SGS6833: 대기과학

5주 차 강의자료

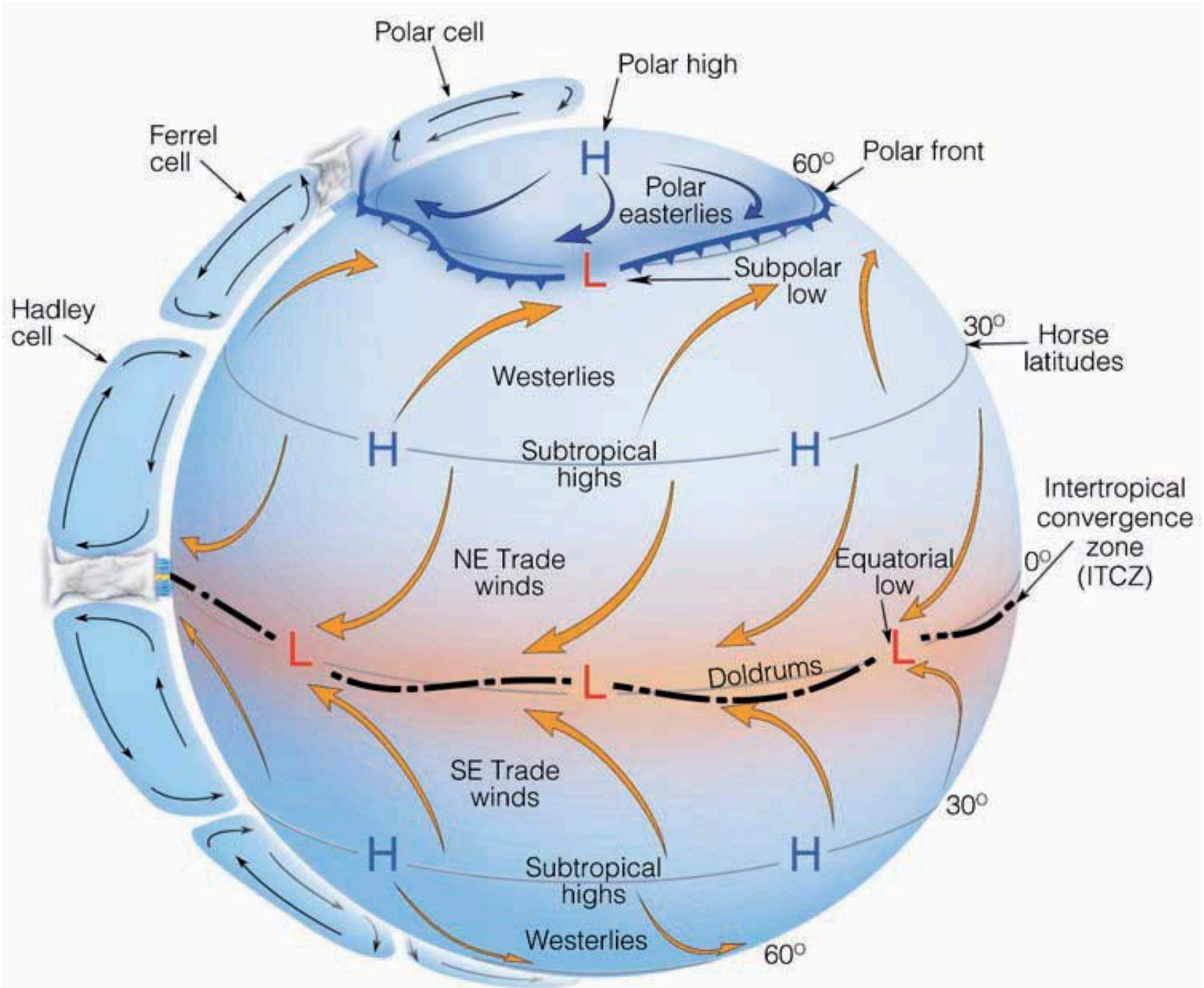
지난 시간

- 기압과 바람
  - 지균풍
  - 온도풍
  - 경도풍
  - 지상풍
- 대기대순환: 해들리 순환

오늘의 내용

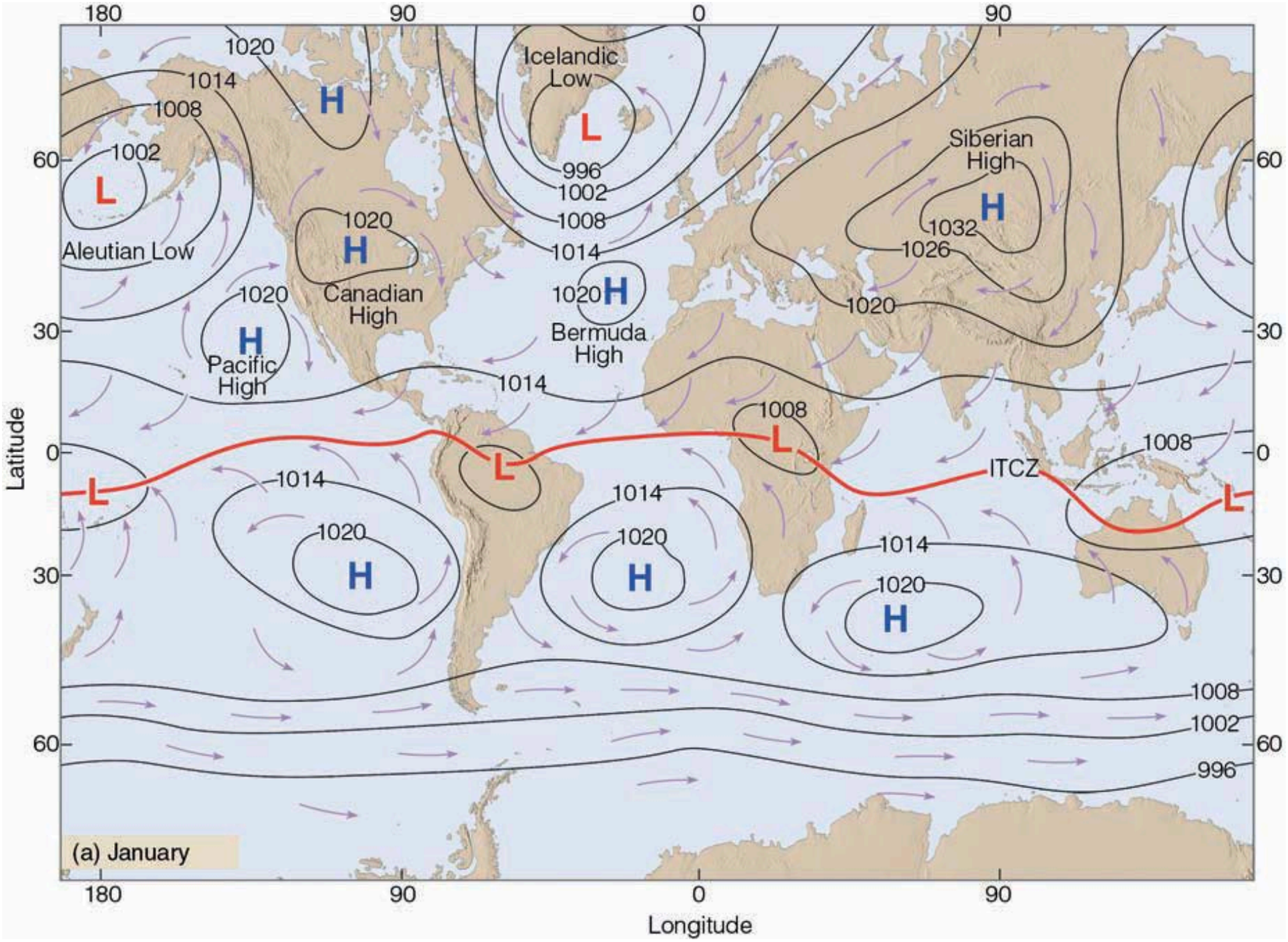
- 대기대순환
- 제트기류
- 해양순환

대기대순환 : three cell model



대기대순환 : three cell model

- 실제 지표면 바람을 설명할 수 있을까?



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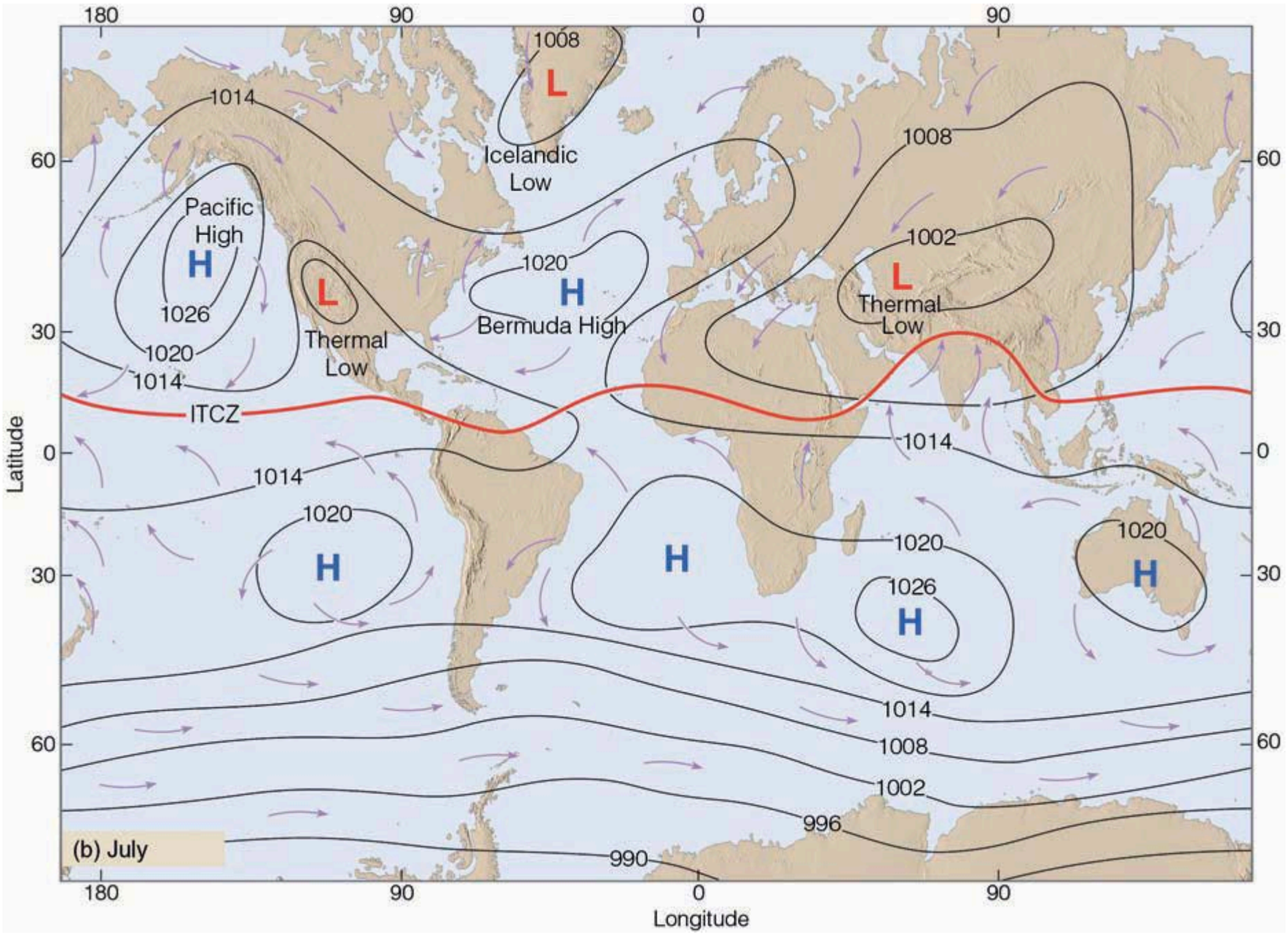
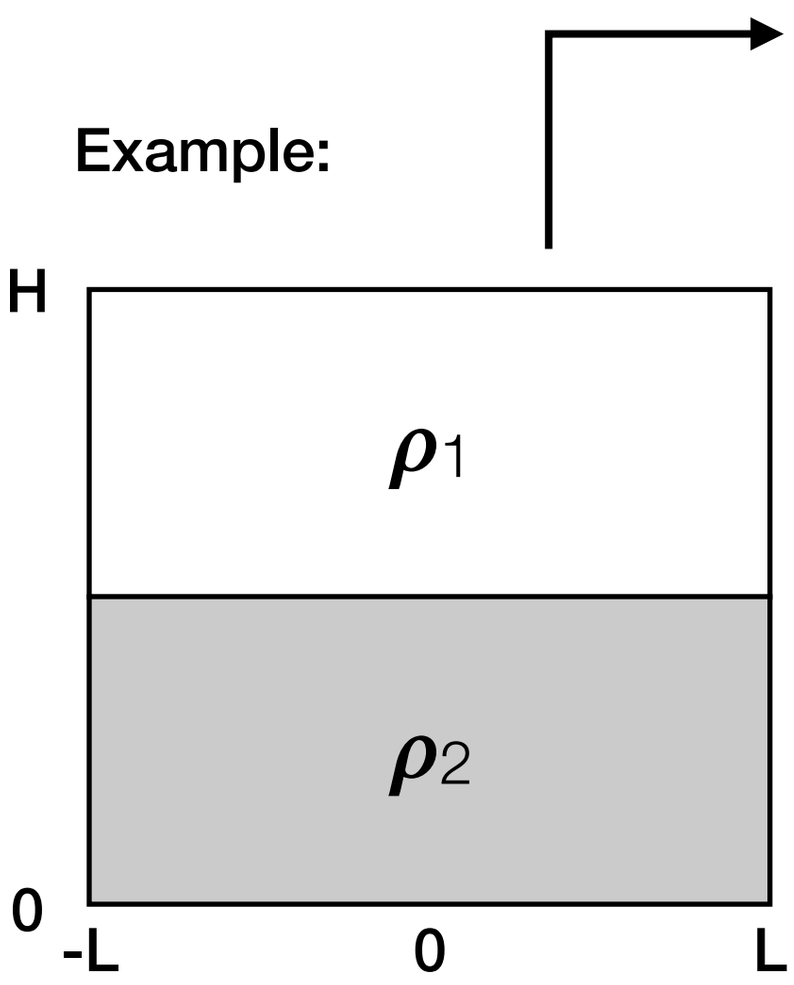


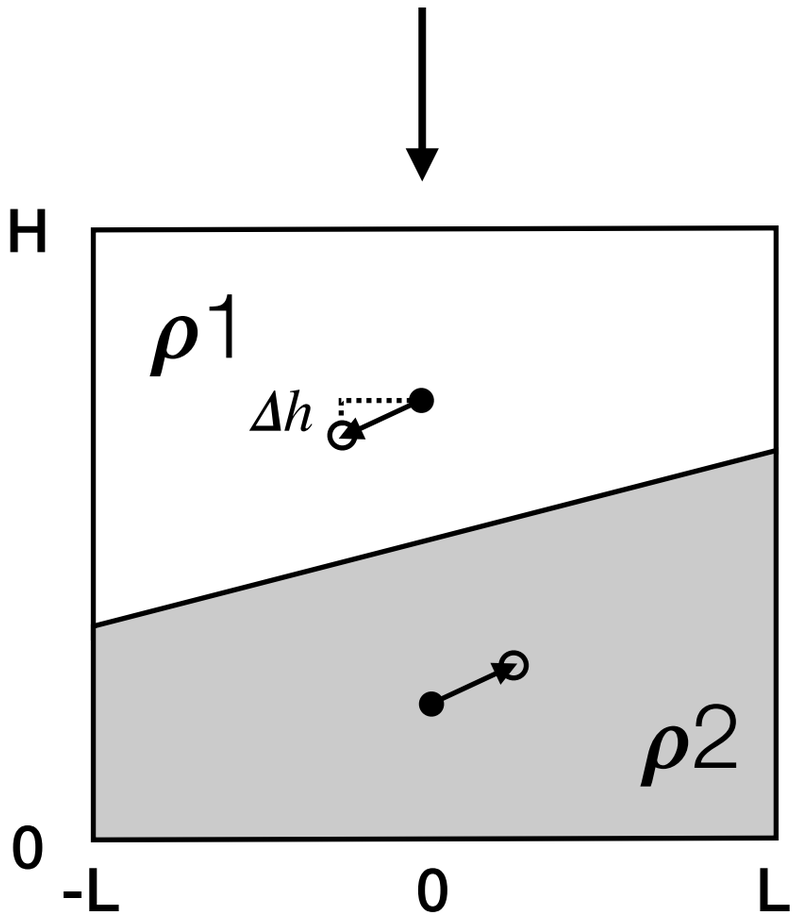
대기대순환: 에너지

- 위치에너지가 생겼을 때 운동에너지로 변환됨

Example:

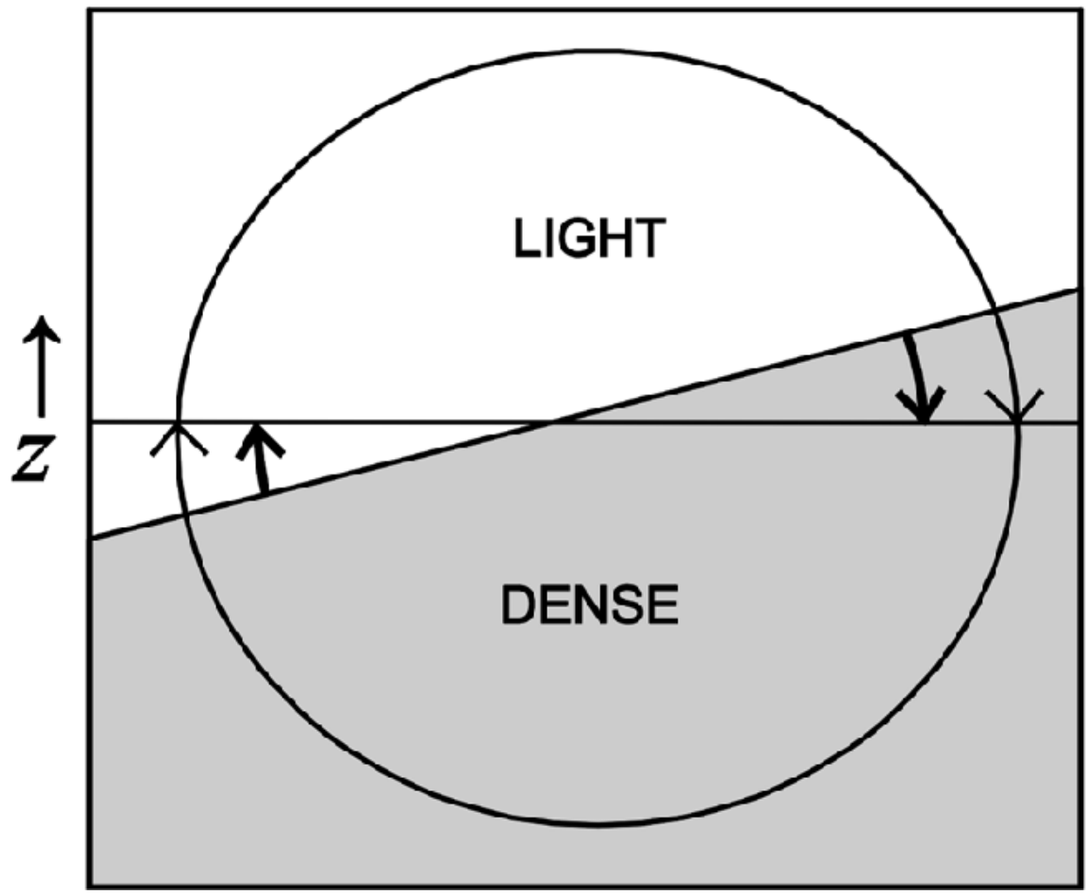


L 쪽의 가열이 두 단면을 기울게 하며, 위치에너지가 커짐



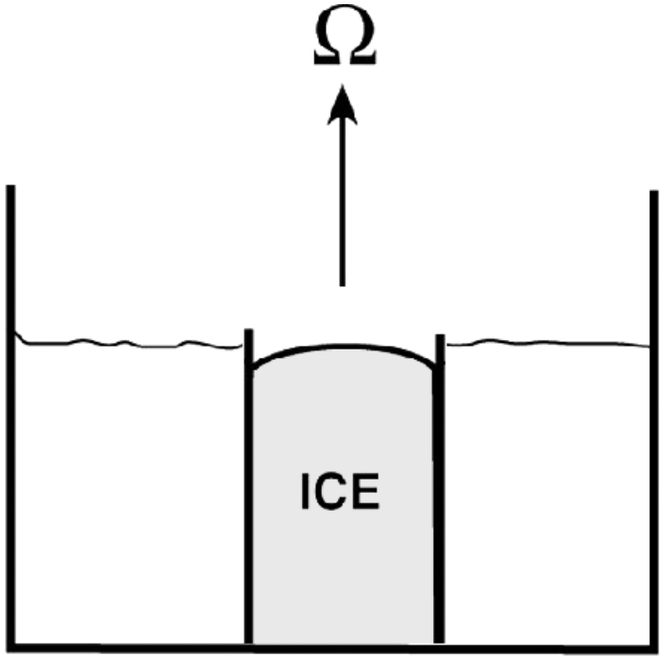
대기대순환: 에너지

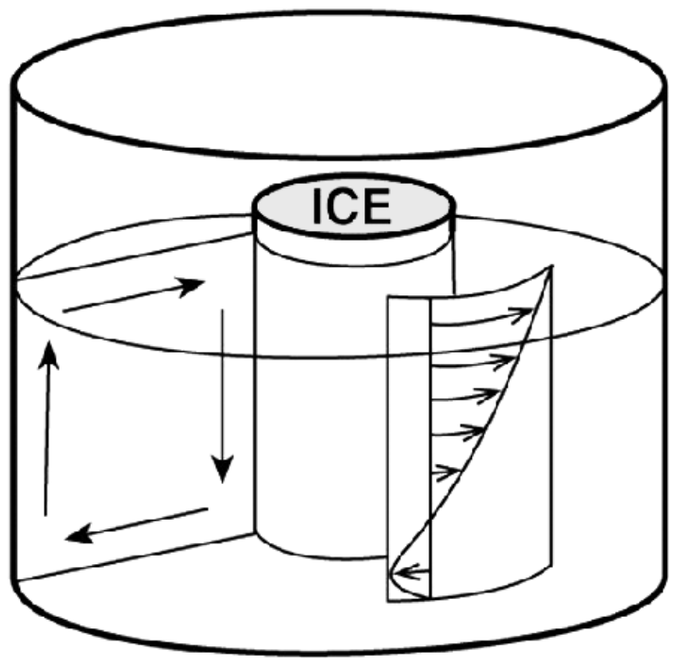
- 회전이 작거나 없을 때 위치에너지가 운동에너지로 바뀌는 방법



해들리 순환 실험

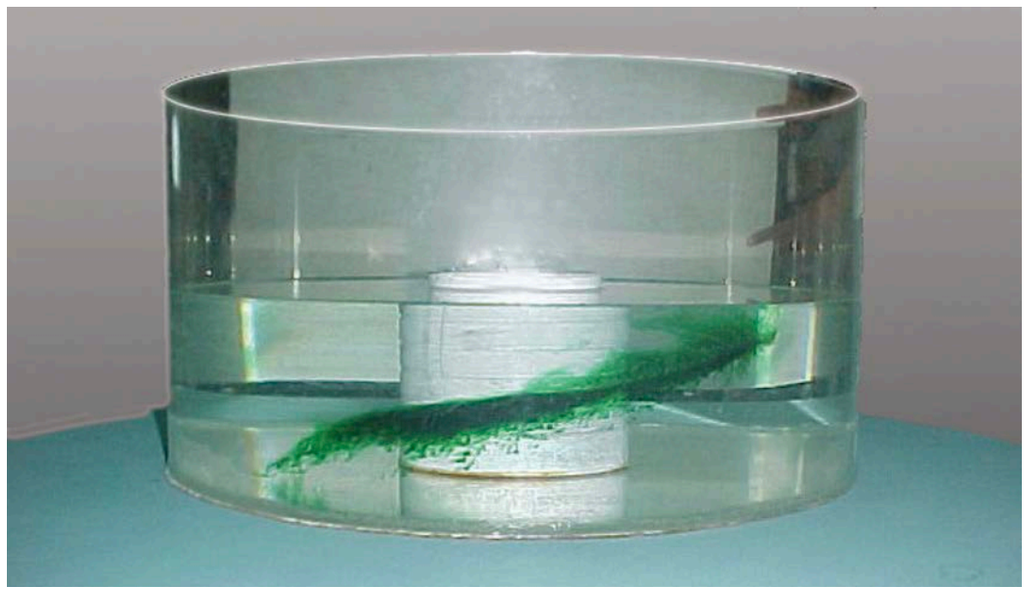
- Visualize the Hadley cell
- Rotation has to be slower (small f) : Ω ~1 rpm (only 1 rotation of the table per minute, which is very slow!)

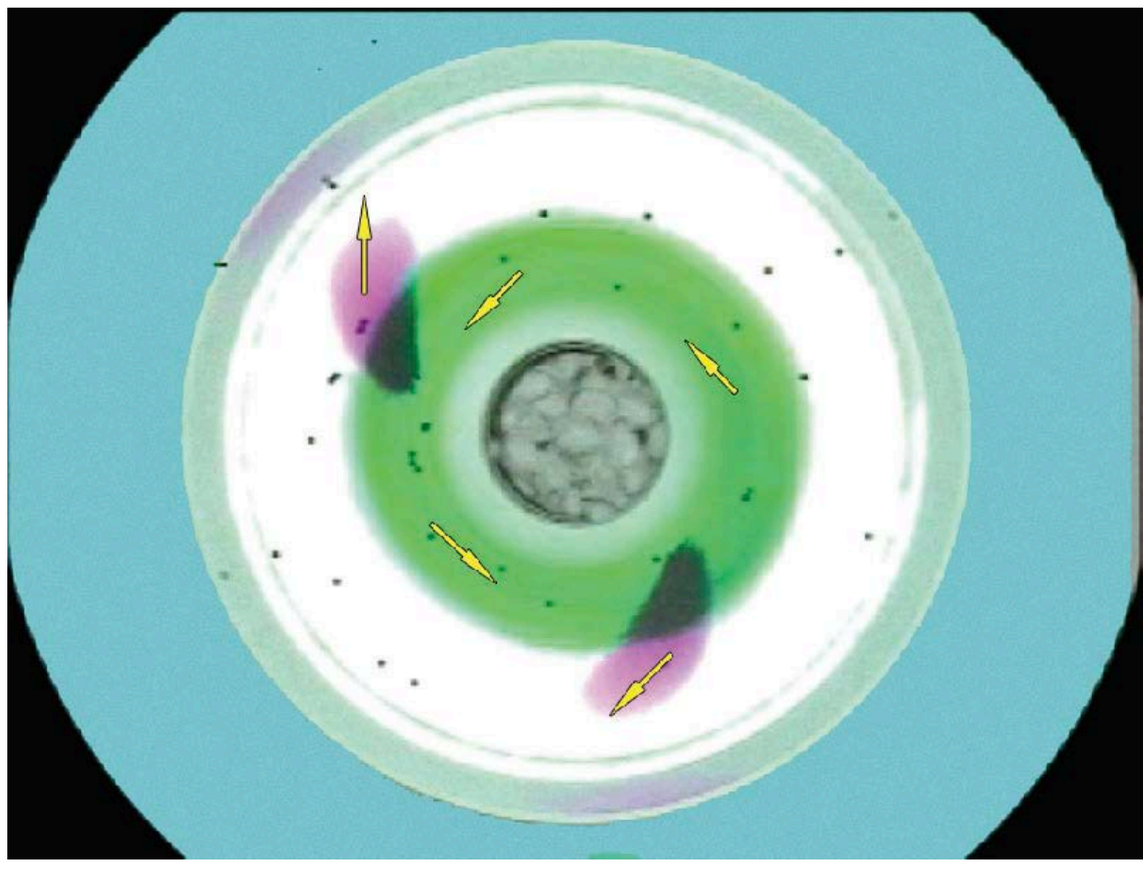




해들리 순환 실험

- Visualize the Hadley cell



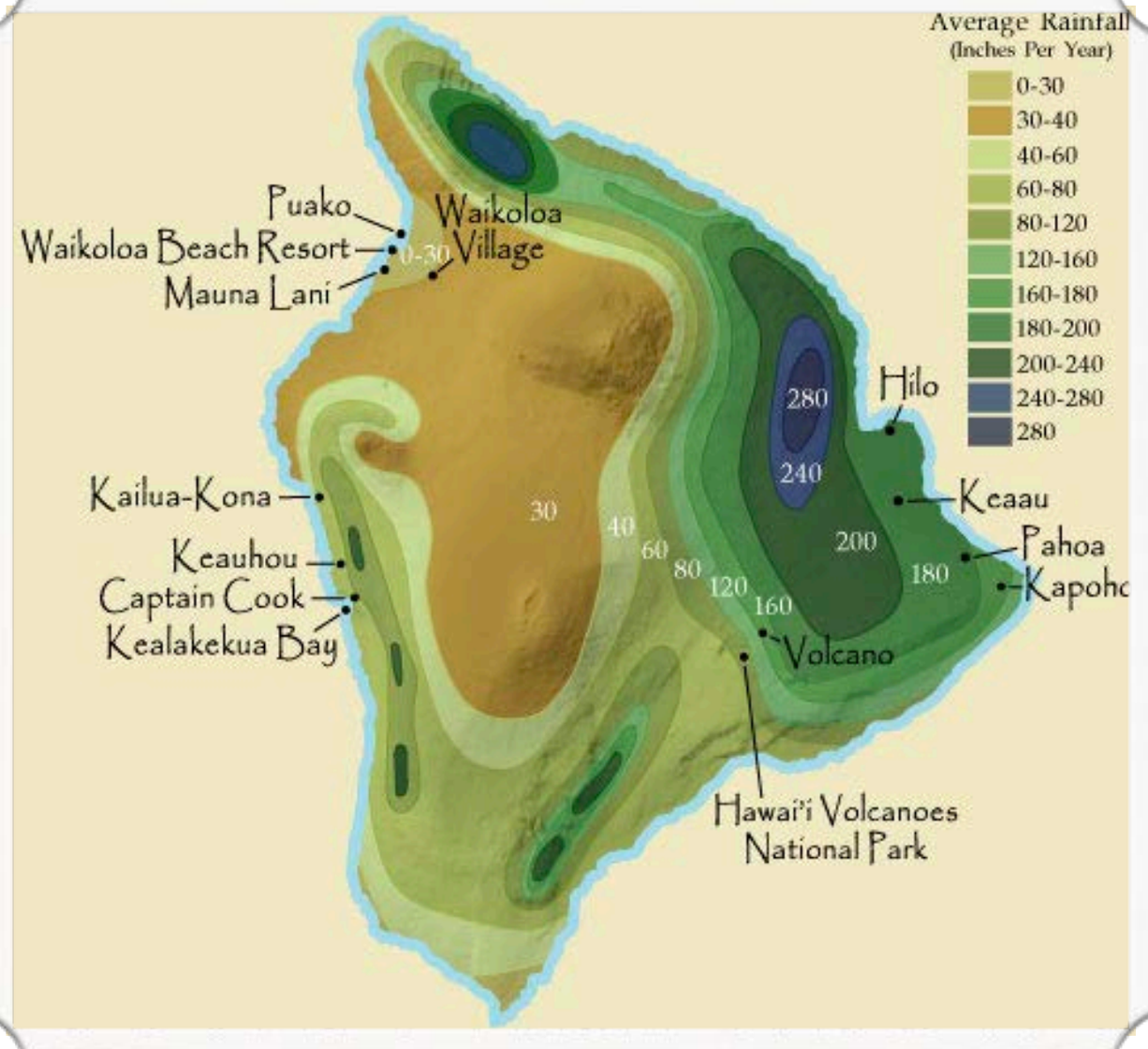


https://youtu.be/7BcDOuJRUoo

Angular momentum conservation: $A = \Omega r^2 + ur$

Ω ~ 0.1 s^{-1} (0.95 rpm) give u from 0 to ~ 8 cm/s when moving fluid from 30 cm to 10 cm

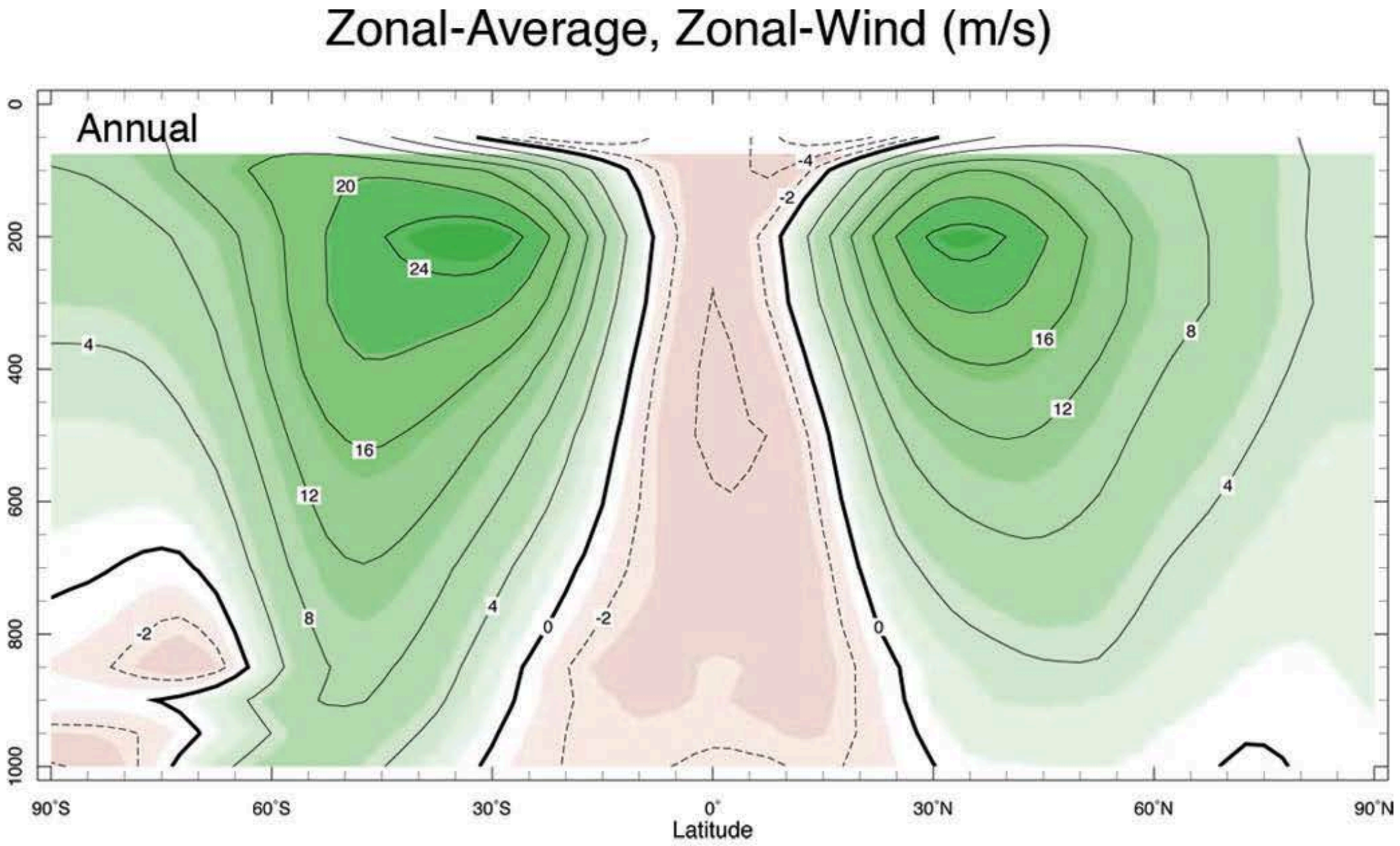
대기대순환 : three cell model



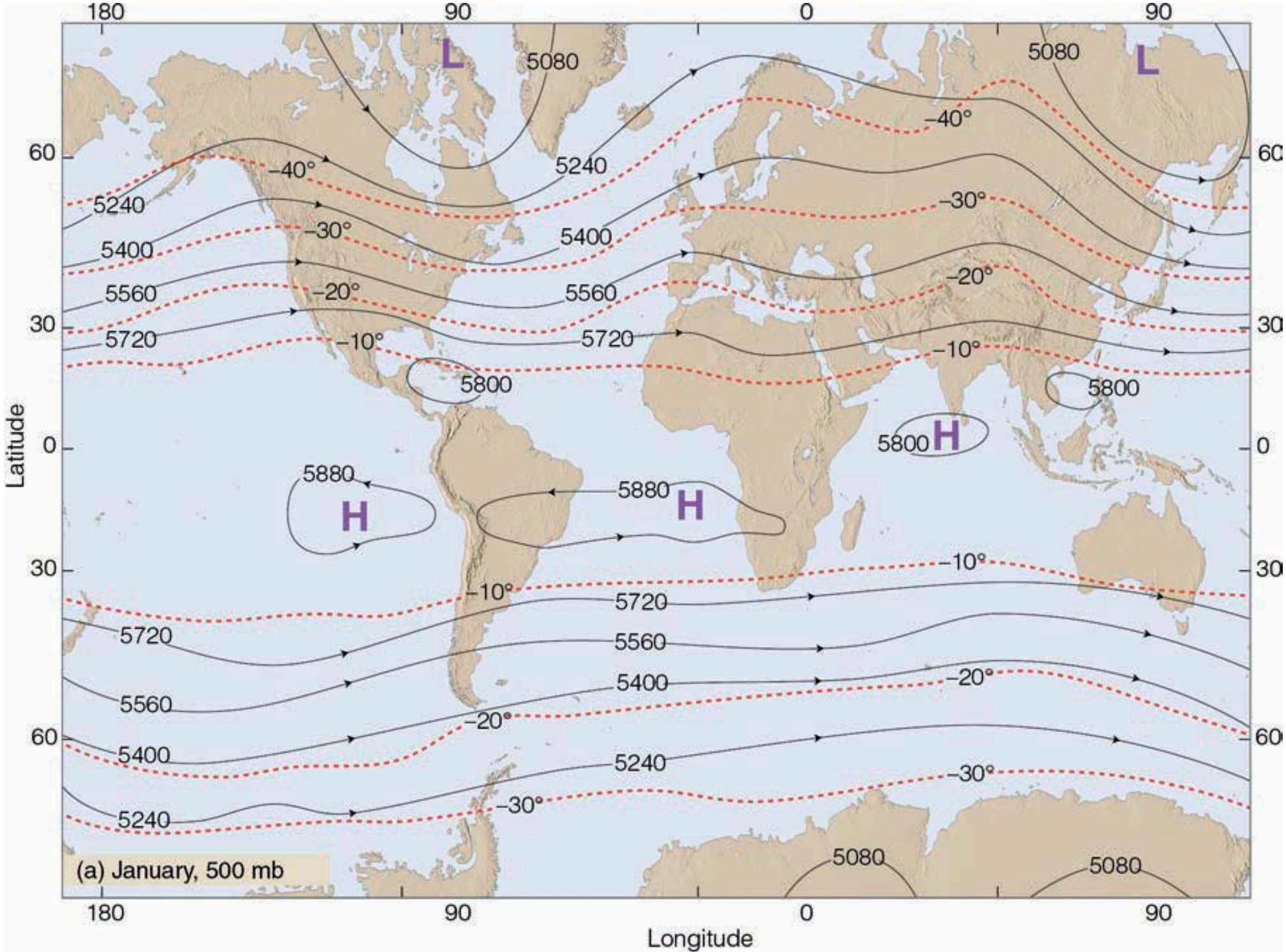
하와이 섬 : 20°N

대기대순환 : three cell model

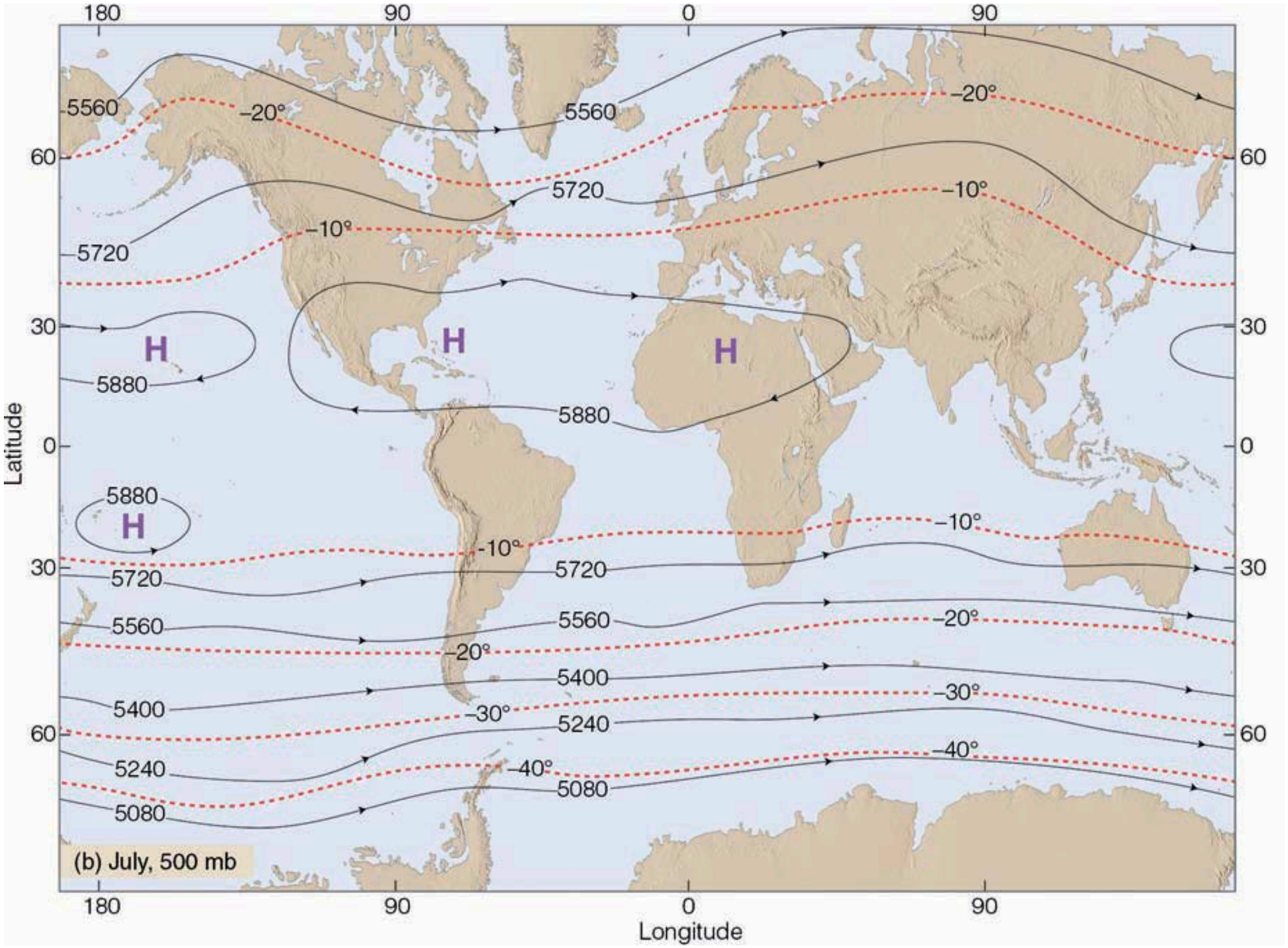
- 페럴순환의 상층부 : 적도로 흐르는 기류는 서쪽으로 분다?



상층


180
90
0
90
L
5080
5080
L
60
60
−40°
5240
−40°
5240
−30°
5400
−30°
5400
5560
−20°
5560
−20°
30
30
5720
−10°
5720
−10°
5800
5800
5800
H
0
0
Latitude
5880
H
5880
H
30
30
−10°
−10°
5720
5720
5560
5560
5400
5400
−20°
−20°
60
60
5240
5240
−30°
−30°
5080
5080
(a) January, 500 mb
180
90
0
90
Longitude

상층


180
90
0
90
60
30
0
30
60
Latitude
Longitude
5560
-20°
5720
-10°
5880
H
-30°
5400
5240
-40°
5080
(b) July, 500 mb

대기대순환: 중위도지역

- 중위도 지역은 적도지역과 다르게 지구 자전효과가 큼
- 남북방향보다 동서방향으로 부는 바람 우세하여야 함 (제트류)
- 그럼…

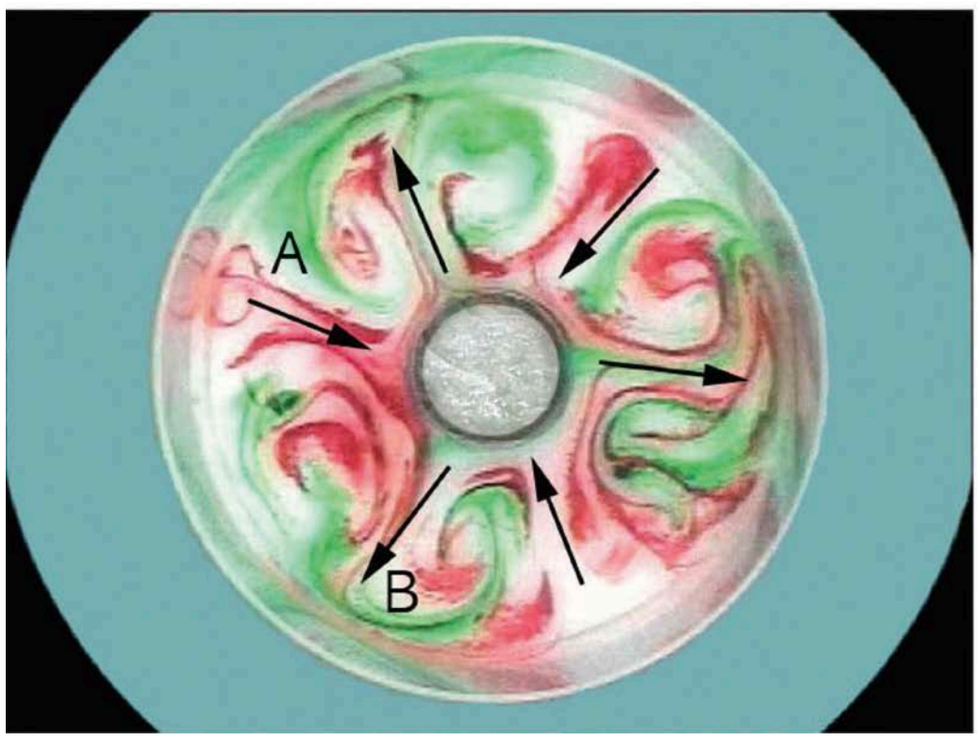
1. 에너지는 어떻게 계속 극지방으로 전달이 될까?
2. 동서방향 바람이 우세함 속에서 남북방향 바람은 어떻게 가능할까?

중위도 지역 순환 실험

- Let’s first evaluate our idea: faster rotation gives us faster zonal flow
- Increase angular velocity in the same experiment setting.
  - Ω from 1 rpm to 10 rpm
- https://youtu.be/bkBG_QokUCY
- Do we see faster zonal flows?
- How is the heat transported?

중위도 지역 순환 실험

- Thermal wind breaks down.
- Eddies are developed.
- Eddies carry cold water outward, and simultaneously warm water inward.
- Eddies transport heat!



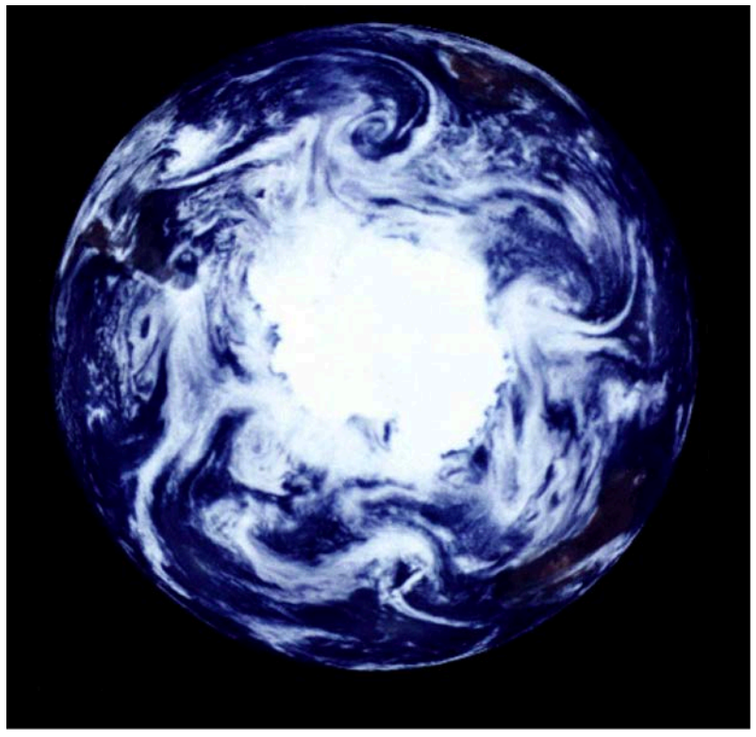
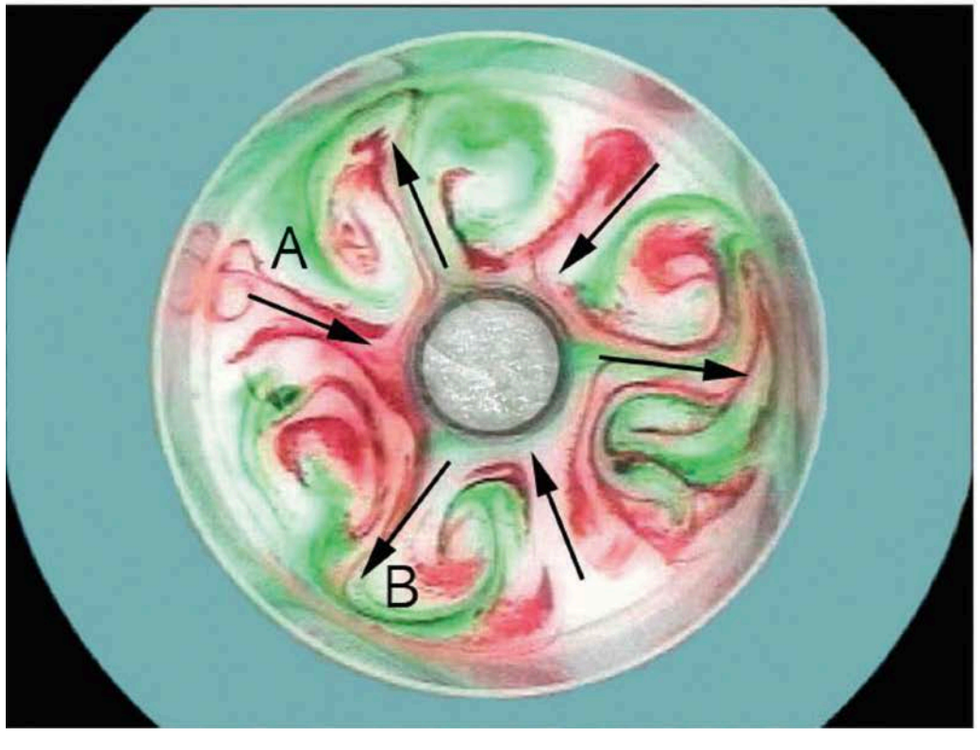


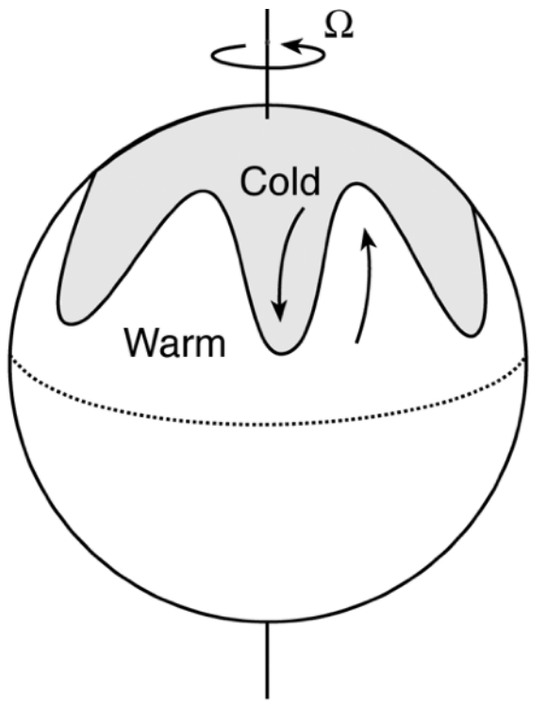
Image from https://www.jpl.nasa.gov/spaceimages/details.php?id=PIA00729

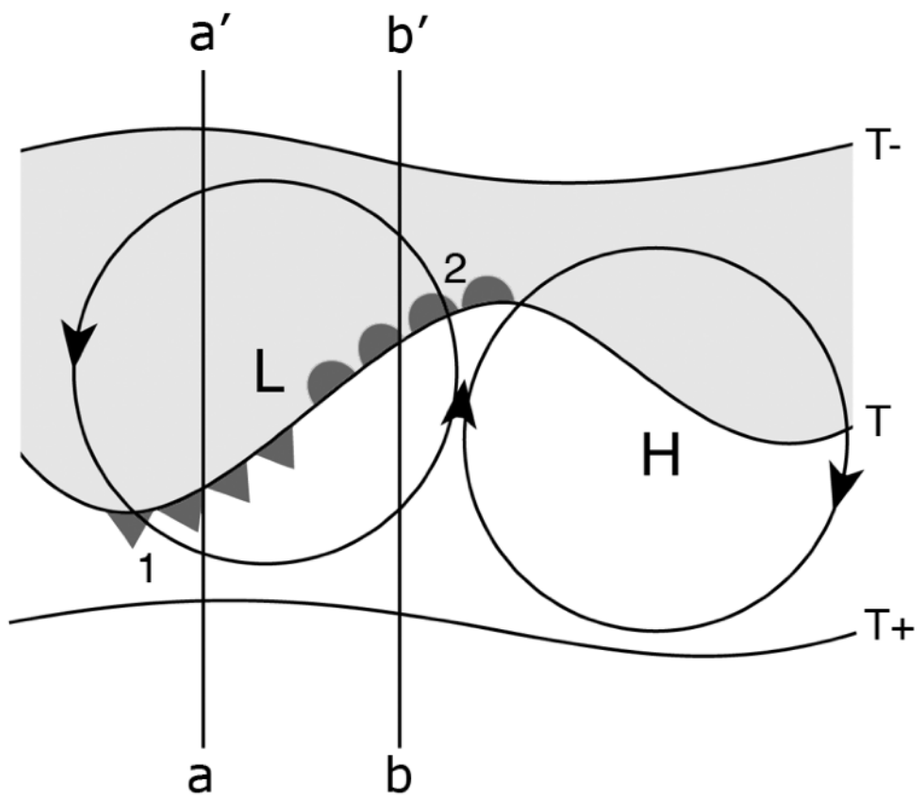
중위도 지역 순환 실험

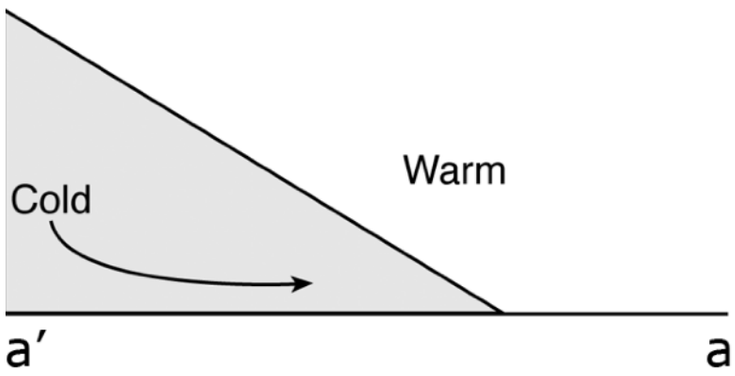


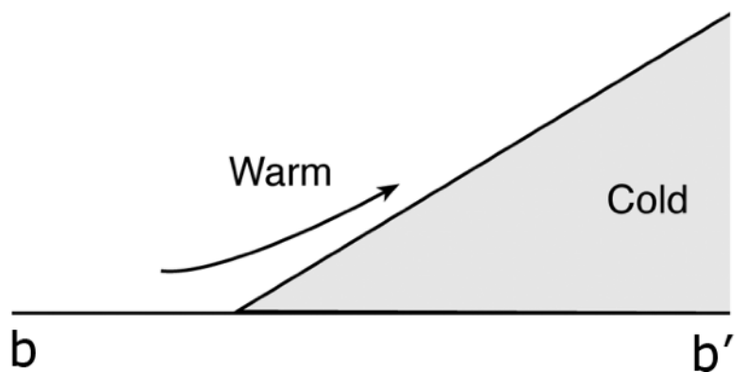
- How about the conservation of angular momentum?
- If it does, we should get the flow with close to 100 cm/s!
- In fact, angular momentum is not conserved because of the presence of zonal pressure gradient associated with eddying motion.

중위도 지역 순환 실험



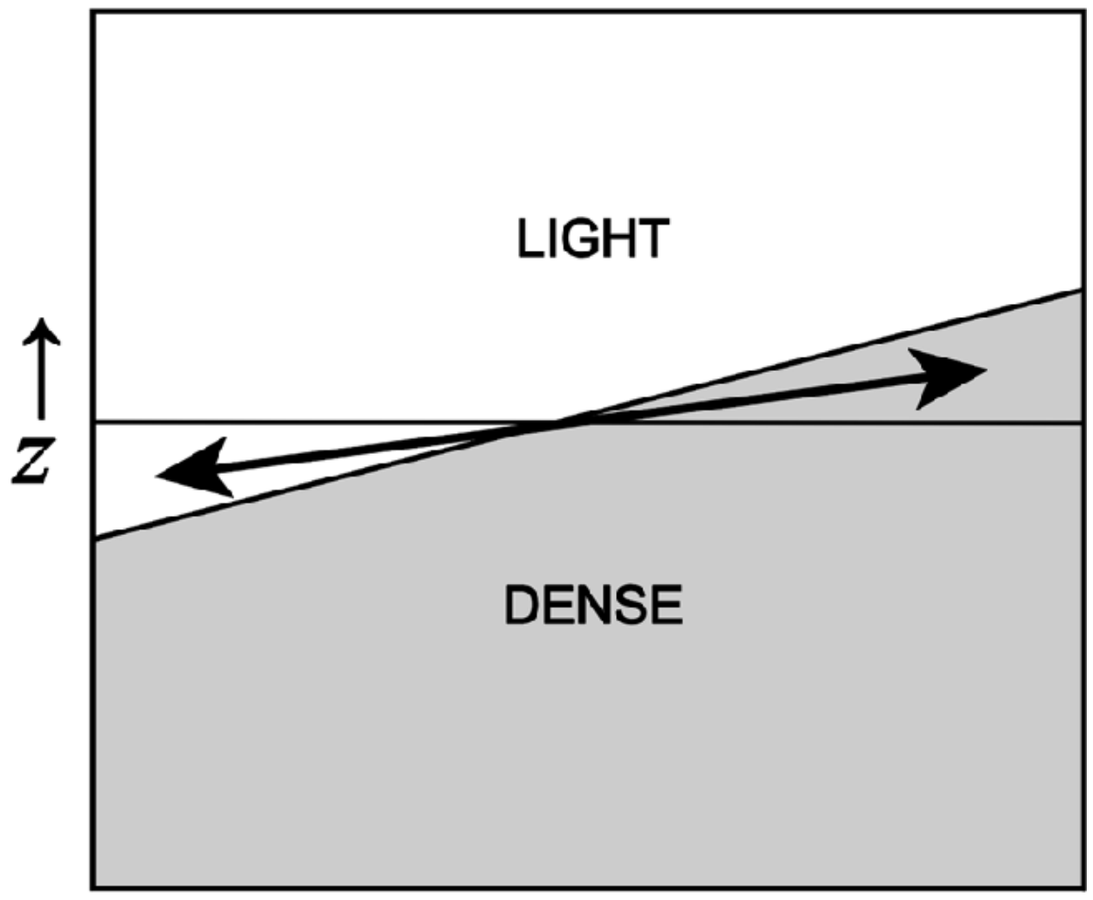


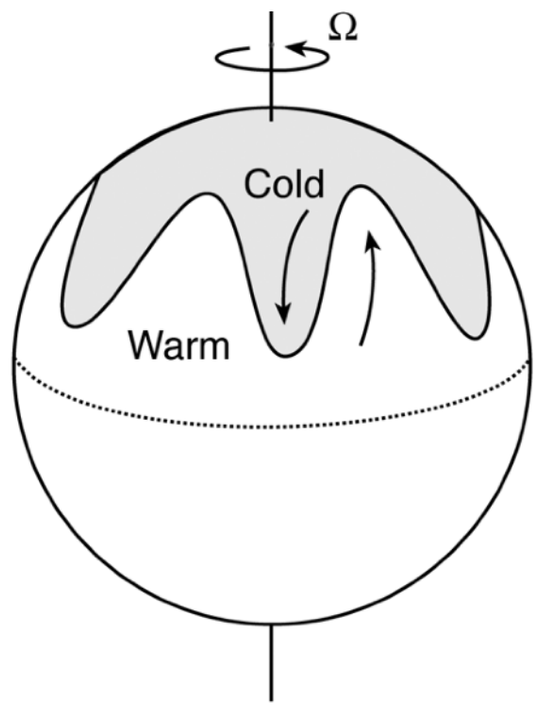




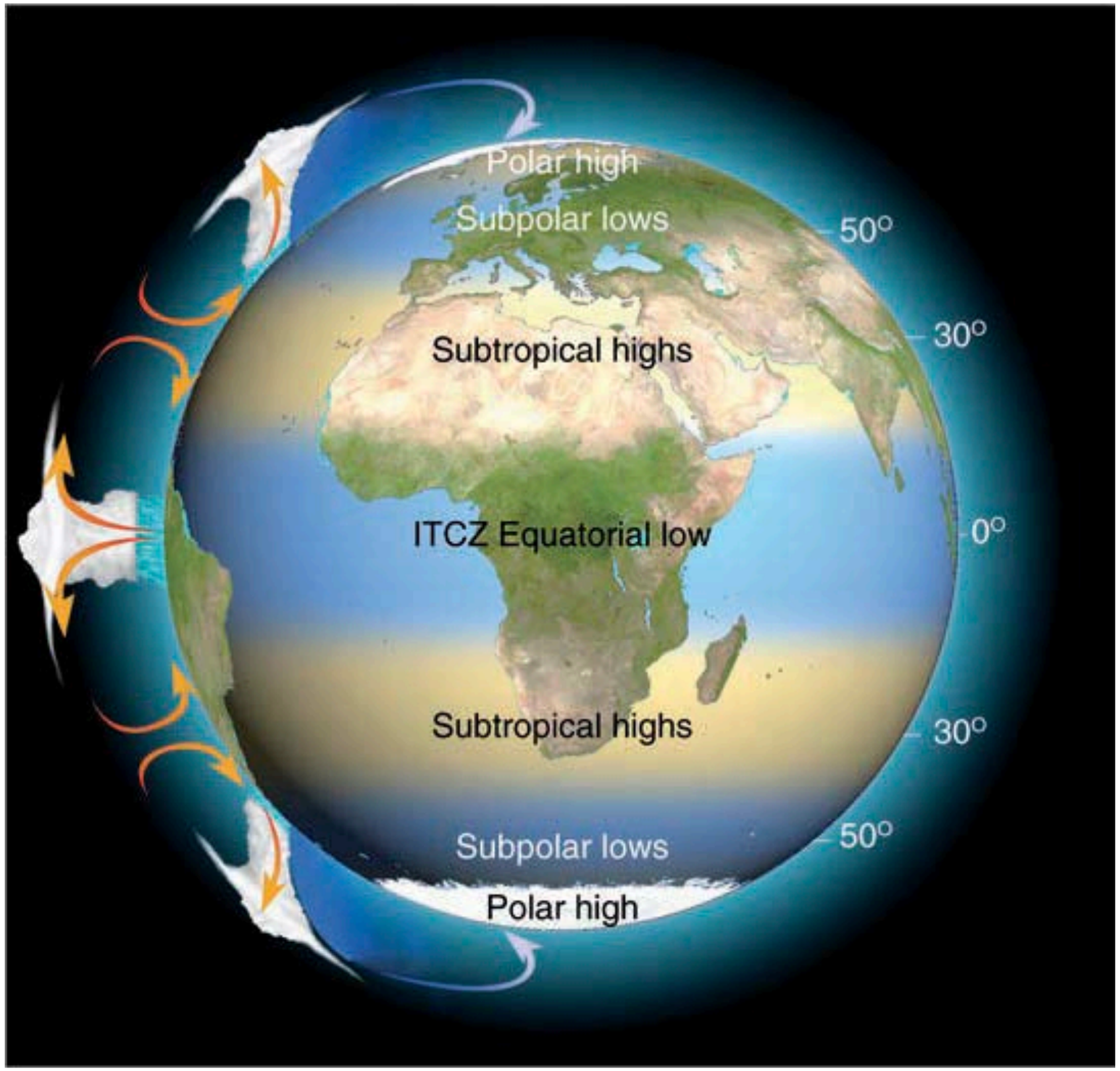
중위도 지역: 에너지

- Release of available potential energy
  - In a rotating fluid, the tilted slope can be maintained in thermal wind balance

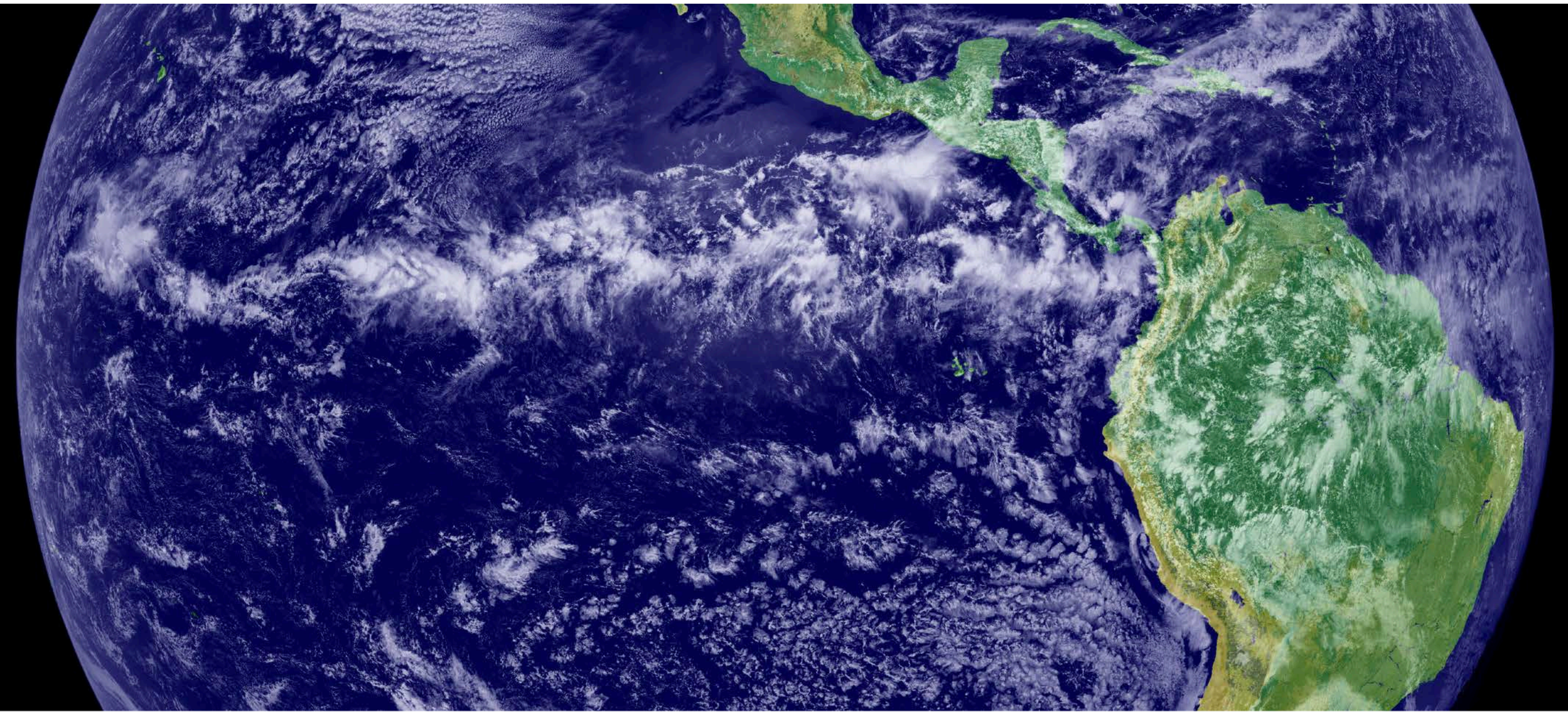




대기대순환과 강수


Polar high
Subpolar lows
50°
30°
Subtropical highs
ITCZ Equatorial low
0°
30°
Subtropical highs
50°
Subpolar lows
Polar high

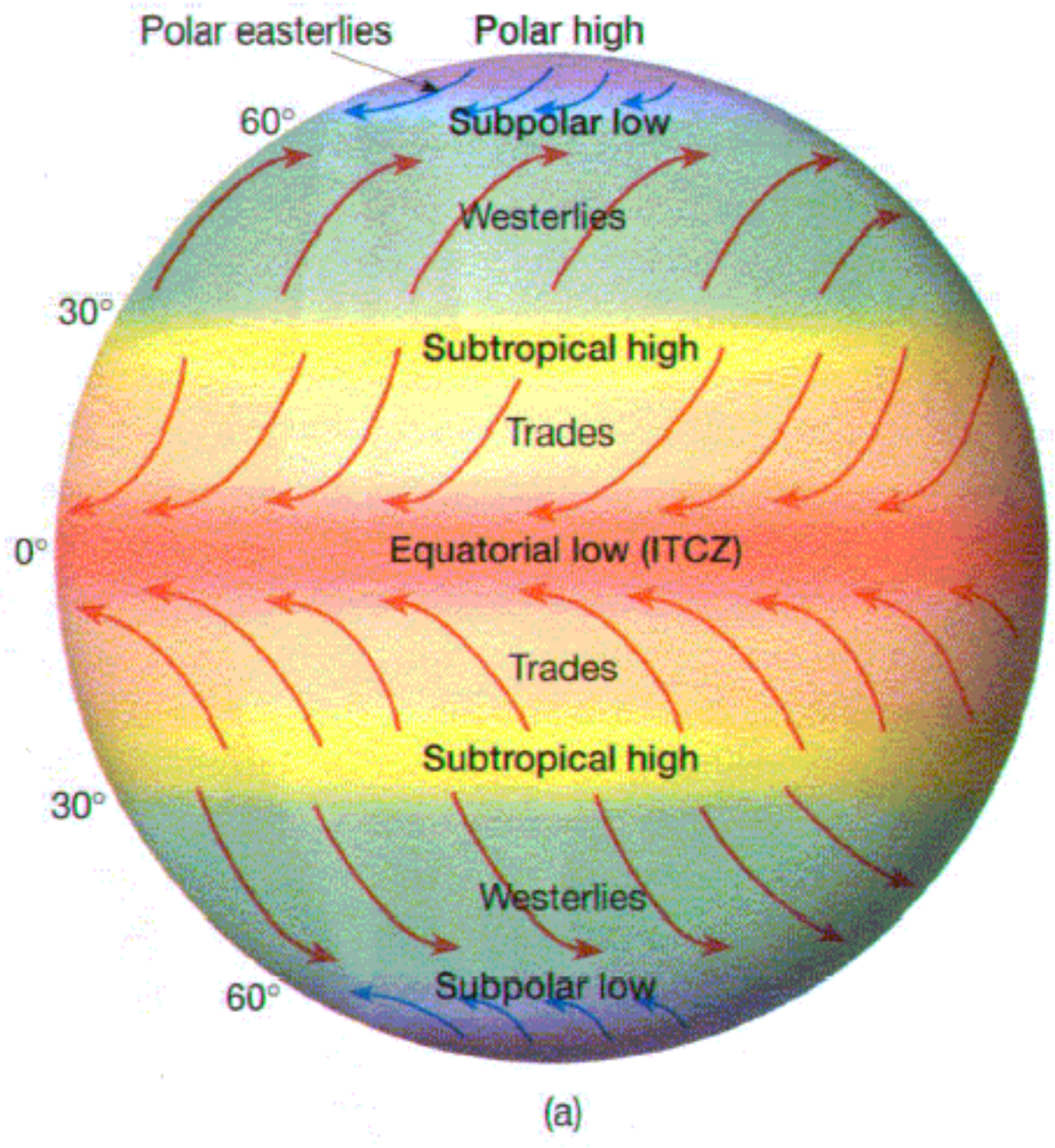
대기대순환과 강수



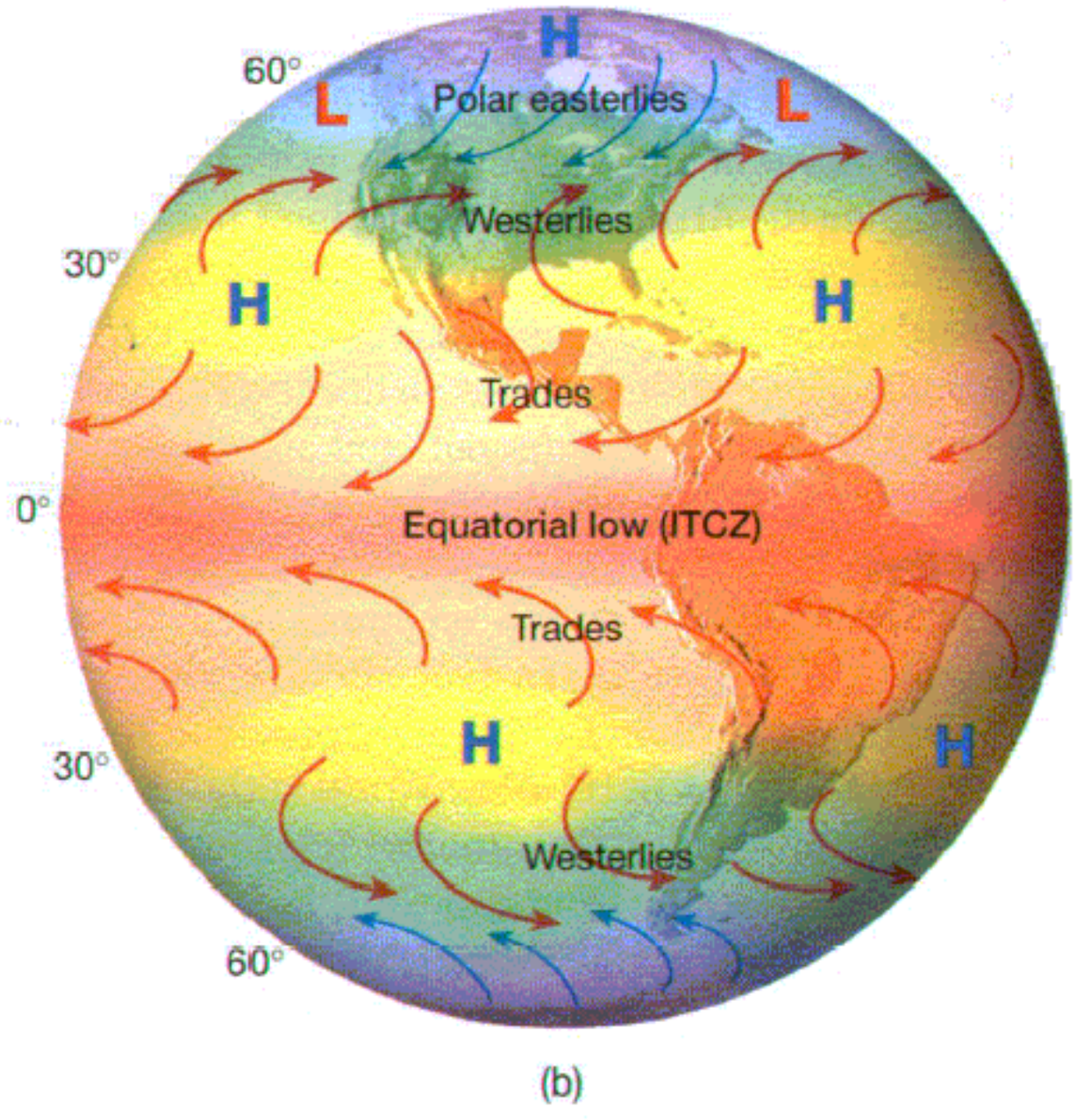
대기대순환과 강수


Deserts of the World
Deserts
ARCTIC OCEAN
ASIA
NORTH AMERICA
North American Desert
EUROPE
Kara Kum
Gobi
Thar Desert
PACIFIC OCEAN
ATLANTIC OCEAN
Sahara
Deserts of the Arabian Peninsula
AFRICA
PACIFIC OCEAN
SOUTH AMERICA
Sechura Desert
Atacama Desert
Patagonian Desert
Kalahari Desert
INDIAN OCEAN
AUSTRALIA
Australian Desert
ATLANTIC OCEAN
ANTARCTICA

대기대순환과 해양과 대륙



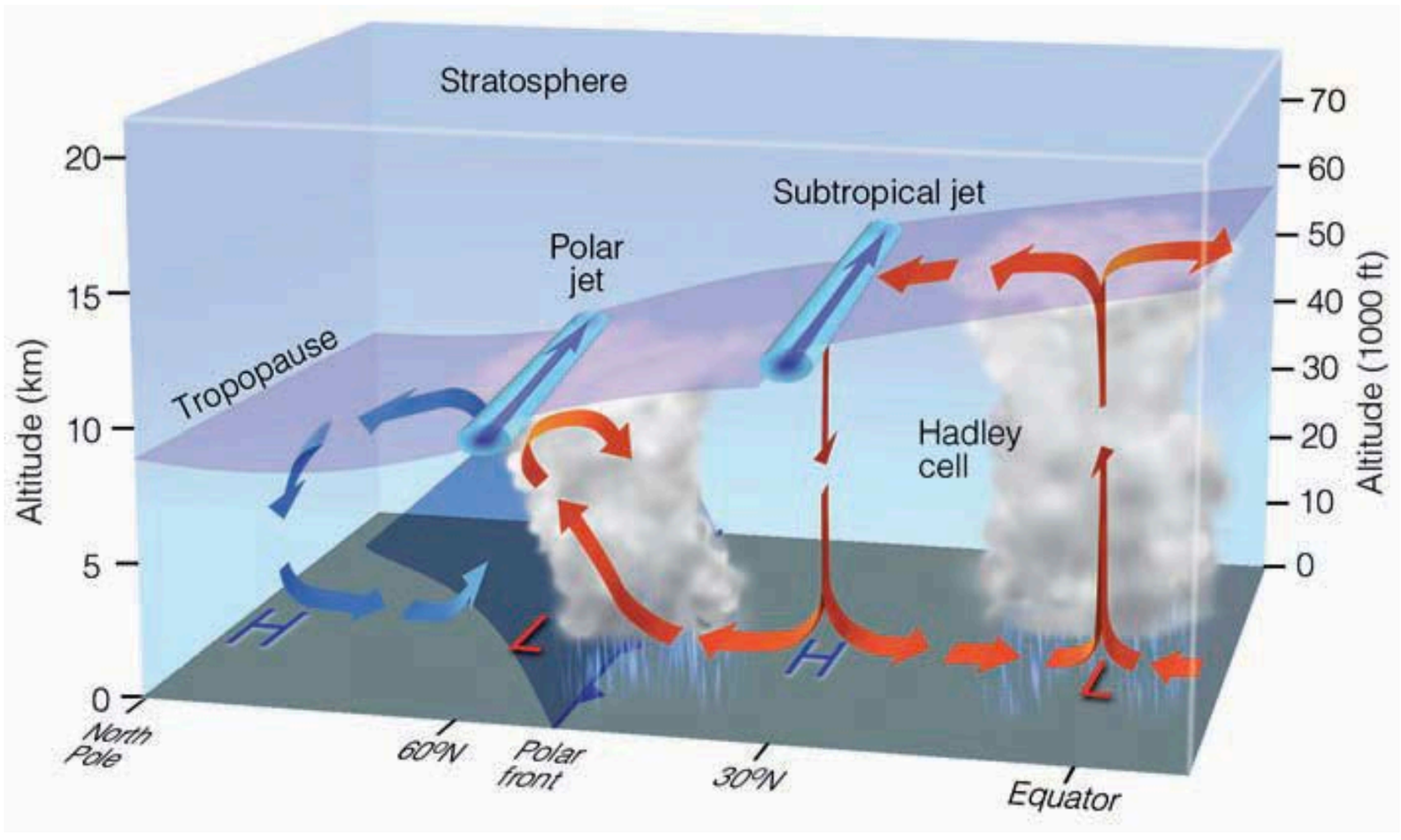
땅이 없을 때 예상되는 지상바람



대륙으로 인한 변화

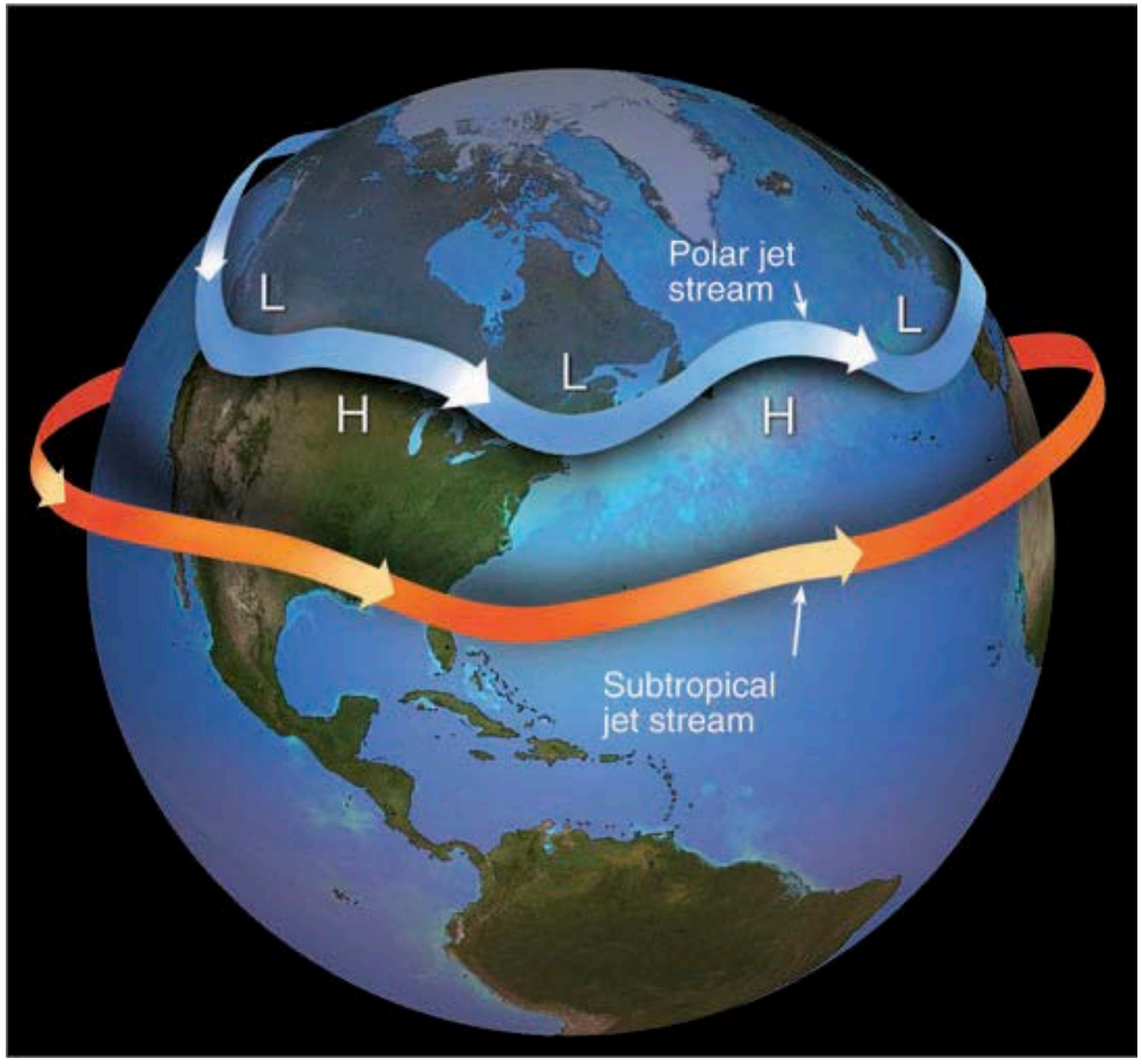
제트류

- 2차세계대전 때 발견
- 온도풍
- 겨울철 온도경도가 여름철보다 심하기 때문에 제트류도 겨울이 더 강함

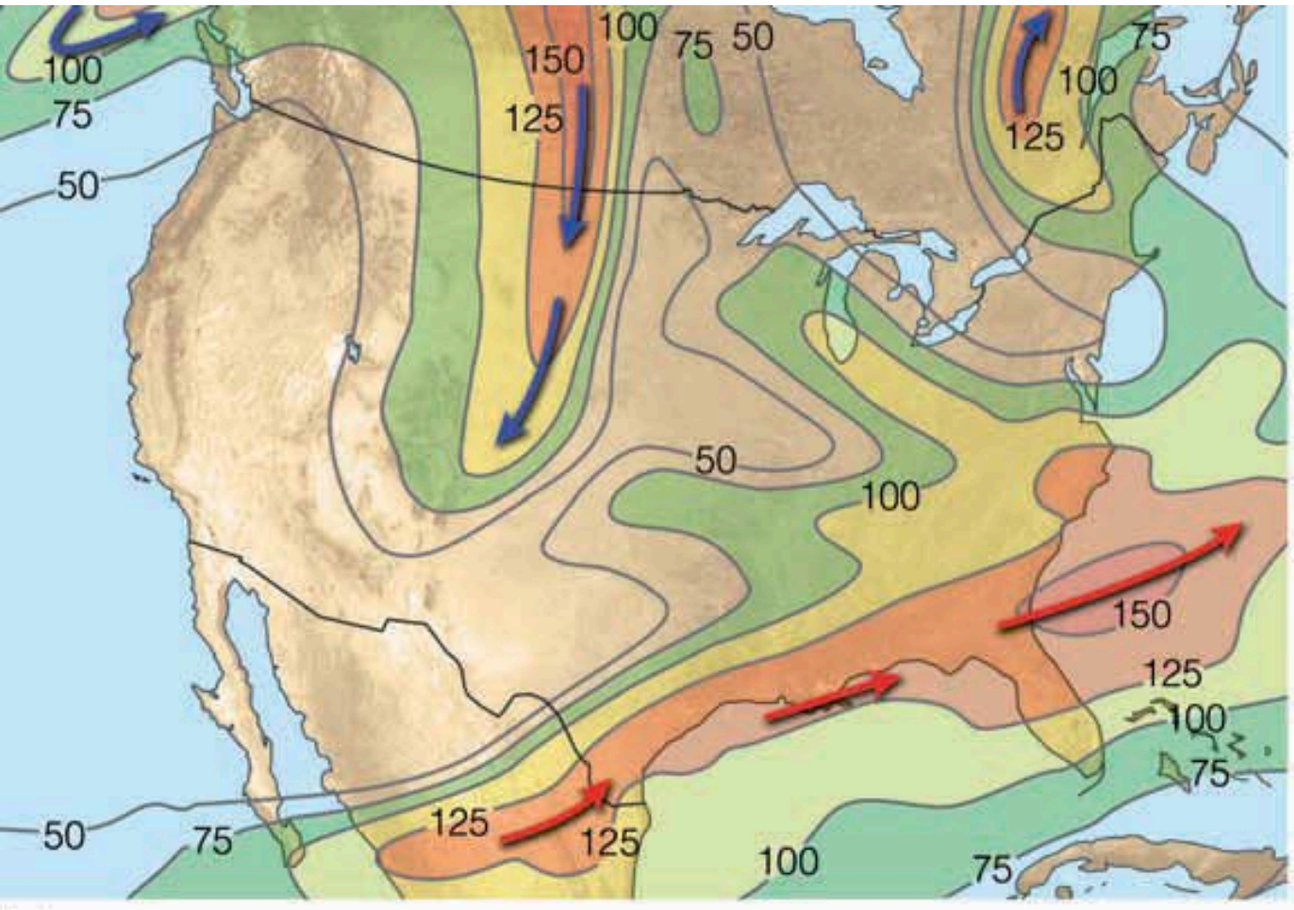


제트류

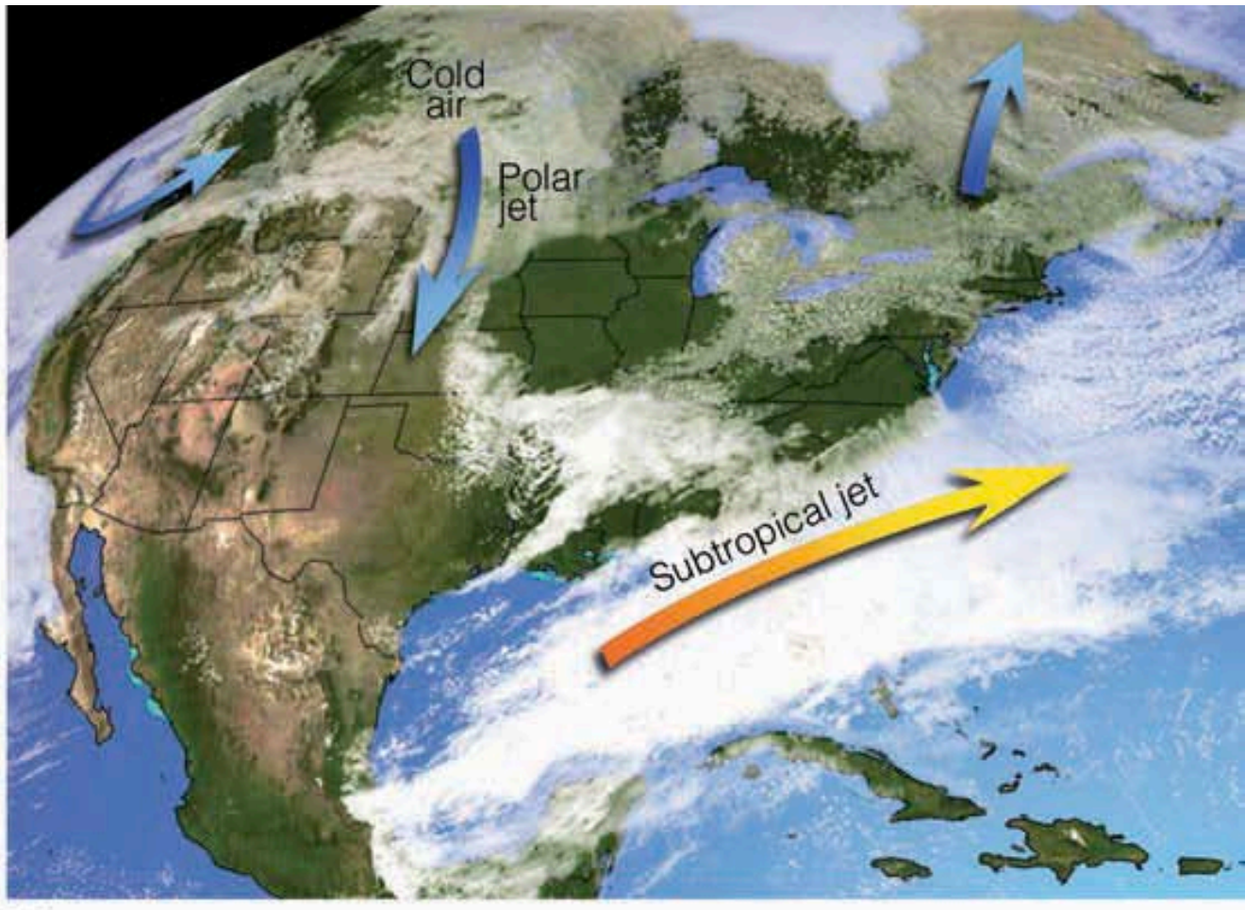
- Polar jet 이 남북으로 요동
- Subtropical jet과 합쳐지기도 함
- Polar jet이 두 개로 나뉘어지기도 함
-



제트류

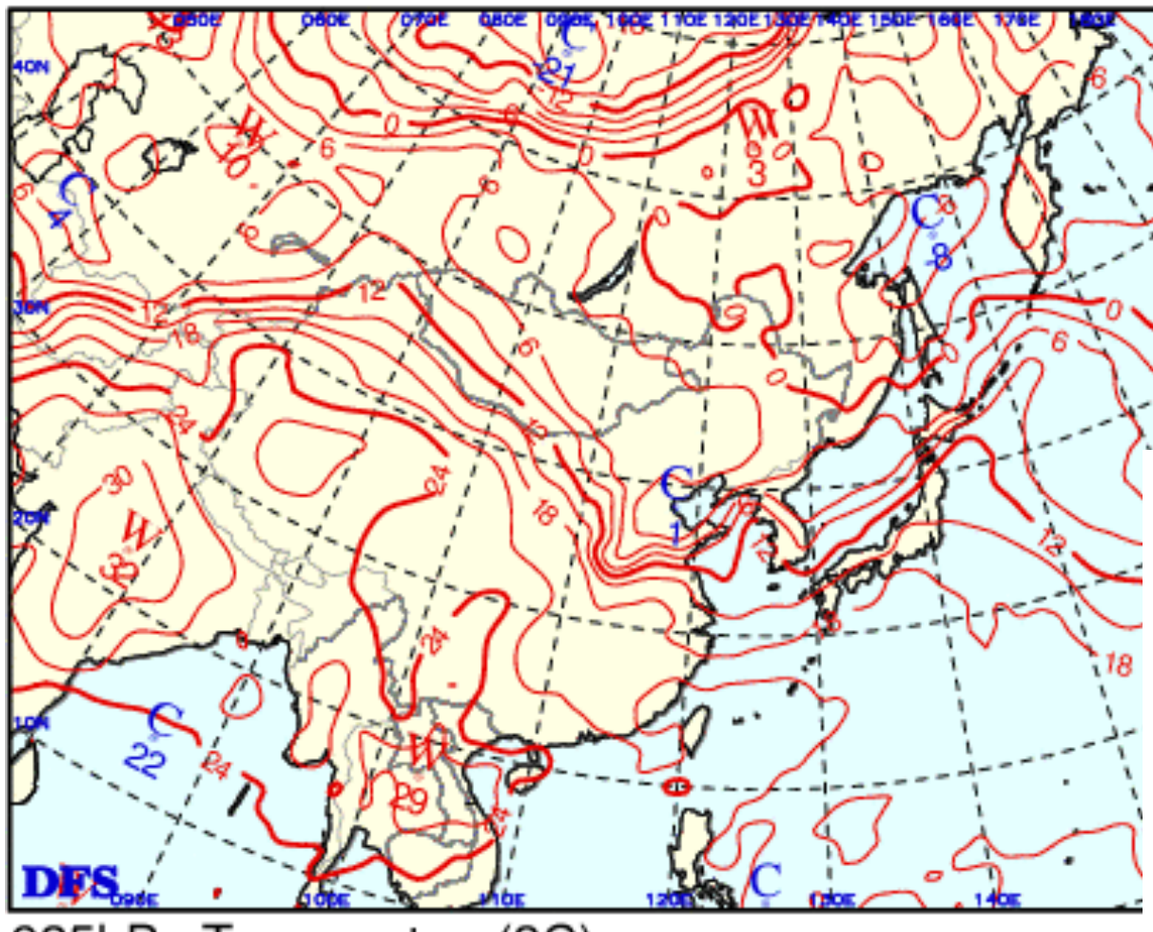

100
75
50
150
125
100
75
50
75
100
125
50
100
150
125
100
75
50
75
125
125
100
75

(a)

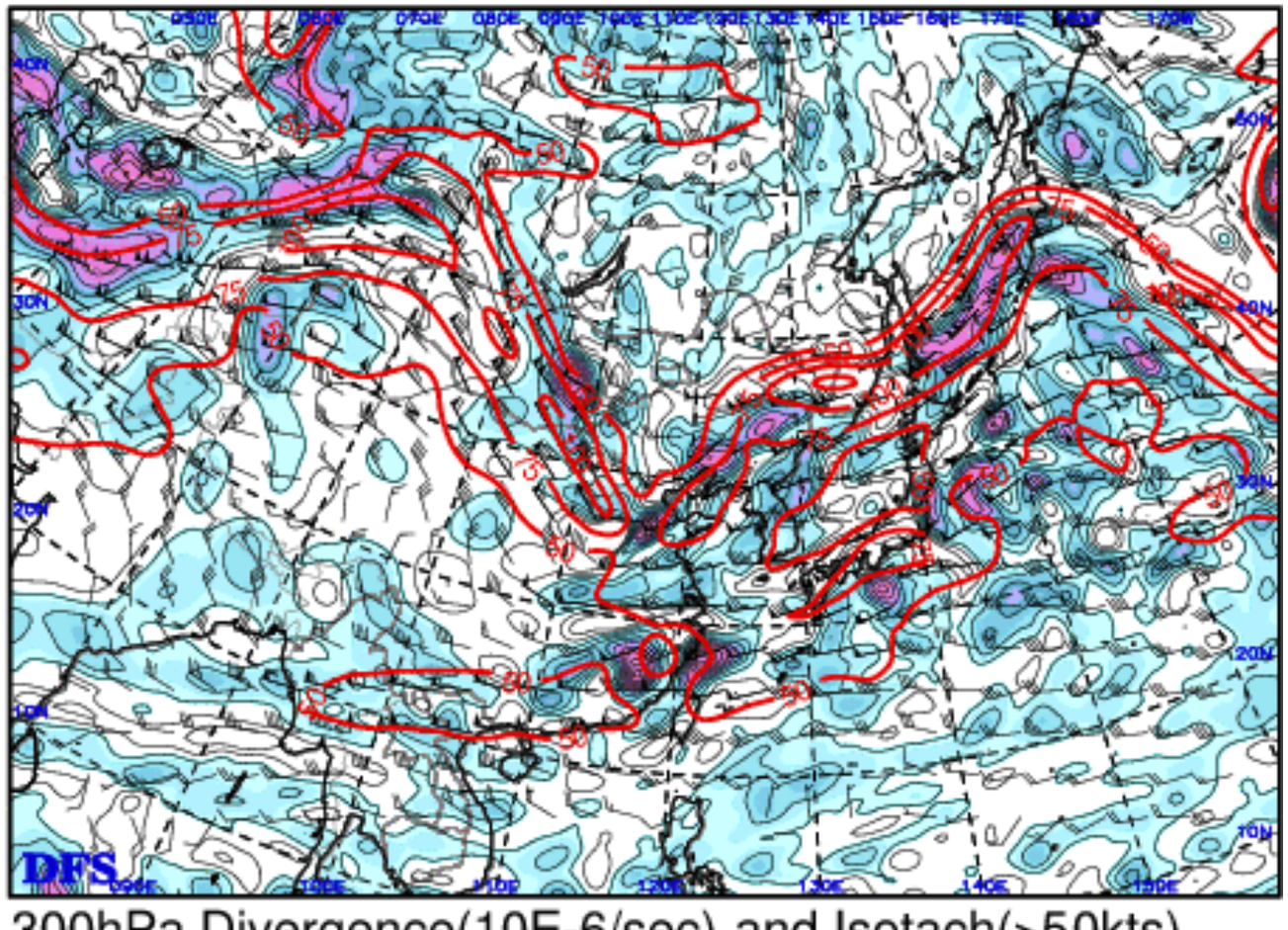

Cold
air
Polar
jet
Subtropical jet

(b)

제트류



925hPa Temperature(3C)



300hPa Divergence(10E-6/sec) and Isotach(>50kts)

운동량 전달

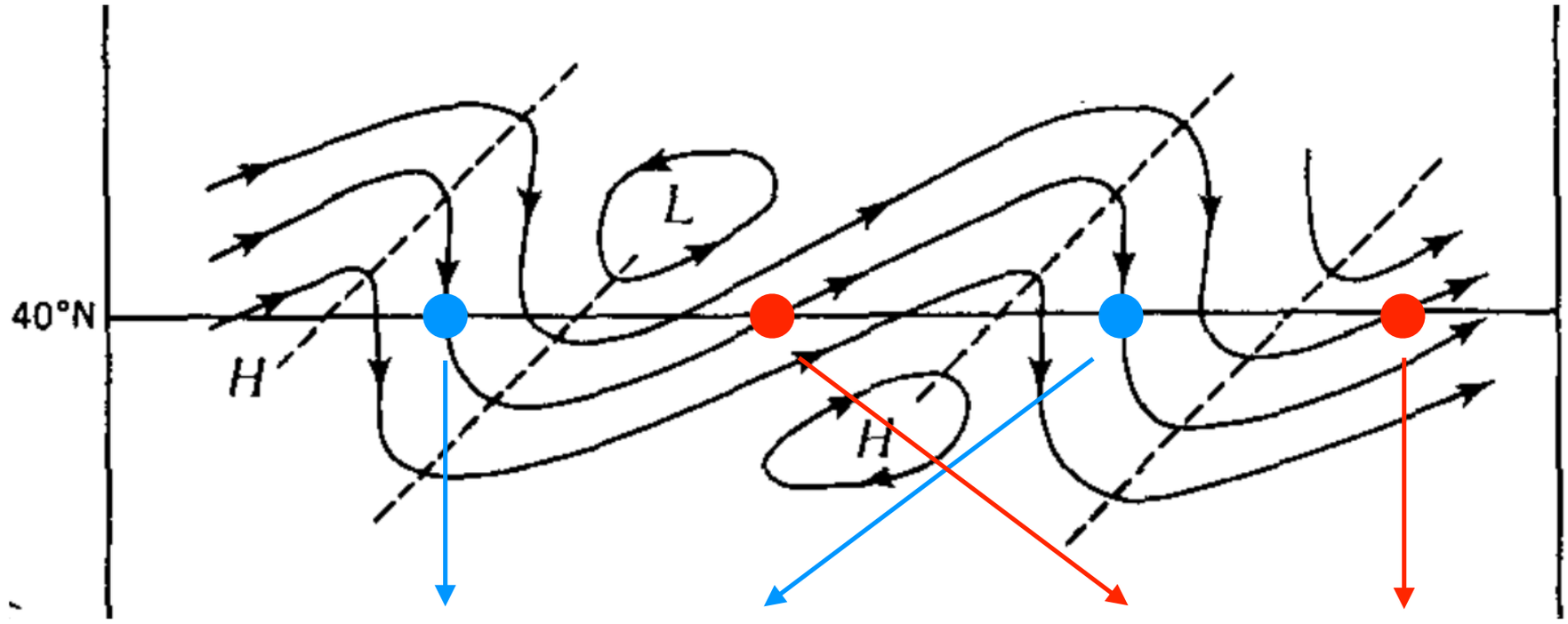
- 열대지방 : 무역풍은 지구 자전과 반대방향 → 지구의 자전을 느리게 하는 역할
- 중위도 지방 : 편서풍은 지구 자전과 같은 방향 → 지구의 자전을 빠르게 하는 역할

- 마찰이 열대지방의 무역풍을 느리게 하며 대기에 운동량 공급
- 마찰이 중위도 지방의 편서풍을 느리게 하며 대기의 운동량 감소
- 대기는 동쪽으로 향하는 운동량을 열대지방에서 중위도로 전달하는 역할

운동량 전달

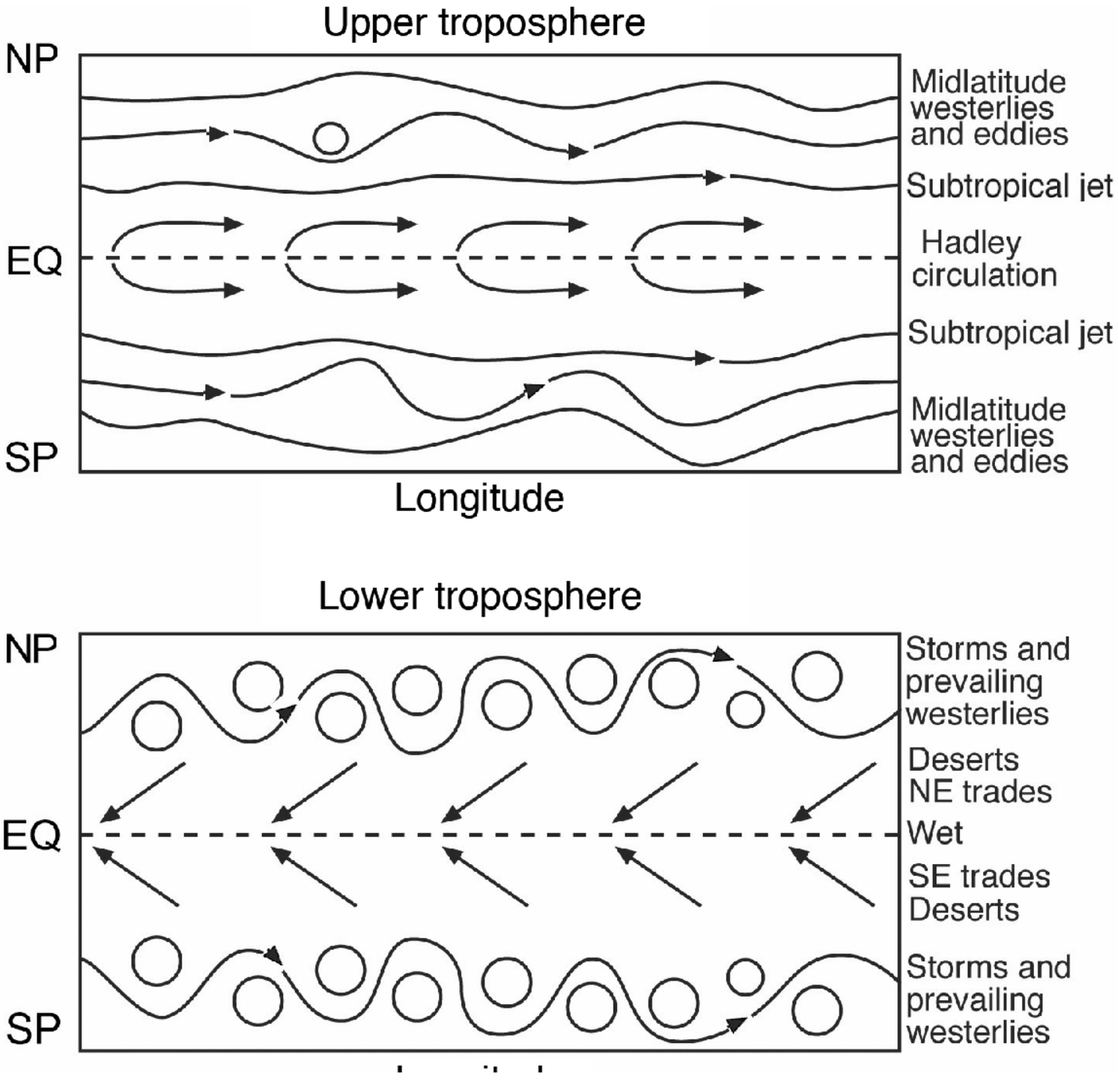
- Eddies in the extratropics also transport westerly momentum to poleward, but how?
- The meridional momentum transport $= v(\Omega r^2 + ur)$

$= v\Omega r^2 + ruv$



$u \sim 0,\ v < 0 \rightarrow uv \sim 0$ $u > 0,\ v < 0 \rightarrow uv > 0$

대기대순환

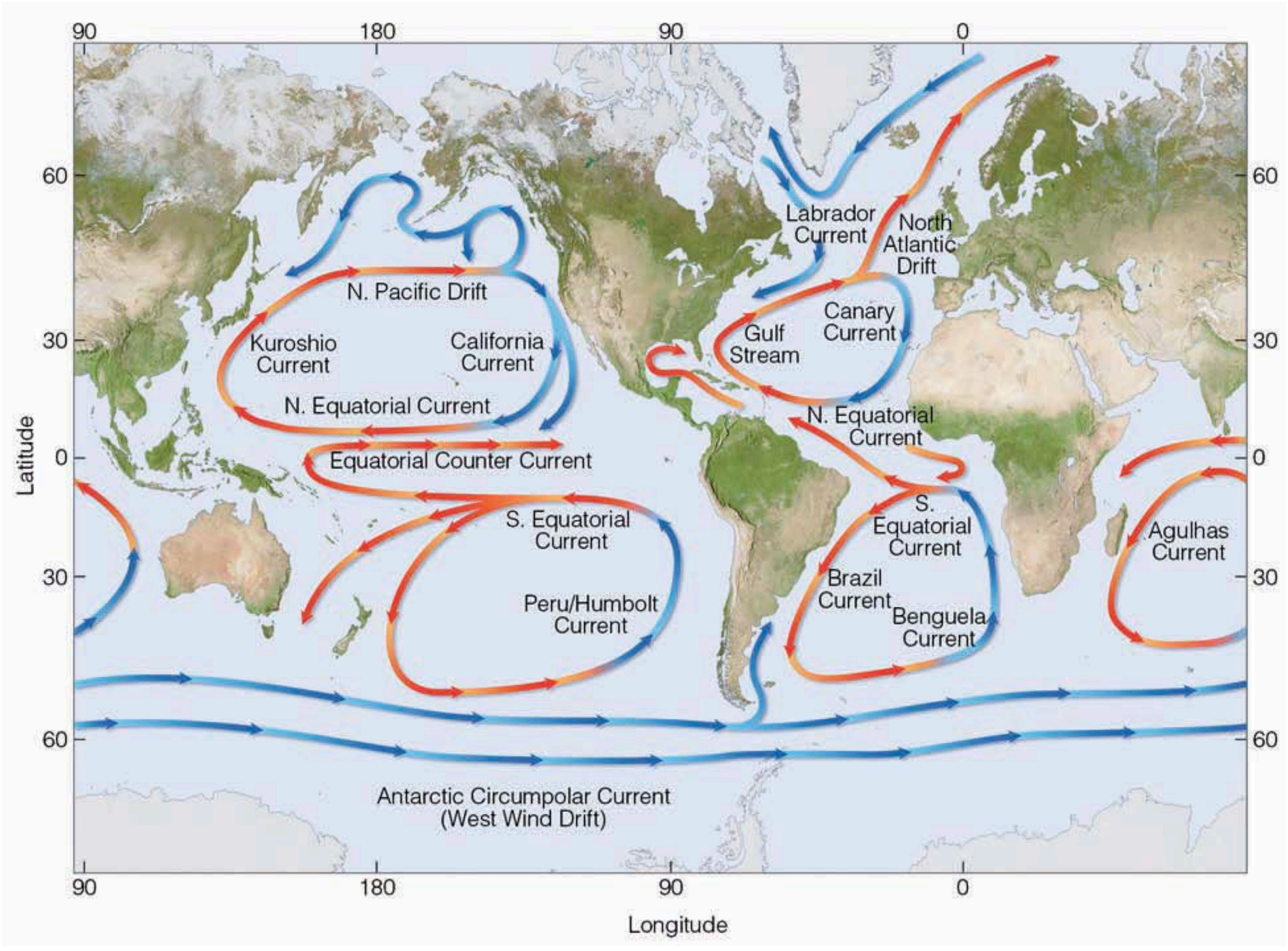


@ tropics : convergence and upward motion → intense rainfall

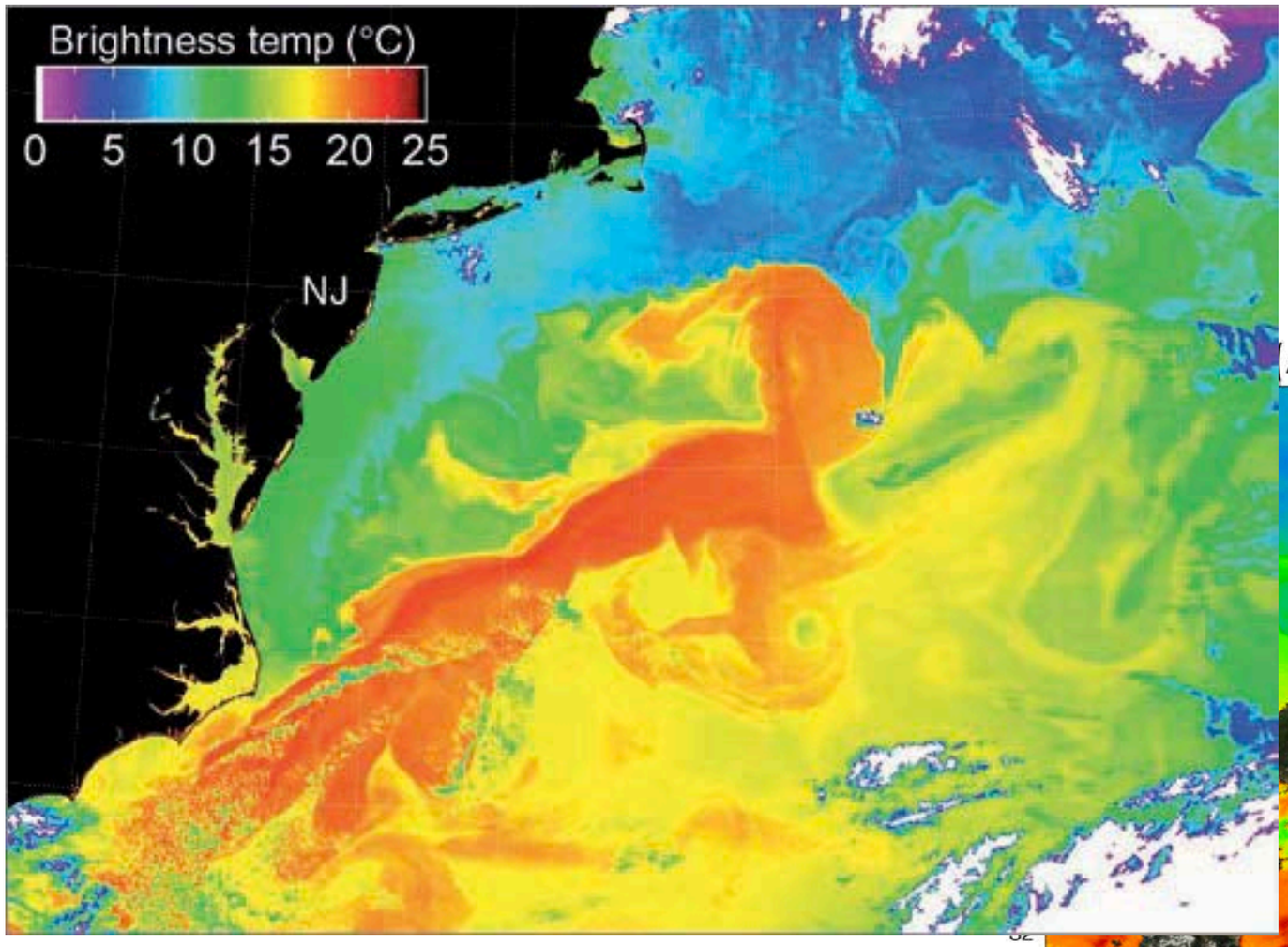
@ midlatitude : sinking and warming → desert belt

@ midlatitude : eddies that go around the globe → control the weather patterns

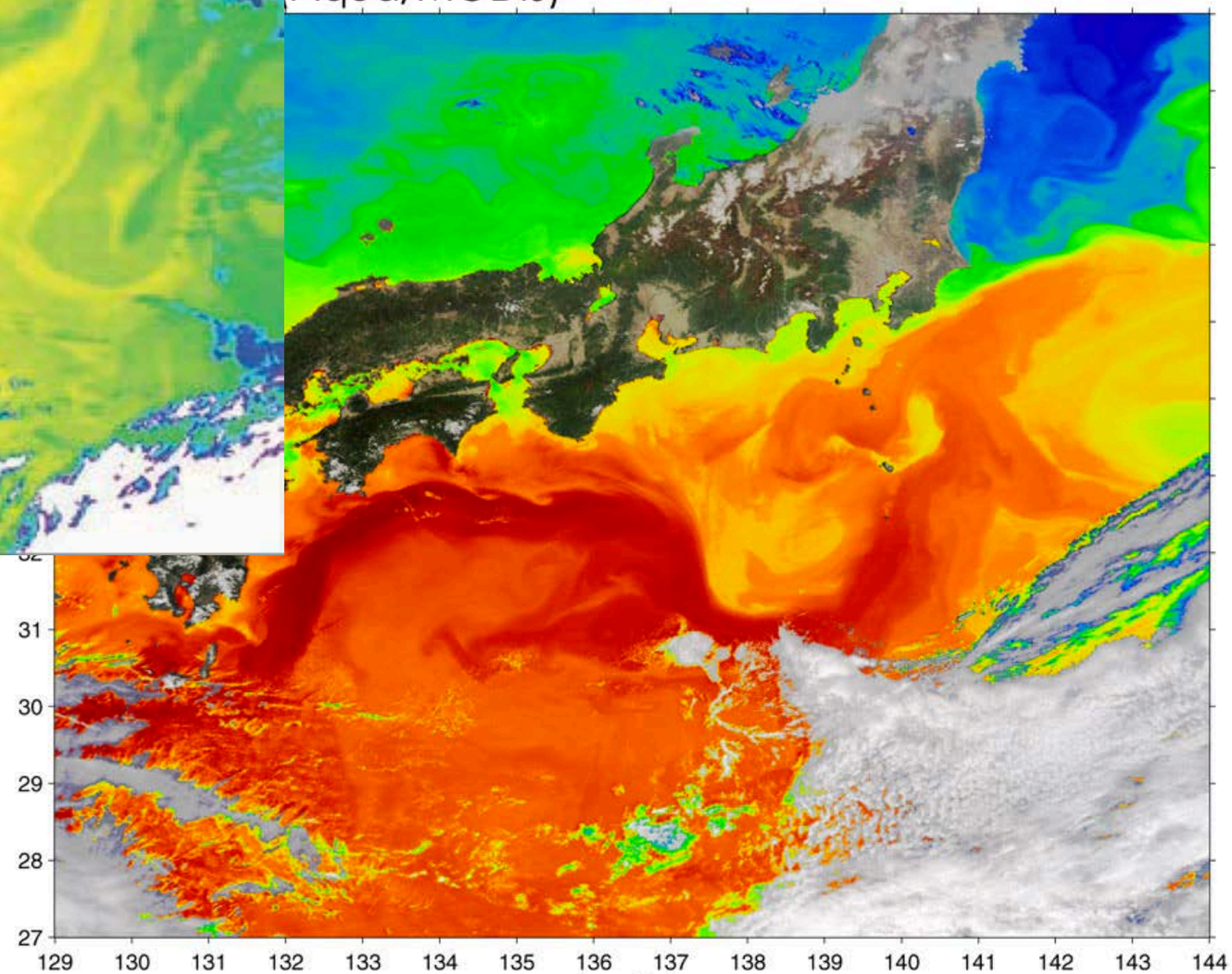
대기-해양 상호작용 : 해류


90
180
90
0
60
30
0
30
60
Latitude
Labrador Current
North Atlantic Drift
N. Pacific Drift
Kuroshio Current
California Current
Gulf Stream
Canary Current
N. Equatorial Current
N. Equatorial Current
Equatorial Counter Current
S. Equatorial Current
S. Equatorial Current
Agulhas Current
Brazil Current
Peru/Humbolt Current
Benguela Current
Antarctic Circumpolar Current (West Wind Drift)
90
180
90
0
Longitude

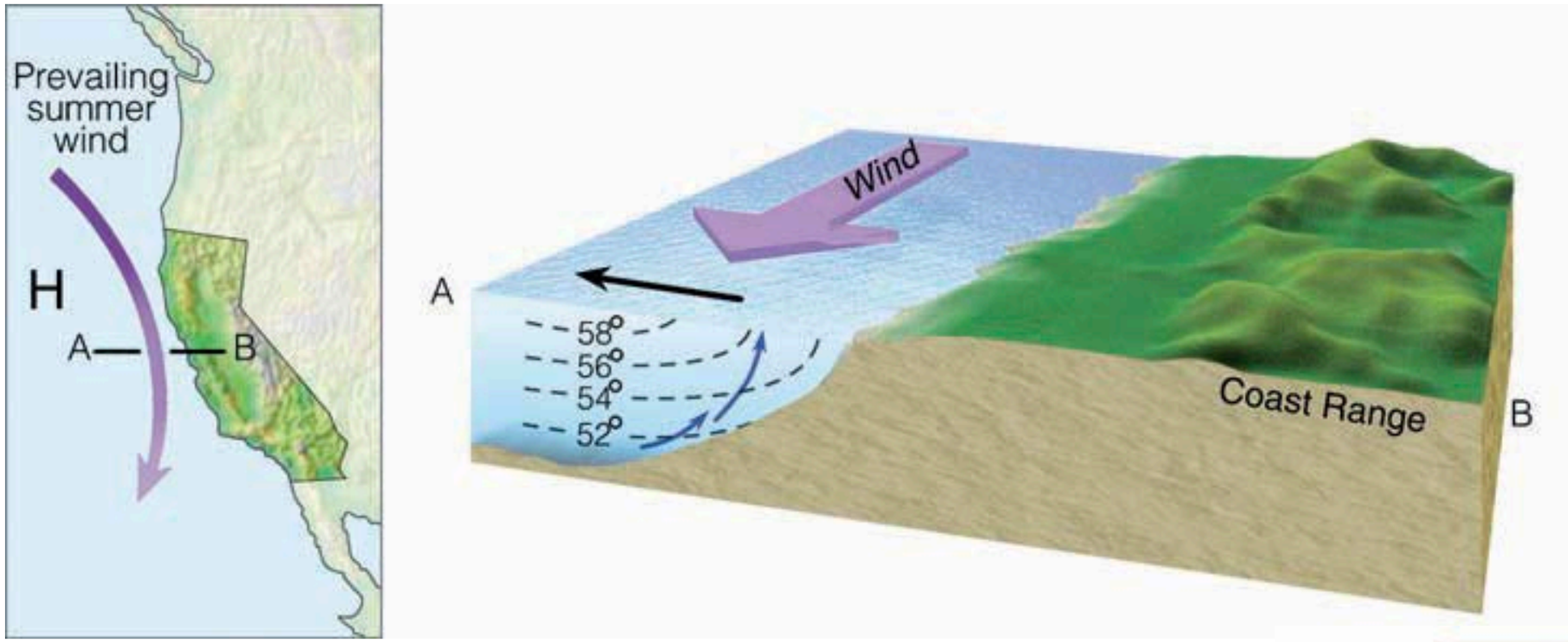
대기-해양 상호작용 : 서안경계류



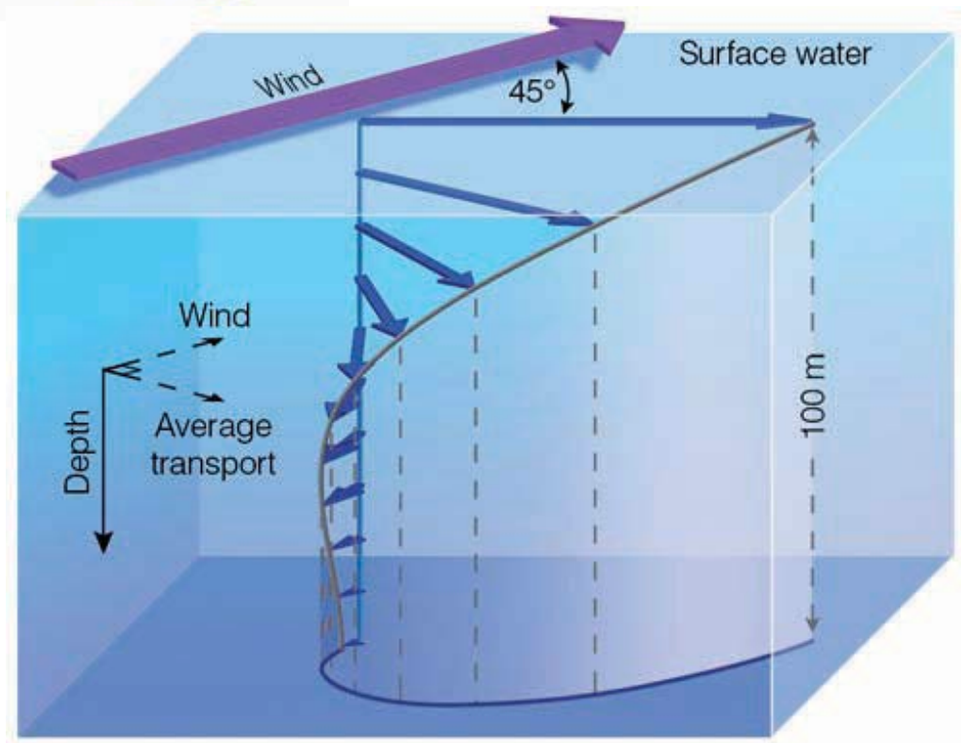
(Aqua/MODIS)



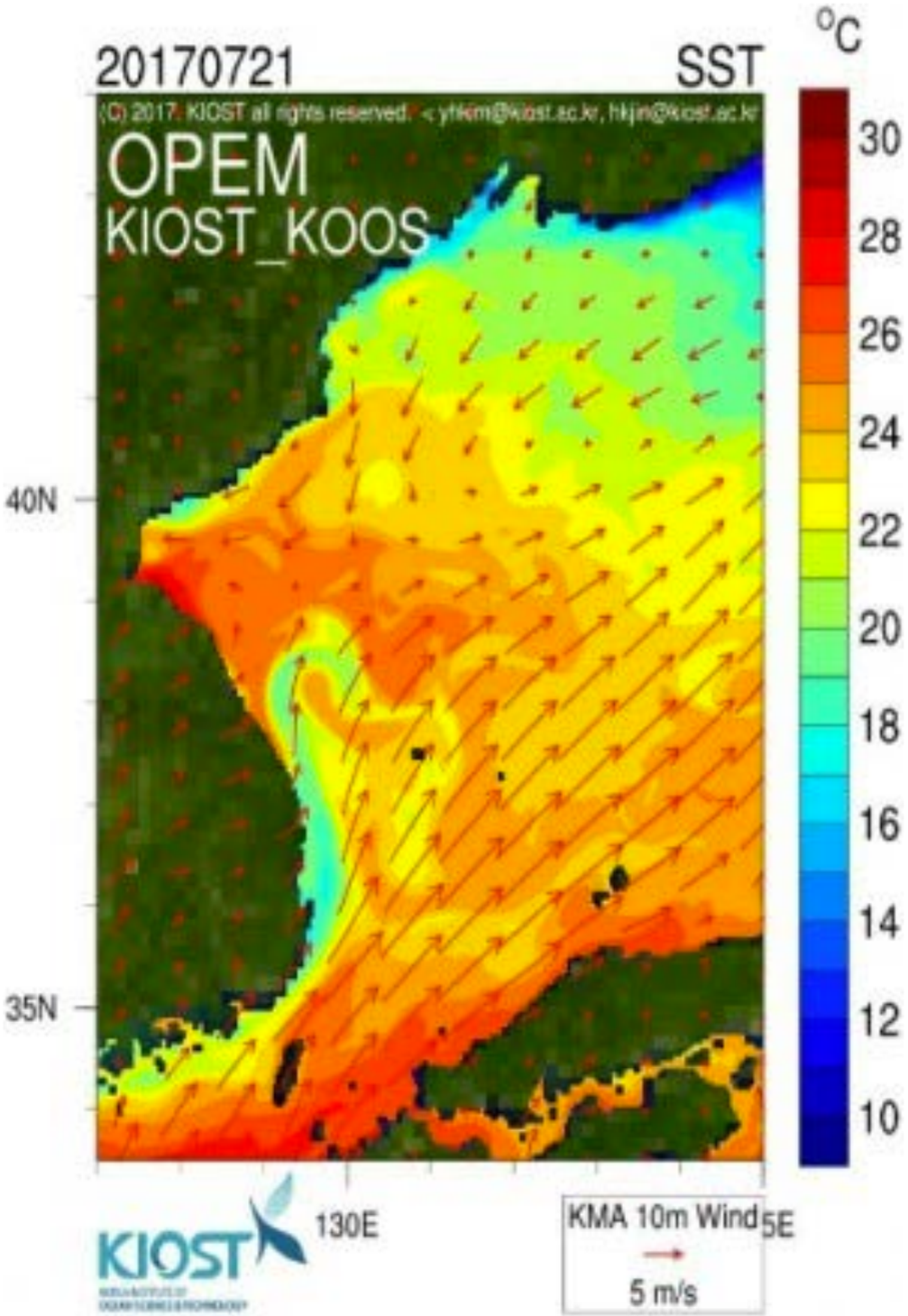
대기-해양 상호작용 : 에크만 수송 / 해안 용승

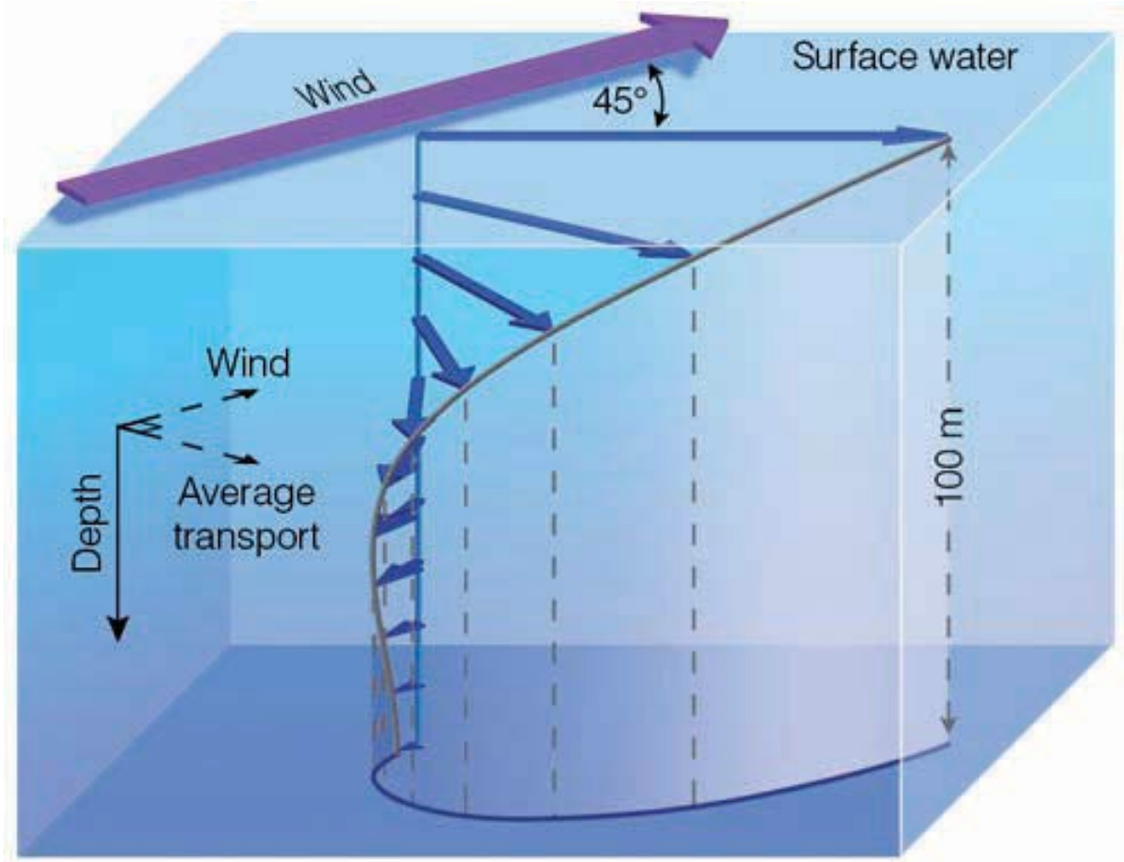


에크만 수송



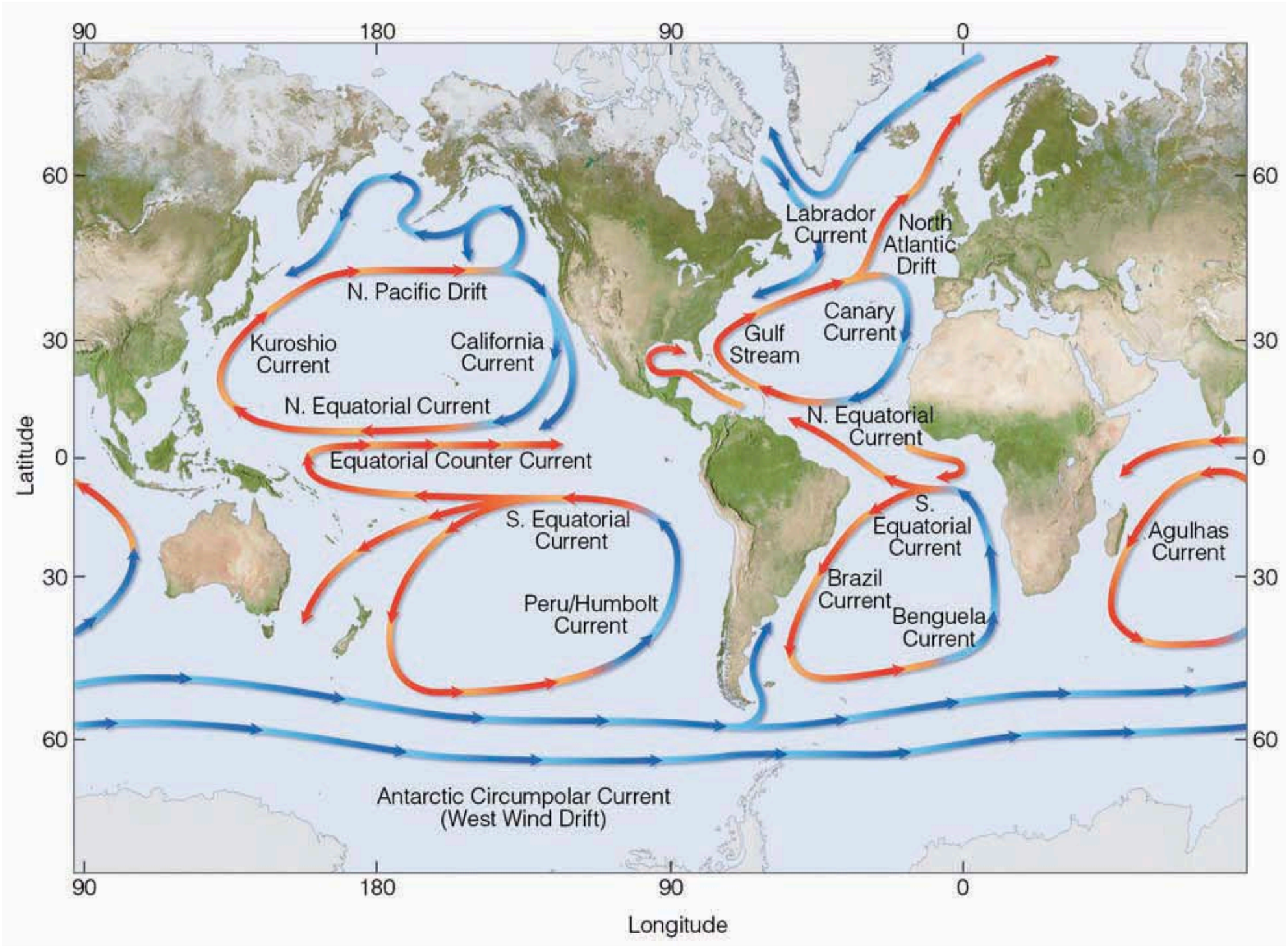
대기-해양 상호작용 : 에크만 수송 / 해안 용승



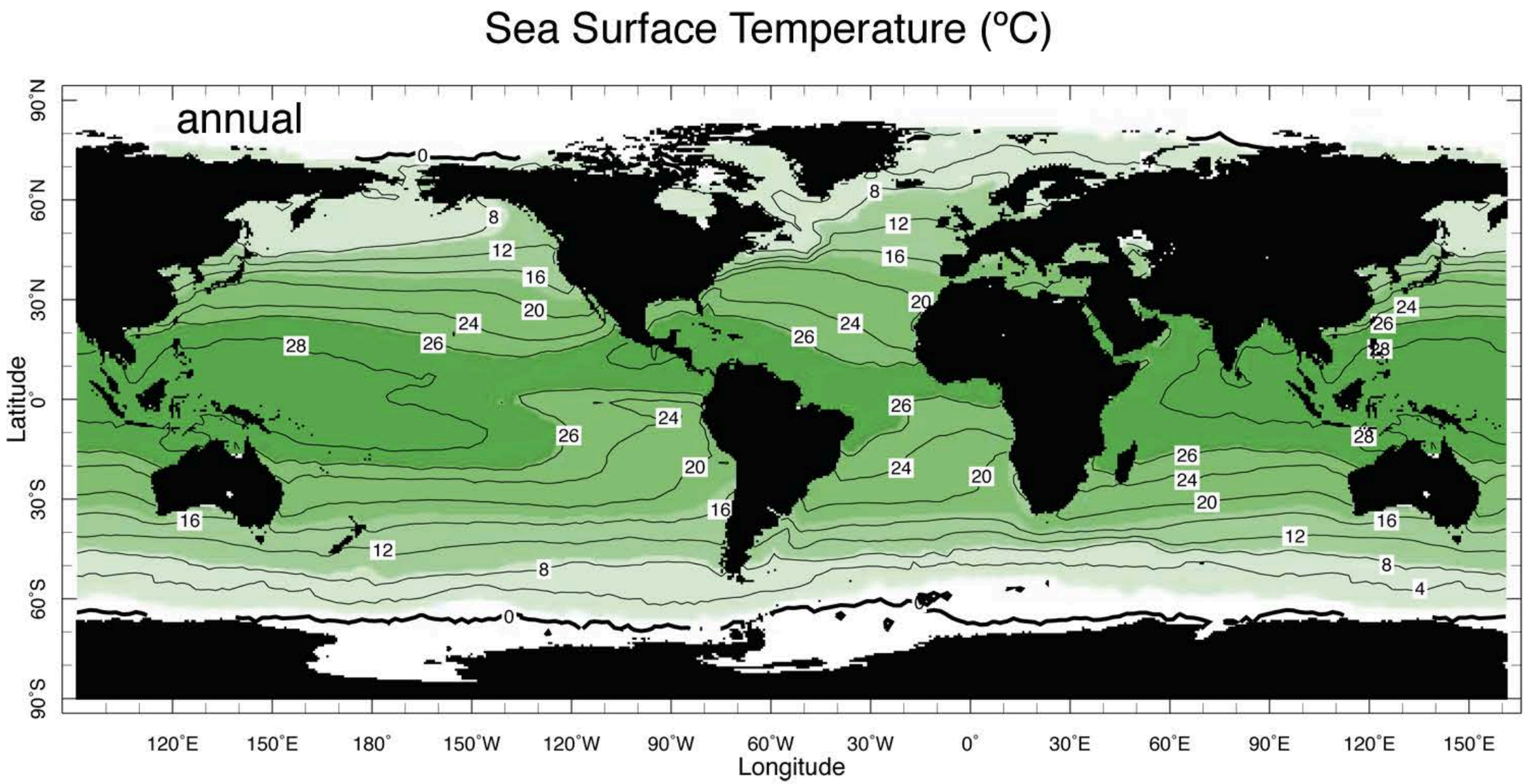


에크만 수송

대기-해양 상호작용 : 에크만 수송 / subtropical gyre



대기-해양 상호작용 : 엘니뇨 / 남방진동



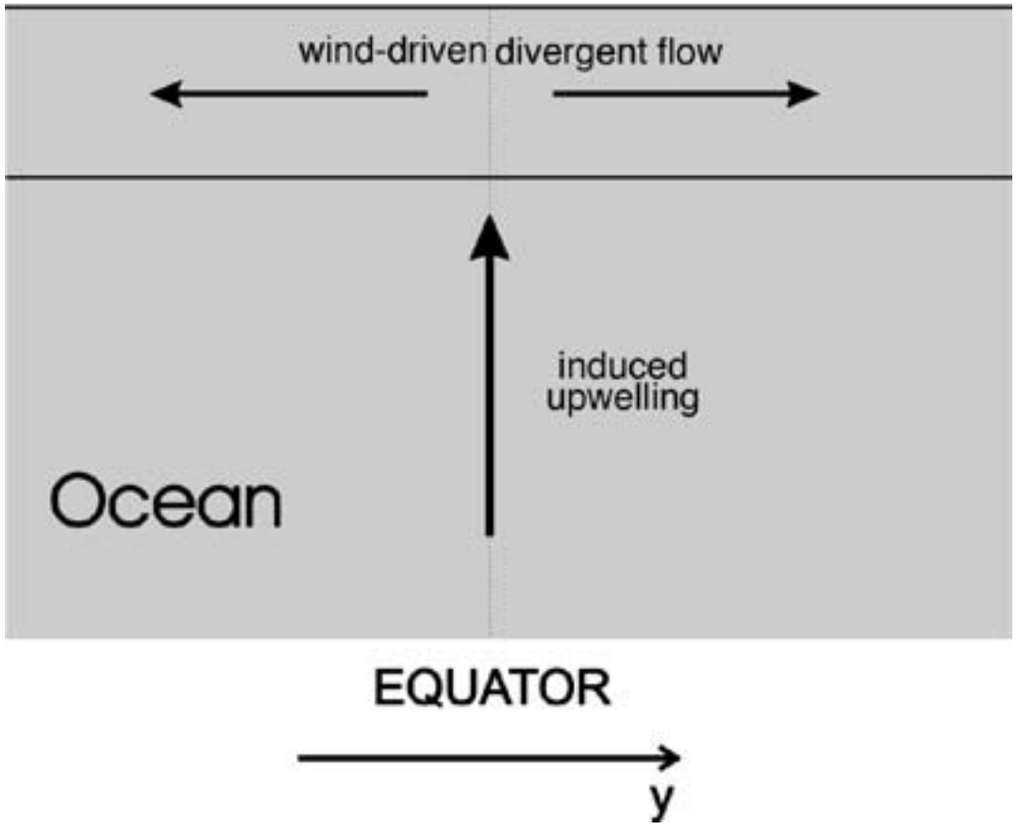
대기-해양 상호작용 : 엘니뇨 / 남방진동

$$\beta V = \frac{1}{\rho_{ref}} \left(\frac{\partial \tau_{wind,y}}{\partial x} - \frac{\partial \tau_{wind,x}}{\partial y} \right)$$

$$\beta V = -\frac{1}{\rho_{ref}} \frac{\partial \tau_x}{\partial y}$$

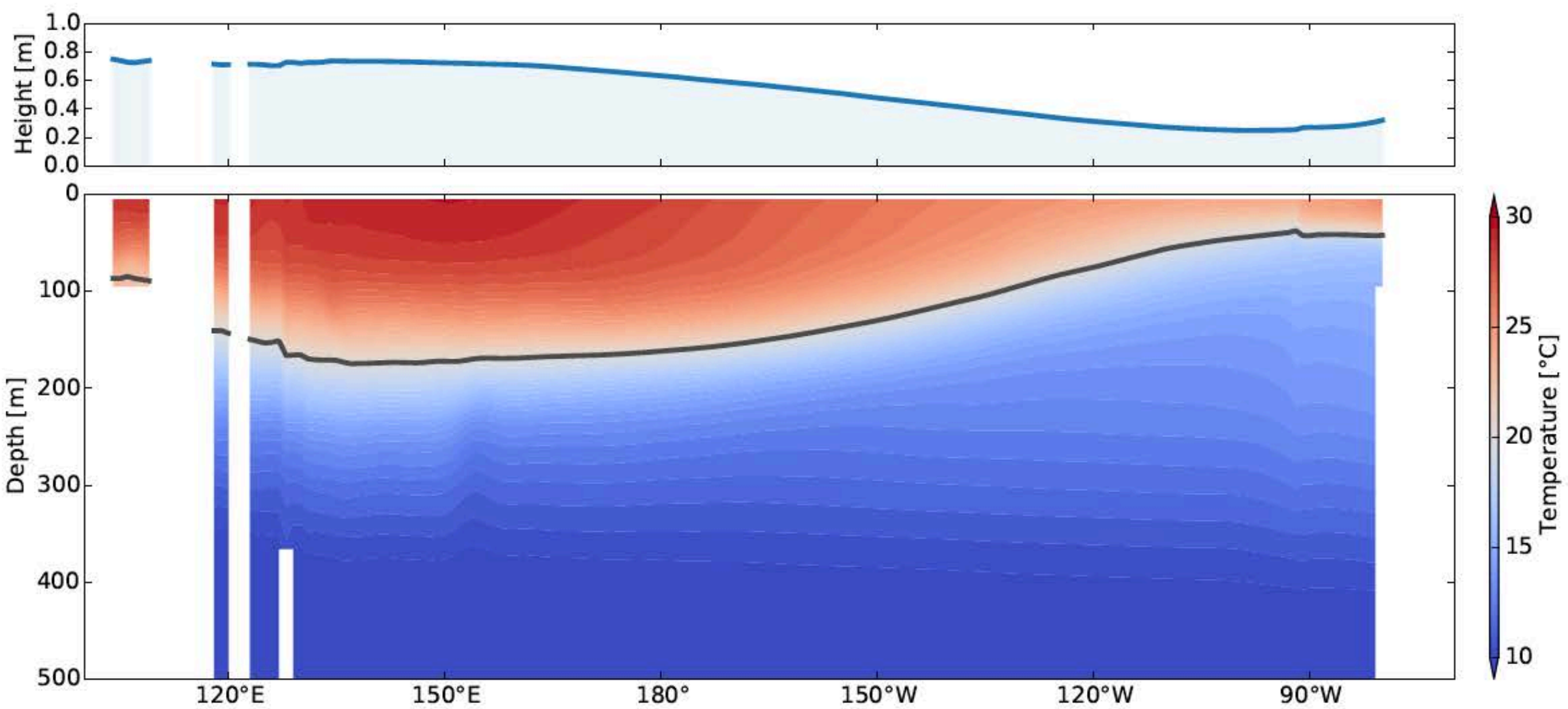
$\beta > 0$ In the northern hemisphere

$\beta < 0$ In the southern hemisphere



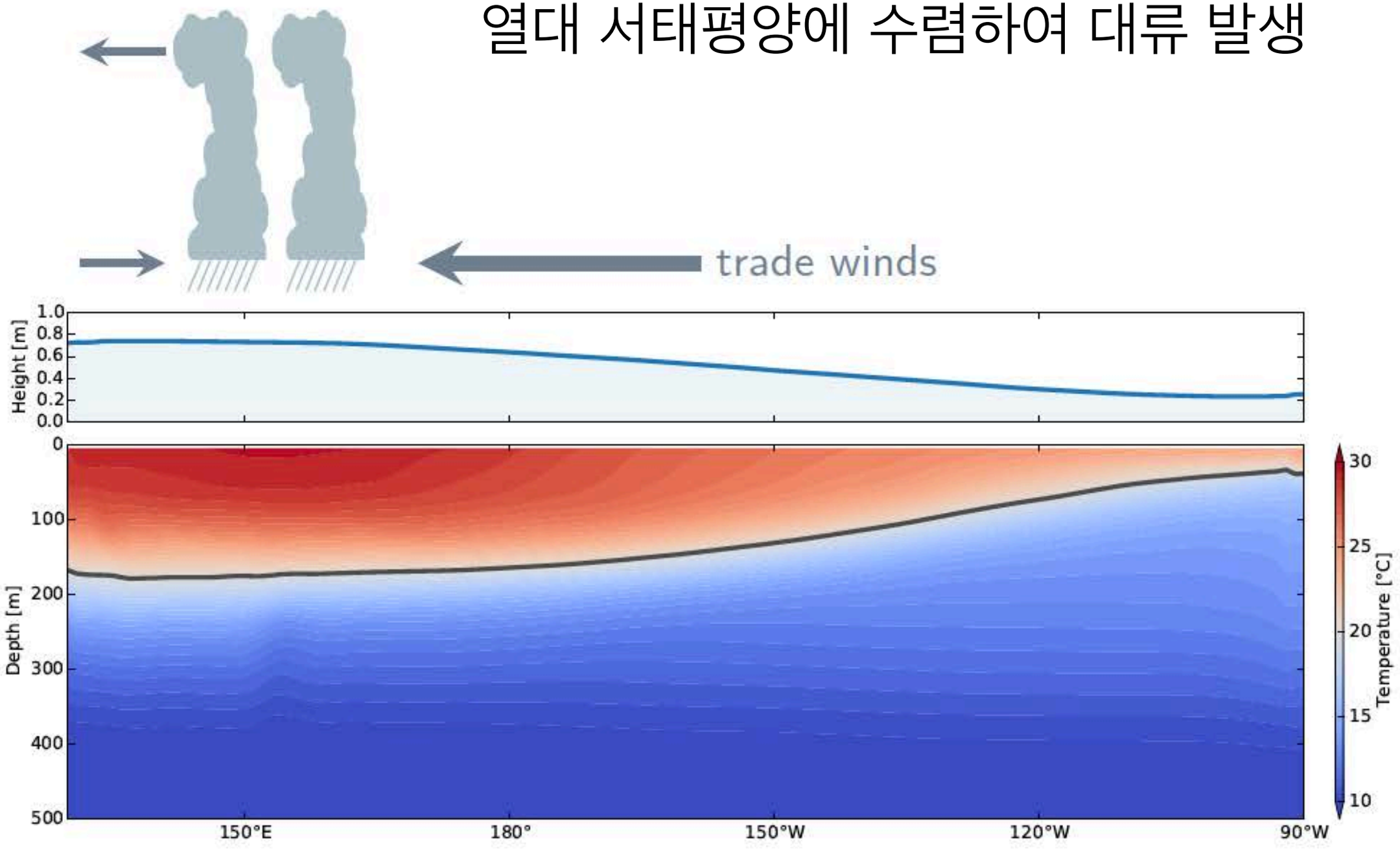
대기-해양 상호작용 : 엘니뇨 / 남방진동, 평년일 때

- 무역풍으로 따뜻한 해수가 북서쪽 (북반구) 혹은 남서쪽 (남반구)로 수송



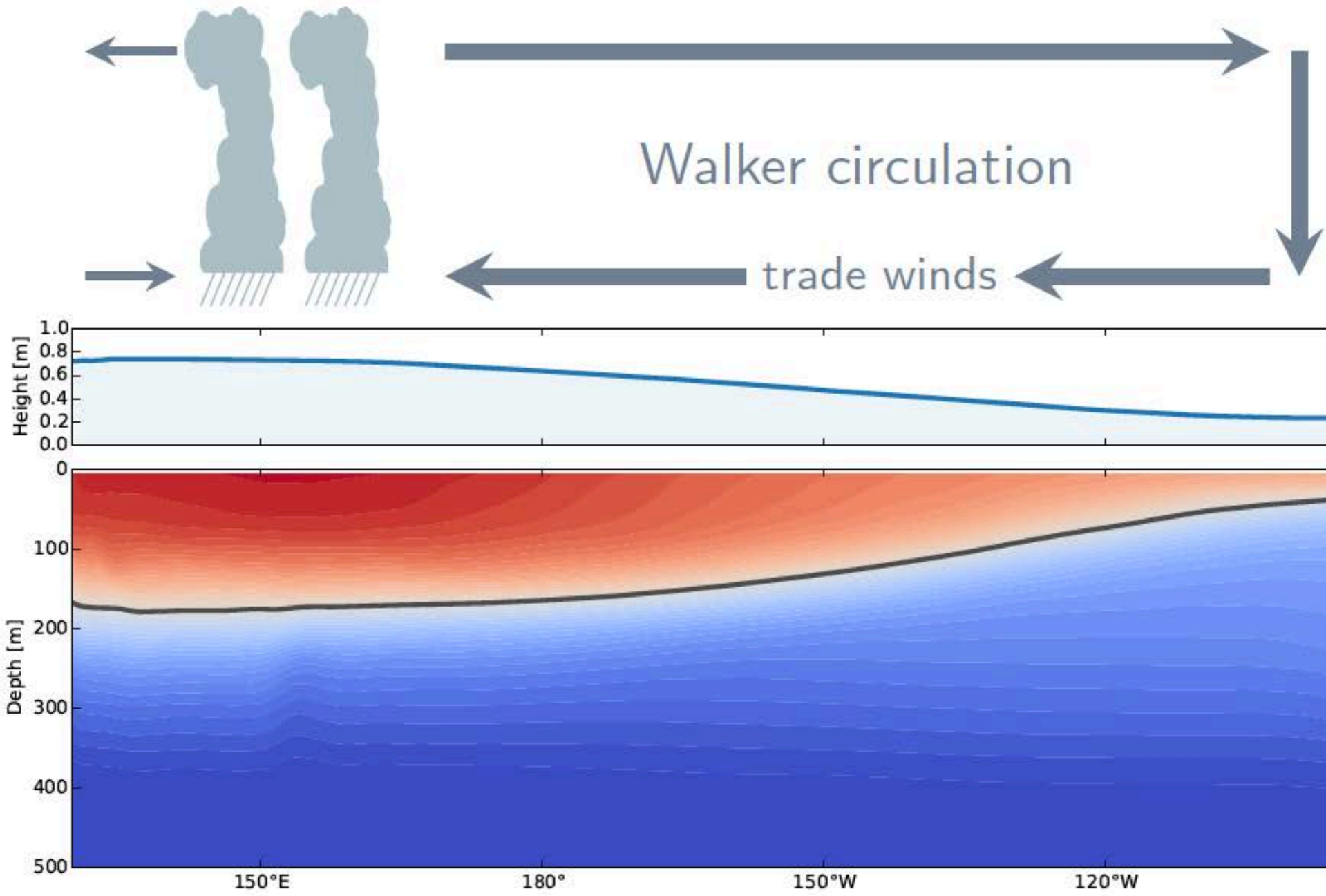
대기-해양 상호작용 : 엘니뇨 / 남방진동, 평년일 때

열대 서태평양에 수렴하여 대류 발생



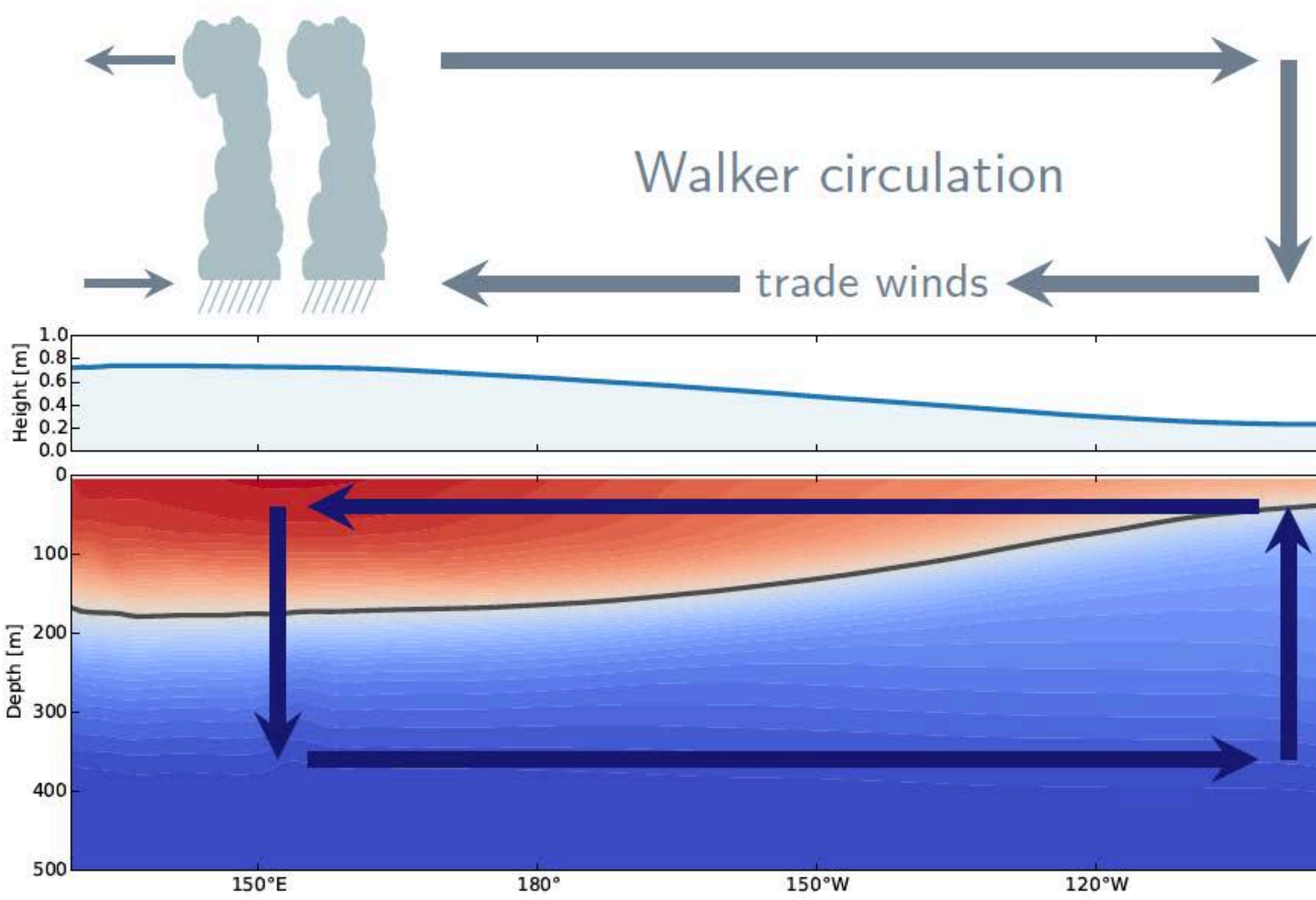
대기-해양 상호작용 : 엘니뇨 / 남방진동, 평년일 때

동서방향의 대기대순환 형성

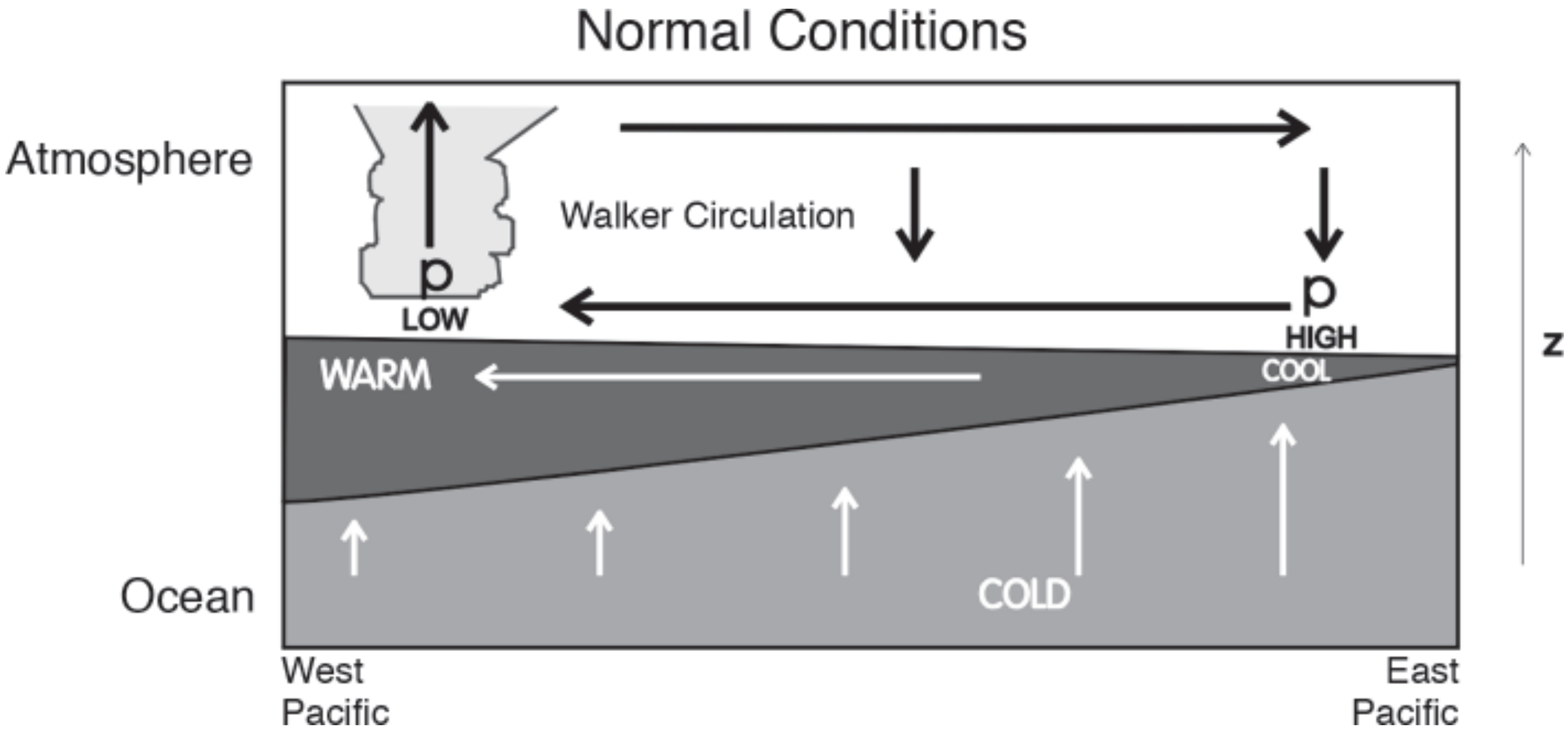


대기-해양 상호작용 : 엘니뇨 / 남방진동, 평년일 때

해류의 순환

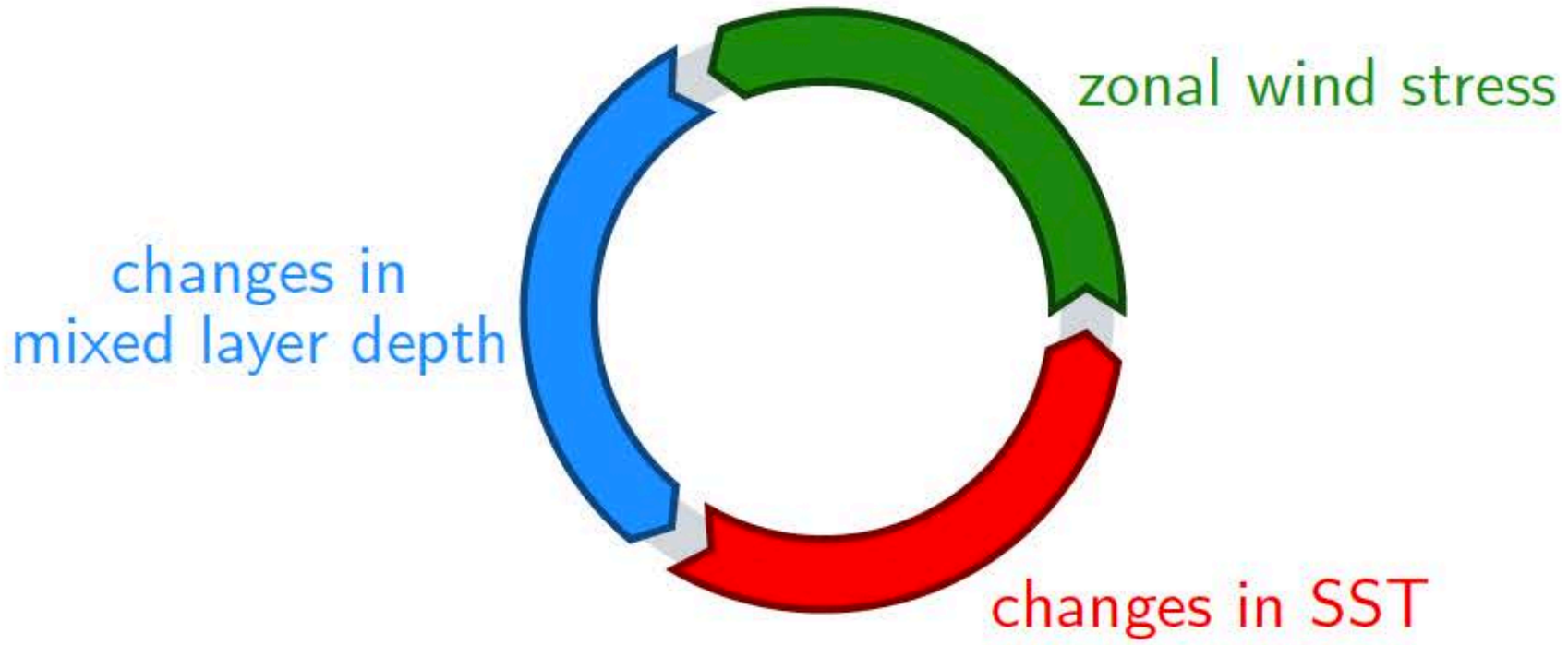


대기-해양 상호작용 : 엘니뇨 / 남방진동, 평년일 때



The Bjerknes feedback

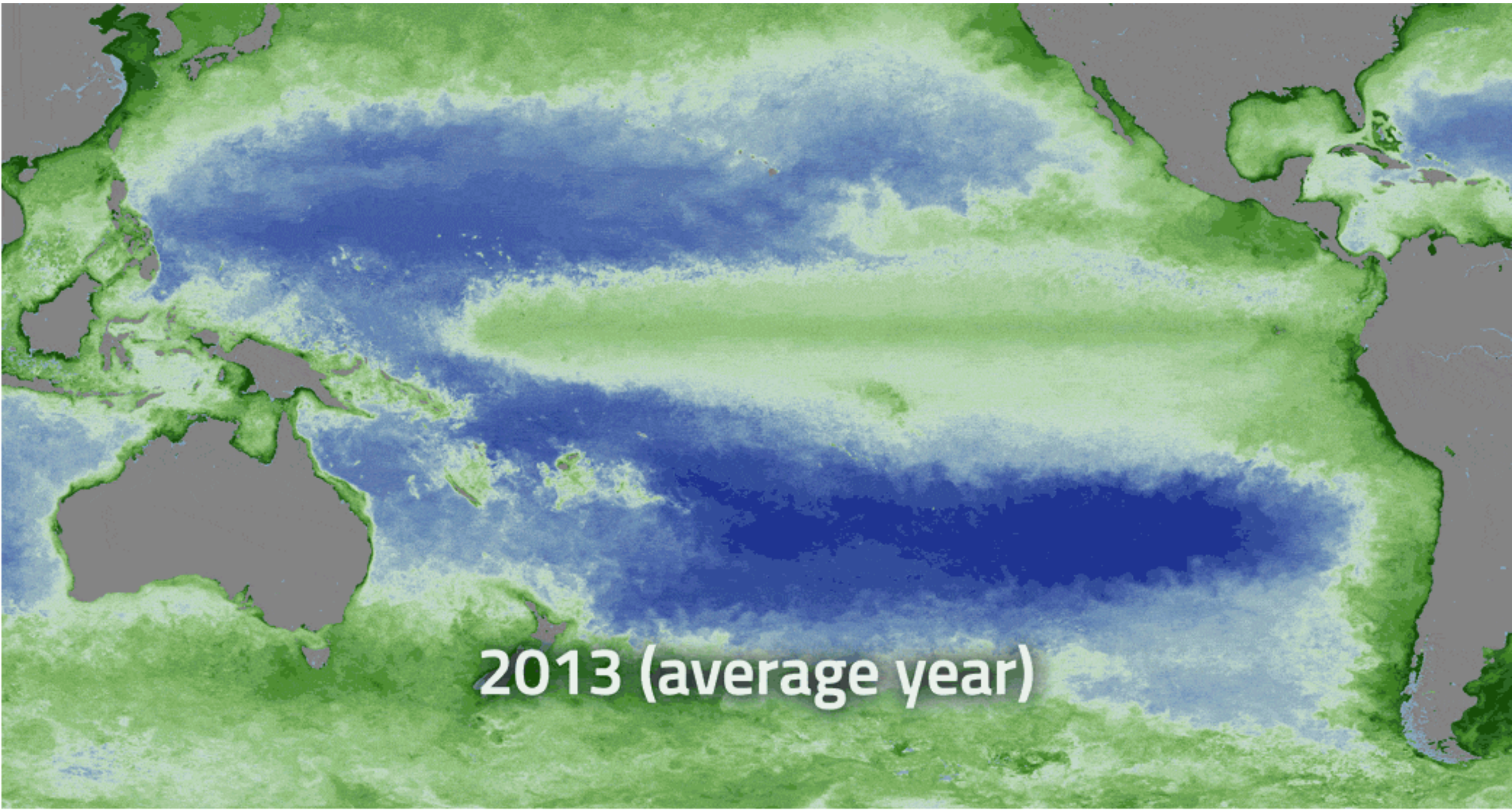
1. Winds flow from low SST to high SST ...
2. which causes upwelling under low SST and downwelling under high SST ...
3. which enhances cooling in the region of low SST and warming in the region of high SST ...
4. which strengthens the winds that flow from low SST to high SST



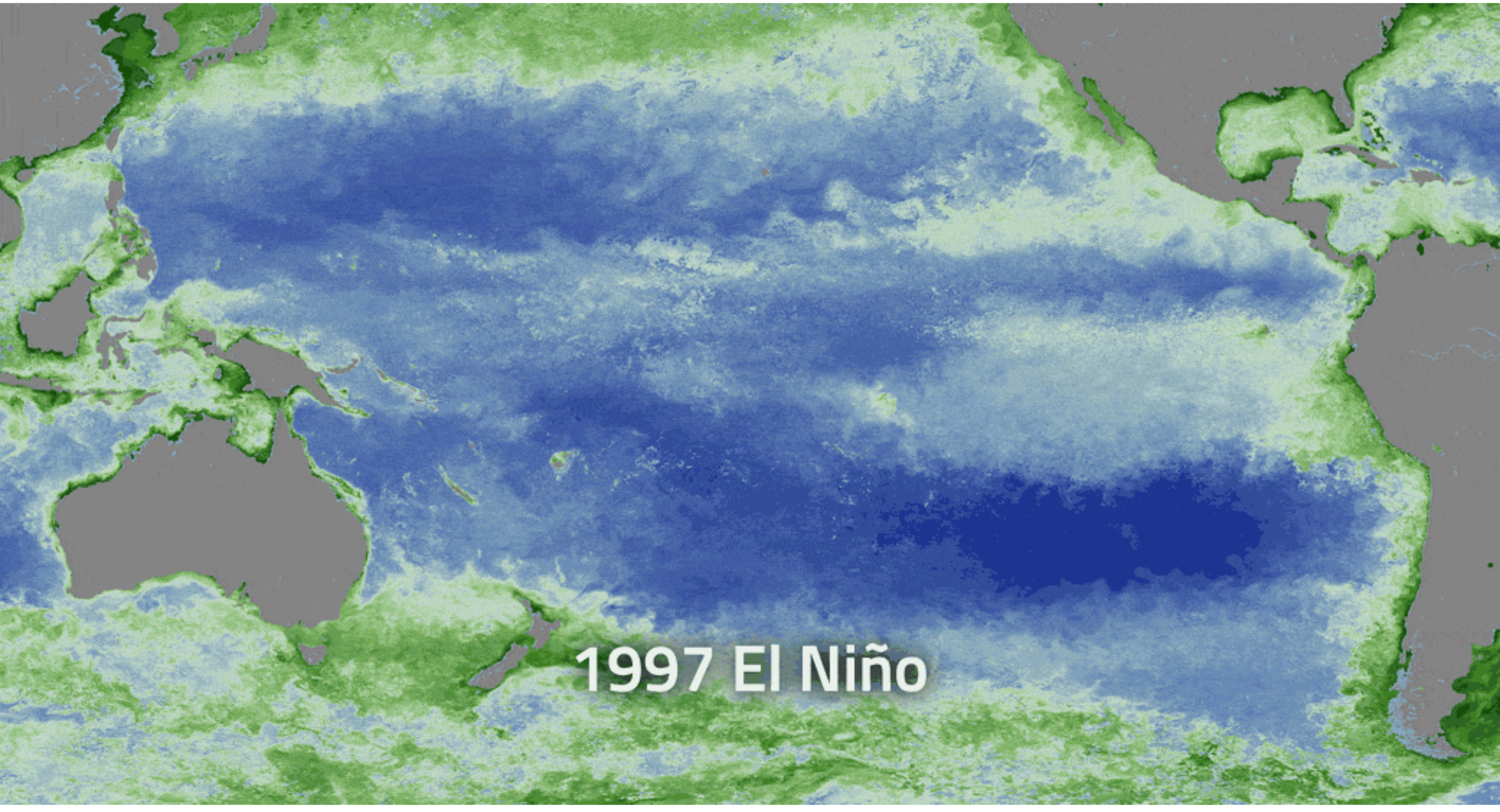
엘리뇨

- 따뜻한 해수가 열대 동태평양에 출현하여 몇 달동안 지속
- 열대 동태평양의 어획량 감소

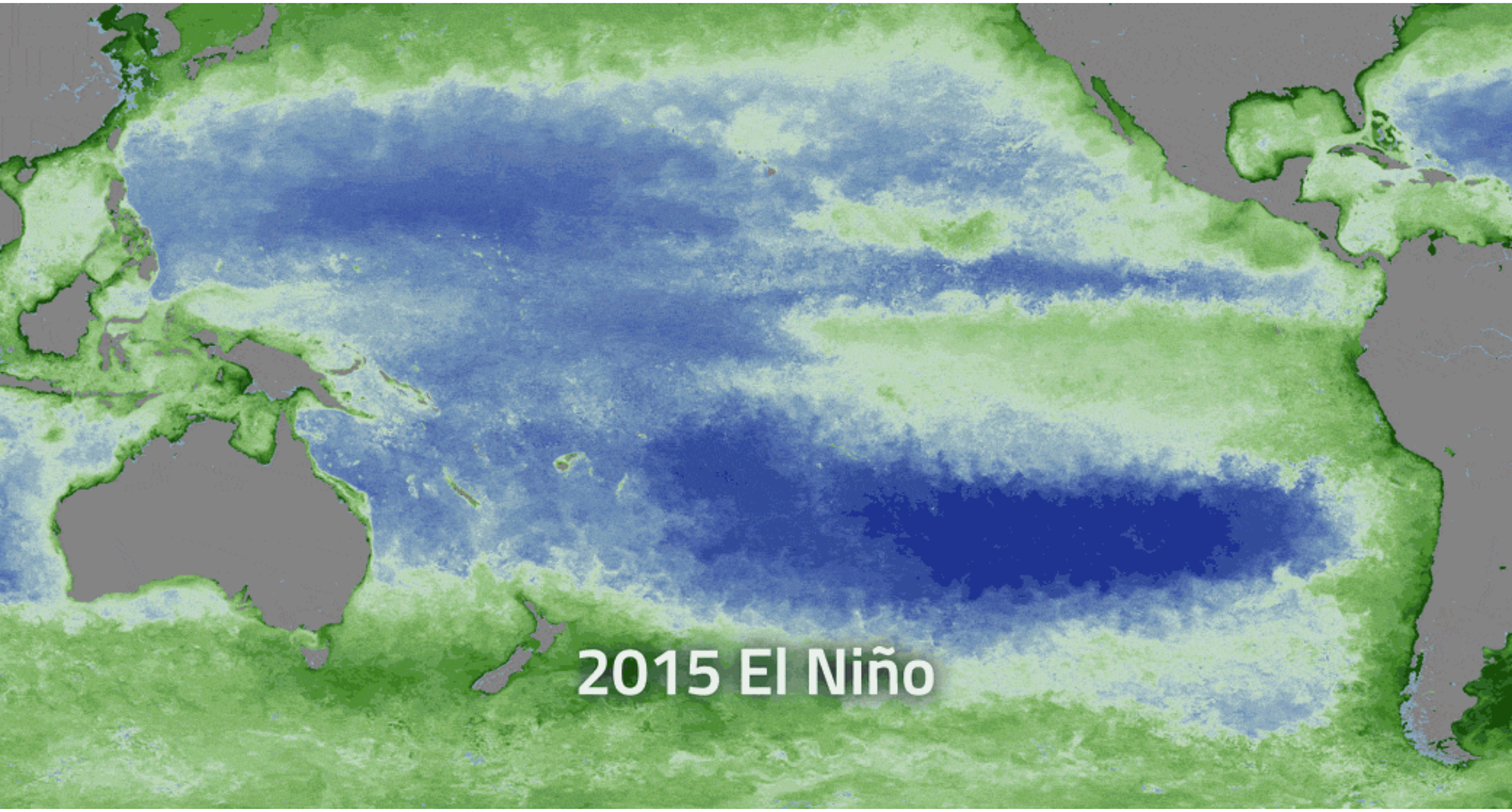
Satellite chlorophyll

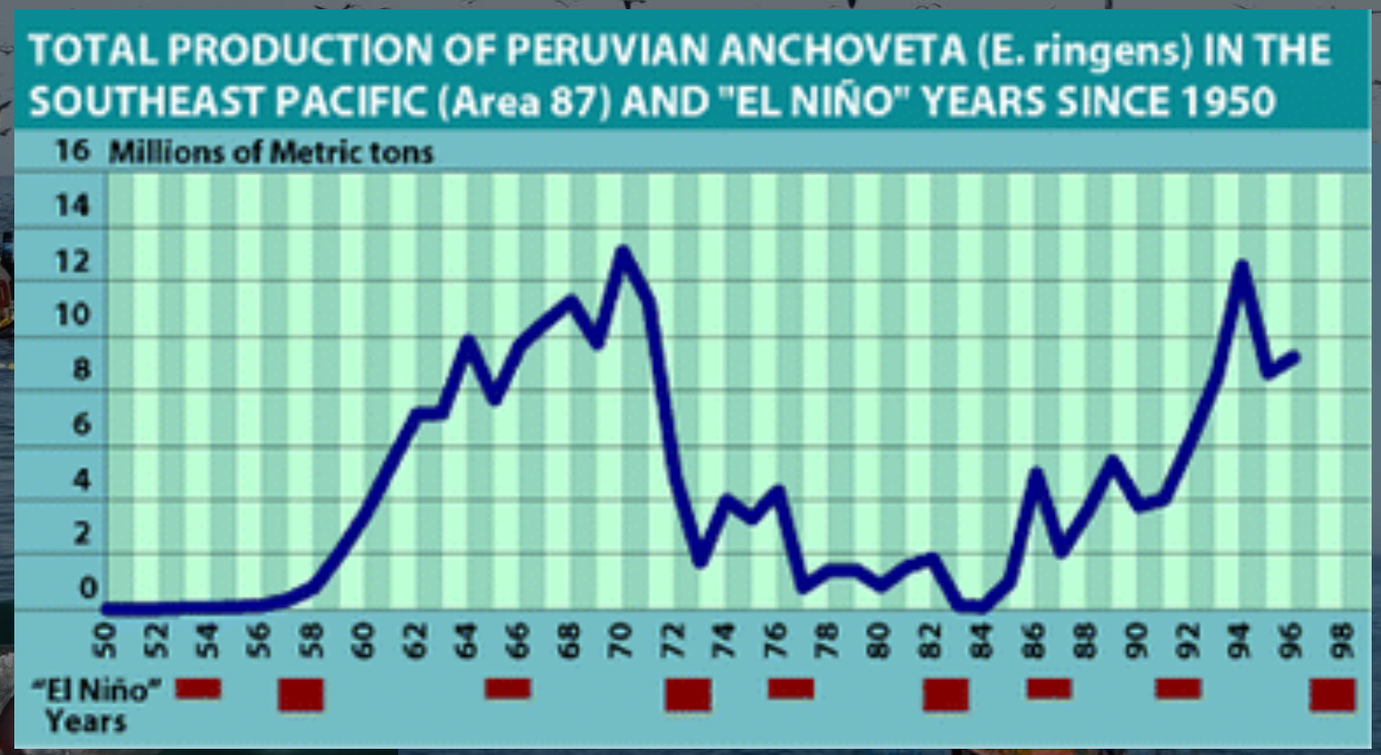


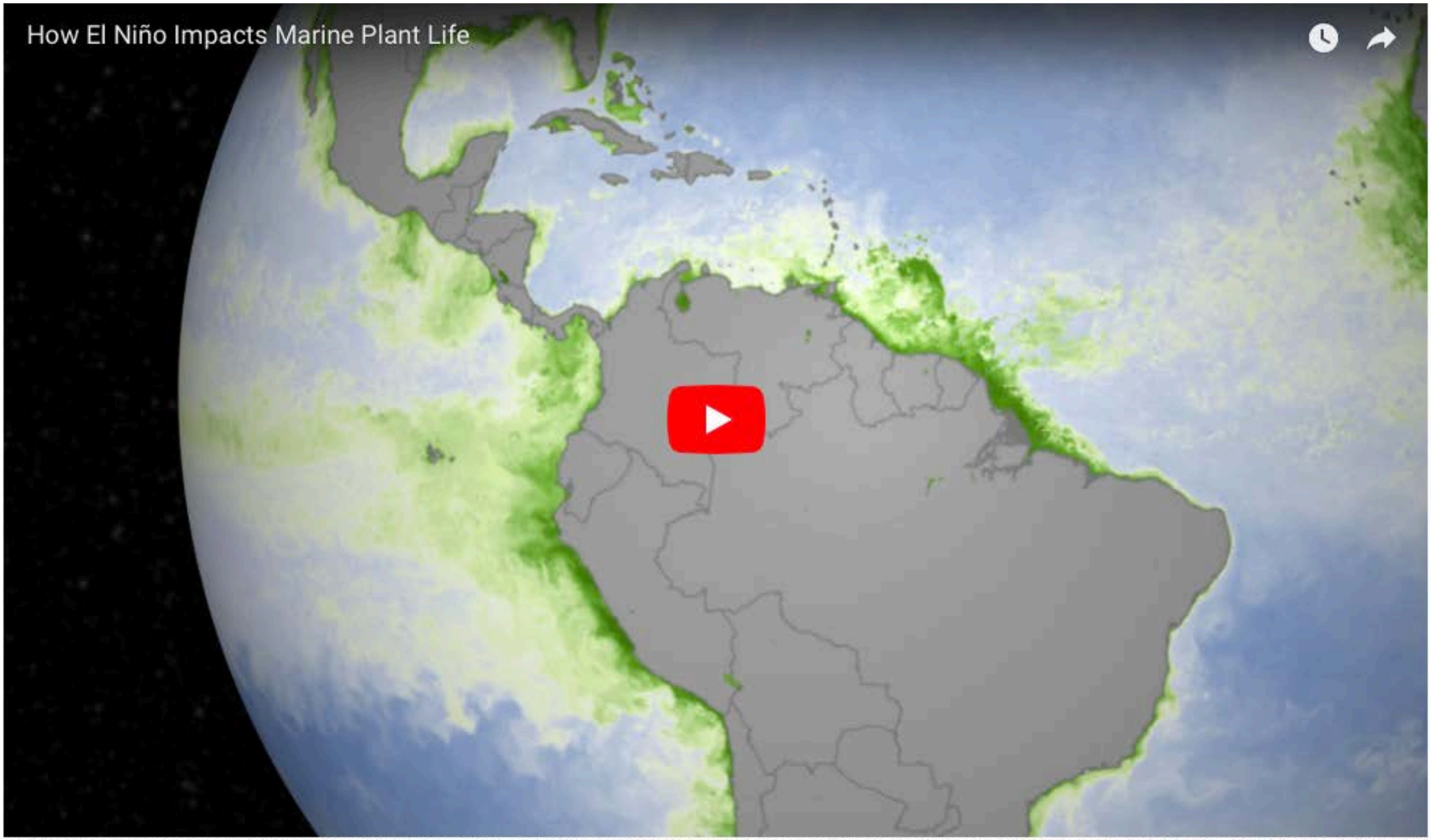
Satellite chlorophyll



Satellite chlorophyll




TOTAL PRODUCTION OF PERUVIAN ANCHOVETA (E. ringens) IN THE SOUTHEAST PACIFIC (Area 87) AND "EL NIÑO" YEARS SINCE 1950
Millions of Metric tons
16
14
12
10
8
6
4
2
0
50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98
"El Niño" Years



El Niño years can have a big impact on the littlest plants in the ocean, and NASA scientists are studying the relationship between the two. Ocean color maps, based on a month's worth of satellite data, show El Niño's impact on phytoplankton.

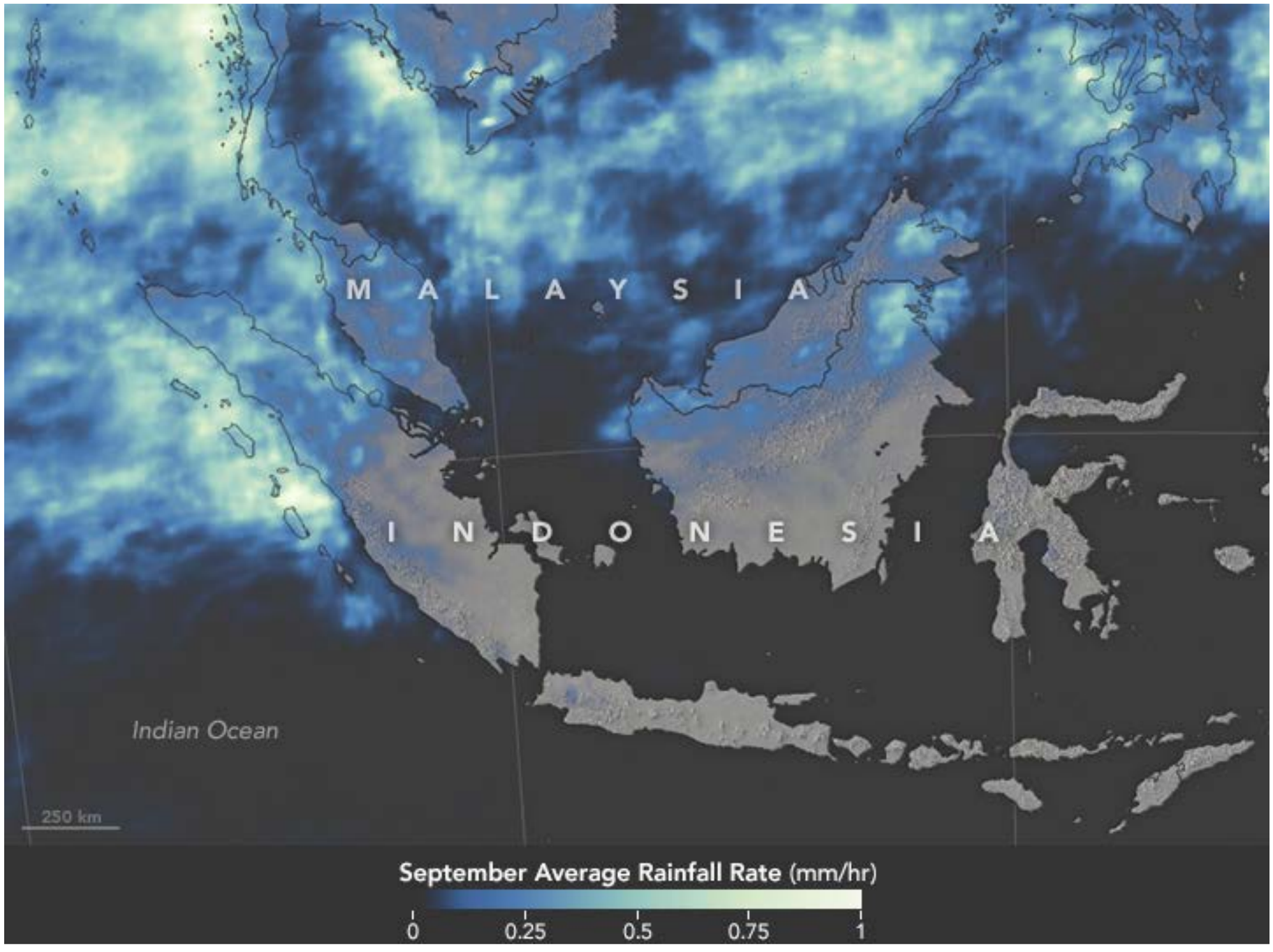
This video is public domain and can be downloaded at the Scientific Visualization Studio

https://youtu.be/sh2KhliHD9A

엘리뇨

- 인도네시아와 오스트리아 지역 가뭄

2015 September



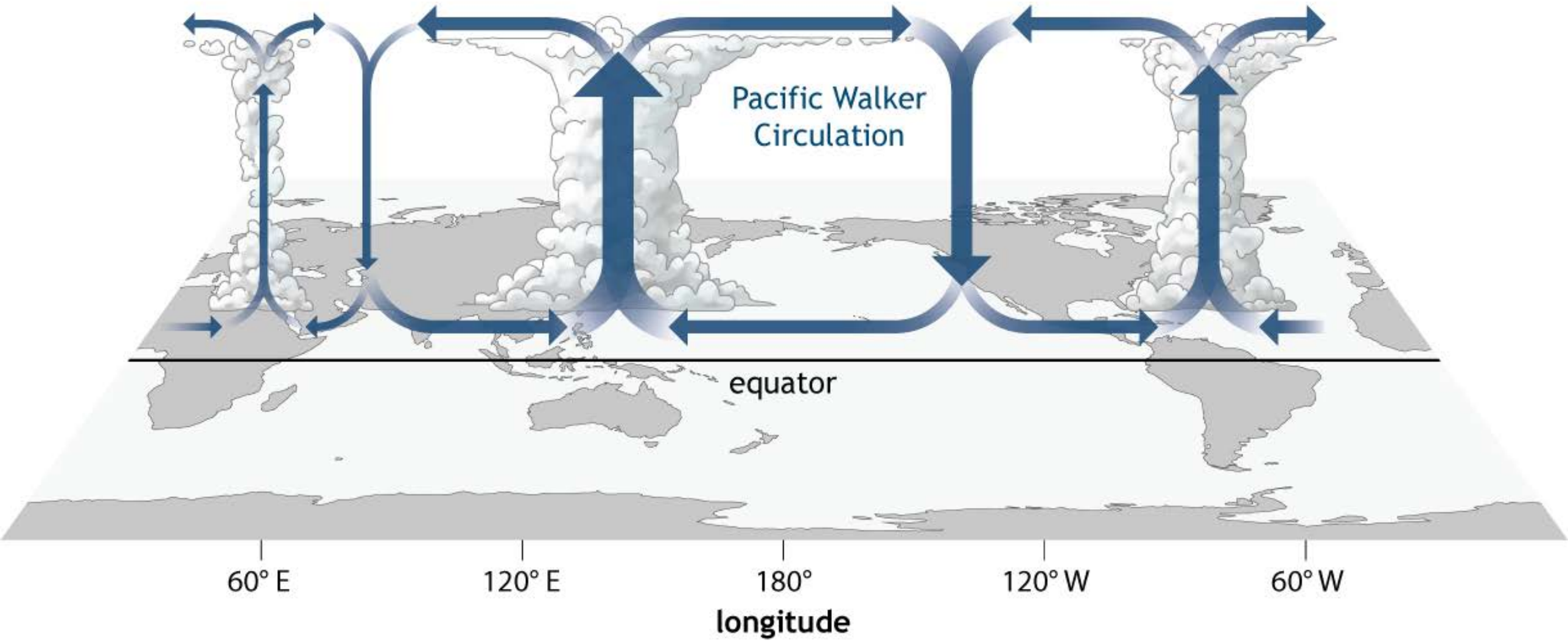
Credits: NASA

2015 September

Credits: NASA

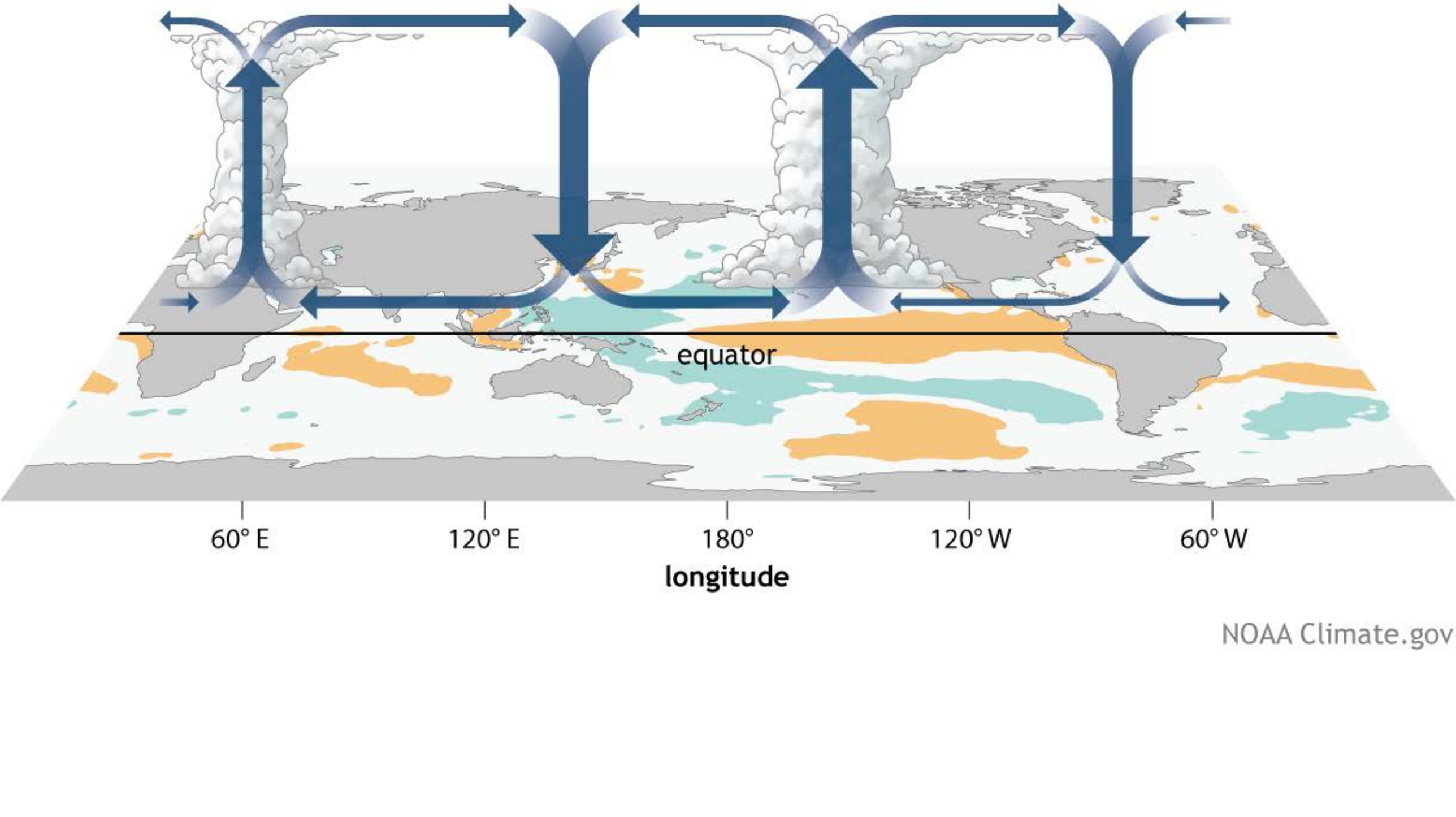
Credits: NASA

Neutral conditions



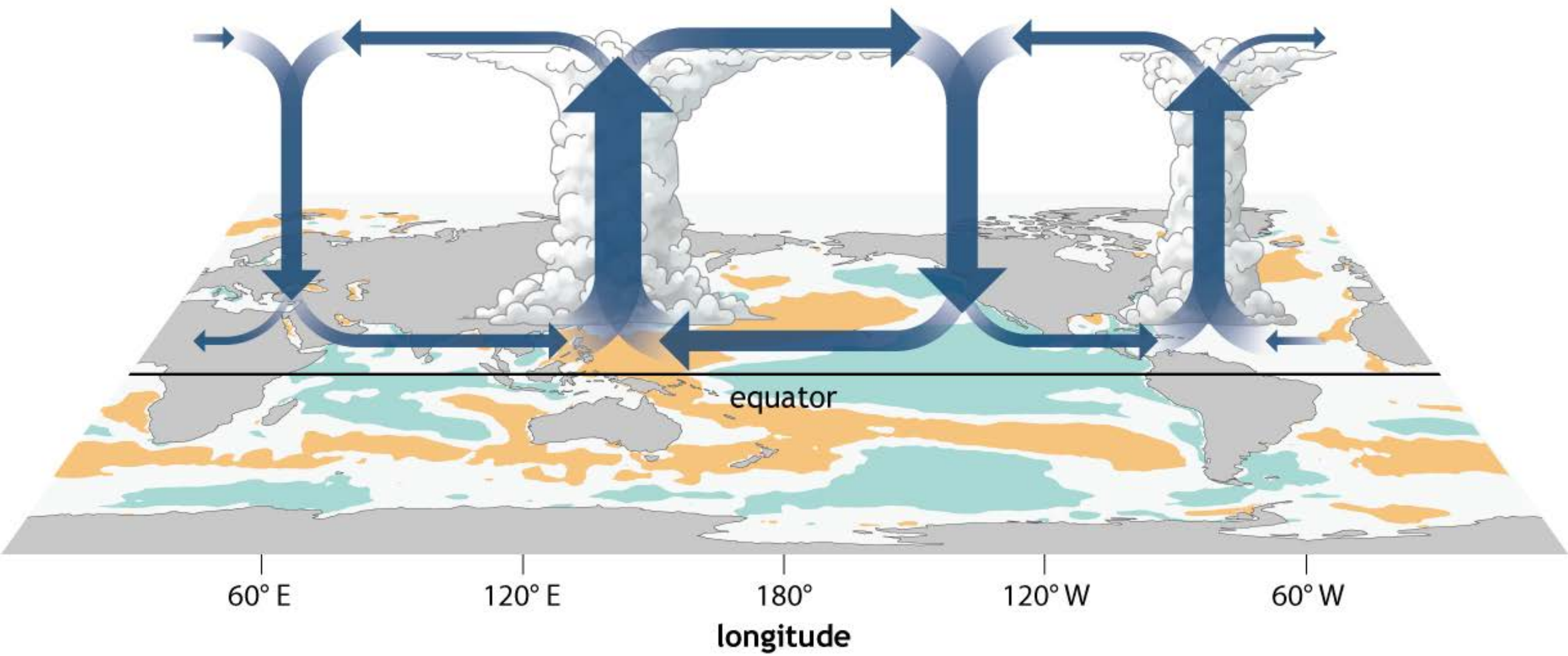
NOAA Climate.gov

El Niño conditions



NOAA Climate.gov

La Niña conditions



NOAA Climate.gov

엘리뇨는 태평양에서 발생하는 현상이지만, 전 지구 기후에 영향을 줌

Warmer SST in the central and eastern tropical Pacific Ocean

↓

Warmer air, more moisture

↓

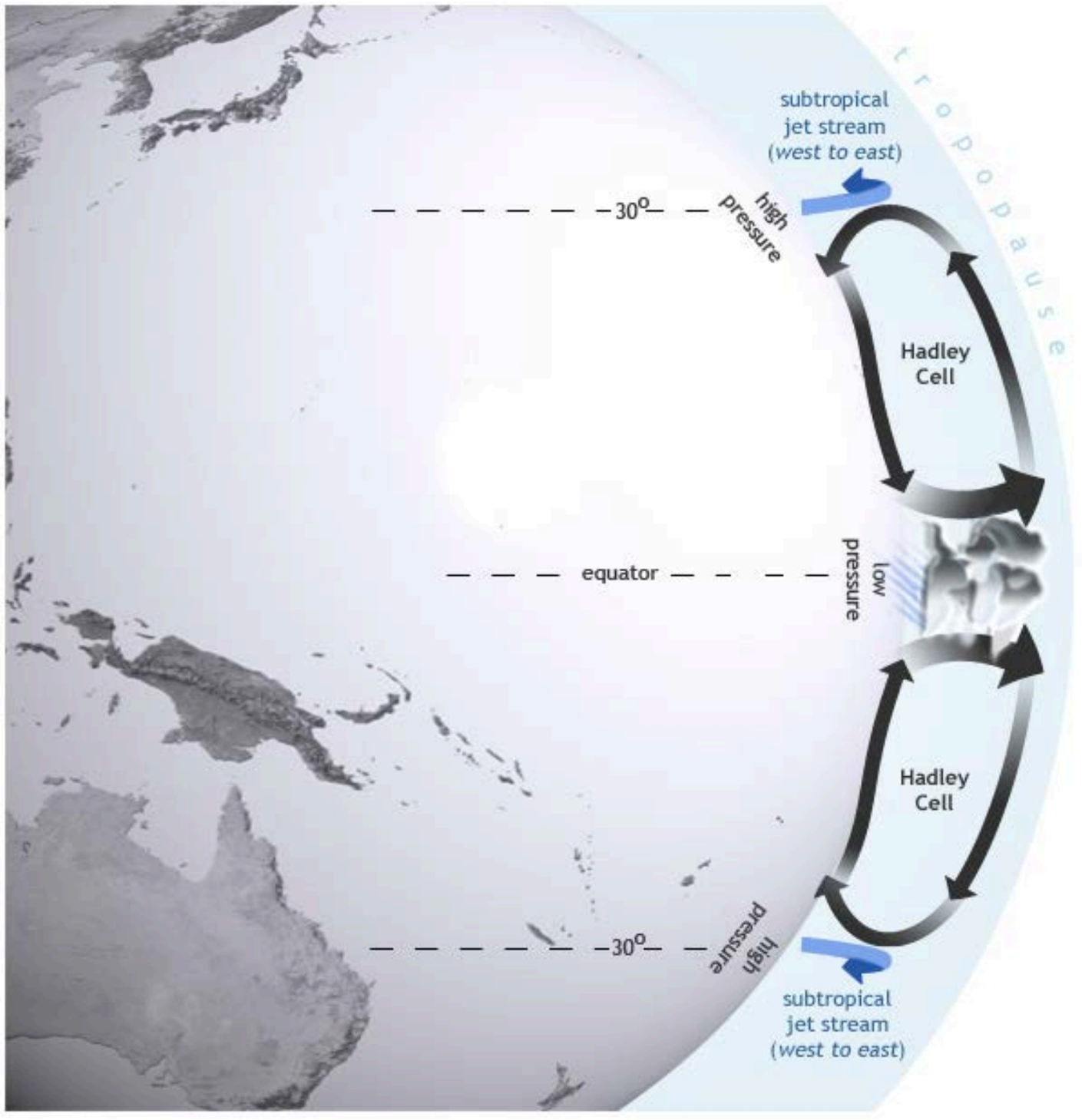
Convection and precipitation, Latent heat release

↓

Stronger Hadley circulation

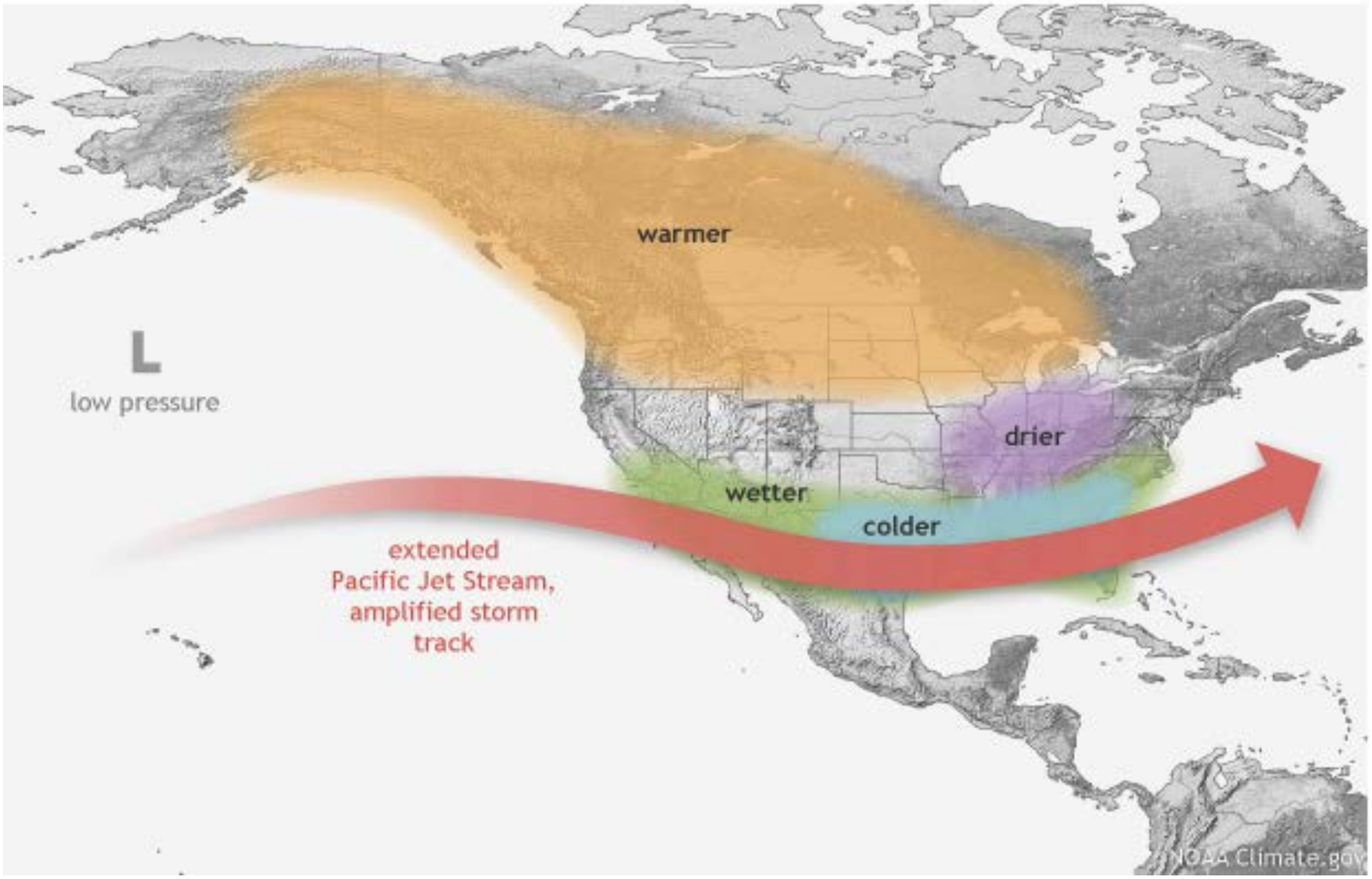
↓

Stronger Hadley circulation, affecting jet stream

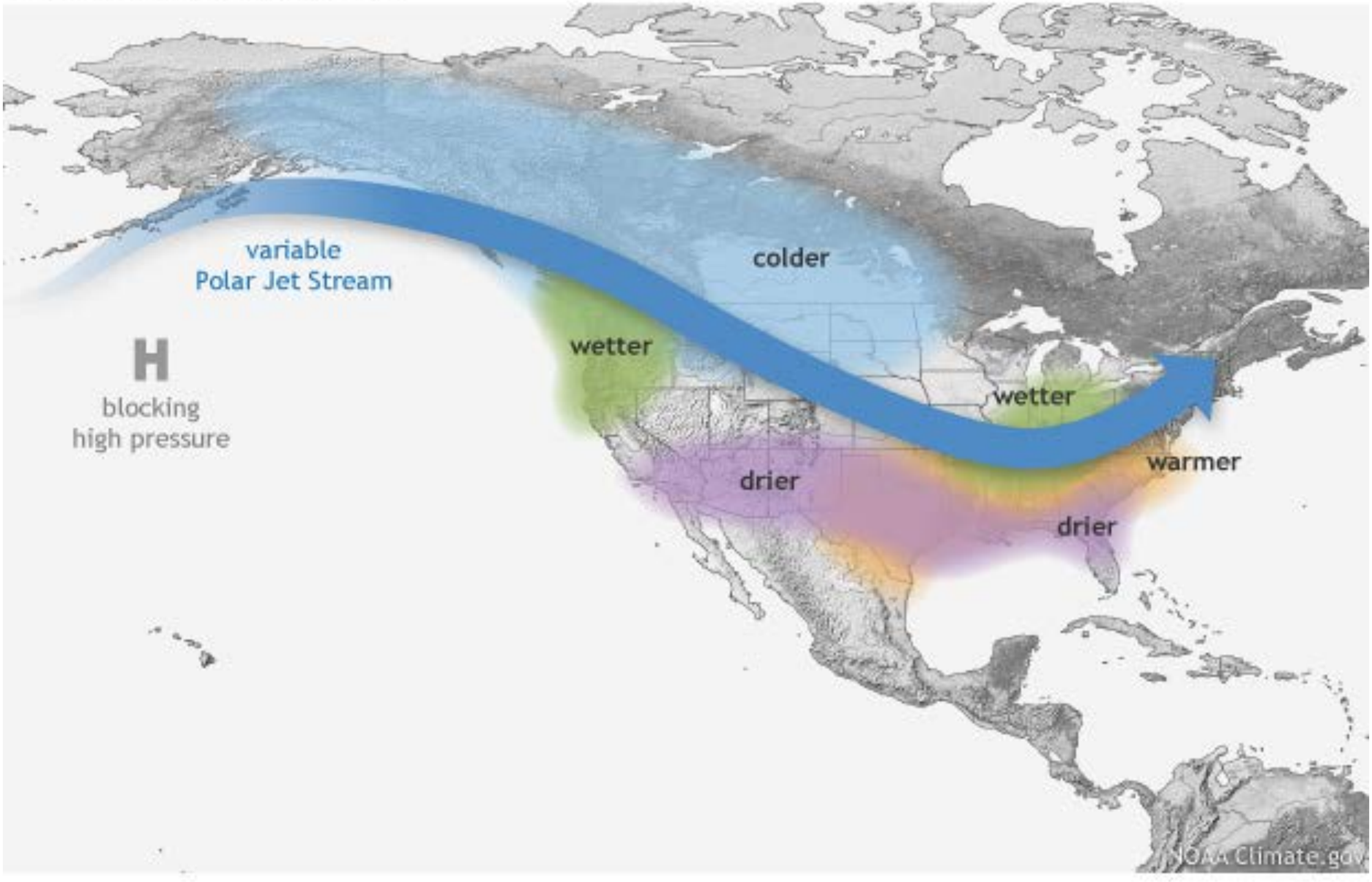


El Niño influences global atmospheric circulation by intensifying the Hadley circulation, in which heat is transferred from the Earth's surface to the upper atmosphere through convection and latent heating. Map by NOAA Climate.gov.

WINTER EL NIÑO PATTERN

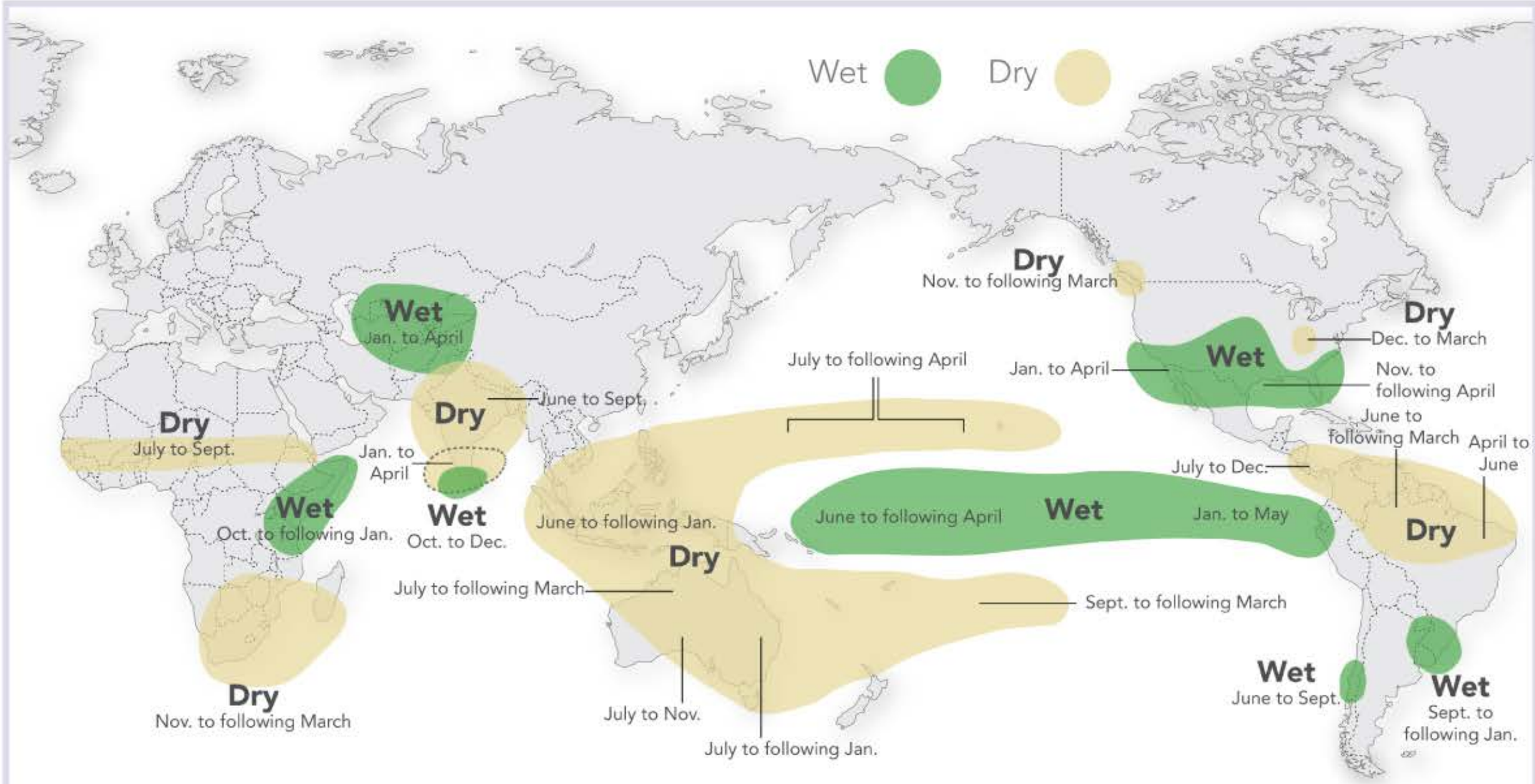


WINTER LA NIÑA PATTERN



El Niño and Rainfall

El Niño conditions in the tropical Pacific are known to shift rainfall patterns in many different parts of the world. Although they vary somewhat from one El Niño to the next, the strongest shifts remain fairly consistent in the regions and seasons shown on the map below.



For more information on El Niño and La Niña, go to: http://iri.columbia.edu/enso/

Sources:
1. Ropelewski, C. F., and M. S. Halpert, 1987: Global and regional scale precipitation patterns associated with the El Nino Southern Oscillation. Mon. Wea. Rev., 115, 1606-1626;
2. Mason and Goddard, 2001. Probabilistic precipitation anomalies associated with ENSO. Bull. Am. Meteorol. Soc. 82, 619-638

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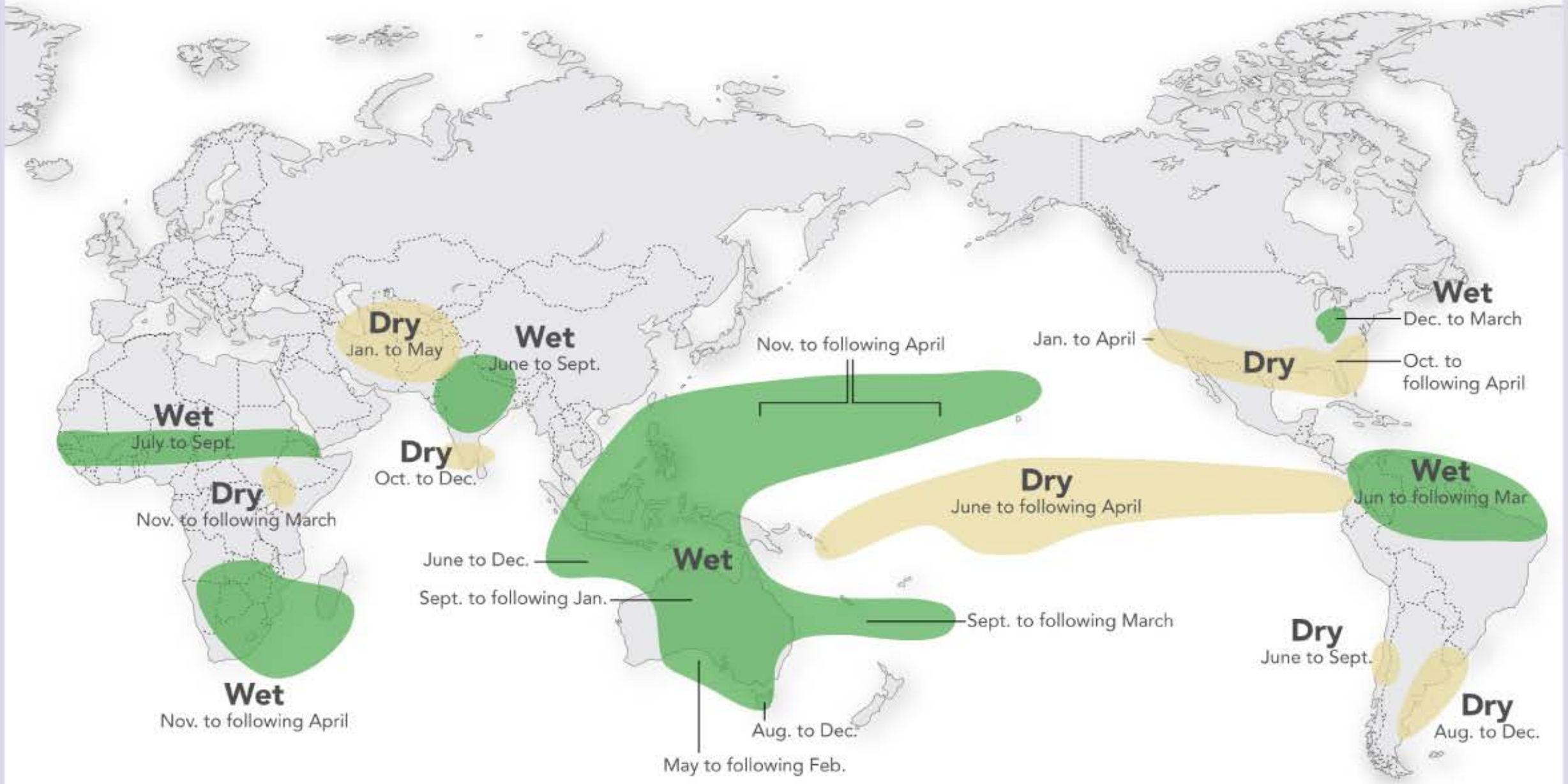
La Niña and Rainfall

La Niña conditions in the tropical Pacific are known to shift rainfall patterns in many different parts of the world. Although they vary somewhat from one La Niña to the next, the strongest shifts remain fairly consistent in the regions and seasons shown on the map below.



For more information on El Niño and La Niña, go to: http://iri.columbia.edu/enso

Sources:
1. Ropelewski, C. F. and M. S. Halpert, 1989: Precipitation patterns associated with the high index phase of the Southern Oscillation. J. Climate., 2, 268 284,
2. Mason and Goddard, 2001. Probabilistic precipitation anomalies associated with ENSO. Bull. Am. Meteorol. Soc. 82, 619-638

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