Skill of Real-time Seasonal ENSO Model Predictions during 2002-2011 – Is Our Capability Increasing?

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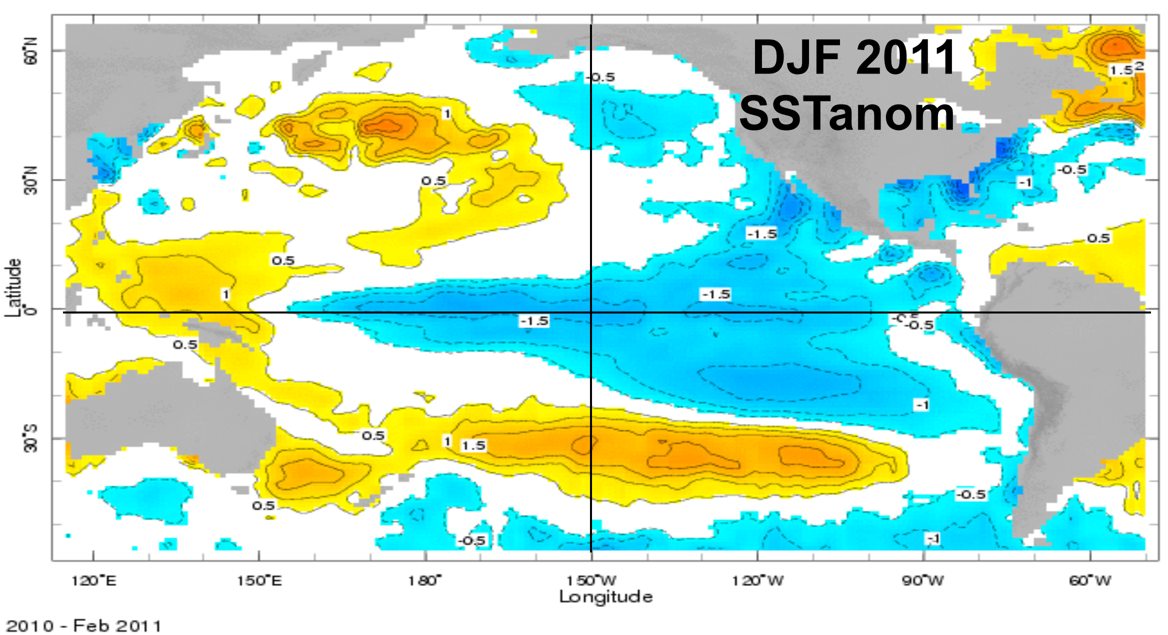
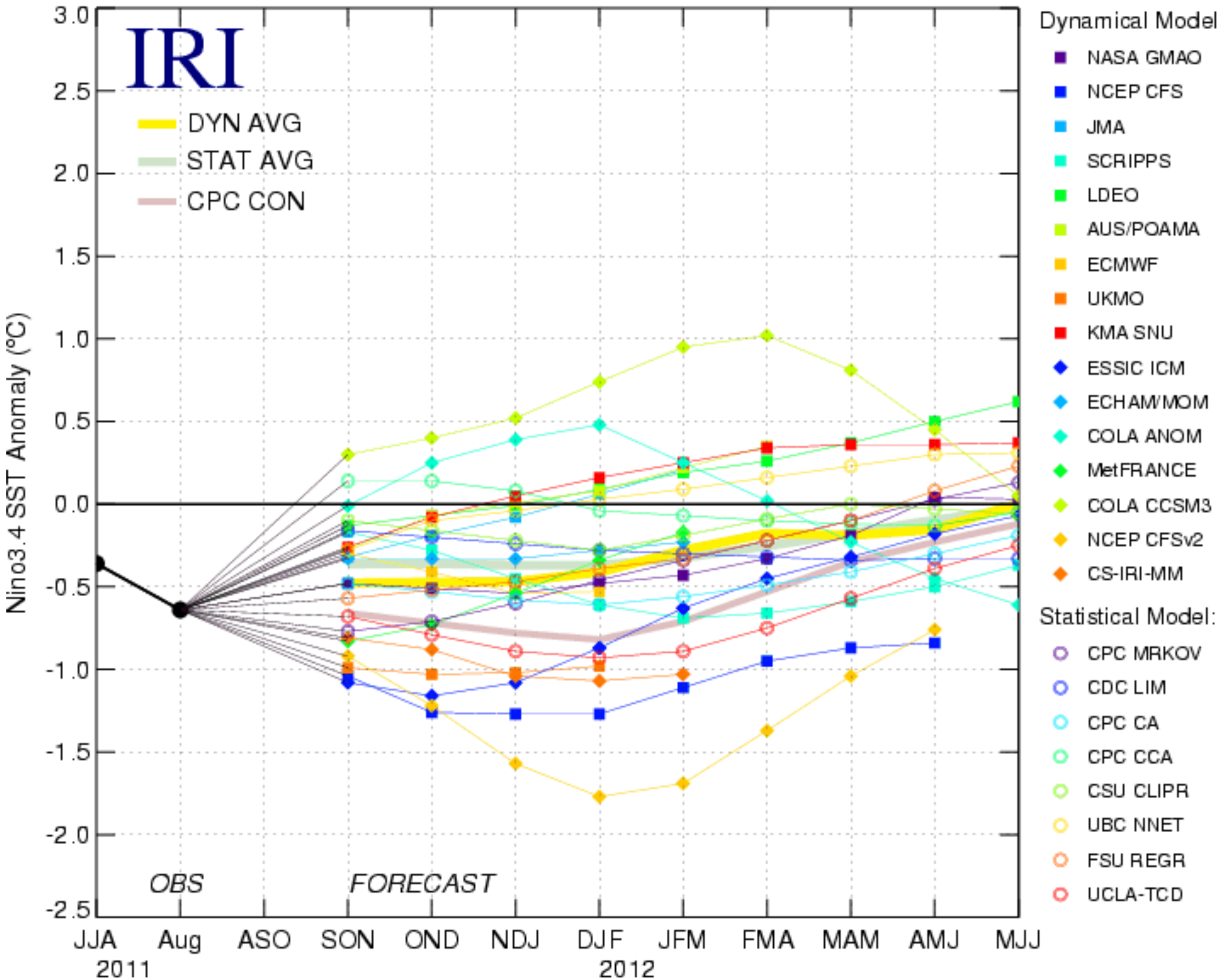
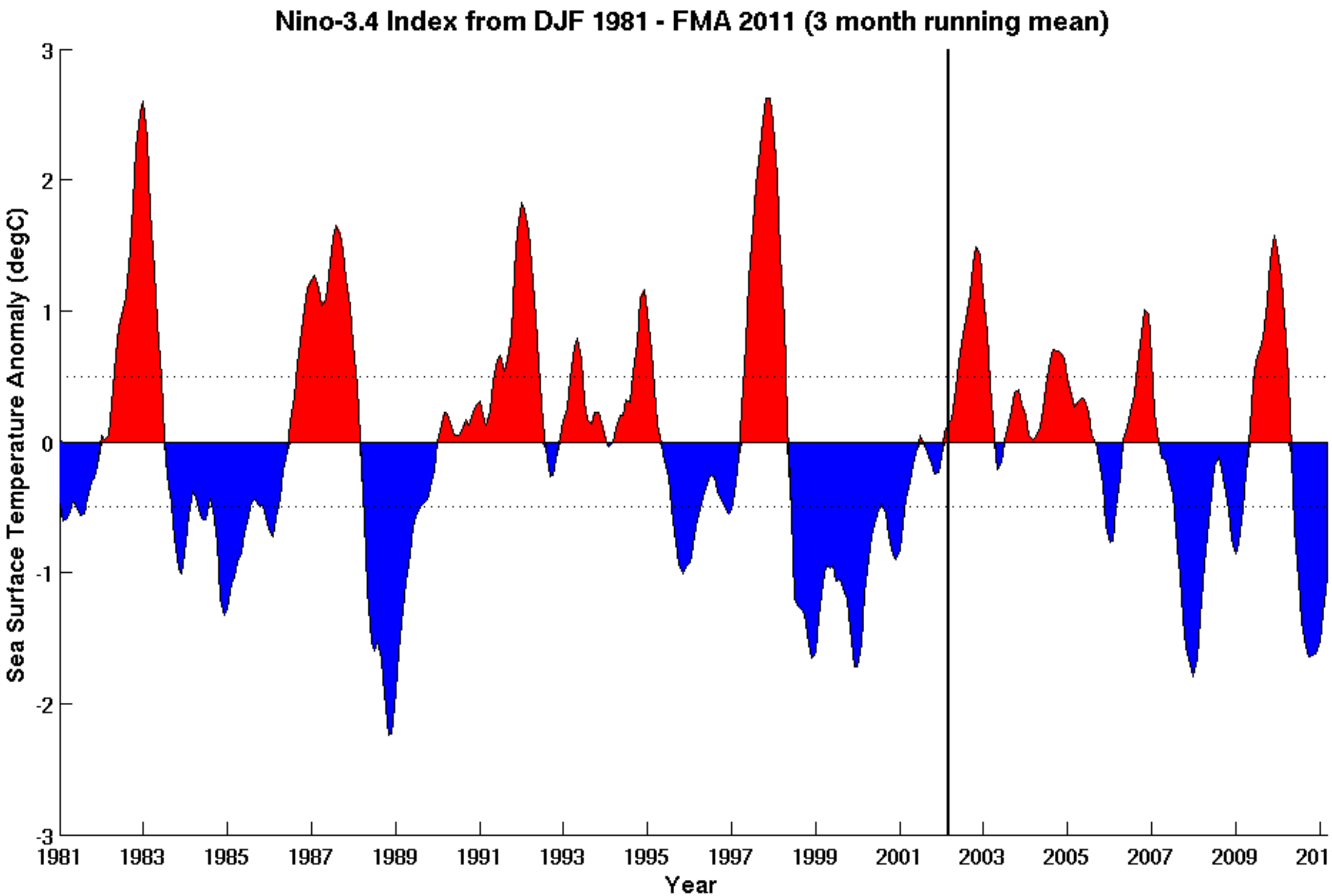


Model Predictions of ENSO from Sep 2011

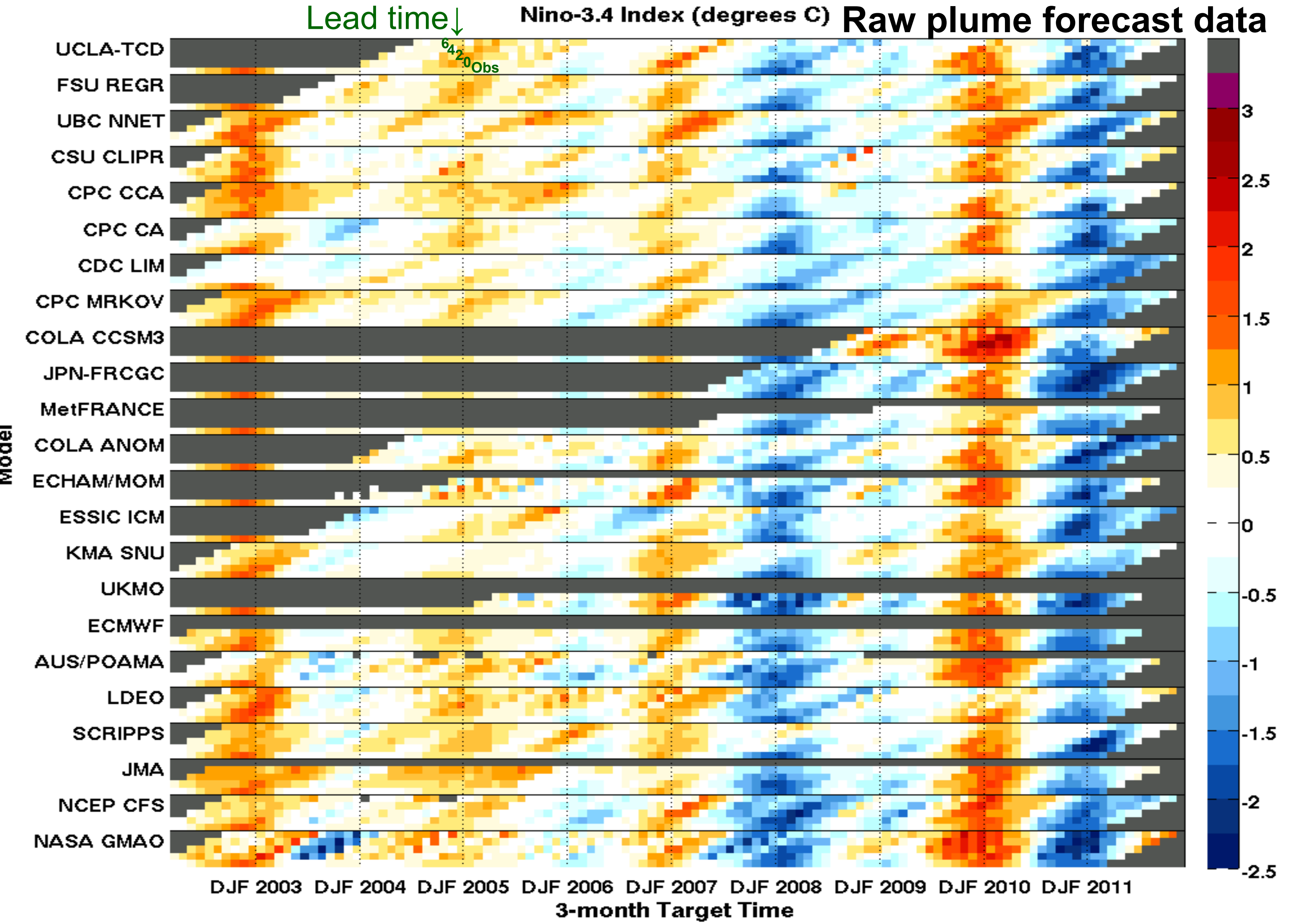


Dynamical Models	Model type
NASA GMAO	Fully coupled
NCEP CFS	Fully coupled
Japan Meteorological Agency	Fully coupled
Scripps Hybrid Coupled Model (HCM)	Comprehensive ocean, statistical atmosphere
Lamont-Doherty	Intermediate coupled
Australia POAMA	Fully coupled
ECMWF	Fully coupled
UKMO	Fully coupled
Korea Met. Agency SNU	Intermediate coupled
Univ. Maryland ESSIC	Intermediate coupled
IRI ECHAM/MOM	Fully coupled, anomaly coupled
COLA Anomaly	Anomaly coupled
COLA CCSM3 (short record)	Fully coupled
Météo France (short record)	Fully coupled
Japan Frontier FRCGC (short record)	Fully coupled
Statistical Models	**Method and predictors**
NOAA/NCEP/CPC Markov	Markov: persistence/transitions in SST and sea level height fields
NOAA/ESRL Linear Inverse Model (LIM)	Refined POP: Preferred persistence and transitions within SST field
NOAA/NCEP/CPC Constructed Analogue (CA)	Analogue-construction of current global SSTs
NOAA/NCEP/CPC Canon Correl Anal (CCA)	Uses SLP, tropical Pacific SST and sub-surface temperature (<2010)
NOAA/AOML CLIPER	Multiple regression from tropical Pacific SSTs
Univ. British Columbia Neural Network (NN)	Uses sea level pressure and Pacific SST
Florida State Univ. Multiple Regression	Uses tropical Pacific SST, heat content, winds
UCLA TDC Multi-level Regression	Uses 60N-30S Pacific SST field

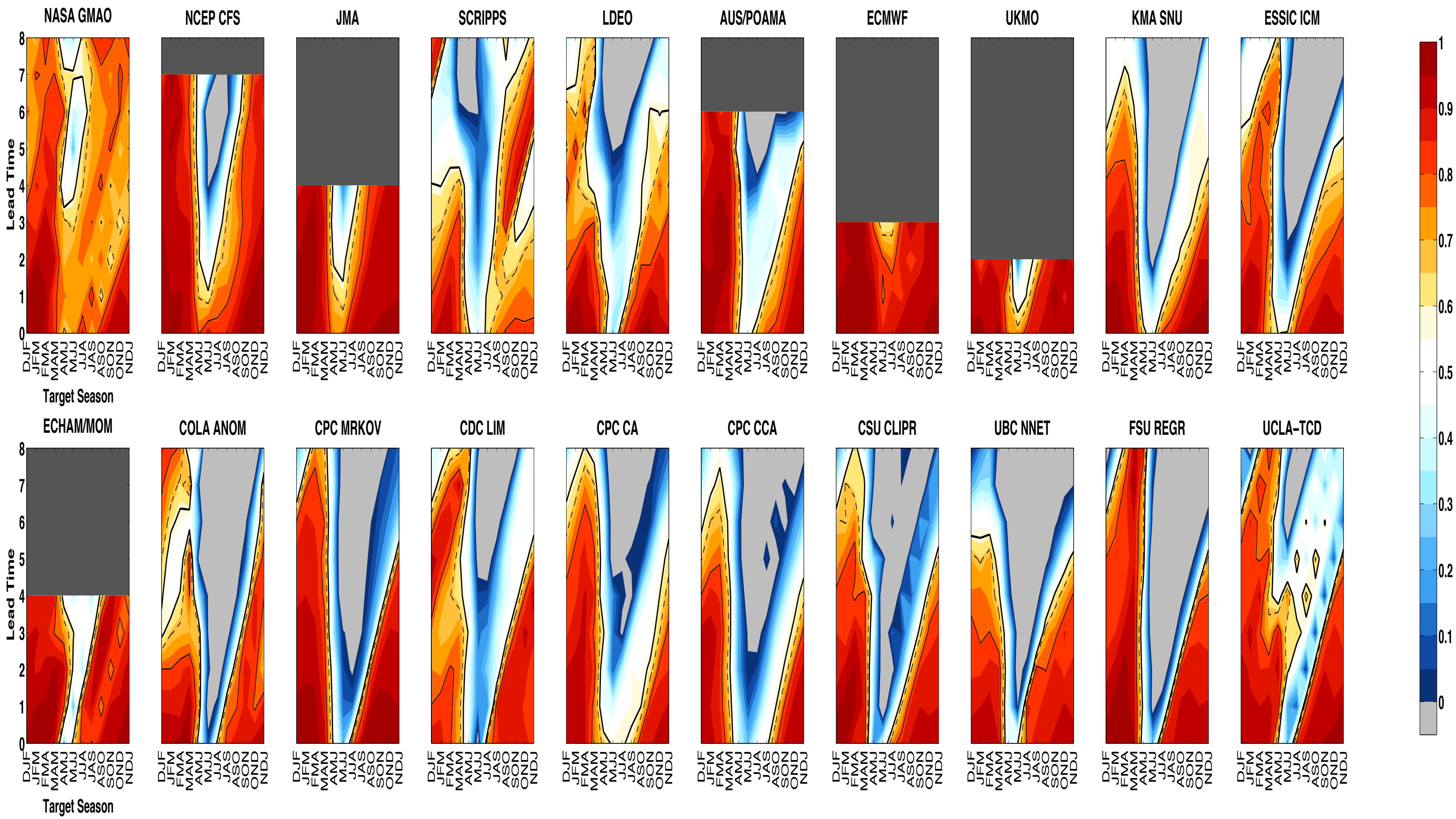


Nino-3.4 Index from DJF 1981 - FMA 2011 (3 month running mean)
Sea Surface Temperature Anomaly (degC)
3
2
1
0
-1
-2
-3
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
Year

Raw plume forecast data

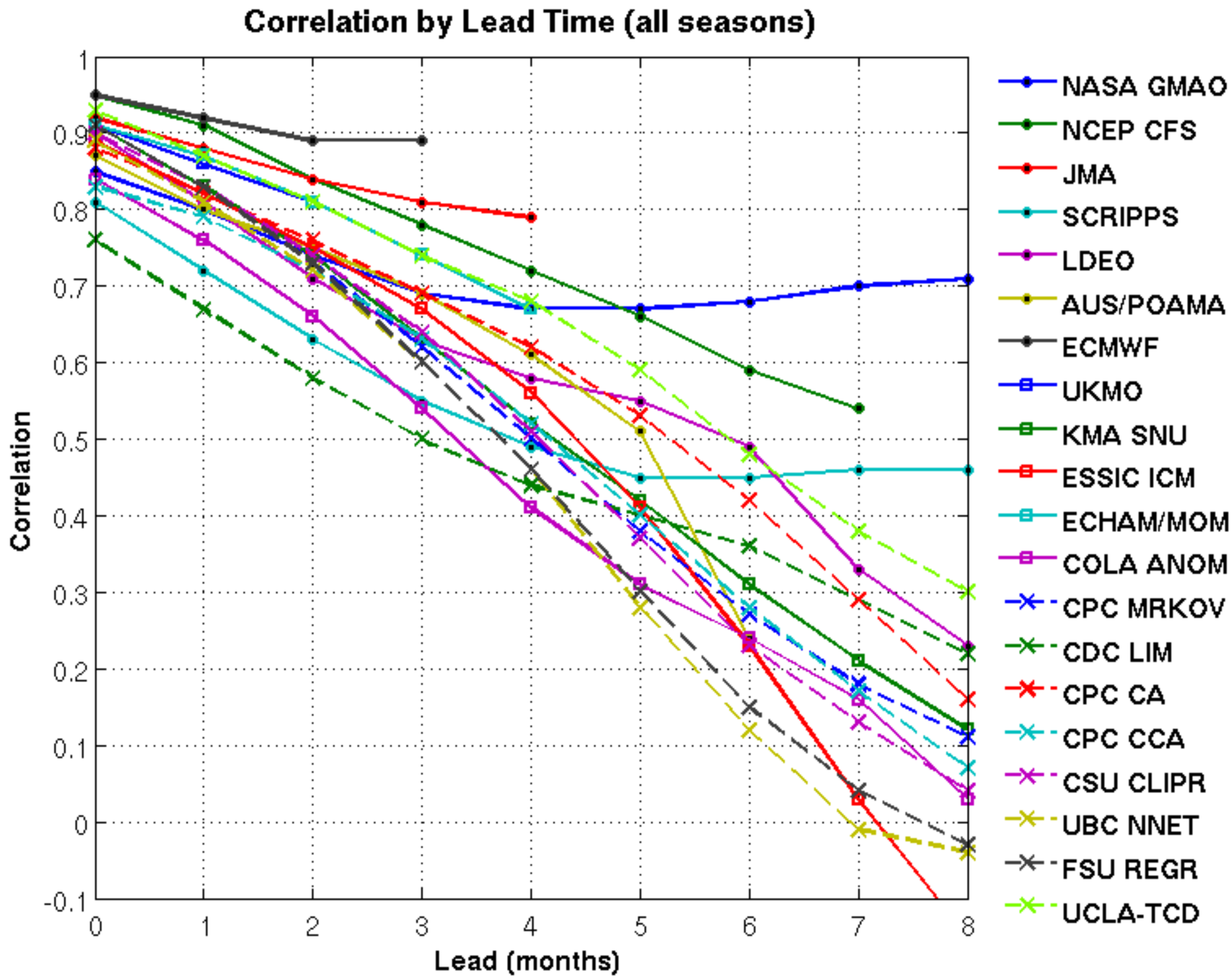


Correlation skill by target season and lead time

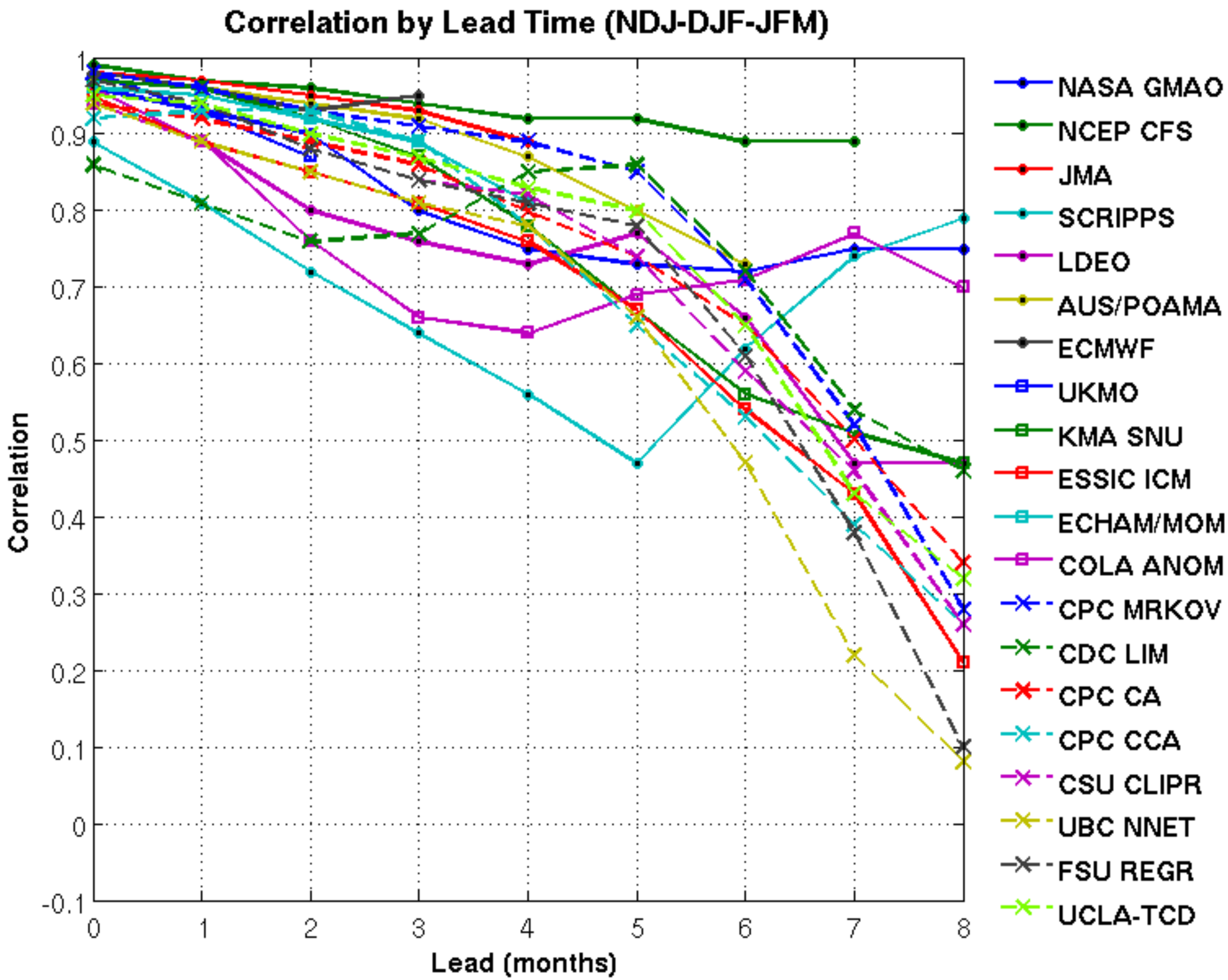


Sampling variability of a correlation coefficient

Sampling variability for n = 9					Sampling variability for n = 30				
lower 2.5%	lower 5%	**Popul correl**	upper 5%	upper 2.5%	lower 2.5%	lower 5%	**Popul correl**	upper 5%	upper 2.5%
-0.66	-0.59	**0.0**	0.59	0.66	-0.36	-0.31	**0.0**	0.31	0.36
-0.45	-0.35	**0.3**	0.75	0.80	-0.07	-0.01	**0.3**	0.55	0.60
-0.11	0.20	**0.6**	0.88	0.90	0.31	0.36	**0.6**	0.77	0.79
0.29	0.40	**0.8**	0.94	0.96	0.62	0.65	**0.8**	0.89	0.90
0.59	0.66	**0.9**	0.97	0.98	0.80	0.82	**0.9**	0.95	0.95



Correlation by Lead Time (all seasons)
Correlation
Lead (months)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
1
2
3
4
5
6
7
8
NASA GMAO
NCEP CFS
JMA
SCRIPPS
LDEO
AUS/POAMA
ECMWF
UKMO
KMA SNU
ESSIC ICM
ECHAM/MOM
COLA ANOM
CPC MRKOV
CDC LIM
CPC CA
CPC CCA
CSU CLIPR
UBC NNET
FSU REGR
UCLA-TCD



Correlation by Lead Time (NDJ-DJF-JFM)
Correlation
Lead (months)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
1
2
3
4
5
6
7
8
NASA GMAO
NCEP CFS
JMA
SCRIPPS
LDEO
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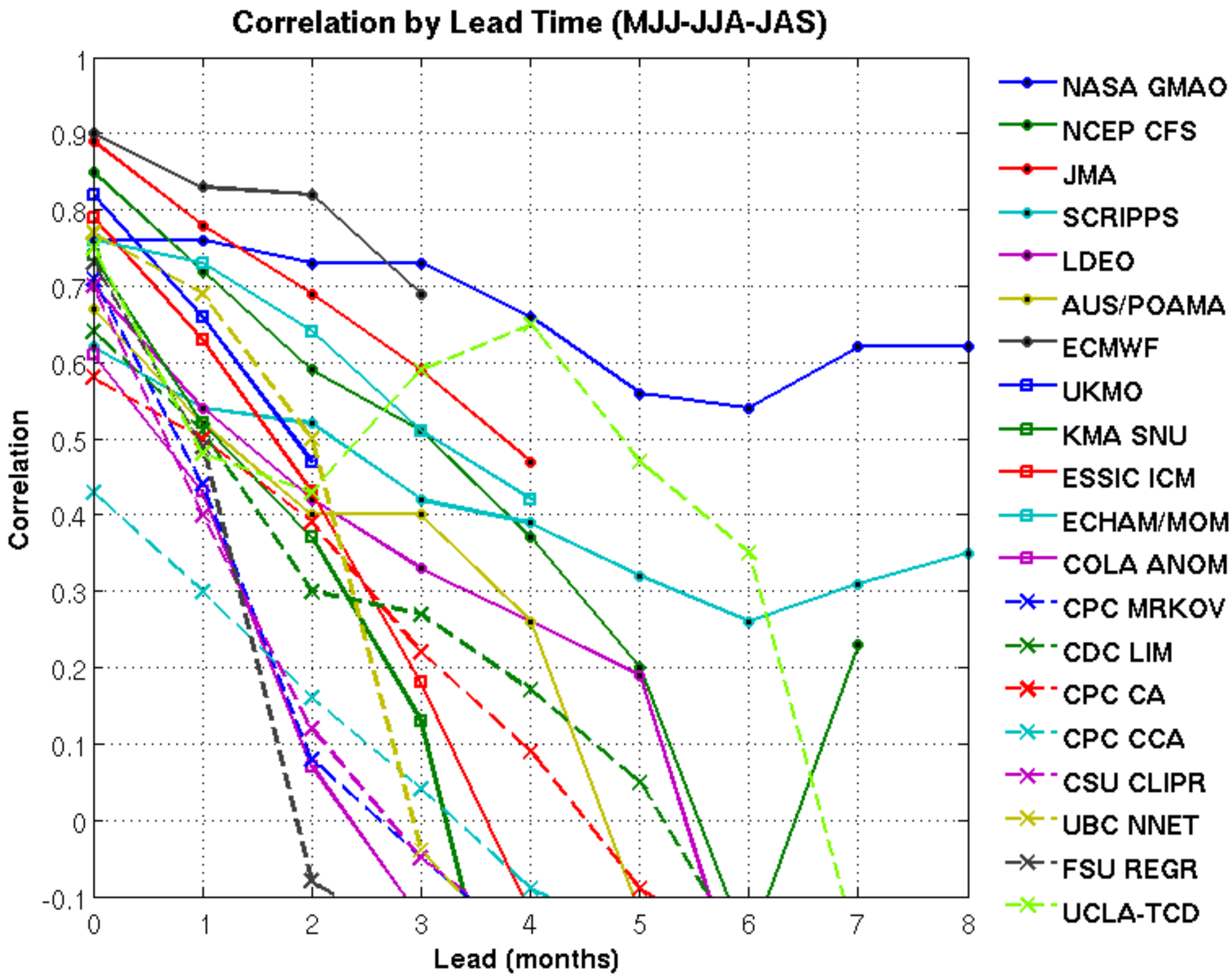


Correlation by Lead Time (MJJ-JJA-JAS)
Correlation
Lead (months)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
1
2
3
4
5
6
7
8
NASA GMAO
NCEP CFS
JMA
SCRIPPS
LDEO
AUS/POAMA
ECMWF
UKMO
KMA SNU
ESSIC ICM
ECHAM/MOM
COLA ANOM
CPC MRKOV
CDC LIM
CPC CA
CPC CCA
CSU CLIPR
UBC NNET
FSU REGR
UCLA-TCD

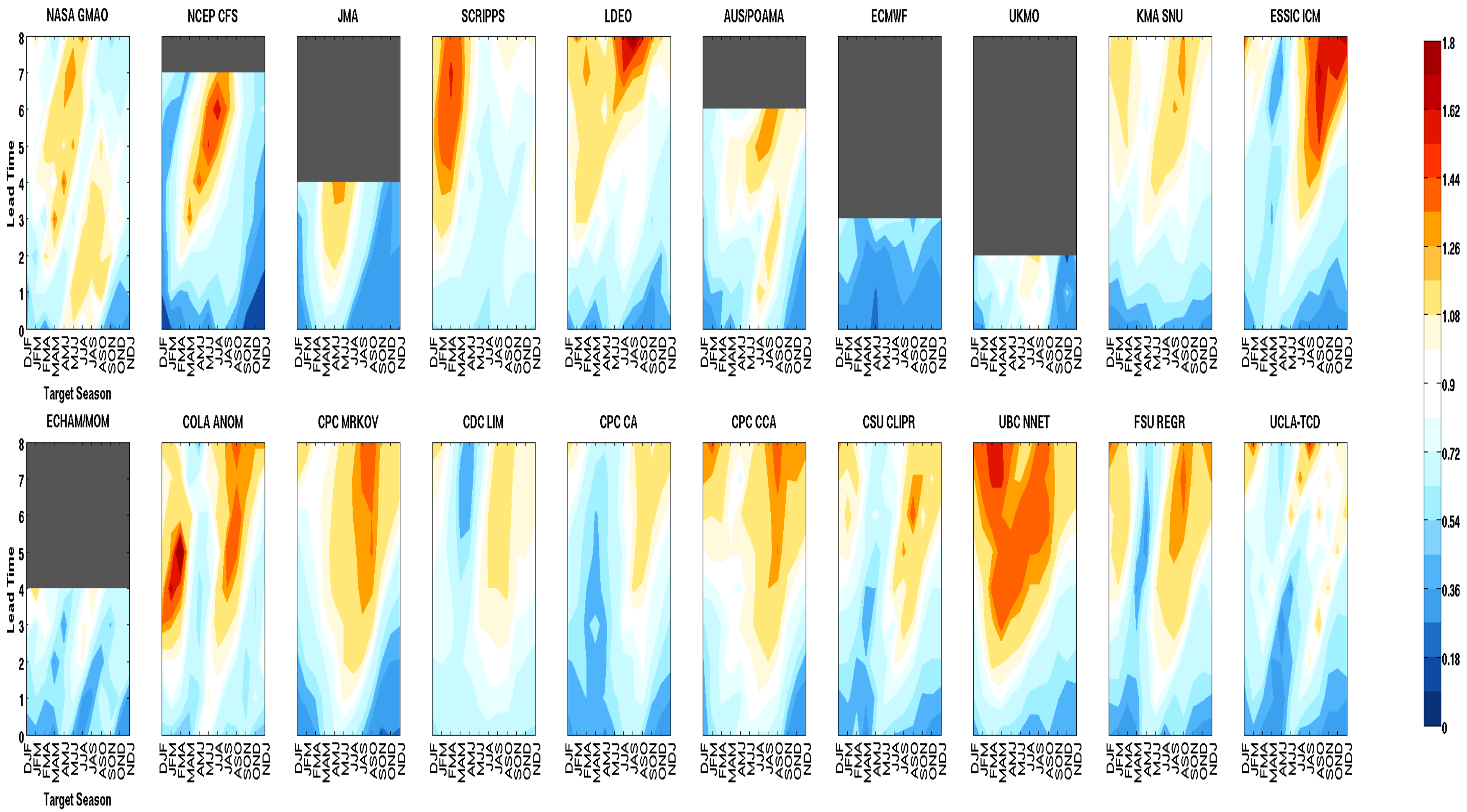
Wilcoxon rank sum test (field significance p=0.034)

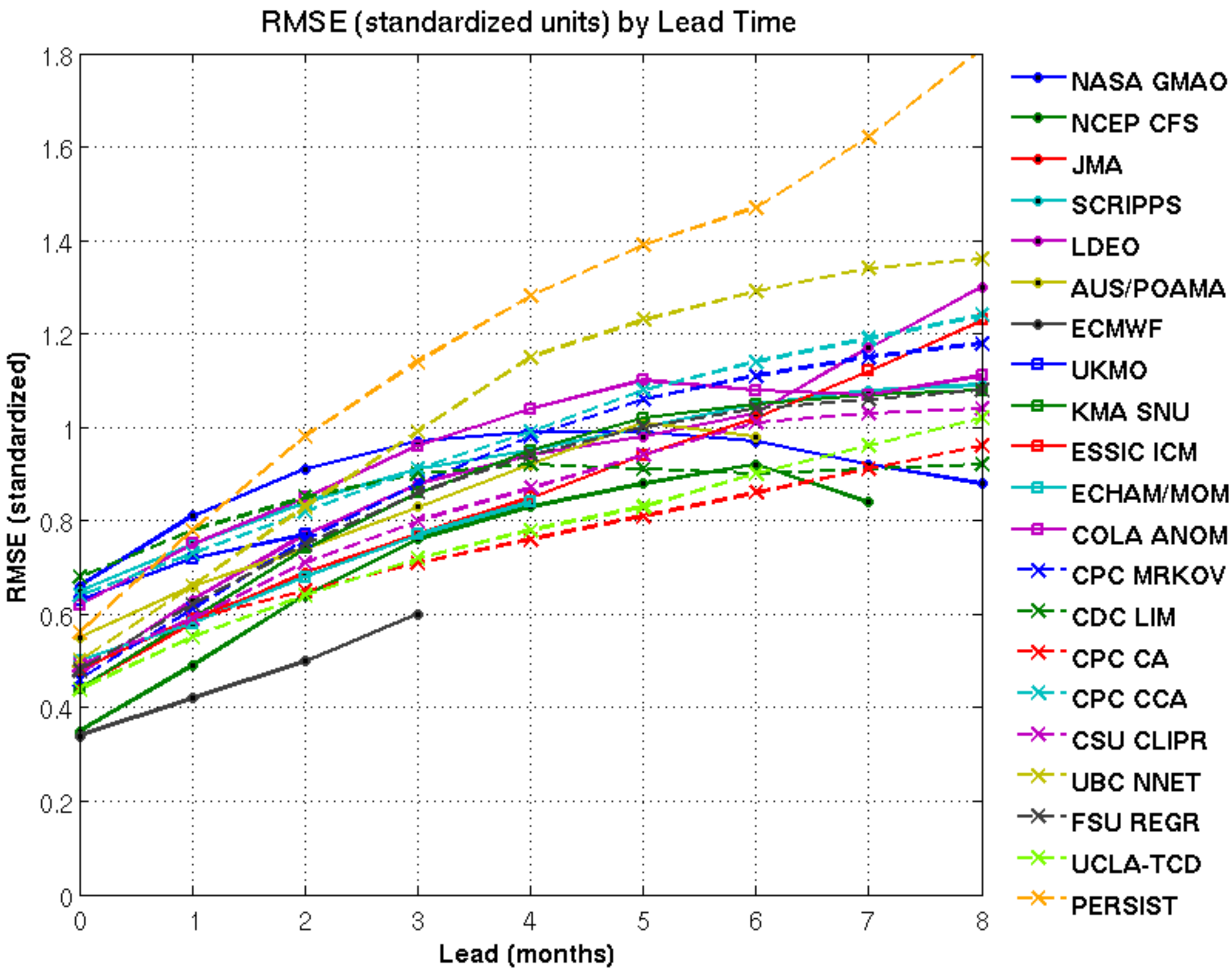
Lead	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ	All
0	0.32	0.19	0.76	0.28	**0.01**	**0.01**	0.09	0.95	0.22	0.41	0.95	0.76	0.70
1	0.88	0.25	0.22	0.32	0.06	**0.003**	**0.02**	0.17	-0.68	0.34	0.68	1.00	0.64
2	1.00	0.76	0.32	0.19	0.17	**0.04**	**0.01**	**0.01**	0.54	-0.73	0.38	0.94	0.22
3	1.00	-0.93	0.32	0.14	0.36	0.19	0.14	**0.01**	**0.01**	0.25	1.00	-0.74	0.12
4	-0.33	-0.37	0.79	0.29	0.48	0.48	0.18	0.25	**0.01**	**0.004**	0.36	-0.21	0.16
5	-0.09	-0.29	-0.40	0.67	0.92	0.60	0.67	0.30	0.34	**0.03**	**0.002**	0.92	0.21
6	0.60	-0.60	-0.75	1.00	0.40	0.46	0.75	-0.83	0.75	0.46	**0.05**	**0.05**	0.25
7	**0.02**	1.00	-0.35	1.00	-0.64	0.20	0.82	0.91	0.70	0.73	0.25	**0.03**	0.35
8	**0.05**	**0.02**	1.00	-0.52	-0.44	1.00	0.19	-0.61	-0.66	-0.88	1.00	**0.05**	0.61

t-test for mean difference (field significance p=0.026)

Lead	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ	All
0	0.27	0.19	0.65	0.22	**0.003**	**0.001**	0.06	0.48	0.41	0.65	0.74	0.46	0.49
1	0.50	0.37	0.12	0.16	**0.04**	**0.000**	**0.01**	0.10	-1.00	0.32	0.73	-0.85	0.29
2	-0.90	0.54	0.33	0.06	0.23	**0.04**	**0.001**	**0.01**	0.16	-0.86	0.29	0.93	0.12
3	-0.98	0.65	0.13	0.13	0.71	0.20	0.07	**0.002**	**0.001**	0.11	-0.90	-0.65	0.09
4	-0.35	-0.39	0.82	0.40	0.26	0.78	0.29	0.12	**0.002**	**0.000**	0.22	-0.19	0.11
5	-0.16	-0.47	-0.31	0.56	-0.93	0.55	0.87	0.17	0.18	**0.004**	**0.001**	0.66	0.18
6	0.34	-0.80	-0.73	-0.62	0.34	0.30	0.70	0.97	0.66	0.28	**0.01**	**0.02**	0.18
7	**0.01**	0.37	-0.39	-0.60	-0.67	0.26	0.42	0.65	0.42	0.51	0.17	**0.01**	0.15
8	**0.04**	**0.02**	0.52	-0.37	-0.45	-0.83	0.13	0.77	0.48	0.66	0.70	0.29	0.34

RMSE (standardized) by target season and lead time

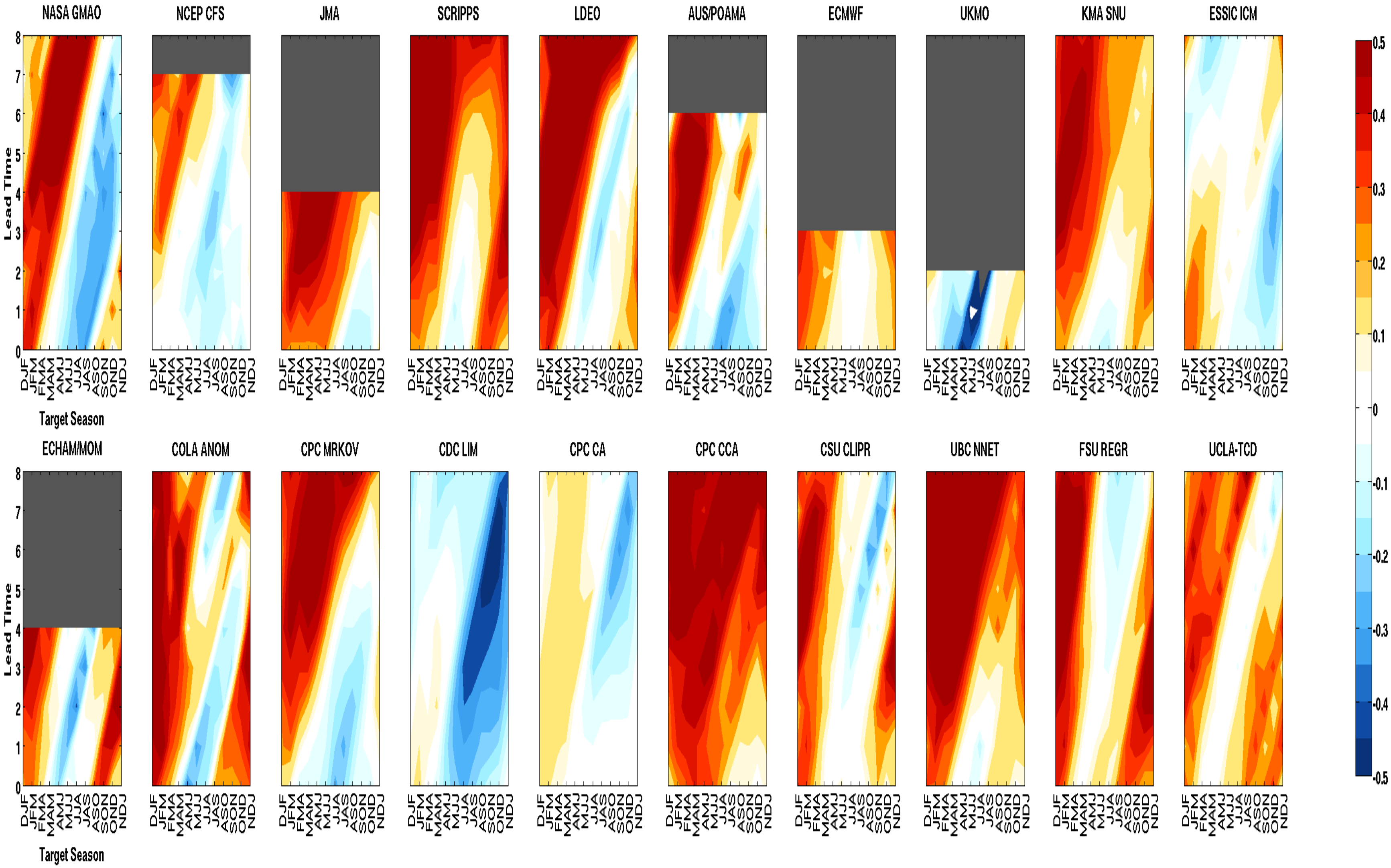




RMSE (standardized units) by Lead Time
RMSE (standardized)
Lead (months)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0
1
2
3
4
5
6
7
8
NASA GMAO
NCEP CFS
JMA
SCRIPPS
LDEO
AUS/POAMA
ECMWF
UKMO
KMA SNU
ESSIC ICM
ECHAM/MOM
COLA ANOM
CPC MRKOV
CDC LIM
CPC CA
CPC CCA
CSU CLIPR
UBC NNET
FSU REGR
UCLA-TCD
PERSIST

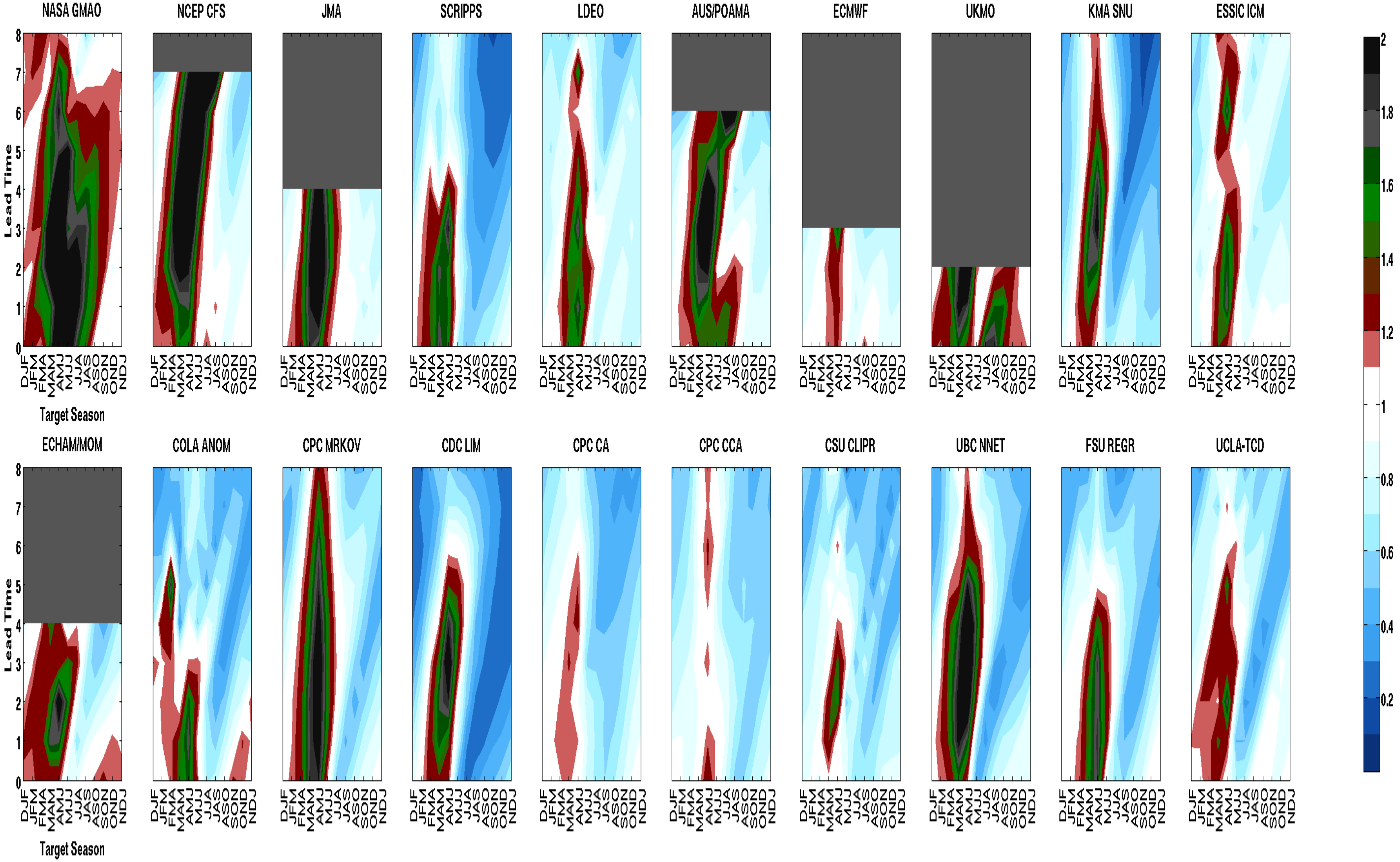
$$\overline{fct} - \overline{obs}$$

Bias by target season and lead time

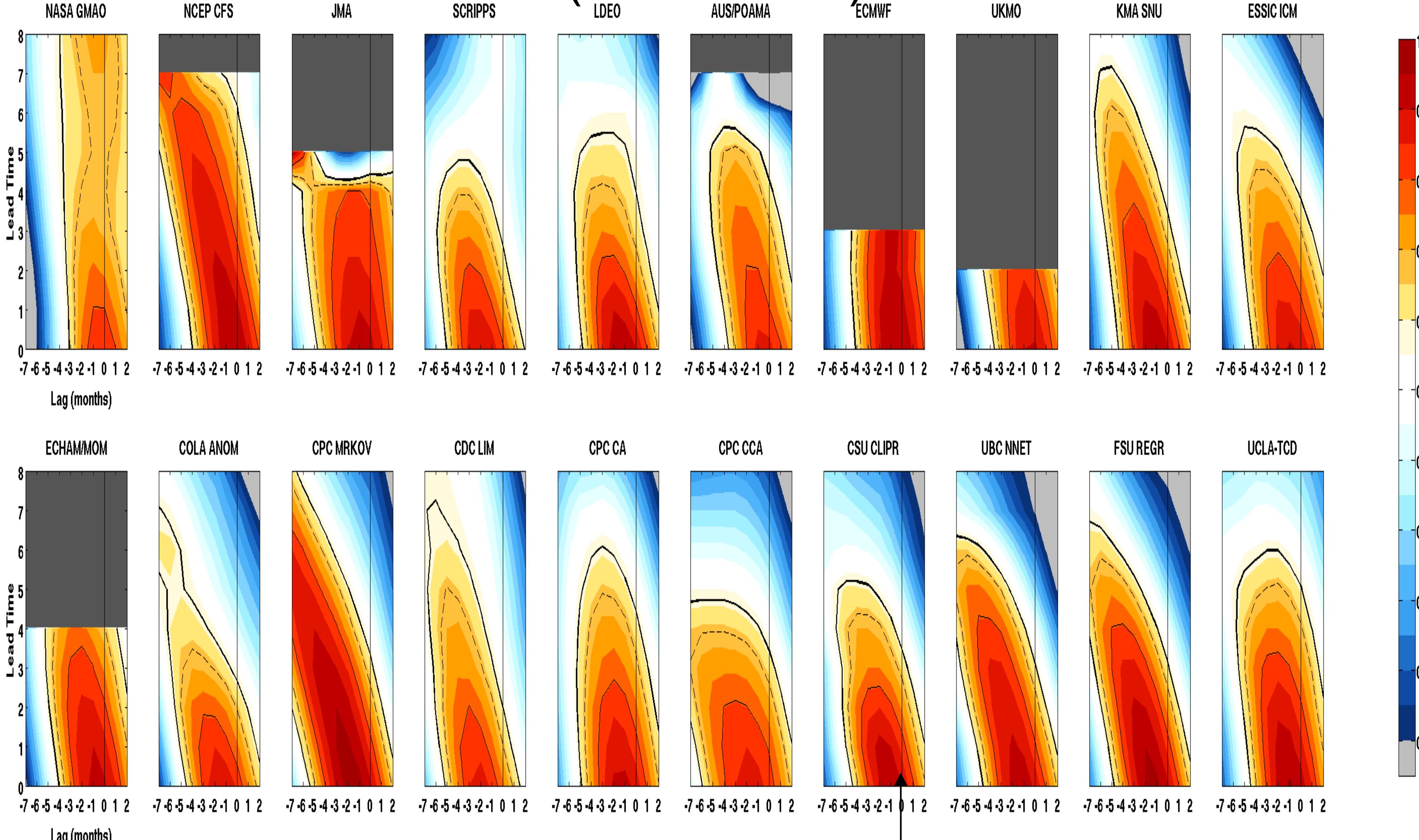


$$\frac{SD_{fct}}{SD_{obs}}$$

Standard deviation ratio by target season and lead time

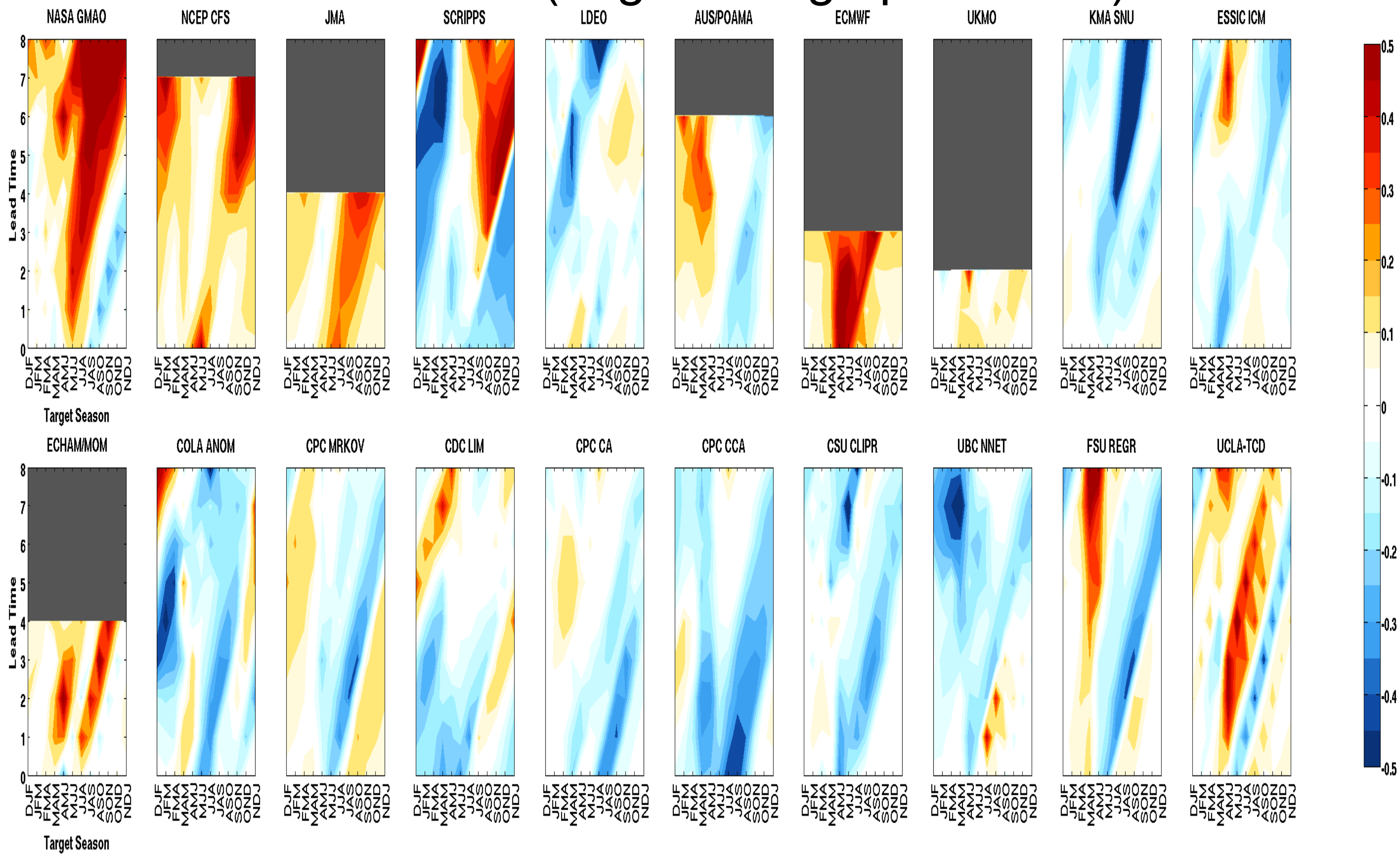


Correlation by lead time and target offset time (all seasons)



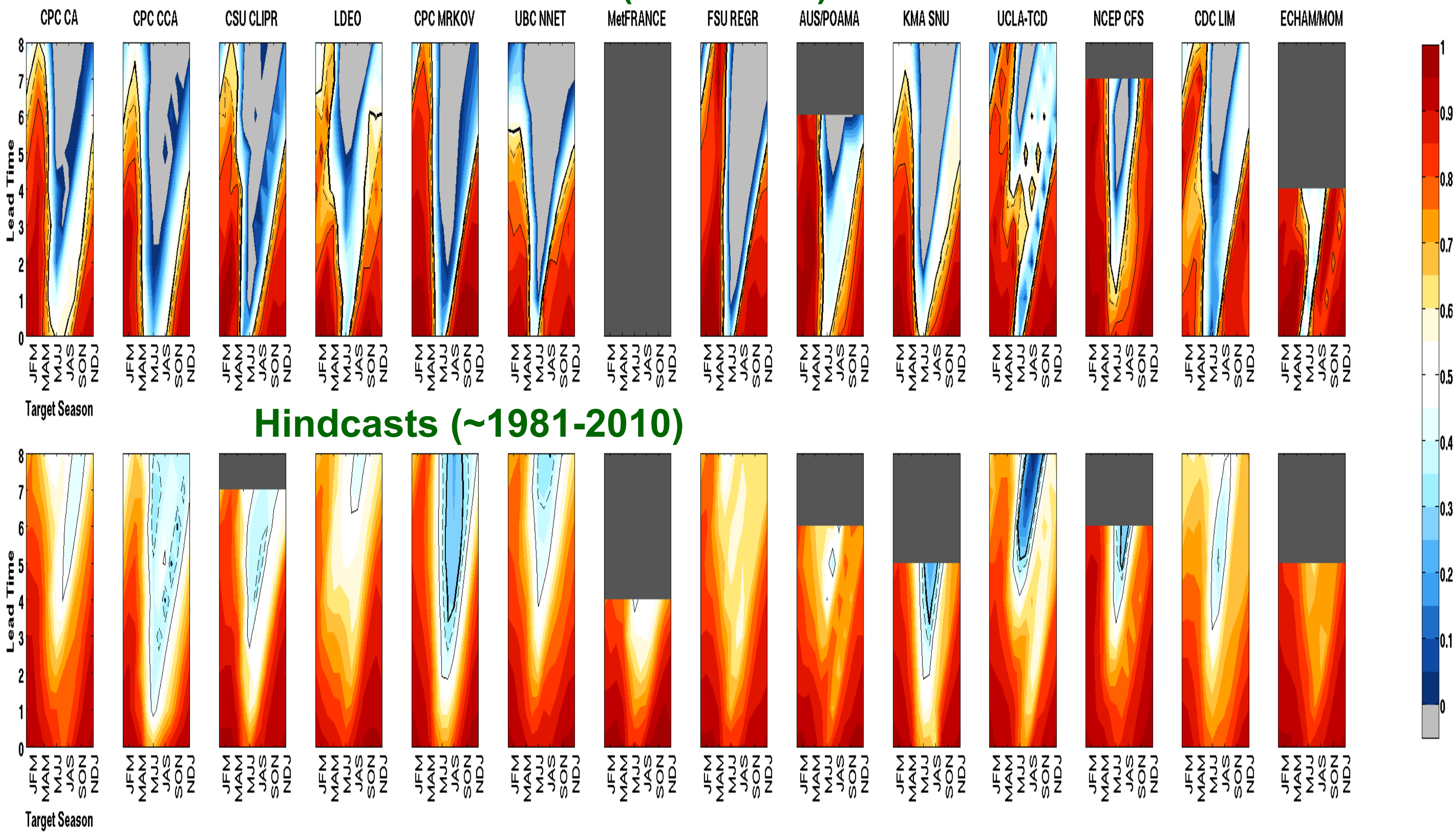
vertical line shows no offset

Squared correlation anomaly with respect to mean squared correlation over all models, by target season and lead time (negative sign preserved)

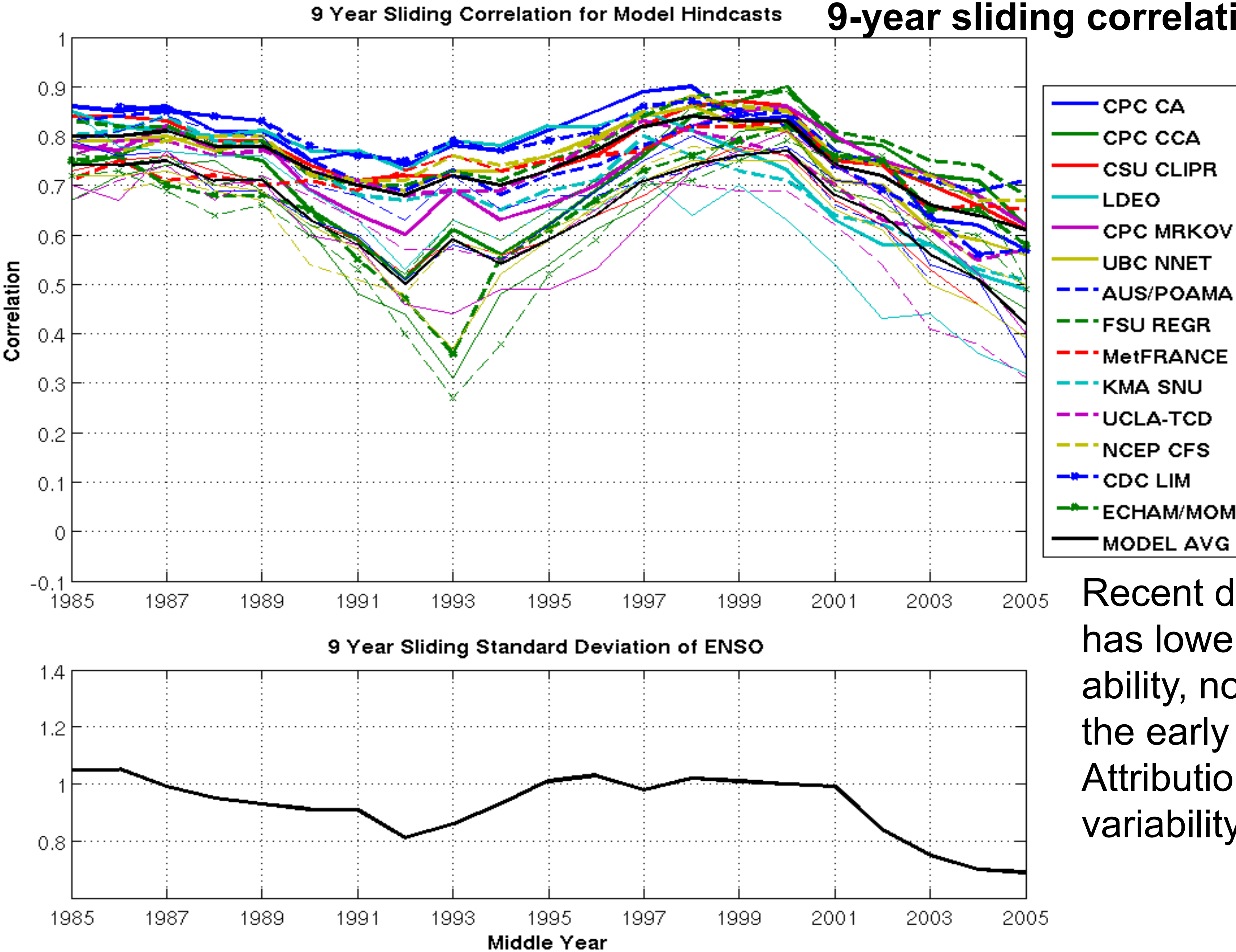


Correlation by target season and lead time: Real-time forecasts vs. longer-term hindcasts

Real-time forecasts (2002-2011)

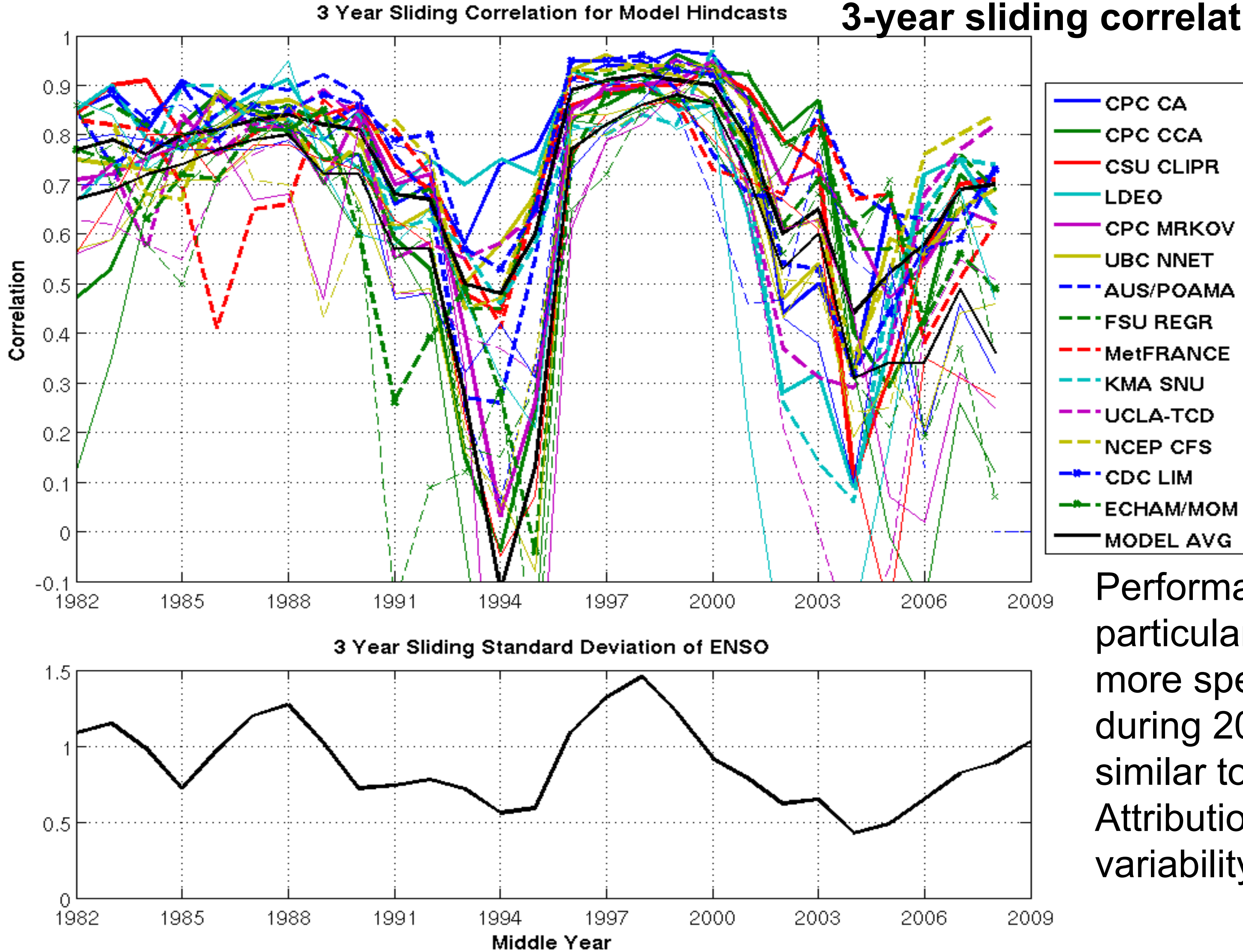


9-year sliding correlation

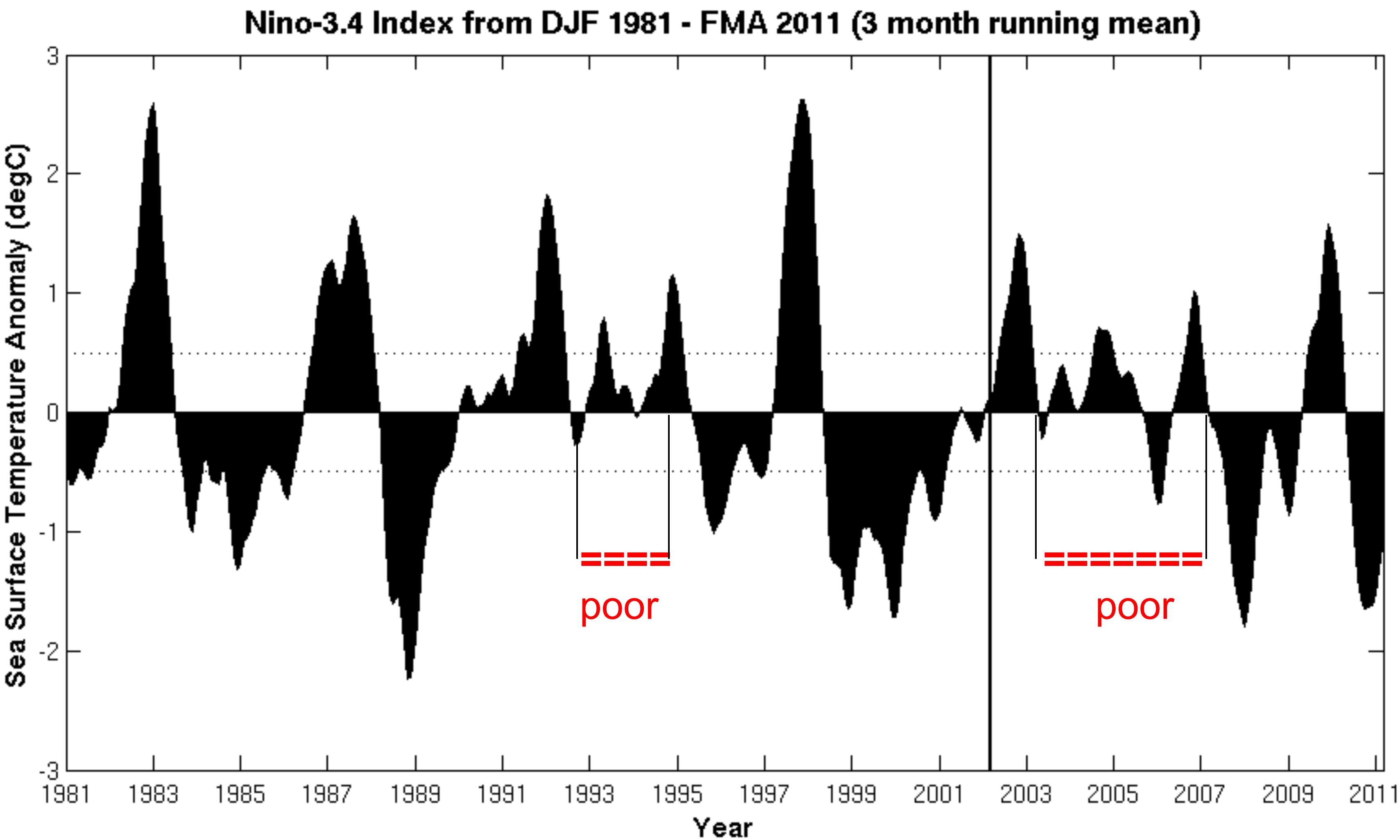


Recent decade
has lower pred
ability, not unlik
the early 1990s
Attribution to lo
variability.

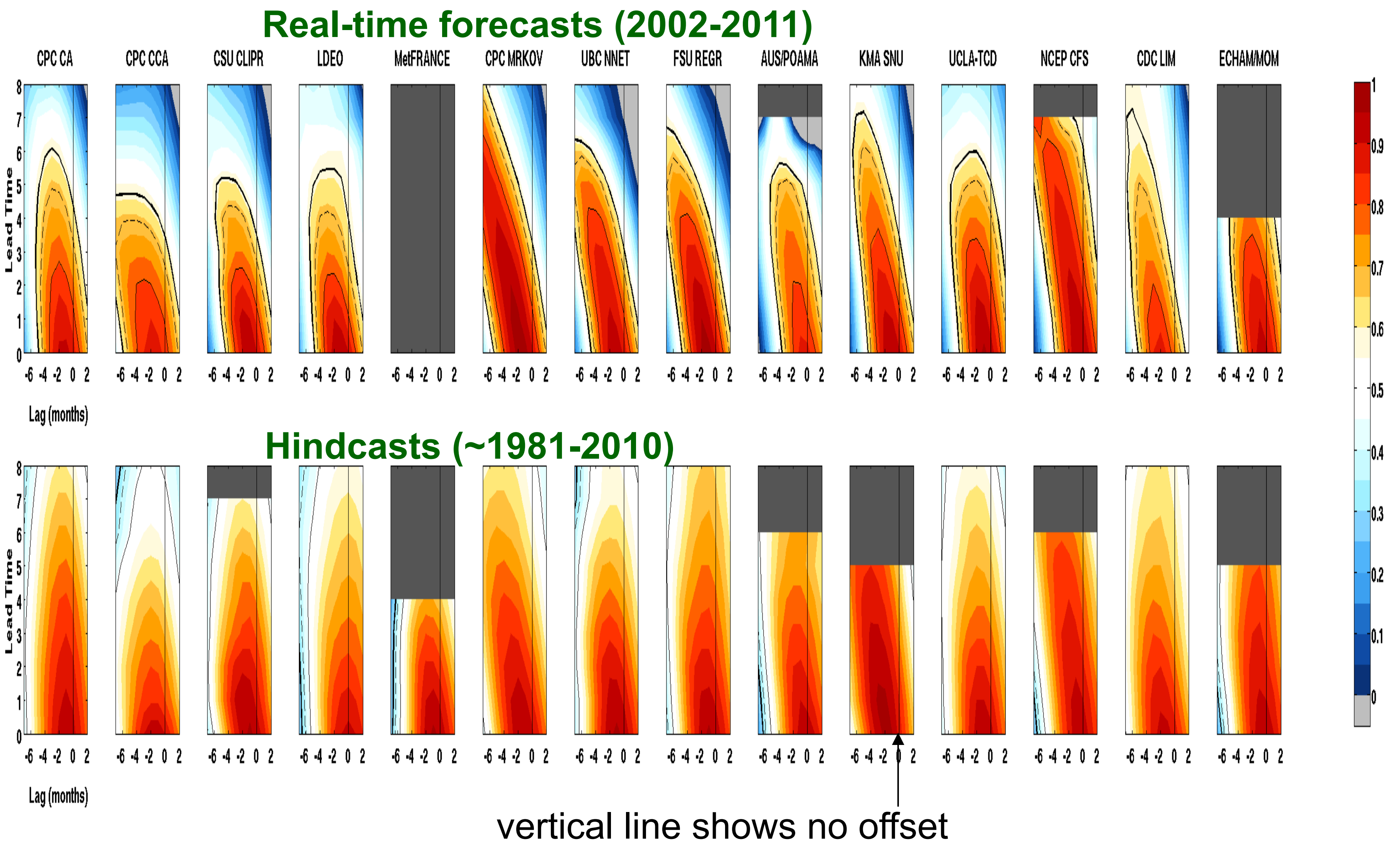
3-year sliding correlation



Performance w
particularly poo
more specifical
during 2004-20
similar to 1993-
Attribution to lo
variability.


Nino-3.4 Index from DJF 1981 - FMA 2011 (3 month running mean)
Sea Surface Temperature Anomaly (degC)
3
2
1
0
-1
-2
-3
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
Year
poor
poor

Correlation by lead time and target offset time (all seasons)



Findings:

1. Gradual upward trend in ENSO prediction performance is outweighed by decadal variations in inherent ENSO predictability, based on signal-to-noise considerations.

2. During 2002-2010, dynamical models outperformed statistical models during the time of year prediction is most difficult. This performance difference is statistically significant.

3. A common systematic error in model ENSO predictions is tendency to persist current observed state, and predict new development too weakly and/or too late.

Future Goal:

Developing a multi-model ensemble forecast for plume, based on multi-model ensemble means and/or or on multi-model individual ensemble members. (Issues: weighting method, prob. expression)