Drastic Change during Global Warming

How well do we know about global warming?

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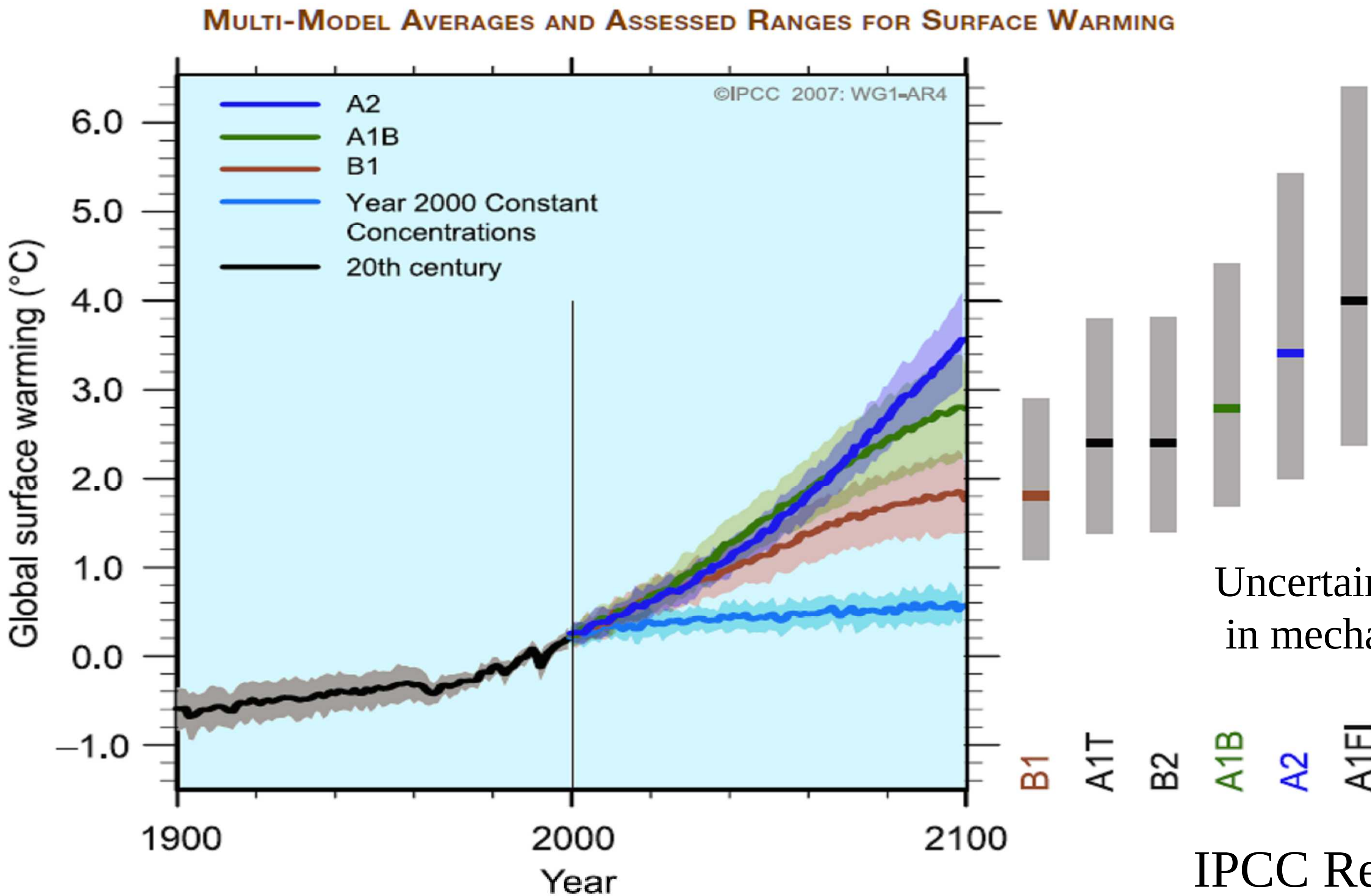
Agenda

- ☼ Global warming is a real and crucial phenomenon.
  (Nobel Peace Prize awarded to IPCC and Al Gore)
- ☼ Do we well know about global warming?
- ☼ Uncertainty larger than 50% on the warming rate
- ☼ Scientific clarification is required on some issues and mechanisms which yield positive feedback in the earth system.
- ☼ Reliable projection on distinct indicators is crucial for scientists to establish credibility.

Global warming in the 21st Century could be 1℃ to 6℃

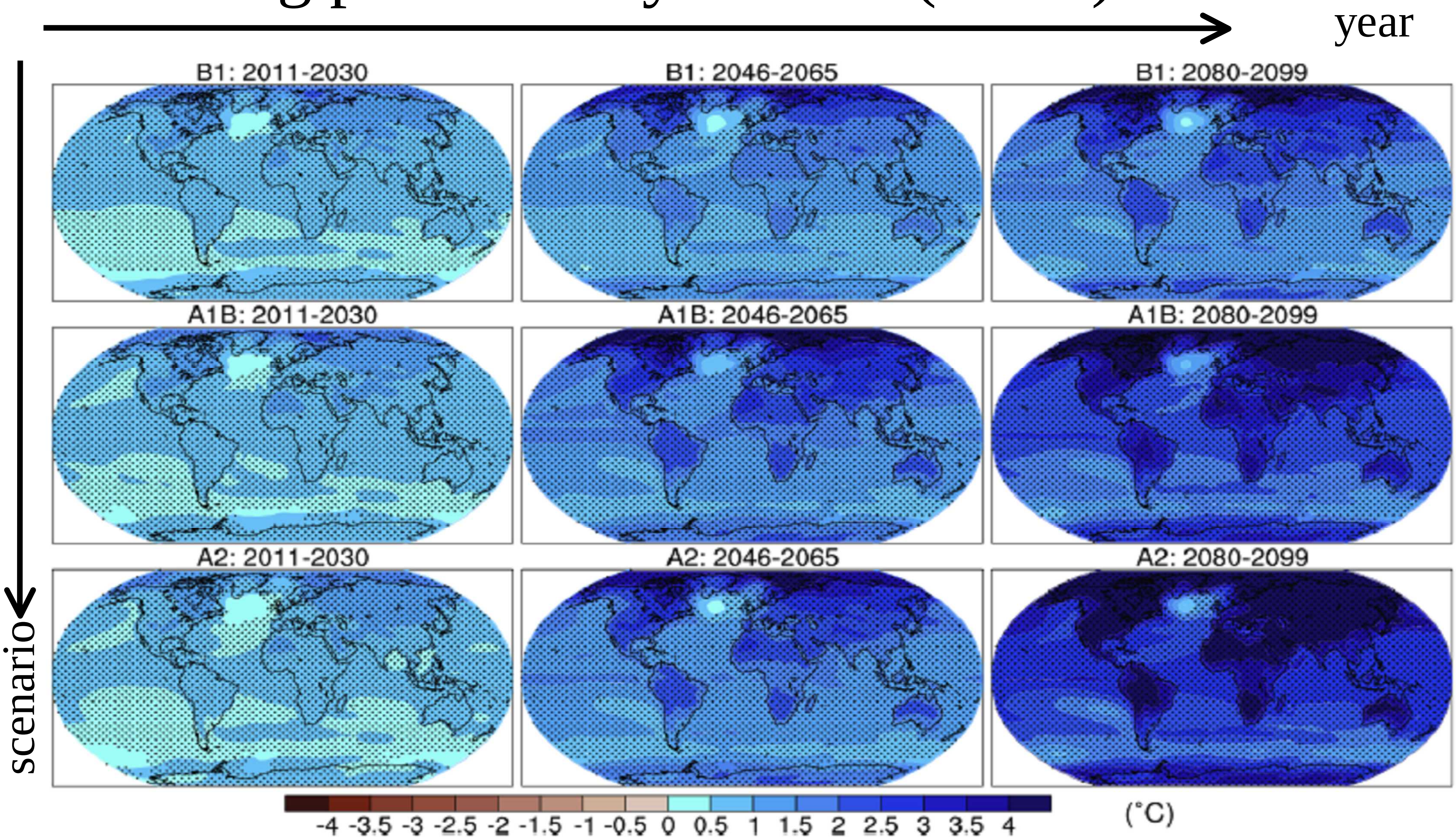


Uncertainty in mechanism

IPCC Report

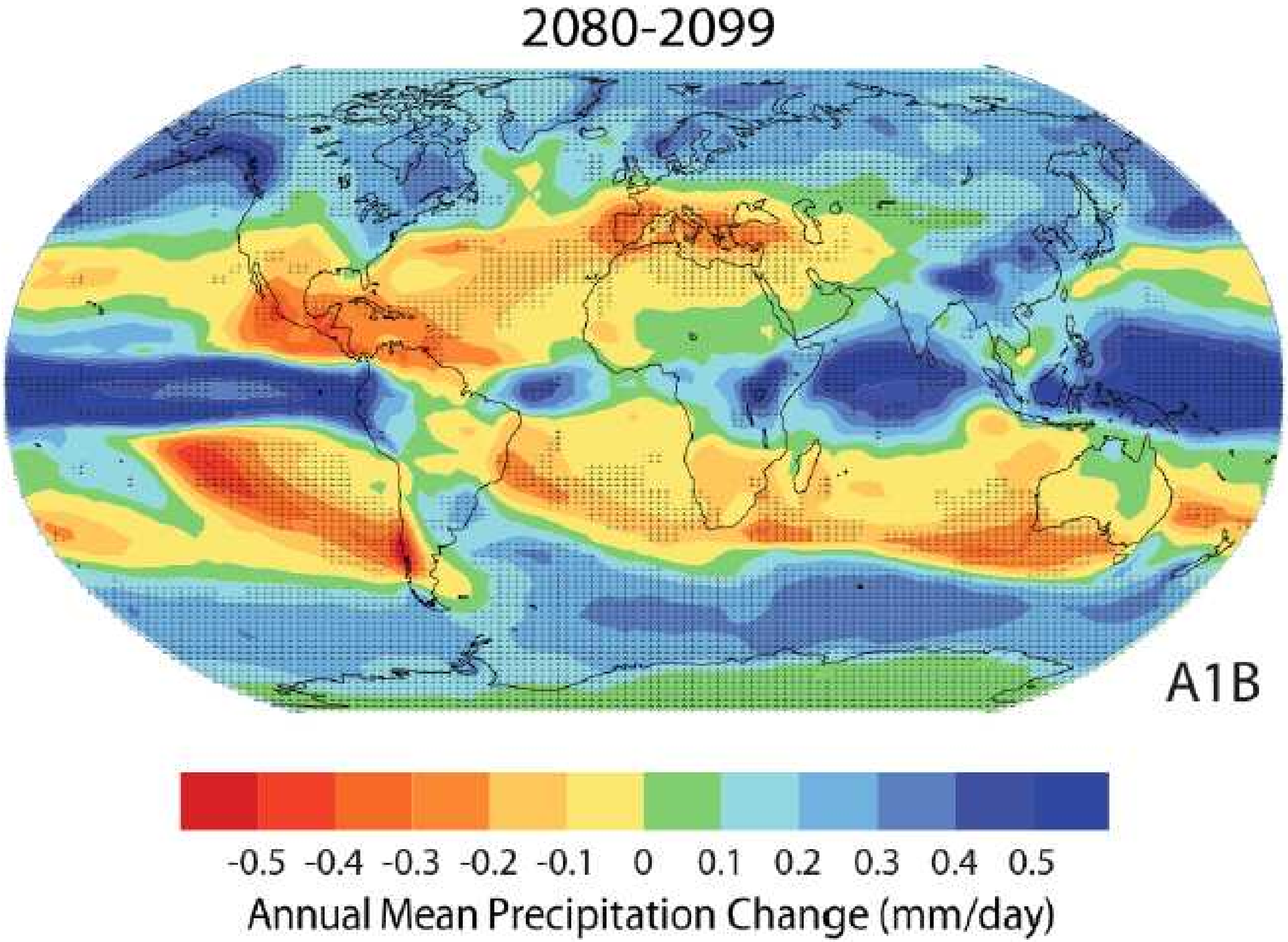
Uncertainty is large due to both scenarios and models.

Warming predicted by models (IPCC)



Temperature projection is important for decision making.

More rain or less rain? (IPCC Report)



Rain changes are now qualitatively better projected. Quantitatively?

Huge Impact on Society

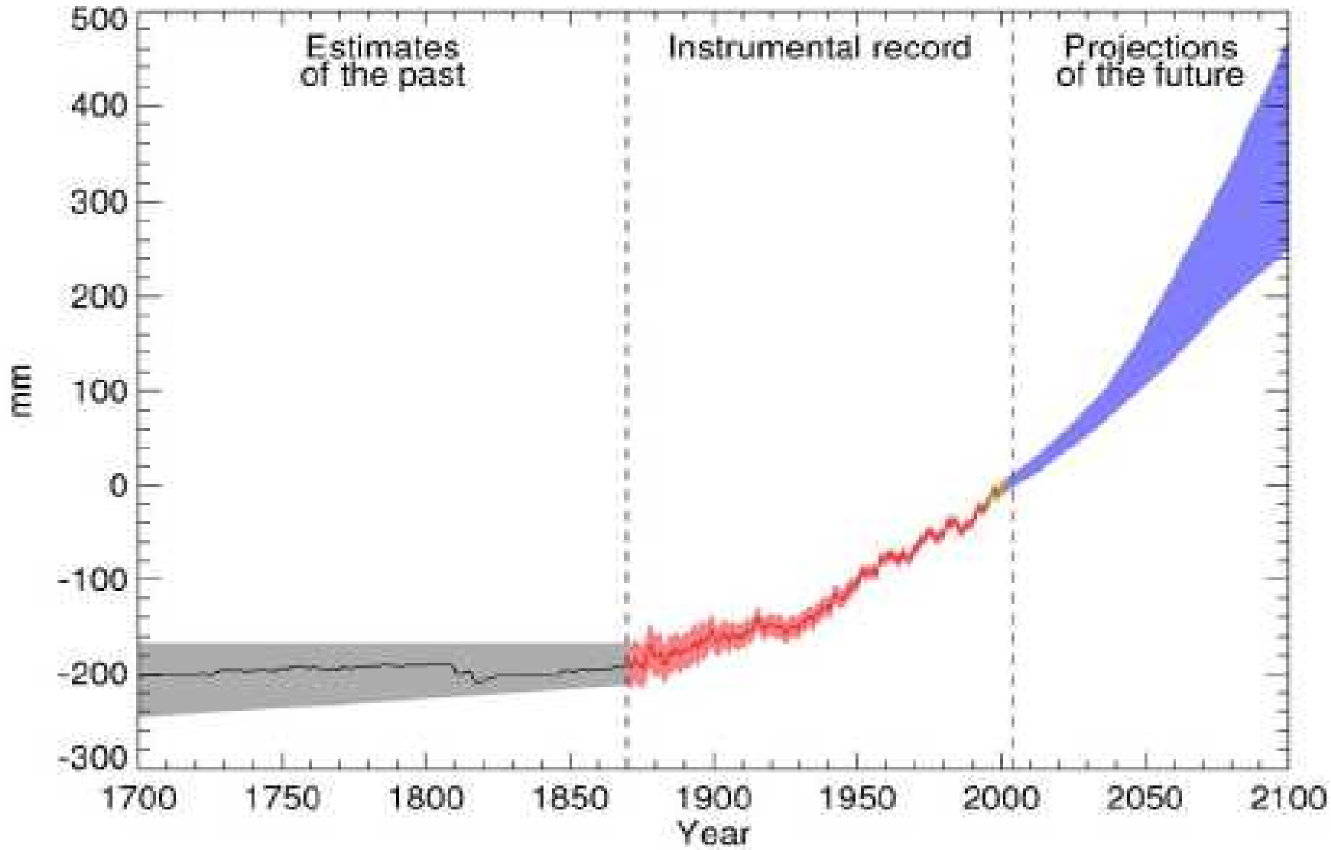
Sea level rise

Tuvalu

Typhoon

Future sea level rise until 2100

Sea level rise will be mainly related to thermal expansion of sea water in the future projection. Only 30 – 50 cm?



Question 5.1, Figure 1. Time-series of global mean sea level in the past and future, relative to zero in 2001. For the period before 1870, we do not have global measurements of sea level. The solid line here is a climate model calculation (Gregory et al., 2006) of sea level change due to natural factors (volcanic and solar variability) and anthropogenic factors; the rather sudden fall early in the 19th century is mainly due to the eruption of Tambora in 1815. The grey shading shows the uncertainty on the estimated long-term rate of sea level change (see Chapter 6, Section 6.4.3). We show a reconstruction of global mean sea-level from tide gauges (Church and White, 2006, Section 5.5.2.1) for 1870-2001, with uncertainties shown by shading, and from satellite altimetry (Cazenave and Nerem, 2004, Section 5.5.2.2) for 1993–2004, both as annual means. For the future we indicate the range of uncertainty due to different choices of emission scenario (see Chapter 10, Section 10.6.5). Beyond 2100 the projections are increasingly dependent on the scenario. Over many centuries or millennia, sea level could rise by several metres (see Chapter 10, Section 10.7.3).

Sea level rise in last 13 years   Thermal expansion

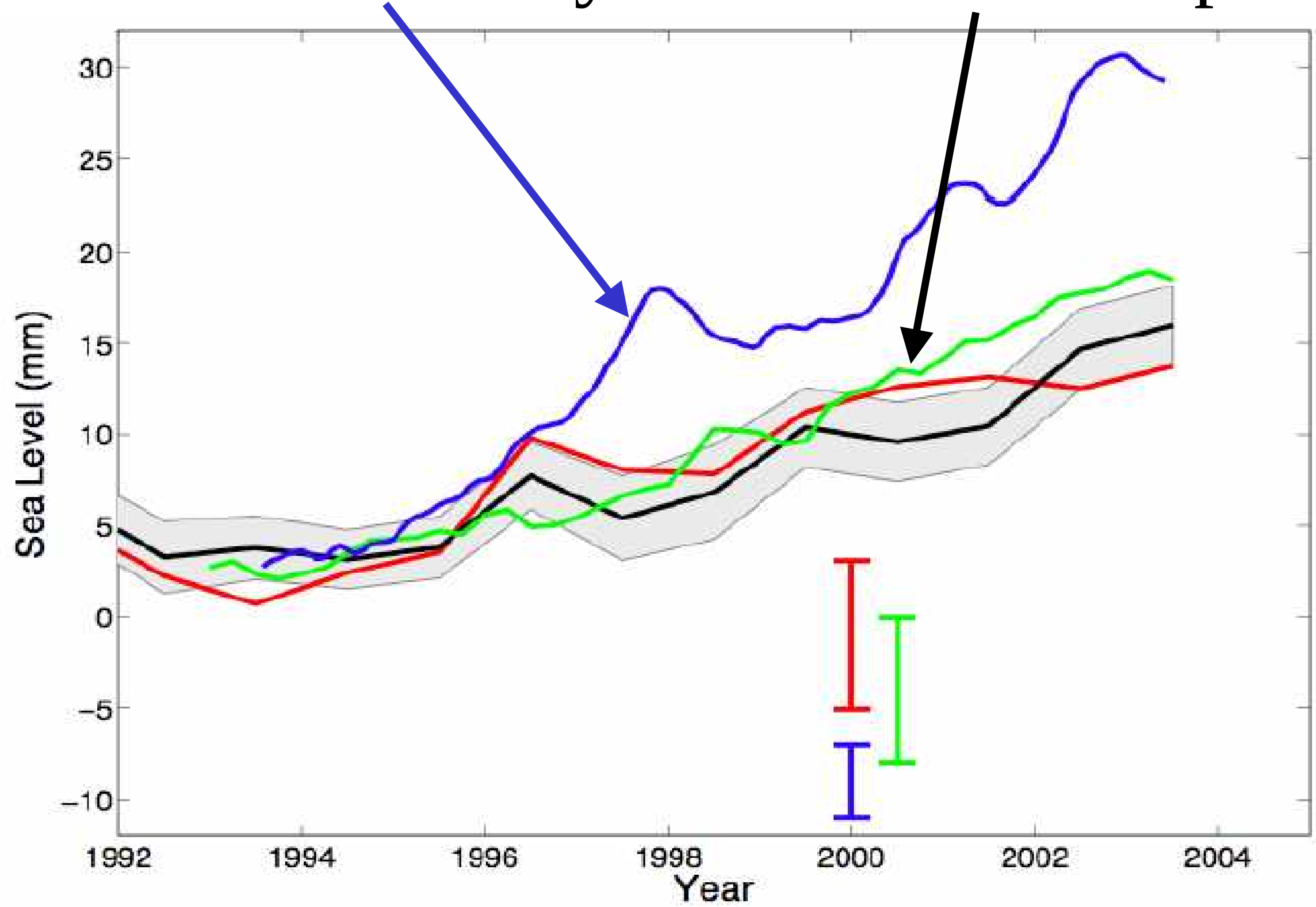
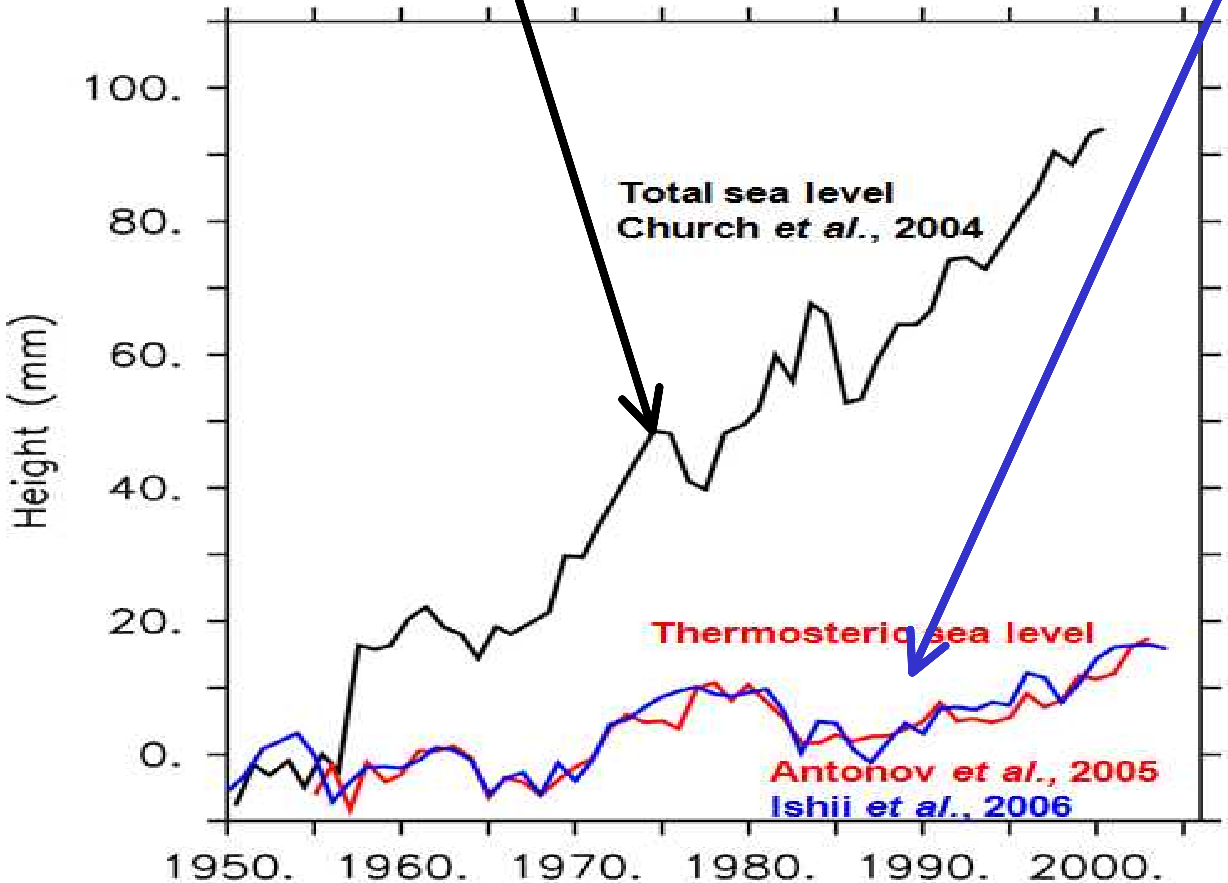


Figure 5.5.7. Thermal expansion curves for 1993–2003, average over 60°S–60°N, based on Levitus et al. (2005a) temperature data (in black; 0–700 m layer), Ishii et al. (2006) (in red; 0–700 m layer) and Willis et al. (2004) (in green; 0–750 m layer). Shaded area and vertical red and green bars represent the 95% errors of the black, red and green curves respectively. The blue curve is the observed global mean sea level by satellite altimetry (yearly-mean, averaged over 65°S–65°N).

The thermal expansion is a major component.

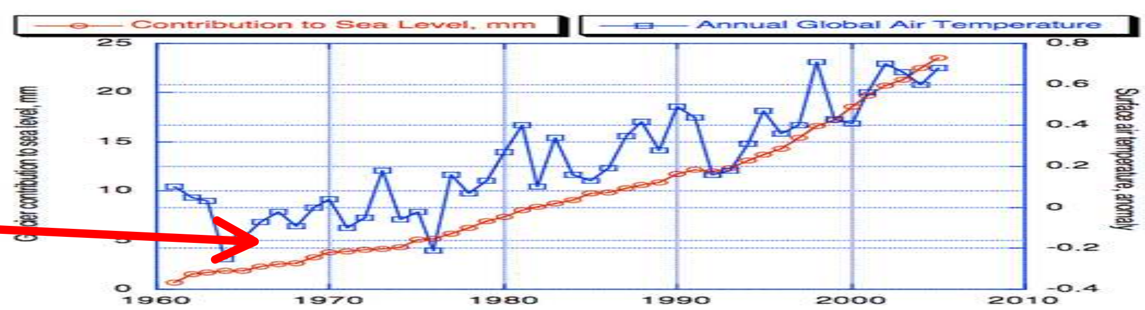
Sea level rise in last 50 years

Thermal expansion



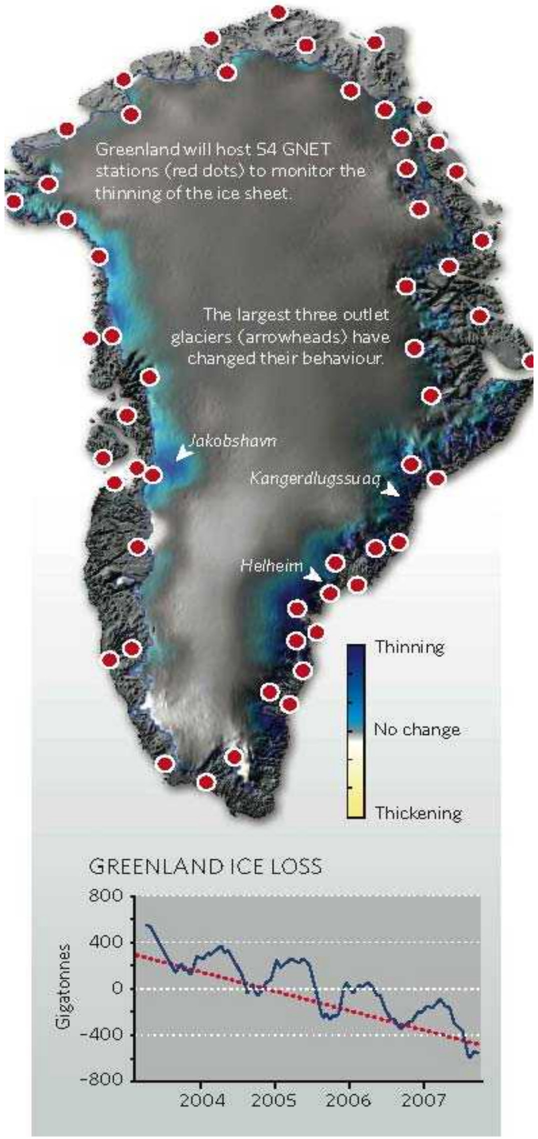
Domingues, Church et al. (Nature, 2008) found the effects of deep ocean warming and Greenland ice sheet melting.

Mountain glaciers



National Snow and Ice Data Center

Recent changes of the Greenland ice sheet



Source: Witze (2008)

Mass balance negative:

sea-level equivalent to

1.5 to 2.5 cm/100years

(Ohmura, 2004)

New satellite gravity

measurements (2002 – 2005):

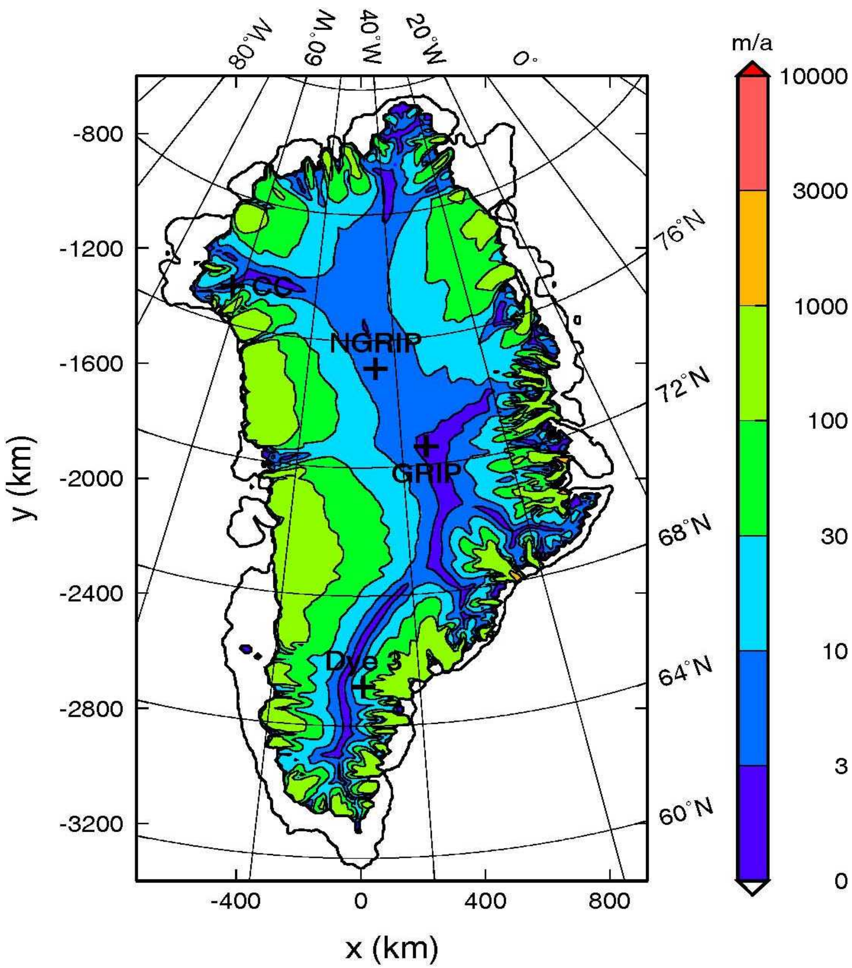
6.6 ± 0.6cm/100years

(Chen et al., 2006)

Simulation results for Greenland

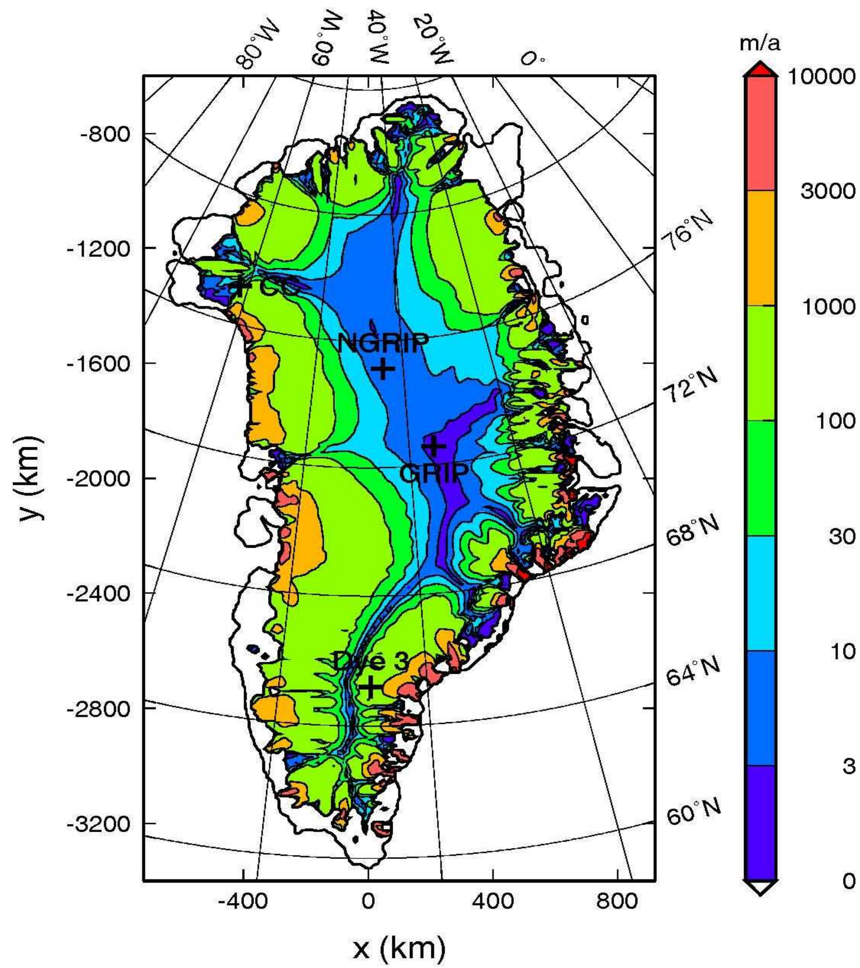
Surface velocity → differs greatly for the two set-ups!

2100 slow basal slide



12cm/100years

2100 fast basal slide

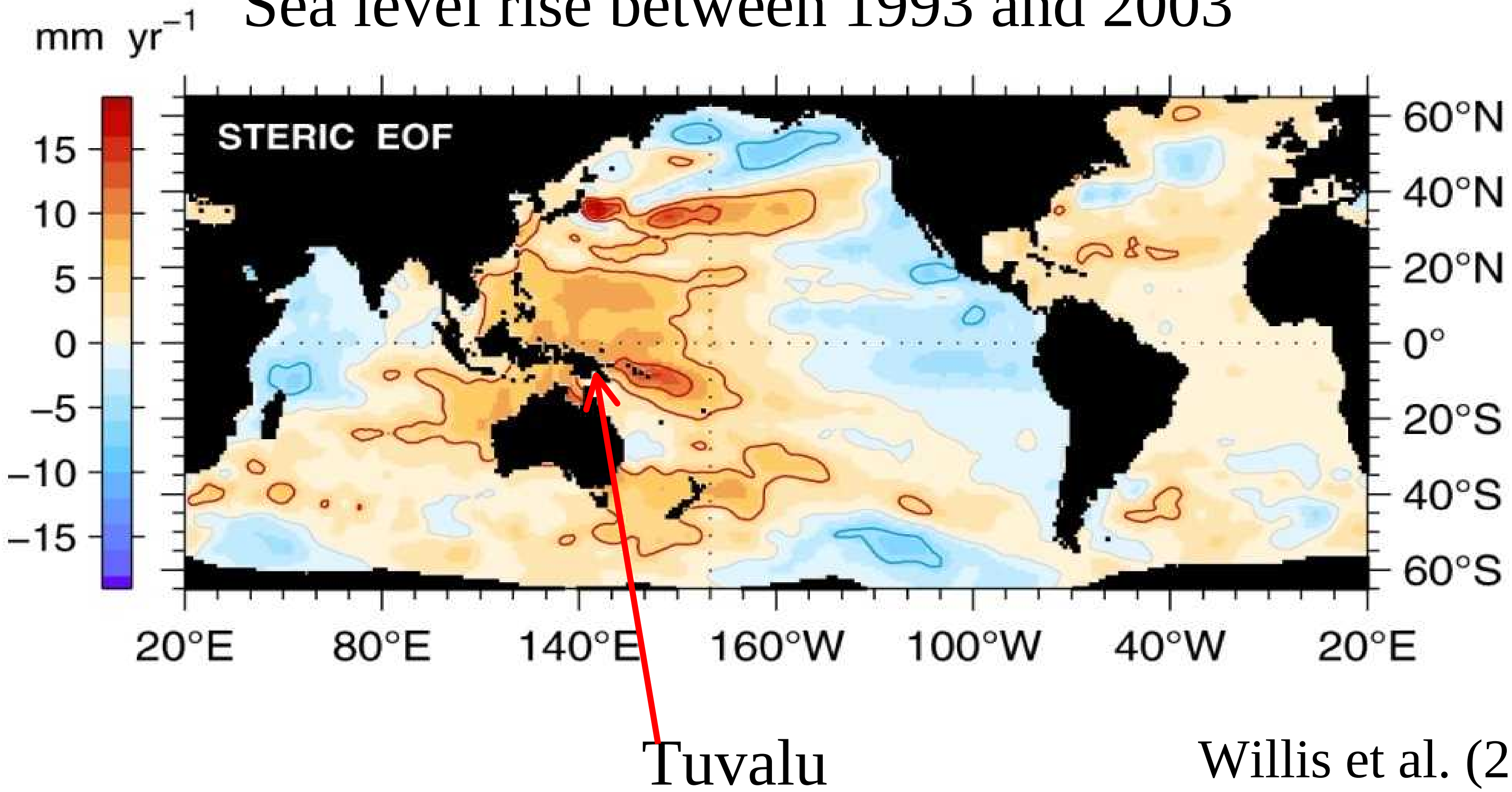


58cm/100years

Year-to-year variability, day-to-day variability

We should remember that sea level rises due to
also wind-driven general circulation,
storm surge and low atmospheric pressure.

Sea level rise between 1993 and 2003



Willis et al. (2004)

Clarify causes and magnitude of sea level rise

- Most scenarios: only 30-50cm rise in the 21st century
- Oceanic thermal expansion near surface is major
  in the recent 10-year period and the future projection,
  but minor in last 50 years.
- Mountain glaciers: comparable
  with the thermal expansion in last 50 years
- In last 50 years, deep ocean warming, and
  ice sheet melting in Greenland seem to be important.
- Is the future projection correct?
  Will the sea level rise 100cm, 150cm or more?
- Short-term variability is superimposed on the trend.

Distinct Indicator

Arctic sea ice

Indigenous people

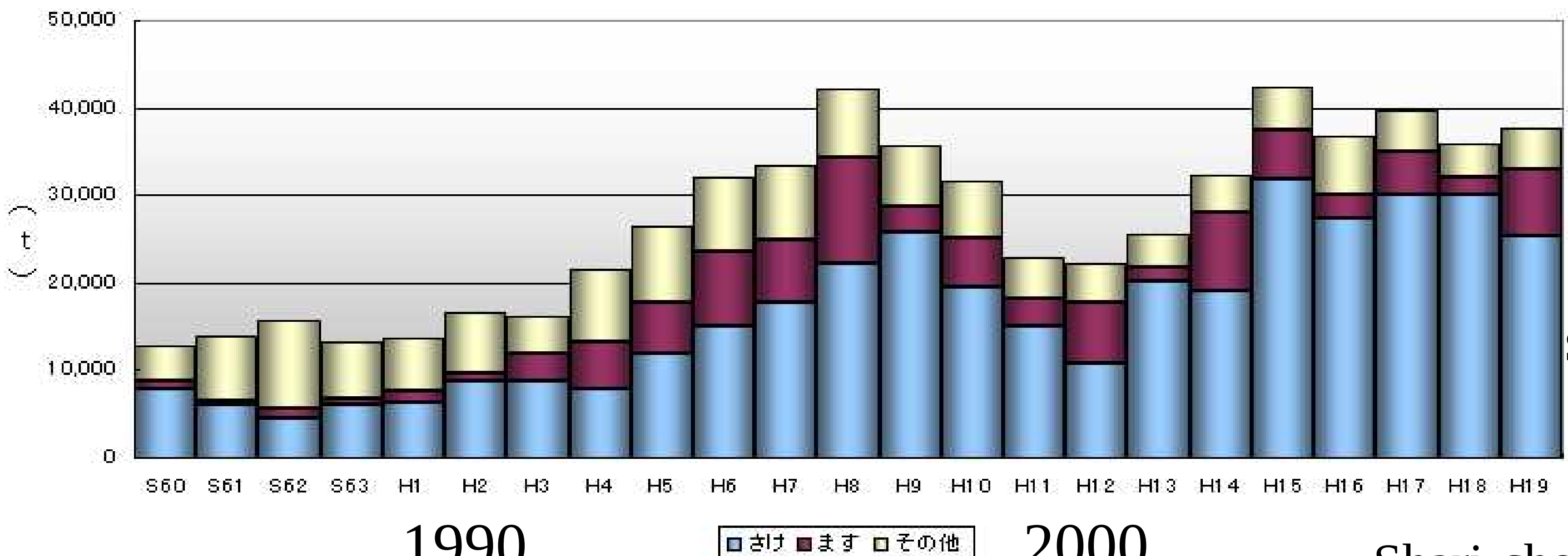
Polar bear

Do you think that global warming is sometimes good for somewhere?

Yes, but it will not continue for long time!

Salmon will not come back to Hokkaido.

Fisheries around Shiretoko



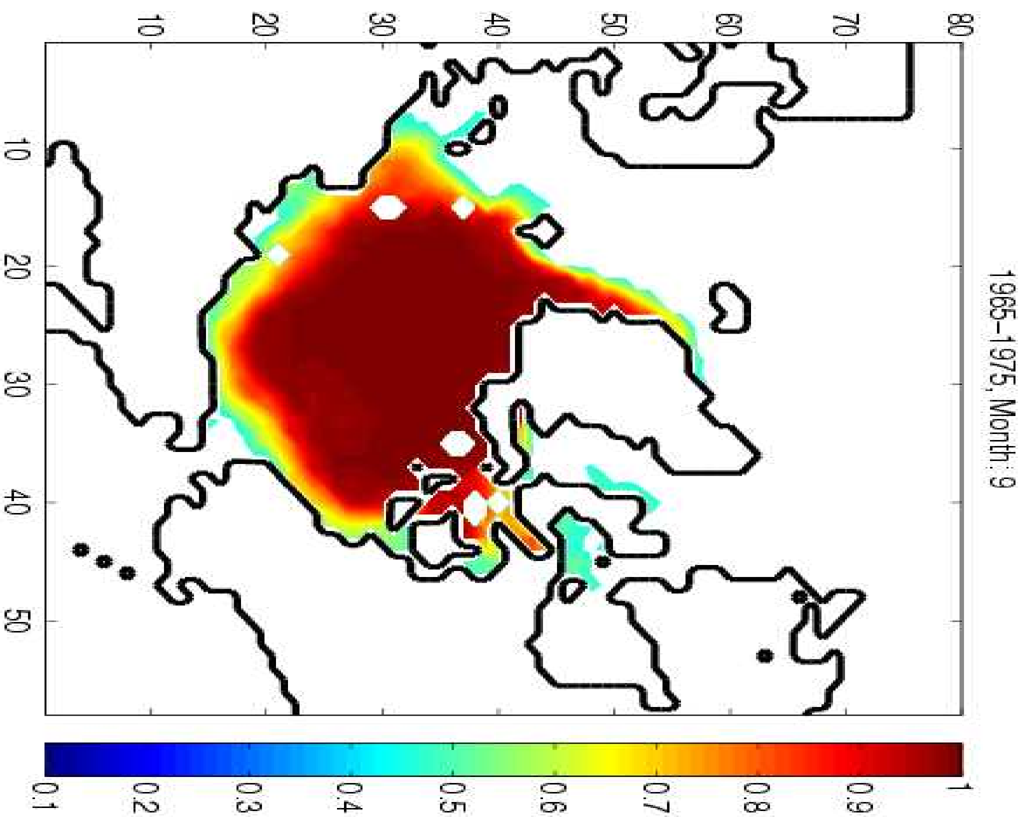
salmon

Shari-cho (2008)

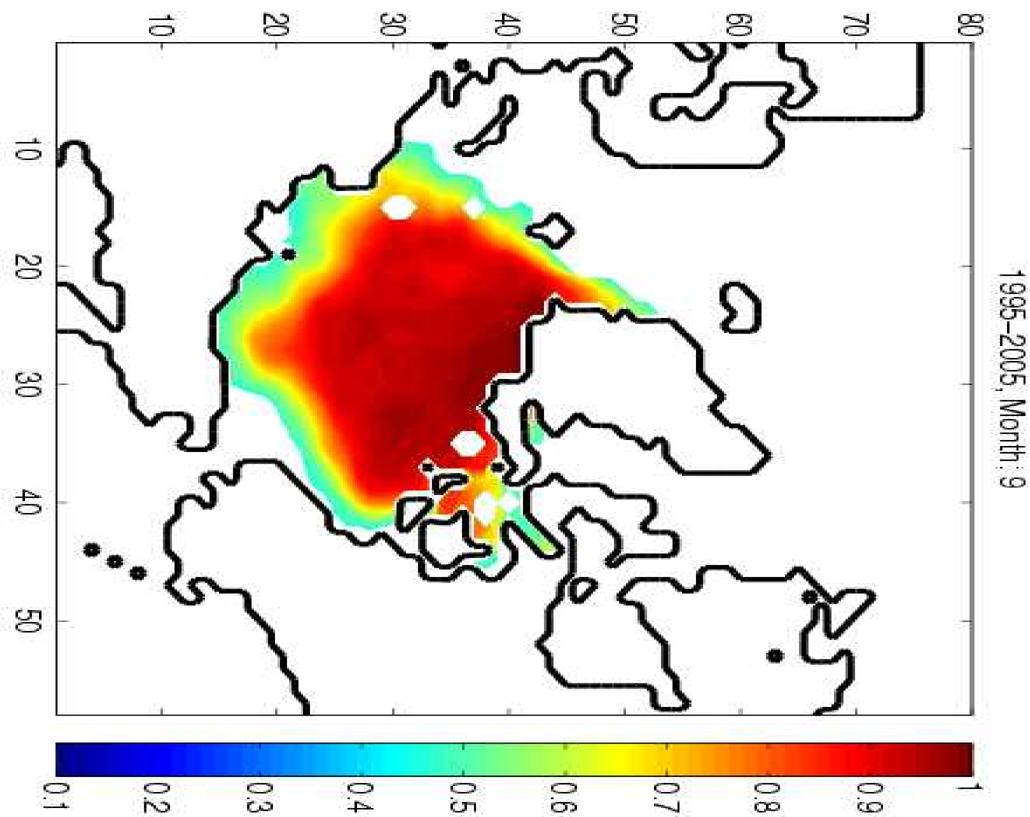
Observed ice cover concentration

Ice reduction is significant in last 30 years.

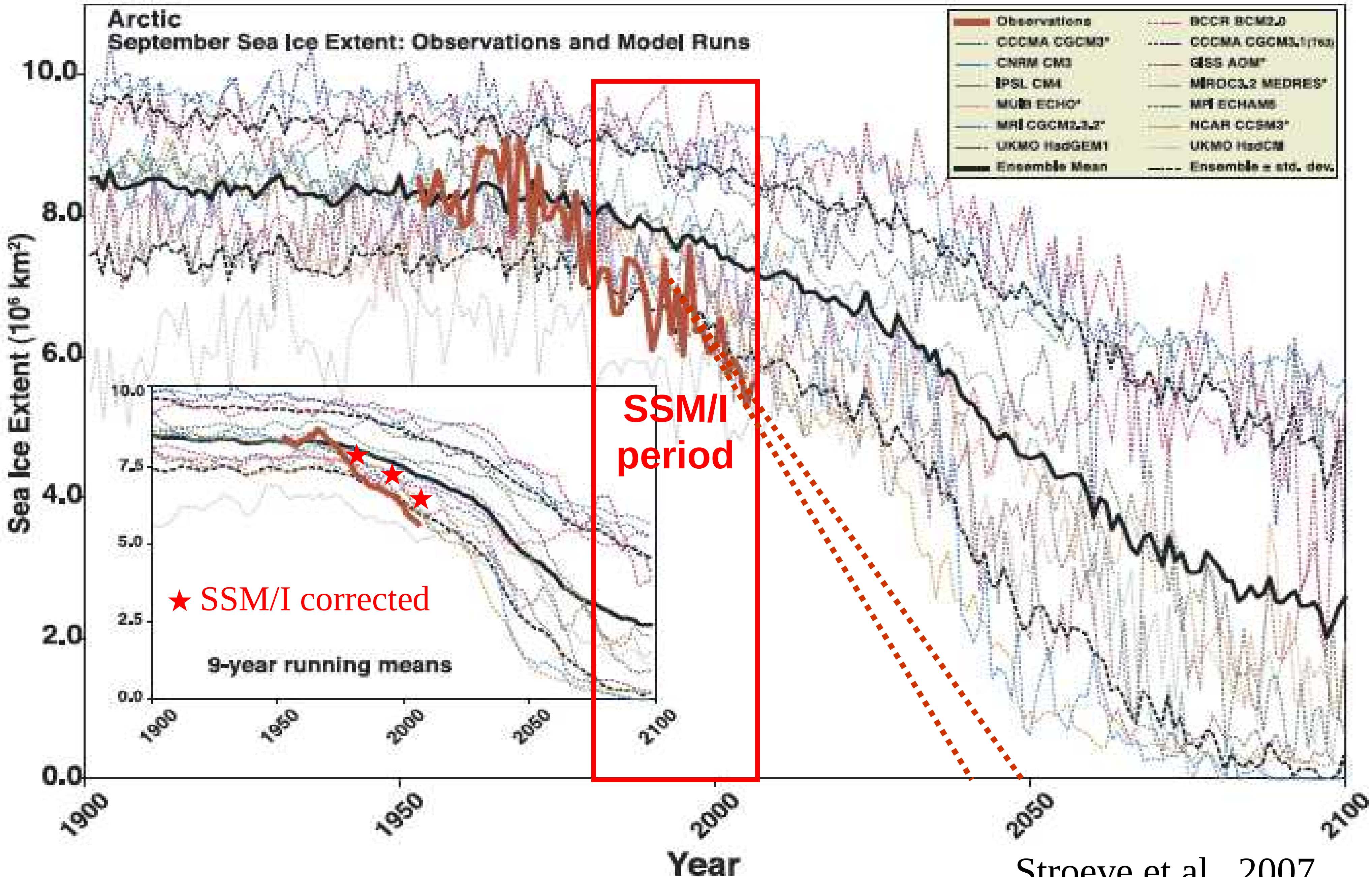
1965-75, Sep



1995-2005, Sep

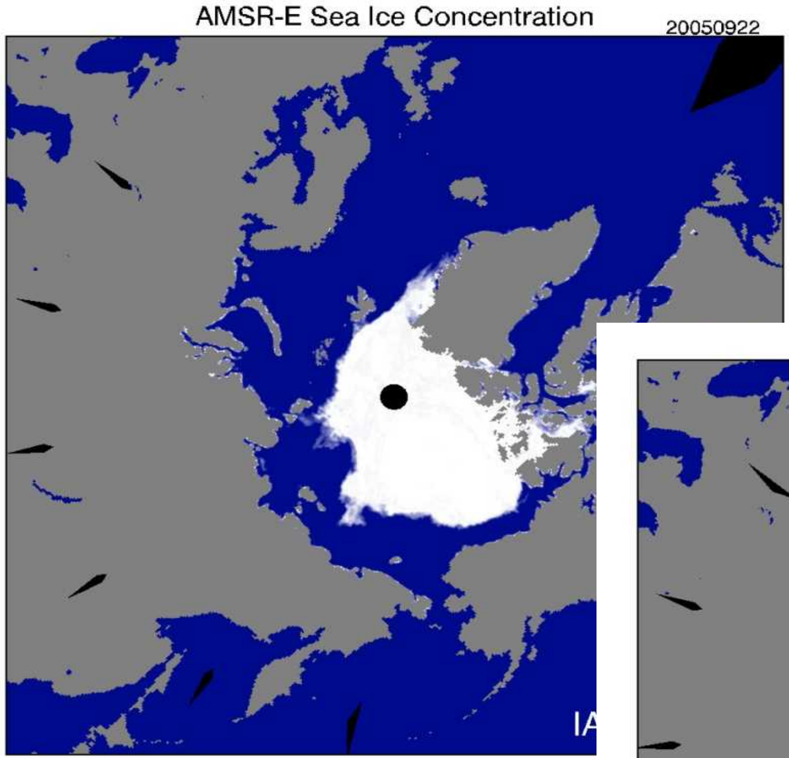


Observed sea ice melt faster than prediction

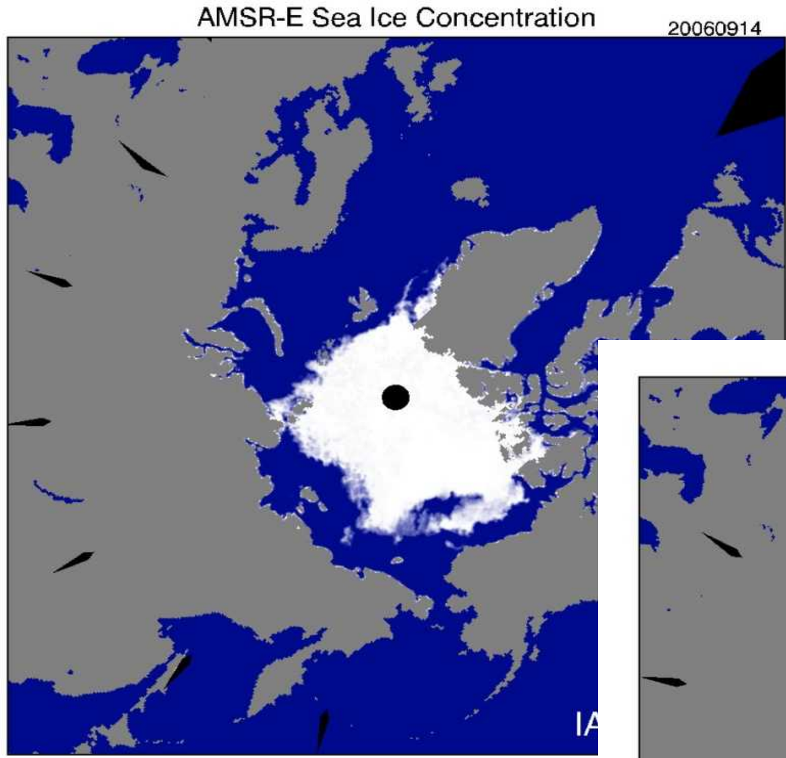


Stroeve et al., 2007

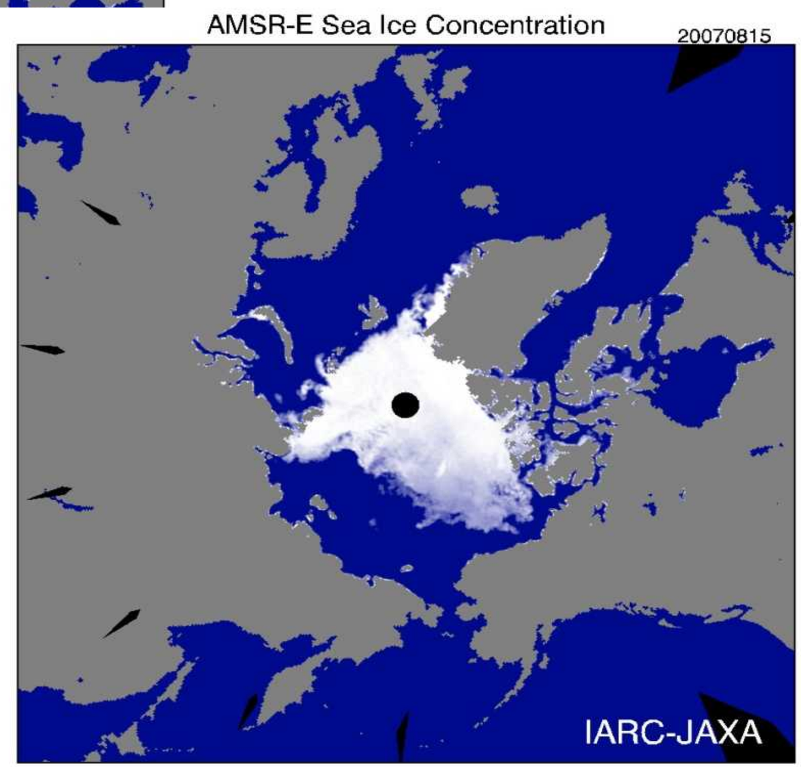
Significant year-to-year variability
→ We should not extrapolate
a few-year data for future projection.



2005



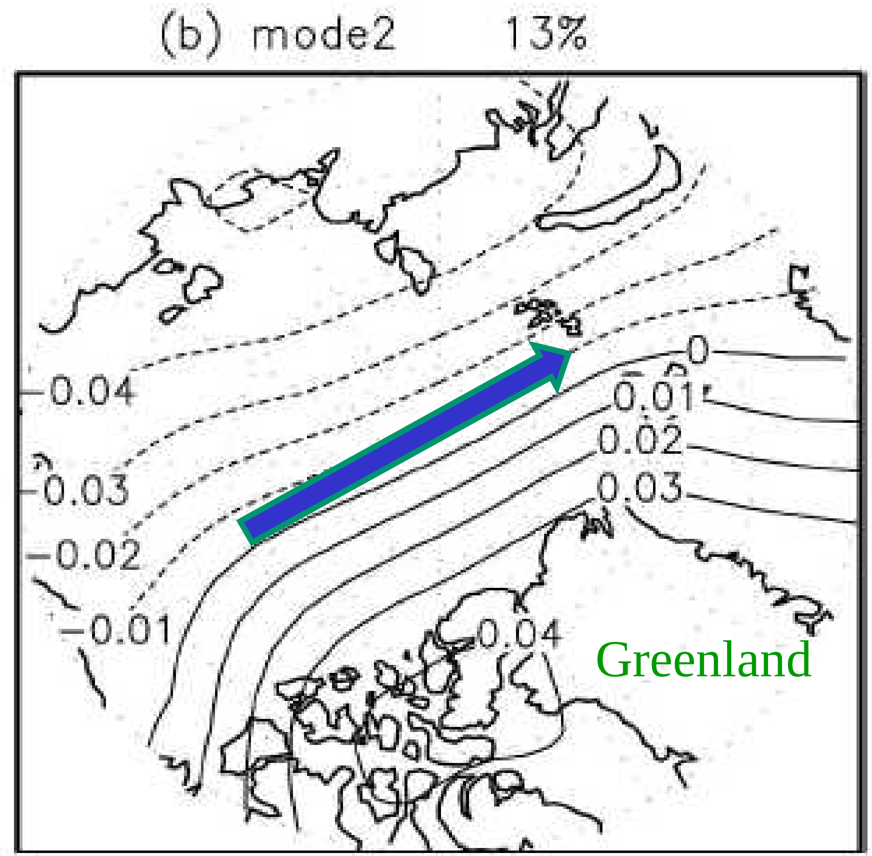
2006



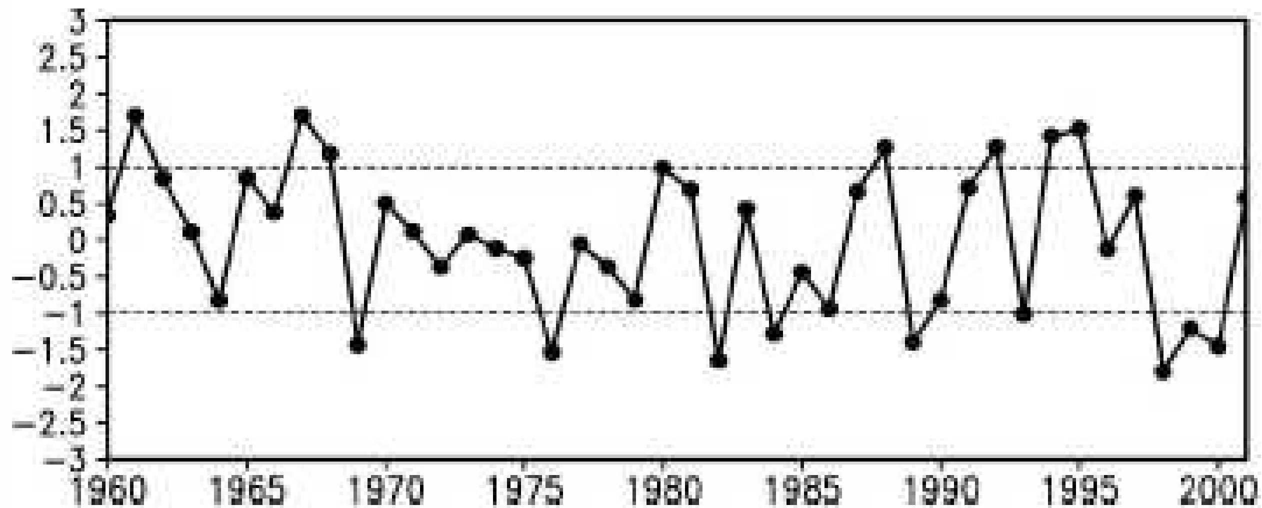
2007

If this decrease rate continues, the ice cover in this summer will possibly reach the IPCC prediction for 2040-2050.

2nd energetic variability in the atmosphere



Wind pushes sea ice from Bering to Greenland Sea.



Wu et al. (2006)

If this EOF mode continues to be positive in future,
sea ice would be pushed out and low in the Pacific sector.

When will summer Arctic sea ice disappear?

- IPCC Report: the ice cover in summer will disappear near the end of this century.
- The recent ice cover reduction was much faster.
- The ice cover was anomalously small in 2007 summer.

- Significant year-to-year variability

  →disappearance by 2020 might be exaggeration.
- We should be concerned with ice thickness.
- A simple extrapolation is not reliable,

  →but important mechanisms should be explored.
- Consequences have to be looked at in long-term too.

Positive Feedback in Earth System

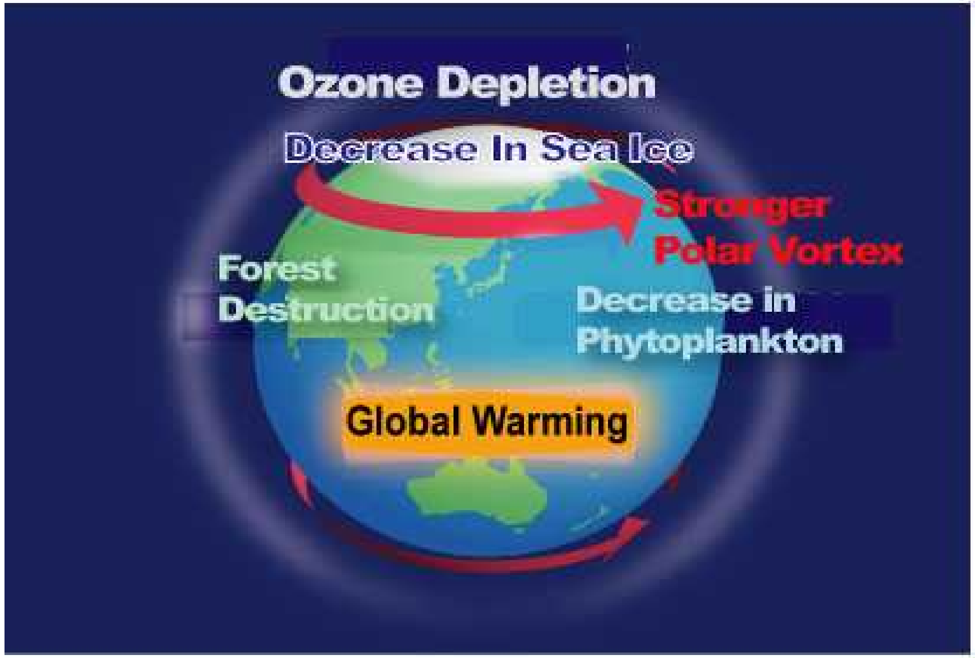
Terrestrial ecosystem
Marine ecosystem & geochemical balance

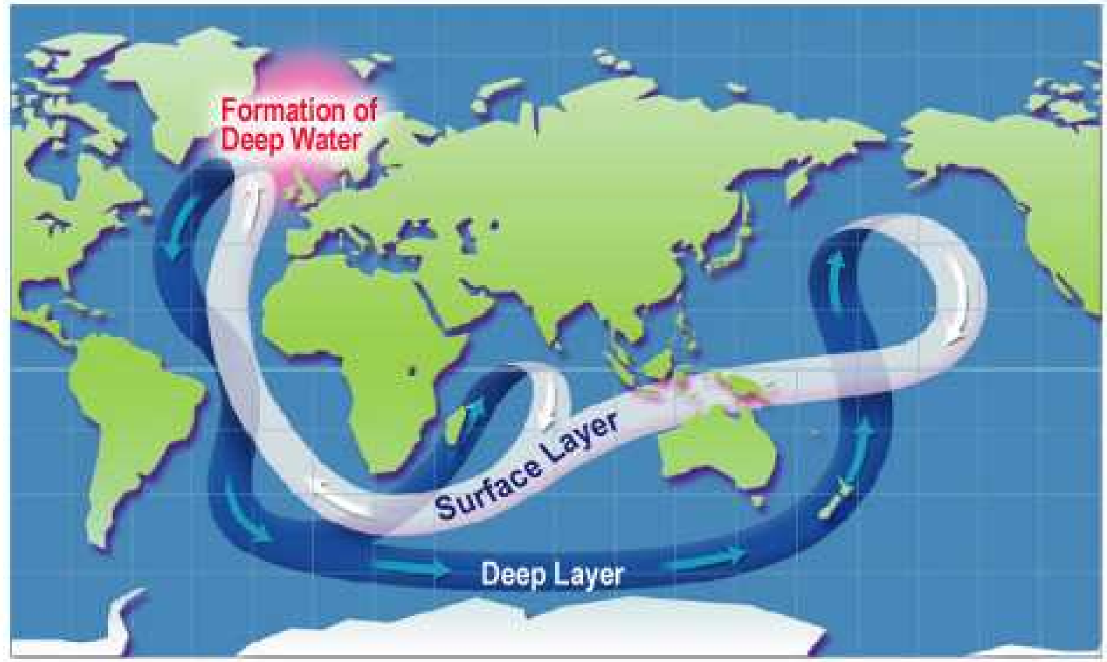
Expanding desert

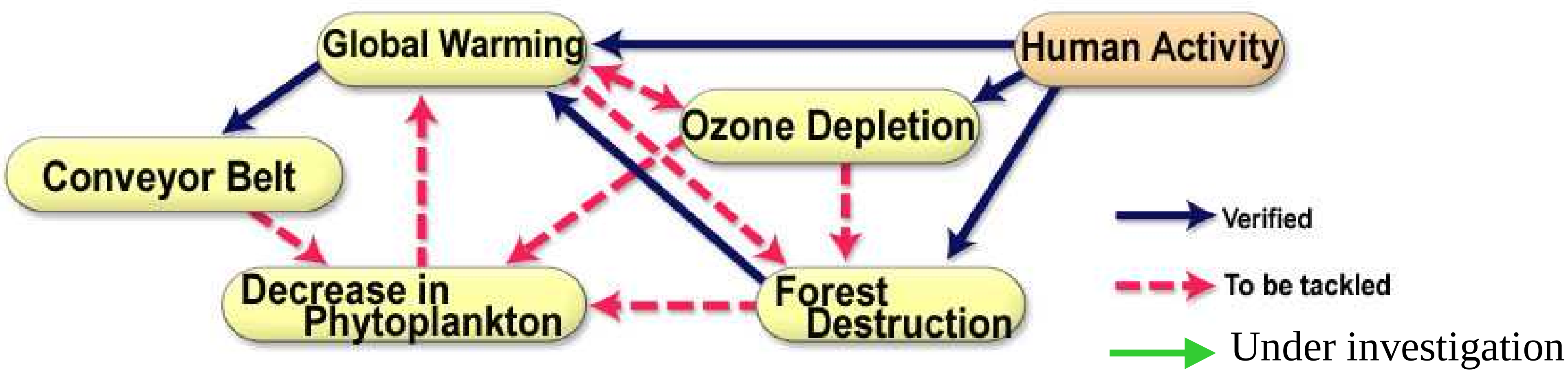
Acid ocean

The topics that we focus on

Clarify the mechanism of Abrupt Change

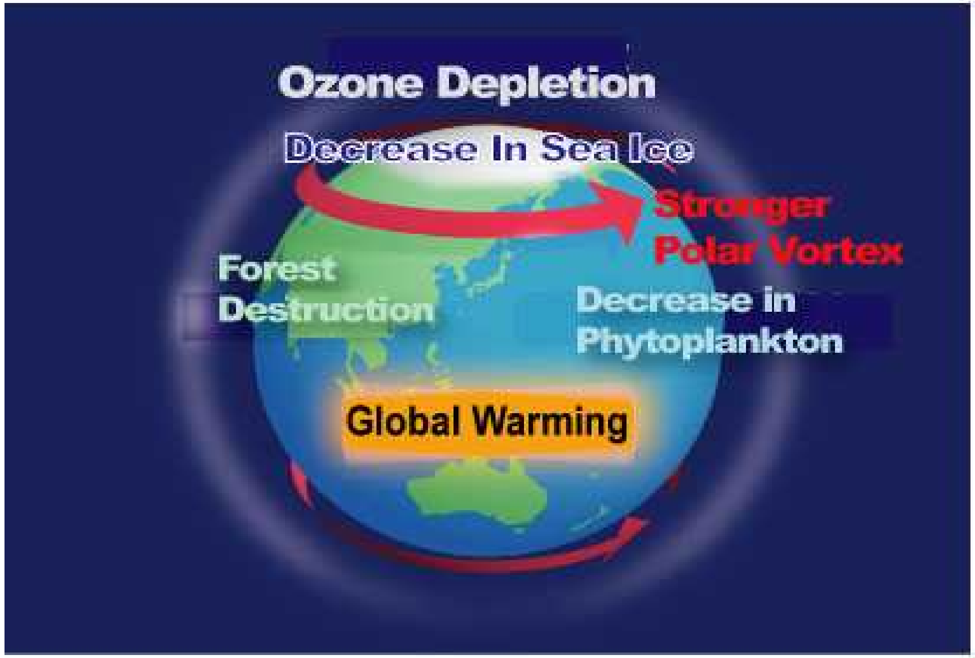


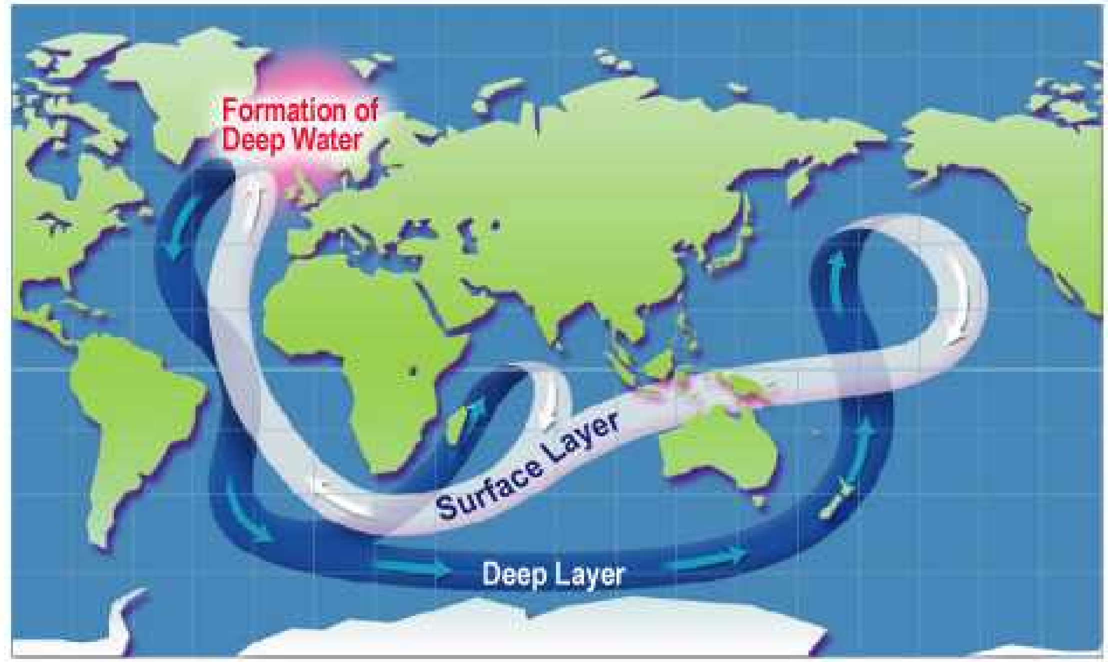


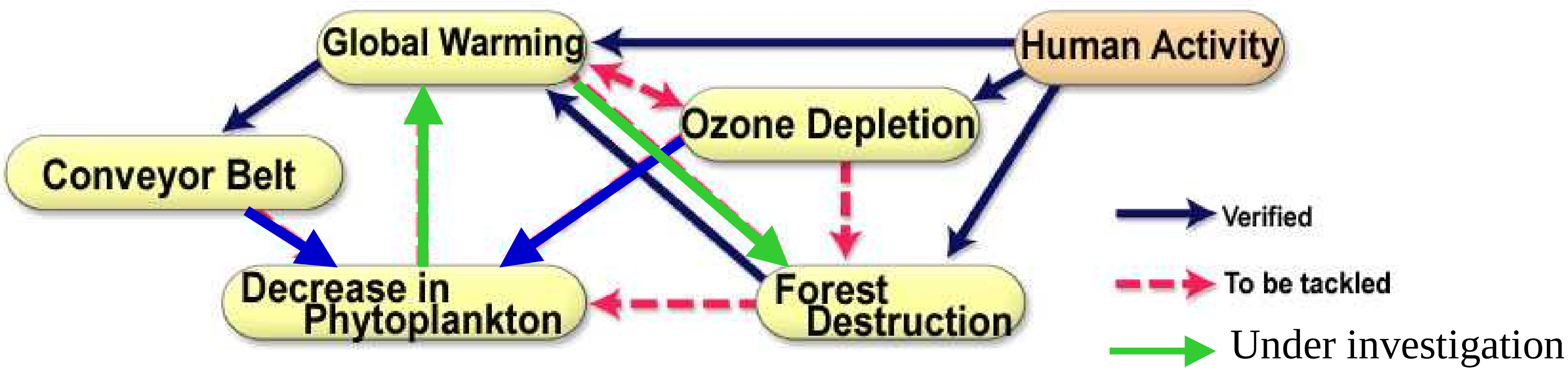


The topics that we focus on

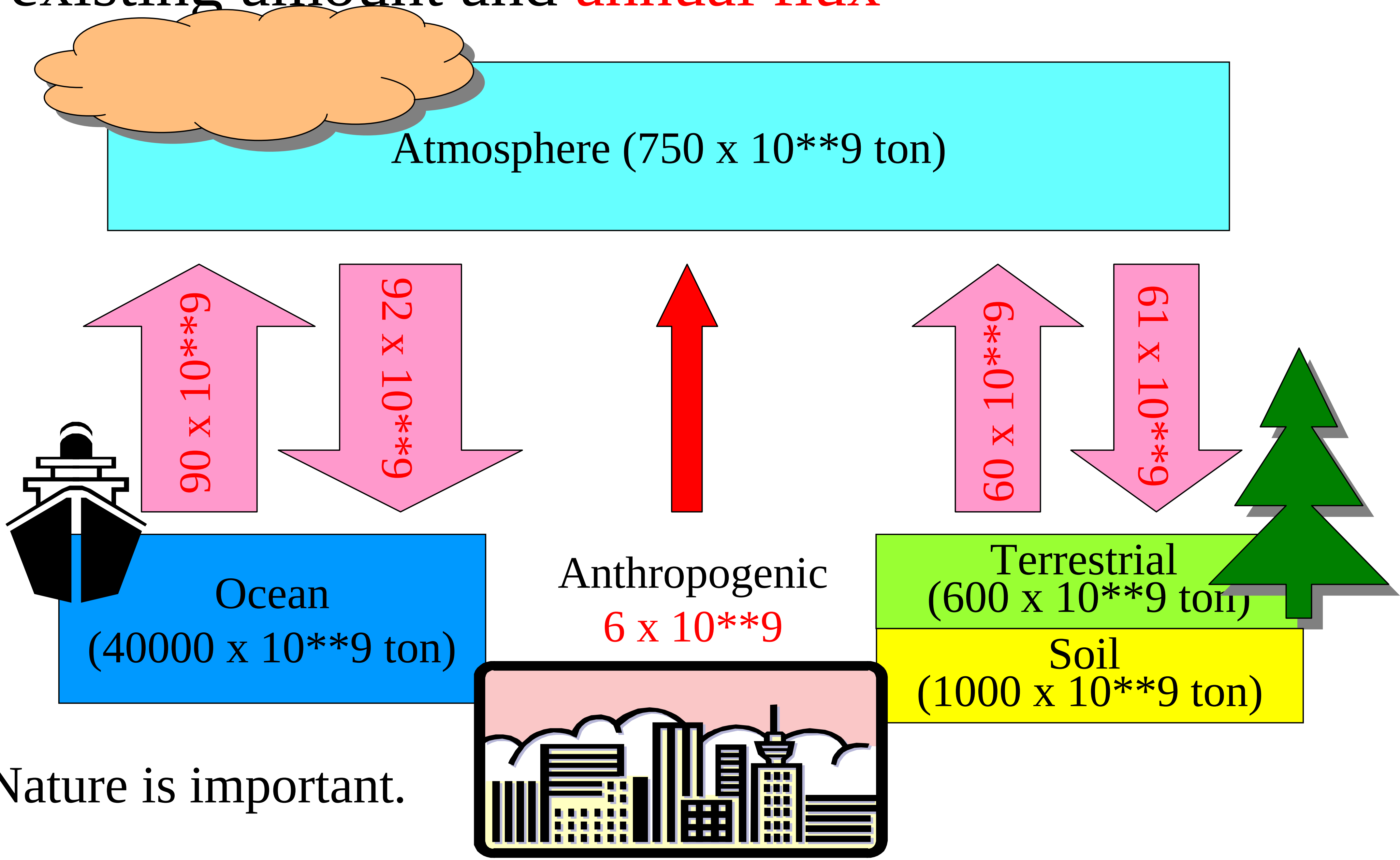
Clarify the mechanism of Abrupt Change







Global Carbon (Dioxide) Cycle
existing amount and annual flux

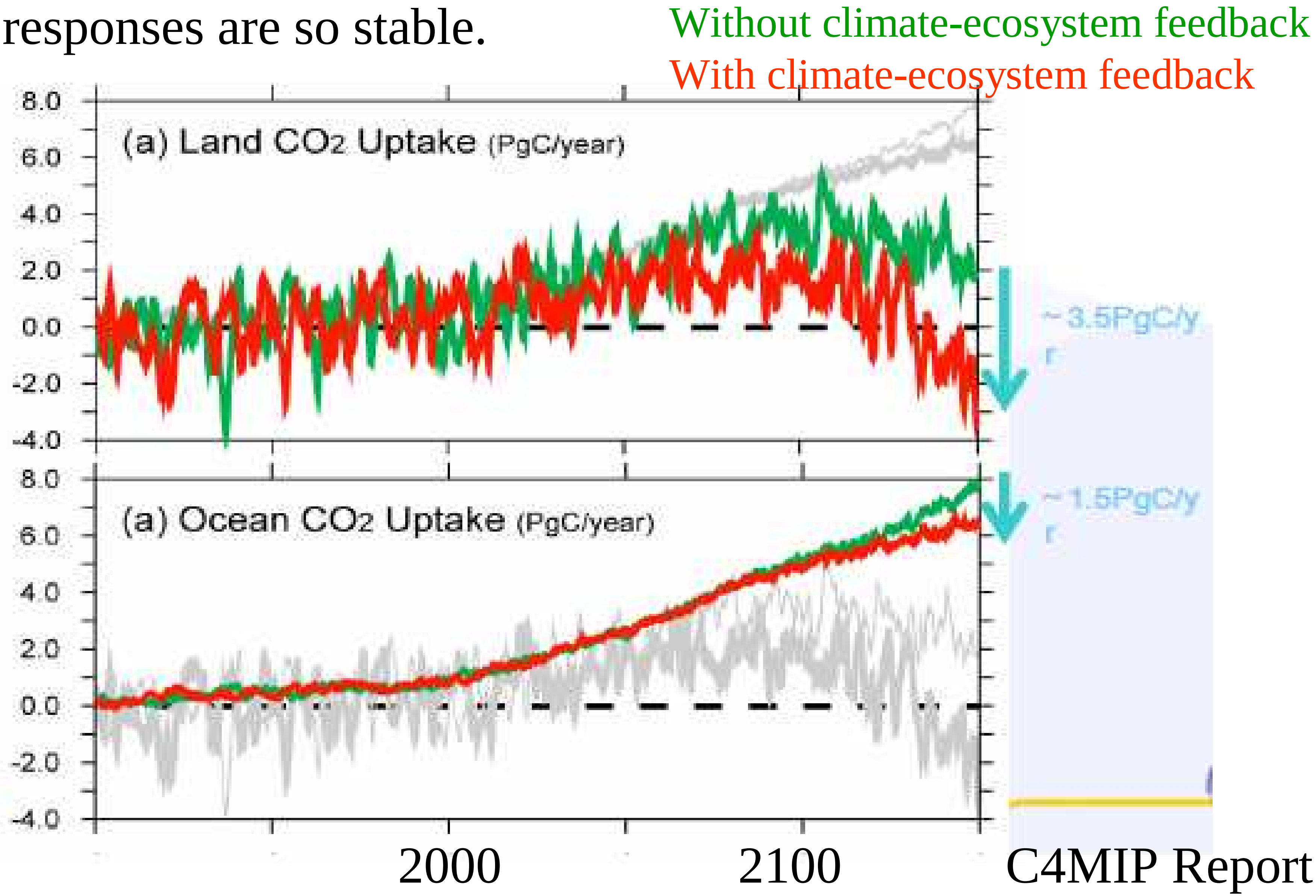


Nature is important.

Sensitivity for carbon uptake or emission by ocean/terrestrial ecosystem

Terrestrial ecosystem will change into source.

Ocean responses are so stable.



C4MIP Report

Larix Deciduous Forest: simulation study

Toda *et al*. (2007)

2 X CO_2, T_{air} + 1〜5℃

→ carbon uptake increases

2 X CO_2, T_{air} + 6〜10℃

→ carbon uptake decreases

Hydrologic cycle is also crucial:

precipitation decrease → productivity decrease

When will terrestrial ecosystem change from sink to source?

- Terrestrial ecosystem will absorb more carbon until mid-21st century.
- The uptake will reduce then, but it is so variable among the future prediction models.
- More careful studies on:

  responses of boreal forests to warming

  responses to drought

  carbon emission from soil such as peat land

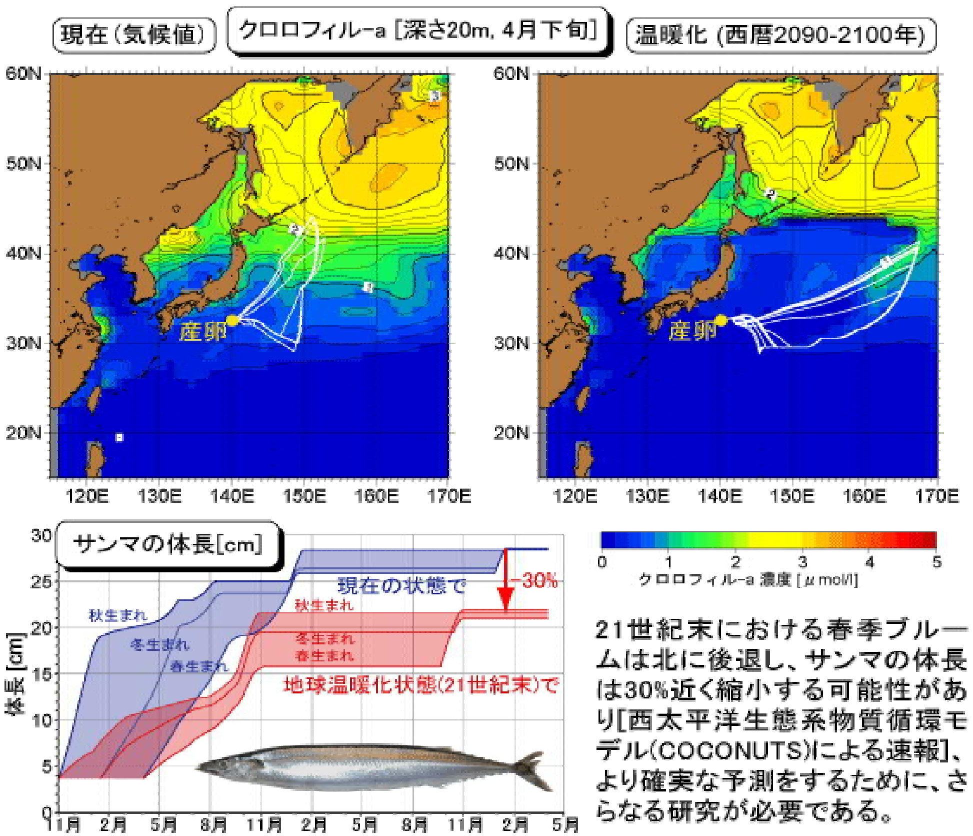
Two examples of marine ecosystem response

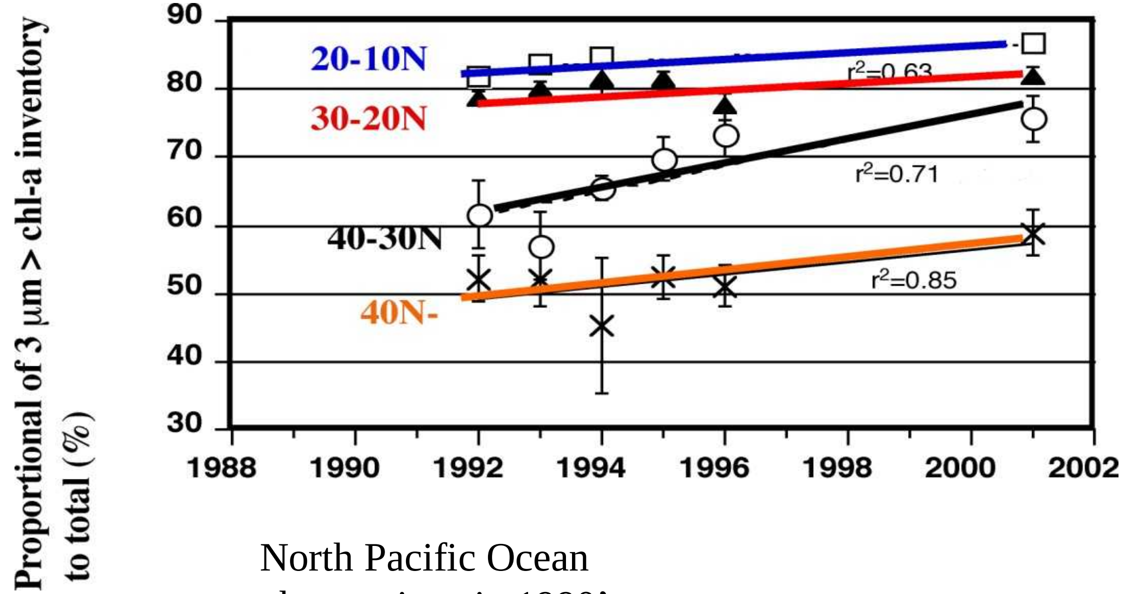
confirmed

Phytoplankton reduction caused by global warming

Yamanaka et al.

Northwest Pacific Ocean
bio-geochemical-physical model





North Pacific Ocean
observations in 1990's

under investigation

Plankton species change reduces alkalinity and CO_2 is emitted

Watanabe et al.

Marine ecosystem change resulting in carbon emission

- In future prediction models, oceanic uptake is so stable with minor feedback from the climate change.
- Subpolar regions with high primary production will shrink significantly.
- Replacement of dominant plankton species will change the ocean from sink to source.

Scientists should

- try to give more information beyond the non-regret policy,
- pursue to clarify mechanisms of positive feedbacks in the earth system,
- think for 50-100 year future and suggest to take immediate action,
- not be too conservative, but not make a false alarm,
- not try to oversell their own research areas/projects,
- give uncertainty in risk assessment.

G8 Summit Symposium

Drastic Change in the Earth System during Global Warming (June 24)

Five hot issues (presenters, moderators)

1. Clarify causes and magnitude of sea level rise
   (J. Church, M. Ikeda)
2. Decay of glaciers and Greenland and Antarctic ice sheets
   (A. Ohmura, R. Greve)
3. When will summer Arctic sea ice disappear?
   (W. Maslowski, M. Ikeda)
4. Carbon uptake or emission by terrestrial ecosystem
   (T. Maximov, A. Itoh, T. Hara)
5. Marine ecosystem change resulting in carbon emission
   (M. Kawamiya, Y. Watanabe)