IPCC
and Attribution and Prediction of Climate

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1988 - The establishment of the IPCC

WMO, UNEP

1990 - First IPCC Assessment Report

1992 - IPCC Supplementary Reports

1992- Adoption of the UNFCCC

1994- Entry into force of the UNFCCC

Ratified by 189 countries

1994 - IPCC Special Report

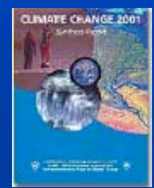
1995 - Second IPCC Assessment Report

1996 - COP-2, 1997 - COP-3…

1997- Adoption of Kyoto Protocol at COP-3

2005 Feb 16- Kyoto Protocol ratified by 164 countries

(But not by USA or Australia)



2001 - Third IPCC Assessment Report

2007 - Fourth IPCC Assessment Report

2007 - Nobel Peace Prize

2009 – AR5 scoping mtg (Venice, July)

- Dec., COP-15 Copenhagen

IPCC reports are useful

The role of the IPCC

is to provide **policy relevant** but not **policy prescriptive** scientific advice to policy makers and the general public.

A major strength of the IPCC process has been the **intergovernmental** process, through reviews and then approval of the **Summary for Policy Makers** on a word-by-word basis. This provides ownership (but is more political) .

This process provides a report in which the content is **determined by the science** while **how it is stated** is determined jointly with the governments.

The process is as important as the report itself.

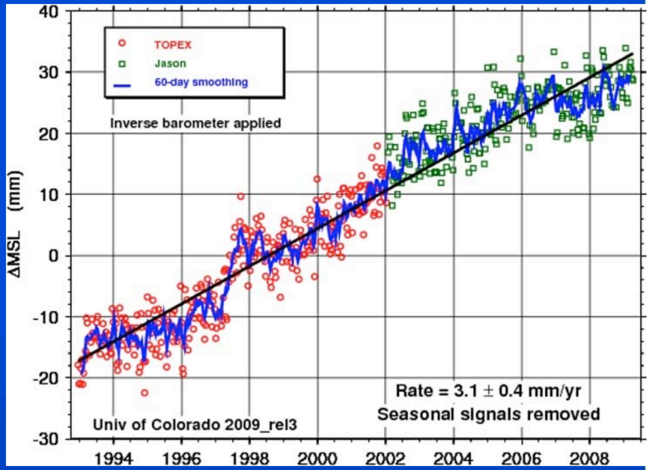
AR5 IPCC (2013)

Chapter 3: Observations: Ocean

Executive Summary

- Changes in ocean interior temperatures and heat budgets
- Ocean salinity change and freshwater budgets
- Sea-level change and extremes
- Ocean biogeochemical changes
- Changes in ocean surface processes
- Changes in ocean circulation
- Decadal variability

Frequently Asked Questions



Chapter 13: Sea Level Change

Executive Summary

- Synthesis of observed sea-level change and its components
- Models for sea-level change
- Projections of globally averaged sea-level rise
- Projections of the regional distribution of sea-level change
- Potential ice-sheet instability and its implications
- Long-term projections
- Extreme sea level events

Frequently Asked Questions

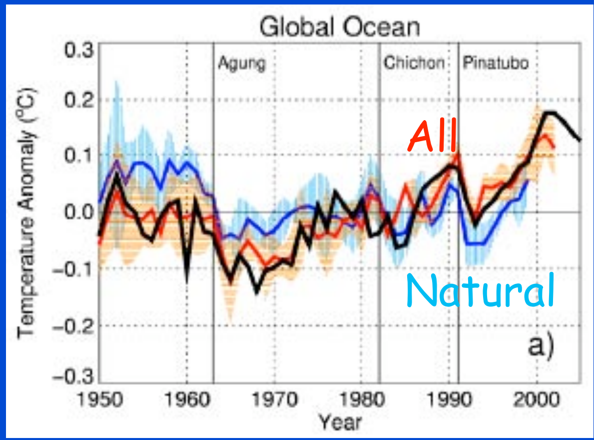
AR5 IPCC (2013)

Ch. 10: Detection and Attribution of Climate Change: from Global to Regional

Executive Summary

- Evaluation of methodologies
- Atmospheric and surface changes
- Changes in ocean properties
- Cryosphere changes
- Extreme events
- Pre-instrumental perspective
- Implications of attribution for projections

Frequently Asked Questions

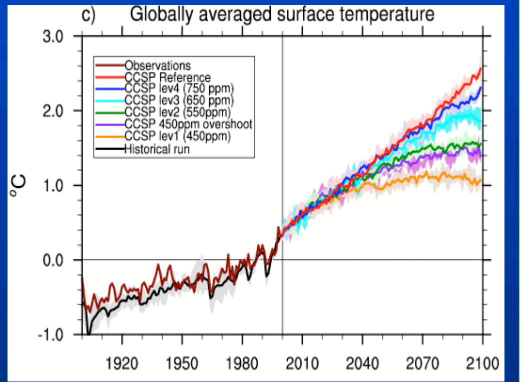


Chapter 11: Near-term Climate Change: Projections and Predictability

Executive Summary

- Climate change projections for the next few decades
- Climate predictions and their reliability
- Predictability of decadal climate variations and change
- Regional climate change, variability and extremes
- Atmospheric composition and air quality
- Possible effects of geoengineering
- Quantification of the range of climate change projections

Frequently Asked Questions



New: Decadal forecasting

- *Initialization*: Ocean, sea ice, land processes.

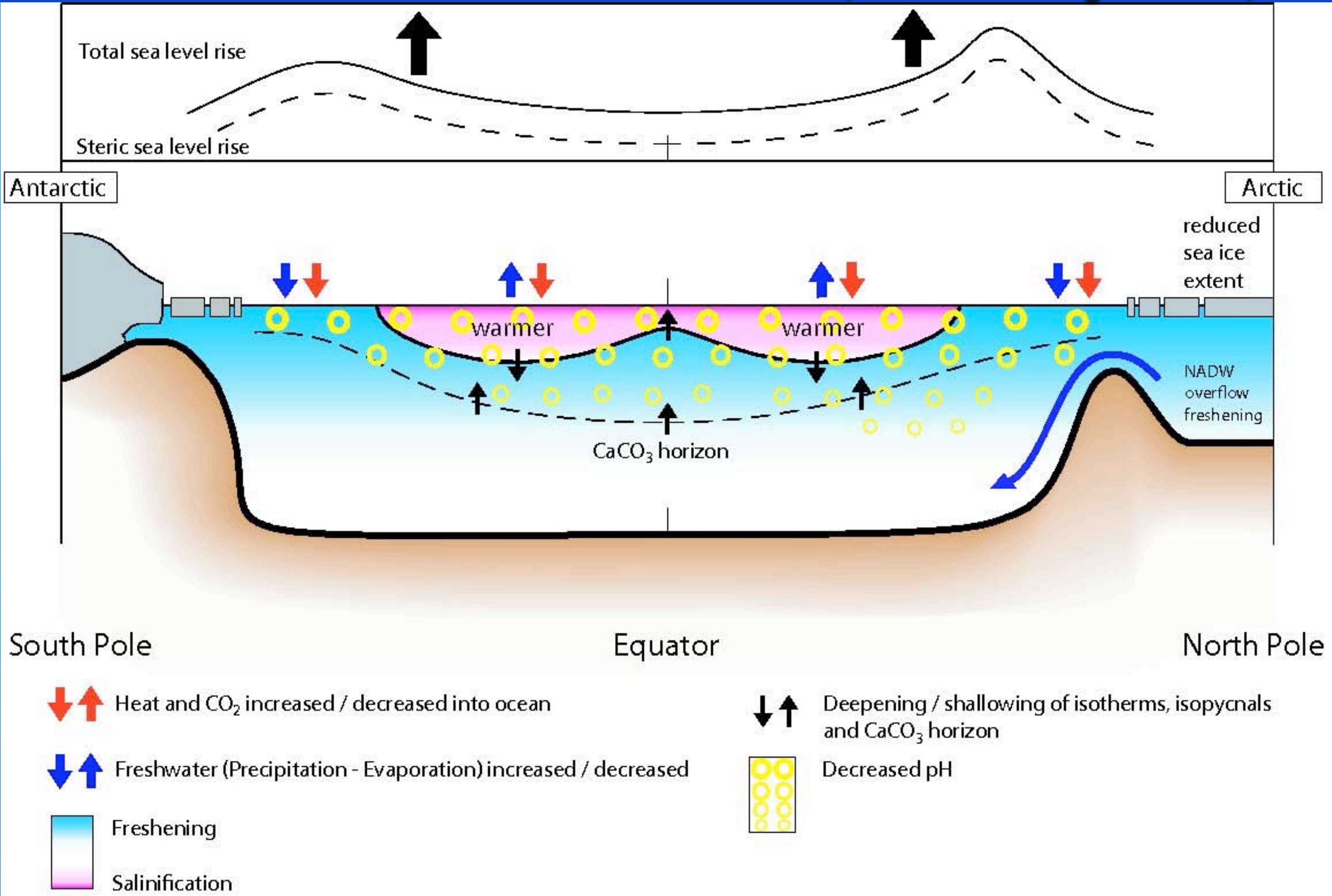
  Observed state of ocean required

- *Forward integration of the coupled model*: The external forcing by green-house gases is prescribed.
- *Ensemble generation:* to give probabilistic nature
- *Calibration of model output*: Because of deficiencies in the component models the coupled model output needs calibration.
- *Verification of results and skill assessment*: a priori knowledge of the quality of the forecast is required based on past performance:

  Observed state of ocean required

Changes in ocean state

from 1950-1960's to 1990-2000's (IPCC 2007 Figure 5.18)

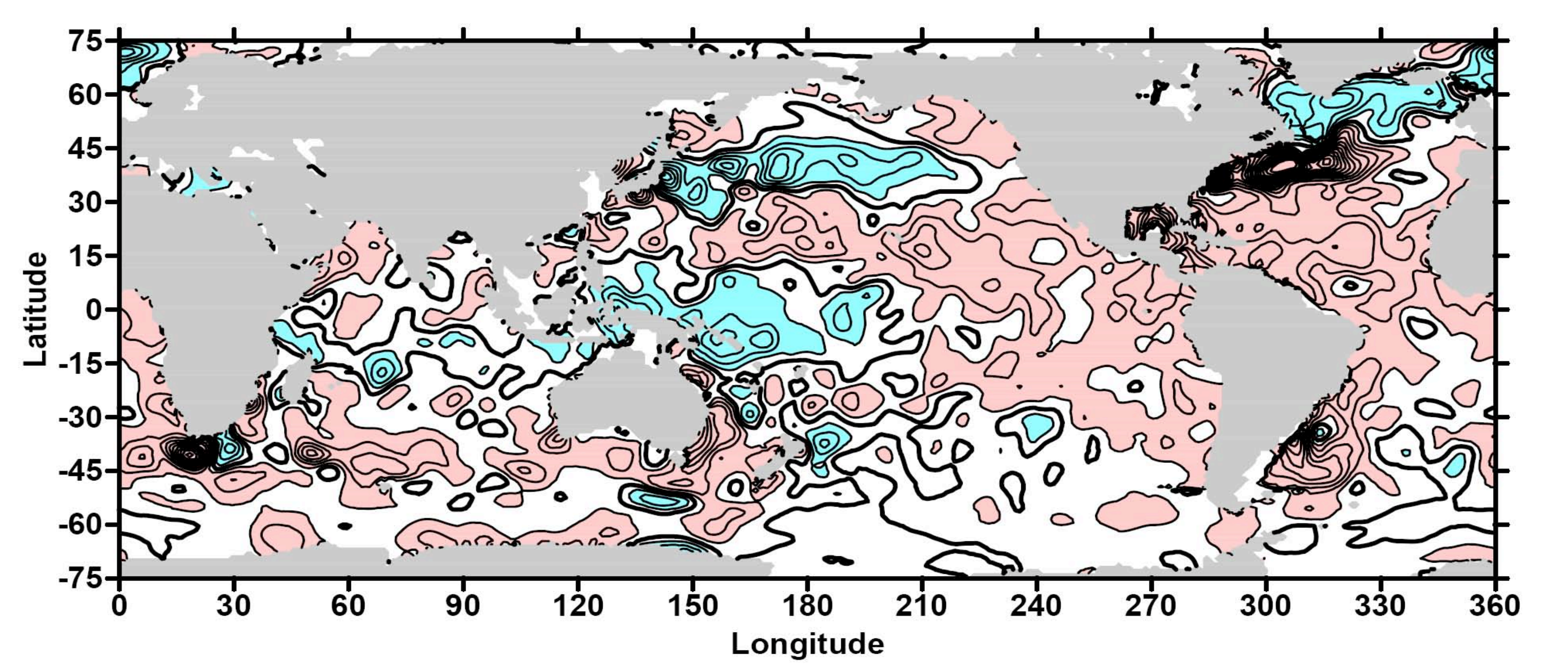


OceanObs'09

IPCC

AR4: Most but not all parts of the **Ocean** warming

Ocean heat content trend 1955-2003

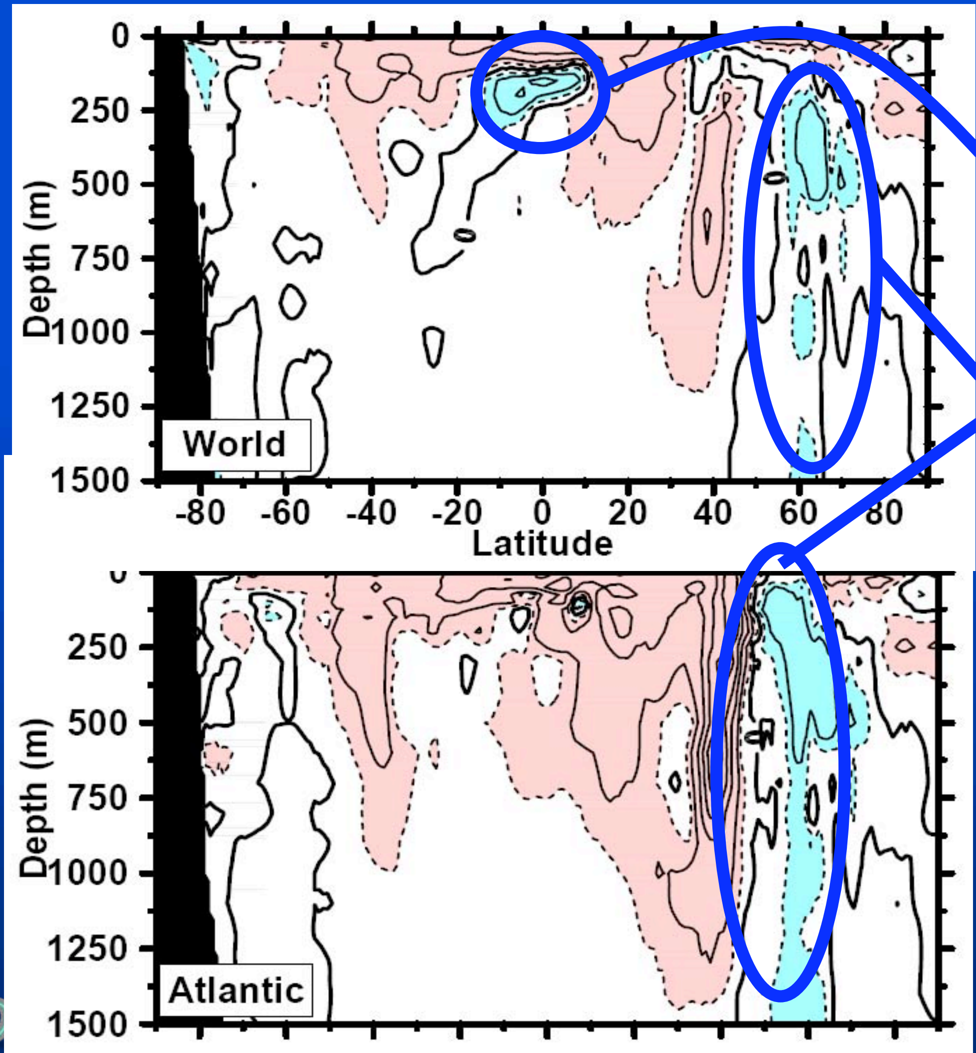


corresponds to **cooling** < -0.25 W/m^2

corresponds to **warming** > 0.25 W/m^2

AR4: Ocean warming strongest near the surface but also penetrates to layers below, in particular in Atlantic Ocean

Zonally averaged temperature trend 1955–2003



Few regions cooling: related to climate variability

Pacific subtropical ocean circulation
El Niño

Changes in NAO, PDO

warming
> 0.025°C per decade

cooling
< -0.025°C per decade

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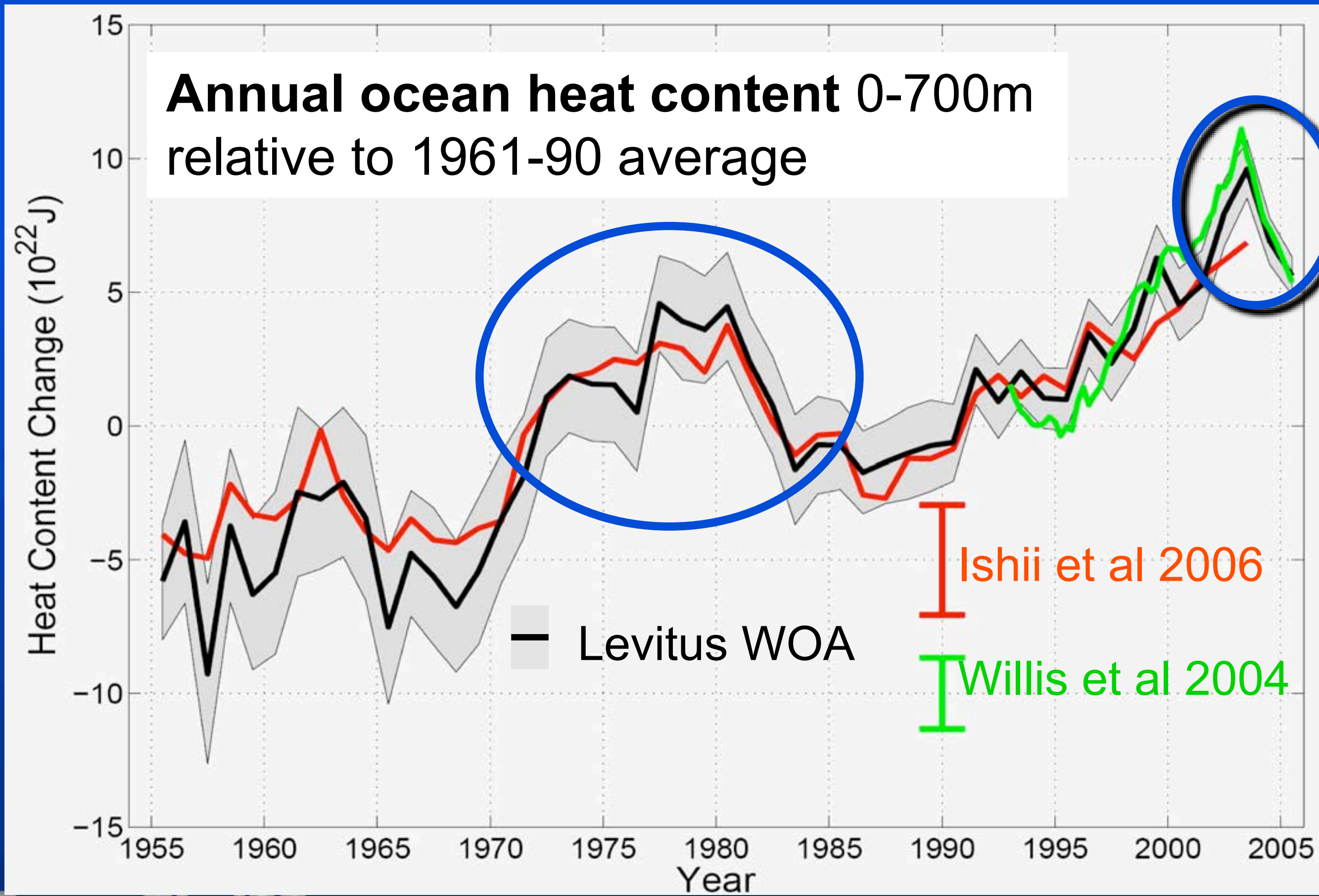
Is ocean warming accelerating?

IPCC: Causes of decadal variability not well understood

- cooling due to volcanism?
- artefact due to temporally changing observing system?

→ **No statement on acceleration possible in AR4**



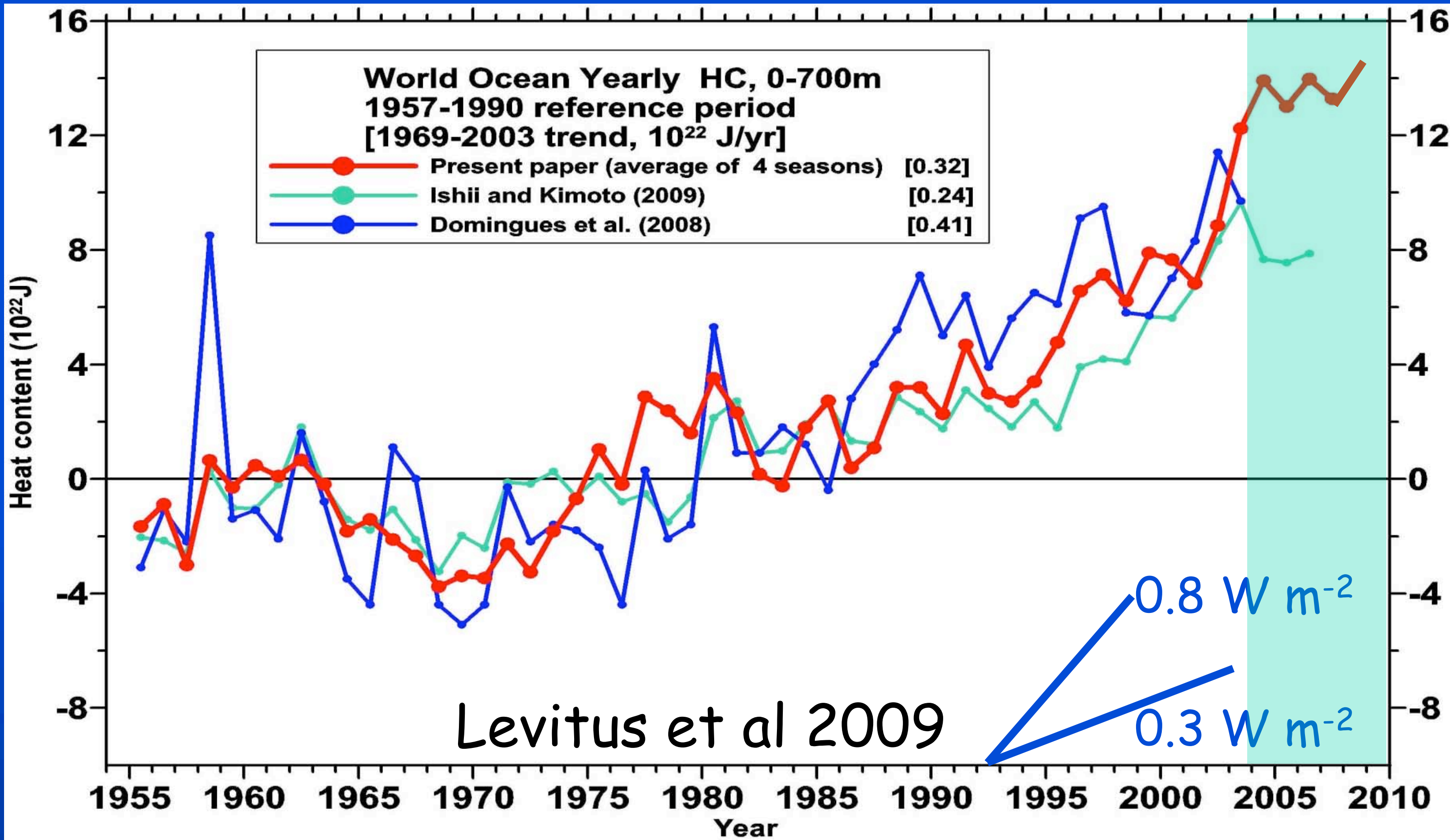
Since then:

Argo problems

XBT drop rate problems

identified

Revised ocean heat content



Yearly time series of ocean heat content (10^{22} J) for the 0-700 m layer from Levitus et al (2009), Domingues et al. (2008) and Ishii and Kimoto (2009) with a base period of 1957-1990. Linear trends for each series for 1969-2007 given in the upper portion of the figure.

Ocean heat content and sea level

Global warming from increasing greenhouse gases creates an imbalance in radiation at the Top-Of-Atmosphere: now order 0.9 W m^{-2}.

Where does this heat go?

Main sink is ocean: thermosteric sea level rise associated with increasing ocean heat content.

Some melts sea ice: no change in SL

Some melts land ice.

SL increases much more per unit of energy from land-ice melt: ratio about 30 to 90 to 1.

Sea-ice melt does not change sea level.

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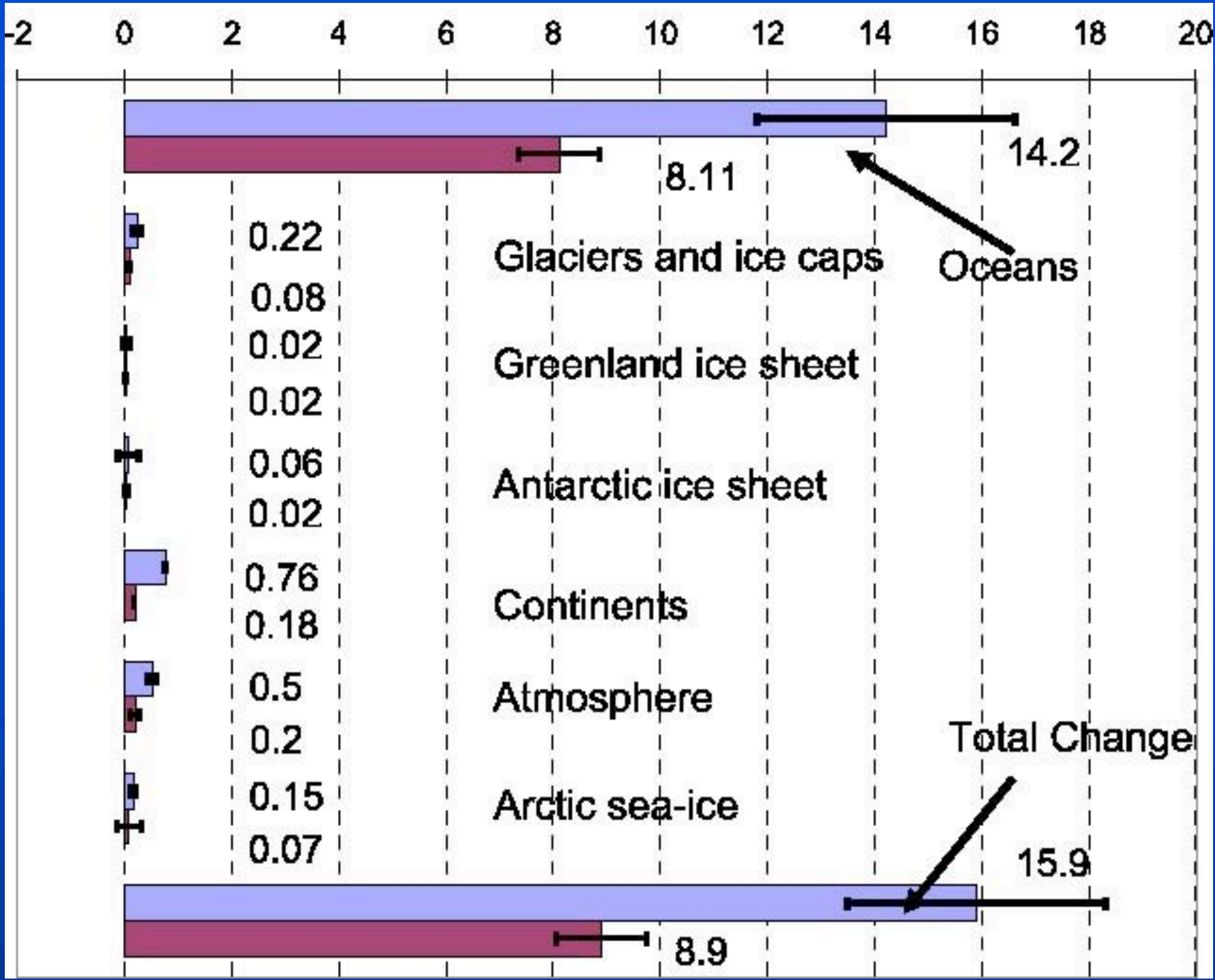
Energy content change 10^{22} J



>90% oceans

1961-2003 (Blue bars)
1993-2003 (Burgundy bars)

Figure 5.4
IPCC AR4

OceanObs'09

IPCC

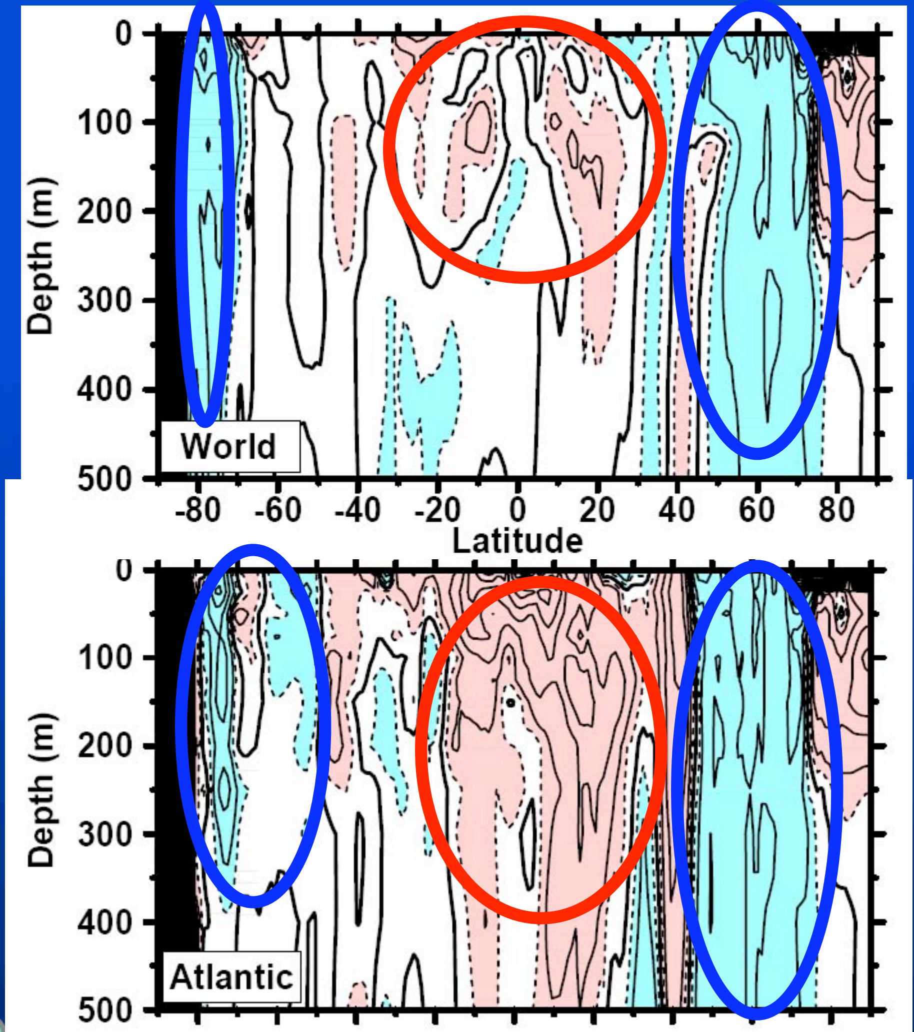
Melting ice

IPCC estimated melting ice contribution to SL rise was 1.2 mm/yr for 1992 to 2003.

- How much is missed?
- Is the Antarctic and Greenland melt a transient (mainly 2002 to 2006) or not?
- Many glaciers are not monitored
- Ocean warming may change basal melting: poorly known
- Ice sheets, buttressing by ice shelves poorly modeled
- Concern future SL rise underestimated
- Need process studies and improved models
- Changes salinity: fresh water budget
  - affects ocean currents (MOC)

Ocean salinities are changing, indicating changes in evaporation and precipitation

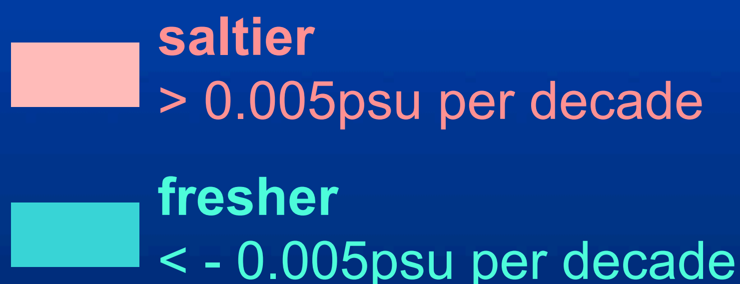
Zonally averaged salinity trend 1955–1998



Tropics in upper oceans
are becoming saltier,
in particular in Atlantic/Indian

Mid-to-high latitudes
are becoming fresher,
in particular in N-Pacific/N-Atlantic

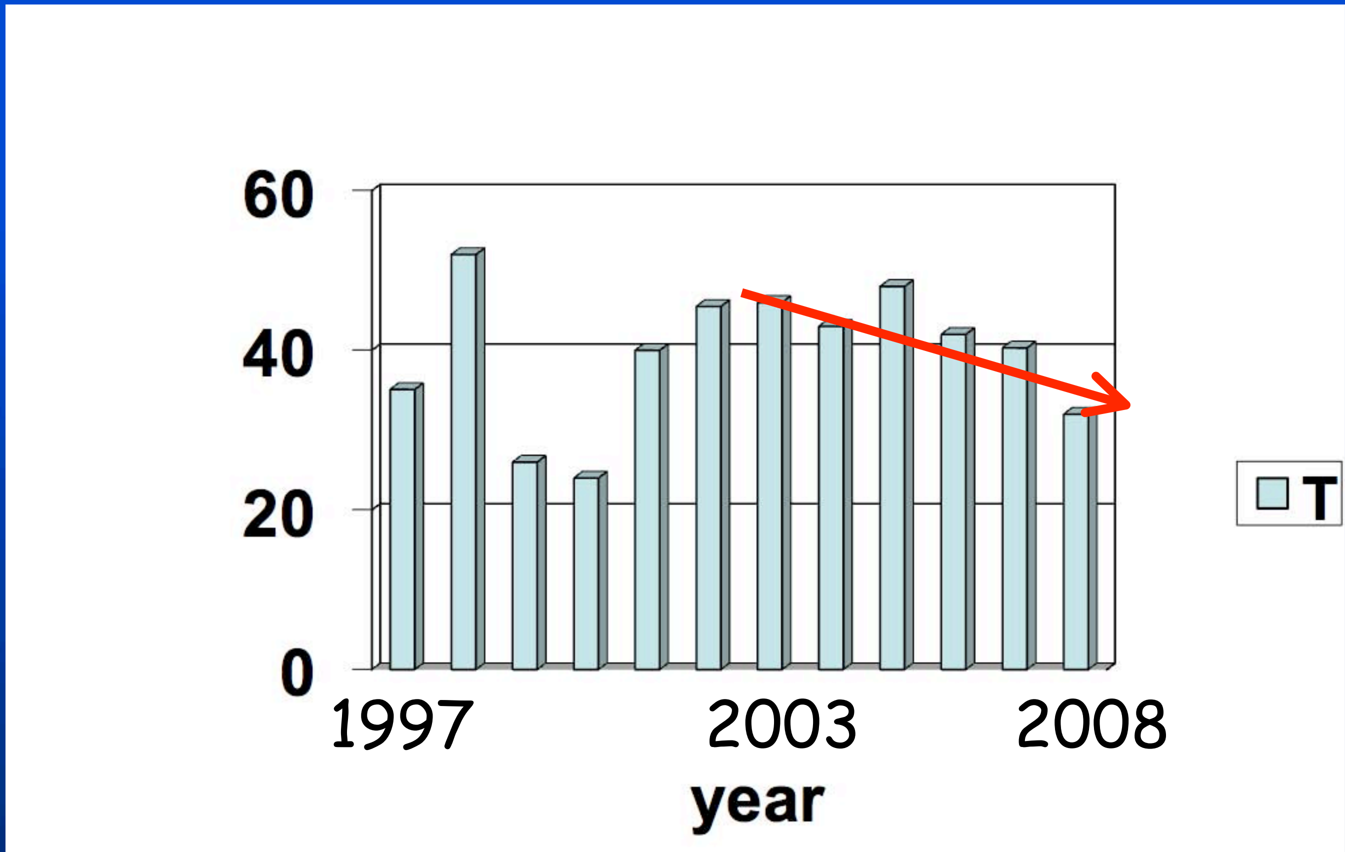
Consistent with increase in atmospheric water transport



IPCC

What about 2003 to 2008?

Global mean surface temperatures



What about post-2003?

Several studies: disparate results:

Thermosteric sea level rise (mm/yr):

Willis et al 2008 JGR:	-0.5 ± 0.5
Cazenave et al 2009 GPC:	0.4 ± 0.1
Leuliette and Miller 2009 GRL:	0.8± 0.8

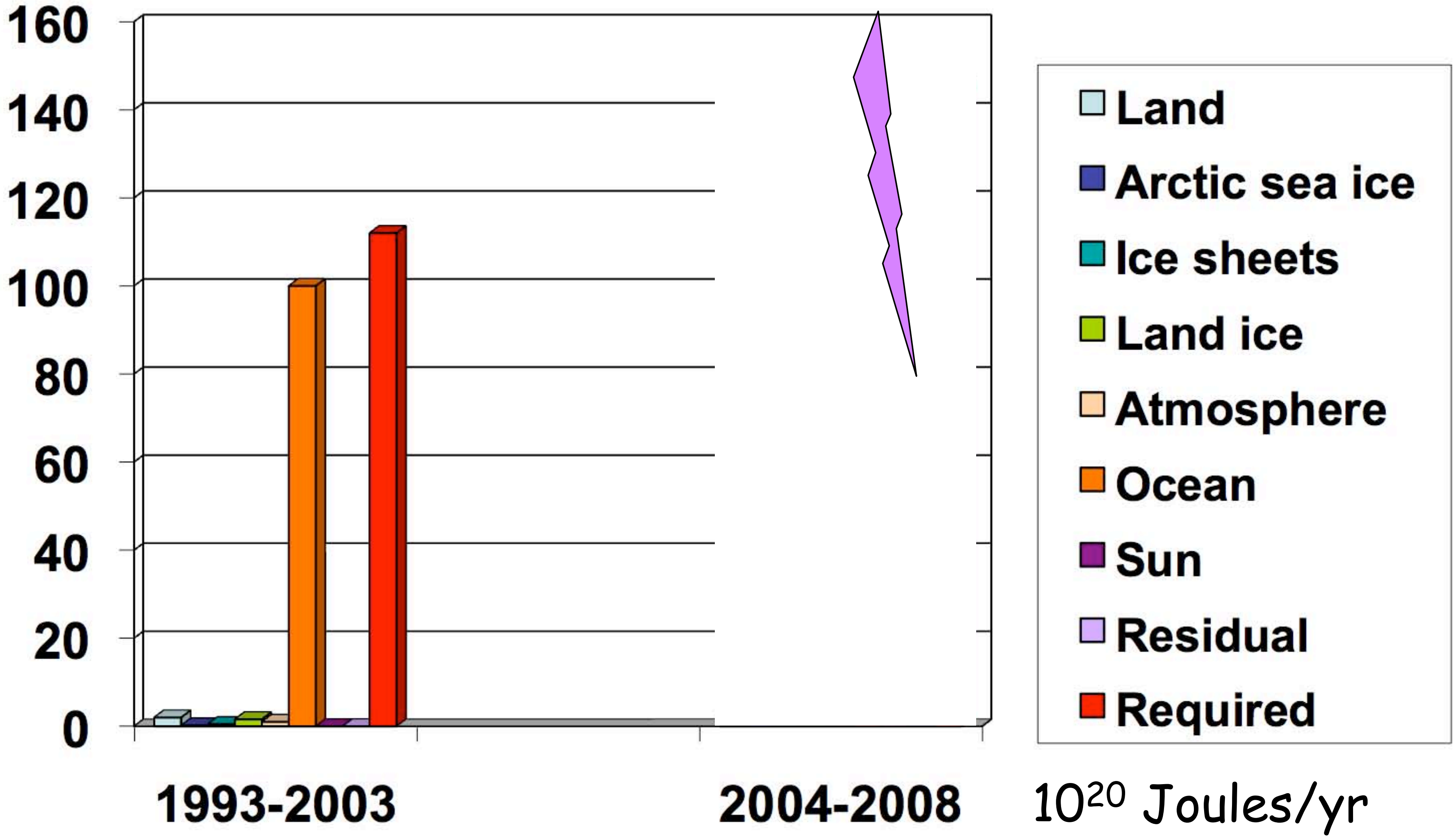
Implication: since 2003, main source of sea level rise is melting of Greenland and Antarctica, and glaciers.

These require about a **factor of ~50 less heat to produce same sea level rise as ocean expansion**

If correct, implies reduction in ocean heat uptake and TOA energy imbalance in past 4 years.

Does NOT solve energy imbalance problem

Where does energy go?



10^{20} Joules/yr

Trenberth 2009

Summary points

- While ocean warming is now clearer from 1970 to 2003 owing to reduced spurious decadal variability, disparate analyses have yet to reach consensus on post 2003. Issues include Argo QC, accounting for missing data, analysis.
- Natural variability plays a strong role in regional variations in ocean heat content and salinity . Need full analyses monthly.
- Ocean salinities vary mainly from changes in Evaporation minus Precipitation (E-P) and the atmospheric circulation. Ocean observations of salinity complement atmospheric moisture budgets: the ocean as a rain gage
- Global warming from increasing greenhouse gases goes mainly into the ocean; some into melting of land and sea ice. Both contribute to sea level rise but using heat to melt land ice contributes about a factor of 50 more. It is essential to balance both **sea level** and **heat** budgets.
- Land ice and Arctic sea ice are decreasing, and post-2002 evidence suggests accelerated melting of the two major ice sheets of Greenland and Antarctica. Is this acceleration sustained or is it a transient?

Summary points

- Melting ice: Many glaciers are not monitored. How much is missed? Ocean warming may change basal melting: poorly known. Ice sheets are buttressed by ice shelves: poorly modeled. Future sea level rise likely underestimated.
- Spatial and temporal observations of ocean salinity were deemed not sufficient, e.g., the Southern Ocean. Issues include instrumental biases, a lack of deep-water salinity data (particularly at high latitudes), insufficient global analyses and incomplete coverage of surface ocean salinities.
- Reanalyses of past data are needed to the extent possible.
- Temporal sampling issues have been revealed in the overturning transport in the Atlantic at 26.5°N, suggesting that earlier *AMOC* trends may have been aliased.
- The oceans have been a sink for order 30% of the emitted carbon dioxide, thereby increasing acidity with biological impacts. Because solubility decreases as the ocean warms, to what degree will the ocean continue to be a sink for carbon dioxide and what are the implications for marine life? Are there other feedbacks, such as from clathrates becoming unstable? How should these be tracked?

Essential Ocean Observations for IPCC

- Sea level: regional and global; daily in storm surges
- Ocean carbon: content every few years and the air-sea exchange seasonally;
- Ocean biogeochemistry: ocean acidification and effects
- Sea surface temperatures: daily, diurnal cycle
- Surface currents
- Sea surface pressure and air-sea exchanges of heat, momentum: sub-daily
- Ocean heat content and transports: sea level, heat capacity, thermal inertia
- Fresh water content and transports: global water cycle; thermohaline circulation, abrupt climate change; precipitation and evaporation;
- Sea ice extent, concentrations, and thickness: sea level, fresh water, albedo, heat content

Needed at least monthly for climate variability including ENSO, climate change, extremes, atmospheric forcings, initial states for coupled model predictions, movement of water, heat, species.

Carbon issues

- Total inorganic carbon in oceans increased by 118 ± 19 GtC between 1750 and 1994 and continues to increase; uptake appears to have slowed after the 1990s, consistent with the expected rate at which the oceans can absorb carbon.
- Decreased oxygen concentrations in the thermocline (~100–1,000 m) in most ocean basins from the early 1970s to the late 1990s.
- Oceans have been a sink for order 30% of the emitted carbon dioxide, thereby increasing acidity with biological impacts. Because solubility decreases as the ocean warms, to what degree will the ocean continue to be a sink for carbon dioxide and what are the implications for marine life?
- Are there other feedbacks, such as from clathrates becoming unstable? How should these be tracked?

Carbon issues

- The credibility and magnitude of prospects for possible positive feedbacks to a warming climate through reductions in the uptake efficiency of carbon dioxide by the ocean, as well as changes in soil and permafrost carbon stores as the land warms, highlight the need to **improve the simulations and predictions of the carbon cycle.**
- Many more models will be systematically run in AR5 and it is important that their uncertainties and dependencies on other chemical species (such as those involved in the nitrogen cycle, which affects the carbon cycle through nutrients and biological activity) be documented and verified by sound process research and **observations.**

Recommendation

- Improving sea level rise projections requires closing the sea-level budget (with observations and models) within realistic uncertainties and monitoring **sea level** and **ocean heat content**. Measurements relevant to understanding sea level rise (i.e. satellite **altimetry** such as Jason and in situ observations from **tide-gauges** fitted with GPS receivers) should be maintained. Specifically, the **Argo** array needs to be maintained and extended into the ice-covered oceans and the deep and abyssal oceans using new technologies.

Atlantic MOC

- Establish and maintain long-term baseline reference networks for ocean quantities, particularly in the North Atlantic;
- Place a major effort on ocean data assimilation and now-casting;
- Improve resolution of ocean model components in global comprehensive models;
- Investigate ocean mixing processes and their parameterisation in coupled climate models;
- Explore parameter space of global models and search for possible thresholds.

Ocean obs needed for predictions

In previous IPCC reports, **projections** of climate change from models have been performed : models not initialized with the observed state and differences in response to the radiative forcings used to project future climate corresponding to assumed prescribed emissions scenarios.
Must perform **predictions** of future climate for up to about 30 years: initial conditions are essential to capture current commitment to future change and slow evolution of the ocean.

The AR5 will include results of experimental predictions for up to a few decades based on models initialized with observations. For the ocean, the key variables are temperatures and salinity. Questions remain about how well this can be done prior to the Argo era.

Ocean observations for IPCC

- Continued high-quality satellite altimeter and gravity records;
- Continued in situ sea-level records
- Sustained upper ocean measurements of temperature and salinity (Argo); improved vertical sampling in the upper layers and also in timeliness (< 24 hours for near-real time data).
- Extension of upper ocean measurements to marginal seas
- Extension of Argo to higher latitudes in regions covered by sea ice
- Design and implement deep (> 2000m) ocean density measurements.
- Greater use of paleo sea-level measurements;
- Data archeology to increase historical sea-level and ocean density data.
- Adding new sensors to Argo, such as dissolved oxygen.
- Maintain and improve baseline networks for tracking AMOC
- coordinated long term ocean carbon observations to evaluate how the ocean uptake is changing and to monitor mechanisms controlling ocean carbon uptake and storage.
- Atmospheric fields and fluxes, including radiation
- Reanalysis and synthesis
- Data assimilation, nowcasting, and model initialization