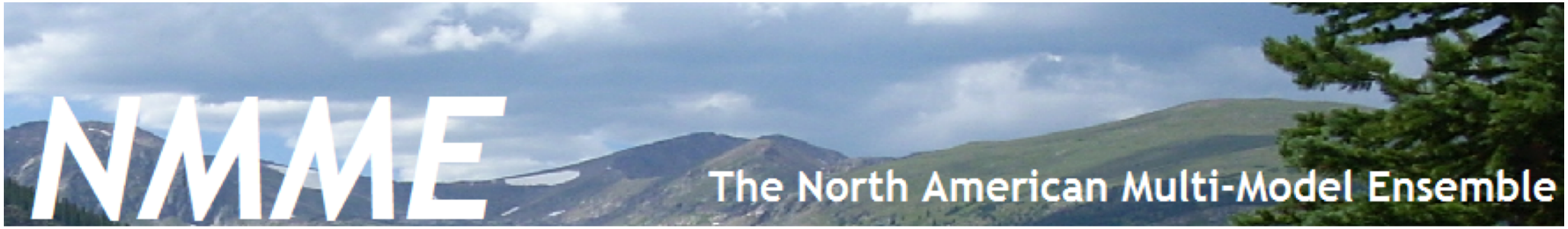

Precipitation and Temperature Forecast Skill in the NMME and SubX

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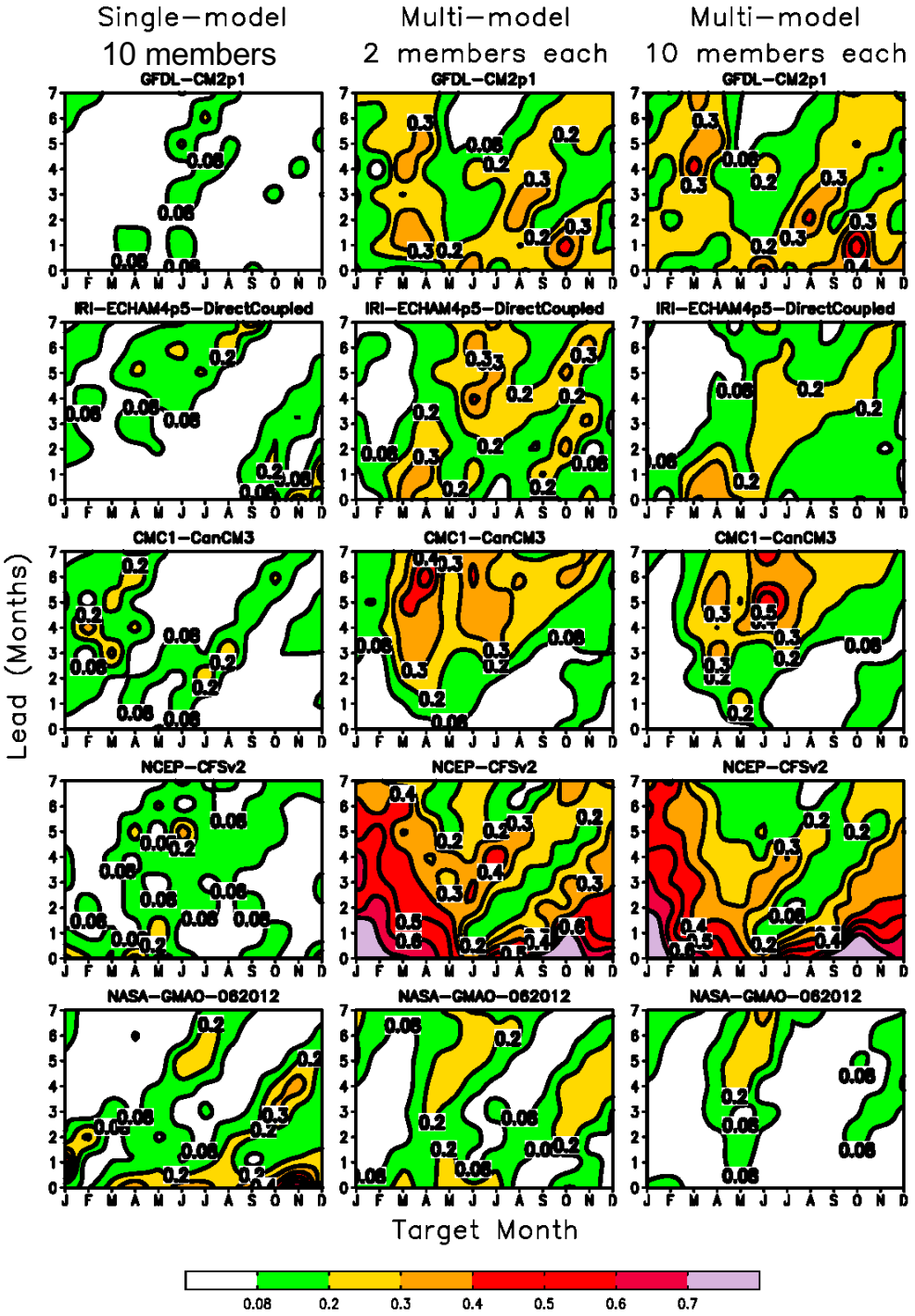
1. ESSIC/CISESS, University of Maryland, College Park
2. Climate Prediction Center/NCEP/NOAA
3. Innovim, LLC

What are NMME and SubX?

- NMME and SubX are **multi-model** forecasting systems running at CPC.
- NMME is a **seasonal** system consisting of 7 coupled climate models (hindcasts from 1981 to 2014; real-time forecasts from 2012), aimed at improving intraseasonal to interannual prediction capability.
- SubX is an experimental **subseasonal** system consisting of 7 coupled climate models (hindcasts from 1999 to 2014; real-time forecasts from 2017), aimed at improving subseasonal prediction capability.
- The multi-model ensemble approach has proven effective at quantifying prediction uncertainty due to uncertainty in model formulation, and has proven to produce better forecast quality (on average) than any single model ensemble.

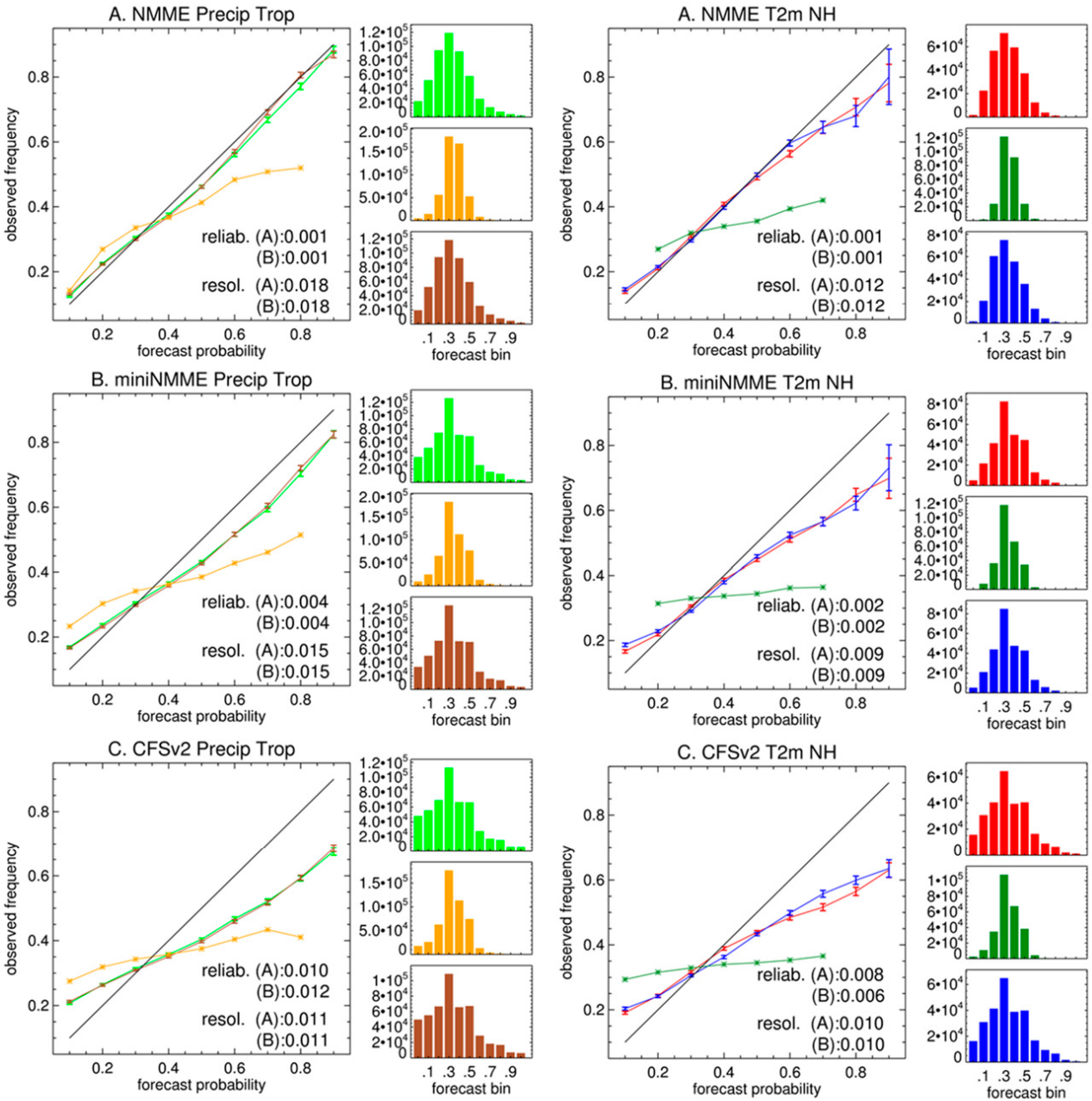


Why MME?

- Skill improvement in Nino3.4 forecasts.
- Left to middle columns: skill improvement by **model diversity**.
- Middle to right columns: skill improvement by increased ensemble size.
- 5-model ensemble.

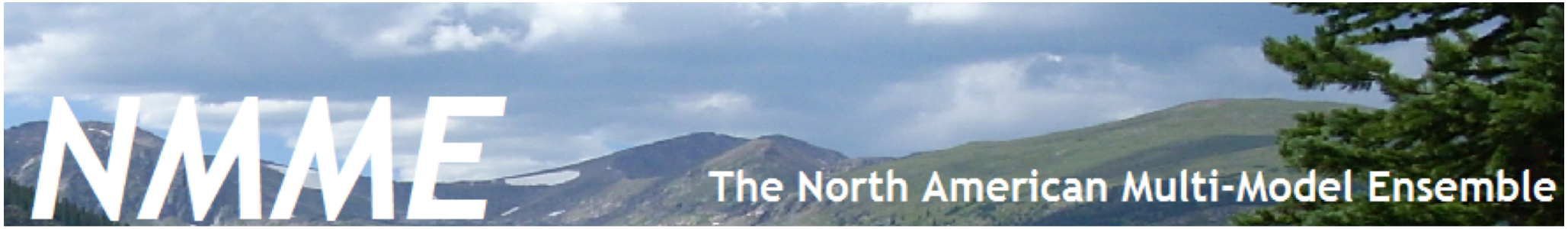
- DelSole, T., Nattala, J., and Tippett, M. K. (2014), Skill improvement from increased ensemble size and model diversity, *Geophys. Res. Lett.*, **41**, 7331– 7342.

Forecast Reliability



- Lead-1 seasonal probabilistic forecasts averaged from all ICs.
- CFSv2: 24 members.
- miniNMME: 24 members, 4 each from 6 models.
- NMME: 75 members.
- Better reliability with **large ensemble**.

- Becker, E. and H. van den Dool, 2016: Probabilistic Seasonal Forecasts in the North American Multimodel Ensemble: A Baseline Skill Assessment. *J. Climate*, **29**, 3015–3026.

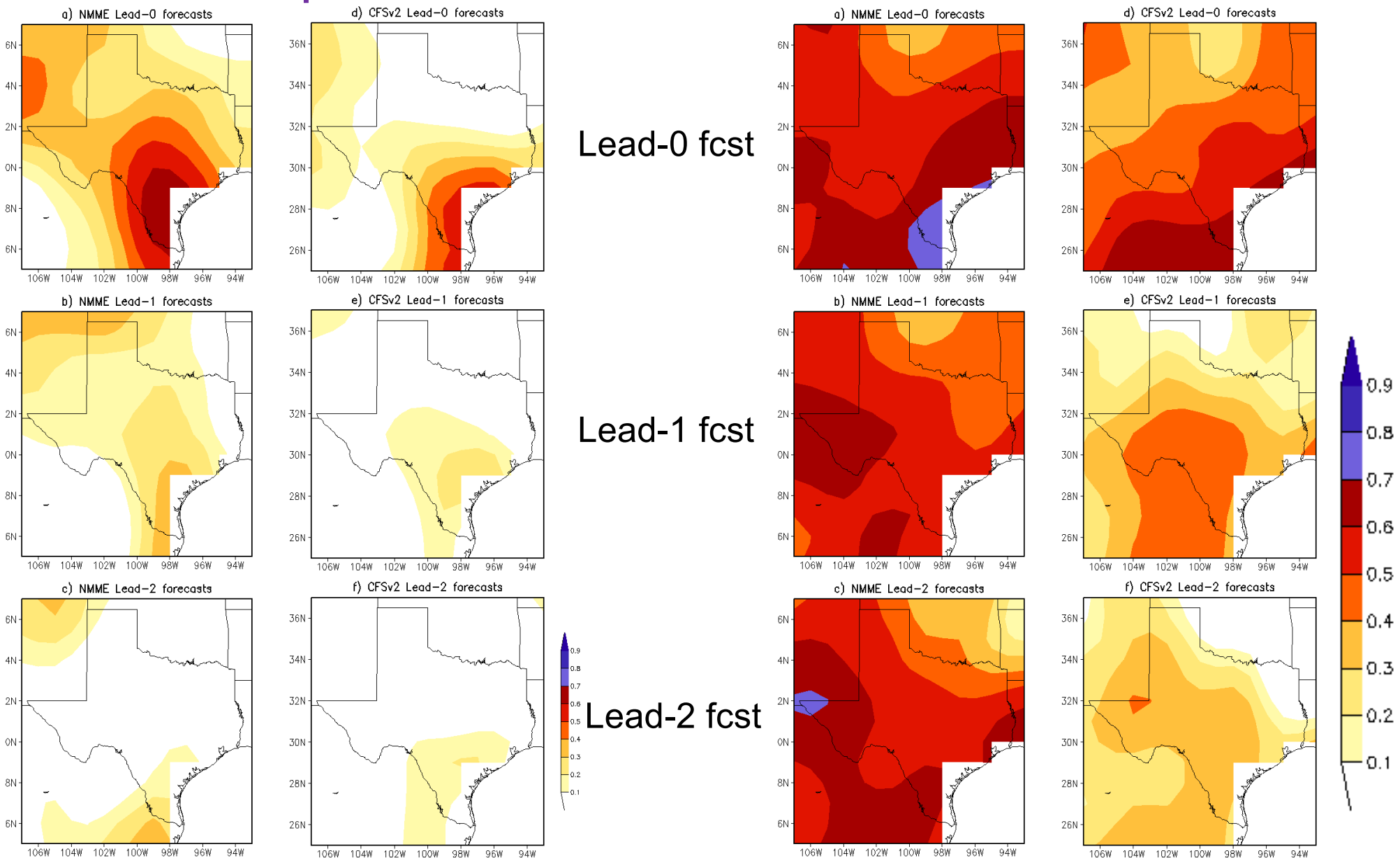


NMME Phase-2 Forecast Providers

Model	Hindcast Period	No. of Member	Arrangement of Members	Lead (months)	Model Resolution: Atmosphere	Model Resolution: Ocean	Reference
NCEP-**CFSv2**	1982-2010	24	4 members (0,6,12,18Z) every 5th day	0-9	T126L64	MOM4 L40 0.25 deg Eq	Saha et al. (2014)
GFDL-**CM2.1**	1982-2010	10	All 1st of the month 0Z	0-11	2x2.5deg L24	MOM4 L50 0.30 deg Eq	Zhang et al. (2007)
GFDL-**FLOR**	1982-2014	24	All 1st of the month 0Z	0-11	0.5x0.5deg L24	MOM4 L50 0.30 deg Eq	Vecchi et al. (2014)
ECCC-**CanCM3**	1981-2010	10	All 1st of the month 0Z	0-11	CanAM3 T63L31	CanOM4 L40 0.94 deg Eq	Merryfield et al. (2013)
ECCC-**CanCM4**	1981-2010	10	All 1st of the month 0Z	0-11	CanAM4 T63L35	CanOM4 L40 0.94 deg Eq	Merryfield et al. (2013)
NCAR-**CCSM4**	1982-2014	10	All 1st of the month	0-11	0.9x1.25deg L26	POP L60 0.3 deg Eq	Gent et al. (2011)
NASA-**GEOS5**	1981-2010	11	4 members every 5th days; 7 members on the last day of the previous month	0-9	1x1.25deg L72	MOM4 L40 1/4 deg at Eq	Rienecker et al. (2008)

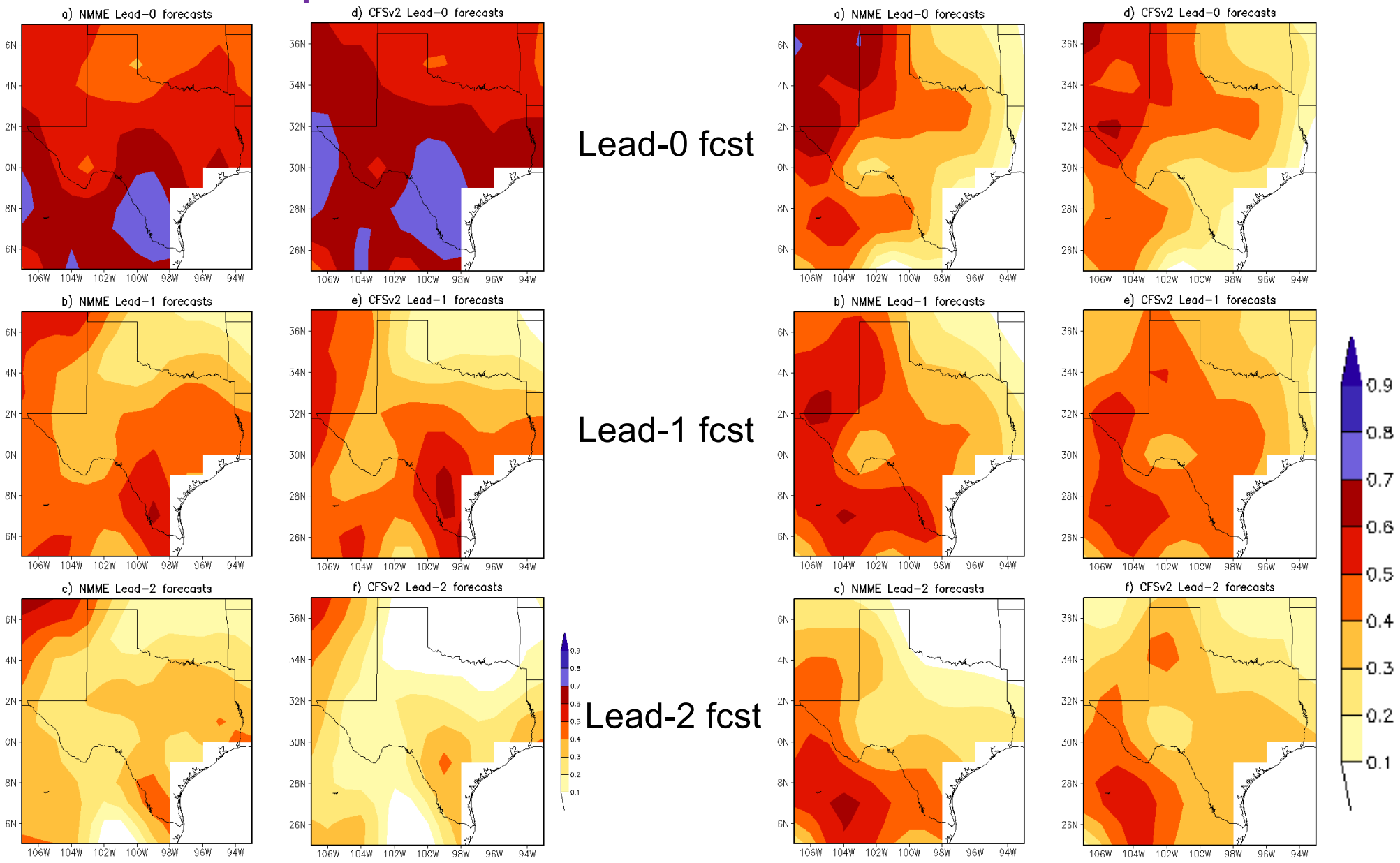
ACC for Seasonal P Forecasts

NMME **IC: April 1** **CFSv2** **NMME** **IC: October 1** **CFSv2**



ACC for Seasonal T Forecasts

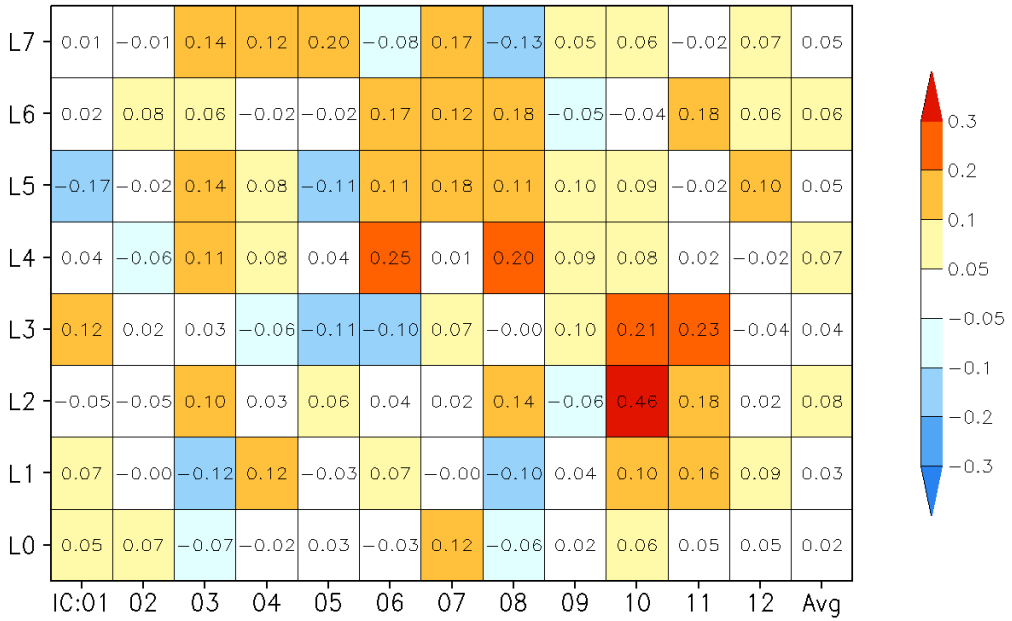
NMME **IC: April 1** **CFSv2** **NMME** **IC: October 1** **CFSv2**



ACC for Monthly P Forecasts

- Averaged over TX/OK.
- Last column is the average of 12 IC months.

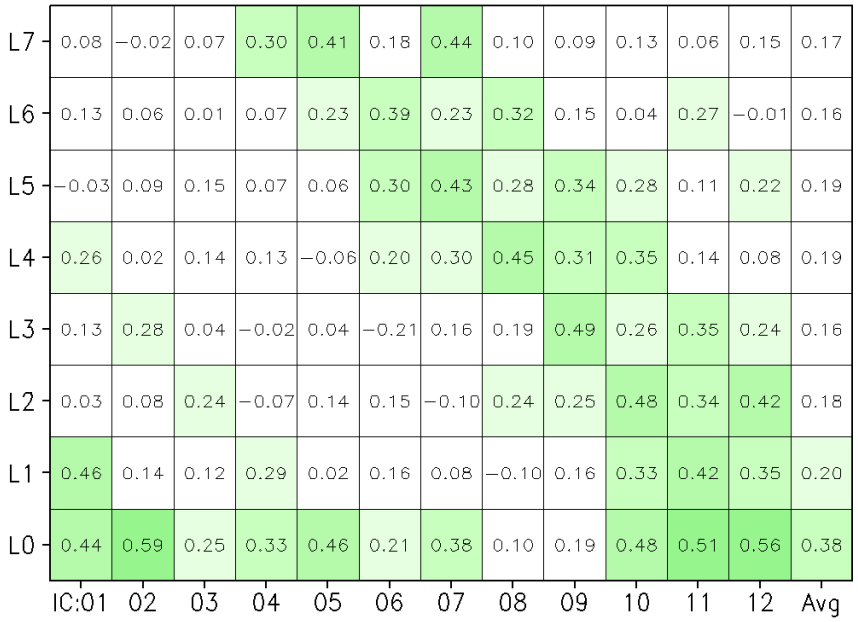
a) NMME−CFSv2



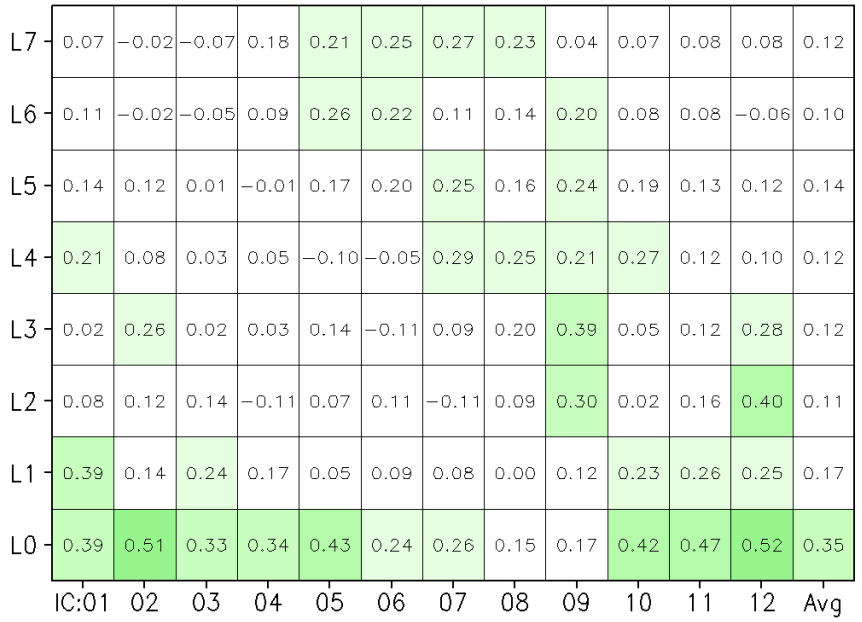
NMME is better

CFSv2 is better

b) NMME



c) CFSv2

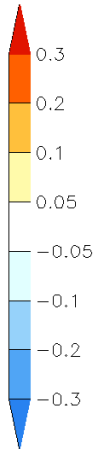


ACC for Monthly T Forecasts

- Averaged over TX/OK.
- Last column is the average of 12 IC months.

a) NMME−CFSv2

	IC:01	02	03	04	05	06	07	08	09	10	11	12	Avg
L7	−0.01	0.08	0.11	0.25	0.04	0.10	−0.02	0.16	0.14	0.17	0.06	−0.02	0.09
L6	0.04	0.18	−0.03	0.09	0.04	0.15	0.12	0.00	0.06	0.02	0.17	0.12	0.08
L5	−0.03	−0.01	0.13	0.23	0.02	0.31	−0.00	0.14	0.02	0.03	−0.05	0.06	0.07
L4	−0.03	0.07	0.00	0.21	−0.06	0.02	0.02	0.17	0.04	0.03	−0.01	0.02	0.04
L3	−0.11	0.02	0.09	0.14	−0.07	0.11	0.06	0.22	0.09	0.09	−0.05	0.03	0.05
L2	0.03	−0.01	−0.06	0.04	−0.01	0.04	0.09	0.09	0.10	0.04	0.11	−0.06	0.03
L1	0.00	−0.04	−0.08	−0.00	−0.05	0.02	0.09	−0.09	0.07	0.09	−0.01	0.16	0.01
L0	−0.03	−0.04	−0.12	−0.12	0.07	−0.05	0.10	−0.01	0.12	0.11	−0.05	−0.06	−0.01



NMME is better

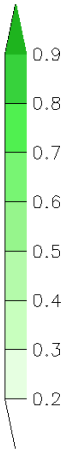
CFSv2 is better

b) NMME

	IC:01	02	03	04	05	06	07	08	09	10	11	12	Avg
L7	0.21	0.14	0.21	0.31	0.22	0.23	0.24	0.41	0.47	0.39	0.42	0.17	0.28
L6	0.08	0.21	0.04	0.13	0.48	0.17	0.22	0.19	0.38	0.50	0.50	0.36	0.27
L5	0.30	0.08	0.31	0.24	0.22	0.40	0.22	0.25	0.26	0.33	0.48	0.50	0.30
L4	0.53	0.37	0.15	0.29	0.05	0.27	0.46	0.29	0.21	0.23	0.43	0.49	0.31
L3	0.47	0.56	0.34	0.10	0.25	0.10	0.23	0.40	0.19	0.26	0.18	0.39	0.29
L2	0.34	0.46	0.48	0.31	0.09	0.18	0.06	0.20	0.44	0.15	0.24	0.20	0.26
L1	0.38	0.35	0.39	0.49	0.31	0.16	0.22	0.07	0.23	0.39	0.17	0.32	0.29
L0	0.60	0.54	0.45	0.58	0.69	0.50	0.44	0.33	0.47	0.27	0.59	0.37	0.49

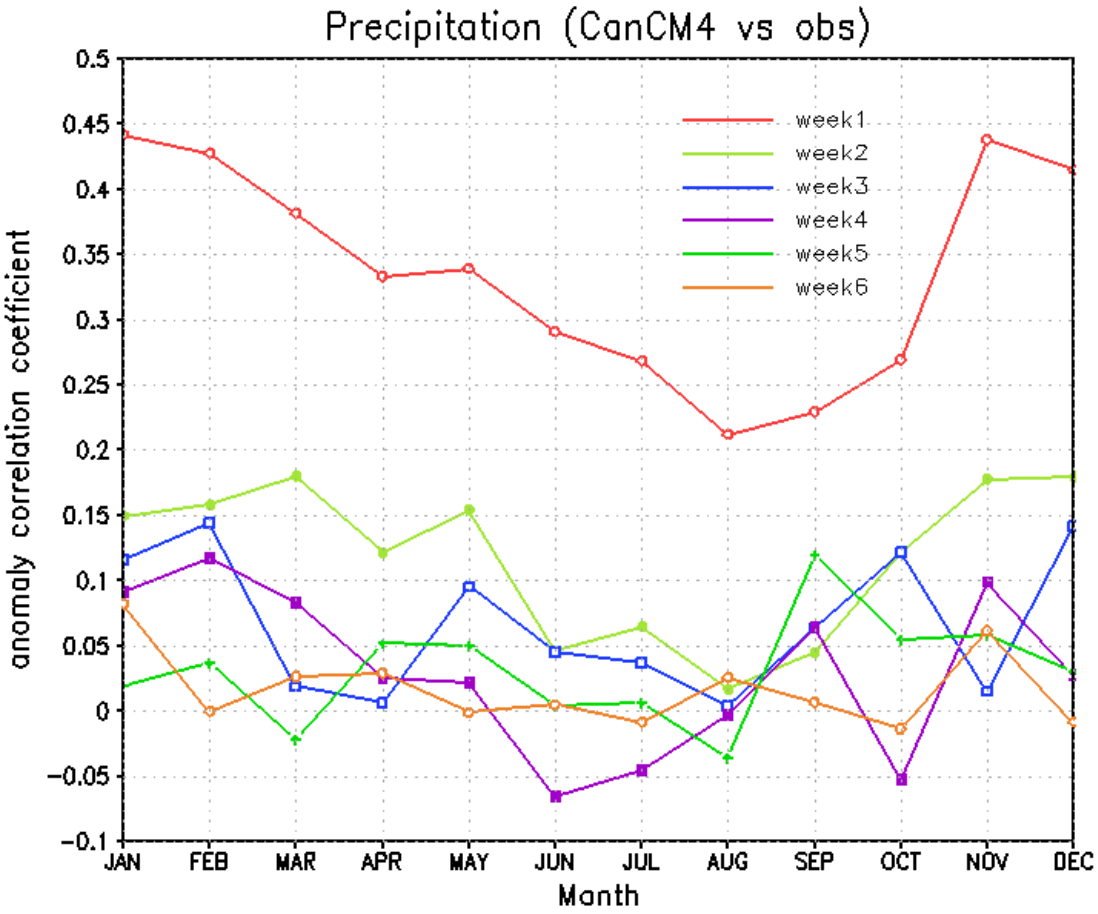
c) CFSv2

	IC:01	02	03	04	05	06	07	08	09	10	11	12	Avg
L7	0.22	0.06	0.10	0.07	0.17	0.13	0.25	0.25	0.33	0.23	0.35	0.19	0.20
L6	0.05	0.03	0.08	0.04	0.44	0.03	0.10	0.19	0.32	0.48	0.33	0.24	0.19
L5	0.33	0.10	0.18	0.01	0.20	0.10	0.22	0.11	0.24	0.31	0.53	0.44	0.23
L4	0.56	0.30	0.15	0.08	0.10	0.25	0.43	0.12	0.18	0.20	0.44	0.47	0.27
L3	0.58	0.54	0.25	−0.04	0.32	−0.01	0.17	0.19	0.10	0.17	0.22	0.36	0.24
L2	0.31	0.47	0.54	0.27	0.09	0.14	−0.03	0.11	0.34	0.12	0.13	0.26	0.23
L1	0.38	0.39	0.47	0.49	0.36	0.14	0.13	0.16	0.16	0.31	0.19	0.16	0.28
L0	0.62	0.58	0.57	0.71	0.63	0.54	0.34	0.34	0.35	0.17	0.64	0.43	0.49



Week 1-6 P Forecast Skill

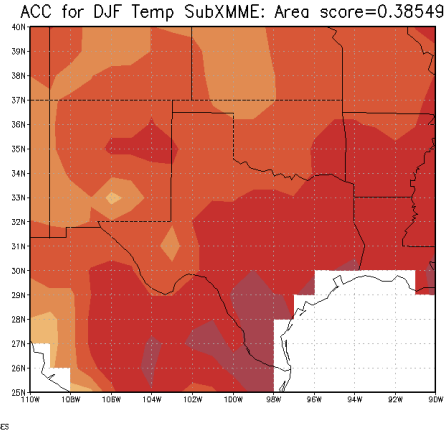
- Based on CanCM4 daily P hindcasts from 1982 to 2010.
- Averaged over CONUS.
- Skill quickly drops after the 1st week and decreases with lead week.
- Week 1-2 P forecasts are more skillful.



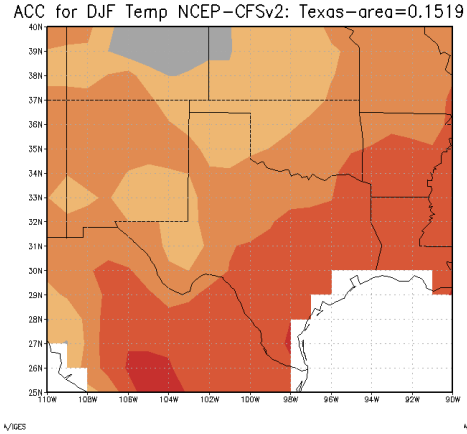
Week of Hindcast Dates and Target Dates	Jan 2	Jan 3	Jan 4	Jan 5	Jan 6	Jan 7	Jan 8	**Jan 9** Forecast Day	**Week 3-4 Outlook: Jan 24 – Feb 06**
Day of the week and Days to Target Dates	Fri 22:35	Sat 21:34	Sun 20:33	Mon 19:32	Tues 18:31	Wed 17:30	Thurs 16:29	**Fri 15:28**	**2 weeks: Sat + 13 days (Fri) → WK34**
Center-Model	---------- **Forecast Grab Period** ----------								
ECCC-GEM 4 members 32 days								Forecast Day	
EMC-GEFS 11 members 35 days								Forecast Day	
ESRL-FIMv2 4 members 32 days								Forecast Day	
NASA-GEOS 4 members 45 days								Forecast Day	
NCEP-CFSv2 4 members 44 days								Forecast Day	
NRL-NESM 4 lagged members 45 days								Forecast Day	
RSMAS-CCSM4 3 members 45 days								Forecast Day	
Coming Soon: CESM-46LCAM5 10 members 45 days								Forecast Day	***Note: Each week the wk34 reforecast is scored and those scores are collected over a selected period**
CESM-30LCAM5 10 members 45 days								Forecast Day	

ACC for Week 3-4 T Forecasts (DJF)

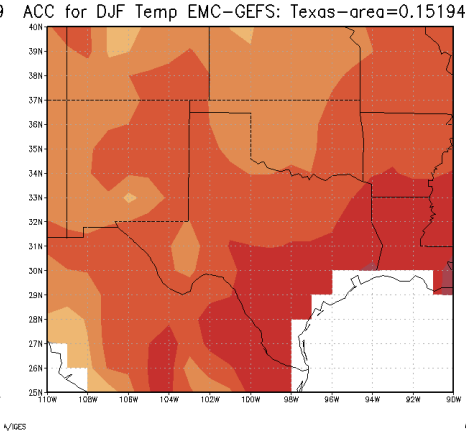
MME



CFSv2



GEFS



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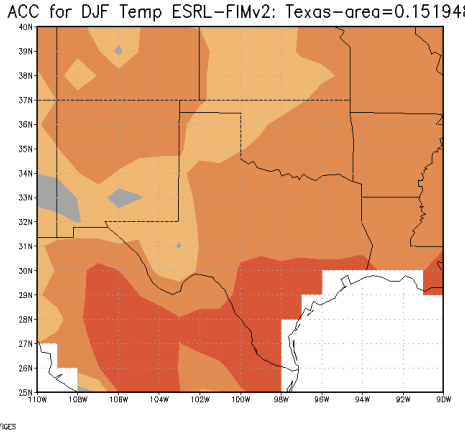
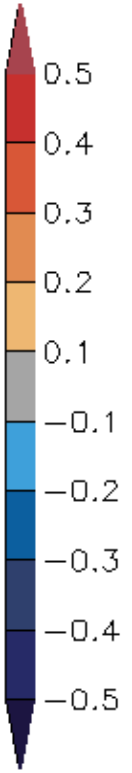
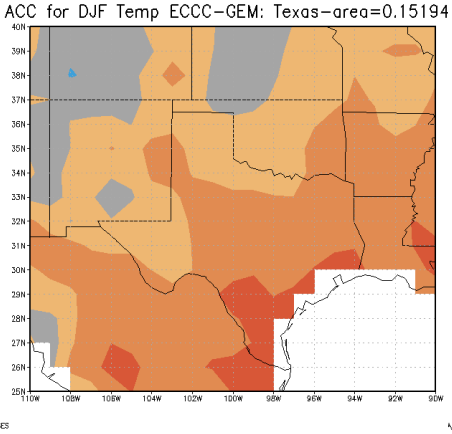
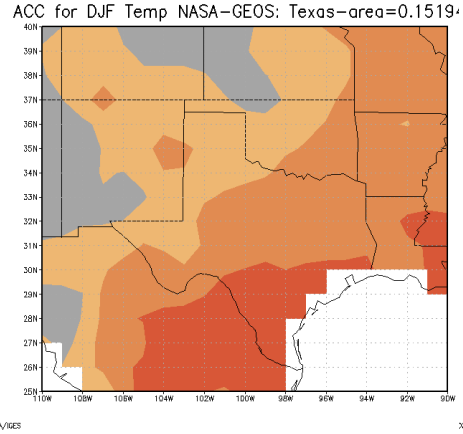




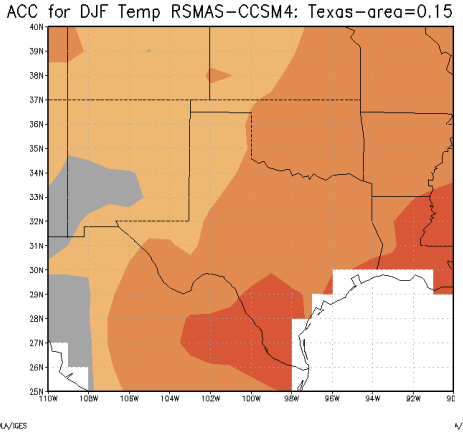
GEM



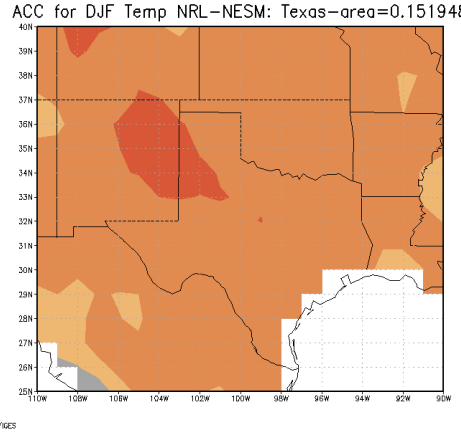
GEOS



CCSM4

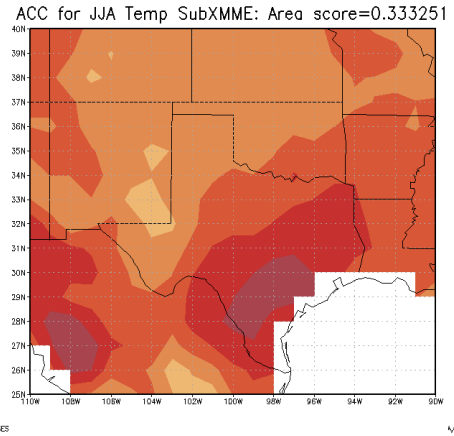


NESM

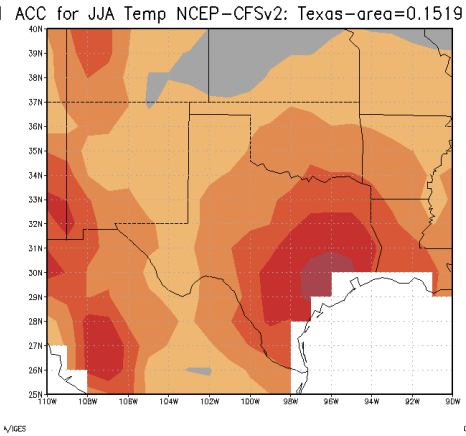


ACC for Week 3-4 T Forecasts (JJA)

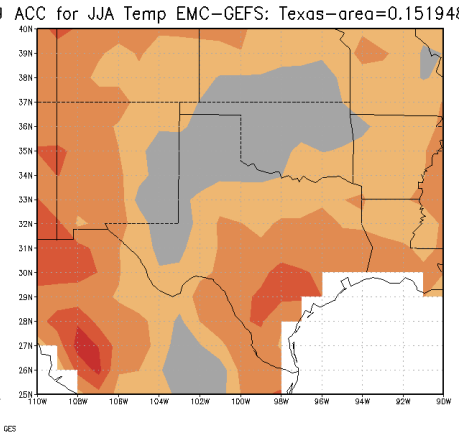
MME



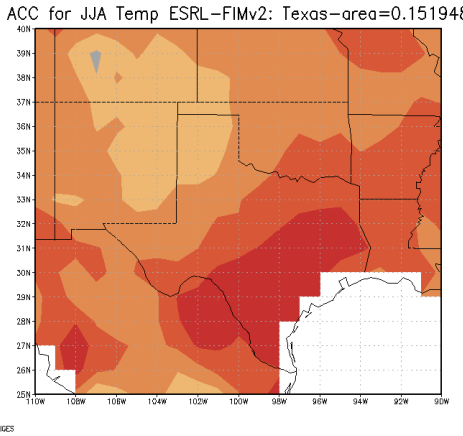
CFSv2



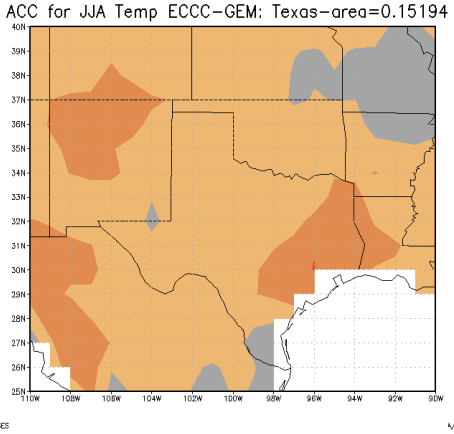
GEFS



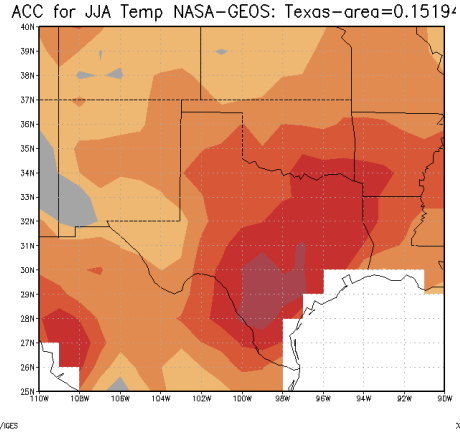
FIM



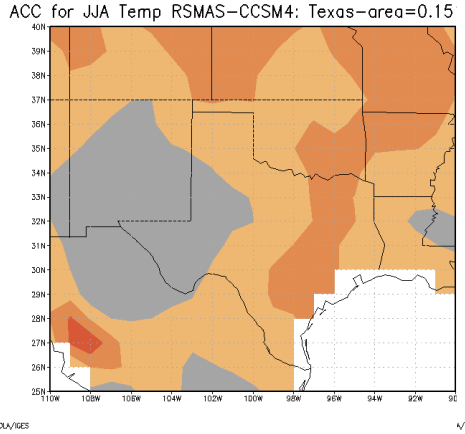
GEM



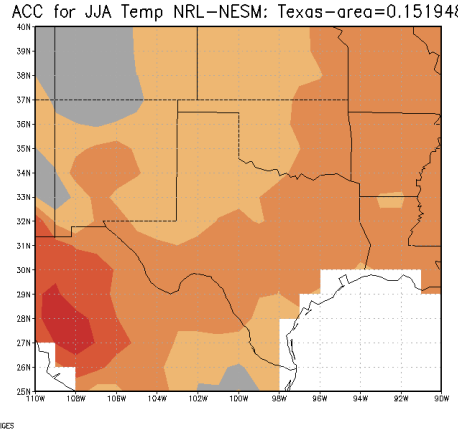
GEOS

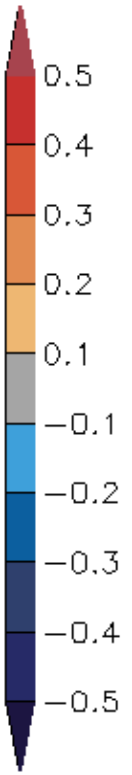


CCSM4



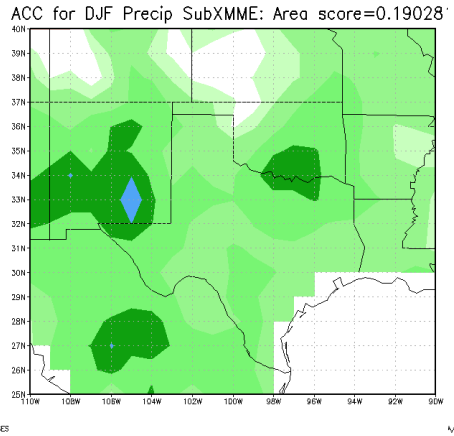
NESM



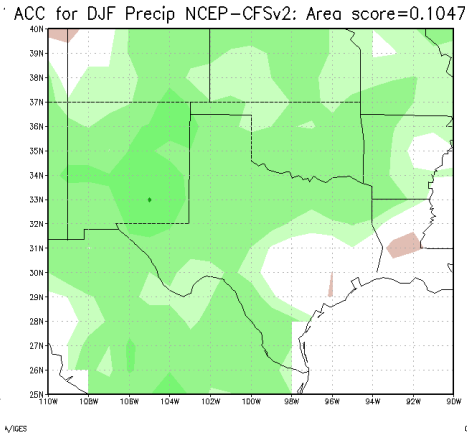


ACC for Week 3-4 P Forecasts (DJF)

MME



CFSv2



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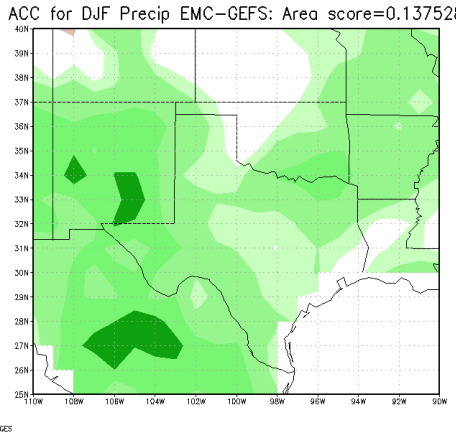

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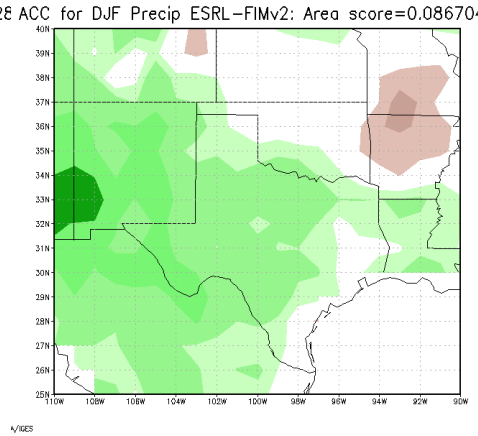
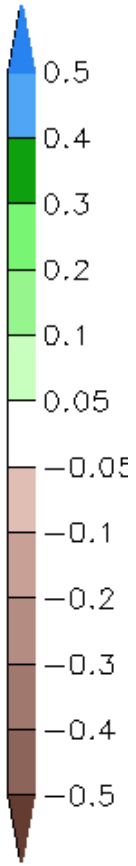
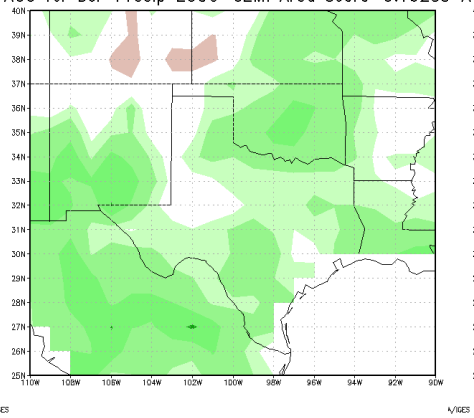
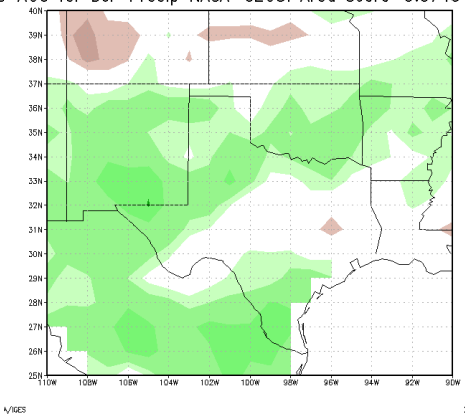




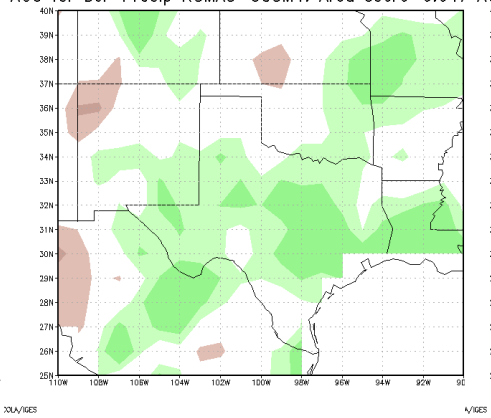
GEM



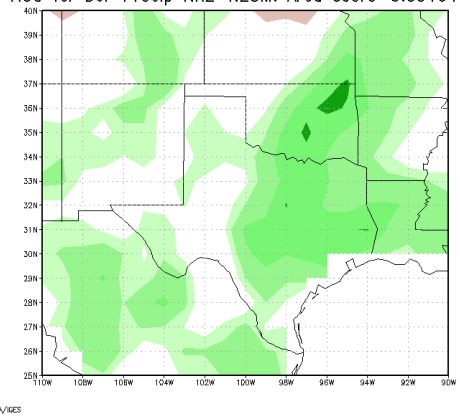
GEOS



CCSM4

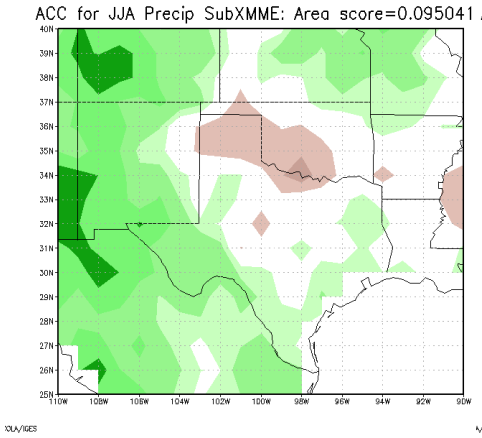


NESM

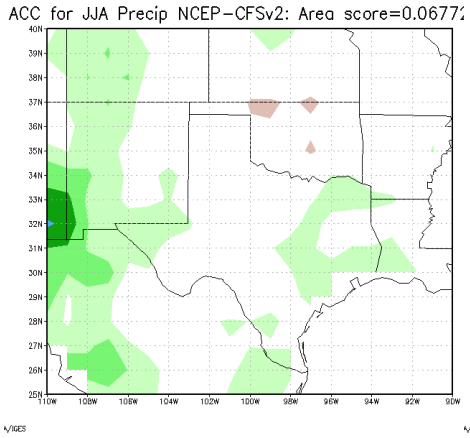


ACC for Week 3-4 P Forecasts (JJA)

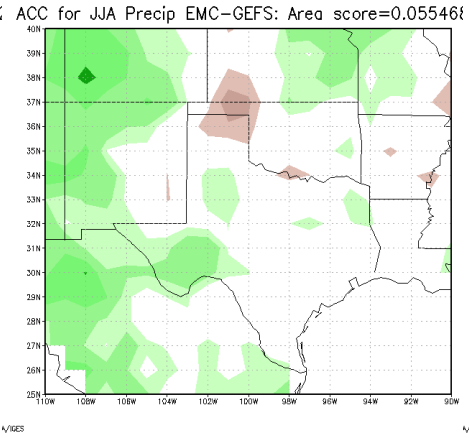
MME



CFSv2



GEFS



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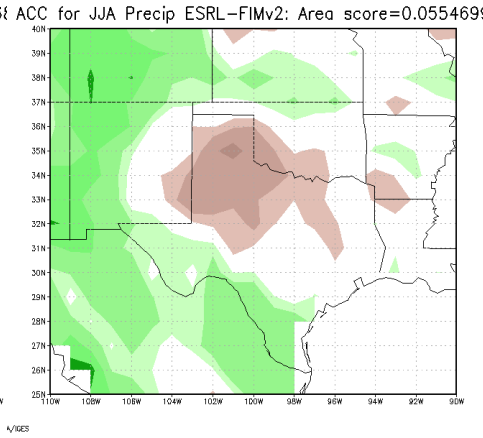
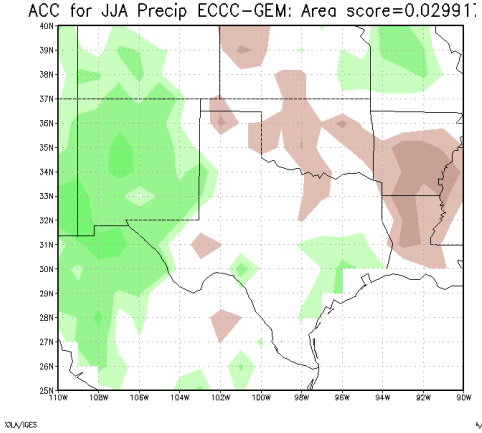
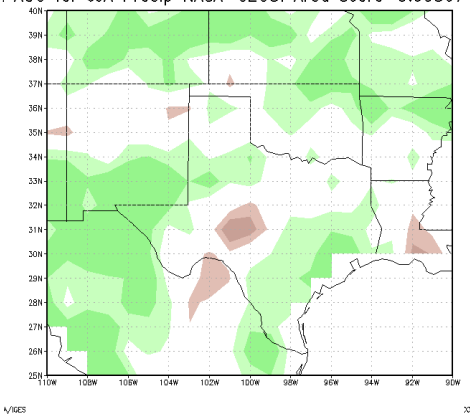


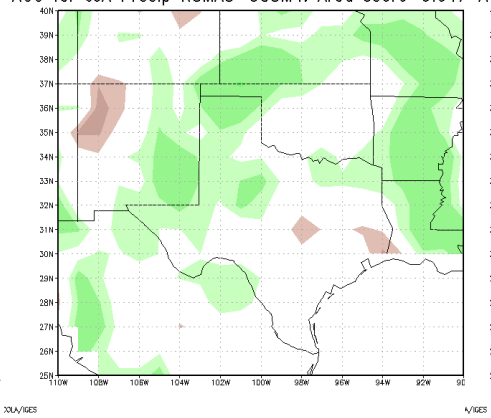
GEM



GEOS



CCSM4



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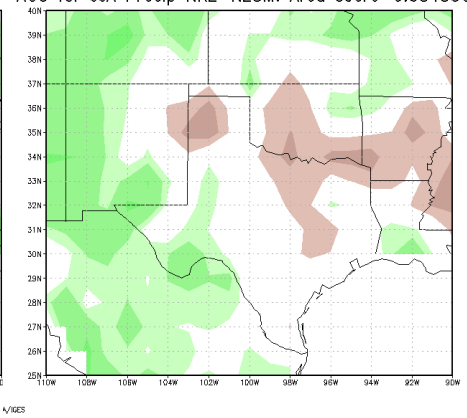
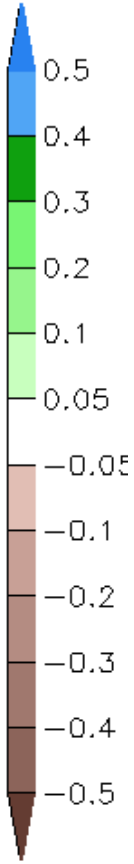
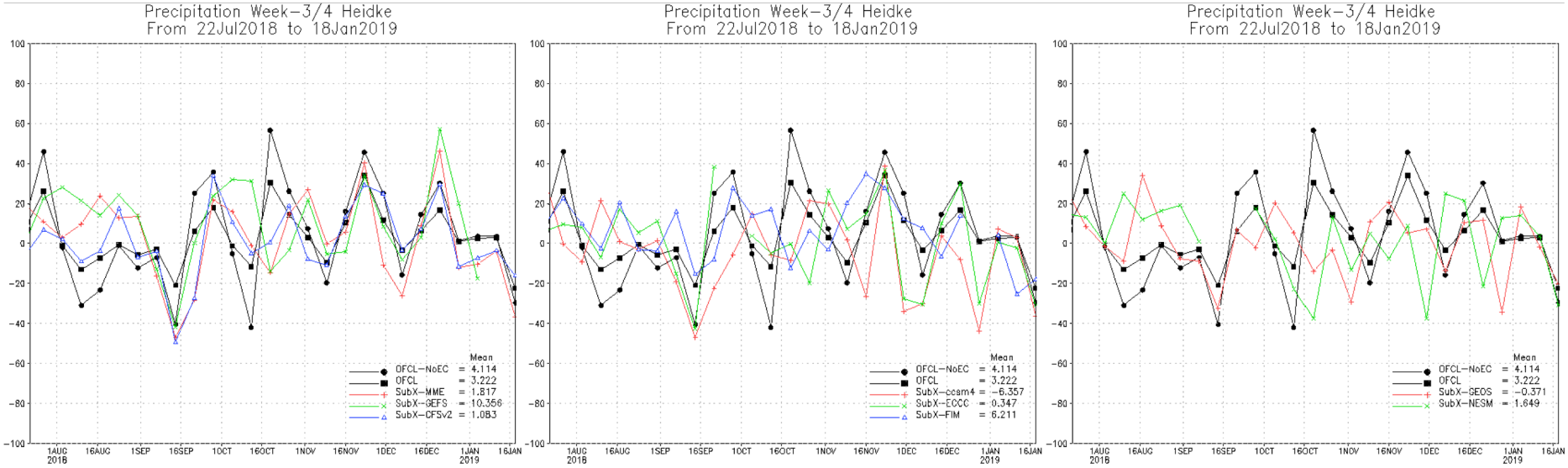
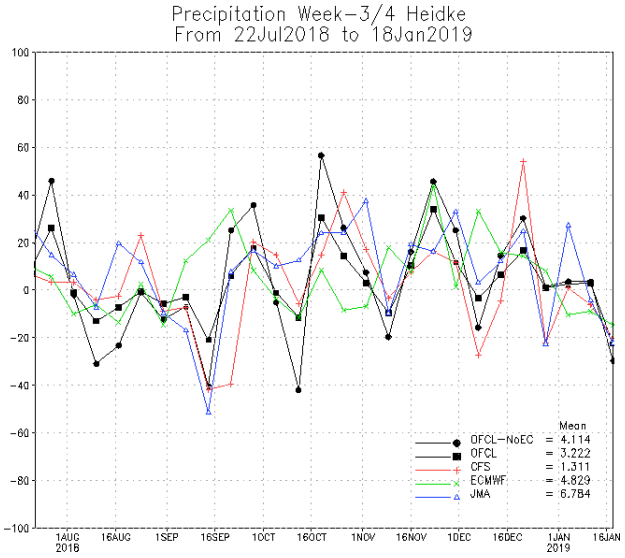
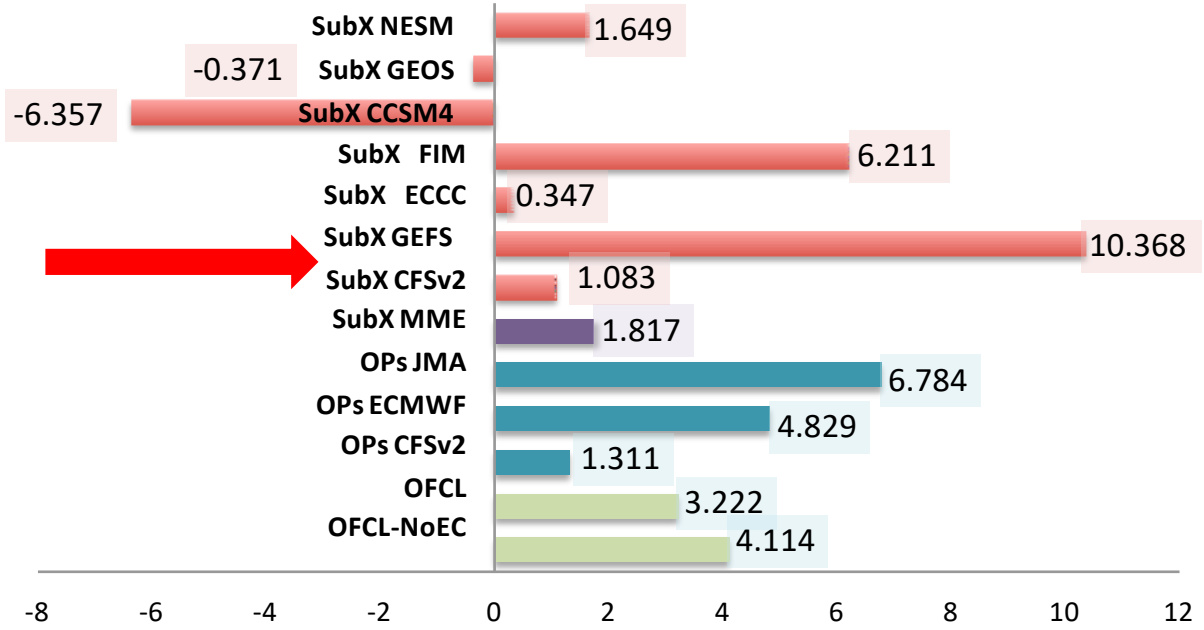




SubX and Operational Models Week 3-4 P Forecasts Heidke Skill Scores over CONUS: 22/7/18 to 18/1/19

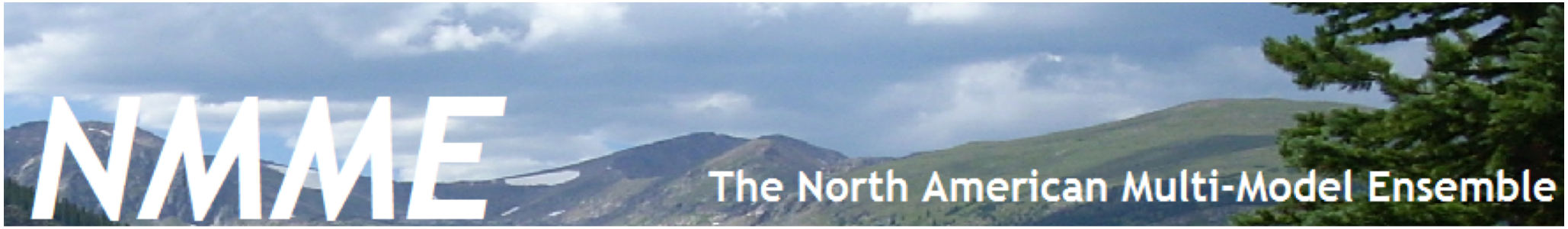






Summary

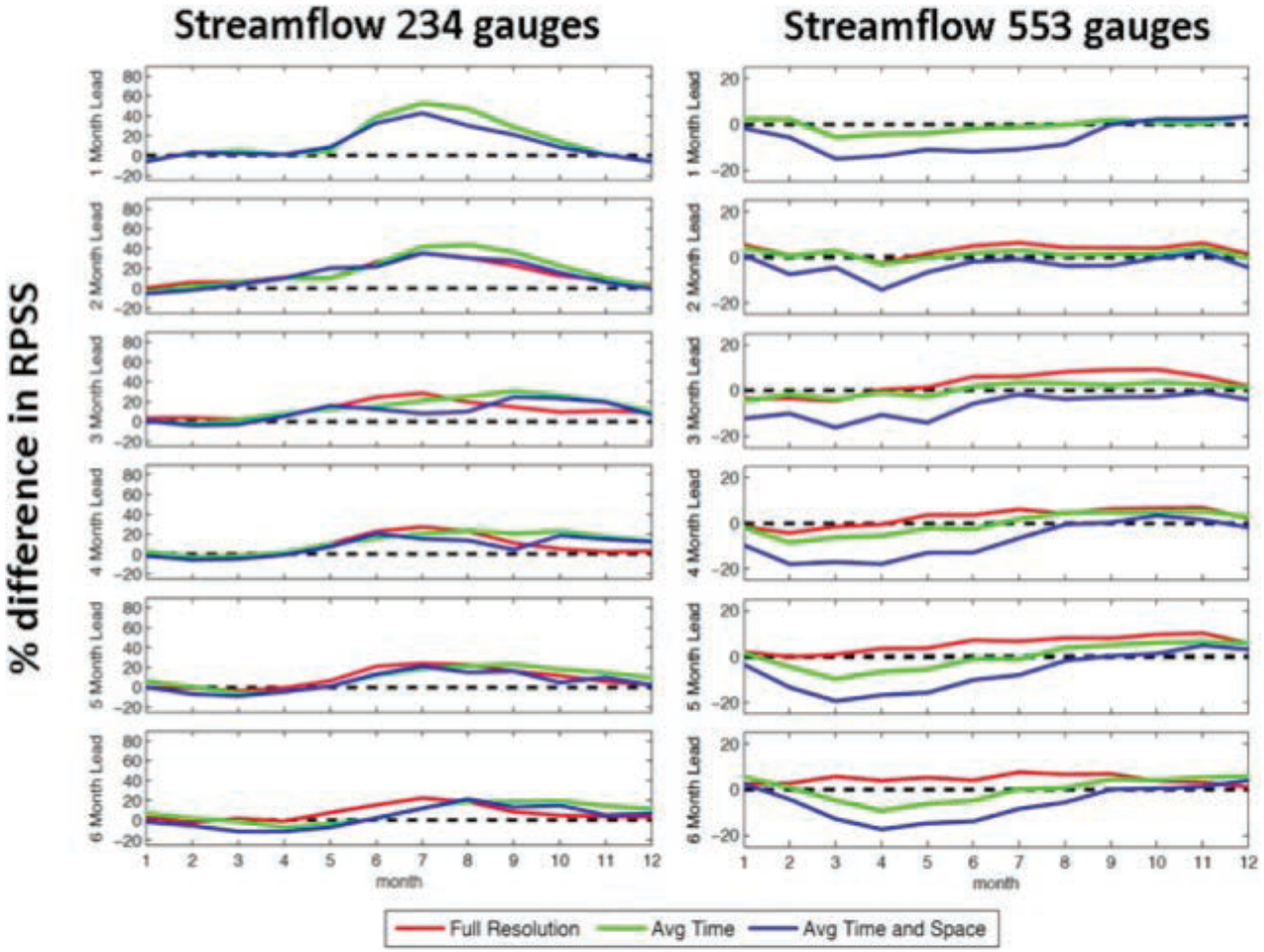
- Multi-model ensemble has an advantage over single model forecasts, but more resources are required.
- Most skill improvement in MME comes from model diversity, while probabilistic forecasts also benefits from large ensemble.
- Skill improvement from NMME over CFSv2 depends on forecast start and lead time, location, and variable.
- In TX/OK, NMME generally improves P forecast skill in wintertime and T forecast skill at longer leads from CFSv2.
- P and T forecast skill varies among models. Choosing models wisely when resources are limited.
- For subseasonal prediction, Week 1-2 P forecasts are more skillful.
- At subseasonal timescales, GEFS generally has higher skill in P forecasts than CFSv2 over the CONUS.



Thank you and questions

Email: lichuan.chen@noaa.gov

Streamflow Forecasts

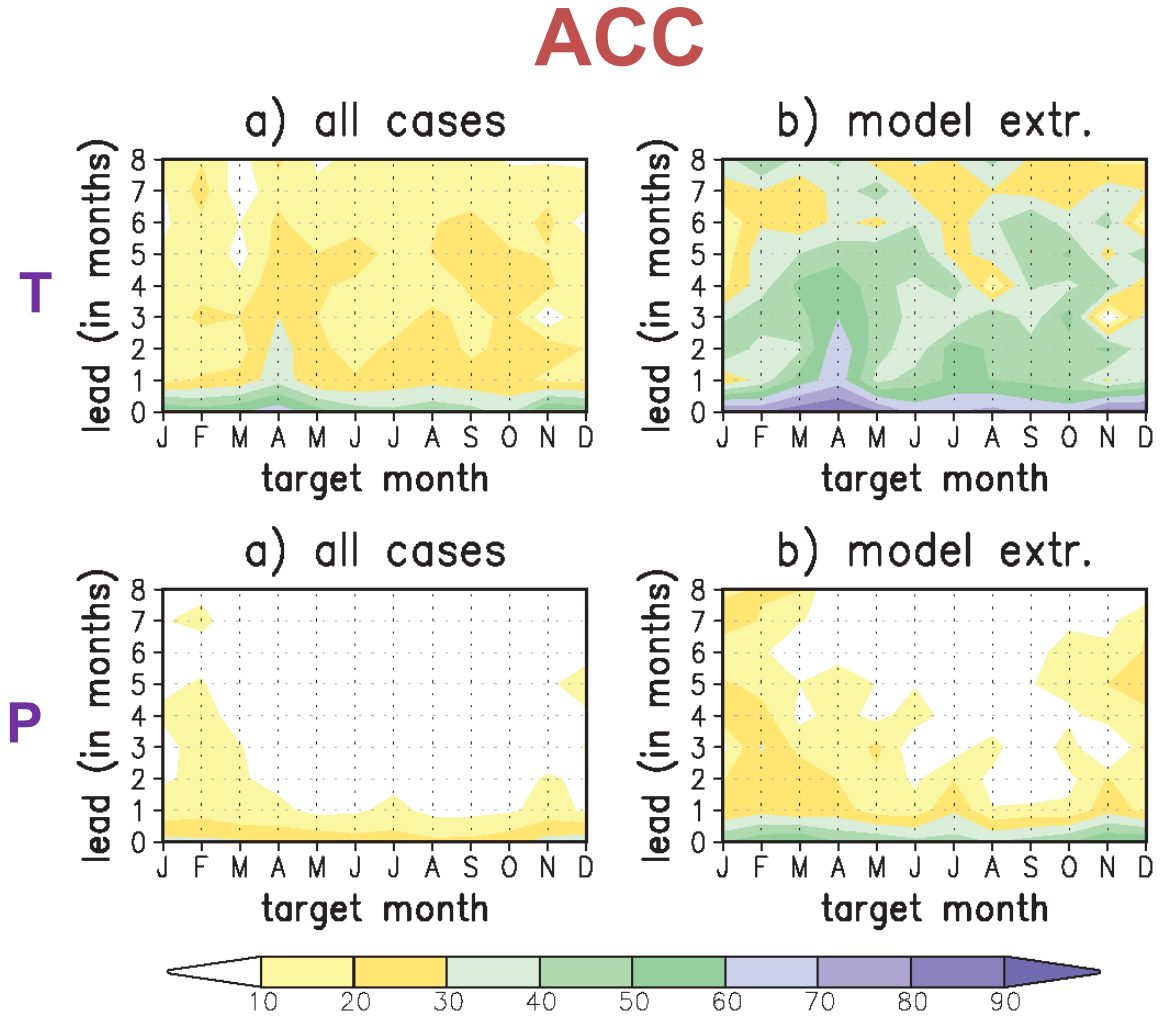


- Skill differences > 0 indicates NMME forecasts are better than ESP.
- Left: in CO.
- Right: in Southeast.

Red: 1/8° resolution; Green: fcst averaged over lead time; Blue: fcst averaged over lead time and domain.

- Kirtman, B.P., and coauthors, 2014: The North American Multimodel Ensemble: Phase-1 Seasonal-to-Interannual Prediction; Phase-2 toward Developing Intraseasonal Prediction. *Bull. Amer. Meteor. Soc.*, **95**, 585–601.

Short-Term Climate Extremes

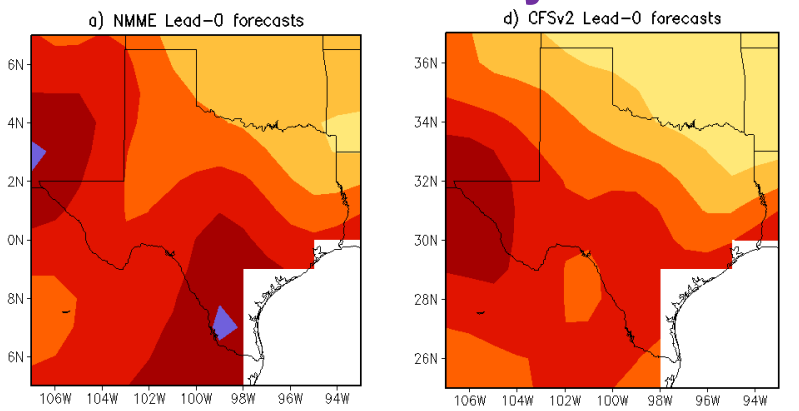


- CFSv2 monthly forecasts over North America.
- Extremes are defined as ±1.645 local standard deviation.
- Better forecast skill in predicting extremes.

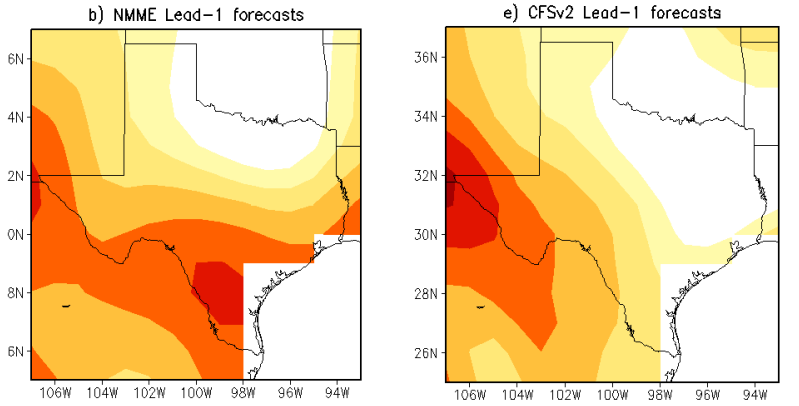
- Becker, E.J., H. van den Dool, and M. Peña, 2013: Short-Term Climate Extremes: Prediction Skill and Predictability. *J. Climate*, **26**, 512–531.

ACC for Seasonal P Forecasts

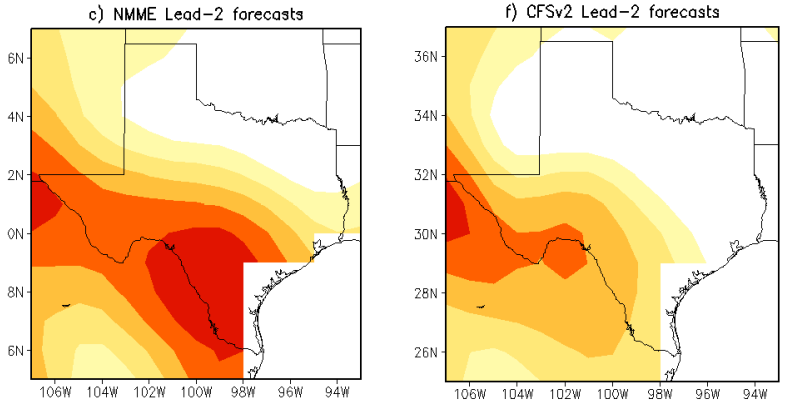
NMME **IC: January 1** **CFSv2**



Lead-0 fcst

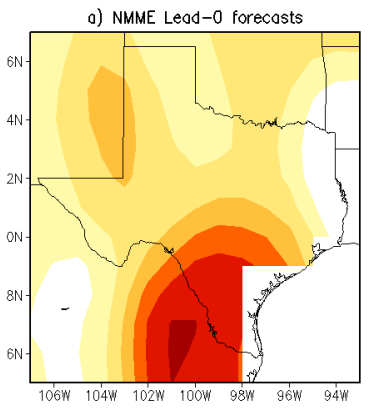


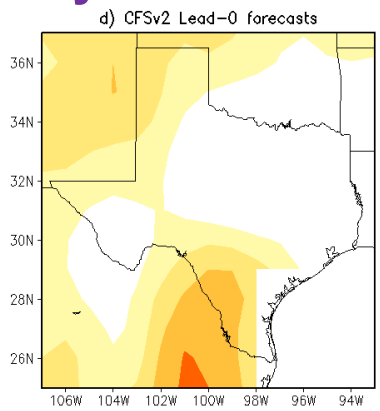
Lead-1 fcst

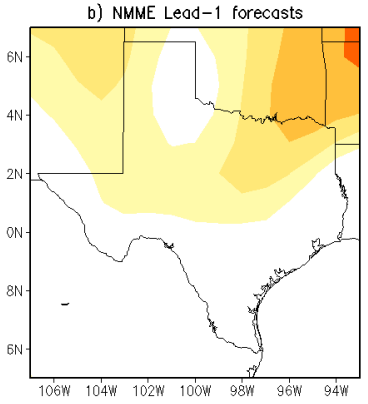


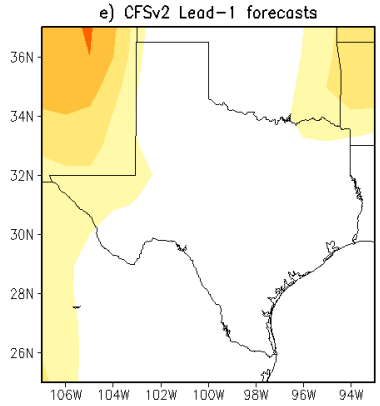
Lead-2 fcst

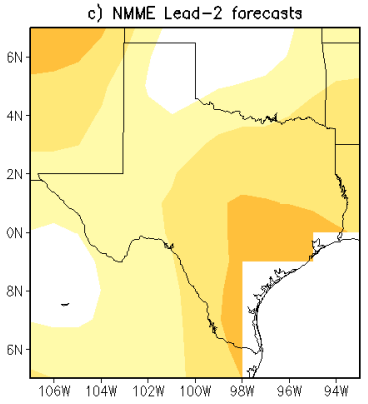
NMME **IC: July 1** **CFSv2**

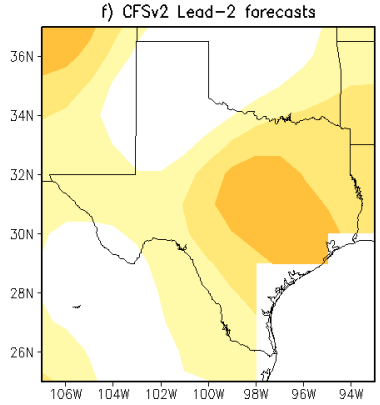


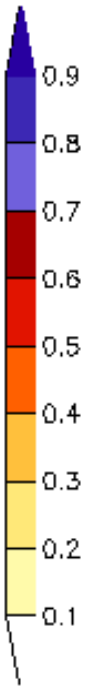












ACC for Seasonal T Forecasts