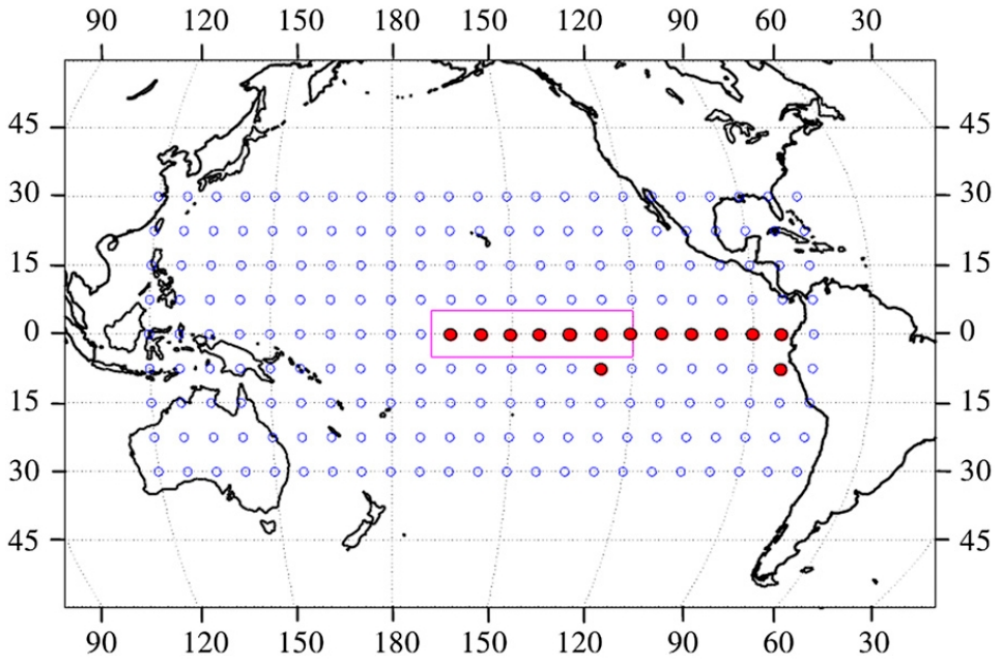
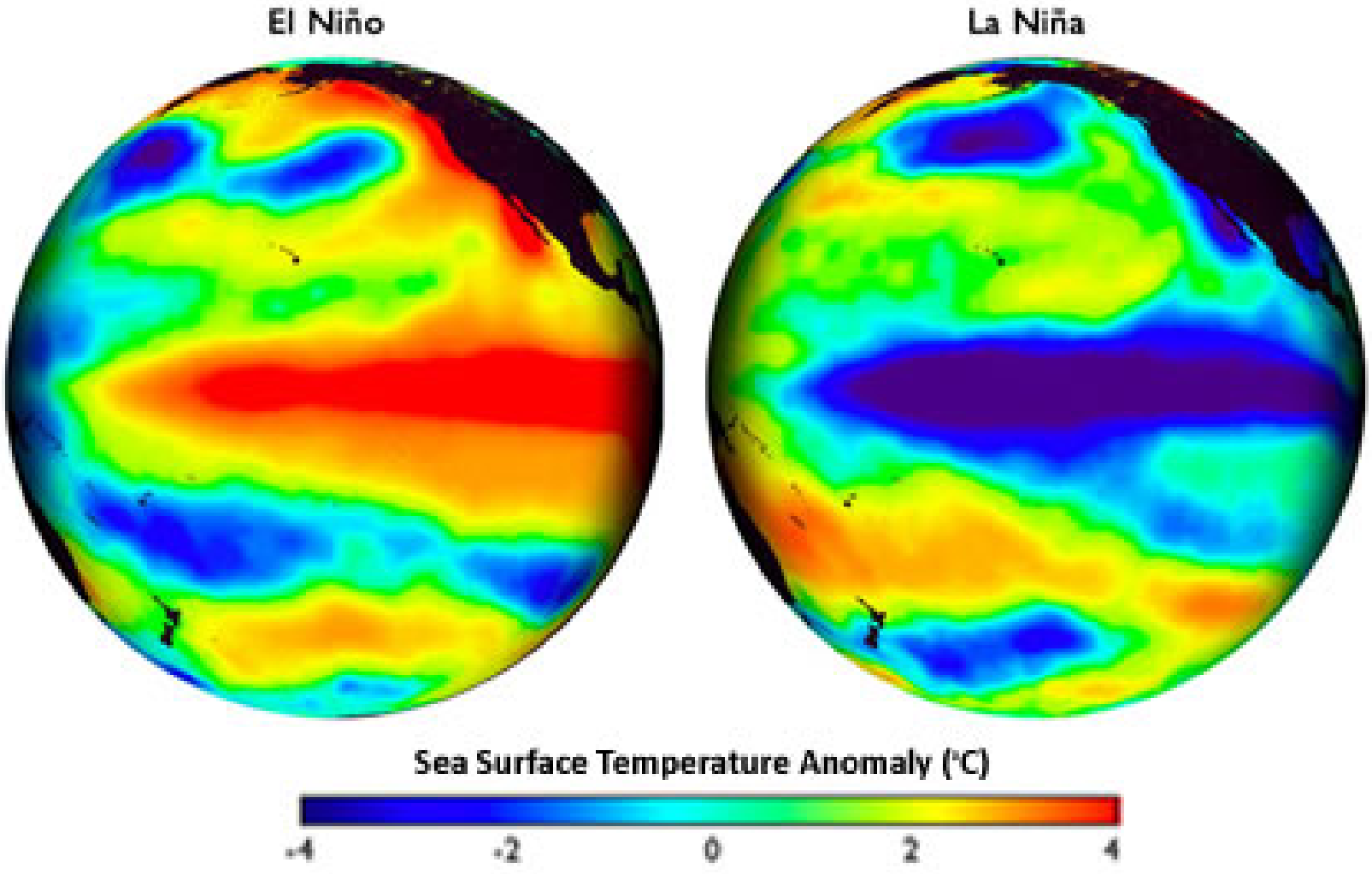
CLIMATE NETWORKS



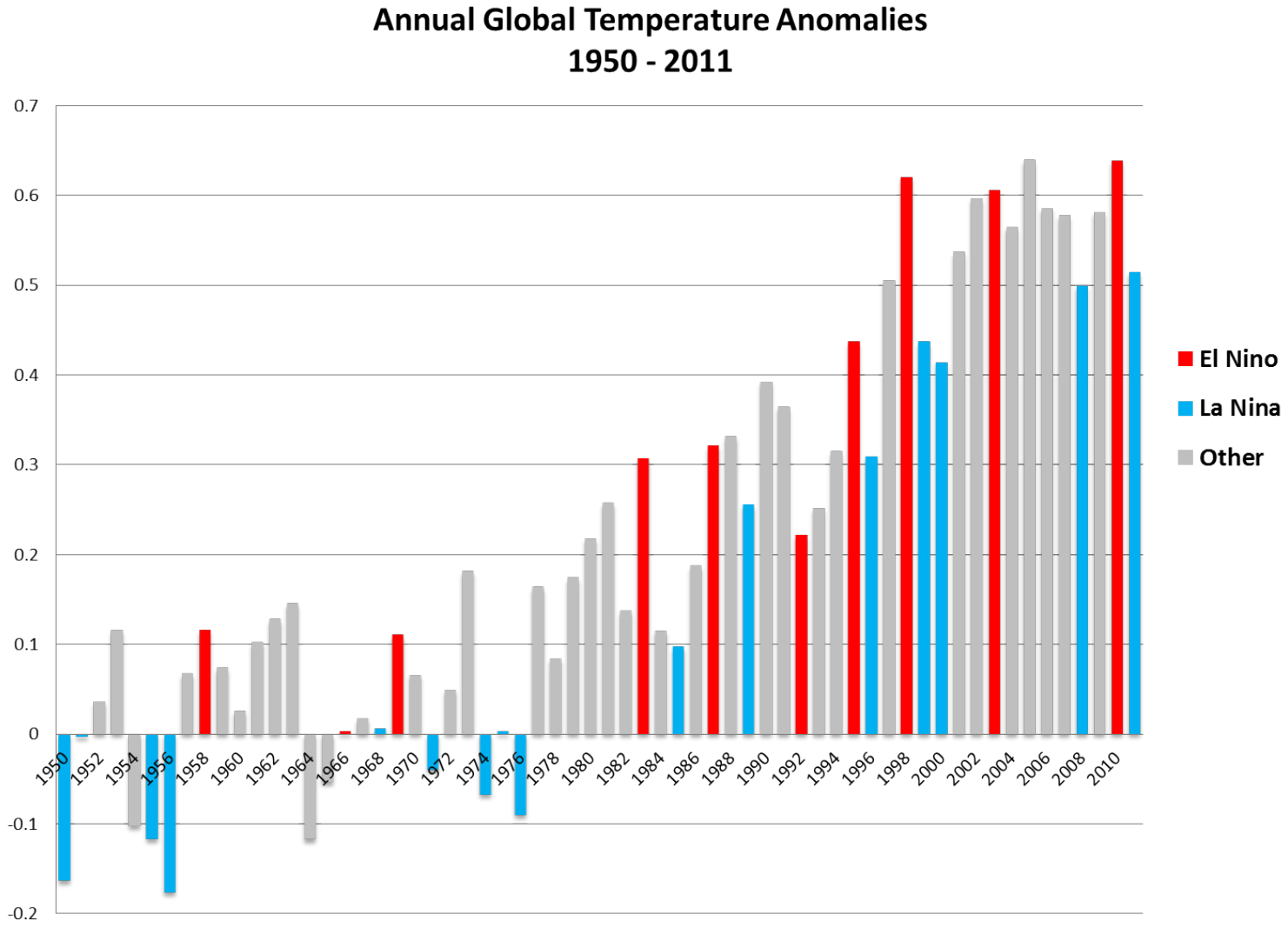
The Azimuth Project

John Baez, Jan Galkowski, Graham Jones, Nadja Kutz, Daniel Mahler, Blake Pollard, Paul Pukite, Dara Shayda, David Tanzer, David Tweed, Steve Wenner *et al*

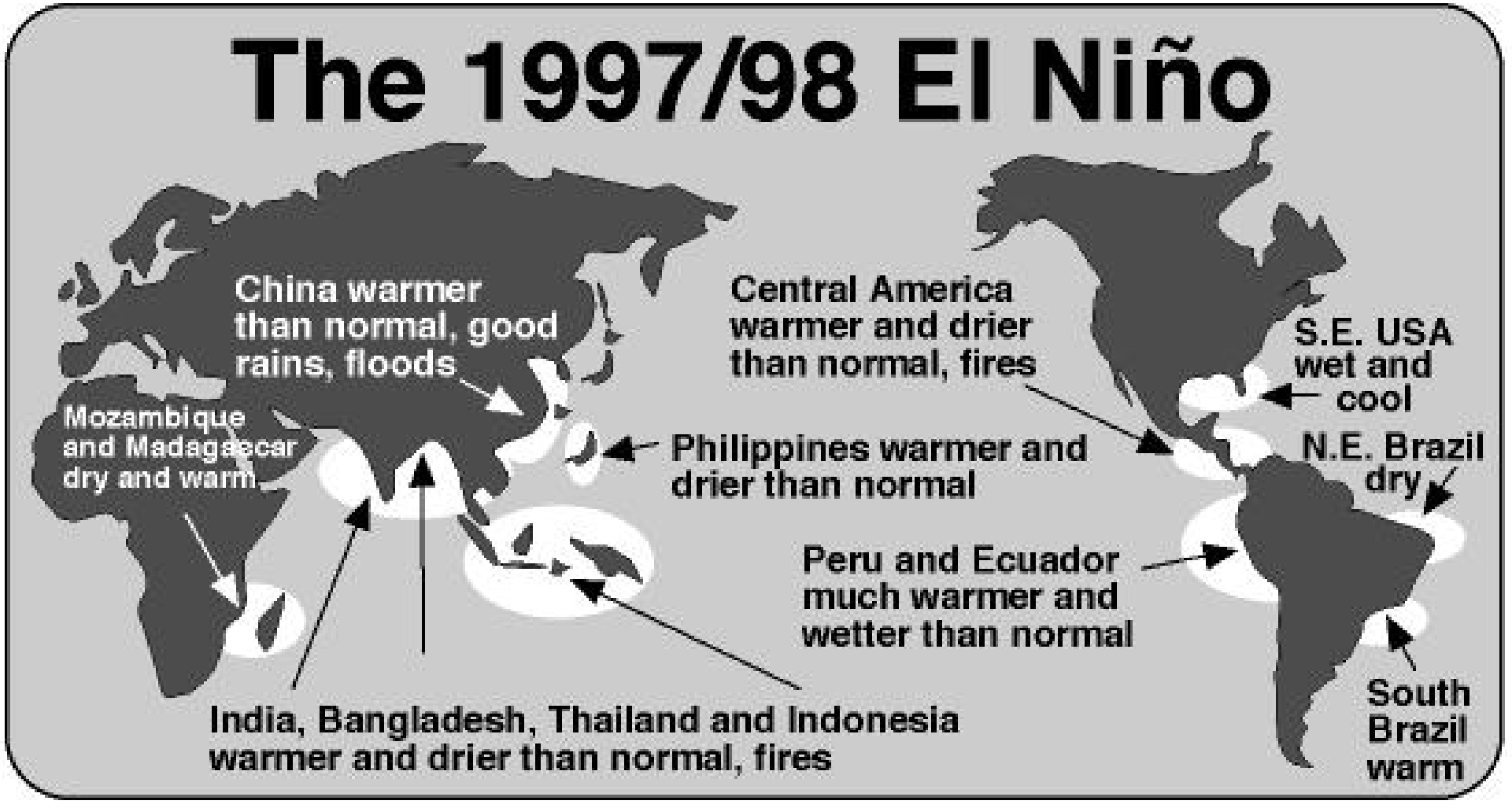
What is El Niño — and its counterpart, La Niña?



El Niño heats up the whole Earth. La Niña cools it down:

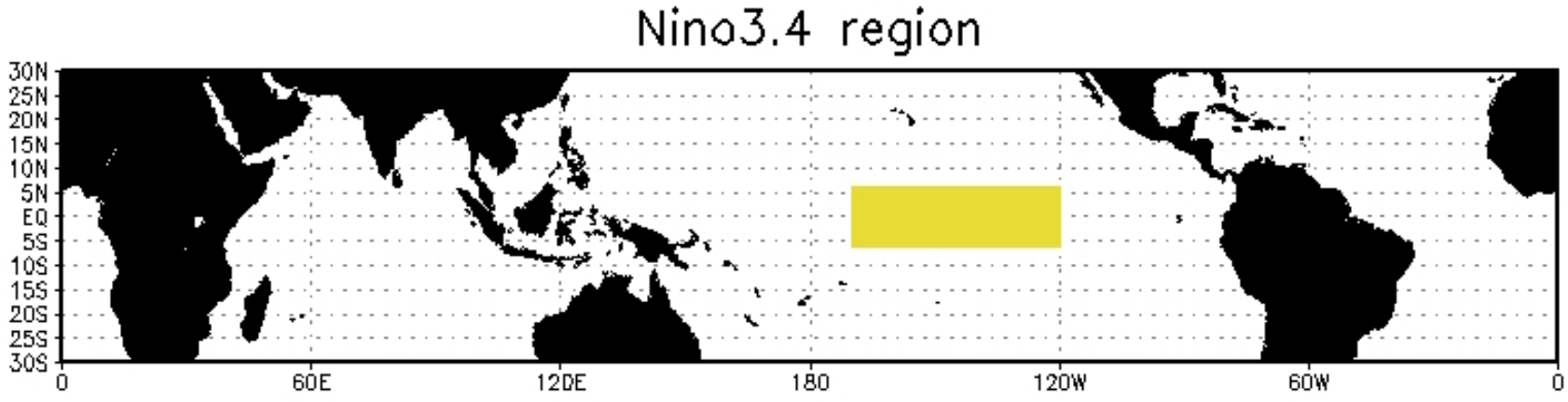


El Niño can cause billions of dollars of damage!

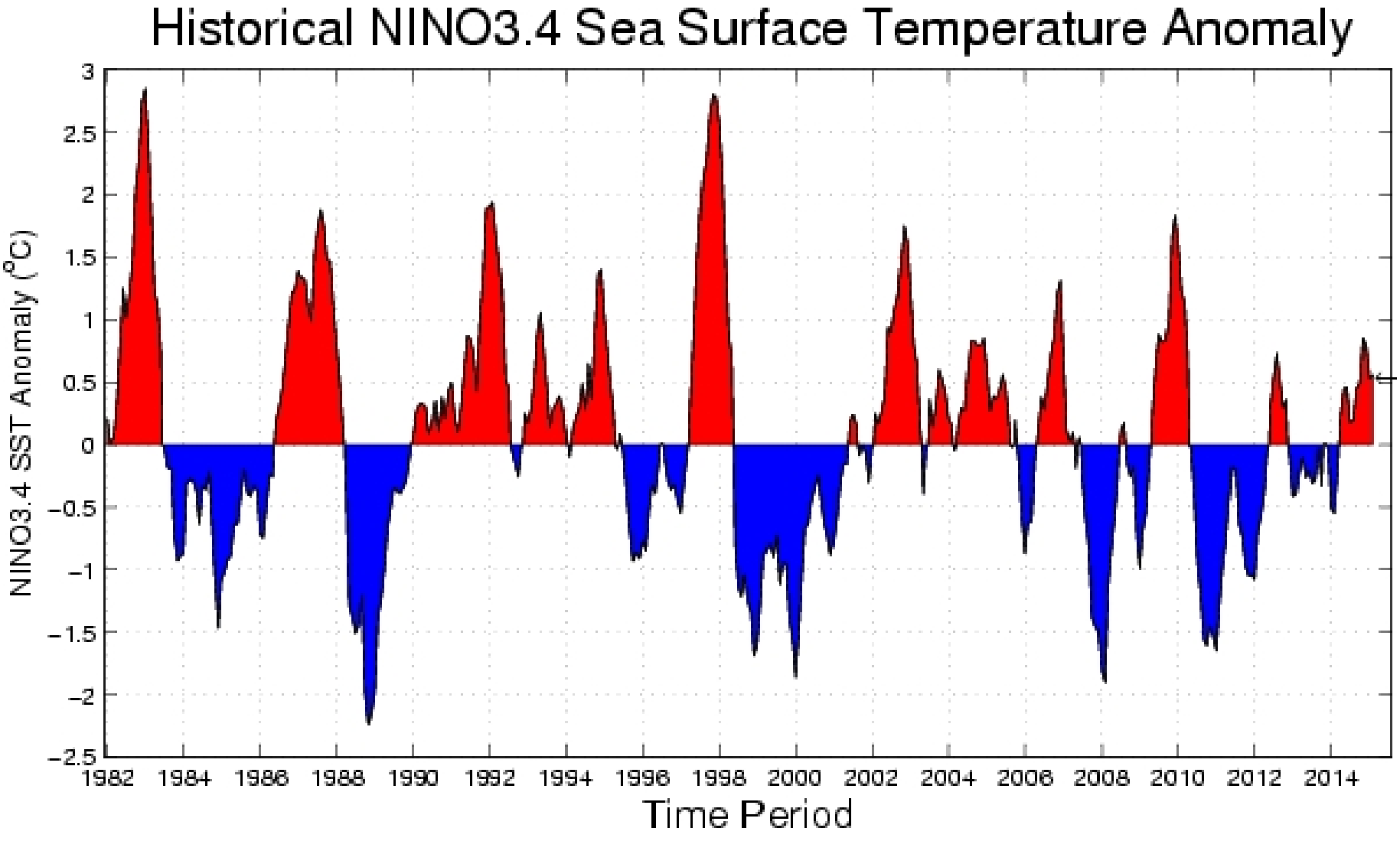


Two closely correlated signs of El Niño:

1) Increased sea surface temperatures in this region:



The **temperature anomaly** in this region—how much warmer it is than usual for this time of year—is called the **Niño 3.4 index**.


Historical NINO3.4 Sea Surface Temperature Anomaly
NINO3.4 SST Anomaly (°C)
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Time Period

2) A decrease in air pressures in the *western* side of the Pacific compared to those further *east*. This is measured by the **Southern Oscillation Index** or **SOI**.

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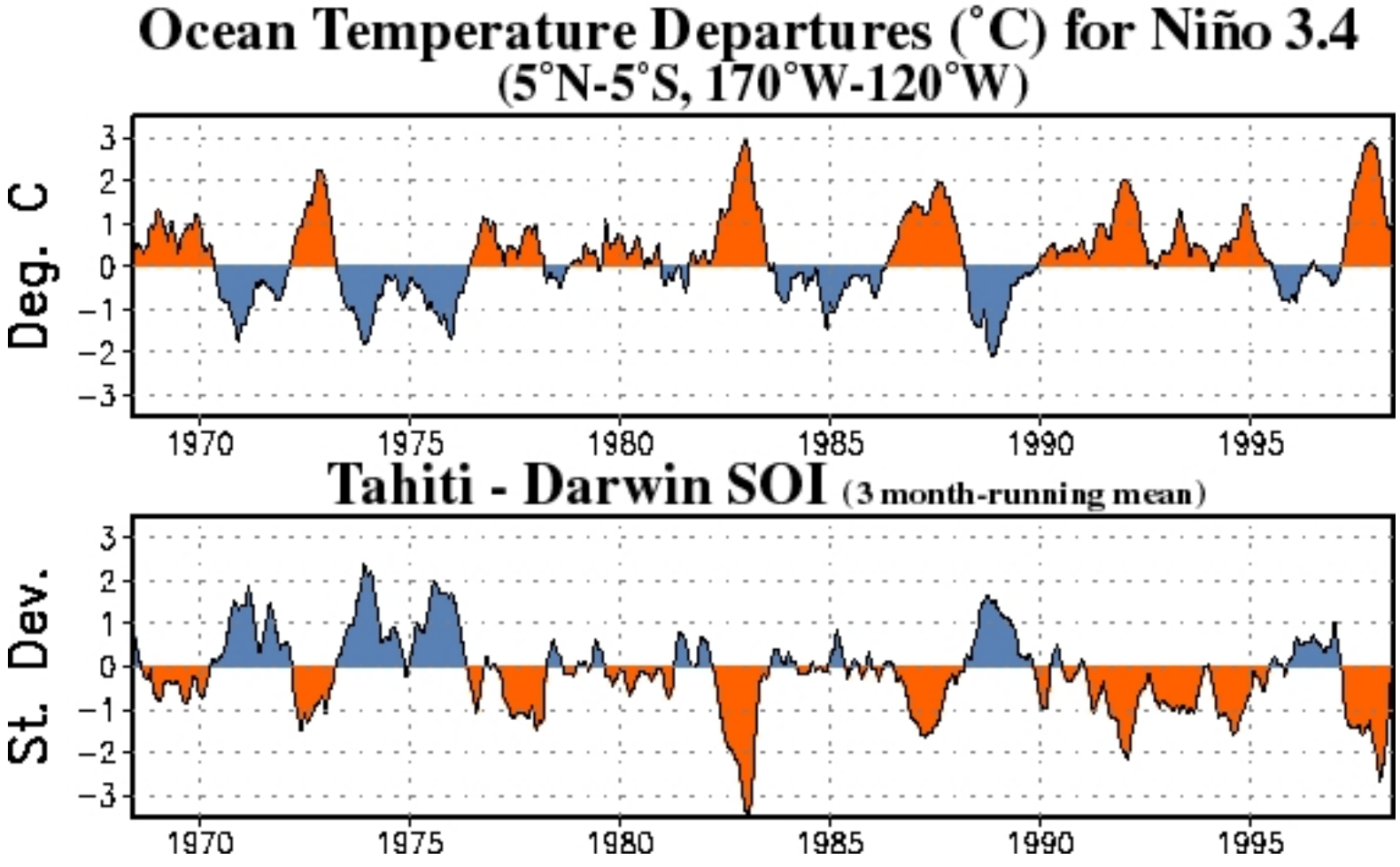
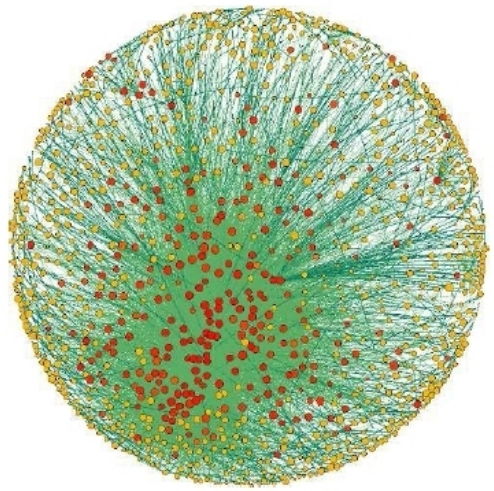


People are starting to study the El Niño Southern Oscillation using ‘complex network theory’.



Vitali, Glattfelder and Battiston:
The network of global corporate control

In Complex Networks in Climate Dynamics, Donges *et al* took daily surface air temperatures on a grid and computed their correlation at different points.

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Let $T_i(t)$ be the temperature anomaly at the ith grid point at month t. They compute the **correlation** of these variables for each pair of grid points i, j:

$$A_{ij} = \frac{\langle T_i T_j \rangle}{\sqrt{\langle T_i^2 \rangle \langle T_j^2 \rangle}}$$

Here the angled brackets $\langle\rangle$ stand for the average. These numbers A_{ij} are between -1 and 1.

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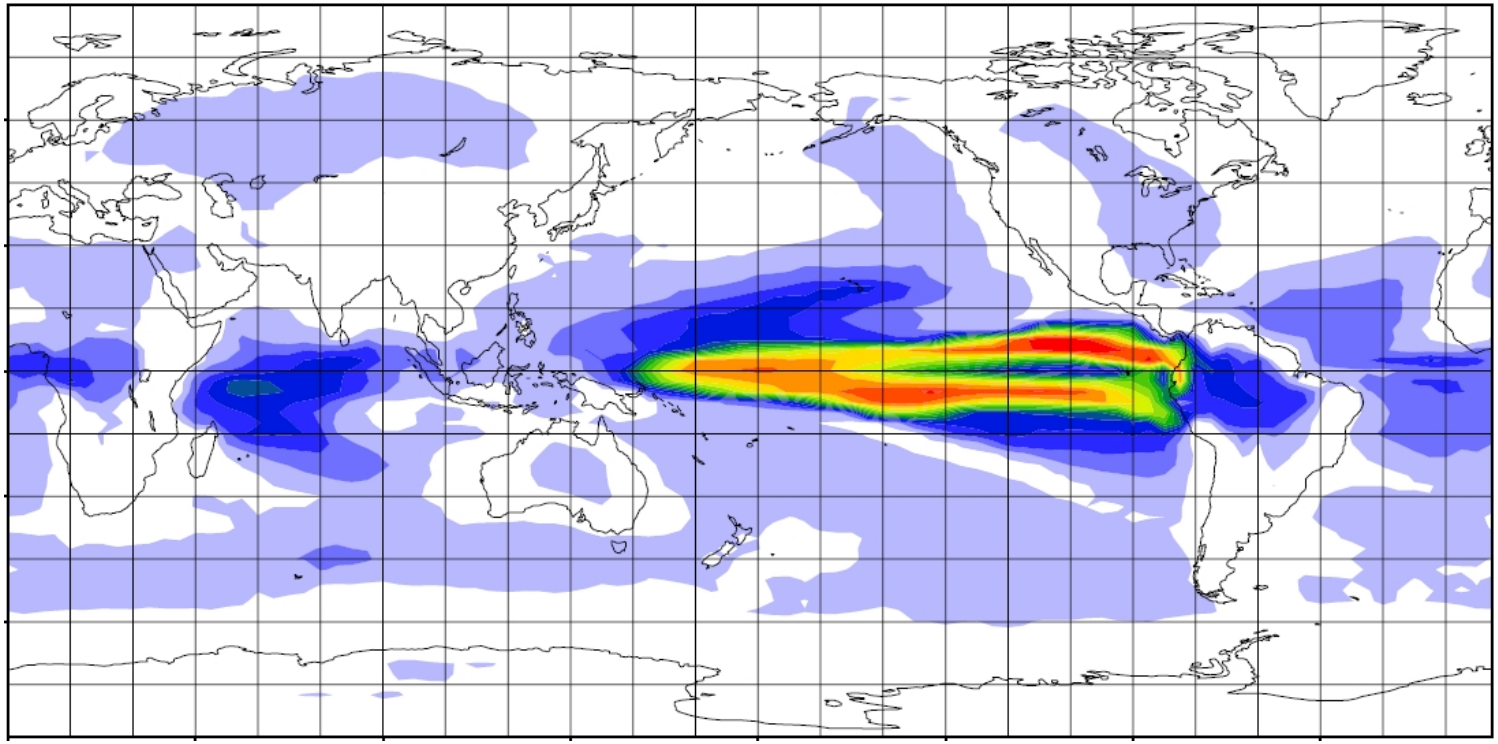
They draw an edge between gid points i and j when $|A_{ij}|$ is bigger than some number. They adjust this number so that 0.5% of the pairs i, j have an edge between them.

Then they use colors to show the grid points that are connected to many others:



A certain patch dominates the world: the **El Niño basin**. The reddest patches are nodes connected to 5% or more of the other nodes: at least 10 times as many as average.

Can we use climate networks to *predict* El Niños?

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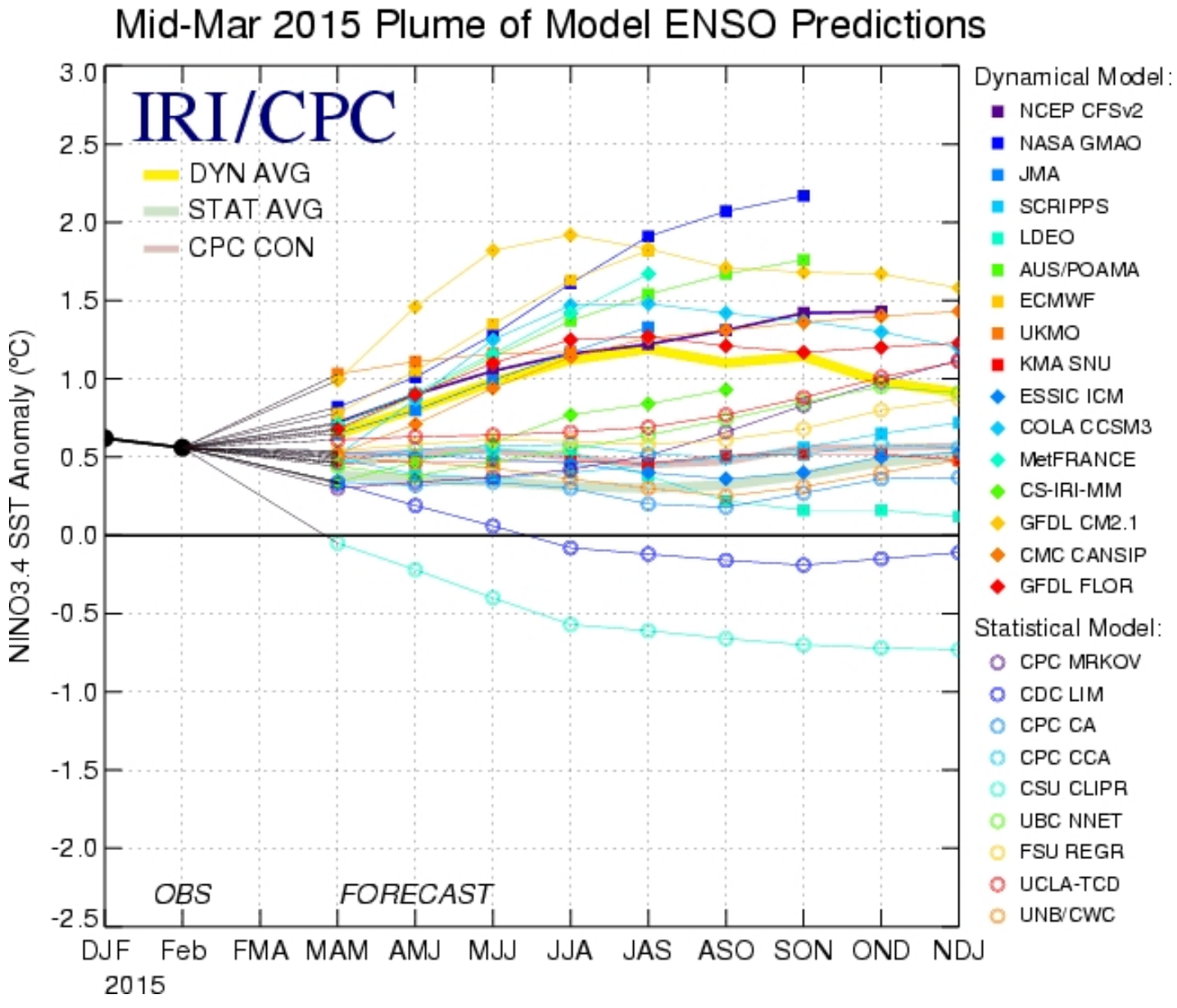
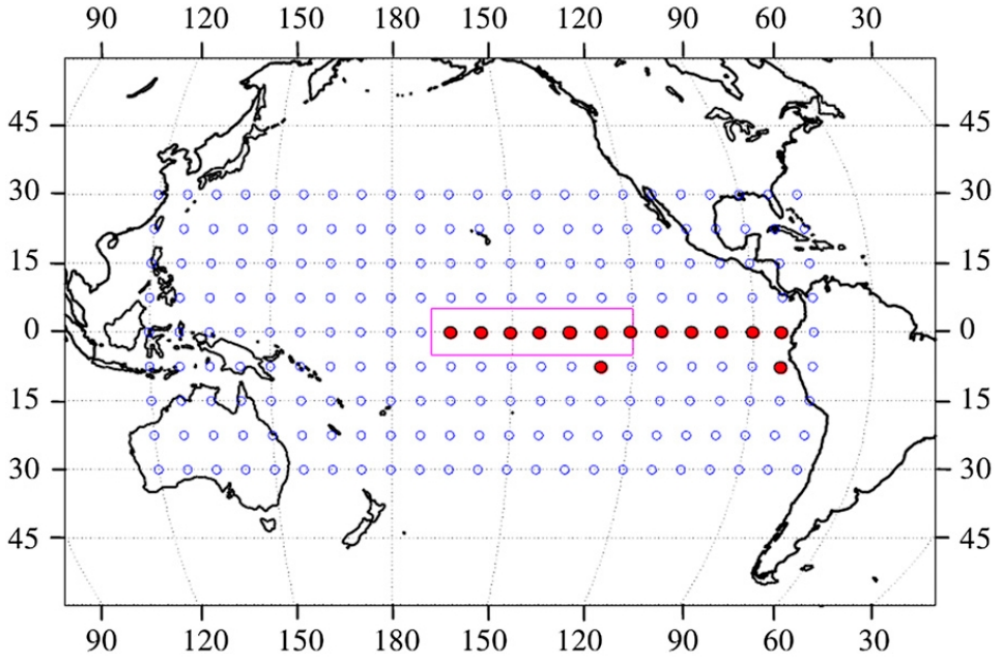
People really want to predict El Niños, because they have huge effects on agriculture, especially around the Pacific ocean.

There are many teams trying to predict the Niño 3.4 index. But it's very hard to predict it more than 6 months in advance!

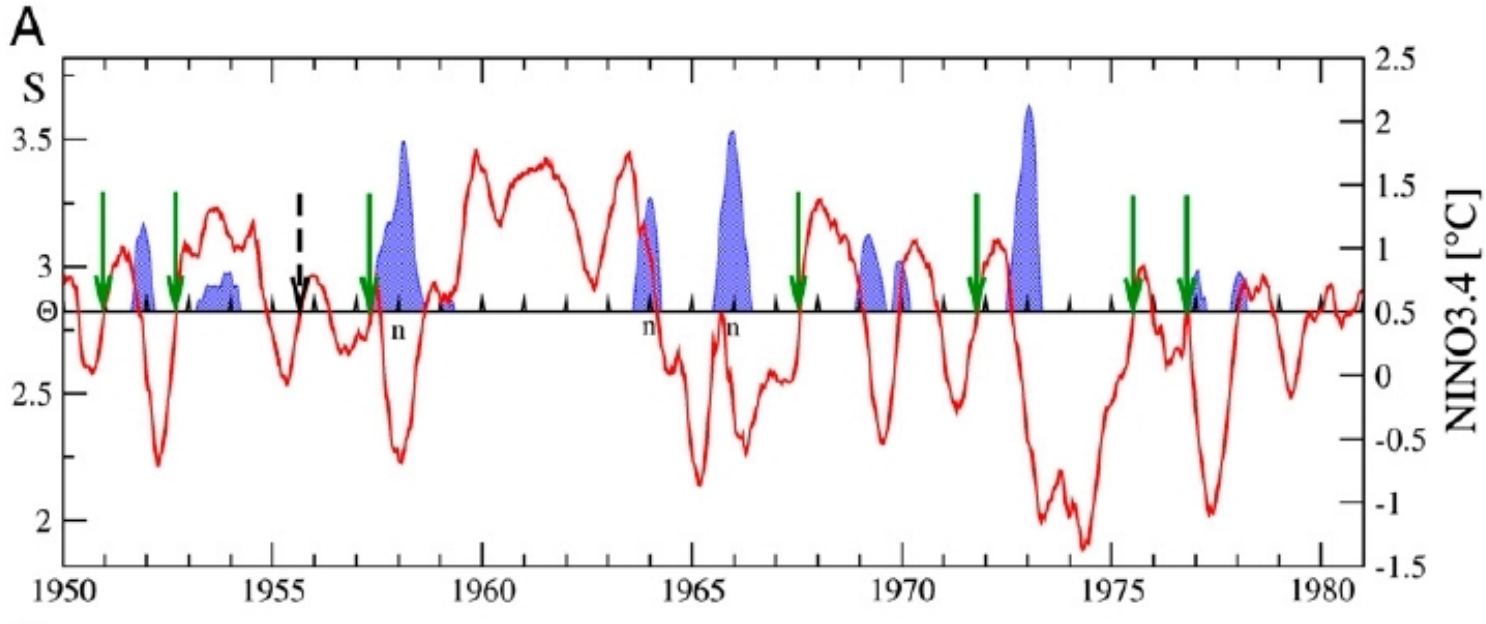

Mid-Mar 2015 Plume of Model ENSO Predictions
IRI/CPC
DYN AVG
STAT AVG
CPC CON
NINO3.4 SST Anomaly (°C)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
OBS
FORECAST
DJF
Feb
FMA
MAM
AMJ
MJJ
JJA
JAS
ASO
SON
OND
NDJ
2015
Dynamical Model:
NCEP CFSv2
NASA GMAO
JMA
SCRIPPS
LDEO
AUS/POAMA
ECMWF
UKMO
KMA SNU
ESSIC ICM
COLA CCSM3
MetFRANCE
CS-IRI-MM
GFDL CM2.1
CMC CANSIP
GFDL FLOR
Statistical Model:
CPC MRKOV
CDC LIM
CPC CA
CPC CCA
CSU CLIPR
UBC NNET
FSU REGR
UCLA-TCD
UNB/CWC

A 2013 paper by Ludescher *et al*, called Very Early Warning of Next El Niño, uses a climate network for El Niño prediction.

They study the correlations between daily surface air temperatures at points *inside* the El Niño basin and at certain points *outside* this region:



Ludescher *et al*



The blue peaks are episodes when the Niño 3.4 index exceeds 0.5 °C.

The red line says how much correlation there is between points *inside* the El Niño basin and points *outside*. When this exceeds a certain threshold, and the Niño 3.4 index is not already over 0.5 °C, they predict it will exceed 0.5 °C in the following calendar year.

They claimed their predictions were correct 3/4 of the time.

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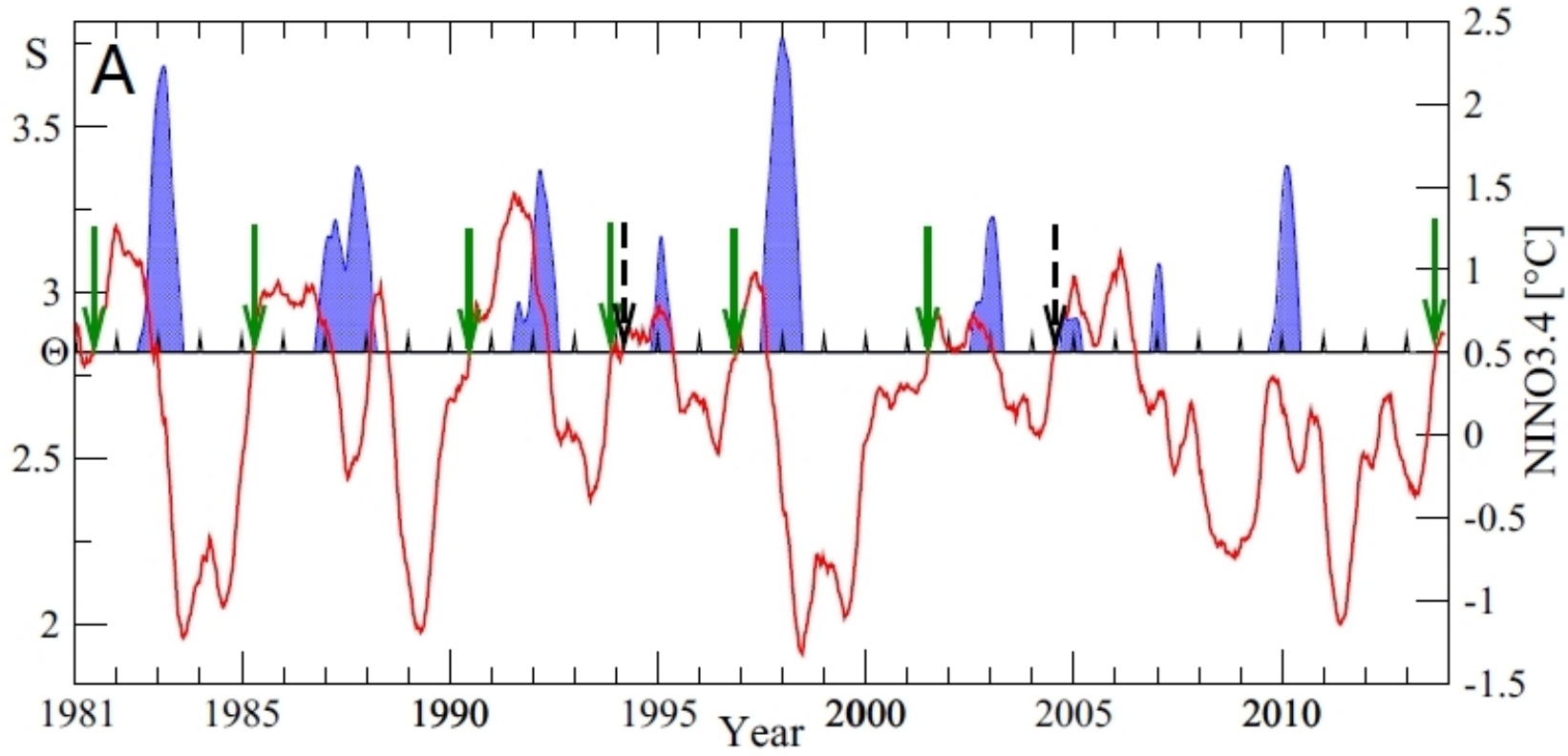
On this basis, they claimed there was a 3/4 chance that the Niño 3.4 index would go over 0.5 °C by the end of 2014.



They were right: it started in November!

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But how much does this success mean? Is Ludescher *et al*'s method really good — or did they just get lucky?

Analysis

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We showed that correlations between temperatures inside the El Niño basin and outside are *real* but *weak* predictor of a high Niño 3.4 index 10 months later.

Summary

The El Niño Southern Oscillation is important but mysterious. Climate networks may help us understand it, but they're certainly not a 'magic bullet'. We need to do a lot more work!

The Azimuth Project showed that people who aren't professional climate scientists can help.