GLOBAL CLIMATE OBSERVING SYSTEM
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# The Earth's Energy Imbalance:

# Where does the energy go ?

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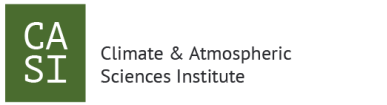
# The Earth's Energy Imbalance:

# Where does the energy go ?









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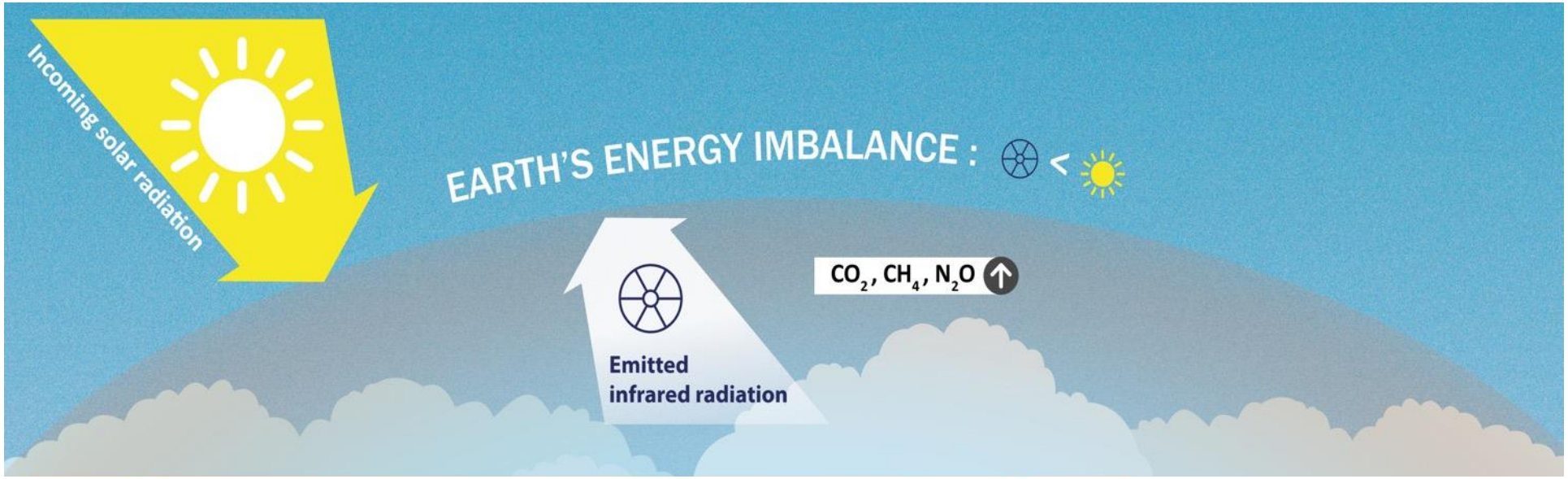
Polar Observation
and Modelling
Natural Environment Research Council


Université de Bretagne Occidentale

# EARTH CLIMATE: EARTH ENERGY IMBALANCE (EEI)

All **energy entering or leaving the Earth climate** system does so in the form of radiation **at the top-of-the-atmosphere** (TOA)



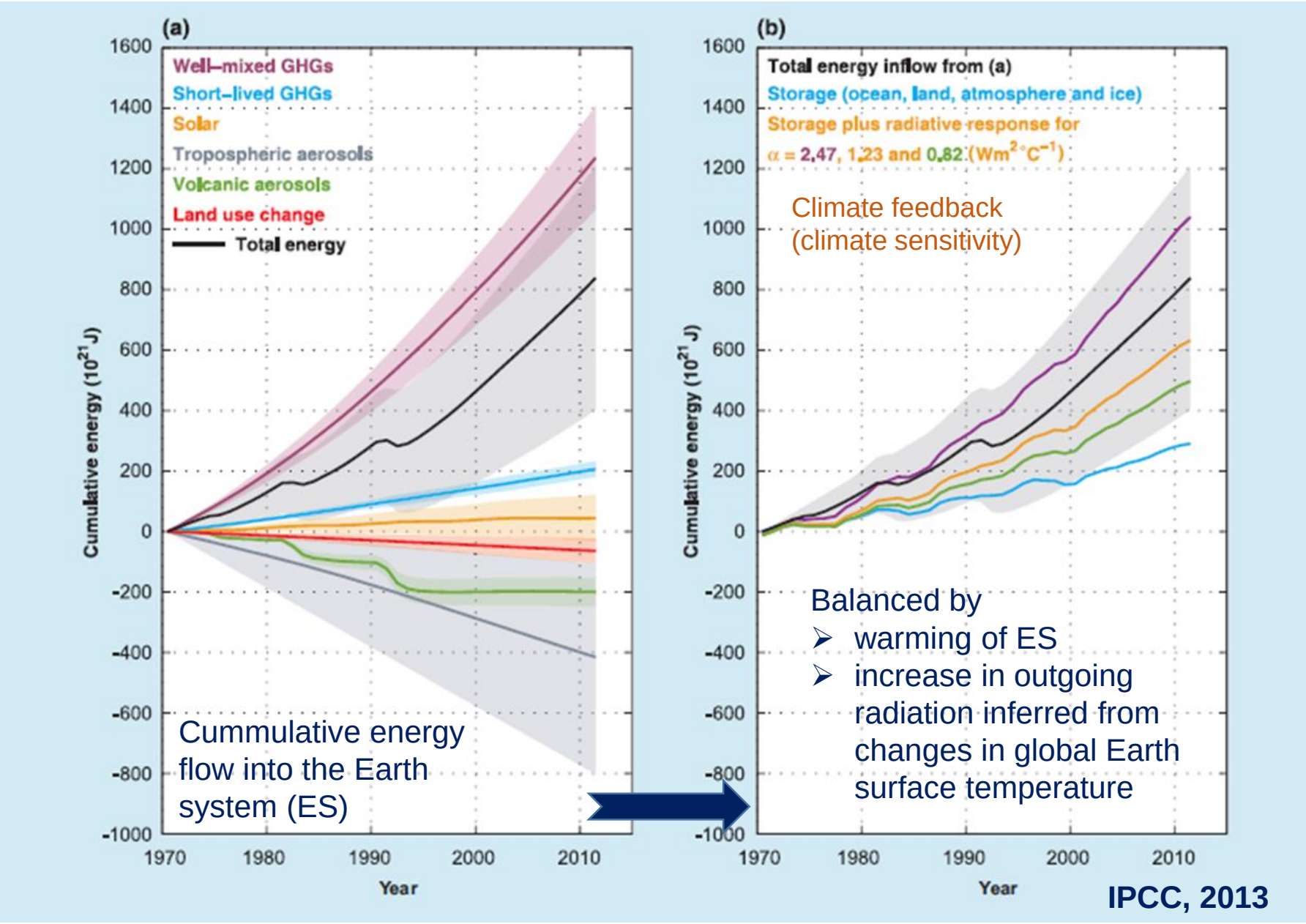

**von Schuckmann et al., 2016**

The difference between incoming solar radiation and outgoing radiation determines the **net radiative flux at TOA**: If the **imbalance is positive** (i.e. less energy going out than coming in), energy in the form of **heat is accumulated in the Earth system** resulting in global warming - or cooling if the EEI is negative.

# ANTHROPOGENIC CLIMATE FORCING

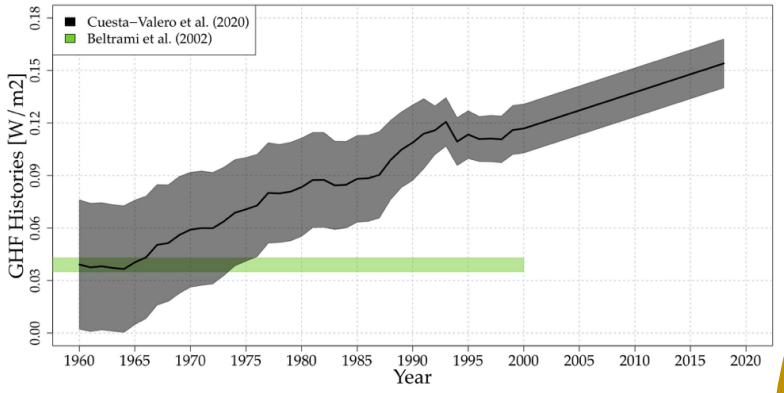
Earth energy budget from 1970-2011

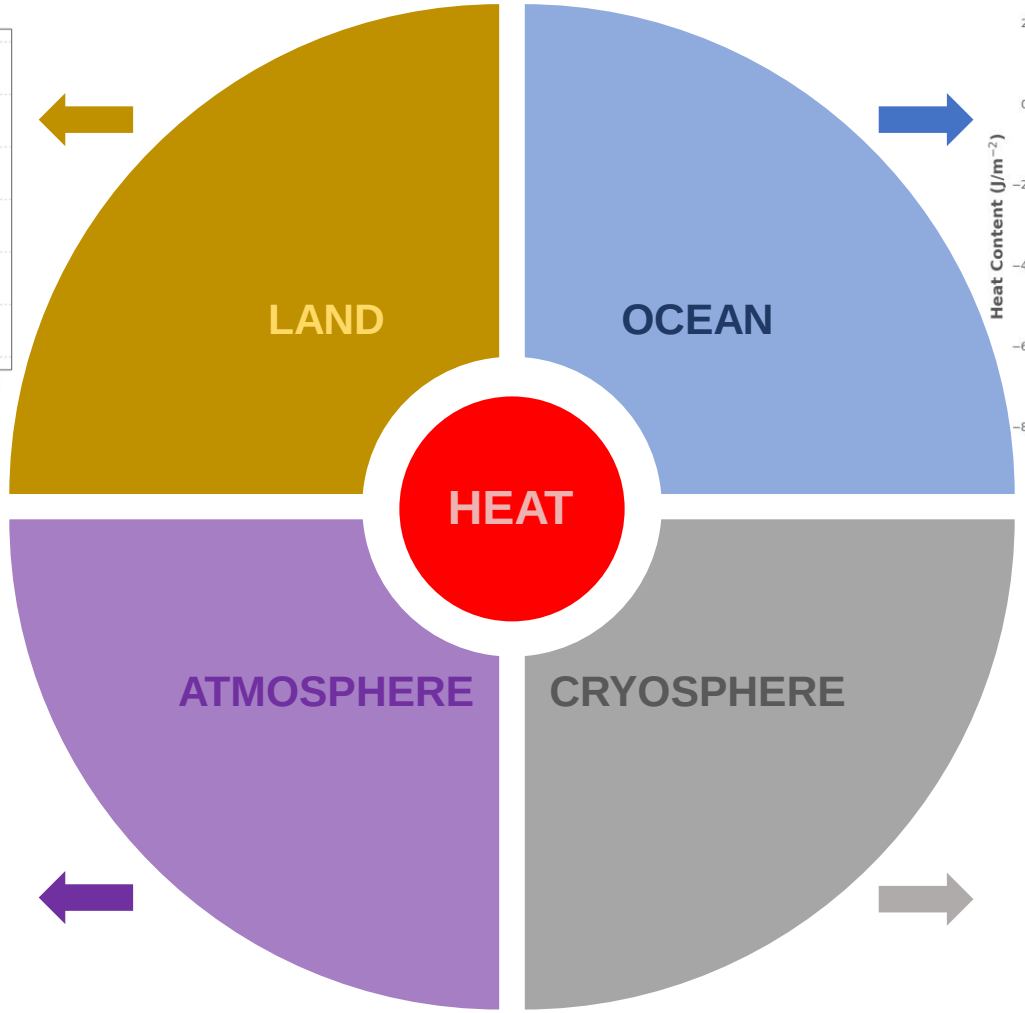
**The Earth is out of energy balance** directly attributable to increases in carbon dioxide and other greenhouse gases in the atmosphere from **human activities**, leading to **heat accumulation in the Earth system**, which is driving global warming (IPCC, 2013).

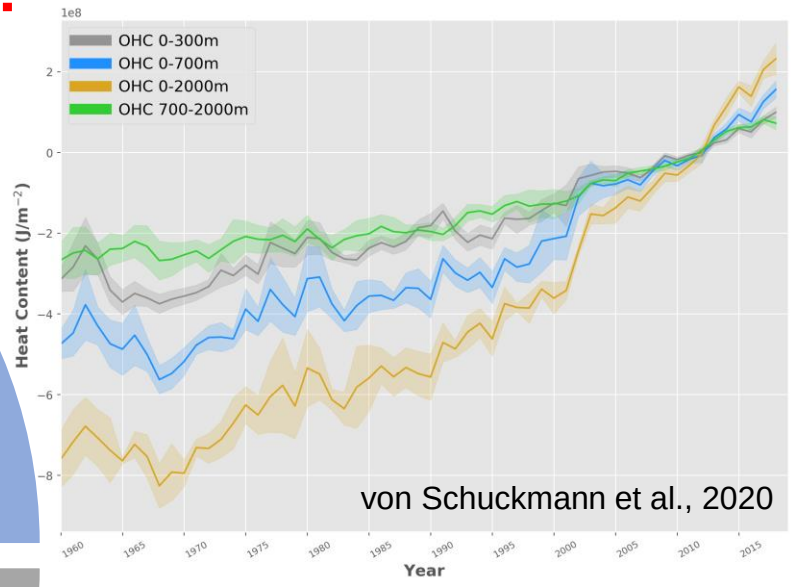


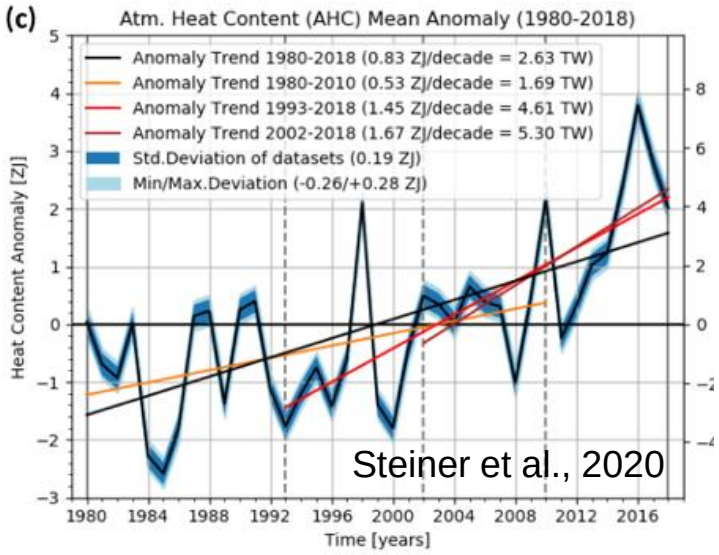
# HEAT STORED IN THE EARTH SYSTEM

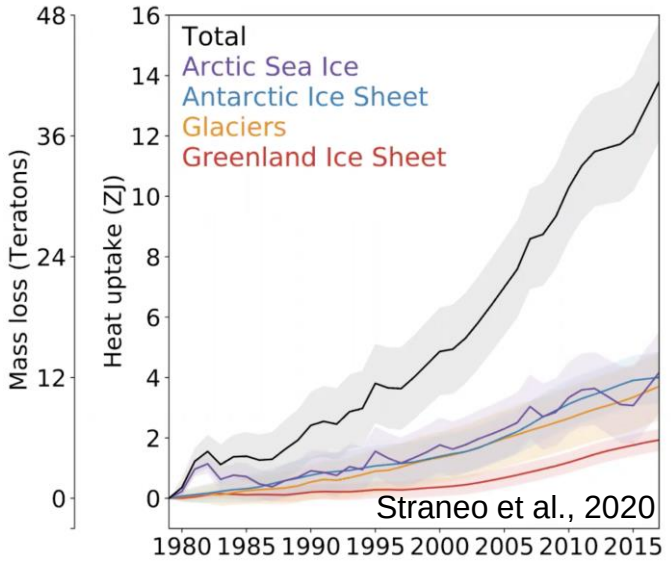
## WHERE DOES THE ENERGY GO?



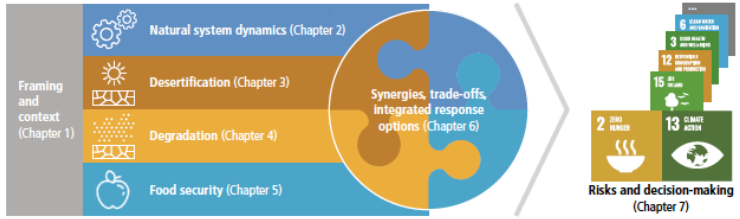




➔ See video (poster session) for more details

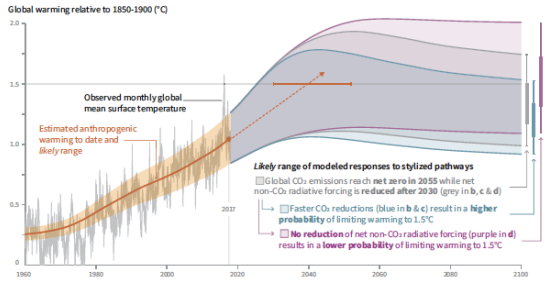
# HEAT STORED IN THE EARTH SYSTEM

## WHY SHOULD WE CARE?

### LAND WARMING

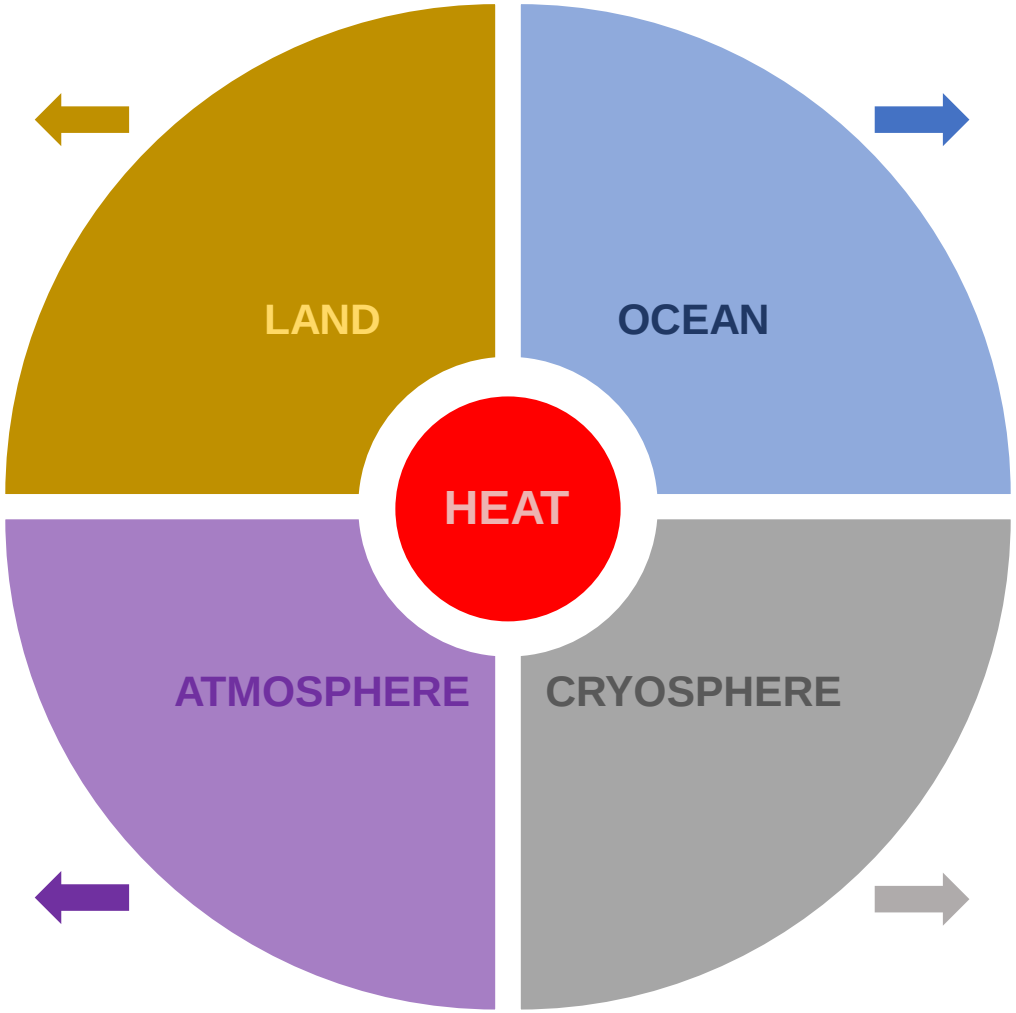



IPCC SRCCL, 2019

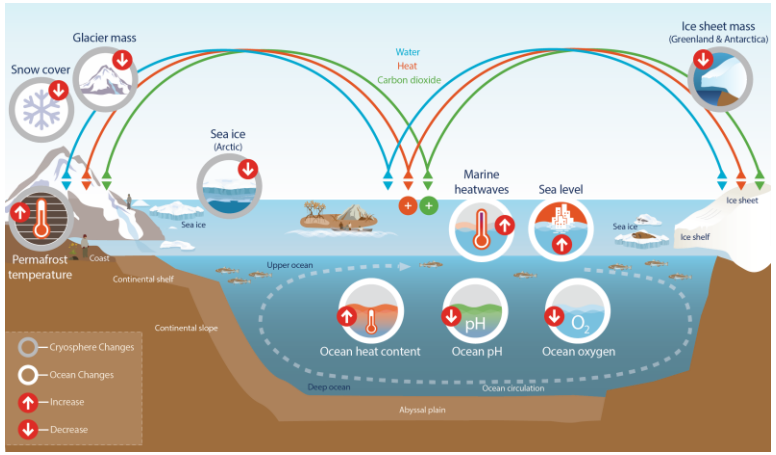



IPCC 1.5°, 2018

### ATMOSPHERE WARMING




### OCEAN WARMING

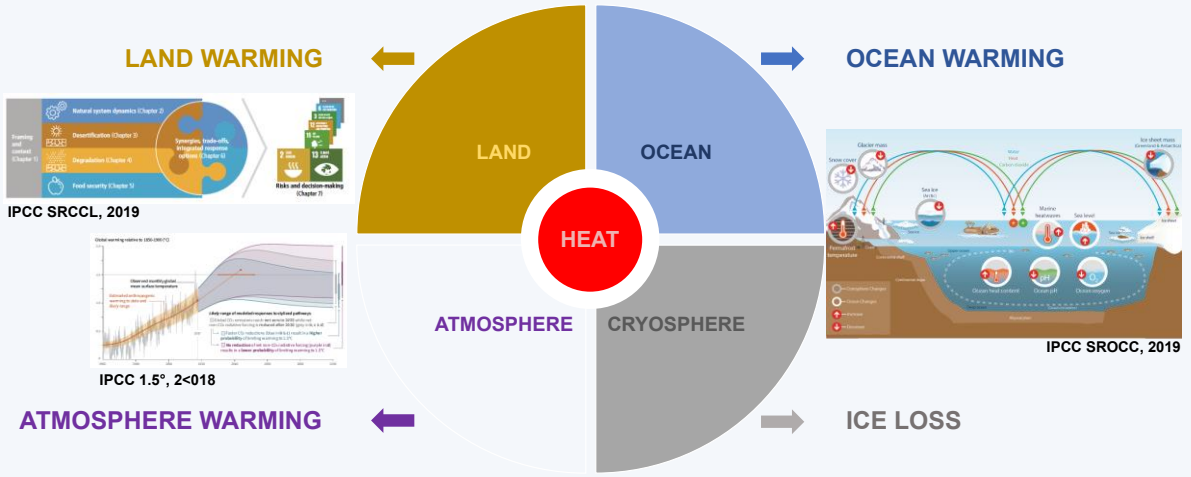



IPCC SROCC, 2019

### ICE LOSS

# HEAT STORED IN THE EARTH SYSTEM

## WHY SHOULD WE CARE?



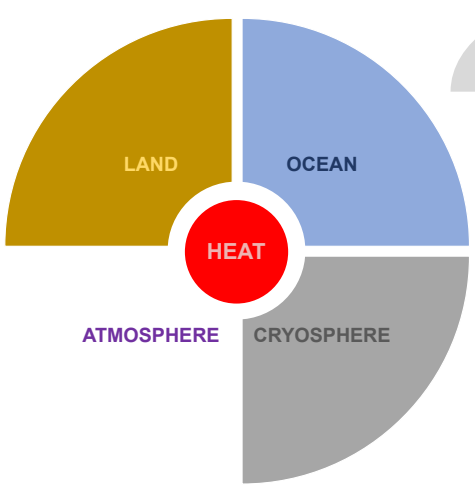

The **various facets and impacts** of observed climate change arise **due to the positive EEI**, which thus represents a **crucial measure of the rate of climate change**.

The EEI is the portion of the forcing that the Earth has not yet been responded to

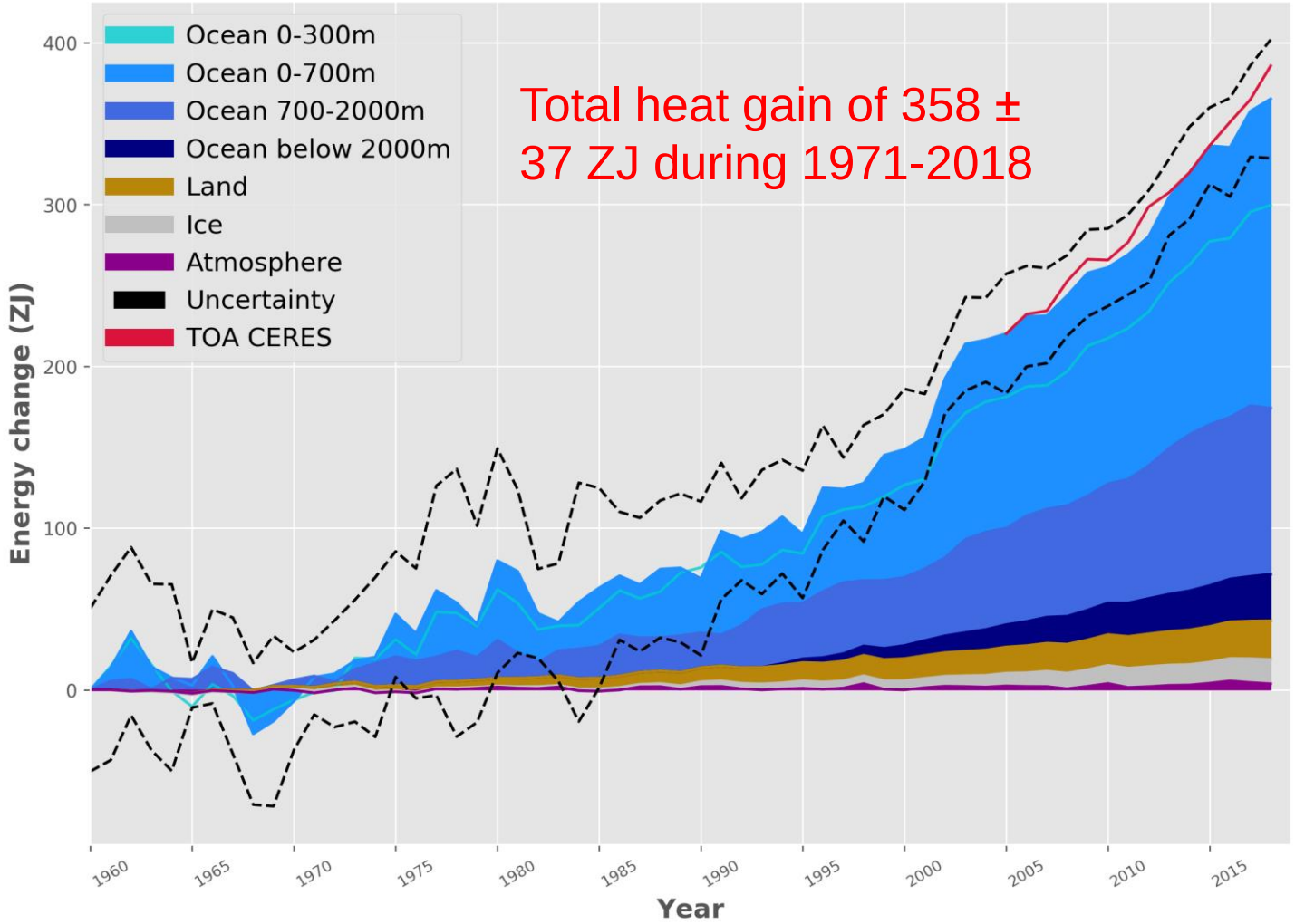
➔ **How much heat is 'in the pipeline'** ?

**The EEI is the most critical number defining the prospects for continued global warming and climate change.**

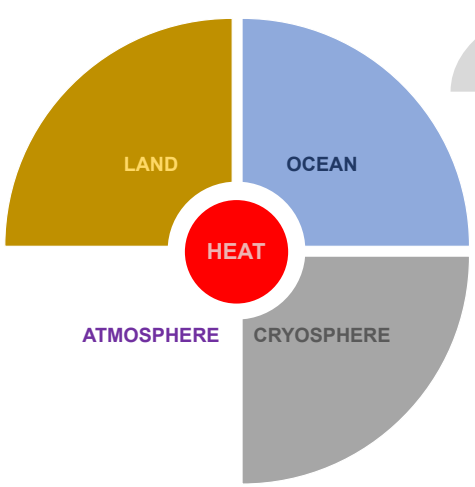
# THE EARTH HEAT INVENTORY



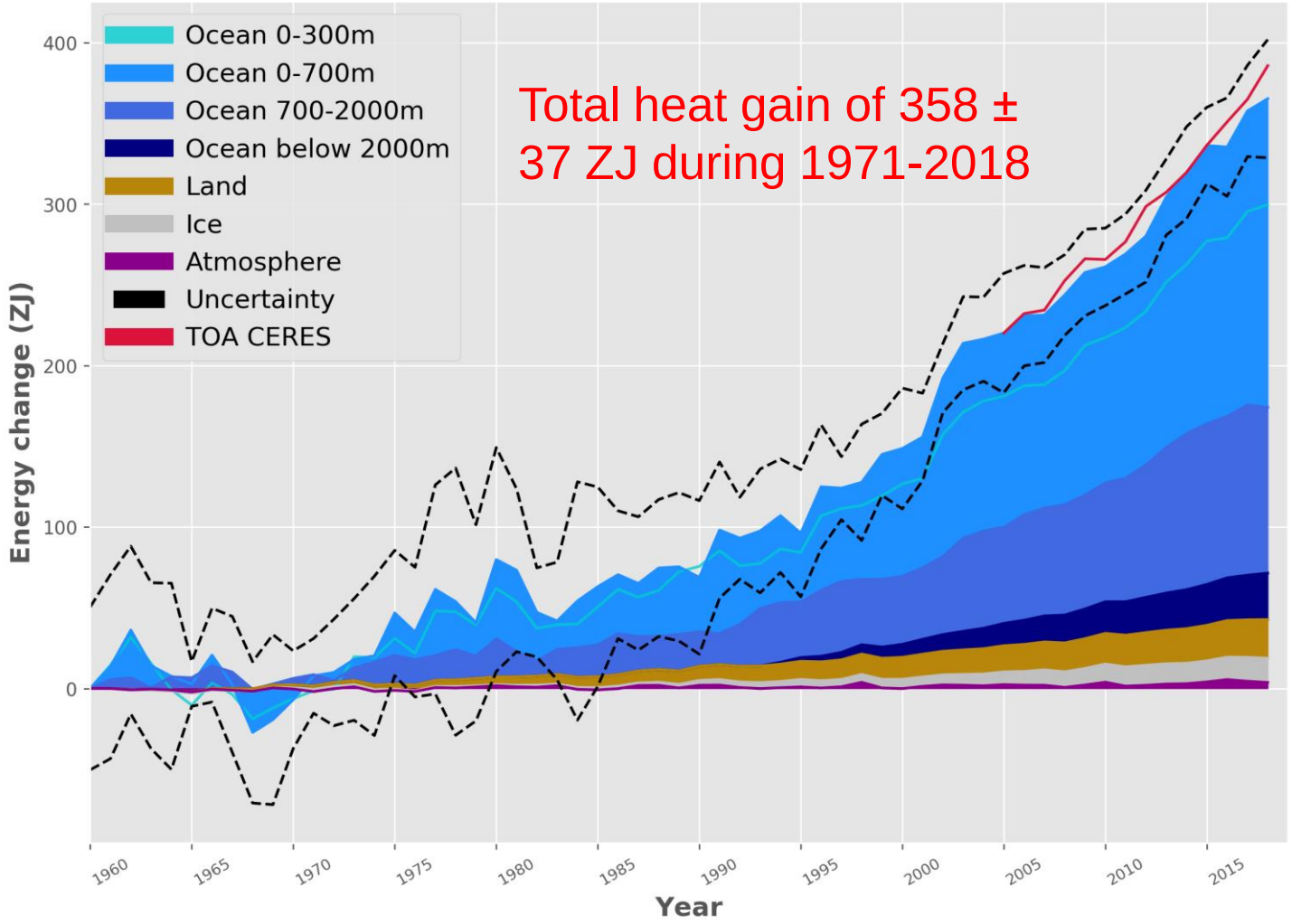

## HOW MUCH?



# THE EARTH HEAT INVENTORY




## HOW MUCH?




## WHERE?

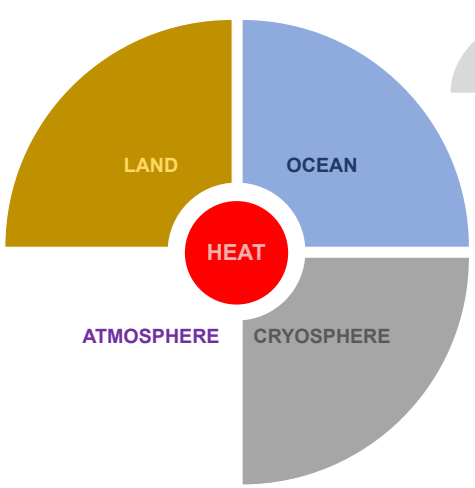
89% OCEAN

6% LAND

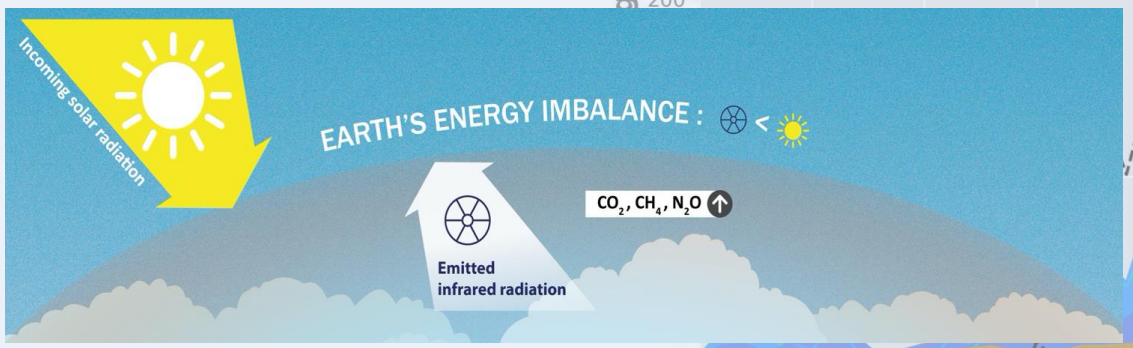
4% CRYOSPHERE

1% ATMOSPHERE

# THE EARTH HEAT INVENTORY

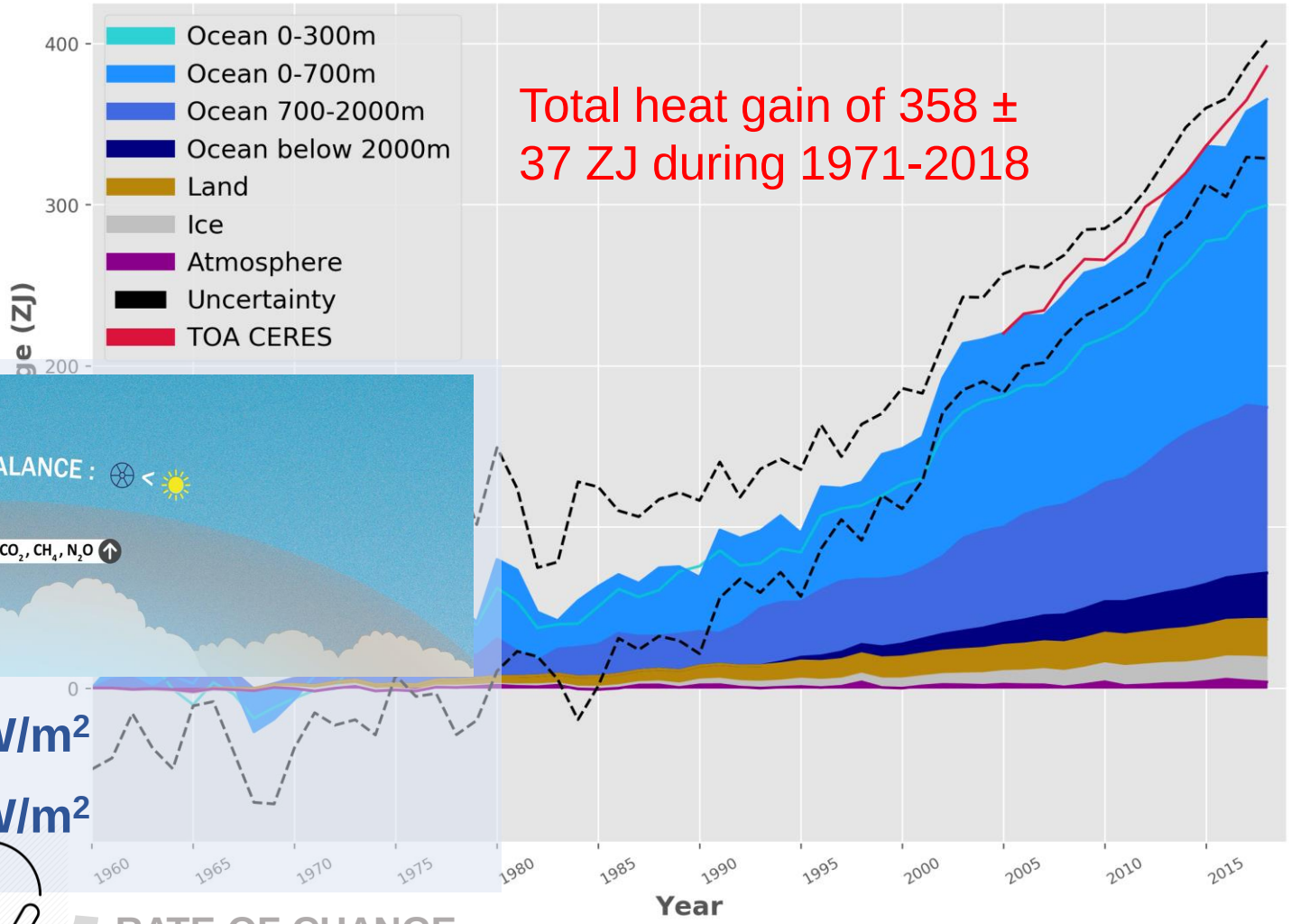



## HOW MUCH?




**1971-2018: 0.47 ± 0.1 W/m²**

**2010-2018: 0.87 ± 0.1 W/m²**




RATE OF CHANGE IN TIME

## WHERE?

**89% OCEAN**

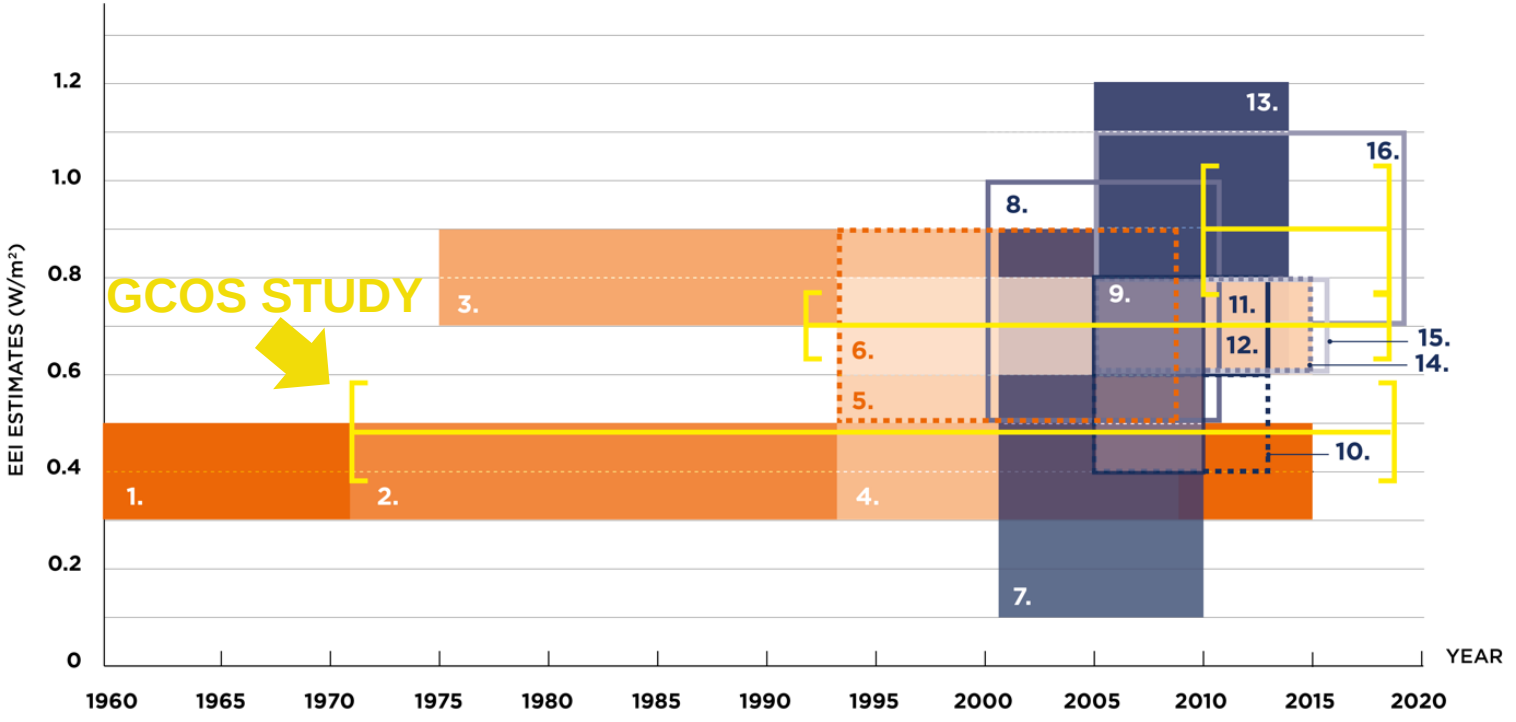
**6% LAND**

**4% CRYOSPHERE**

**1% ATMOSPHERE**

# THE EARTH ENERGY IMBALANCE (EEI)

## EVOLUTION OF THE EEI OVER TIME




1. **1960-2015** 0.4 ± 0.1 W/m² : Cheng et al., 2017
2. **1971-2010** 0.4 ± 0.1 W/m² : IPCC AR5
3. **1975-2009** 0.8 ± 0.1 W/m² : Balmaseda et al., 2013
4. **1993-2008** 0.6 ± 0.3 W/m² : Trenberth, 2010;
5. 0.7 ± 0.2 W/m² : Hansen et al., 2011;
6. **1993-2015** 0.7 ± 0.1 W/m² : von Schuckmann et al., 2017
7. **2001-2010** 0.5 ± 0.4 W/m² : Loeb et al., 2012
8. **2000-2011** 0.5-1 W/m²: Trenberth et al., 2014
9. **2005-2010** 0.6 ± 0.2 W/m²: Hansen et al., 2011
10. **2005-2013** 0.5 ± 0.1 W/m² : Dieng et al., 2017 (OHC in situ)
11. 0.7 ± 0.1 W/m² : Dieng et al., 2017 (OHC satellite)
12. 0.7 ± 0.1 W/m² : Dieng et al., 2017 (OHC reanalysis)
13. **2005-2014** 0.9 ± 0.3 W/m² : Trenberth et al., 2016
14. **2005-2015** 0.7 ± 0.1 W/m² : Johnson et al., 2016
15. **2005-2016** 0.7± 0.1 W/m² : von Schuckmann et al., 2018
16. **2005-2019** 0.9 ± 0.2 : Trenberth, 2020

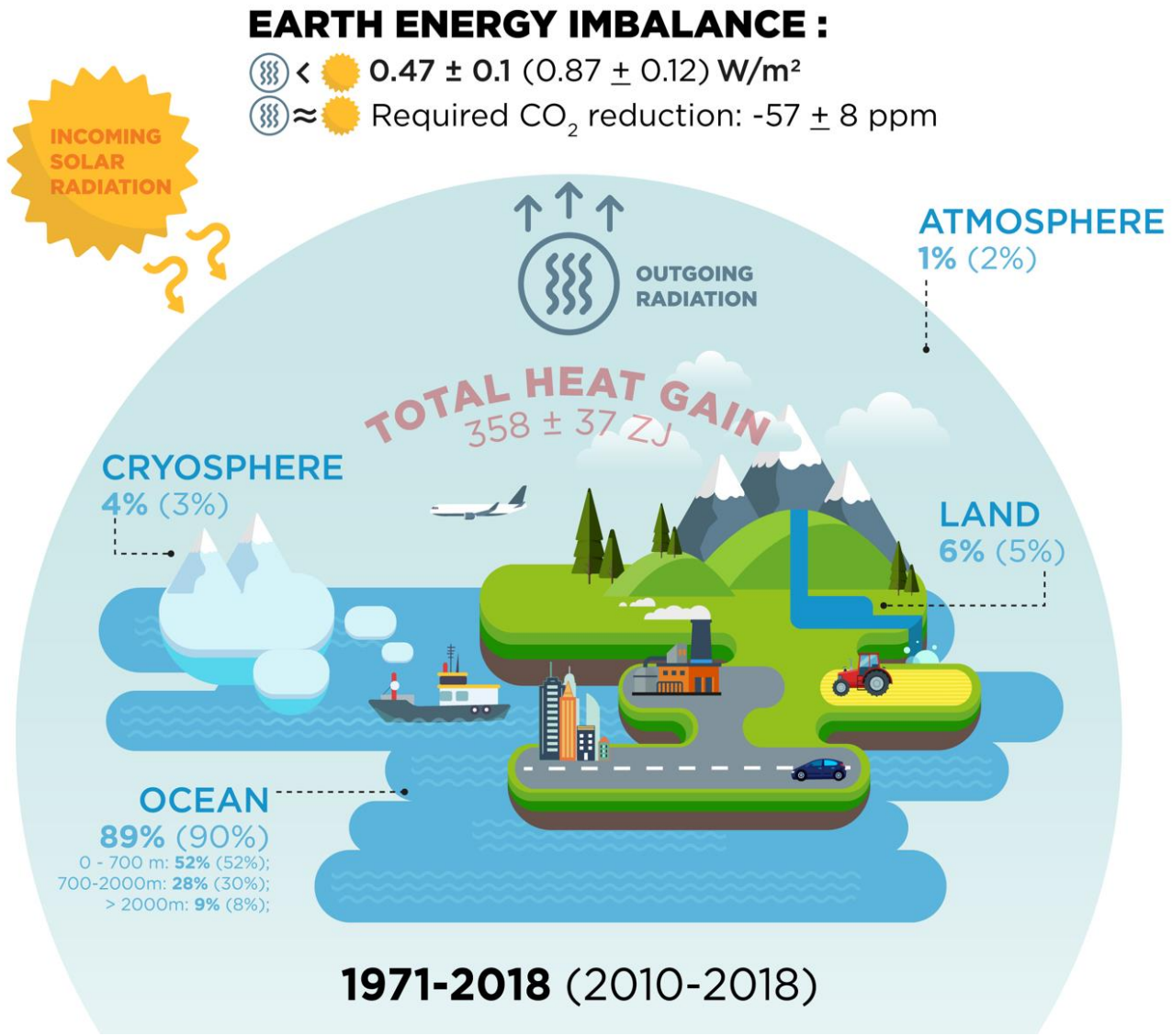
**GCOS Earth heat inventory**
**1971-2018 :** 0.47 ± 0.1 W/m²
**1993-2018 :** 0.69 ± 0.1 W/m²
**2010-2018:** 0.87 ± 0.12 W/m²

**2000-2014**
1.1 ± 0.8 W/m² : Wild, 2020 (CMIP 6)

Our results show that the EEI continues at a comparable rate as reported in IPCC AR5

Our results also show that the EEI is increasing, and – compared to the long-term rate - has doubled over the past decade

# KEY MESSAGES

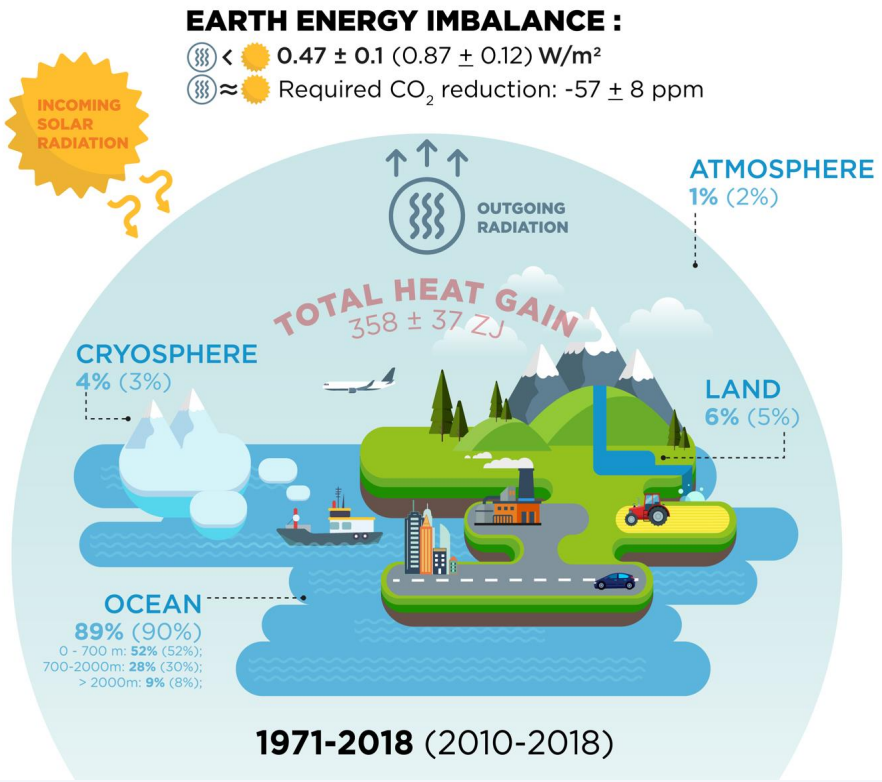



During 2010-2018, the EEI amounts to 0.87 ± 0.12 W/m2.

Stabilization of climate, the goal of the universally agreed UNFCCC in 1992 and the Paris agreement in 2015, requires that EEI be reduced to approximately zero to achieve Earth's system quasi-equilibrium.

The amount of CO2 in the atmosphere would need to be reduced from 410 ppm to 353 ppm to increase heat radiation to space by 0.87 W/m2, bringing Earth back towards energy balance.

# KEY MESSAGES




This simple number, **EEI, is the most fundamental metric** that the scientific community and public must be aware of, as the **measure of how well the world is doing in the task of bringing climate change under control**, and we call for an implementation of the EEI into the global stocktake based on best available science.

Continued quantification and reduced uncertainties in the Earth heat inventory can be best achieved through the **maintenance of the current global climate observing system**, its **extension** into areas of gaps in the sampling, as well as to **establish an international framework for concerted multi-disciplinary research** of the Earth heat inventory as presented in this study.

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# THANK YOU !