New Model ENSO Diagnostics

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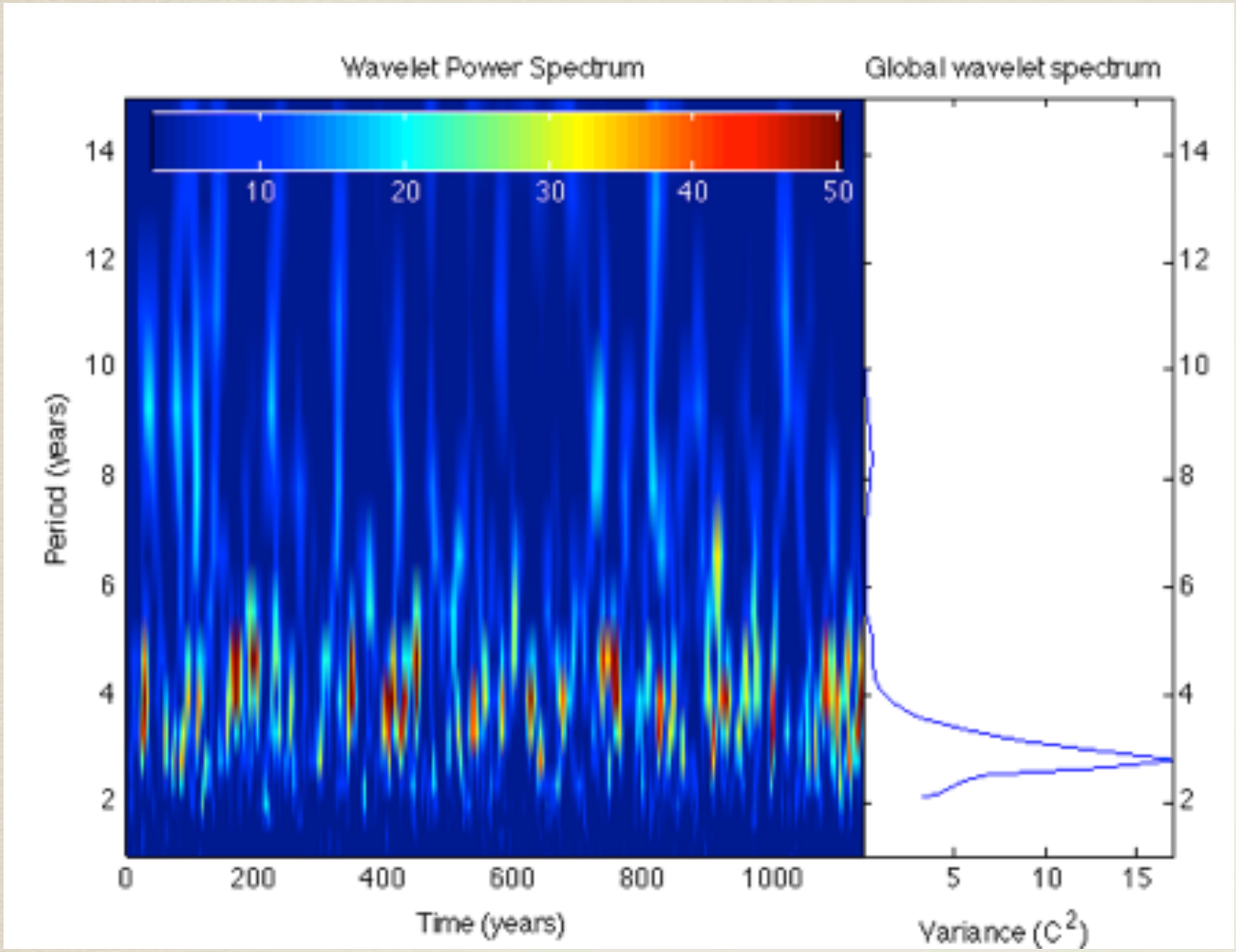
CIRES Graduate Student Fellowship

Primary model run: 1200 years, T31x3 CCSM3.5

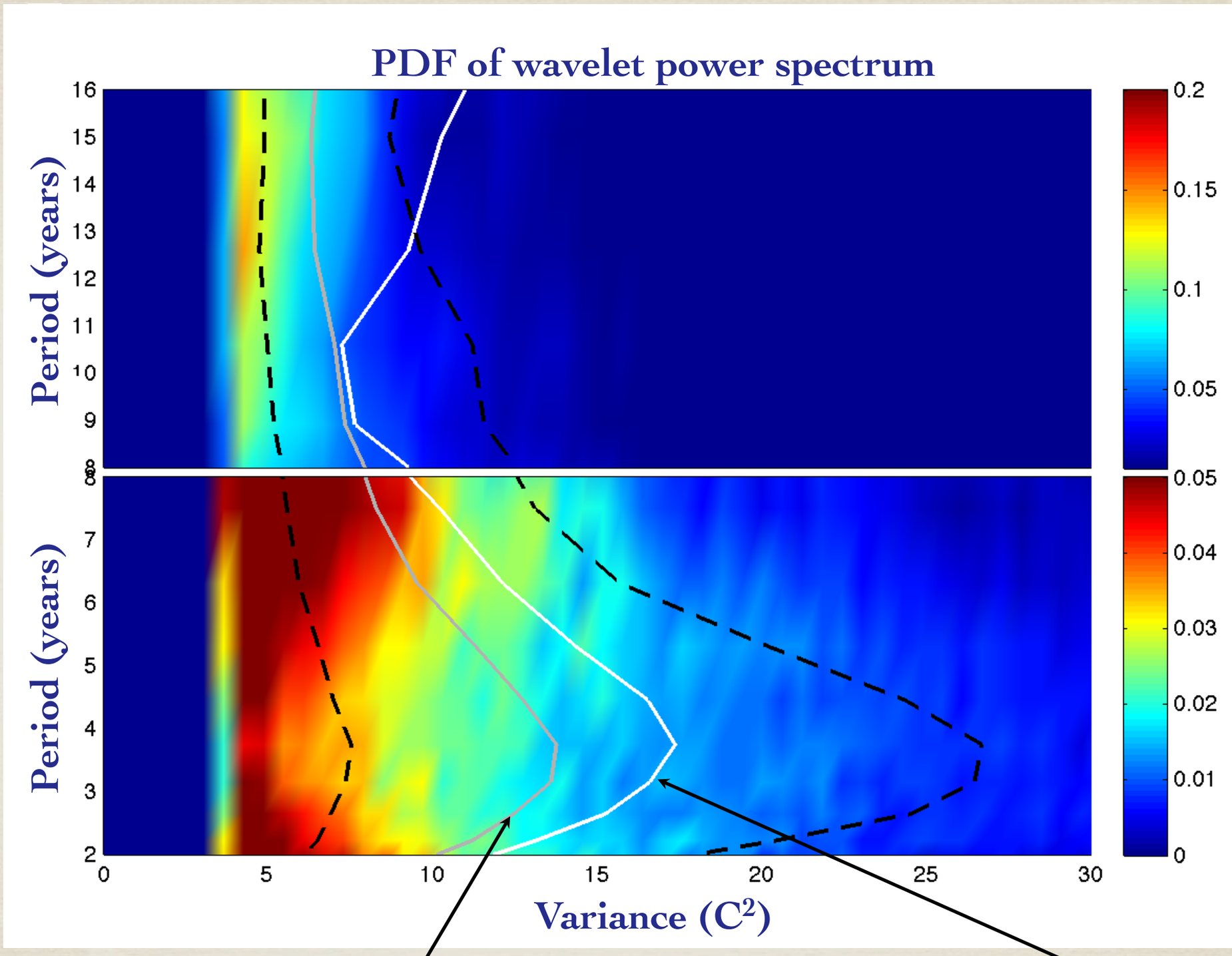


NINO3.4 SST

Global wavelet spectrum: peak near 3 years

Significant spectral variations in ENSO

Run compares well to CORE forcing hindcast



Mean from data:
Large & Yeager (2004)
covering 1949-2003

Model median

Recipe for Testing ENSO

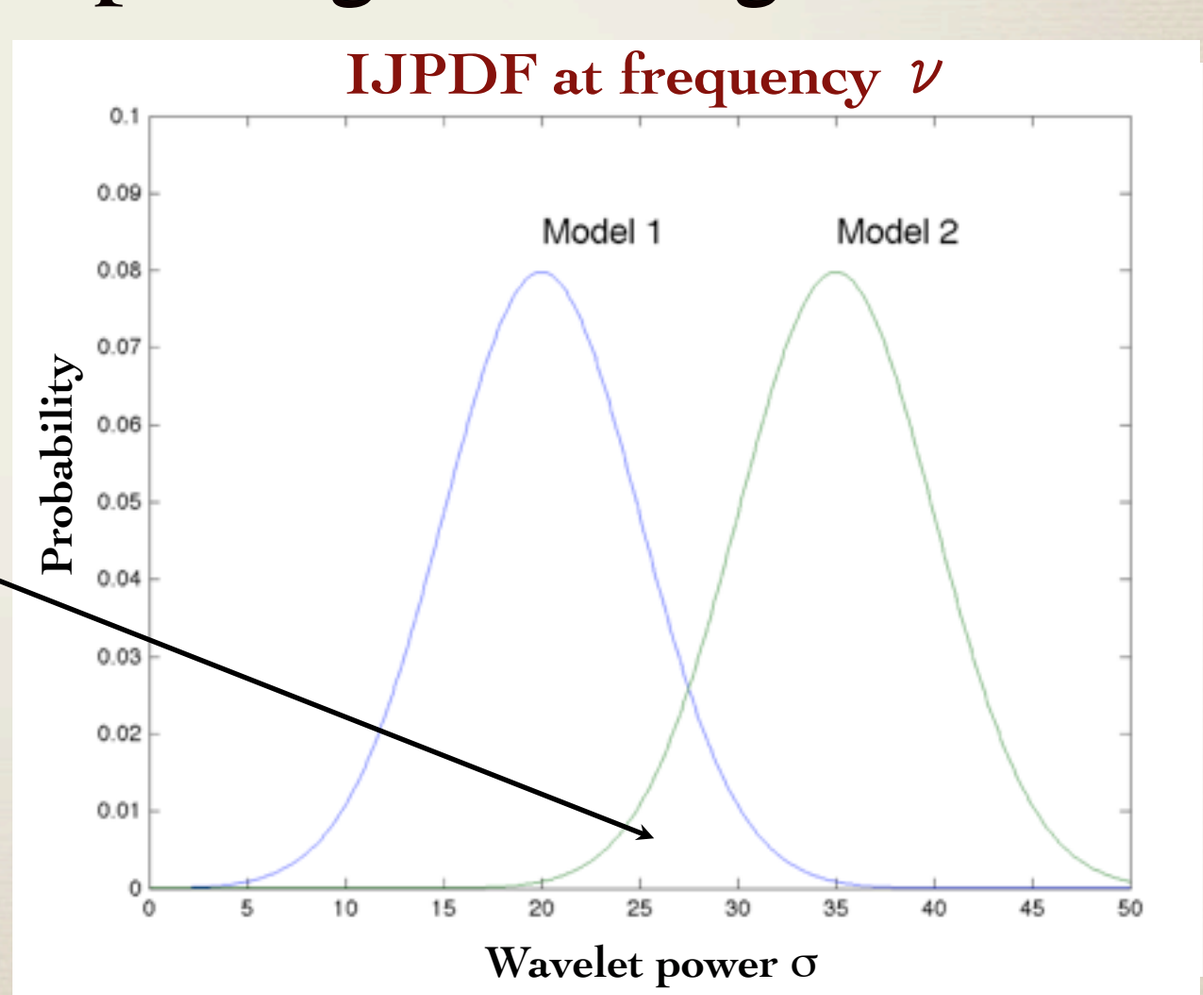
0. Pick a time series, any time series... I use NINO3.4 SST.

1. Form the probability distribution function of the wavelet power at each frequency

2. Calculate the amount of overlap using the "integrated joint PDF"

$$IJPDF(\nu) = \int_0^\infty F(\sigma,\nu)d\sigma = \int_0^\infty f_1(\sigma,\nu)f_2(\sigma,\nu)d\sigma$$

Result is between 0 and 1



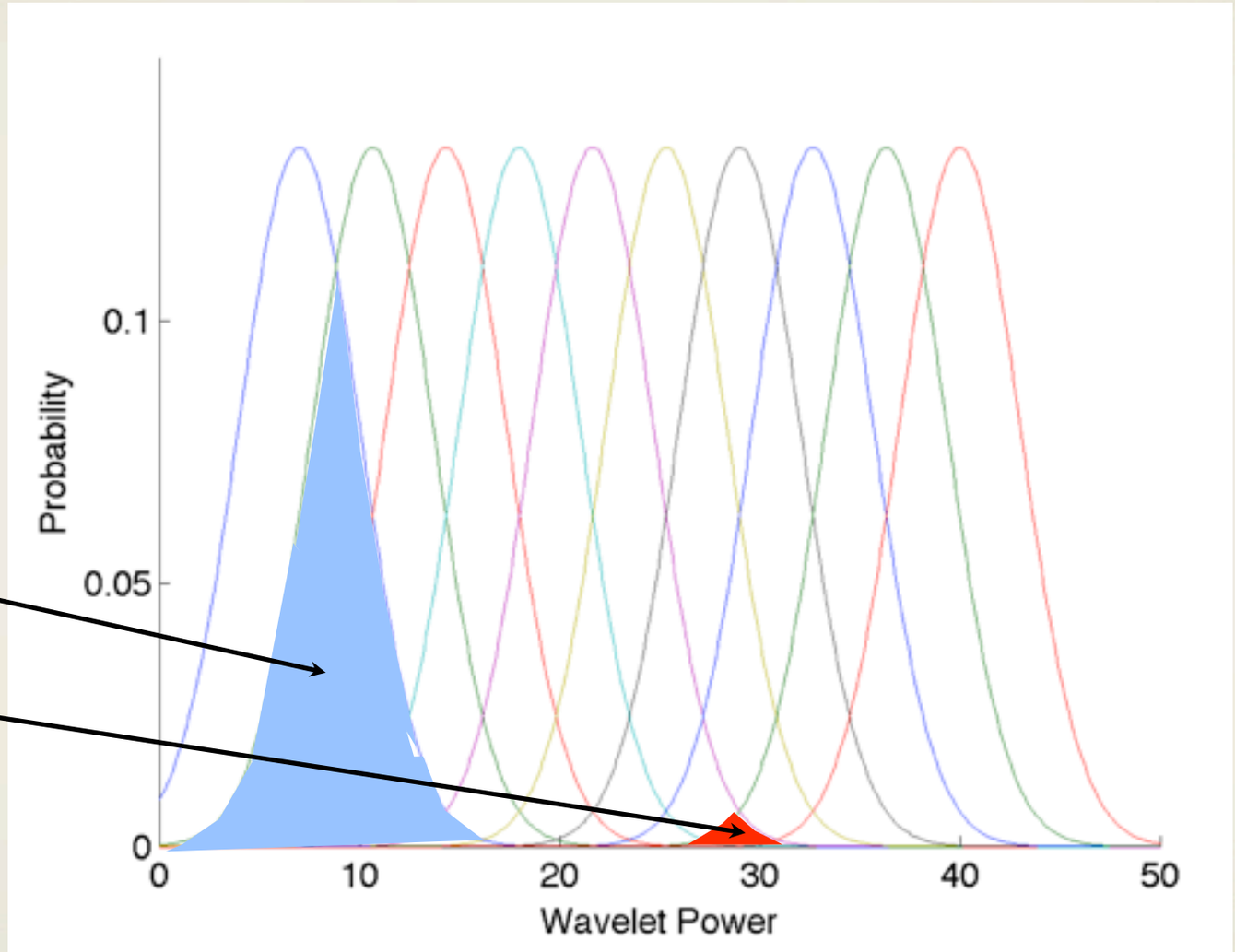
Recipe for Testing ENSO

3. Find confidence intervals using subsamples of the data

Range of IJPDFs will be derived:

Large overlap

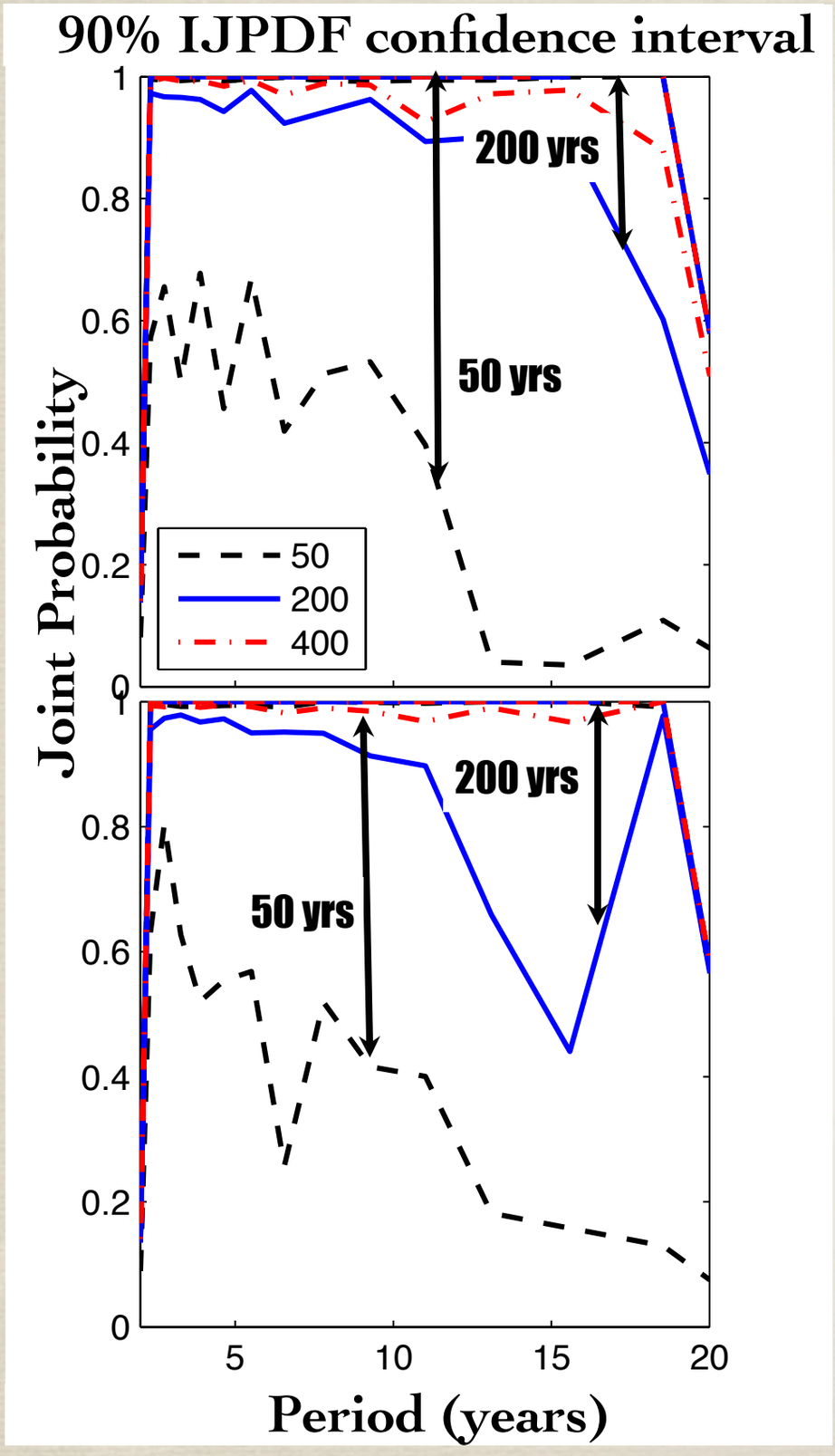
Small overlap



90% confidence intervals: distance between 5th, 95th percentiles of IJPDF dist.

4. Hypothesis testing for consistency between time series

EXAMPLE 1: Model "Self-Overlap"



Take all possible subintervals of a given length

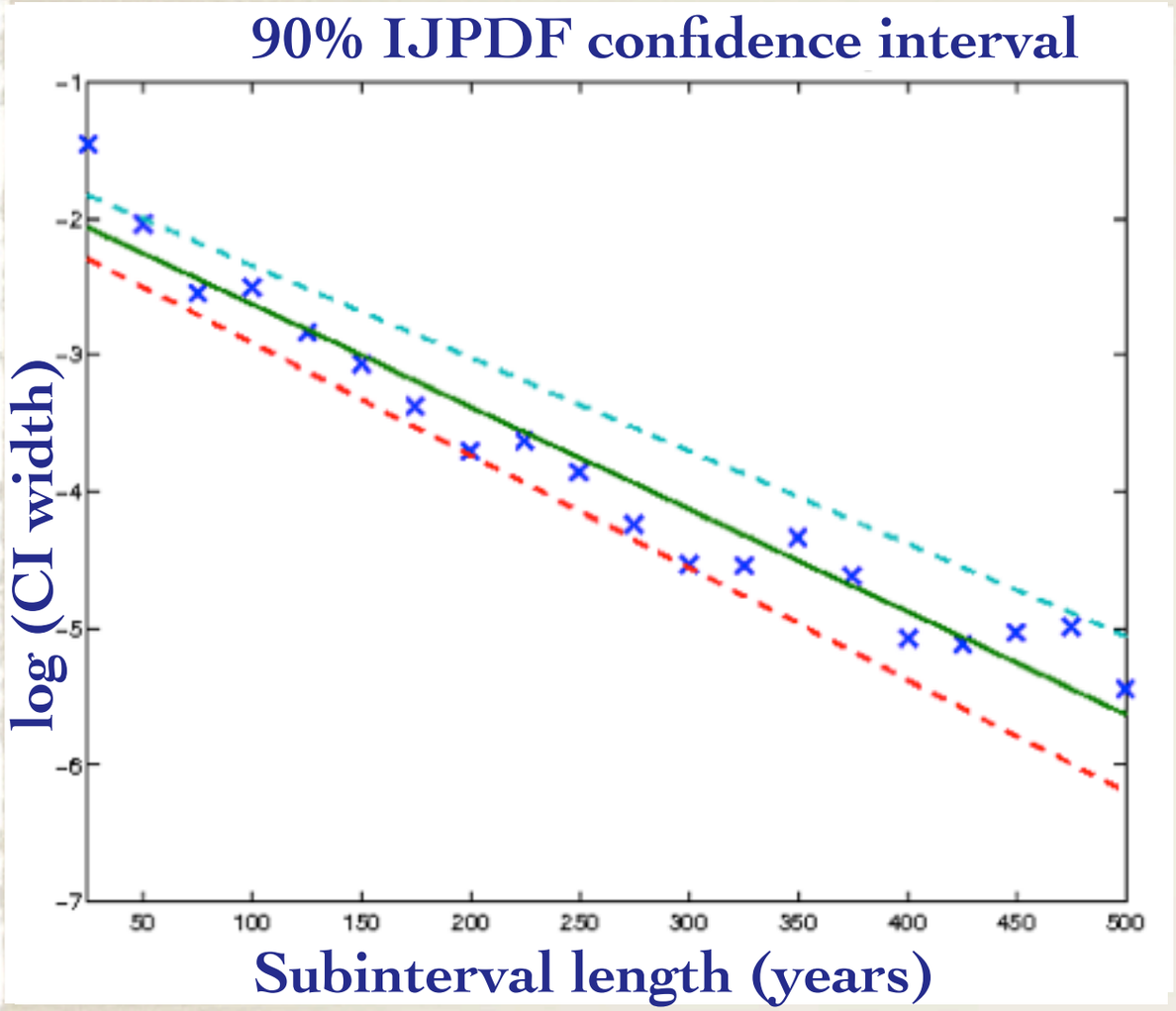
Compute IJPDF values for subintervals vs. entire run

This forms its own distribution

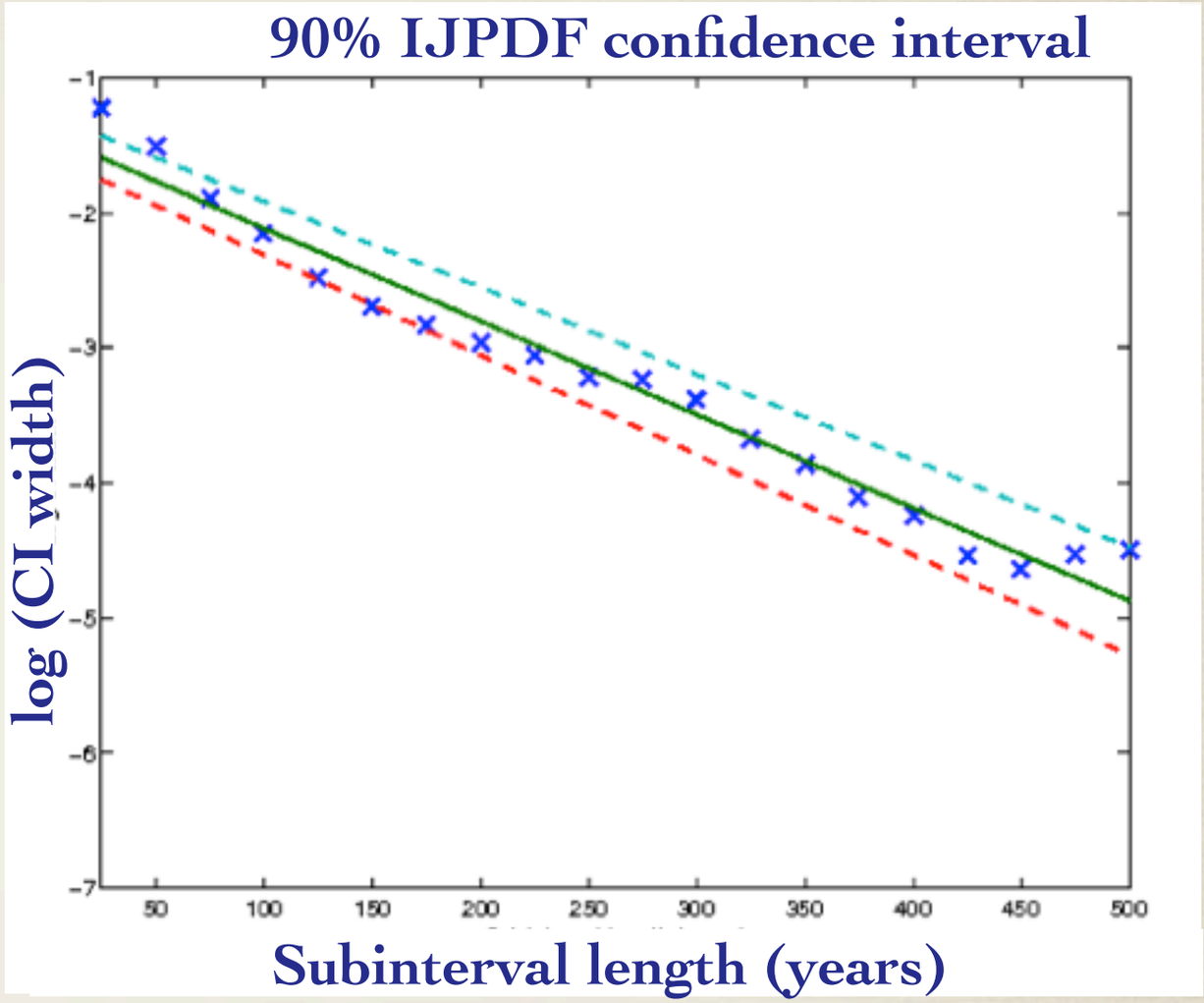
90% confidence interval = distance between 5th, 95th percentiles

EXAMPLE 1: Model "Self-Overlap"

1200 year CCSM3.5 run



2000 year GFDL CM2.1 run



90% confidence interval gets smaller with "chunk" length

Dependence is ~exponential

FIT SLOPE IS IDENTICAL TO 90% CONFIDENCE!

Why Test Model Self-Overlap?

1. Amount of overlap between "chunks" of a run and the full run is dependent on the "chunk" length

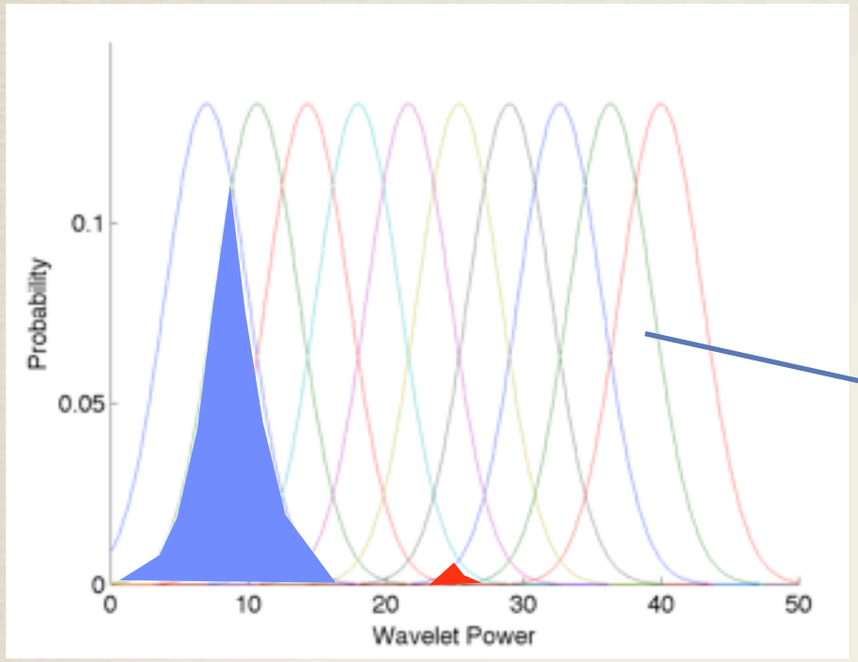
2. The dependence holds across models

3. This can be used to predict how long you should run any climate model for a given accuracy

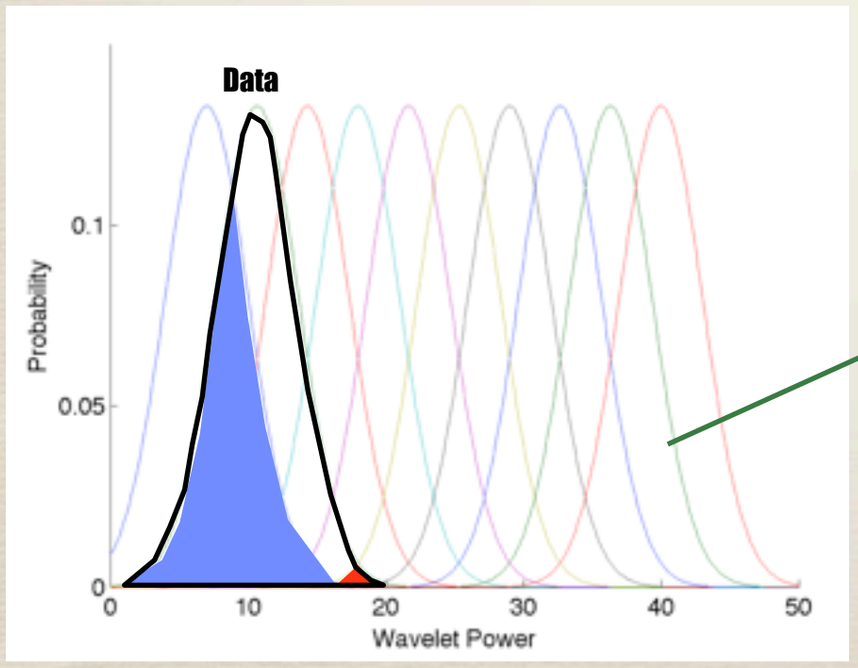
for example: to get within 10% of "real" ENSO, run for at least 250 years

Hypothesis Testing Procedure

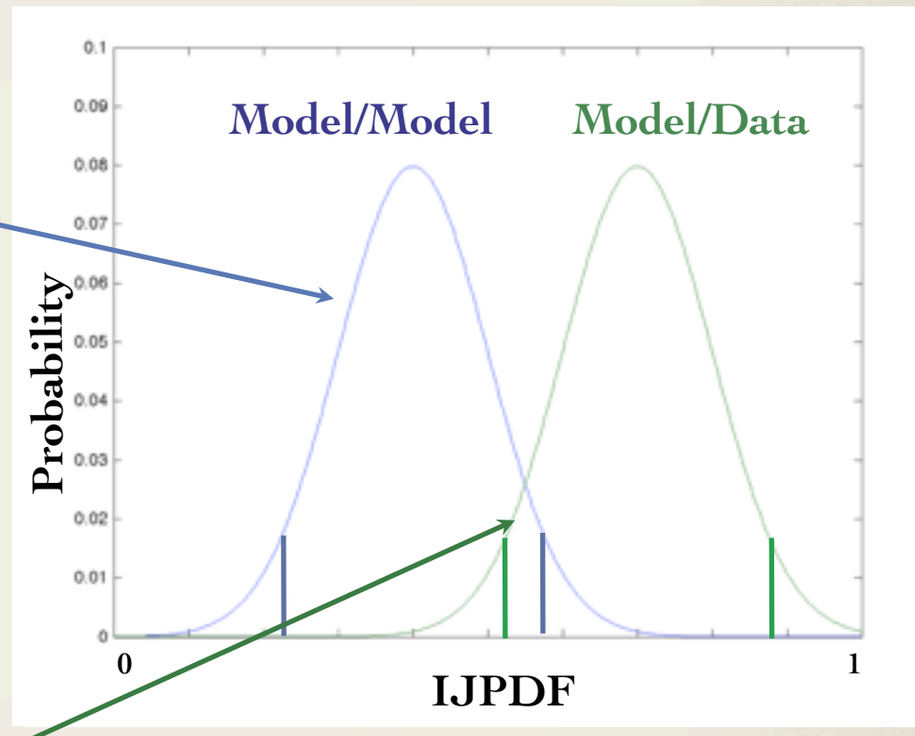
Model Subintervals vs. Each Other



Model Subintervals vs. Data



Construct two IJPDF distributions



Do confidence intervals overlap at significance α?
No: reject null (distributions differ)
Yes: do not reject null

Why Hypothesis Testing?

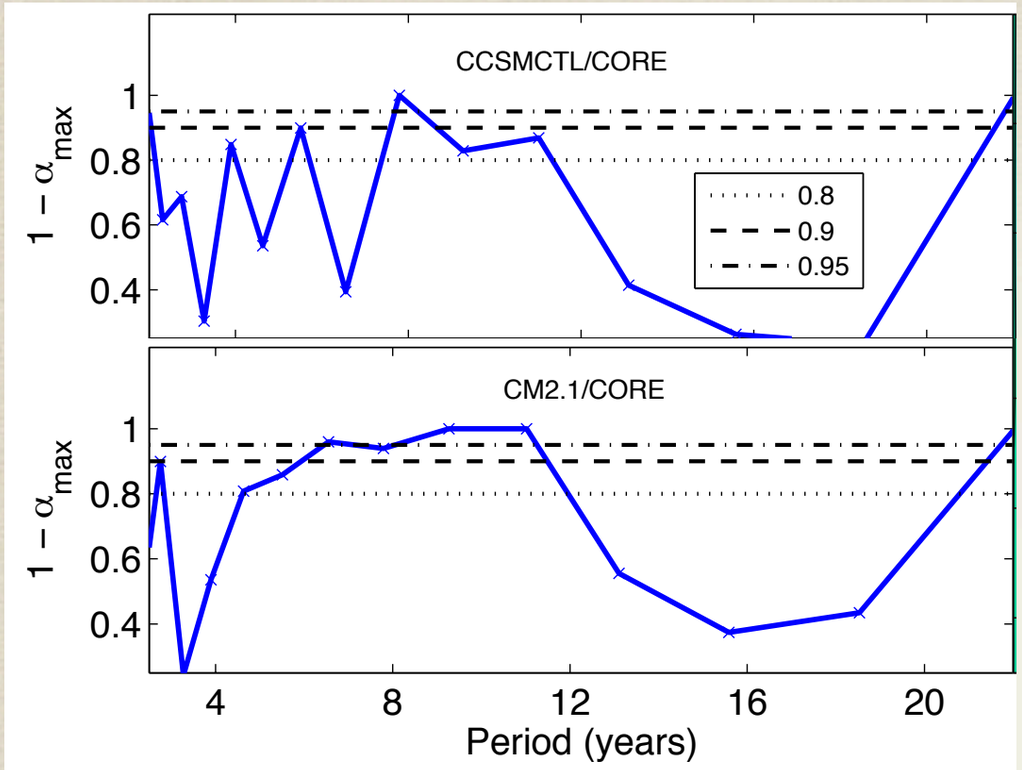
1. Quantifies amount of agreement between model runs/ model and data, at any frequency

2. Minimum run length needed to measure statistically significant differences can be obtained

3. Accuracy of short model runs can be tested without running for a long time

4. Tuning can be performed as a function of frequency

Hypothesis Testing Results



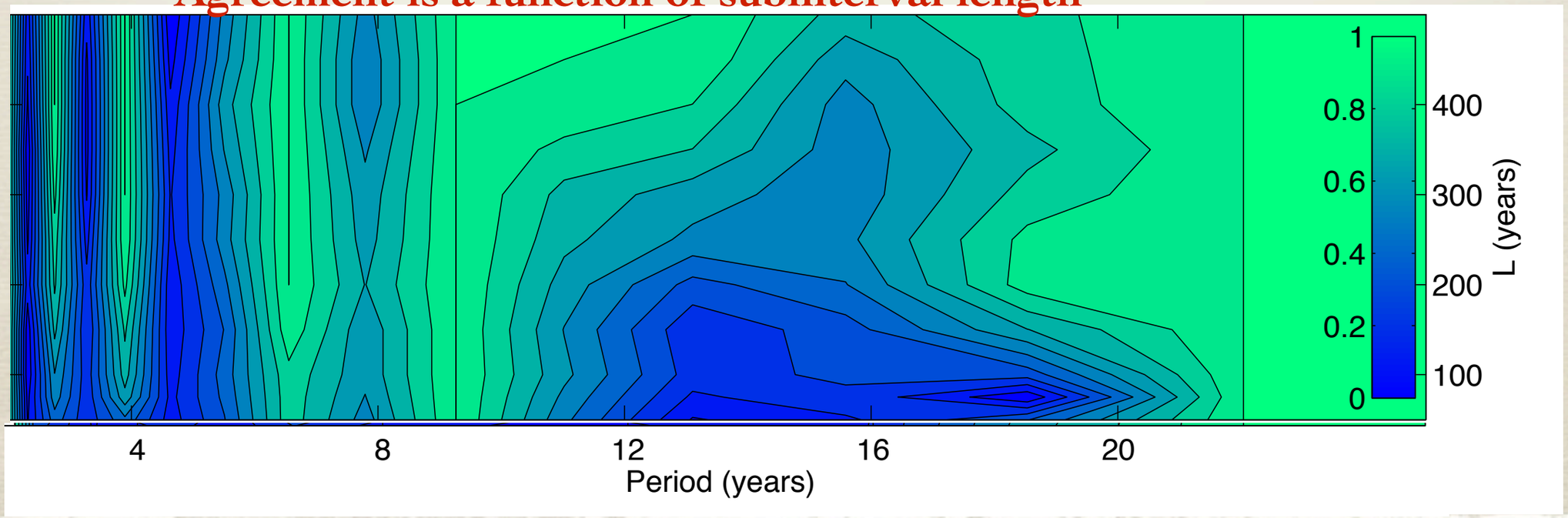
1 - α_{max}: minimum significance at which two distributions differ

CCSM3.5: consistent with data at 80-90% for most of ENSO band

CM2.1: differs from data at > 90% for most of ENSO band

CCSM3.5 vs. CM2.1: differ at >90% in several bands.

Agreement is a function of subinterval length



Conclusions

Statistically robust way to measure agreement between time series

Method is universal - any time series from any source

Range of self-overlap falls off exponentially with length

Universal "scaling" relation, applies across models: at least 300-400 years needed

CCSM3.5 agrees with observations through most of the ENSO band

CCSM and CM do NOT agree in the 4-8 year band

Neither model performs well at long periods