Clivar research focus

Consistency between planetary energy balance and ocean heat storage (CONCEPT-HEAT)

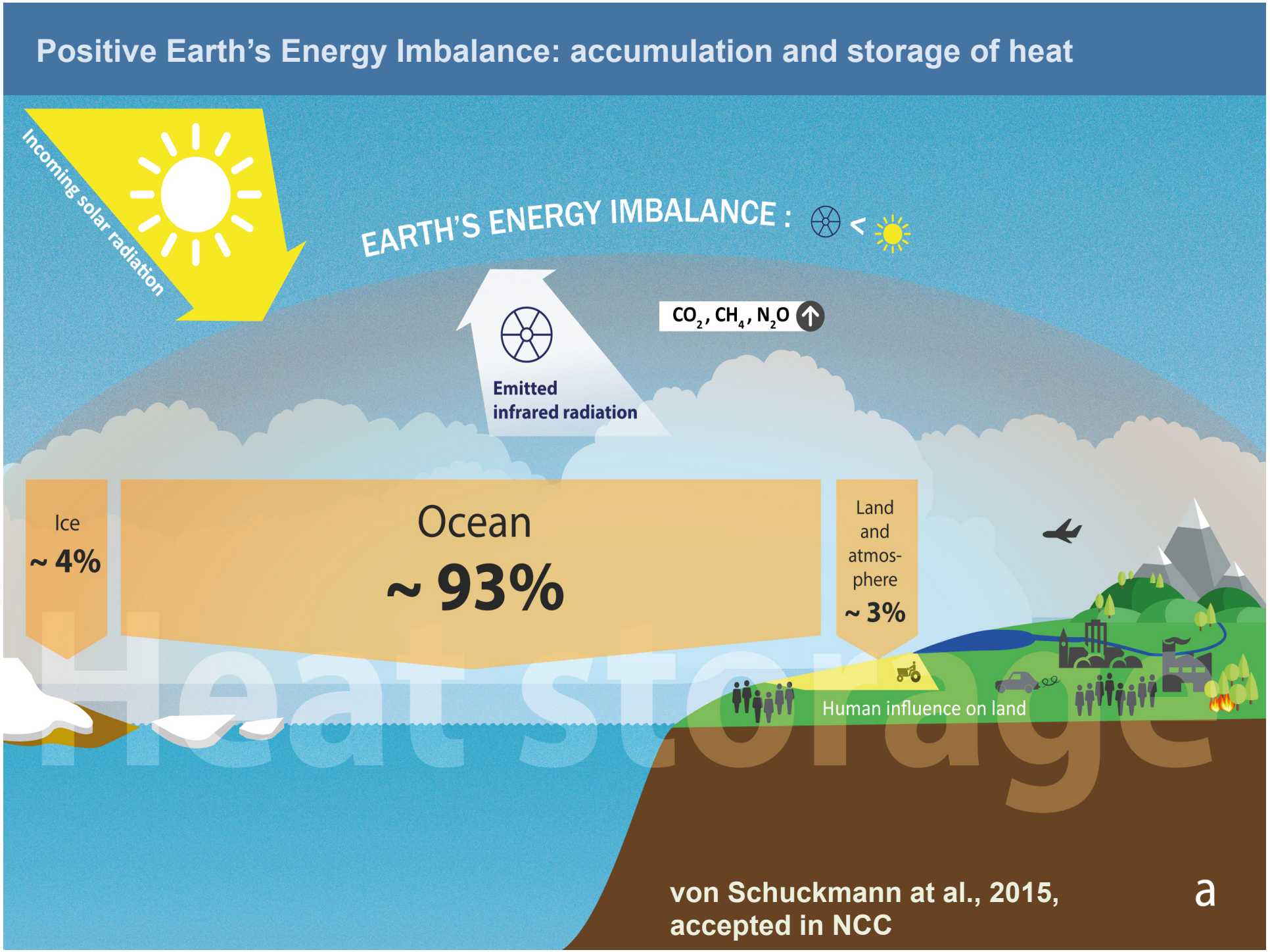
Co-chairs:

K. von Schuckmann, K. Trenberth

Scientific steering team members:

C.-A. Clayson; C. Domingues; S. Gulev; K. Haines; N. Loeb; M. Palmer; P.-P. Mathieu; R. Weller; M. Wild; Y. Xue

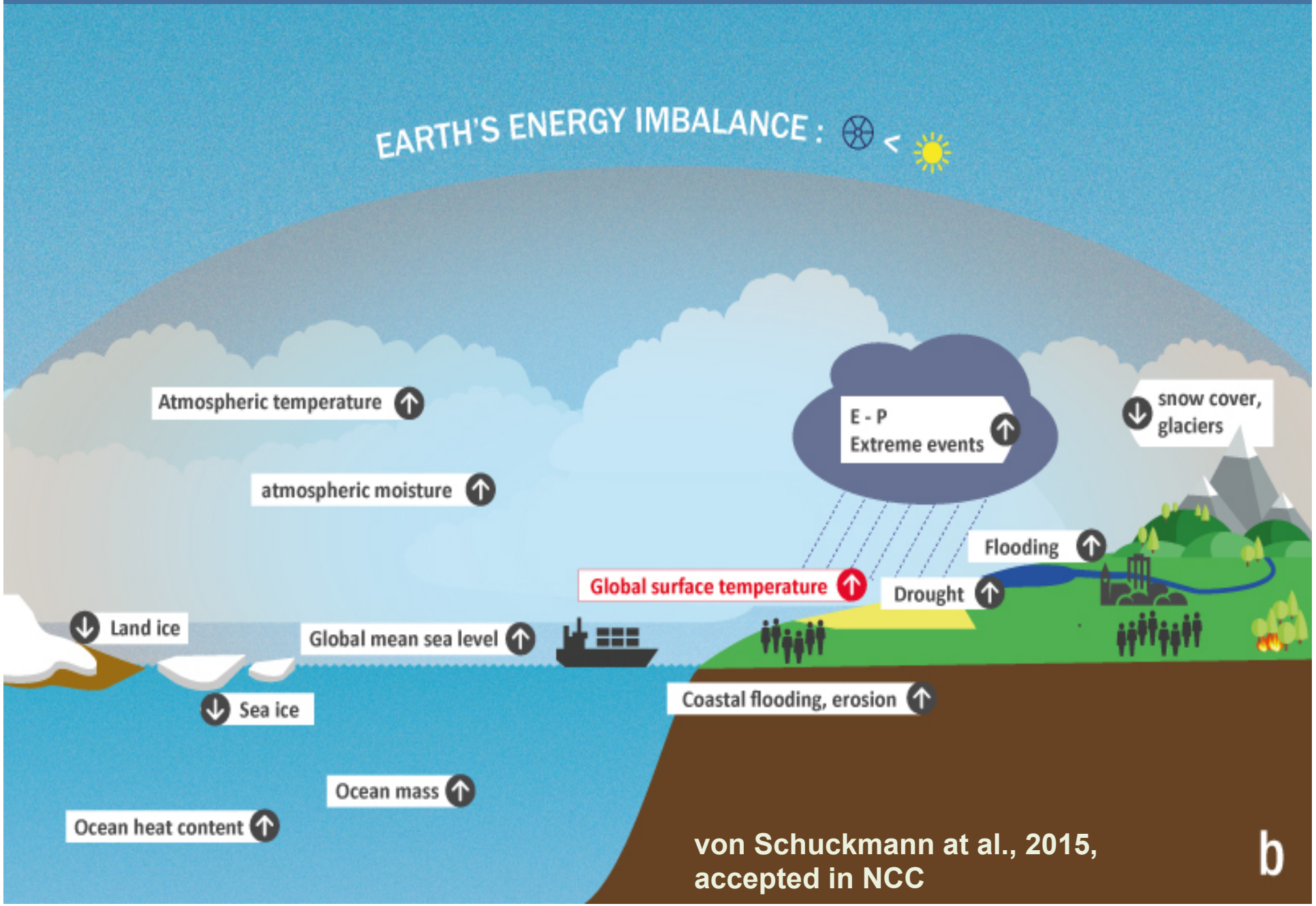
Positive Earth's Energy Imbalance: accumulation and storage of heat



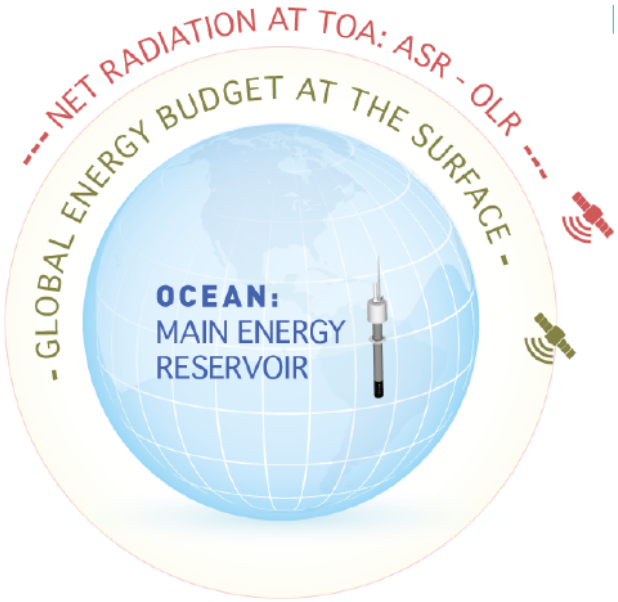
von Schuckmann at al., 2015, accepted in NCC

a

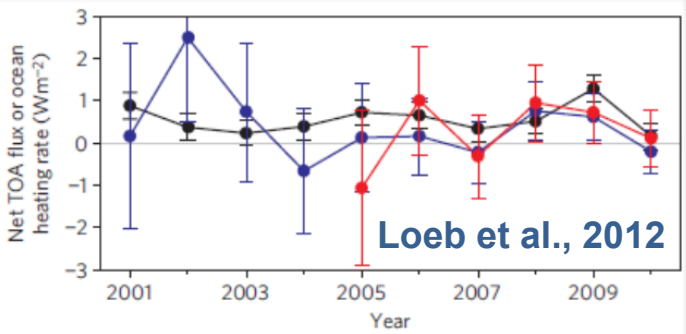
“Symptoms” of positive EEI



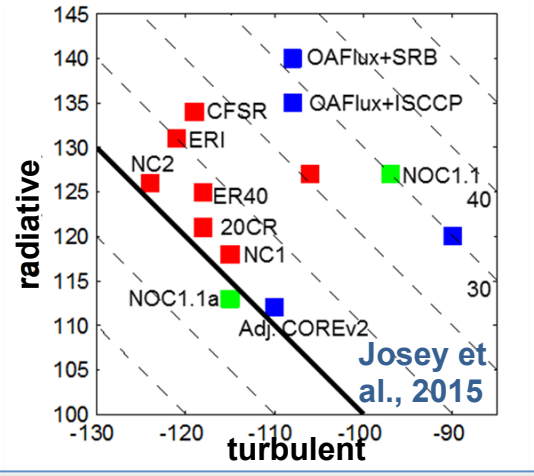
Different approaches determining Earth's energy imbalance



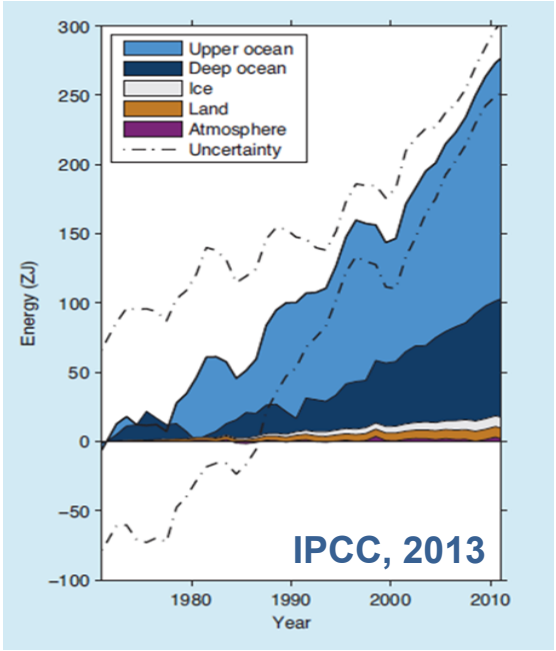
Radiation at TOA



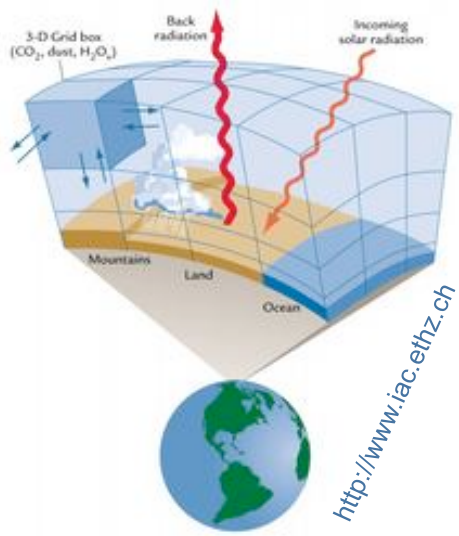
Surface flux



Storage inventory (OHC)



Hindcast and climate projection



Different approaches determining Earth's energy imbalance: TOA & OHC

Estimates of EEI

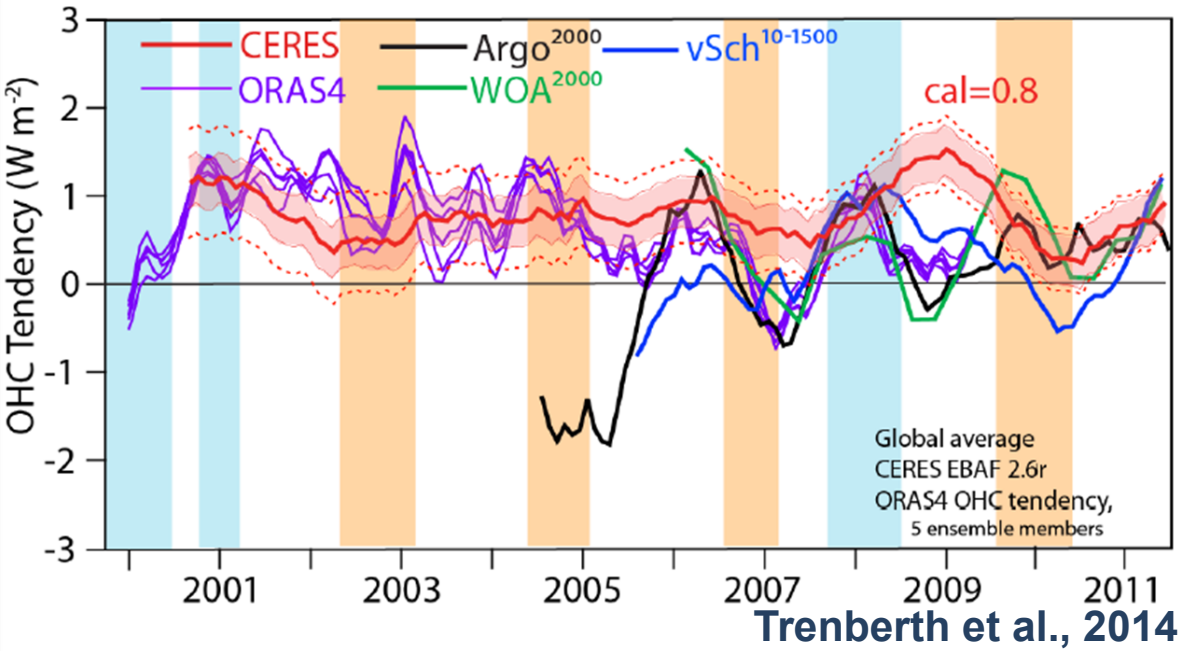
1993-2008: 0.8 to 0.9 Wm^2
(Trenberth et al., 2011; Trenberth and Fasullo, 2011; Hansen et al., 2011; Balmaseda et al., 2013b)

1993-2008: 0.57 Wm^2
(Hansen et al., 2001 with Levitus et al., 2009 OHC, or similar with Johnson et al., 2012 OHC)

2001-2010: 0.50 ± 0.43Wm^2
(Loeb et al., 2012 with Lyman et al., 2010 OHC (up-dated)).

2005-2010: 0.58 ± 0.15Wm^2
(Hansen et al., 2011 with Argo OHC, von Schuckmann and Le Traon, 2011)

2001-2011: 0.5-1 Wm^2 (Trenberth et al., 2014, range from different OHC estimates)



Trenberth et al., 2014

"Missing energy" remains at interannual time-scales:

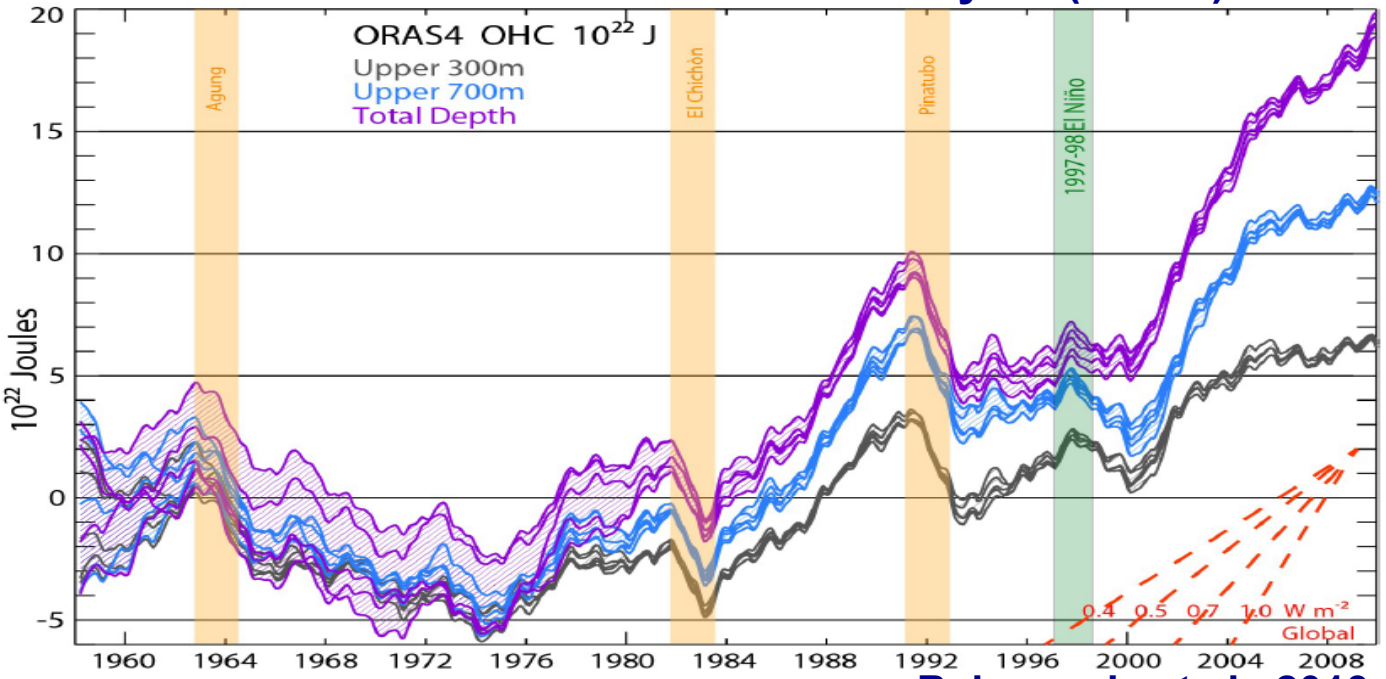
All OHC estimates show CERES 2007 cooling, all miss CERES warming in 2008/2009

➔ unable to achieve closure at interannual scales

➔ remaining errors either in CERES or **OHC**

Different approaches determining Earth's energy imbalance: OHC

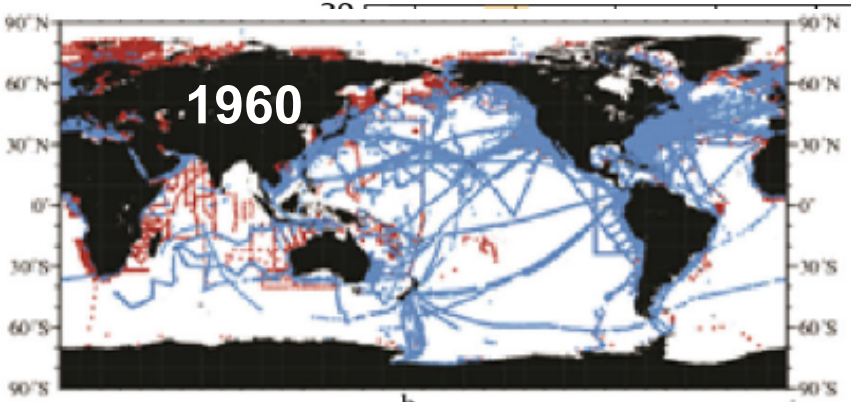
Global OHC from an ocean reanalysis (ORS4)



Balmaseda et al., 2013

Different approaches determining Earth's energy imbalance: OHC

Global OHC from an ocean reanalysis (ORS4)

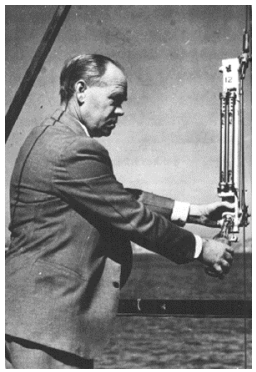


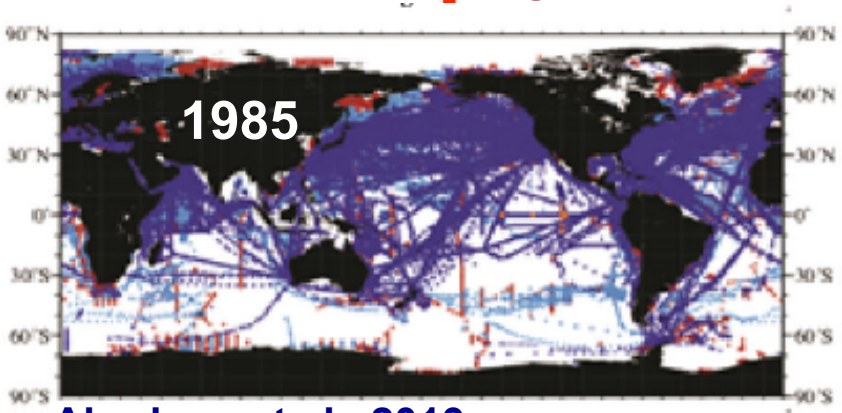
Abraham et al., 2013

Balmaseda et al., 2013

Historical measurements

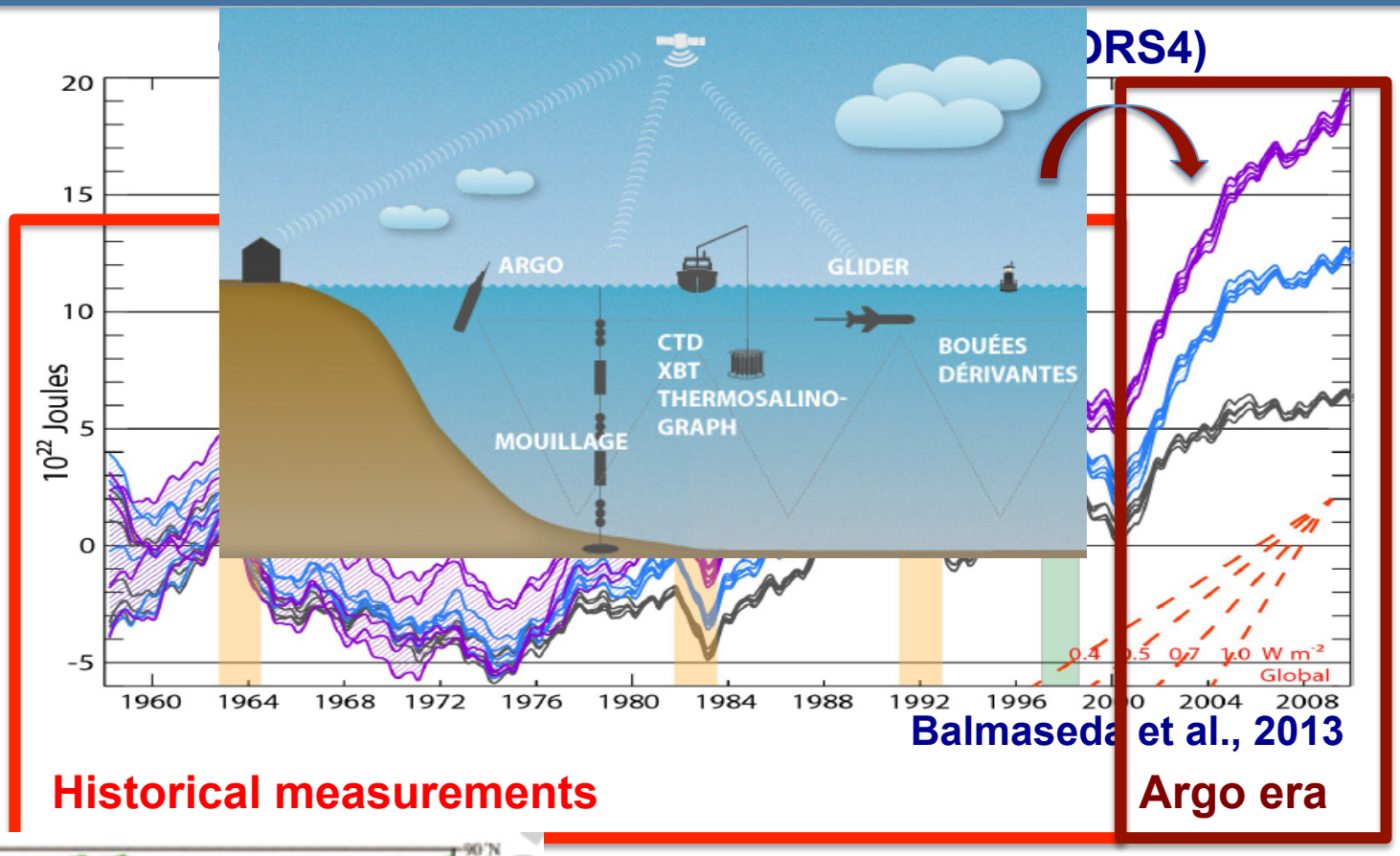
Argo era

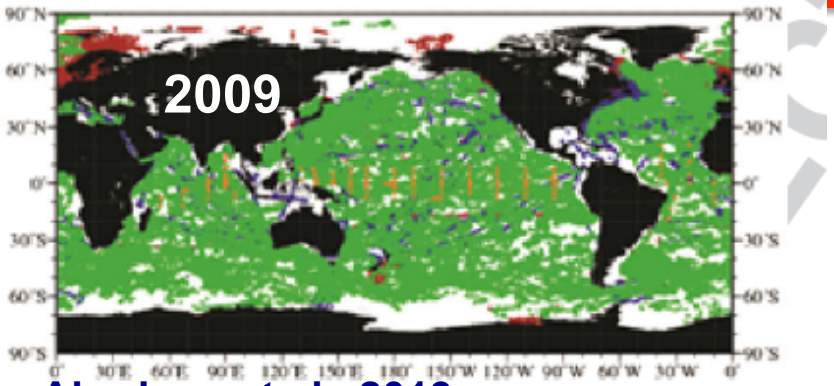




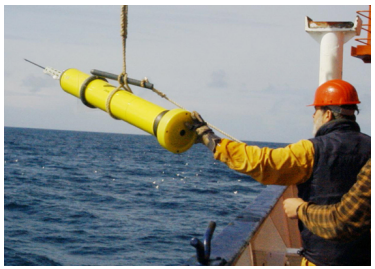
Abraham et al., 2013

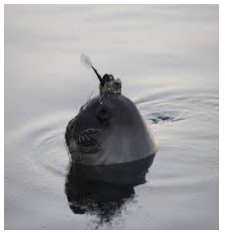
Different approaches determining Earth's energy imbalance: OHC





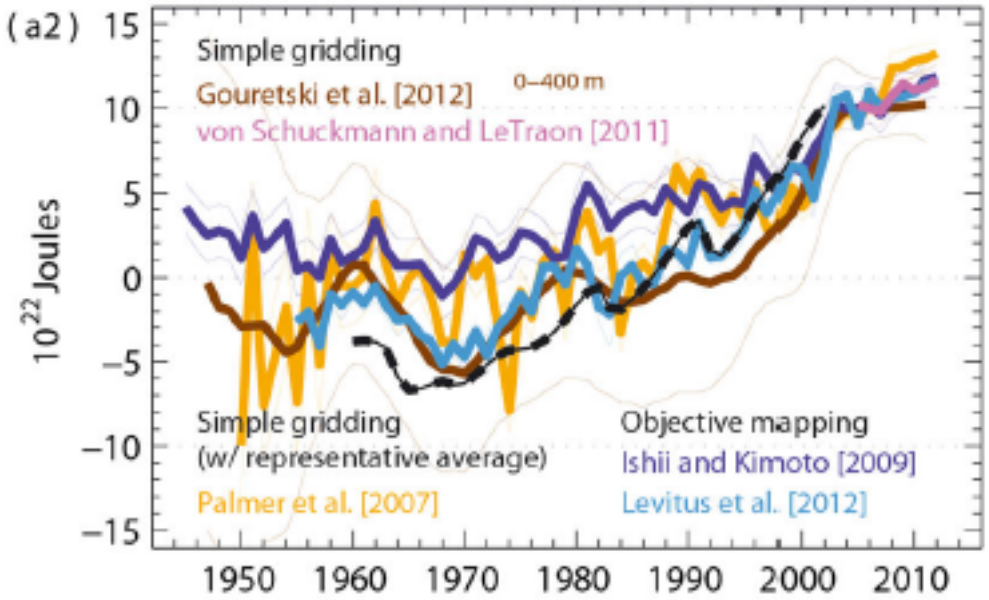
Abraham et al., 2013



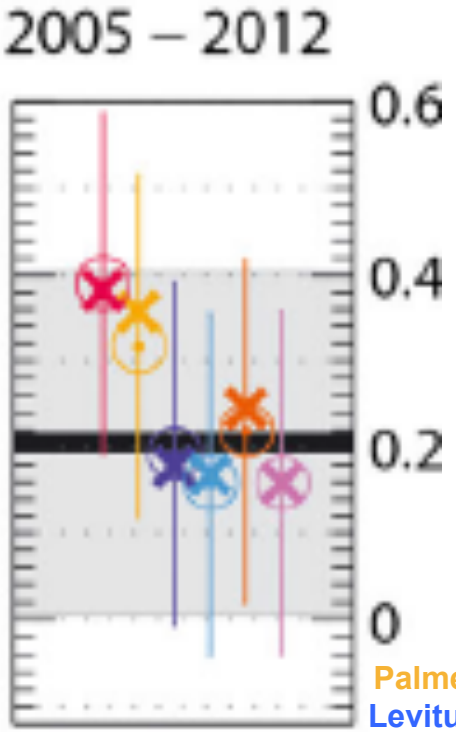


Different approaches determining Earth's energy imbalance: OHC

Global Ocean Heat Content: Historical data & Argo era



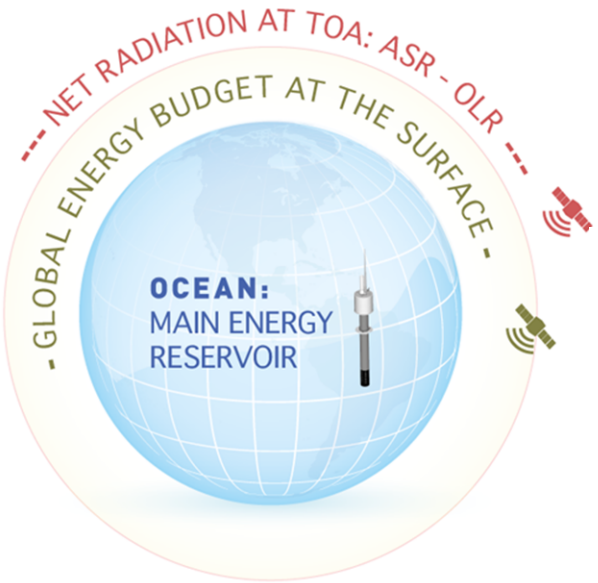
Abraham et al., 2013



Palmer et al., 2007
Levitus et al., 2012
von Schuckmann & Le Traon, 2011
Johnson et al., 2013
Ishii and Kimoto, 2009
Domingues et al., 2008

- Differences in upper-ocean heat storage between analyses/periods.
- Differences in "interannual to decadal variability" between analyses.
- All estimates show a multi-decadal increase in OHC in both, upper and deep ocean regions.

Detect changes in EEI with an accuracy of < 0.1 Wm^{-2} on multiannual-to-decadal timescales and < 0.5 Wm^{-2} on subannual-to-interannual timescales



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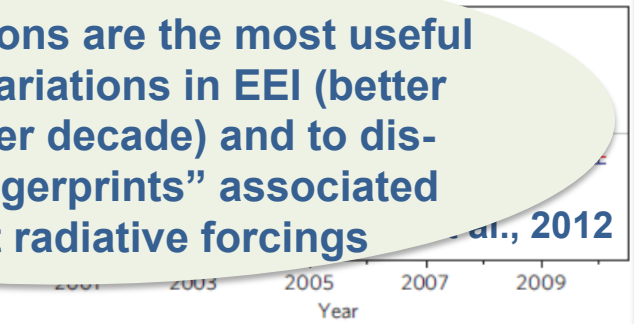
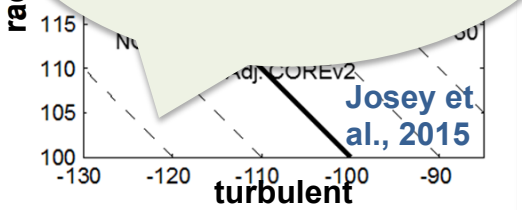
Satellite observations are the most useful means to track variations in EEI (better than 0.3 W m^{-2} per decade) and to dis-entangle the "fingerprints" associated with different radiative forcings



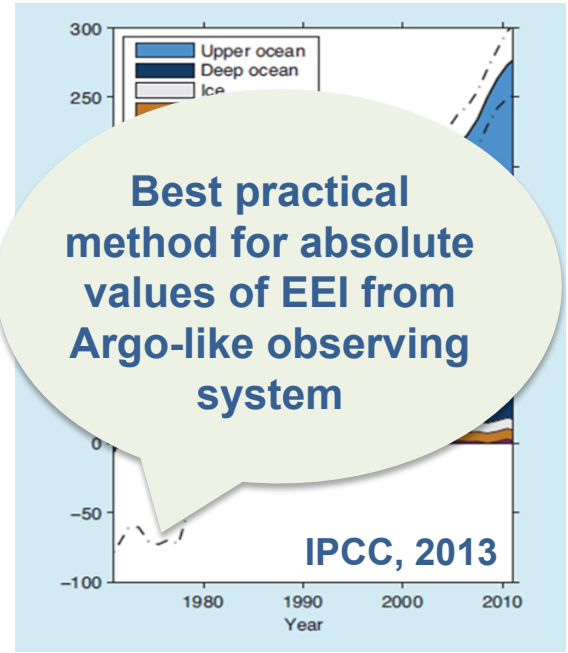
Surface flux

Still large uncertainties, but... improvements under the way through regional budget constraints



Ocean heat content

Best practical method for absolute values of EEI from Argo-like observing system



Climate models

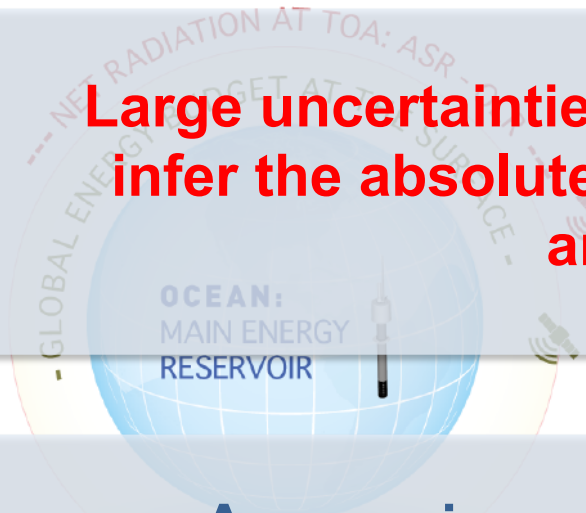
Can provide greater insights into the underlying mechanisms, but implementation of radiative forcings needs to be improved

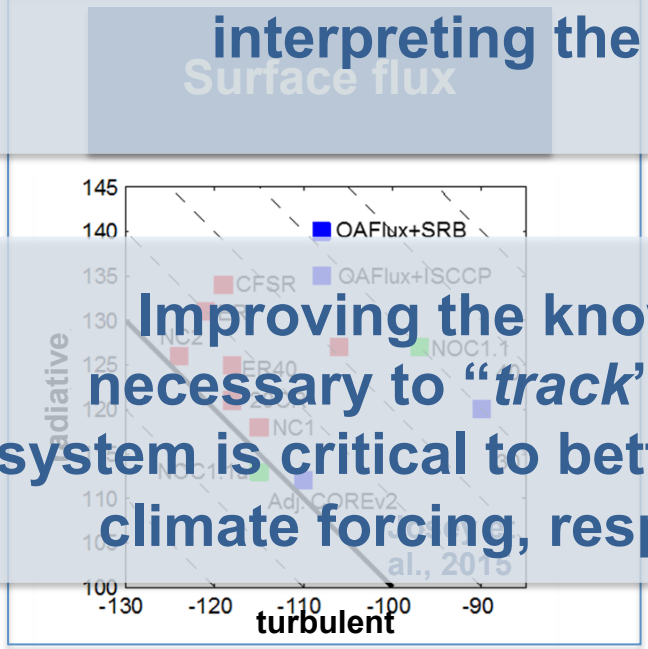
Different approaches determining Earth's energy imbalance

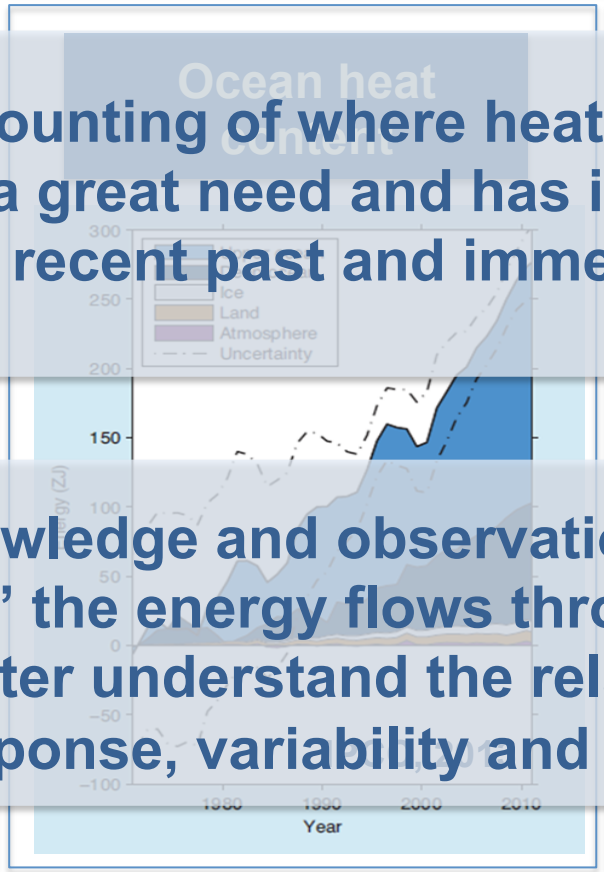
Large uncertainties in our estimates challenge our ability to infer the absolute measure of the Earth Energy Imbalance and its changes over time.

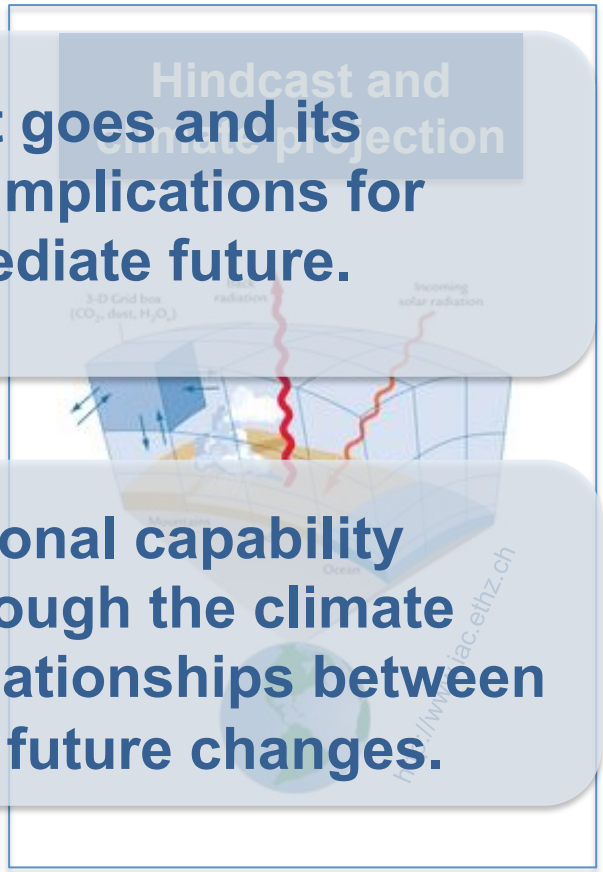
An ongoing accounting of where heat goes and its manifestations is a great need and has implications for interpreting the recent past and immediate future.

Improving the knowledge and observational capability necessary to "*track*" the energy flows through the climate system is critical to better understand the relationships between climate forcing, response, variability and future changes.





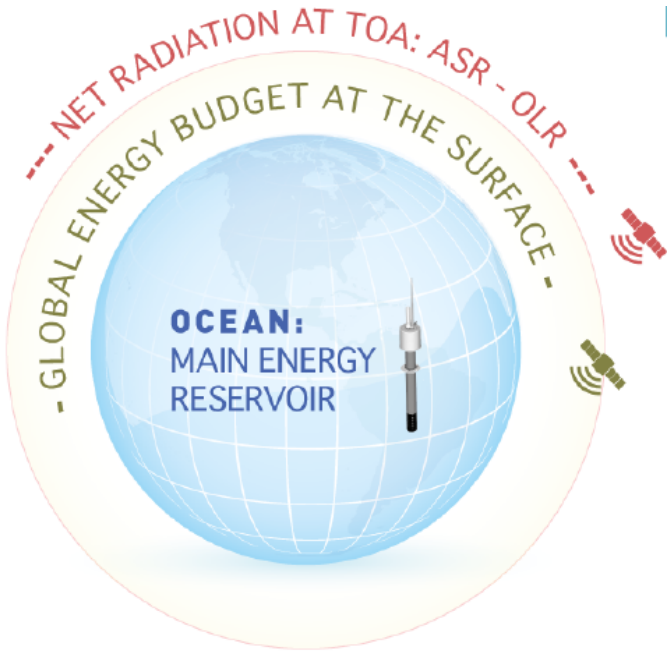




CLIVAR research focus CONCEPT-HEAT:

Consistency between planetary energy balance and ocean heat storage

An overall goal is to **bring together different climate research communities** all concerned with the energy flows in the Earth's System to advance on the **understanding of the uncertainties through budget constraints**:



- **Atmospheric radiation**
- **Ocean Heat Content**
- **Earth's surface fluxes**
- **Climate variability and change**
- **Data assimilation & operational services (R&D)**
- **Climate projection**
- **Global sea level**

Remote sensing	In situ	Reanalysis systems	Numerical model

CLIVAR research focus CONCEPT-HEAT:

Consistency between planetary energy balance and ocean heat storage

More precisely, this **CLIVAR research focus CONCEPT-HEAT has the main objective to build up a pluri-disciplinary synergy community for climate research** aiming to work on two different issues:

1. Quantify Earth's energy imbalance, the ocean heat budget, and atmosphere-ocean turbulent and radiative heat fluxes, their observational uncertainty, and their variability for a range of time and space scales using different observing strategies (e.g., in-situ ocean, satellite), reanalysis systems, and climate models.

2. Analyze the consistency between the satellite-based planetary heat balance and ocean heat storage estimates, using data sets and information products from global observing systems (remote sensing and in situ) and ocean reanalysis, and compare these results to outputs from climate models to obtain validation requirements (for model and observations).

CLIVAR research focus CONCEPT-HEAT:

Consistency between planetary energy balance and ocean heat storage

Key scientific questions

Question A: **What is the magnitude and the uncertainties of our estimates of Earth's energy imbalance (EEI), and how does it vary over time?**

Question B: **Can consistency between planetary heat balance and ocean heat storage achieved and what are the major limitations?**

Question C: **How are TOA net radiation and ocean heating rate distributed in space and time?**

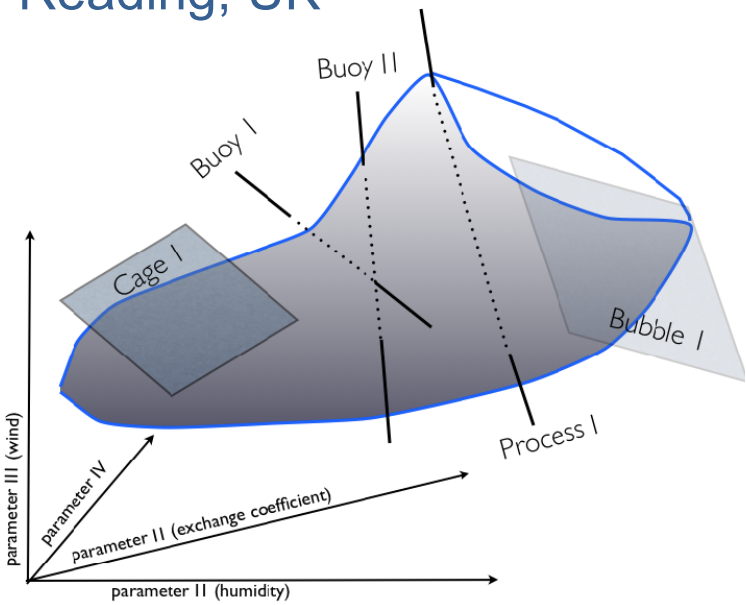
Question D: **How can we improve validation requirements for and from coupled climate models to improve estimates of EEI?**

Question E: **How can we better constrain the surface energy fluxes and their spatio-temporal variations at regional scale?**

CLIVAR CONCEPT-HEAT: Development

Joint CLIVAR-ESA scientific consultation workshop on: Earth Observations Measurement Constraints on OHC 03.-04. July 2013, University of Reading, UK

Magdalena Balmaseda, Matthew Palmer, Roger Barry, Richard Allan, Keith Haines, Sergey Gulev, Christopher Merchant, Karina von Schuckmann, Tony Lee, Bernard Barnier, Norman Loeb, Anny Cazenave, Andrea Storto, Svetlana Jevrejeva, Liz Kent, Caroline Katsman, Rowan Sutton, Aida Alvera Azcarate, Rainer Hollmann, Bertrand Chapron, Carol Ann Clayson, Pierre-Philippe Mathieu, Diego Fernandez, Gabriel Jordà, Nico Caltabiano, Gregory Johnson, Josh Willis



STSE Support To Science Element

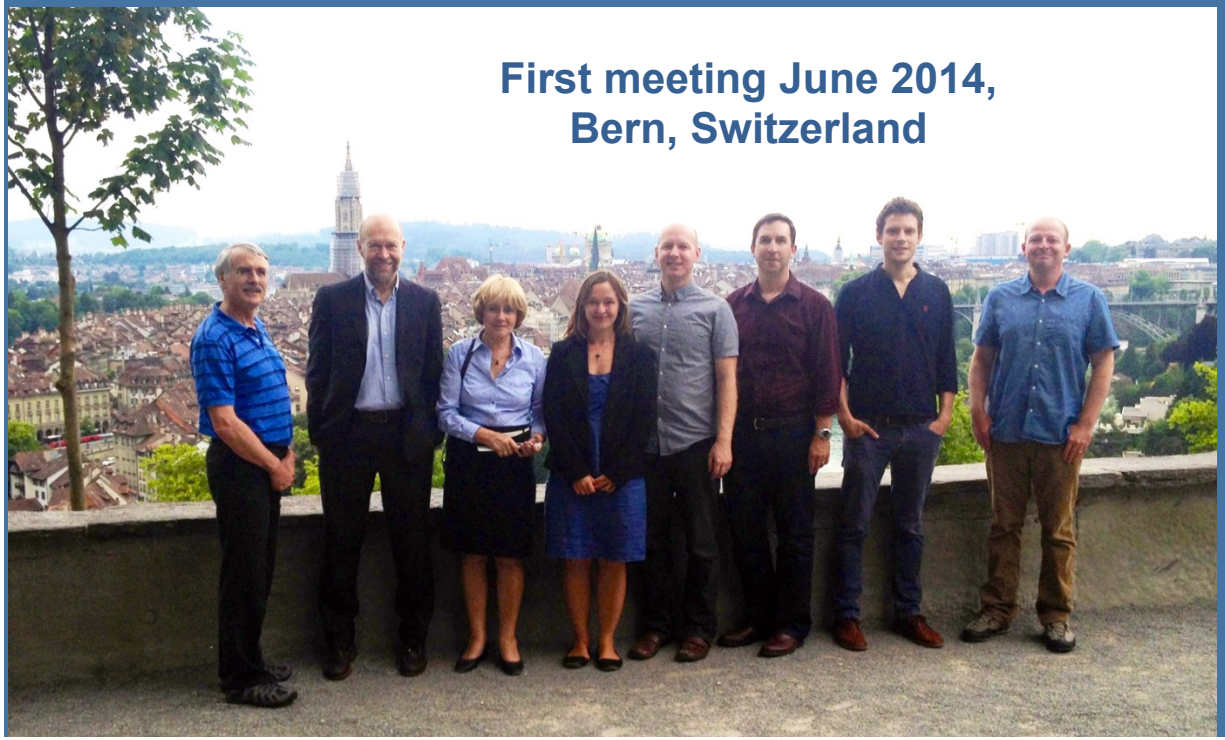
ESA – STSE
Ocean heat flux
www.oceanheatfluf.org

esa

CLIVAR CONCEPT-HEAT: Development

The absolute measure of the Earth Energy Imbalance and its changes over time are vital pieces of information related to climate change as this is the single quantity defining the status of global climate change and expectations for continued global warming.

ISSI working group: "Consistency of Integrated Observing Systems monitoring the energy flows in the Earth System"



First meeting June 2014,
Bern, Switzerland

K. von Schuckmann
A. Cazenave, D. Chambers, J. Hansen, S. Josey, Y. Kosaka, N. Loeb, P.P. Mathieu, B. Meyssignac, M. Palmer, K. Trenberth, M. Wild

Perspective paper NCC accepted
(von Schuckmann et al., 2015)

CLIVAR CONCEPT-HEAT: Development

Break-out session during Pan-CLIVAR meeting (July 2014)

.. and **SEVERAL** side-discussion in smaller groups

➔ Development of key scientific questions

➔ Basis for the development of the CONCEPT-HEAT white paper

CLIVAR research focus CONCEPT-HEAT:

Consistency between planetary energy balance and ocean heat storage

First CONCEPT-HEAT workshop, Met Office, Exeter (29.09.-01.10.2015)

CLIVAR research focus CONCEPT-HEAT:

Consistency between planetary energy balance and ocean heat storage

First CONCEPT-HEAT workshop, Met Office, Exeter (29.09.-01.10.2015)

EEI

most fundamental measure for climate change

FINDINGS

Estimate EEI locally and as a function of time

The estimation of OHC plays a key role for climate science

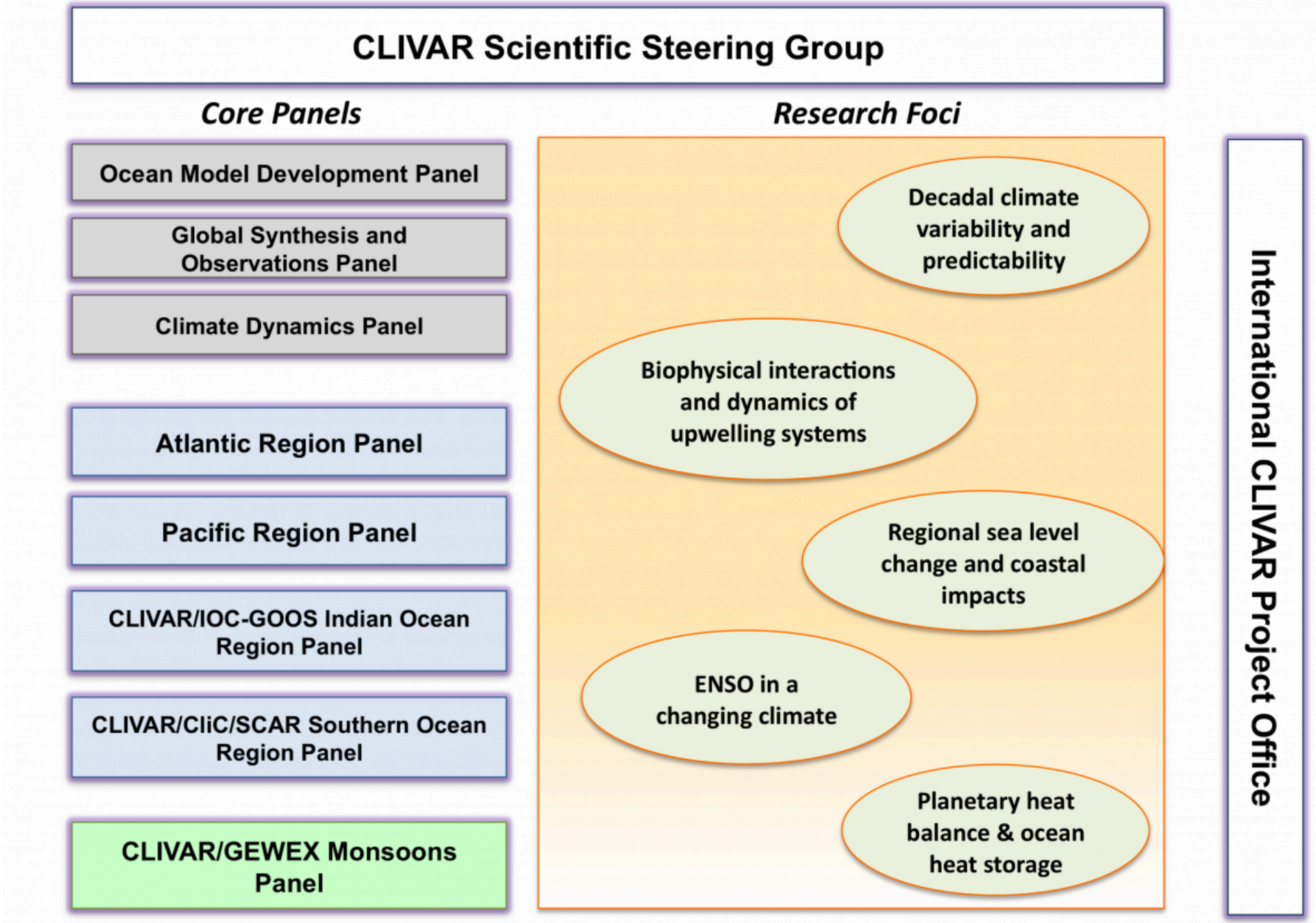
Studies of energy flows in climate modes

Concept of Cages:
- TOA flux and atmos. energy transport divergence;
- ocean transport divergence & changes in OHC;
- directly computing air-sea fluxes.

- Improved ocean observation system
- Improve OHC estimate capability

- Vertical disposition of heat in the oceans
- Horizontal redistribution of heat in the oceans

- Development of recommendation letters from CONCEPT-HEAT to different research and operational instituions and structurations
- Webpage, summer school, conference session, …


CLIVAR Scientific Steering Group
Core Panels
Ocean Model Development Panel
Global Synthesis and Observations Panel
Climate Dynamics Panel
Atlantic Region Panel
Pacific Region Panel
CLIVAR/IOC-GOOS Indian Ocean Region Panel
CLIVAR/CliC/SCAR Southern Ocean Region Panel
CLIVAR/GEWEX Monsoons Panel
Research Foci
Decadal climate variability and predictability
Biophysical interactions and dynamics of upwelling systems
Regional sea level change and coastal impacts
ENSO in a changing climate
Planetary heat balance & ocean heat storage
International CLIVAR Project Office