Differential imprints of different ENSO flavors in global patterns of seasonal precipitation extremes

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Federal Ministry of Education and Research

COSY$_{CC^2}$

The El Niño/Southern Oscillation

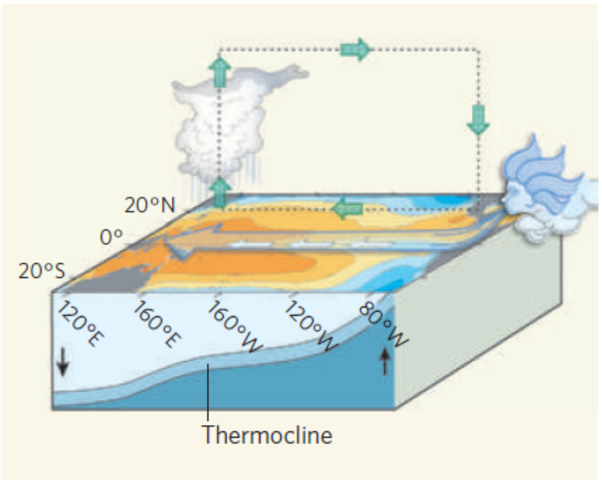
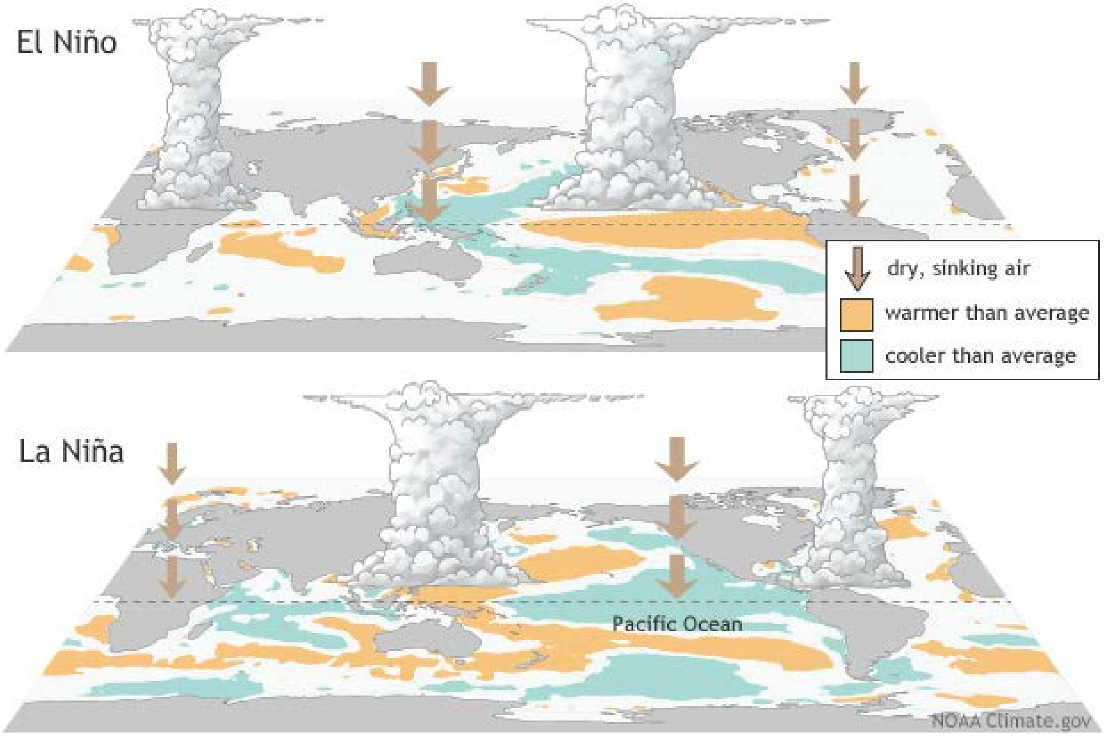


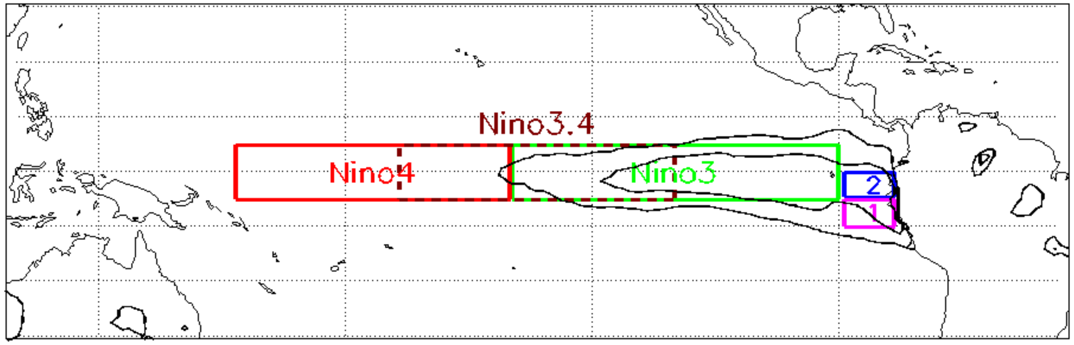
Figure 1 | Normal conditions in the tropical Pacific. Warm surface water and air are pushed to the west by prevailing winds. A consequence is upwelling of cold water on the eastern side, and a shallow thermocline (a subsurface boundary that marks a sharp contrast between warm upper waters and colder deeper waters). Opposite oceanographic conditions prevail on the western side. In the atmosphere, the west is warmer and wetter. Here and in Figure 2, redder colours denote warmer waters, bluer colours denote cooler waters.

(Ashok & Yamagata, Nature, 2009)

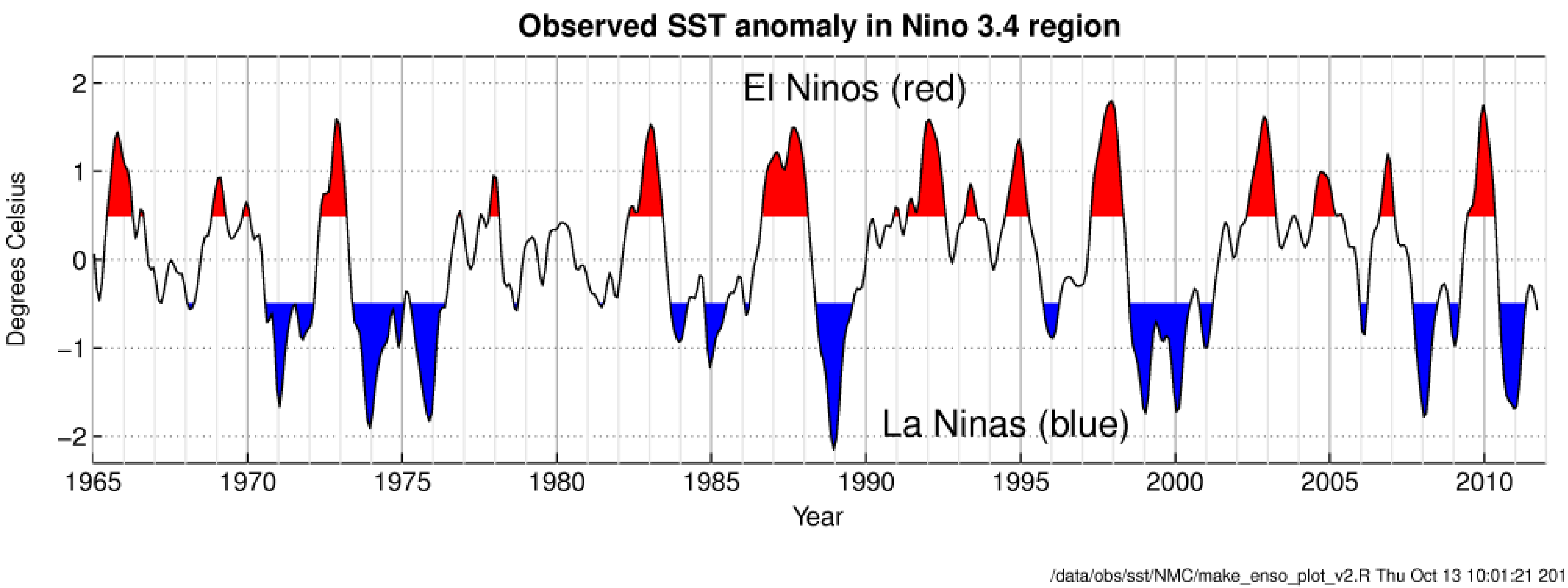


www.climate.gov/enso

Characterizing the El Niño/Southern Oscillation



Curtesy: William M. Connolley, https://commons.wikimedia.org/w/index.php?curid=8010087



Two different types of El Niño

Vol 461 | 24 September 2009 | doi:10.1038/nature08316

nature

LETTERS

El Niño in a changing climate

Sang-Wook Yeh[1], Jong-Seong Kug[1], Boris Dewitte[2], Min-Ho Kwon[3], Ben P. Kirtman[4] & Fei-Fei Jin[3]

Two Types of El Niño Events: Cold Tongue El Niño and Warm Pool El Niño

JONG-SEONG KUG* AND FEI-FEI JIN

School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, Honolulu,

SOON-IL AN

Department of Atmospheric Sciences, Yonsei University, Seoul, South Korea

(Manuscript received 13 May 2008, in final form 20 August 2008)

Asia-Pac. J. Atmos. Sci., 50(1), 69-81, 2014
DOI:10.1007/s13143-014-0028-3

REVIEW

Recent Progress on Two Types of El Niño: Observations, Dynamics, and Future Changes

Sang-Wook Yeh[1], Jong-Seong Kug[2], and Soon-Il An[3]

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[2]*Korea Institute of Ocean Science and Technology, Ansan, Korea*
[3]*Department of Atmospheric Sciences, Yonsei University, Seoul, Korea*

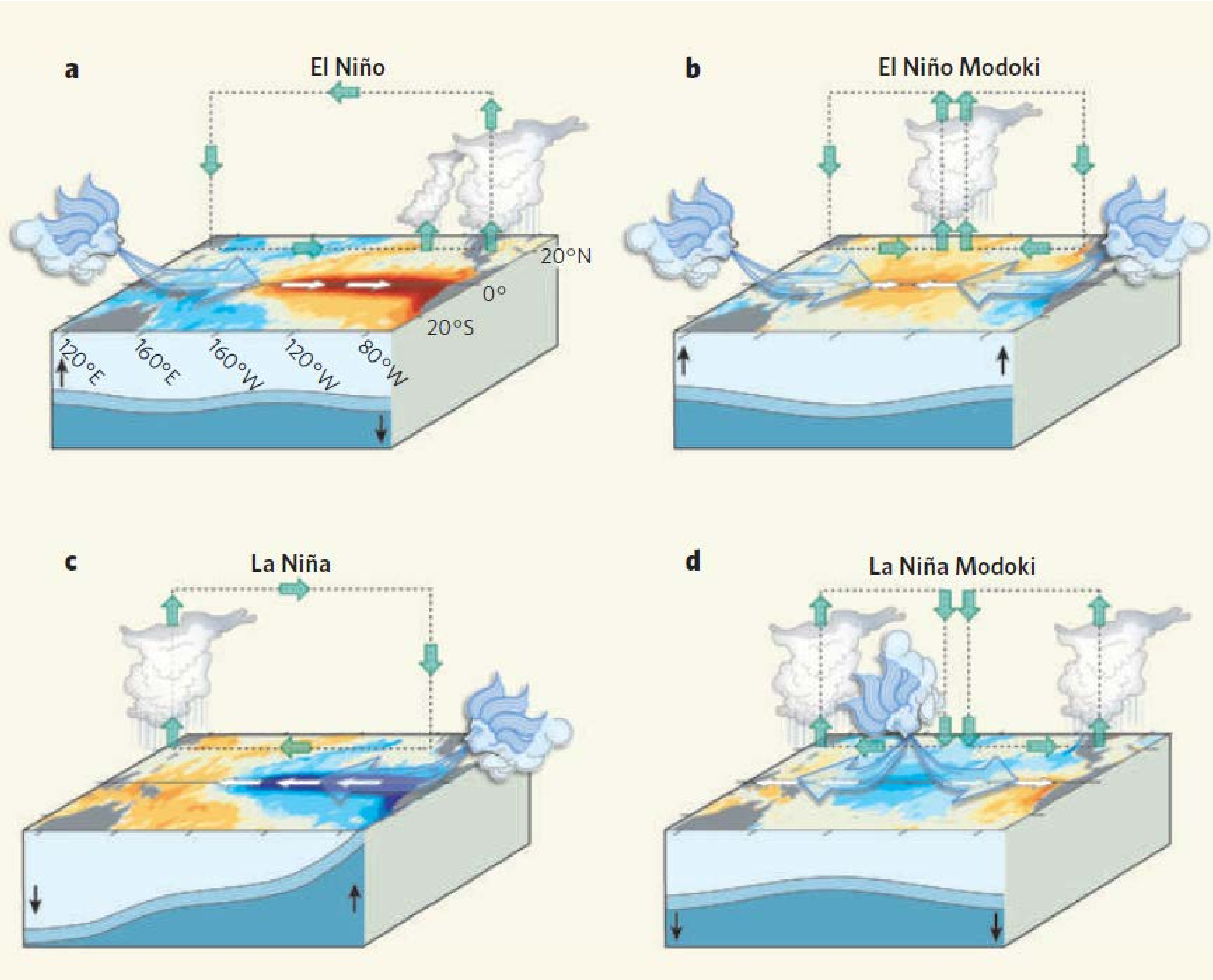
(Manuscript received 26 November 2013; accepted 8 January 2014)

GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L14603, doi:10.1029/2010GL044007, 2010

Increasing intensity of El Niño in the central-equatorial Pacific

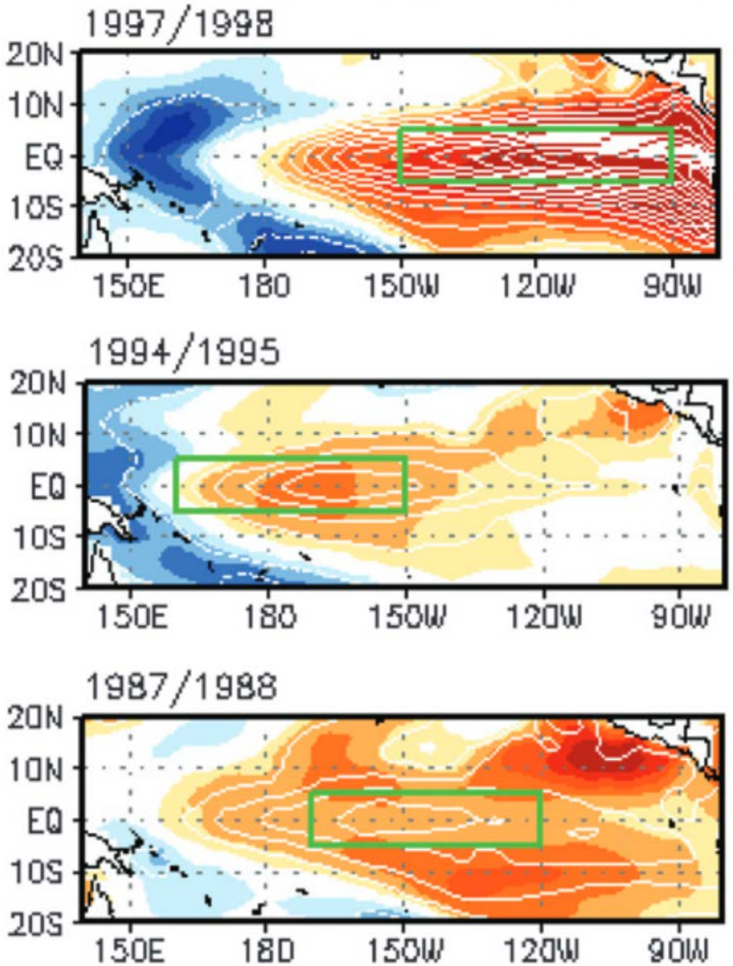
Tong Lee[1] and Michael J. McPhaden[2]

Received 15 May 2010; revised 7 June 2010; accepted 17 June 2010; published 24 July 2010.



(Ashok & Yamagata, Nature, 2009)

Discriminating El Niño flavors



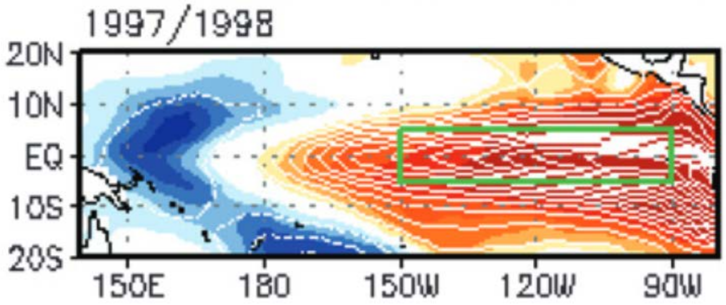
Canonical (East Pacific) El Niño

Dateline (Central Pacific) El Niño
(El Niño Modoki)

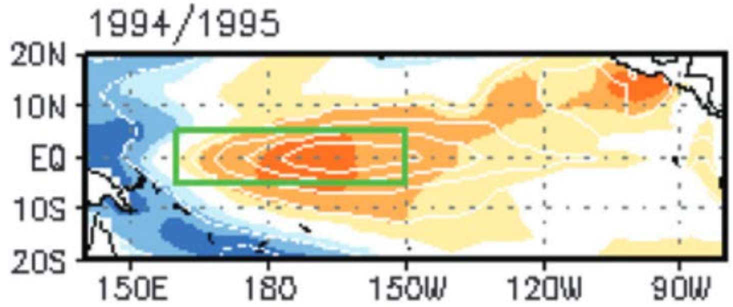
?

(Kug et al., J. Clim., 2009)

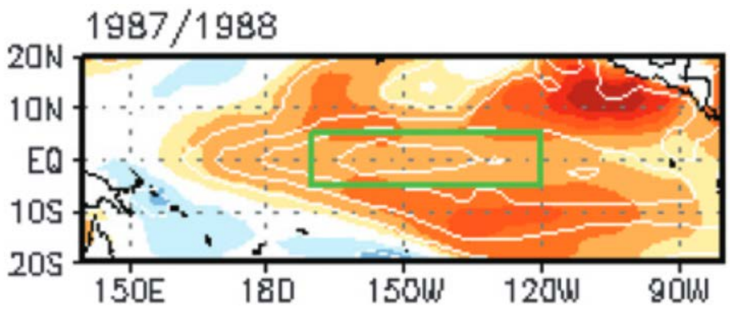
Discriminating El Niño flavors



Canonical (East Pacific) El Niño



Dateline (Central Pacific) El Niño (El Niño Modoki)



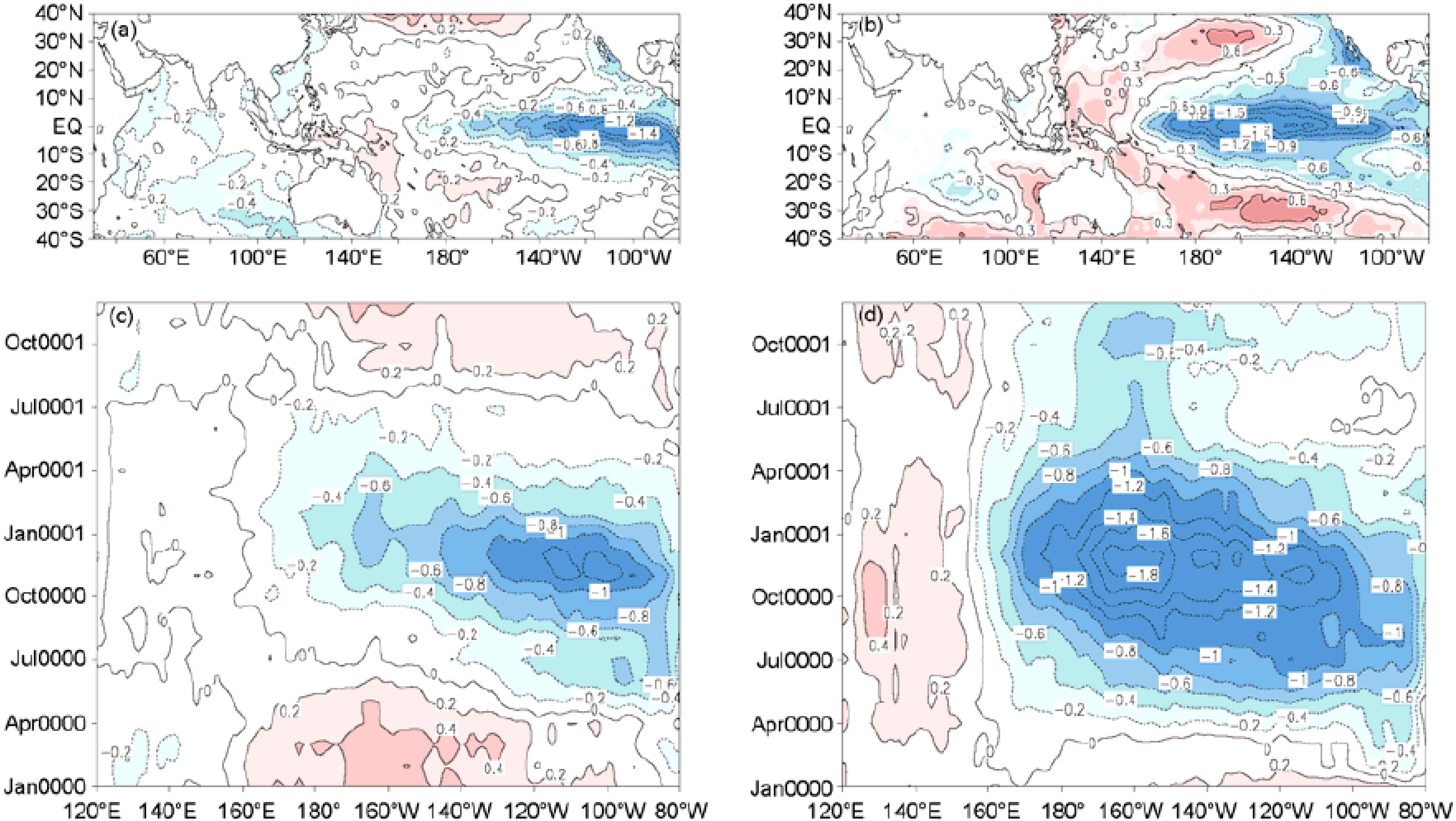
(Kug et al., J. Clim., 2009)

Mixed form? (Kug et al., J. Clim., 2009)
Canonical? (Kim et al., GRL, 2011; Hu et al., Clim. Dyn., 2012)
Central Pacific? (Larkin & Harrison, GRL, 2005)

	Kug et al. [2009]	*Kim et al.* [2011]	*Hu et al.* [2011]	*Larkin et al.* [2005]	*Hendon et al.* [2009]	*Graf et al.* [2012]	*Yeh et al.* [2009]	*Kim et al.* [2009]	Literature Synthesis
1953/1954	-	-	-	-	-	-	-	-	-
1957/1958	-	-	**EP**	**EP**	-	**EP**	**EP**	**EP**	**EP**
1958/1959	-	-	-	-	-	-	-	-	-
1963/1964	-	-	-	**CP**	-	**CP**	EP	EP	-
1965/1966	-	-	**EP**	**EP**	-	**EP**	**EP**	**EP**	**EP**
1968/1969	-	-	**CP**	**CP**	-	**CP**	**CP**	-	**CP**
1969/1970	-	-	EP	EP	-	-	EP	**CP**	-
1972/1973	**EP**	**EP**	**EP**	**EP**	-	**EP**	**EP**	**EP**	**EP**
1976/1977	**EP**	**EP**	-	**EP**	-	**EP**	**EP**	**EP**	**EP**
1977/1978	**CP**	**CP**	-	**CP**	-	**CP**	**CP**	-	**CP**
1979/1980	-	-	-	-	-	-	b	-	-
1982/1983	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**
1986/1987	b	EP	EP	**CP**	**CP**	**CP**	EP	-	-
1987/1988	b	-	**CP**	EP	EP	-	EP	EP	-
1991/1992	b	EP	EP	EP	**CP**	**CP**	EP	**CP**	-
1994/1995	**CP**	**CP**	**CP**	**CP**	**CP**	**CP**	**CP**	**CP**	**CP**
1997/1998	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**
2002/2003	**CP**	**CP**	**CP**	EP	**CP**	**CP**	b	**CP**	-
2004/2005	**CP**	**CP**	-	-	**CP**	**CP**	**CP**	**CP**	**CP**
2006/2007	-	EP	**CP**	**CP**	-	-	EP	-	-
2009/2010	-	**CP**	-	-	-	**CP**	-	-	**CP**

What about La Nina?

(Yuan & Yan, Chin. Sci. Bull., 2013)



What about La Nina?

Possible criteria suggested in literature:

- **Location of strongest negative SST anomaly**
- **Sign of difference between normalized Nino3 and Nino4 indices**

⇒ **Objective classification?**

Type	La Niña	Mature phase	SSTA propagating direction
EP	1954–1957	Nov 1955–Jan 1956	east to west
	1964–1965	Oct–Dec 1964	east to west
	1967–1968	Jan–Mar 1968	east to west
	1970–1971	Jul–Sep 1970	east to west
	1978	Jun–Aug 1978	east to west
	1995–1996	Sep–Nov 1995	east to west
	2005–2006	Nov 2005–Jan 2006	east to west
CP	1973–1974	Nov 1973–Jan 1974	east to west
	1975–1976	Sep–Nov 1975	west to east
	1983–1985	Nov 1984–Jan 1985	west to east
	1988–1989	Nov 1988–Jan 1989	east to west
	1998–2001	Jan–Mar 2000	west to east
	2007–2009	Jan–Mar 2008	east to west
	2010–2012	Nov 2010–Jan 2011	west to east

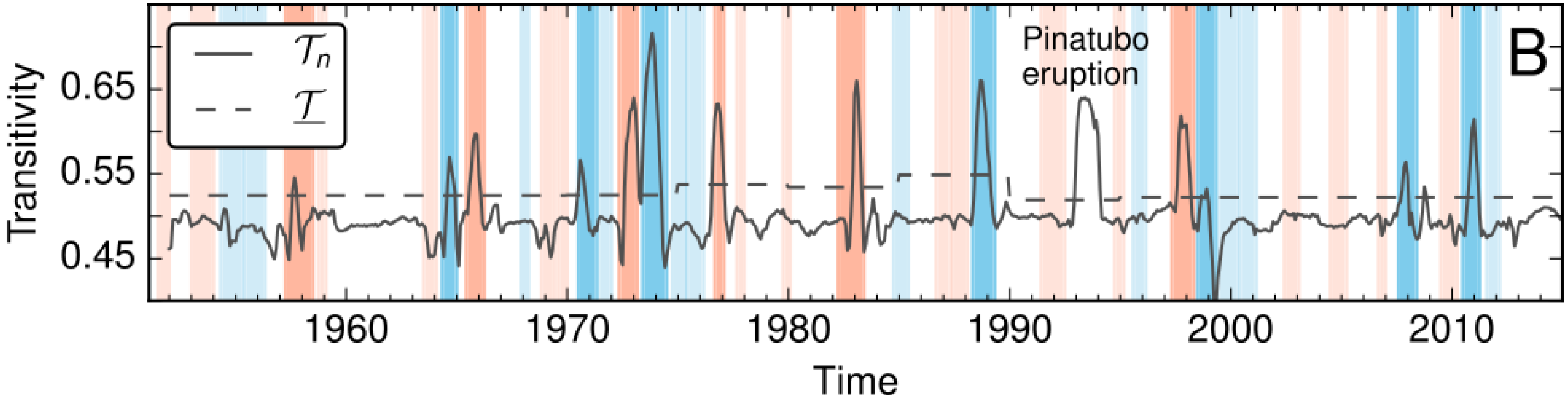
(Yuan & Yan, Chin. Sci. Bull., 2013)

Discriminating El Niño and La Niña flavors

Problem: systematic distinction between different East and Central Pacific El Niños and La Niñas using a single index

Approach: Use sophisticated mathematical concepts (climate network analysis) taking global instead of regional information into account ***[details: lecture on Wednesday]***

⇒ New index for automated discrimination between both flavors



(Wiedermann et al., GRL, 2016)

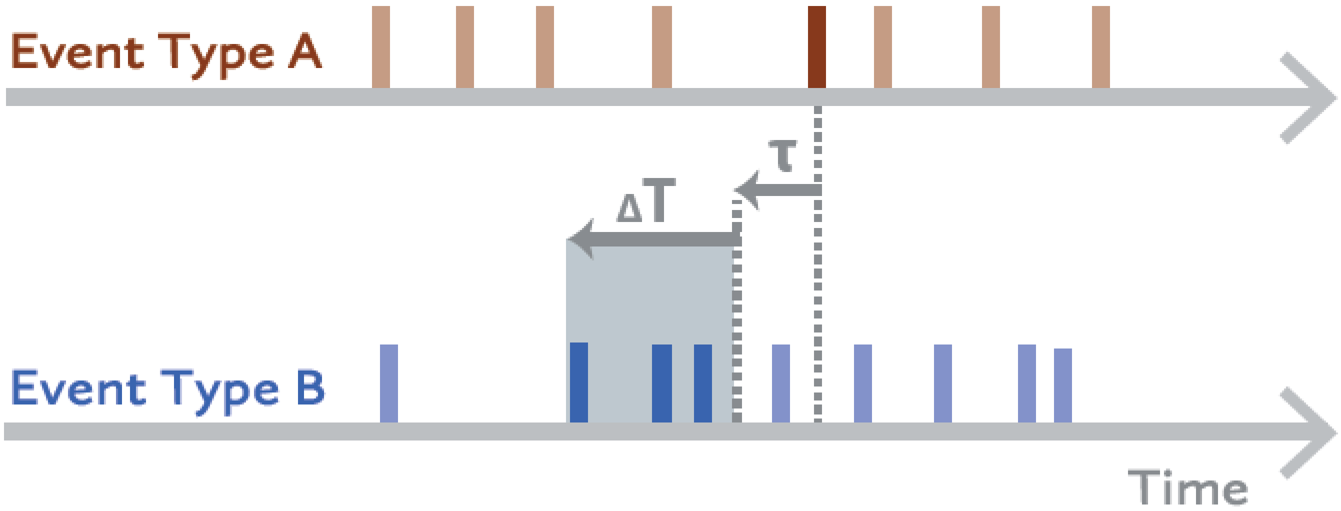
	Kug et al. [2009]	*Kim et al.* [2011]	*Hu et al.* [2011]	*Larkin et al.* [2005]	*Hendon et al.* [2009]	*Graf et al.* [2012]	*Yeh et al.* [2009]	*Kim et al.* [2009]	Literature Synthesis	This study
1953/1954	-	-	-	-	-	-	-	-	-	CP
1957/1958	-	-	**EP**	**EP**	-	**EP**	**EP**	**EP**	**EP**	EP
1958/1959	-	-	-	-	-	-	-	-	-	CP
1963/1964	-	-	-	**CP**	-	**CP**	EP	EP	-	CP
1965/1966	-	-	**EP**	**EP**	-	**EP**	**EP**	**EP**	**EP**	EP
1968/1969	-	-	**CP**	**CP**	-	**CP**	**CP**	-	**CP**	CP
1969/1970	-	-	EP	EP	-	-	EP	**CP**	-	CP
1972/1973	**EP**	**EP**	**EP**	**EP**	-	**EP**	**EP**	**EP**	**EP**	EP
1976/1977	**EP**	**EP**	-	**EP**	-	**EP**	**EP**	**EP**	**EP**	EP
1977/1978	**CP**	**CP**	-	**CP**	-	**CP**	**CP**	-	**CP**	CP
1979/1980	-	-	-	-	-	-	b	-	-	CP
1982/1983	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**	EP
1986/1987	b	EP	EP	**CP**	**CP**	**CP**	EP	-	-	CP
1987/1988	b	-	**CP**	EP	EP	-	EP	EP	-	CP
1991/1992	b	EP	EP	EP	**CP**	**CP**	EP	**CP**	-	CP
1994/1995	**CP**	**CP**	**CP**	**CP**	**CP**	**CP**	**CP**	**CP**	**CP**	CP
1997/1998	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**	**EP**	EP
2002/2003	**CP**	**CP**	**CP**	EP	**CP**	**CP**	b	**CP**	-	CP
2004/2005	**CP**	**CP**	-	-	**CP**	**CP**	**CP**	**CP**	**CP**	CP
2006/2007	-	EP	**CP**	**CP**	-	-	EP	-	-	CP
2009/2010	-	**CP**	-	-	-	**CP**	-	-	**CP**	CP
TPR	1.0	0.57	0.62	0.6	0.67	1.0	0.5	0.75	1.0	

Event coincidence analysis

Take one of the series as reference and count number of cases in which at least one event in the other series occurs within in given time window relative to the timing of the reference event

⇒ **Asymmetric property (potential for establishing directionality statements)**

⇒ **Distinction between "trigger" and "precursor" tests**



Event coincidence analysis

Sufficiently many yet sparse and uncorrelated events: independent Poisson processes as null model – analytical significance bounds: binomial distribution

$$P(K \geq K_e) = \sum_{K^*=K_e}^{N_A} P(K^*; N_A, 1-(1-p)^{N_B})$$

with

$$P(K; N_A, 1-(1-p)^{N_B}) = \binom{N_A}{K} \left(1 - \left(1 - \frac{\Delta T}{T-\tau}\right)^{N_B}\right)^{K} \left(\left(1 - \frac{\Delta T}{T-\tau}\right)^{N_B}\right)^{N_A-K}$$

If conditions for this approximation do not hold: numerical approximation of test statistics (sequences with random event times, random event sequences with conserved waiting time distribution, etc.)

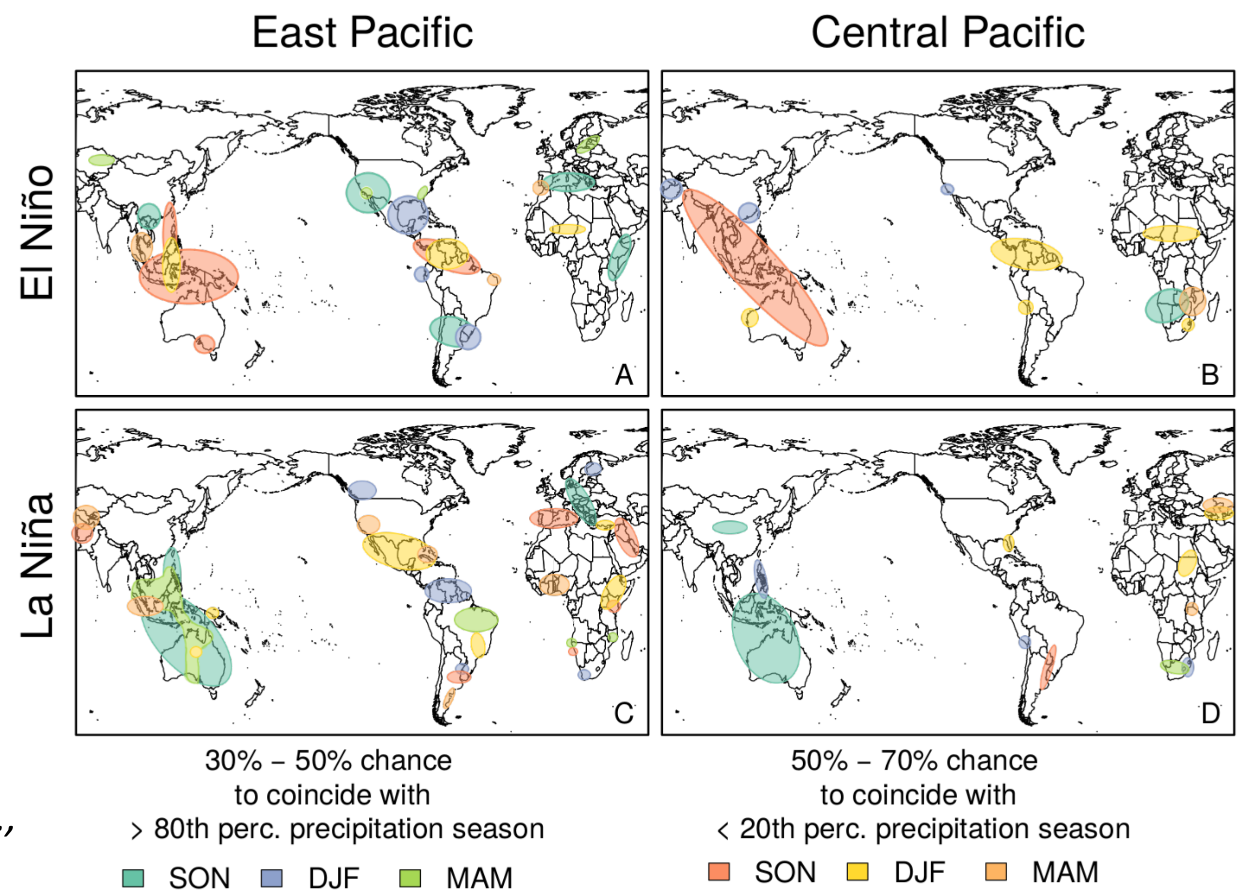
$\Rightarrow$ **hierarchy of possible surrogates and, hence, statistical tests**

Various recent applications

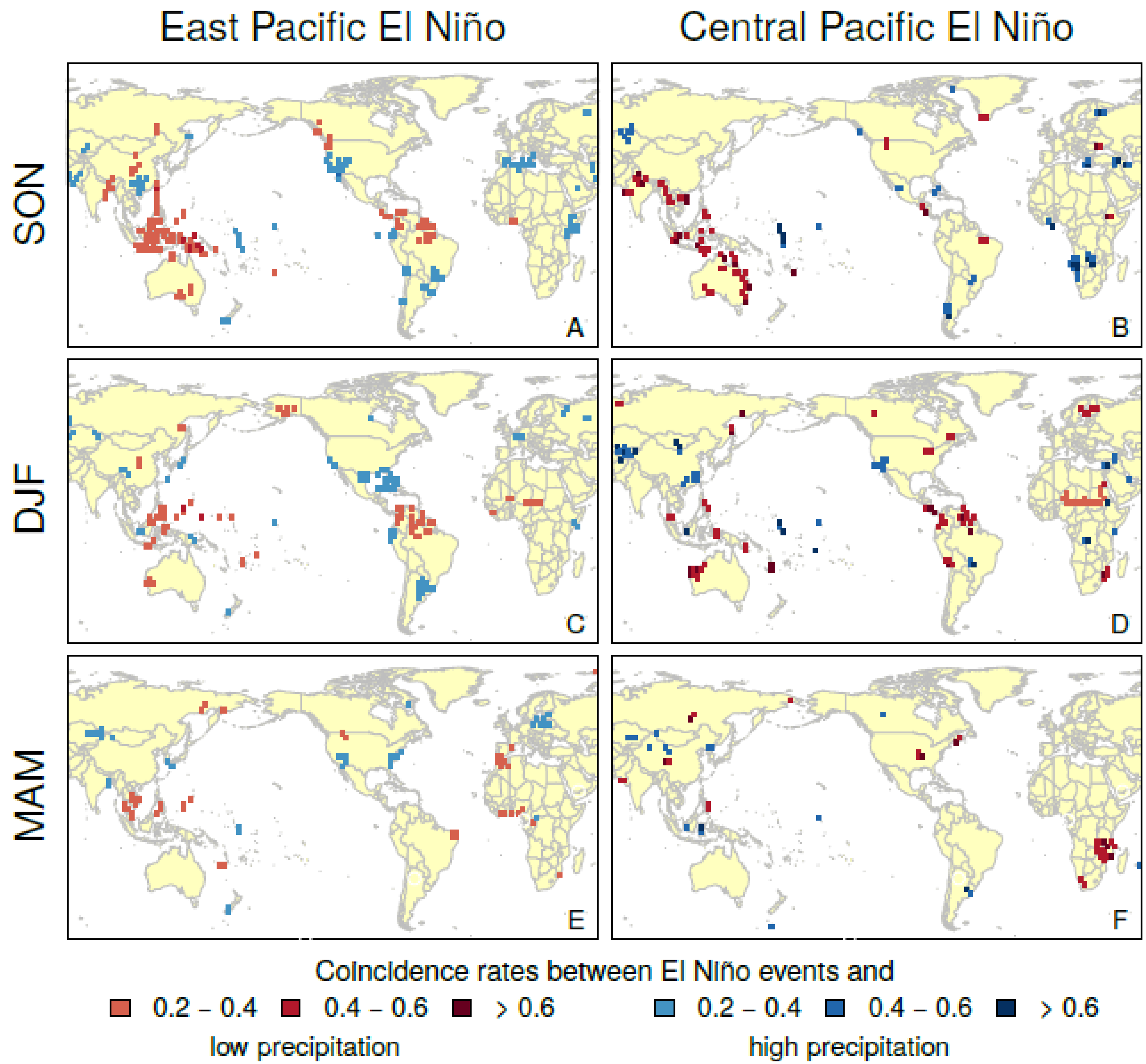
- Major steps in hominin evolution vs. large-scale dynamical reorganizations of African climate over the last 5 Myr (Donges et al., PNAS, 2011)
- Anomalous historical tree growth in Europe vs. years with very (un)favourable climate conditions (Rammig et al., Biogeosciences, 2015)
- Anomalous flowering dates of German shrubs vs. seasonal temperature extremes during specific times of the year (Siegmund et al., Biogeosciences, 2016)
- Anomalous daily tree growth based on dendrometer data vs. extraordinary meteorological conditions (Siegmund et al., Frontiers in Plant Science, 2016)
- Anomalous vegetation greenness vs. extraordinary land surface temperatures (Baumbach et al., Biogeosciences Discussions, 2017)
- Regional epidemic outbreaks vs. flood events (Donges et al., EPJST, 2016)
- Outbreak of violent conflicts vs. high economic impact natural hazards (Schleussner et al., PNAS, 2016)

Regional impacts of El Niño and La Niña flavors

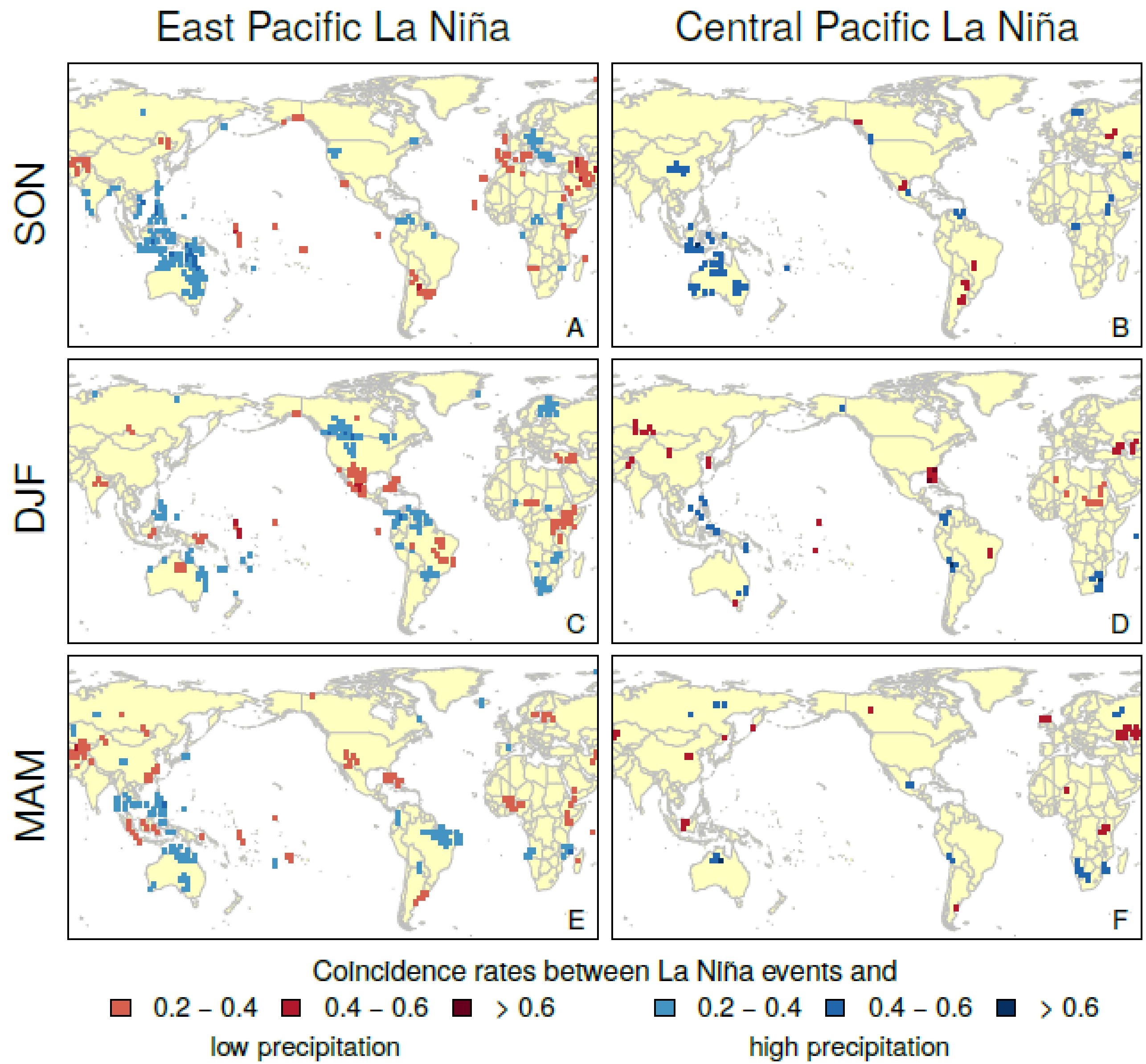
Simultaneous occurrence with extremely low/high seasonal precipitation sums



(Wiedermann et al., under review)



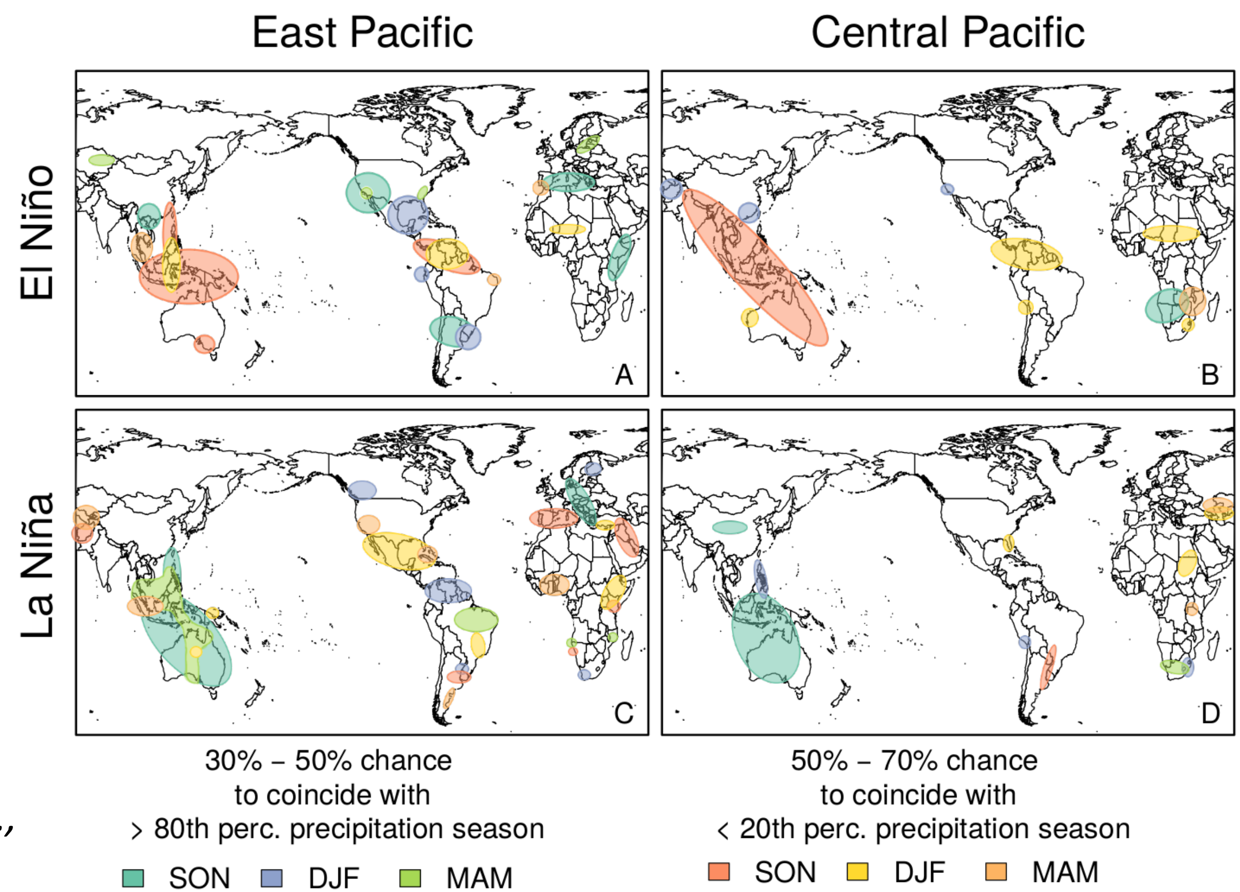
(Wiedermann et al., under review)



(Wiedermann et al., under review)

Regional impacts of El Niño and La Niña flavors

Simultaneous occurrence with extremely low/high seasonal precipitation sums



(Wiedermann et al., under review)

Conclusions

- **Systematic discrimination between different flavors of El Niño and La Niña** *(Radebach et al., PRE, 2013; Wiedermann et al., GRL, 2016)*

- **Event coincidence analysis as new statistical analysis tool for quantifying interrelationships between distinct events – included in software packages `CoinCalc` (R) and `pyunicorn` (Python) [both available at GitHub]**

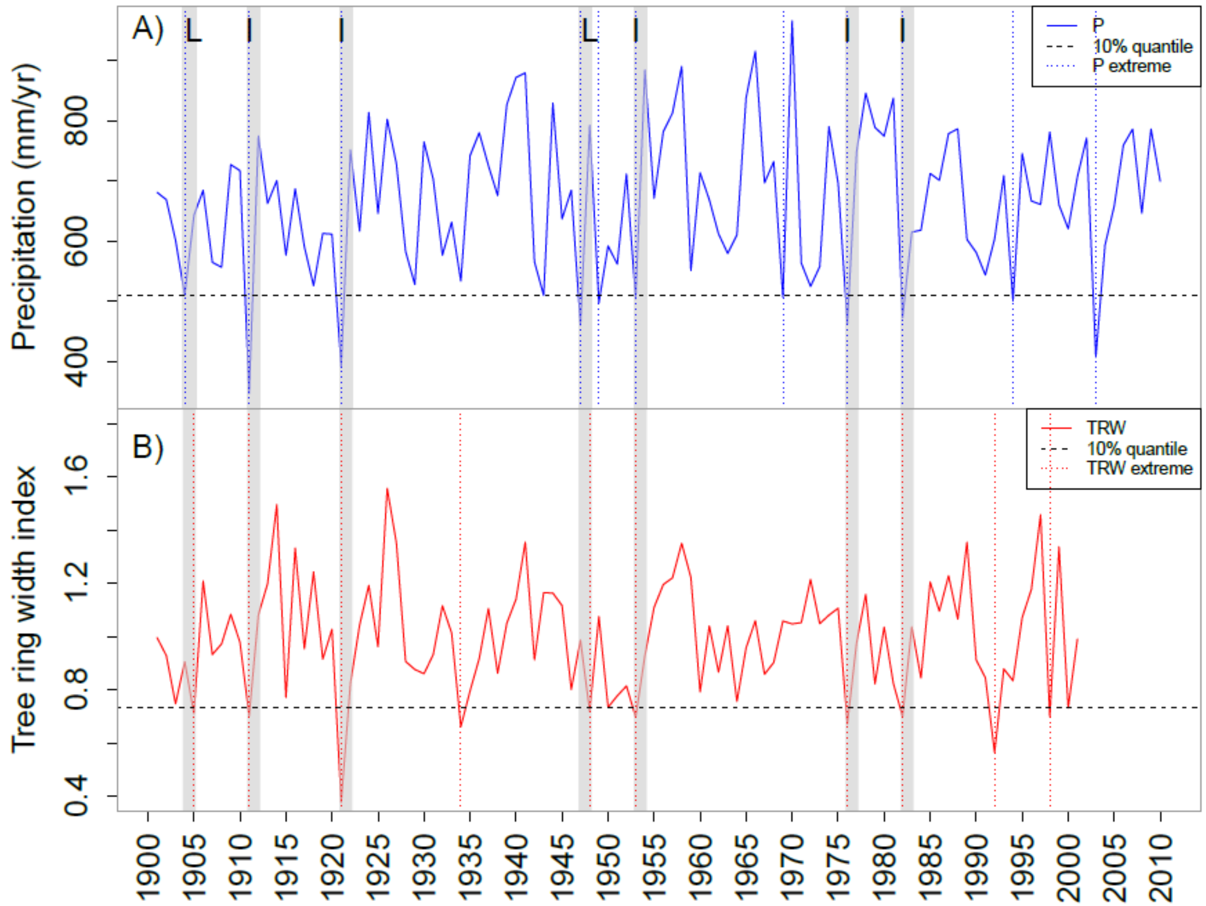
- **Distinct regional impact patterns of both flavors in terms of seasonal precipitation extremes around the globe** *(Wiedermann et al., under review, arXiv: 1702.00218)*

- **Work in progress: obtain and interpret regional impact patterns for**
  - **seasonal temperature extremes**
  - **occurrence of short-term extremes in precipitation / temperature**
  - **productivity of natural and managed terrestrial ecosystems (agriculture, forestry)**

Backup slides

Example 1: Tree-ring widths

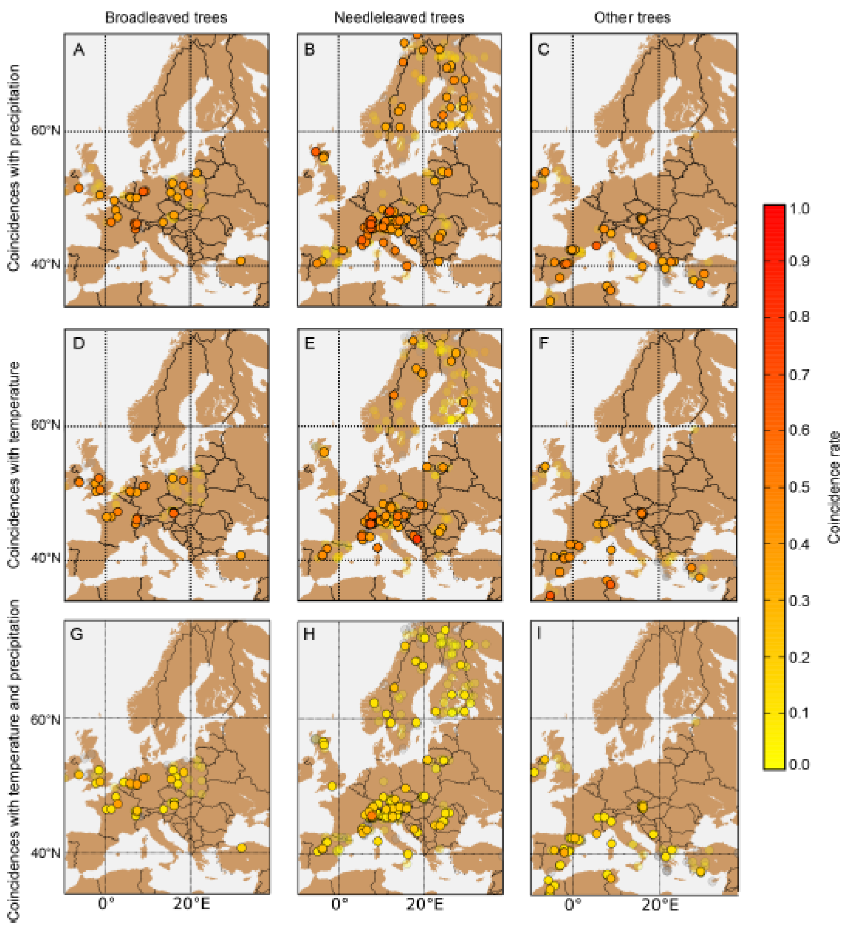
[back]

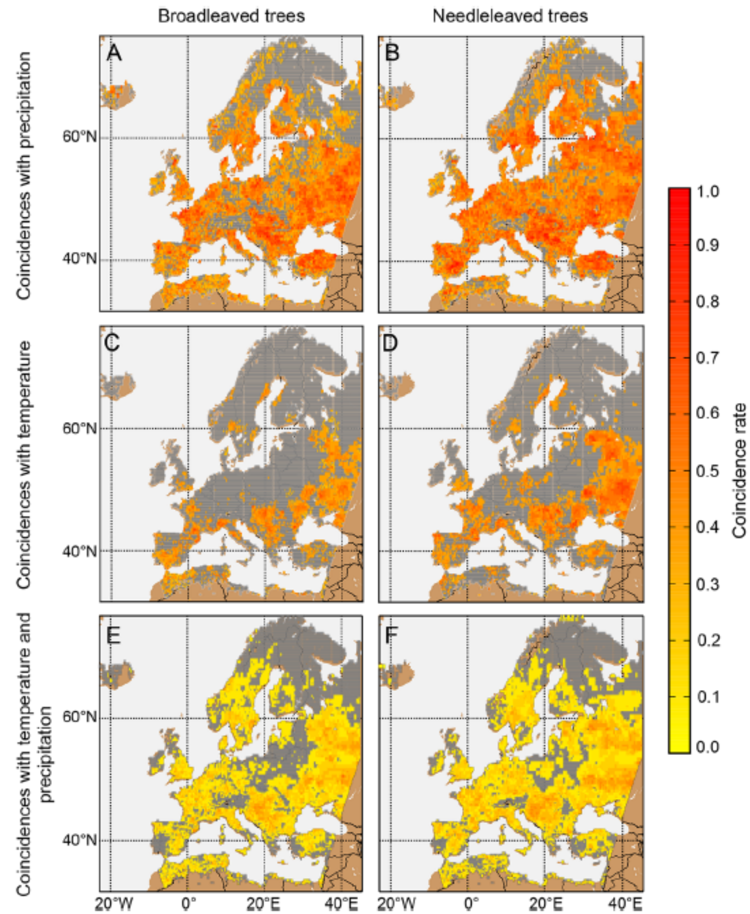


Rammig et al., Biogeosciences, 2015

Example 1: Tree-ring widths & model

[back]

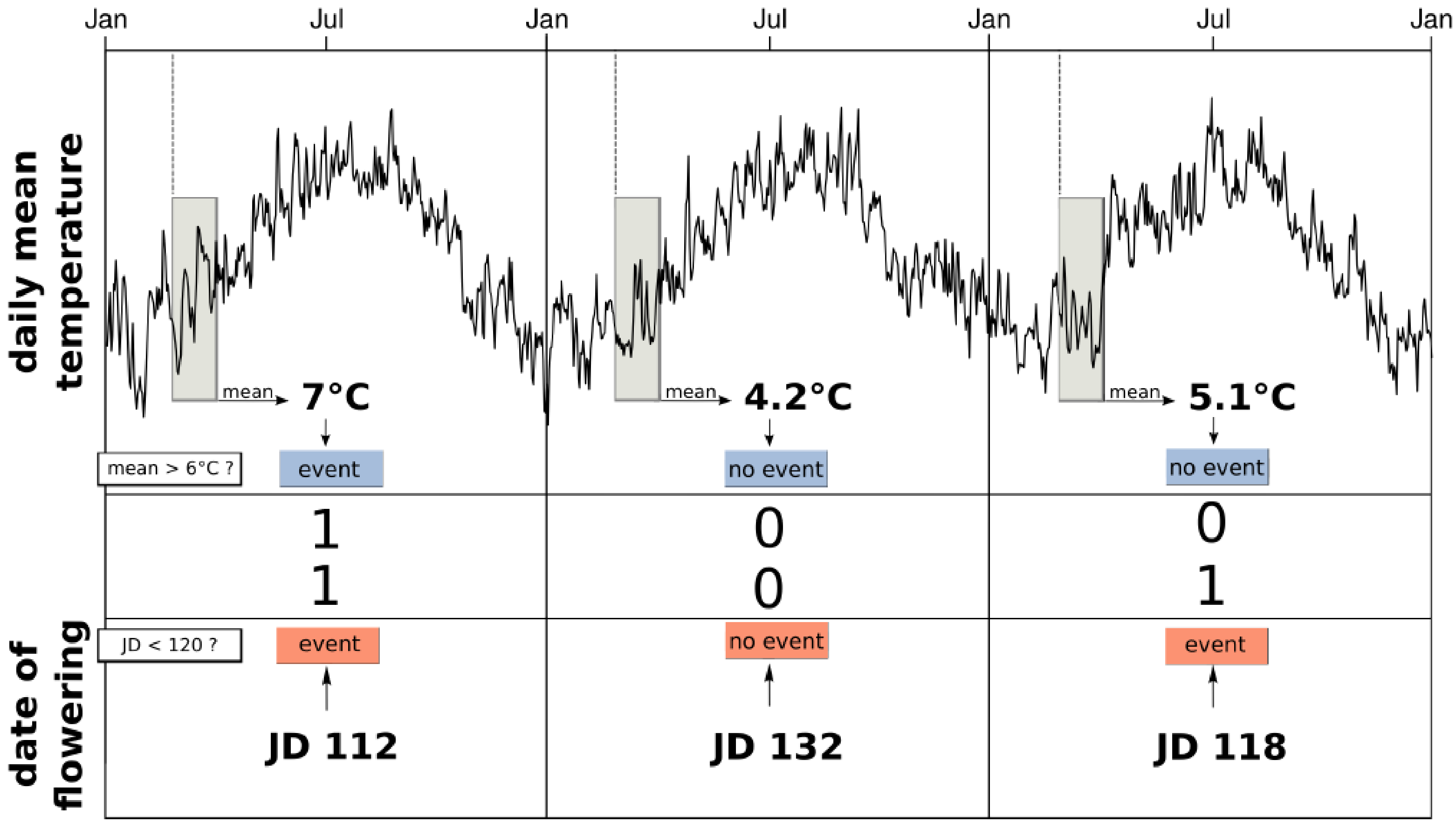




Rammig et al., Biogeosciences, 2015

Example 2: Plant Phenology

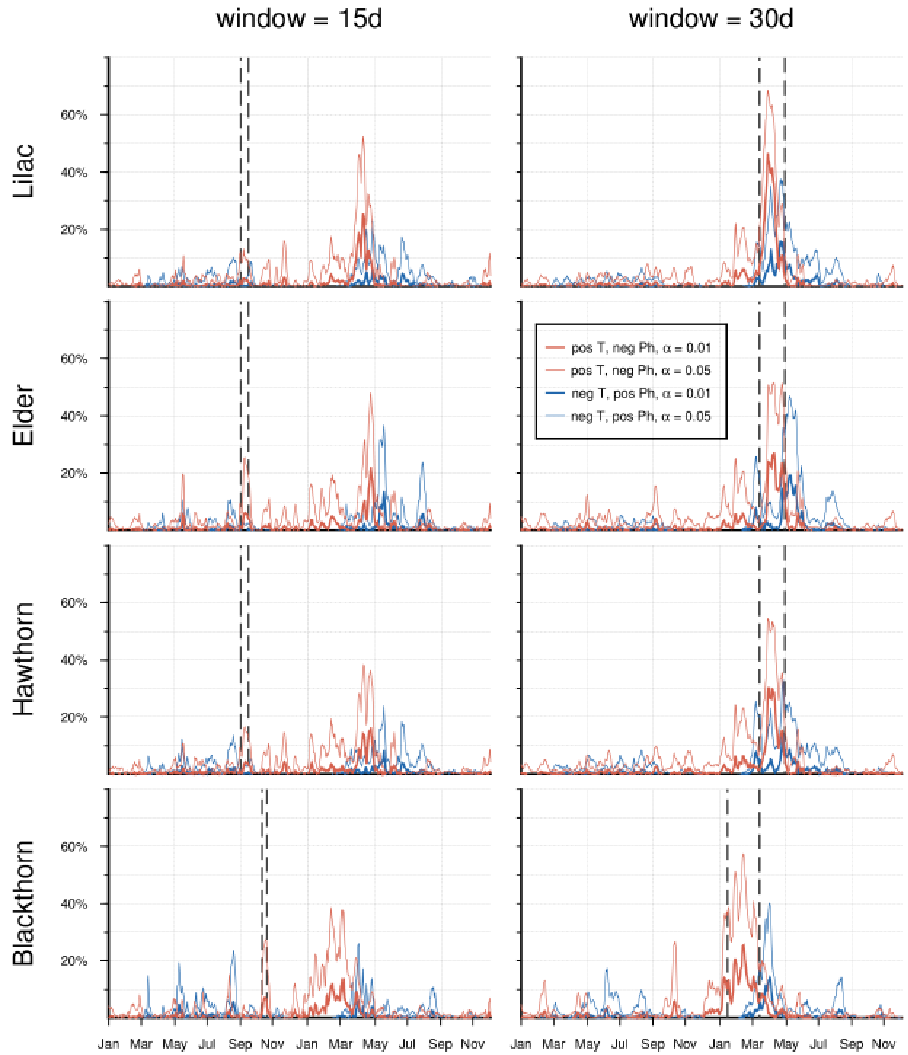
[back]



Siegmund et al., Biogeosciences, 2016

Example 2: Plant Phenology

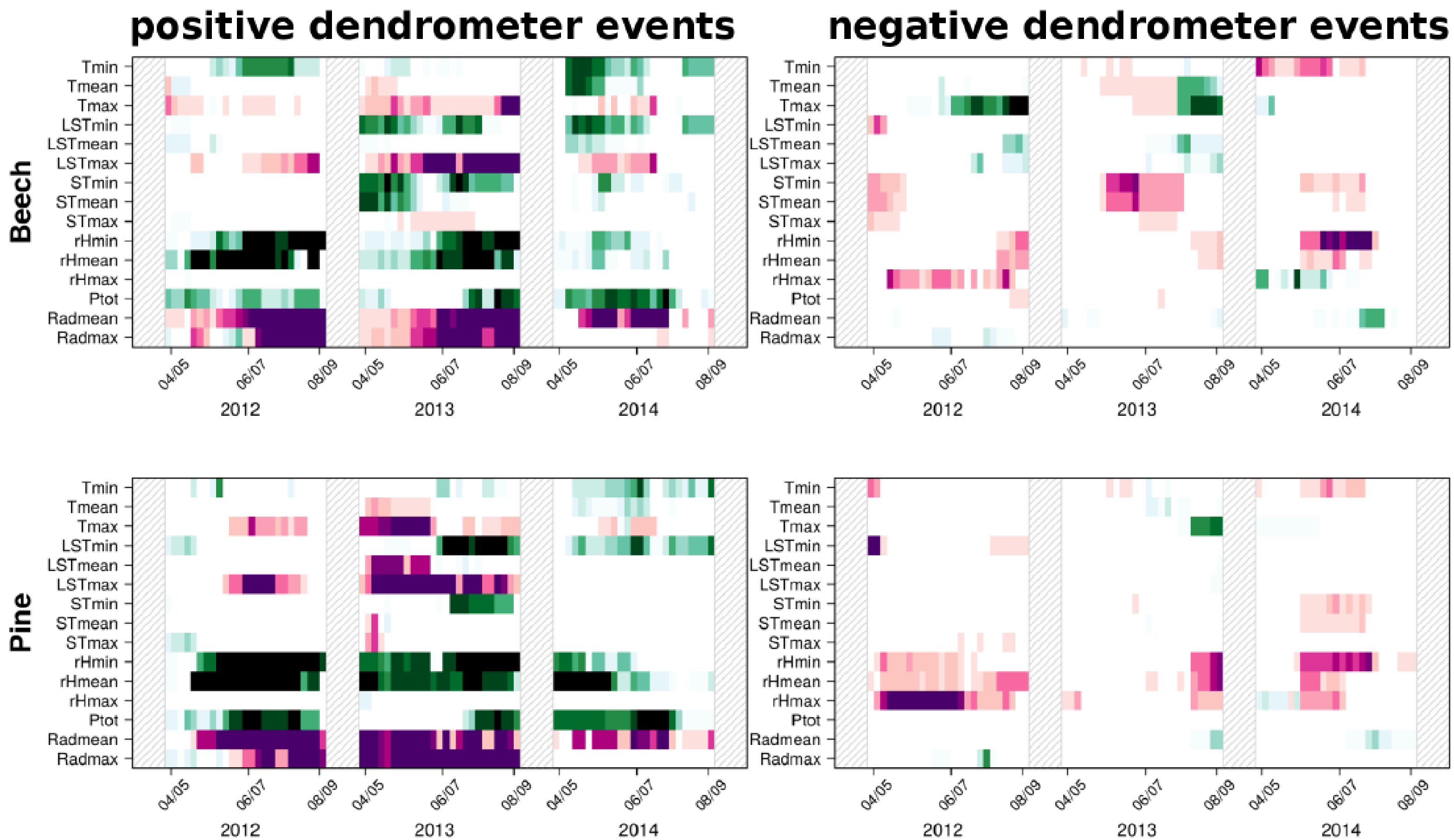
[back]



Siegmund et al., Biogeosciences, 2016

Example 3: Dendrometer

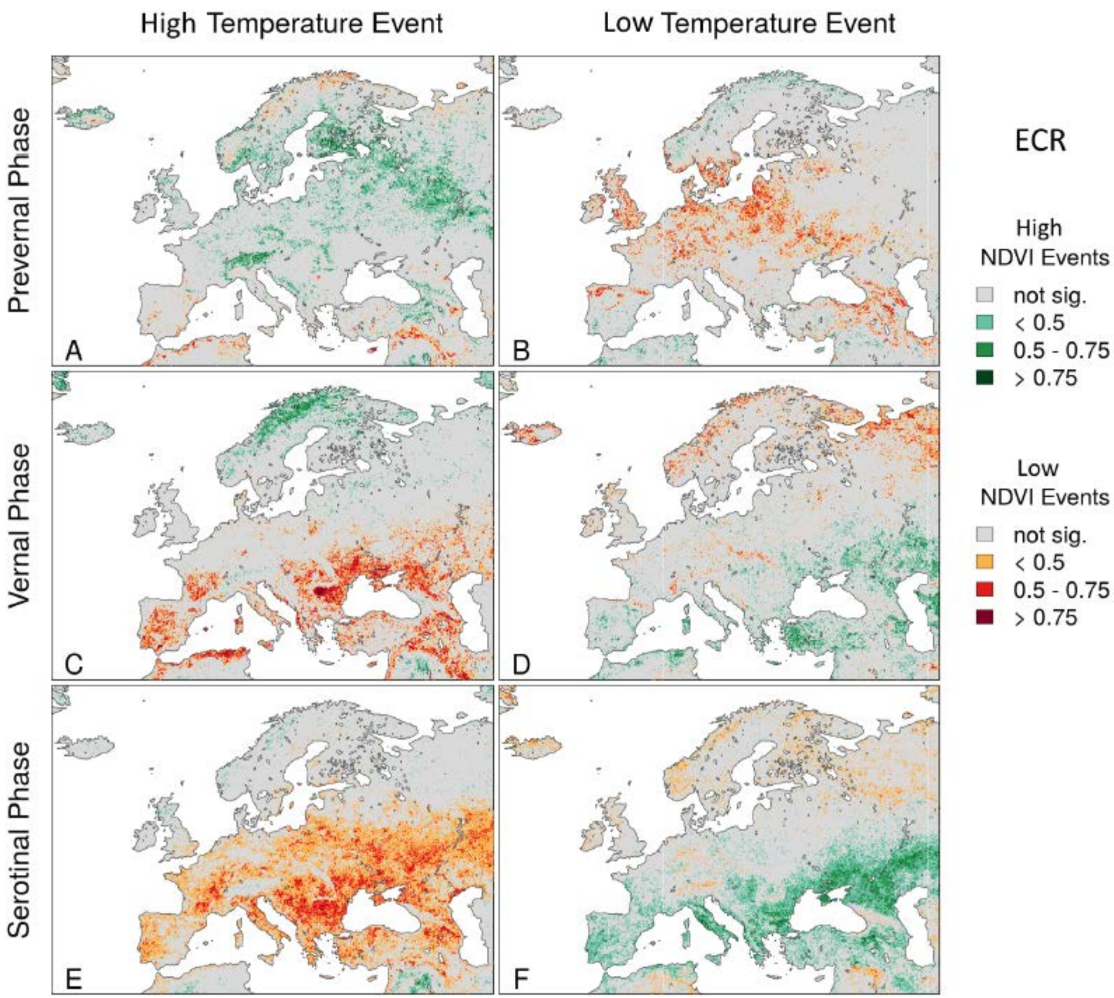
[back]



Siegmund et al., Front. Plant Sci., 2016

Example 4: Remote sensing – NDVI vs. LST

[back]

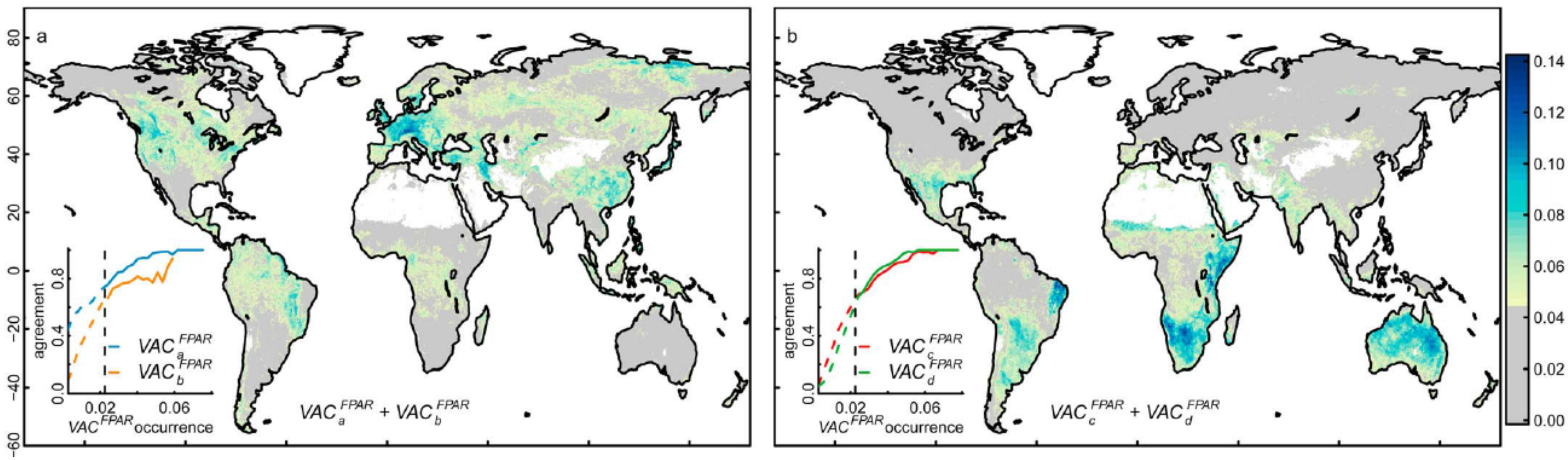


Baumbach et al., Biogeosciences Disc., 2017

Example 4: Remote sensing – FPAR vs. ET

[back]

Sign of Anomalies		Index	SM Regime	Status
$T-$	FPAR/ET–	VAC_a	energy-limited	wettening, atmospheric control
$T+$	FPAR/ET+	VAC_b	energy-limited	drying, atmospheric control
$T+$	FPAR/ET–	VAC_c	transitional	drying, land/vegetation control
$T-$	FPAR/ET+	VAC_d	transitional	wettening, land/vegetation control



Zscheischler et al., GRL, 2015