Monitoring the Earth water and energy cycle response to climate change with space gravimetry: future needs

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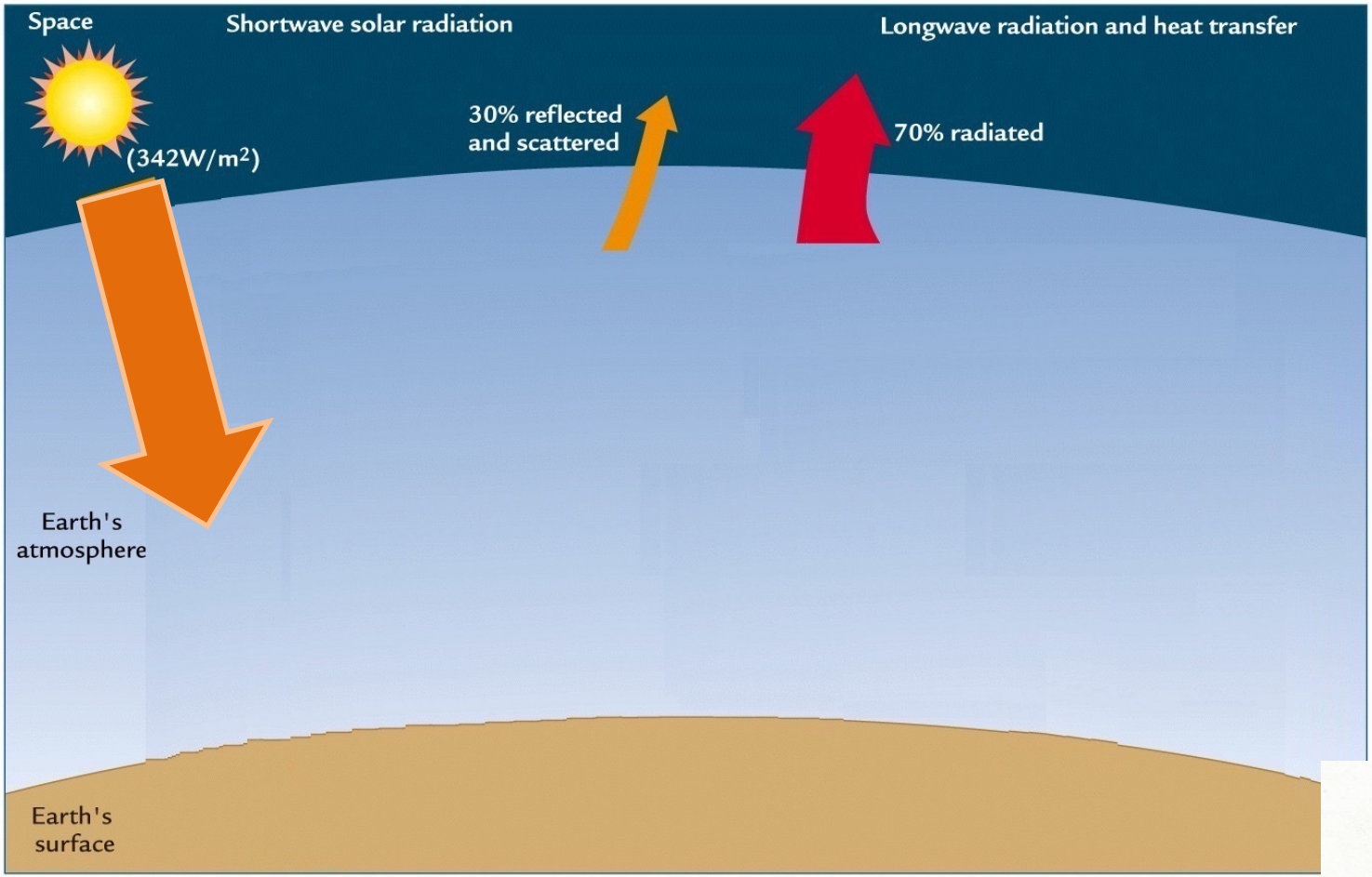
The global water-energy cycle response to greenhouse gases emissions and consequences

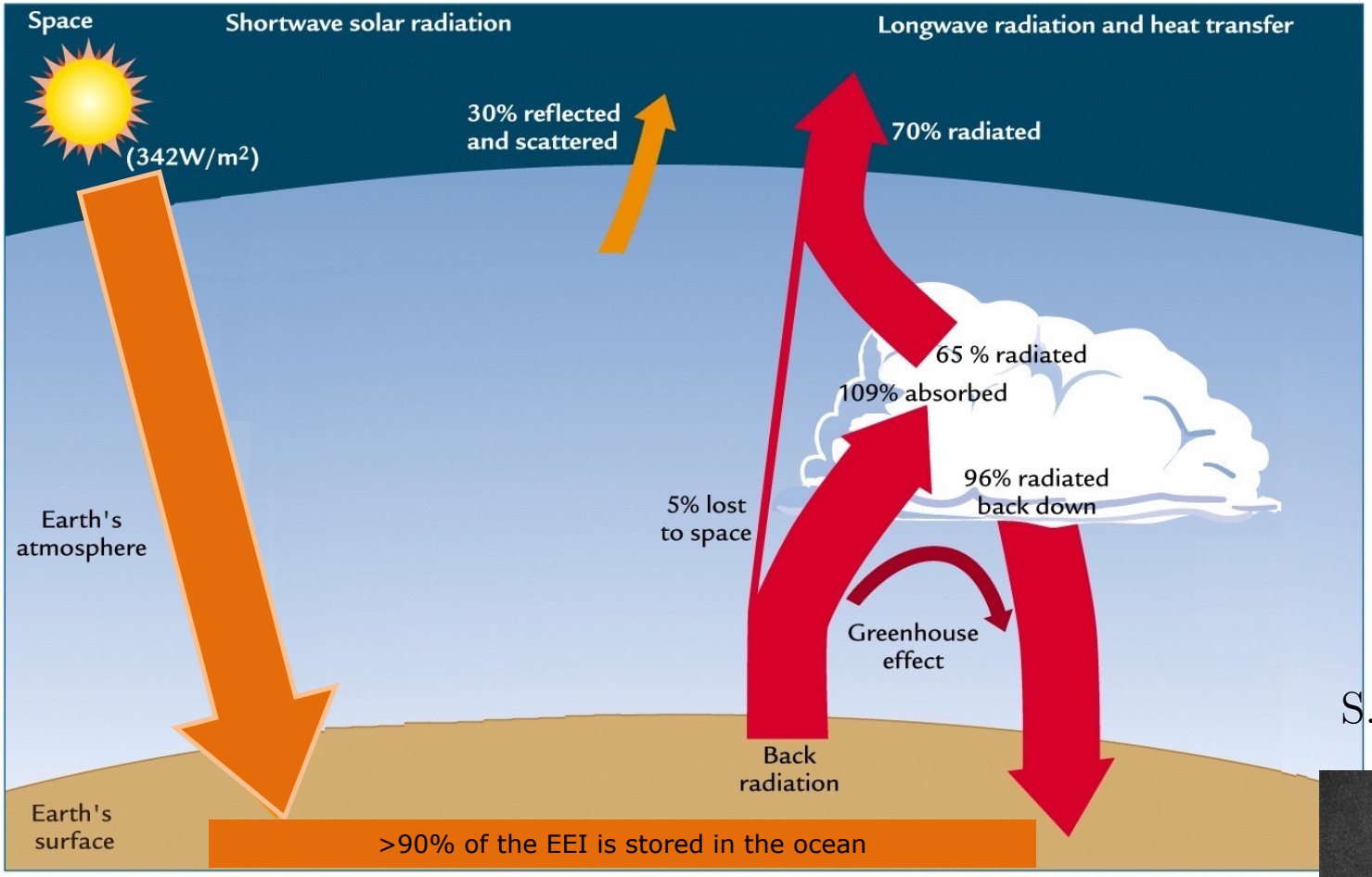
Earth energy budget and climate change



$$0 = F - R(T_s)$$

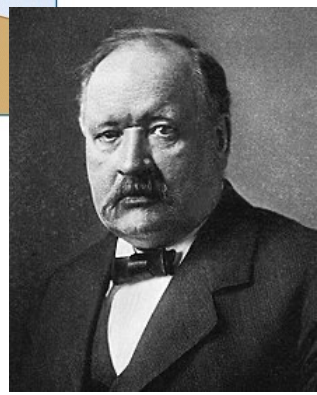
J.Fourier

Earth energy budget and climate change

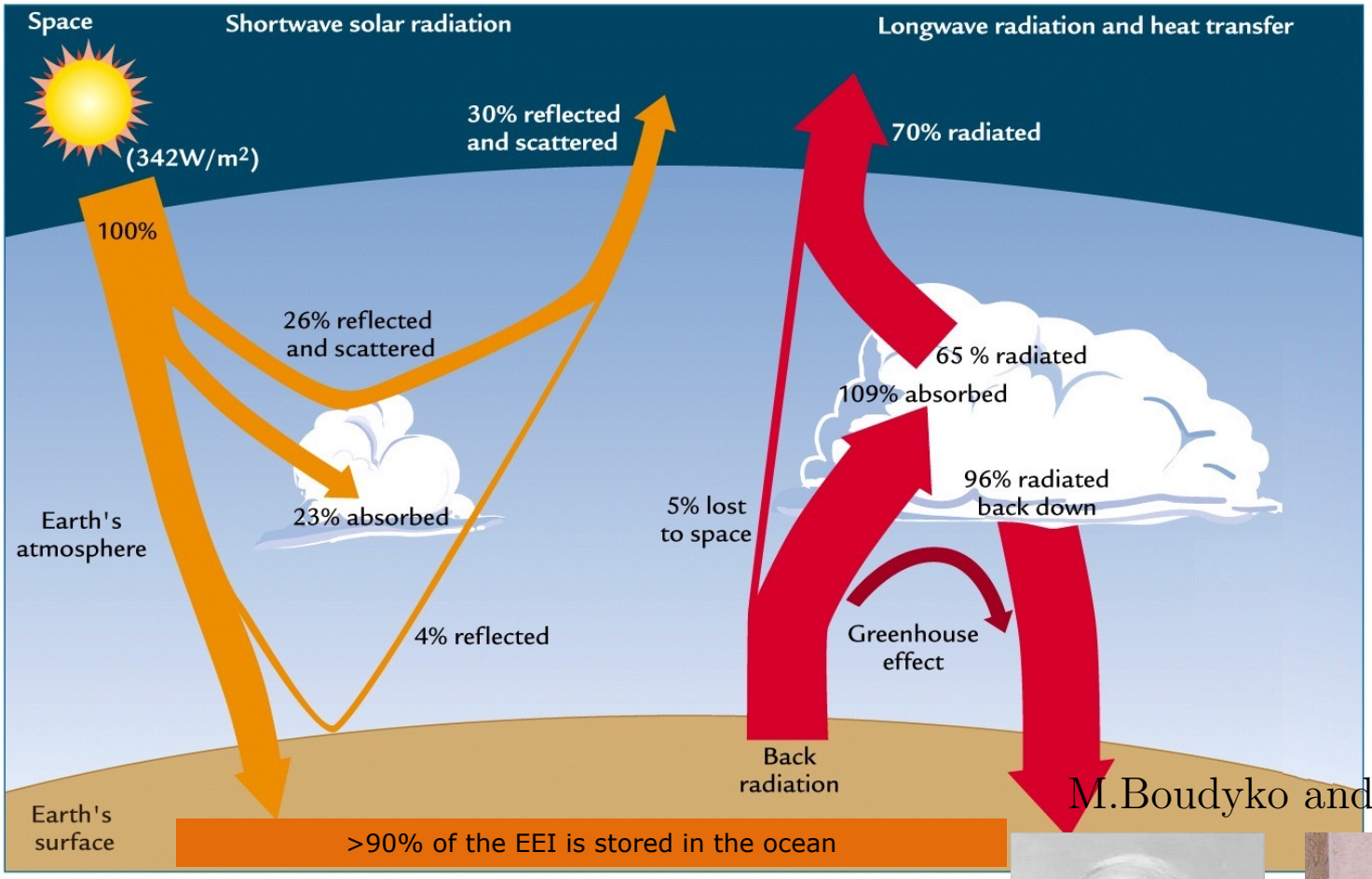


$$EEI = F - R(T_s, P_{CO_2}, P_{H_2O})$$

S.Arrhenius



Earth energy budget and climate change

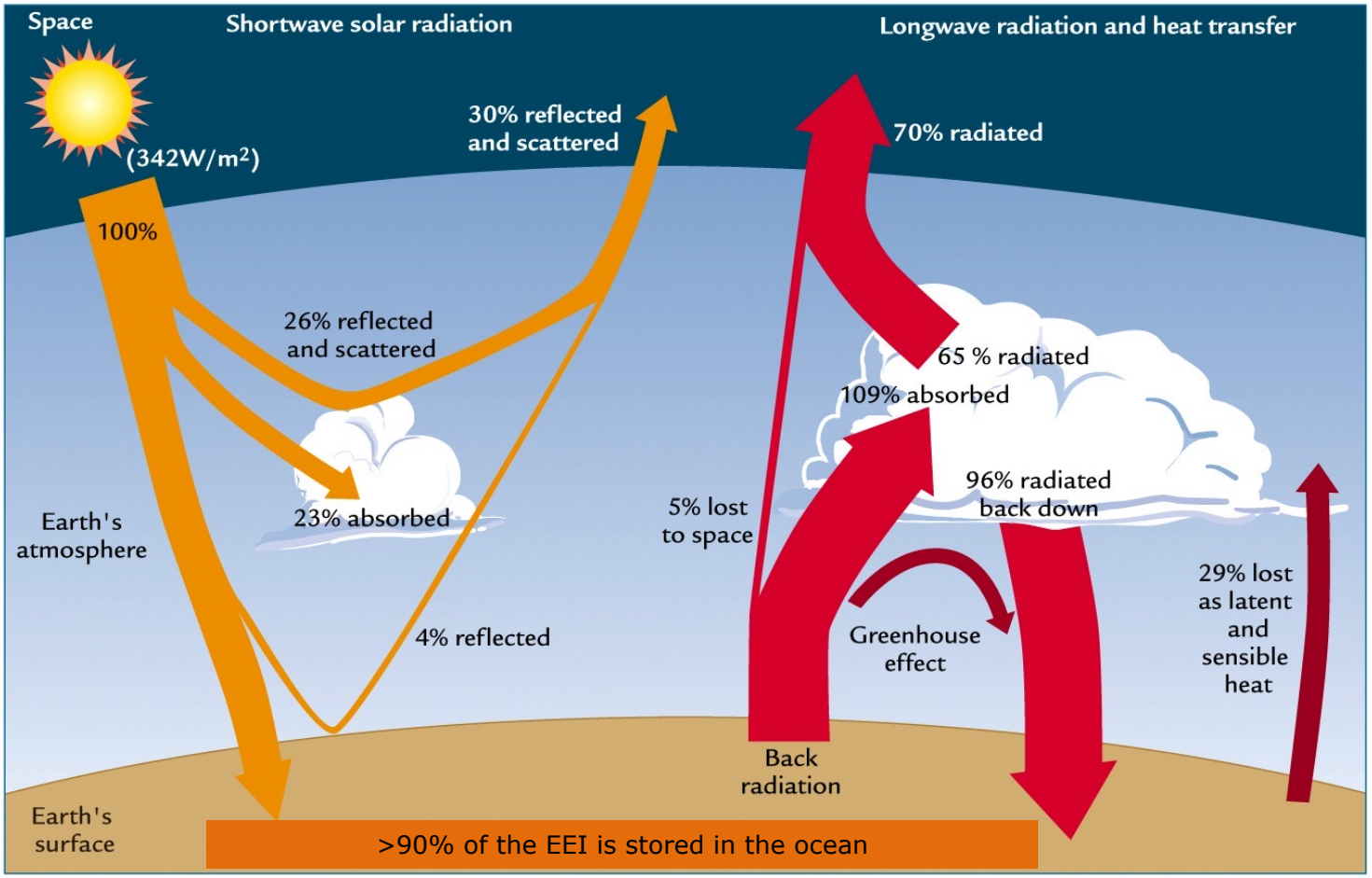


M.Boudyko and W.Sellers

$$EEI = F - R(T_s, P_{CO_2}, P_{H_2O}, A_I) \approx F - \lambda T_s$$

For Ts small.

Earth energy budget and climate change

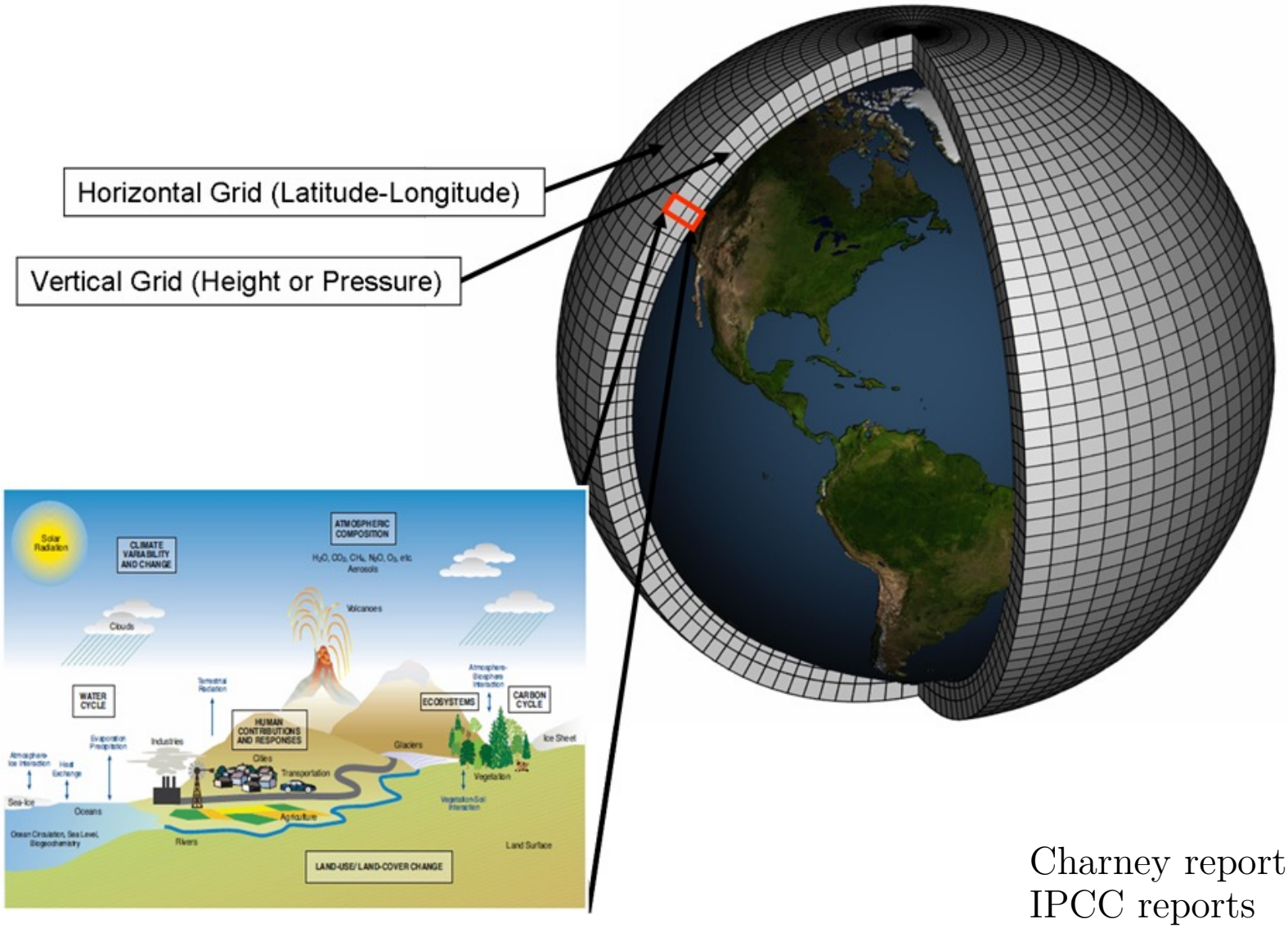


S.Manabe

$$EEI = F - R\left(T_s, P_{CO_2}, P_{H_2O}, A_I, C\right) \approx F - \lambda T_s$$

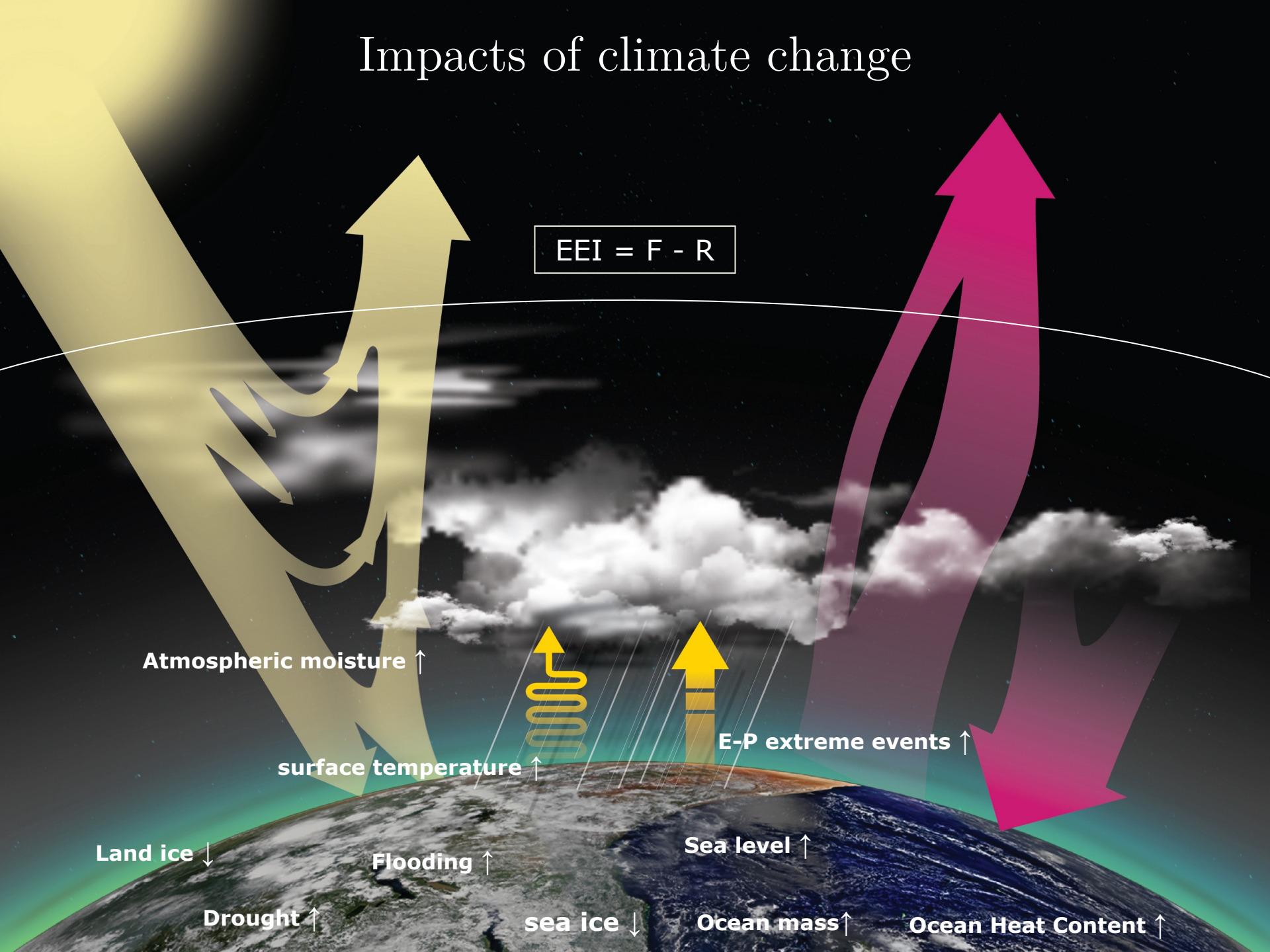
For Ts small, at global scale and under radiative-convective equilibrium

Global circulation and climate change



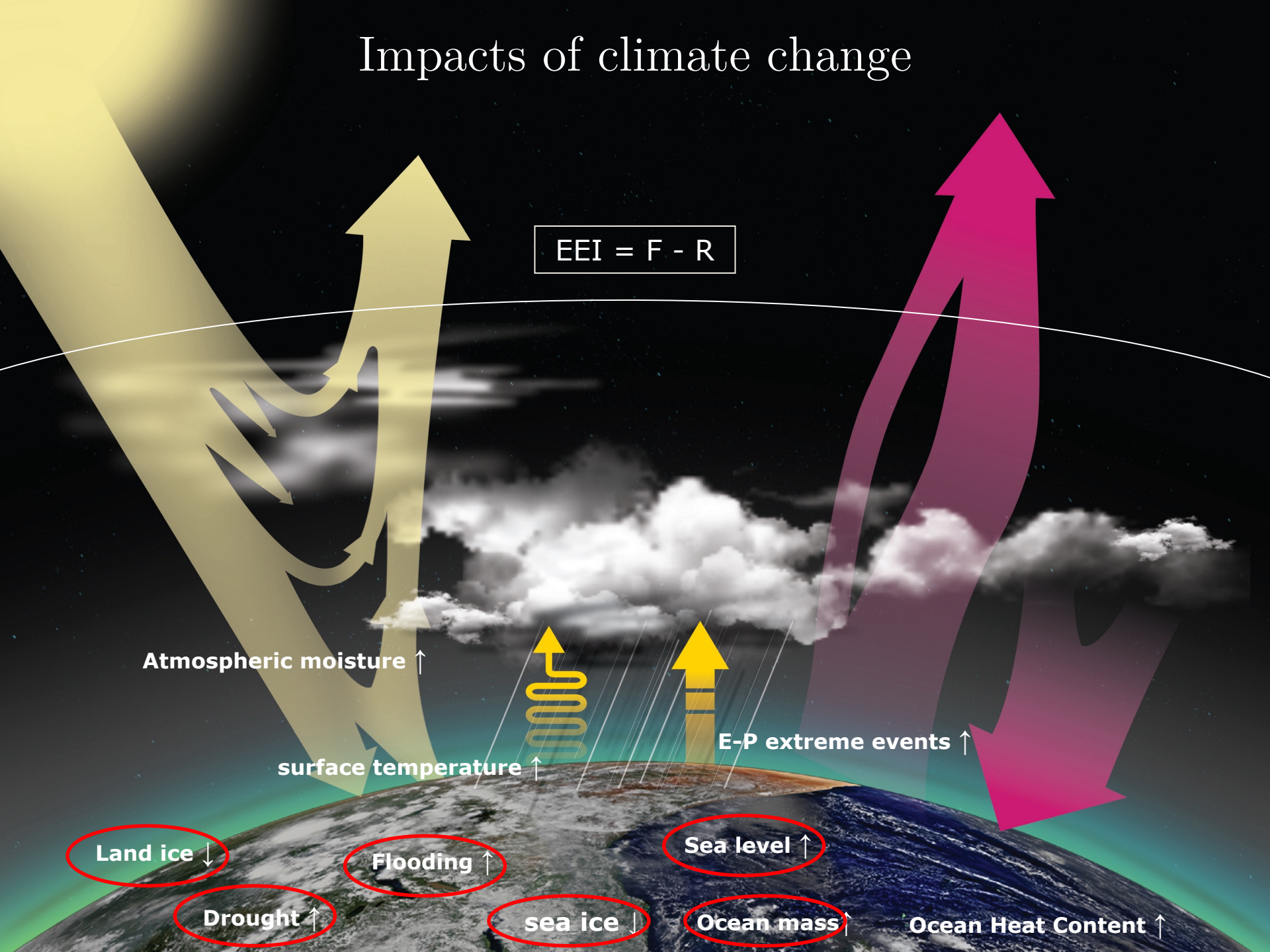
Charney report 1979
IPCC reports

Impacts of climate change



Space gravimetry and the monitoring of climate change impacts

Impacts of climate change



Maturity of the GRACE record

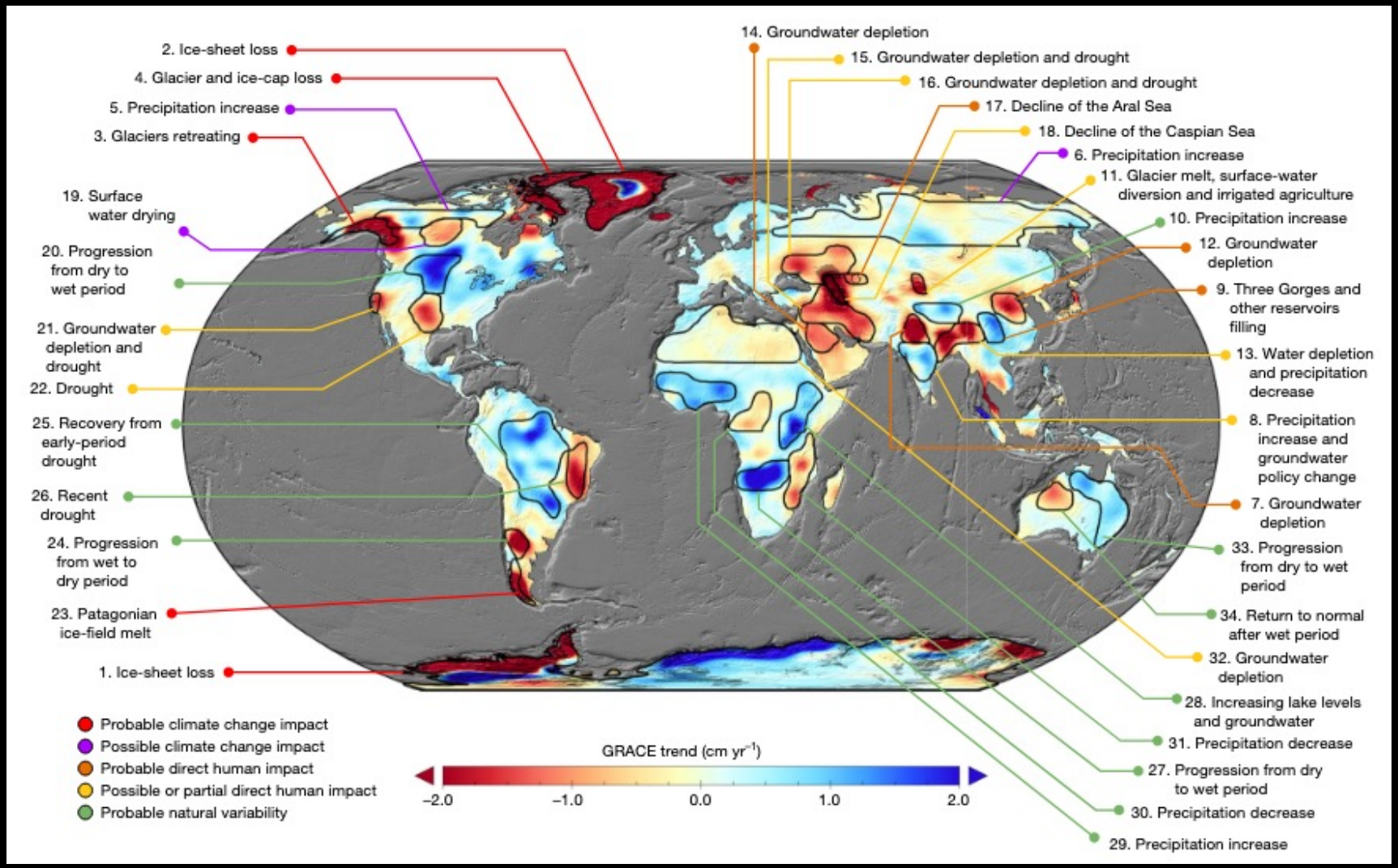
- Global coverage
- low ratio of missing data (except at the end of GRACE mission)
- Robust validation against altimetry (laser radar) and in situ measurements
- estimate of the associated uncertainty including time correlation in errors
- High stability: $<\pm 0.5$ mm.yr^{-1} of drift over 20yr

mmSLE/yr	Ocean mass	Greenland	Antarctica	Arctic islands	Glaciers & TWS
Inversion method	0.06	0.01	**0.05**	0.01	**0.06**
geocenter	**0.19**	<0.01	0.03	<0.01	**0.22**
C20	0.01	<0.01	<0.01	<0.01	0.02
filtering	0.01	<0.01	0.02	<0.01	0.01
GIA	0.03 (0.4)	0.03	0.01	<0.01	0.04
TOTAL	0.24 (0.5)	0.03	0.04	0.01	0.27

From Blazquez et al. 2018

Space Geodesy: satellite altimetry and space gravimetry

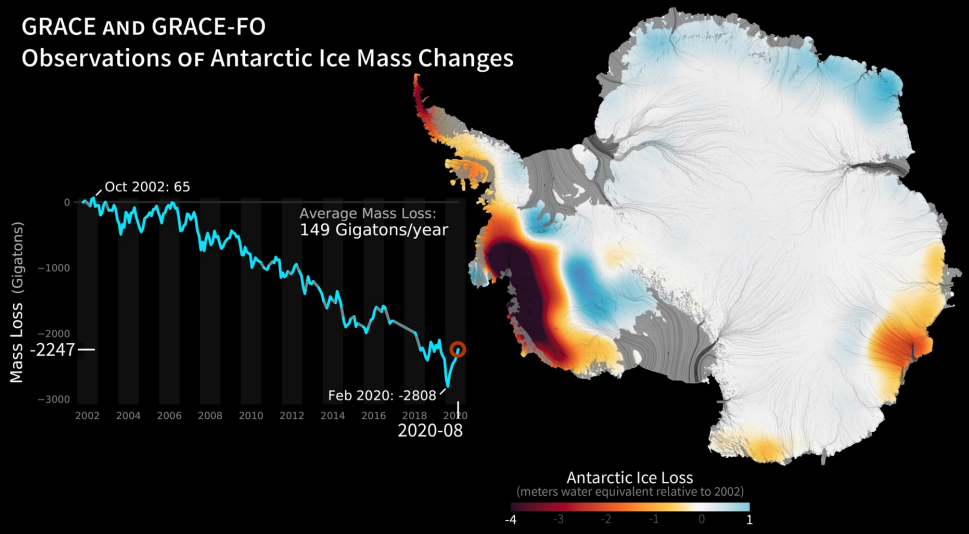
- Terrestrial water storage

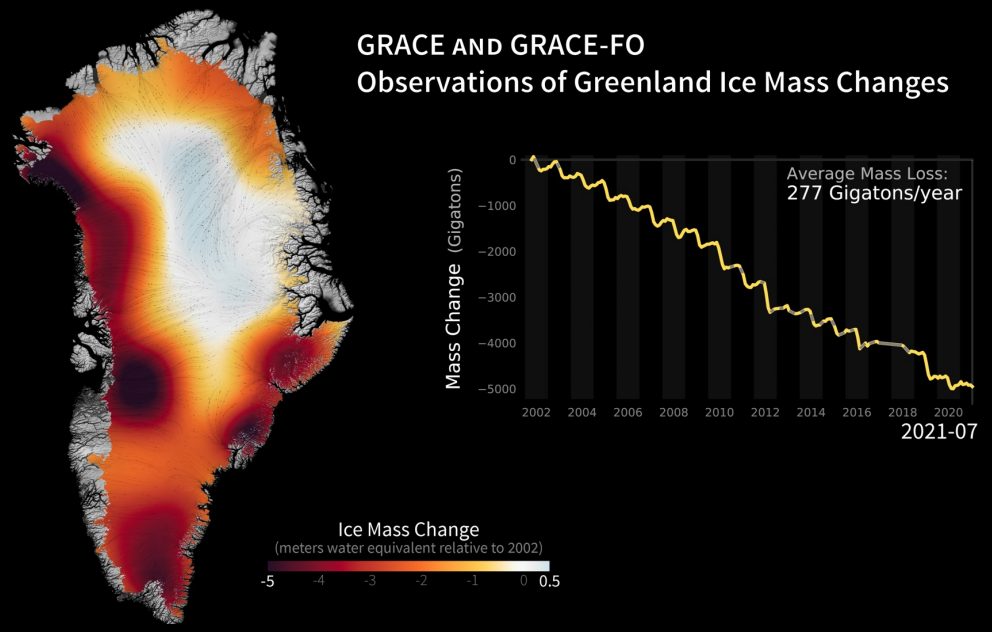


From Rodell et al., 2018

Space Geodesy: satellite altimetry and space gravimetry

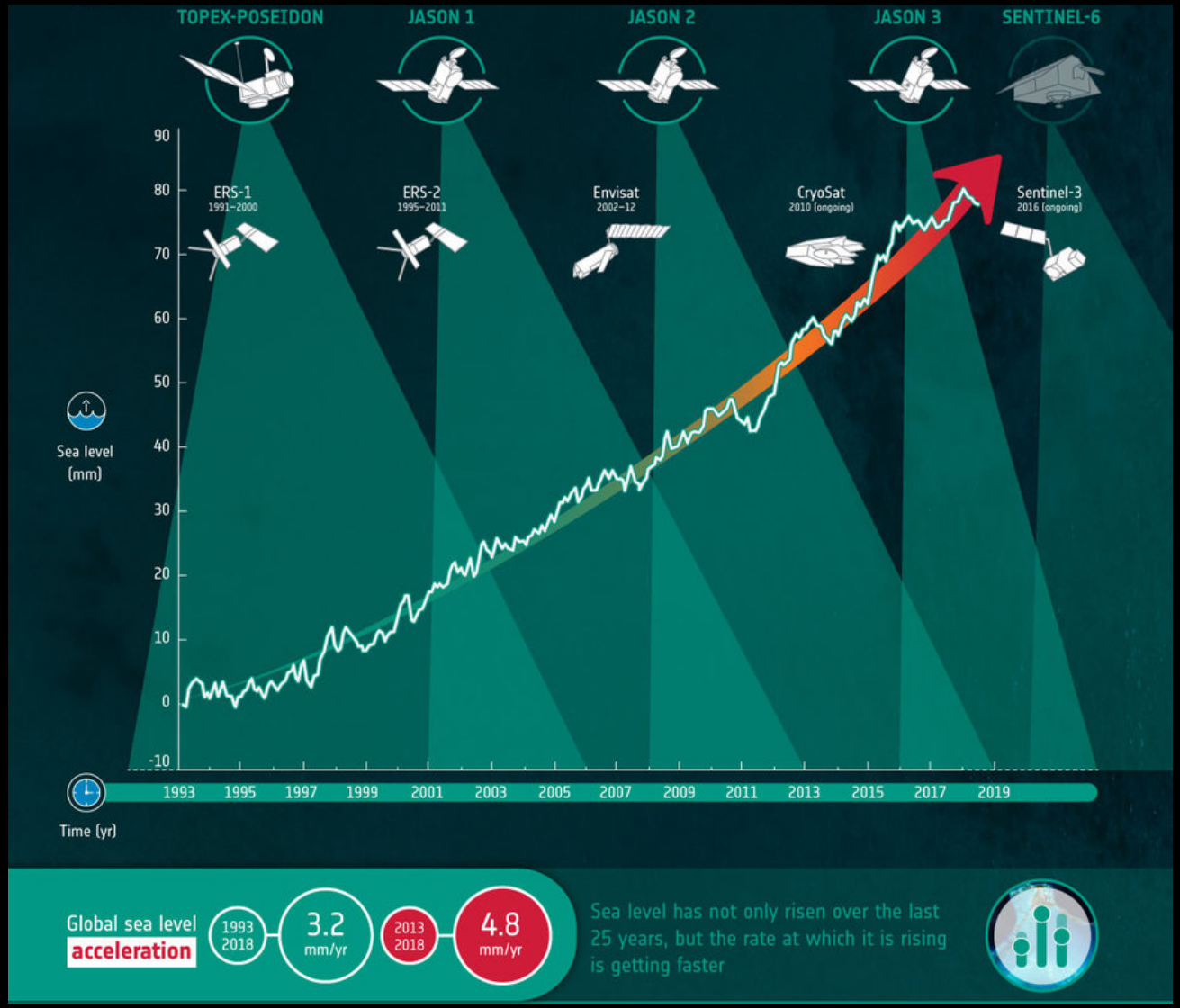
- Ice sheet mass loss and contribution to sea level rise





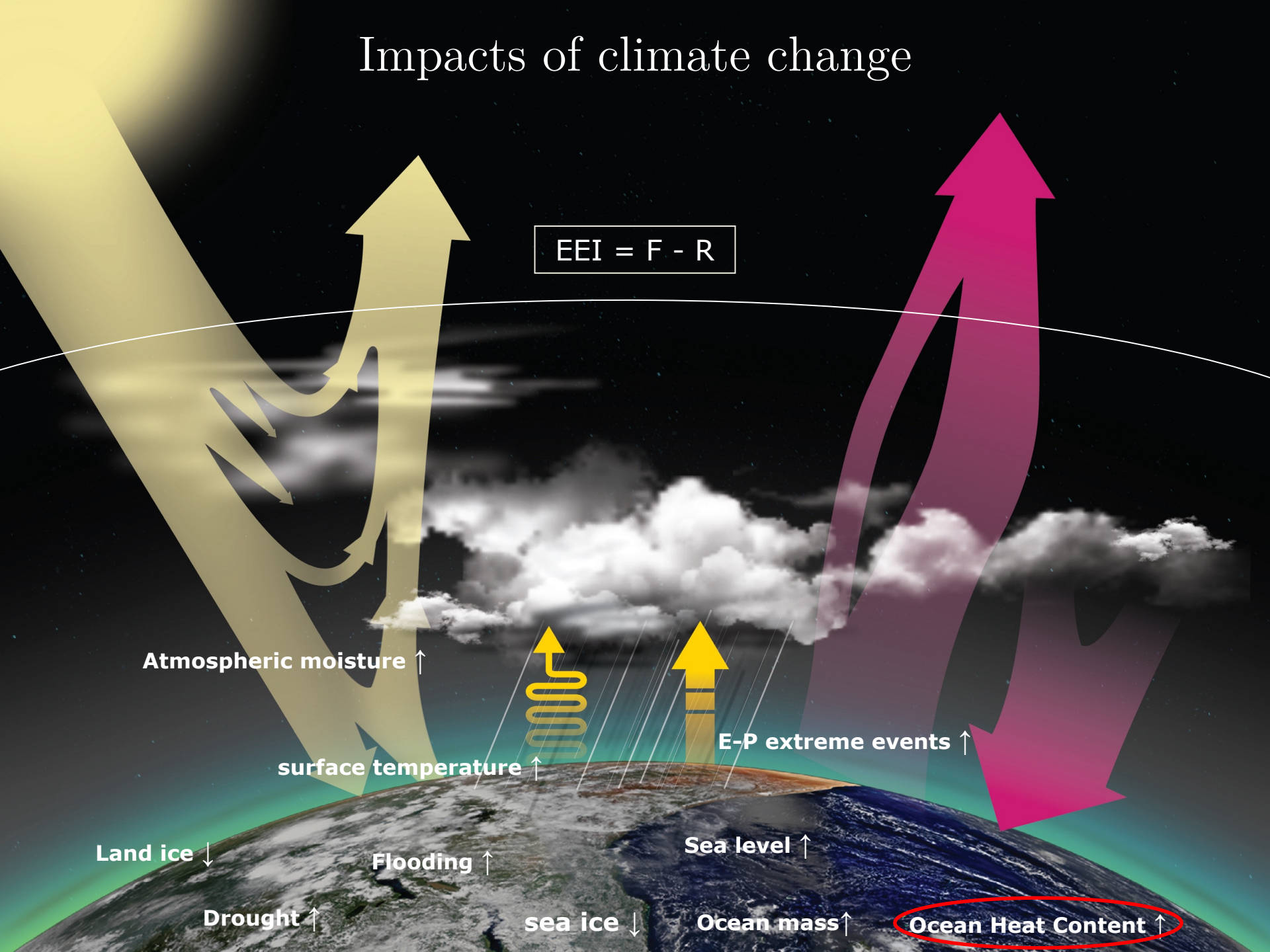
Space Geodesy: satellite altimetry and space gravimetry

- Ice sheet mass loss, glaciers mass loss and contribution to sea level rise



Space gravimetry and the monitoring of the causes for climate change

Impacts of climate change



OHC from satellite altimetry and space gravimetry

Closure of the sea level budget:

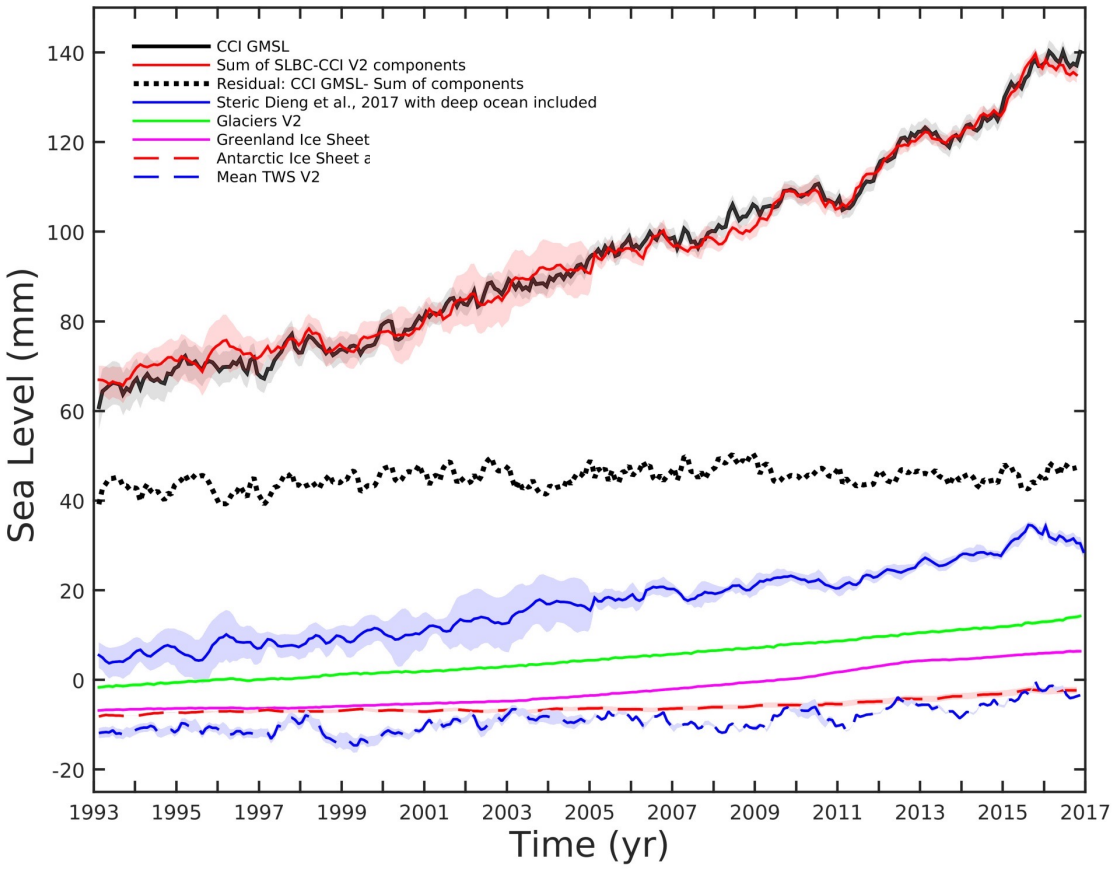
Trend uncertainty over 2005-2015 (90%CL)

Altimetry: 3.4±0.4 mm.yr^{-1}

Argo: 1.3±0.4 mm.yr^{-1}

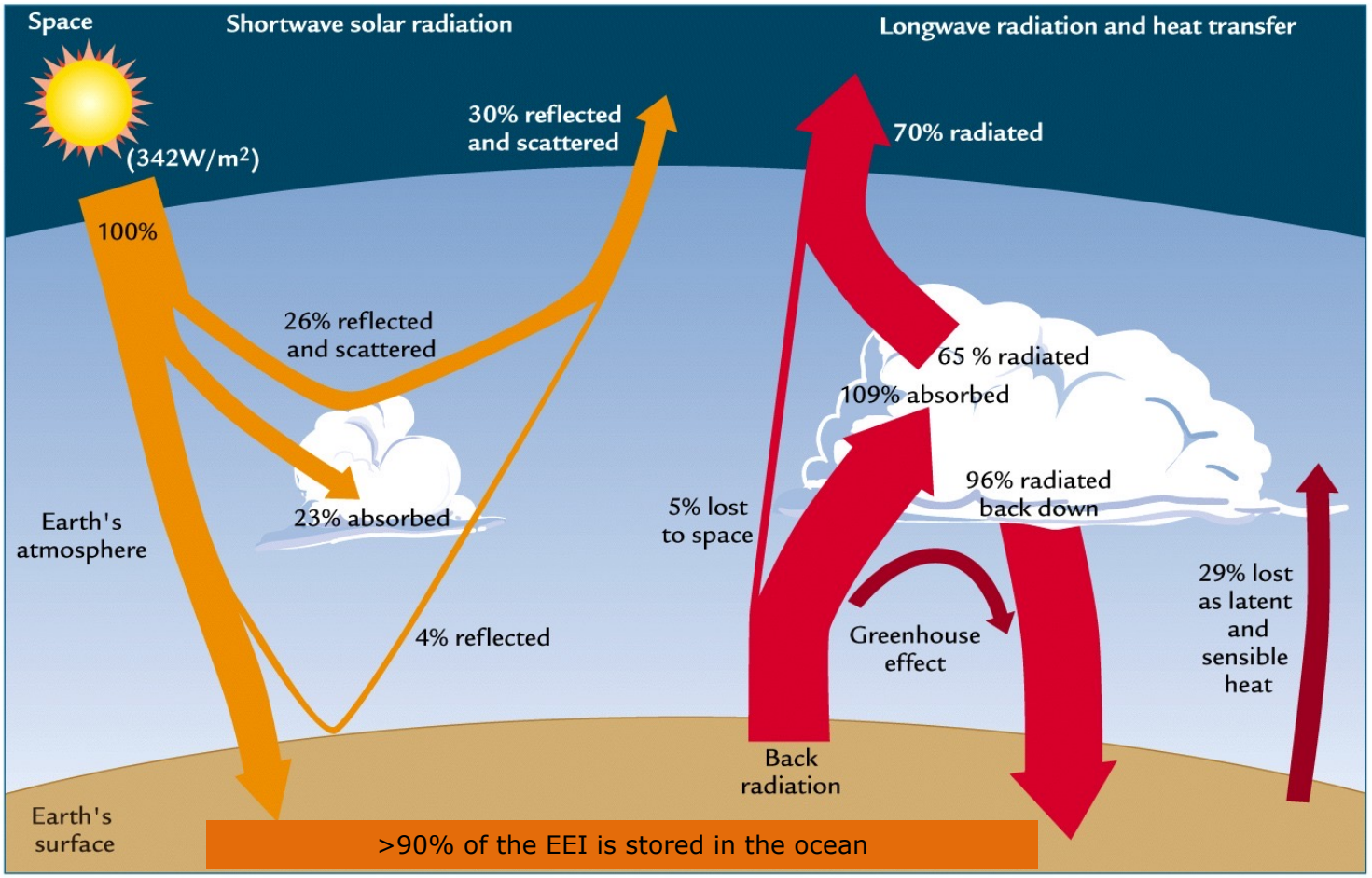
OM: 1.9±0.5 mm.yr^{-1}

Closure: 0.2±0.5 mm.yr^{-1}



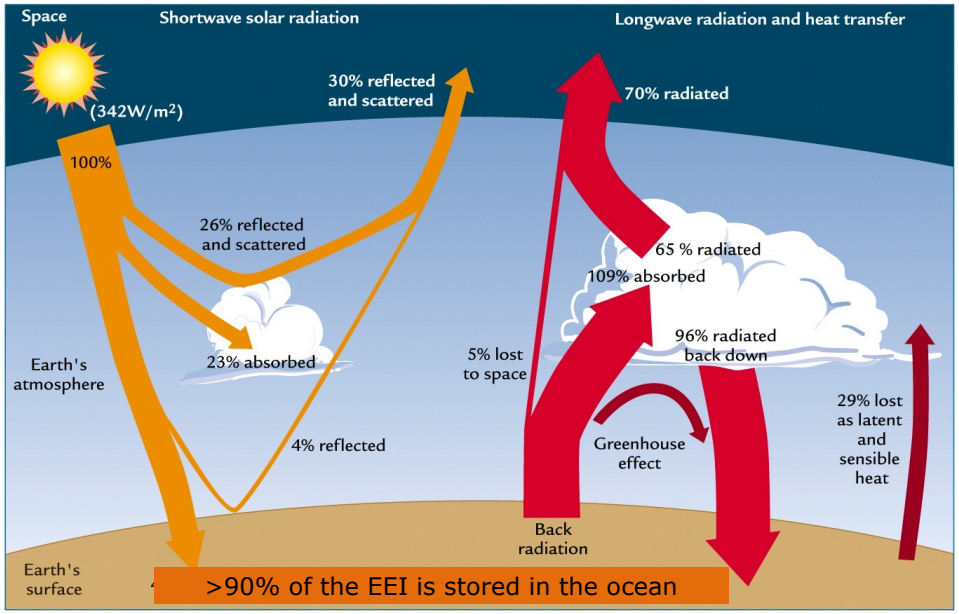
From ESA sea level budget closure project, update in 2020

Geodesy and causes for climate change?

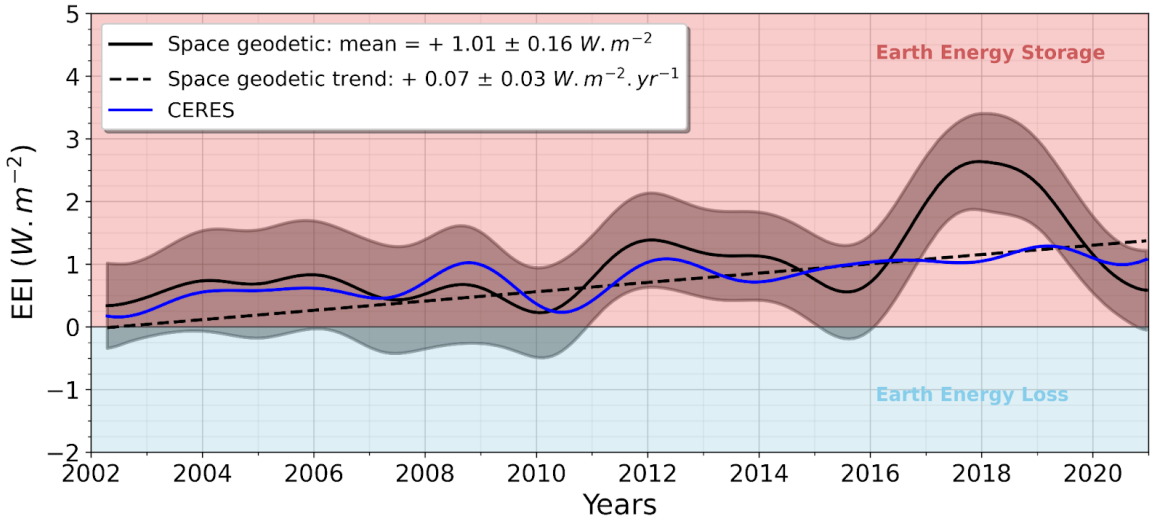


$$EEI = F - R\left(T_s, P_{CO_2}, P_{H_2O}, A_I, C\right)$$

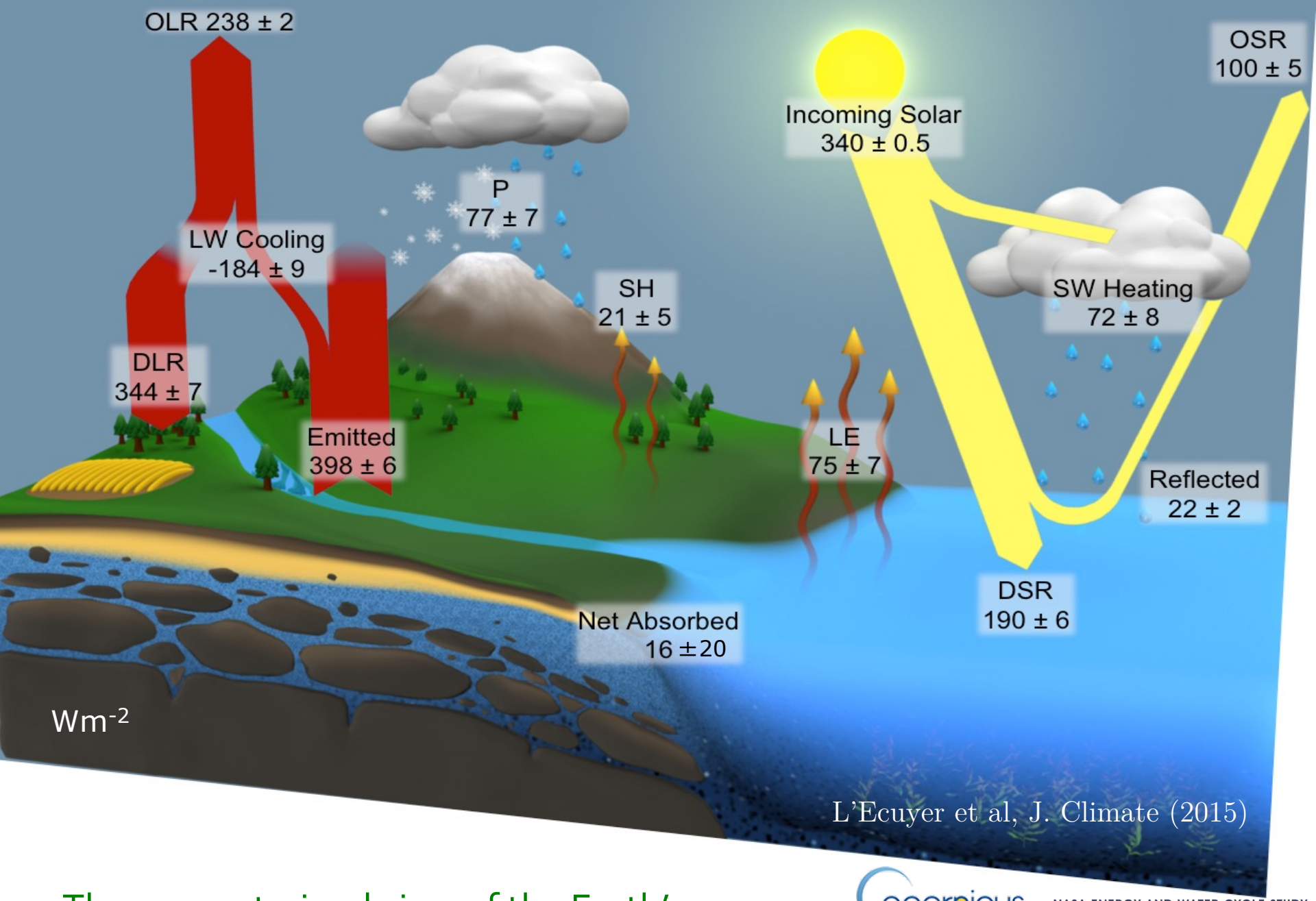
Geodesy and causes for climate change?



$$EEI = F - R\left(T_s, P_{CO_2}, P_{H_2O}, A_I, C\right)$$



Updated from Marti et al. 2021

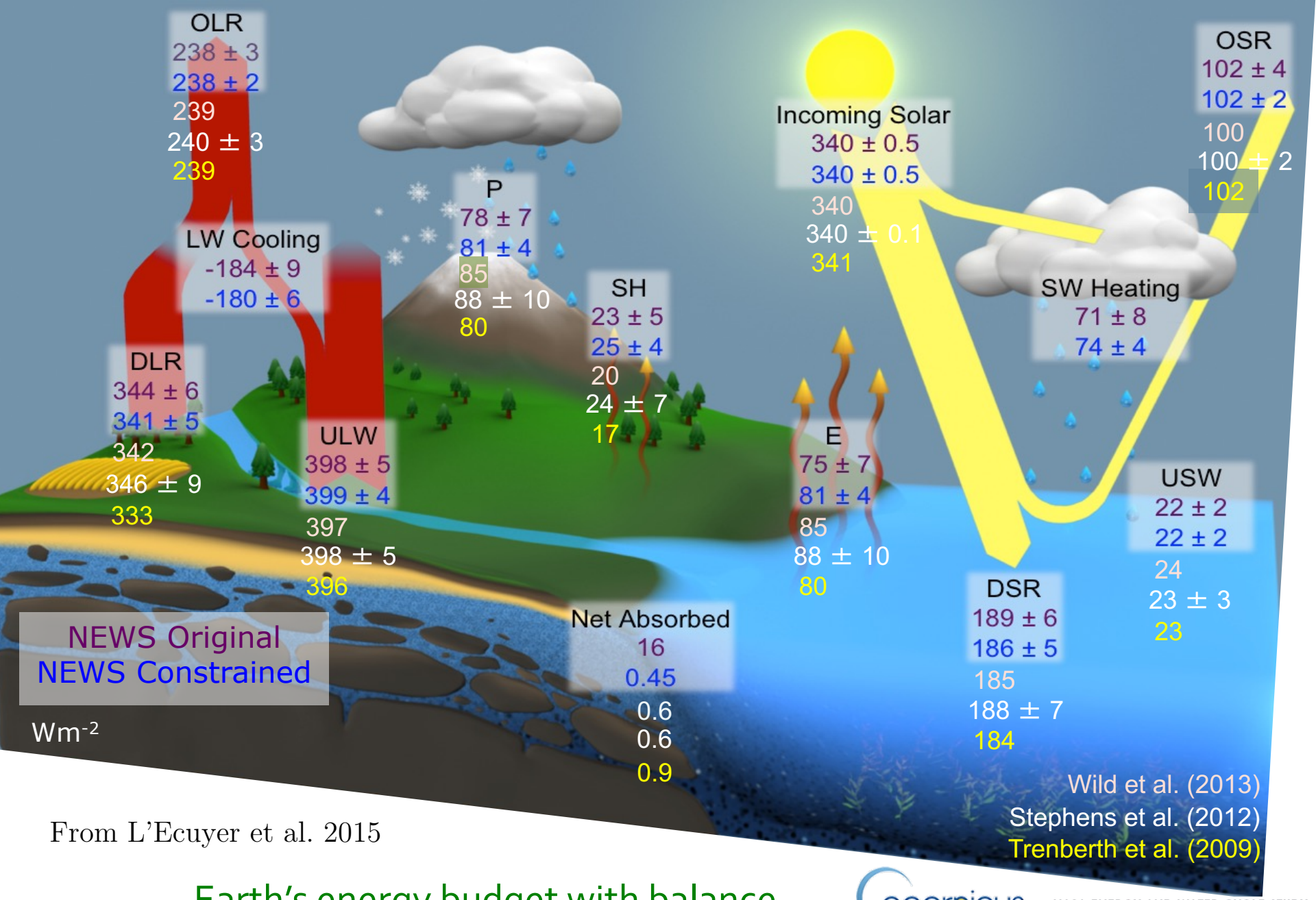


The unconstrained view of the Earth's energy budget does not balance

Copernicus Europe's eyes on Earth

Climate Change Service

NASA ENERGY AND WATER CYCLE STUDY NEWS



From L'Ecuyer et al. 2015

Earth's energy budget with balance constraints imposed.

Copernicus Europe's eyes on Earth

Climate Change Service

NASA ENERGY AND WATER CYCLE STUDY NEWS

Tentative identification of future needs

	Current situation GRACE-GRACE-FO	Near futur 2028-2040 MAGIC (goal)	Longer term >2040 (Desirable target)
	300kmx300km Monthly RMS: 3cm EWH 20yr trend: ±0.5mm/yr EWH	100kmx100km Weekly RMS: 1.5 cm EWH 10yr trend ±0.5mm/yr EWH	? ? ?
	Measuring climate change impacts		
Sea level/Ice sheet mass loss	Detect and quantify at regional scale	Detect and quantify at large basin scale	Need: Detect and quantify at basin scale down to 10km (typical length of the ablation zone)
Land water/glaciers	Detect and quantify at regional scale	Detect and quantify at regional scale	to detect and quantify at catchment scale 3km/3km
Large scale ocean transport	Detect at regional scale (AMOC)	Detect and quantify at regional scale (AMOC)	Need : Detect and quantify in key small areas e.g. Bering strait, Denmark Strait, Drake passage And close to the coast
	Measuring causes for climate change		
Earth Energy imbalance/OHC/ ocean mass	Detect and quantify at global scale	Detect and quantify at regional scale	Need: Quantify OHC in highly dynamical regions (WBC) for regional heat budget