

# Global Warming: How and Why

S. Manabe,  
Princeton University



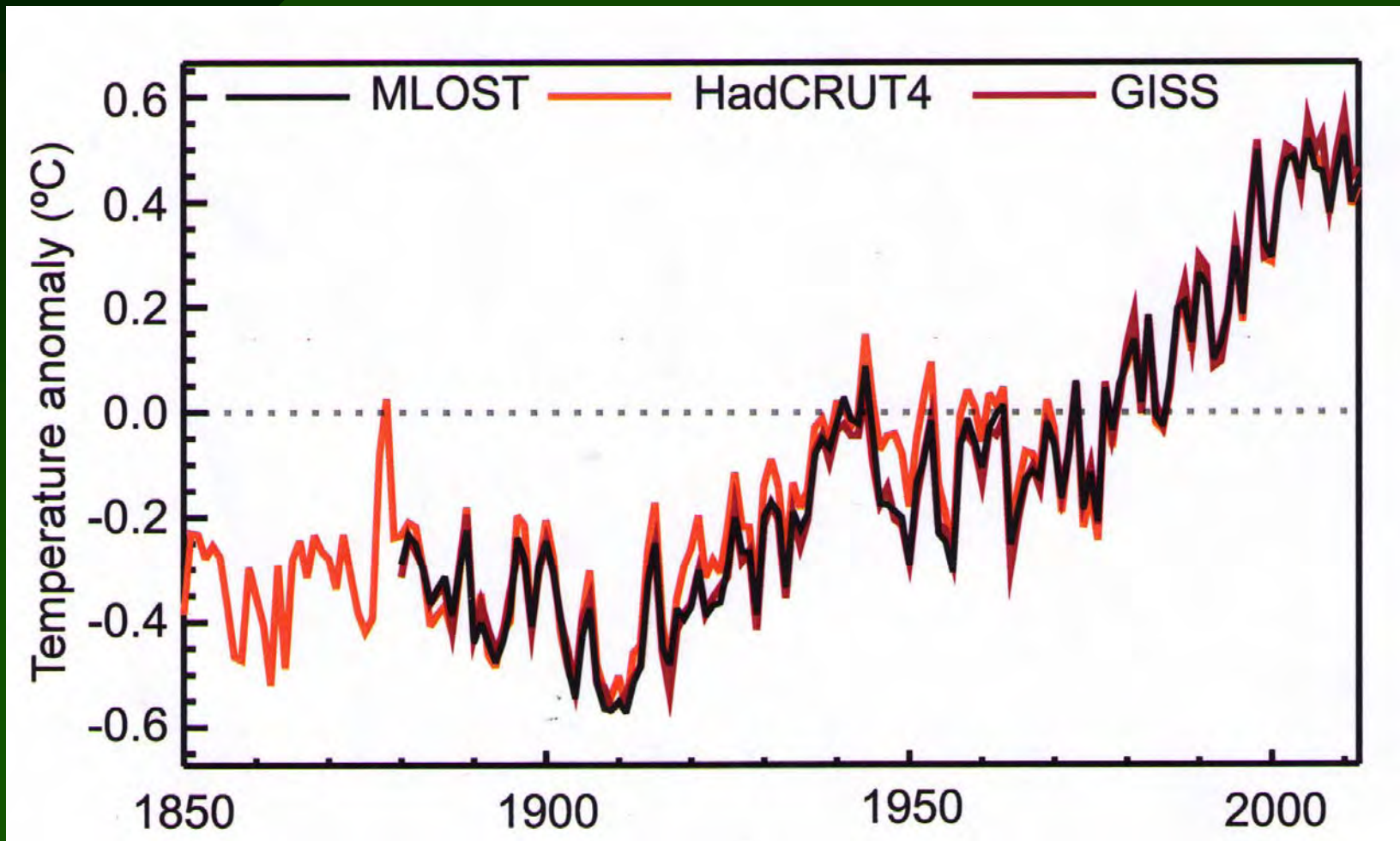
To USA, September, 1958





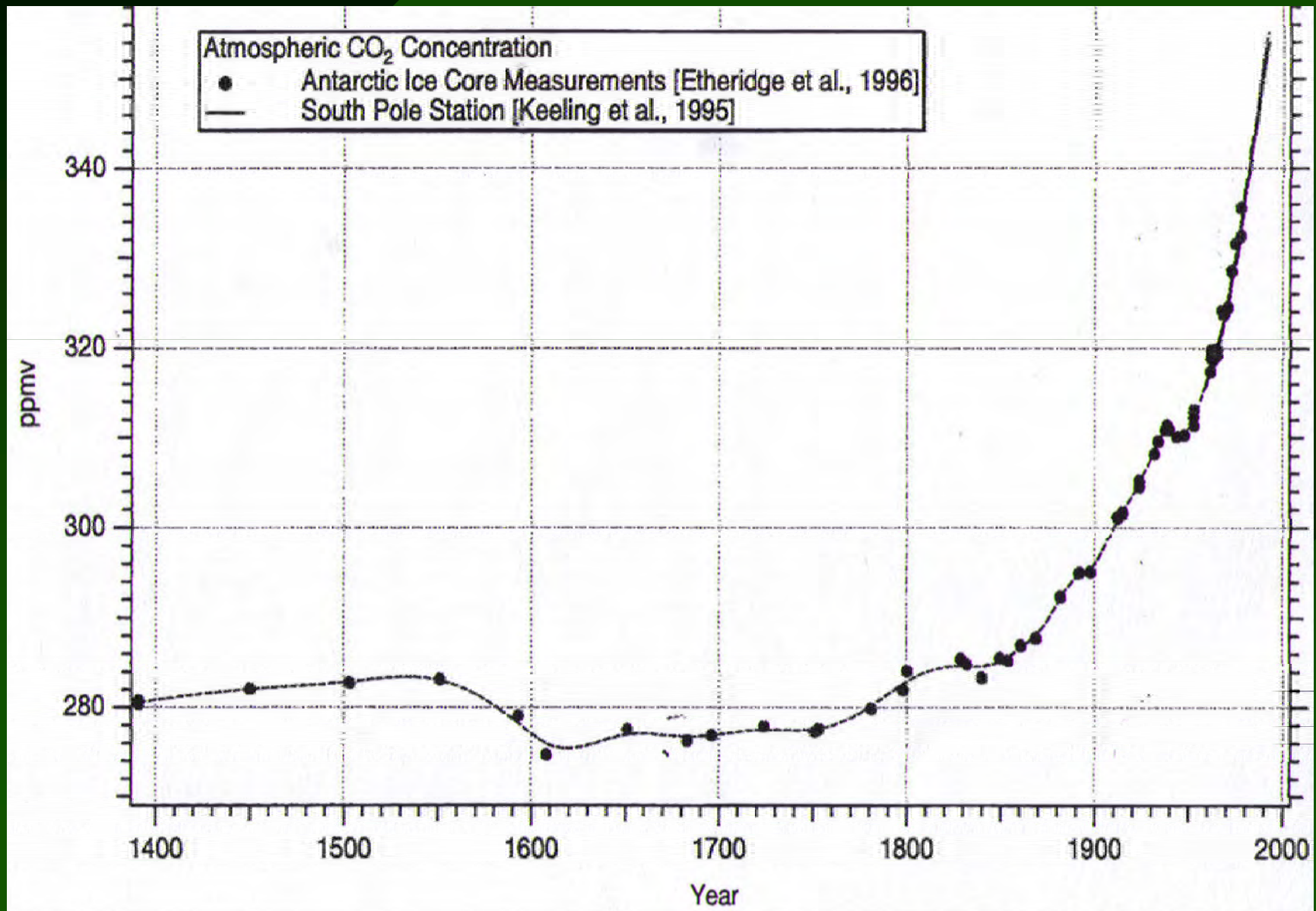
# Annual Mean, Global Mean Surface Temperature

陸面水面温度の全球年平均値 (3つの観測データセット)



# CO<sub>2</sub> Concentration at South Pole

## 南極での大気中二酸化炭素濃度





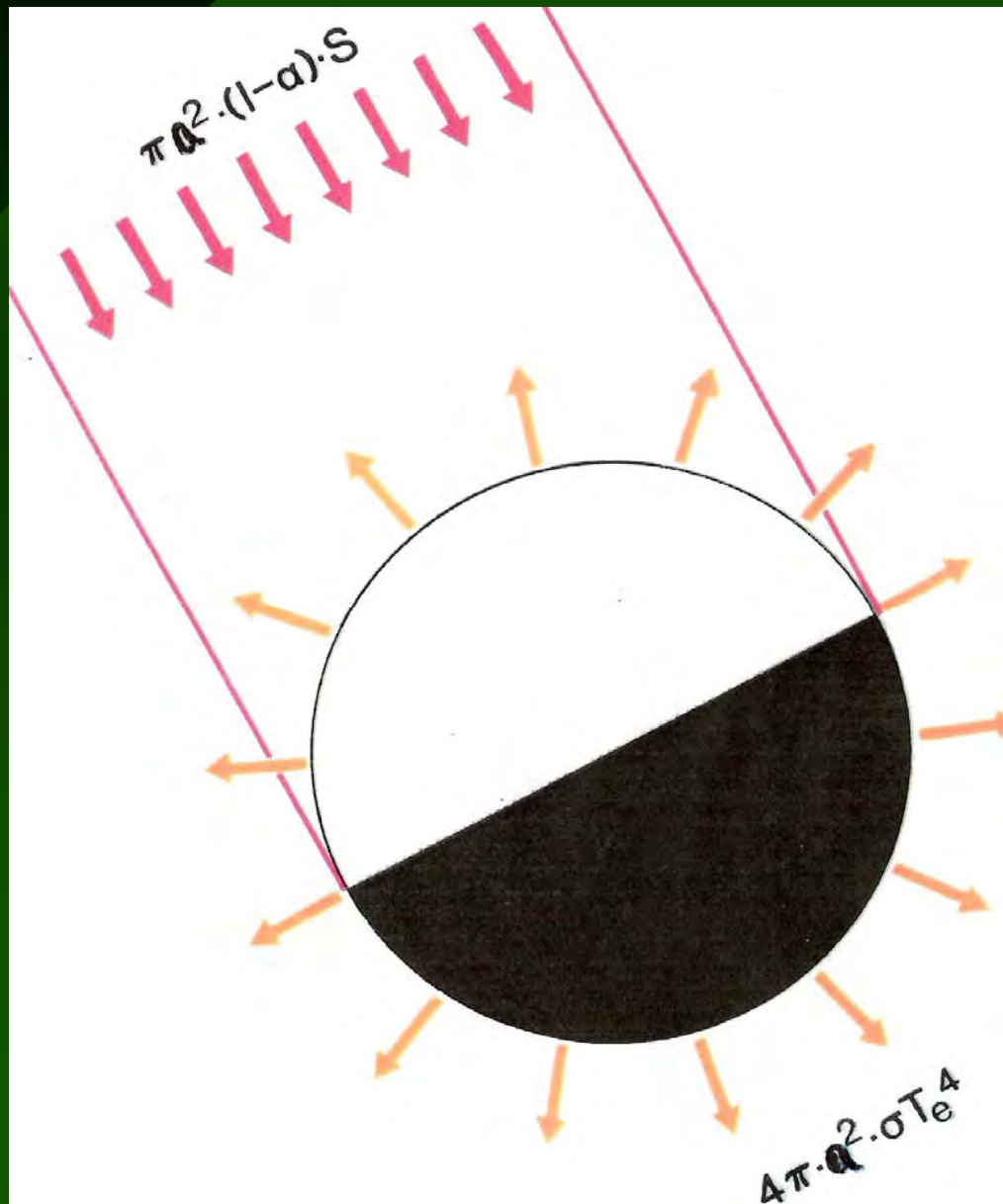
# Composition of the Atmosphere

大気組成 (重量パーセント) 赤字は温室効果ガス成分

| <i>Constituent</i>                 | Approximate<br>percent by weight |
|------------------------------------|----------------------------------|
| Nitrogen (N <sub>2</sub> )         | 75.3                             |
| Oxygen (O <sub>2</sub> )           | 23.1                             |
| Argon (Ar)                         | 1.3                              |
| *Water Vapor (H <sub>2</sub> O)    | ~0.25                            |
| *Carbon Dioxide (CO <sub>2</sub> ) | 0.046                            |
| Carbon Monoxide (CO)               | ~1 x 10 <sup>-5</sup>            |
| Neon (Ne)                          | 1.25 x 10 <sup>-3</sup>          |
| Helium (He)                        | 7.2 x 10 <sup>-5</sup>           |
| *Methane (CH <sub>4</sub> )        | 7.3 x 10 <sup>-5</sup>           |
| Krypton (Kr)                       | 3.3 x 10 <sup>-4</sup>           |
| *Nitrous Oxide (N <sub>2</sub> O)  | 7.6 x 10 <sup>-5</sup>           |
| Hydrogen (H <sub>2</sub> )         | 3.5 x 10 <sup>-6</sup>           |
| *Ozone (O <sub>3</sub> )           | ~3 x 10 <sup>-6</sup>            |

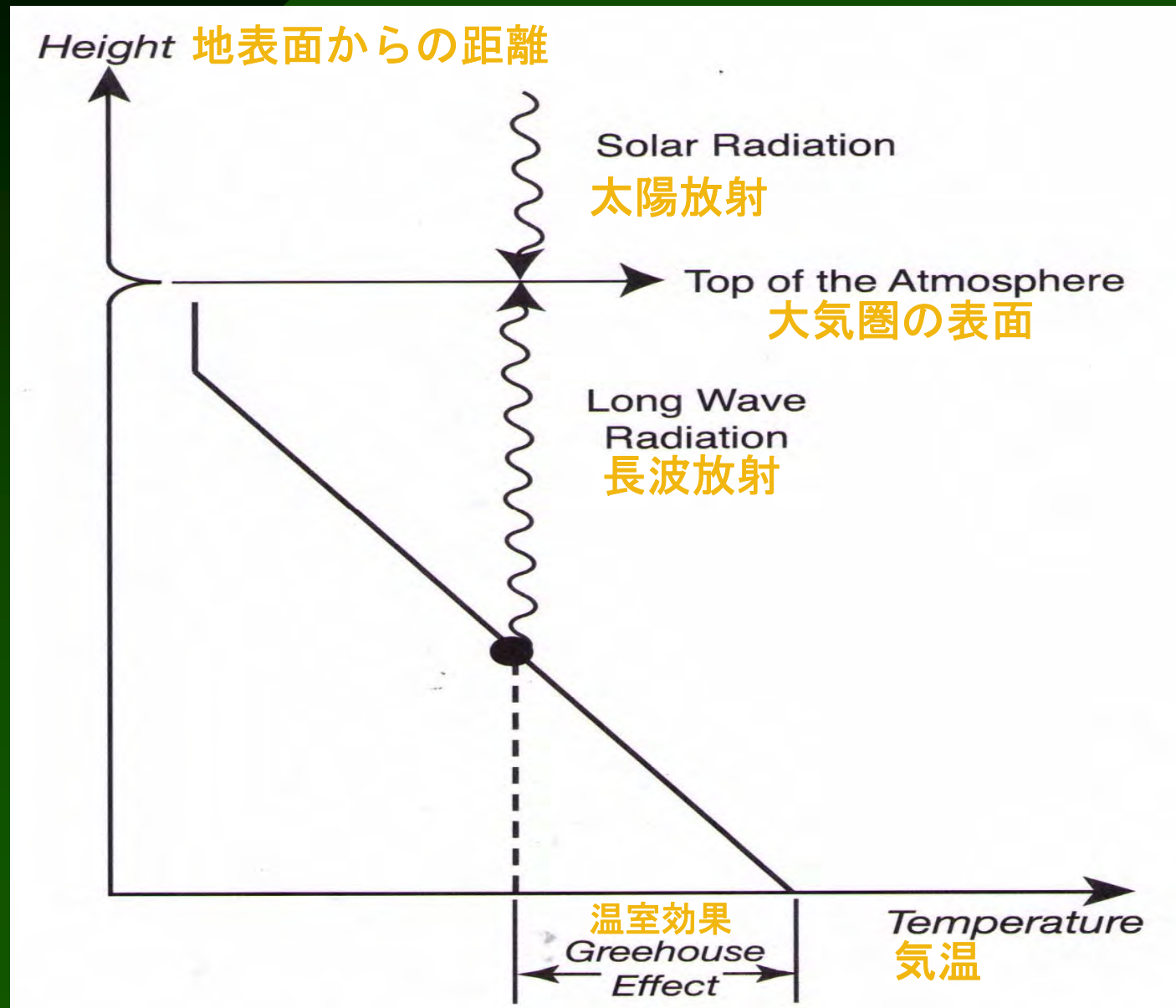
# Radiative Heat Balance of Earth

地球全体としての放射熱収支



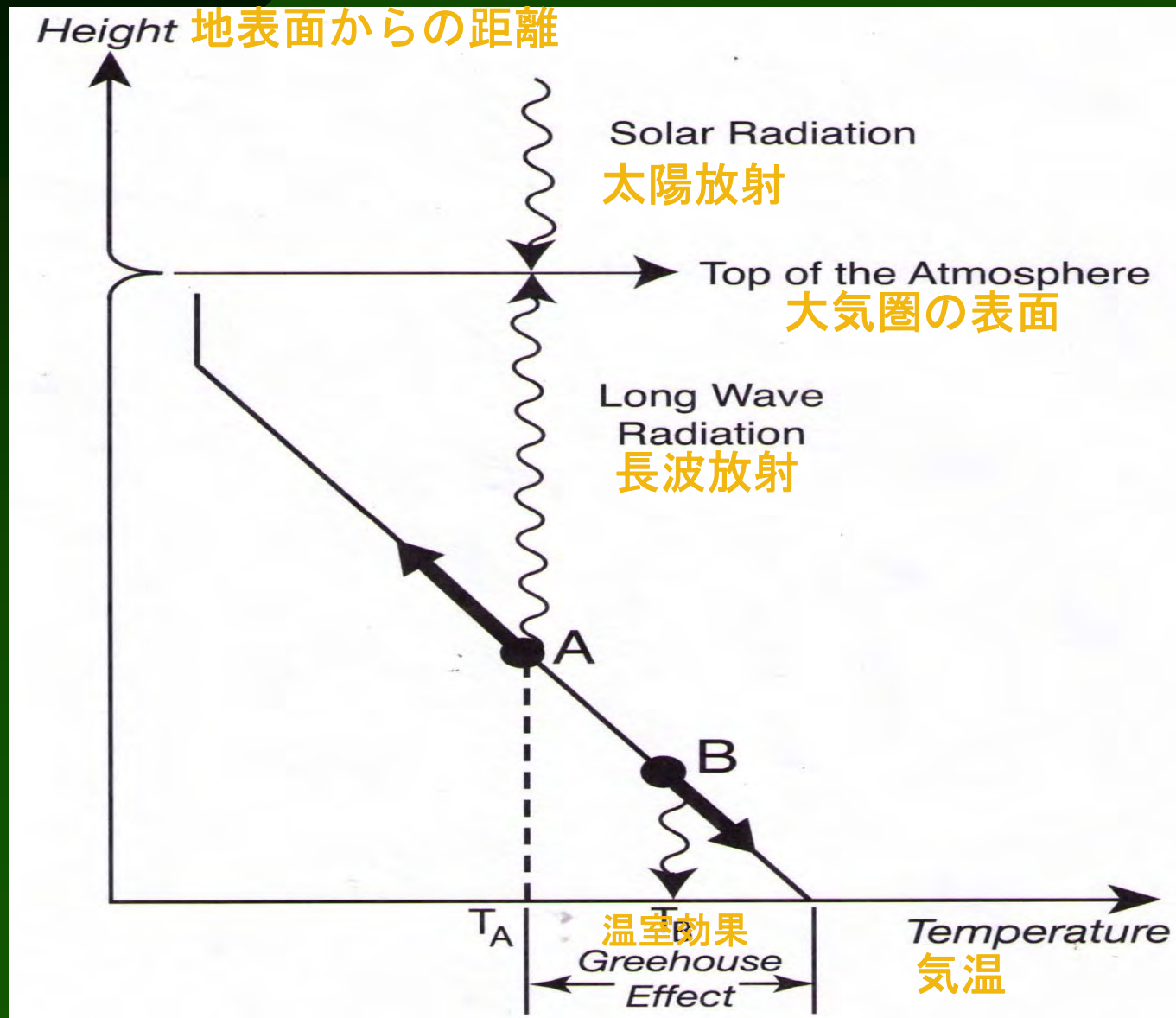
# Greenhouse Effect of the Atmosphere

## 大気による温室効果



# Mechanism of Global Warming

## 地球温暖化のメカニズム





# Residence Time of GHGs

温室効果ガスの滞留時間

- Long residence time:

$\text{CO}_2$ ,  $\text{N}_2\text{O}$ , CFC,  $\text{CH}_4$  -----

二酸化炭素 亜酸化窒素 フロン メタン

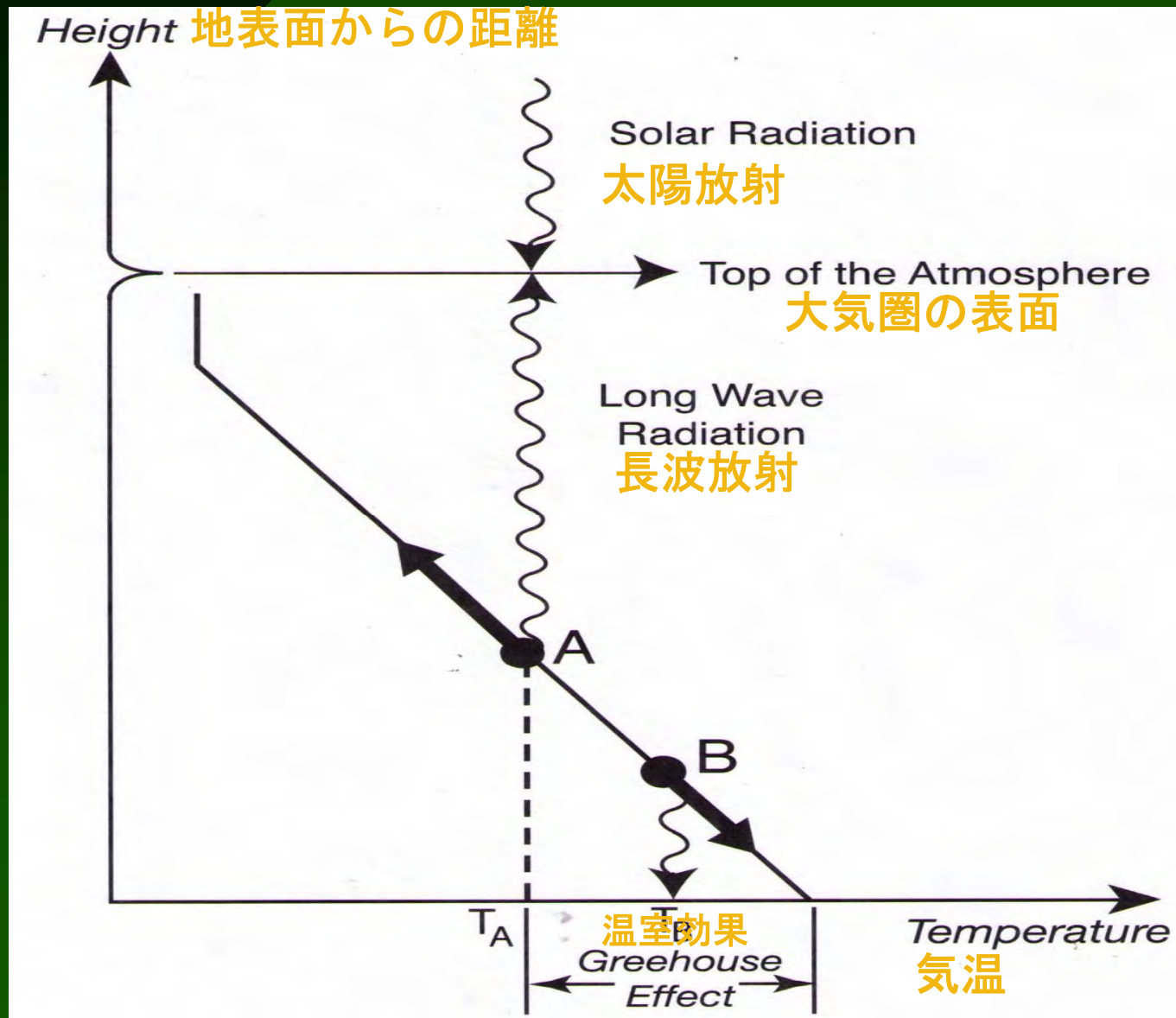
- Short residence time:

$\text{H}_2\text{O} \rightarrow$  Water Vapor Feedback

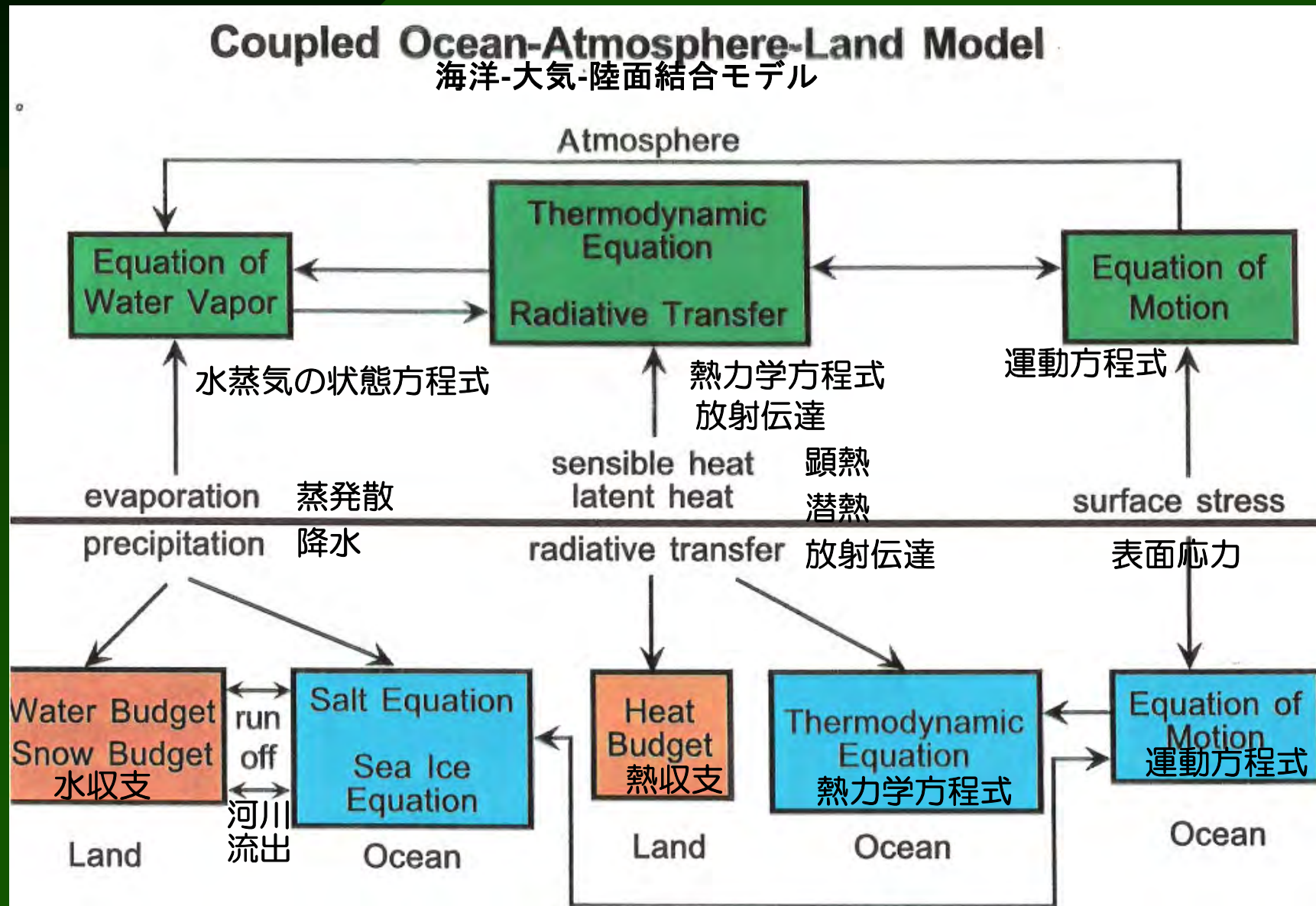
水蒸気フィードバック

# Mechanism of Global Warming

## 地球温暖化のメカニズム

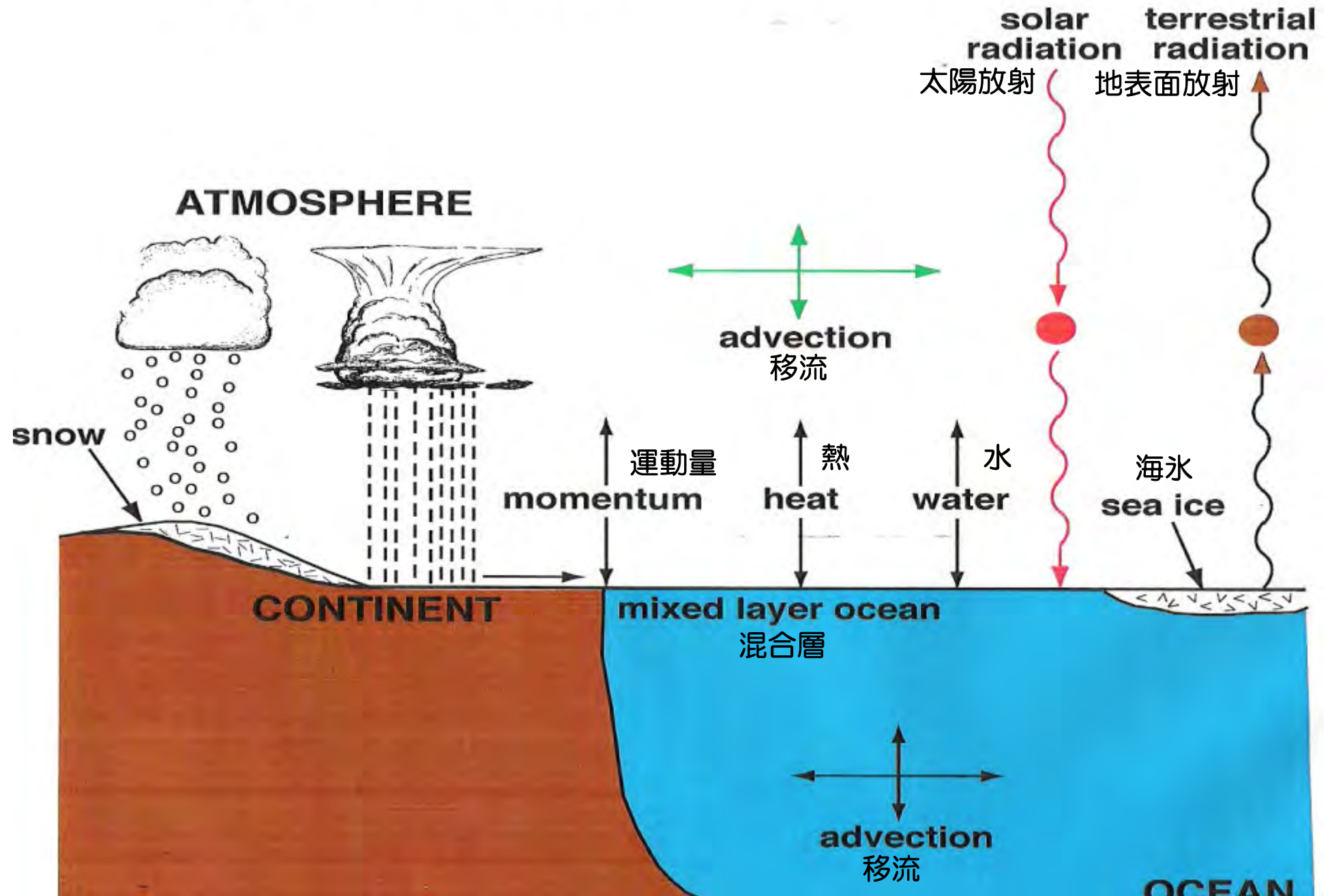


# Manabe & Bryan, 1969



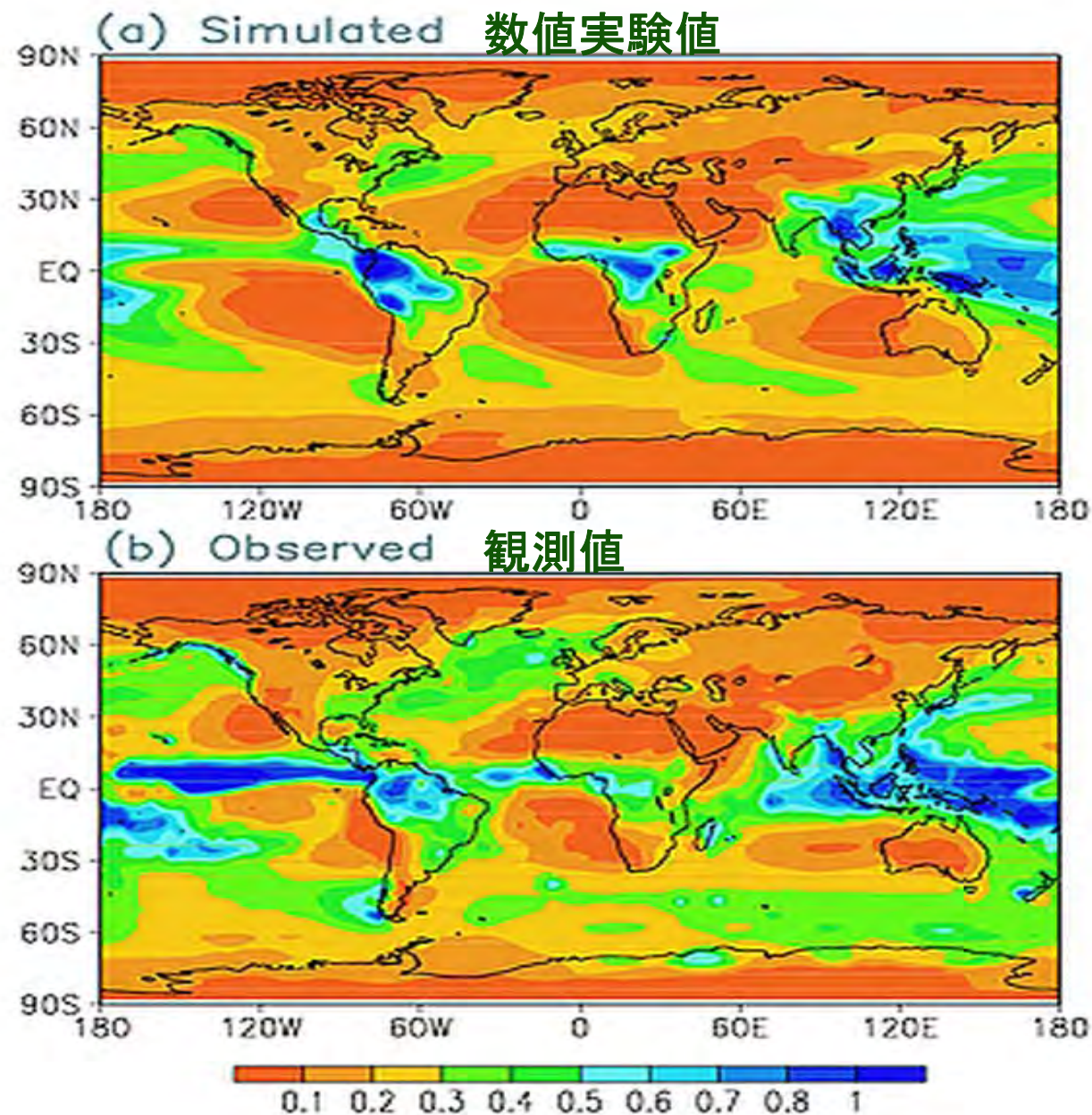


# Physical Processes in a Model



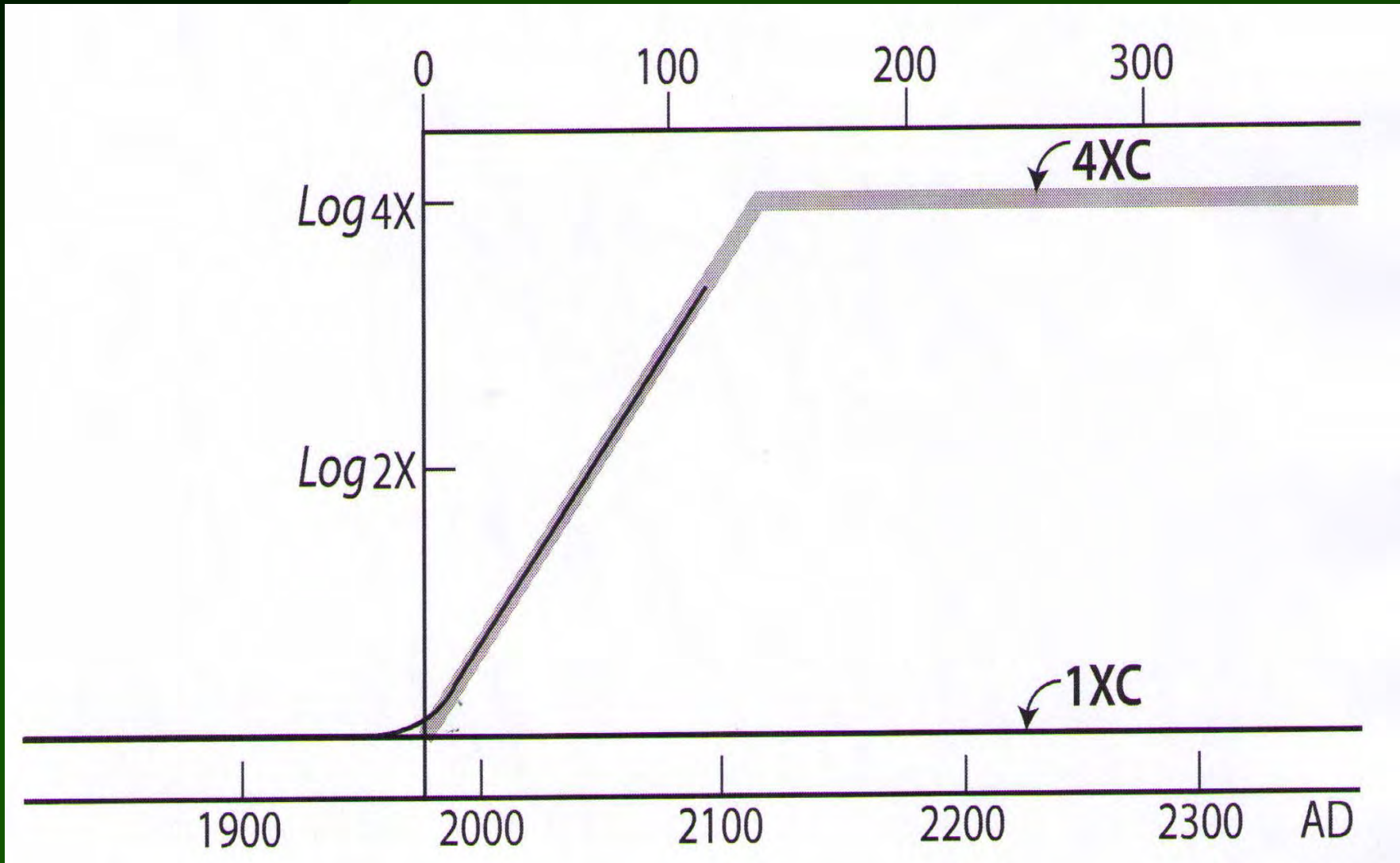
# Annual Mean Precipitation, cm/day

年平均降水量



# Temporal Variation of CO<sub>2</sub>-Input

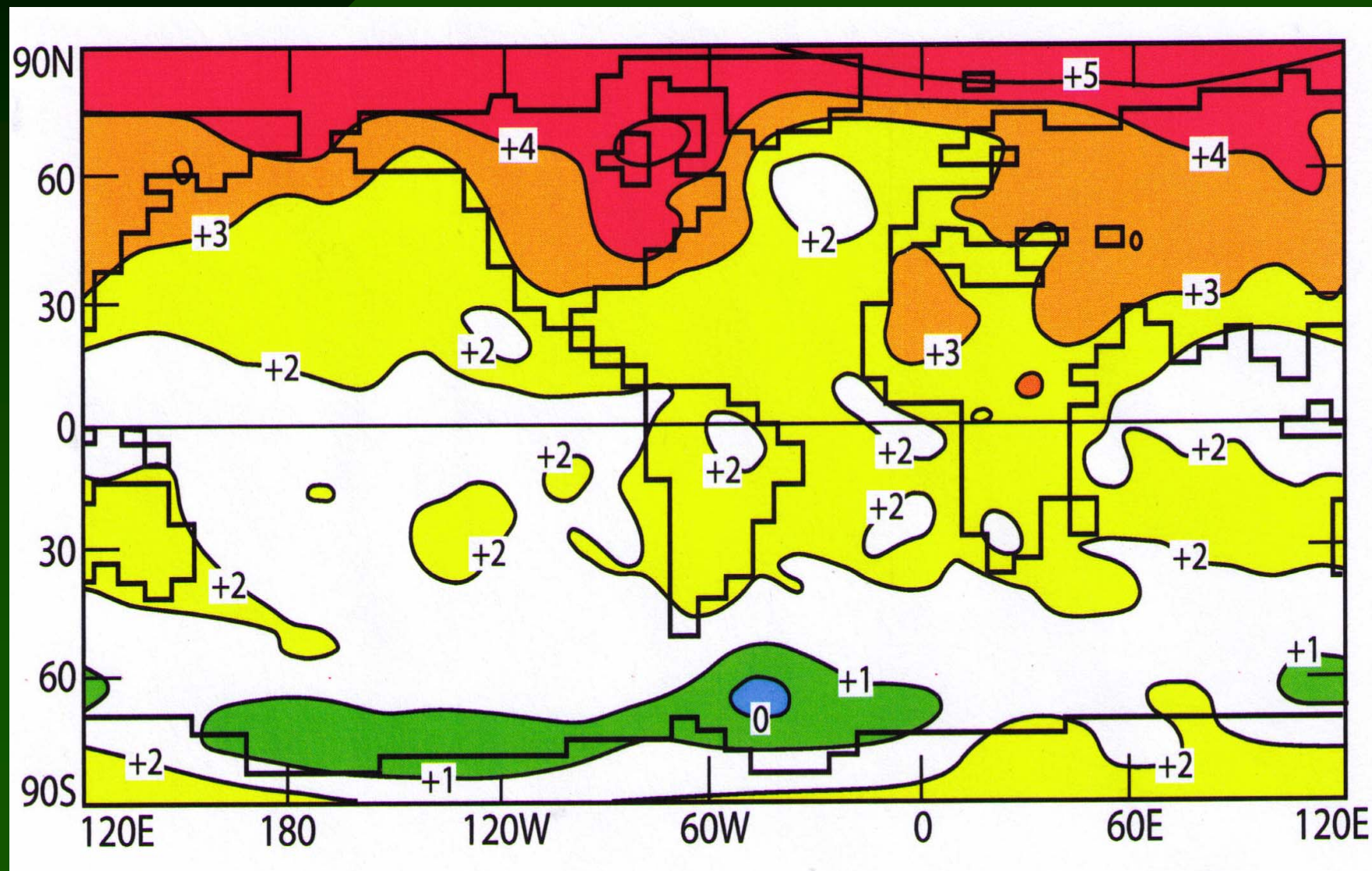
CO<sub>2</sub>濃度の時間変化





# Change in Surface Air Temperature, °C

Stouffer, Manabe, Bryan (1989)

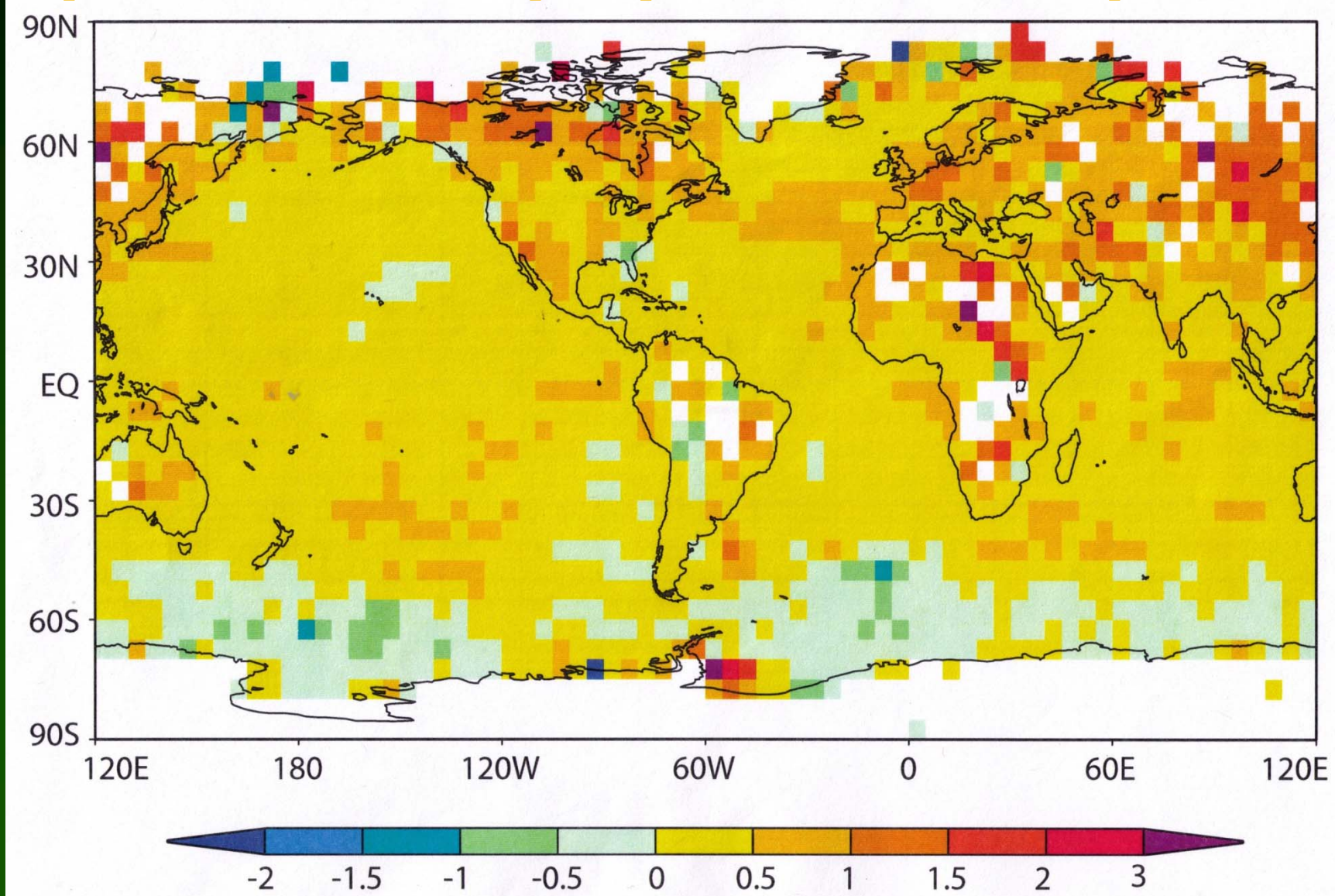




# Surface Temperature Change (°C)

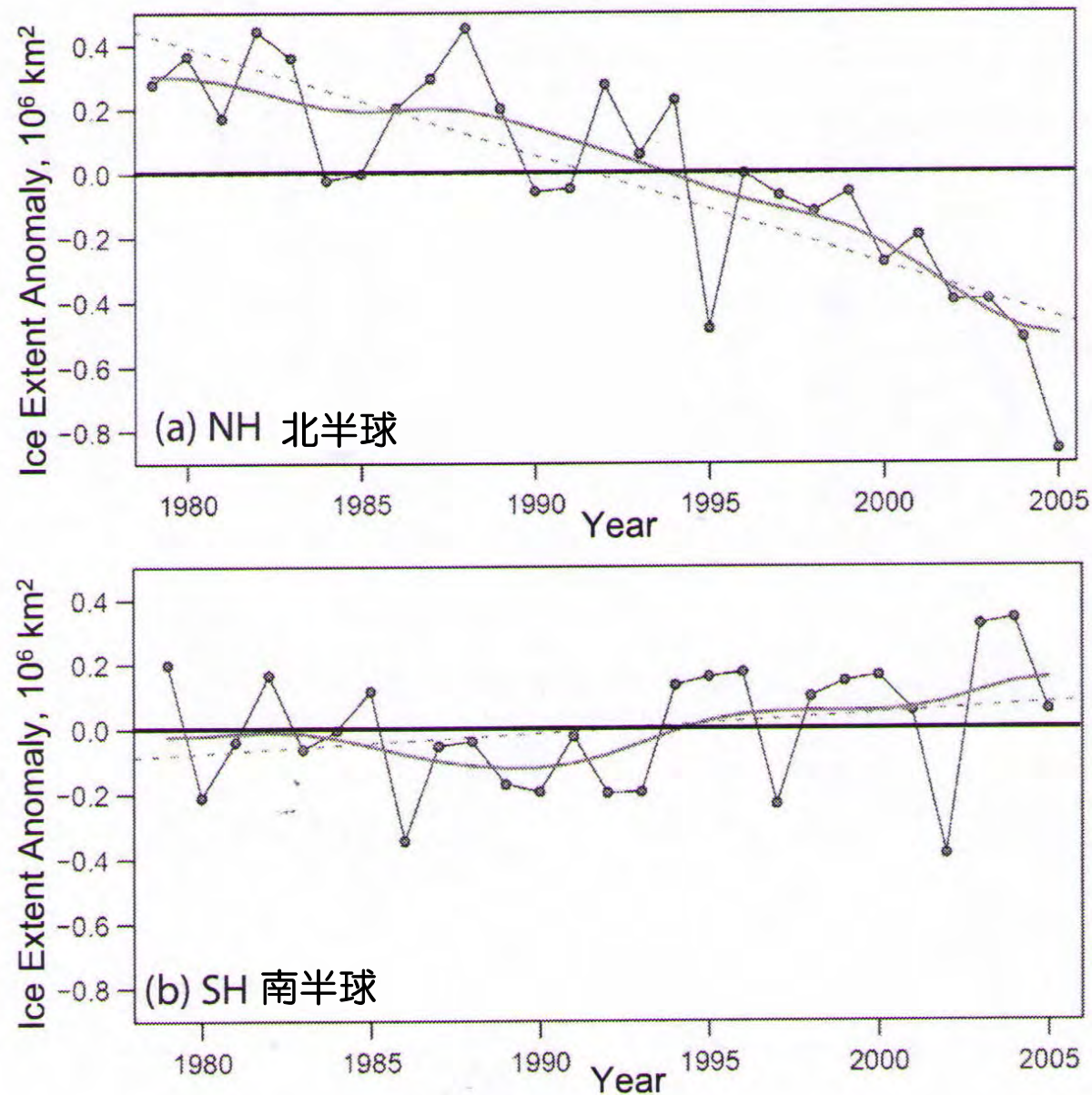
(1991-2011) minus (1960-1990)

[1991~2011年の平均気温] から[1960~1990年の平均気温]を引いた値



# Sea Ice Extent Anomaly, $10^6 \text{ km}^2$

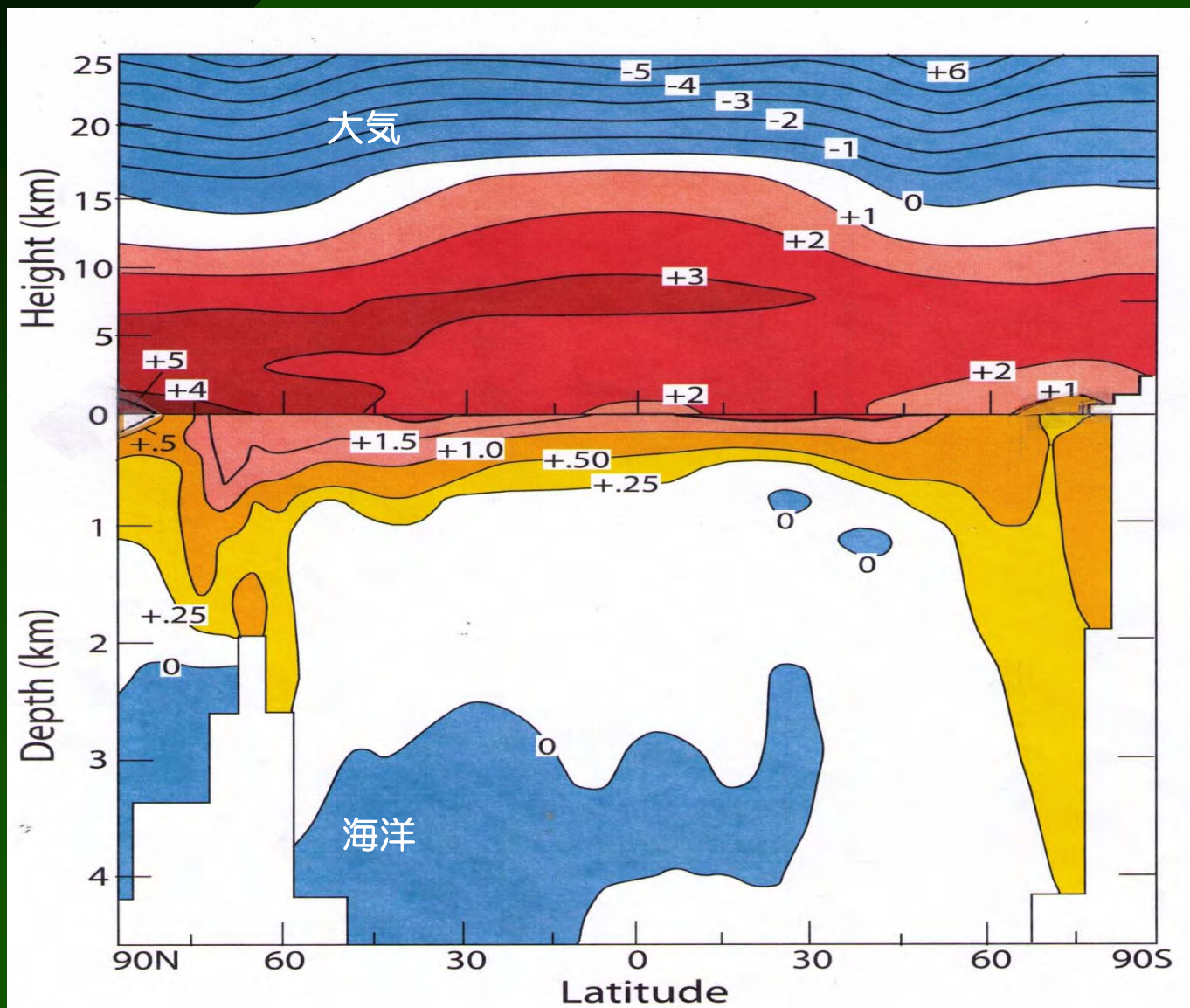
海氷面積の時間変化と偏差





# Zonal Mean Temperature Change, °C

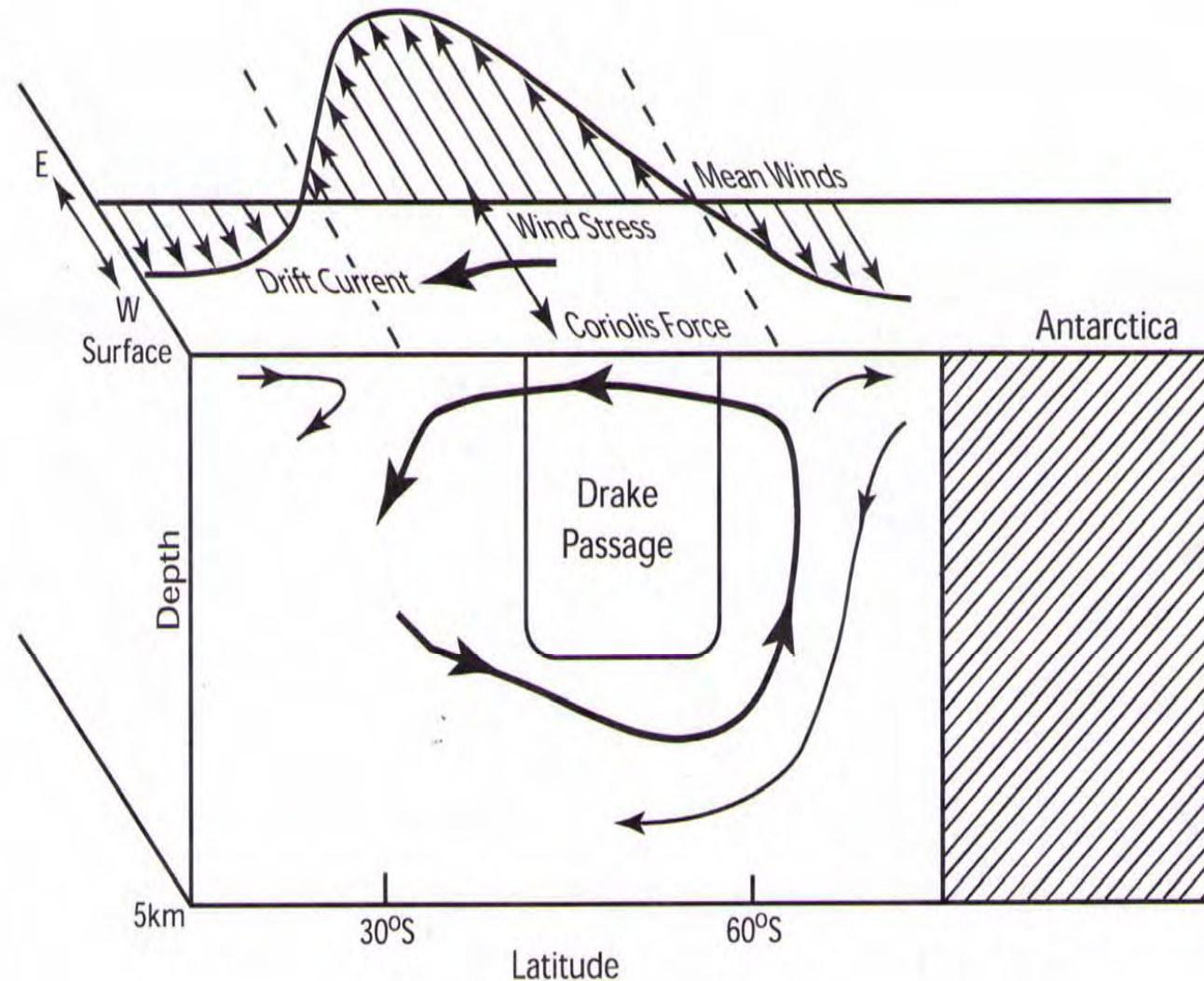
気温・水温の緯度平均値



# Dynamics of Meridional Overturning Circulation in Southern Ocean

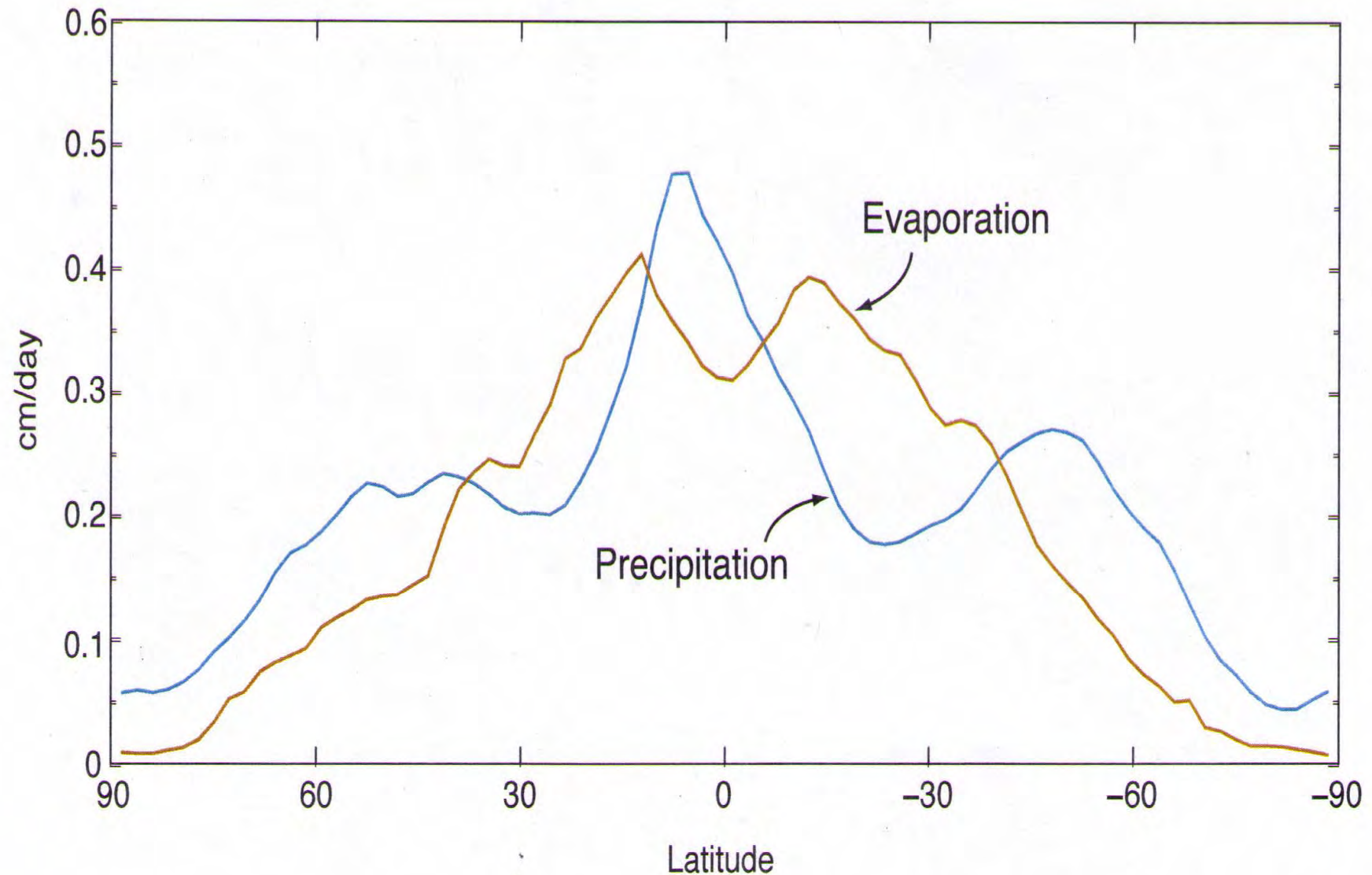
Held, 1993

南極海での子午面循環のダイナミクス



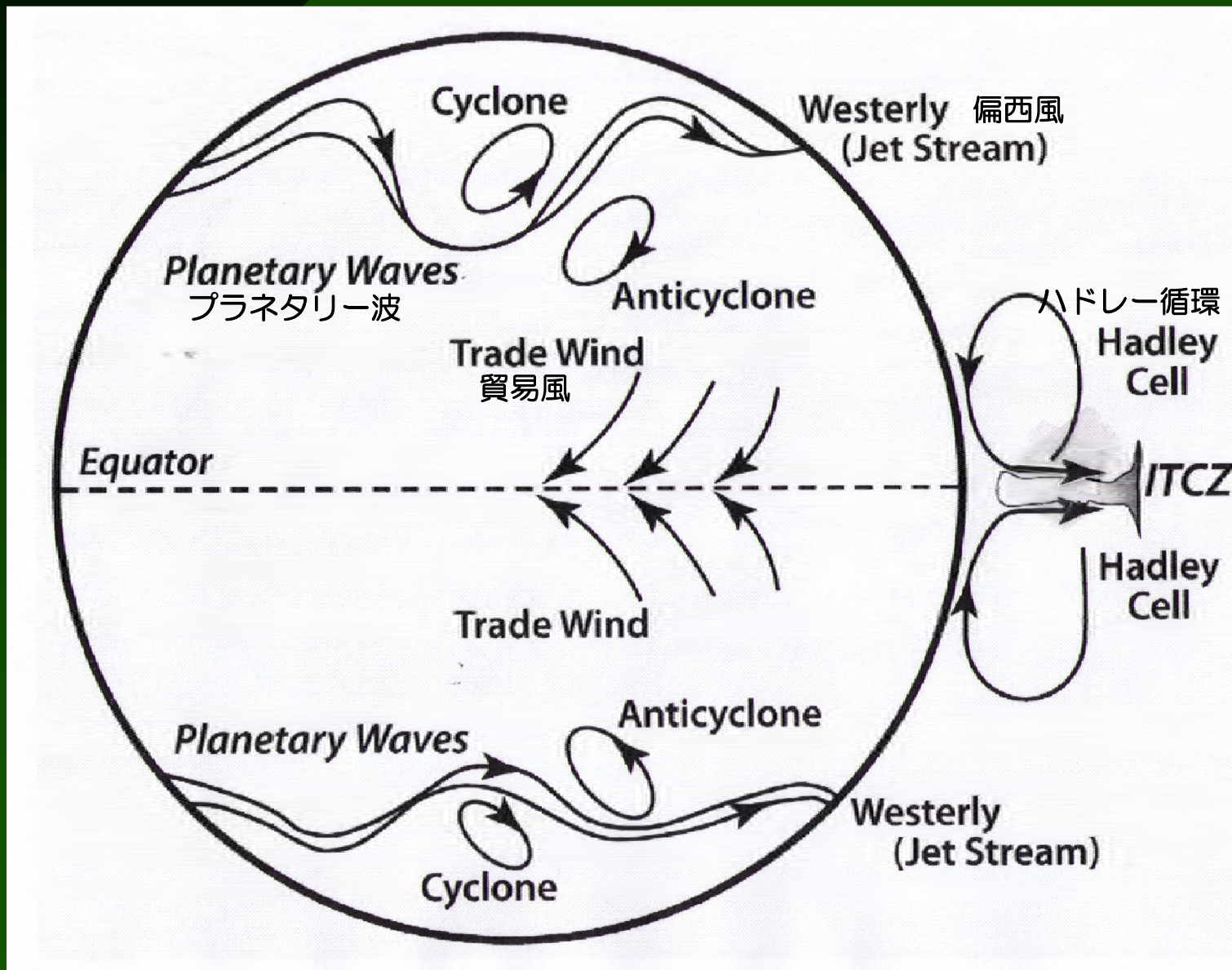
# Precipitation & Evaporation, Simulated

降水量と蒸発量の緯度平均値（シミュレーション）



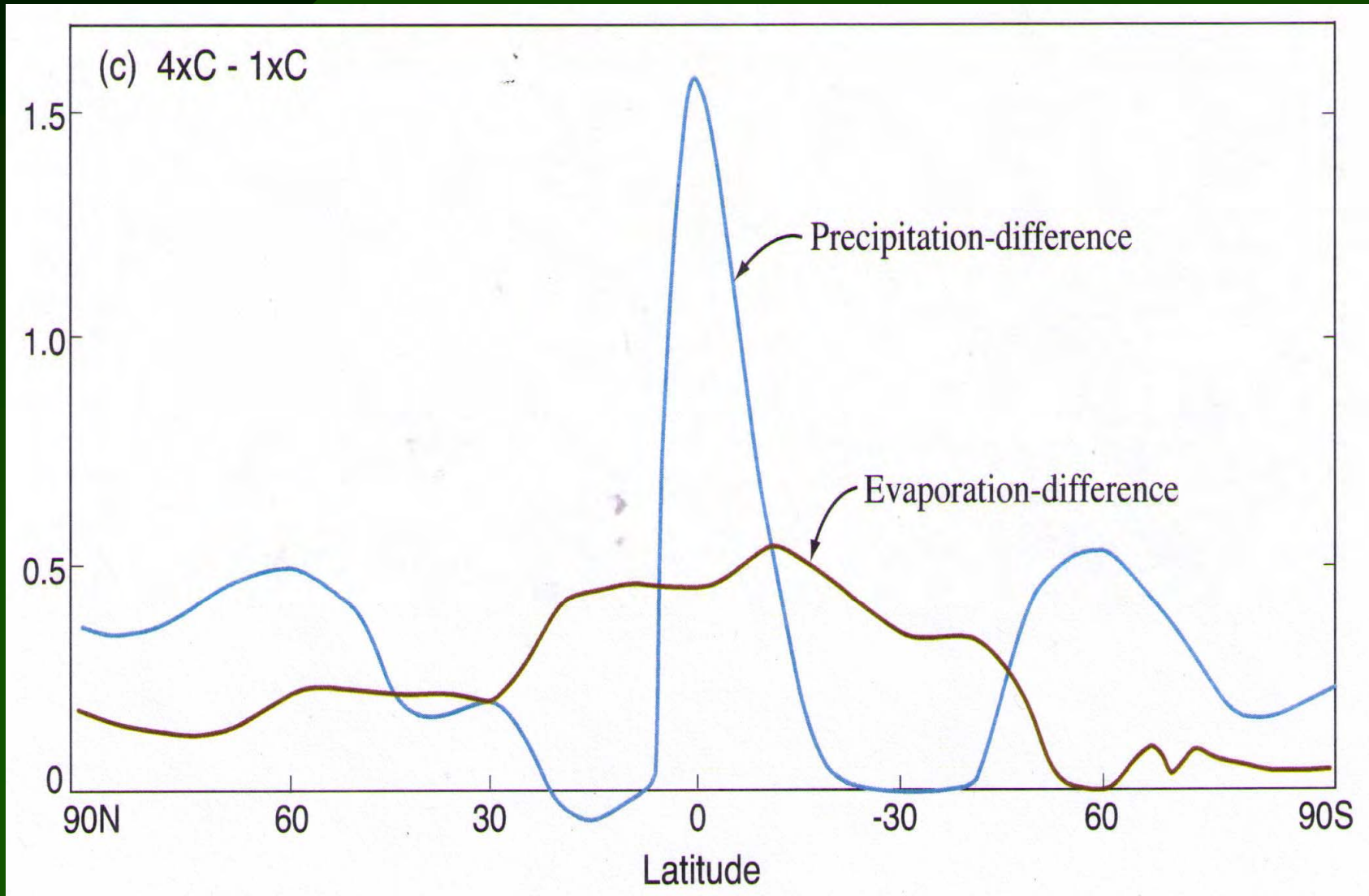


# Atmospheric Circulation 大気循環



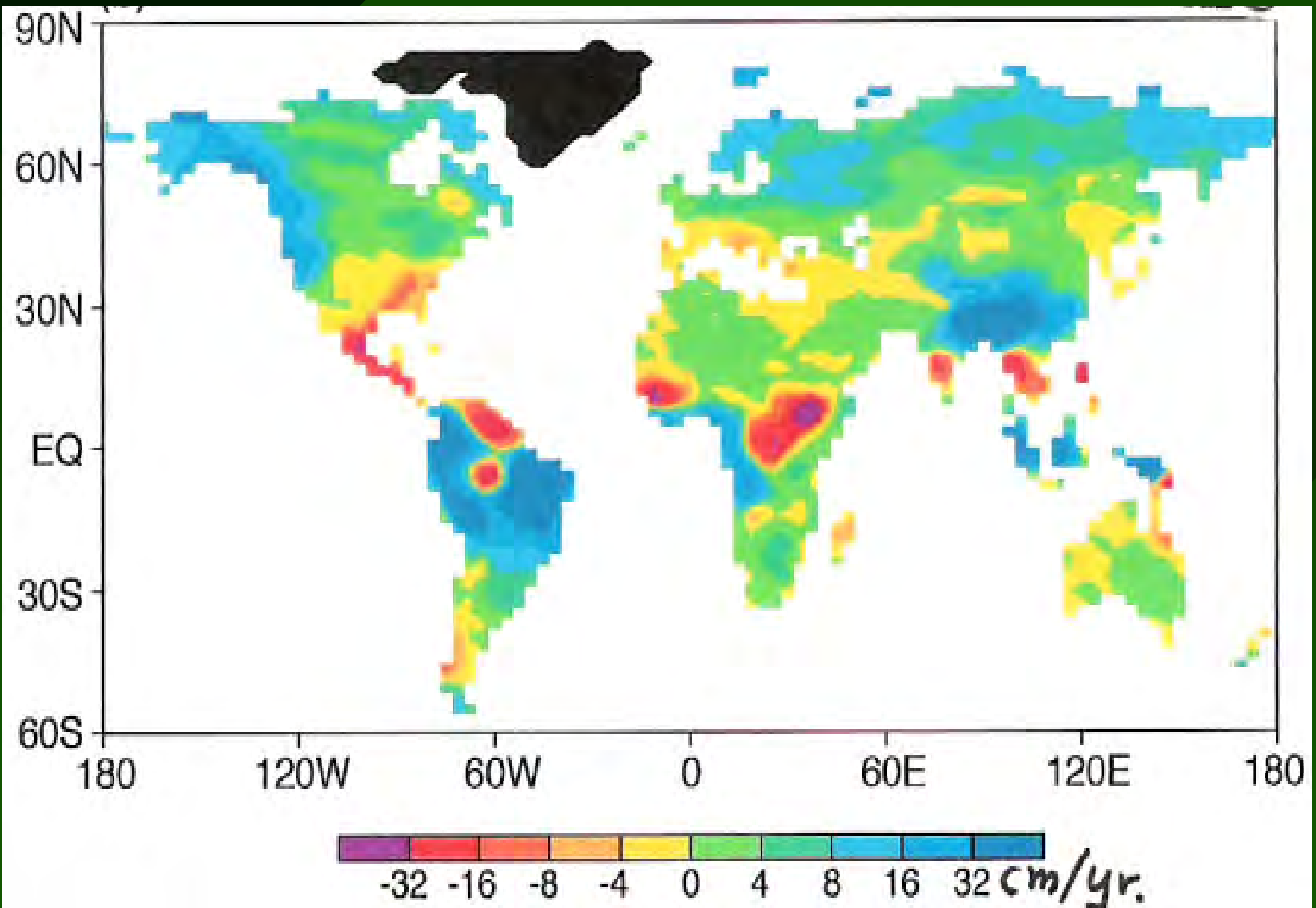
# Change due to CO<sub>2</sub>-Quadruppling

CO<sub>2</sub>濃度を4倍にした時の変化量の緯度平均（シミュレーション）



# Change in Annual Mean Runoff due to 4xCO<sub>2</sub>

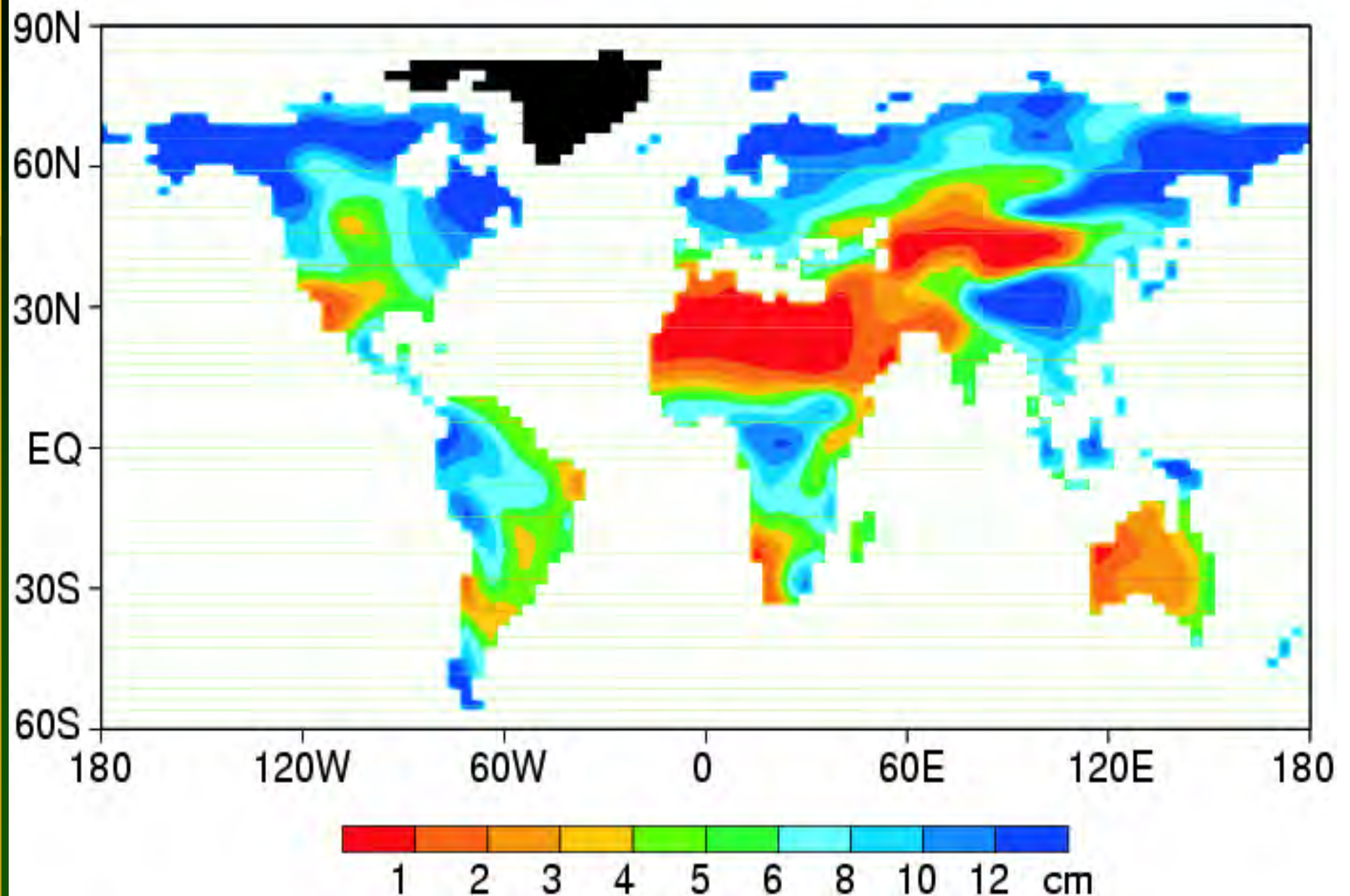
CO<sub>2</sub>排出量を4倍にした時の年平均河川流量の変化（シミュレーション）  
Manabe, Milly, & Wetherald, 2004



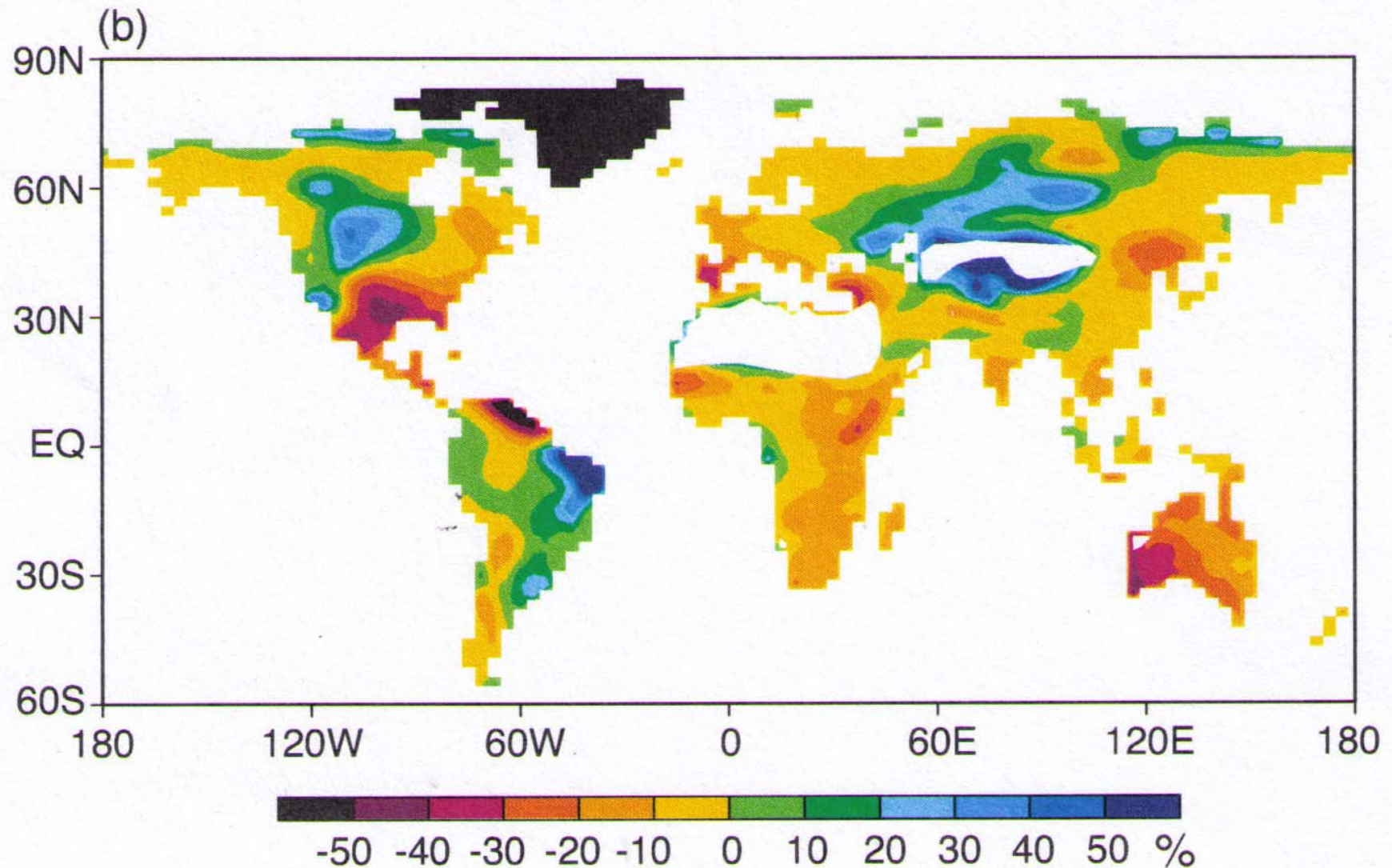


# Simulated Distribution of Soil Moisture

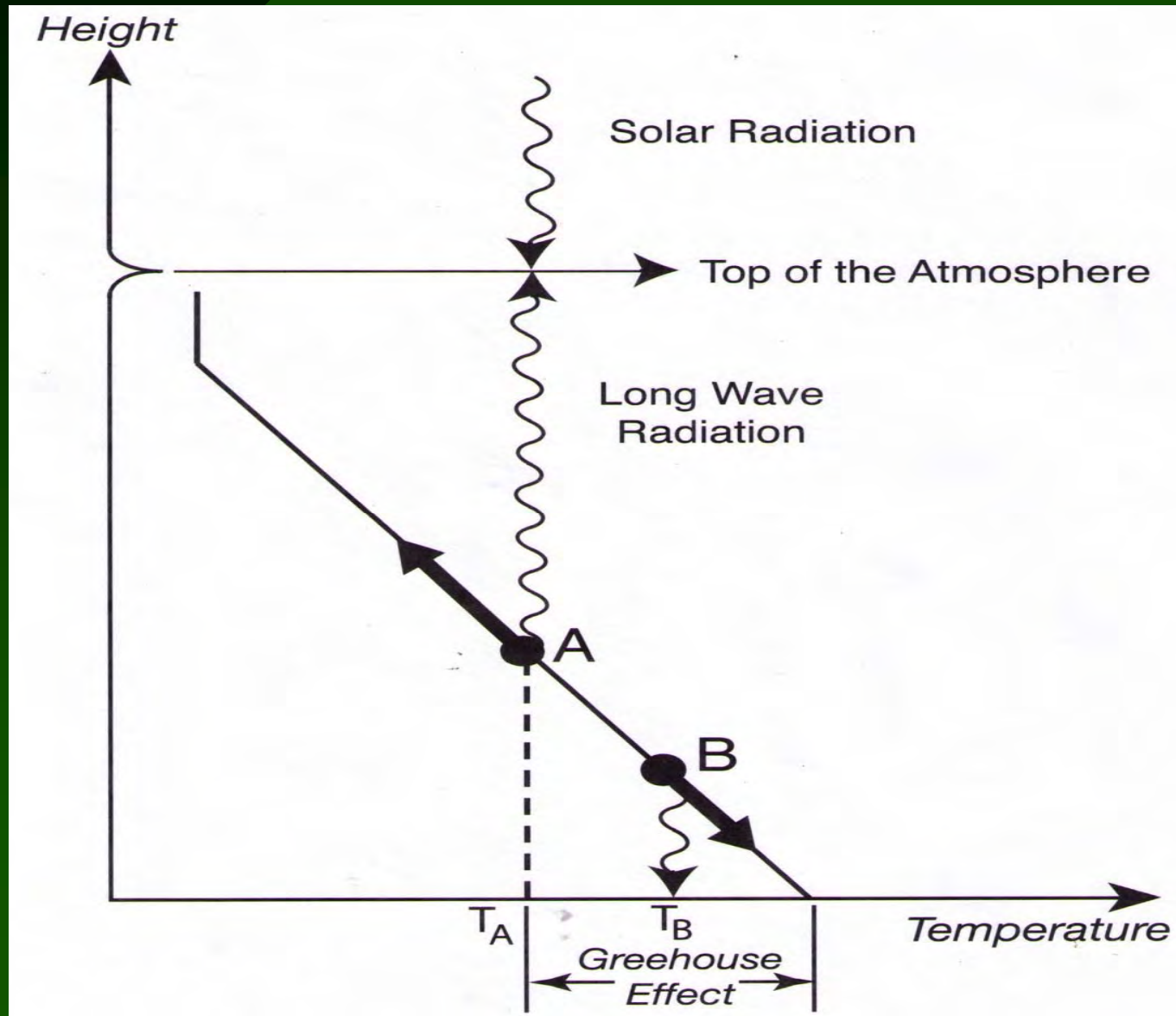
CO<sub>2</sub>排出量を4倍にした時の 年平均土壌水分量 (シミュレーション)



## Change (percentage of pre-industrial value) in Annual Mean Soil Moisture ( $4\times\text{CO}_2$ )

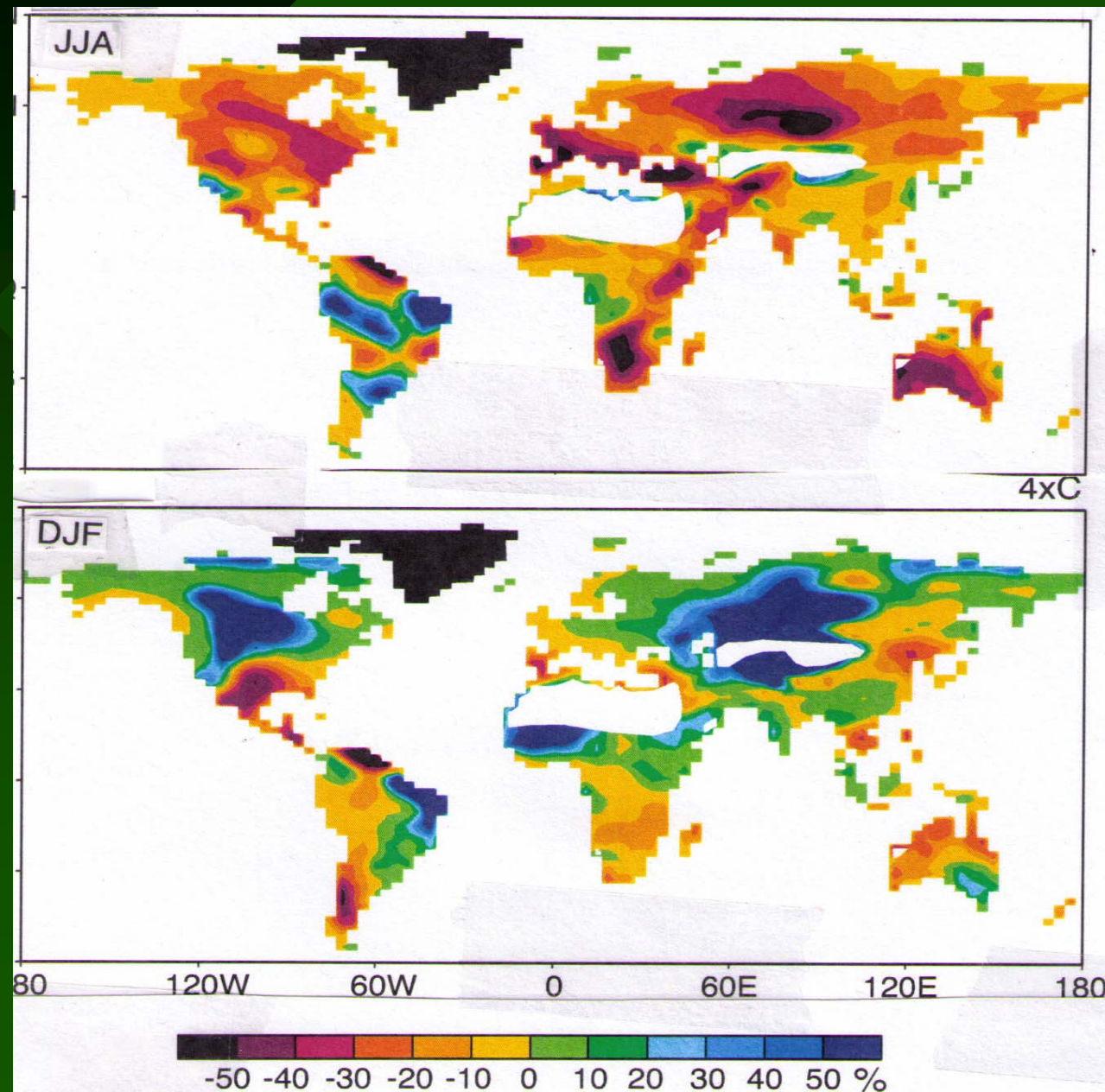


# Mechanism of Global Warming





## Seasonal Contrast of of soil Moisture Change (%)



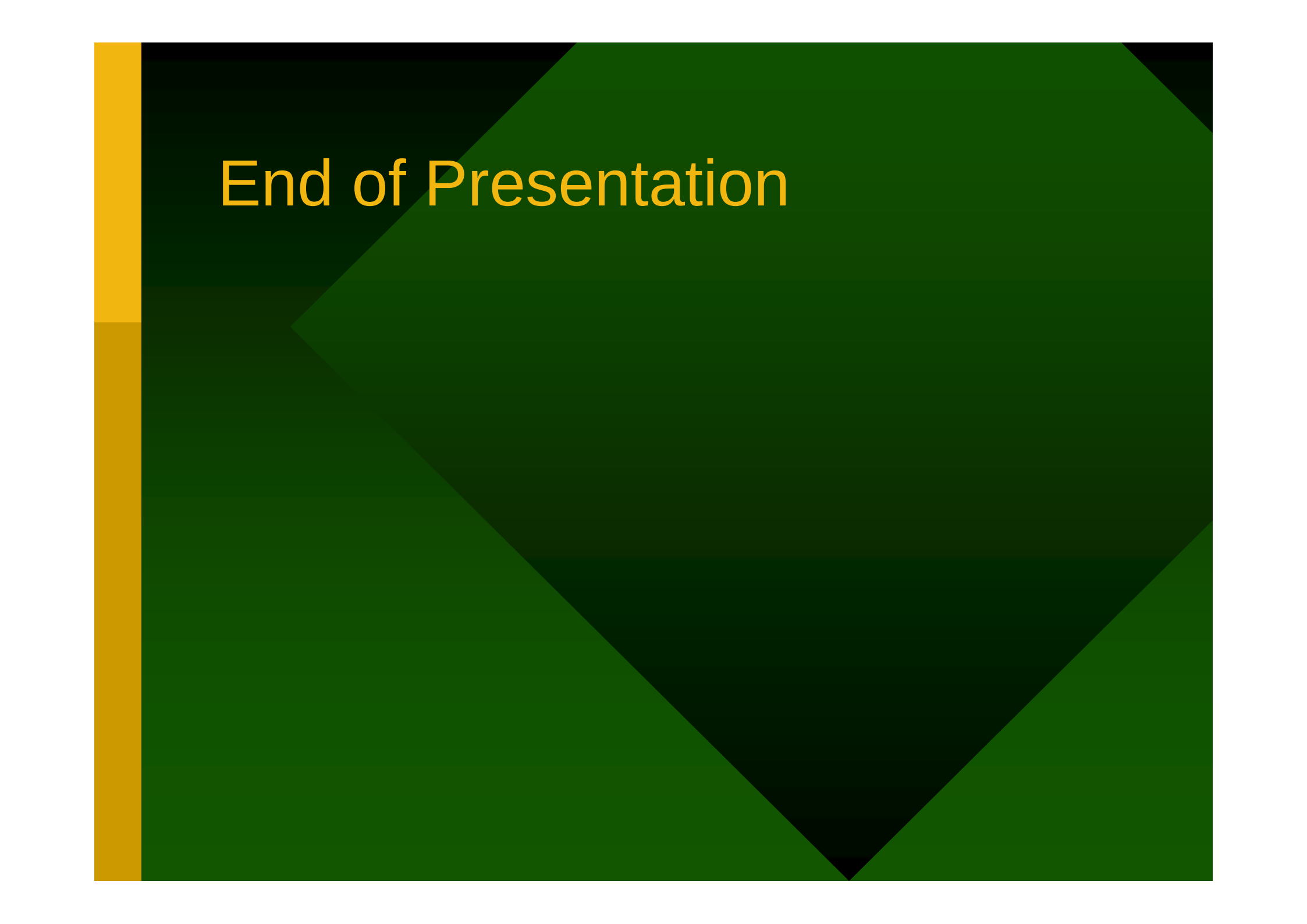
# Summary

- Enhance the Existing Contrast between Water-Rich and Water-Poor Regions of the World
- Present very serious challenge to the water resources managers of the world
- Long-term, global-scale monitoring of the Earth System

# Climatic Impacts in Japan

- Increasing frequency of heavy rainfall and flooding during the late baiu- and typhoon season
- Reduction and early disappearance of snow cover over mountains
- Increasing hot summer days
- Increasing price of Agricultural Imports ?
- Increasing agricultural productivity in northern Japan?



The slide features a dark green background with a large, lighter green geometric shape resembling a stylized arrow pointing left. A vertical yellow bar is positioned on the left side of the slide.

End of Presentation