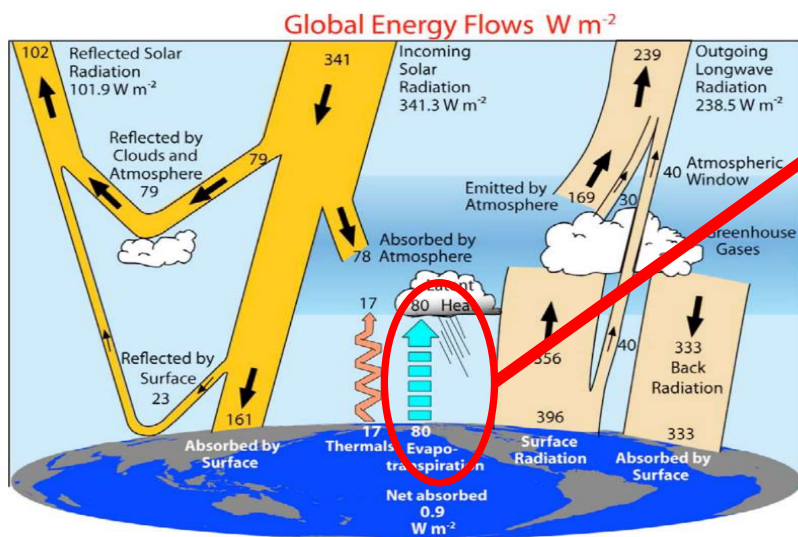
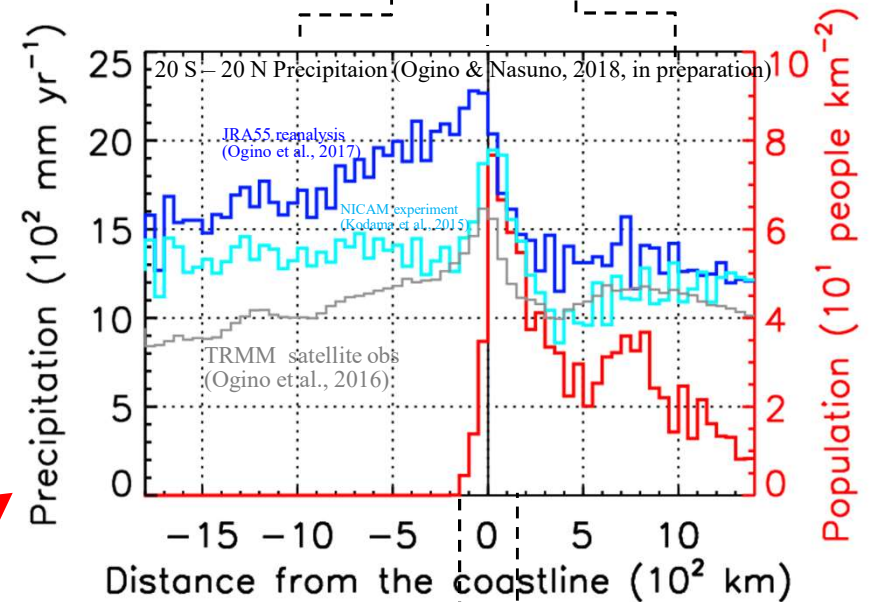
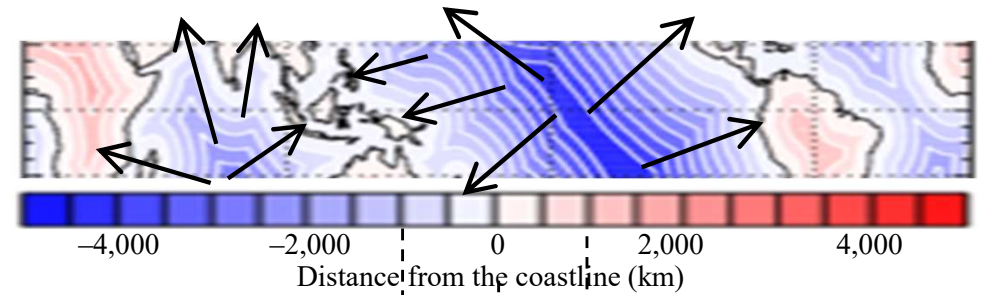


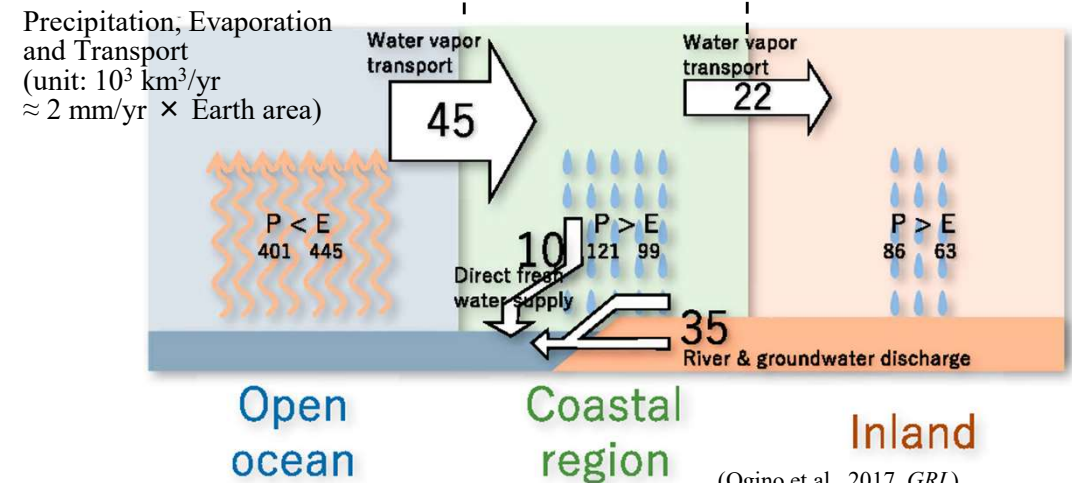
Appendix: Climate-human activity interaction

Rainfall & latent heat centered near tropical coast
 ↓
 Fresh water provided by rainfall
 ↓
 Biosphere restricted by fresh water
 ↓
 Human activity encroaching biosphere
 ↓
 Land use modified by human activity
 ↓
 Clouds & sea-land breezes controlled by land use



(Trenberth et al., 2009, IPCC)

80 W/m²
 ≈ 1000 mm/yr

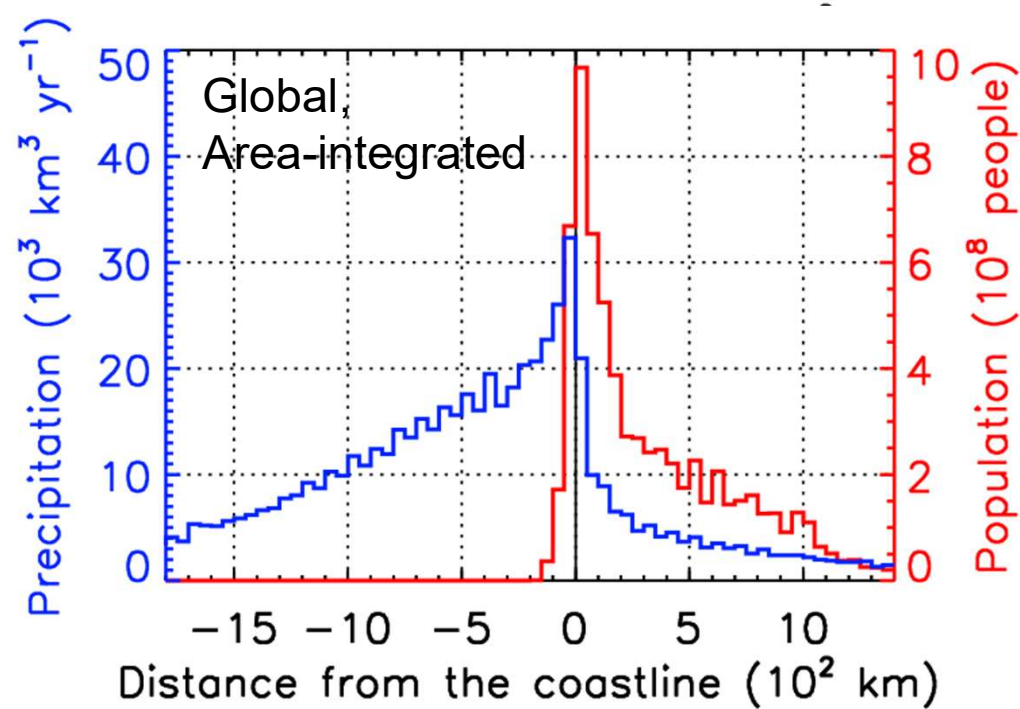
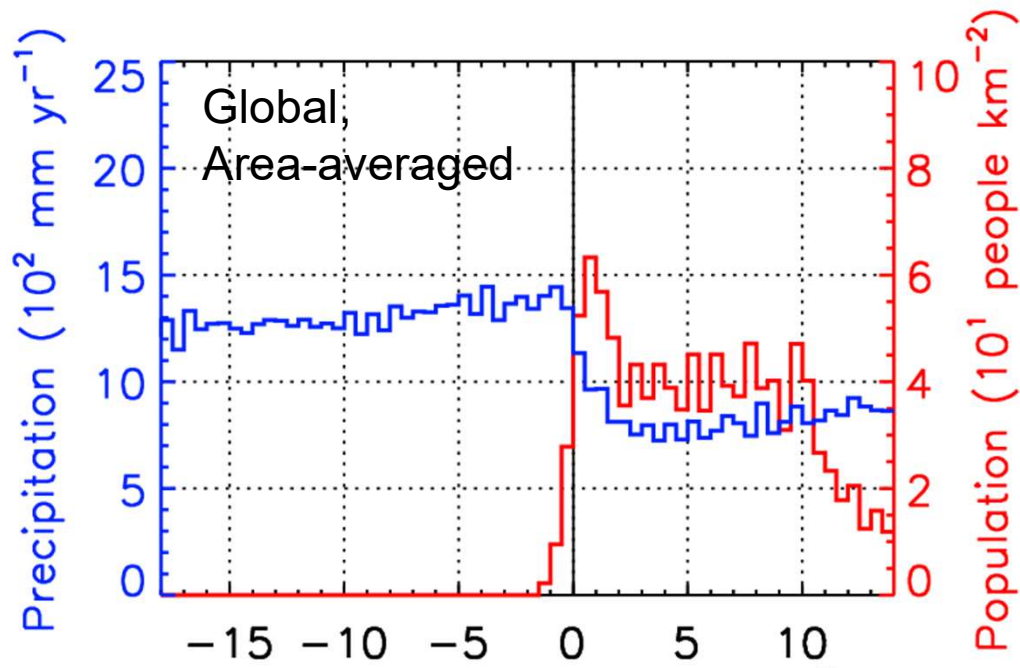


(Ogino et al., 2017, GRL)

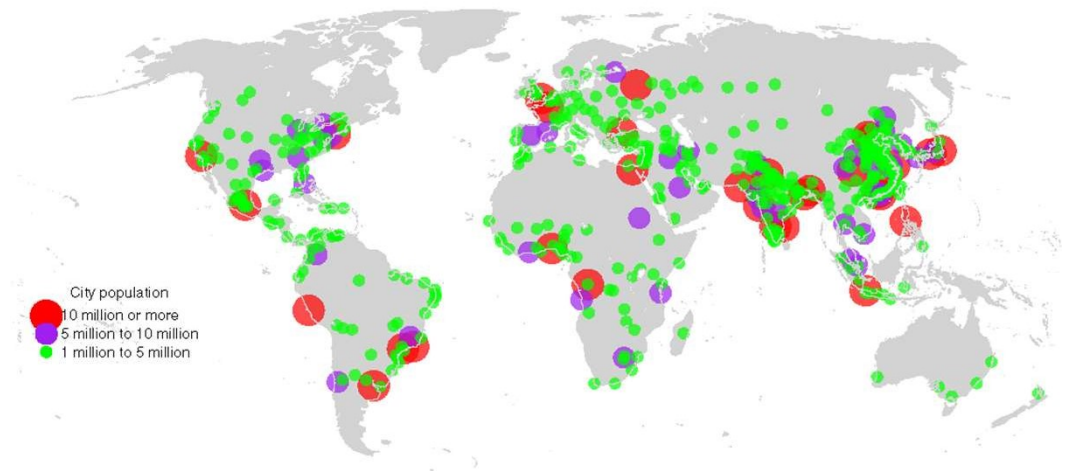
Rainfall-Population relation

as function of DFC

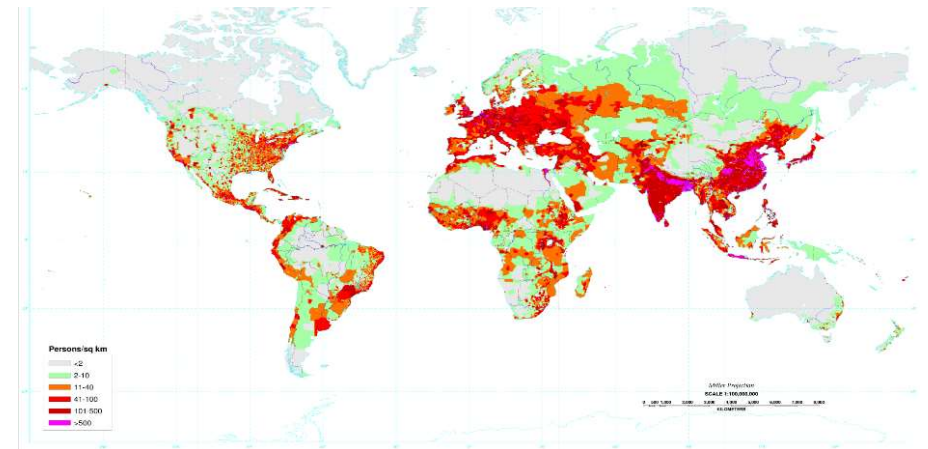
(Ogino, 2018, personal communication)



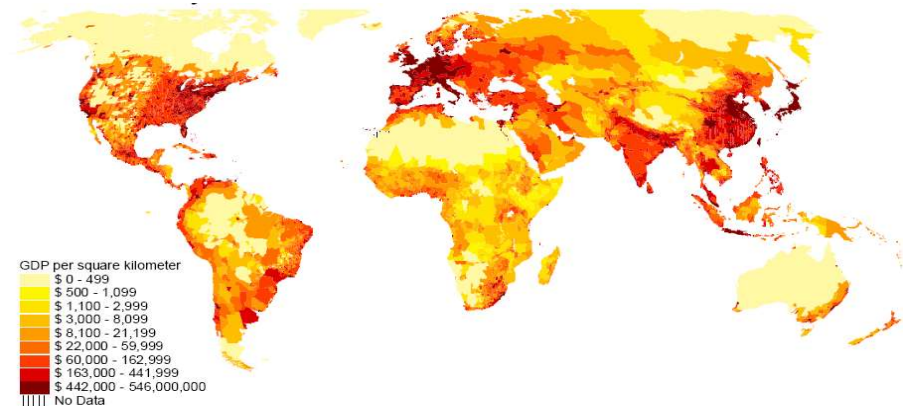
Megacities in 2016 (UN, 2016)



Population density in 1994 (Gallup e al., 1999; USDA, 2000)



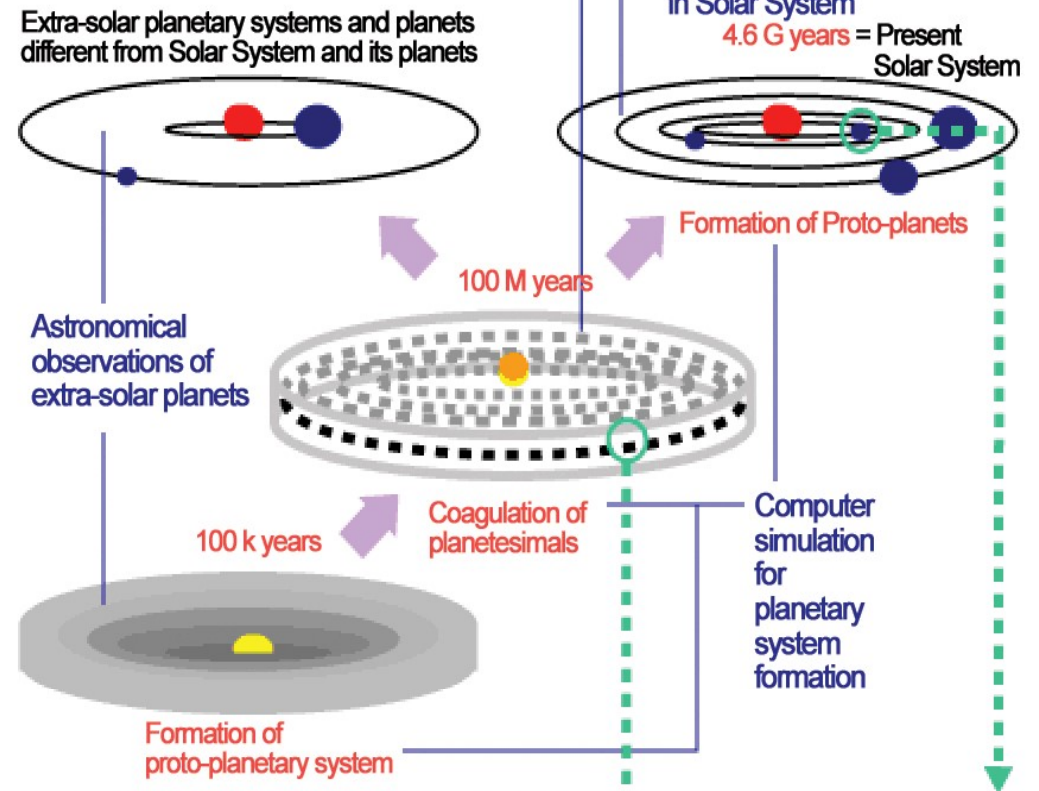
GDP density in 1995 (Gallup e al., 1999)



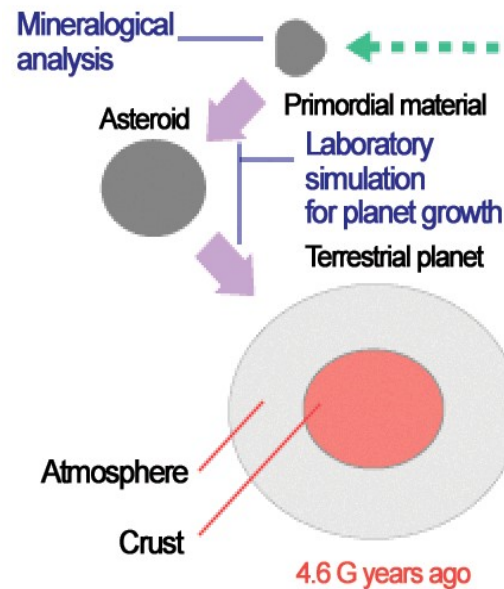
7.2. History of the Earth system

- Universe:
13.7 billion years
- Solar System (Planets):
4.5 billion years
- Earth with continents, oceans & lives
- Sufficient Oxygen and Landing of lives
400 million years
- Human beings
5 million years

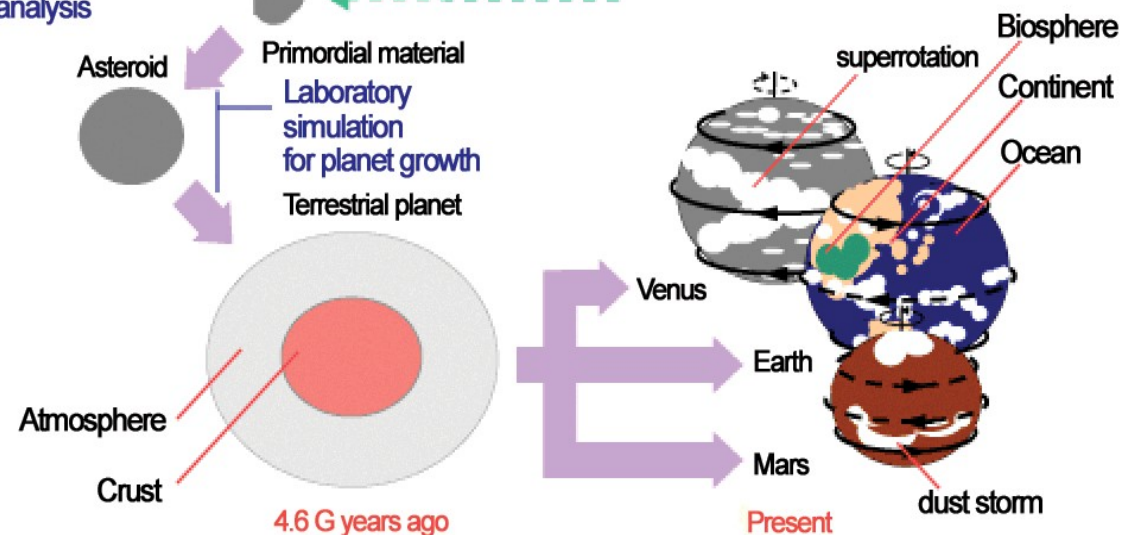
(1) Origin of Planetary Systems



(2) Evolution of primordial material

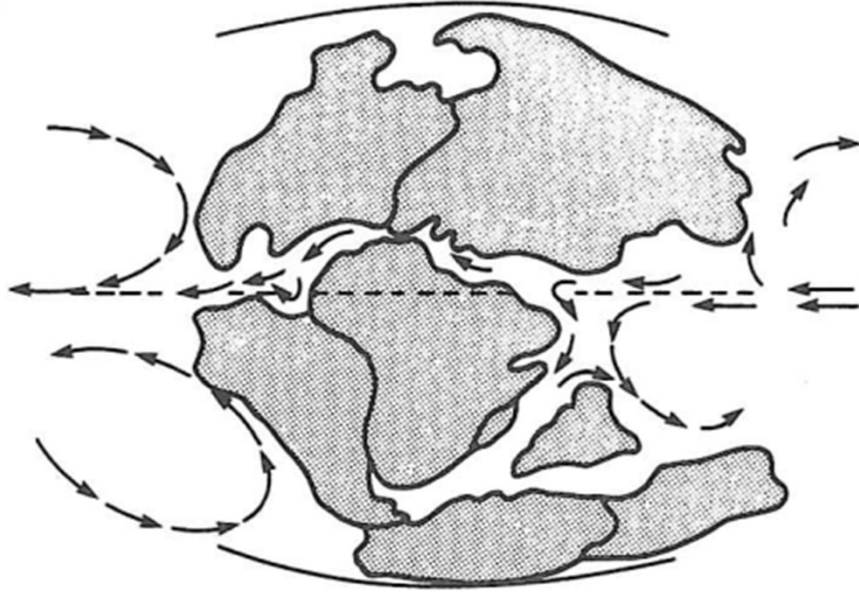


(3) Diversity of planets



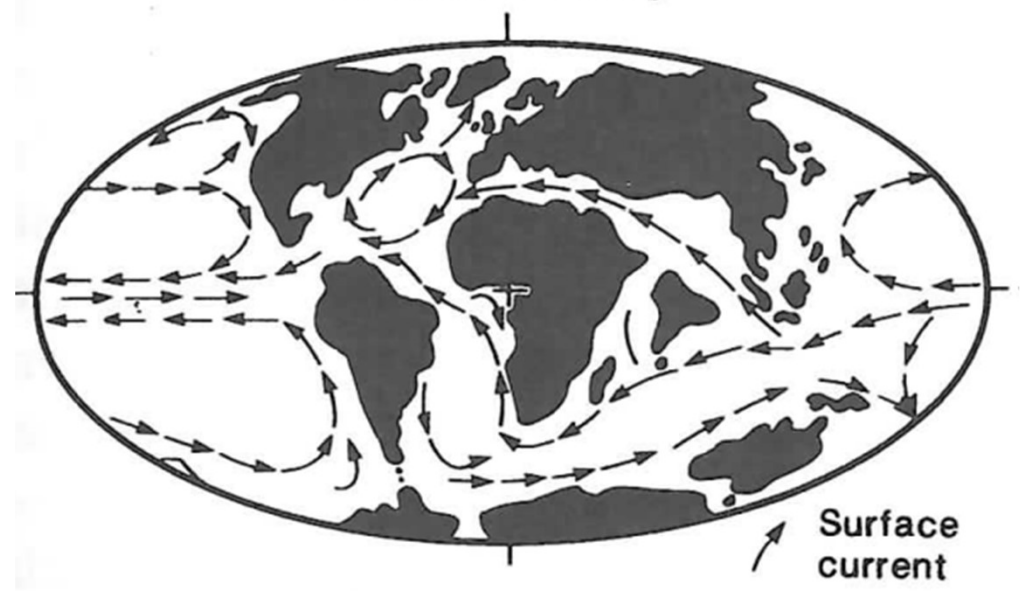
Jurassic 175 my

(a)

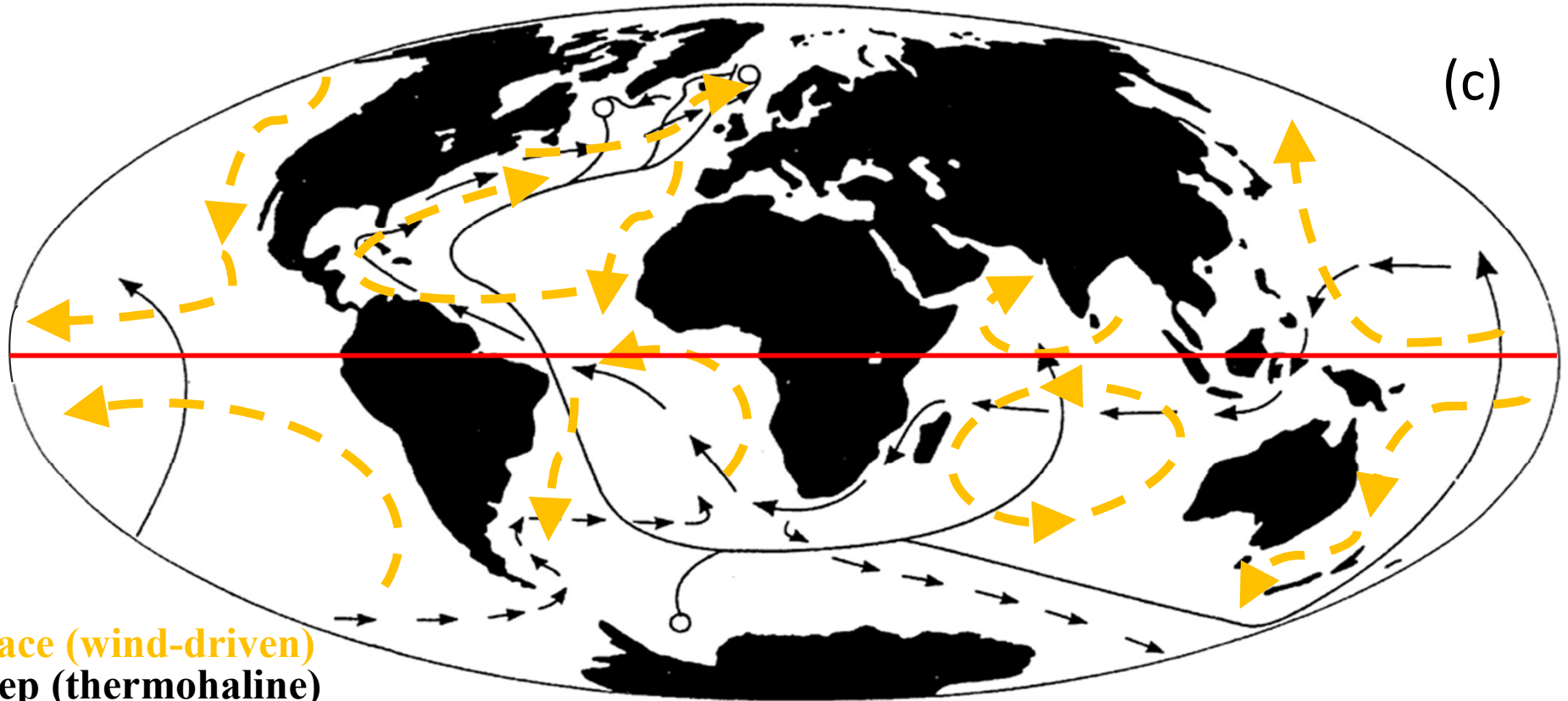


Paleocene 60my

(b)



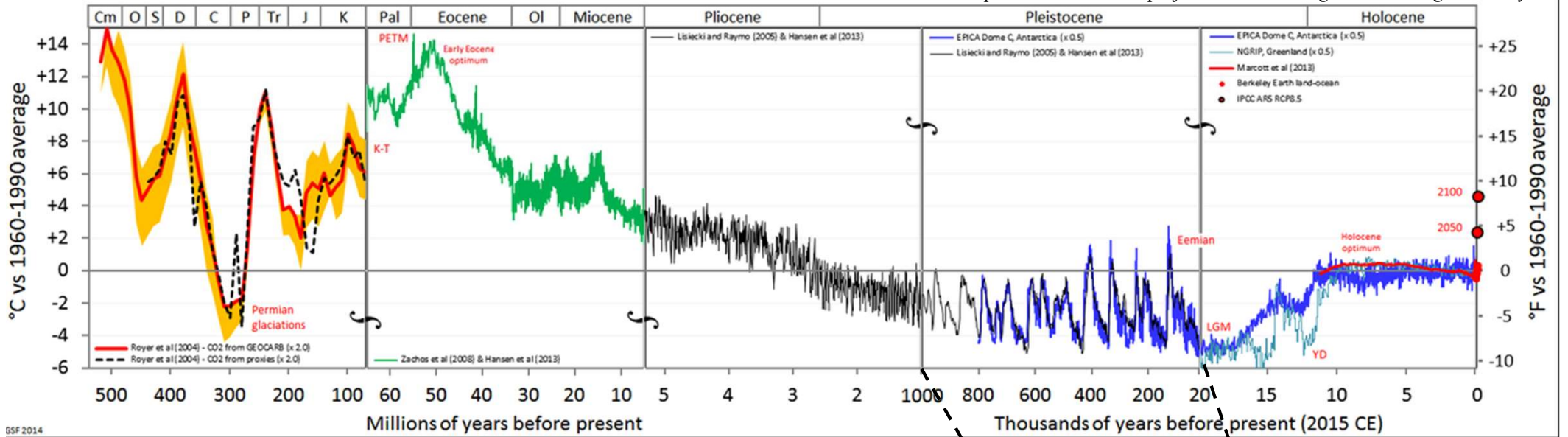
(c)



Surface (wind-driven)
& deep (thermohaline)

Temperature of Planet Earth

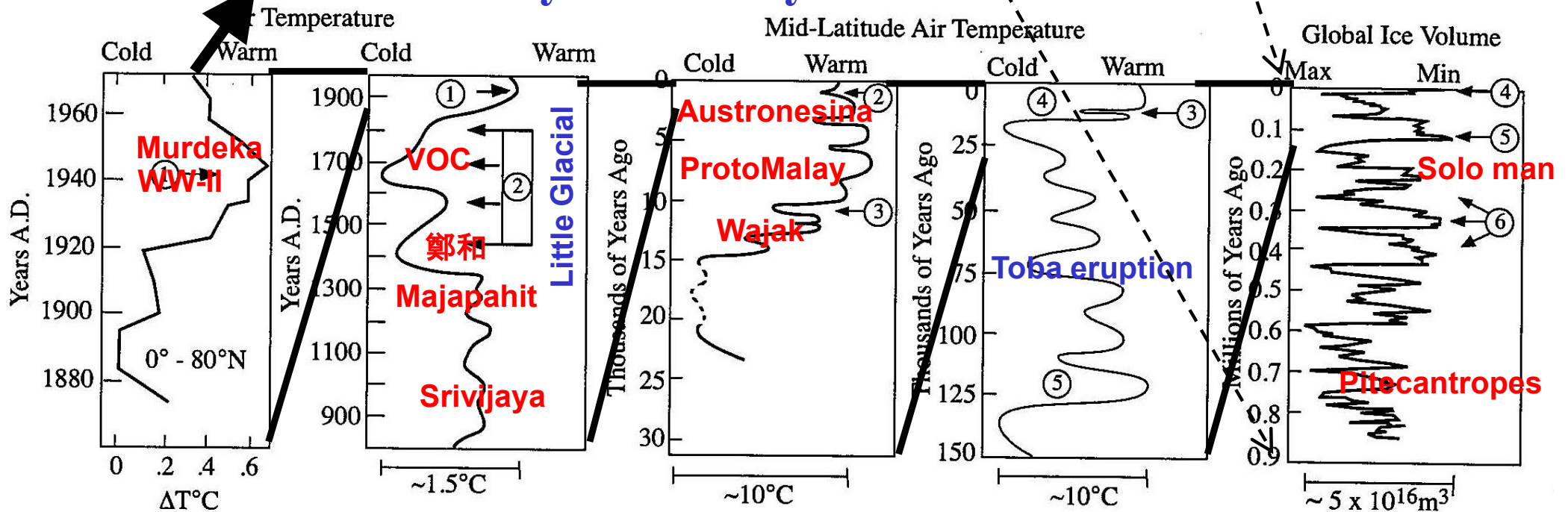
<http://ossfoundation.us/projects/environment/global-warming/natural-cycle>



OSF 2014

Recent 1 Myear history of Climate and IMC

(NASA, 1992)



(a) The Last 10^2 Years

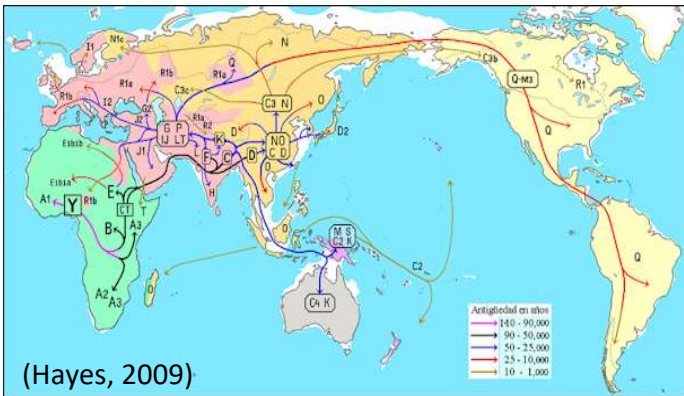
(b) The Last 10^3 Years

(c) The Last 10^4 Years

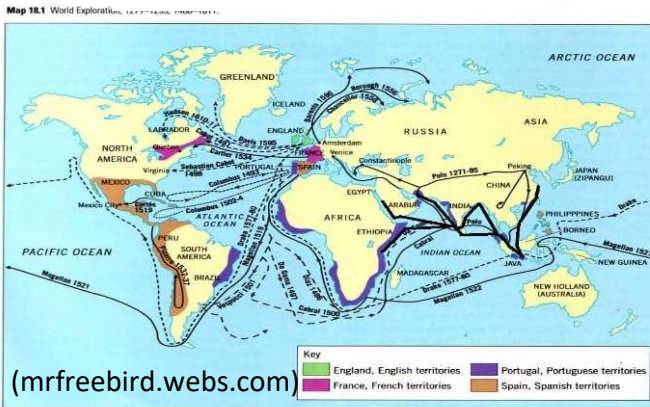
(d) The Last 10^5 Years

(e) The Last 10^6 Years

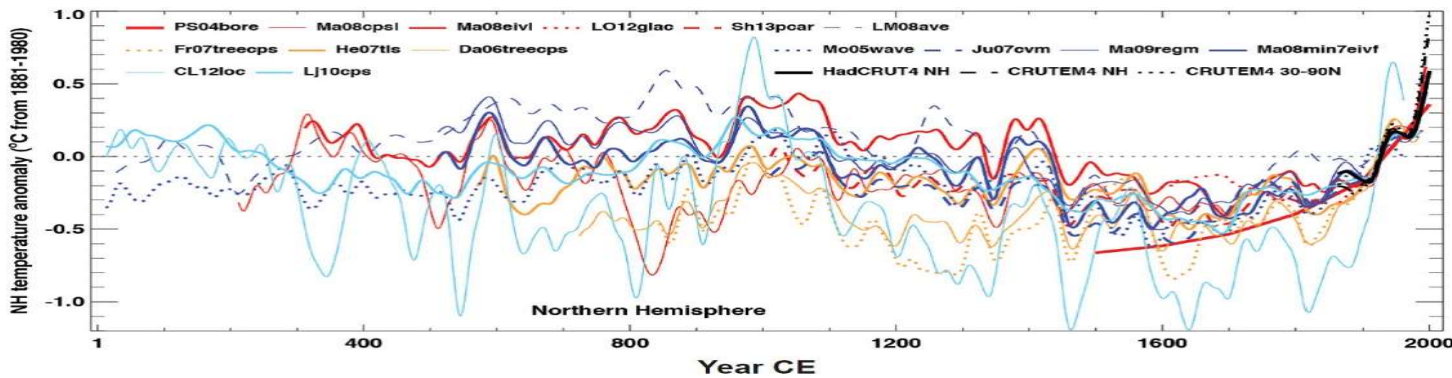
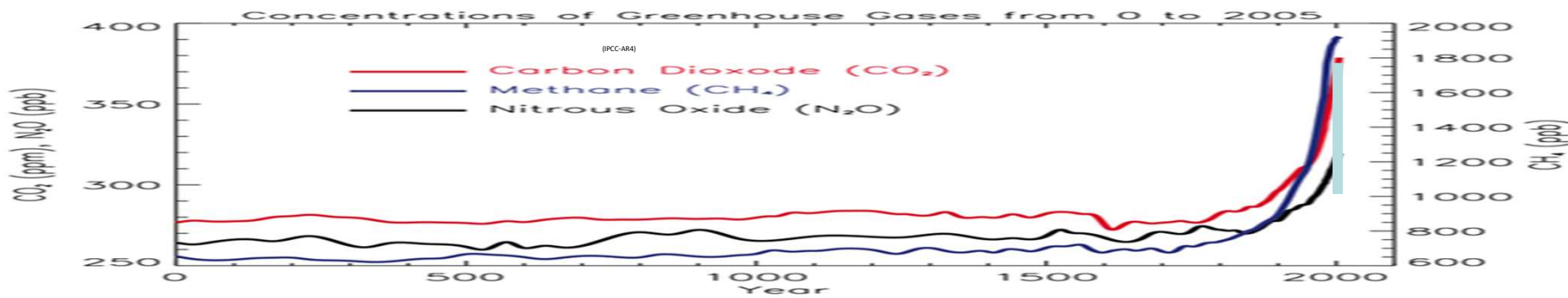
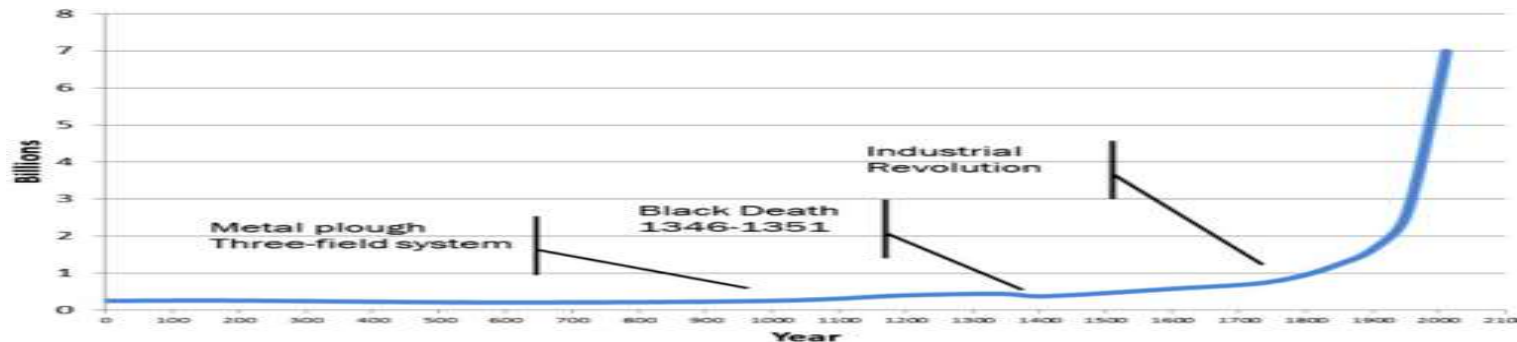
"Great Journey"



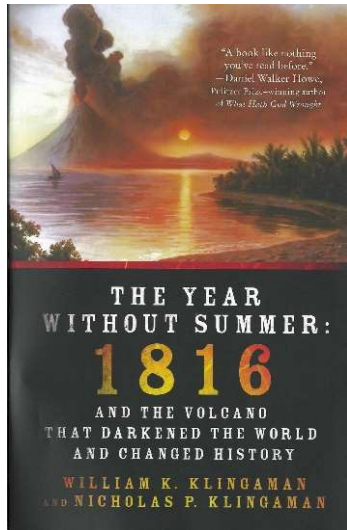
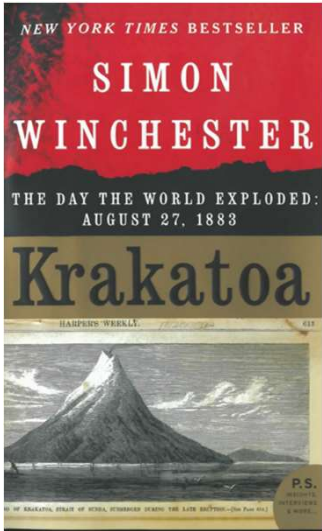
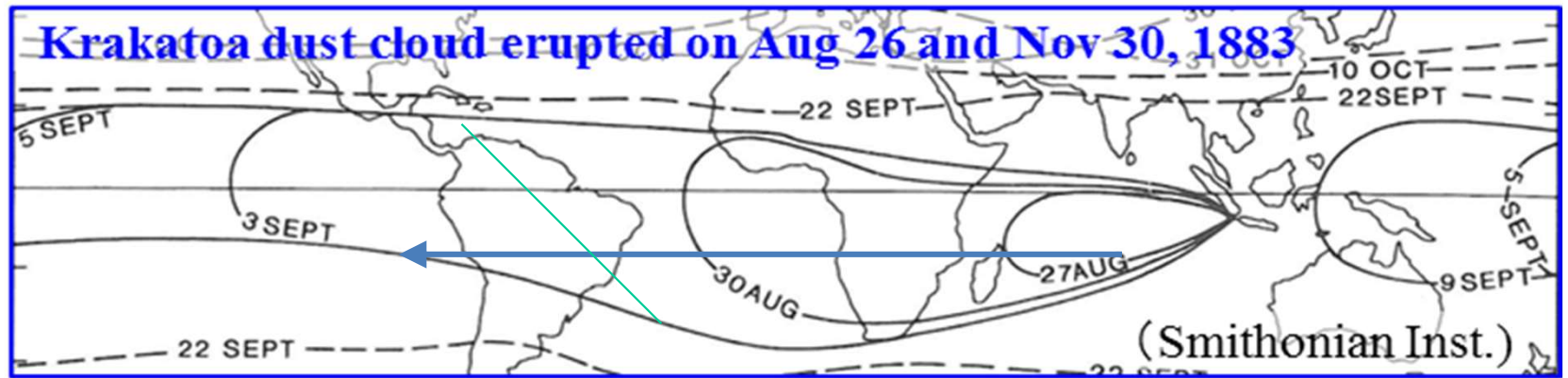
"Great Voyages"



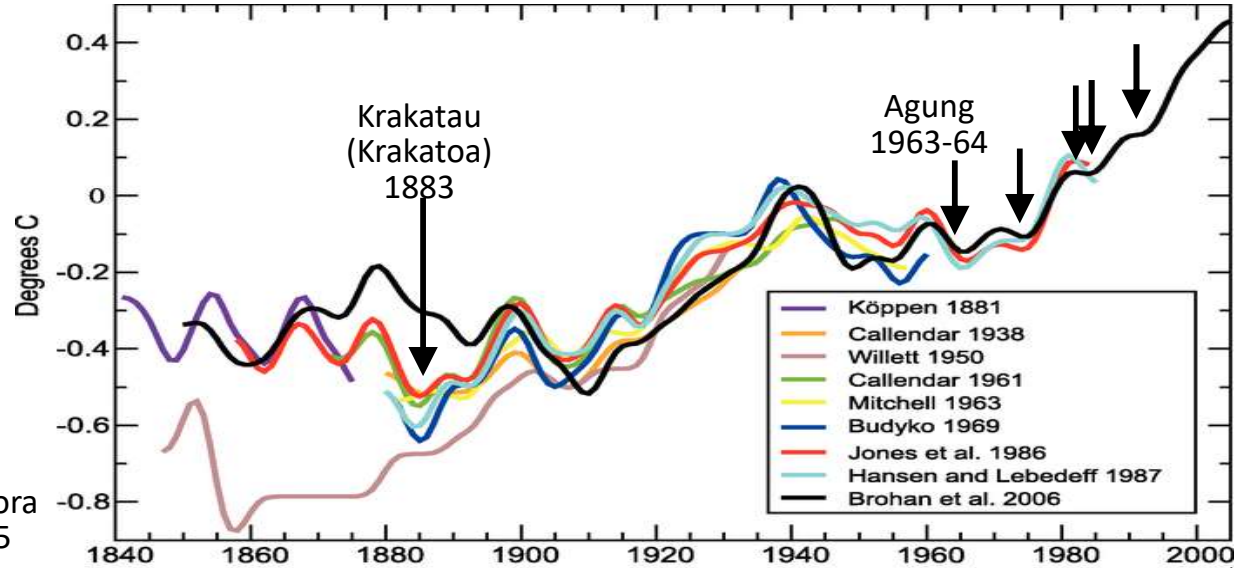
"Megacities"



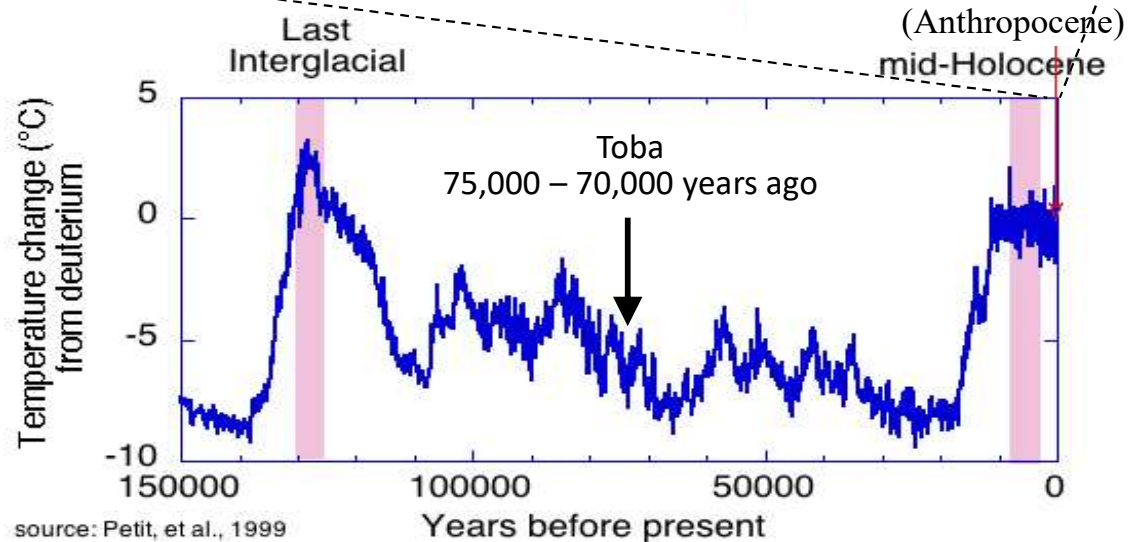
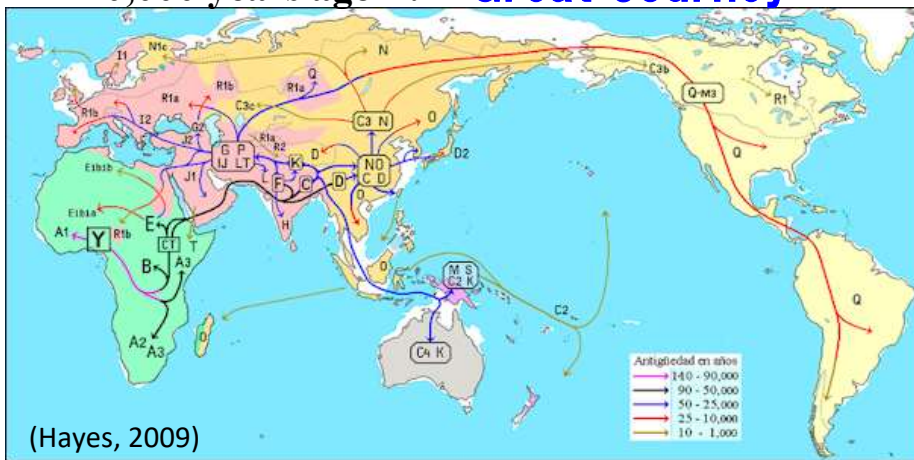
IMC volcanic climate control



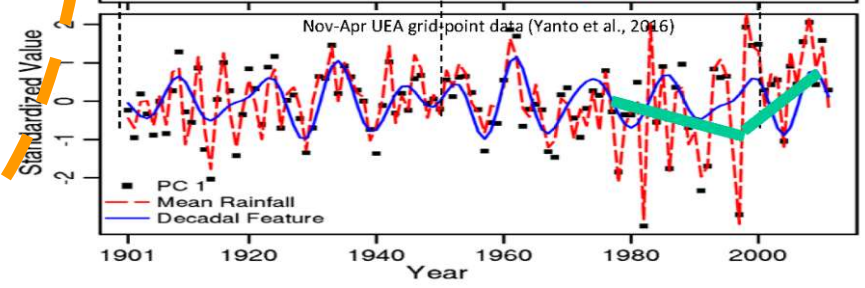
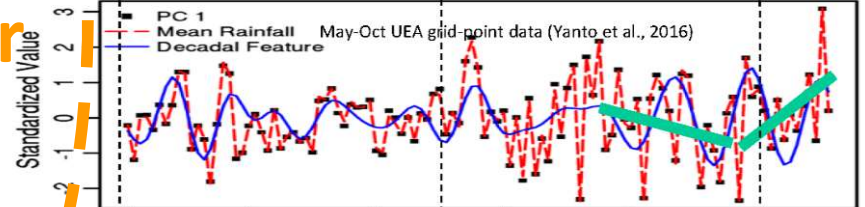
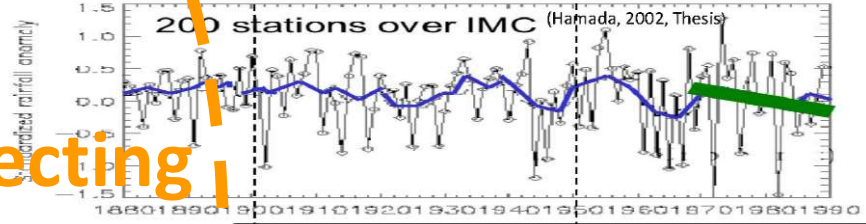
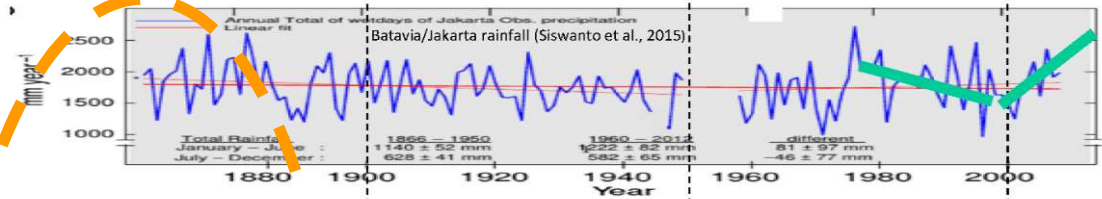
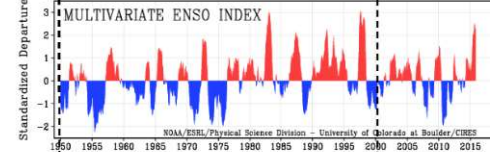
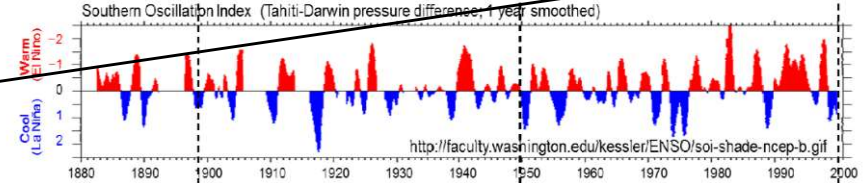
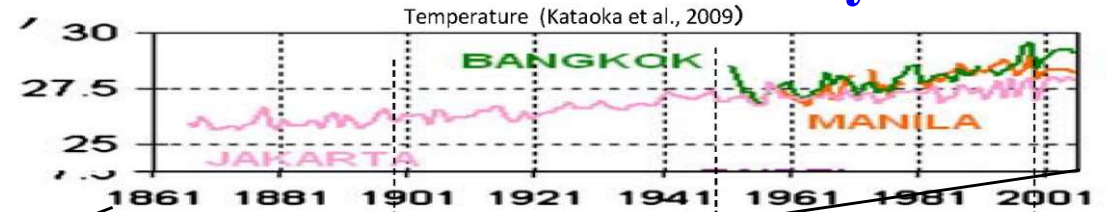
Tambora 1815



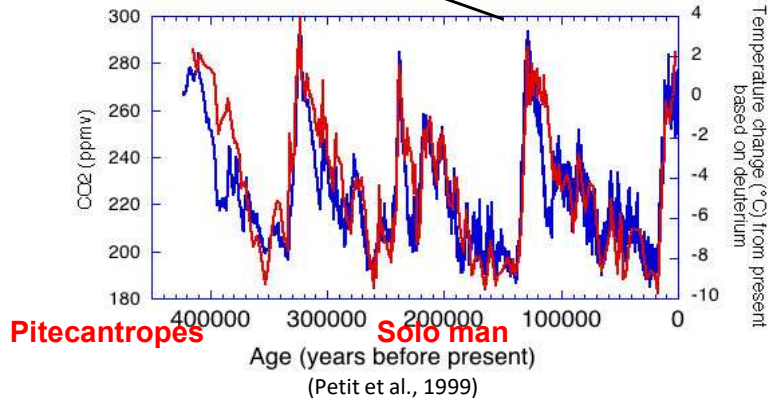
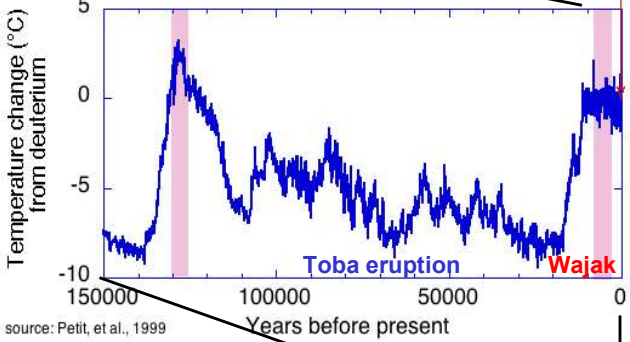
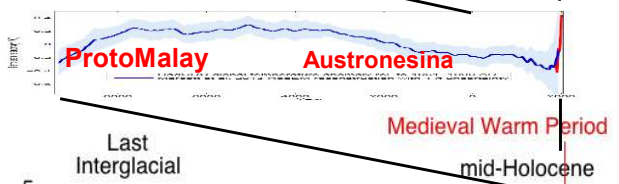
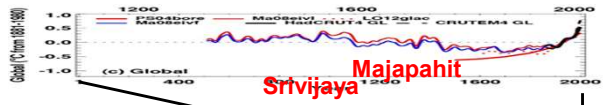
140,000 years ago - : "Great Journey"

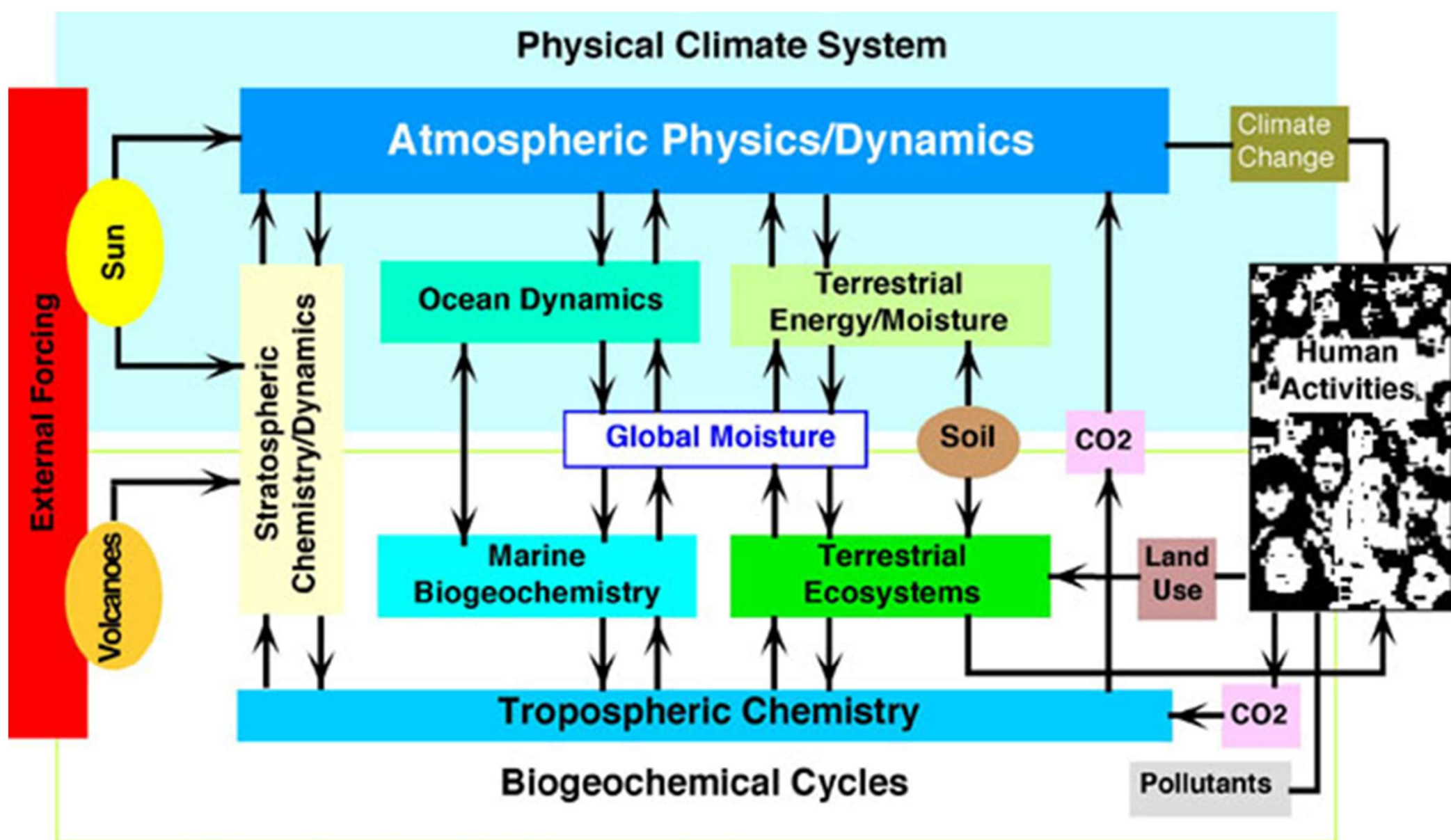


Surface data for 200 years

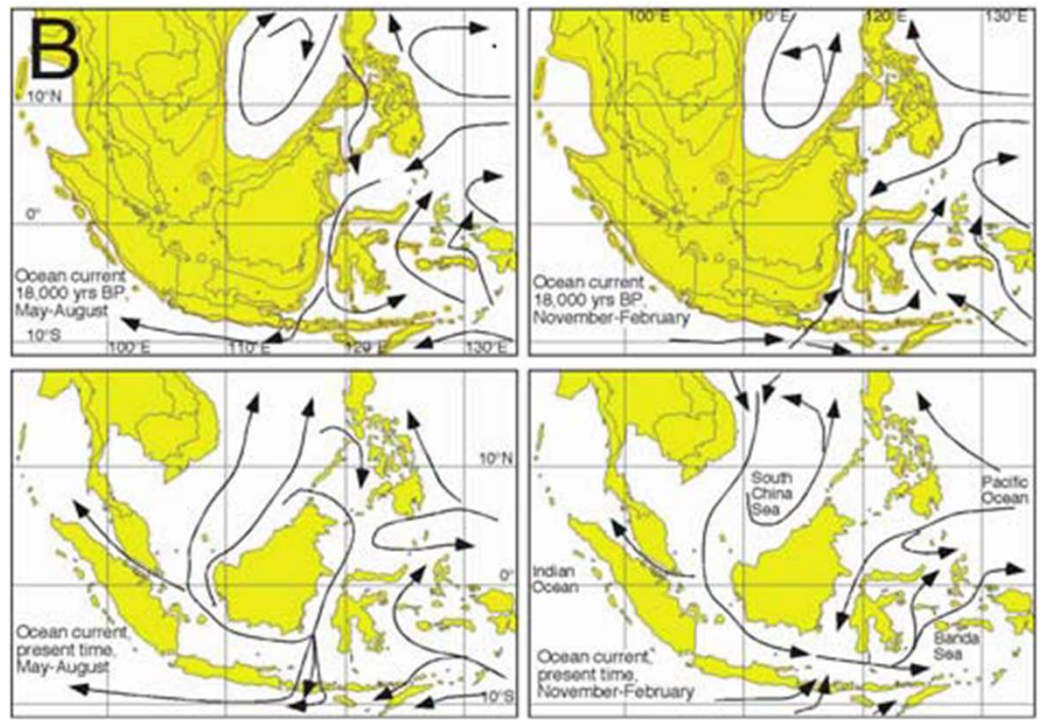


Collecting data for 19C

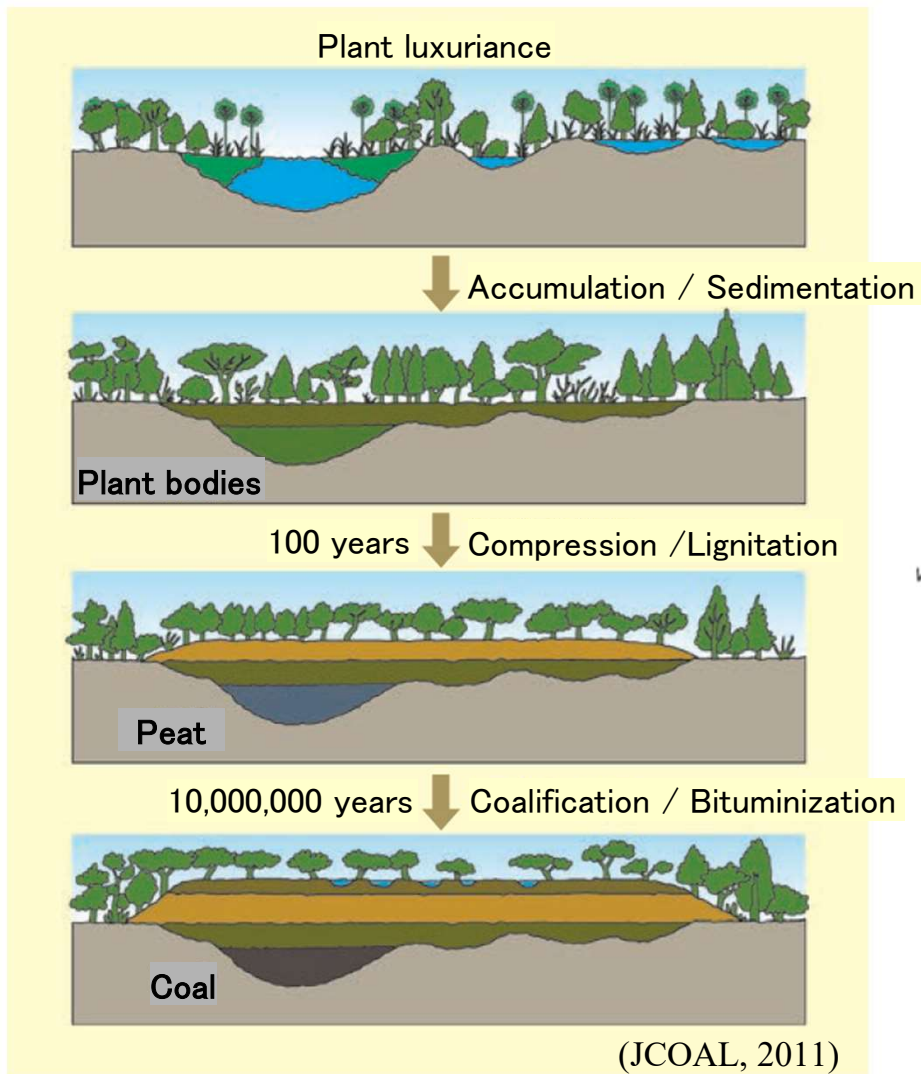
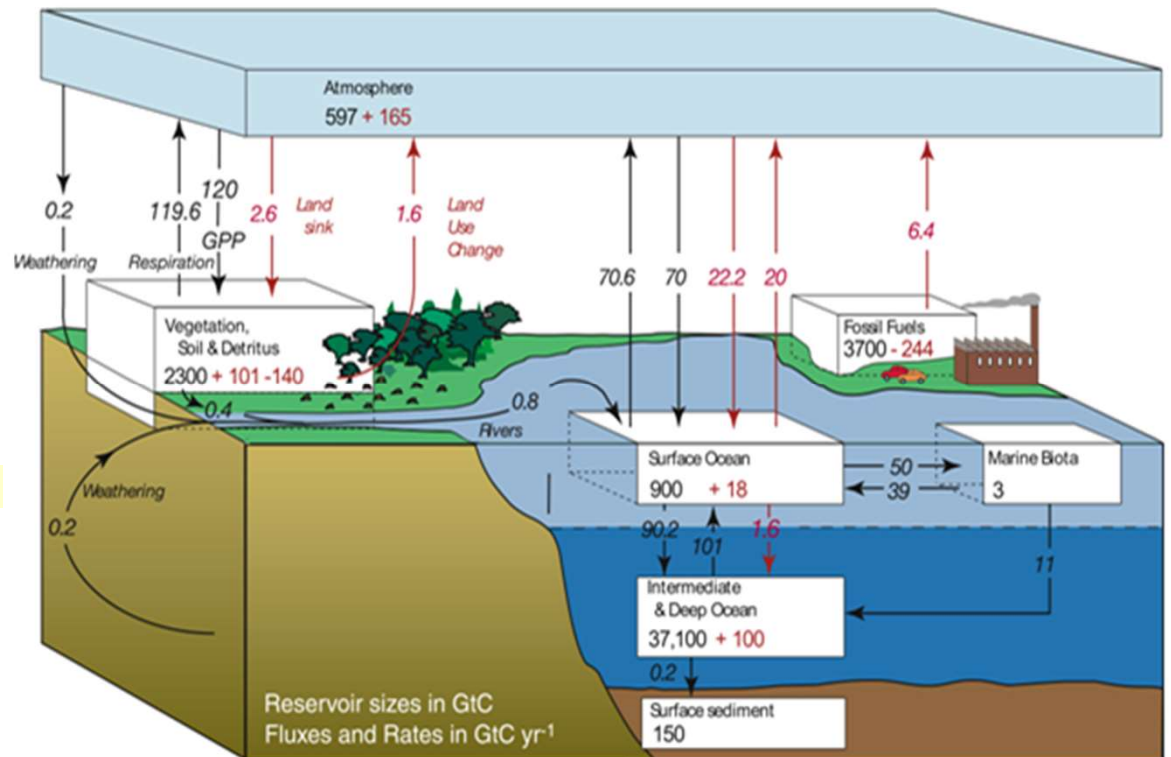




(from Earth System Science: An Overview, NASA, 1988)

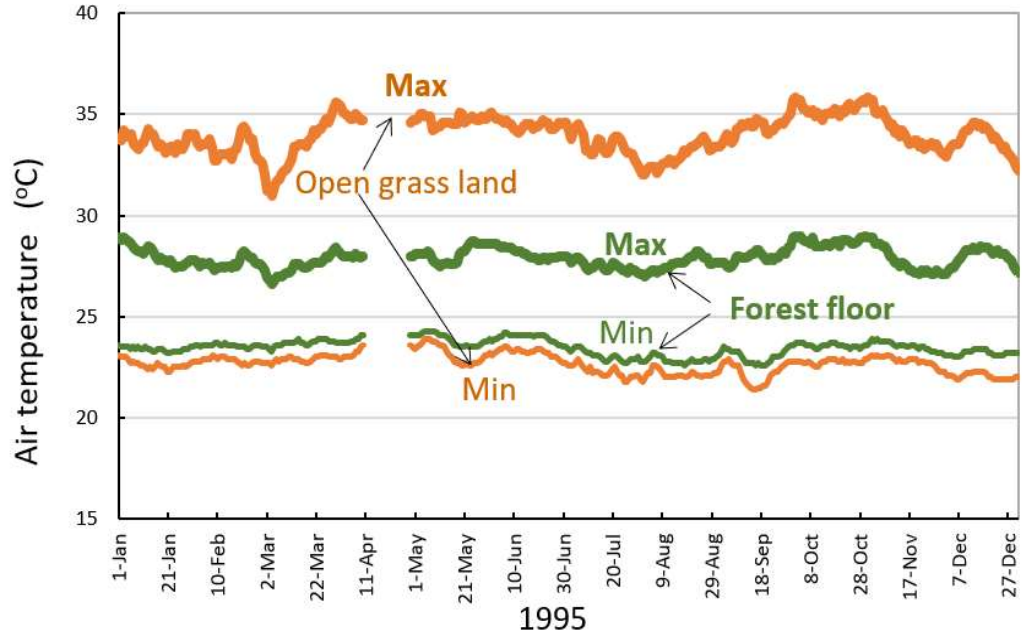
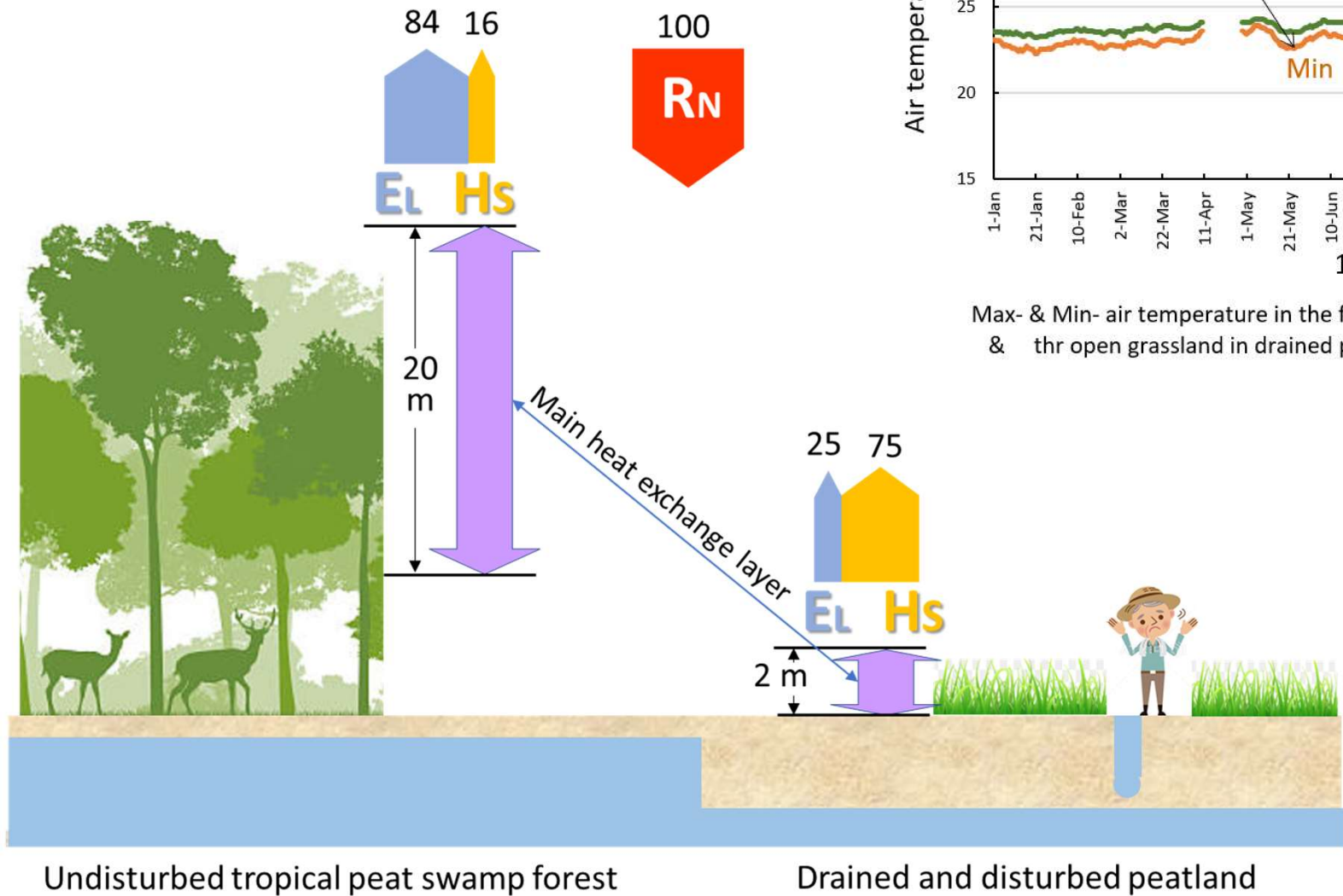


Global Carbon Cycle (IPCC-AR4)



Effect of human impact on heat balance of tropical peatland

R_N : Net radiation
 H_s : Sensible heat
 E_L : Latent heat

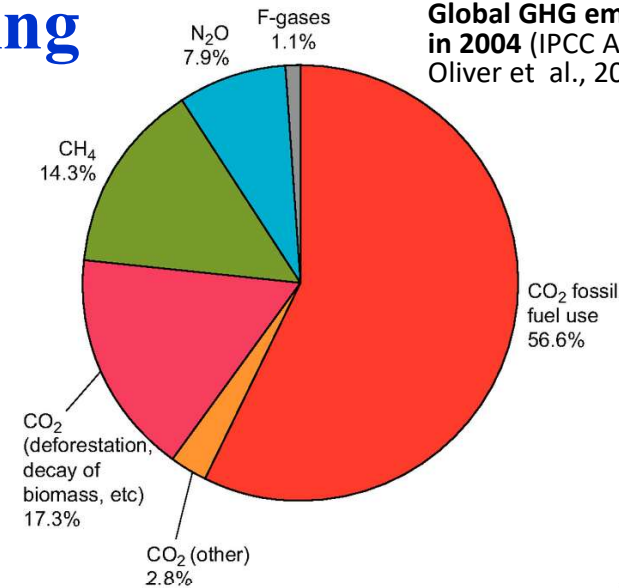


Max- & Min- air temperature in the forest floor of tropical peat swamp forest & thr open grassland in drained peatland, Central Kalimantan

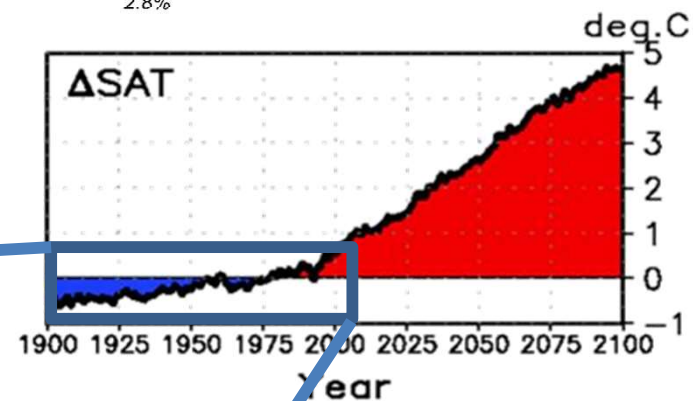
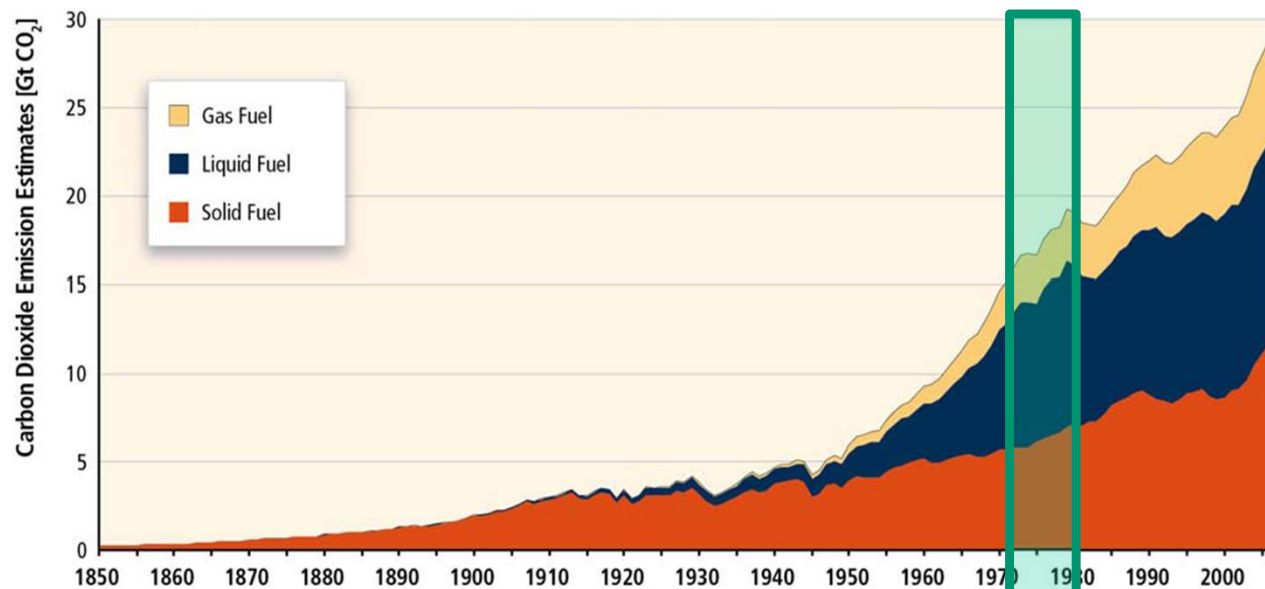
(H. Takahashi & M. Osaki, personal comm.)

Greenhouse gas (GHG) increase and warming

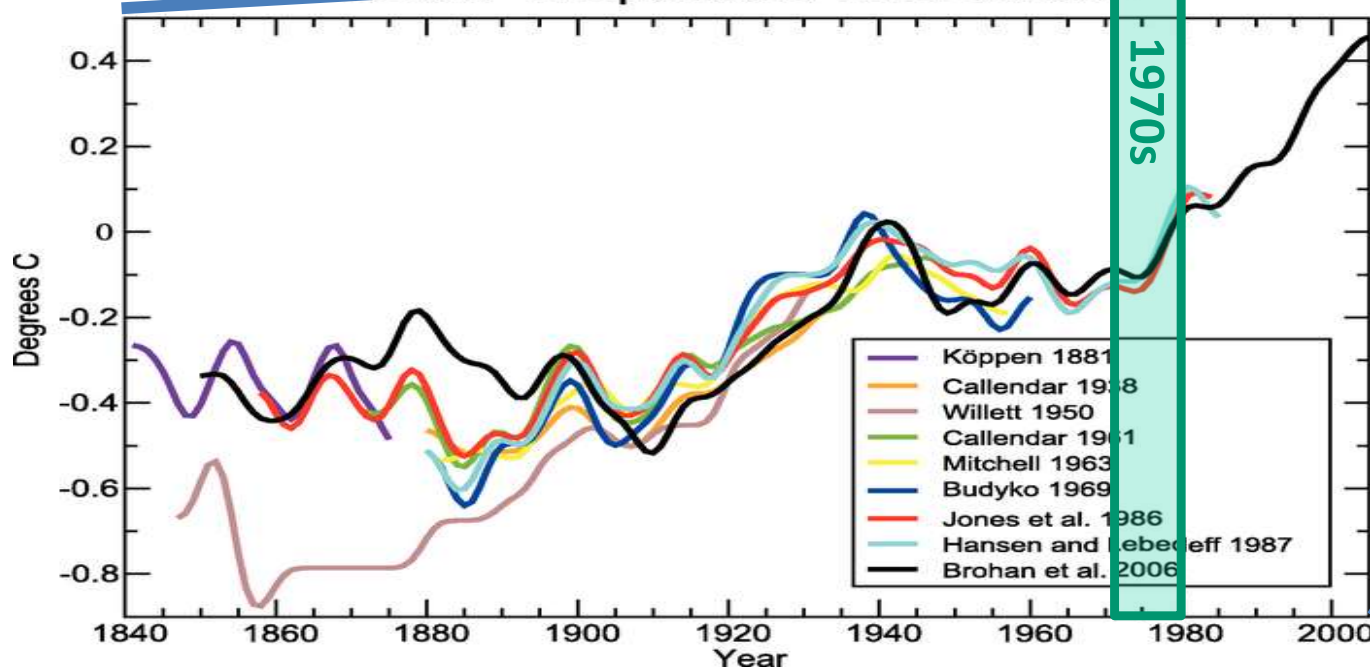
Global GHG emissions in 2004 (IPCC AR4-III; Oliver et al., 2006)



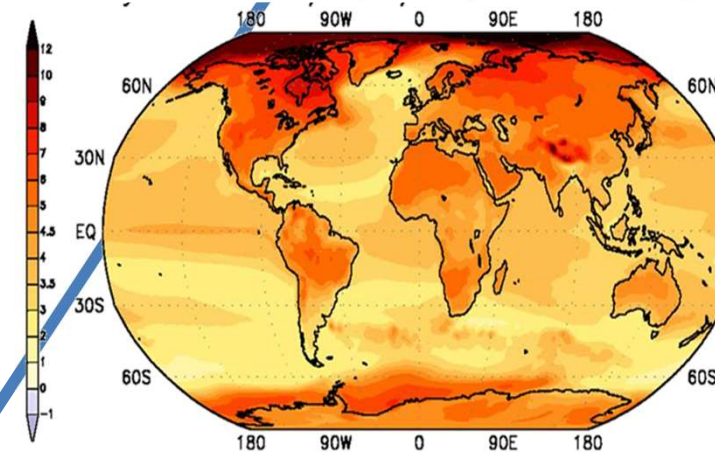
Global CO₂ emissions from fossil fuel burning (IPCC SREEN; Boden & Marland, 2010)



Global Temperature Time Series (IPCC AR4-I)

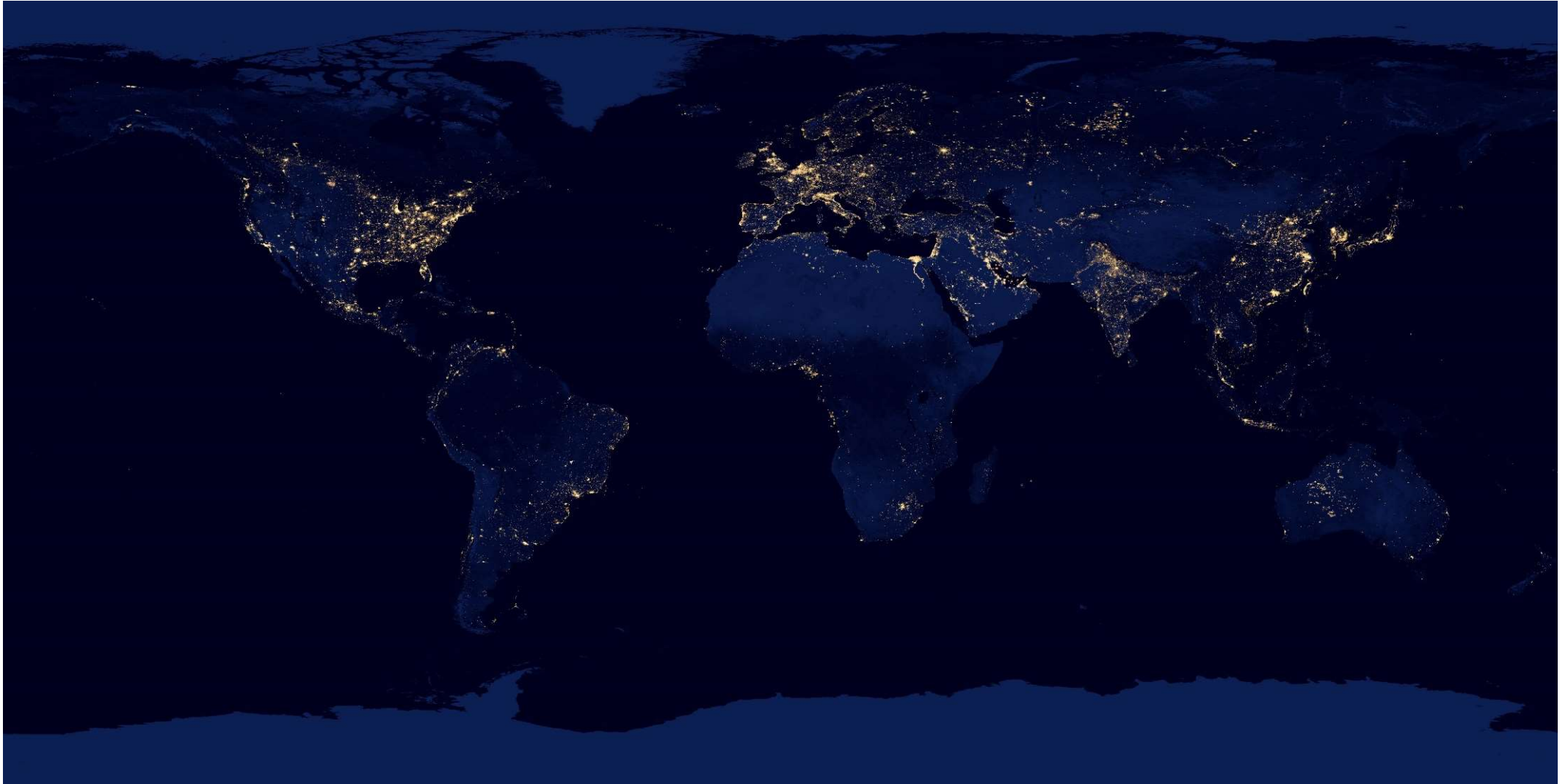


T (2071-2100) - T (1971-2000)

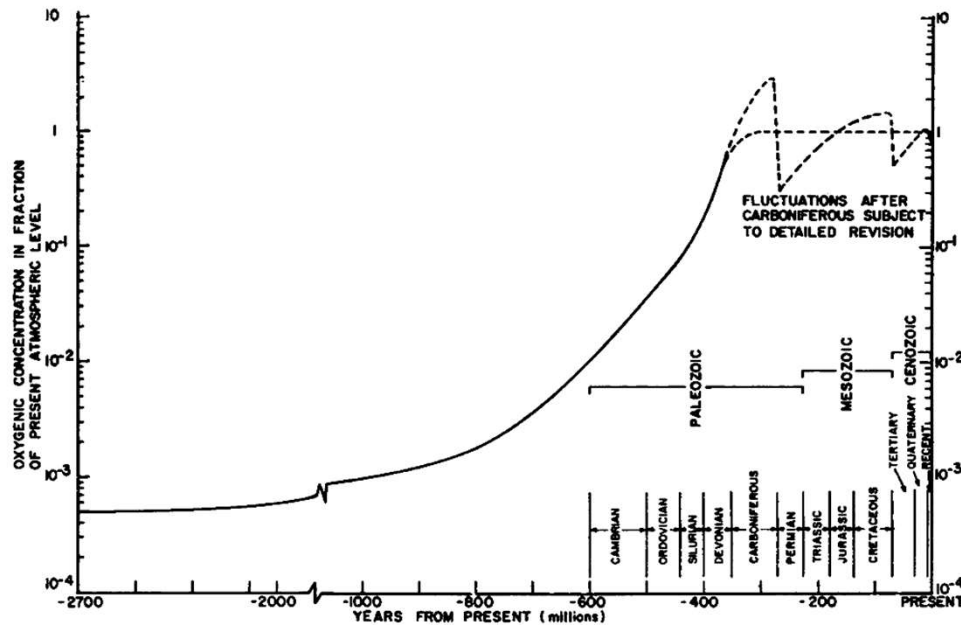


(IPCC AR4-CCSR/NIES)

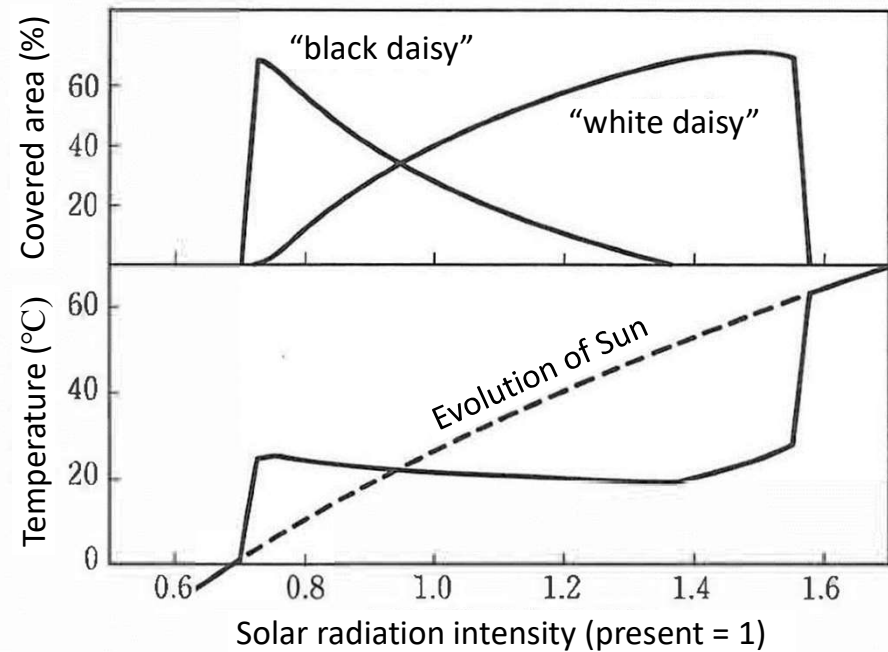
7.4. Bio-anthroposphere and the Earth system



Biosphere-atmosphere interaction and climate



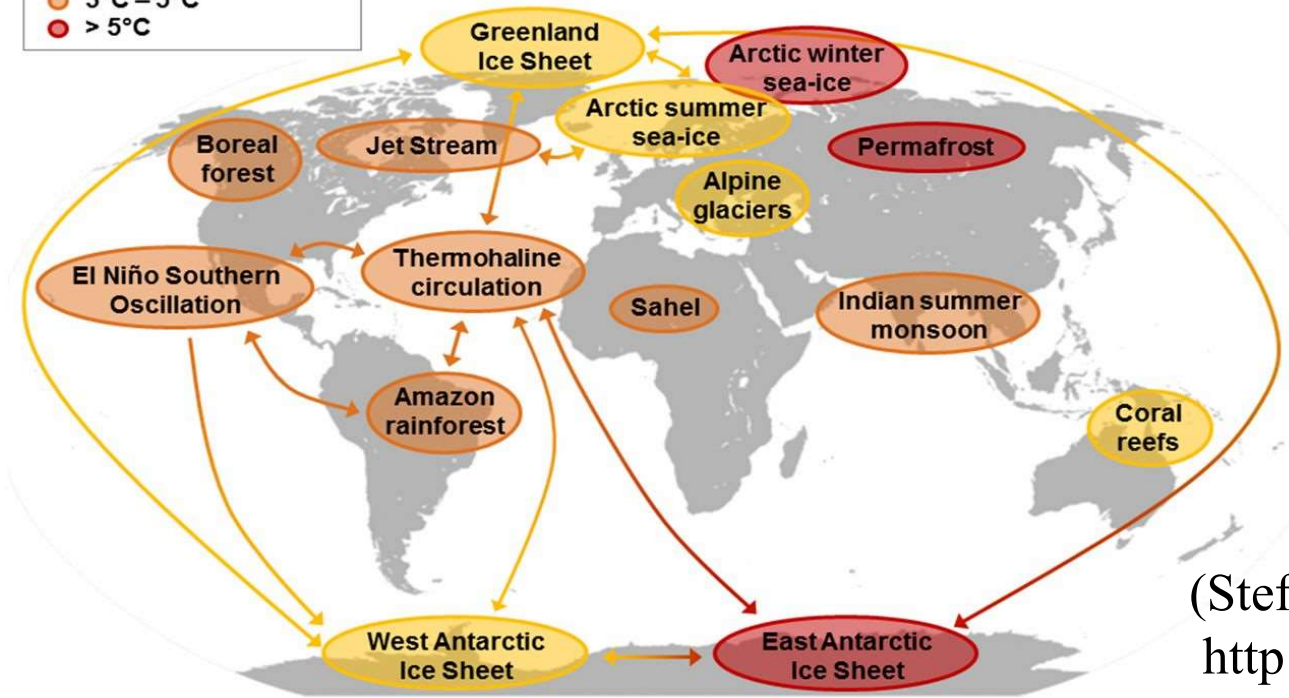
Berkner and Marshall (1965)
Plant evolution → O₂ increase
Animal evolution → CO₂ increase



Watson and Lovelock (1983)
“black daisy” → Albedo decrease/warming
“white daisy” → Albedo increase/cooling

Tipping elements at risk:

- 1°C – 3°C
- 3°C – 5°C
- > 5°C



Risk for 'Hothouse Earth'

(Steffen et al., 2018, *PNAS*)

<http://www.pnas.org/content/115/33/8252>

