Michael Hantel[1)] and Leopold Haimberger[1)]

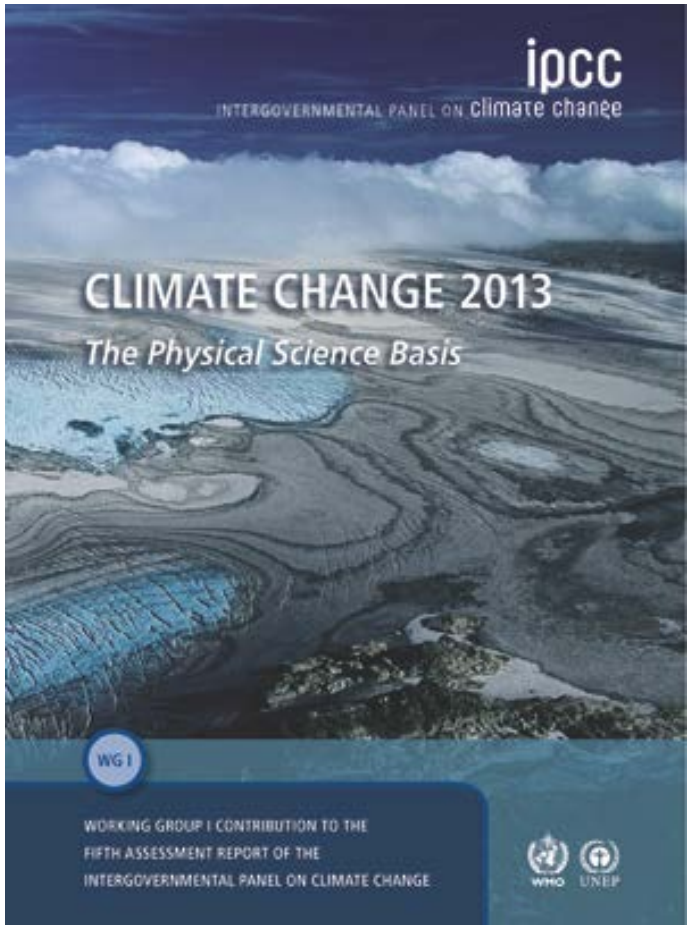
Carbon in the climate system[2)]

[1)]ÖAW & University of Vienna (IMGW)
[2)]Presentation, given at *Commission for Interdisciplinary Ecological Studies* (ÖAW), 21 Nov. 2016

Demonstrate the CO2-Problem with an animation on YouTube:

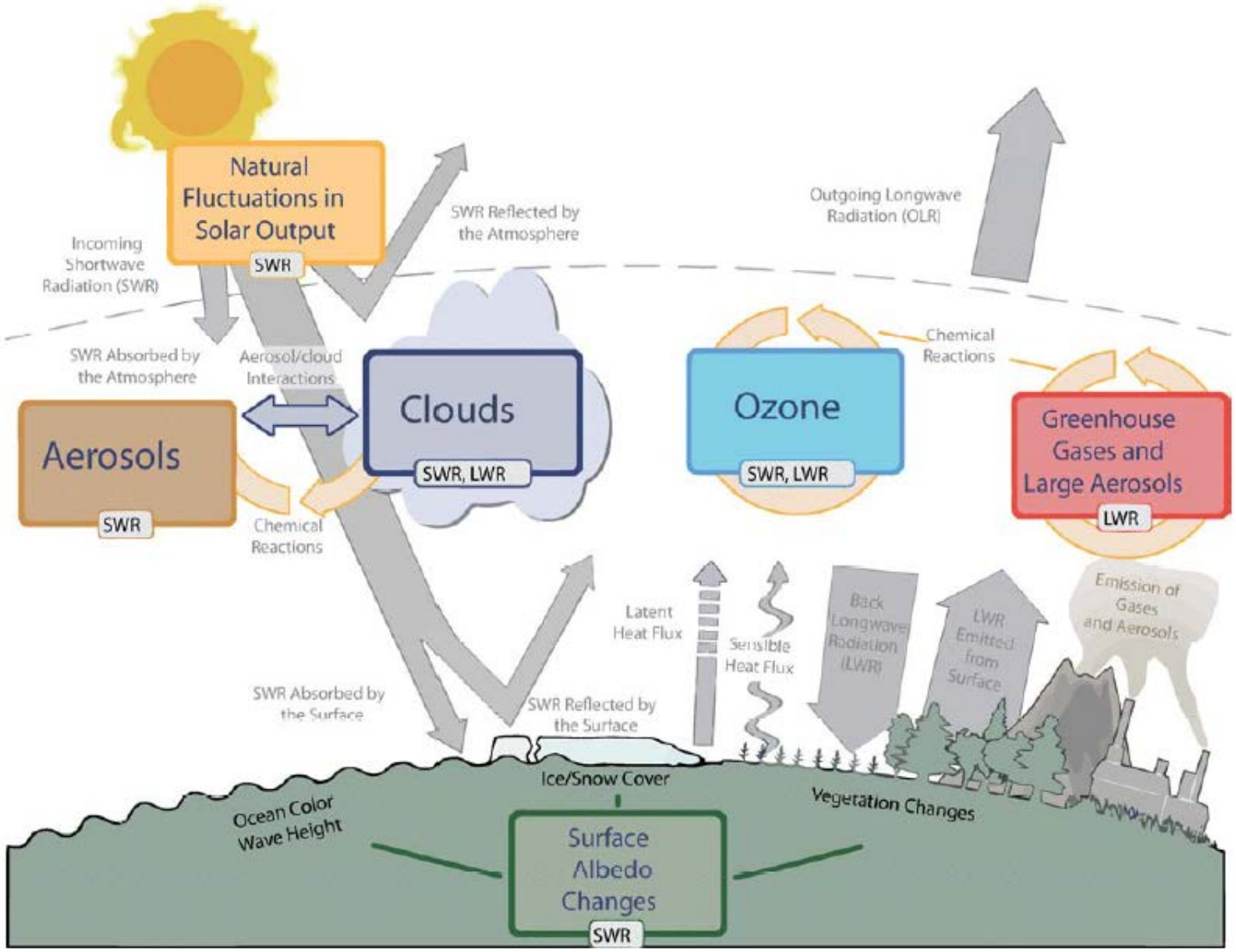
Go to https://www.youtube.com/watch?v=t0dXjmoA0dw

Relevance of carbon in the climate system?



Carbon in the climate system

- Carbon characteristics
- Budget
- Results



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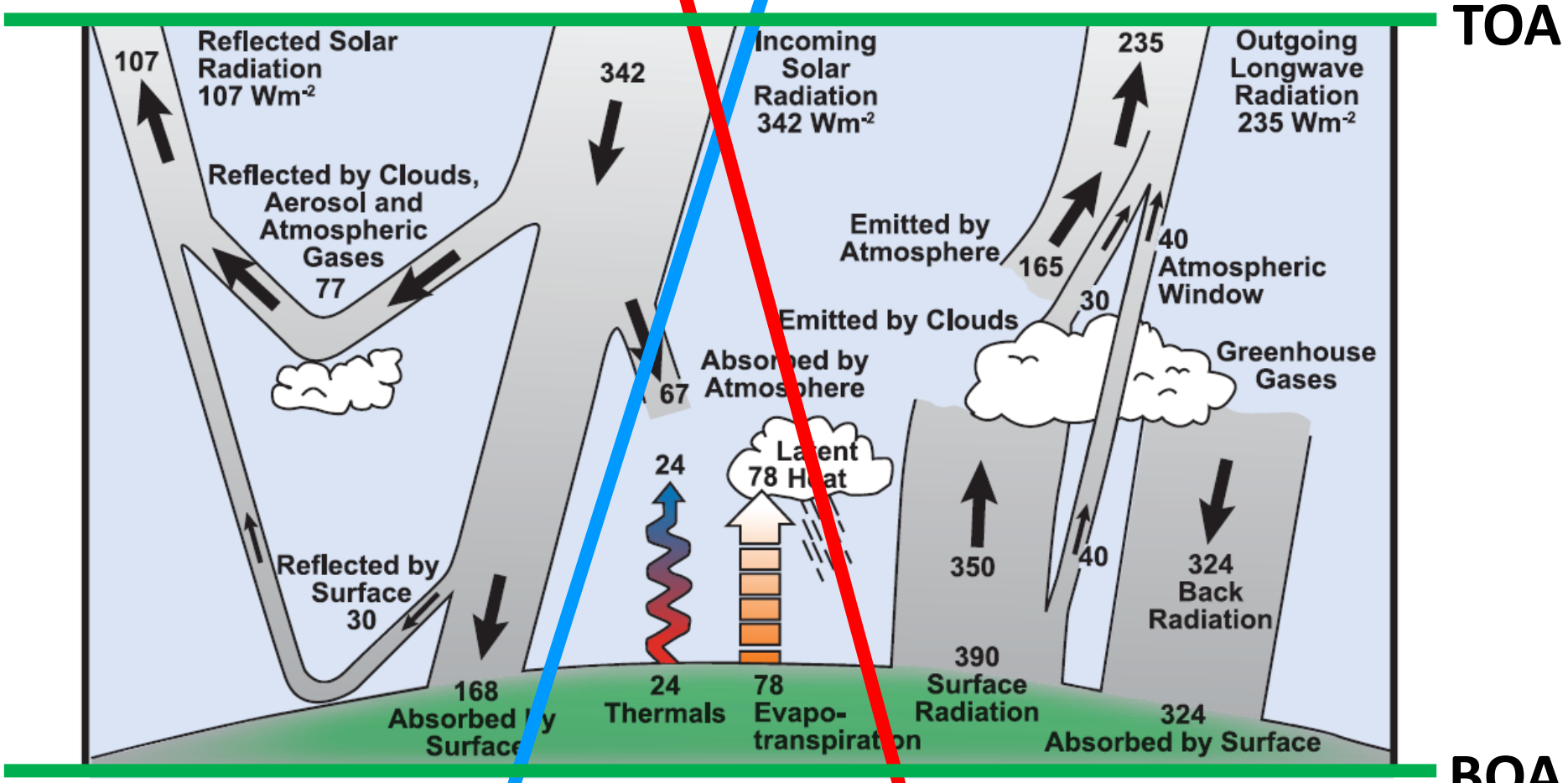
Vertical energy fluxes in the climate system



Solar radiation

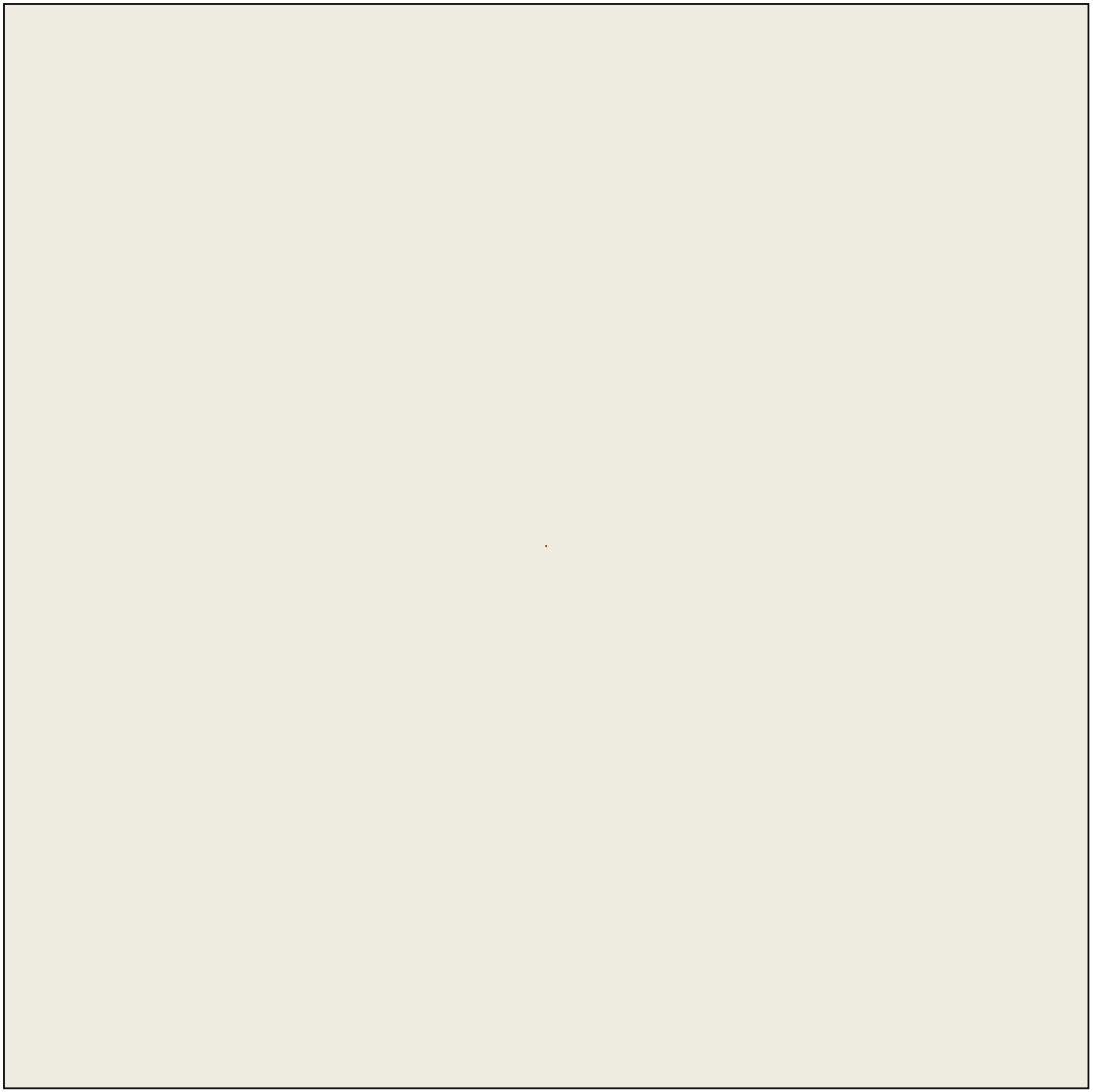
Heat flux

Moisture flux

Terrestr.radiation

Global greenhouse effect: 33°C

• Oxygen	21%	0°C
• Nitrogen	78%	0°C
• Argon	1%	0°C
• Water vapor H20	(0-4%)	21°C
• Ozone 03	(0.03 ppm)	2°C
• Carbon dioxide CO2	(280-400 ppm)	8°C
• Methane CH4	(600-1800 ppb)	1°C
		33°C



Biological energy storage

Energie	+	$6CO_2$	+	$6H_2O$	→	$C_6H_{12}O_6$	+	$6O_2$
Sonnenlicht	+	Kohlen-dioxid	+	Wasser	→	Zucker/ organ. Materie	+	Sauer-stoff

Spring

Fall

Biological energy use

$C_6H_{12}O_6$	+	$6\ O_2$	→	$6\ CO_2$	+	$6H_2O$	+	Energie
Zucker/ organ. Materie	+	Sauer-stoff	→	Kohlen-dioxid	+	Wasser	+	Körper-energie

The budget perspective of the climate system

Concept: *A state quantity like CO2 is subject to three possible change mechanisms:*

- *Time* change: Storage **S**
- *Space* change: Outflow **A**
- *Matter* change: Phase flux **U**

Fundamental budget formula

$$S + A + U = 0$$

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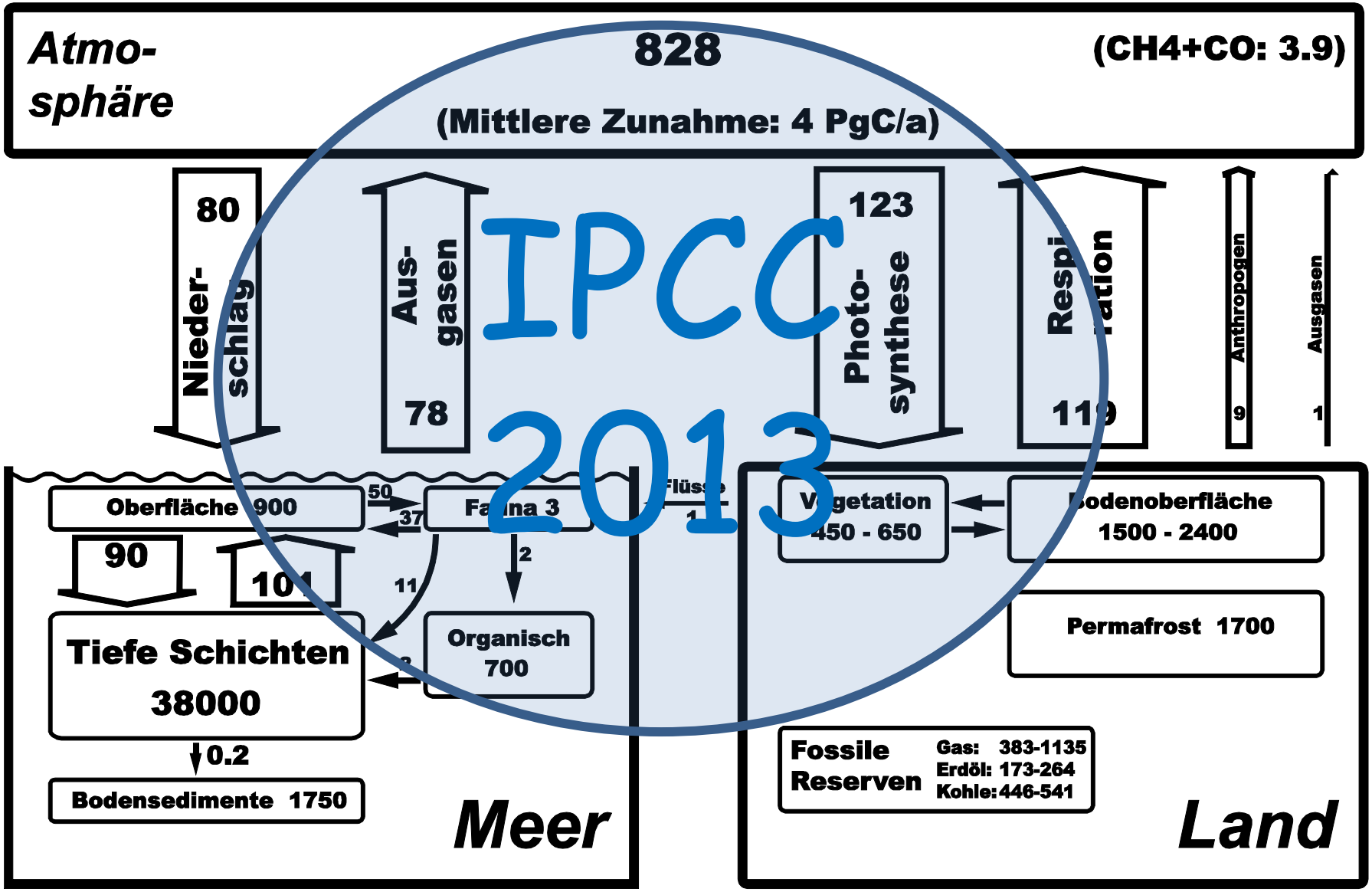
Fig. 8.2 from Hantel & Haimberger 2016



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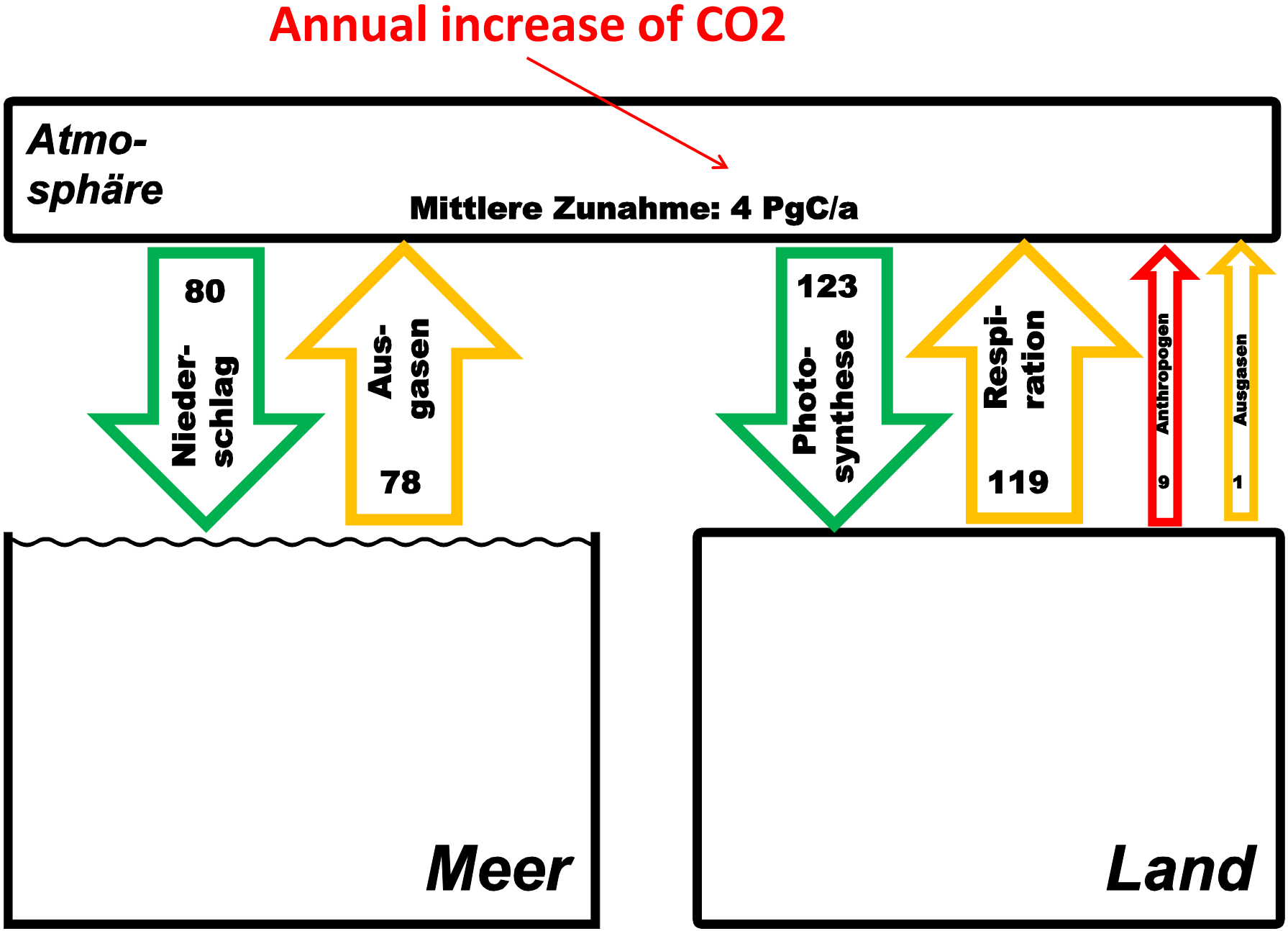
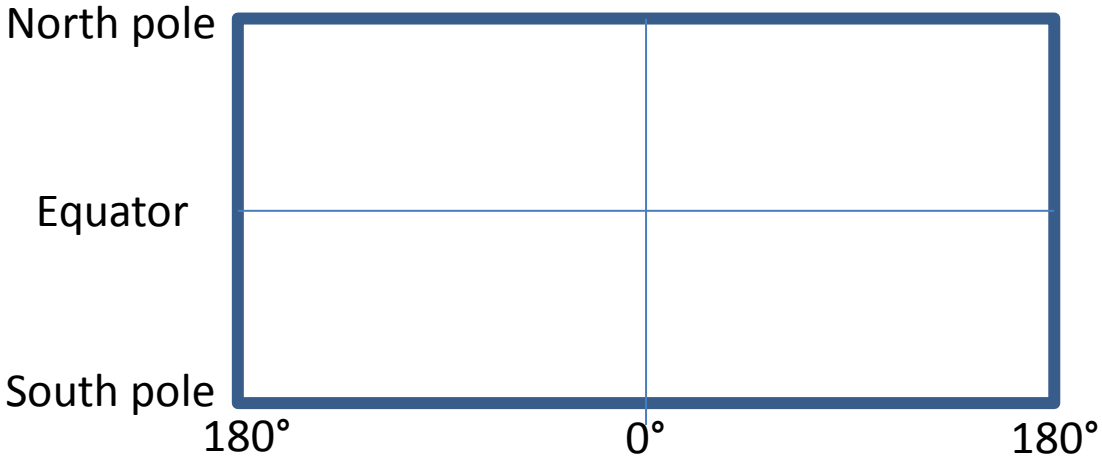

Annual increase of CO2
Atmo-
sphäre
Mittlere Zunahme: 4 PgC/a
80
Nieder-
schlag
Aus-
gasen
78
123
Photo-
synthese
Respi-
ration
119
Anthropogen
9
Ausgasen
1
Meer
Land

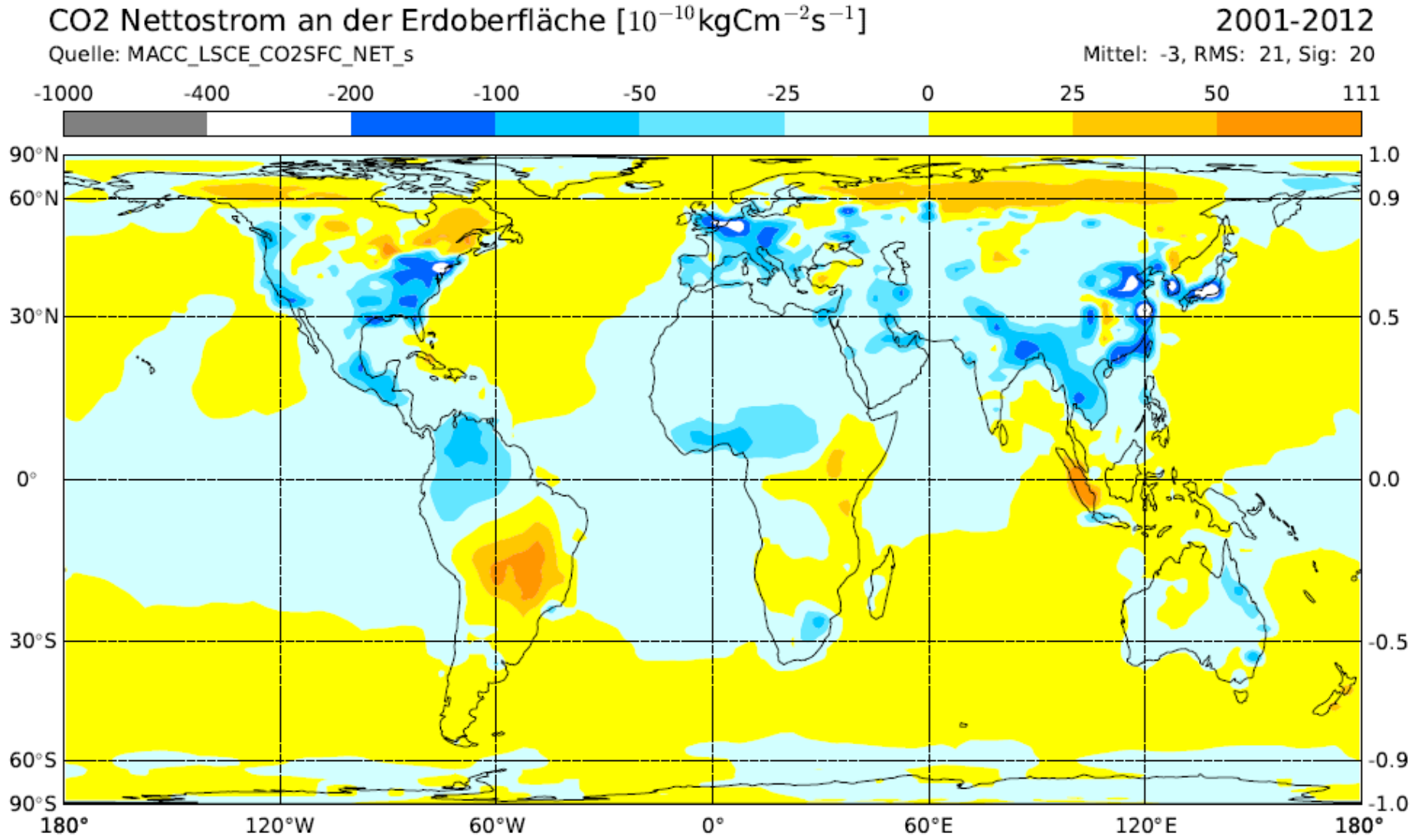
CO2 budget equation for an atmospheric column

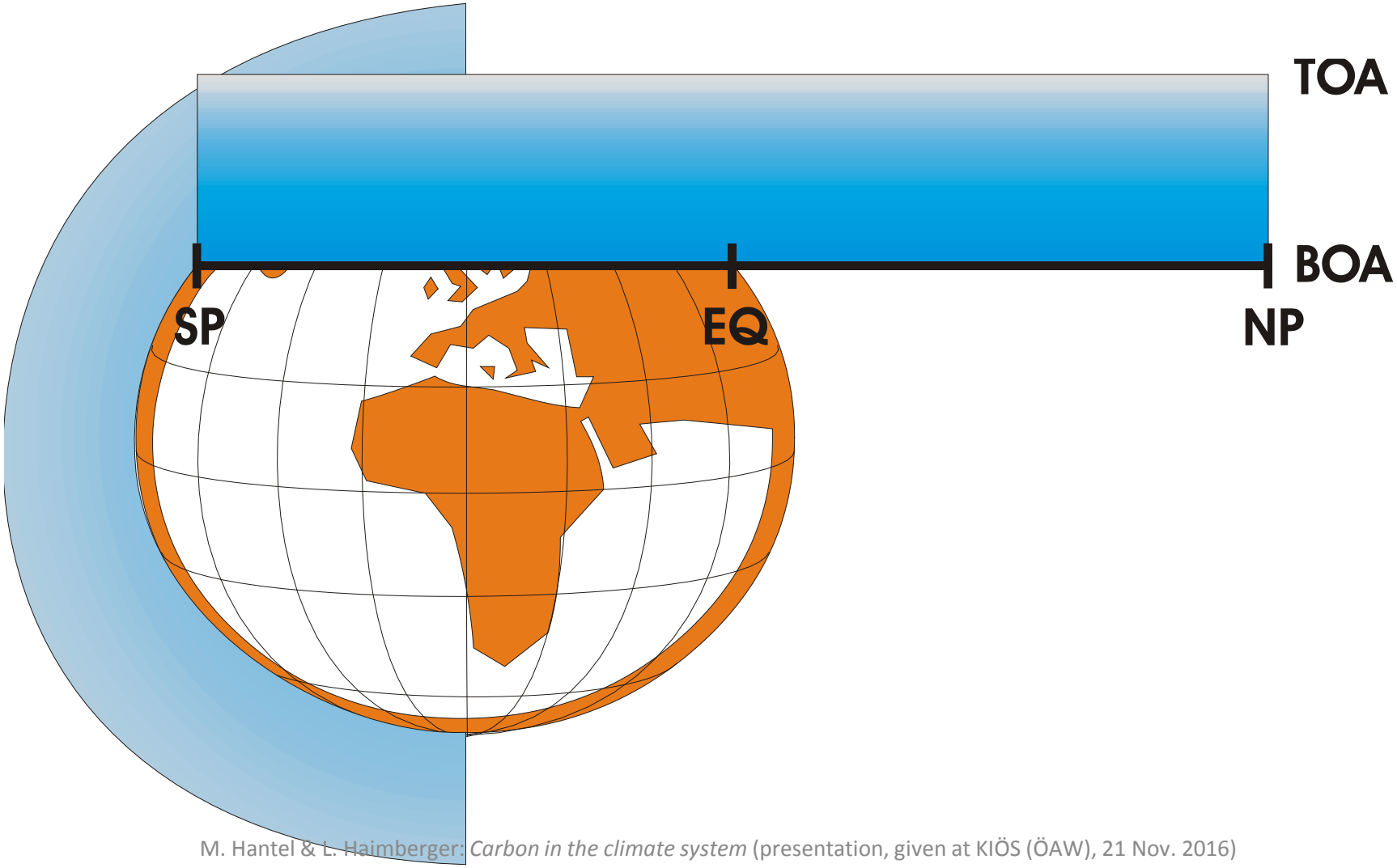
$$\frac{\partial C}{\partial t} + \nabla \cdot C + U_{ap} + U_{nb} + U_o = 0$$

Storage **Outflow** **Phase flux**

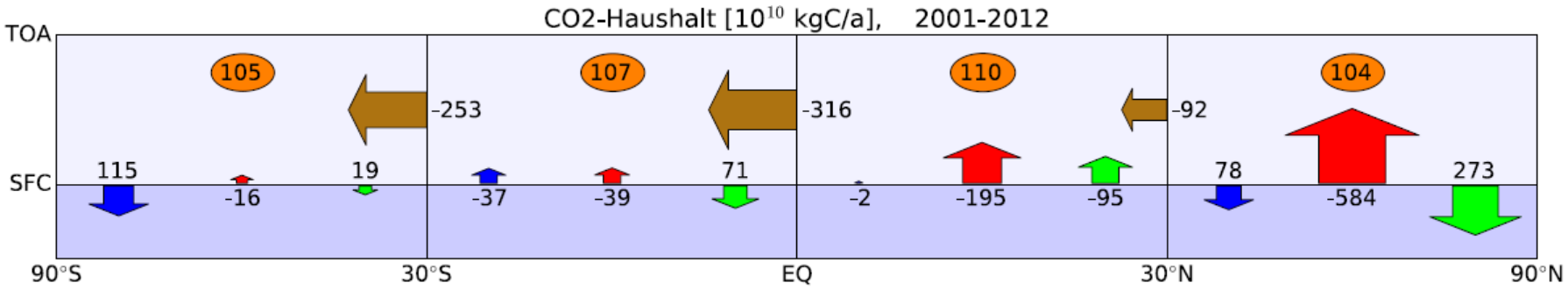
S + **A** + **U** = 0



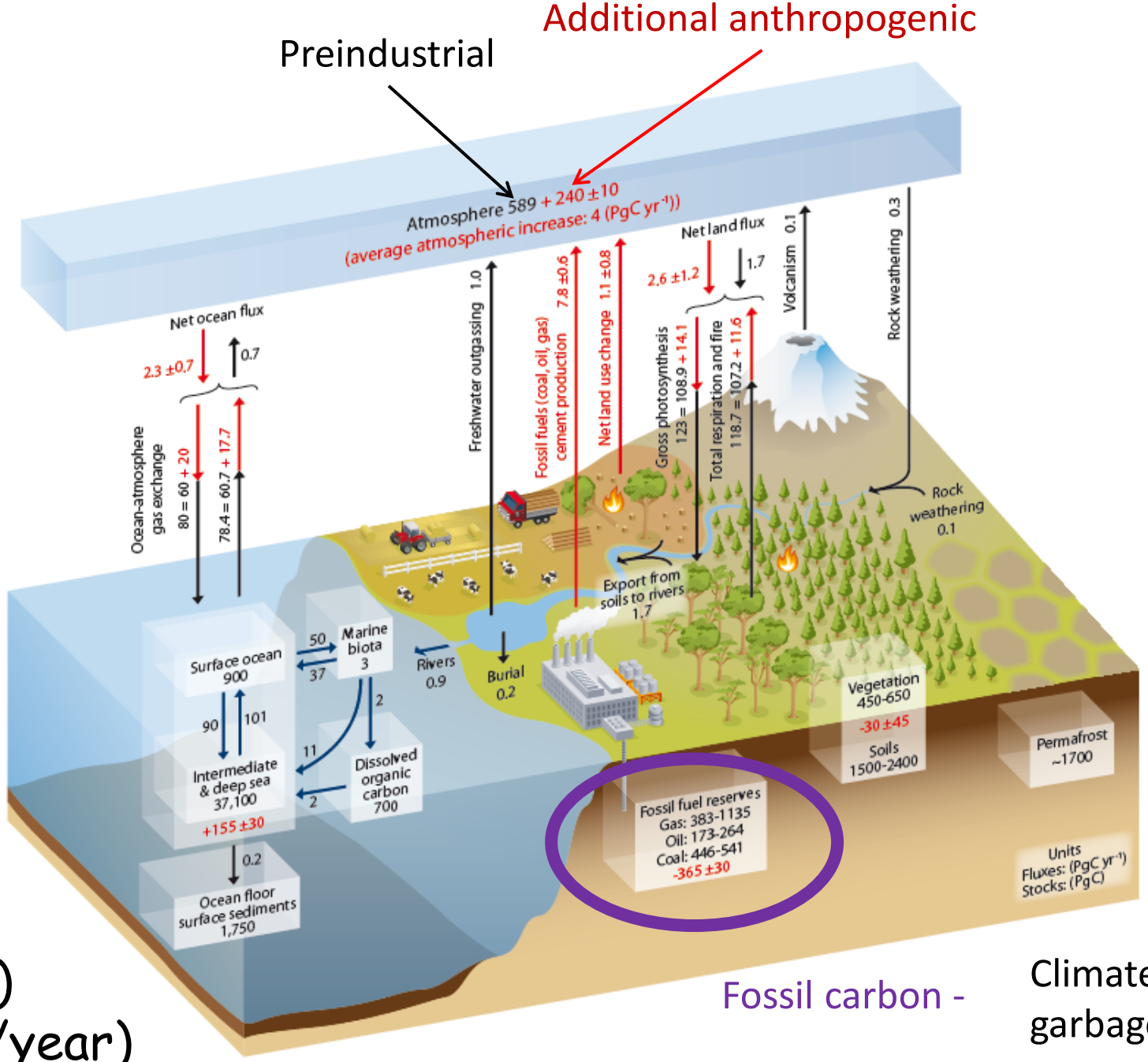

CO2 Nettostrom an der Erdoberfläche [10^{-10}kgCm^{-2}s^{-1}]
2001-2012
Quelle: MACC_LSCE_CO2SFC_NET_s
Mittel: -3, RMS: 21, Sig: 20
-1000
-400
-200
-100
-50
-25
0
25
50
111
90°N
60°N
30°N
0°
30°S
60°S
90°S
1.0
0.9
0.5
0.0
-0.5
-0.9
-1.0
180°
120°W
60°W
0°
60°E
120°E
180°


TOA
BOA
SP
EQ
NP

CO2-budget 2001-2012



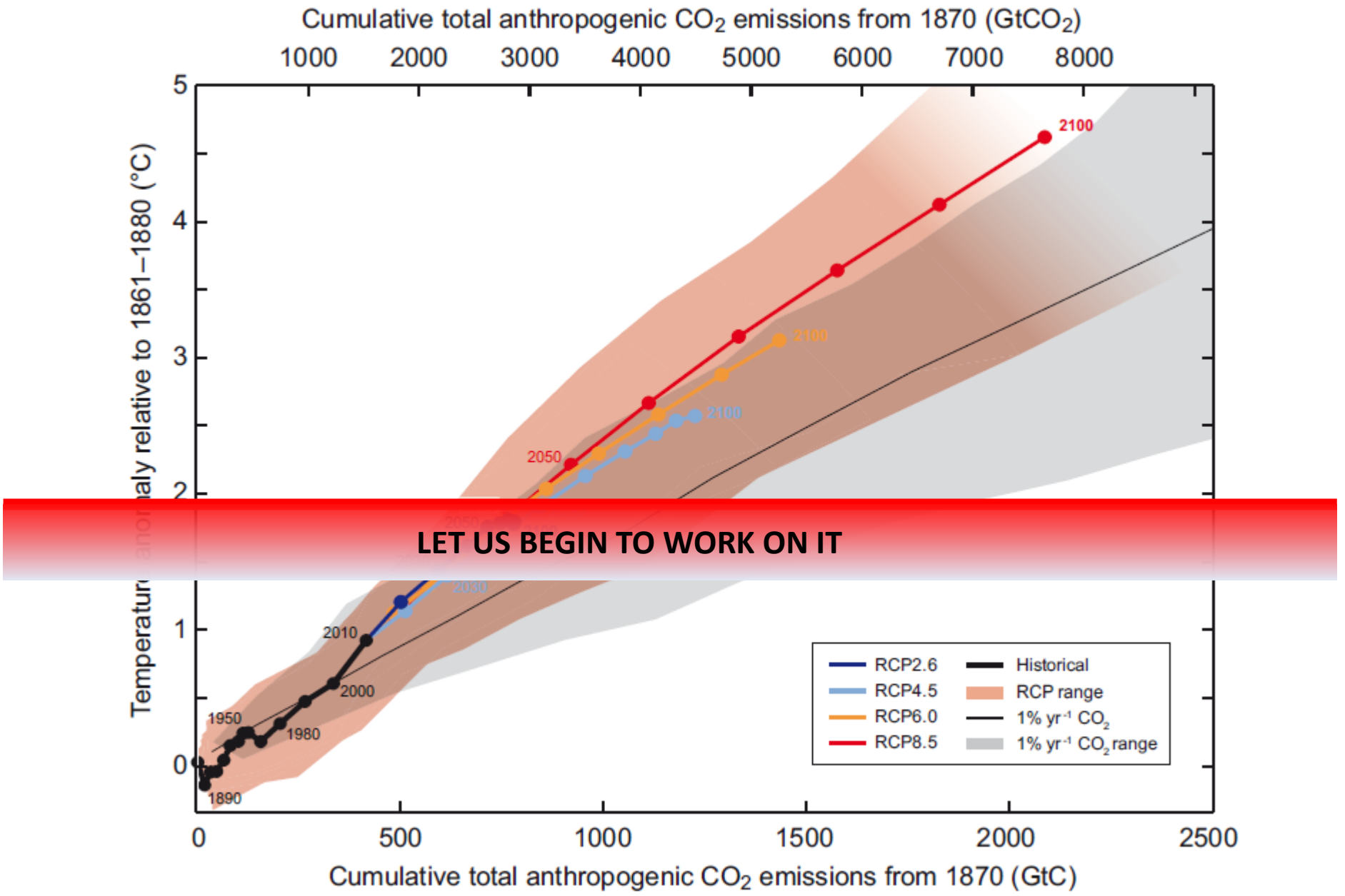
IPCC 2013*)



*)Stocks (PgC)
Fluxes (PgC/year)

Fossil carbon -

Climate garbage



LET US BEGIN TO WORK ON IT

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