Estimating the chance of El Niño from subsurface temperature anomalies

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39th Climate Diagnostics and Prediction Workshop
St. Louis, Missouri

MOTIVATION

- *One variable*, **subsurface temperature,** captured the attention of many scientists and members of the public earlier this year.
- So how good of a predictor is it?
- Makes more physical sense to take into account *many variables* to predict ENSO.

But, what were the chances of El Niño based on equatorial Pacific subsurface temp. anomalies alone?

THEORETICAL & PHYSICAL BASIS

Subsurface temperatures across the equatorial Pacific are a well known precursor of ENSO.

(1) Wyrtki (1975, 1985)

-- Sea level in western Pacific builds up before El Niño. Trigger sends warm water eastward.

-- As El Nino peaks, sea level begins to decrease

(2) Delayed Oscillator (Schopf and Suarez, 1988; Battisti, 1988)

-- westerly wind anom. induce downwelling Kelvin wave that depresses the equatorial thermocline/increasing subsrfc. temp.

-- El Niño terminates when Rossby waves reflect off western boundary, inducing upwelling Kelvin wave

(3) Recharge-Discharge (Jin, 1997)

-- warm water recharges on the equator. During El Niño, westerly wind anom. leads to divergence of heat off of the equator

-- discharge results in transition to cool phase of ENSO

DATASETS & METHODS

GOAL: create a "best estimate" of the probability (%) of El Niño based on equatorial subsurface temperatures (avg. of surface to 300m).

OBSERVATIONAL DATASETS (limited sample size + observational error):

GODAS: 1980-2014 (only *real-time*)
SODA v2.2.4: 1950-2010 (less coverage of in situ prior to ~1950)

500 YEAR FREE RUNS OF CGCMs (more samples + model error):

NCEP CFSv1: Modular Ocean Model 3/ GFS (2003) Atmospheric Model
GFDL CM2.1: Modular Ocean Model 4 (OM3.1)/ AM2.1 Atmospheric Model (see Wittenberg et al., 2006) – *pre-industrial* (1860) simulation

METHODS:

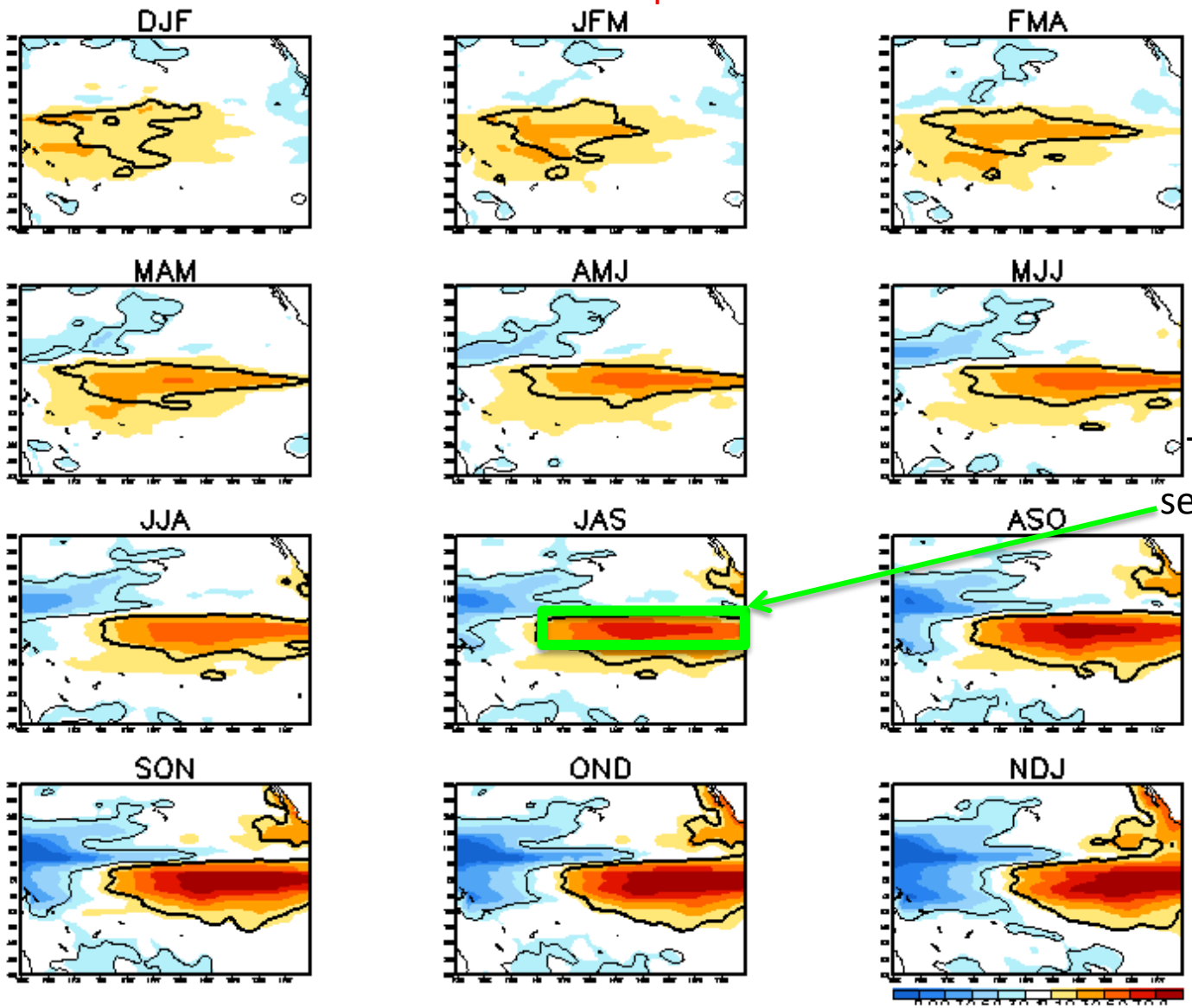
(1) Least Squares Regression and Correlation (% variance explained)
(2) Scatterplots
(3) Marginal, P(E), and conditional probabilities, P(E|T)

Lagged Regression of **Preceding** Subsurface Temp. Anom. onto ***NDJ Niño-3***

GODAS 1980-present

Thin/thick black contour indicate 95% level

Shading is the regression coefficient.



To form time series will avg. 180°-100°W on equator

This season (NDJ) is simultaneous

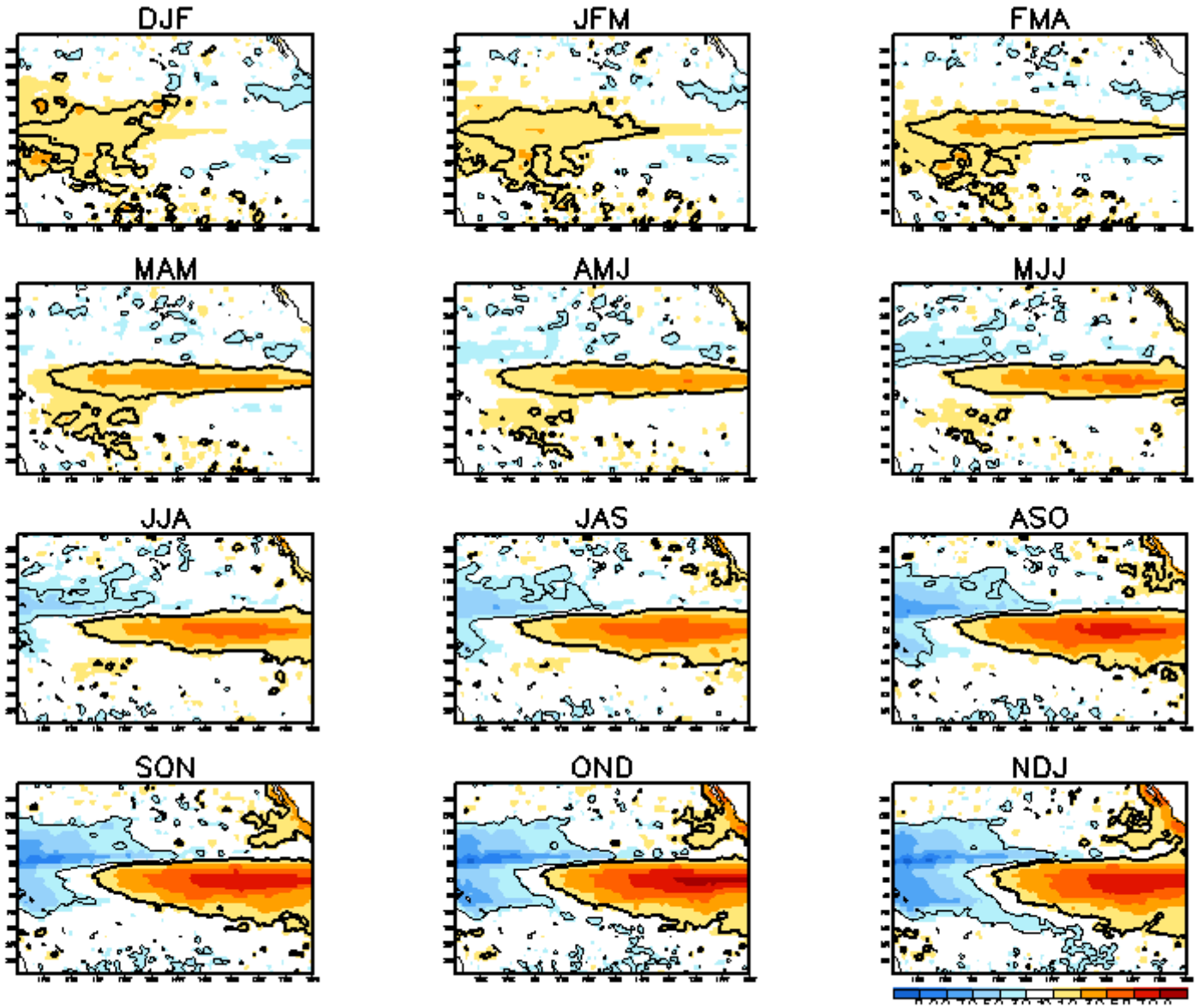
- Zonal pattern of anomalies on the equator during FMA-MJJ.
- Anomalous East-West dipole emerges during JAS-NDJ.

Lagged Regression of **Preceding** Subsurface Temp. Anom. onto ***NDJ Niño-3***

SODA 1950-2010

Thin/thick black contour indicate 95% level

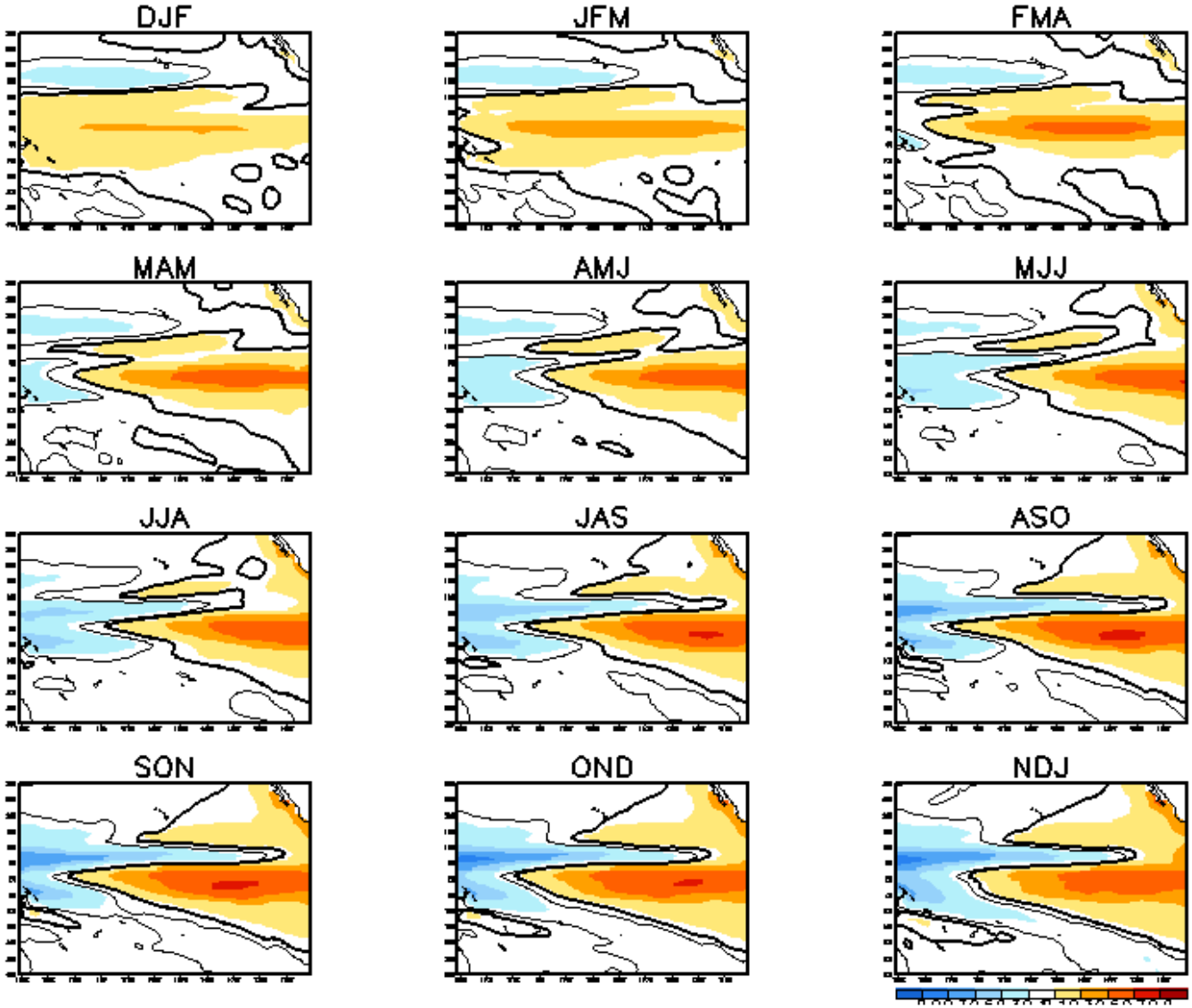
Shading is the regression coefficient.



- Anomaly pattern is very similar to GODAS

Lagged Regression of **Preceding** Subsurface Temp. Anom. onto ***NDJ Niño-3***

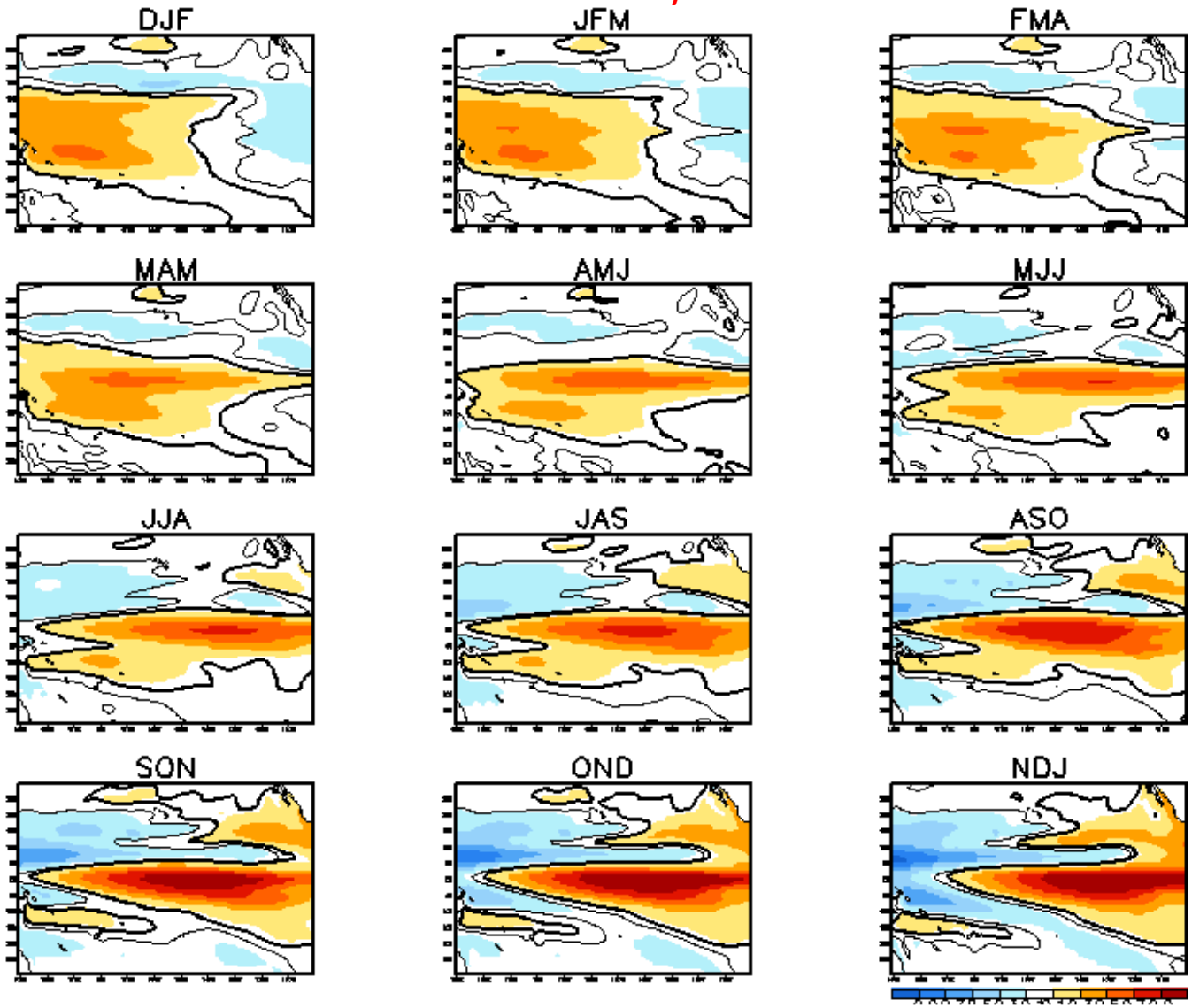
NCEP CFSv1 500 year run



- Stronger east-west equatorial dipole than GODAS/SODA during MAM-JAS.

Lagged Regression of **Preceding** Subsurface Temp. Anom. onto ***NDJ Niño-3***

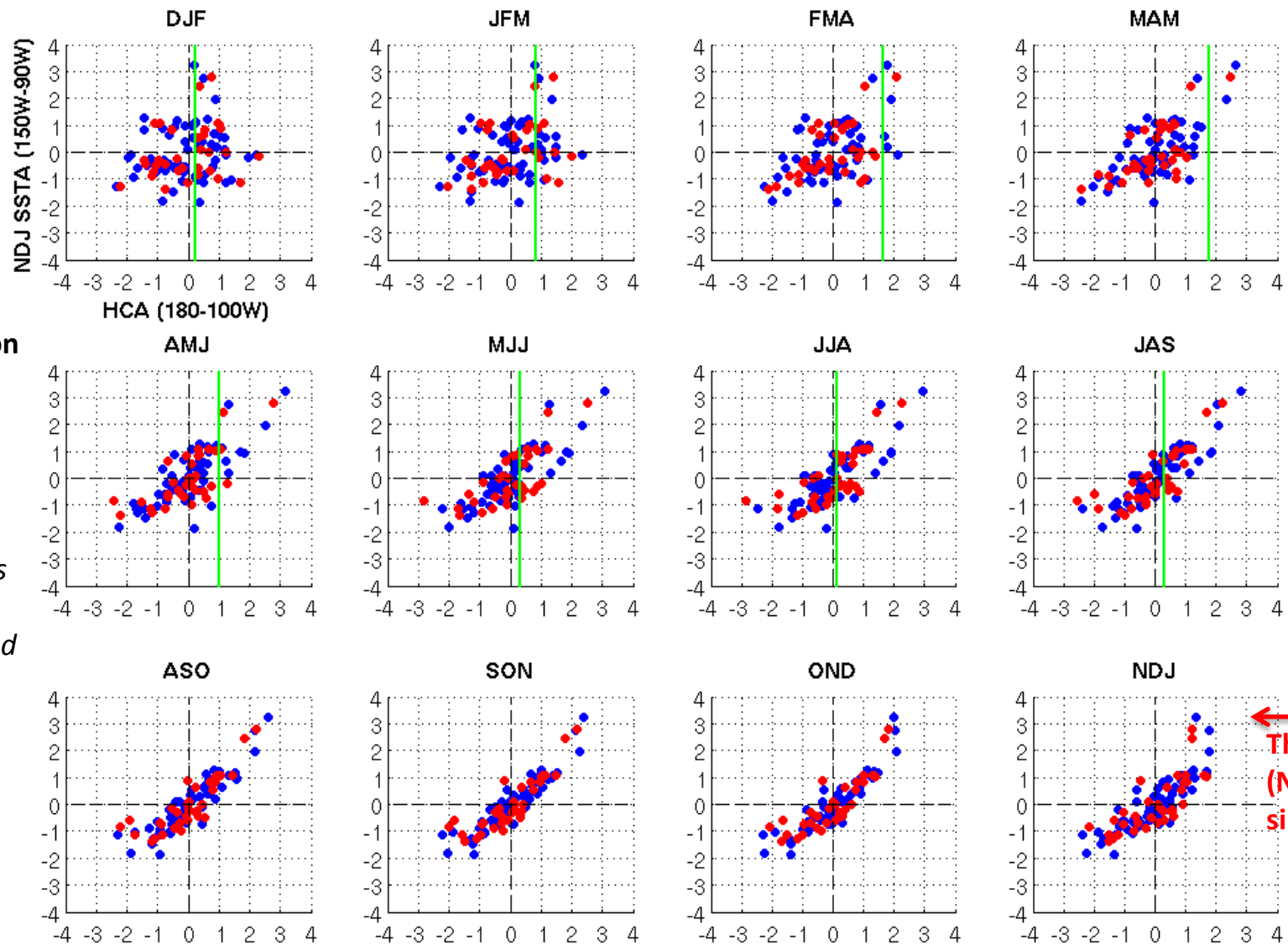
GFDL CM2.1 500 year run



- During DJF-FMA, stronger east-west dipole than CFSv1/GODAS/SODA
- More zonal than GODAS/SODA: positive anom. on EQ. after MAM

Scatter Plot of **Preceding** Subsurface Temp. Anom. (x-axis) and NDJ Niño-3 (y-axis)

Blue: SODA 2.2.4 Red: GODAS/ERSSTv3b Green: GODAS during 2014



3mo. Season applies to Subsrfc. Temp. on x-axis

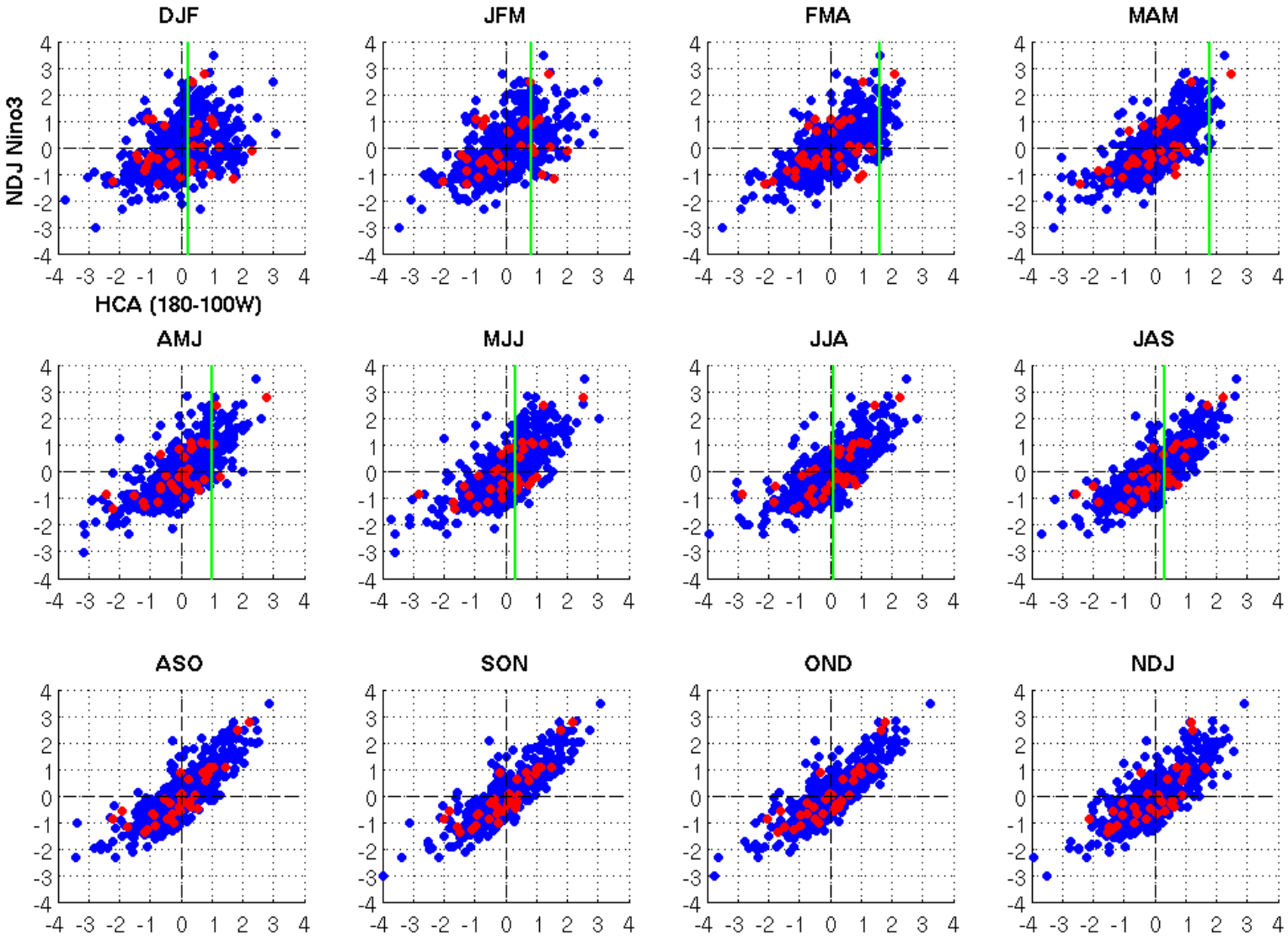
Both indices are standardized

This season (NDJ) is simultaneous

Fairly linear orientation from AMJ on. Decent overlap between datasets.

Scatter Plot of **Preceding** Subsurface Temp. Anom. (x-axis) and NDJ Niño-3 (y-axis)

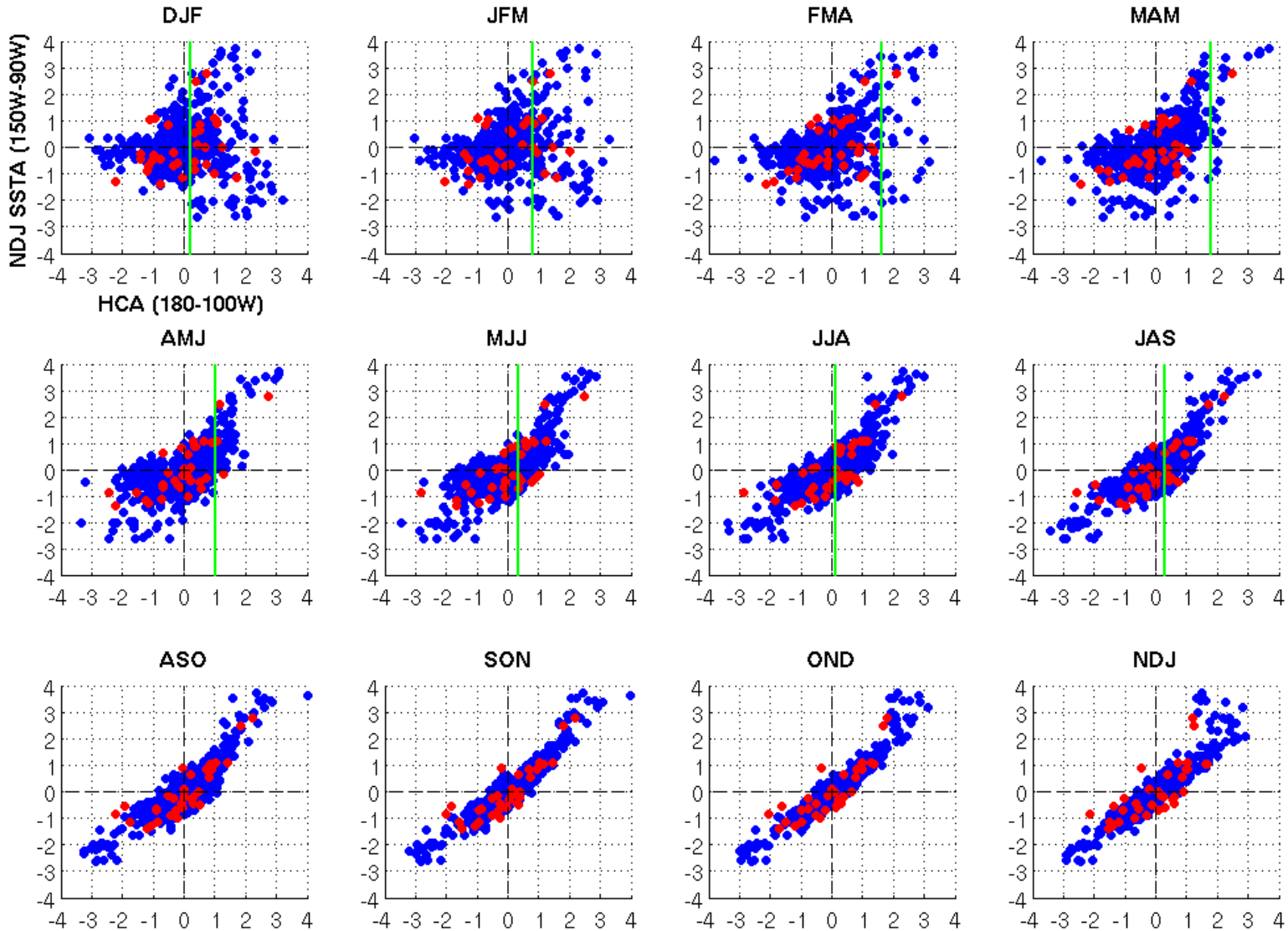
Blue: NCEP CFSv1 Red: GODAS/ERSSTv3b Green: GODAS during 2014



Also, fairly linear orientation especially after AMJ. More spread (more samples)

Scatter Plot of **Preceding** Subsurface Temp. Anom. (x-axis) and NDJ Niño-3 (y-axis)

Blue: GFDL CM2.1 Red: GODAS/ERSSTv3b Green: GODAS during 2014

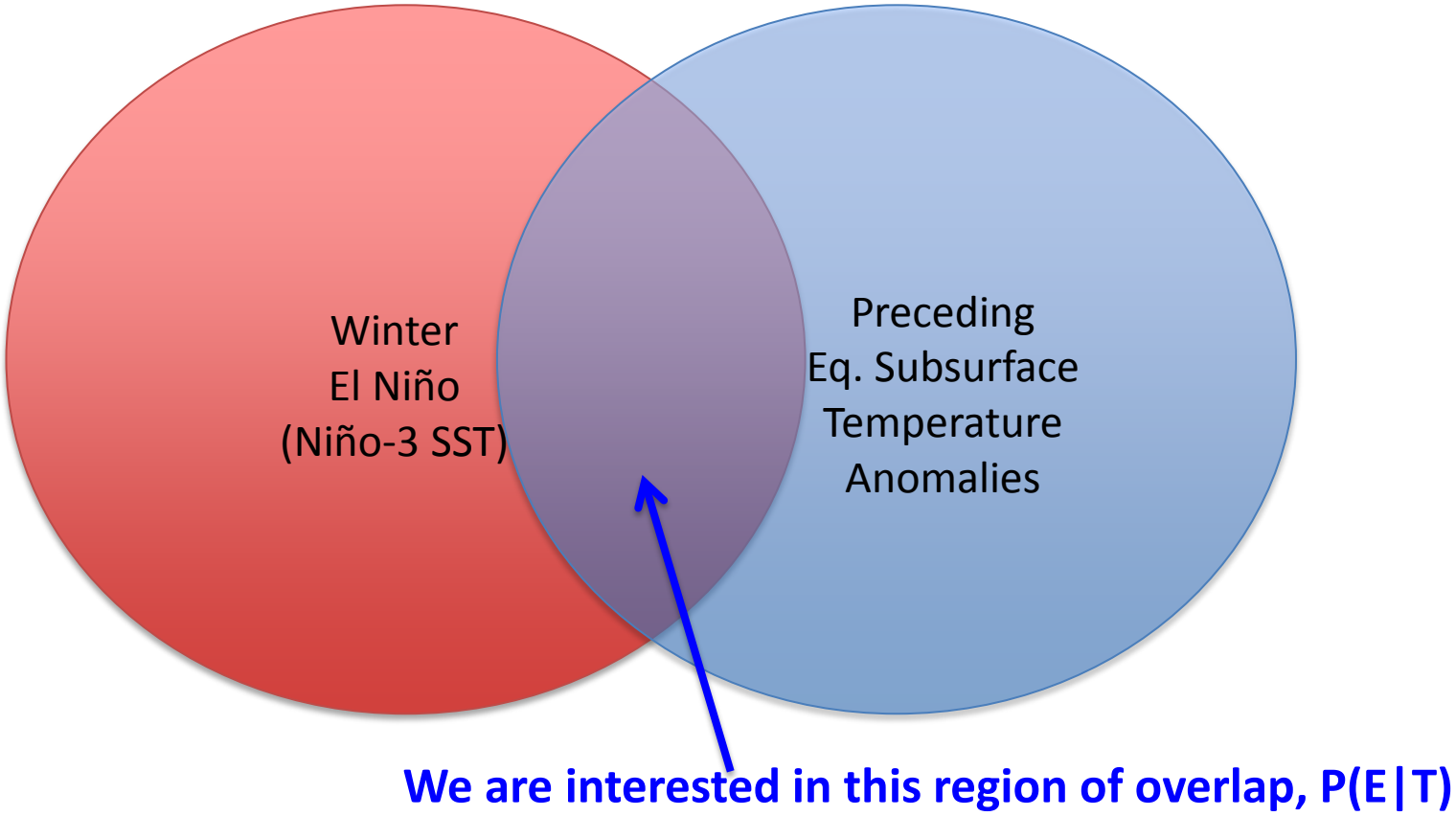


In 2nd half of year, less spread in Nino-3 values in GFDL run. More data points at the extremes.

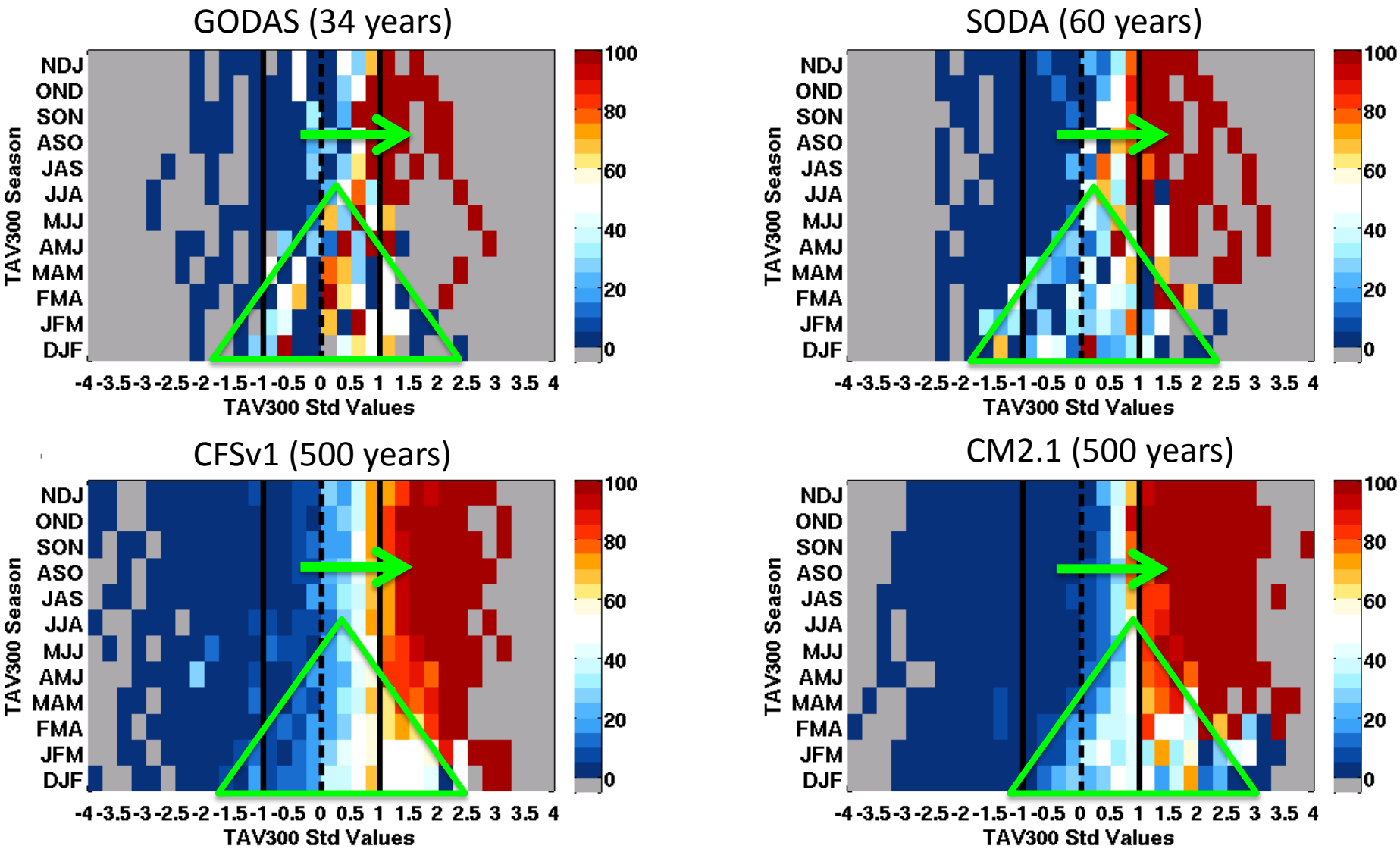
Marginal and Conditional Probabilities

Marginal Probability: P(E) "Probability of El Nino" (>0.5σ during NDJ)

Conditional Probability: P(E|T) "Probability of El Nino GIVEN *preceding* subsurface temperature anomalies"

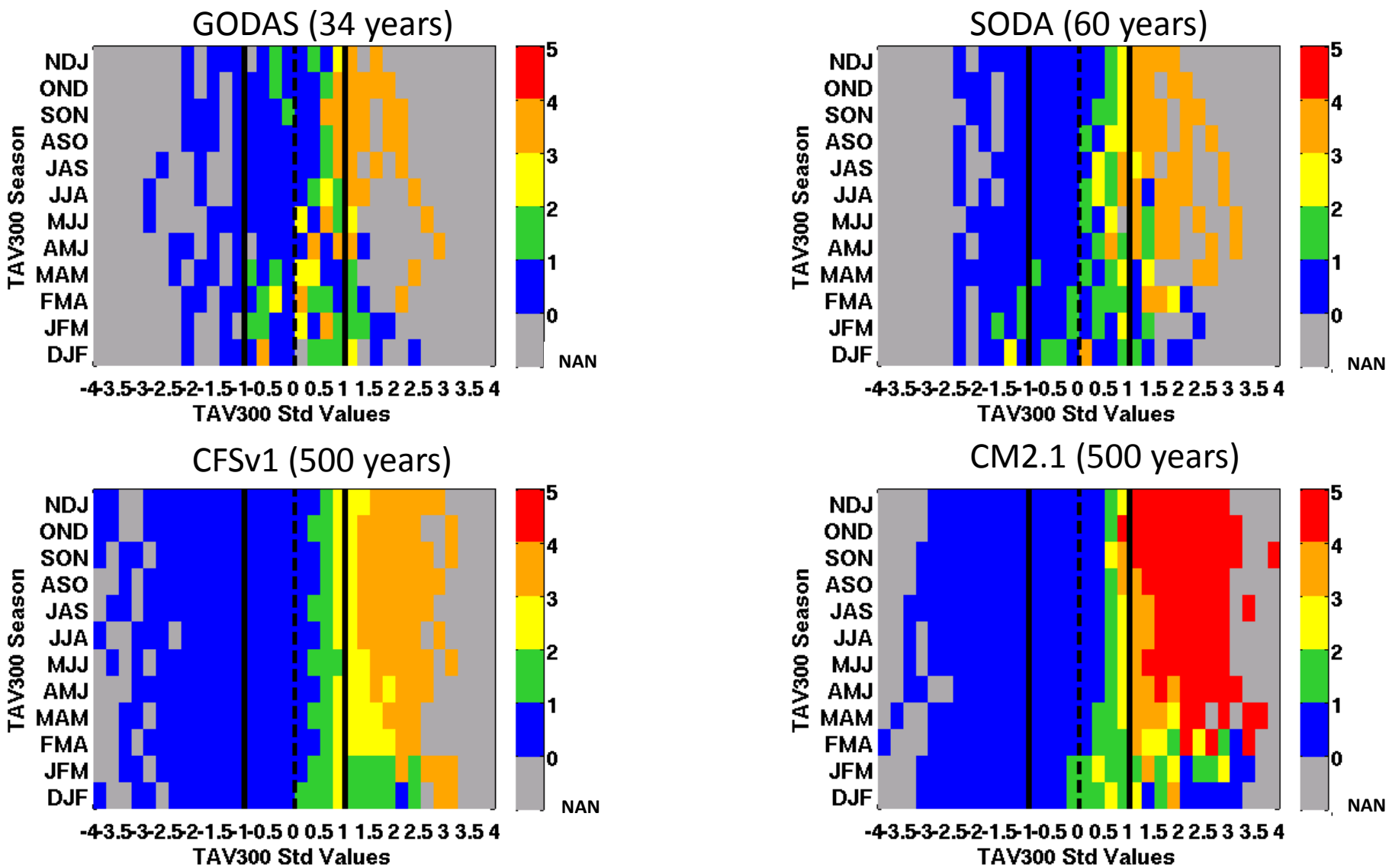


Probability of NDJ El Nino given Subsurface Temp. P(E|T)



- In GODAS/SODA: more variation among probabilities during first half of year compared to models.
- Fairly steep gradient in probabilities during second half of the year in all datasets

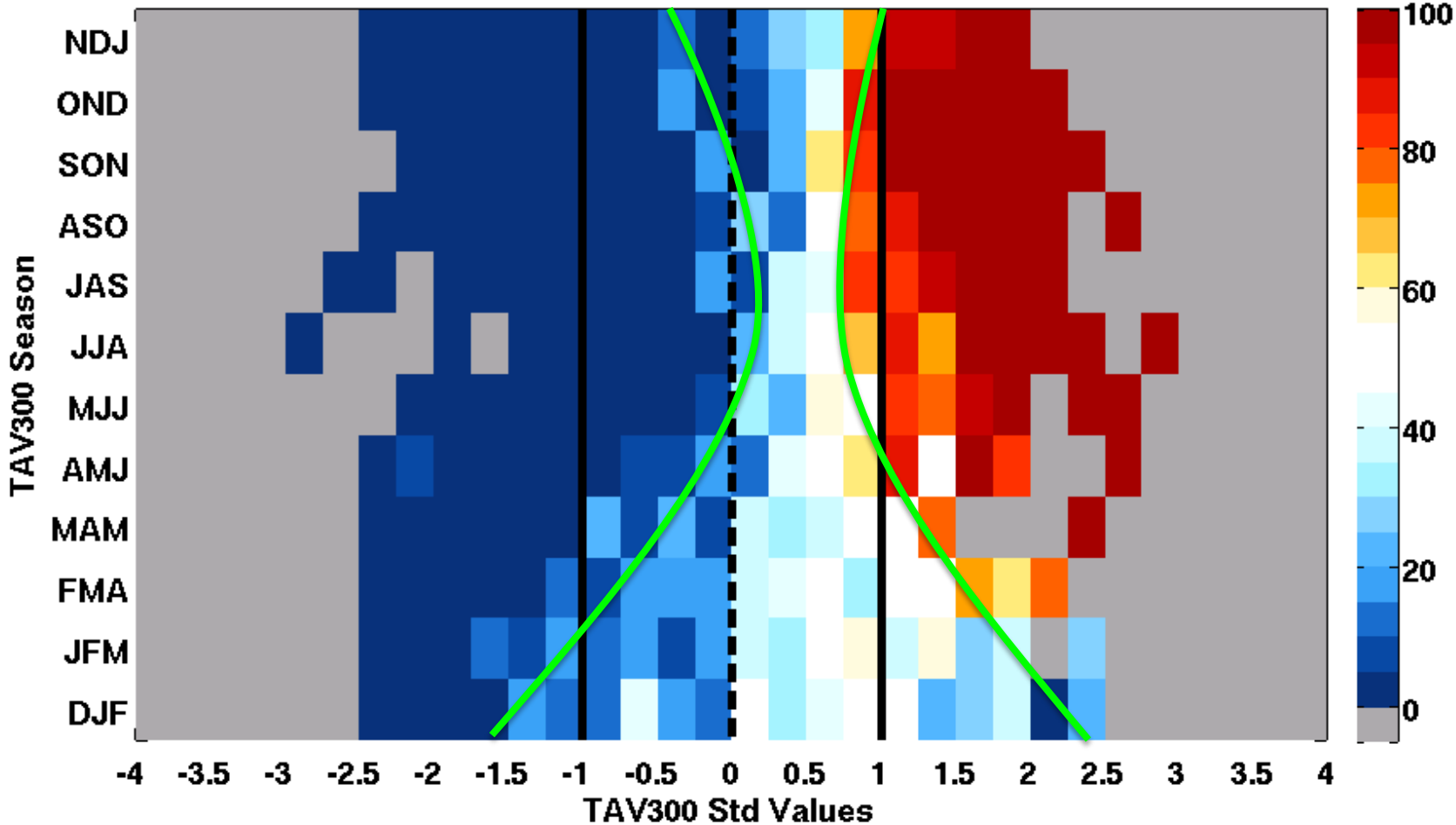
Ratio P(E|T) / P(E): How much do odds increase?



- Large enough positive subsrfc. temp. *alone* can at least triple normal odds in favor of El Niño
- Prior to AMJ, tilt toward increased chances of El Nino (ratio>1/green) for positive subsrfc. temp. values is more pronounced in the models

"Best Estimate" Multi-dataset Mean Probability of El Nino given Subsurface Temp. P(E|T)

(requires at least 3 datasets)

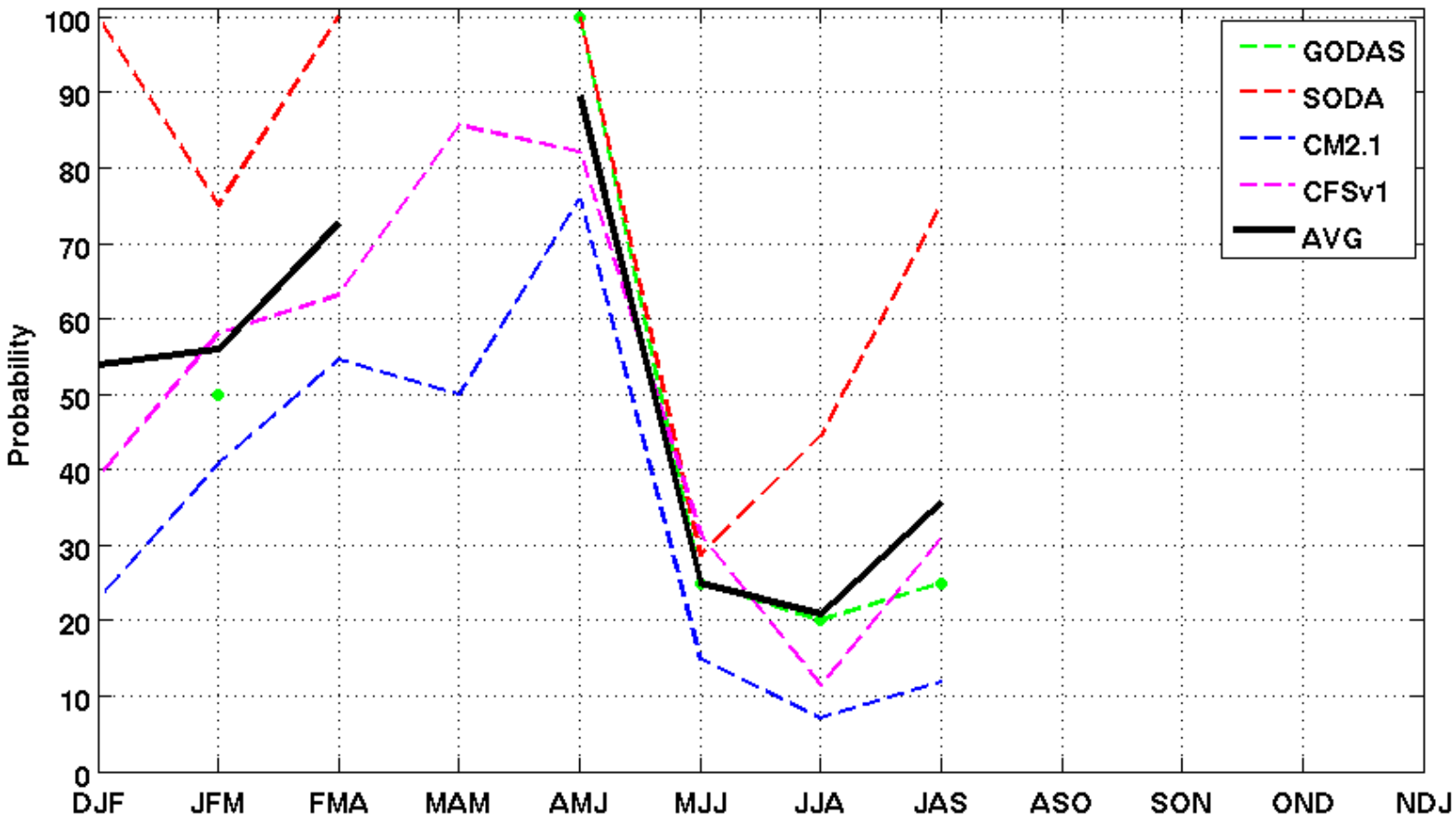


<u>Prior to AMJ:</u> Chances of El Nino are ~10-50% for wide range of subsurface temp. values. >50% chance of El Nino only occurs for large positive values (> 1sigma) during FMA-AMJ.

<u>After AMJ :</u> Chances of El Nino increase rapidly across small range of subsurface temp. values

Based on Subsurface Temperature Anomalies during 2014, what were the odds of an NDJ El Niño?

(*requires at least three datasets*)



CONCLUSIONS/FUTURE WORK

- Earlier in the year, spread of ENSO outcomes is larger, but *positive* subsrfc. temp. tilt odds toward El Niño (ratio > 1). Models appear to more strongly tilt odds in favor.

- A least squares fit (subsrfc. temp. scales with Niño-3) appear more appropriate during the second half of the year.

- Positive subsrfc. temp. large enough during FMA-AMJ 2014 for a roughly >50% chance in El Niño (AMJ: >75%). Recently, chances are closer to 35%.

- Each dataset has limitations, so the "best estimate" probability is only as good as the input

  -- Add other reanalysis/model datasets to the average

  -- Weight datasets by ability to correctly capture seasonal cycle

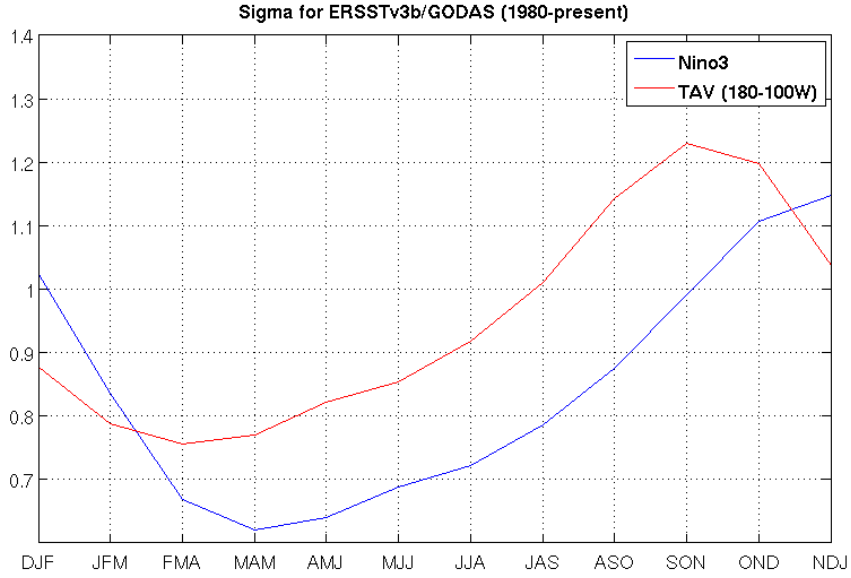
- Only establishes *potential skill* based on past records/free run models.

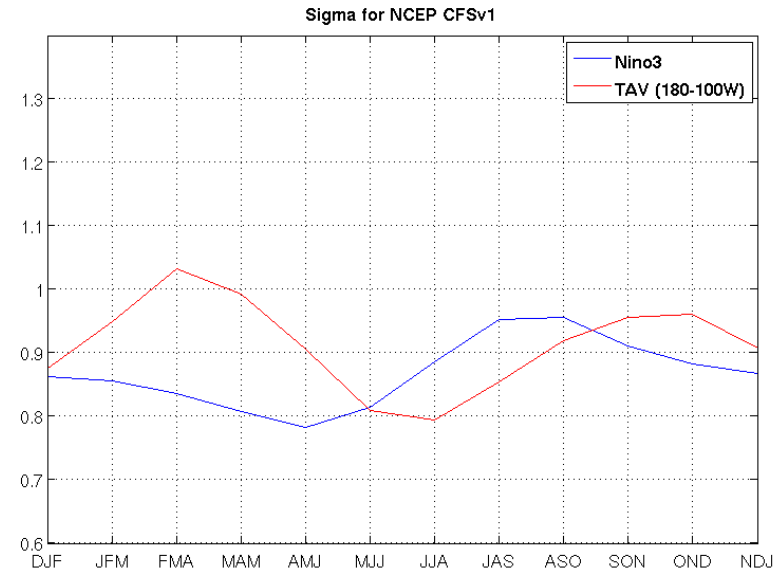
  -- Evaluate same relationships in CFSv2 hindcasts

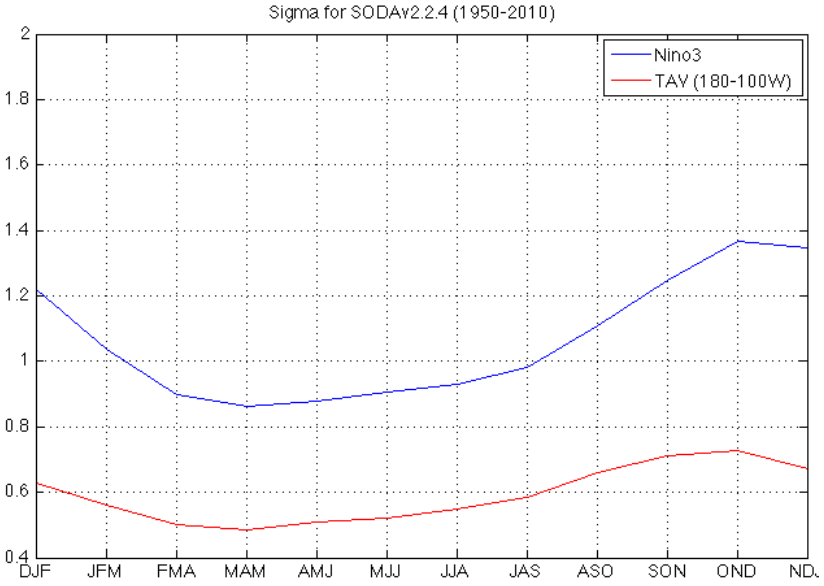
EXTRA SLIDES

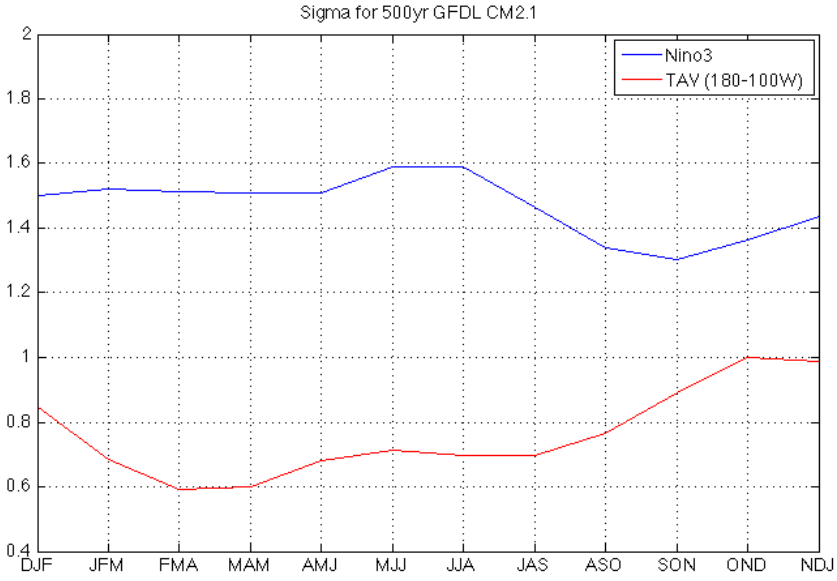
180-100W Temp. (red) and Nino-3 SST (blue) Standard Deviation for GODAS/ERSSTv3b, CFSv1, SODA 2.2.4, and CM2.1

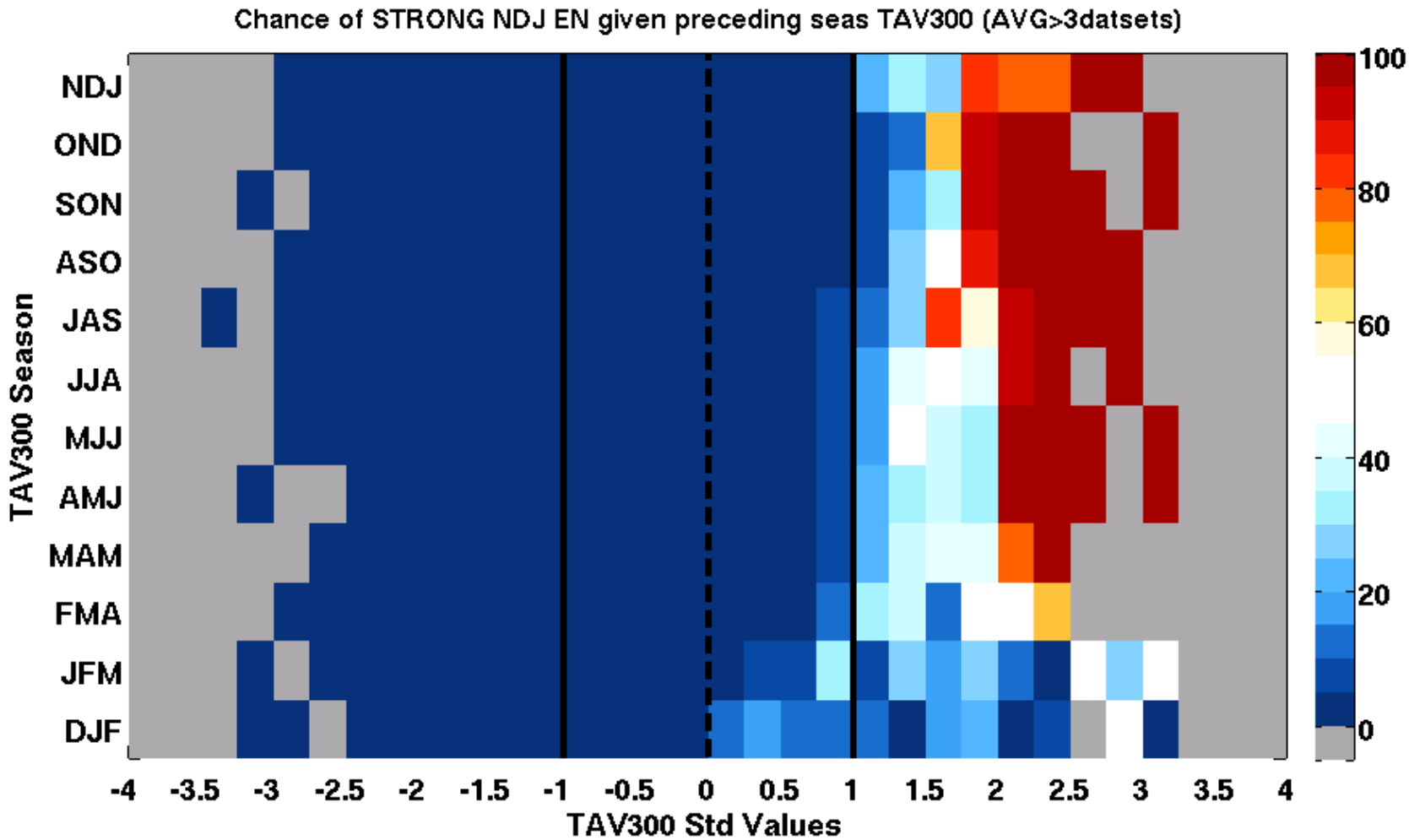
(watch out for y-axis differences)









"Best Estimate" Multi-dataset Mean Probability of STRONG El Nino given Subsurface Temp. P(E|T)

(requires at least 3 datasets)