

CHAPTER 7

THE GLOBAL CLIMATE SYSTEM



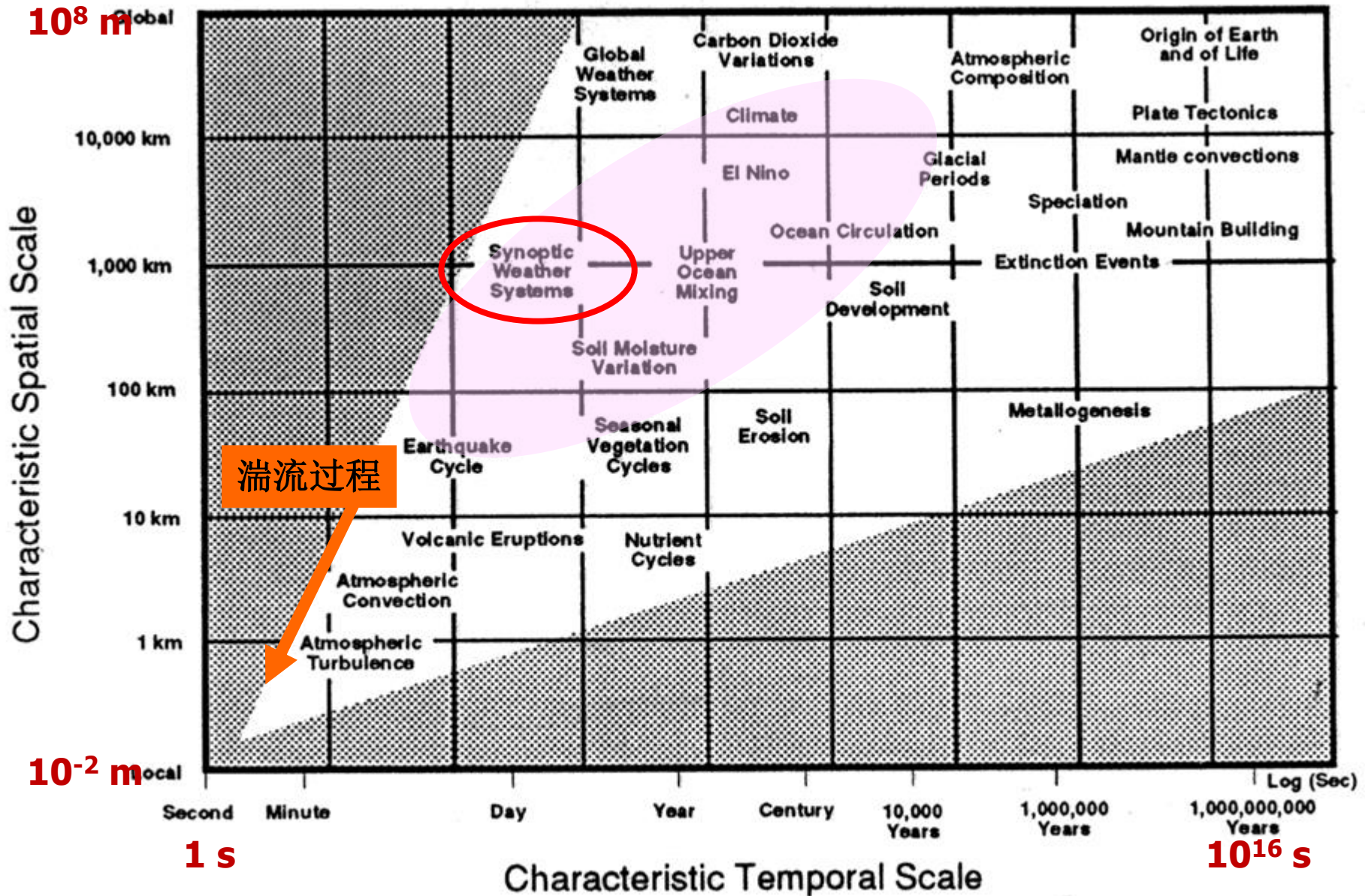
气候

- 气候系统：一个复杂的、各部分相互作用的系统，包括大气、陆地表面、冰雪、海洋和其它水体以及生物
- 传统/狭义上，气候通常被描述为从数月 to 数百万年的一段时间内（通常采用30年的时间段）的气温、降水、风等气象变量的平均值及变率

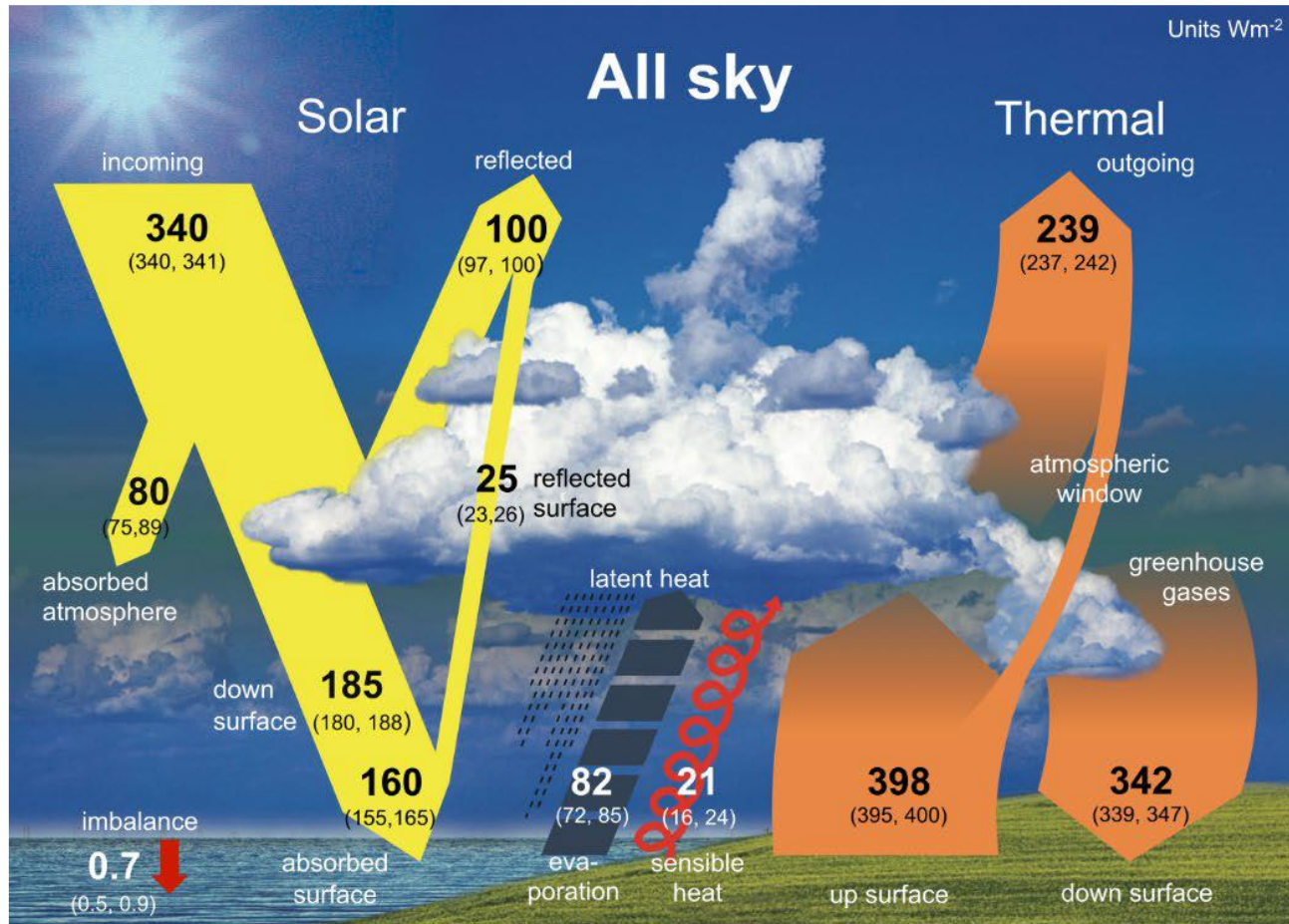


我们最关心的问题：气候系统的变化、原因机制（自然强迫、内部变率、人类活动）、对相关自然和人文环境的影响、以及未来气候变化和应对

Spatiotemporal Scales in the Earth Climate System



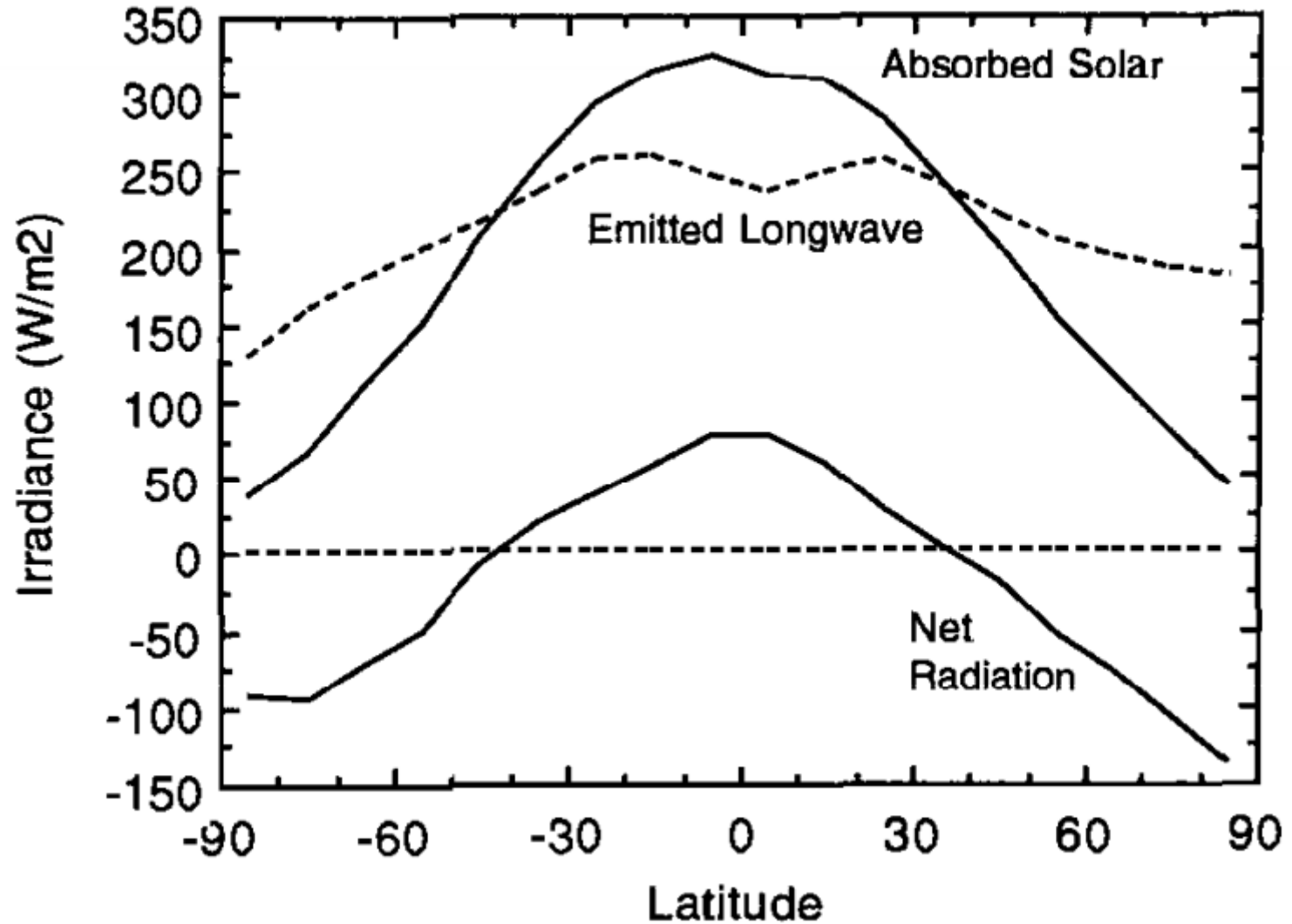
Earth Energy Budget



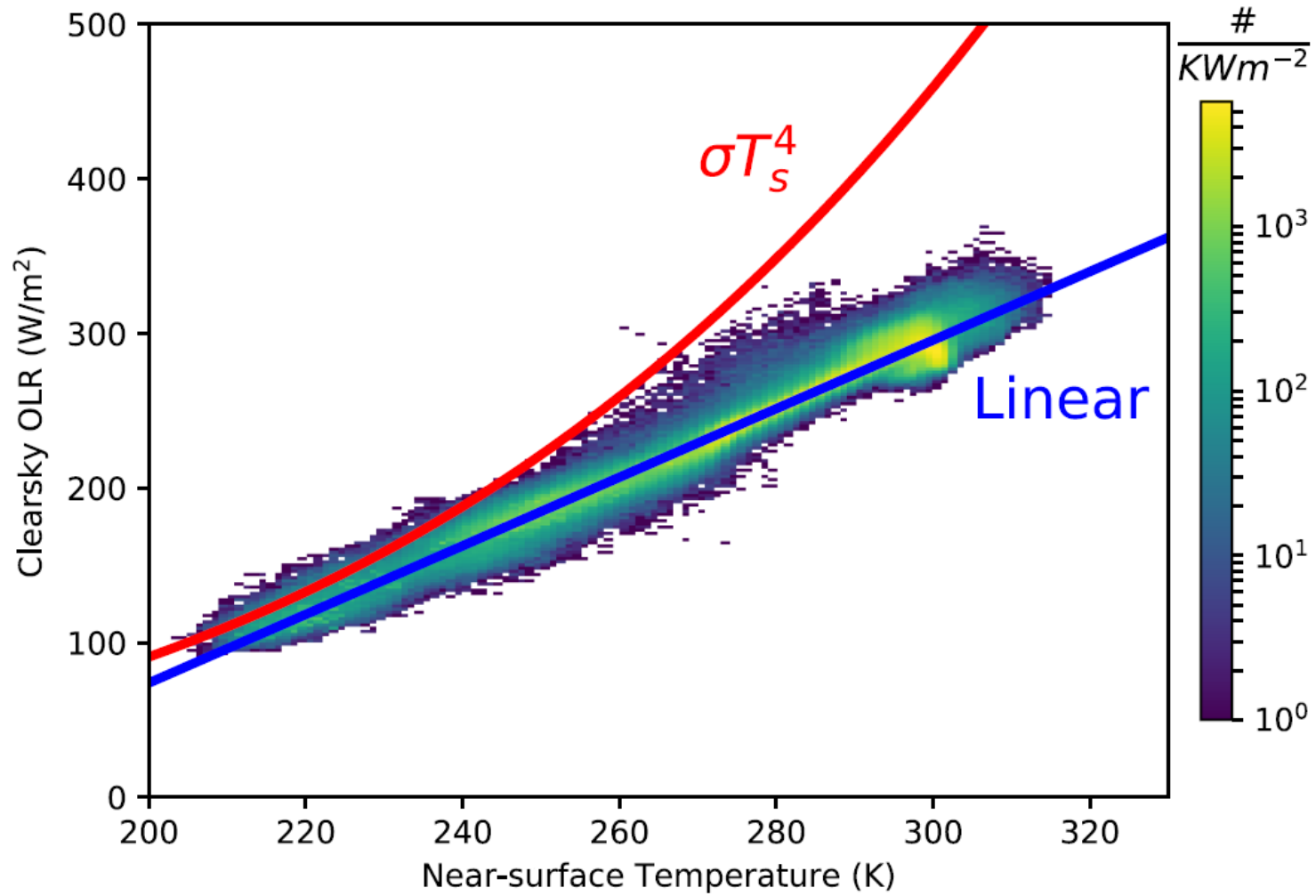
IPCC, 2021

- Energy balance: Atmosphere $80 + (398 - 40) + 21 + 82 - 342 - (239 - 40)$, Surface $160 + 342 - 398 - 21 - 82$, Earth TOA $340 - 100 - 239$
- Planetary albedo: $\sim 29\%$ (surface 7%, atmosphere 22%)

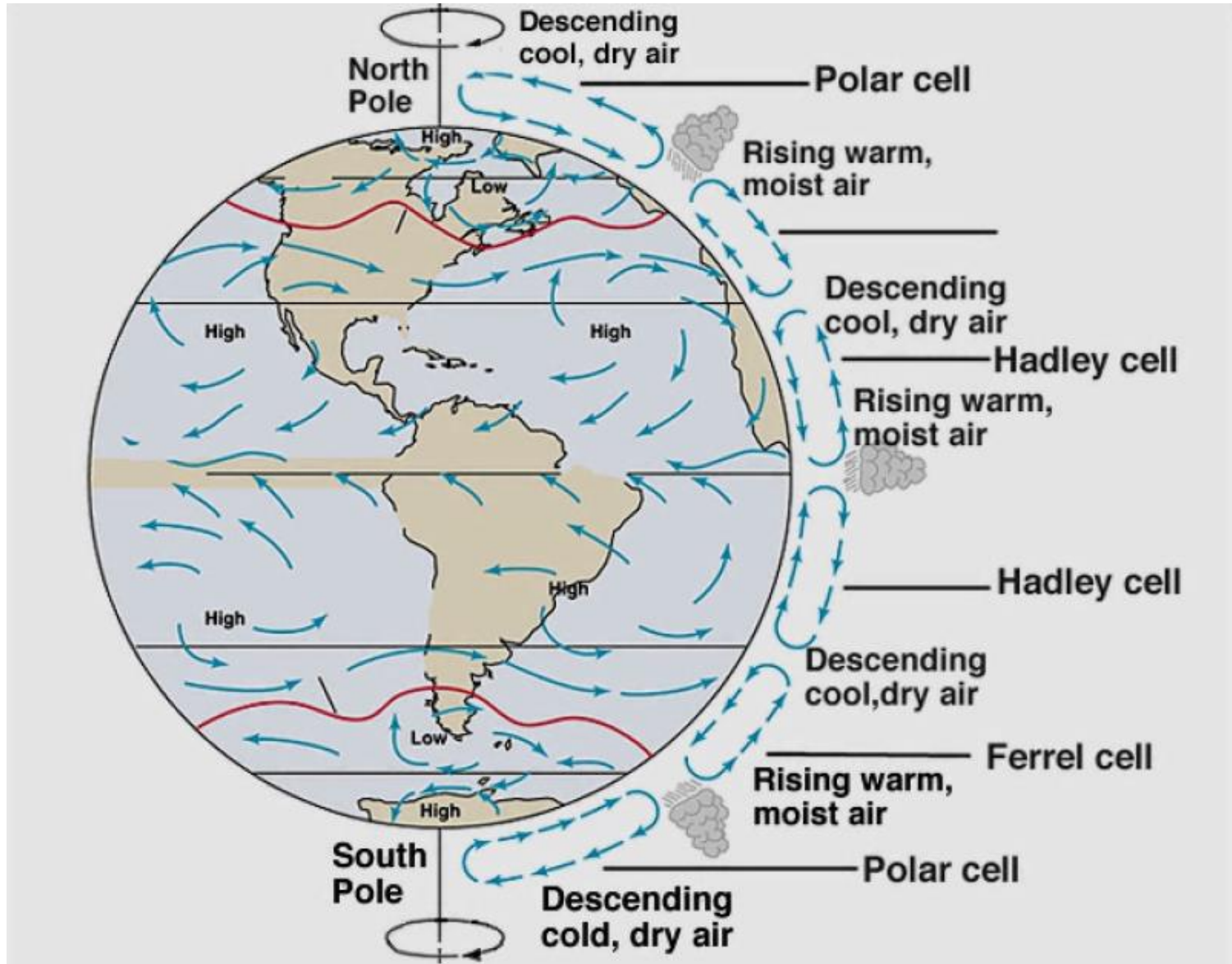
TOA Net Flux (Solar + Longwave): Meridional Distribution



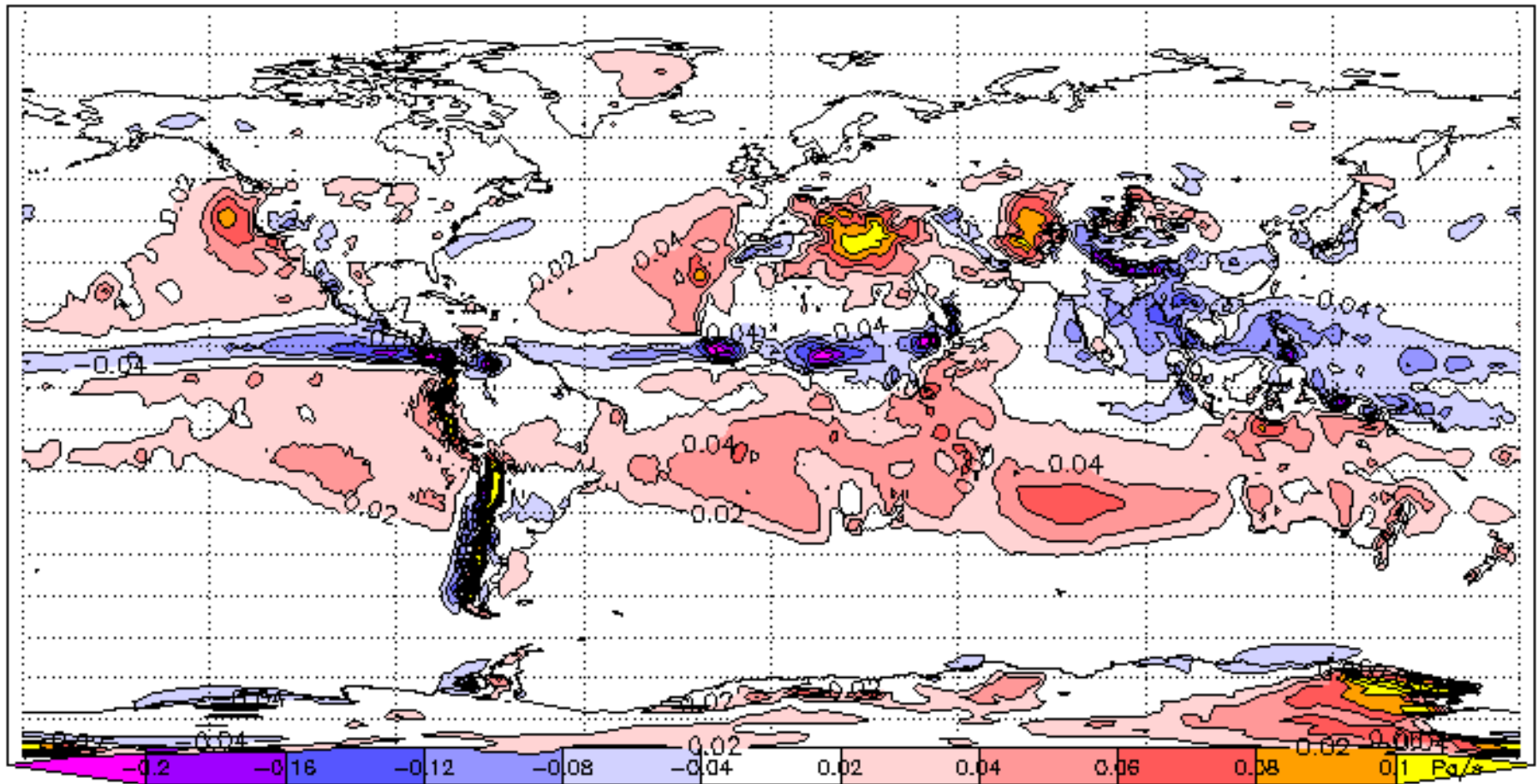
F_{LW} As a Linear Function of Surface Temperature



Meridional Circulation



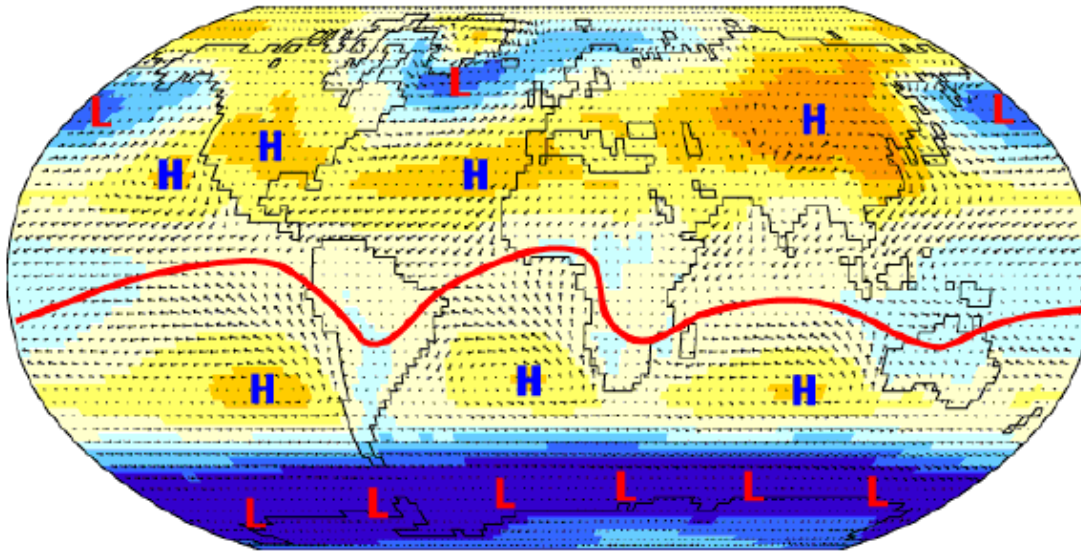
Hadley Circulation: Vertical Velocity $\omega = dp/dt$



ITCZ & Semi-Permanent Highs and Lows

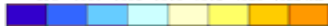
Sea-Level Pressure and Surface Winds

Jan



ITCZ

995 1000 1005 1010 1015 1020 1025 mb

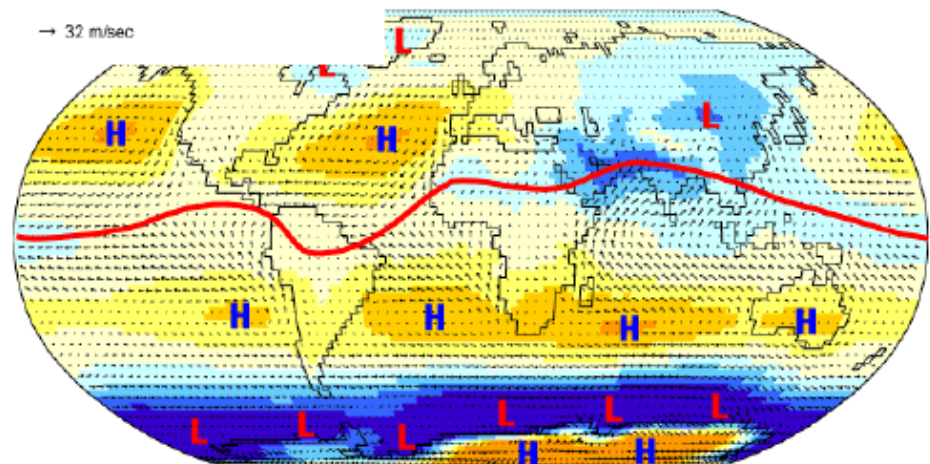


→ 1 → 2 → 4 → 8 → 16 → 32 m/sec

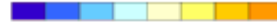
Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies

nds

Jul



995 1000 1005 1010 1015 1020 1025 mb

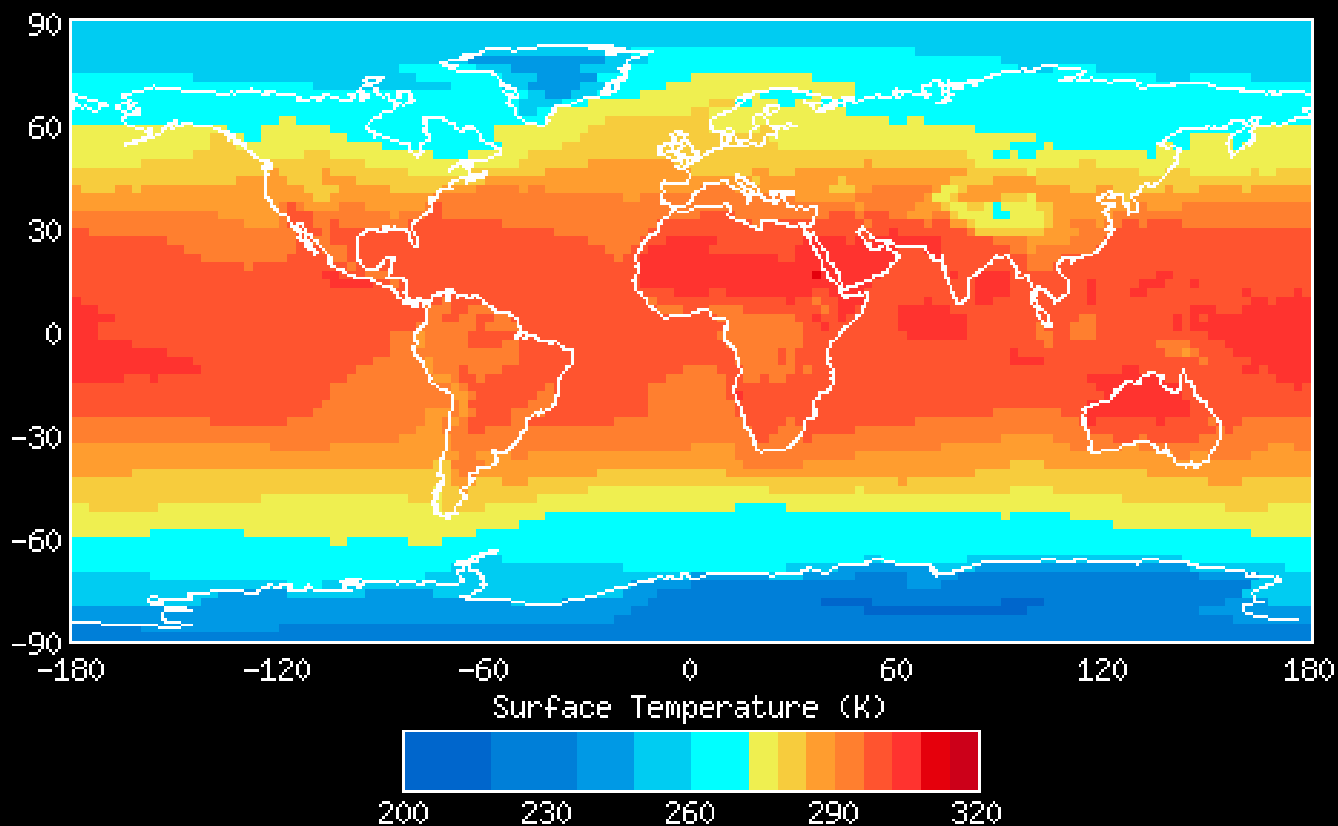


→ 1 → 2 → 4 → 8 → 16 → 32 m/sec

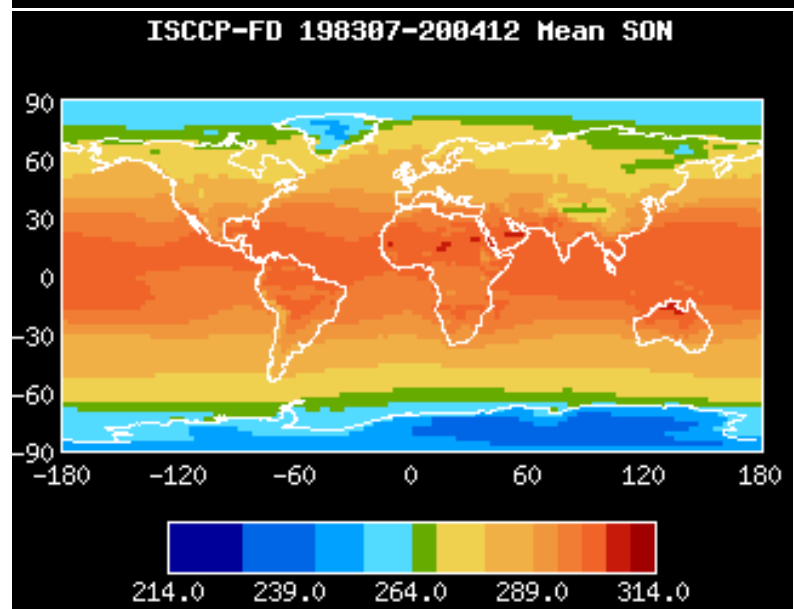
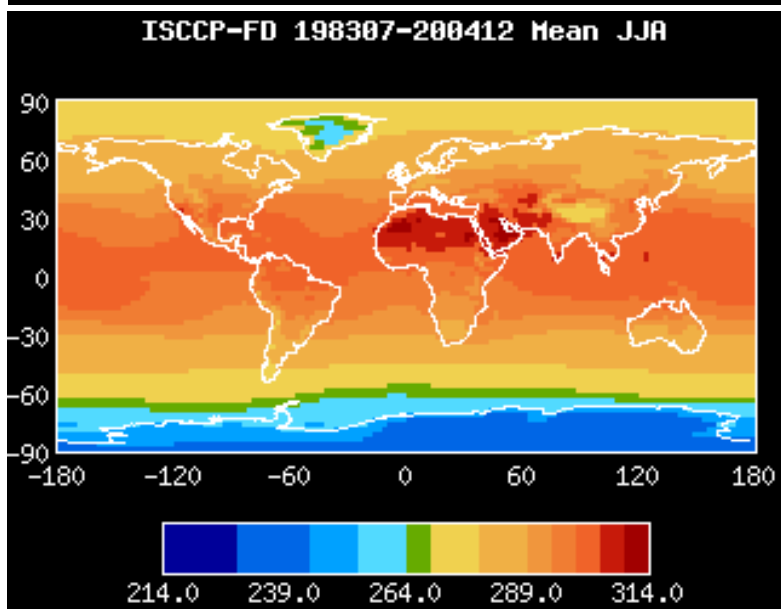
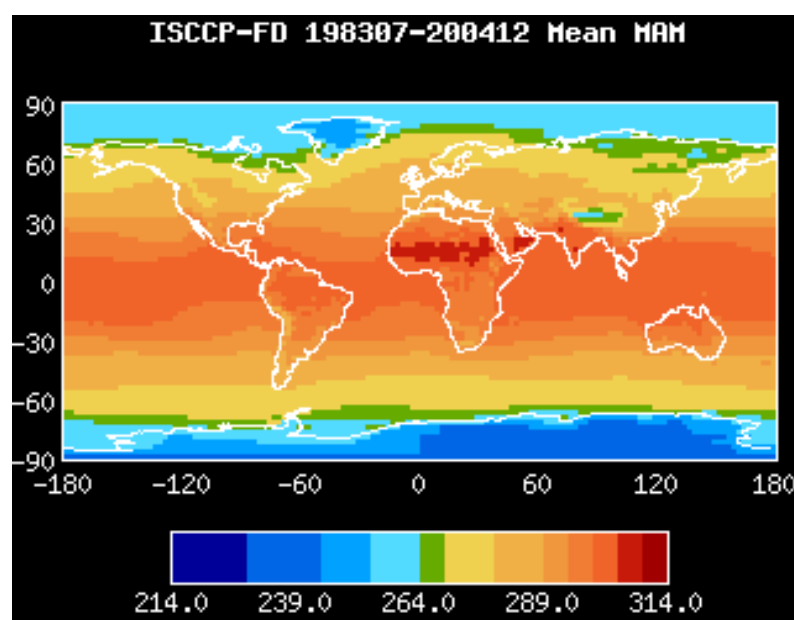
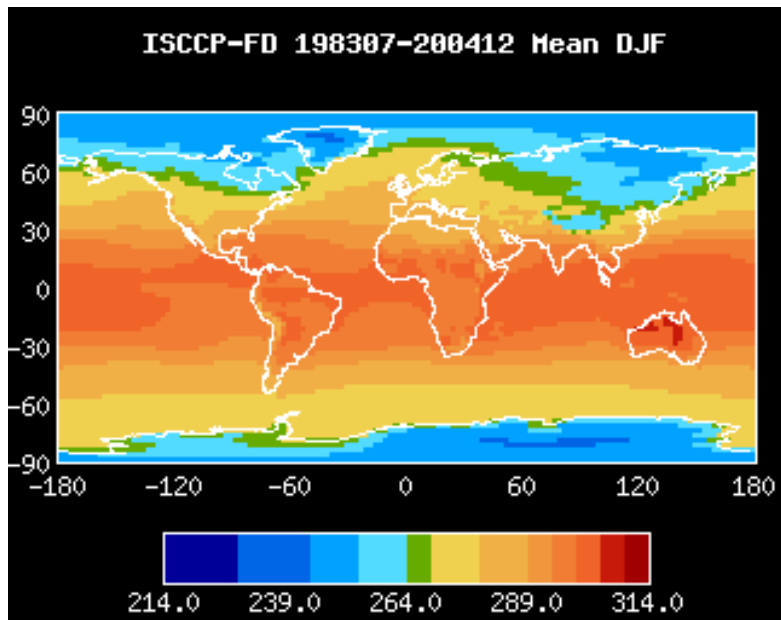
Data: NCEP/NCAR Reanalysis Project, 1959-1997 Climatologies

Global Surface Temperature: 1983-2009

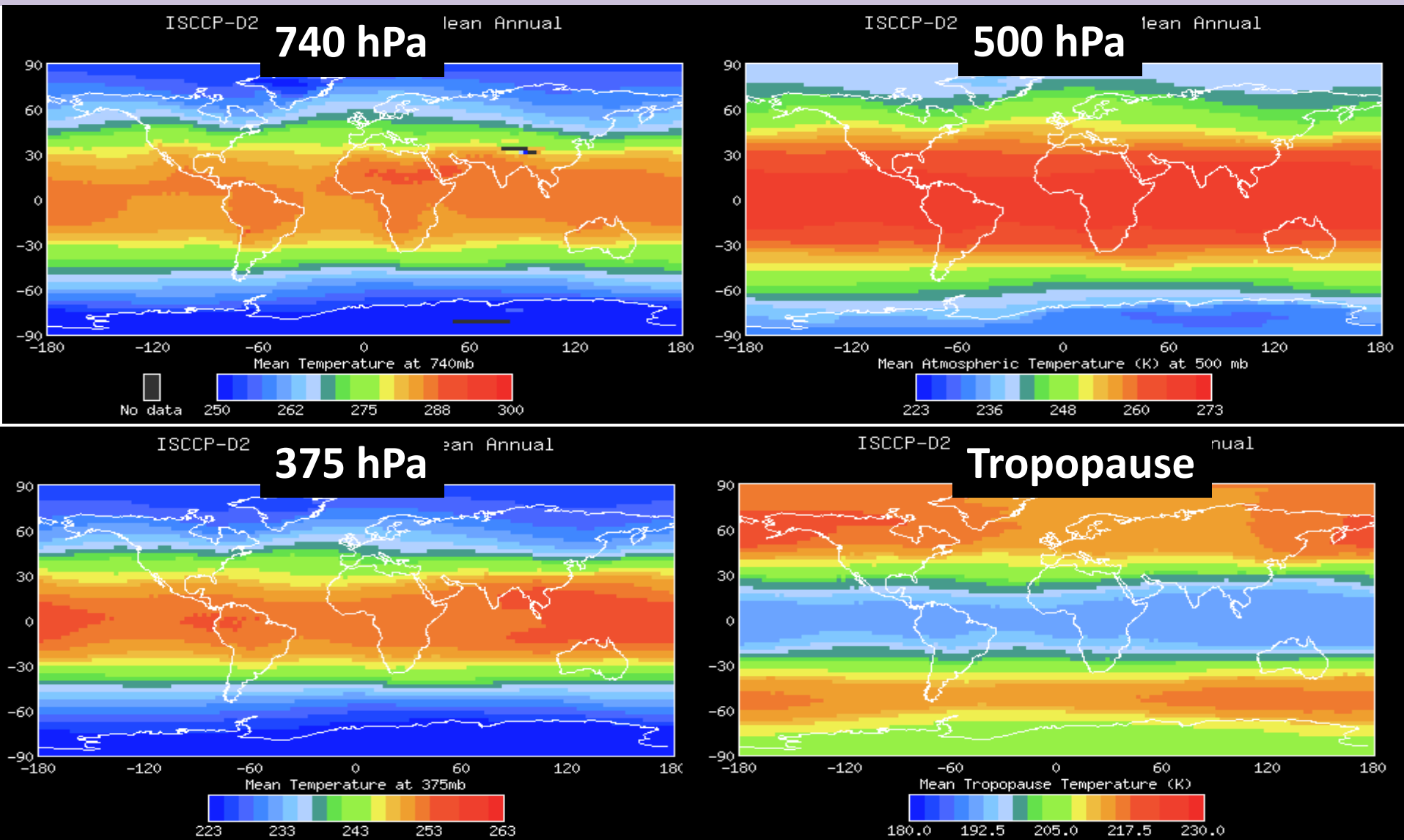
ISCCP-D2 198307-200912 Mean Annual



Global Seasonal Surface Temperature: 1983-2004



Global Temperature: 1983-2009



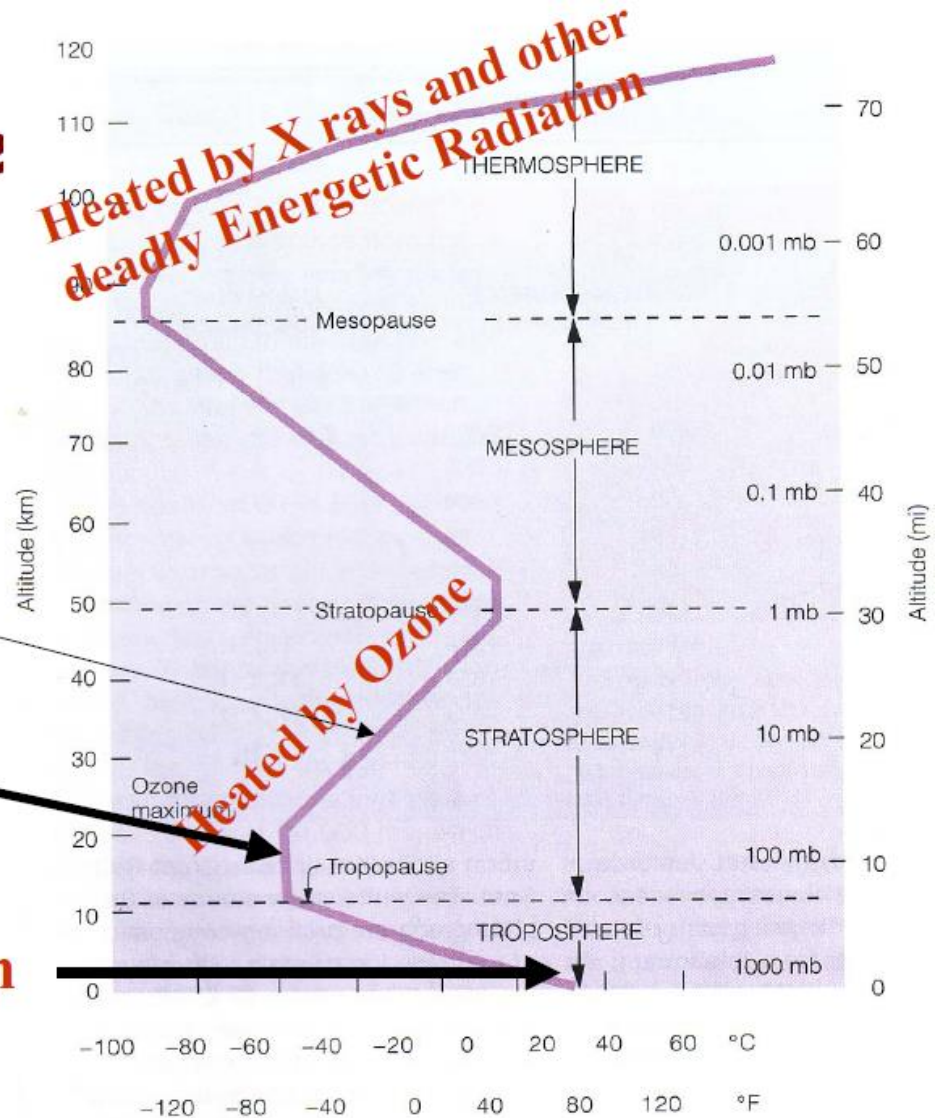
Vertical Distribution of Air Temperature and Its Drivers

Temperature Structure of the Atmosphere

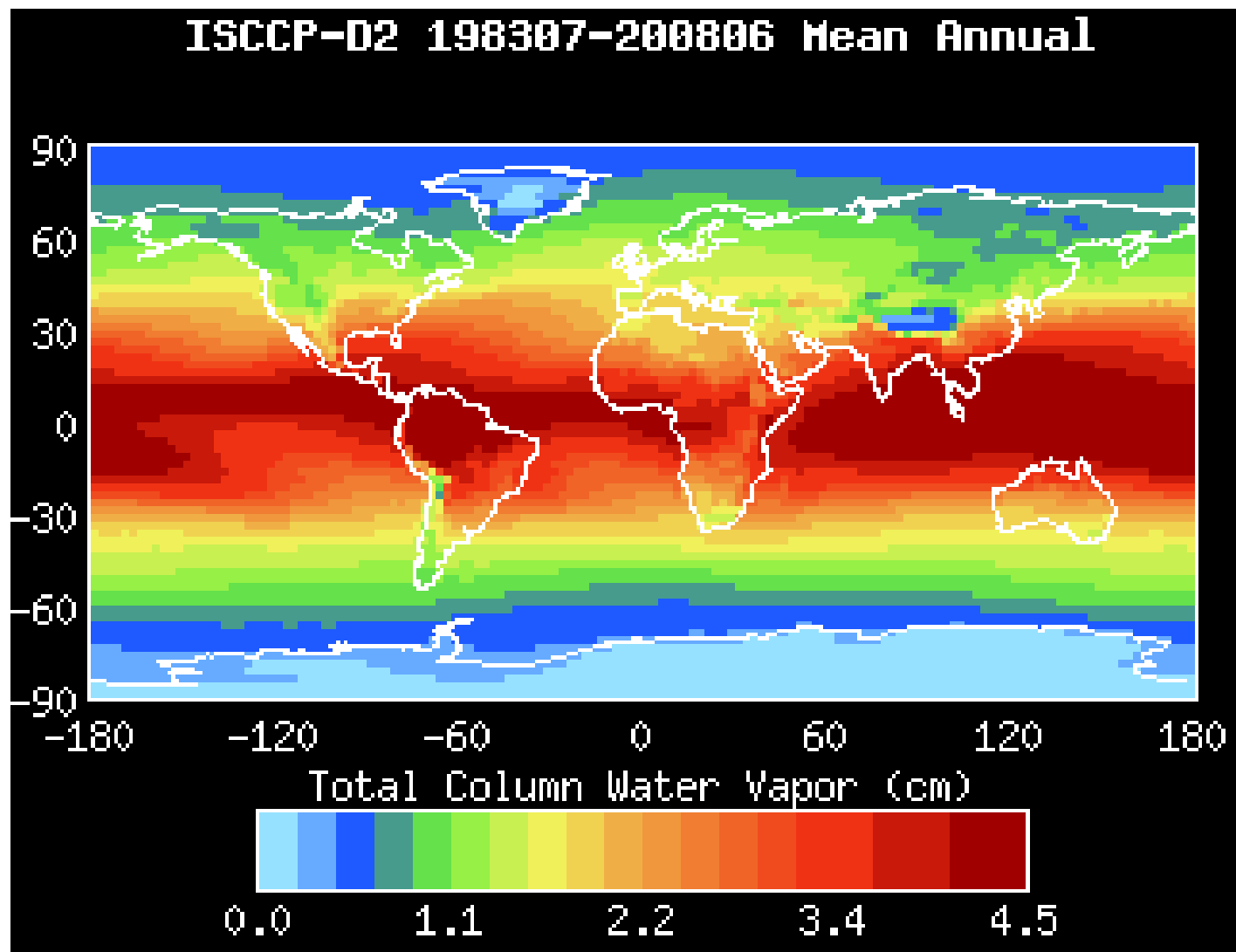
Inversion Layer

Isothermal Zone

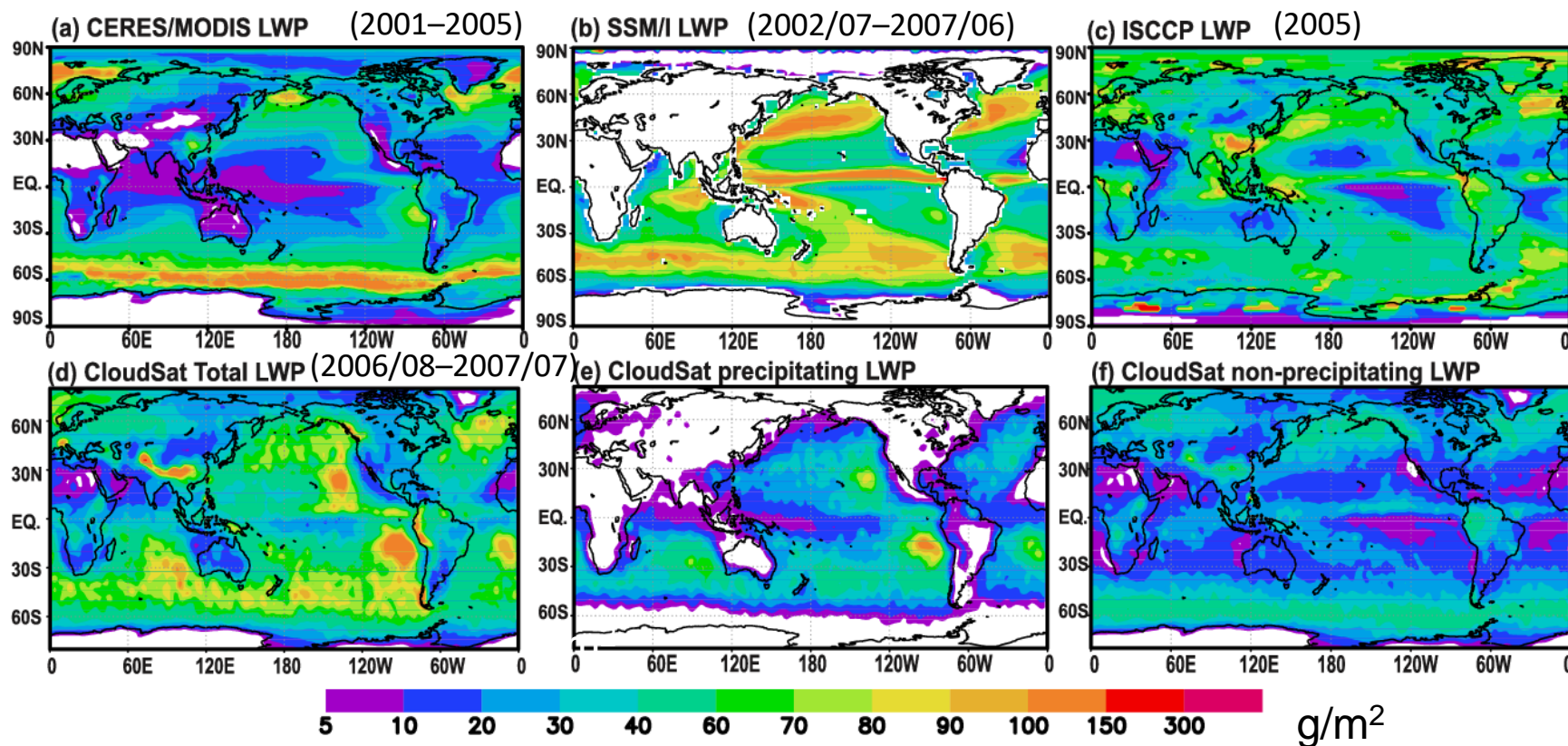
Heated by the Sun



Global Water Vapor Content: 1983-2008



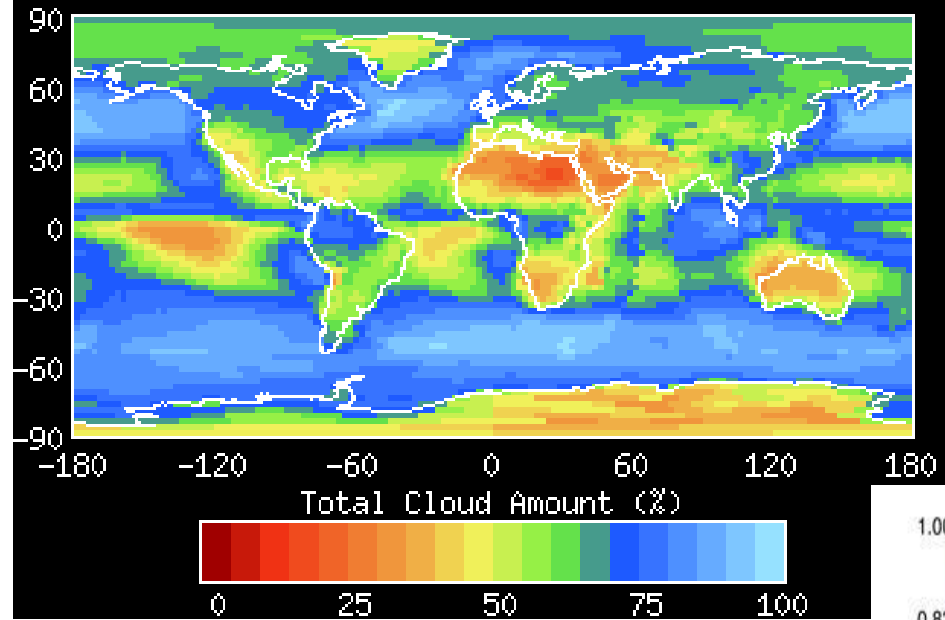
Global Cloud Water Content: 1983-2008



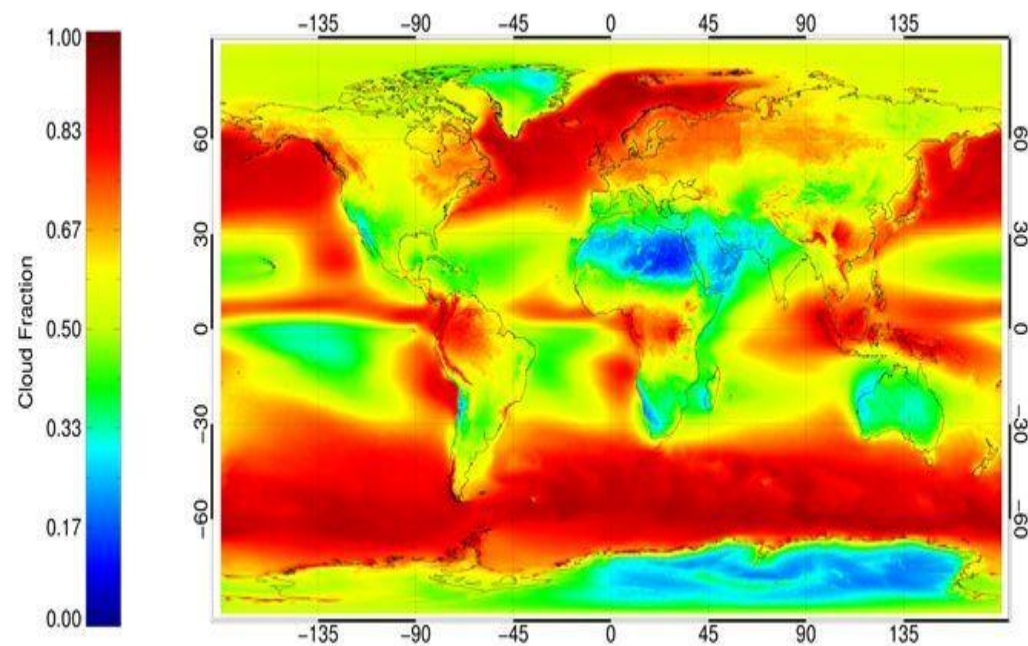
1 mm = 1000 g/m^2

Global Cloud Cover

ISCCP-D2 198307-200806 Mean Annual

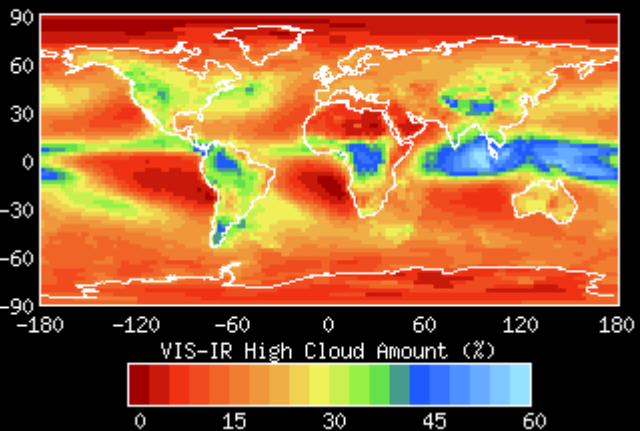


CLARA-A2 (1982-2015)

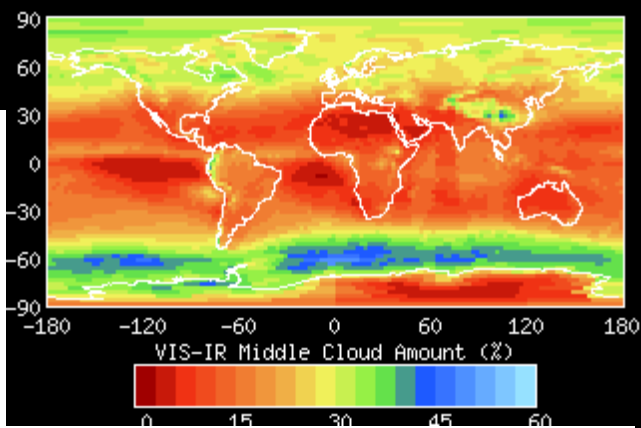


Global Cloud Cover: 1983-2008

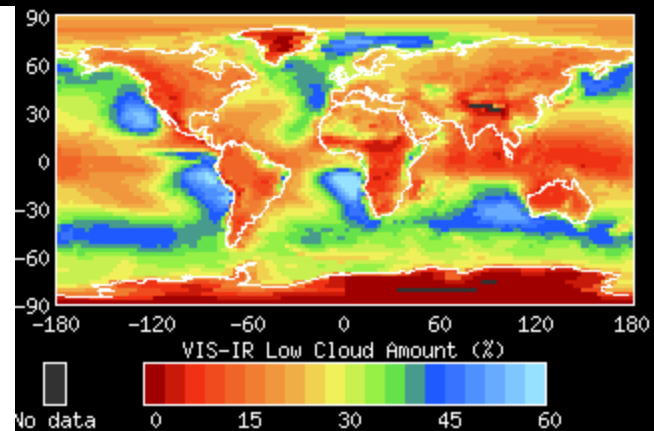
ISCCP-D2 198307-200806 Mean Annual



ISCCP-D2 198307-200806 Mean Annual

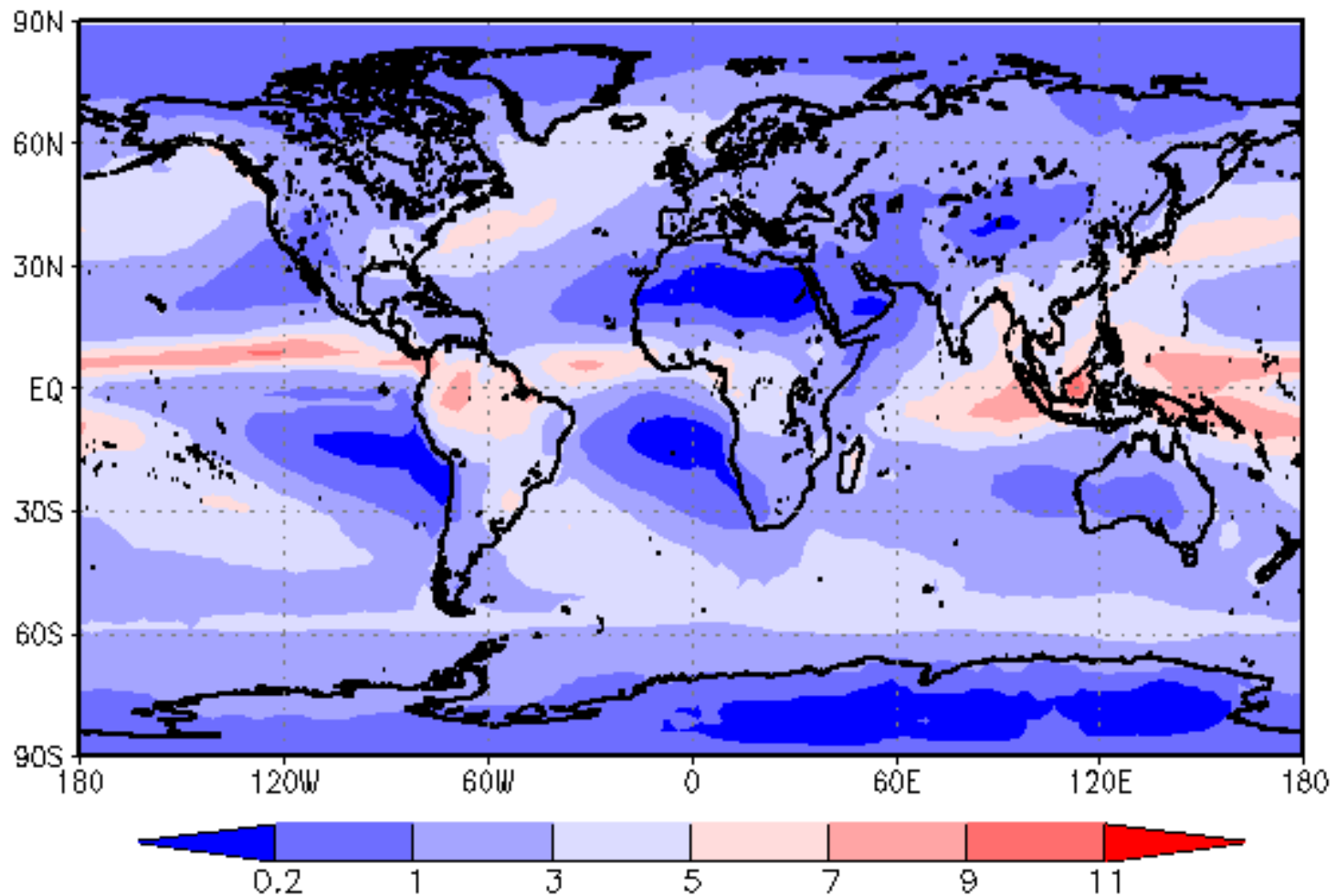


ISCCP-D2 198307-200806 Mean Annual



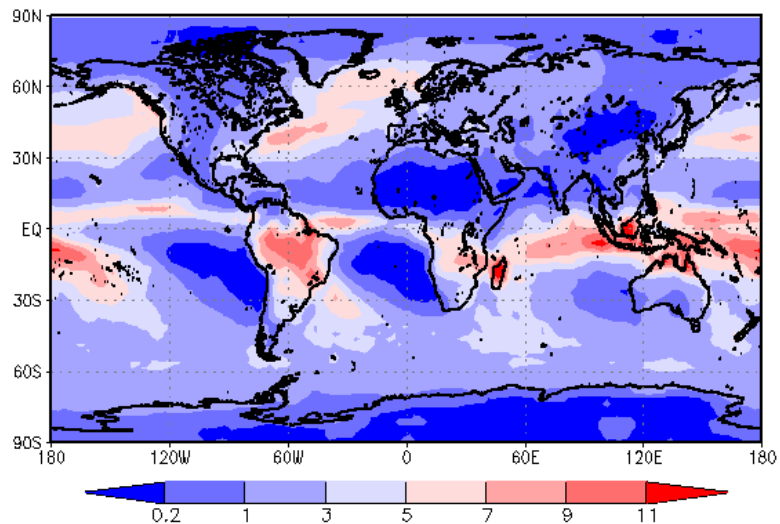
Global Precipitation: 1979-2008

GPCP Monthly Mean Precipitation Rate (mm/day)
Average of 1/1979--4/2008

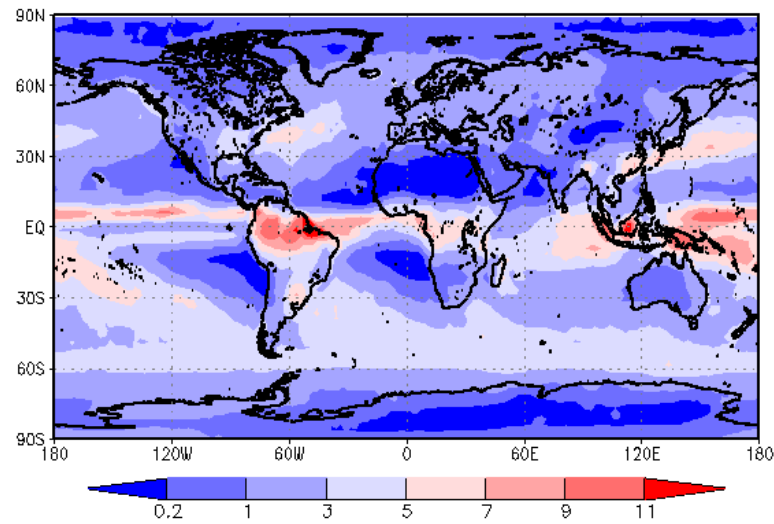


Global Seasonal Precipitation: 1979-2008

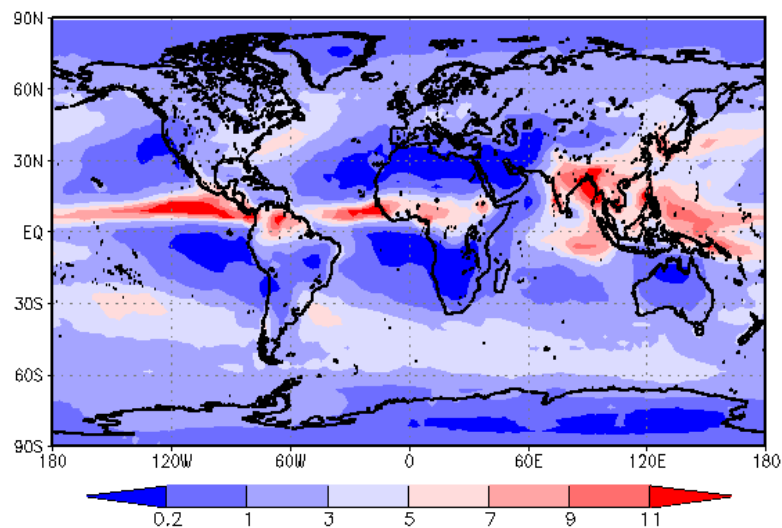
GPCP Monthly Mean Precipitation Rate (mm/day)
Calendar month JAN Average of 1979--2008



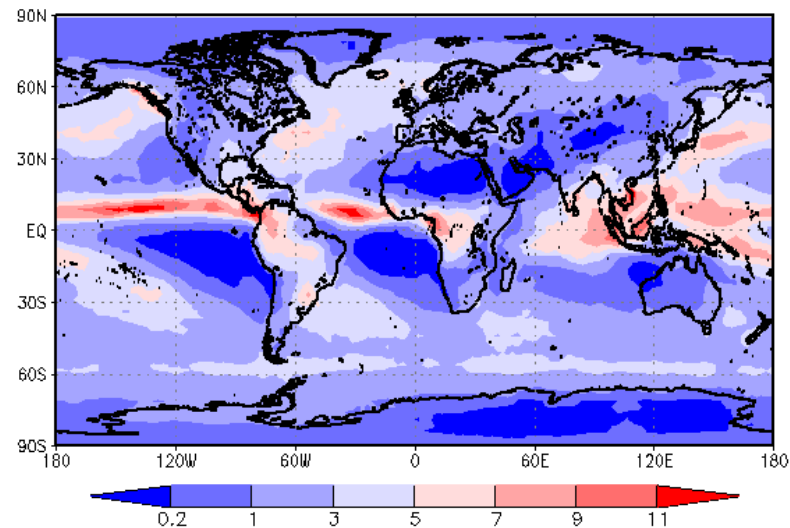
GPCP Monthly Mean Precipitation Rate (mm/day)
Calendar month APR Average of 1979--2008



GPCP Monthly Mean Precipitation Rate (mm/day)
Calendar month JUL Average of 1979--2008

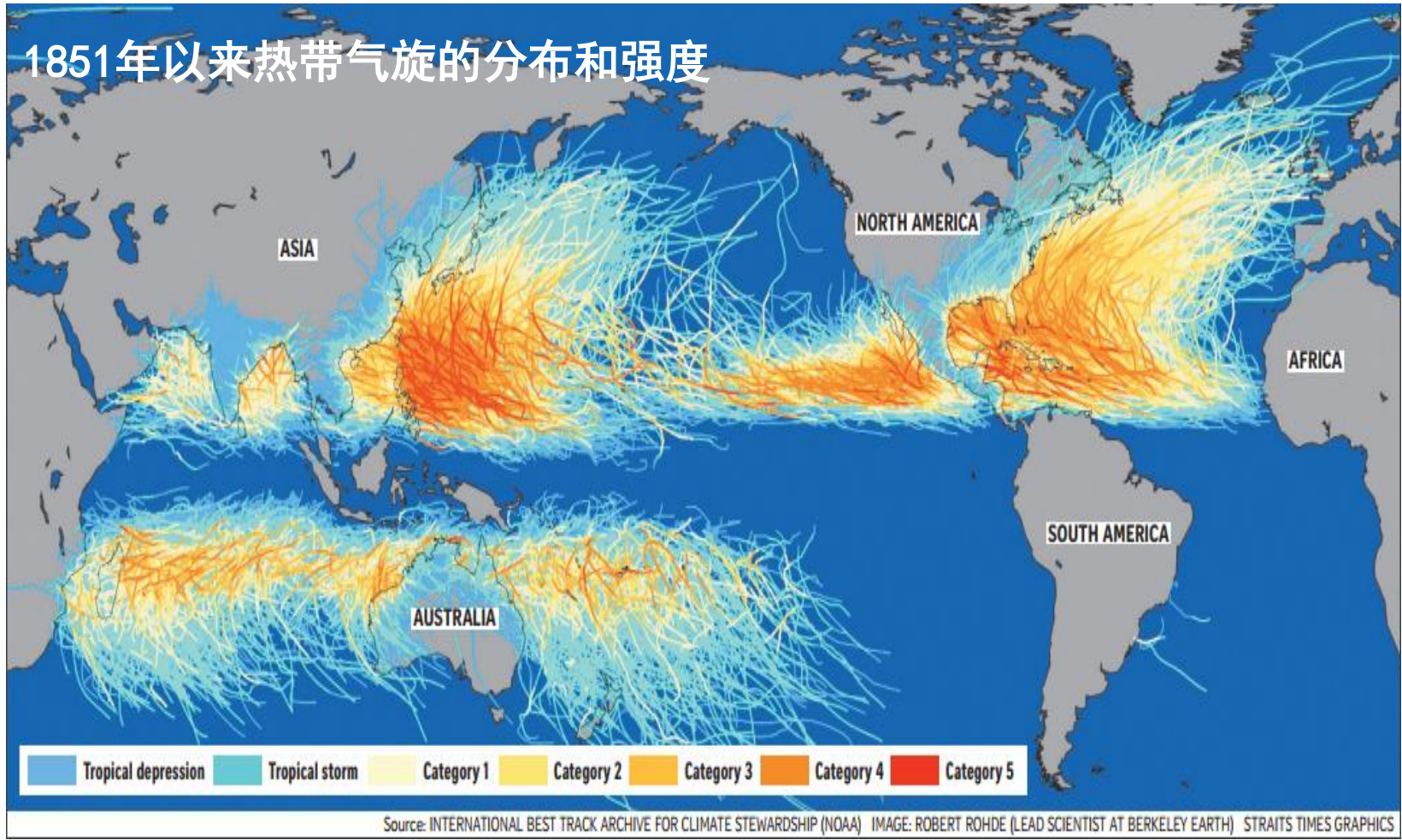


GPCP Monthly Mean Precipitation Rate (mm/day)
Calendar month OCT Average of 1979--2008



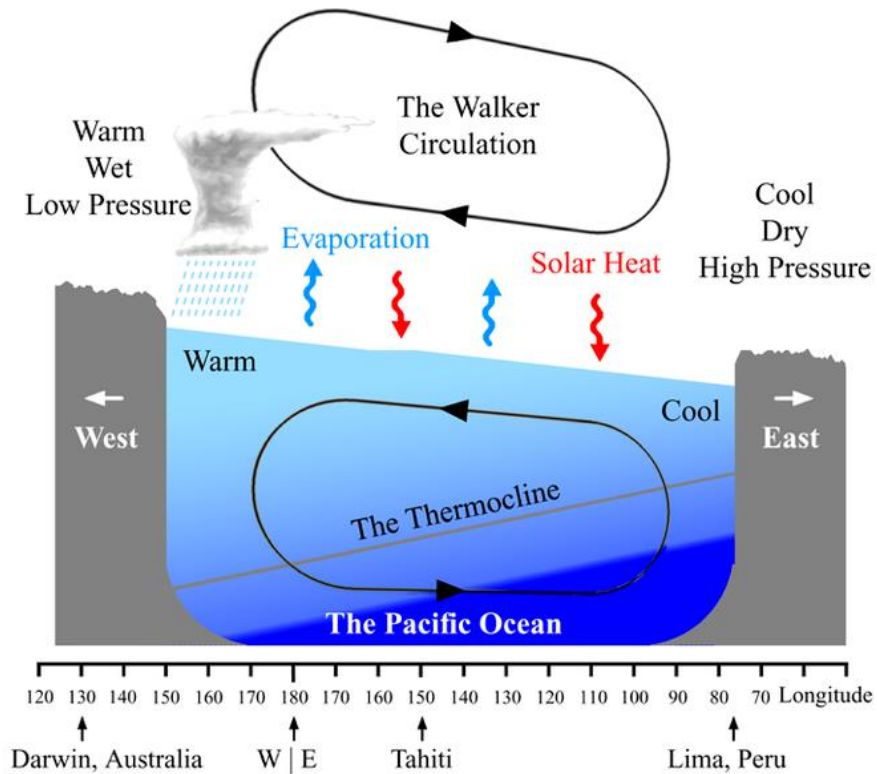
Tropical Cyclones

1851年以来热带气旋的分布和强度

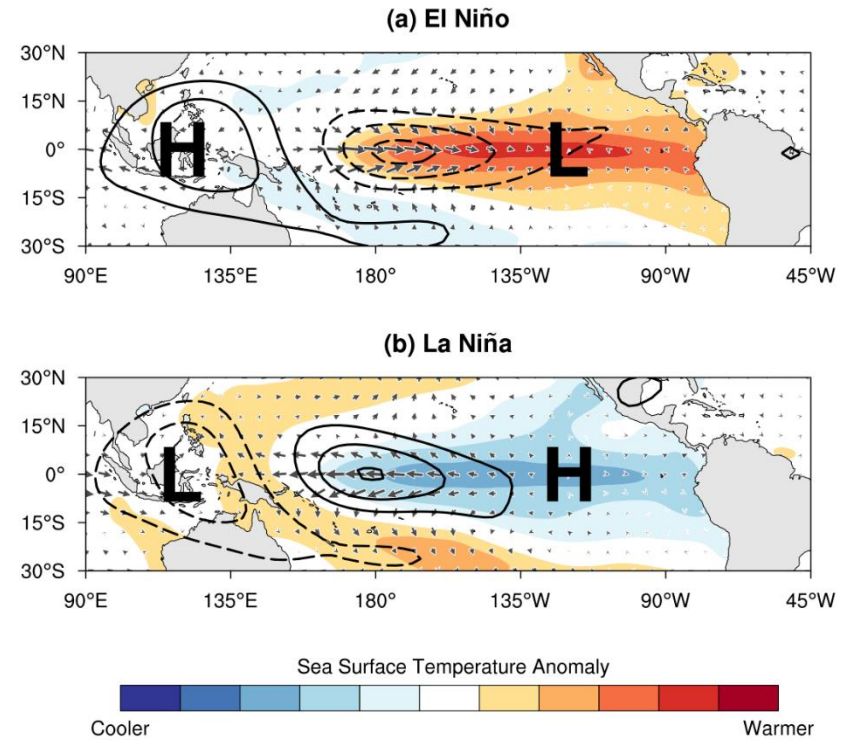


Walker Circulation and ENSO

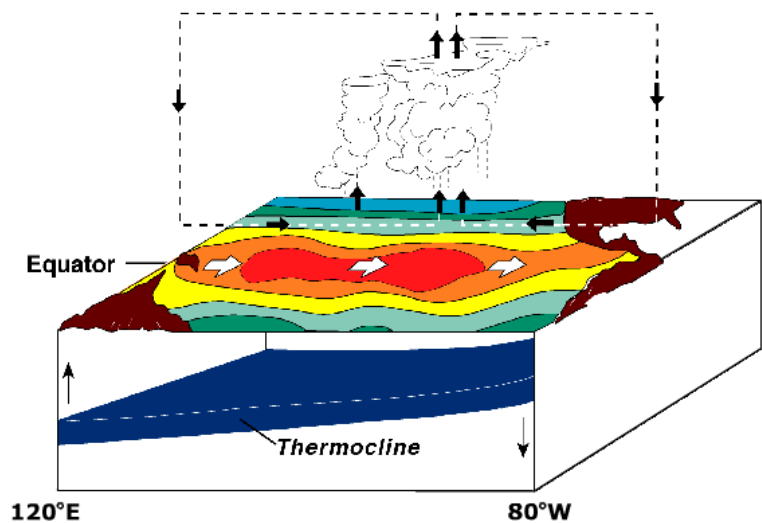
Walker circulation



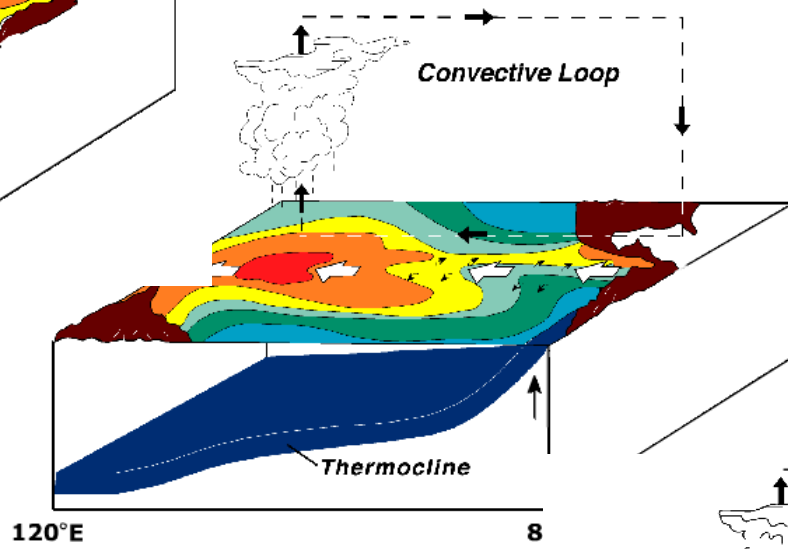
ENSO



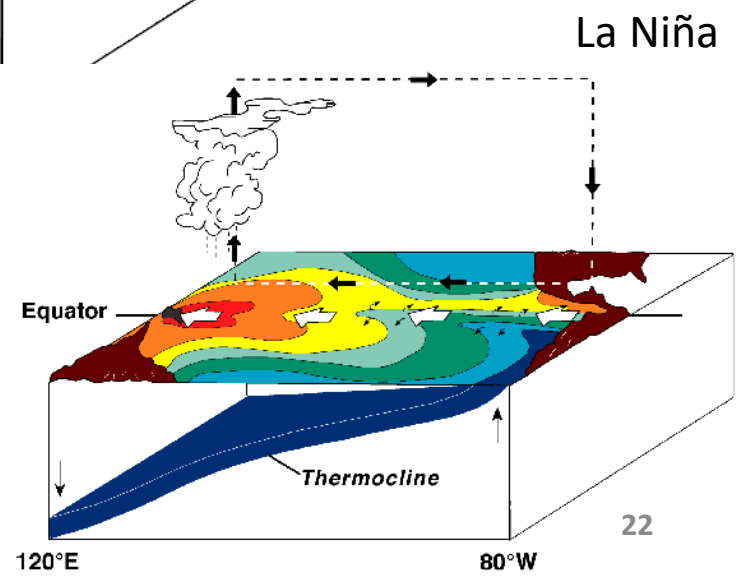
ENSO: 厄尔尼诺、拉尼娜、南方涛动



El Niño



Normal

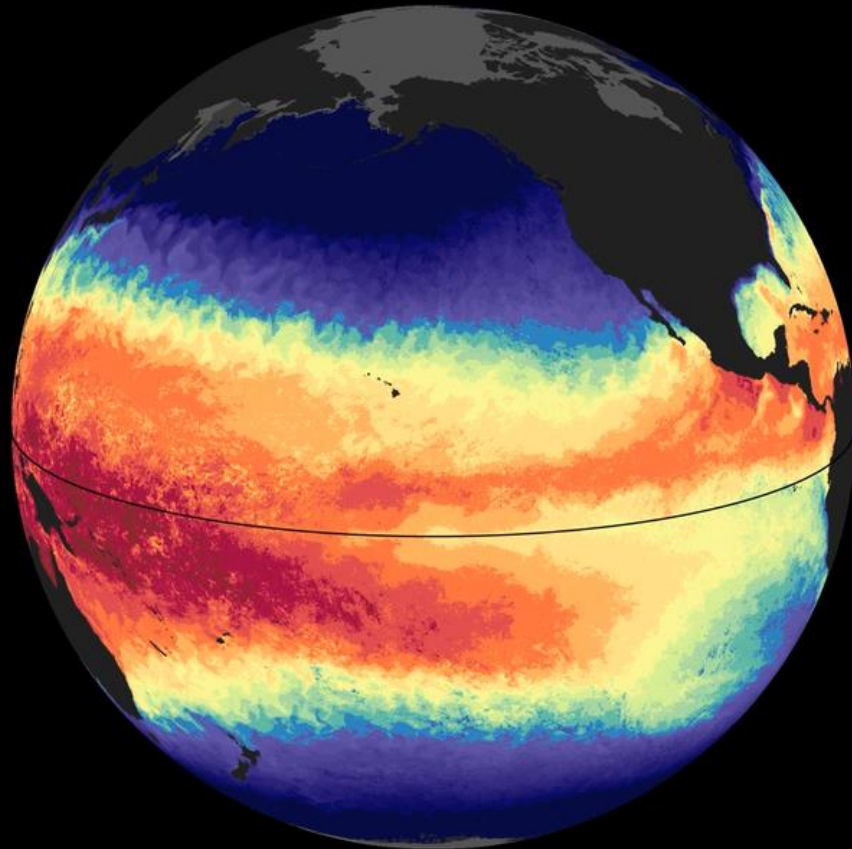


La Niña

- El Niño (La Niña): 赤道东太平洋的异常升(降)温
- Southern Oscillation: 东、西太平洋的地面气压差, El Niño (La Niña) 年为负(正)
- El Niño/La Niña 与SO为一个周期2-7年的准气候现象的两个表现

El Niño in 2015

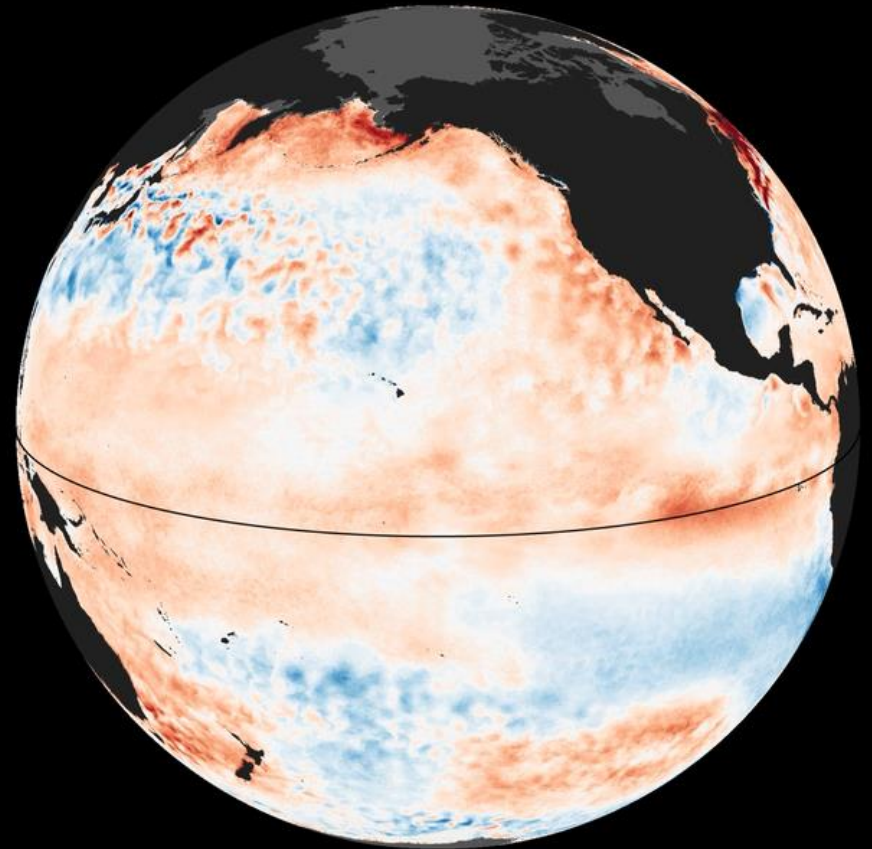
Sea Surface Temperature



Sea Surface Temperature (°C)

0 8 16 24 32

Sea Surface Temperature Anomaly



Sea Surface Temperature Anomaly (°C)

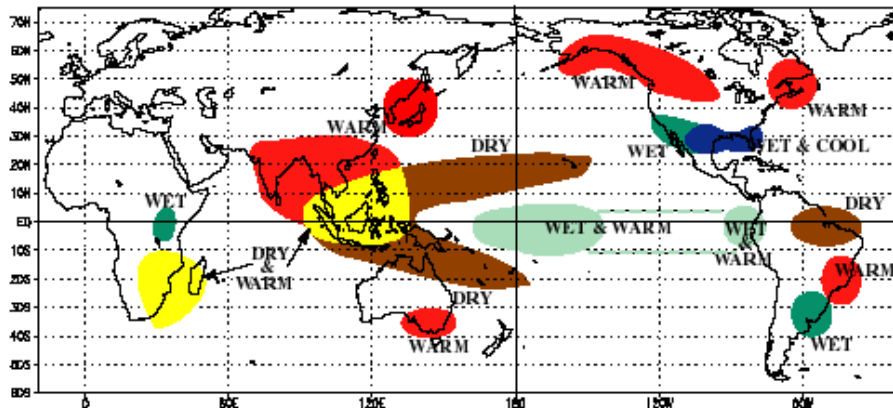
-4 0 4

2015-01-01

El Niño (La Niña): Regional Impacts

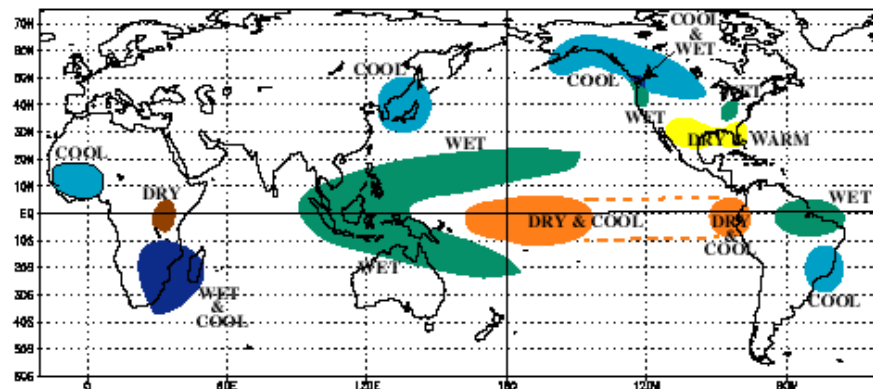
El Niño

WARM EPISODE RELATIONSHIPS DECEMBER - FEBRUARY

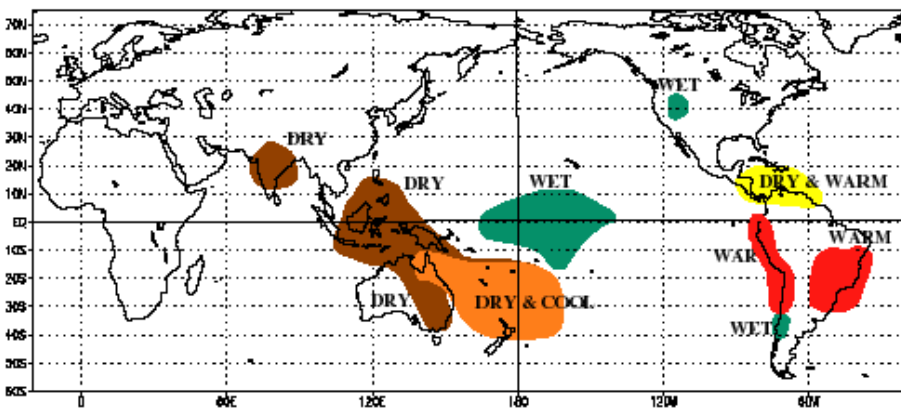


La Niña

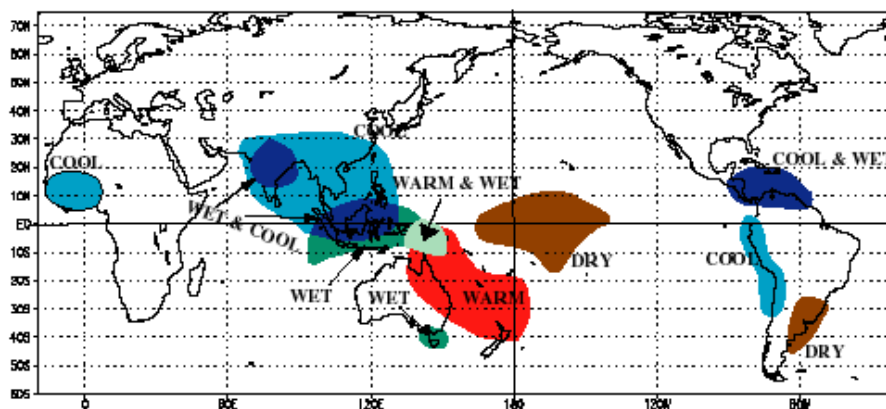
COLD EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



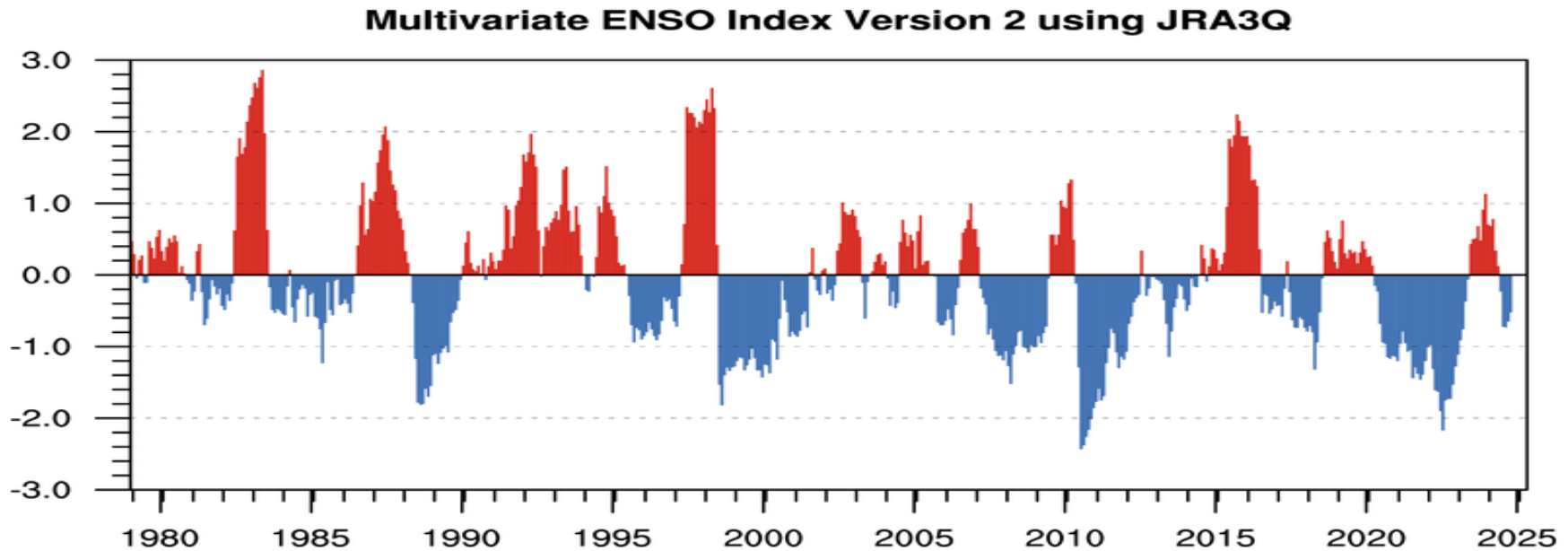
WARM EPISODE RELATIONSHIPS JUNE - AUGUST



COLD EPISODE RELATIONSHIPS JUNE - AUGUST



ENSO Index: MEI (NOAA)

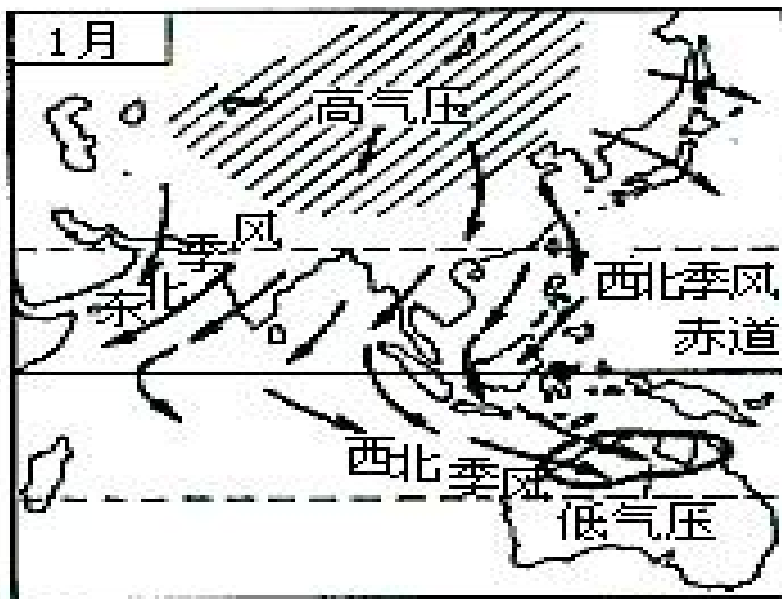


- Index: Positive for El Niño and negative for La Niña
- Data: the time series of the leading combined Empirical Orthogonal Function (EOF) of five different variables (sea level pressure (SLP), sea surface temperature (SST), zonal and meridional components of the surface wind, and outgoing longwave radiation (OLR)) over the tropical Pacific basin (30S-30N and 100E-70W)
- Procedure: Sliding bi-monthly, normalization, standardization, co-variance matrix, 1st PC
- Details: <https://psl.noaa.gov/enso/mei/>

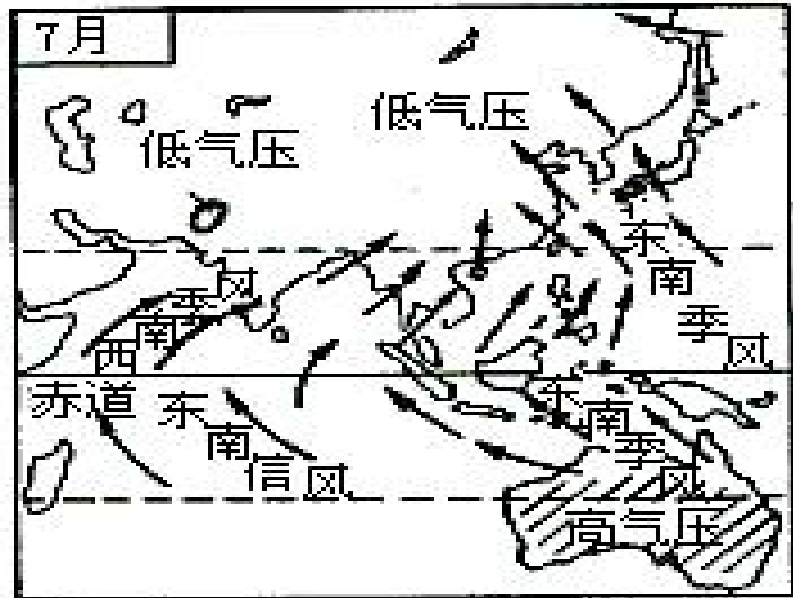
Monsoon

Play movie

季风



冬季风

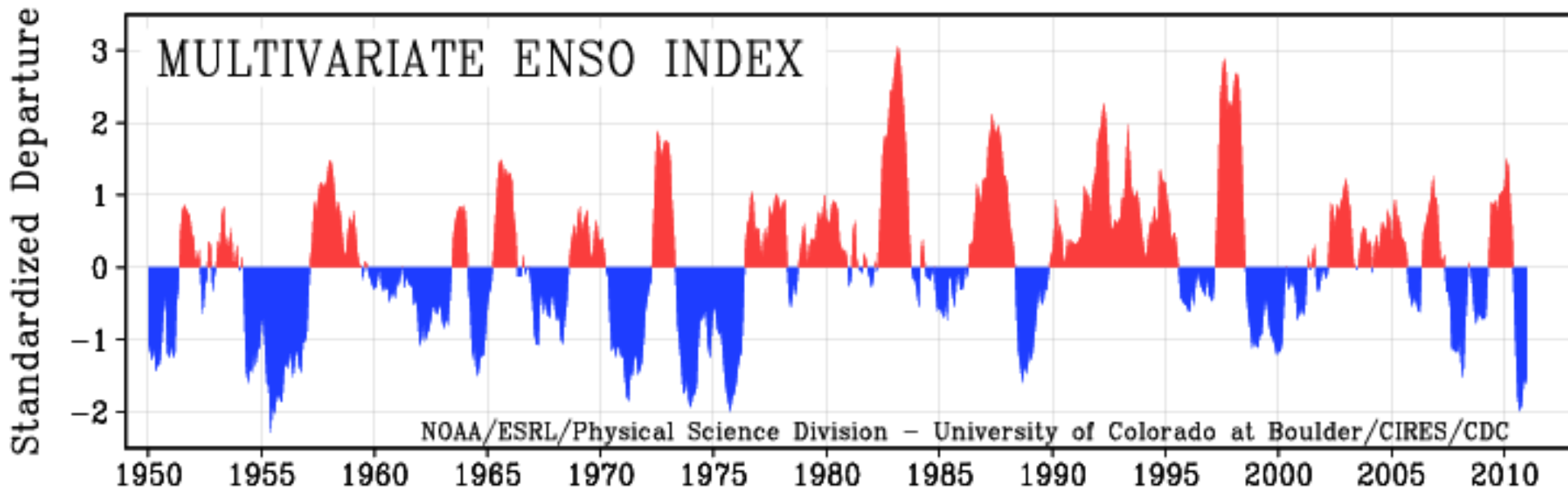


夏季风

亚洲1月、7月的季风图

- ✓ 季风是由于大陆和海洋在一年之中增热和冷却程度不同，在大陆和海洋之间大范围的、风向随季节有规律改变的风。
- ✓ 季风伴随着降水变化，是大气环流的重要组成部分。
- ✓ 季风由海陆热力学差异（即温差）引起，可视为大尺度的‘海陆风’。
- ✓ 东亚季风是我国降水的重要来源，也是我国气候的主要影响因子。

东亚季风指数



- El Niño次年夏天：东亚季风变弱，雨带长期停留在我国南方，南方洪涝，北方干旱
- La Niña：相反。

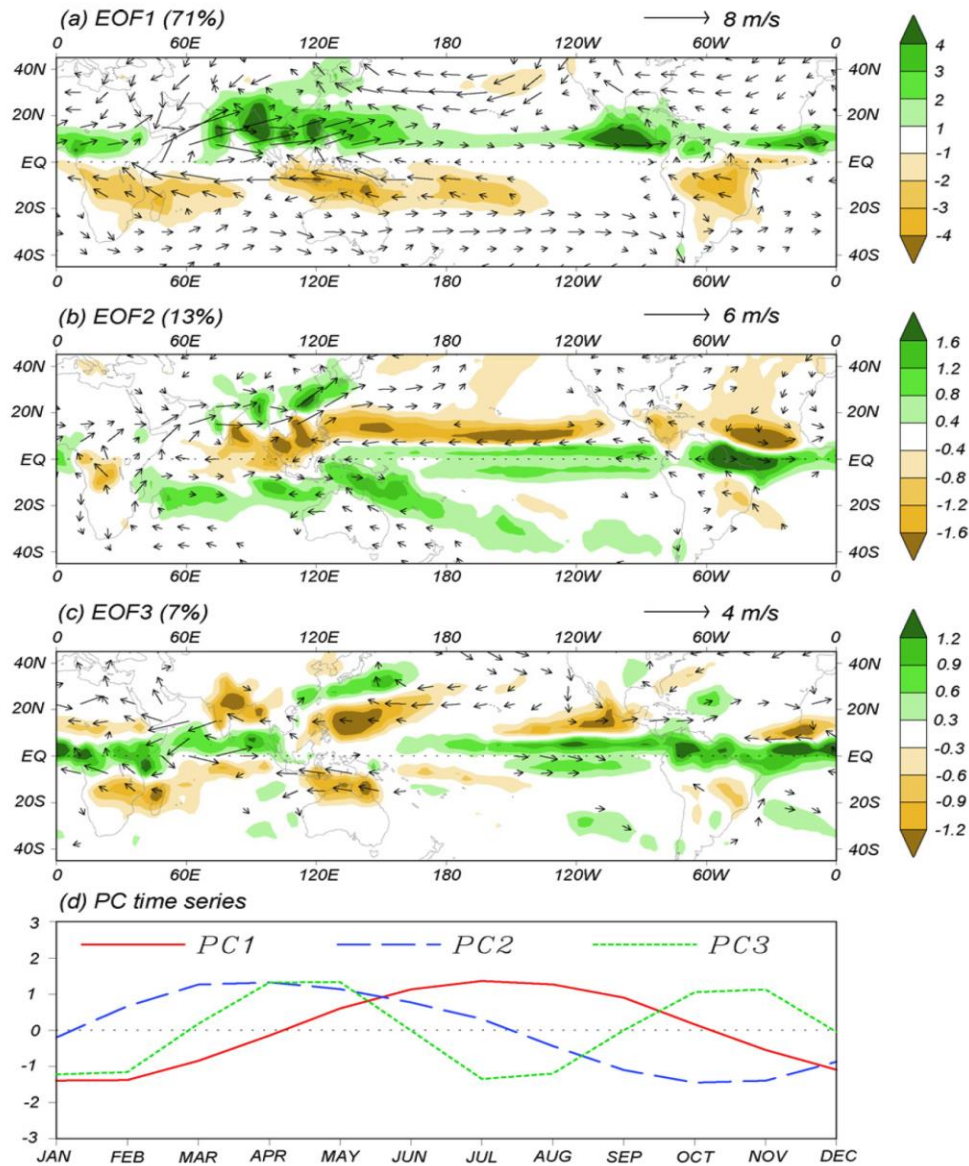


东亚夏季风强度指数(3)变化

Variation of East Asian summer monsoon index (3)

Climate Diagnostics and Prediction Division/NCC/CMA

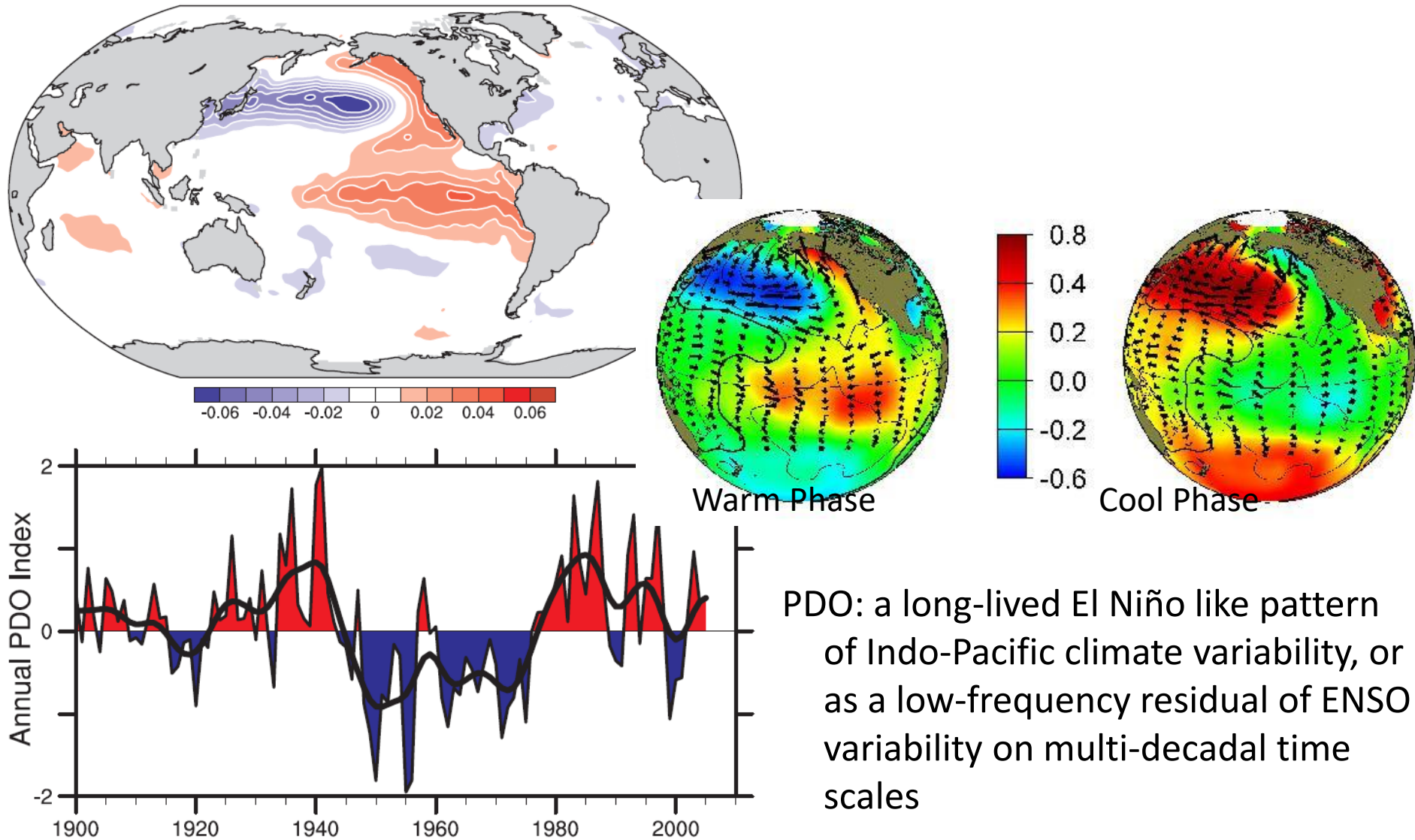
Global Monsoon



Quiz

- 1. Why is cloud top higher in summer than in winter over East China?**
- 2. Why is there subsidence in the subtropics?**
- 3. Explain the circulation around the Tibetan Plateau**
- 4. Why are the PDO and AMO changes look like T?**

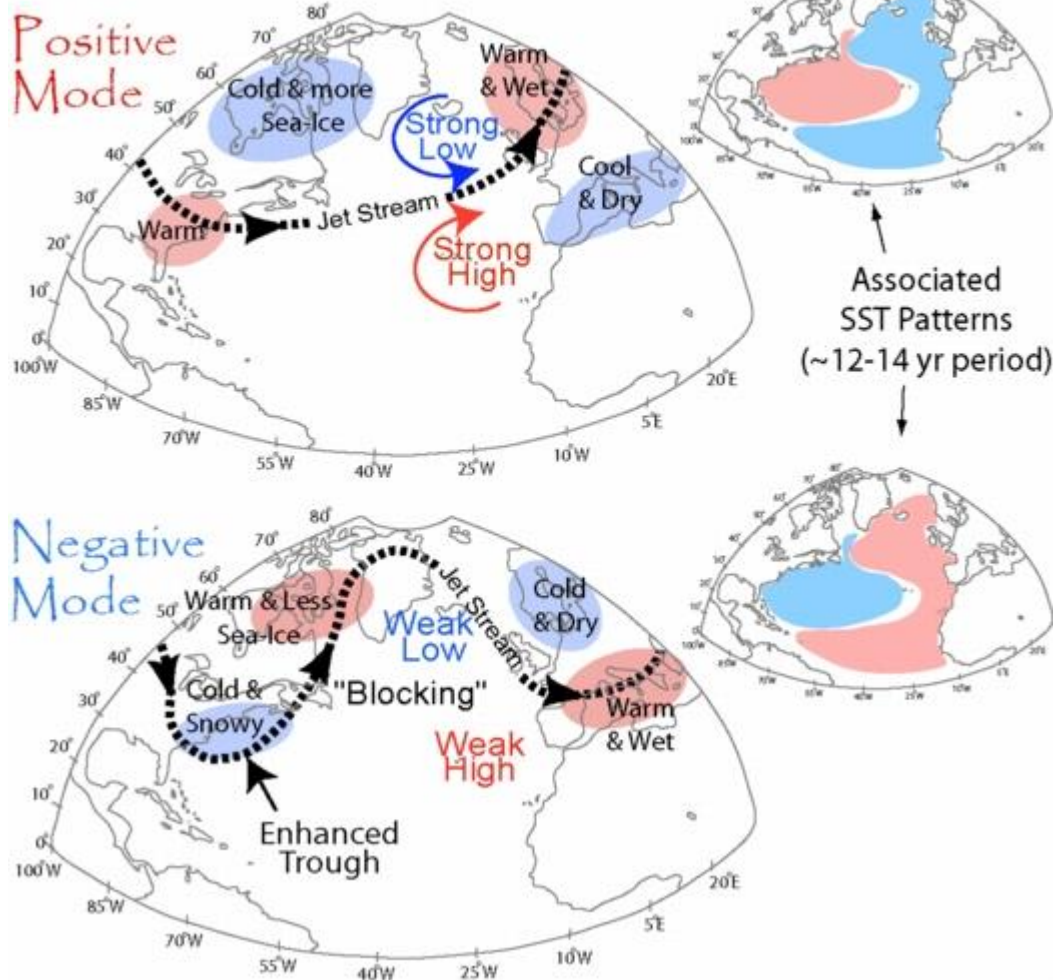
Pacific Decadal Oscillation (PDO)



PDO: a long-lived El Niño like pattern of Indo-Pacific climate variability, or as a low-frequency residual of ENSO variability on multi-decadal time scales

North Atlantic Oscillation (NAO)

North Atlantic Oscillation

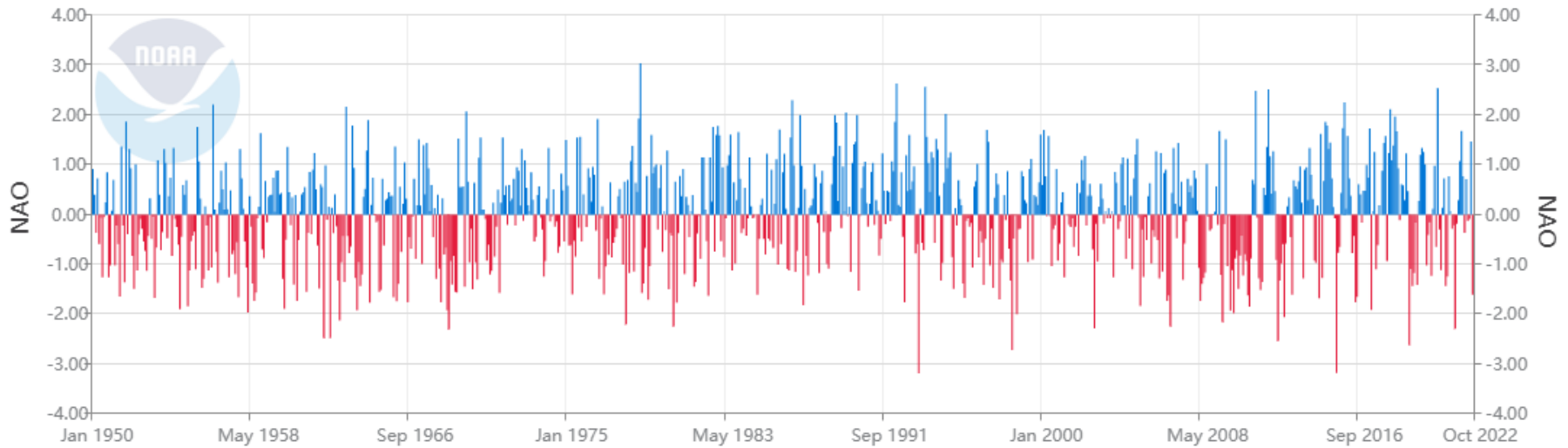


NAO: a climatic phenomenon in the North Atlantic Ocean of fluctuations in the difference of atmospheric pressure at sea level between the Icelandic low and the Azores high

NAO is one of the most important manifestations of climate fluctuations in the North Atlantic and surrounding humid climates

NAO Index

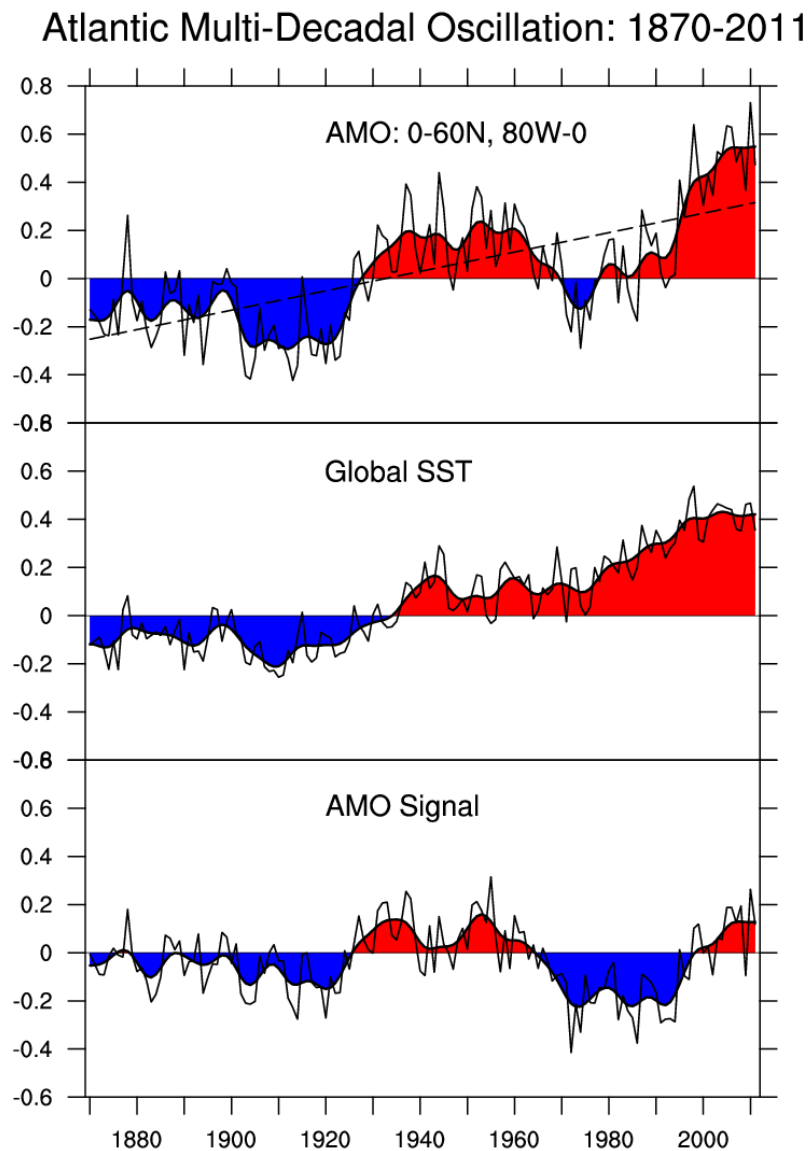
North Atlantic Oscillation (NAO)



<https://www.ncdc.noaa.gov/teleconnections/nao/>

Atlantic Multi-decadal Oscillation (AMO)

AMO: Over the instrumental period (since the 1850s), North Atlantic SSTs show a 65 to 75 year variation (0.4° C range), with a warm phase during 1930 to 1960 and cool phases during 1905 to 1925 and 1970 to 1990

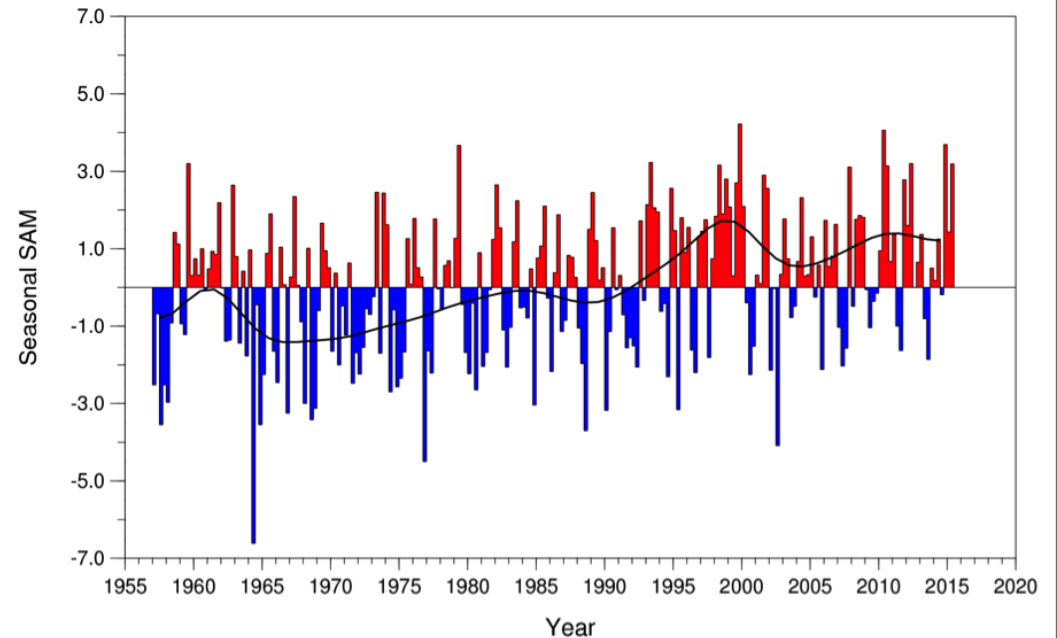
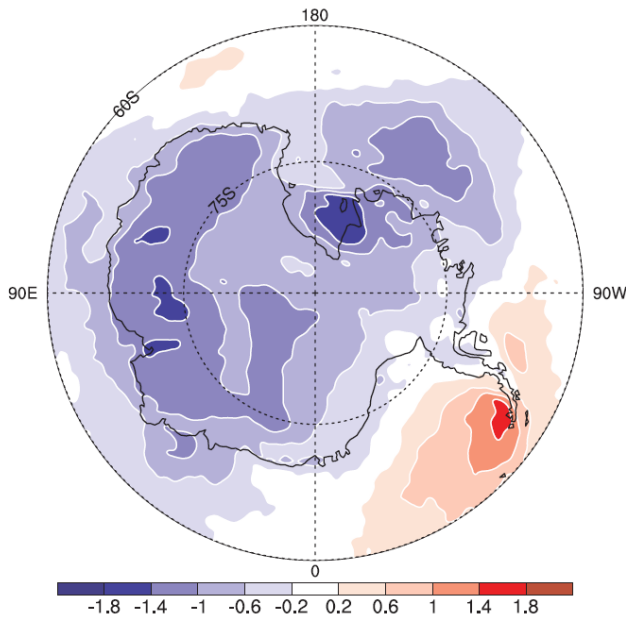
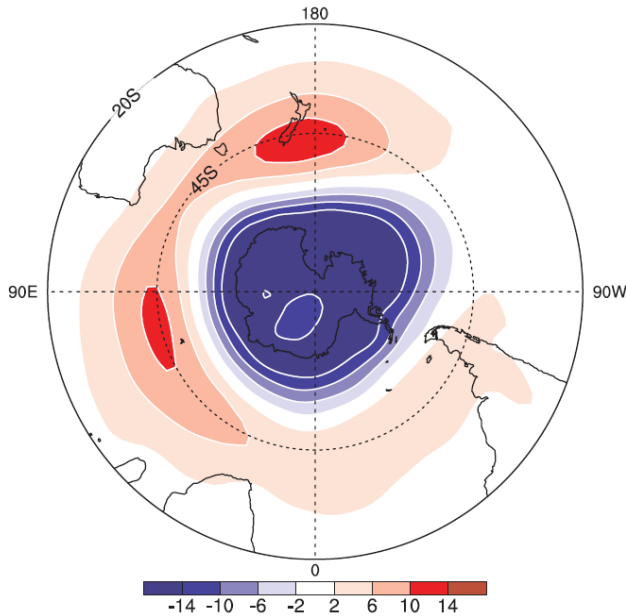


Southern Annular Mode (SAM)

Antarctic Oscillation (AAO)

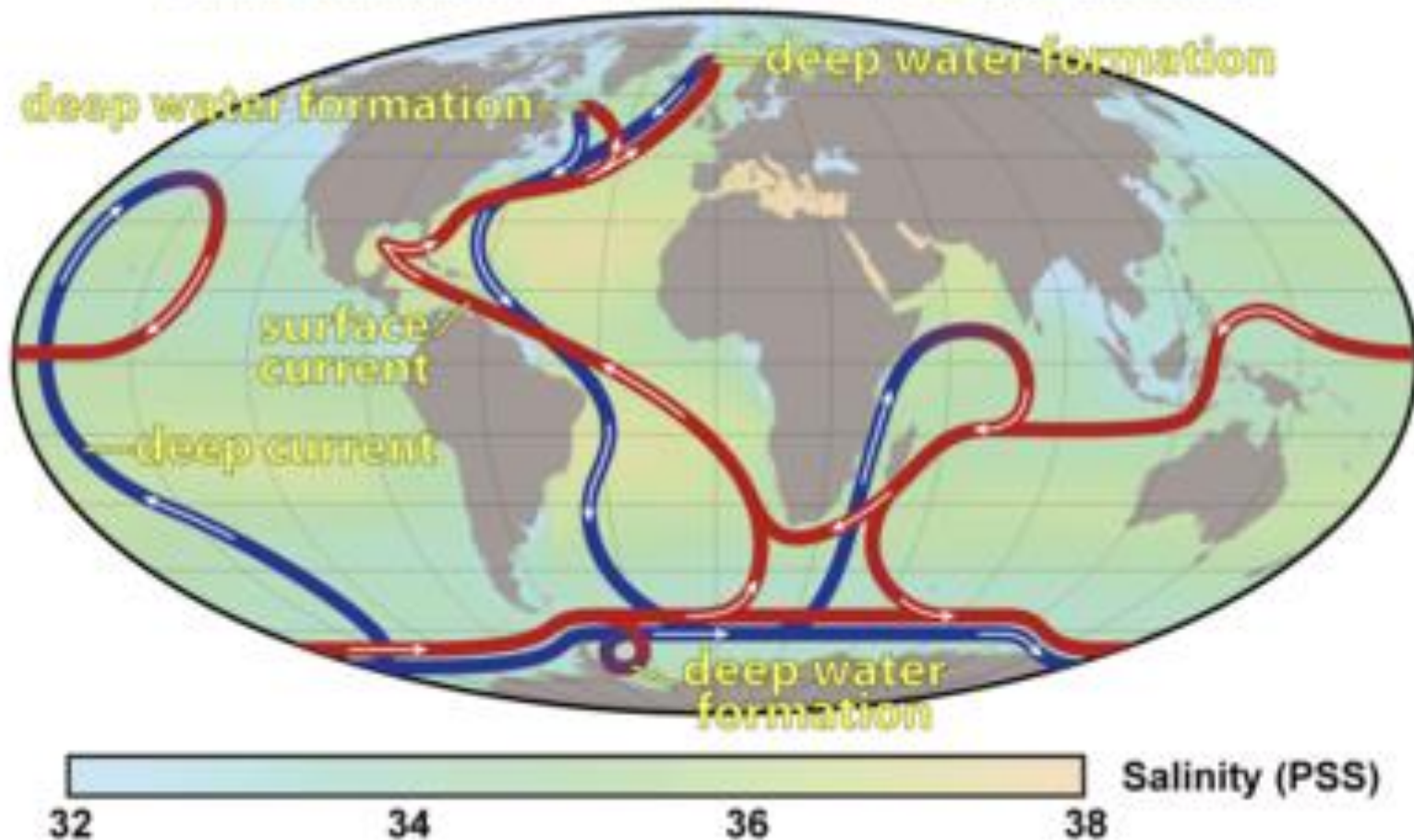
SAM index (station-based): Difference in MSLP between SH middle and high latitudes (usually 40° S and 65° S)

SAM is the principal mode of variability of the atmospheric circulation in the SH extratropics



Thermohaline Circulation, or MOC

Thermohaline Circulation



Driver: density gradient in association with temperature and salt content