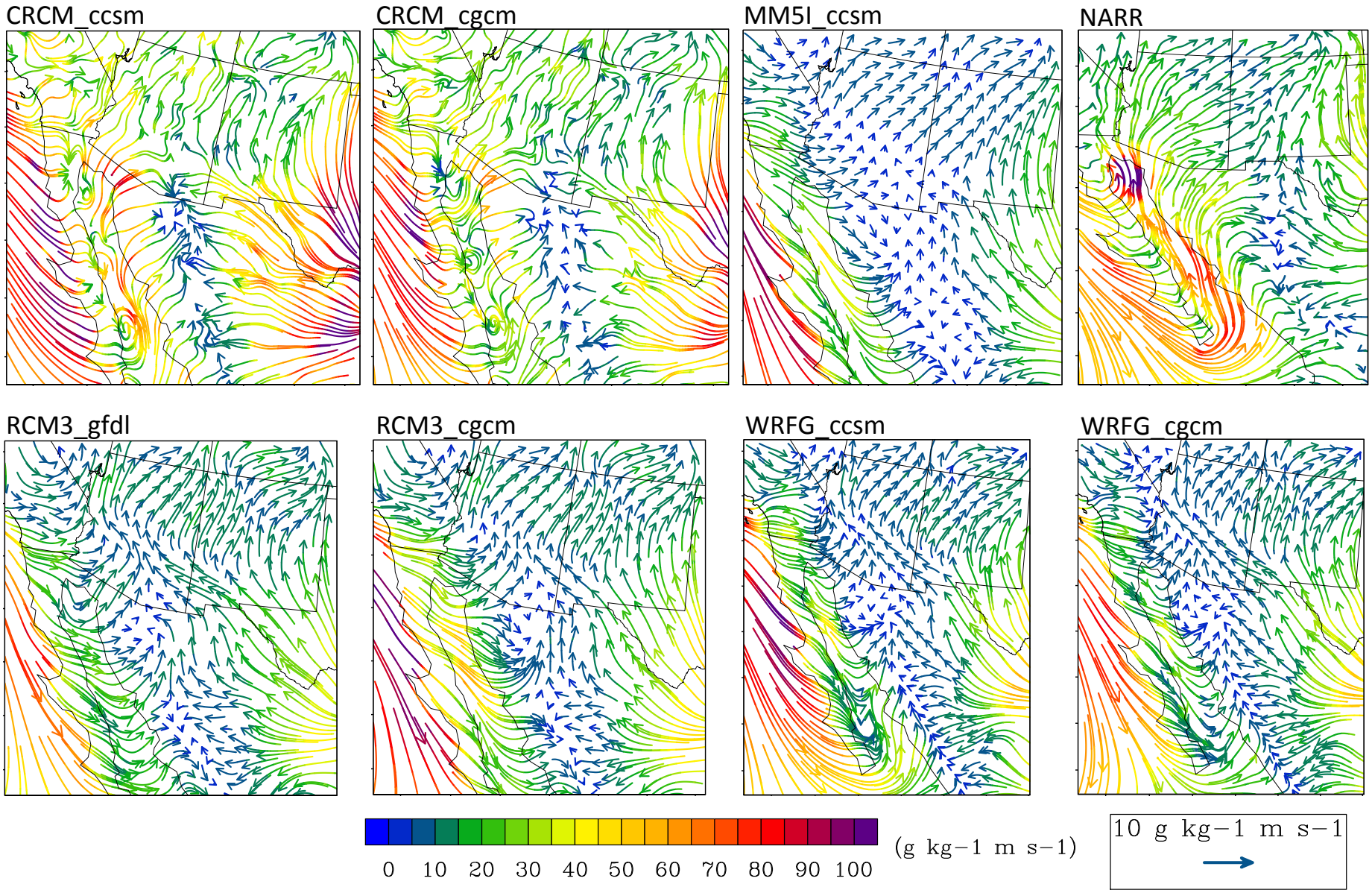


JJAS
Average
Sounding



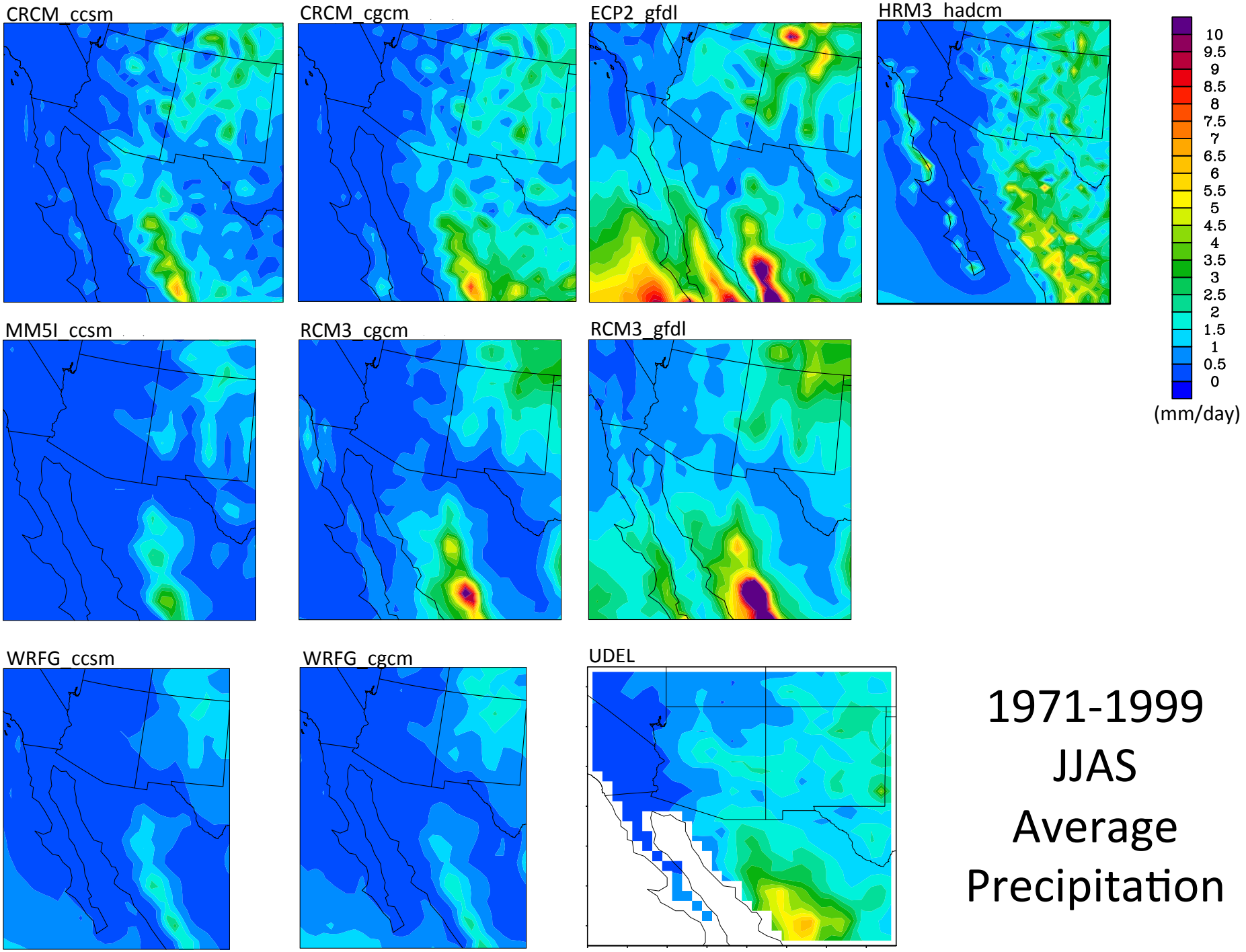
Verification Part 2

CURRENT GCM DRIVEN SIMULATIONS



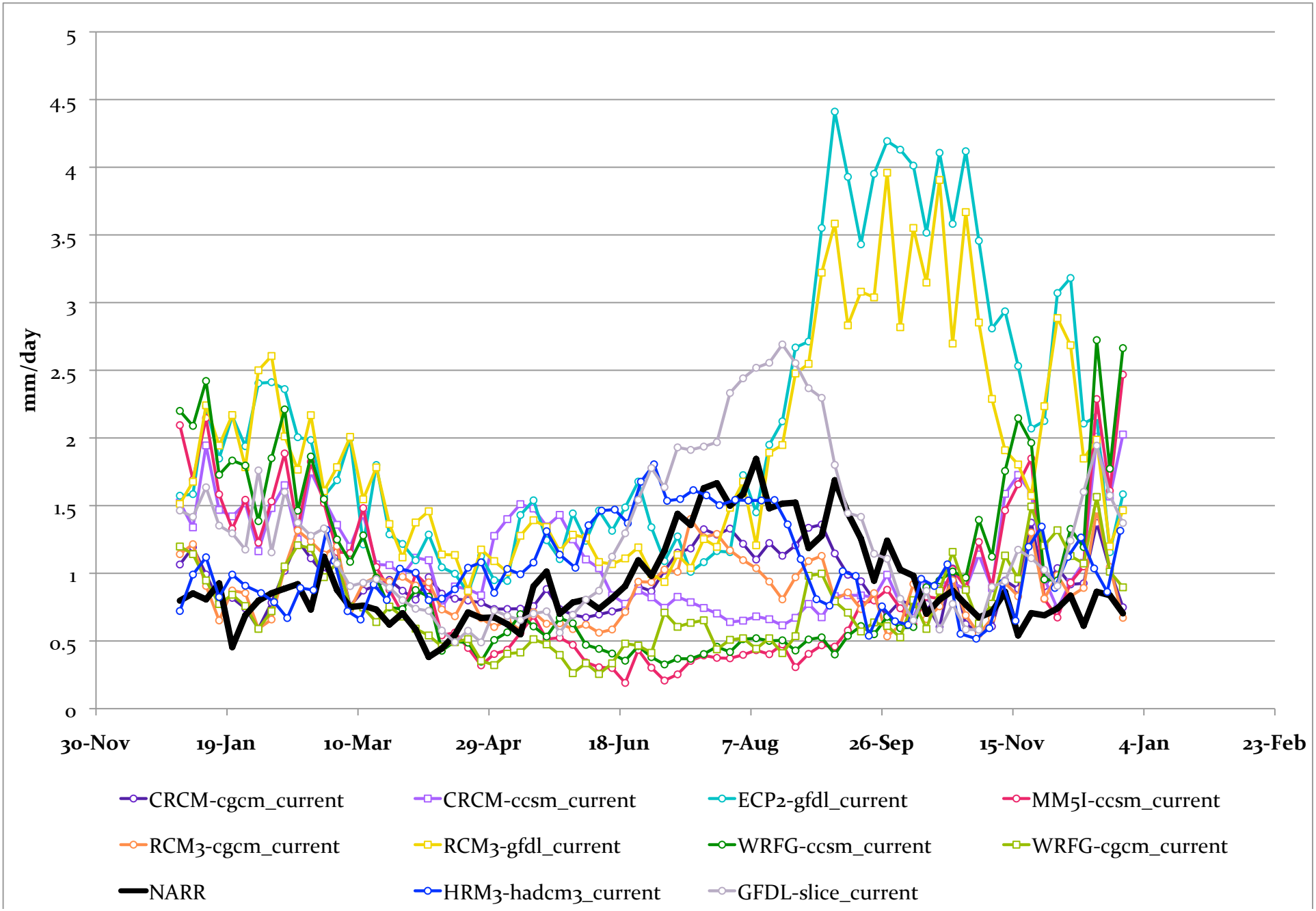
1971-1999 JJAS Near-Surface Moisture Flux: GCM-driven

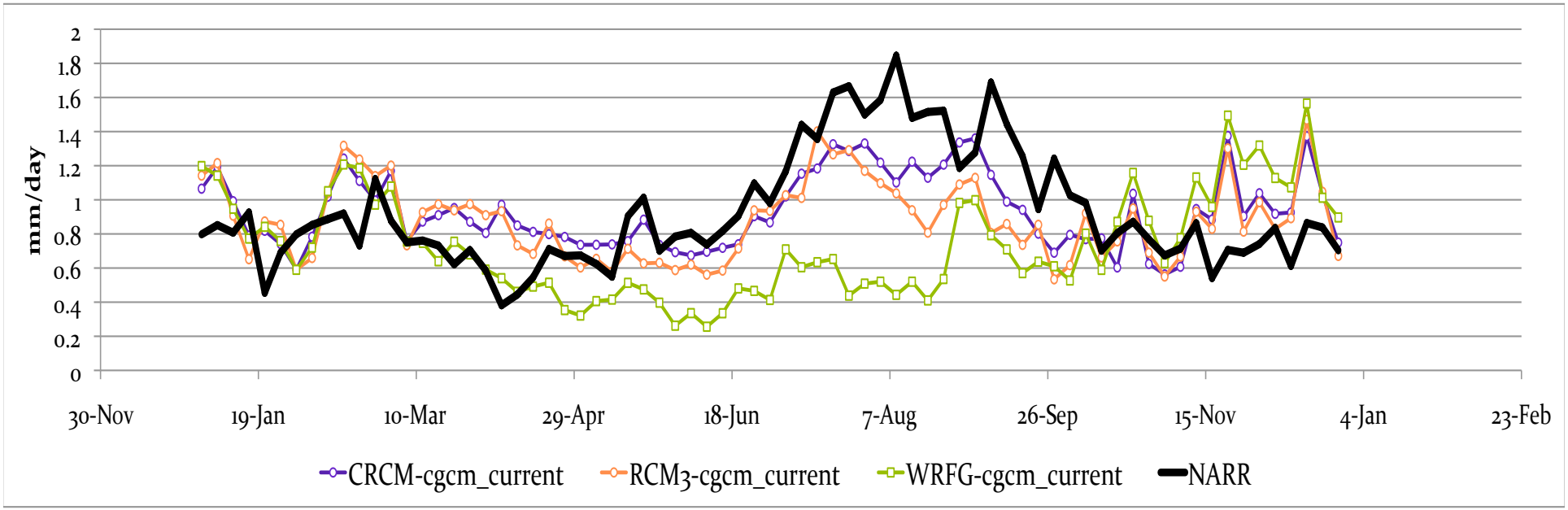
(NARR 1980-2004)

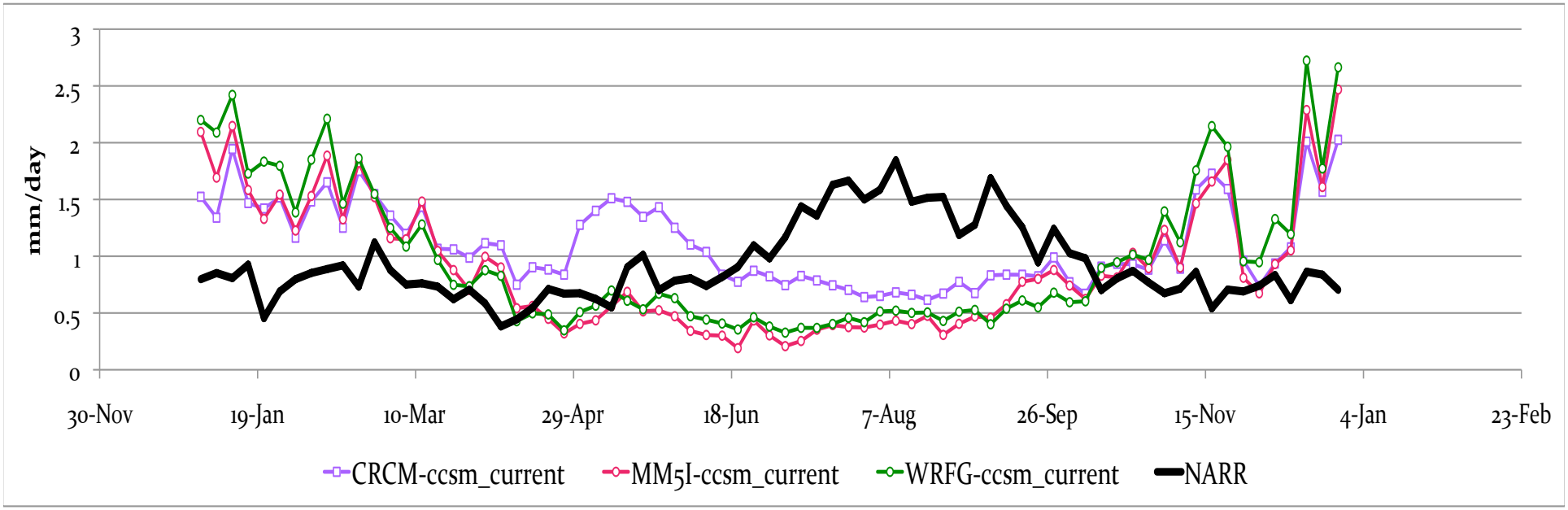


1971-1999 JJAS Average Precipitation

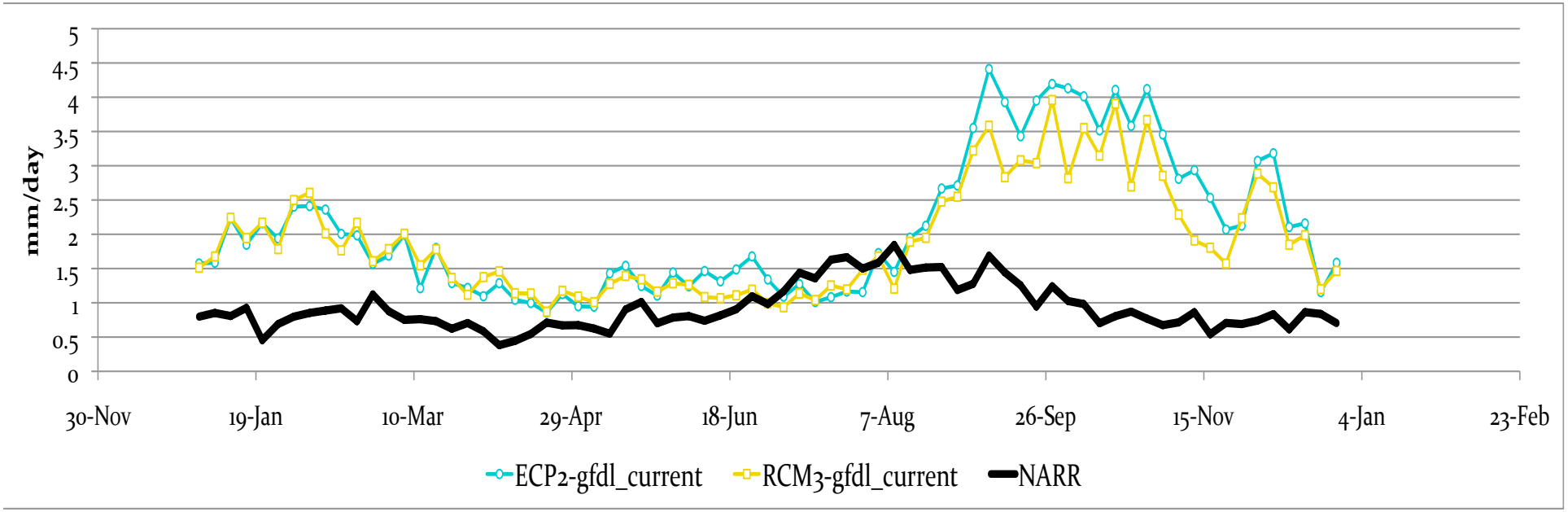
GCM-driven 5-day Average Precipitation Climatology

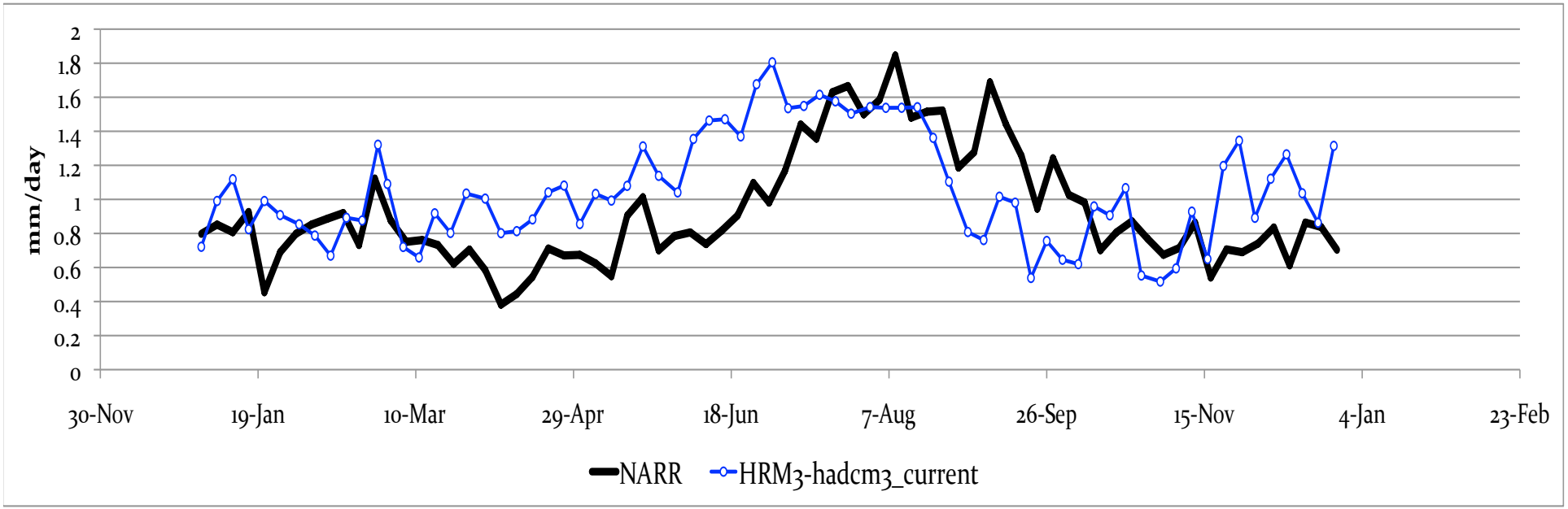




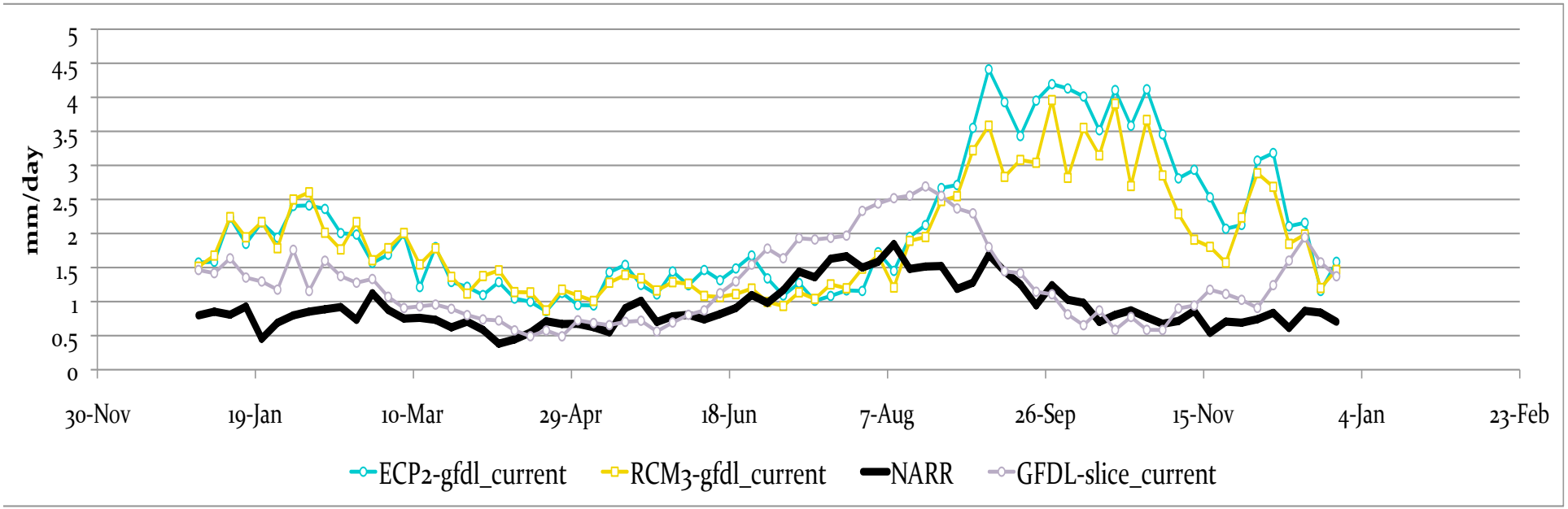


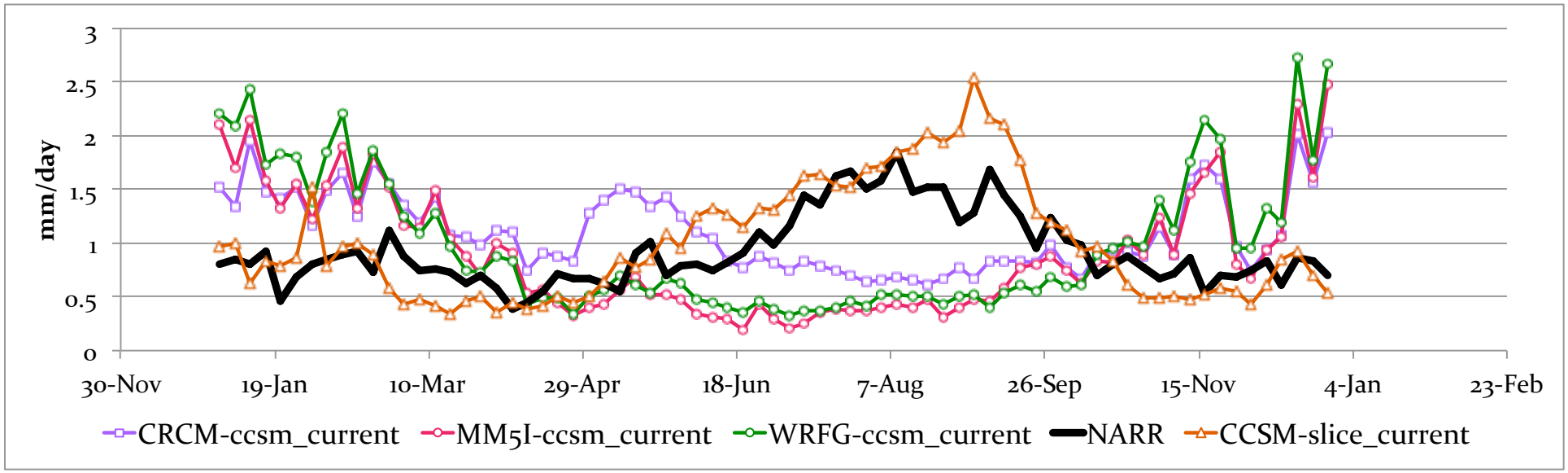
5-day Average Precipitation Climatology



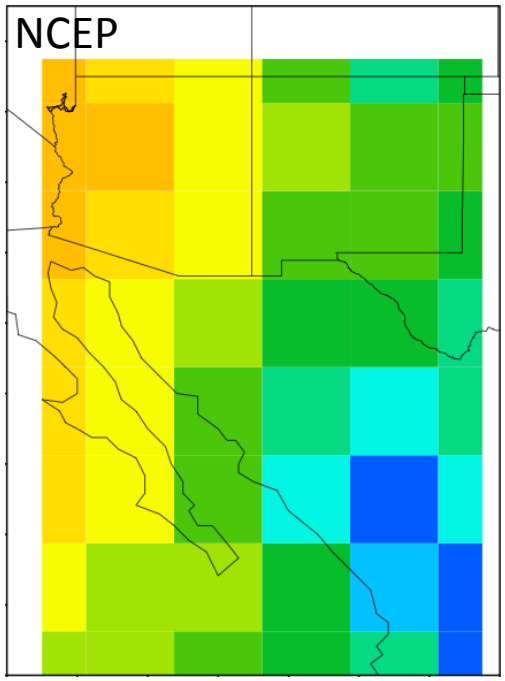


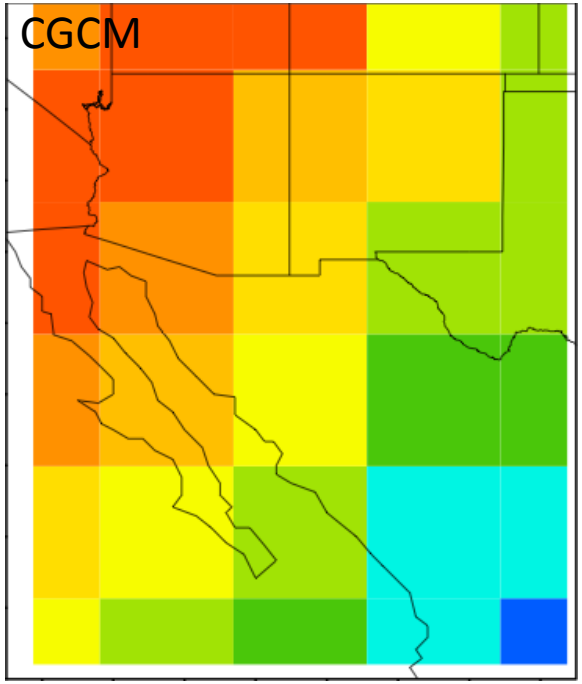
5-day Average Precipitation Climatology

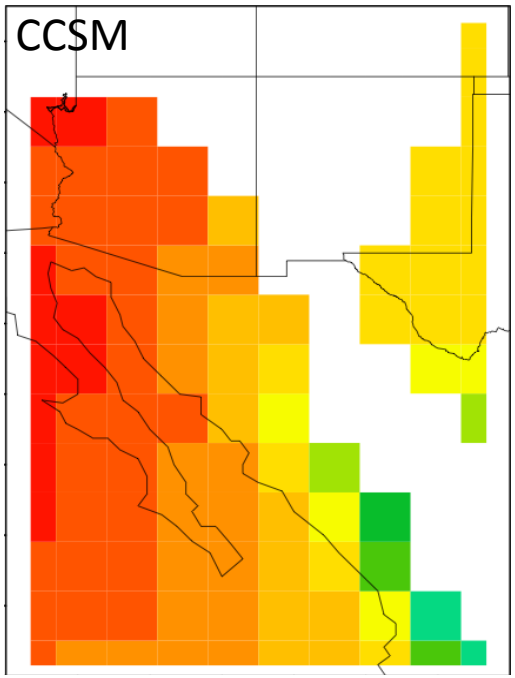


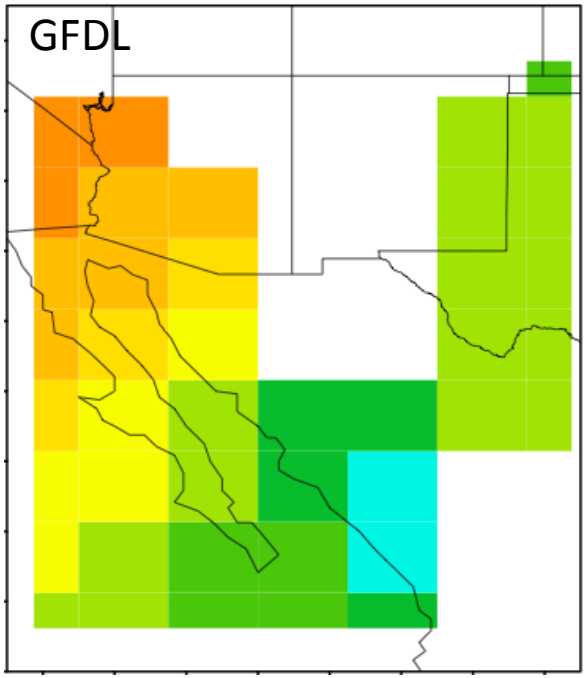


5-day Average Precipitation Climatology

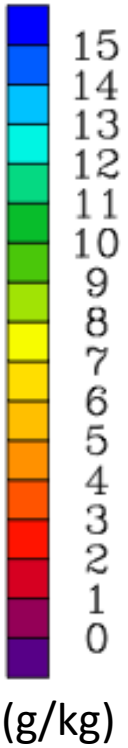






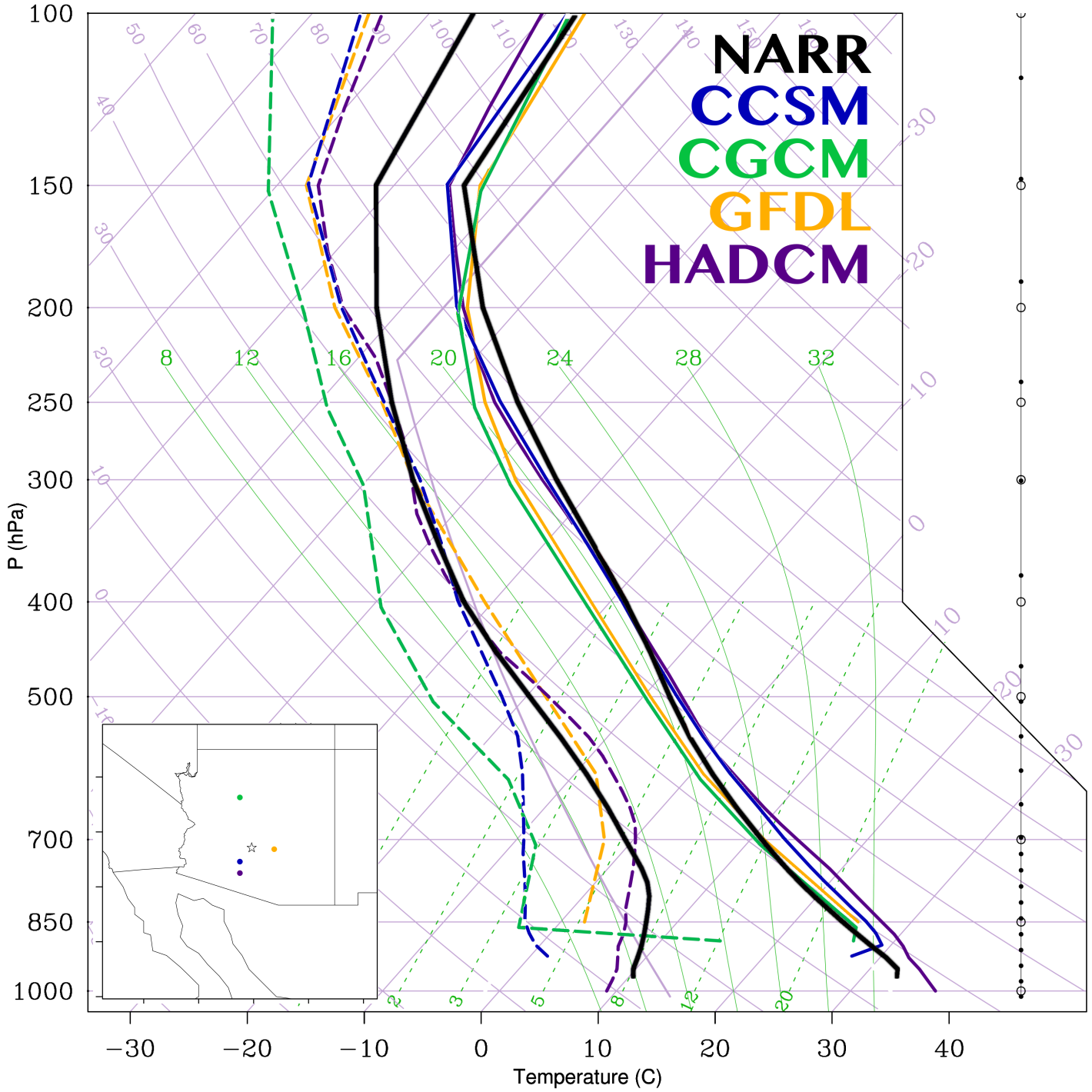


Why do the CGCM and CCSM driven simulations not capture the monsoon signal in precipitation?

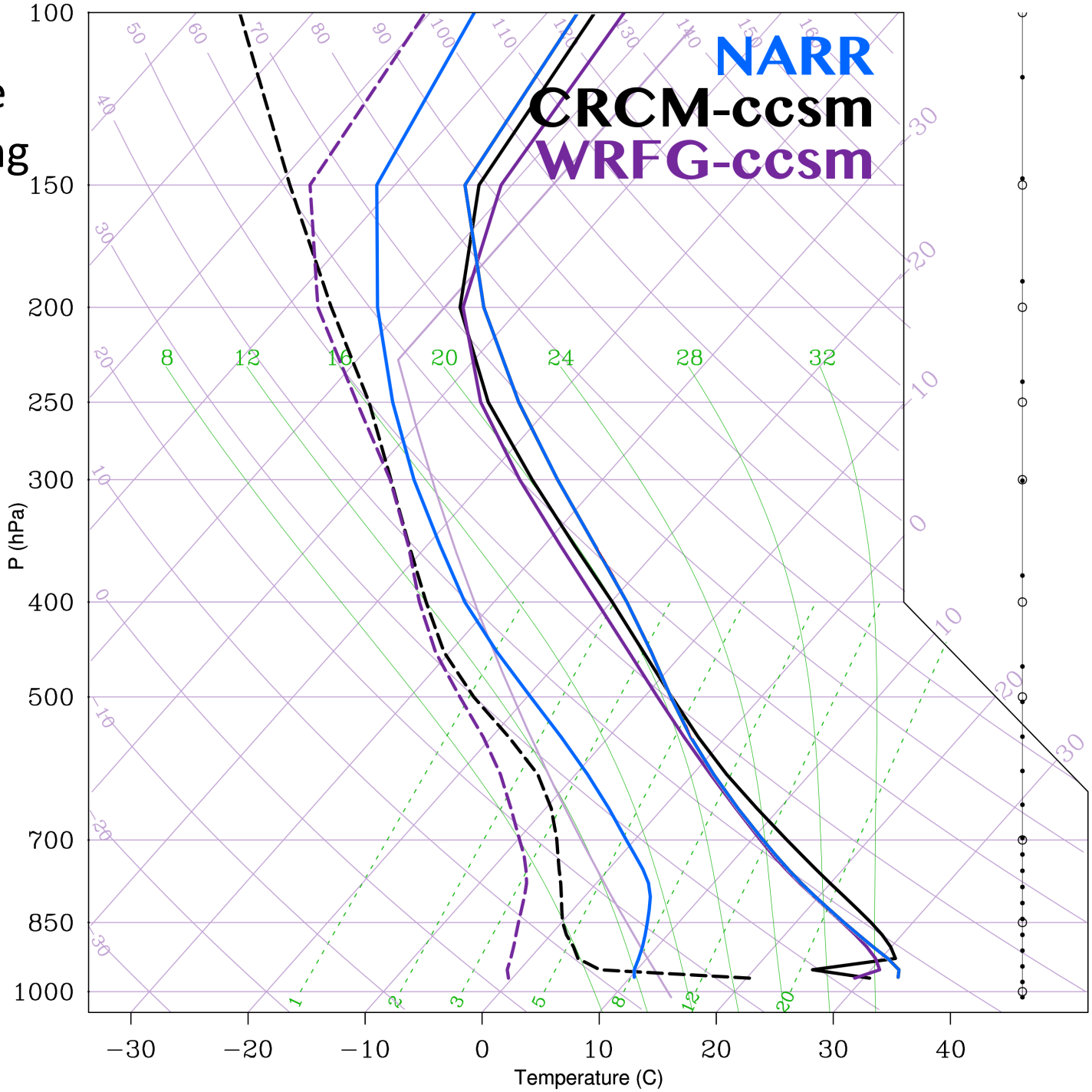


850mb Specific Humidity
JJAS 1971-1999

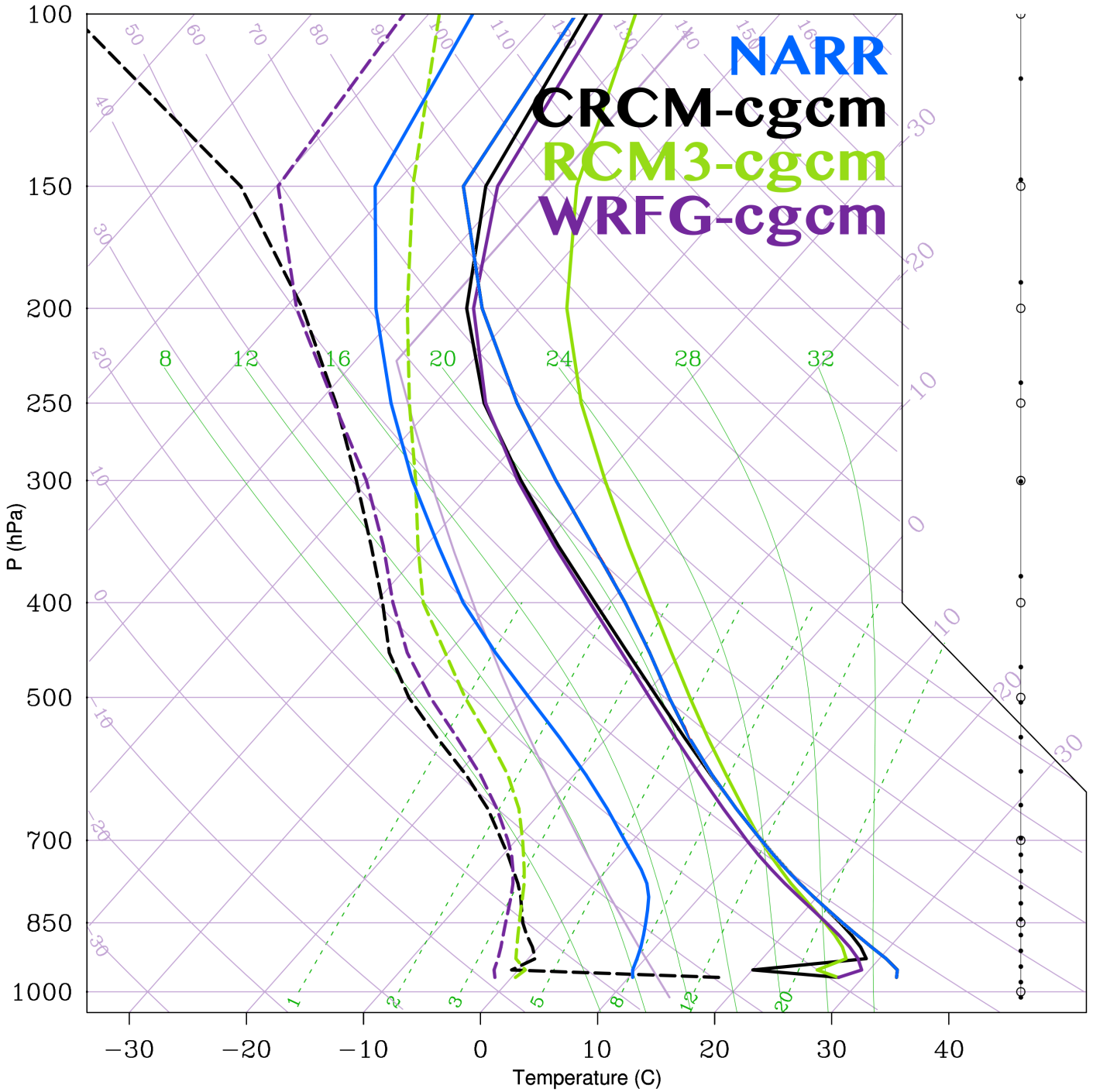
JJAS
Average
Sounding



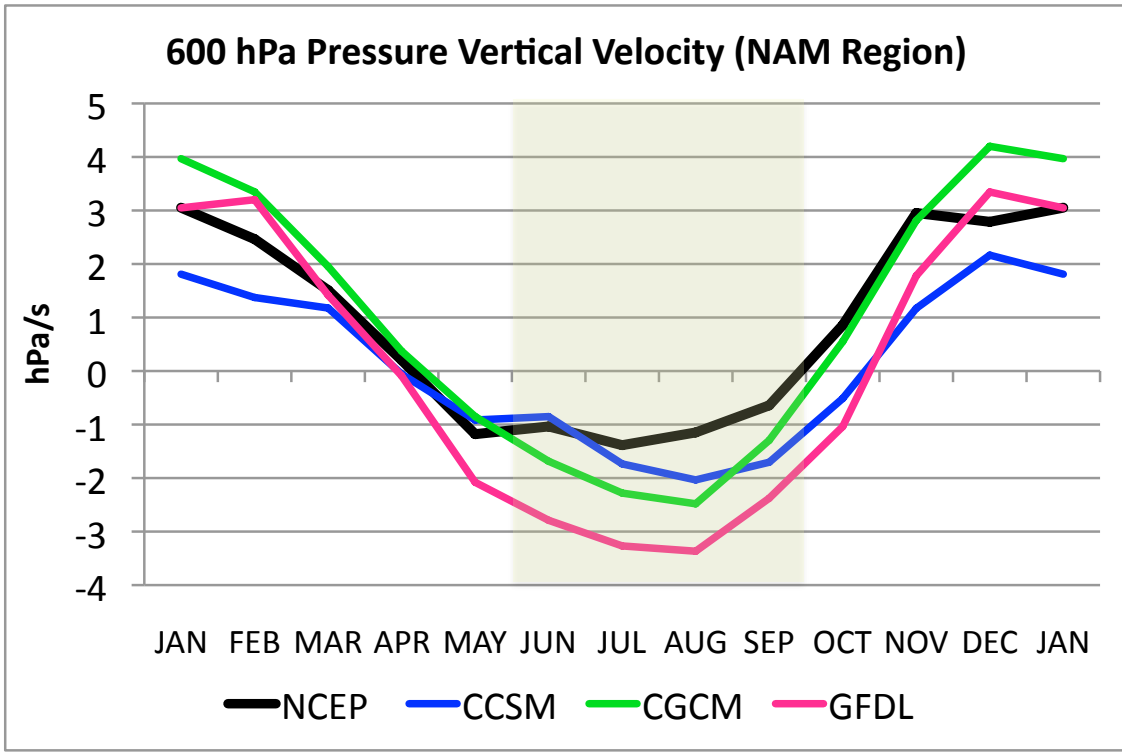
JJAS
Average
Sounding

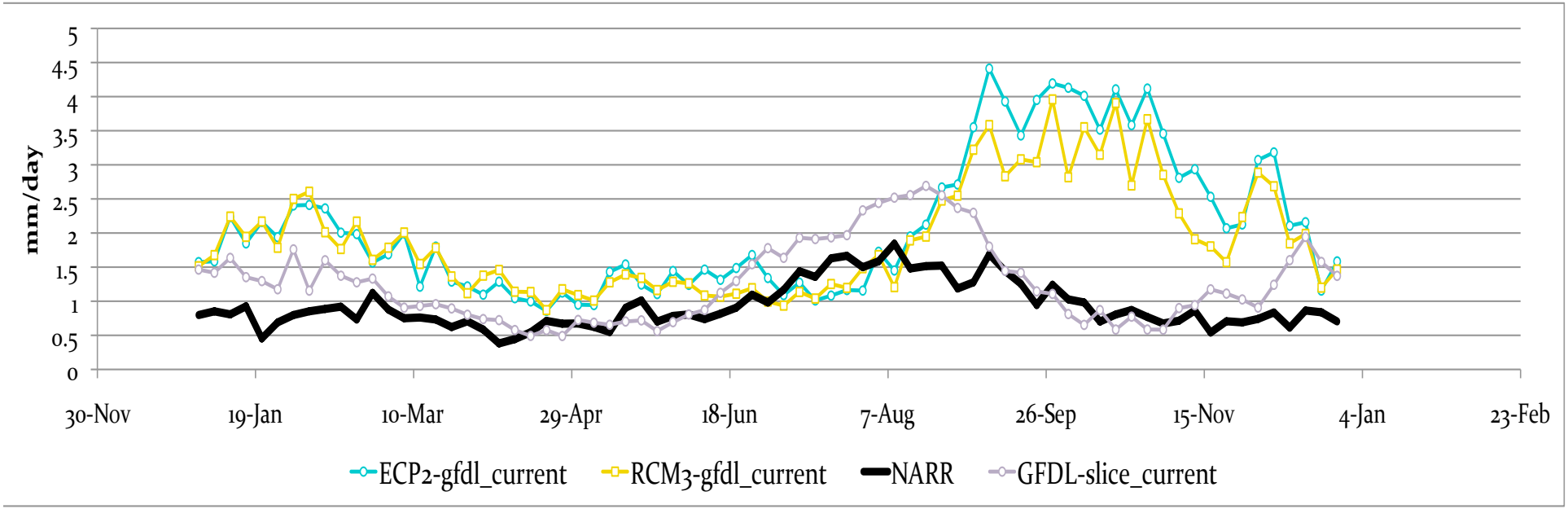


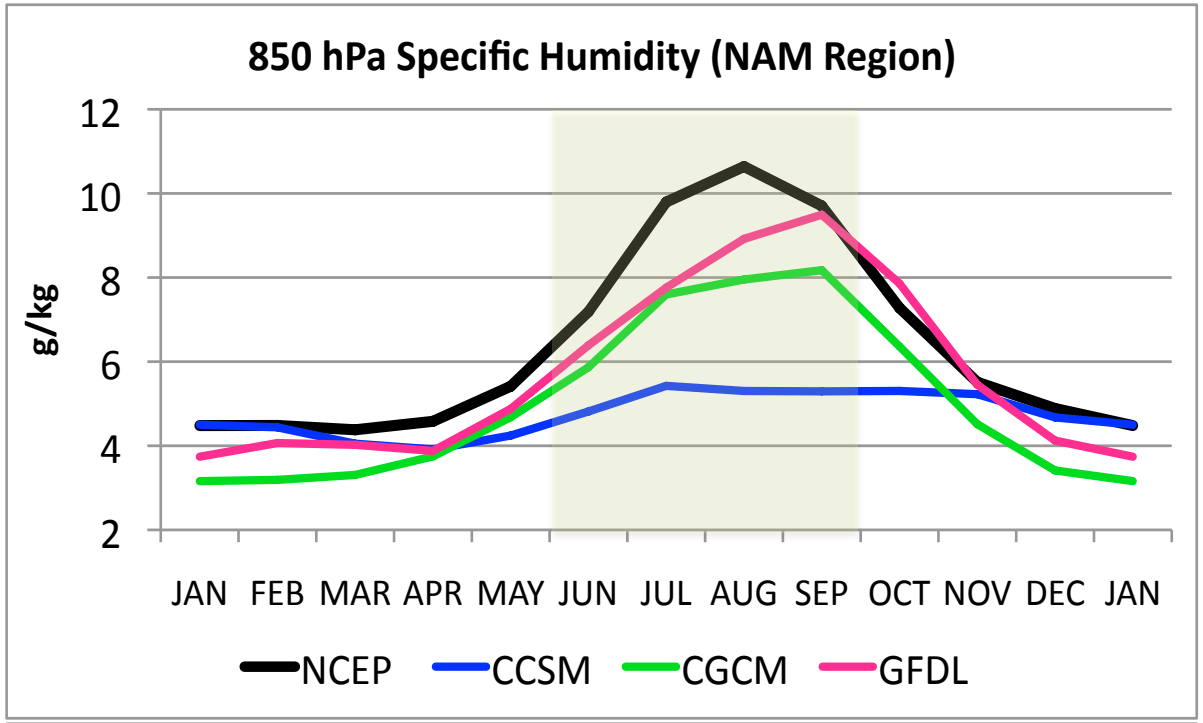
JJAS
Average
Sounding

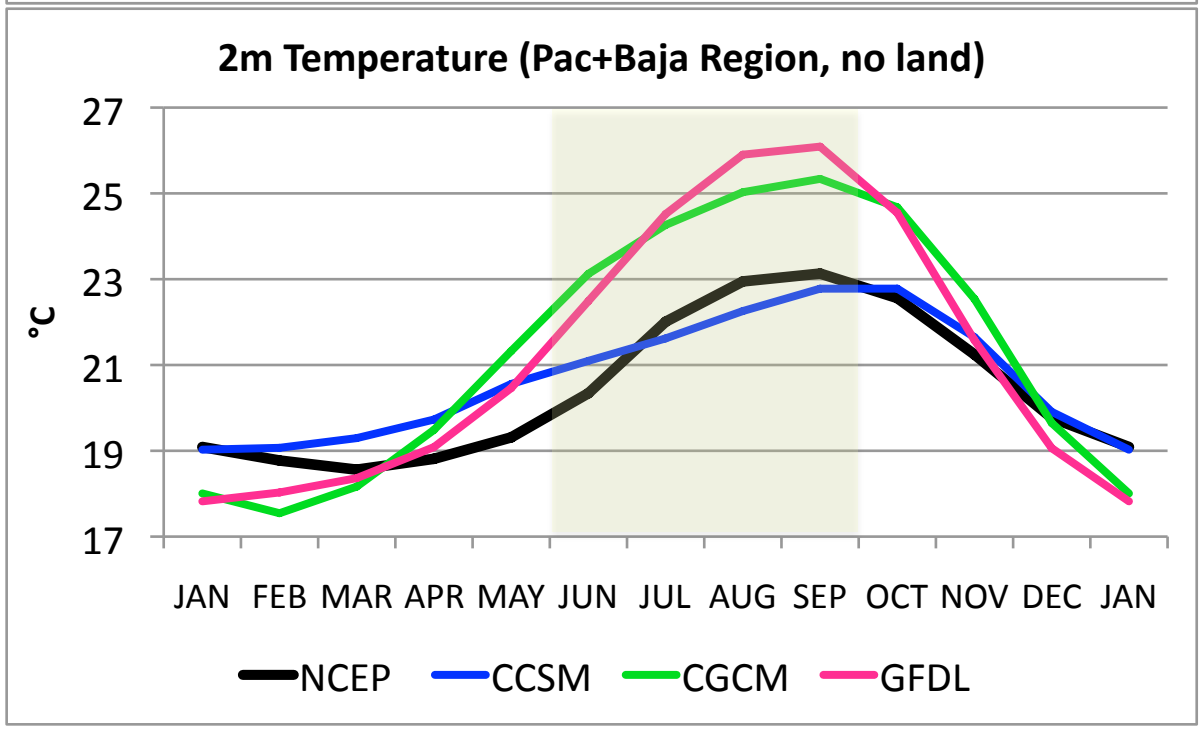


What might be causing the excessive late season precipitation in the GFDL-driven simulations?





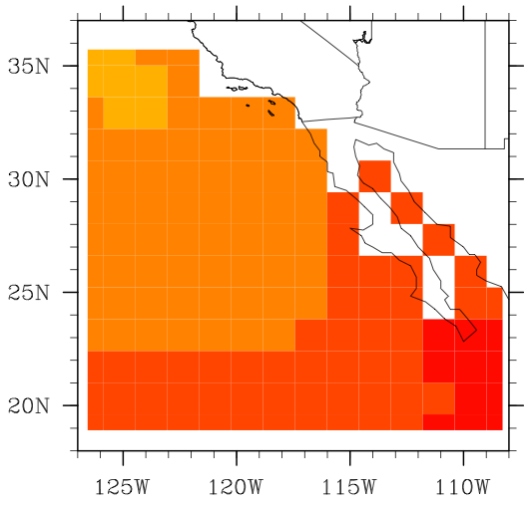


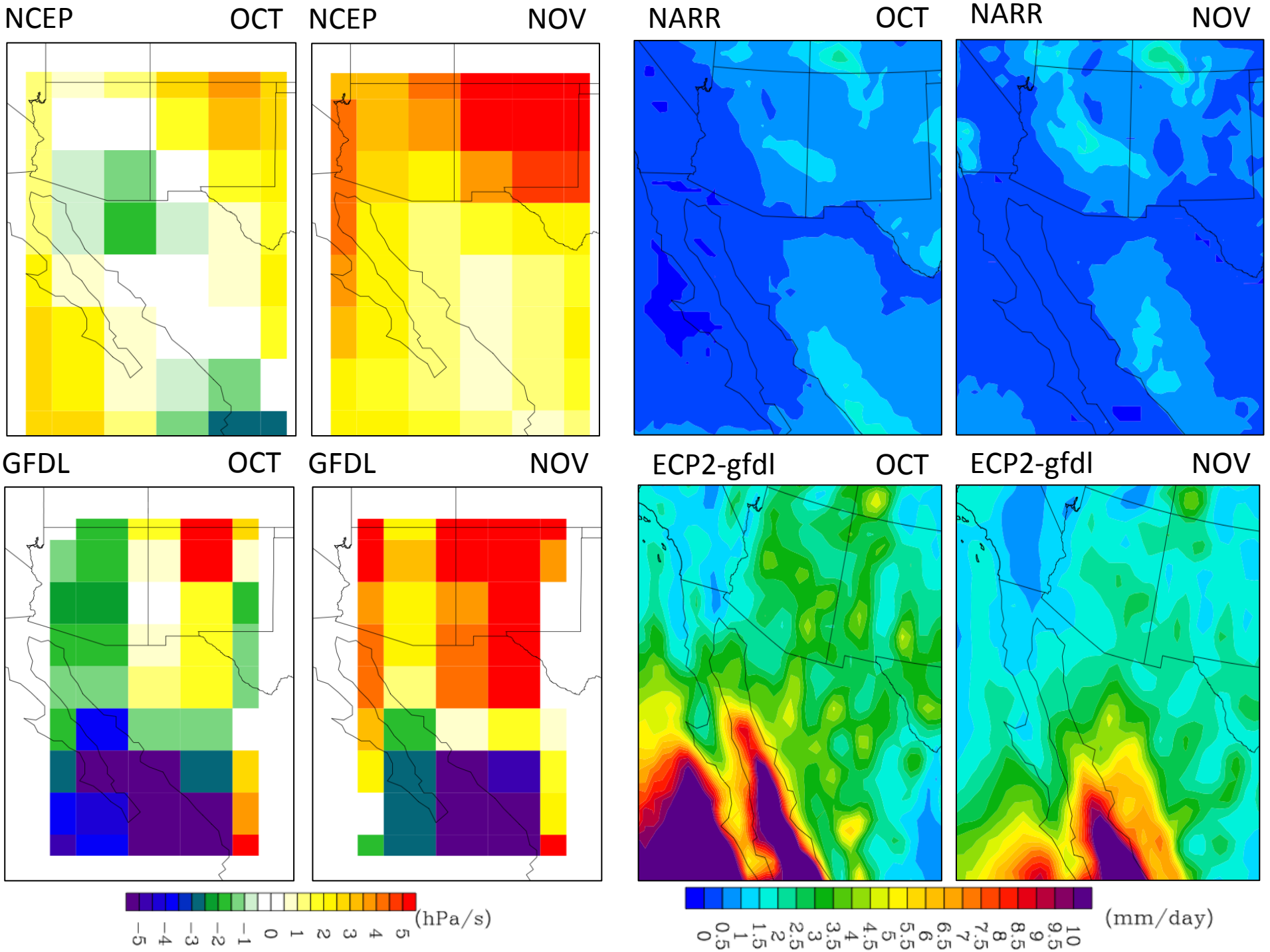


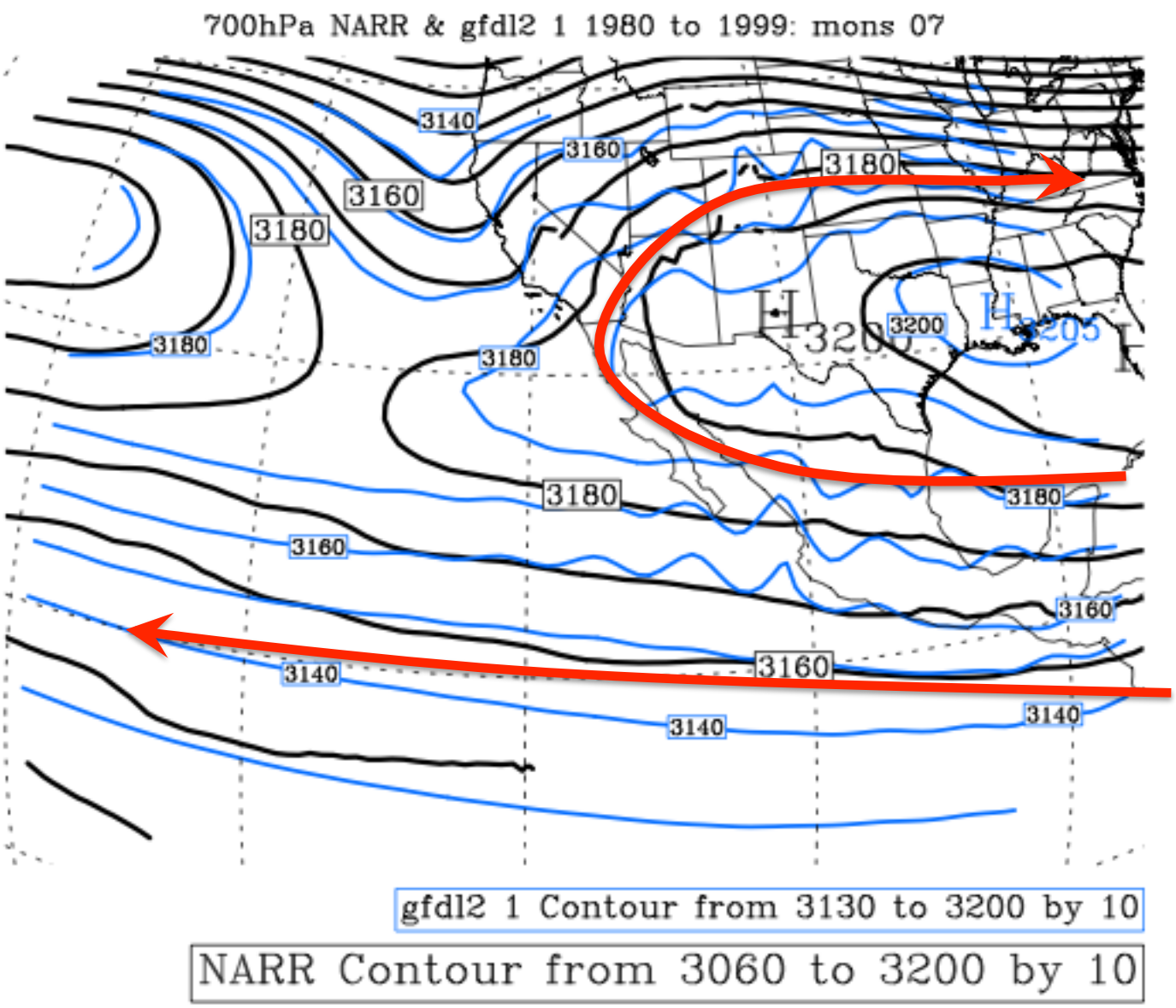
850 hPa Specific Humidity

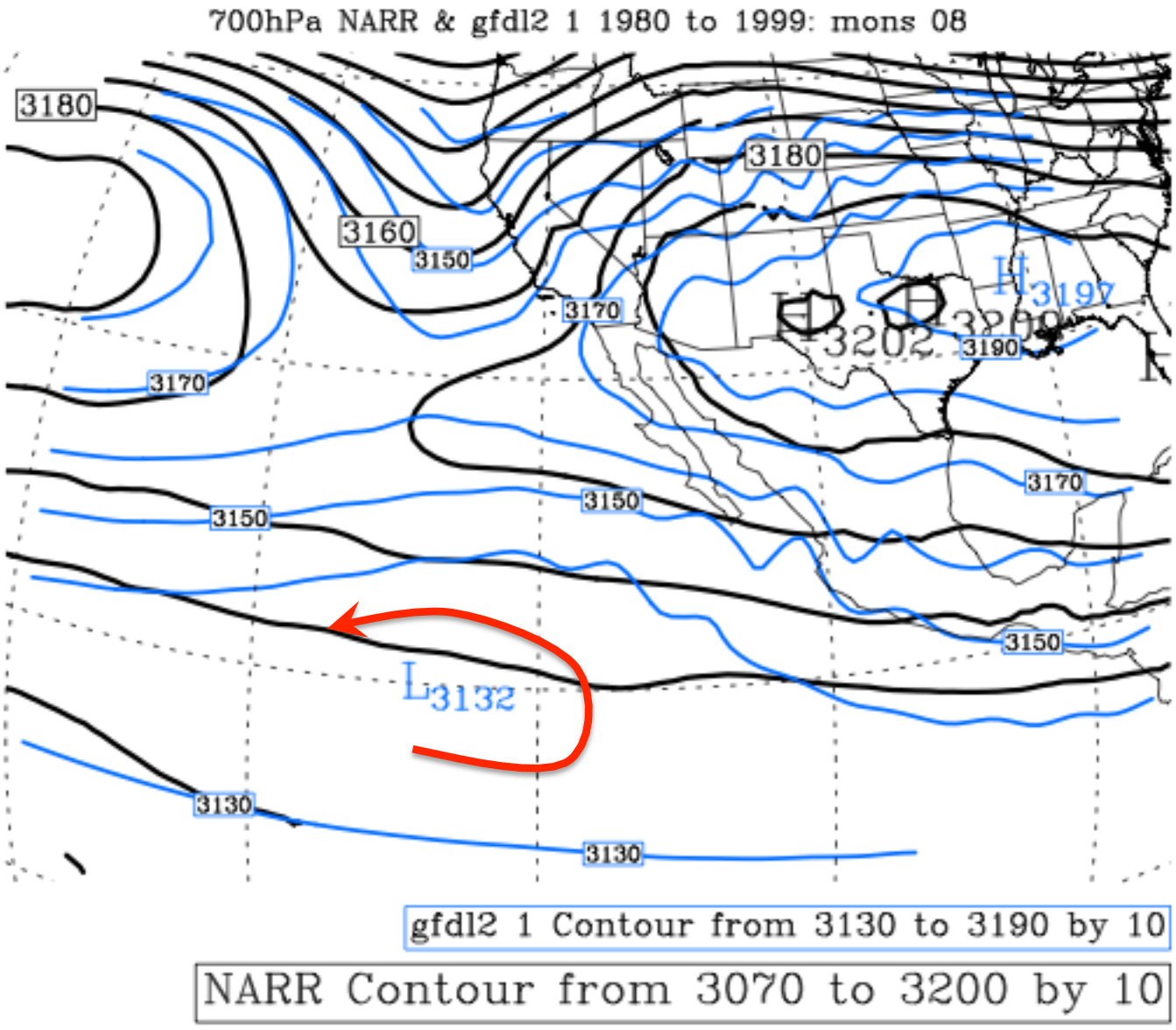
~&~

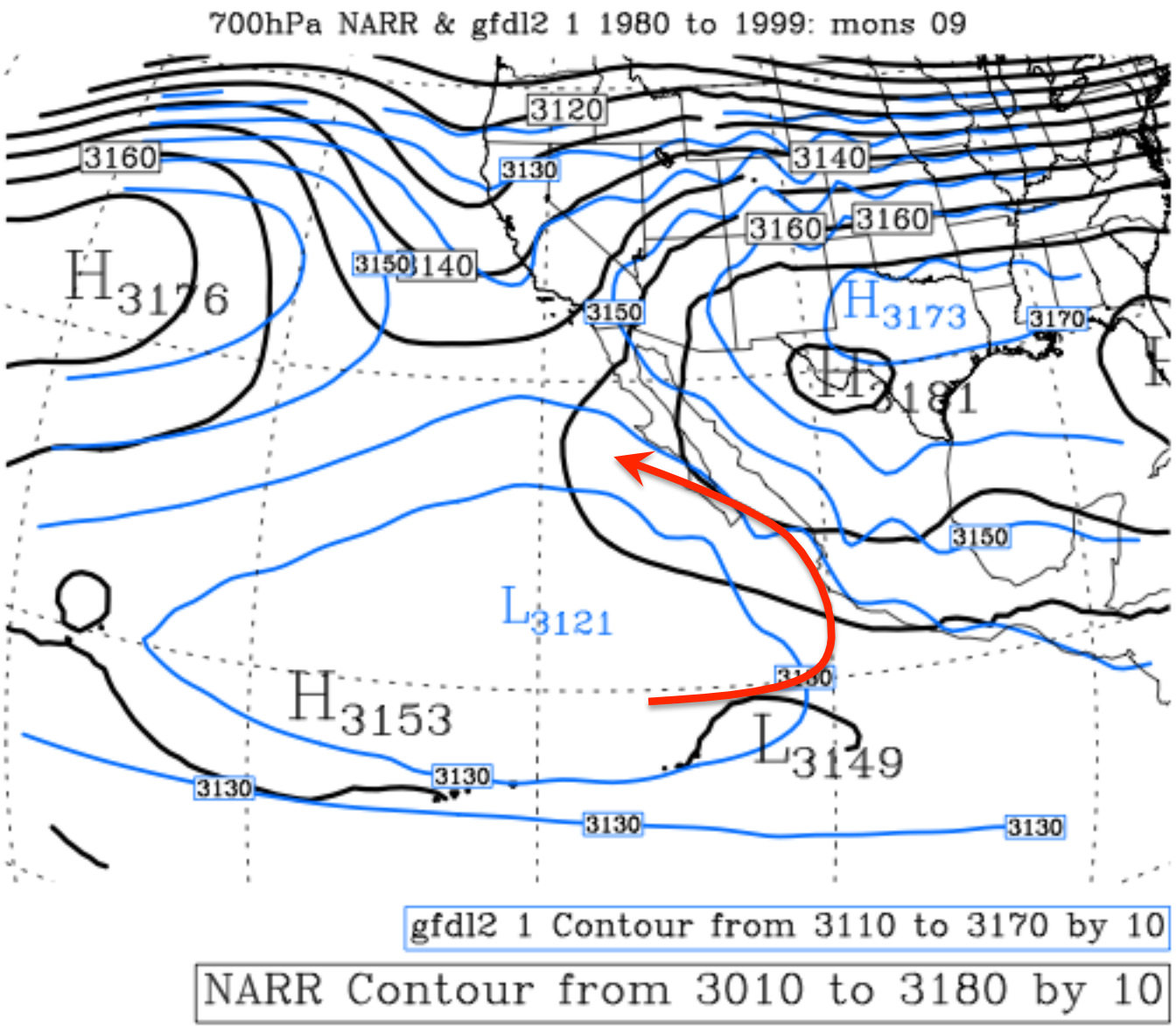
2m Temperature Over Water

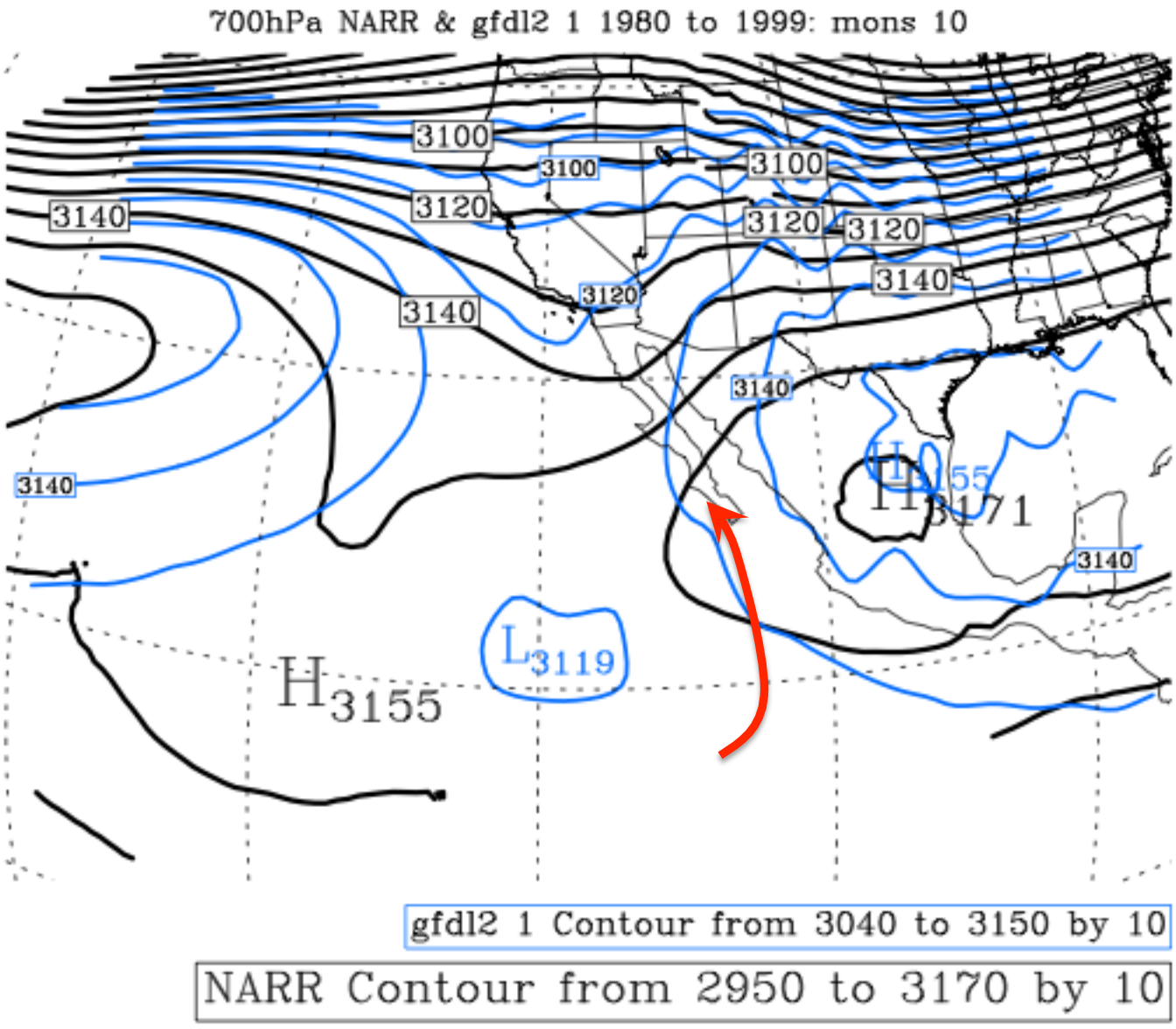


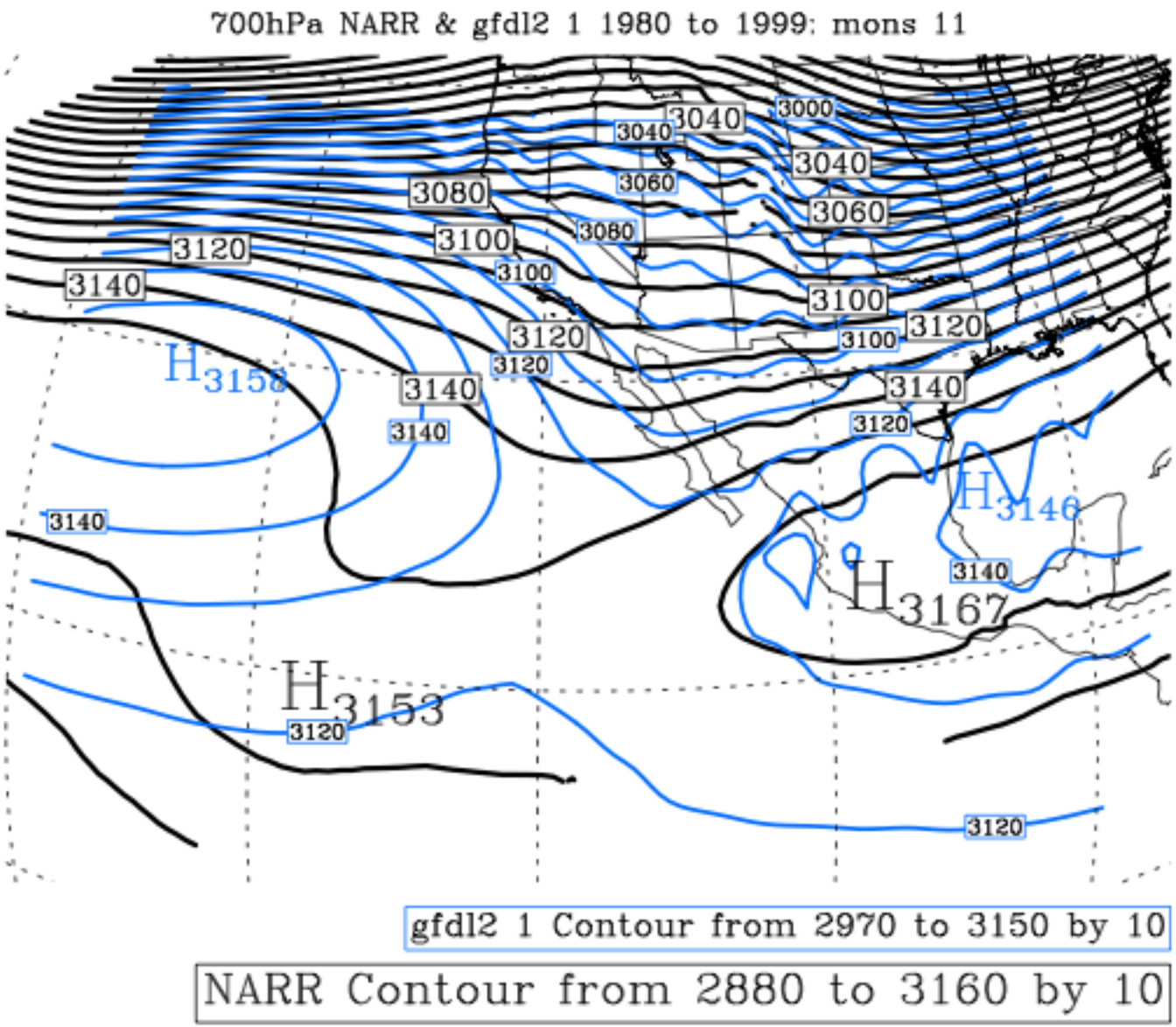

NCEP OCT
NCEP NOV
NARR OCT
NARR NOV
GFDL OCT
GFDL NOV
ECP2-gfdl OCT
ECP2-gfdl NOV
−5 −4 −3 −2 −1 0 1 2 3 4 5
(hPa/s)
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10
(mm/day)

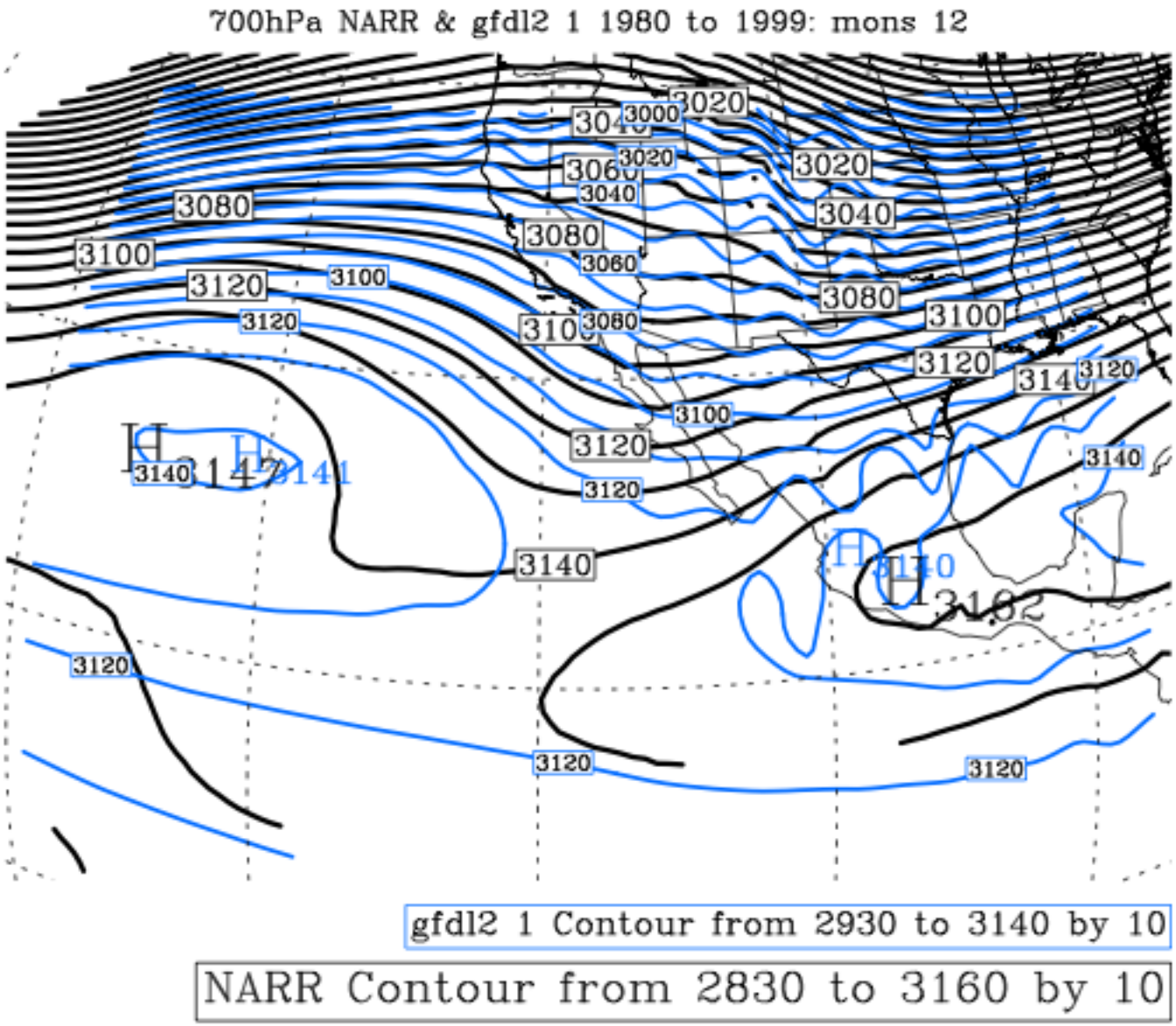

700hPa NARR & gfdl2 1 1980 to 1999: mons 07
3140
3160
3180
3160
3180
3180
3180
3200
3180
3160
3160
3140
3160
3140
3140
gfdl2 1 Contour from 3130 to 3200 by 10
NARR Contour from 3060 to 3200 by 10


700hPa NARR & gfdl2 1 1980 to 1999: mons 08
3180
3160
3150
3170
3180
3190
3170
3150
3150
3170
3150
3130
3130
H 3197
3202
L 3132
gfdl2 1 Contour from 3130 to 3190 by 10
NARR Contour from 3070 to 3200 by 10


700hPa NARR & gfdl2 1 1980 to 1999: mons 09
3120
3160
3130
3140
3160
3160
3150
3140
3150
3170
H3176
H3173
L3181
3150
L3121
H3153
3130
L3149
3130
3130
3130
gfdl2 1 Contour from 3110 to 3170 by 10
NARR Contour from 3010 to 3180 by 10


700hPa NARR & gfdl2 1 1980 to 1999: mons 10
3100
3100
3100
3120
3120
3120
3140
3140
3140
3140
3140
3140
3120
H3155
L3119
H3171
gfdl2 1 Contour from 3040 to 3150 by 10
NARR Contour from 2950 to 3170 by 10


700hPa NARR & gfdl2 1 1980 to 1999: mons 11
3040
3000
3040
3040
3060
3080
3060
3080
3100
3120
3100
3140
3100
3120
3120
3100
3120
3140
3140
3120
3140
3140
3140
3120
3120
H3158
H3146
H3167
H3153
gfdl2 1 Contour from 2970 to 3150 by 10
NARR Contour from 2880 to 3160 by 10


700hPa NARR & gfdl2 1 1980 to 1999: mons 12
3020
3000
3040
3060
3080
3100
3120
3140
H 3147
H 3141
H 3140
H 3162
gfdl2 1 Contour from 2930 to 3140 by 10
NARR Contour from 2830 to 3160 by 10

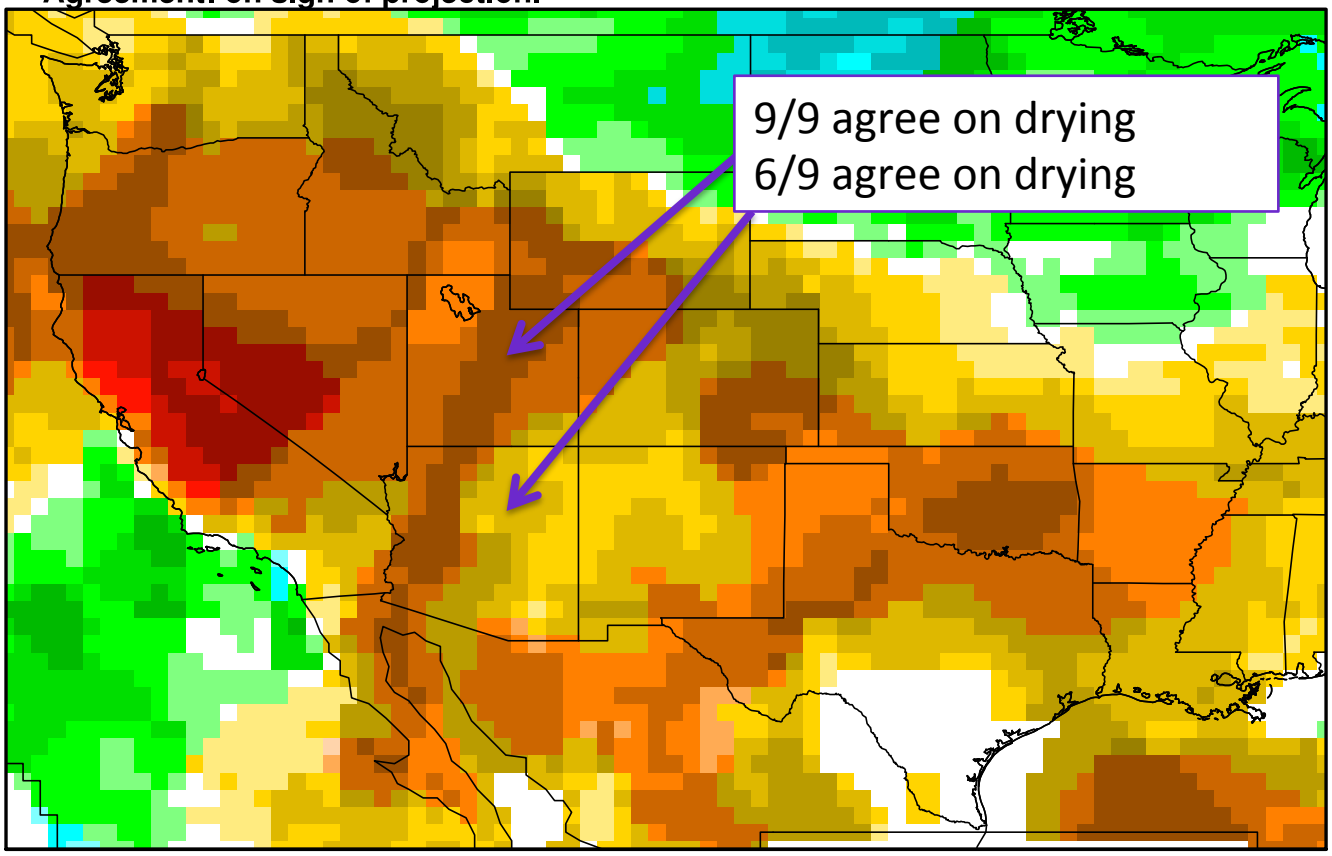
Climate Change

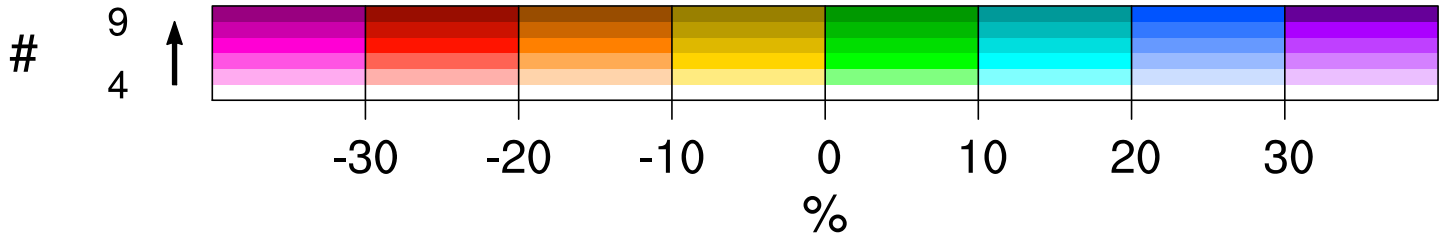
FUTURE GCM DRIVEN SIMULATIONS

ENSEMBLE MEAN CHANGE: Precipitation

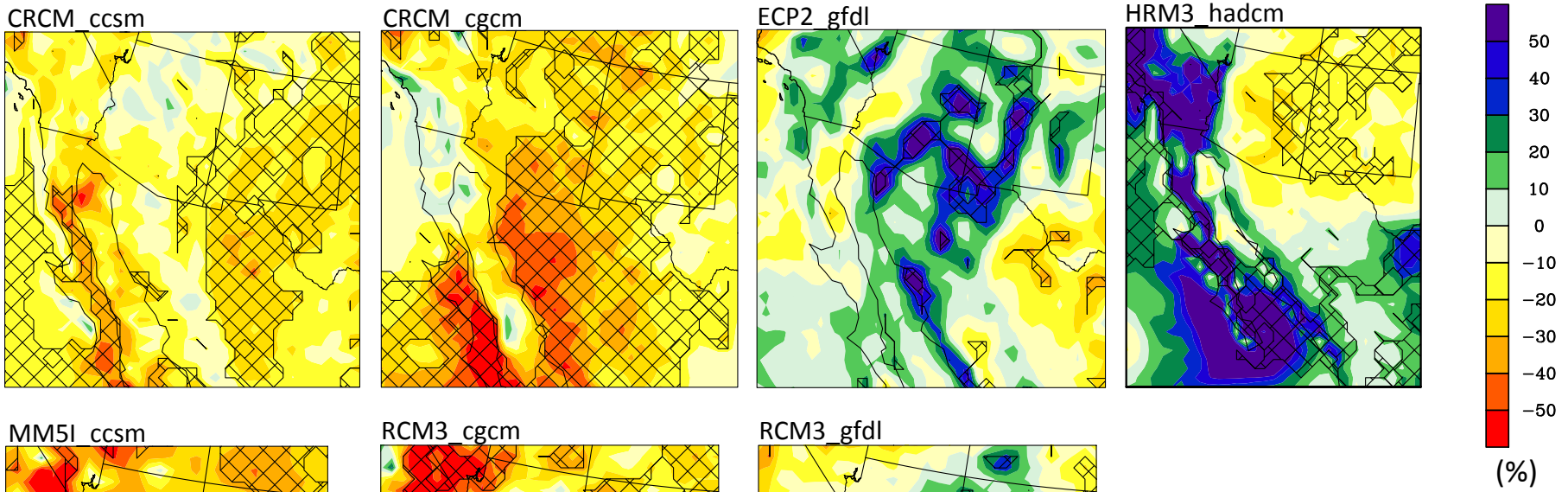
1971-1999 vs. 2041-2069 Months: 06,07,08,09

Agreement: on sign of projection.



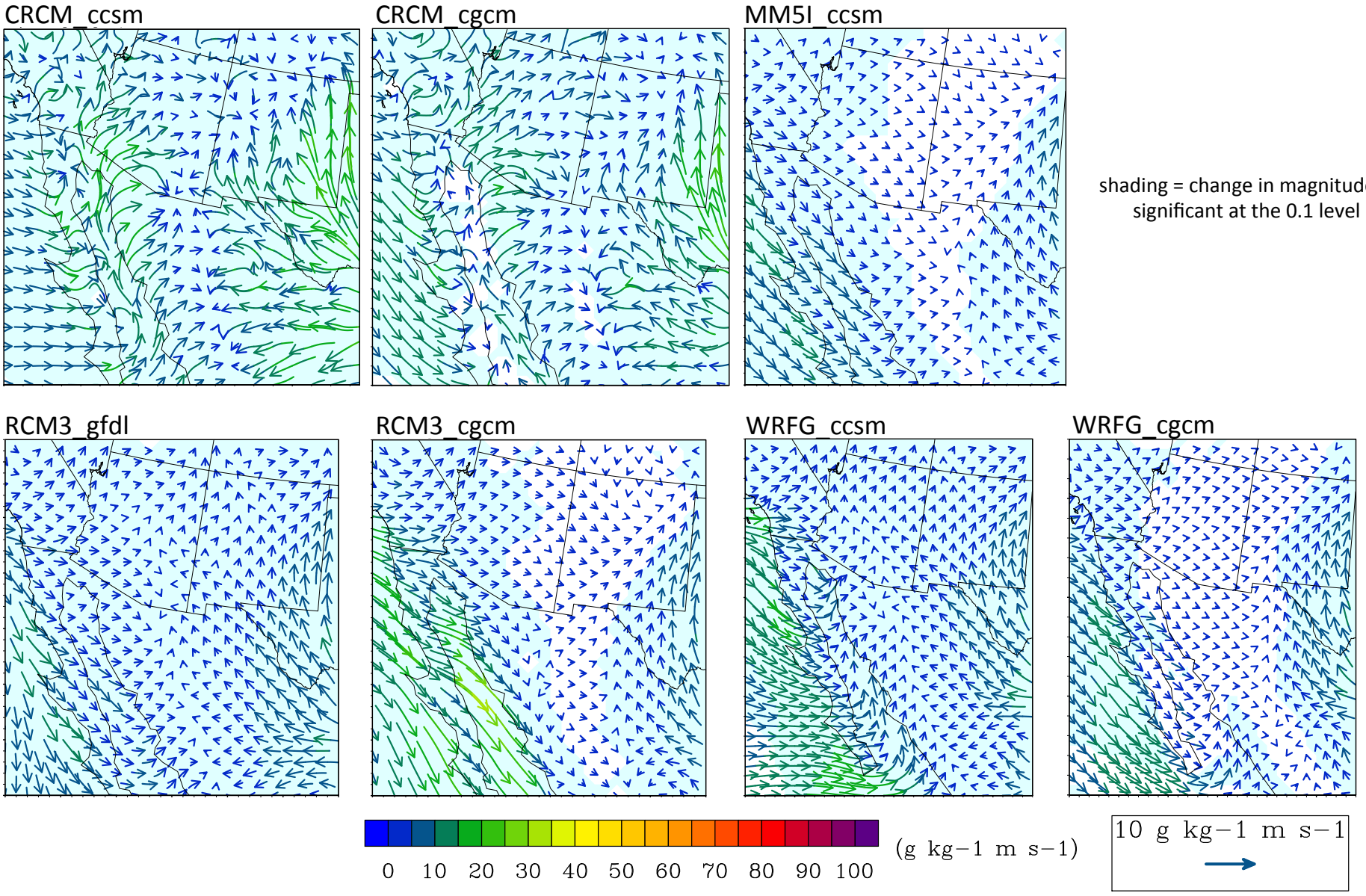


9 RCM JJAS Mean Change



2041-2069 : 1971-1999
JJAS
Average Precipitation
Percent Difference

Hatching indicates statistically significant changes at the 0.1 level. Method = bootstrapping.



2041-2069 : 1971-1999 JJAS
Near-Surface Moisture Flux Difference

Final Comments

- The ability of the models to capture monsoon system rainfall is heavily determined by driving GCM.
- Bias in near surface moisture flux/wind fields is heavily determined by the RCM.
- Future work will include examining the driving GCMs to determine, more specifically, how they are influencing the RCMs in terms of their ability to simulate a monsoon system and in terms of their influence on the RCM projections. Additional RCM analysis will follow.
- Clearly, for this region, this will be an interesting ensemble of models to work with for this process-based credibility analysis. The projections may be similar, but the differences in the RCMs and GCMs are striking.