Emission pathways reducing the risk of dangerous climate change

Kirsten Zickfeld

Climate Modelling Group
School of Earth and Ocean Sciences
University of Victoria

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- Many others who have contributed to the development of the UVic Earth System climate model.

Outline

- What is “dangerous climate change”?
- The UVic Earth System Climate Model
- Experimental design
- Results: CO_2 emissions compatible with specified temperature targets
- Conclusions

UNFCCC Article 2

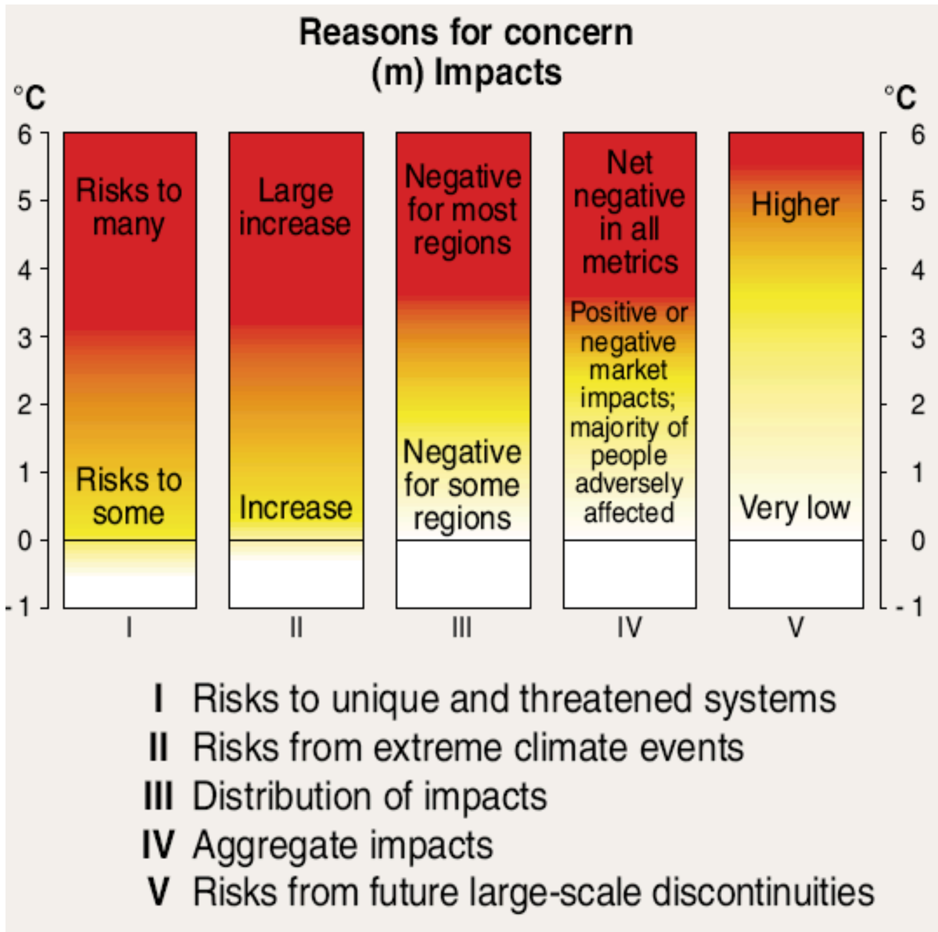
"The ultimate objective of this convention … is to achieve … stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.
Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

What is “dangerous”?

Interpretation of Article 2 involves

- Scientific assessment of what impacts might be associated with different levels of greenhouse gas concentrations or levels of climate change.
- Normative evaluation by policy-makers of which impacts and associated likelihoods constitute “dangerous anthropogenic interference”.

IPCC's reasons for concern



IPCC, TAR, Synthesis Report, 2001

Motivation

- Recent international climate policy discussions framed around limiting global mean temperature increase to 2°C relative to pre-industrial times.
- Earlier studies have linked specific CO_2 concentration levels with the probability of meeting the 2°C target.
- Probability of meeting that target is 'likely' ($p<0.33$) at CO_2 equivalence concentration levels below 450 ppmv.
- Link to allowable CO_2 emissions usually provided by integrated assessment models including highly simplified representation of the carbon cycle.
- Scope of this study: Consistently derive cumulative emissions compatible different temperature targets using state-of-the-art climate-carbon cycle model.

The UVic Earth System Climate Model

- “Intermediate complexity” model.
- Suited for climate studies on decadal to millennial time-scales.
- Computationally efficient (~160 model years in 1 day).

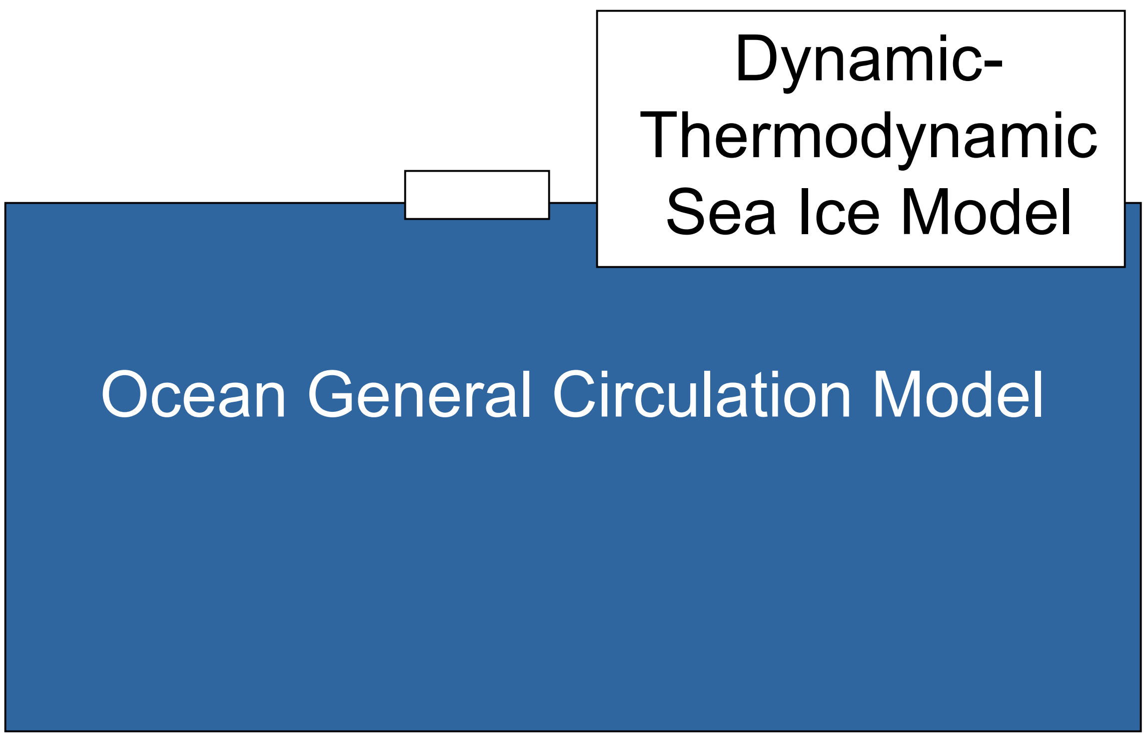
The UVic Earth System Climate Model

Ocean General Circulation Model

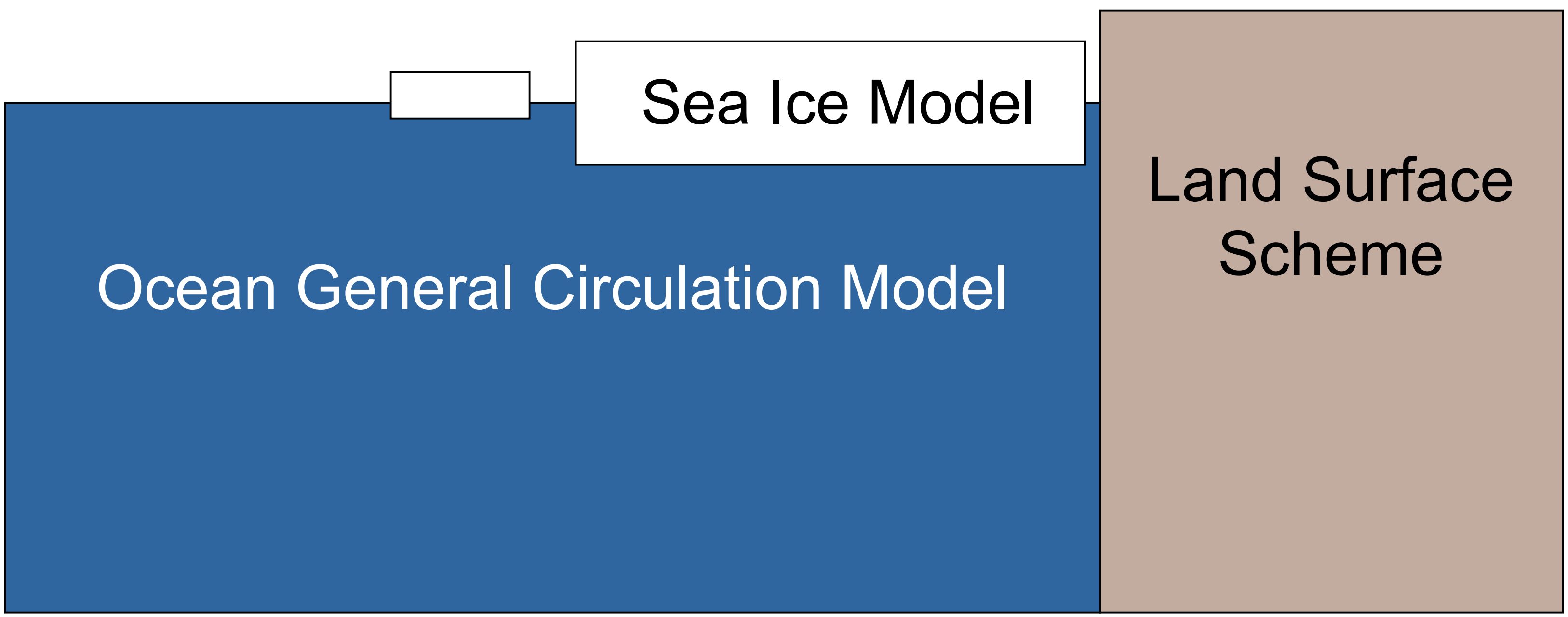
MOM 2

19 vertical layers

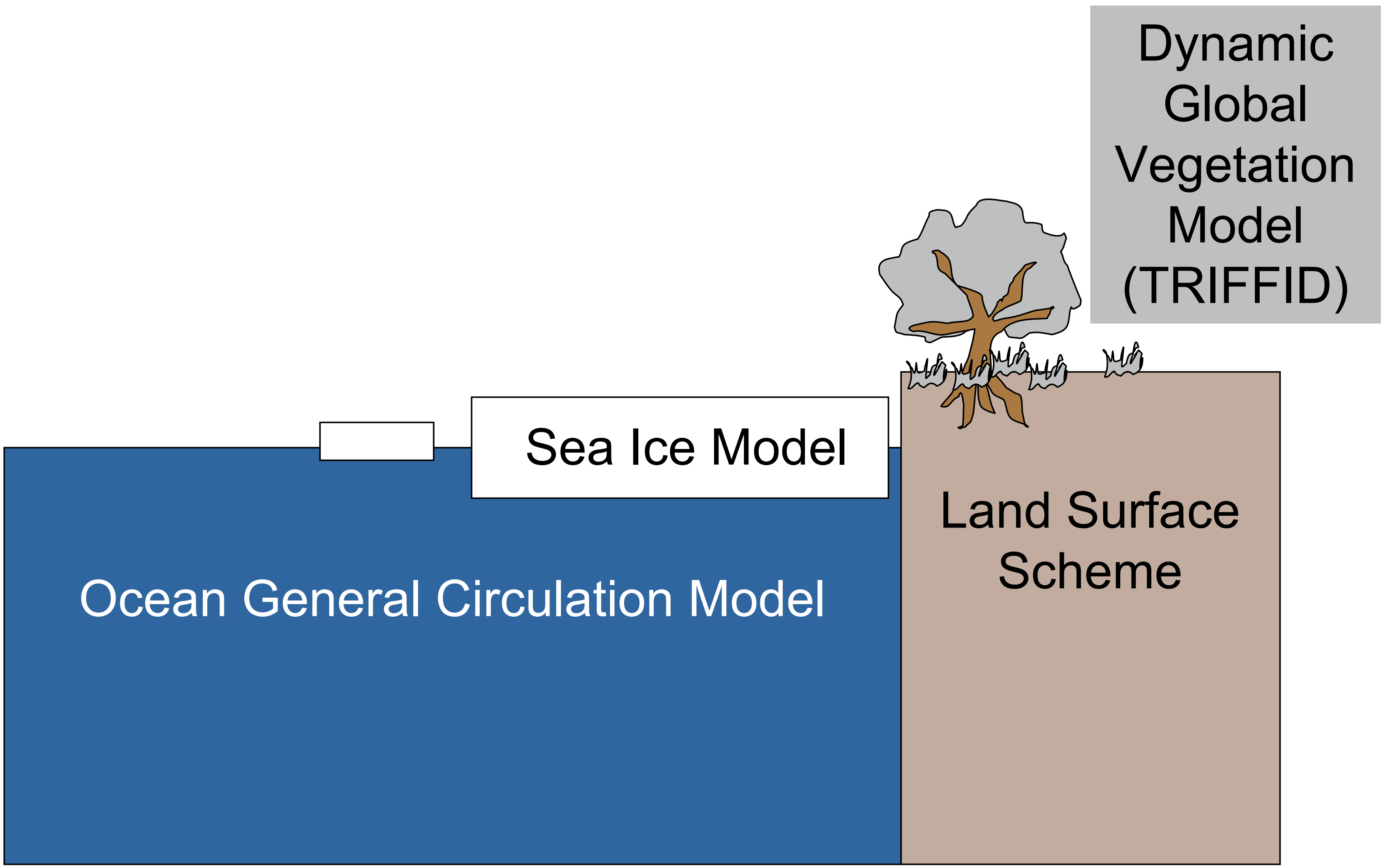
The UVic Earth System Climate Model



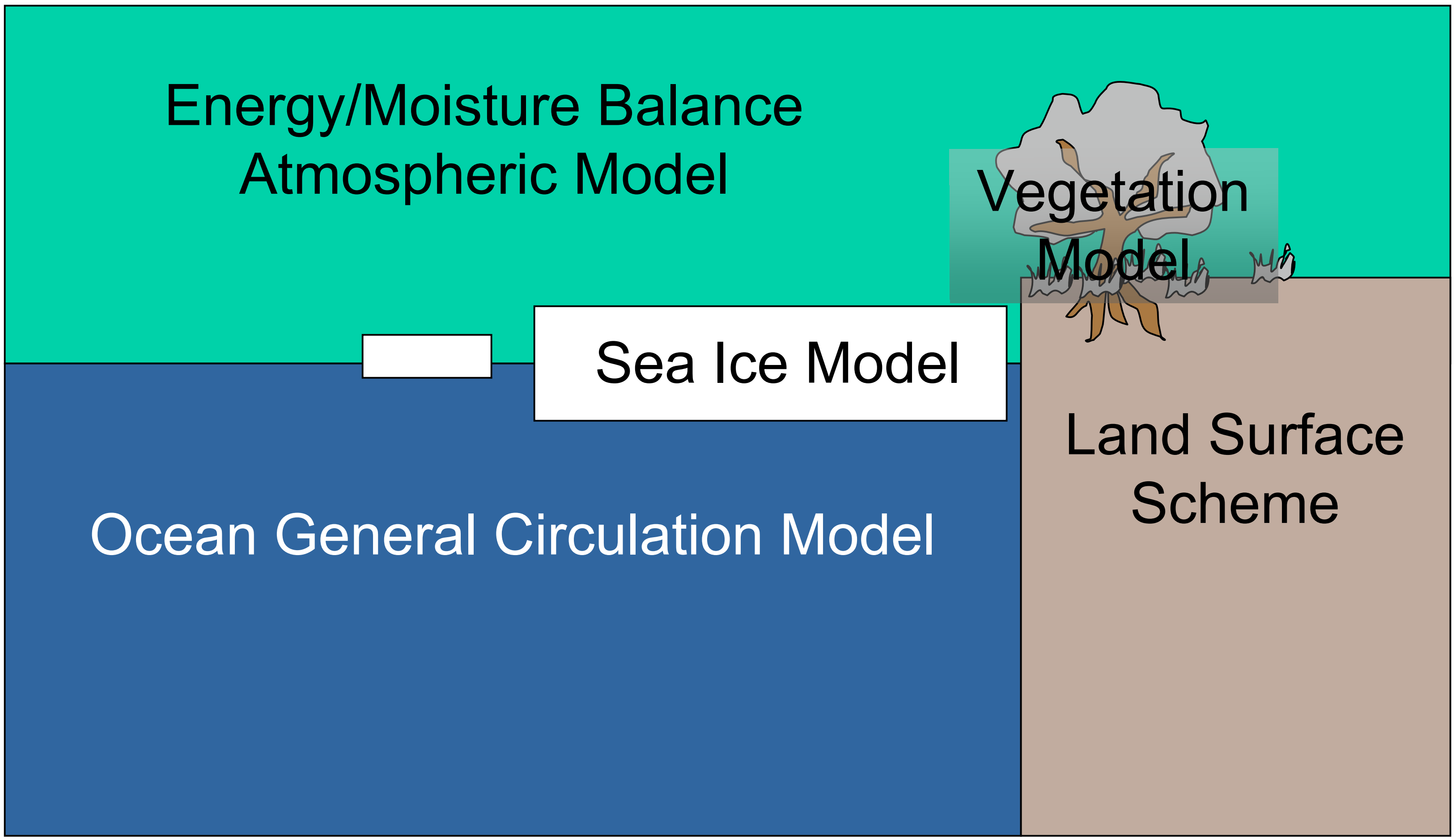
The UVic Earth System Climate Model



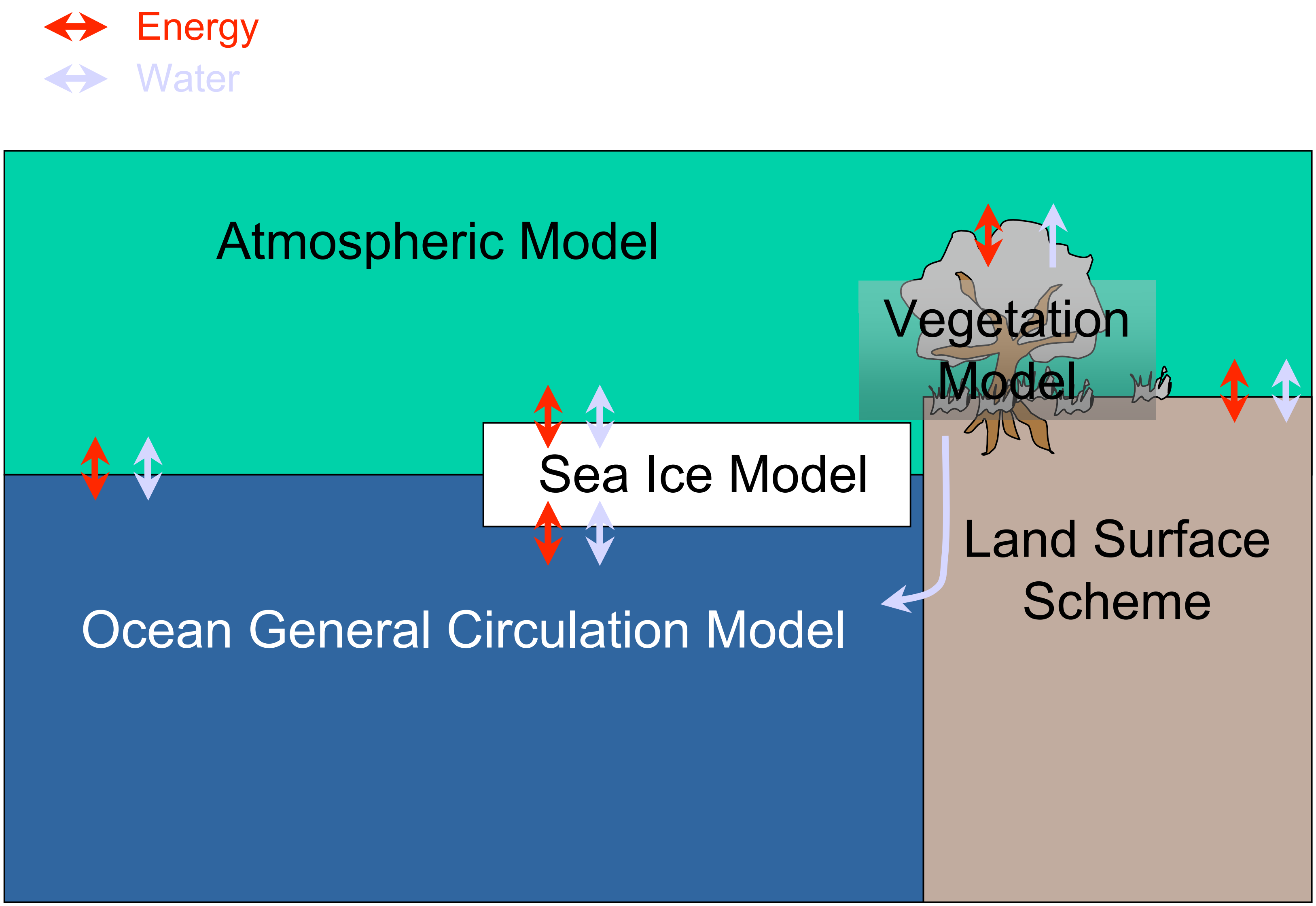
The UVic Earth System Climate Model



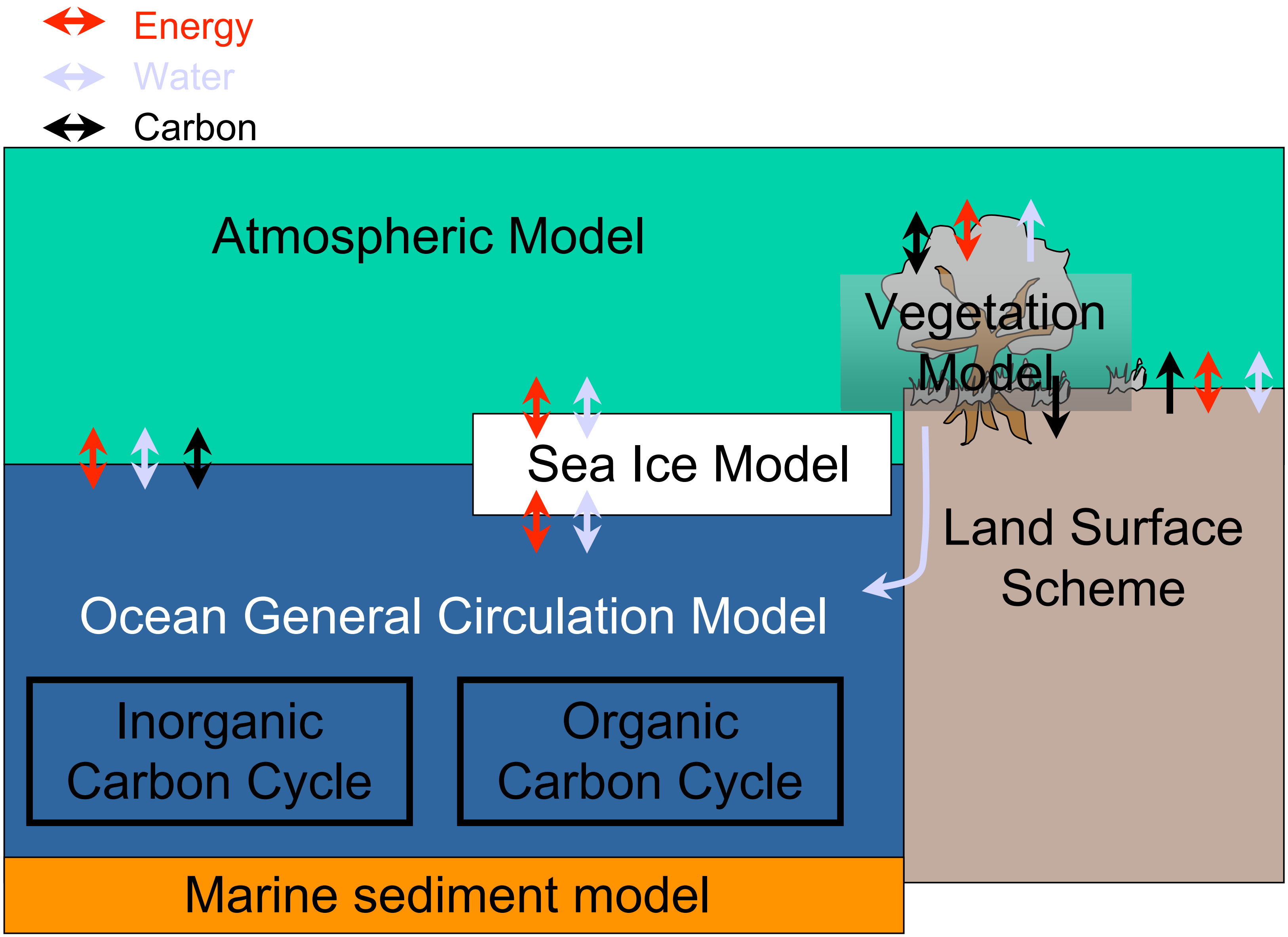
The UVic Earth System Climate Model



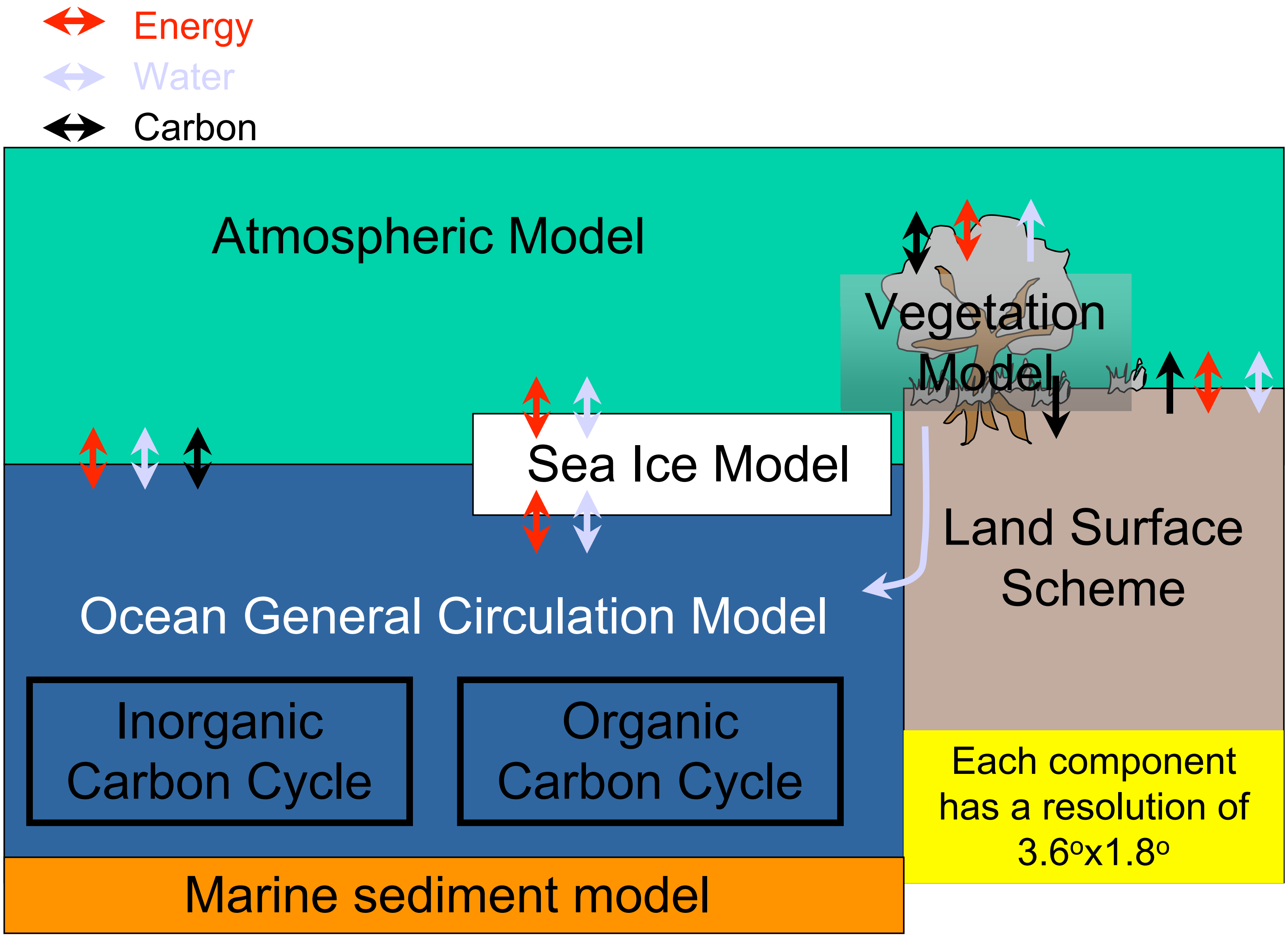
The UVic Earth System Climate Model



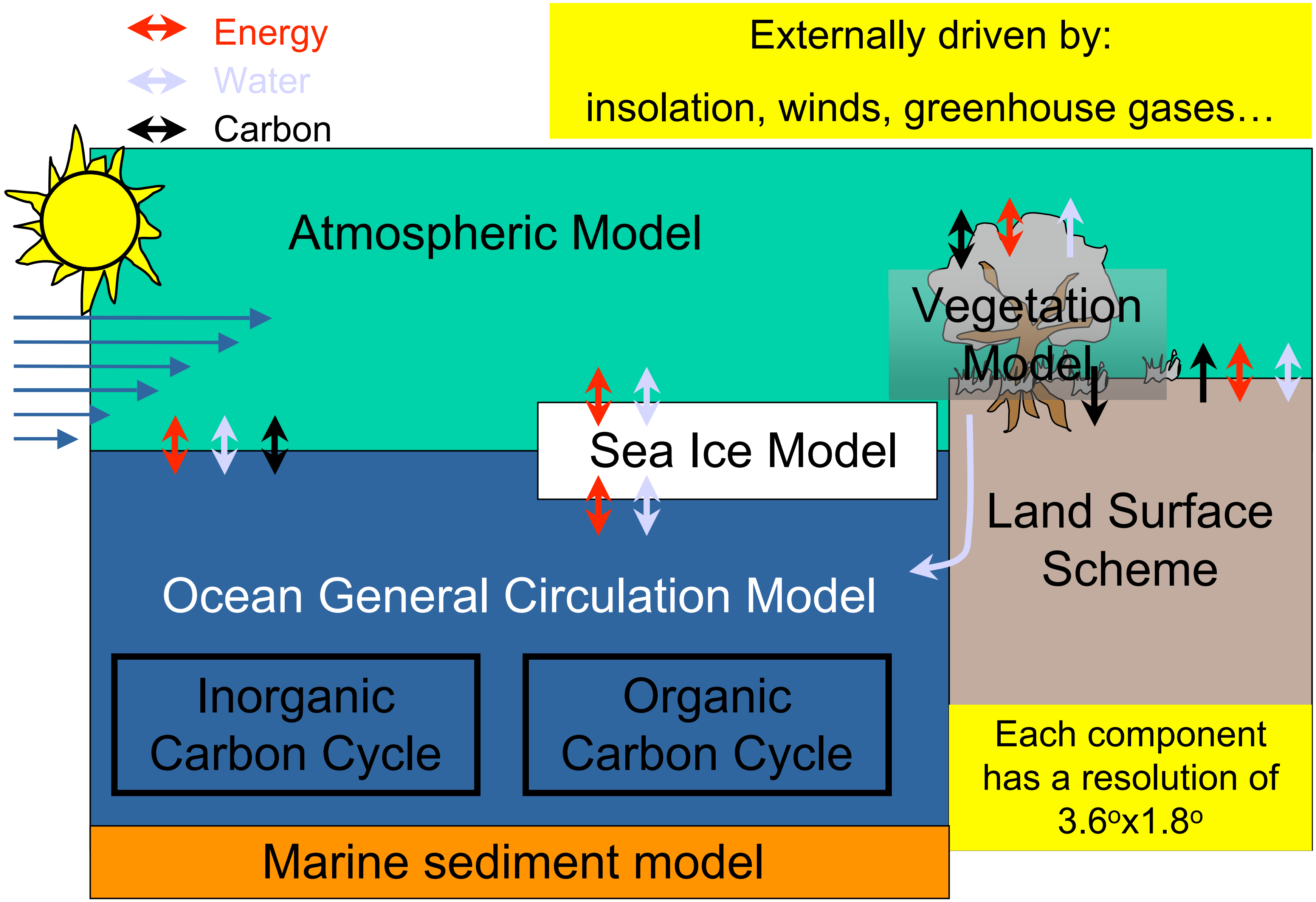
The UVic Earth System Climate Model



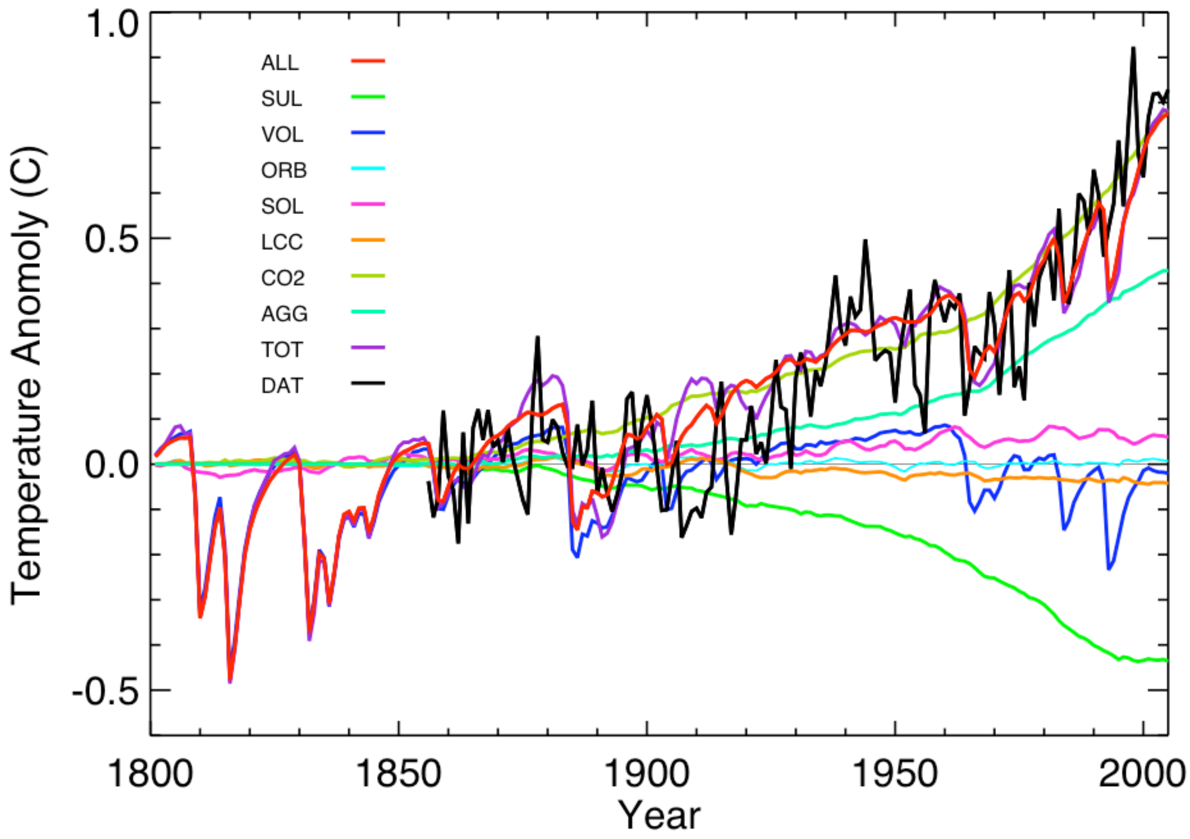
The UVic Earth System Climate Model



The UVic Earth System Climate Model

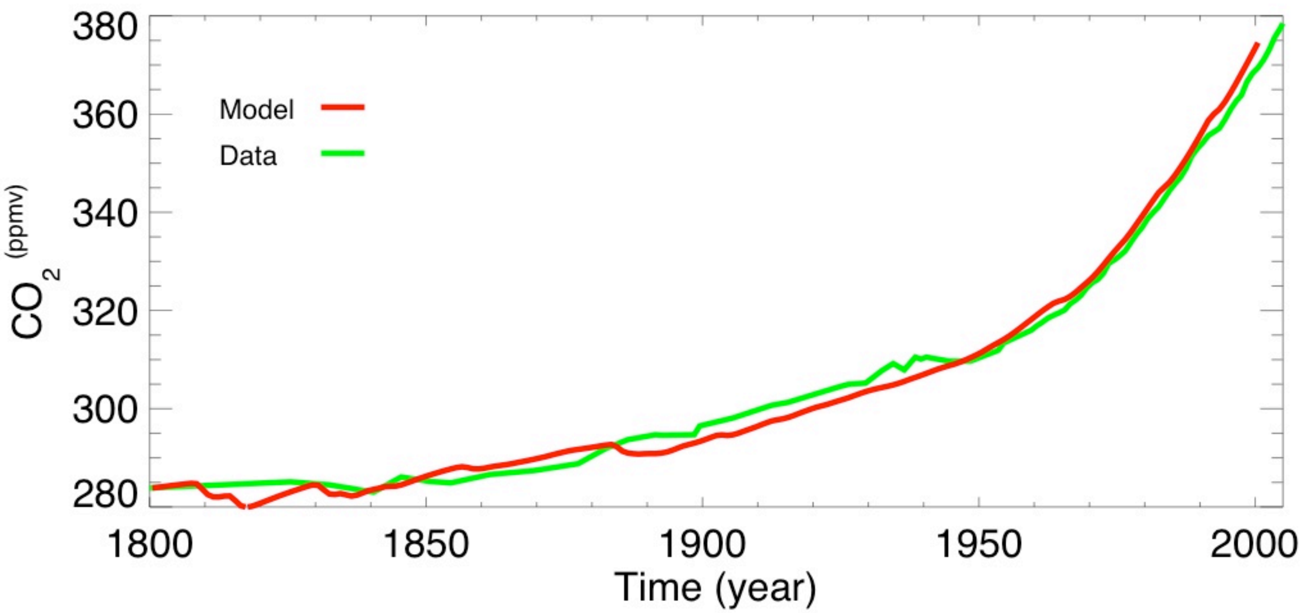


Model evaluation: Historical temperature change



Data: Jones et al. (2006)

Model evaluation: Historical CO_2 change



Data: Keeling et al., 2005

Experiment design

- Over the historical period (1800-2000) the model is driven by known forcings (greenhouse gases, sulphates, solar irradiance, volcanoes, land cover change).
- From 2000 on the model computes the CO_2 emissions consistent with a specified temperature profile ("temperature tracking"). Most non-CO_2 forcing agents are hold constant at year-2000 levels.
- Proportional control:

$$E(t) = k(\Delta T^{DATA}(t) - \Delta T(t))$$

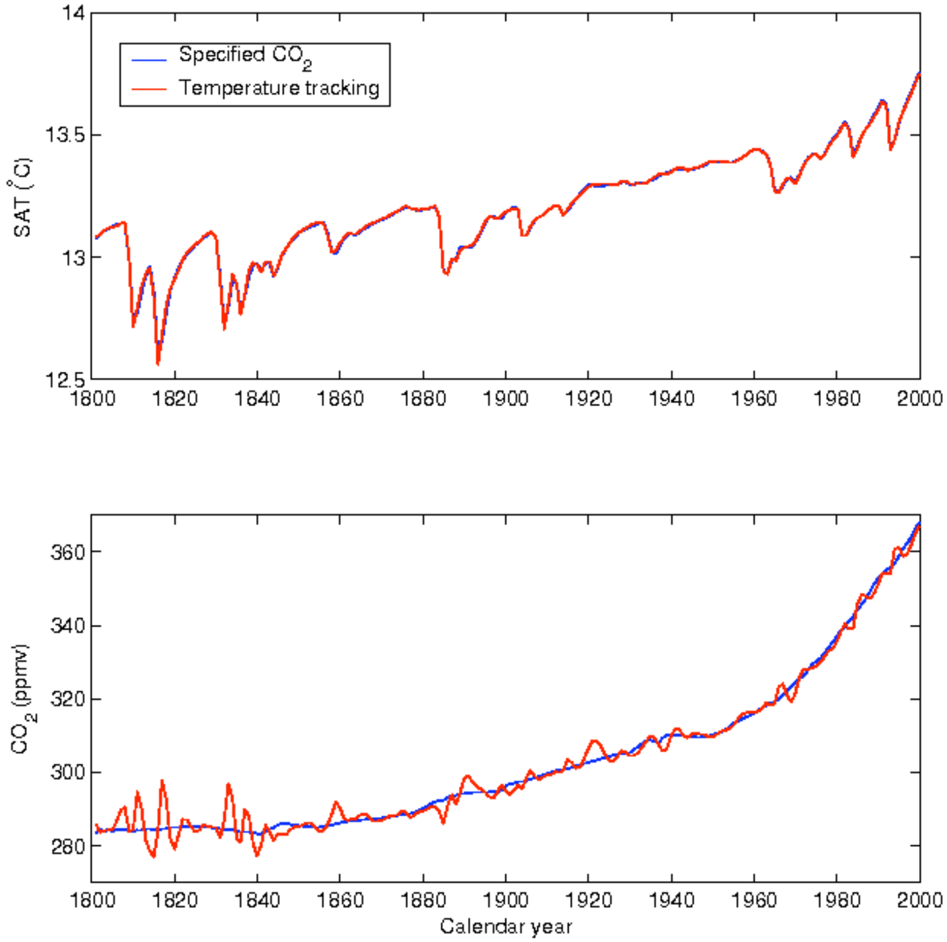
E - CO_2 emissions

k - constant

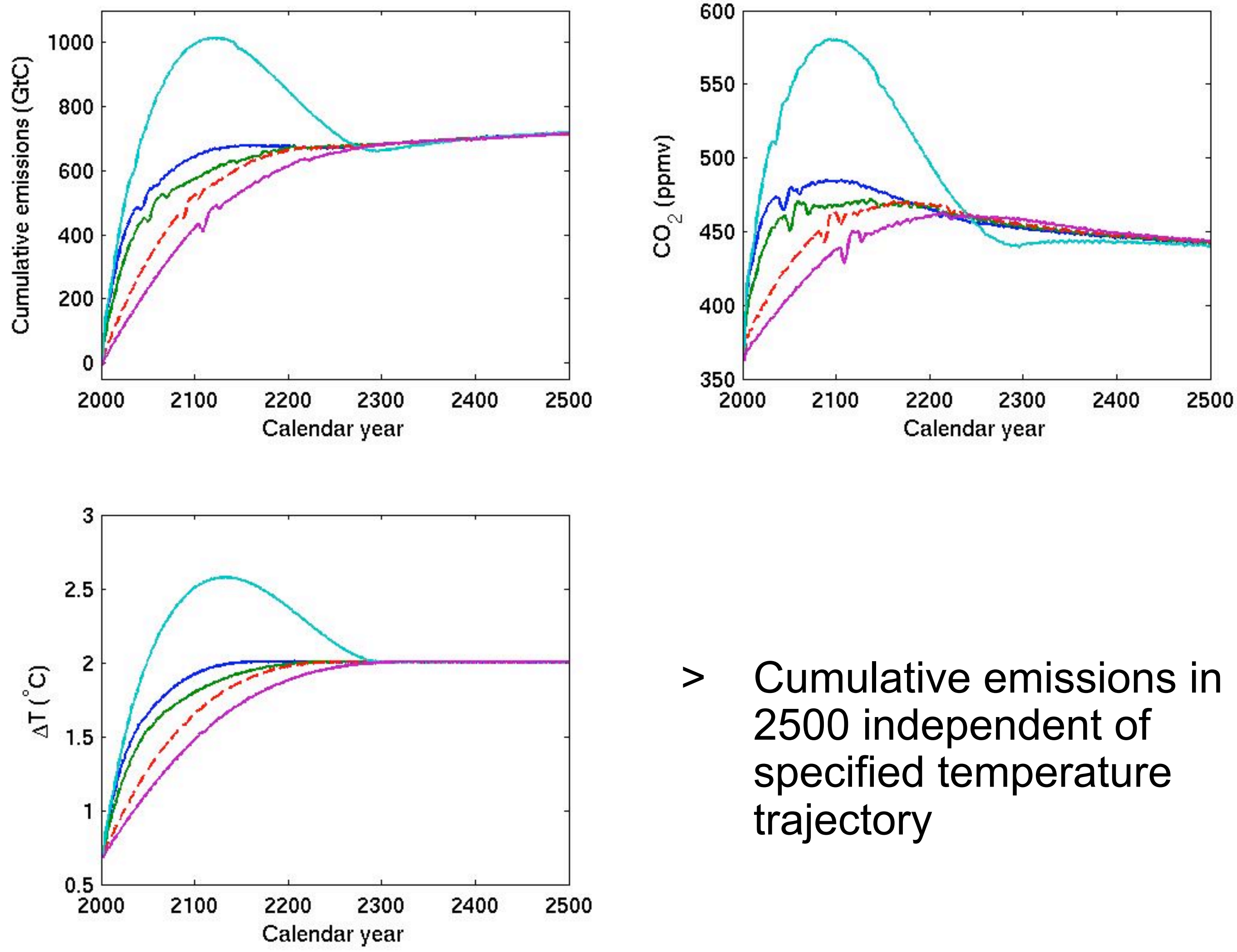
ΔT^{DATA} - prescribed temperature anomaly

ΔT - modelled temperature anomaly

Temperature tracking

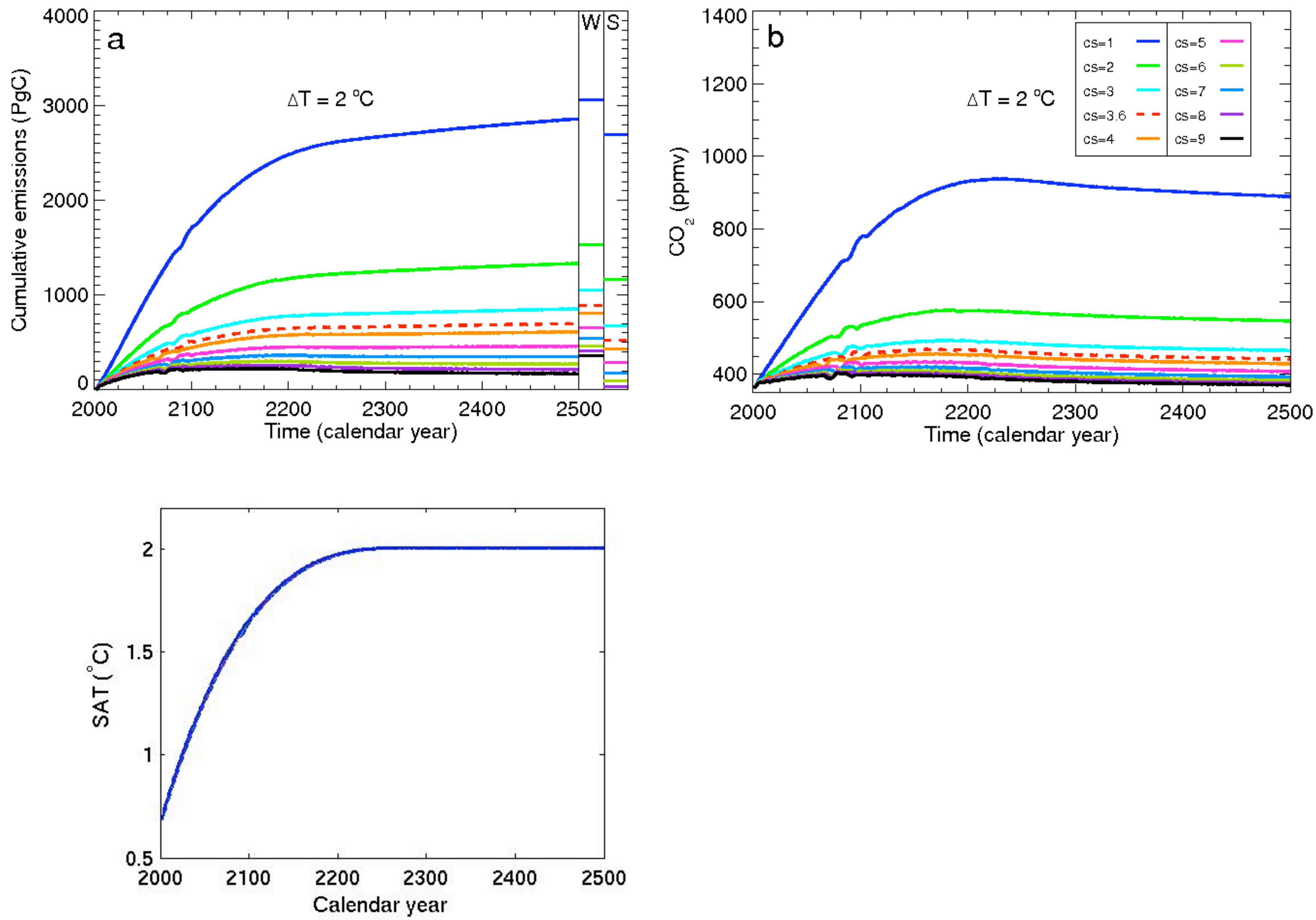


Cumulative emissions meeting 2°C target

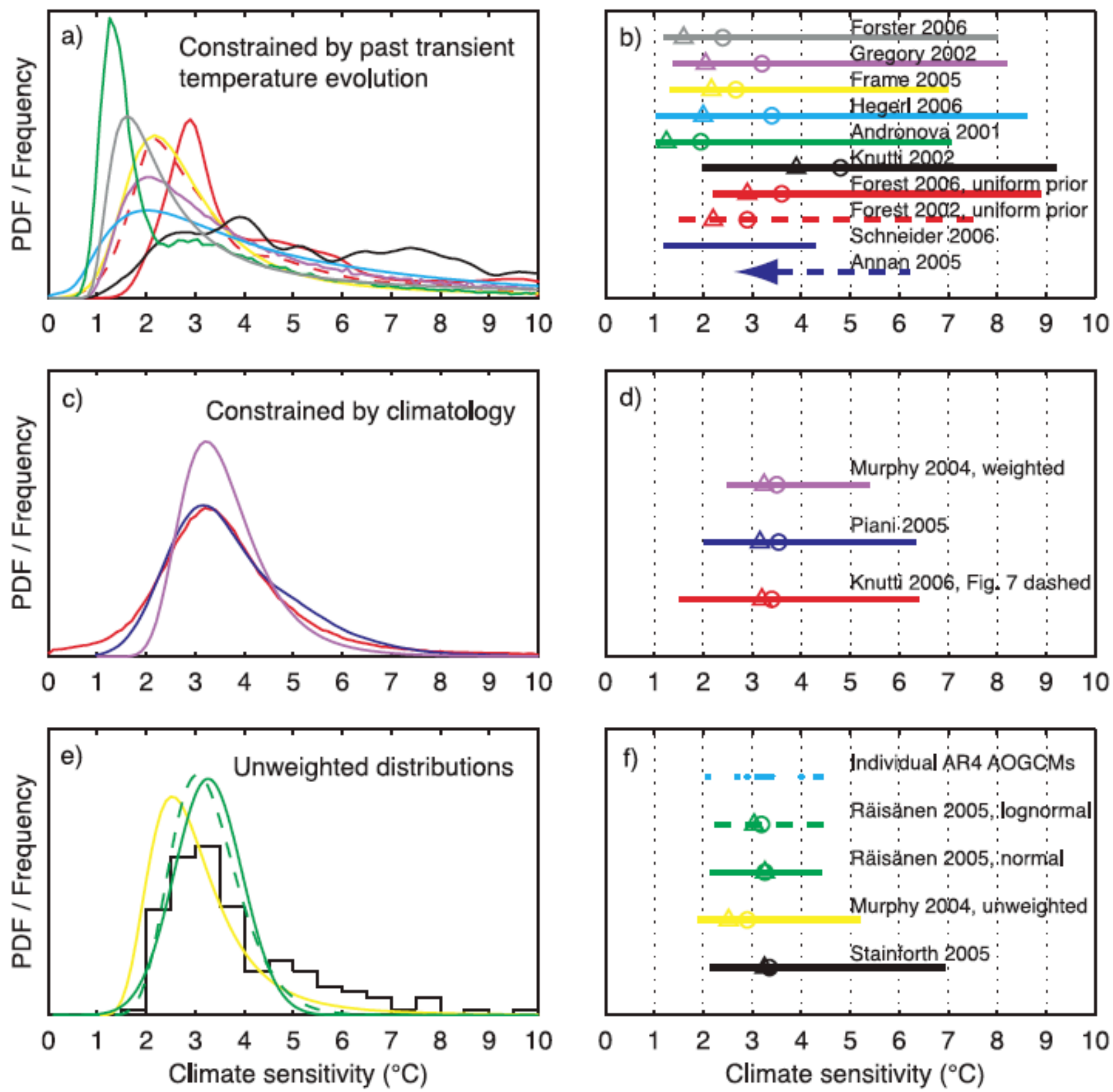


> Cumulative emissions in 2500 independent of specified temperature trajectory

Variation of climate sensitivity



PDFs for climate sensitivity



IPCC 2007, WG I, Ch 10

Probability of exceeding temperature target

Given $E(cs^0, \Delta T^{GOAL})$

$$P(\Delta T(E) \geq \Delta T^{GOAL}) = \int_{cs^o}^{\infty} P(cs = x)\, dx$$

$$= P(cs \geq cs^0)$$

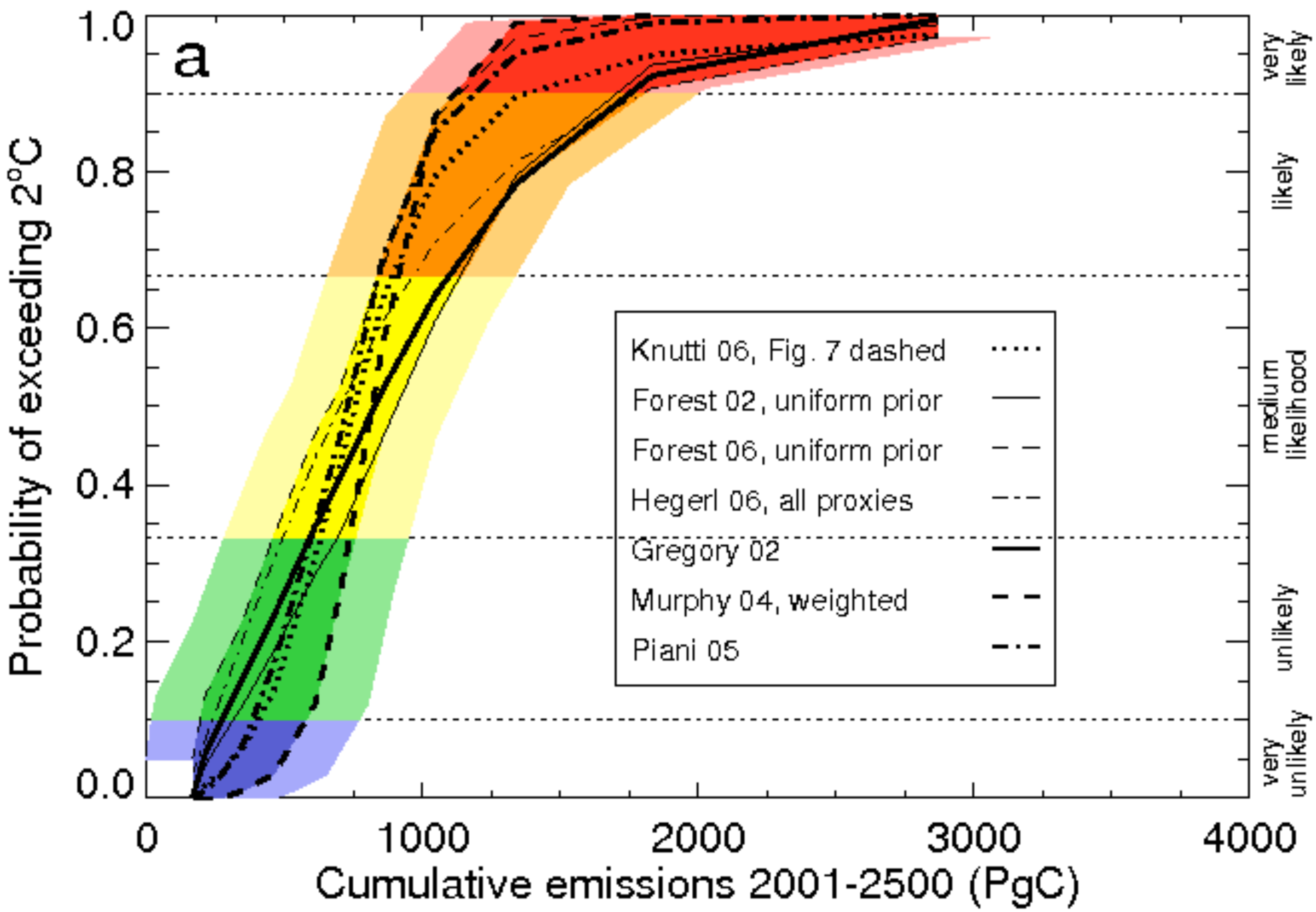
ΔT^{GOAL} - Temperature target

cs - Equilibrium climate sensitivity

$P(cs = \Delta T)$ - Climate sensitivity PDF

$P(cs \geq \Delta T)$ - Climate sensitivity CDF

Probability of exceeding 2°C target



Conclusions

- Cumulative CO_2 emissions compatible with 2°C target independent of path taken to stabilization.
- To limit global mean temperature rise to 2°C above pre-industrial with a probability of 0.33 cumulative emissions after 2000 must not exceed 640 PgC (range: 280-930 PgC).
- We suggest shift in focus from allowable greenhouse gas concentrations to total allowable emissions.
- Path independency may facilitate international climate policy negotiations: Countries are allocated total emissions shares. No need to agree on common time-line.

Thank you for your attention!

Contact:

Dr. Kirsten Zickfeld

Climate Modelling Group
School of Earth and Ocean Sciences
University of Victoria
Ian Stewart Complex
PO Box 3055 Stn CSC
Victoria, BC, V8W 3P6

Tel.: +1-250-4724008
Email: zickfeld@ocean.seos.uvic.ca
WWW: http://climate.uvic.ca/people/zickfeld