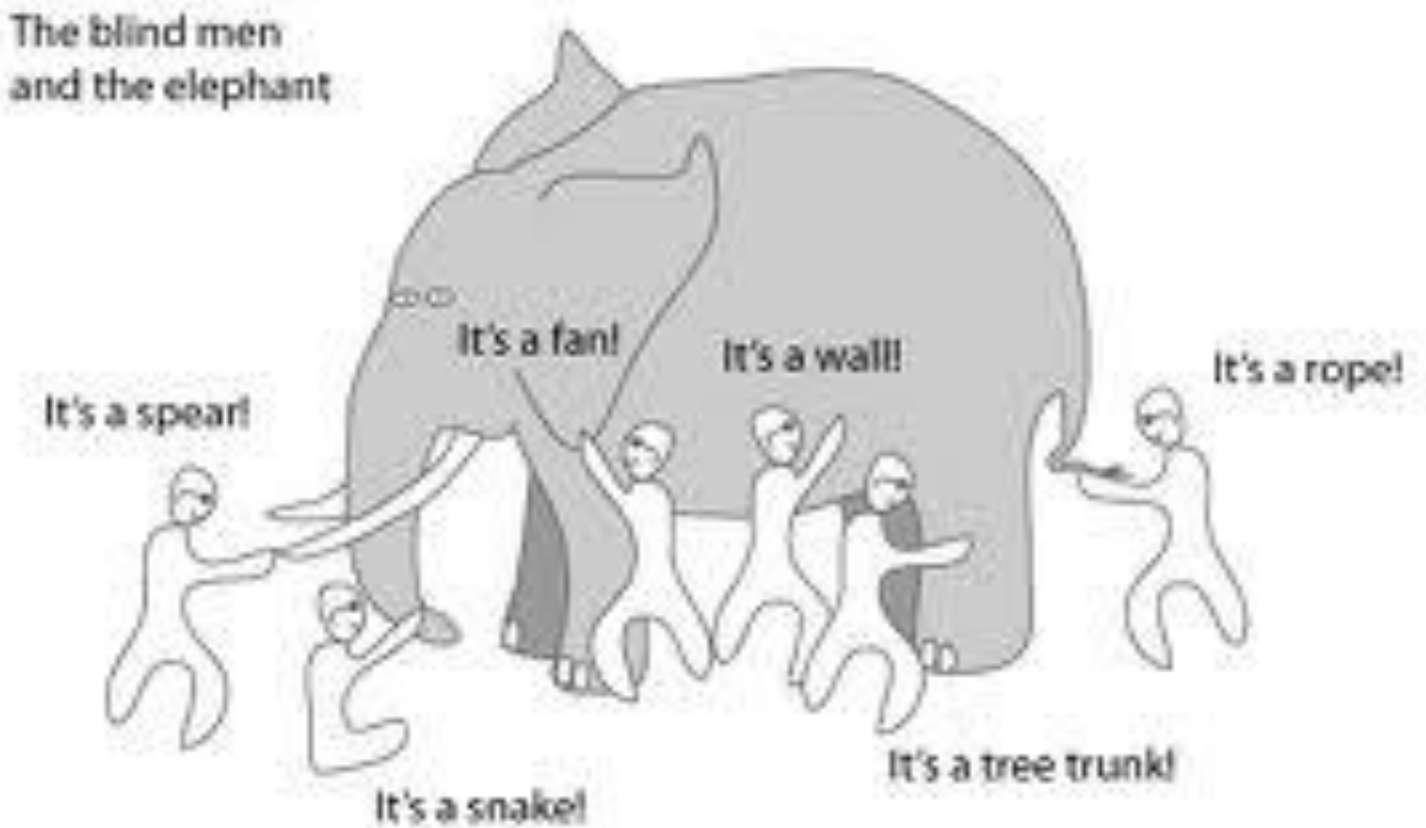
Is the dry zone of the land shifting poleward?

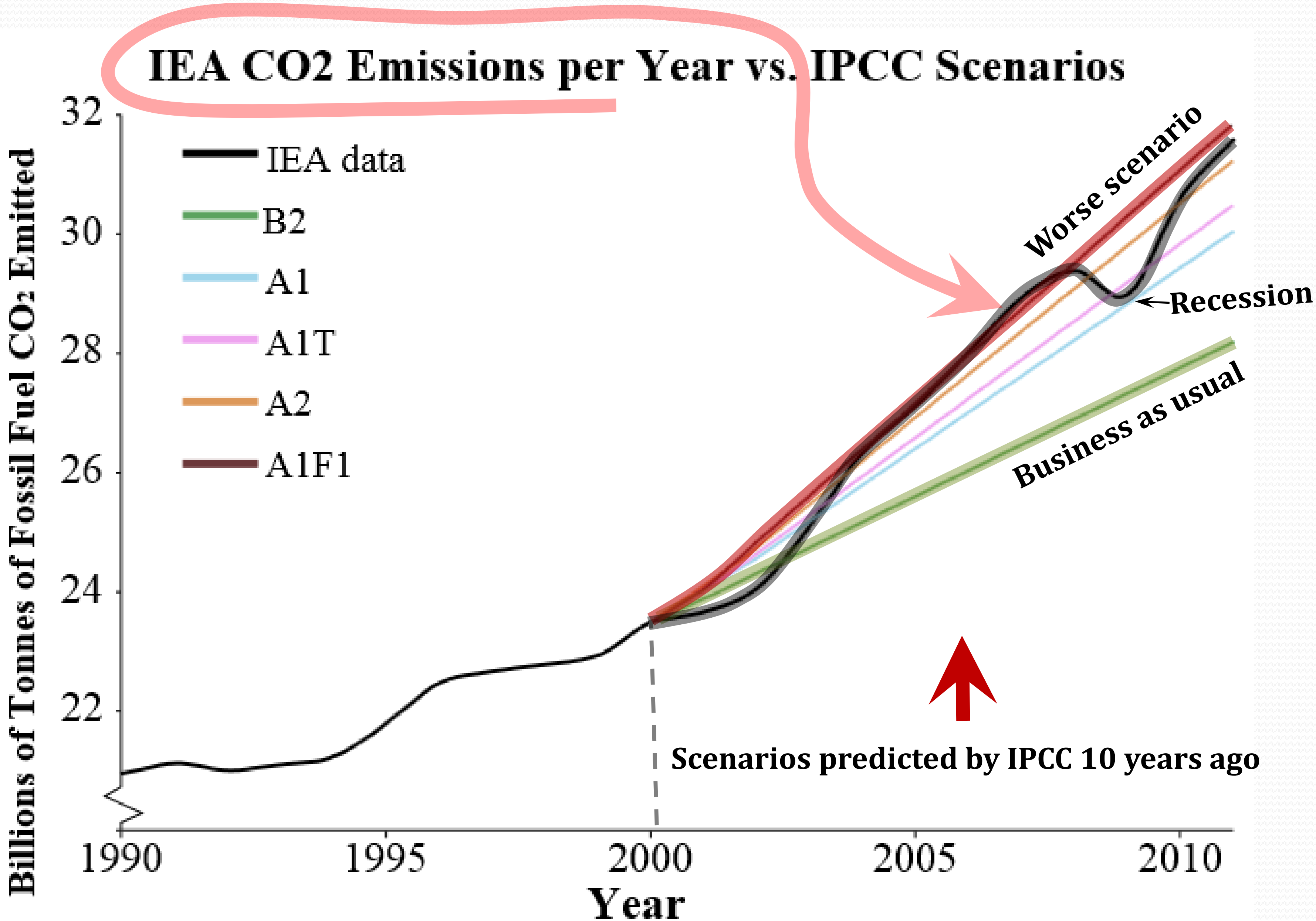
Chuixiang (Tree) Yi, Suhua Wei, Katherine Jensen, George Hendrey

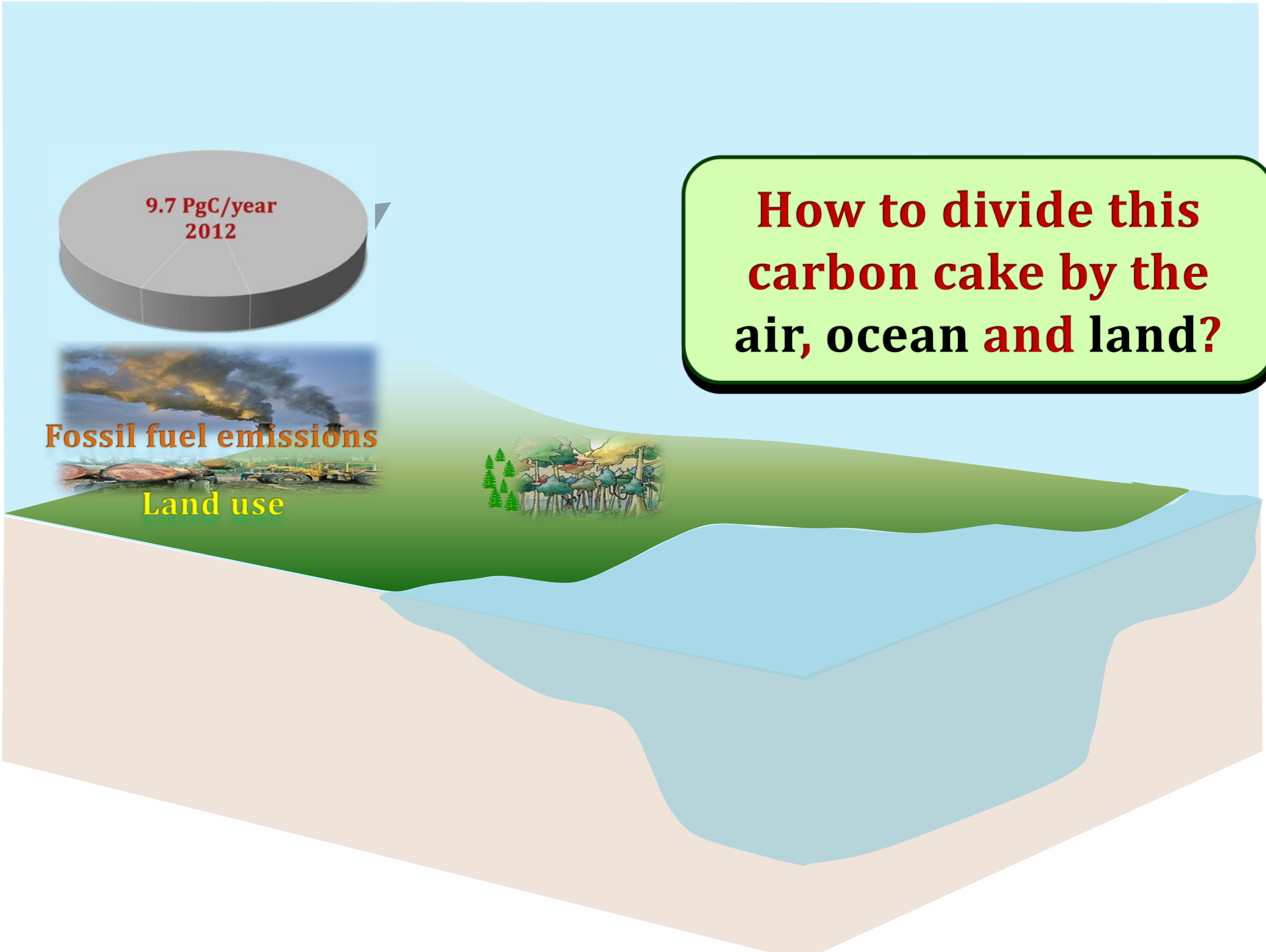
School of Earth and Environmental Sciences
Queens College, City University of New York

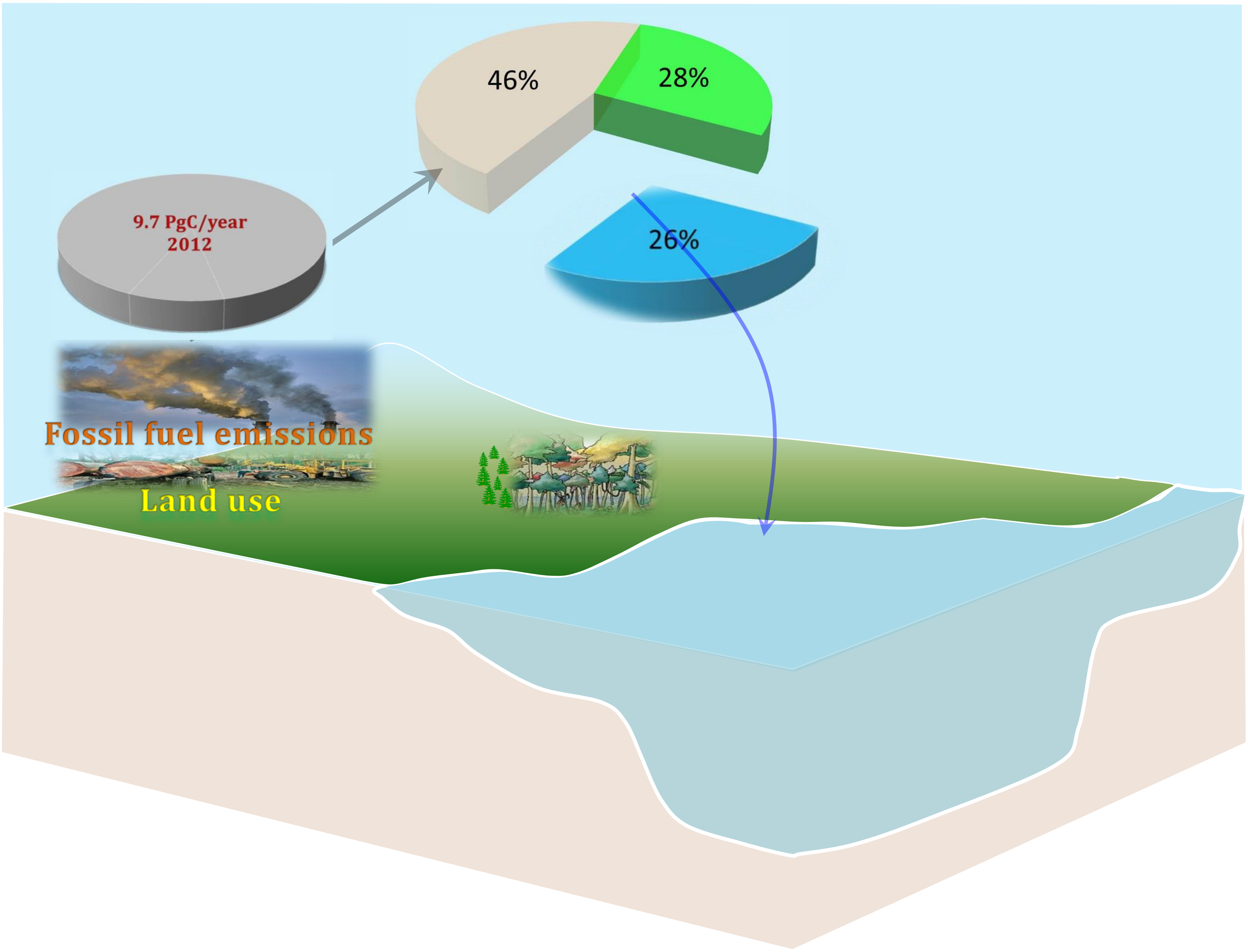

The blind men
and the elephant
It's a fan!
It's a wall!
It's a rope!
It's a spear!
It's a tree trunk!
It's a snake!

FLUXNET

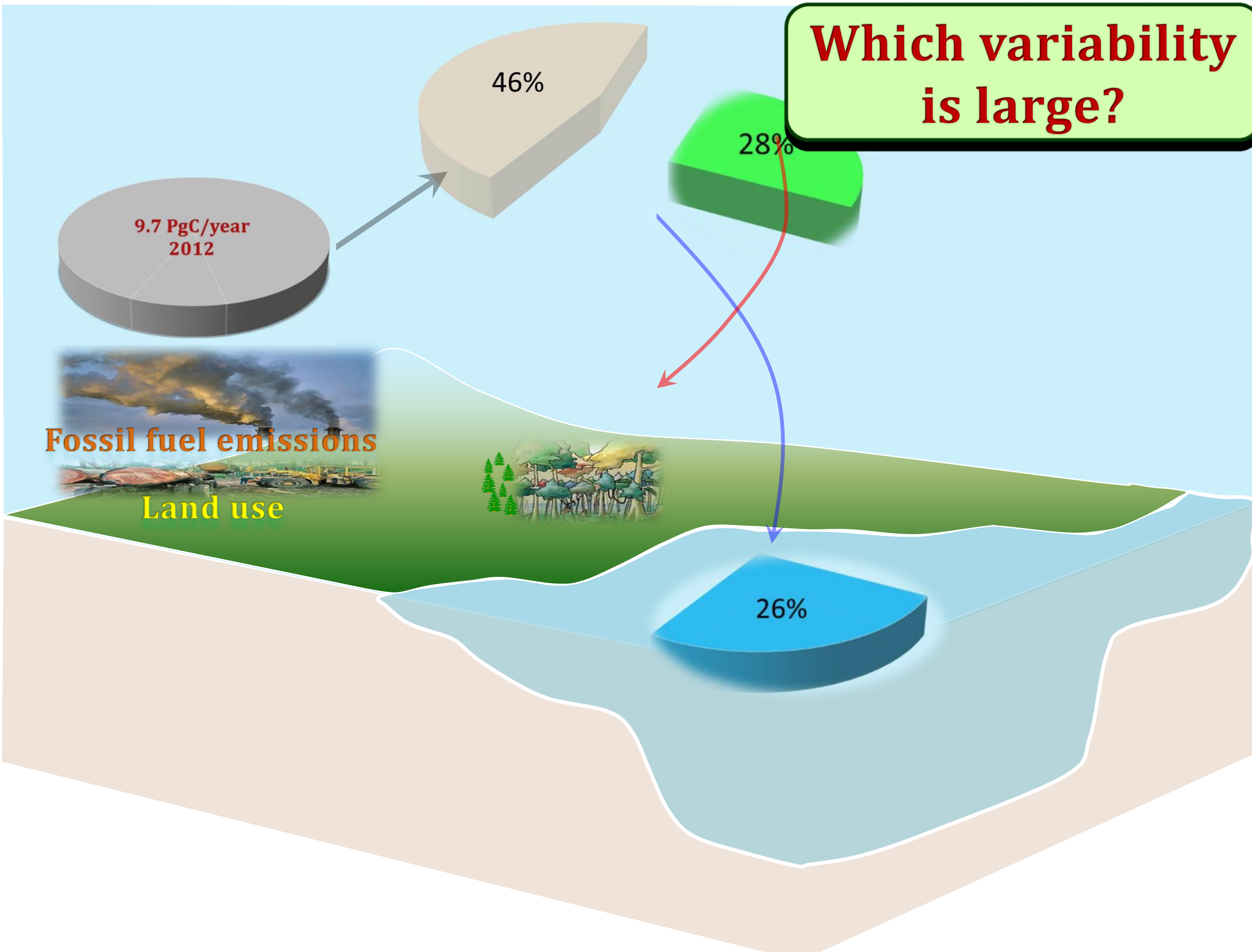
CO_2 Emissions: Worse than Predictions!



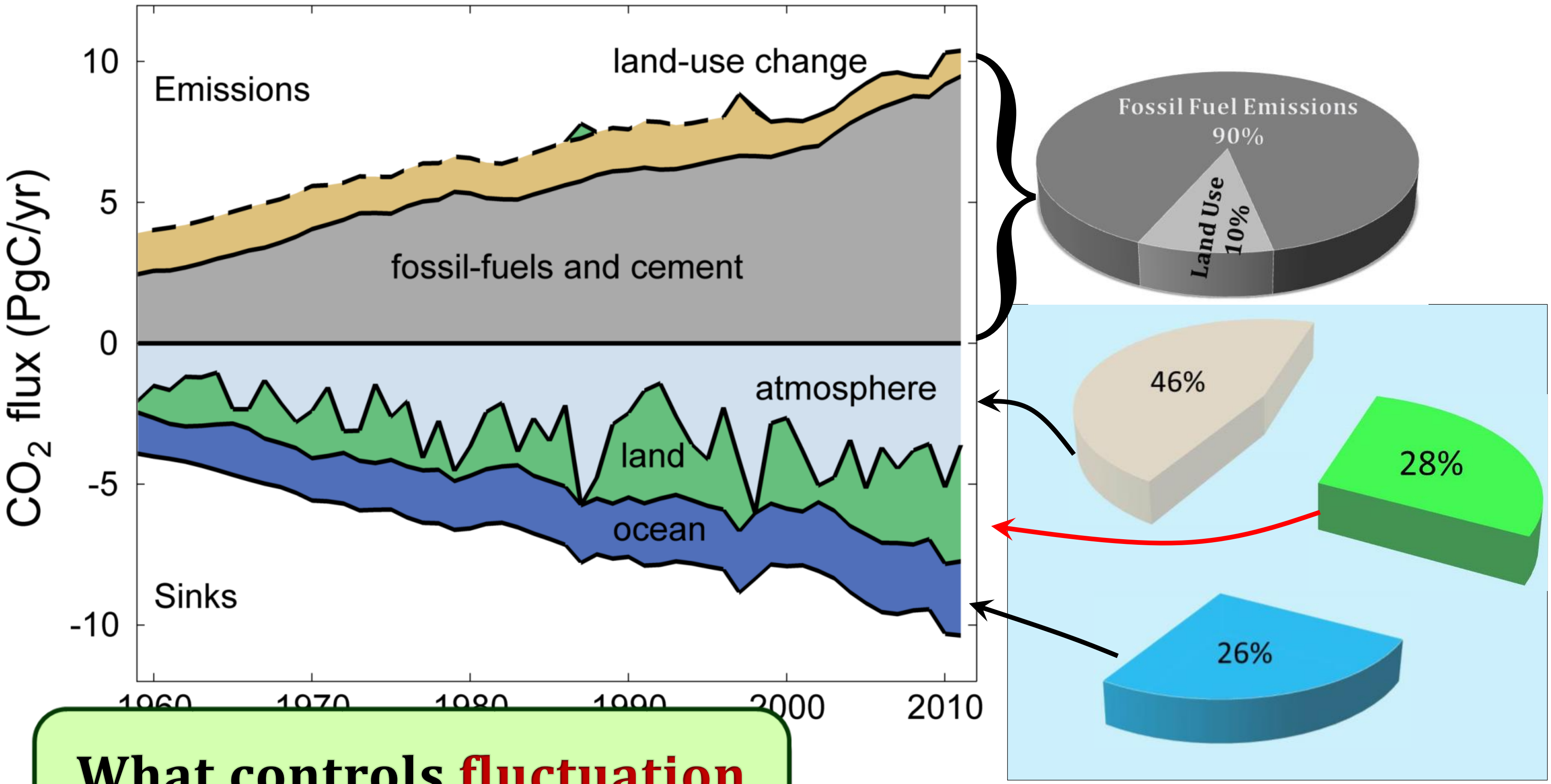

9.7 PgC/year
2012
Fossil fuel emissions
Land use
How to divide this carbon cake by the air, ocean and land?



46%
28%
9.7 PgC/year
2012
26%
Fossil fuel emissions
Land use


Which variability is large?
9.7 PgC/year
2012
46%
28%
26%
Fossil fuel emissions
Land use

Global Carbon Budget



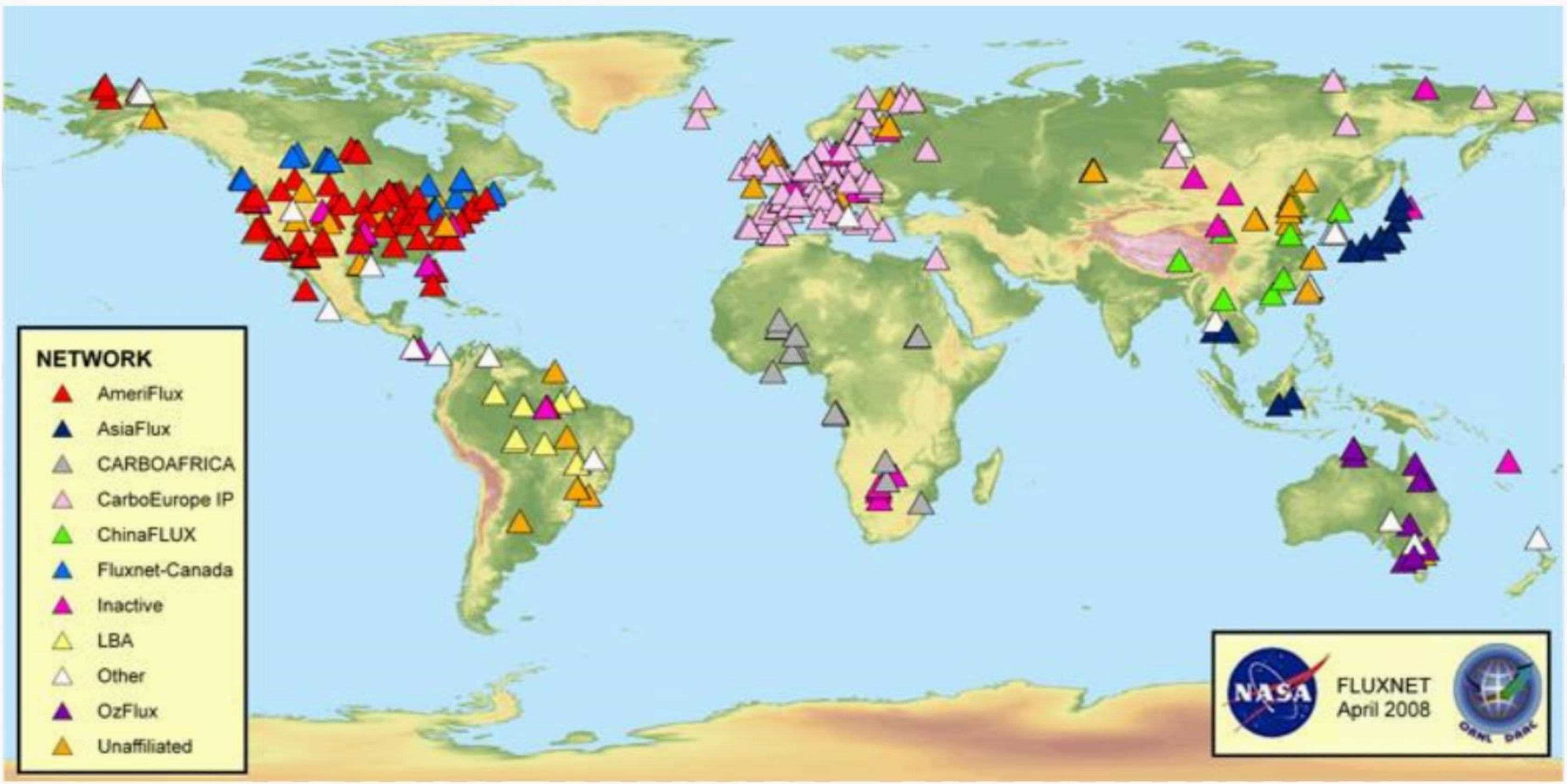
What controls fluctuation in land carbon sink?

The dashed land-use change line does not include management-climate interactions

The land sink was a source in 1987 and 1998 (1997 visible as an emission)

Source: [Le Quéré et al. 2012](); [Global Carbon Project 2012]()

Hypothesis


NETWORK
AmeriFlux
AsiaFlux
CARBOAFRICA
CarboEurope IP
ChinaFLUX
Fluxnet-Canada
Inactive
LBA
Other
OzFlux
Unaffiliated
NASA
FLUXNET
April 2008

IOP Publishing ENVIRONMENTAL RESEARCH LETTERS
Environ. Res. Lett. 5 (2010) 034007 (10pp) doi:10.1088/1748-9326/5/3/

Climate control of terrestrial carbon exchange across biomes and continents

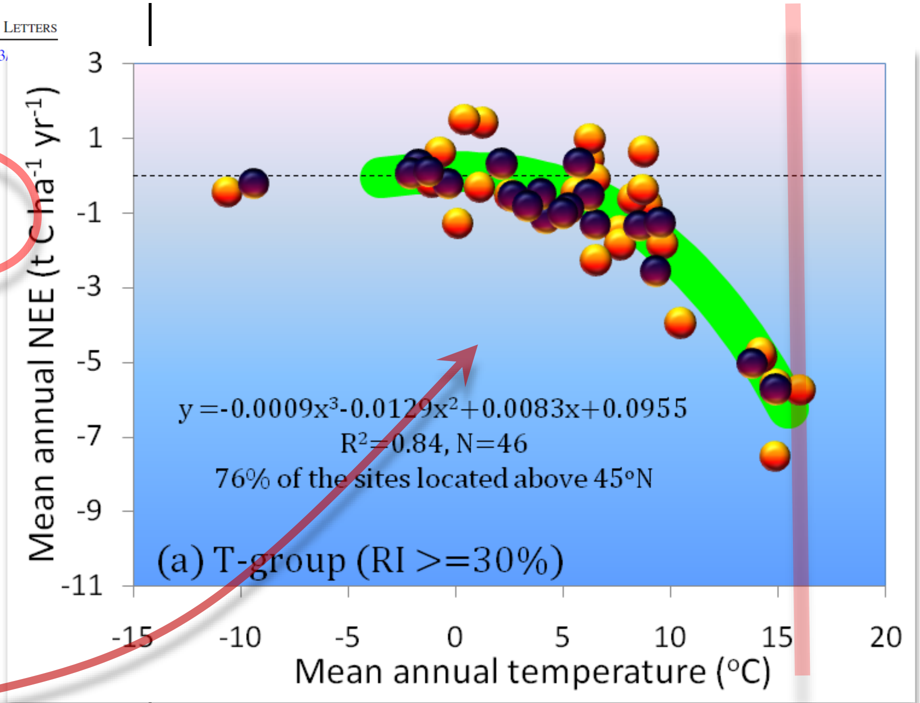
Chuixiang Yi[1], Daniel Ricciuto[2], Runze Li[3], John Wolbeck[1], Xiyan Xu[1],
Mats Nilsson[4], Luis Aires[5,117], John D Albertson[6,117], Christof Ammann[7,117],

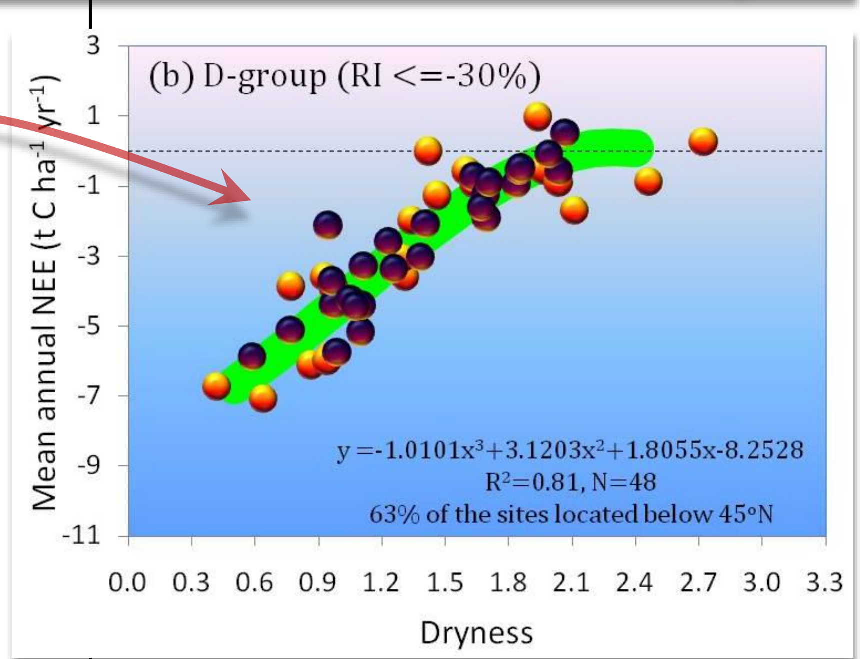
NEE (CO2 Flux) is highly limited by mean annual temperature at mid- and high-latitudes.

László Haszpra[53,117], Bernard Heinesch[10,117], Carole Helfter[54,117], Dimmie Hendriks[55,117],

NEE (CO2 Flux) is highly limited by dryness at mid- and low latitudes;

Mukufute M Mukelabai[84,117], J William Munger[85,117], May Myklebust[65,117],
Zoltán Nagy[86,117], Asko Noormets[87,117], Walter Oechel[88,117], Ram Oren[89,117],
Stephen G Pallardy[90,117], Kyaw Tha Paw U[39,117], João S Pereira[59,117],
Kim Pilegaard[57,117], Krisztina Pintér[86,117], Casimiro Pio[91,117], Gabriel Pita[92,117],
Thomas L Powell[93,117], Serge Rambal[94,117], James T Randerson[46,117],
Celso von Randow[95,117], Corinna Rebmann[64,117], Janne Rinne[96,117], Federica Rossi[77,117],
Nigel Roulet[97,117], Ronald J Ryel[98,117], Jorgen Sagerfors[4,117], Nobuko Saigusa[99,117],
María José Sanz[100,117], Giuseppe-Scarascia Mugnozza[101,117], Hans Peter Schmid[102,117],
Guenther Seufert[103,117], Mario Siqueira[89,117], Jean-François Soussana[62,117],
Gregory Starr[104,117], Mark A Sutton[105,117], John Tenhunen[106,117], Zoltán Tuba,[86,117,118],
Juha-Pekka Tuovinen[11,117], Riccardo Valentini[107,117], Christoph S Vogel[108,117],





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Environ. Res. Lett. 5 (2010) 034007 (10pp) doi:10.1088/1748-9326/5/3/034007

Climate control of terrestrial carbon exchange across biomes and continents

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Mats Nilsson[4], Luis Aires[5,117], John D Albertson[6,117], Christof Ammann[7,117],

Threshold temperature 16°C

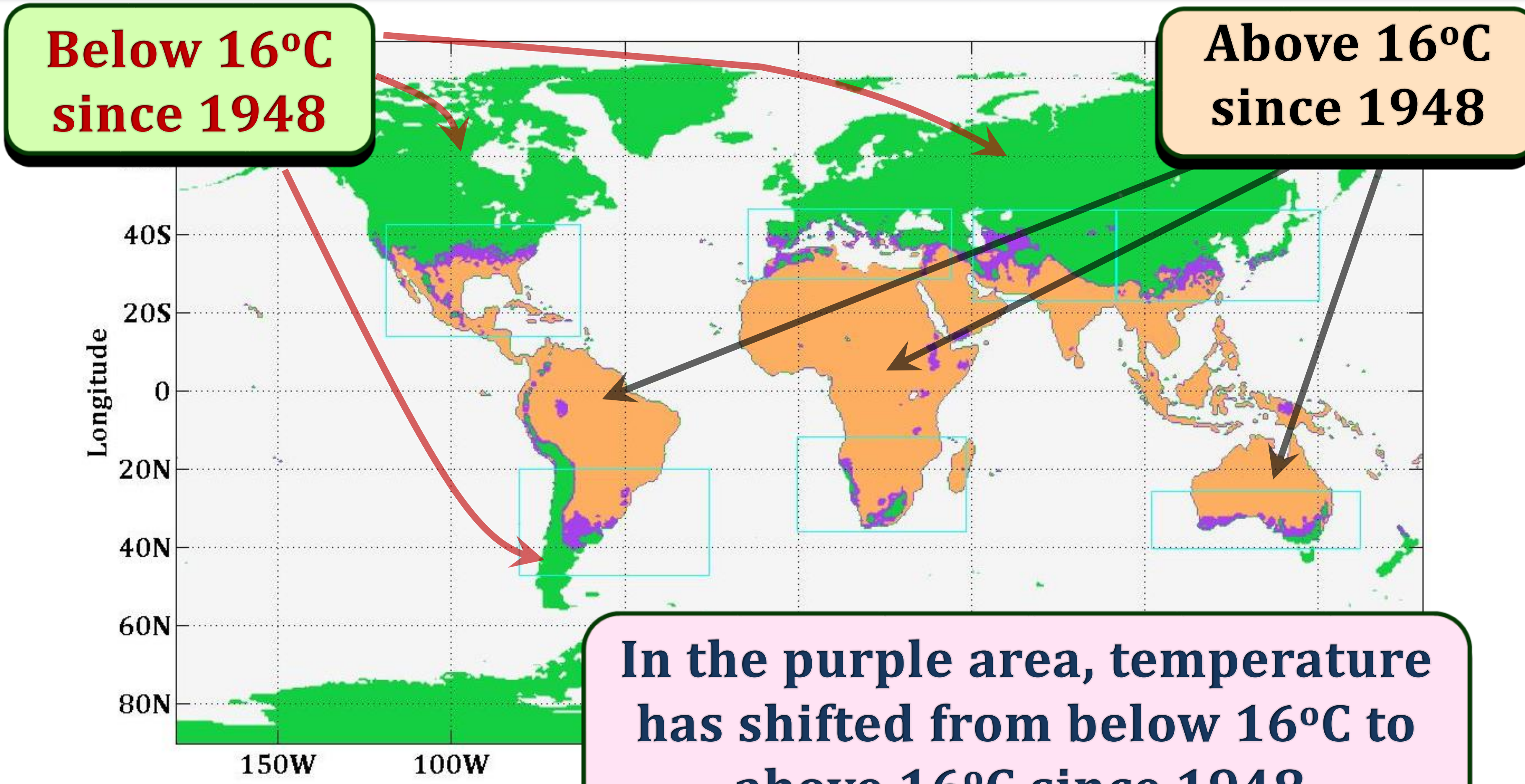
We found that the sensitivity of NEE (CO_2 flux) to mean annual temperature breaks down at 16°C, above which dryness influence overrules temperature influence.

Meelis Mölder[58,117], John Moncrieff[27,117], Russell K Monson[79,117], Leonardo Montagnani[80,81,117],

Where is the 16°C boundary?
Does it shift with warming climate?

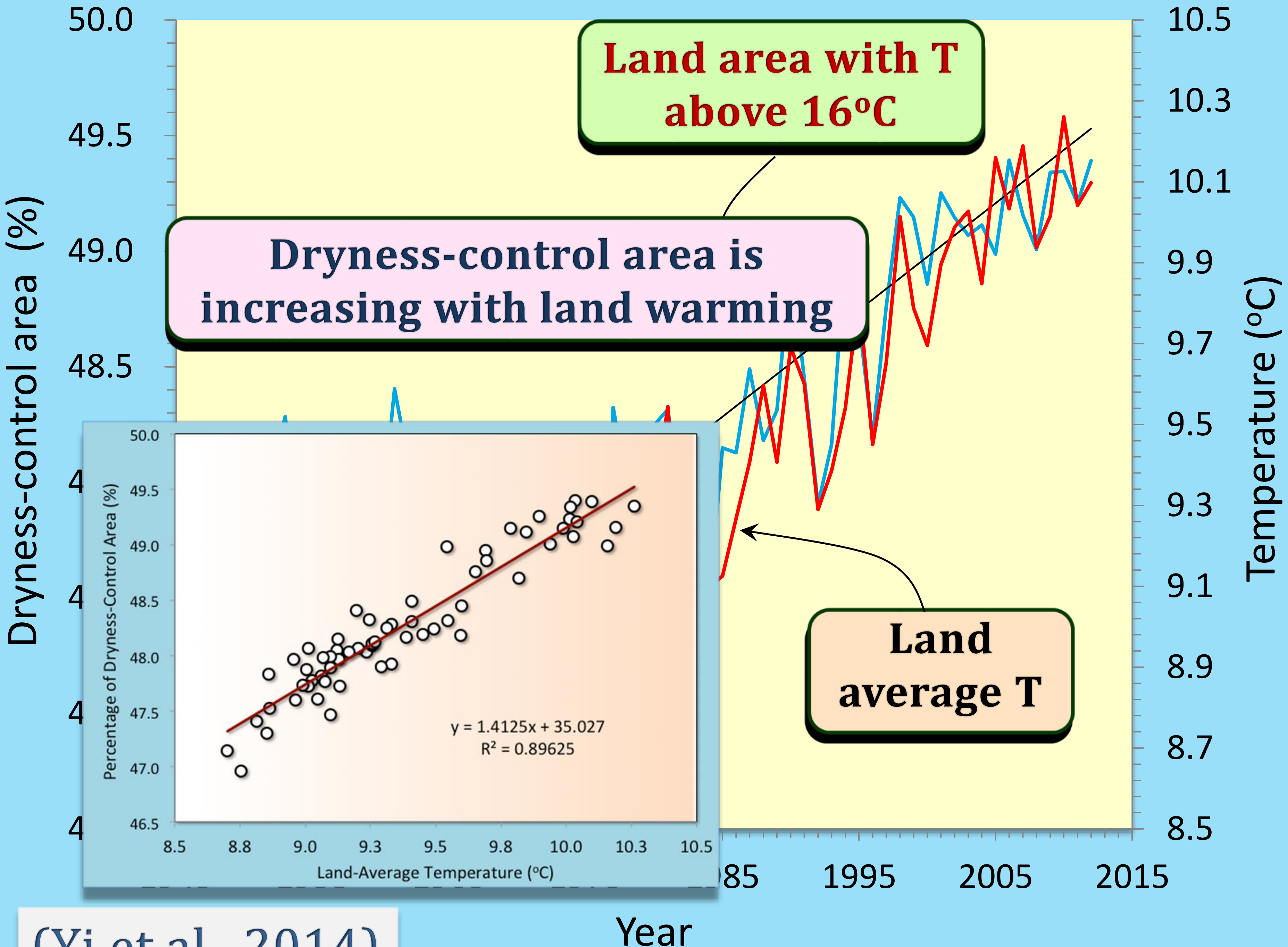
Juha-Pekka Tuovinen[11,117], Riccardo Valentini[107,117], Christoph S Vogel[108,117],

Mean annual temperature 16°C boundary

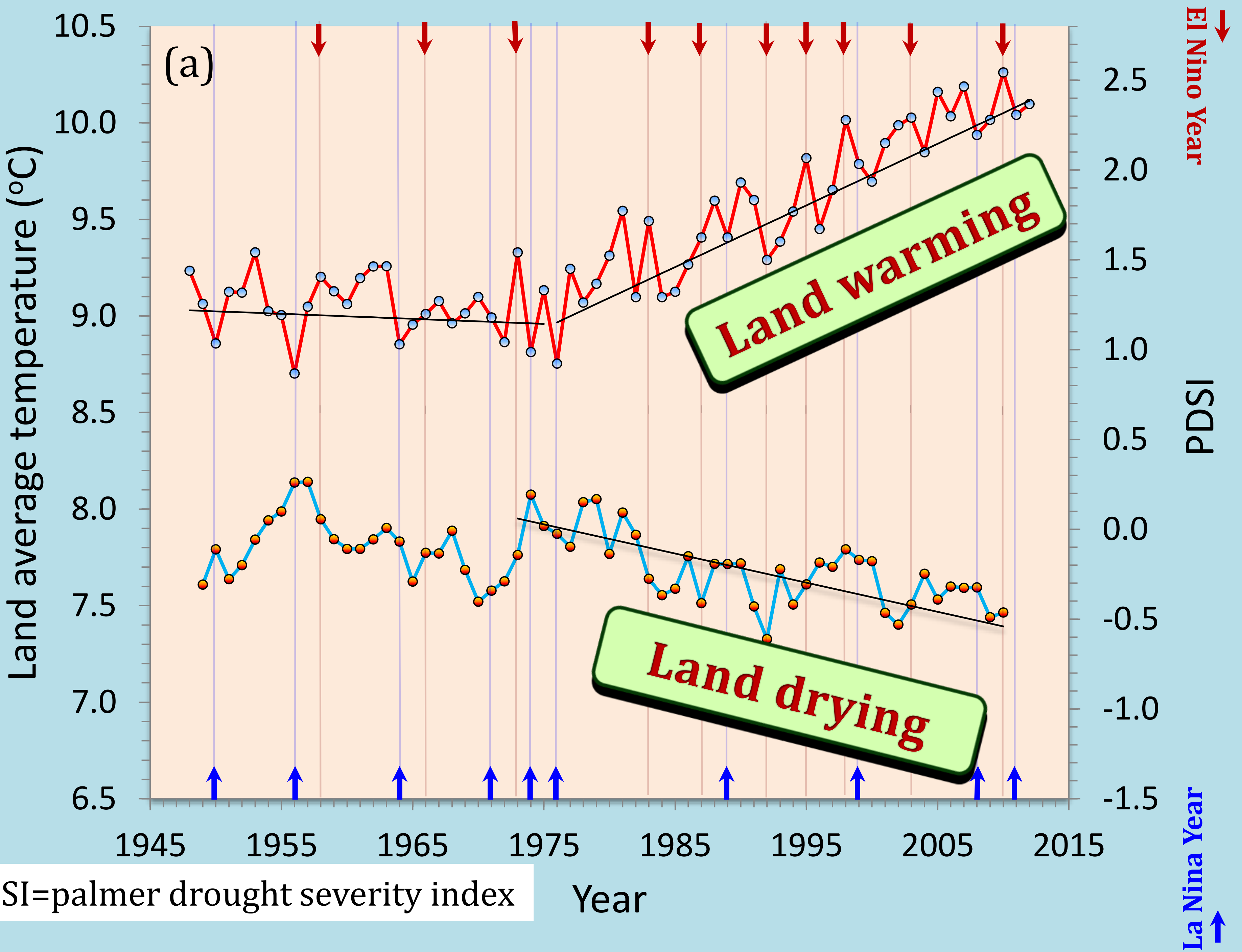


In the purple area, temperature has shifted from below 16°C to above 16°C since 1948.

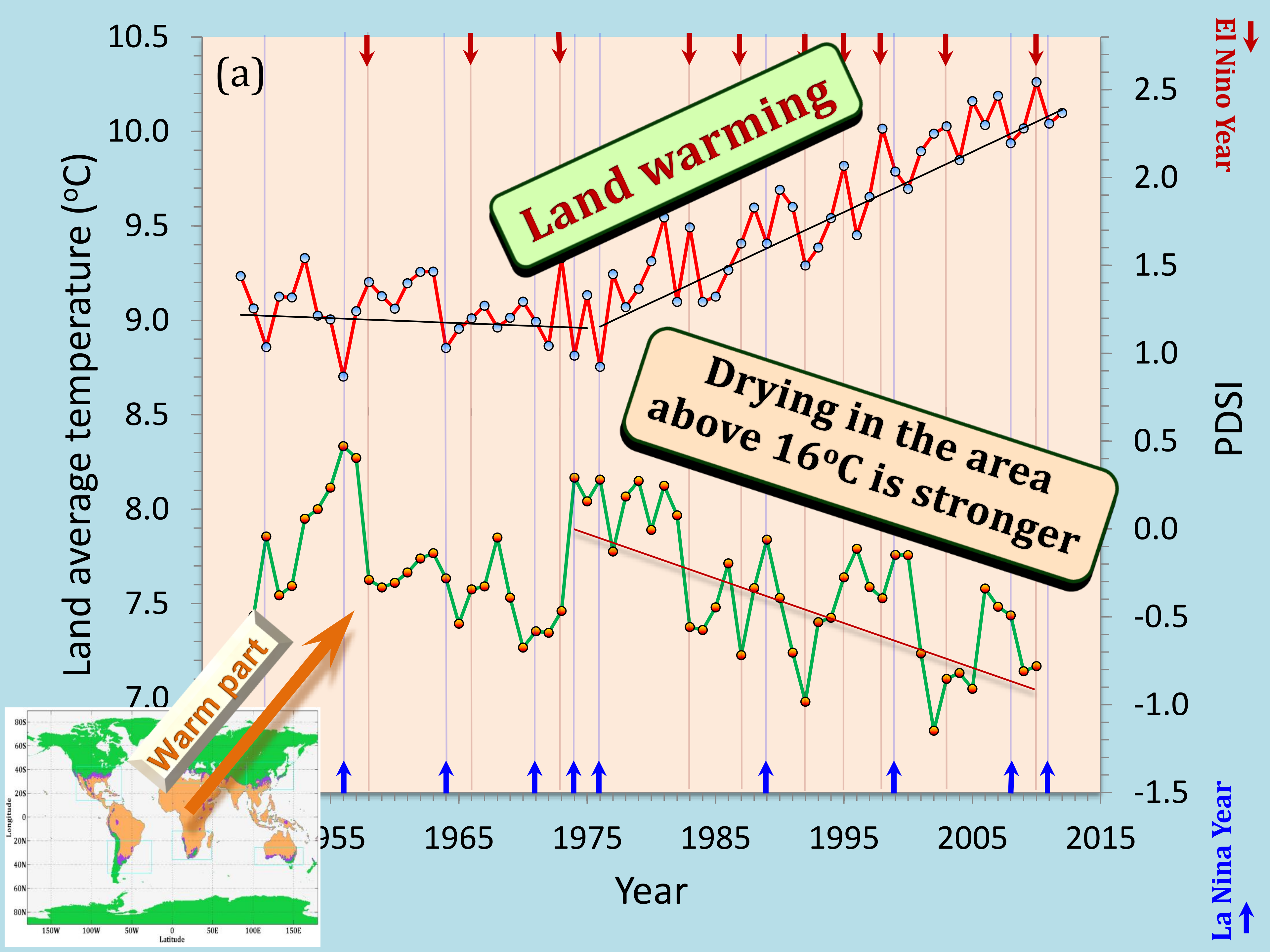
(Yi et al., 2014)


Land area with T above 16ºC
Dryness-control area is increasing with land warming
Land average T
Dryness-control area (%)
Temperature (ºC)
Year
50.0
49.5
49.0
48.5
10.5
10.3
10.1
9.9
9.7
9.5
9.3
9.1
8.9
8.7
8.5
1995
2005
2015
y = 1.4125x + 35.027
R² = 0.89625
Percentage of Dryness-Control Area (%)
Land-Average Temperature (ºC)
46.5
47.0
47.5
48.0
8.5
8.8
9.0
9.3
9.5
9.8
10.0
10.3

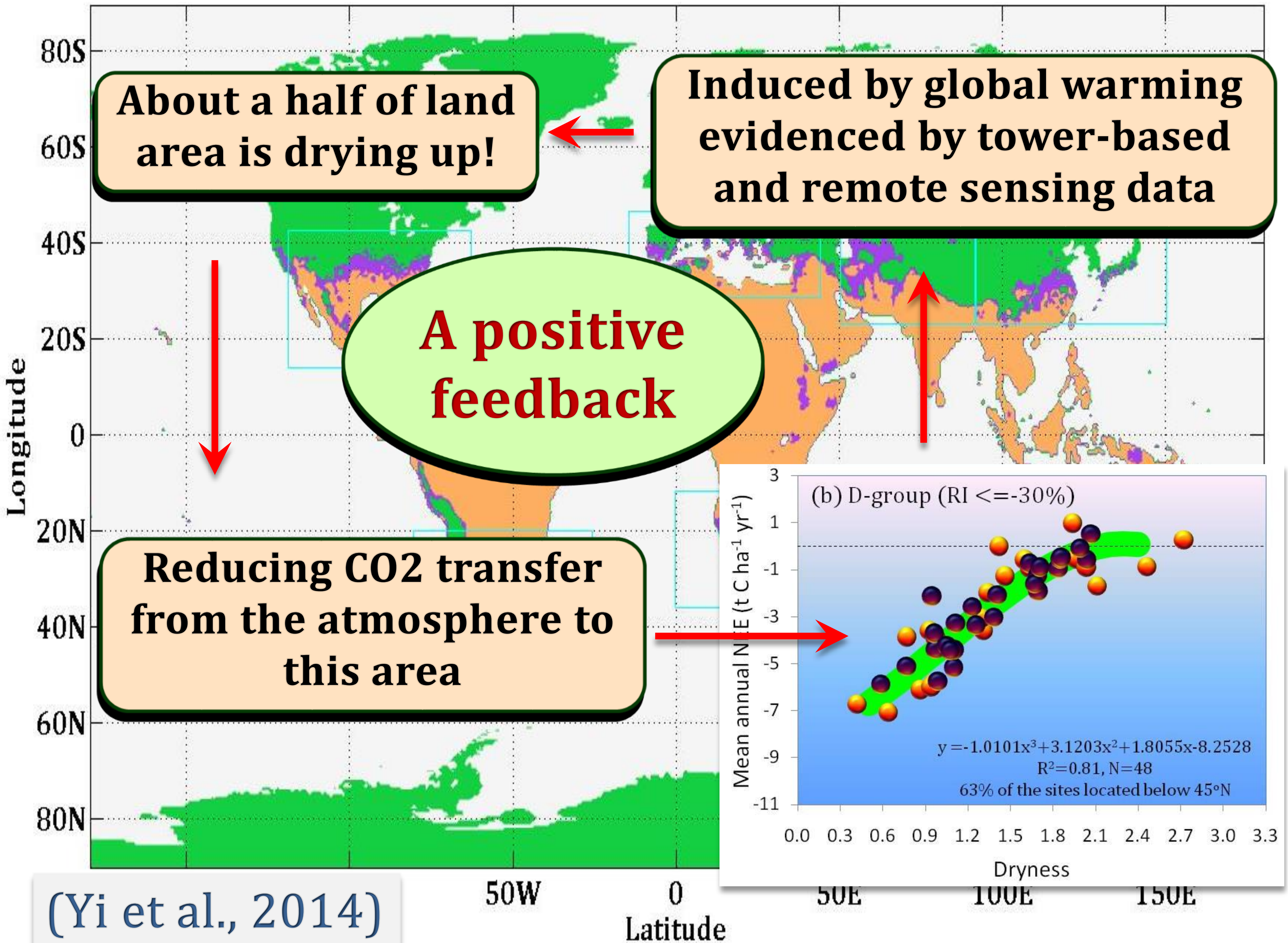
(Yi et al., 2014)



PDSI=palmer drought severity index

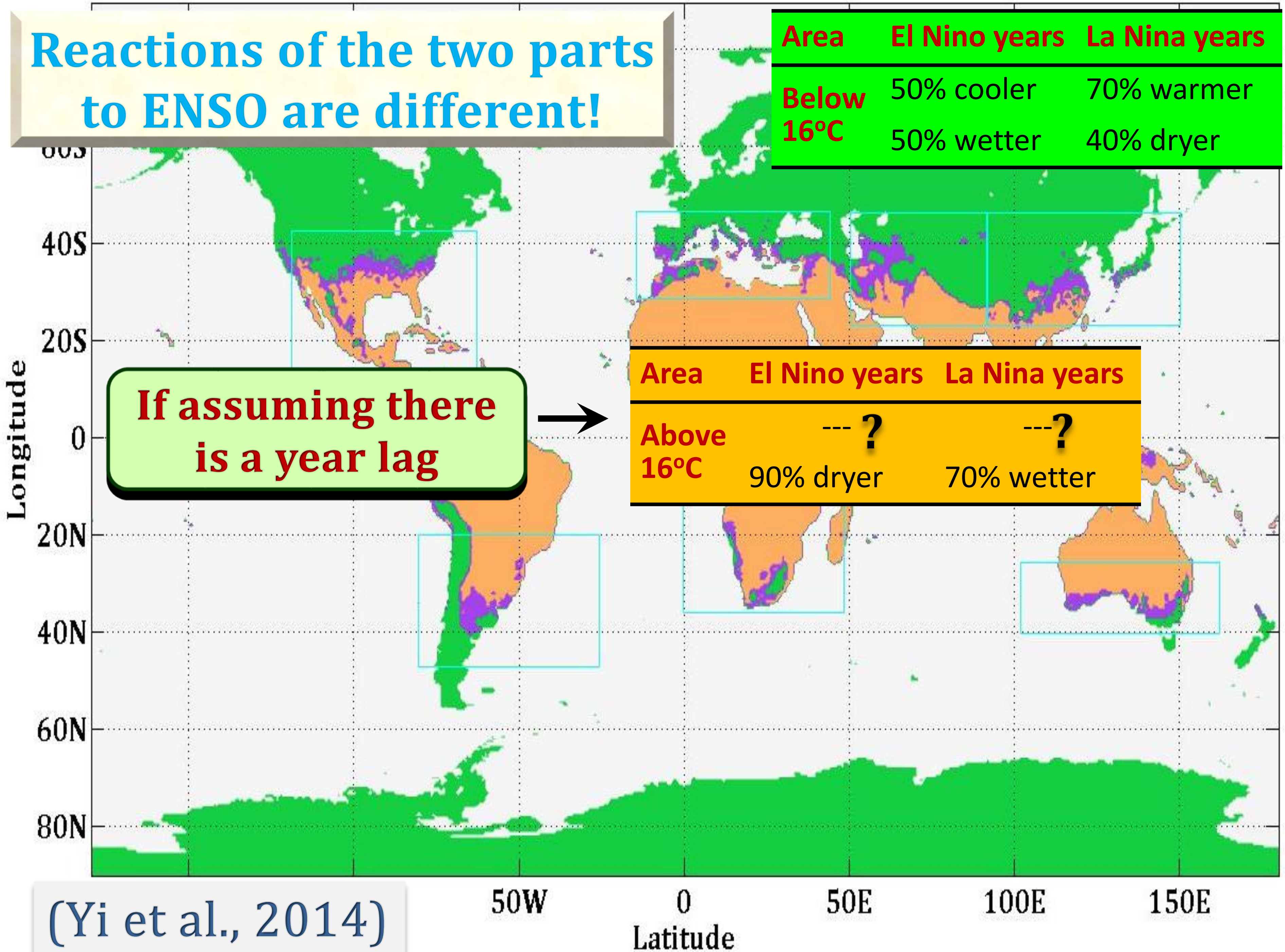


(a)
Land warming
Drying in the area above 16°C is stronger
Warm part
Land average temperature (°C)
PDSI
Year
El Nino Year
La Nina Year
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
1955
1965
1975
1985
1995
2005
2015
Longitude
Latitude



80S
60S
40S
20S
0
20N
40N
60N
80N
Longitude
50W
0
50E
100E
150E
Latitude
About a half of land area is drying up!
Induced by global warming evidenced by tower-based and remote sensing data
A positive feedback
Reducing CO2 transfer from the atmosphere to this area
(b) D-group (RI <=-30%)
Mean annual NEE (t C ha-1 yr-1)
3
1
-1
-3
-5
-7
-9
-11
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7
3.0
3.3
Dryness
y =-1.0101x3+3.1203x2+1.8055x-8.2528
R2=0.81, N=48
63% of the sites located below 45°N
(Yi et al., 2014)

Reactions of the two parts to ENSO are different!



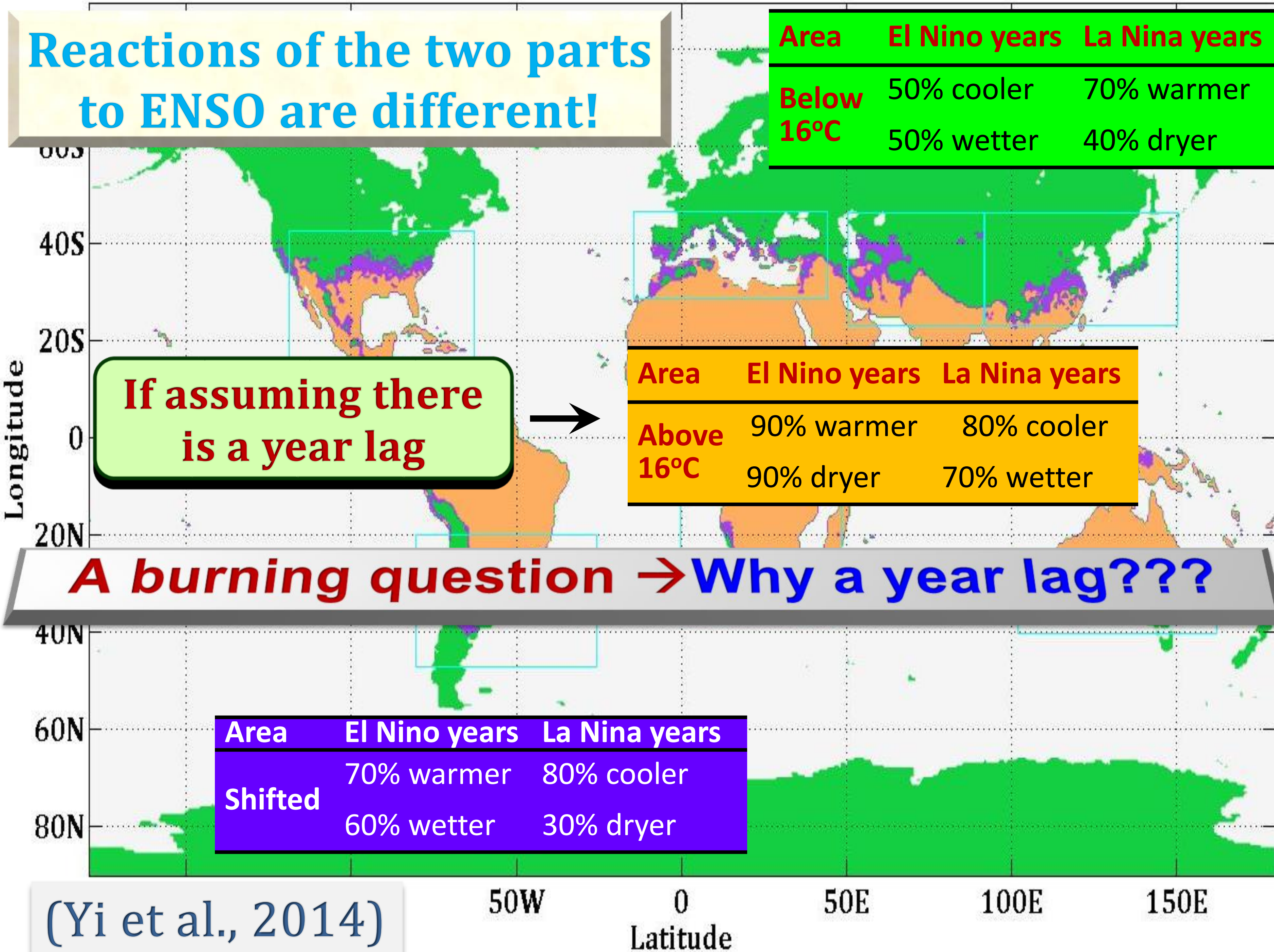
Area	El Nino years	La Nina years
Below 16°C	50% cooler 50% wetter	70% warmer 40% dryer

If assuming there is a year lag →

Area	El Nino years	La Nina years
Above 16°C	--- ? 90% dryer	---? 70% wetter

(Yi et al., 2014)

Reactions of the two parts to ENSO are different!



Area	El Nino years	La Nina years
Below 16ºC	50% cooler 50% wetter	70% warmer 40% dryer

If assuming there is a year lag →

Area	El Nino years	La Nina years
Above 16ºC	90% warmer 90% dryer	80% cooler 70% wetter

A burning question → Why a year lag???

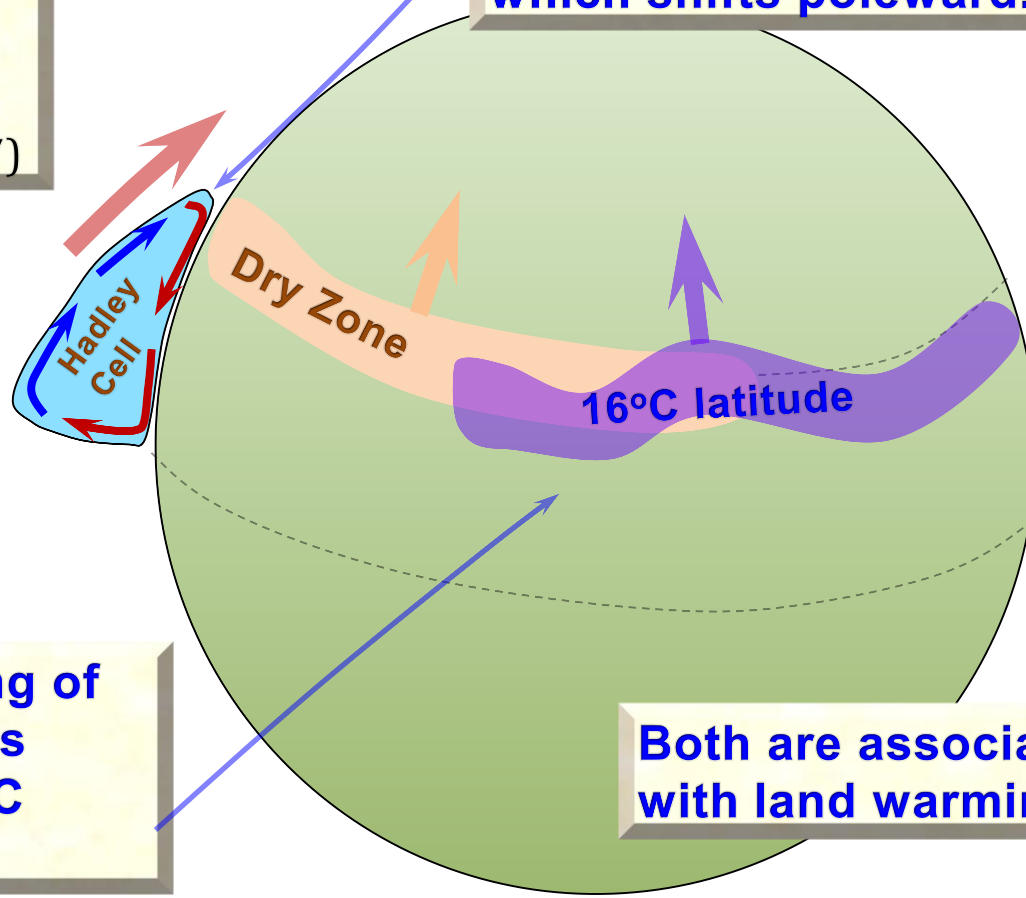
Area	El Nino years	La Nina years
Shifted	70% warmer 60% wetter	80% cooler 30% dryer

(Yi et al., 2014)

Poleward expansion of HC and 16°C latitude is coincident

The poleward expansion with warming climate has been observed by many investigators (Lu et al., 2012; Evans et al., 2013; Hu and Fu, 2007)

The HC north descending branch produces dry zone which shifts poleward.



The poleward shiftting of 16°C latitudinal belt is coincided with the HC poleward expansion.

Both are associated with land warming

Findings and open questions

- Global warming extends dryness-control area
- Warmer land (>16^{o}C) is drying, carbon sink is weakening
- Warmer land (>16^{o}C) and colder land (<16^{o}C) have different performances to ENSO events
- Why is the reaction of warmer-land temperature to ENSO events one year lagged?
- The switch of climate-control of CO2 fluxes induces a positive feedback to global warming.
- Almost a half of land is drying and ability to absorb CO2 from the atmosphere is weakening, likely accelerating global warming.
- Poleward expansion of HC and 16^{o}C latitude is coincident.
- The shifted area is expected to double in 2050, most are OSH land, cropland and desert, most venerable to climate change.

Thank you!

Acknowledgements

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