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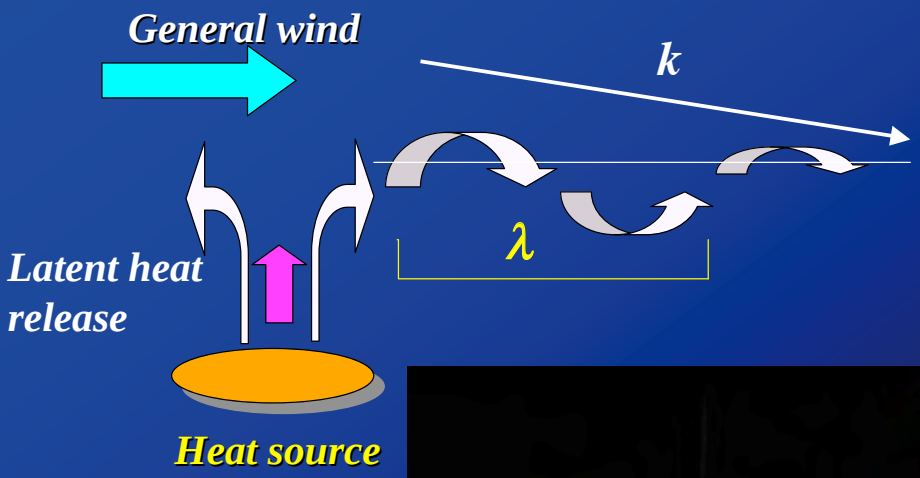
Modeling study of the earth's environmental change and global warming phenomenon

Terry Nakajima
Center for Climate System Research
The University of Tokyo
（teruyuki@ccsr.u-tokyo.ac.jp）

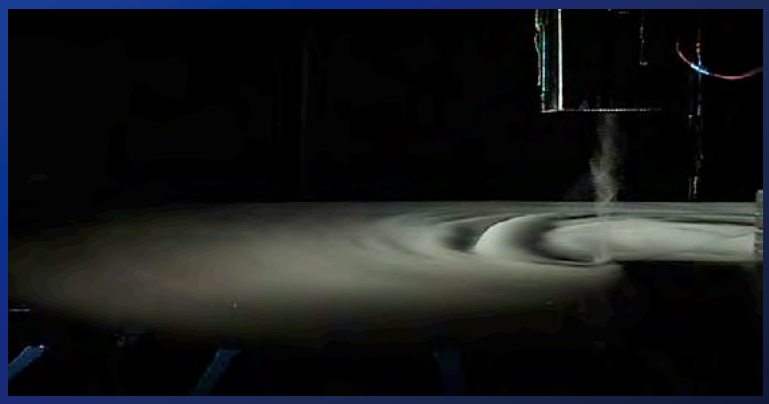
Earth’s climate and its changes

- Climate: Persistent characteristics of the weather (Temperature, humidity, wind velocity...)
- Ocean, land and ice to be included in the modern view
- Earth’s fluid dynamics and physical/chemical condition
- Characteristic cycles
  - Weather (several days)
  - Seasonal change (12 months)
  - El Nino/La Nina change (4 years)
  - Decadal change (10 years)
  - ???? (100 years to 10 Ka)
  - Glacial/Interglacial change, Milankovitch cycle (100 Ka)
  - Continental drift, Wilson cycle (0.5 Ba)
  - Earth and solar evolution (4.5 Ba)

Weather forecasting

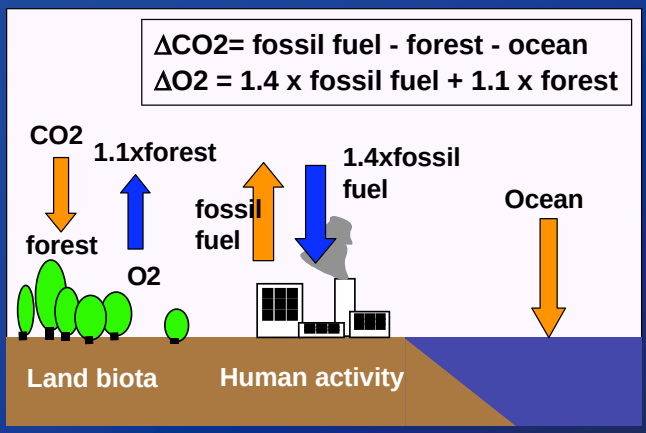


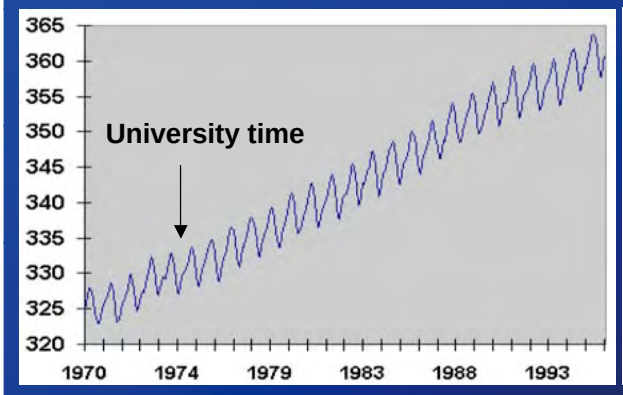
- Wavelength
- Attenuation coeff.

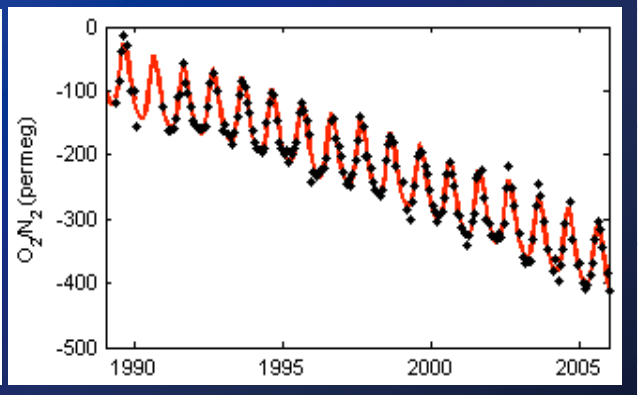


Man-made effects...

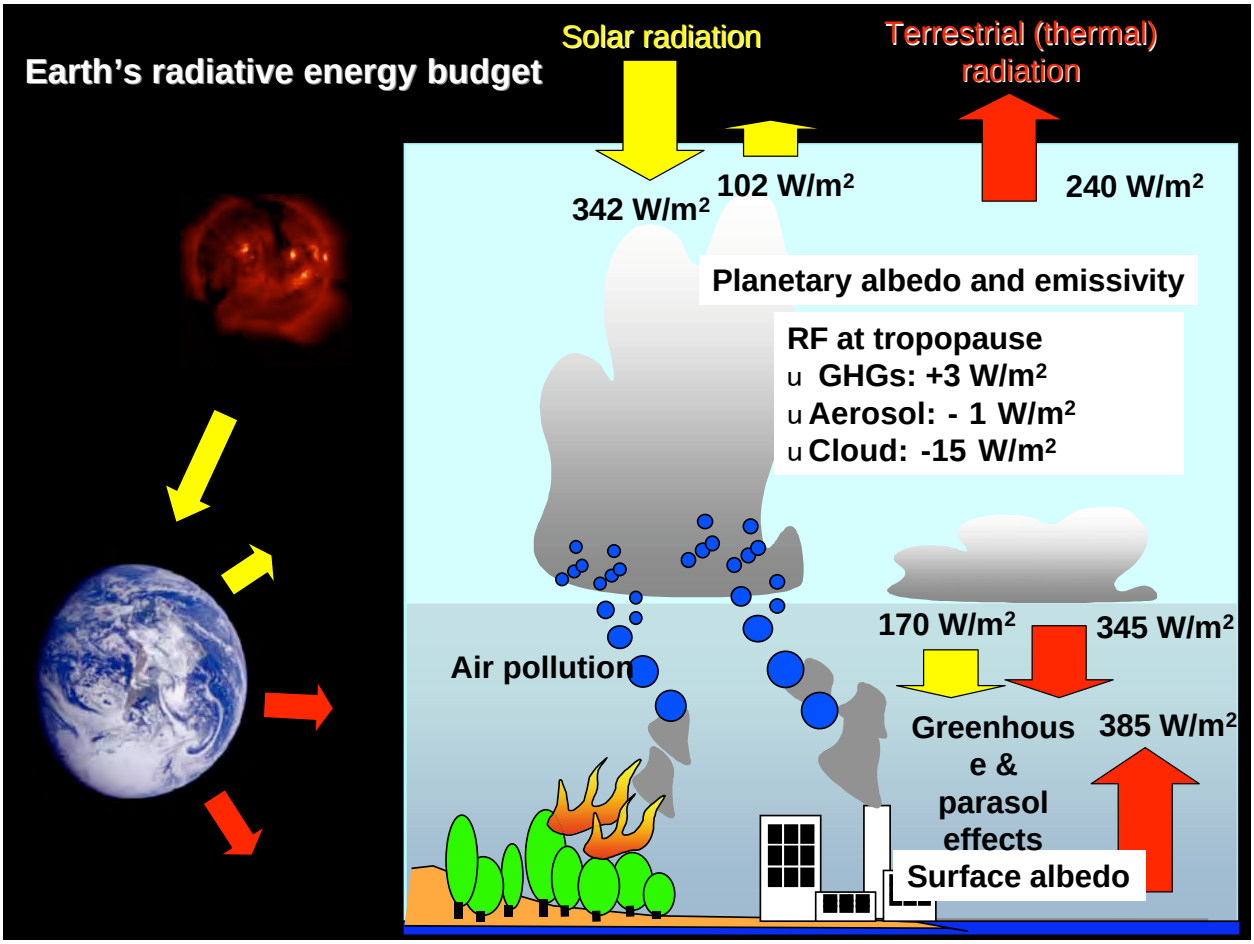
from Scripps Institute web





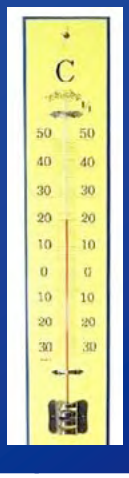


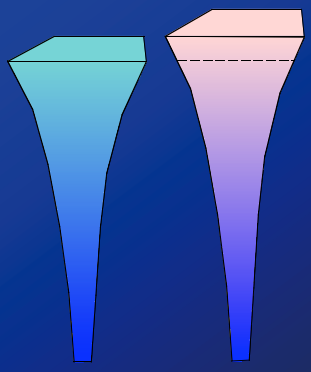
Charles D. Keeling Ralph Keeling



Sea level change due to temperature change

- 1 degree increase impact
  - 1 km train rai: $dL = k_L$ x L = 1.1E-5 x 1E5 cm = 1.1 cm
  - 300m depth ocean thermal expansion
    $dx=k_V$ x D = 2.1E-4 x 3E4 cm = 6.3 cm
  - 4000m depth ocean thermal expansion
    $dx=k_V$ x D = 2.1E-4 x 4E5 cm = 84 cm
- cf. Total melting of Greenland ice: 7m; Antarctic ice: 70m



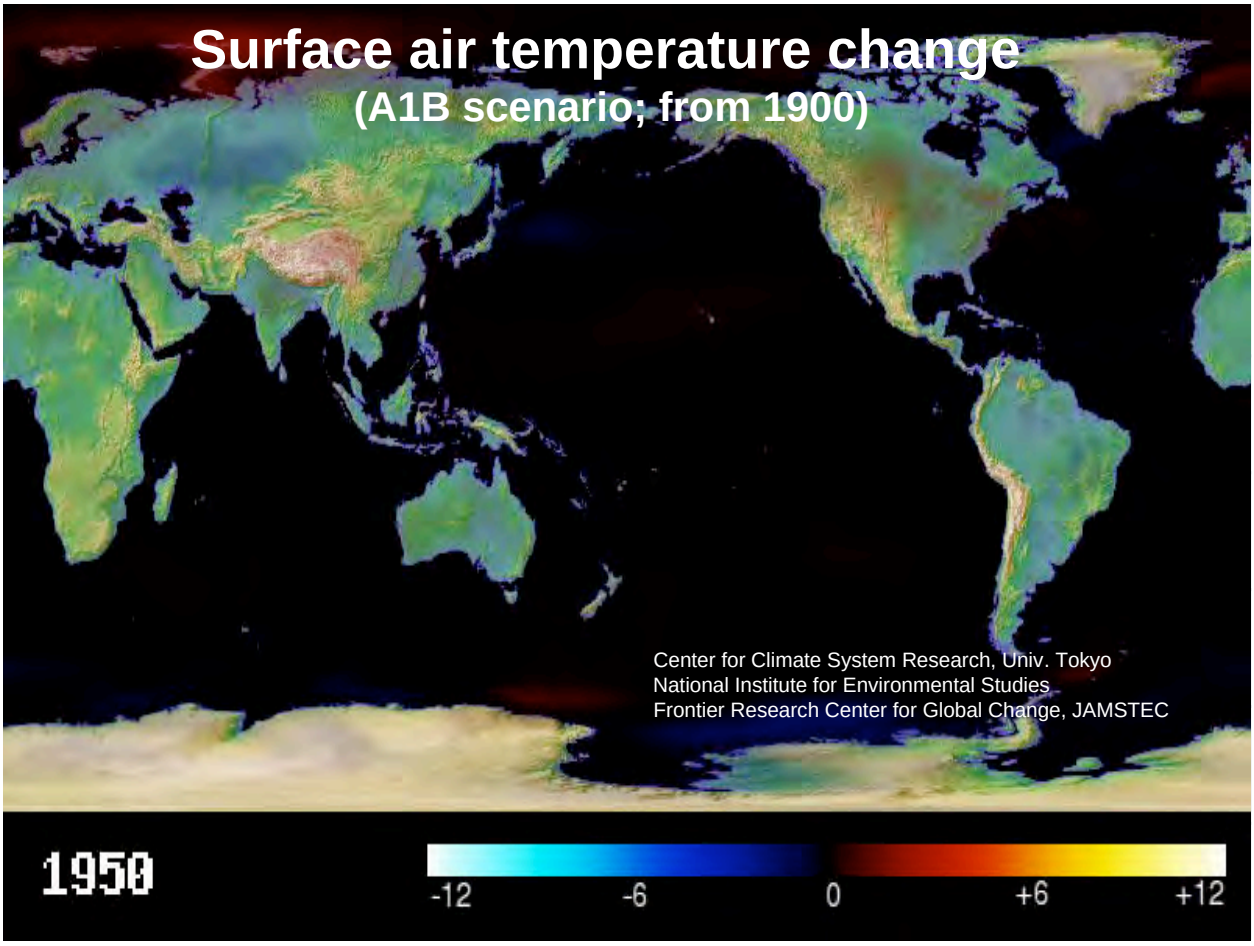


Current ocean column Warmed column

Linear exp. coeff. (k_L)
Iron: 1.1E-5 /deg

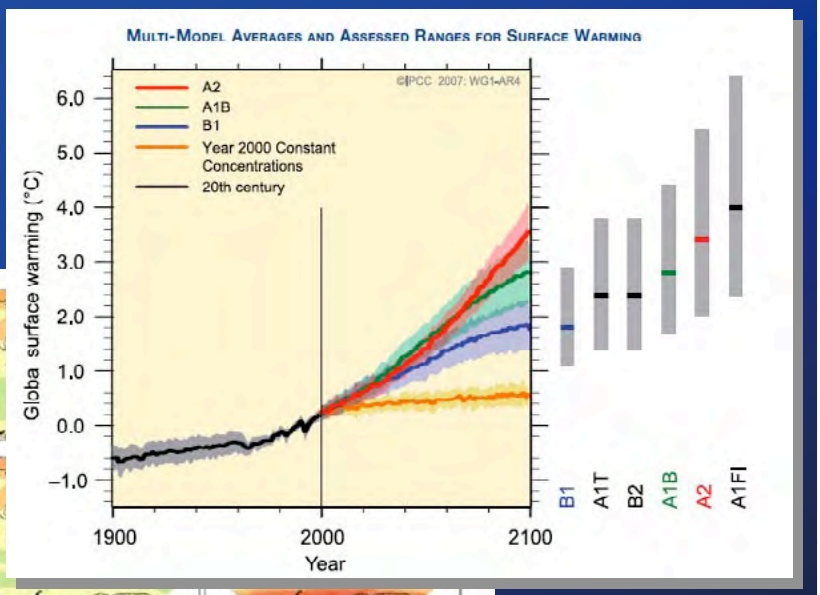
Volume exp. coeff. (k_V)
Water: 2.1E-4/deg
Alcohol: 1.2E-3/deg
Mercury: 1.8E-4/deg

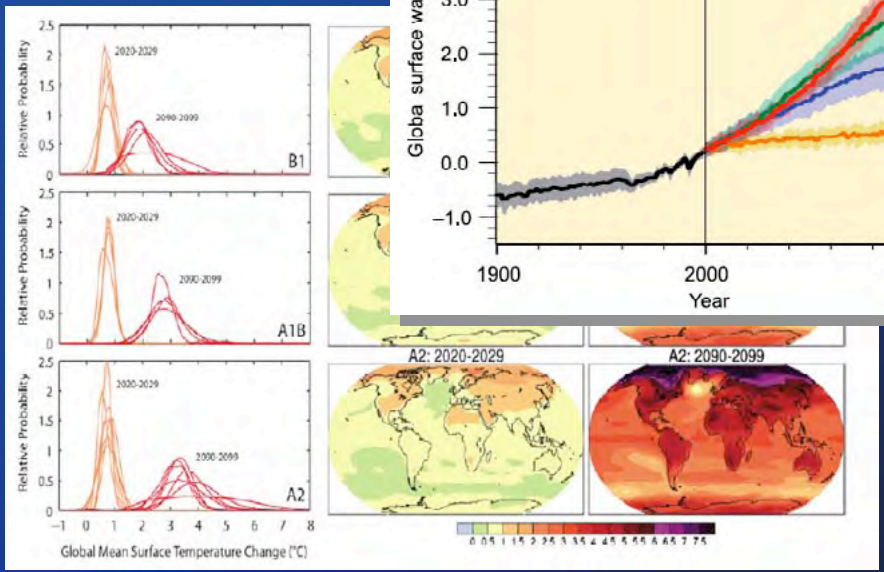
Surface air temperature change
(A1B scenario; from 1900)



Climate prediction

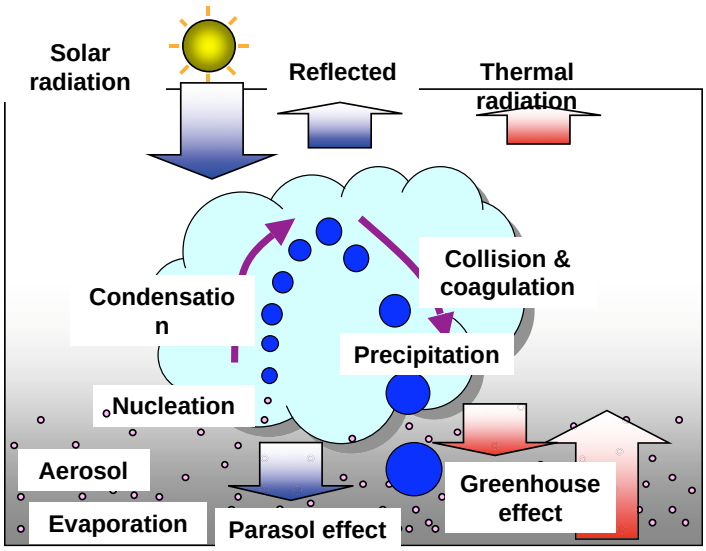
- Uncertainties still large
- Model uncertailty: half
- PDF





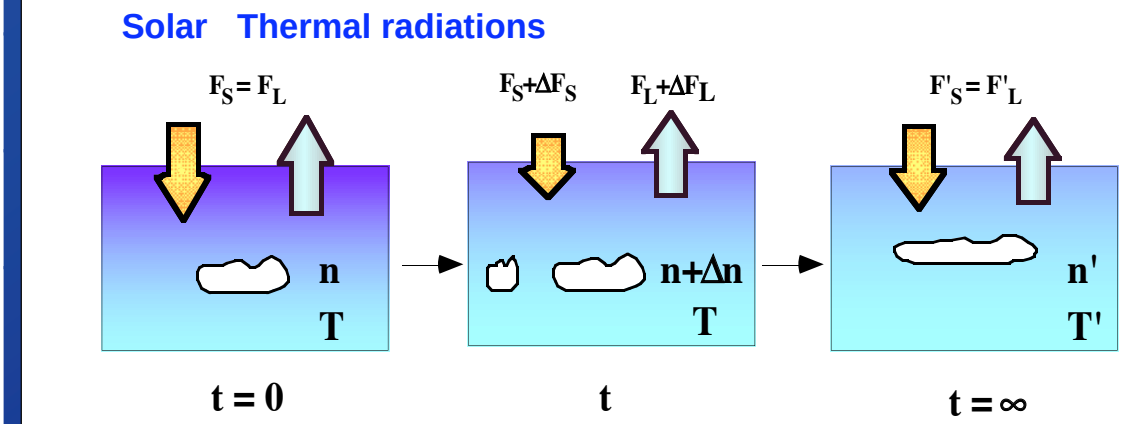
Forcing mechanisms

- Greenhouse and parasol effects
- Direct scattering and absorption of radiation (Direct effect)
- Increased cloud droplet number (Decreased size; 1st indirect effect)
- Decreased precip. efficiency (Cloud lifetime effect, 2nd indirect effect)
- Increased top height, fraction etc. (Other indirect effects)

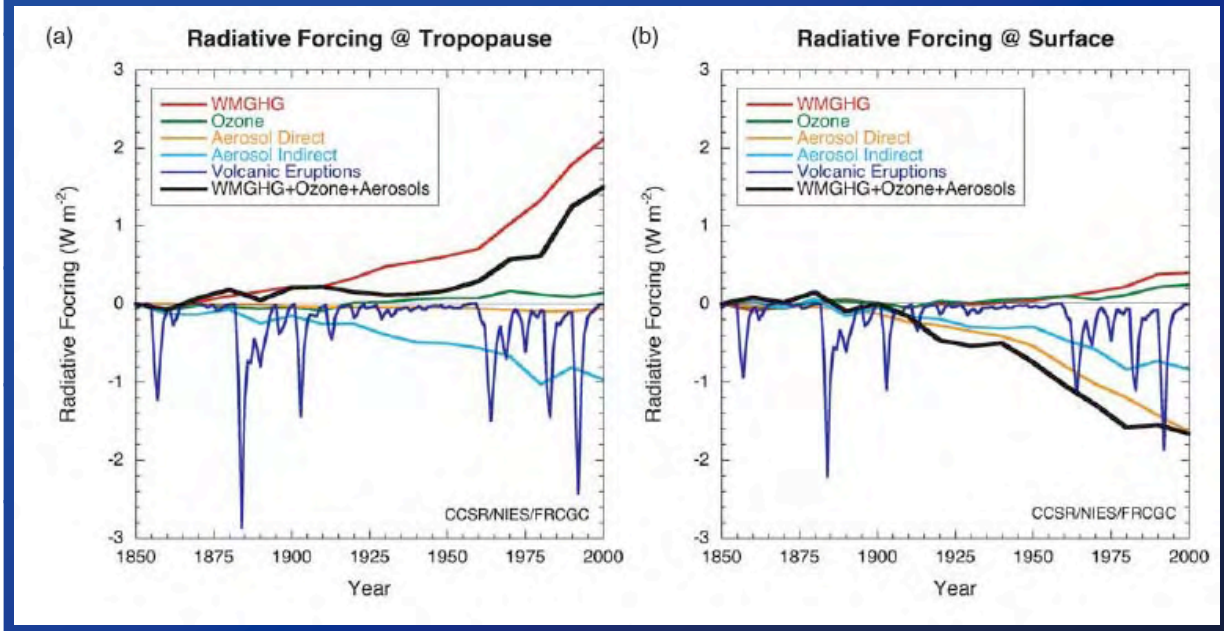


Radiative forcing driving the climate system

- RF= Radiative energy imbalance at tropopause when the factor changes with the environment is as the same; Net = SW + LW (W/m^2)
- Positive: warming; negative: cooling

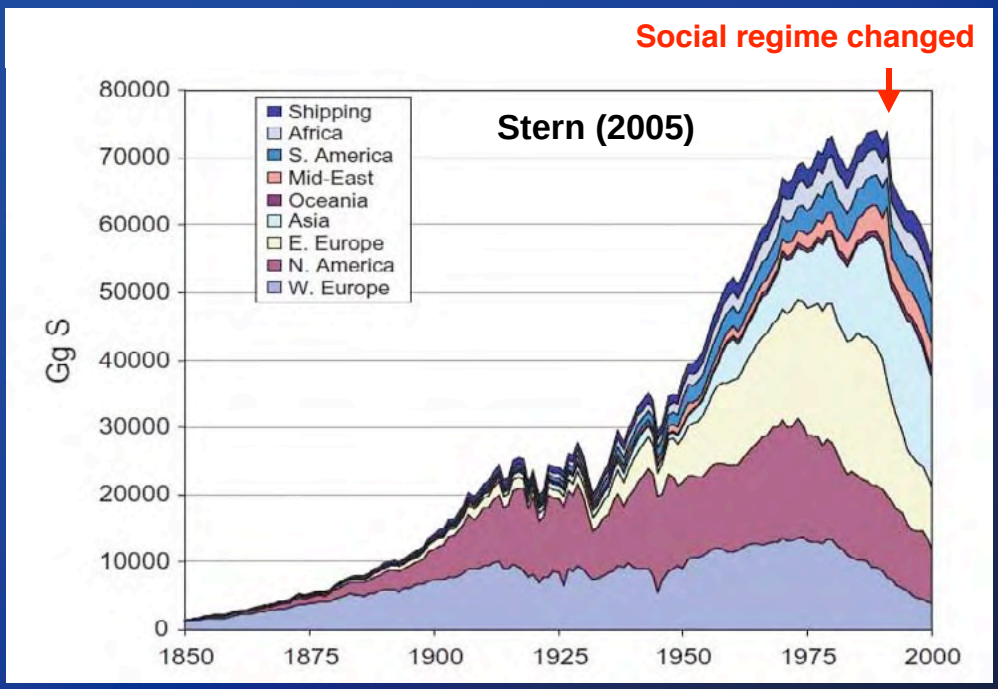


RF changes during 1850-2000 IPCC/AR4



[redacted]

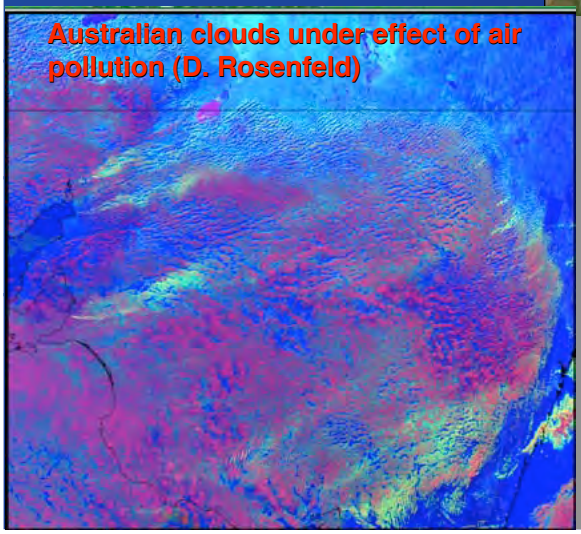
Sulfur emission by human activities during 1850-2000

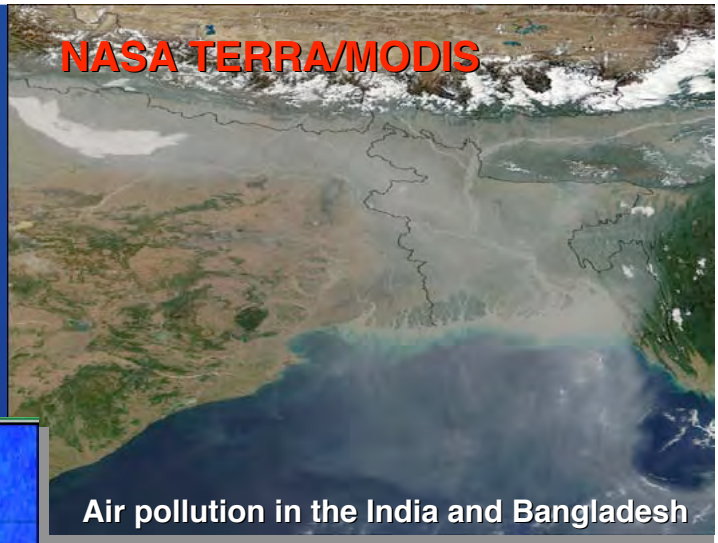


1991: THE FALL OF THE SOVIET UNION AND THE RISE OF RUSSIA

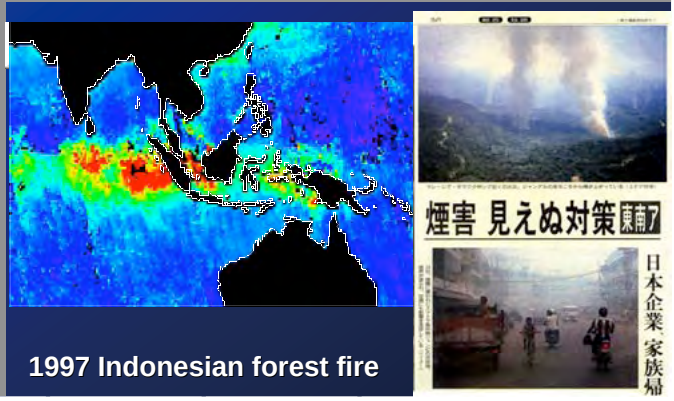
STANDING UP FOR FREEDOM: Russian Federation President Boris Yeltsin stood atop an armored personnel carrier in Moscow Aug. 19, 1991, to urge Russians to resist a central government takeover by Soviet hardliners. Russians proved their courage and their love for freedom in 1991, ending Soviet domination in Eurasia with a peaceful determination that stood in stark contrast to the terror imposed on them for seven decades. AP Photo (http://www.fas.org/news/russia/2000/russia/part01.htm)

Global scale air pollution





Air pollution in the India and Bangladesh



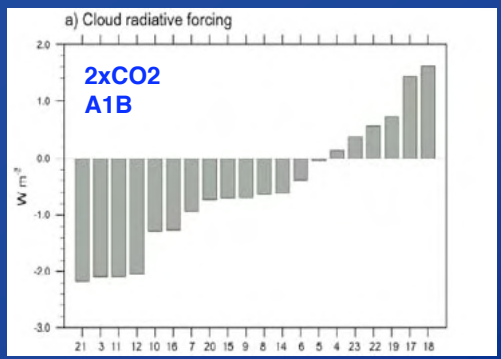
1997 Indonesian forest fire

Issues in aerosol impacts

- Assessment still has large uncertainties
- Clouds getting brighter to cancel the warming
- Surface forcing of aerosols much larger than GHG forcing
- that causes spatial inhomogeneity of forcing
- to change circulation and precipitation

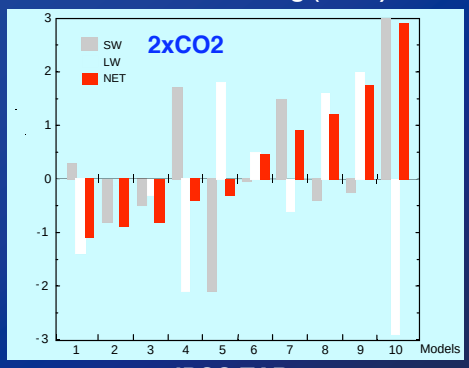
Cloud modeling by General Circulation models (GCMs)

- Clouds accelerate or deccelate the warming?
- Uncertainties not reduced
- Deep convective cloud change???

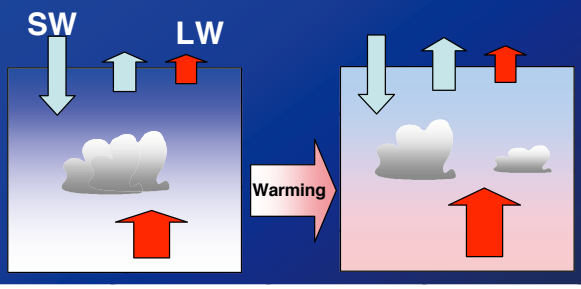


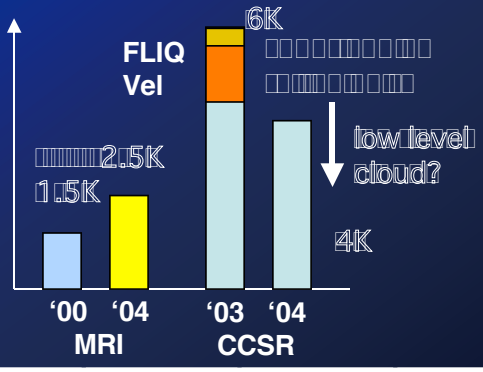
(2080-2099)-(1980-1999) IPCC-AR4, ch10

TOA cloud forcing (W/m²)

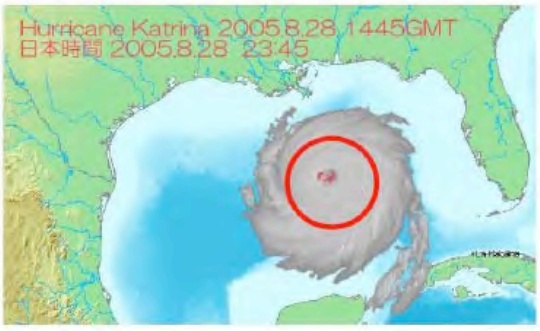


IPCC TAR



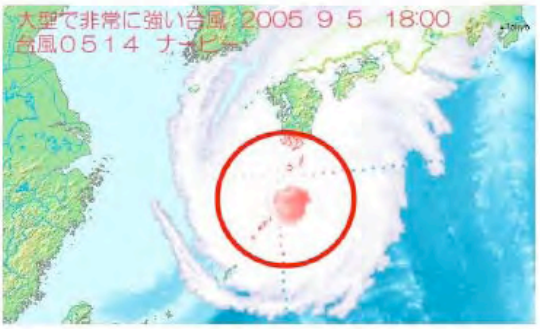


Katrina and Typhoon#14



Katrina

カトリーナ
ハリケーン
気圧：９０２ hPa
最大風速：７５m/s
最大瞬間風速：９０m/s
暴風半径：140km～220km
カテゴリー５（米）



#14

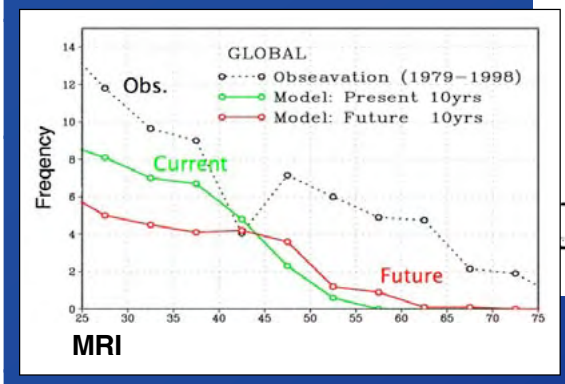
台風１４号（T0514)ナービー
大型で非常に強い台風
気圧：９３５hPa
最大風速：４５m/s
暴風半径：300km
風速15m/s以上の強風域：
西側６５０km、東側850km
北北西へ時速15?で移動

ベースの地図はDemis web siteより引用

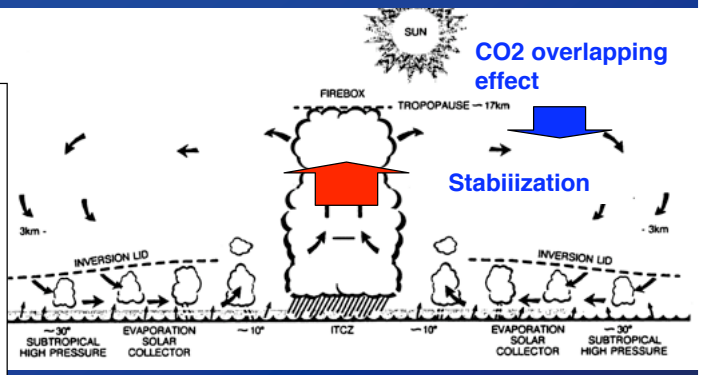
【 台風１４号ナービー （T０５１４） 】

http://www.geocities.jp/sora2005/2koramu1KATORI-NAHIKAKU.html

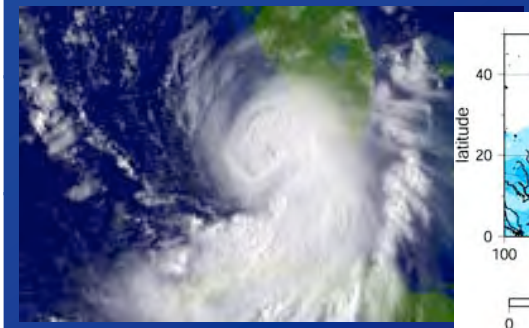
Typhoon change?



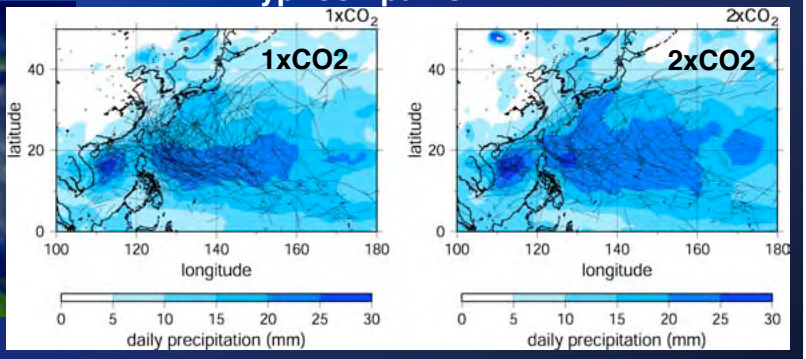
MRI



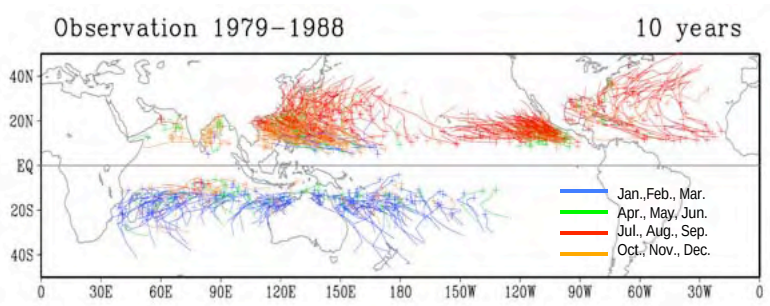
□Sugi et al., ,2002)

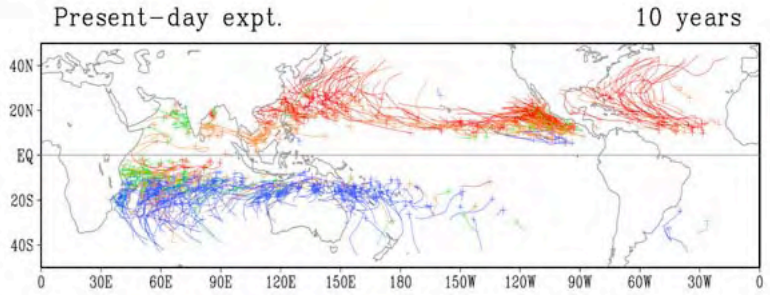


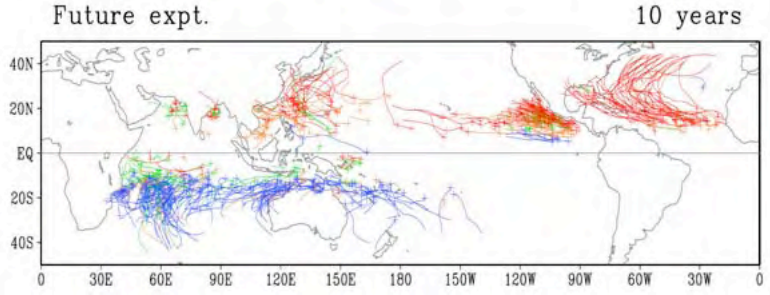
Typhoon paths

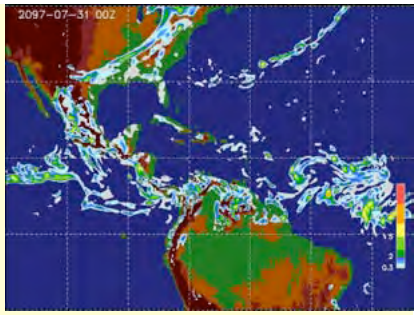


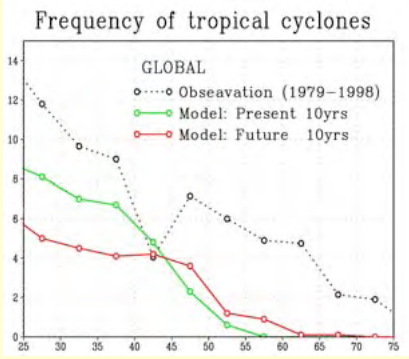
Hasegawa and Emori (2005)







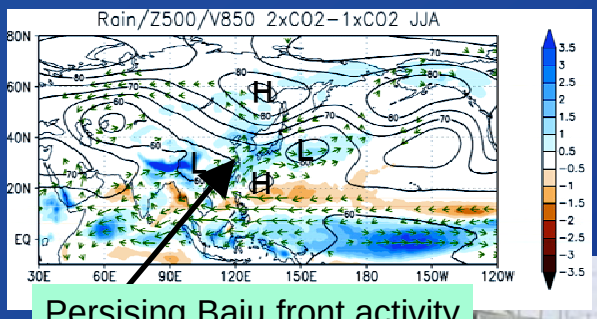




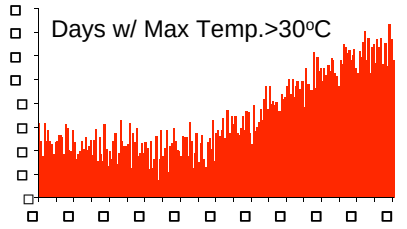
Max surface wind speed (m/s)

(Oouchi et al., 2005)

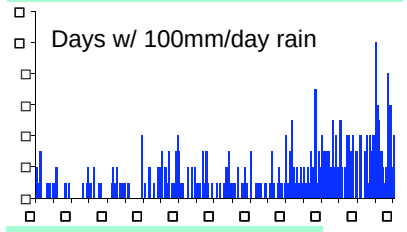
Hydrological cycle change



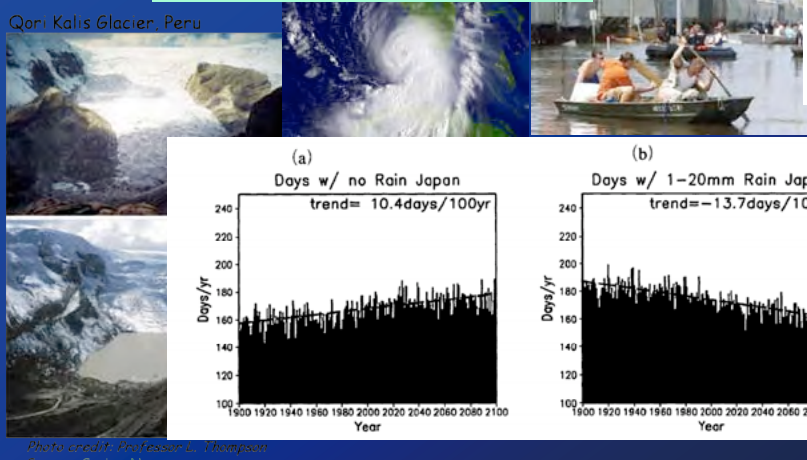
Persising Baiu front activity



Hot summer days increase



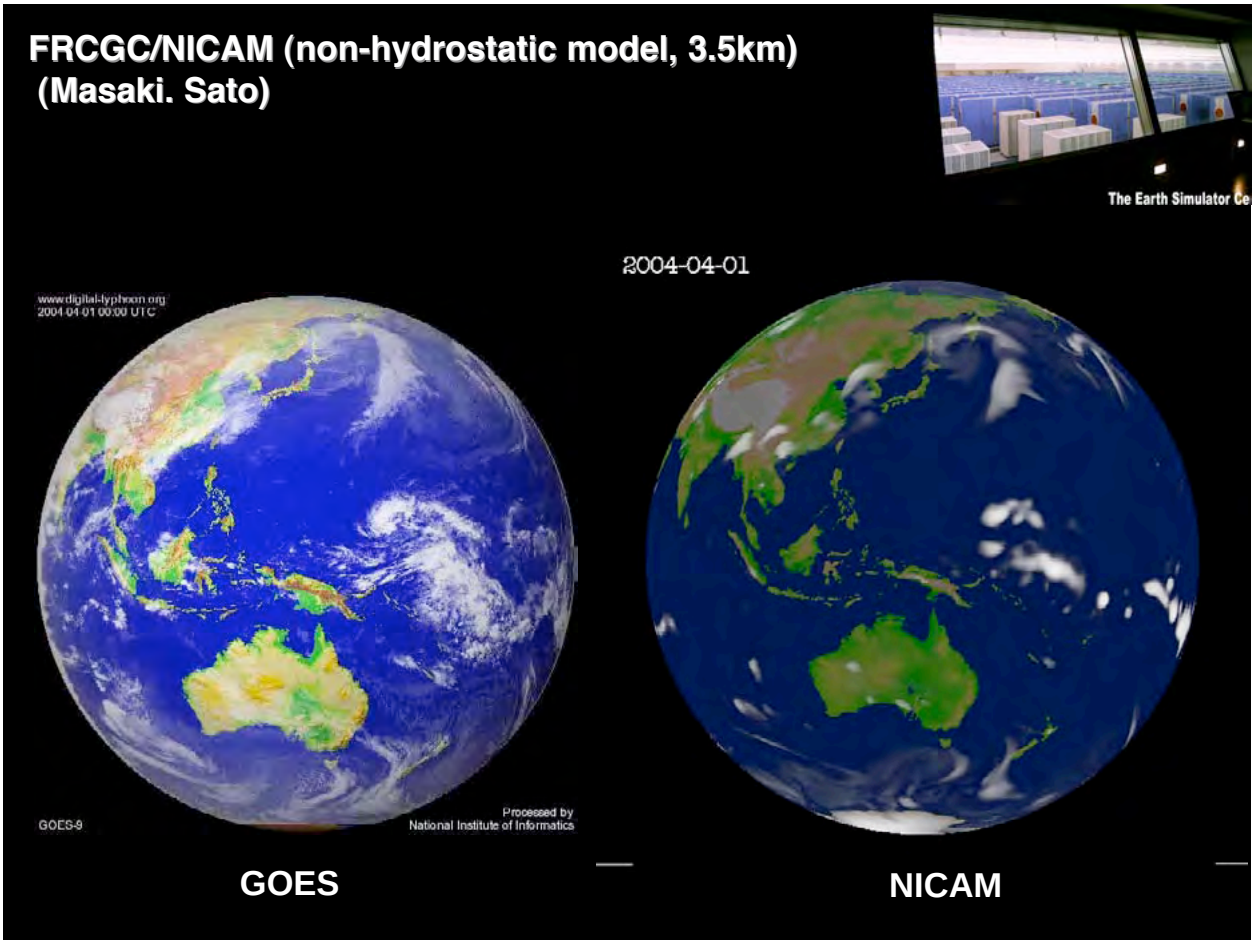
Heavy rain increases



Kimoto (2005) MIROC exp

Precipitation and tropical cyclones change?

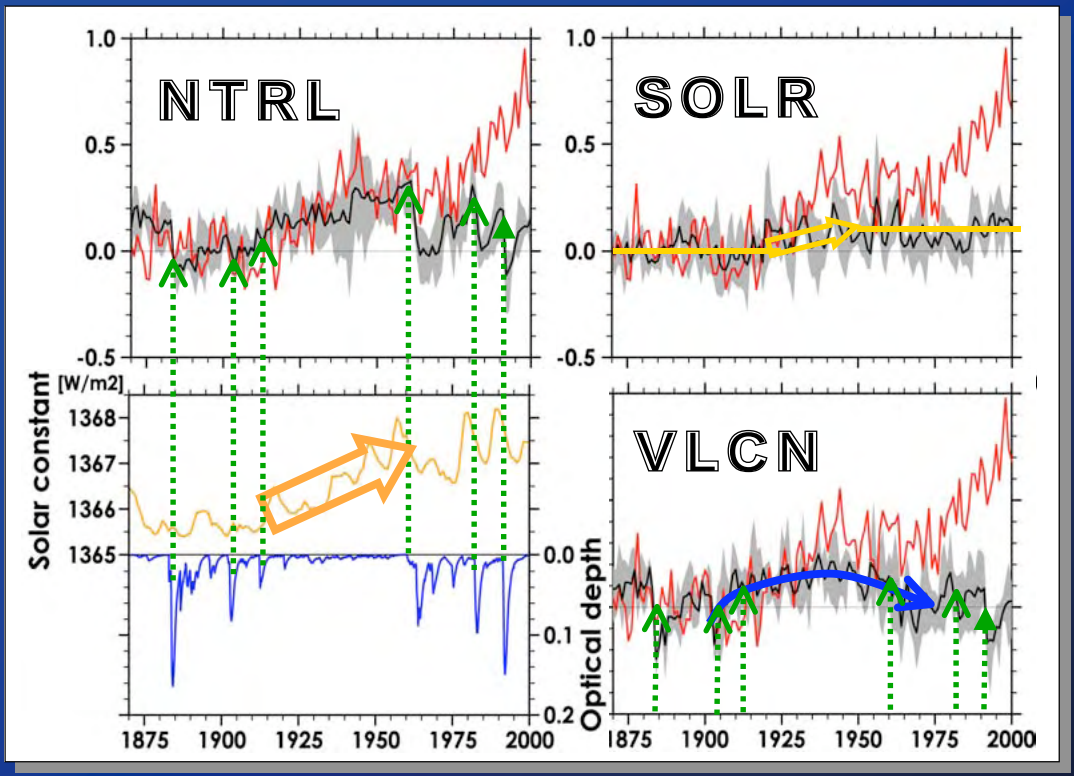
- High impact to water resource and crop production assessment
- Tropical cyclones may decrease in frequency, but increase intensity
- Intense rainfall may increase in East Asia
- Baiu frontal activity may become more persistent
- Still not fully confirmed by observation
  - Knutson and Tuleya (2004), Emanuel (2005), Webster et al. (2005), Chan (2006) etc
  - GPCP data not showing a similar trend
- High resolution modeling needed
- also for Ocean current simulation: Primary and fish production in ocean



Other issues

- More processes should be included in climate modeling
- Dynamic global vegetation models (DGVM)
- Oishi's experiment to introduction of DVM for 4xCO2
  - Land biota C budget: -78 GtC of respiration
  - Soil C budget: +25GtC of organic matter decomposition
  - DGVM made a net increase of +328GtC
  - Warming: +8～+20K vs DGVM contribution: +1～+4K
- Dynamic vegetation mechanisms may accelerate the warming
- Solar forcing highly uncertain in 100 to 1000 year change
- Can we learn from paleo climate study?
  - Glacial period
  - 100 years to 10 Ka change is not well understood

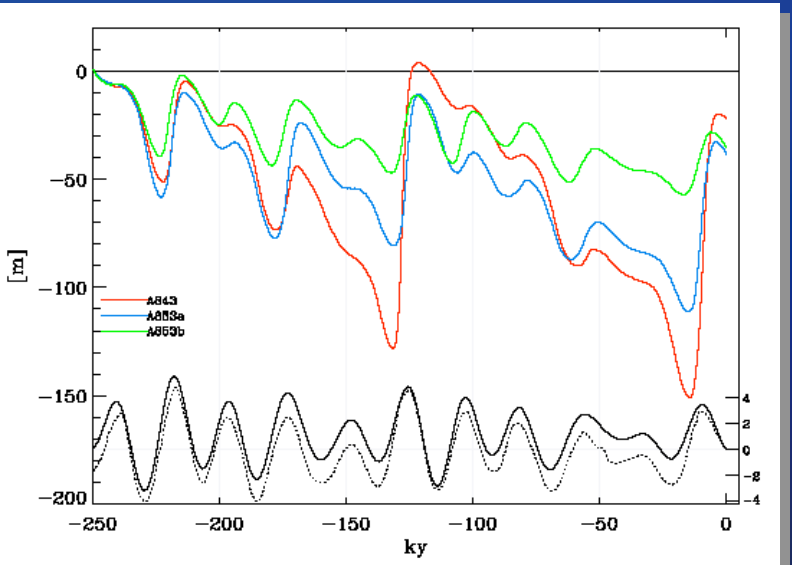
Simulation of 20th century climate



K-1 Project

Milankovitch cycle of glacial/ interglacial cycle

A. Abe (2006)



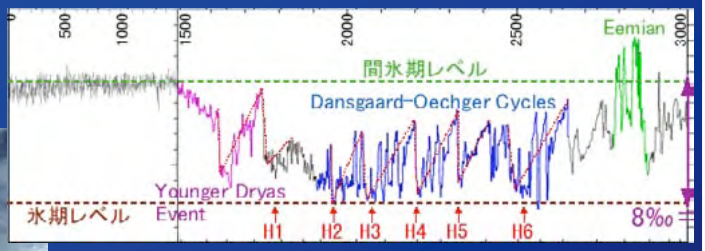
Earth's orbital change only

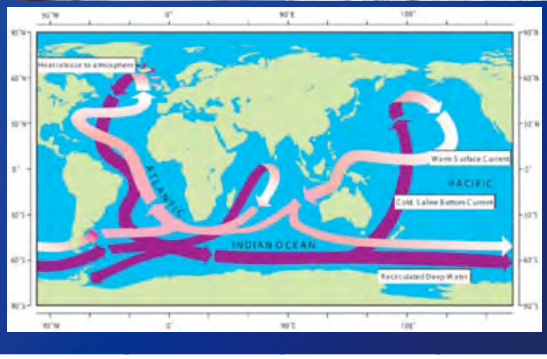
+ crust deformation

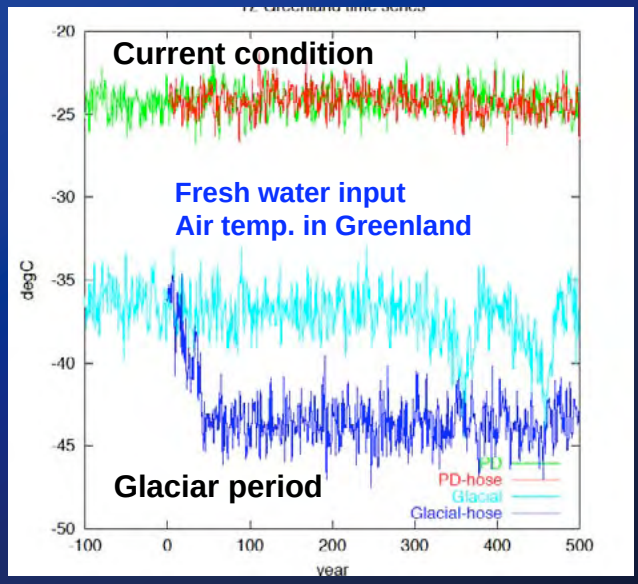
+ CO2

100Ka saw-tooth like variation may be caused by a non-linear feedback in the atmosphere-ice sheet-earth's crust system.

Feedback through deep ocean current







A. Abe et al.（2007）

Milestones

1991 2001 2005 2010

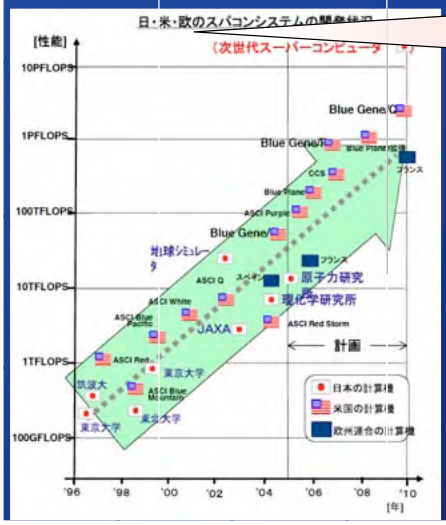
99 External Review

1st period (2004-2009)

2nd period

IPCC-AR4

UNFCCC 1st commitment period (2008-2012)



100km

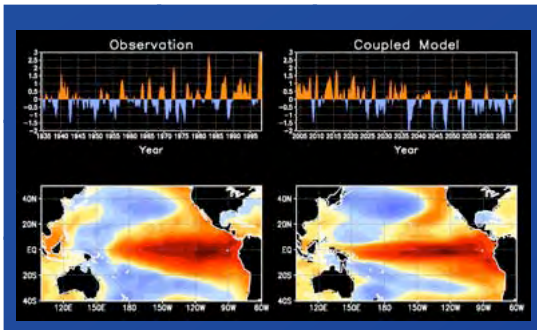
Global 3.5km

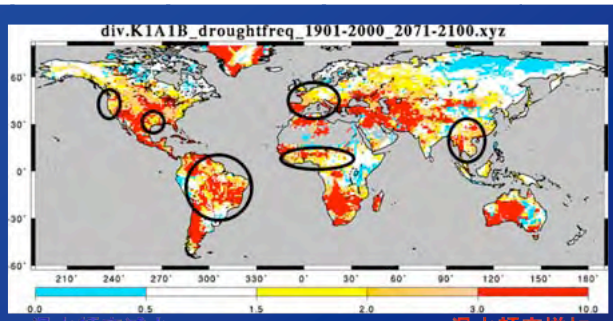
Earth Simulator (2002-)

10PFlops machine

RR2002（2002-2006）

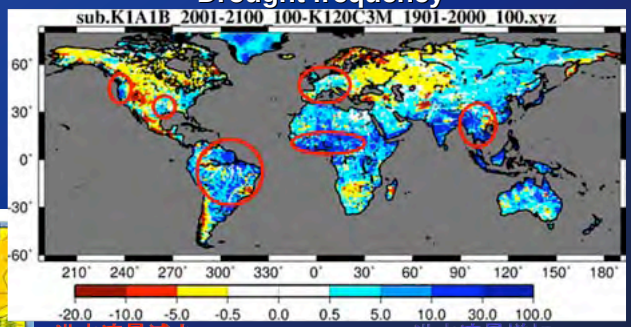
RR2007（2007-2011）



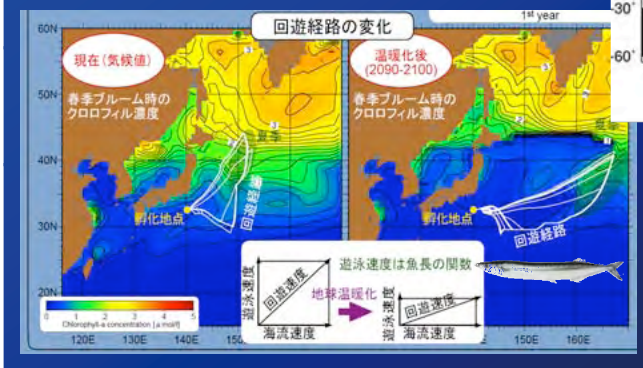


渇水頻度減少 Drought frequency 渇水頻度増加

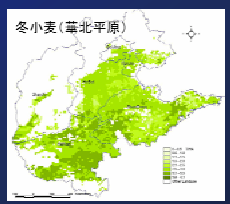
Climate simulation to Assessments



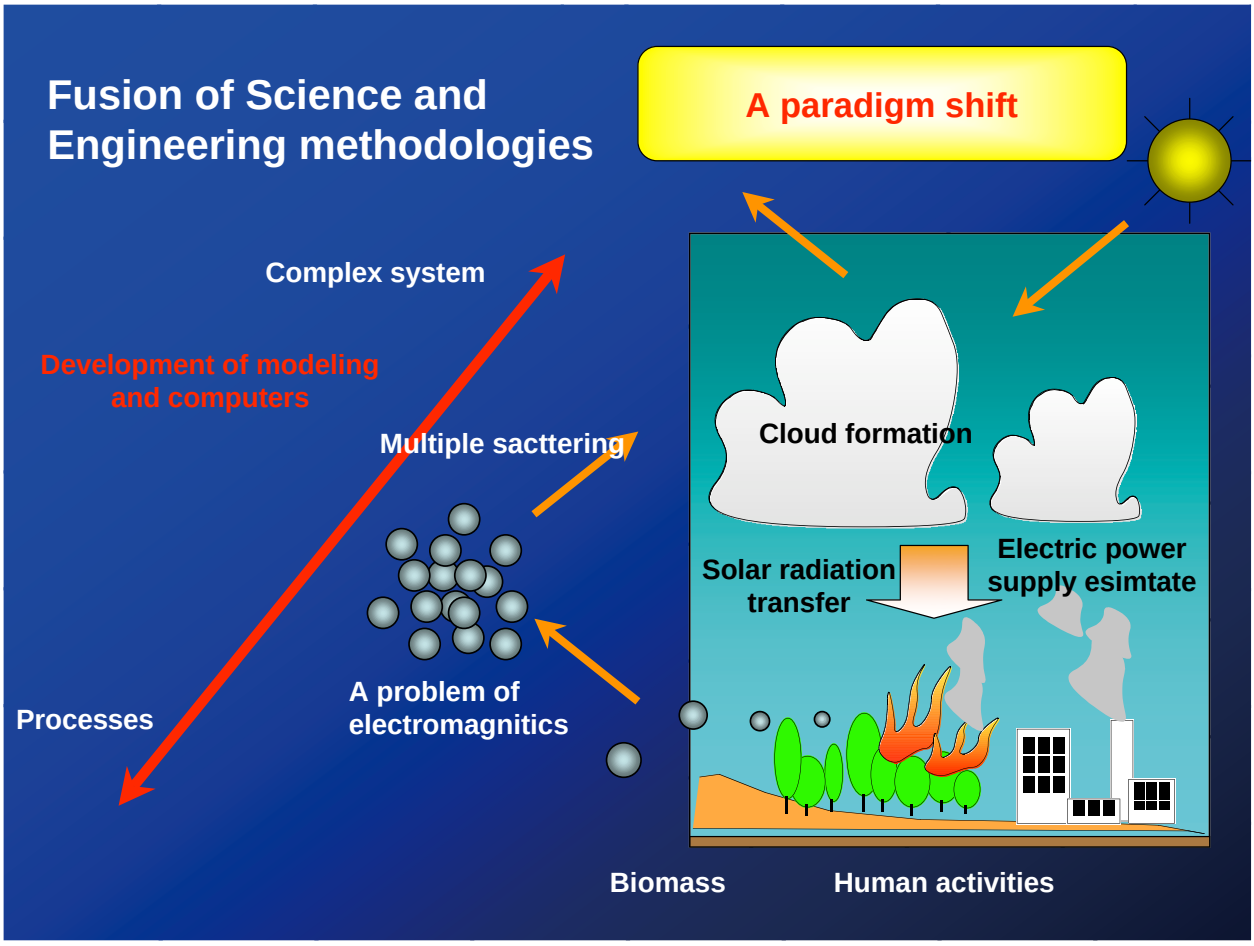
洪水流量減少 Flood frequency 洪水流量増加



Hirabayashi et al. (2006)



Winter wheat yield (Yang, 2006)



Conclusions

- Various change mechanisms being simulated
- Large uncertainties still exist
- Cloud and precipitation process difficult
- Applications being increased with model getting more comprehensive
- Science and engineering methods to be combined for simulating the complex system
- Impact studies started
- We need large computers
- We MUST reduce human activity stresses to nature