Revisited sea level budget over 2005-2015 indicates a large Earth energy imbalance

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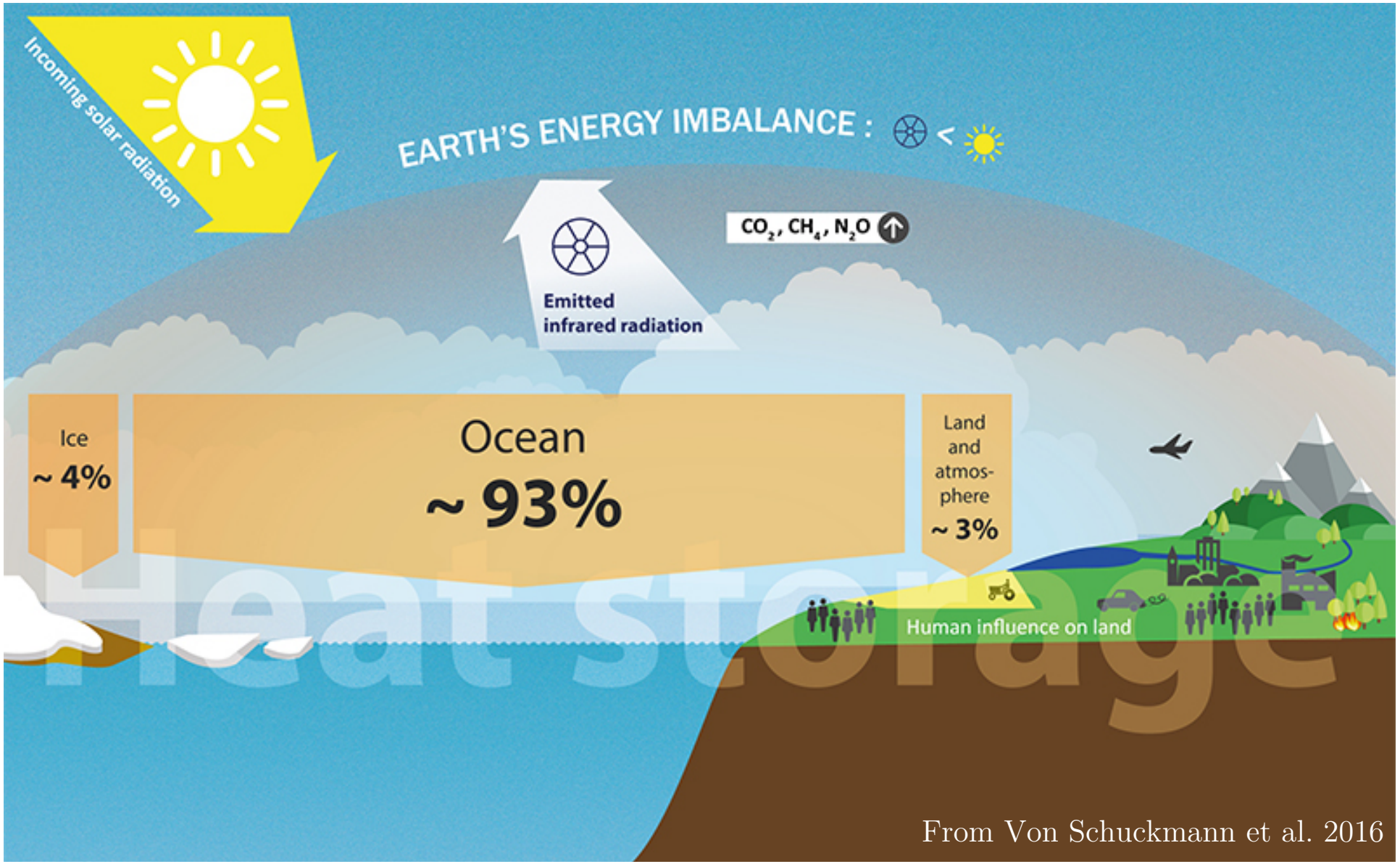
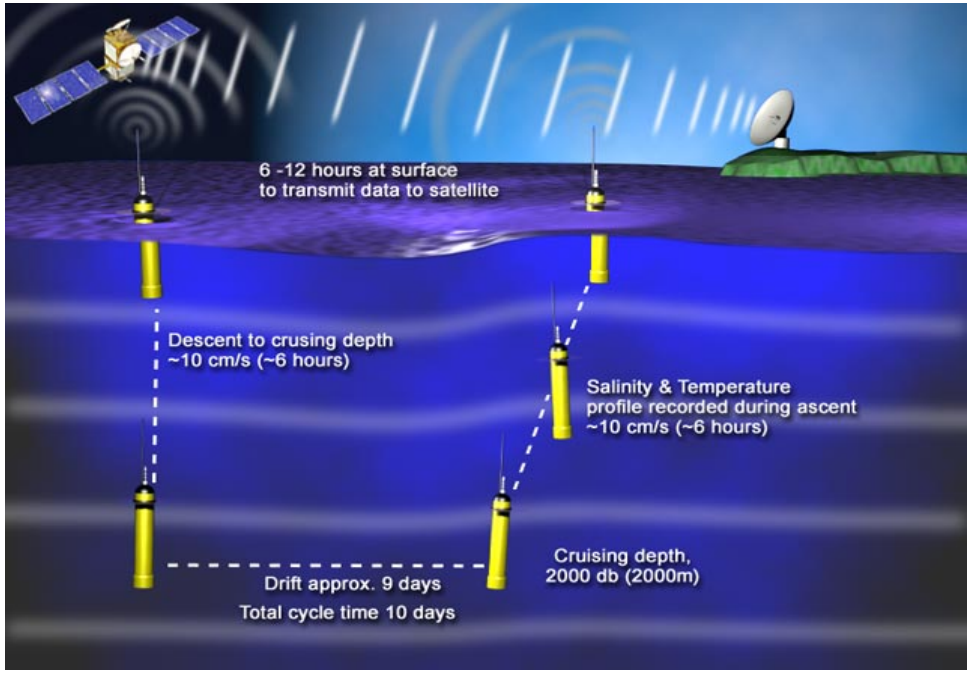
GEWEX conference, May 2018, Canmore

Energy storage in the climate system

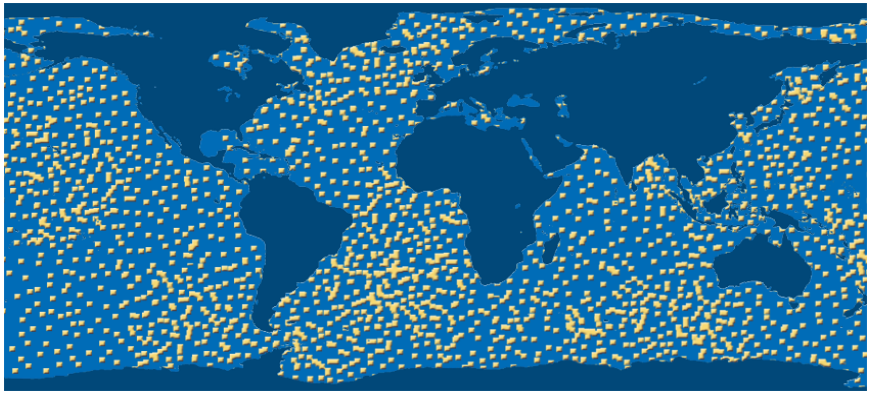


From Von Schuckmann et al. 2016

OHC estimation from Argo since the 2000s

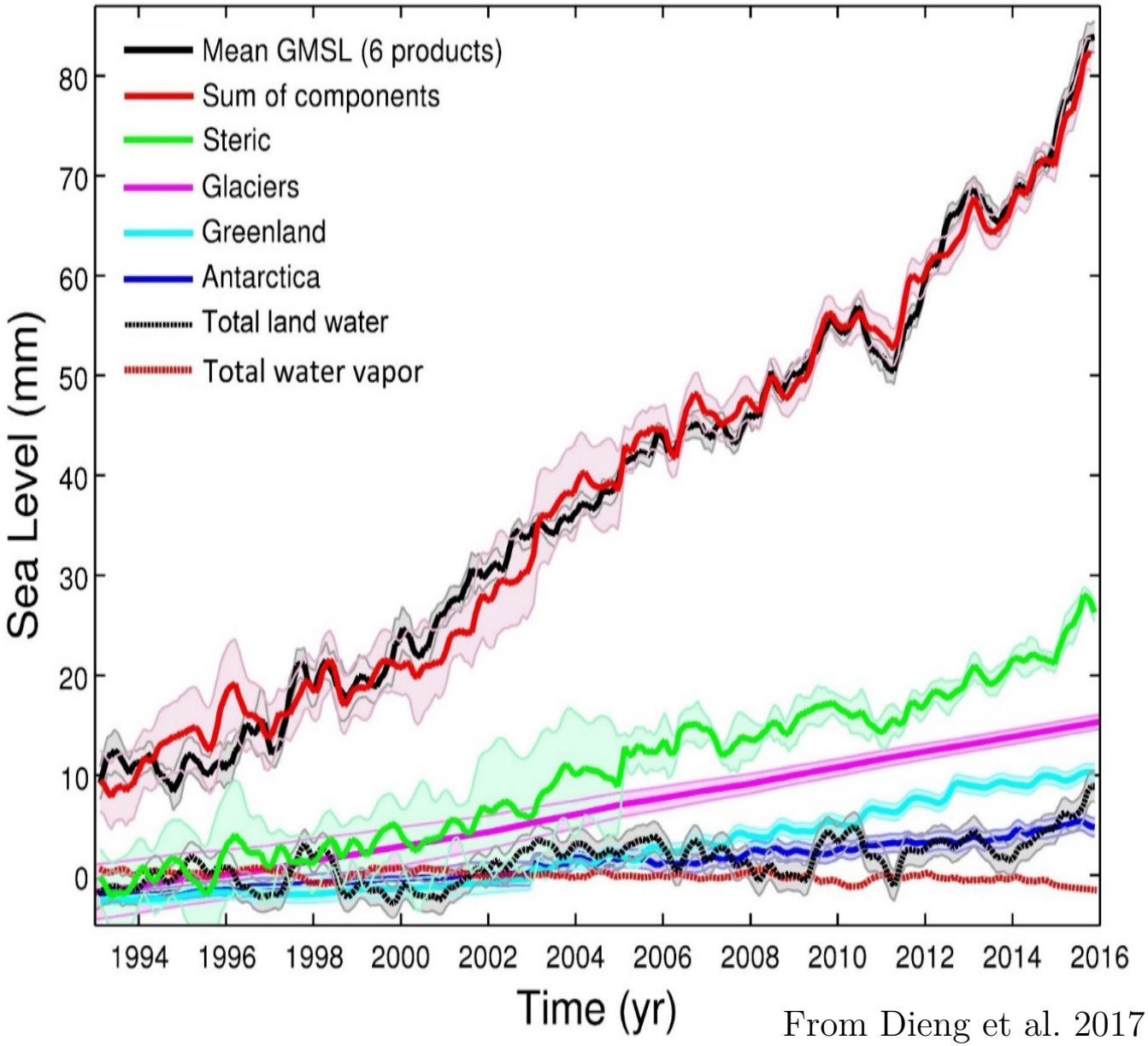


Global coverage on the 4th of May 2018



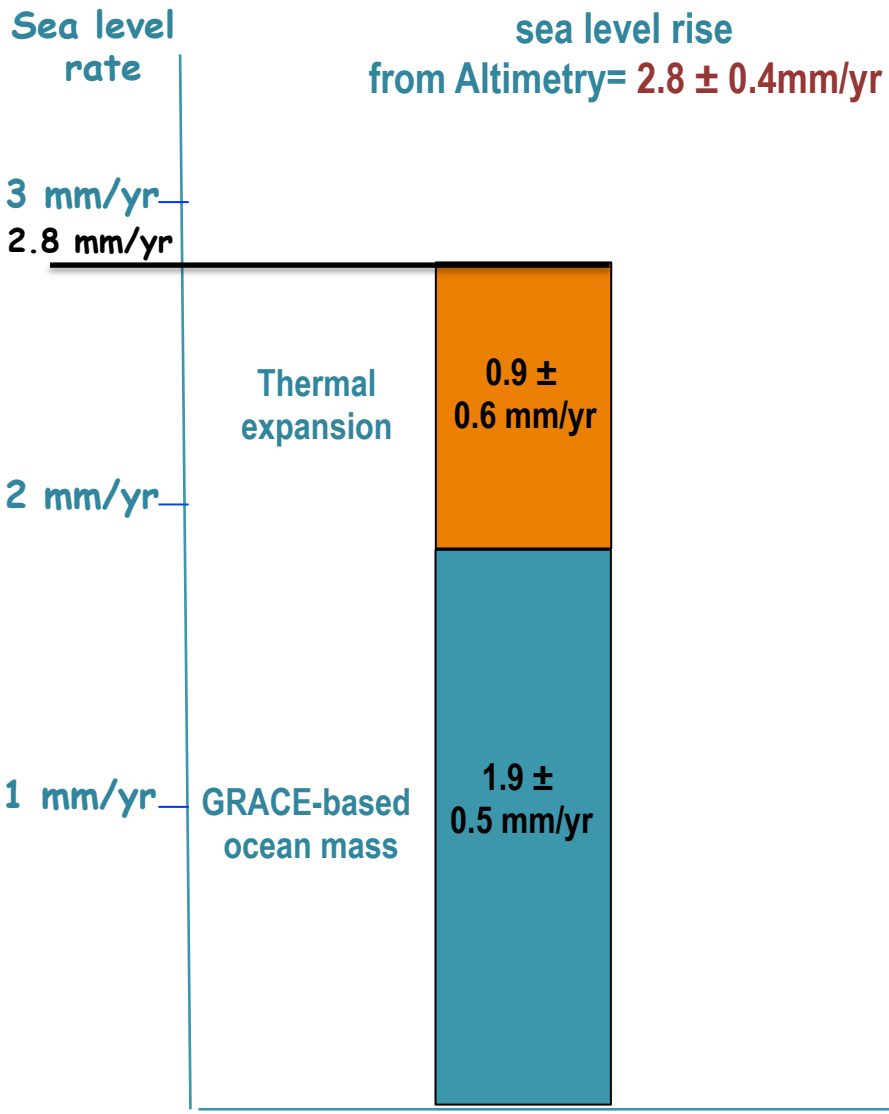
global OHC from Argo $0.6 \pm 0.5 W.m^{-2}$ ($1.65\ \sigma$, i.e. 90% CL)

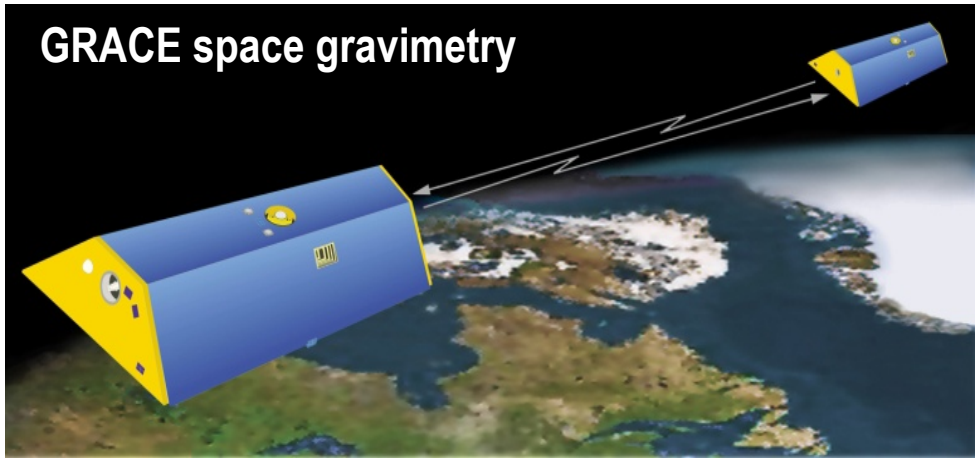
Alternative approach



From Dieng et al. 2017

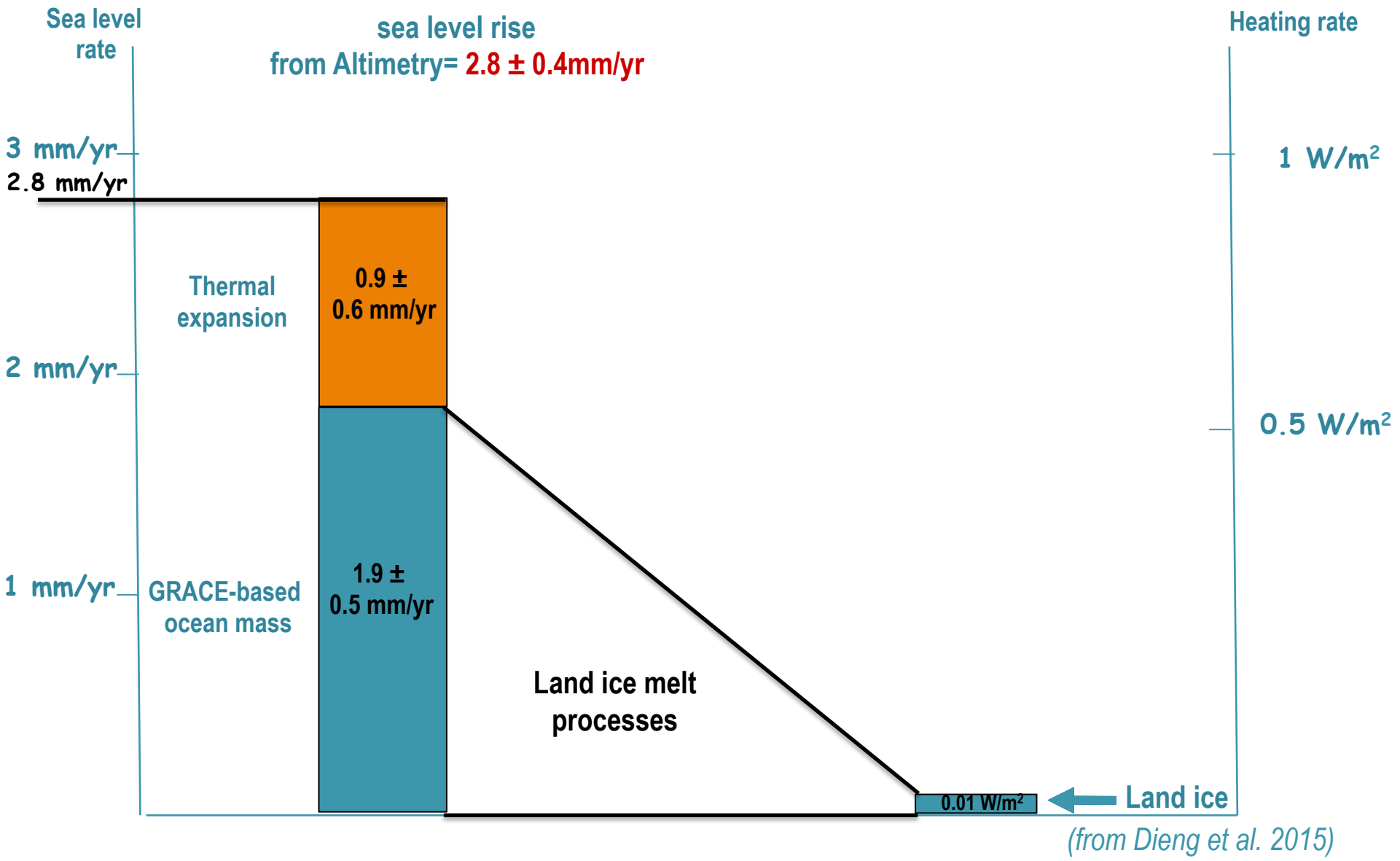
Earth Energy imbalance : 2005-2013





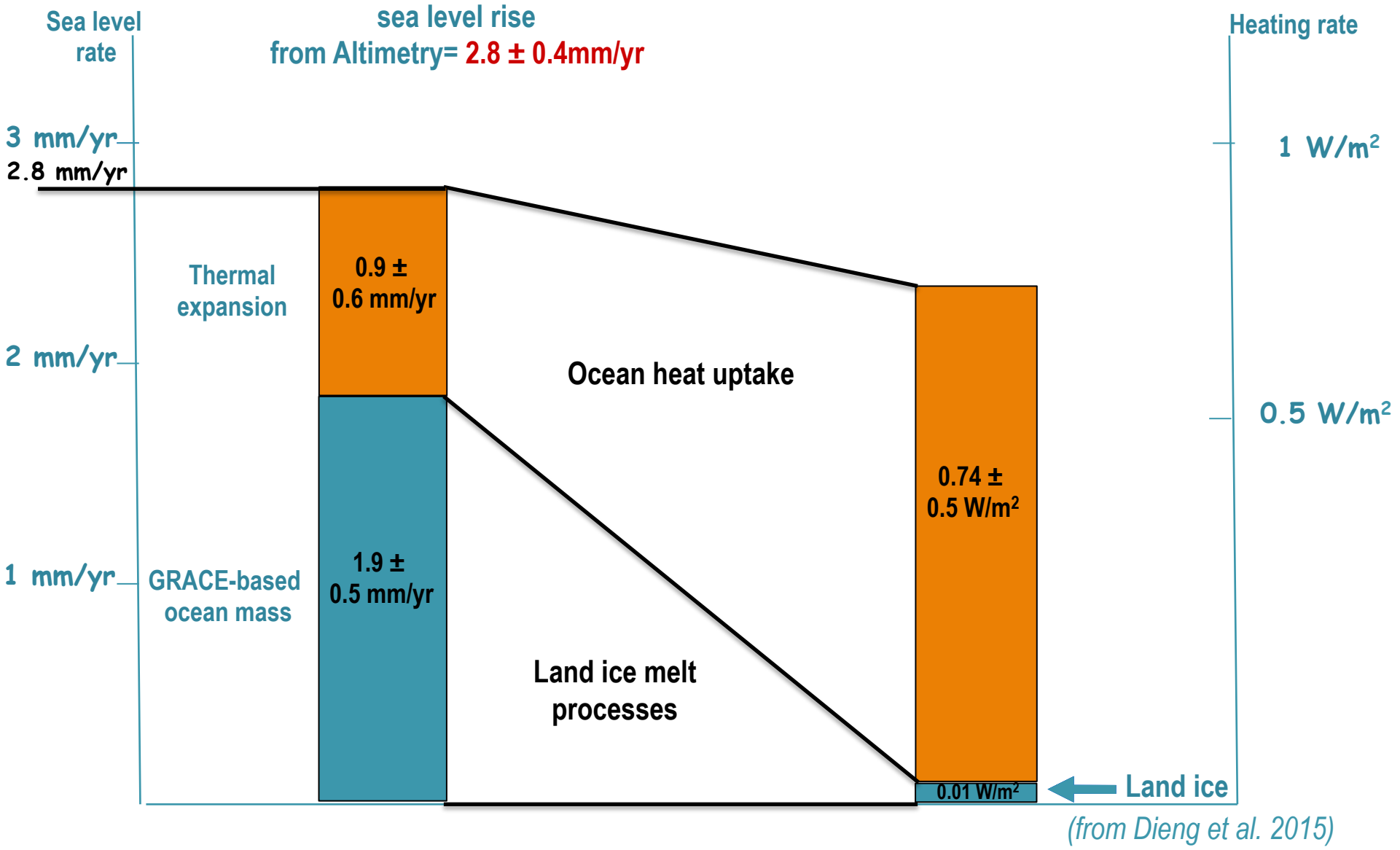
(from Dieng et al. 2015)

Earth Energy imbalance : 2005-2013



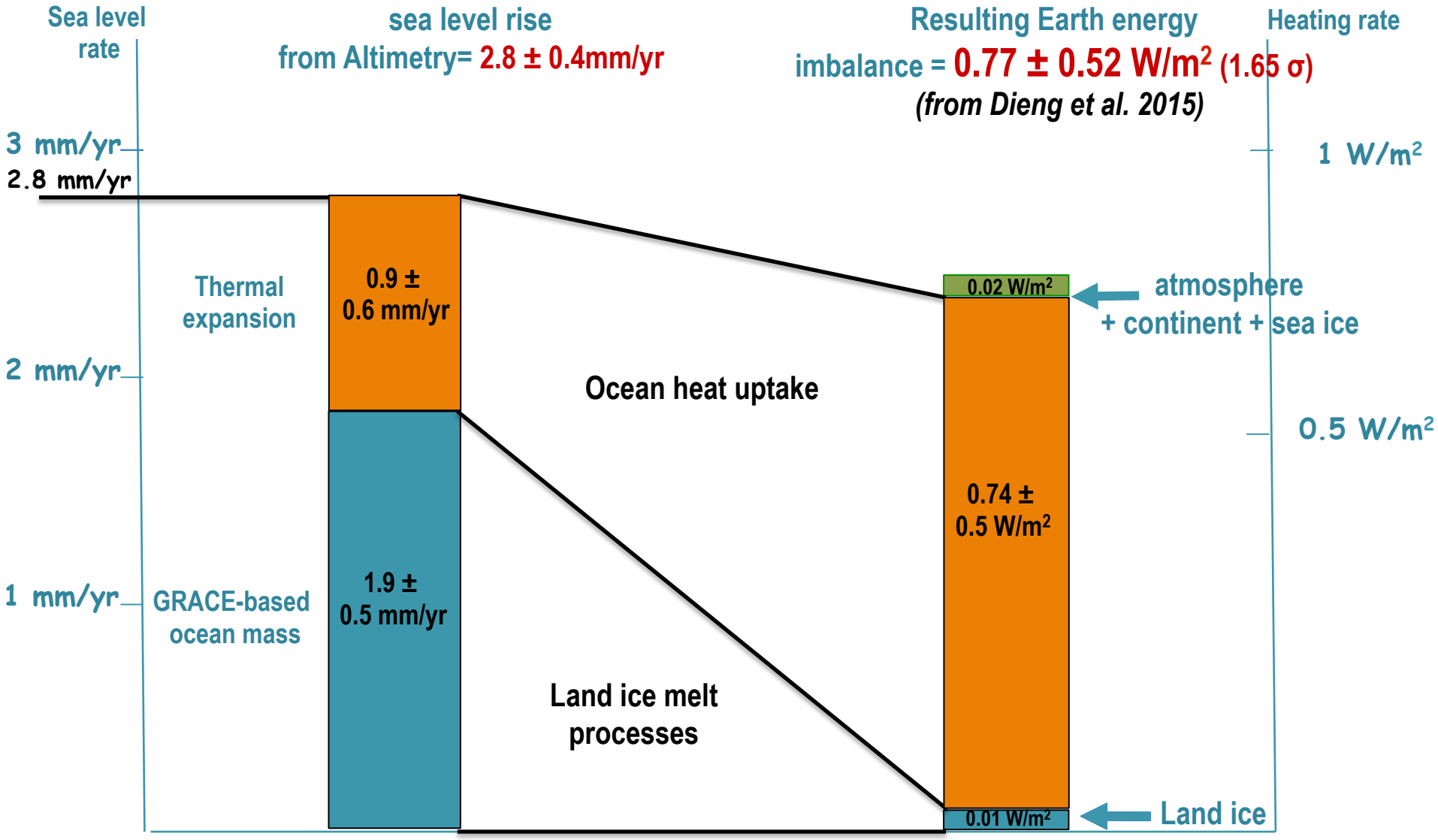
(from Dieng et al. 2015)

Earth Energy imbalance : 2005-2013

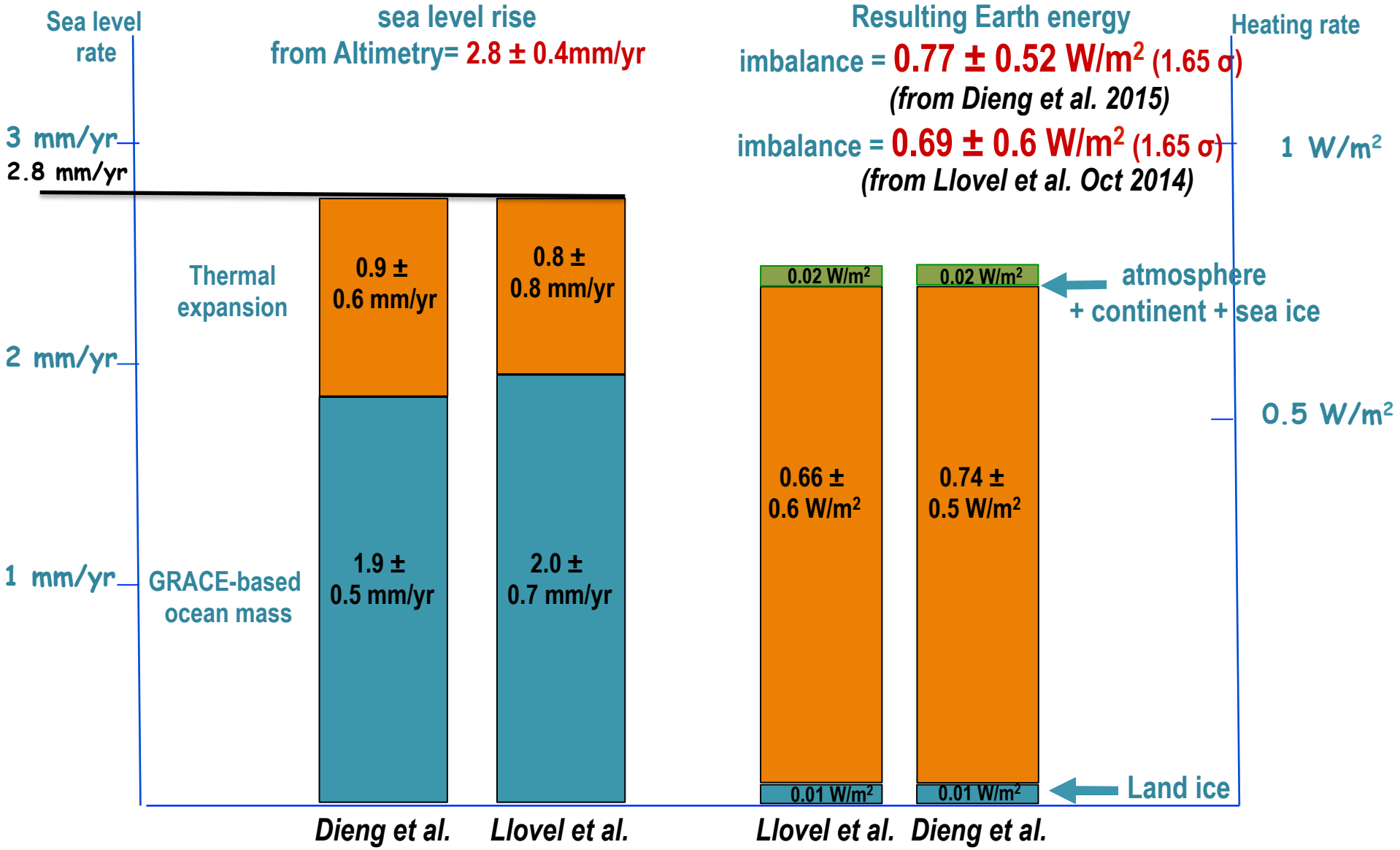


(from Dieng et al. 2015)

Earth Energy imbalance : 2005-2013



Earth Energy imbalance : 2005-2013

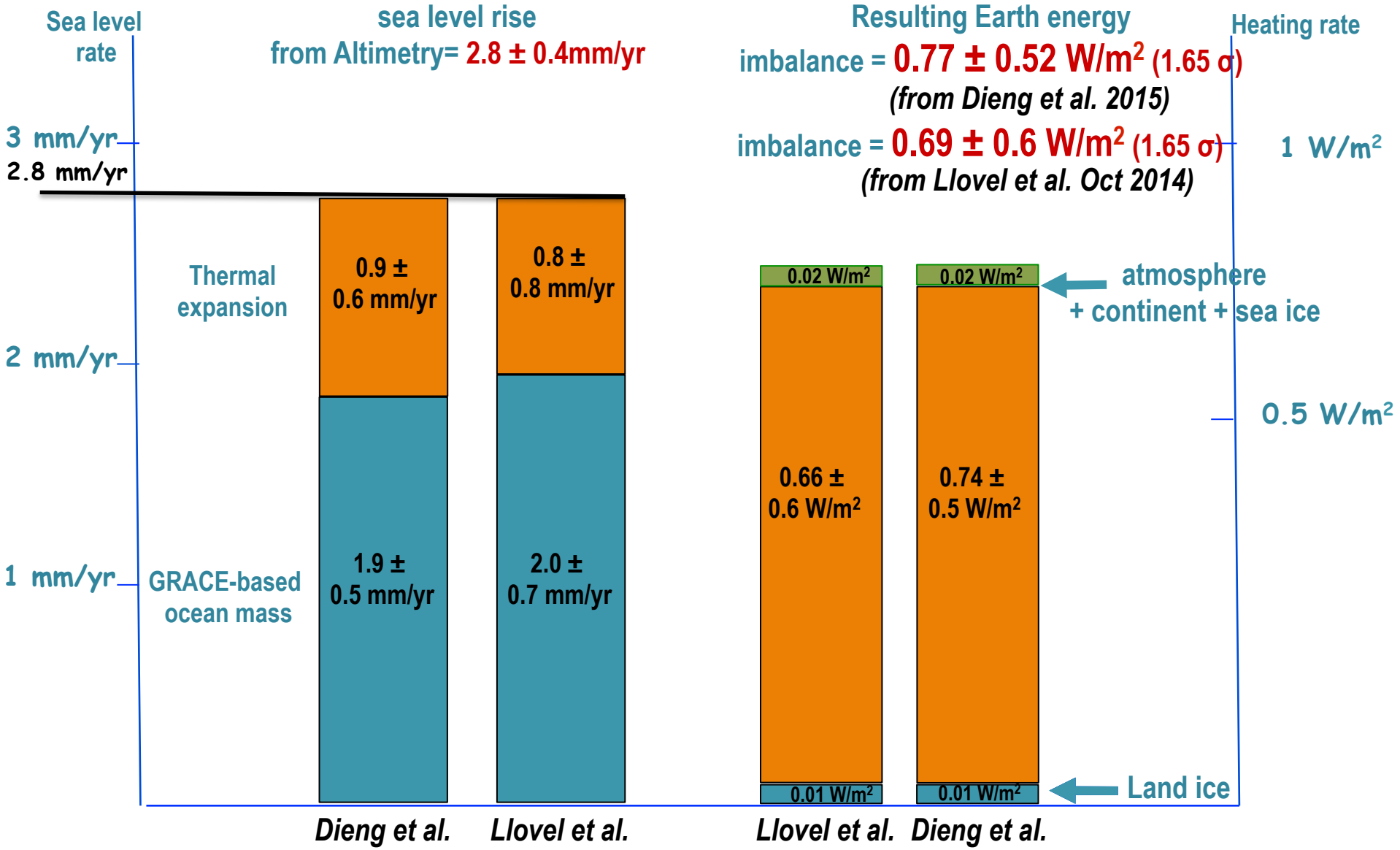


Global mean sea level trend: error budget

Source	Trend error (mm/yr)
Orbit (Beckley et al., Ablain et al.)	0.25
Wet atmos. (TMR/JMR drift) (Ablain et al.)	0.3
Dry atmos. (pressure fields) (Ablain et al.)	0.1
Sea state bias (Ablain et al.)	0.1
Quadratic sum	0.41
Tide gauge calibration (Micthum and Nerem; Beckley et al.; Ablain et al.)	0.4

Updated from Ablain et al. 2015

Earth Energy imbalance : 2005-2013

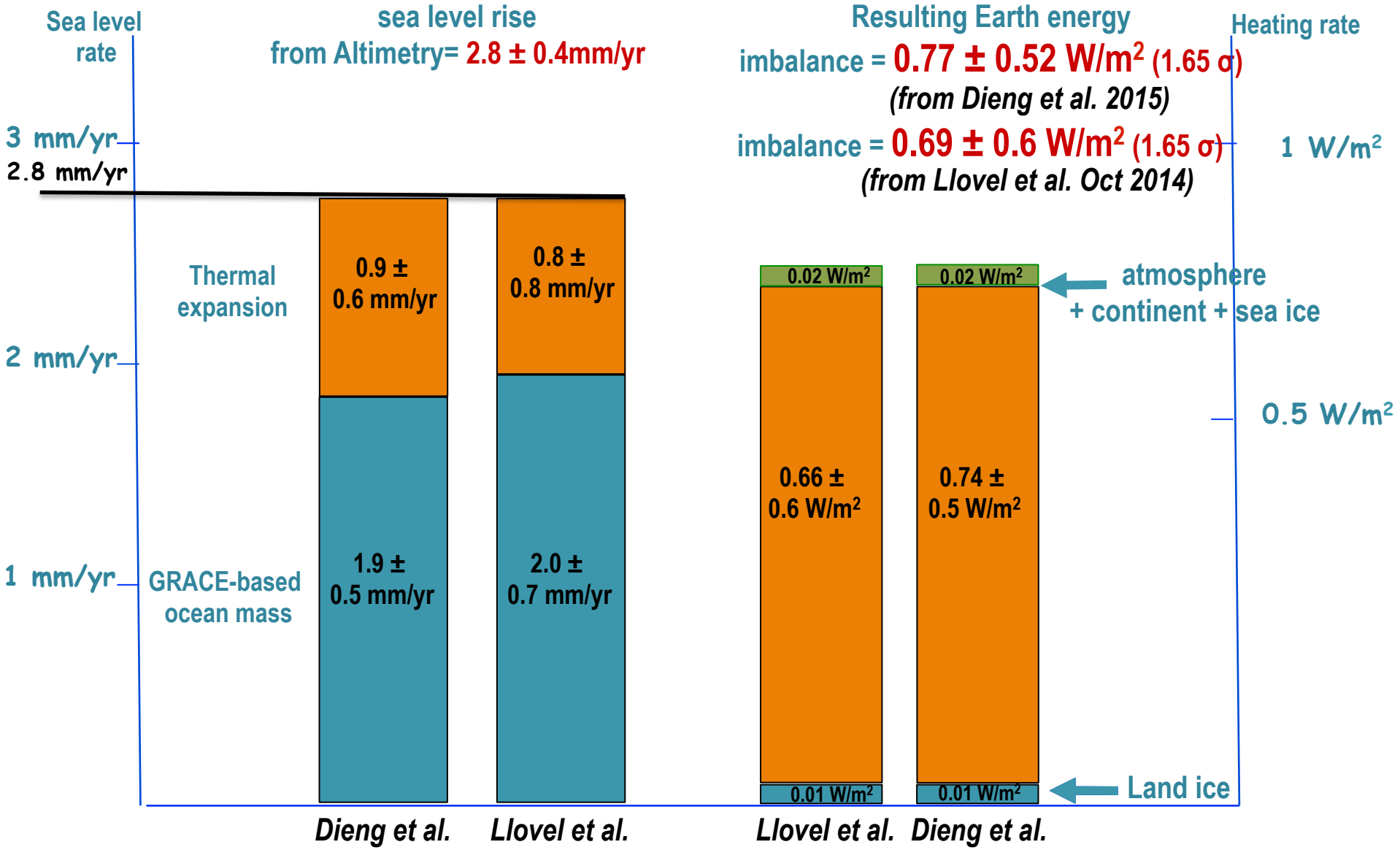


Uncertainty in Ocean mass changes from GRACE

(mmSLE/yr)	GOM	Greenland	Antarctica	Arctic islands	Glacier &TWS
Processing center	0.08	0.02	0.04	0.02	0.08
Geocenter motion	**0.55**	0.05	**0.17**	0.04	**0.63**
$C_{2,0}$	0.03	0.01	0.02	0.01	0.01
Filtering	0.02	0.01	0.01	0.02	<0.01
Leakage correction	0.03	<0.01	<0.01	<0.01	0.03
GIA	**0.23**	0.01	**0.13**	0.03	**0.12**
Total Uncertainty	0.52	0.06	0.18	0.06	0.56
RMS Uncertainties	0.60	0.06	0.22	0.06	0.64
Interaction	0.08	<0.01	0.03	<0.01	0.08

From Blazquez et al. in revision

Earth Energy imbalance : 2005-2013



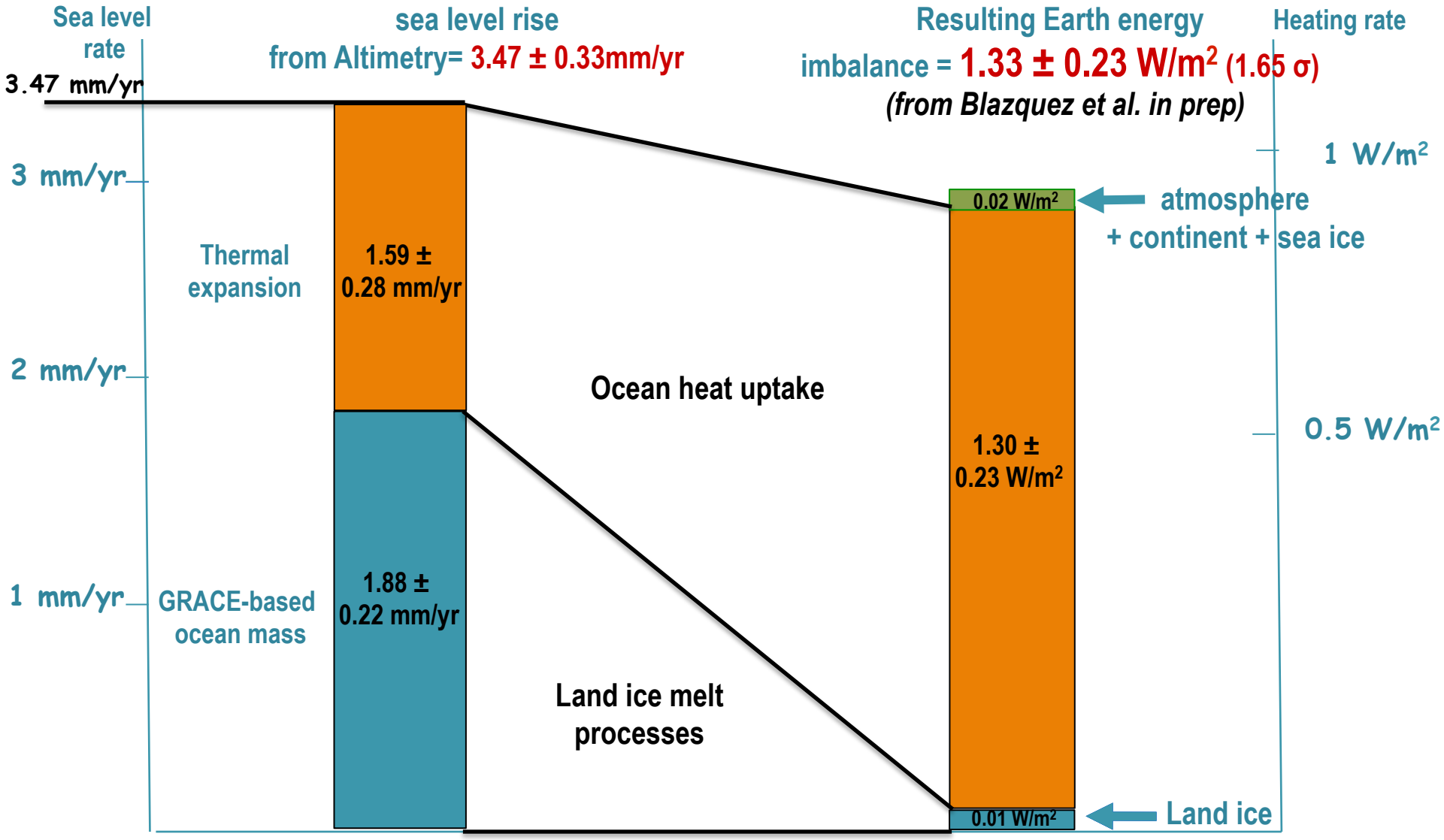
Revisit of the sea level budget

1. New period: 2005-2015

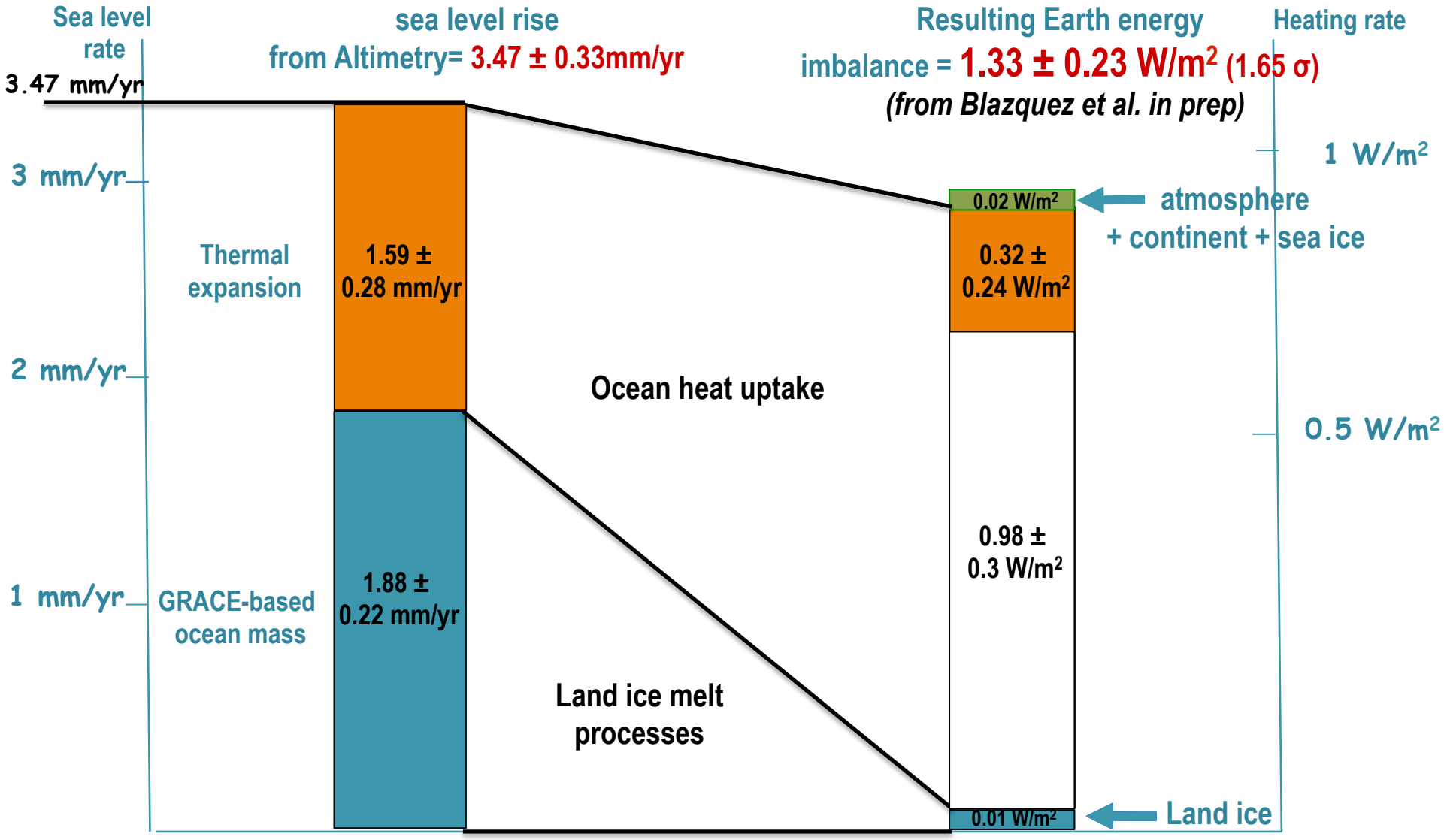
2. Improved orbit, improved wet-tropo corrections and improved intersatellite calibration allow to decrease the uncertainty in the global sea level trend from satellite altimetry

3. Sea level budget closure assessed in the center of mass of the Earth (as close as possible).

Revisited sea level budget (centre of mass) and Earth Energy imbalance : 2005-2015



Revisited sea level budget (centre of mass) and Earth Energy imbalance : 2005-2015



Conclusions

1. Sea level (from satellite altimetry) minus ocean mass (from space gravimetry) is a satellite alternative to Argo for the OHC estimation

2. The revisited sea level budget in the center of mass of the Earth suggest that past OHC estimates (0.73 ± 0.6 W.m^{-2}) are biased low. Our current best estimate over 2005-2015 is 1.3 ± 0.23 W.m^{-2}

3. Comparison with Argo down to 2000 m depth suggests that this EEI is consistent with a significant deep ocean warming of 0.3 ± 0.24 W.m^{-2} (below 2000m)

4. The residual error bar is essentially due to the wet tropo correction in altimetry and GIA correction in GRACE. The error bar in Altimetry is backed up by TG records (high confidence). No external validation for GRACE error bars (medium confidence)

Caution Note : when reporting errors from other studies it is important to translate them to the same level of confidence

Perspectives

1. The salt budget in the ocean can give a new constraint on the ocean mass estimate and help in validating the error budget in GRACE

2. Improvement of the wet tropospheric correction in altimetry should allow to further reduce the error bars (down to 0.2 $W.m^{-2}$?)

3. Regional estimates from satellites will allow to determine where the heat goes in the ocean (horizontally): important for interannual to decadal climate variability (like the hiatus)

Earth Energy imbalance : 2005-2013