Understanding the Role of Land-Atmospheric Interaction in the NCEP Coupled Forecast System (CFS) on Drought Forecast Skill for the 2011 and 2012 US Droughts

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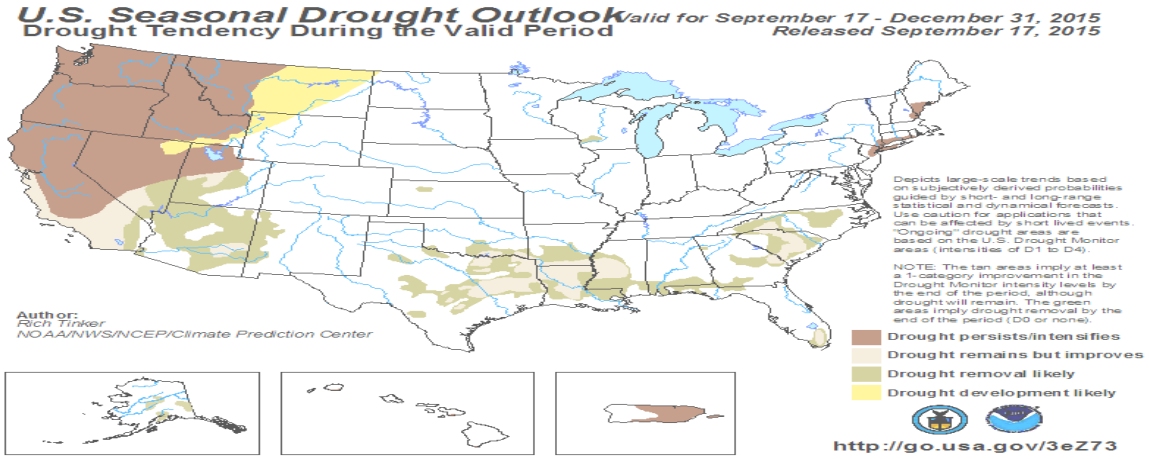
EMC/NCEP/NWS



NOAA's 40th Climate Diagnostics and Prediction Workshop

Denver, Colorado, 26-29 October 2015

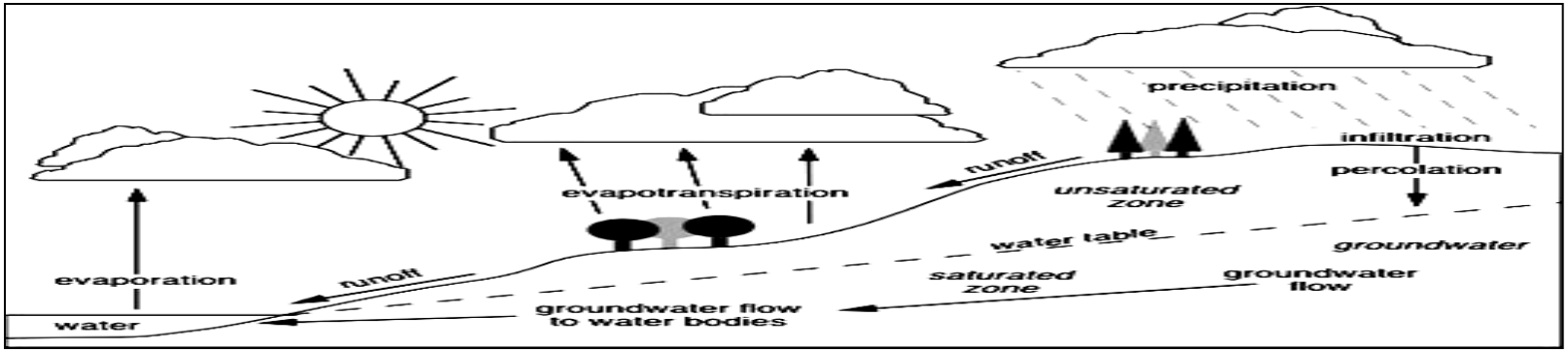
Outline

- **Motivation**
- **Introduction to land-atmospheric interactions, Noah LSM limitations and the way to improve the model performance.**
- **CFS Experiment Design and Configuration.**
- **Skill assessment.**
- **Summary.**

Motivation

- **The NCEP CFS has limited scale in predicting extreme weather/climate, especially drought development, intensification, and demise.**
- **Investigate the role of vegetation in sub-seasonal to seasonal time scale in the forecast model.**
- **Attempt to improve the model performance from the land perspective.**

Land Surface Model interactions with its parent atmospheric model



Energy, moisture flow and momentum exchanges

- The incoming radiation heats the ground, the absorbed energy is partitioning into latent, sensible, ground, and snow-related fluxes.
- Rain/snow falls on the ground, runoff, infiltration, and evaporation, ground water flow
- The energy and water exchanges are impacted by surface properties, Greenness Vegetation Fraction (GVF) is one of the most important factors.

Land Model in a Coupled Setting

as lower boundary conditions

- ✓ **Requires necessary atmospheric forcing from its parental atmospheric model.**

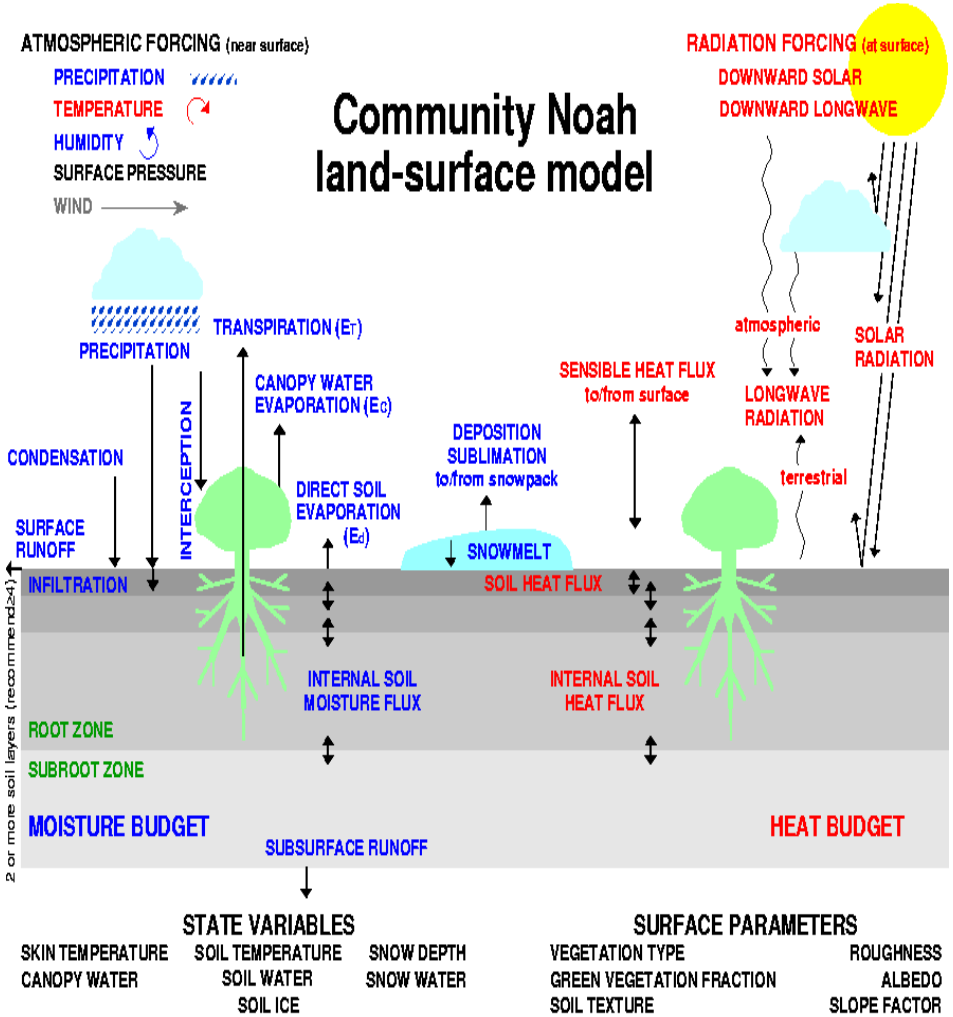
- ✓ **Requires appropriate physics parameterizations to represent land-surface processes (for relevant time/spatial scales) to provide fluxes to the hosting model.**

- ✓ **Requires Corresponding land surface properties in a coupled setting, e.g. land use/land cover (vegetation type), soil type, surface albedo, snow cover, surface roughness, etc.**

- ✓ **provide surface state variables to its parent atmospheric model,**

  e.g. Deep soil moisture for seasonal predictions, as soil moisture has "long memory", like o ocean SST.

Limitations in Noah LSM



ftp://ftp.emc.ncep.noaa.gov/mmb/gcp/ldas/noahlsm

- **A combined surface layer of vegetation canopy and ground and uses climatological GVF, which has important on surface evaporation. Such structure impedes further developments on dynamic vegetation model.**

- **Neglect of the effects of zero-displacement height (d_0) on CH; thus a smaller CH over forest regions.**

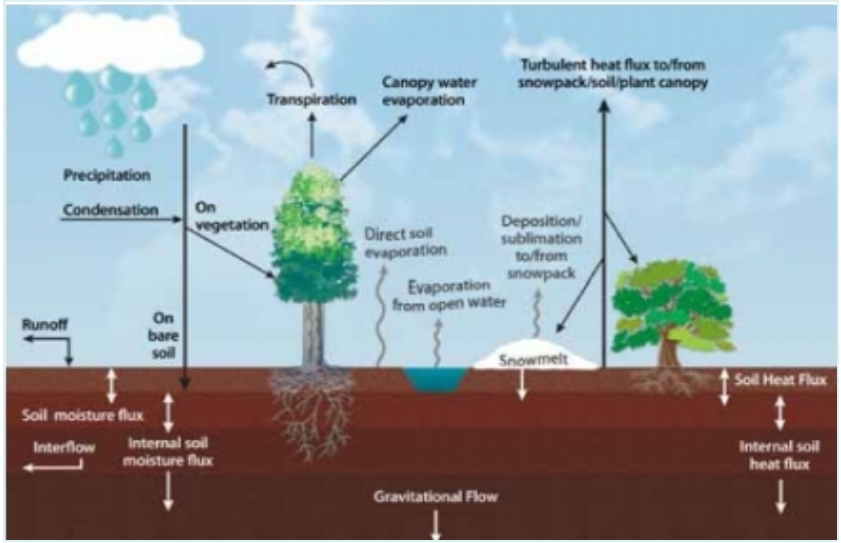
- **A bulk layer of snow and soil. The ground heat flux can not be accurately resolved for a thick snowpack.**

- **Too shallow soil column (2-meter deep) and free drainage at the soil bottom. Groundwater effects are neglected.**

Examine and Improve Drought Prediction Skills via Changing Vegetation Treatment in CFS

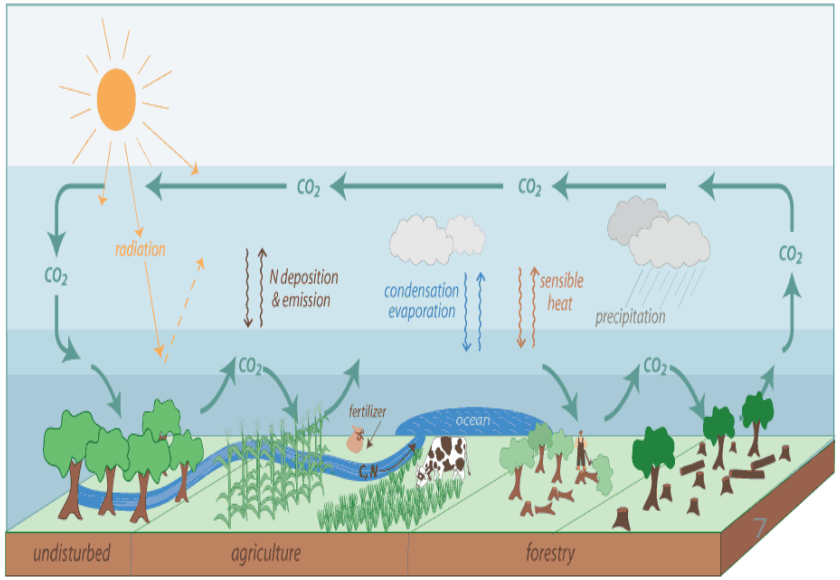
Step 1:

Replace the climo GVF with Satellite Obs to examine the role of vegetation evaporation.



Step 2:

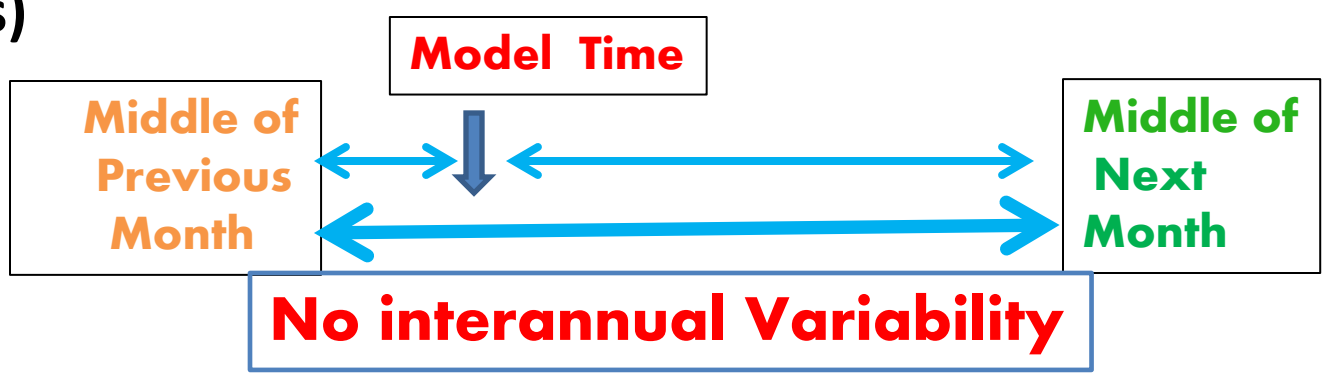
Replace the Noah LSM with A new Noah MP LSM with dynamic vegetation (interactive).



Monthly Green Vegetation Fraction (GVF) Climatology in Current Ops (AVHRR NOAA 18)

(1989, 1990, 1995, 1996, 1997 and 2001)

The monthly vegetation dataset used in the GFS/CFS is 16km (0.144 degree). The actual GVF used in the calculation is interpolated from two monthly data based on the "distances" between the model date and the two adjacent months (the monthly value is assumed to be valid in the middle of the months)



Ensemble Surface Physics with Noah-MP

(JGR: Niu et al., 2011 and Yang et al., 2011)

Noah-MP contains several options for land surface processes

1. **Dynamic vegetation/vegetation coverage (4 options – default: off)**
2. **Canopy stomatal resistance (2 options – default: Ball-Berry)**
3. **Canopy radiation geometry (3 options – default: shadows – f(sun))**
4. **Soil moisture factor for stomatal resistance (3 options – default: Noah)**
5. **Runoff and groundwater (4 options – default: TOPMODEL)**
6. **Surface layer exchange coefficients (4 options – default: MP M-O)**
7. **Supercooled soil liquid water/ice fraction (2 options – default: no iter)**
8. **Frozen soil permeability options (2 options – default: linear effects)**
9. **Snow surface albedo (2 options – default: CLASS)**
10. **Rain/snow partitioning (3 options – default: Jordan f(T))**
11. **Lower soil boundary condition (2 options – default: fixed bottom T)**
12. **Snow/soil diffusion solution (2 options – default: flux boundary)**

CFS Experiments

Veg Climo ⇨ Satellite Retrieval

Cntrl CFS (Noah 2.7 with and w/o Weekly AVHRR satellite obs)

Ops GFS + Noah 2.7 with old **ssib veg + zobler soil**
(13 categories in vegetation and 9 classifications in soil)

Noah LSM ⇨ Noah MP LSM w Dveg

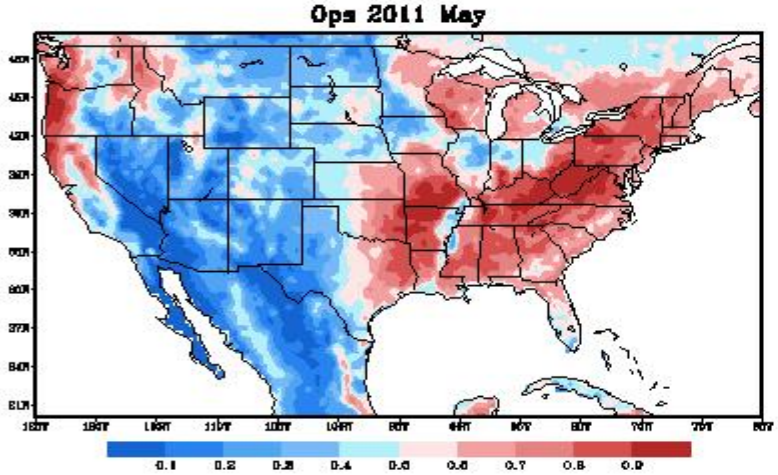
Exp CFS Noah MP (with and without Dynamic veg option)

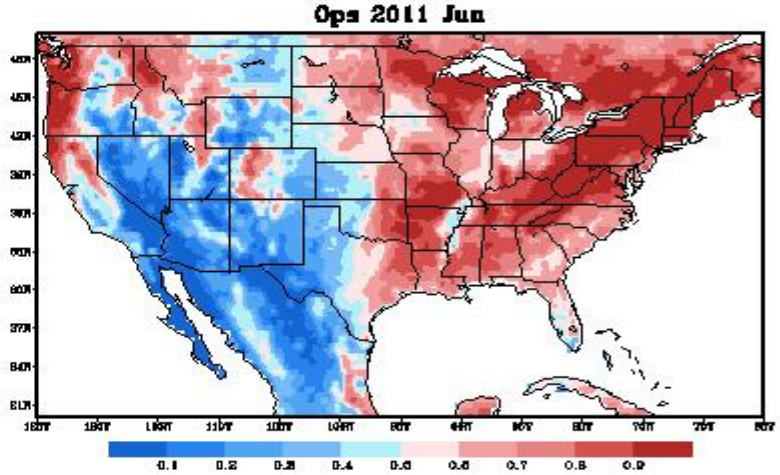
Ops GFS + Noah MP with new **modis veg + statsgo soil**
(20 categories in vegetation and 16 classifications in soil)

1. Use **4** ensemble members with Initial Conditions from **00z of May 1-4** over
2. Selected **11** years:82,86,87,88,91,96,99,00,07,11,12 (0.5°C ,MJJ, Ňino 3.4)
3. Including **warm**, **cold** and **neutral** ENSO indices

Ops GVF (Climo)

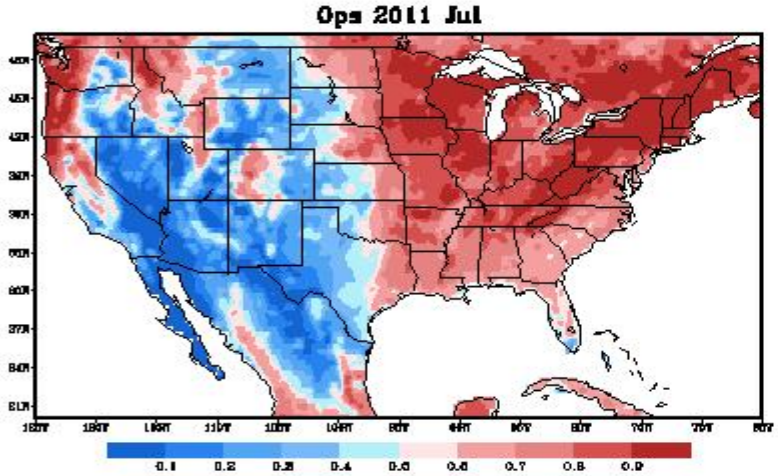
May

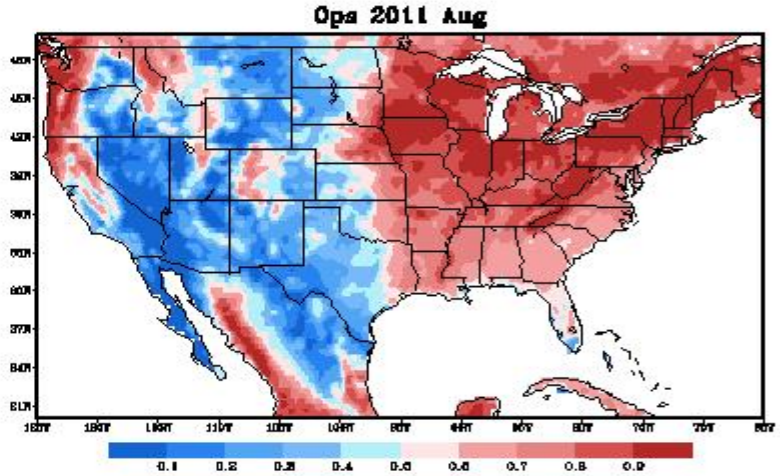




June

July

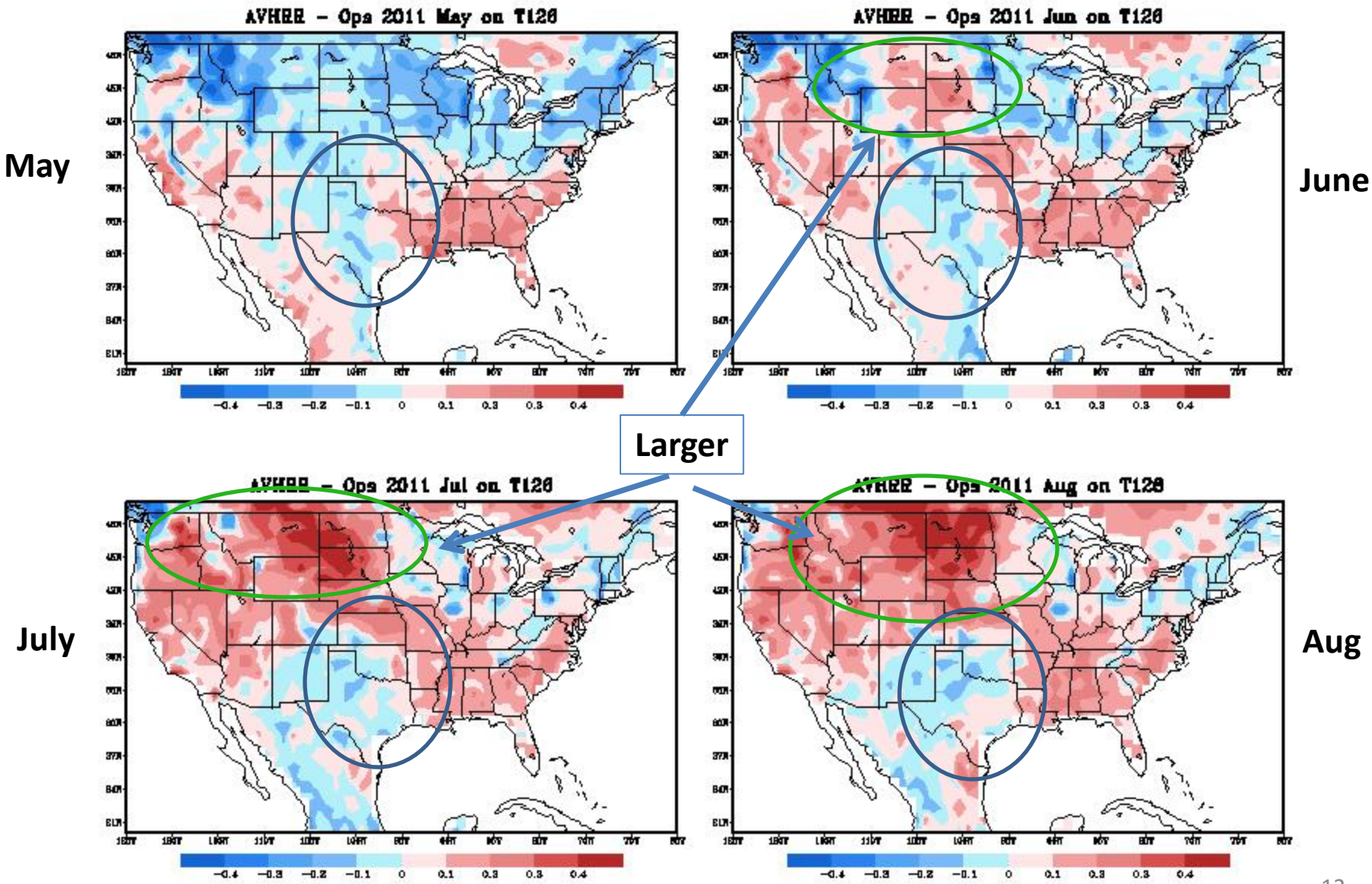




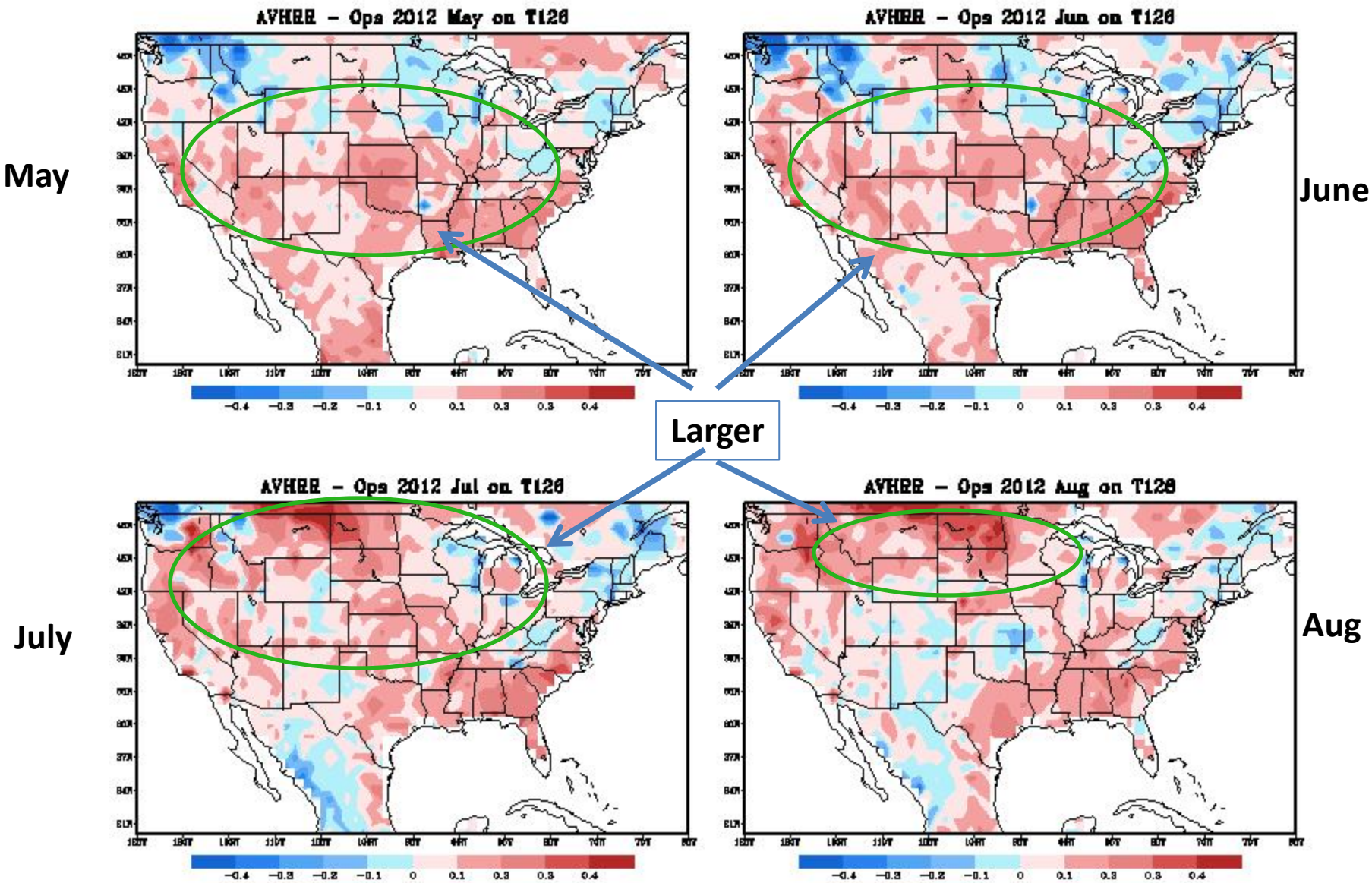
Aug

Seasonality (May –August) in Ops GVF

AVHRR – Ops on T126 Grid (case 2011)



(AVHRR – Ops on T126 Grid case 2012)



Overall Skill Evaluation

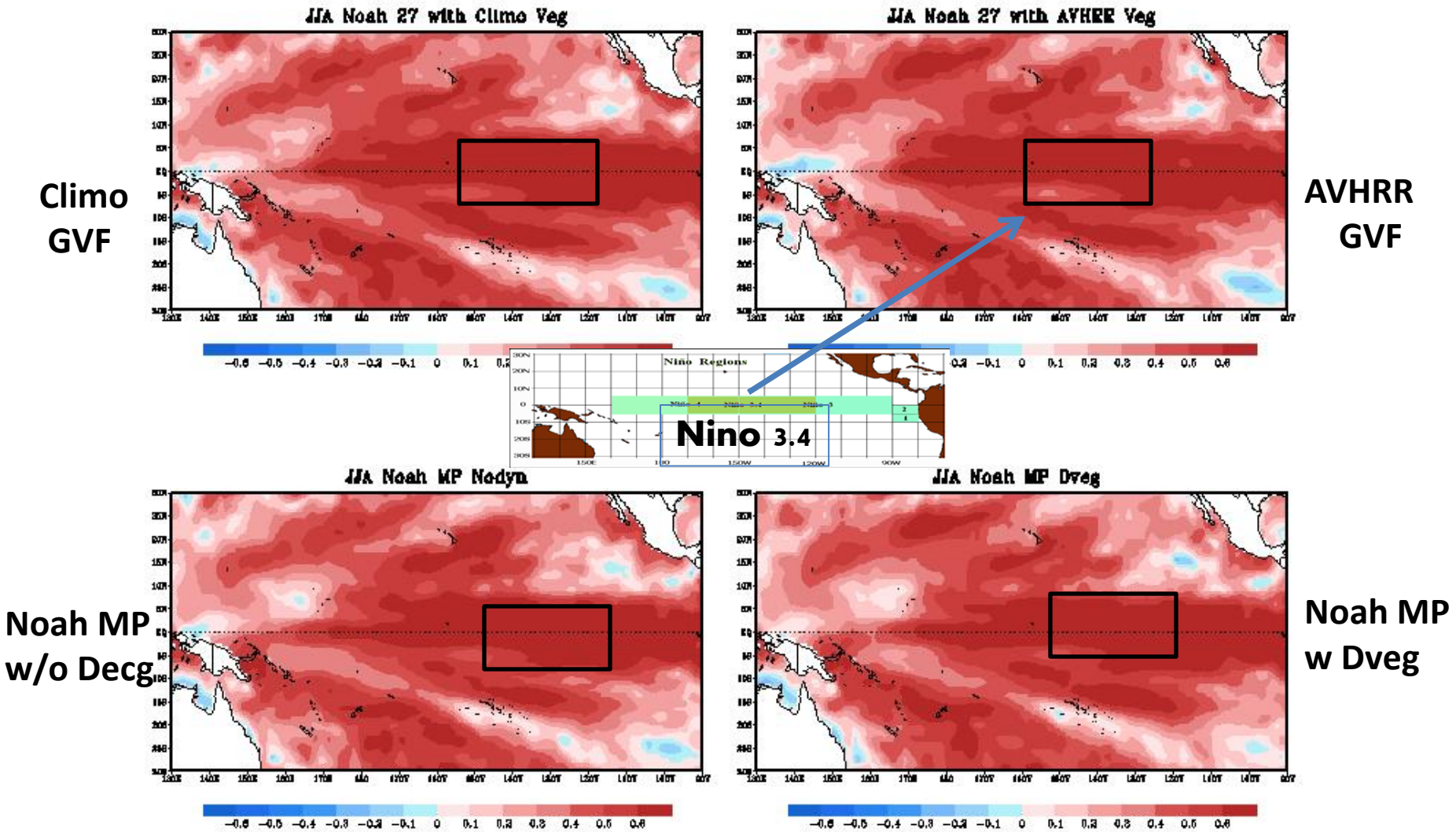
SST, Preip, and T2m

(avgd over 11 yrs)

$$r = \frac{\sum_{i=1}^{n}\left((x_i - \bar{x})(y_i - \bar{y})\right)}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

Anomaly Correlation (AC) Coefficient

CFS JJA SST AC Skill

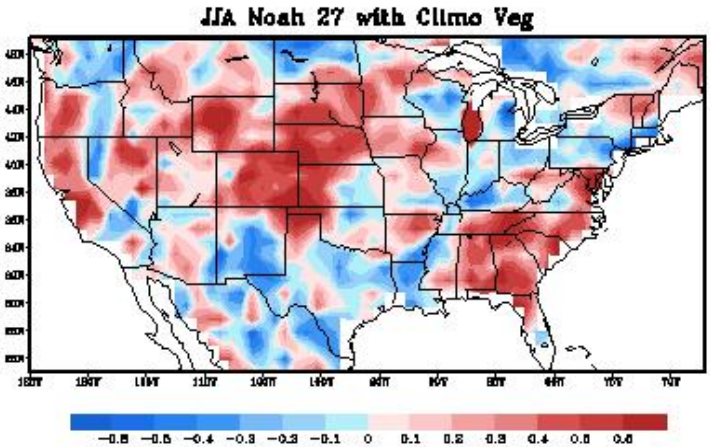


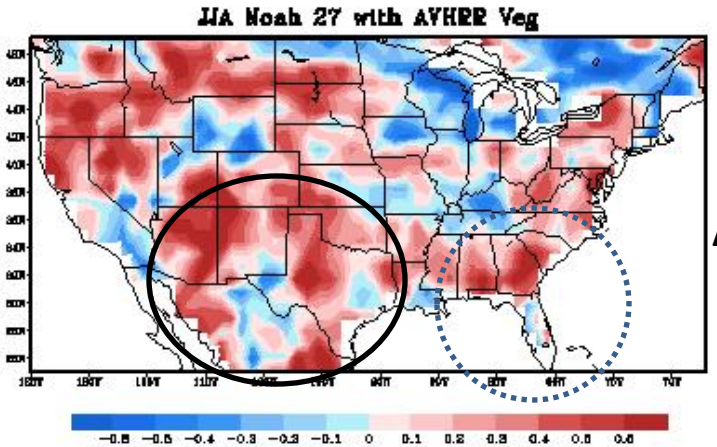
Tropical SSTs <u>have the most important impact</u> on U.S. summer predictions

<u>Small</u> differences on the tropical SST skills among the different veg treatments

CFS JJA Precip AC Skill

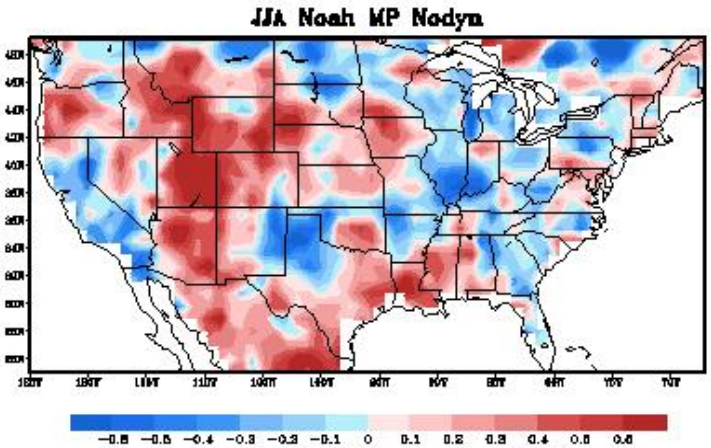
Climo GVF

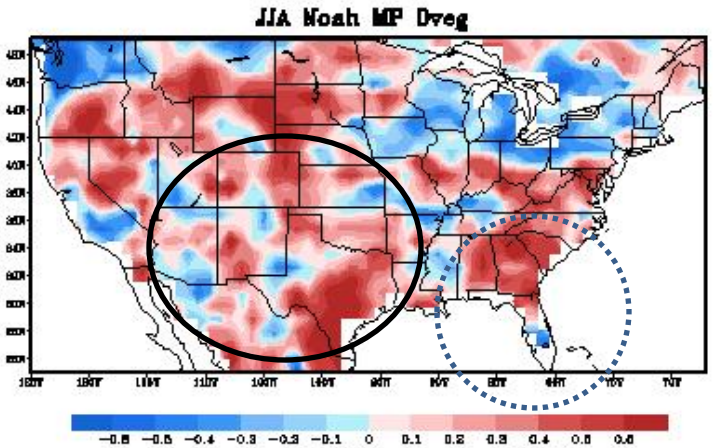




AVHRR GVF

Noah MP w/o Dveg



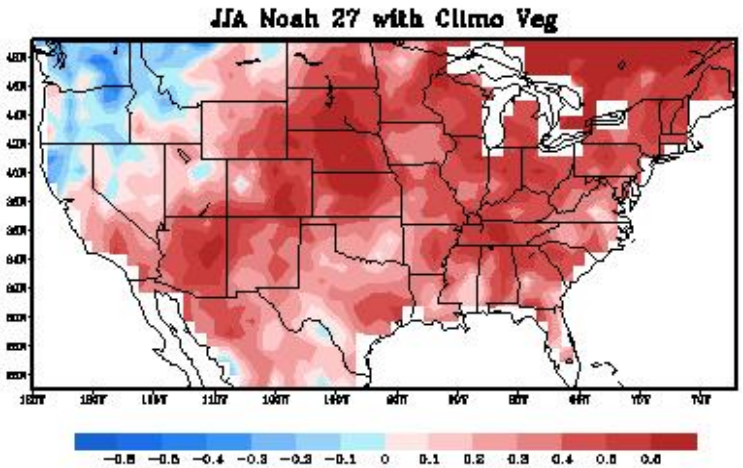


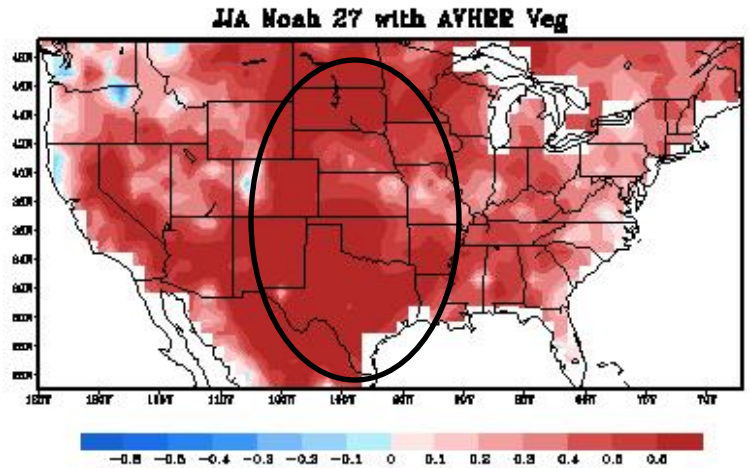
Noah MP w /Dveg

CFS with GVF retrieval and the Noah MP w/Dveg gains some skill over most of the western part of the country without skill loss over the southeast

CFS JJA T2m AC Skill

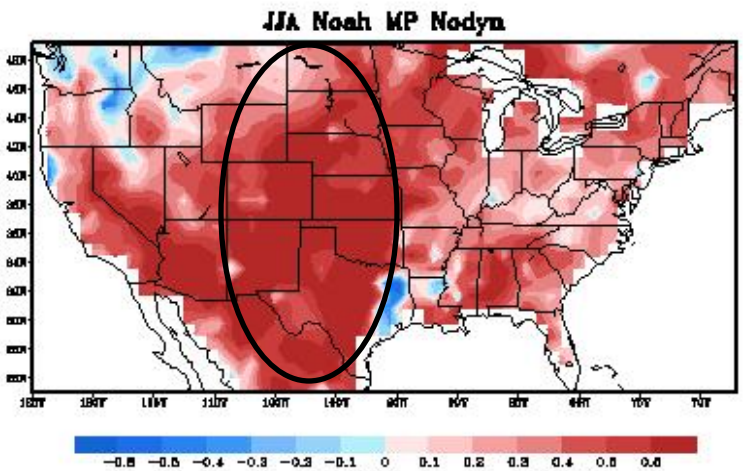
Climo GVF

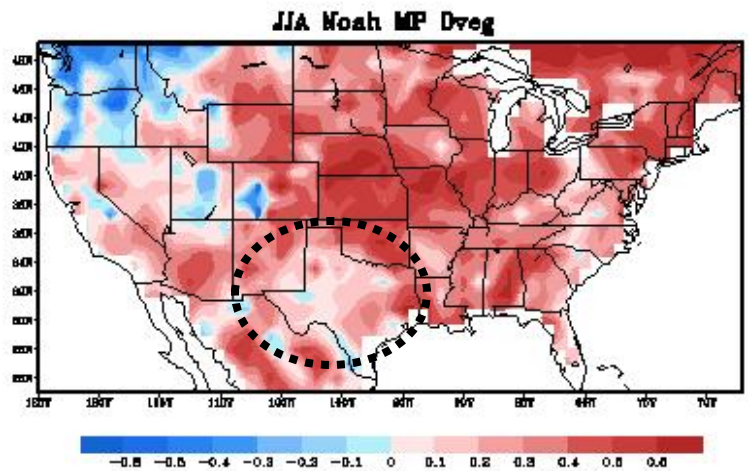




AVHRR GVF

Noah MP w/o Dveg





Noah MP w/ Dveg

The CFS with real GVF and Noah MP w/o Dveg is better

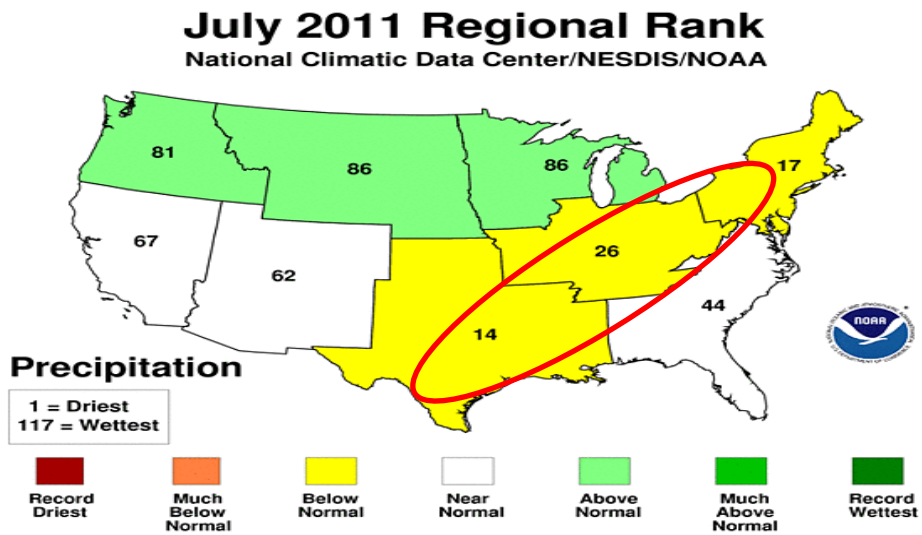
Degraded performance over Texas with Noah MP w/Dveg even though Precip skill is relatively higher.

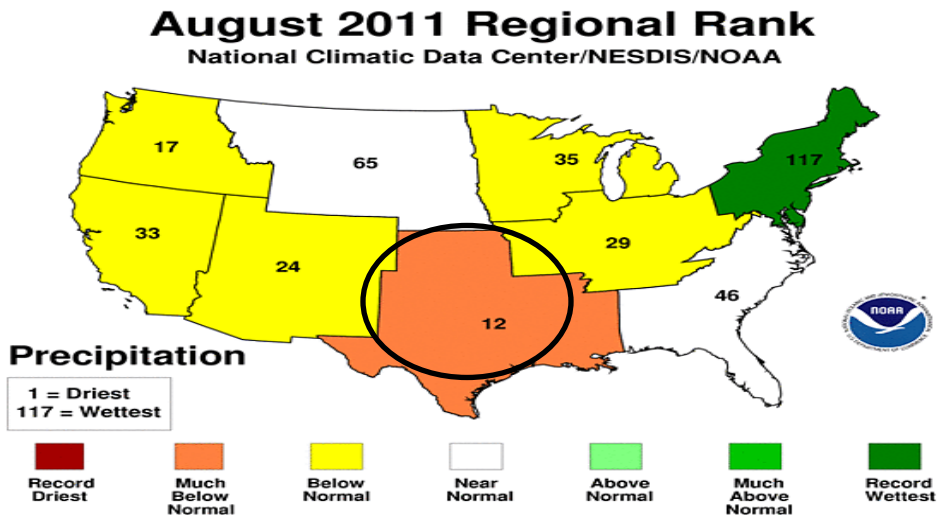
Special Cases: 2011 and 2012

precipitation and T2m from the CFS with *different vegetation treatments* and with the Noah MP Dveg on

Summer Precipitation Anomaly

(2011 Texas Drought)



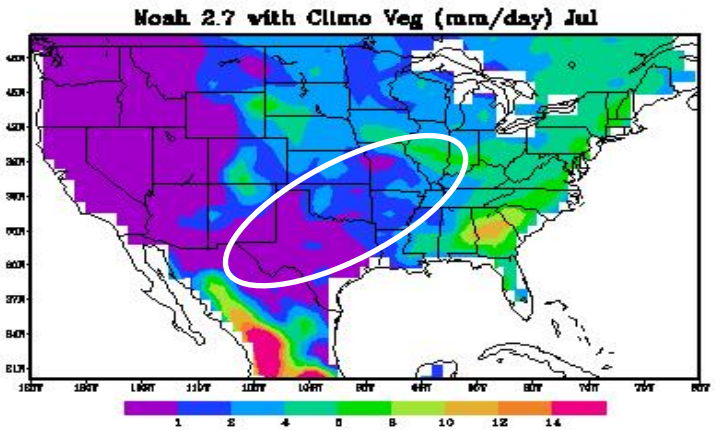


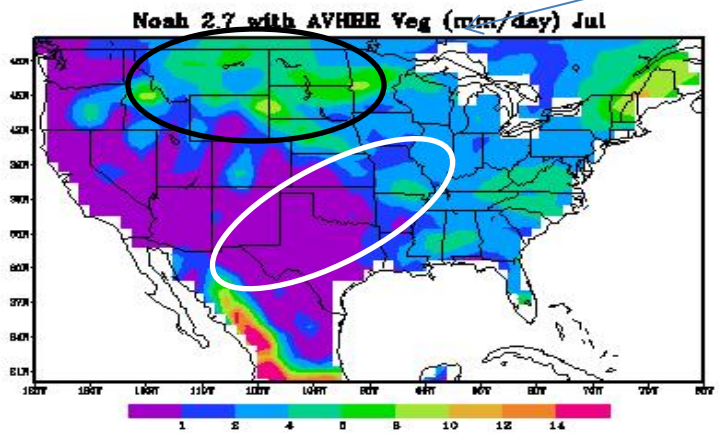
Predicted Precipitation with Different Vegetation Treatments (July and August)

Predicted Precipitation for July 2011 Compared to Observation

Higher GVF

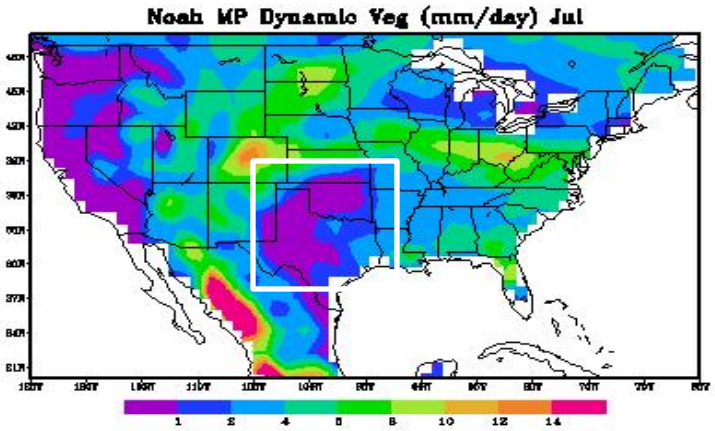
Climo GVF

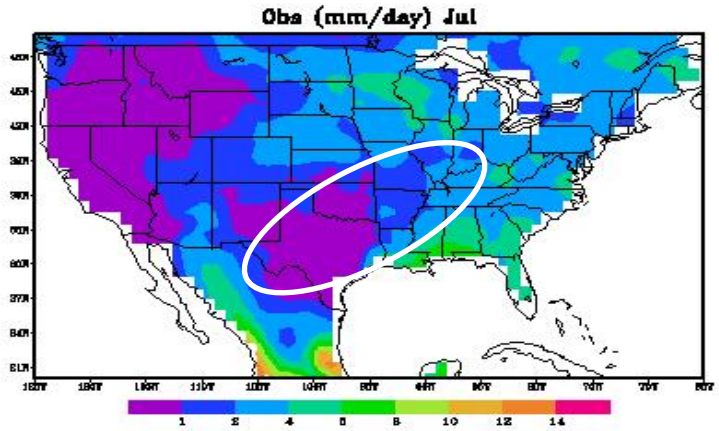




AVHRR GVF

Noah MP





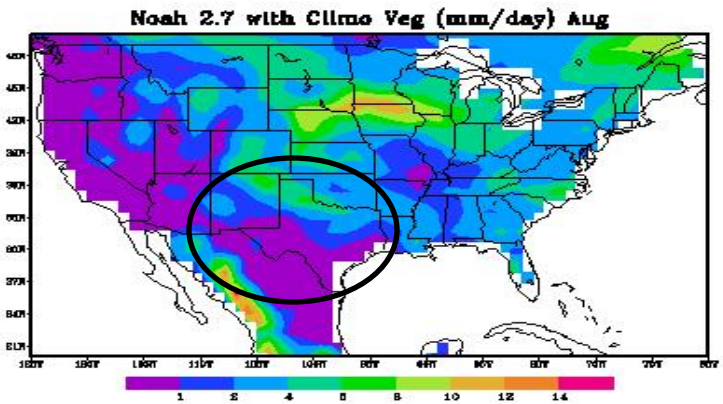
Obs

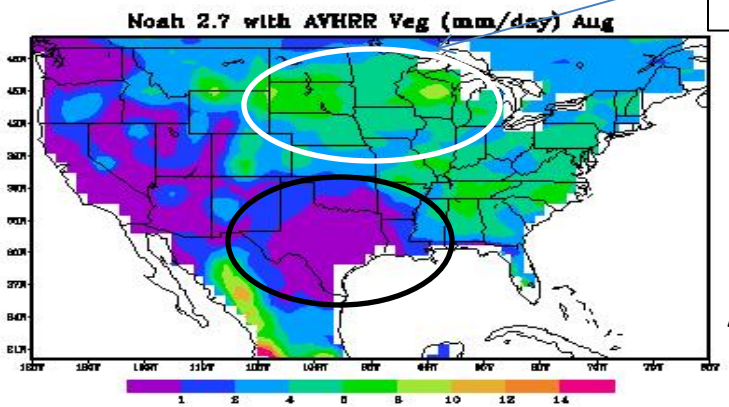
CFS with climo and AVHRR GVF are better than with the Noah MP even though the CFS with the Noah MP can hold the Texas drought and has higher overall prediction skill over the west.

Predicted Precipitation for August 2011 Compared to Observation

Higher GVF

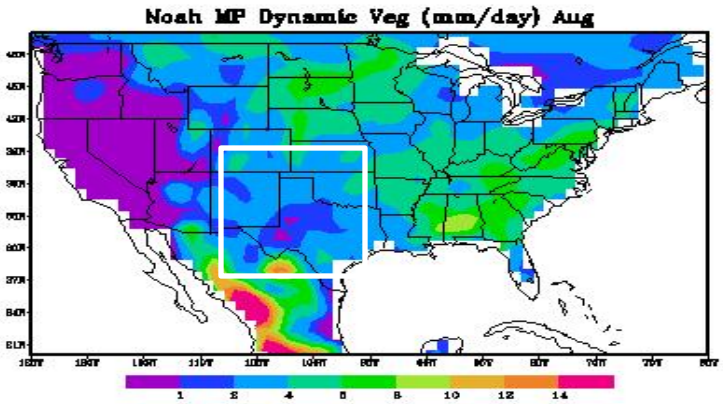
Climo GVF

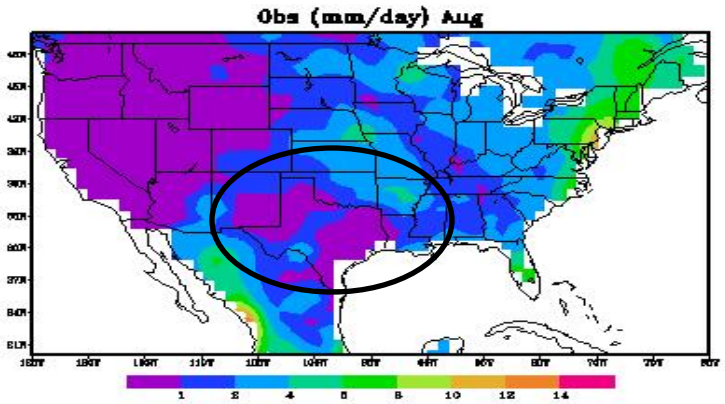




AVHRR GVF

Noah MP





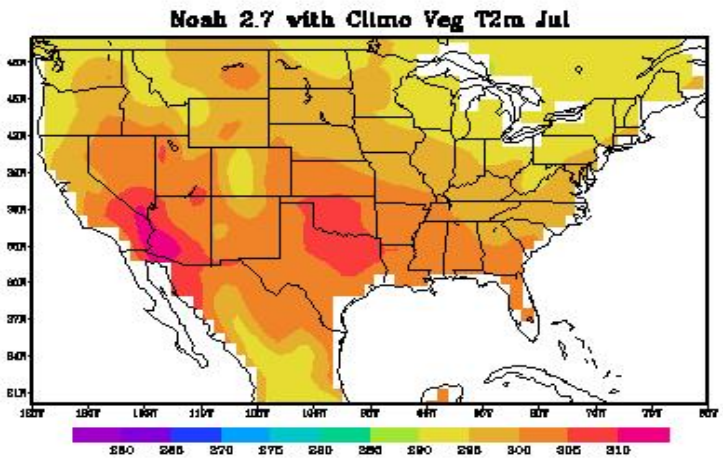
Obs

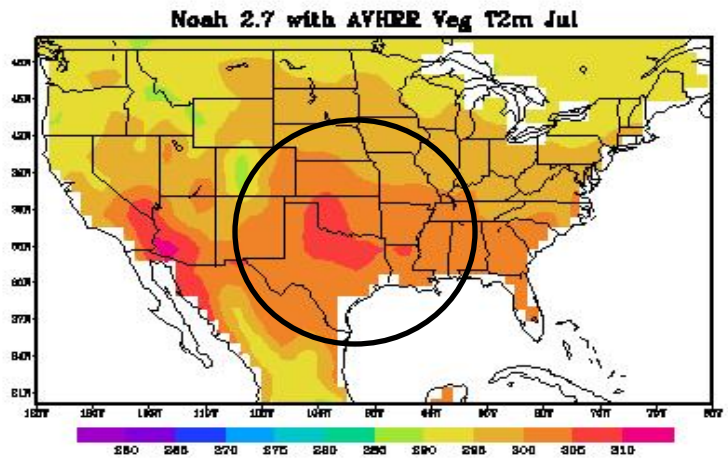
CFS with climo and AVHRR GVF are better than with the Noah MP even though the CFS with the Noah MP show less precip over the state of Texas

Predicted T2m with different Vegetation Treatments (July and August)

Predicted T2m for July 2011 Compared to Observation

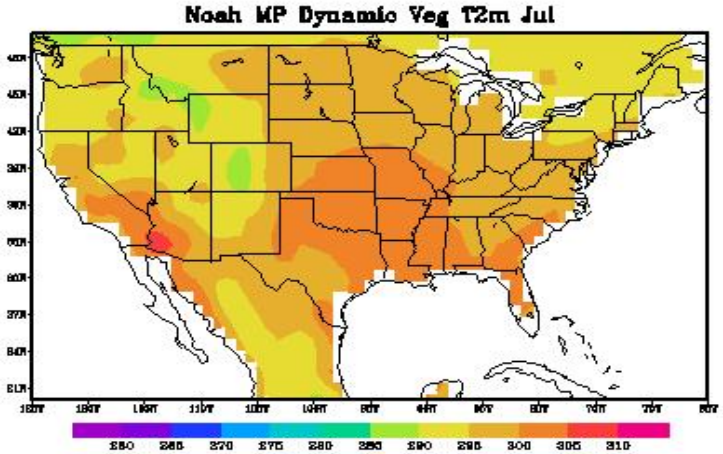
Climo GVF

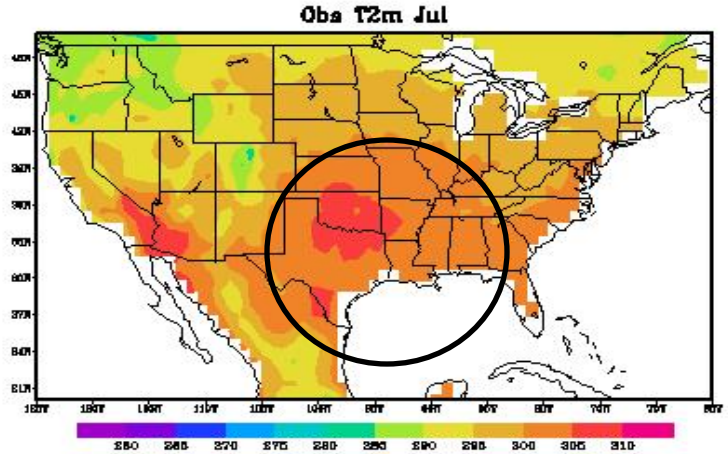




/HRR GVF

Noah MP



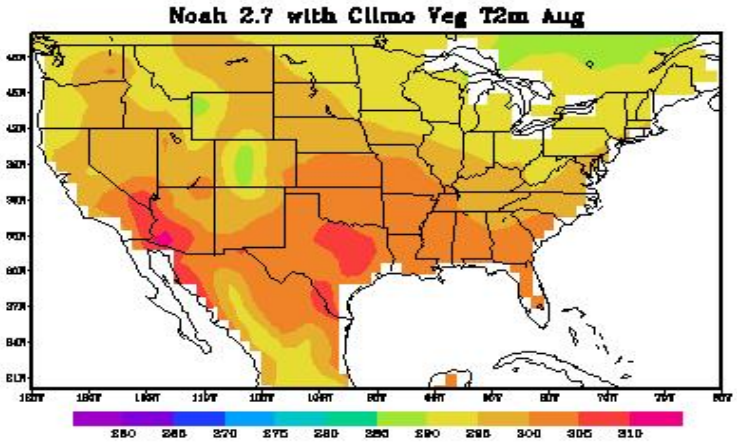


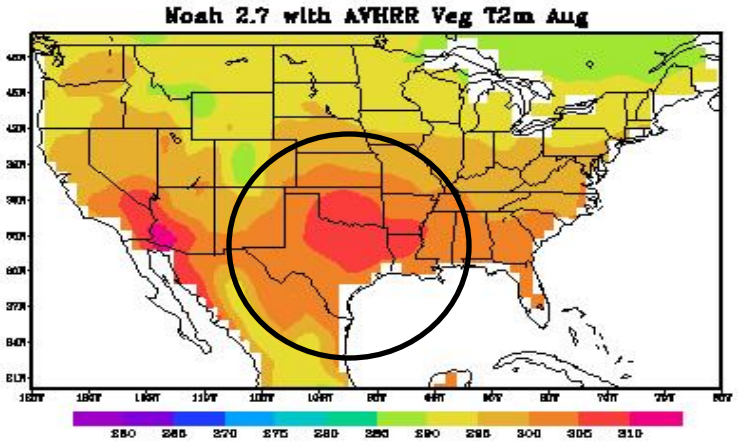
Obs

CFS with the AVHRR GVF is the best. The high temp is located over the Texas

Predicted T2m for August 2011 Compared to Observation

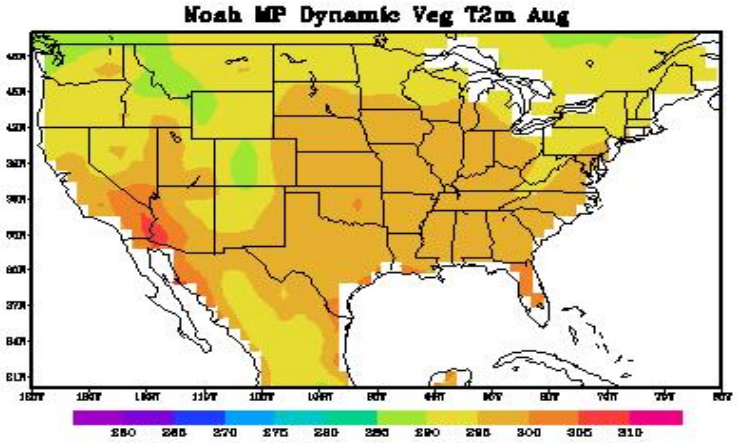
Climo GVF

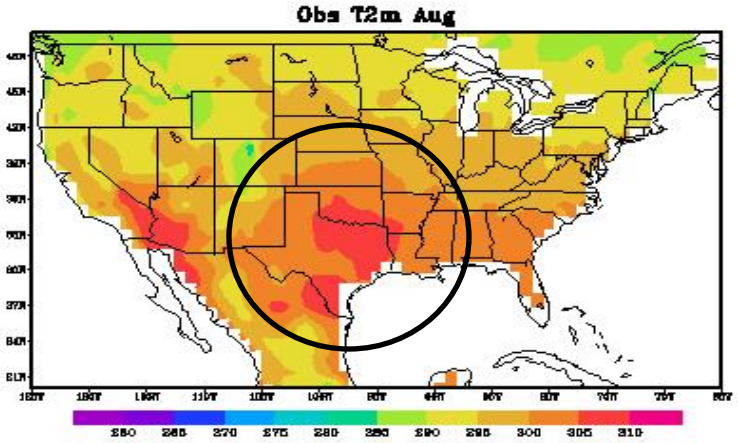




AVHRR GVF

Noah MP



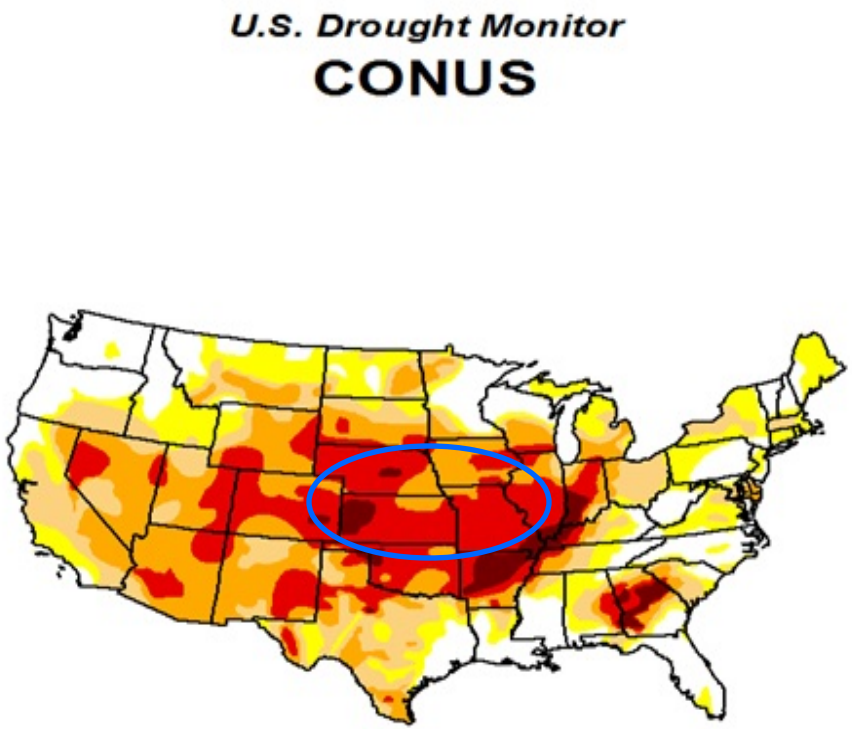


Obs

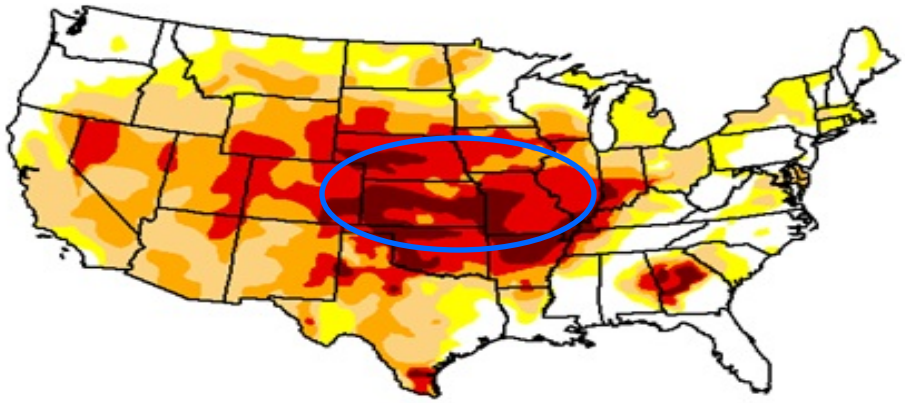
CFS with the AVHRR GVF is the best, high **bias with Climo veg, low bias with Noah MP with Dveg along the Gulf sates even though the pattern looks similar.**

Summer Precipitation Anomaly

(2012 Mid-west Drought)



July

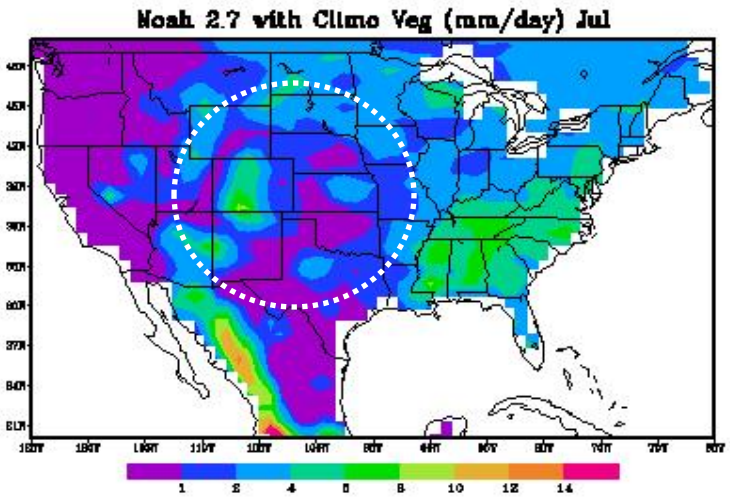


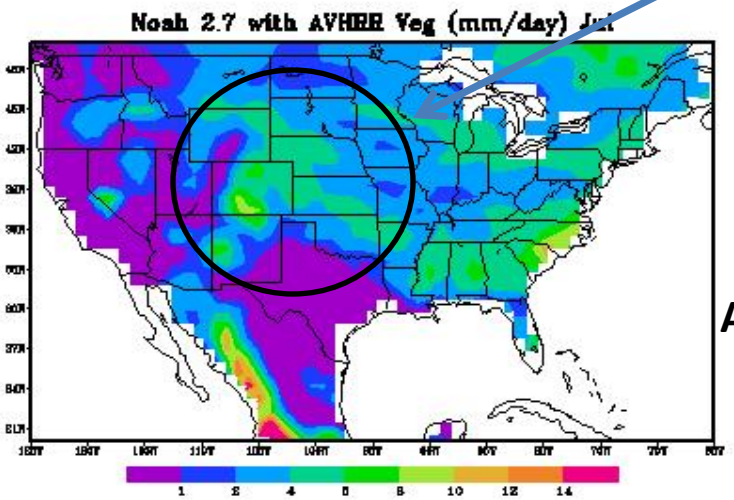
August

Predicted Precipitation for July 2012 Compared to Observation

Higher GVF

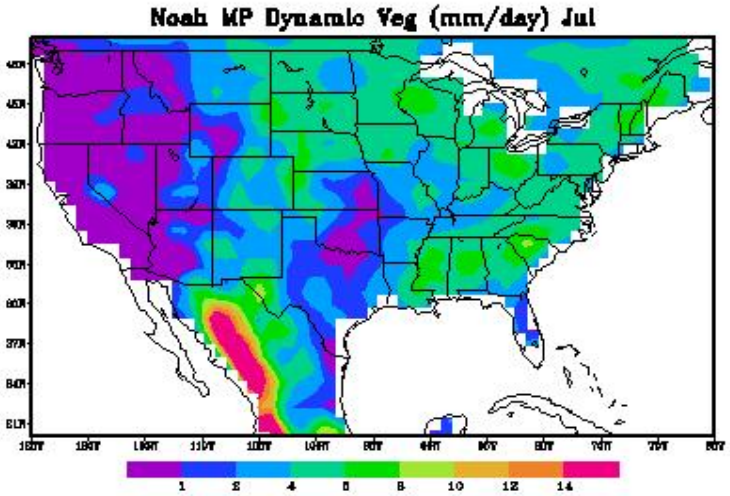
Climo GVF

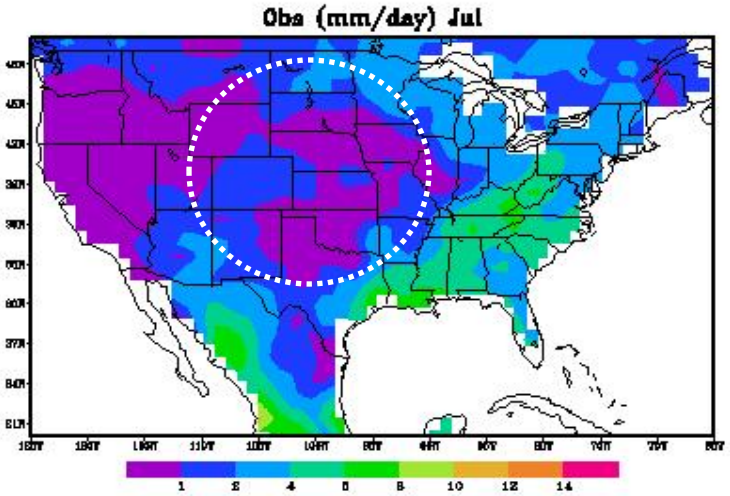




AVHRR GVF

Noah MP





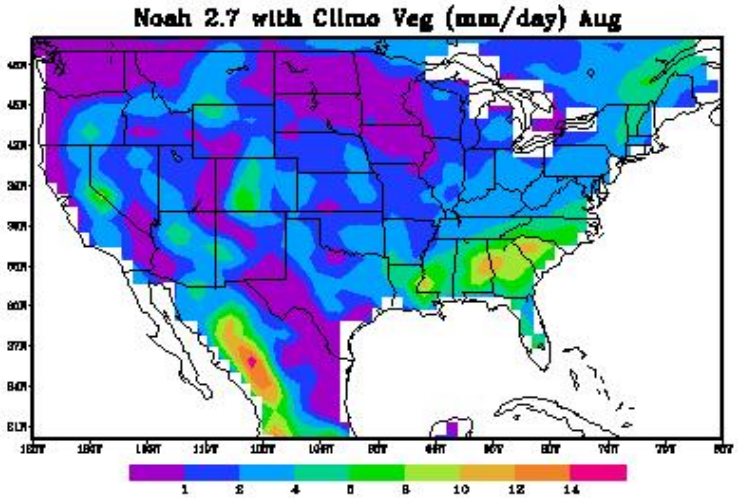
Obs

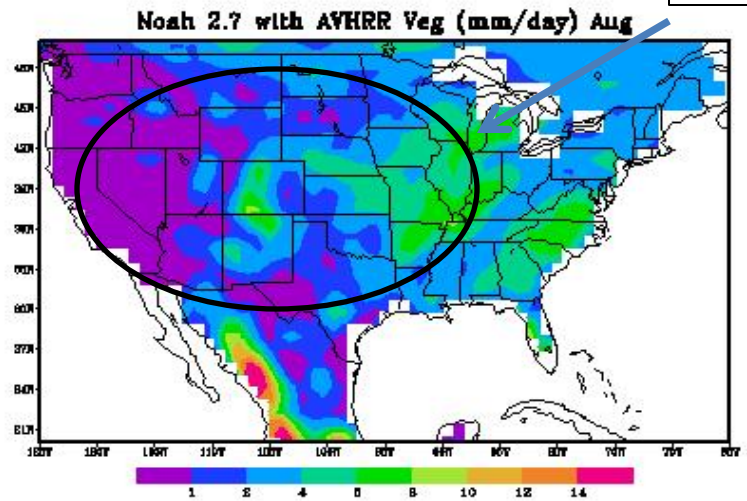
CFS with the AVHRR GVF seems to have more precip because of higher GVF

Predicted Precipitation for August 2012 Compared to Observation

Higher GVF

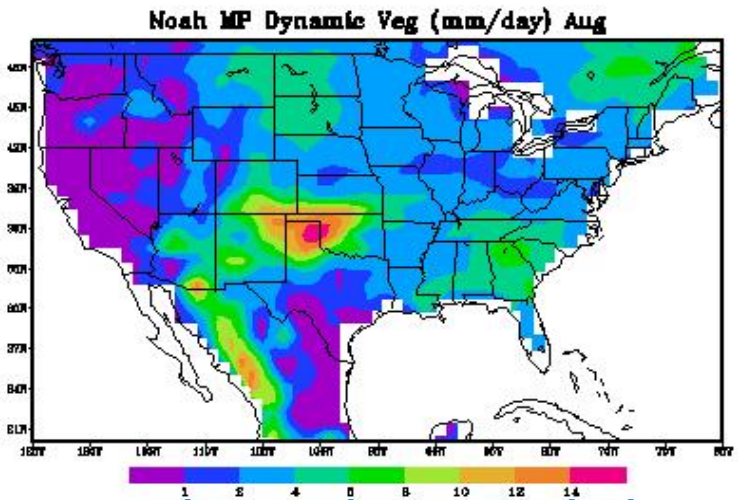
Climo GVF

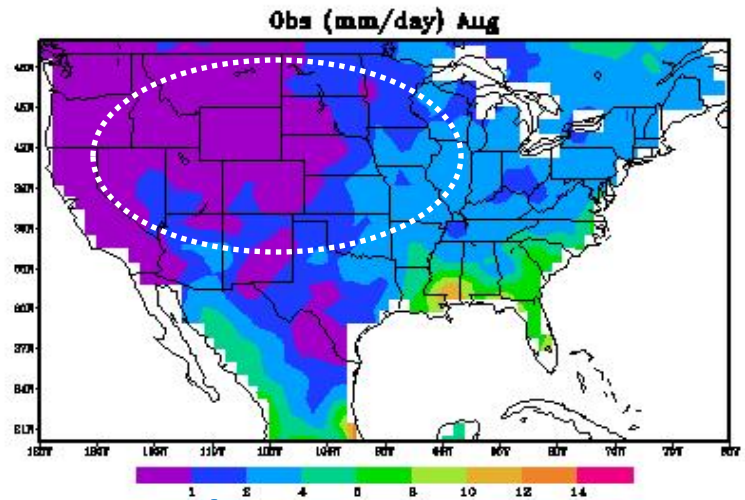




AVHRR GVF

Noah MP



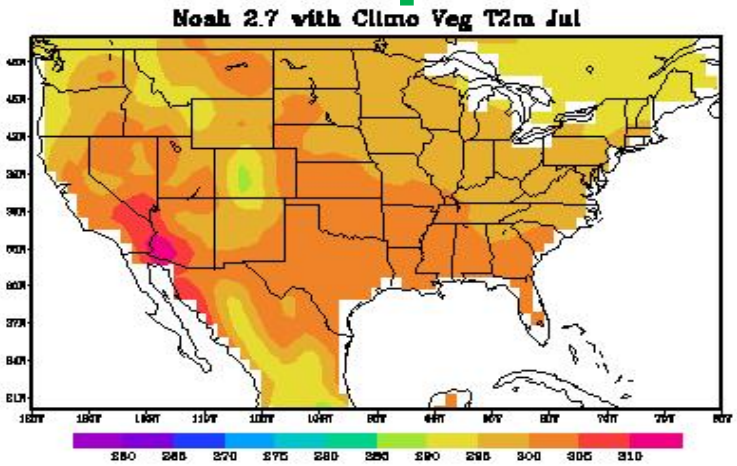


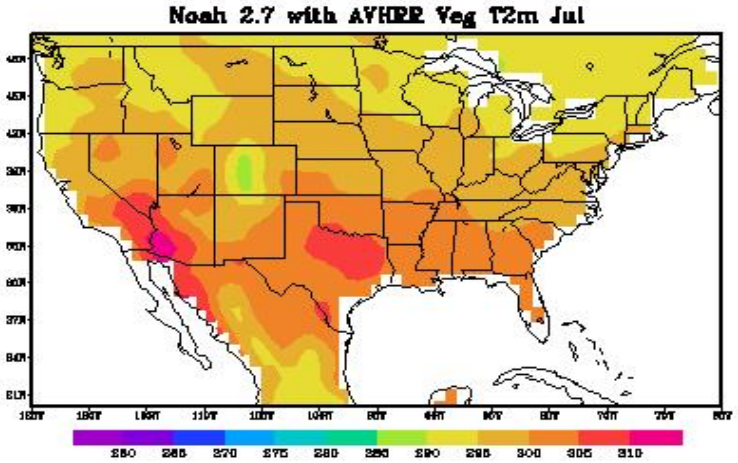
Obs

Like in July, CFS with the AVHRR GVF has more precip, but does well over the Northwest

Predicted T2m for July 2012 Compared to Observation

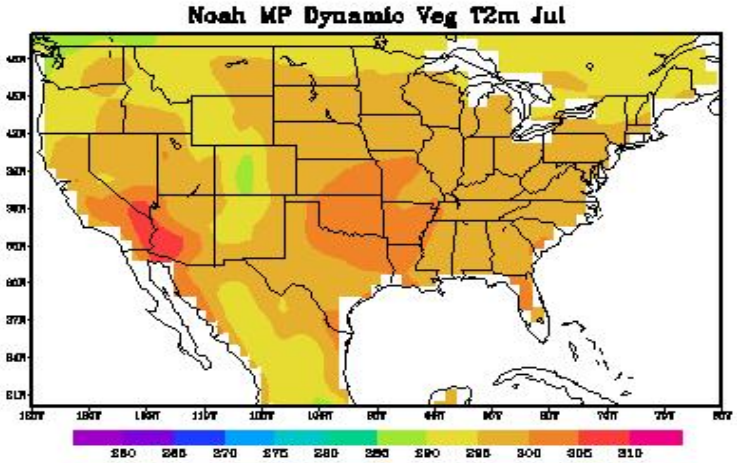
Climo GVF

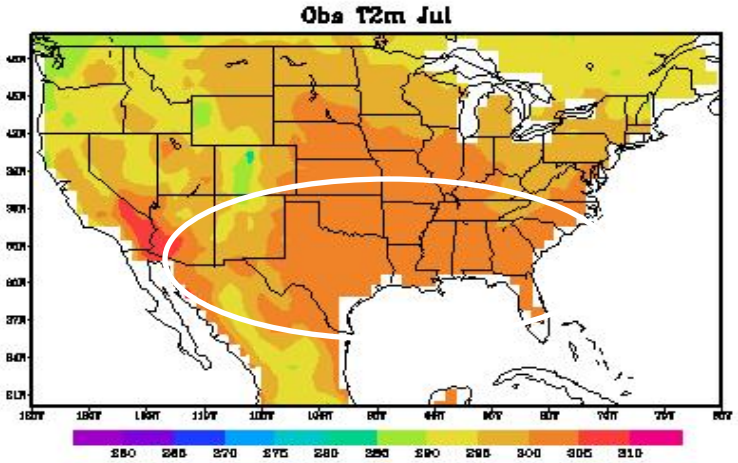




AVHRR GVF

Noah MP



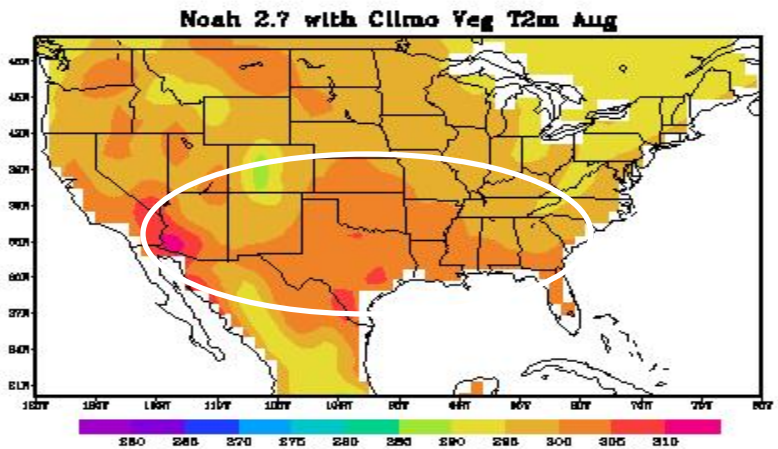


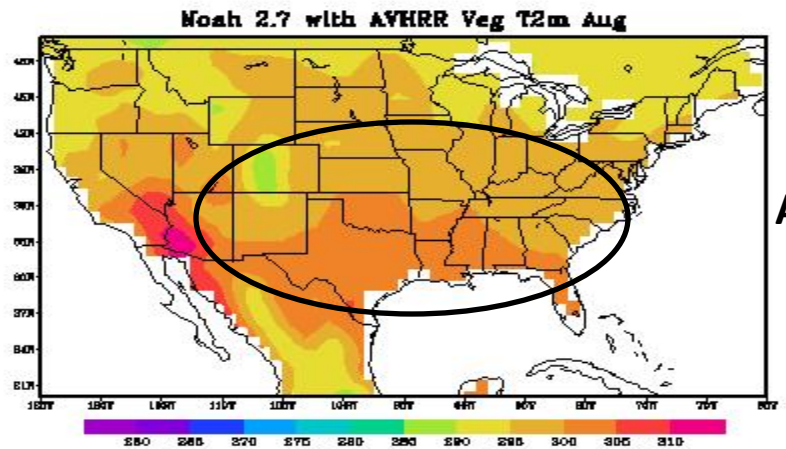
Obs

All have similar performance, CFS with the AVHRR GVF seems better, high Bias with Climo veg, low bias with Noah MP

Predicted T2m for August 2012 Compared to Observation

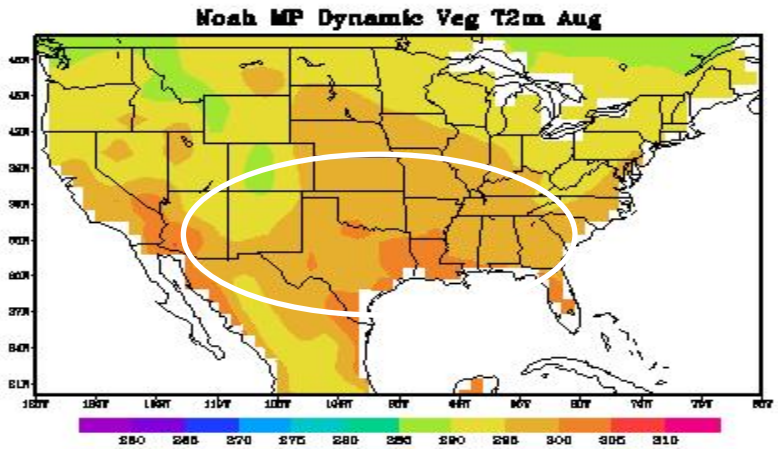
Climo GVF

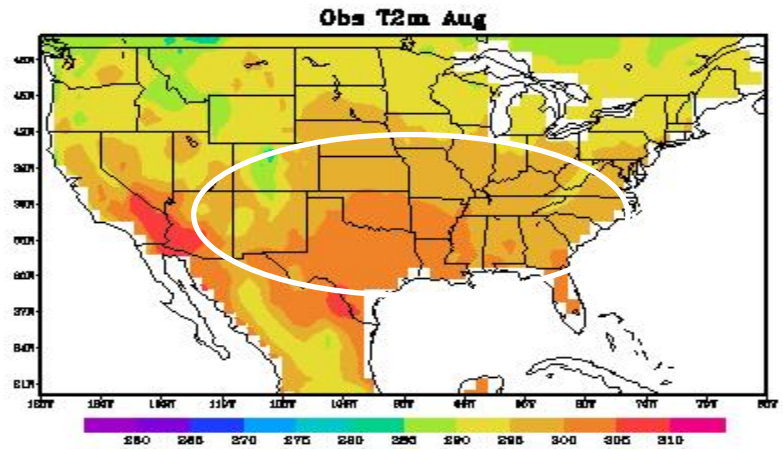




AVHRR GVF

Noah MP





Obs

All have similar performance, CFS with the AVHRR GVF seems better

Summary/Future Work

- Seasonal precip and T2m prediction using AVHRR GVF appears better. The CFS performance is sensitive to GVF treatment. Noah MP shows promising positive results.
- New ICes are needed (HRLDAS/GLDAS offline). The performance my be impacted owning to CFSRR ICes.
- More CFS testing with NOAH MP is needed.
- More years are needed (Stable Climo).
- Further analyses needed (soil moisture, GVF from Noah MP, evaporation etc.).

Thank you!

Questions?