

# 해양/대기 상호작용 (엘니뇨/라니냐)

# ▶ 엘니뇨의 주기성

(Wittenberg 2009, GRL)

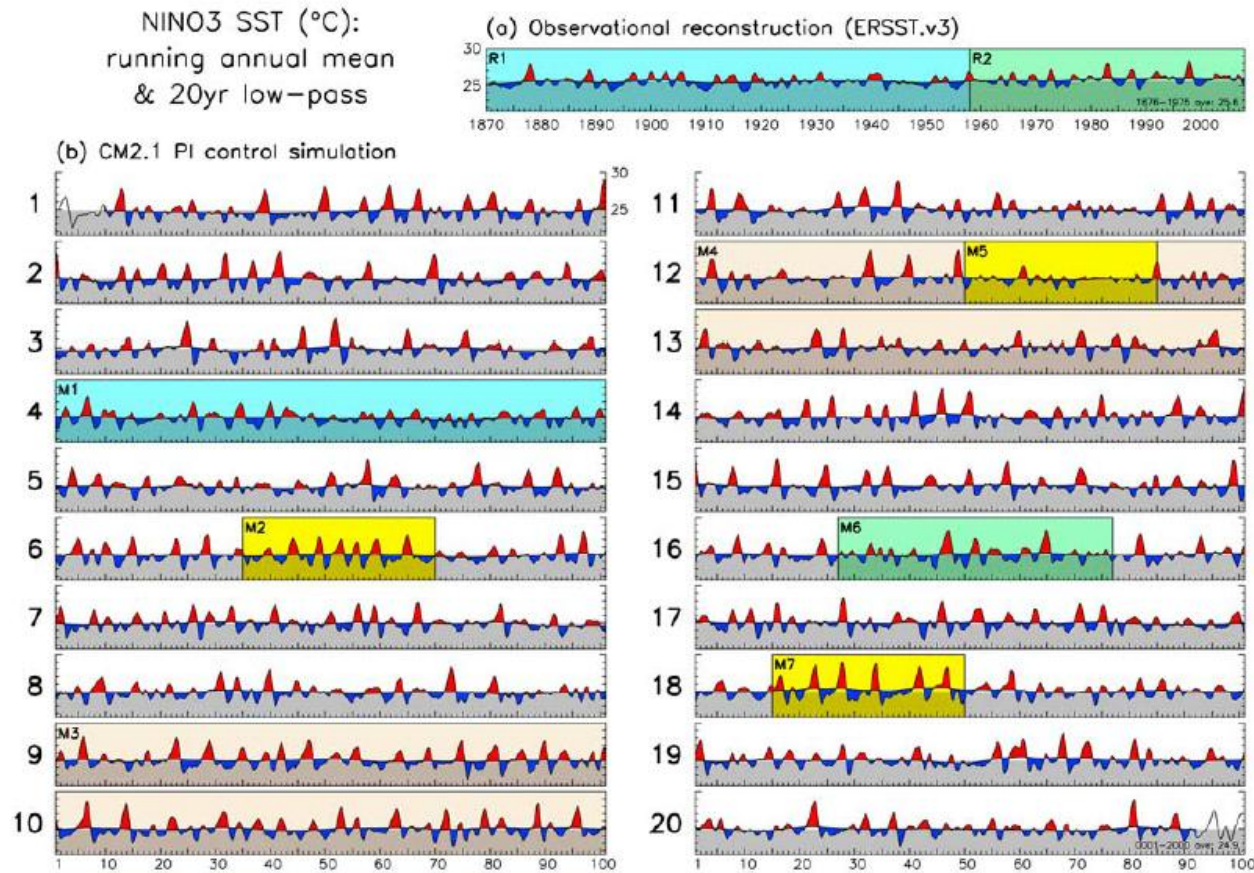
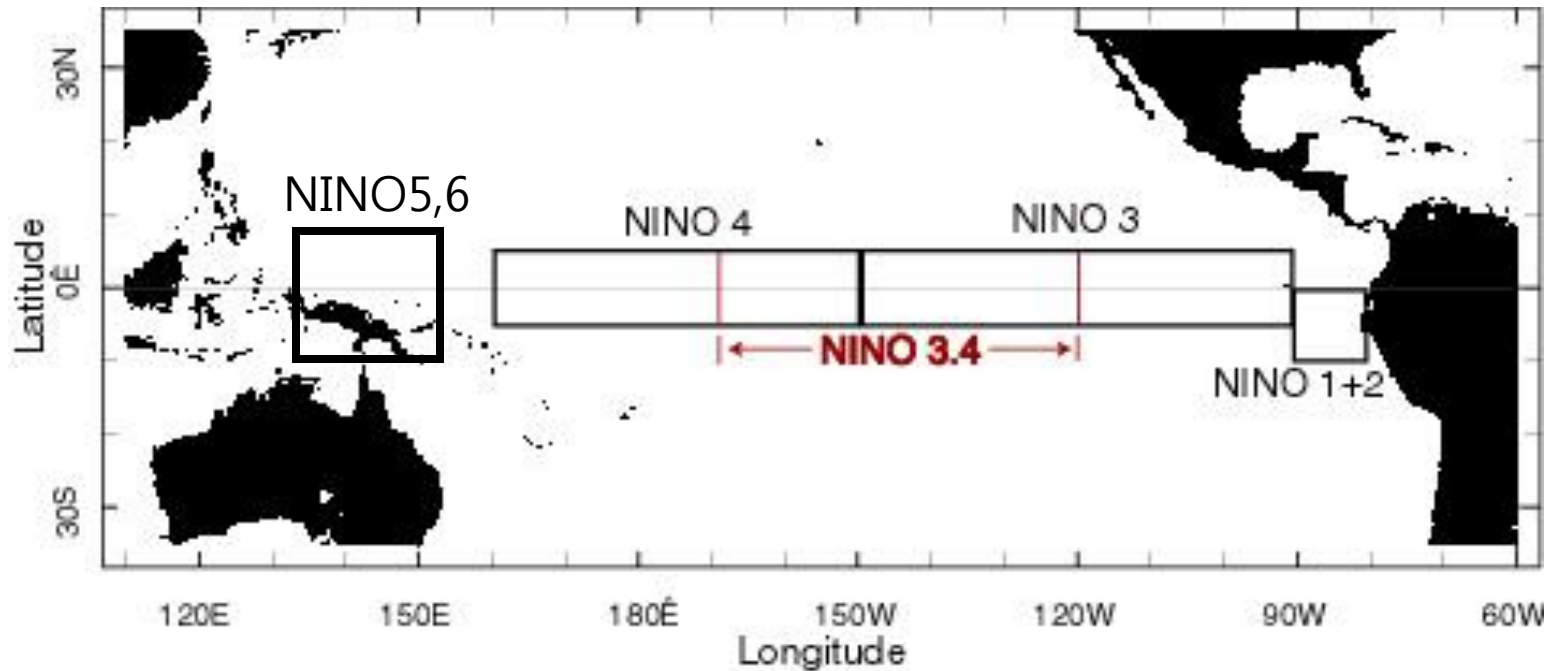


Figure 1. SST (°C) averaged over the NINO3 region (150°W–90°W, 5°S–5°N), for (a) the ERSST.v3 historical reconstruction of *Smith et al.* [2008], and (b) the 20 consecutive centuries (numbered) from the CM2.1 pre-industrial control run. Red/blue shading highlights departures of the running annual-mean SST from the multidecadal background state, where the latter is obtained via a 211-month triangle smoother which transmits (25, 50, 75)% of the time series amplitude at periods of (15, 20, 30) yr. Unshaded time series ends in Figure 1b indicate the half-width of the triangle smoother; ends of the observed time series in Figure 1a are zero-padded prior to smoothing. The top of the gray bar is the long-term mean, indicated at the bottom right of each plot. Labeled epochs are discussed in the text.

## ▶ 엘니뇨 감시 해역

### Nino Indices



# ▶ 엘니뇨/라니냐 역사: Historical El Nino / La Nina events

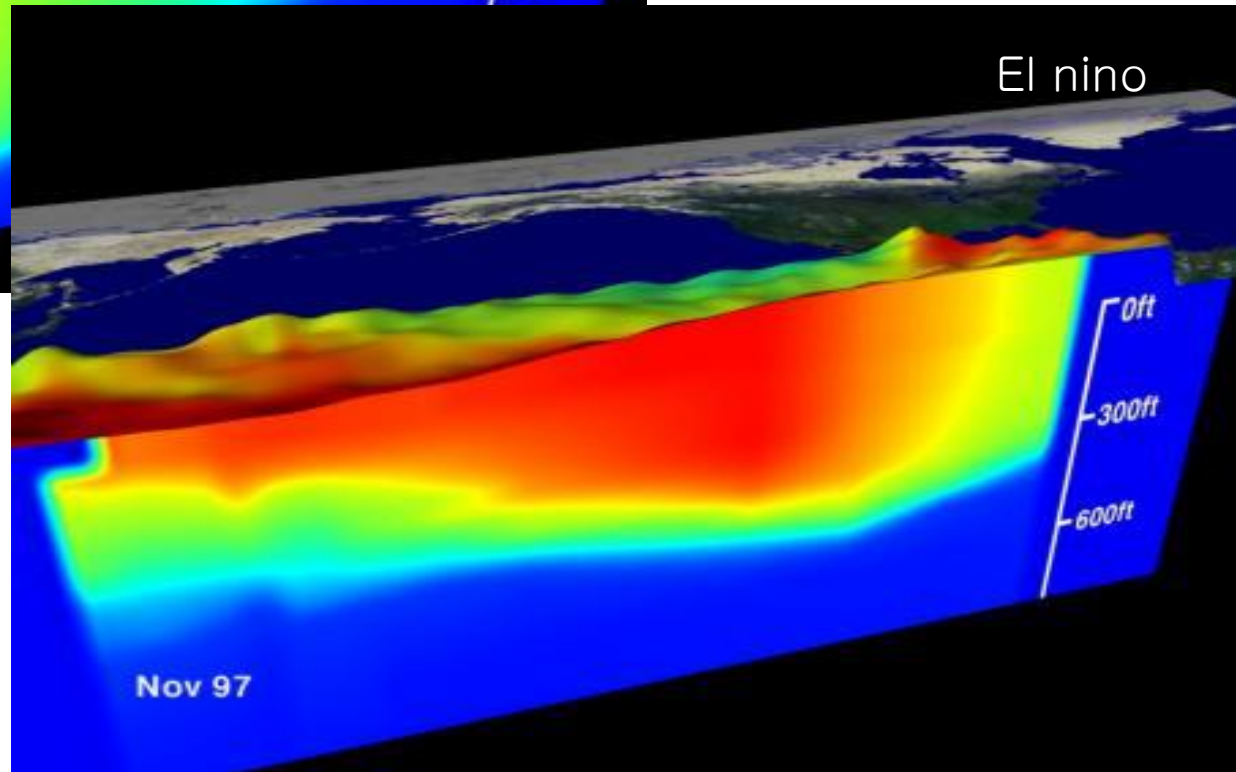
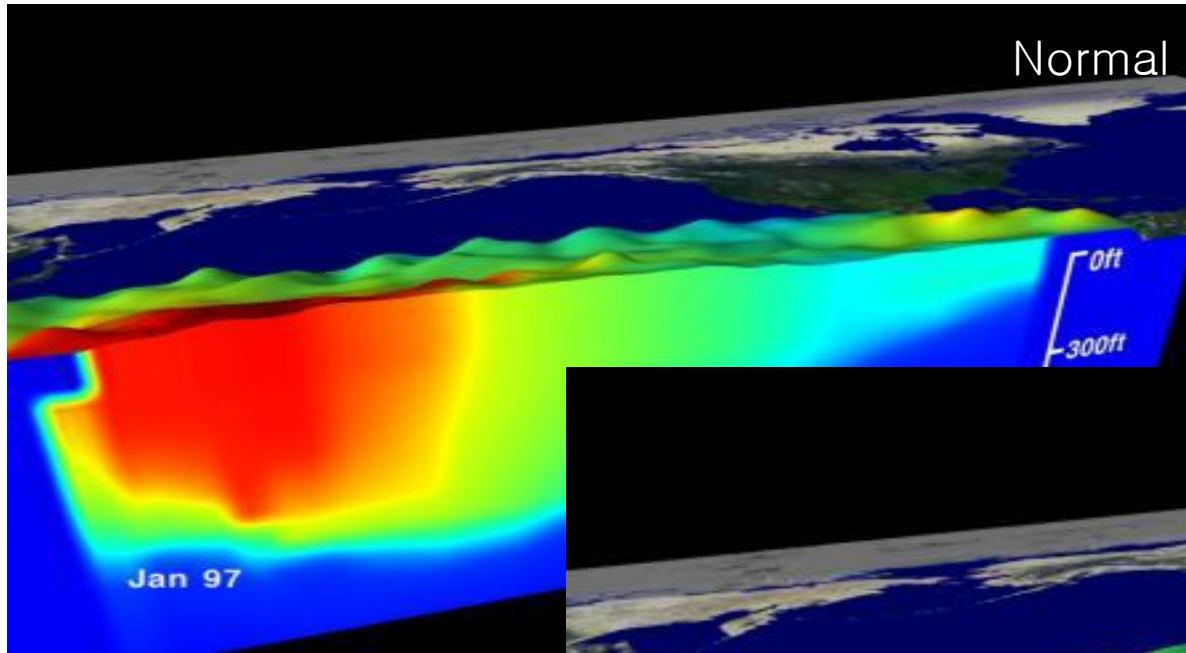
SST anomalies in the Niño 3.4 region (5°N-5°S, 120°-170°W) (from NOAA CPC)

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1950	-1.4	-1.3	-1.2	-1.2	-1.1	-0.9	-0.6	-0.5	-0.4	-0.5	-0.6	-0.7
1951	-0.8	-0.6	-0.4	-0.2	0.0	0.4	0.6	1.0	1.1	1.2	1.1	0.9
1952	0.6	0.4	0.3	0.3	0.3	0.1	-0.1	0.0	0.2	0.2	0.2	0.3
1953	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8
1954	0.7	0.5	0.1	-0.4	-0.5	-0.5	-0.6	-0.7	-0.8	-0.7	-0.7	-0.7
1955	-0.7	-0.7	-0.7	-0.8	-0.8	-0.8	-0.8	-0.7	-1.1	-1.4	-1.7	-1.6
1956	-1.1	-0.8	-0.6	-0.5	-0.5	-0.5	-0.5	-0.6	-0.5	-0.5	-0.5	-0.5
1957	-0.3	0.1	0.4	0.7	0.9	1.0	1.1	1.2	1.2	1.3	1.5	1.8
1958	1.8	1.6	1.2	0.9	0.7	0.6	0.5	0.3	0.3	0.4	0.5	0.6
1959	0.6	0.6	0.5	0.3	0.2	-0.1	-0.2	-0.3	-0.1	0.0	0.1	0.0
1960	-0.1	-0.2	-0.2	-0.1	-0.1	0.0	0.1	0.2	0.2	0.1	0.1	0.1
1961	0.0	0.0	0.0	0.1	0.3	0.4	0.2	-0.1	-0.3	-0.3	-0.2	-0.1
1962	-0.2	-0.3	-0.3	-0.3	-0.2	-0.2	0.0	-0.1	-0.2	-0.3	-0.4	-0.5
1963	-0.4	-0.2	0.1	0.3	0.3	0.5	0.8	1.1	1.2	1.3	1.4	1.3
1964	1.1	0.6	0.1	-0.4	-0.6	-0.6	-0.6	-0.7	-0.8	-0.8	-0.8	-0.8
1965	-0.6	-0.3	0.0	0.2	0.5	0.8	1.2	1.5	1.7	1.9	1.9	1.7
1966	1.4	1.1	0.9	0.6	0.4	0.3	0.3	0.1	0.0	-0.1	-0.1	-0.2
1967	-0.3	-0.4	-0.5	-0.4	-0.2	0.1	0.1	-0.1	-0.3	-0.3	-0.3	-0.4
1968	-0.6	-0.8	-0.7	-0.5	-0.2	0.1	0.4	0.5	0.5	0.6	0.8	1.0
1969	1.1	1.1	1.0	0.9	0.8	0.6	0.5	0.5	0.8	0.9	0.9	0.8
1970	0.6	0.4	0.4	0.3	0.1	-0.2	-0.5	-0.7	-0.7	-0.7	-0.8	-1.0
1971	-1.2	-1.3	-1.1	-0.8	-0.7	-0.7	-0.7	-0.7	-0.7	-0.8	-0.9	-0.8
1972	-0.6	-0.3	0.1	0.4	0.6	0.8	1.1	1.4	1.6	1.9	2.1	2.1
1973	1.8	1.2	0.6	-0.1	-0.5	-0.8	-1.0	-1.2	-1.3	-1.6	-1.9	-2.0
1974	-1.9	-1.6	-1.2	-1.0	-0.8	-0.7	-0.5	-0.4	-0.4	-0.6	-0.8	-0.7
1975	-0.5	-0.5	-0.6	-0.7	-0.8	-1.0	-1.1	-1.2	-1.4	-1.5	-1.6	-1.7
1976	-1.5	-1.1	-0.7	-0.5	-0.3	-0.1	0.2	0.4	0.6	0.7	0.8	0.8
1977	0.6	0.6	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.7	0.8	0.8
1978	0.7	0.5	0.1	-0.2	-0.3	-0.3	-0.3	-0.4	-0.4	-0.3	-0.1	-0.1
1979	-0.1	0.1	0.2	0.3	0.2	0.0	0.0	0.2	0.3	0.5	0.5	0.6

1980	0.5	0.4	0.3	0.3	0.4	0.4	0.3	0.1	-0.1	0.0	0.0	-0.1
1981	-0.4	-0.6	-0.5	-0.4	-0.3	-0.3	-0.4	-0.4	-0.3	-0.2	-0.2	-0.1
1982	-0.1	0.0	0.1	0.3	0.5	0.7	0.7	1.0	1.5	1.9	2.1	2.2
1983	2.2	1.9	1.5	1.2	0.9	0.6	0.2	-0.2	-0.5	-0.8	-0.9	-0.8
1984	-0.5	-0.3	-0.3	-0.4	-0.5	-0.5	-0.3	-0.2	-0.3	-0.6	-0.9	-1.1
1985	-1.0	-0.9	-0.7	-0.7	-0.7	-0.6	-0.5	-0.5	-0.5	-0.4	-0.4	-0.4
1986	-0.5	-0.4	-0.2	-0.2	-0.1	0.0	0.3	0.5	0.7	0.9	1.1	1.2
1987	1.2	1.3	1.2	1.1	1.0	1.2	1.4	1.6	1.6	1.5	1.3	1.1
1988	0.8	0.5	0.1	-0.2	-0.8	-1.2	-1.3	-1.2	-1.3	-1.6	-1.9	-1.9
1989	-1.7	-1.5	-1.1	-0.8	-0.6	-0.4	-0.3	-0.3	-0.3	-0.3	-0.2	-0.1
1990	0.1	0.2	0.3	0.3	0.2	0.2	0.3	0.3	0.4	0.3	0.4	0.4
1991	0.3	0.2	0.2	0.3	0.5	0.7	0.8	0.7	0.7	0.8	1.2	1.4
1992	1.6	1.5	1.4	1.2	1.0	0.7	0.3	0.0	-0.2	-0.3	-0.2	0.0
1993	0.2	0.3	0.5	0.6	0.6	0.5	0.3	0.2	0.2	0.2	0.1	0.1
1994	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.5	0.7	1.0	1.2
1995	1.0	0.8	0.6	0.3	0.2	0.0	-0.2	-0.4	-0.7	-0.8	-0.9	-0.9
1996	-0.9	-0.8	-0.6	-0.4	-0.3	-0.2	-0.2	-0.3	-0.3	-0.3	-0.4	-0.5
1997	-0.5	-0.4	-0.1	0.2	0.7	1.2	1.5	1.8	2.1	2.3	2.4	2.3
1998	2.2	1.8	1.4	0.9	0.4	-0.2	-0.7	-1.0	-1.2	-1.3	-1.4	-1.5
1999	-1.5	-1.3	-1.0	-0.9	-0.9	-1.0	-1.0	-1.1	-1.1	-1.3	-1.5	-1.7
2000	-1.7	-1.5	-1.2	-0.9	-0.8	-0.7	-0.6	-0.5	-0.6	-0.6	-0.8	-0.8
2001	-0.7	-0.6	-0.5	-0.4	-0.2	-0.1	0.0	0.0	-0.1	-0.2	-0.3	-0.3
2002	-0.2	0.0	0.1	0.3	0.5	0.7	0.8	0.8	0.9	1.2	1.3	1.3
2003	1.1	0.8	0.4	0.0	-0.2	-0.1	0.2	0.4	0.4	0.4	0.4	0.3
2004	0.3	0.2	0.1	0.1	0.2	0.3	0.5	0.7	0.8	0.7	0.7	0.7
2005	0.6	0.4	0.3	0.3	0.3	0.3	0.2	0.1	0.0	-0.2	-0.5	-0.8
2006	-0.9	-0.7	-0.5	-0.3	0.0	0.1	0.2	0.3	0.5	0.8	1.0	1.0
2007	0.7	0.3	-0.1	-0.2	-0.3	-0.3	-0.4	-0.6	-0.8	-1.1	-1.2	-1.4
2008	-1.5	-1.5	-1.2	-0.9	-0.7	-0.5	-0.3	-0.2	-0.1	-0.2	-0.5	-0.7
2009	-0.8	-0.7	-0.5	-0.2	0.2	0.4	0.5	0.6	0.8	1.1	1.4	1.6
2010	1.6	1.3	1.0	0.6	0.1	-0.4	-0.9	-1.2	-1.4	-1.5	-1.5	-1.5
2011	-1.4	-1.2	-0.9	-0.6	-0.3	-0.2	-0.2	-0.4	-0.6	-0.8	-1.0	-1.0
2012	-0.9	-0.6	-0.5	-0.3	-0.2	0.0	0.1	0.4	0.5	0.6	0.2	-0.3
2013	-0.6											



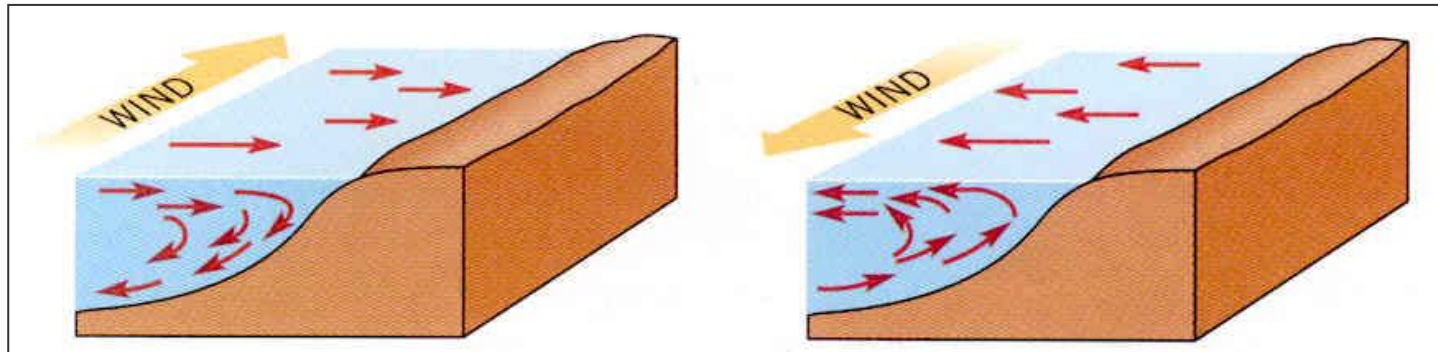
▶ 엘니뇨: Originally, an “oceanic” phenomenon ?



## ▶ 리뷰: 용승, 침강

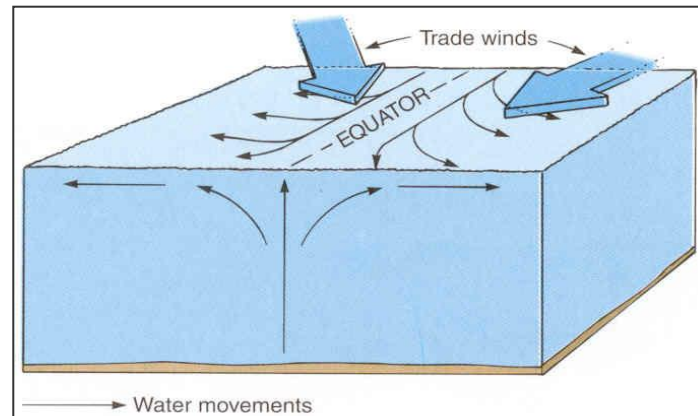
### ① 연안 용승

- 북(남)반구에서 해안선에 나란하게 북풍(남풍)계열 바람이 부는 경우 표층수는 에크만 수송에 의해 해수가 바다 쪽으로 이동
- 낮아진 해면을 보충하기 위하여 200 ~ 300m 깊이의 층에서 차가운 물이 솟아오르는 현상
- 미국의 캘리포니아 연안과 **남아메리카의 페루 연안**, 아프리카의 서해안, 우리나라의 동해안

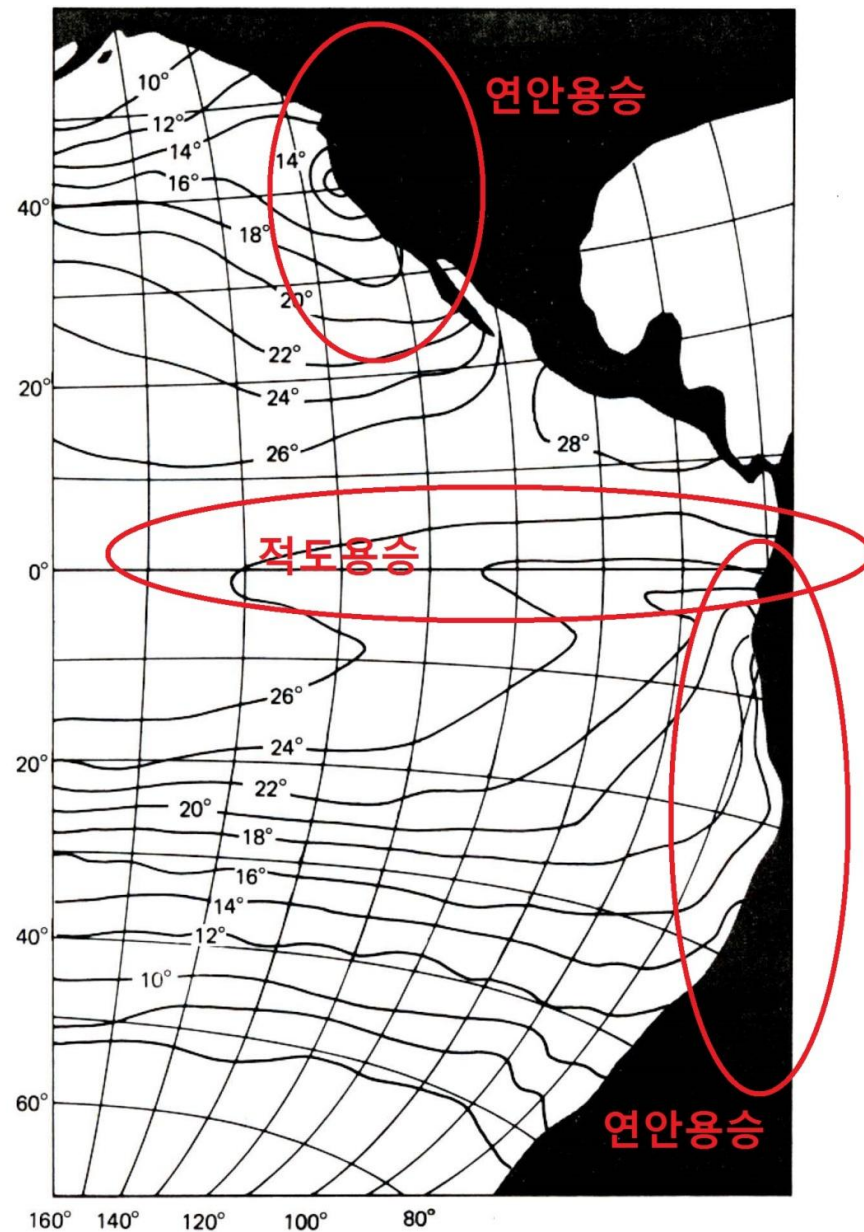


### ② 적도 용승

- 적도의 동부해역 :  
무역풍에 의해 표면해수의  
발산이 일어나 용승이 일어남



## ▶ 리뷰: 용승, 침강 (동태평양 7월 평균 수온 분포도)



## ▶ 엘니뇨 기원: 페루 연안의 해황

봄~가을 : 남동무역풍

- 페루 연안 해역에서 연안과 평행하게 남풍 봄 → 에크만 수송으로 표층의 해수를 외해로 이동 → 심층으로부터 찬 해수가 용승
- 연안 용승으로 영양 염류가 풍부한 해수가 유입되어 ‘앤초비’라는 정어리 어장 형성



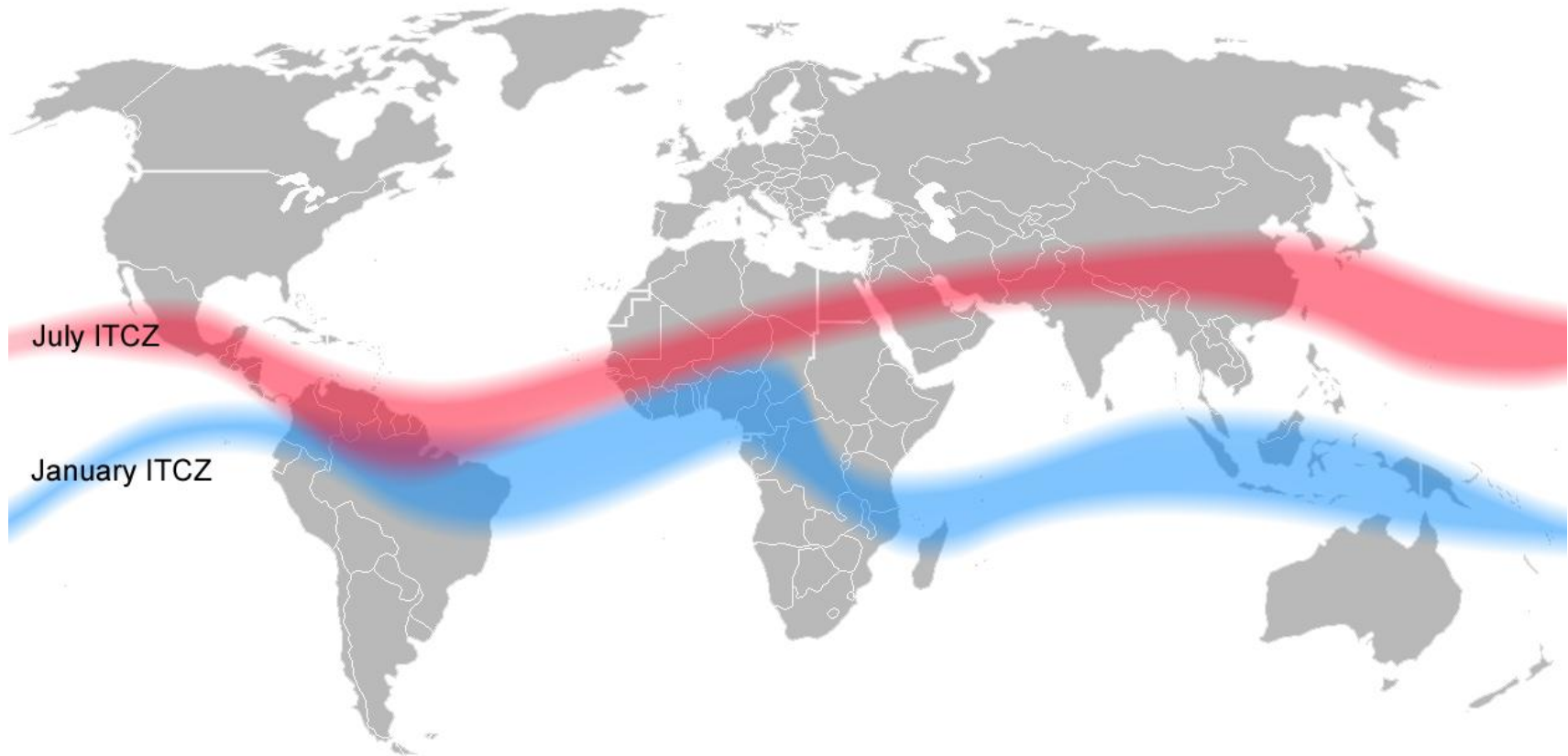
남반구 12월 ~3월경

- 열대 수렴대(ITCZ)가 적도 부근으로 남하
- 페루, 에콰도르 부근의 남동 무역풍 약화  
→ 용승 감소 → 해수면 수온 상승 → 어장 파괴
- 북쪽으로부터 난류가 내려옴
- El Nino : 신의 아들, 어린 예수그리스도



## ▶ Seasonal shift in the ITCZ

[http://www2.palomar.edu/users/pdeen/animations/23\\_weatherpat.swf](http://www2.palomar.edu/users/pdeen/animations/23_weatherpat.swf)

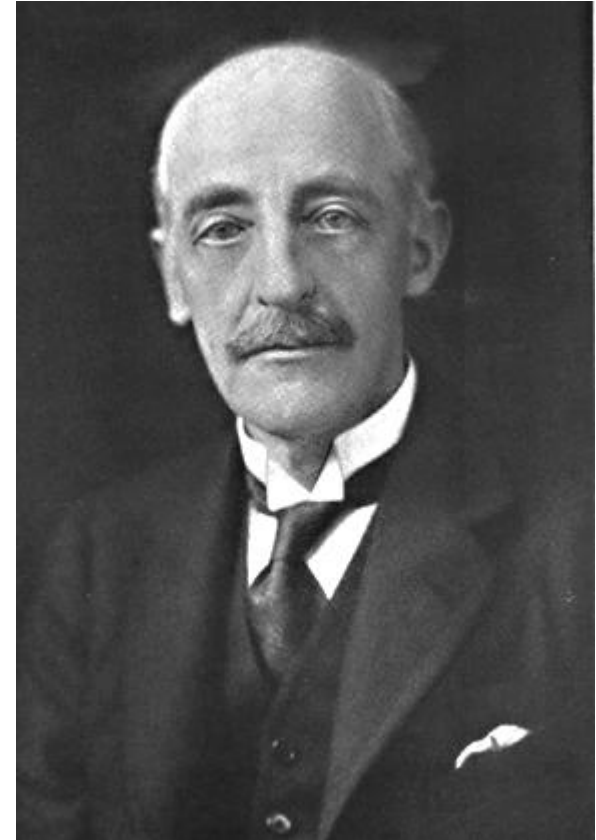


## ▶ 남방진동 (Southern Oscillation): An "atmospheric" phenomenon

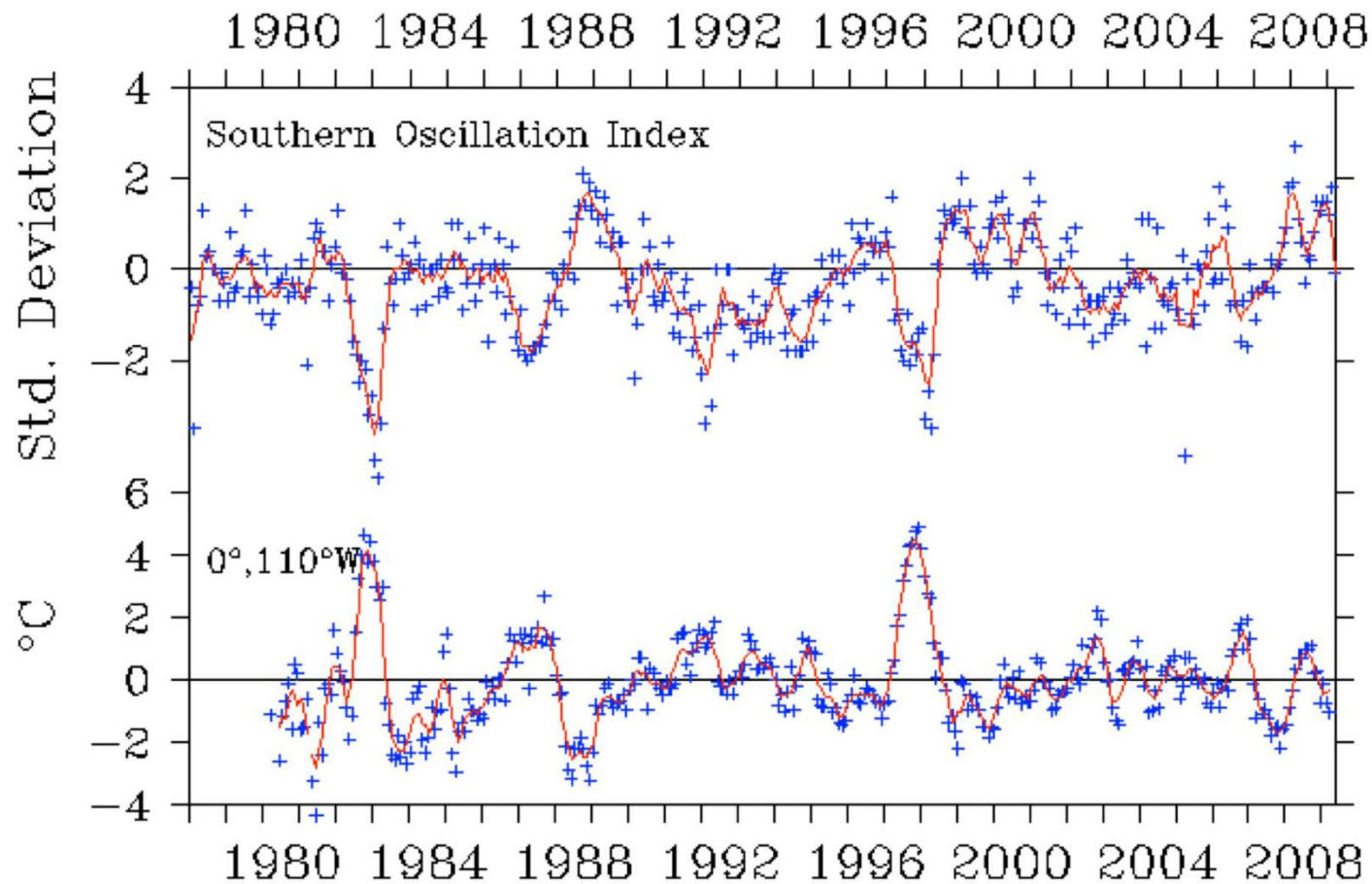
서태평양 지역의 기압이 낮아질수록 동태평양 지역의 기압이 높아지고, 서태평양 지역의 기압이 높아지면 동태평양 지역의 기압은 낮아지는 기압 분포의 시소현상

In the 1920s The British scientist Sir **Gilbert Walker** empirically identified that some notable climate anomalies—changes in atmospheric pressure and circulation—happen around the world every few years. He invented the term for those climate oscillations, "the **Southern Oscillation**."

While stationed in India studying monsoons, Sir Gilbert observed pressure differences in the equatorial Pacific Ocean. He noticed "a seesaw" of atmospheric pressure measured at two sites: **Darwin** in Australia, the Indian Ocean, and in **Tahiti**, an island in the South Pacific. When atmospheric pressure rises at Darwin it falls in Tahiti, and vice versa.



## ▶ 남방진동지수 (SOI: Southern Oscillation Index)



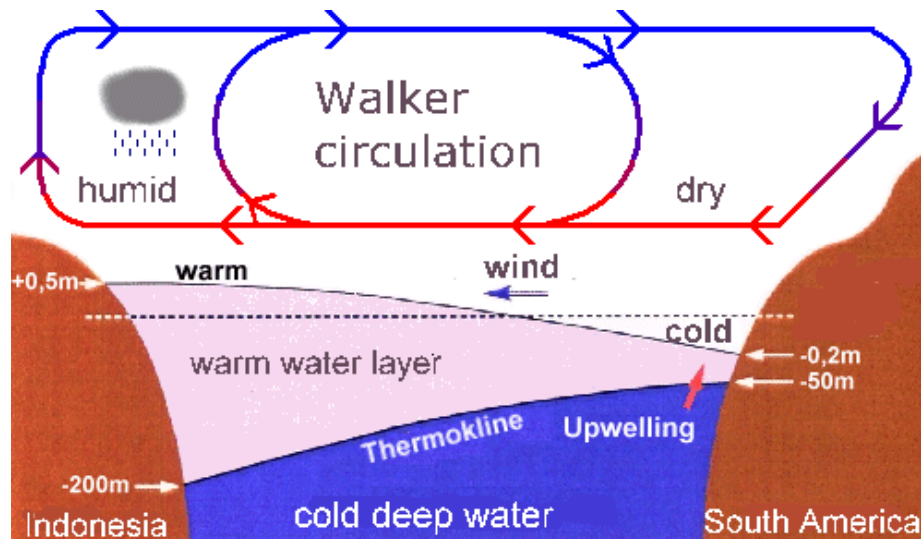
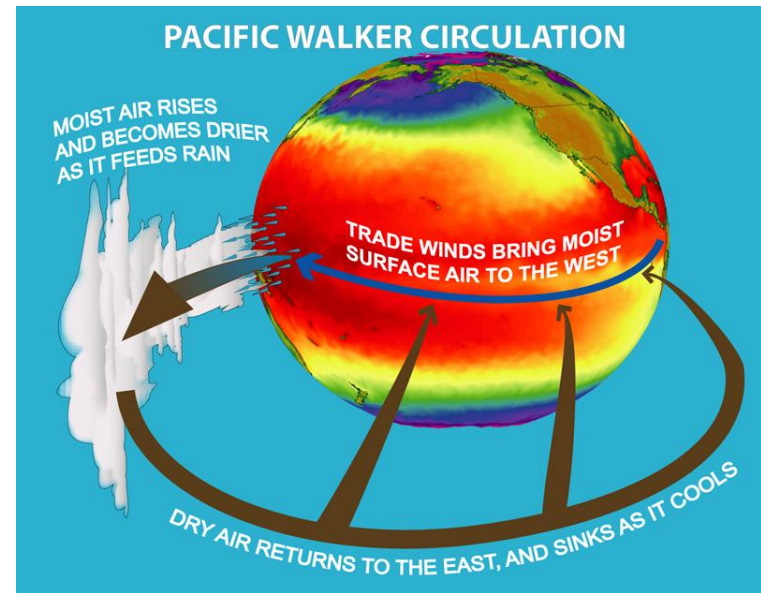
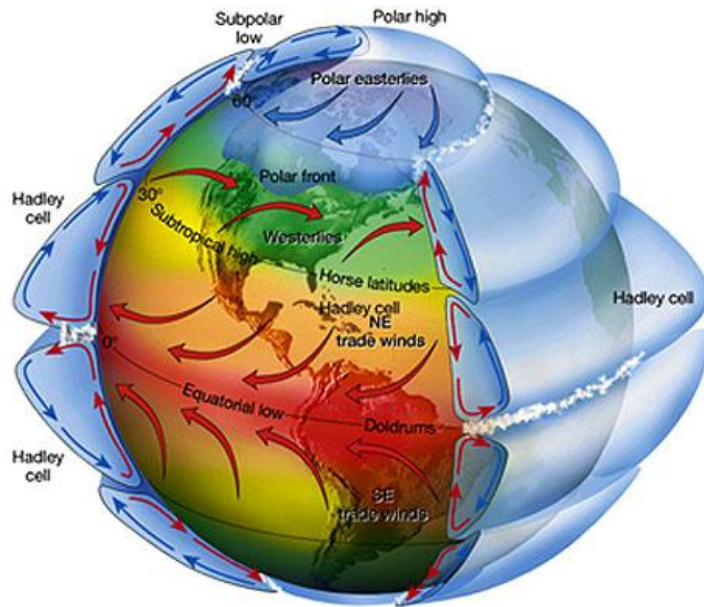
Anomalies From Reynolds and Smith (2002) SST Climatology

Monthly Mean

Five Month Running Mean

$$SOI = [SLP(Tahiti) - SLP(Darwin)]/STD$$

# ► Walker circulation / Hadley circulation



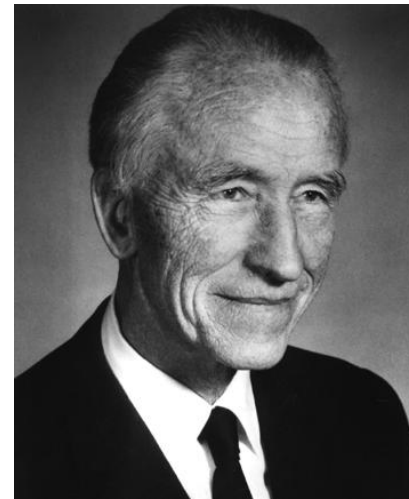


## ▶ 엘니뇨/남방진동 (ENSO): An “ocean-atmospheric” phenomenon

태평양 상에서 해수면 온도(고도)의 분포는 대기층의 기압 분포와 밀접한 연관이 있다.

- 서태평양의 해수면 온도가 높은 열대지역 저기압 형성 → 상승기류 생성 → 일부가 동태평양 남아메리카 연안에서 하강(고압부) → 이러한 기압분포가 서태평양 지역의 상승기류와 동태평양 지역의 하강기류를 연결하는 무역풍을 일으켜 동서 순환(워커 순환)을 형성
- 두 지역의 해면 기압차이를 지수화한 남방진동지수의 변동은 동태평양 적도 지역의 해수면 온도 편차의 변동과 잘 일치하며, 남방진동과 엘니뇨 현상은 대기와 해양이 밀접히 결부된 현상으로 엘니뇨와 남방진동을 함께 ENSO(El Nino and Southern Oscillation)라 한다.

- **Jacob Bjerknes** was the first one to recognize that El Nino is not just an oceanic phenomenon (in his 1969 paper).
- In stead, he hypothesized that the warm waters of El Nino and the pressure seasaw of Walker's Southern Oscillation are part and parcel of the same phenomenon: the ENSO.
- Bjerknes's hypothesis of coupled atmosphere-ocean instability laid the foundation for ENSO research.



## ▶ 엘니뇨/라니냐 정의

### 엘니뇨 현상

- 페루 연안에 한정되지 않고 동태평양 적도 부근 해역의 해수면 온도가 평년보다  $0.5^{\circ}\text{C}$  이상 높은 상태로 6개월 이상 지속되는 현상
- 주기 : 3 - 5 ( 2 - 7 ) 년 (Interannual cycle)

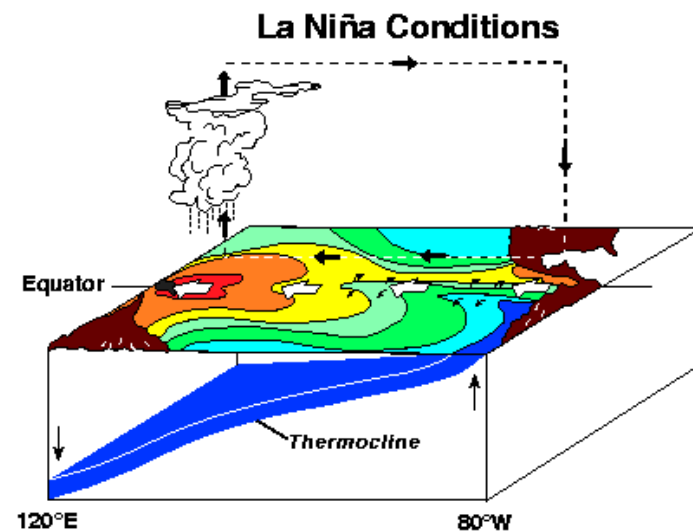
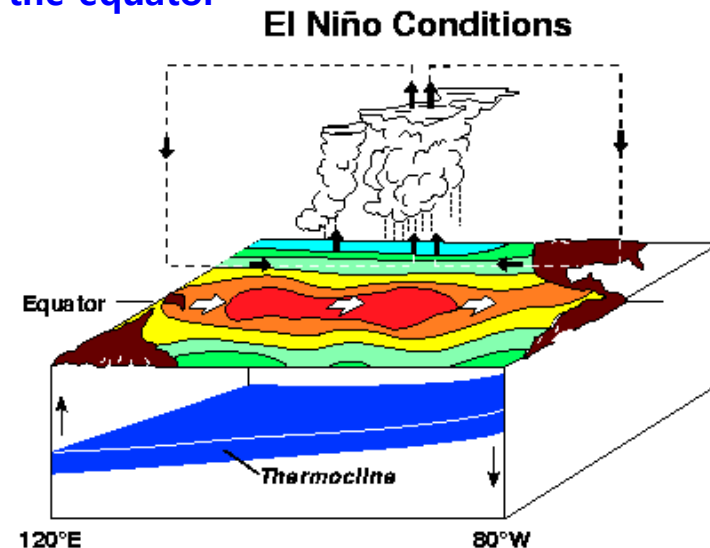
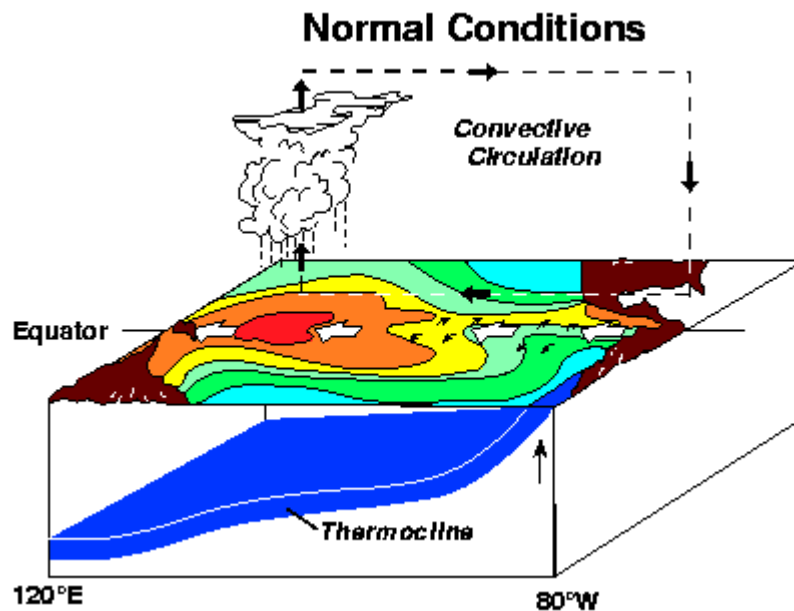
### 라니냐 현상

- 프린스턴 대학 Philander 교수가 최초 사용
- 동태평양 적도 부근 해역의 해수면 온도가 평년보다  $0.5^{\circ}\text{C}$  이상 낮은 상태로 6개월 이상 지속되는 현상
- 적도 무역풍이 평년보다 강해져 서태평양의 해수면과 수온이 평년보다 높아지고, 동태평양에서는 용승이 강해지고 수온이 낮아져 엘니뇨와 반대되는 현상 (여자아이)

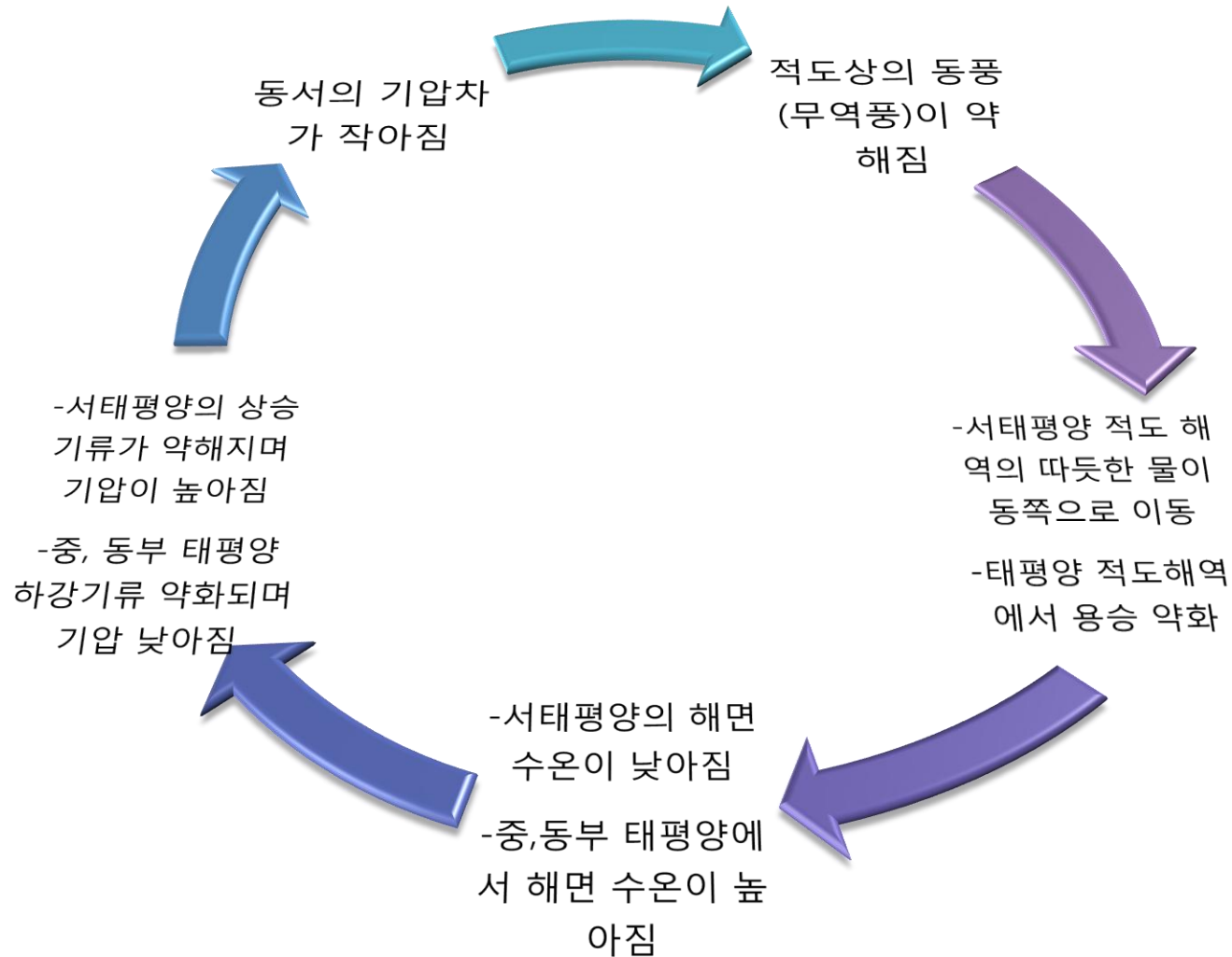
The screenshot shows the Princeton University website header with navigation links: Links & Resources, Employment Opportunities, Forrester Campus, and a search bar. Below the header is the AOS (Atmospheric and Oceanic Sciences) banner. The left sidebar contains a menu with links: Home, About Us, People (selected), Faculty, Research Staff, Graduate Students, 2012 Summer Interns, Alumni, Ph.D. Program, PostDoc Program, and News and Events. The main content area displays the 'AOS Faculty Profile' for George Philander, including a portrait photo and contact information: Professor, Ph.D. Harvard; Address: M46 Guyot Hall; Phone: (609) 258-5683; E-mail: gphilander at princeton.edu. Below the contact info is a link to a 'New Freshmen Seminar: The Hedgehog and the Fox: How Nelson Mandela can help us cope with Global Warming' with lead instructor Prof. George Philander and associated faculty Prof. David Medvigy and Prof. Tom Duffy.

# ► ENSO, It's a coupled Atmosphere-Ocean System

1. Changes in atmospheric circulation
2. Redistribution of warm upper ocean water along the equator



## ▶ 엘니뇨의 성장 (Positive feedback)





## ▶ 엘니뇨의 소멸 (Negative feedback)

Common Positive feedback



Different Negative feedback

Different Time delay

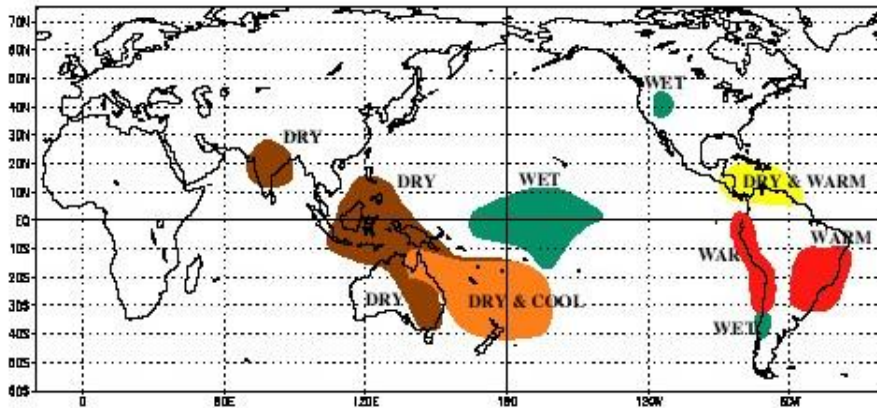
- ▶ Delayed Oscillator (Schopf and Suarez(1988), Battisti and Hirst(1989))
- ▶ Western Pacific Oscillator (Weisberg and Wang(1997))
- ▶ Recharge-Discharge Oscillator (Jin(1997))
- ▶ Advective-reflective Oscillator (Picaut et al.(1997))

## ▶ 엘니뇨 영향 (원격상관: Teleconnections)

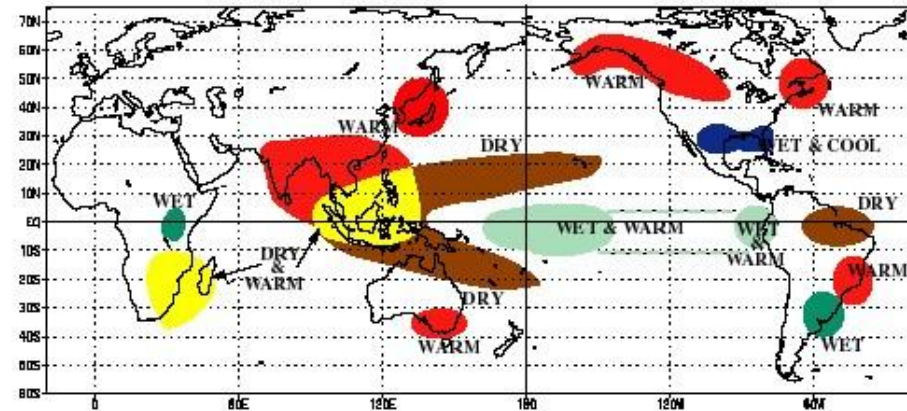
ENSO is a primary factor of global climate change

Horel and Wallace (1981), Rasmusson and Wallace (1983)

WARM EPISODE RELATIONSHIPS JUNE - AUGUST



WARM EPISODE RELATIONSHIPS DECEMBER - FEBRUARY

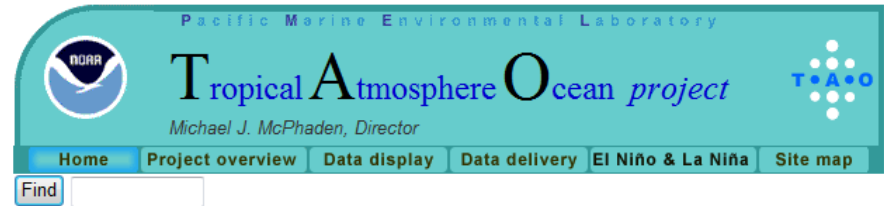
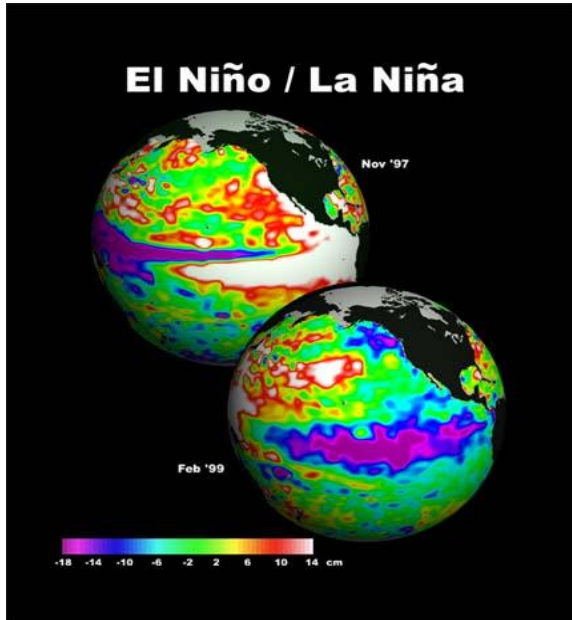


Schematic of Temperature and Precipitation  
(After Ropelewski and Halpert (1986, 1987, 1989, 1992))

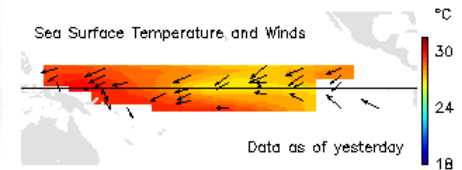
# ▶ 엘니뇨 관측

## In-Situ Observation

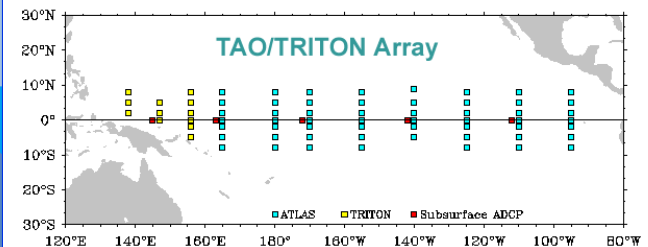
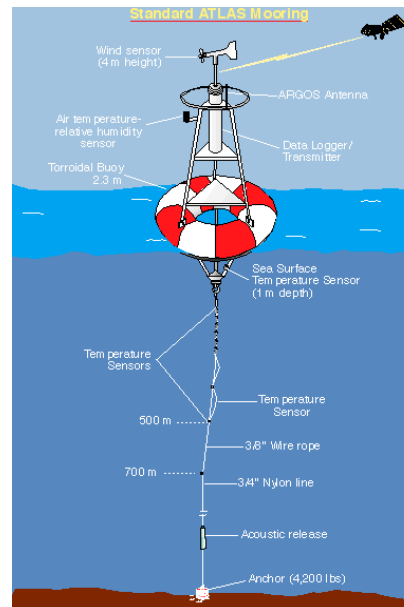
### Space-Based Observations



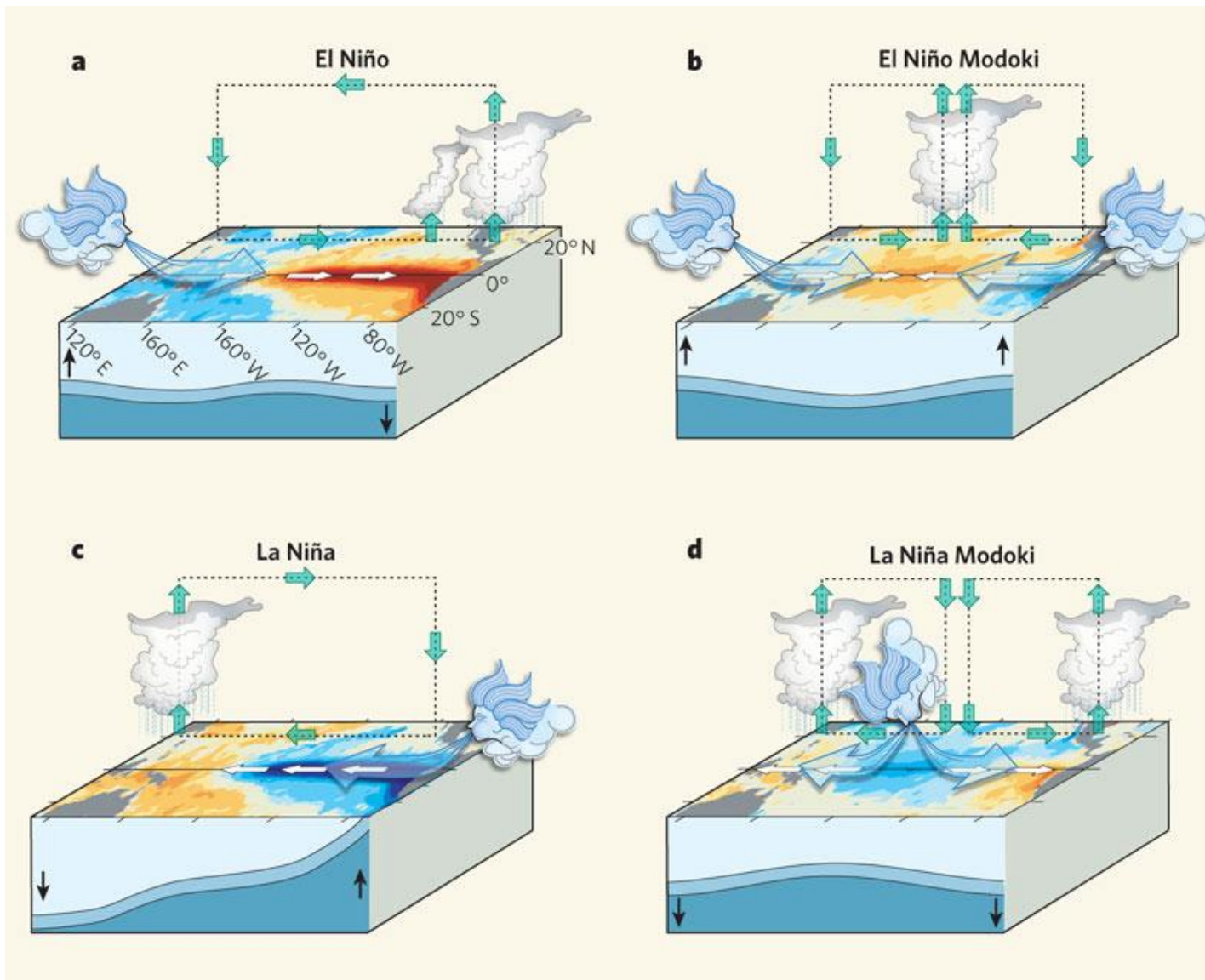
Real-time data from moored ocean buoys for improved detection, understanding and prediction of El Niño and La Niña.



[The TAO Story](#)



## ▶ 엘니뇨 연구 (최근 연구)





# 수고하셨습니다..!!

1. 해양학 및 해양의 구조 (해양의 기원, 해저 지형, 해양 관측)
2. 해수의 성질 (수온, 염분, 압력, 밀도, T-S diagram, 용존 산소, 음파, 해색)
3. 해양 순환
4. 해양/대기 상호작용 (엘니뇨 /라니냐)
5. 파랑 및 조석
6. 주요 해역 (한반도 포함) 해황 분석