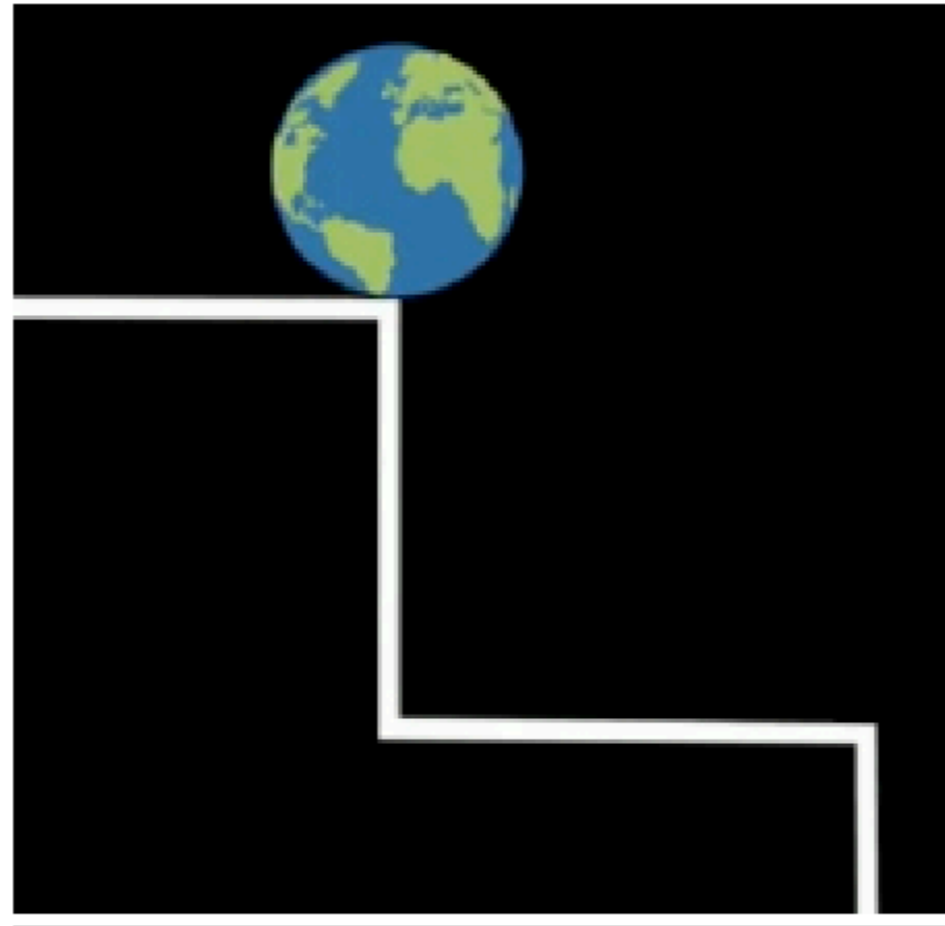


Is er een 'point of no return' in klimaatverandering?



Henk A. Dijkstra, IMAU, Departement Natuur-
en Sterrenkunde, Universiteit Utrecht

Overzicht

1. Forcing - respons

kritische condities

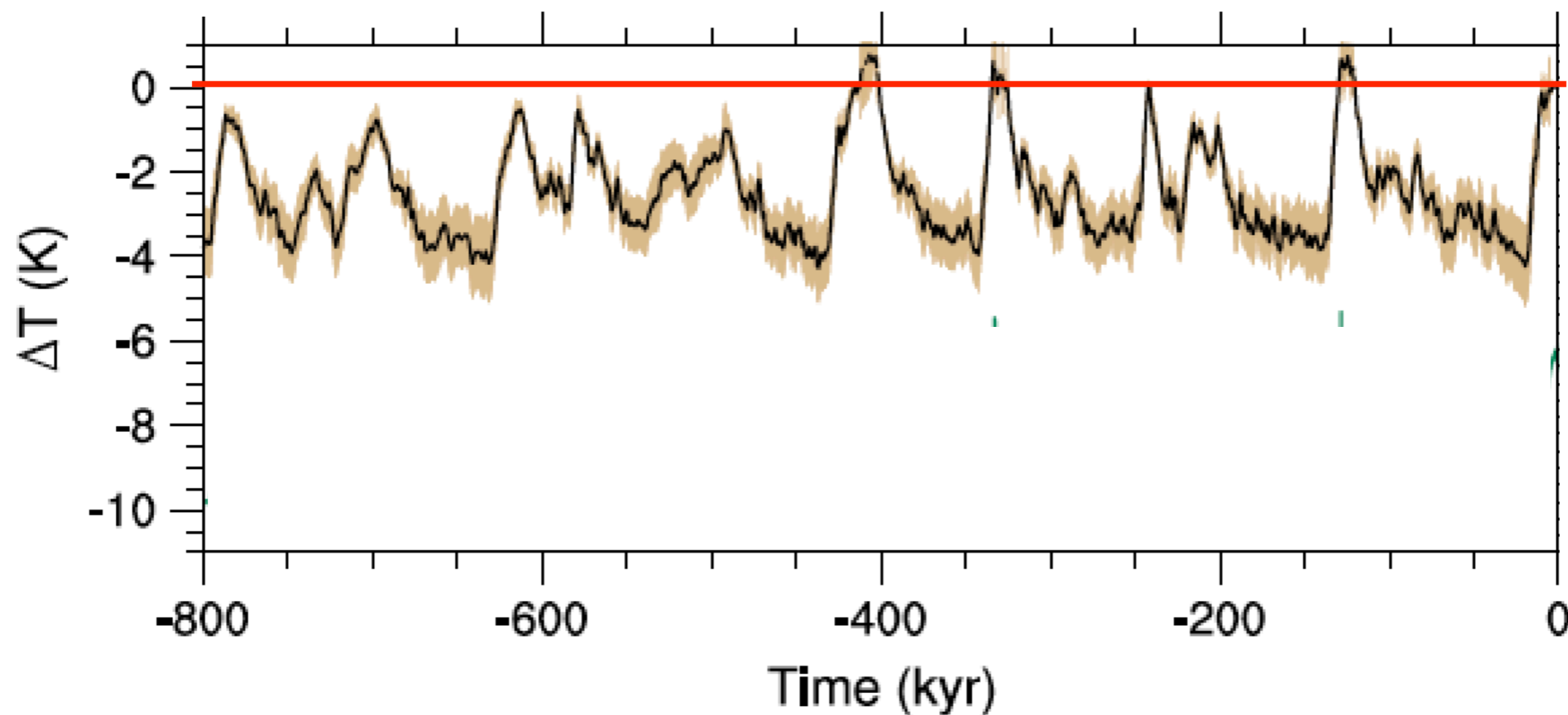
2. Klimaatgevoeligheid

forcing vs. terugkoppeling

3. Klimaatmodellen

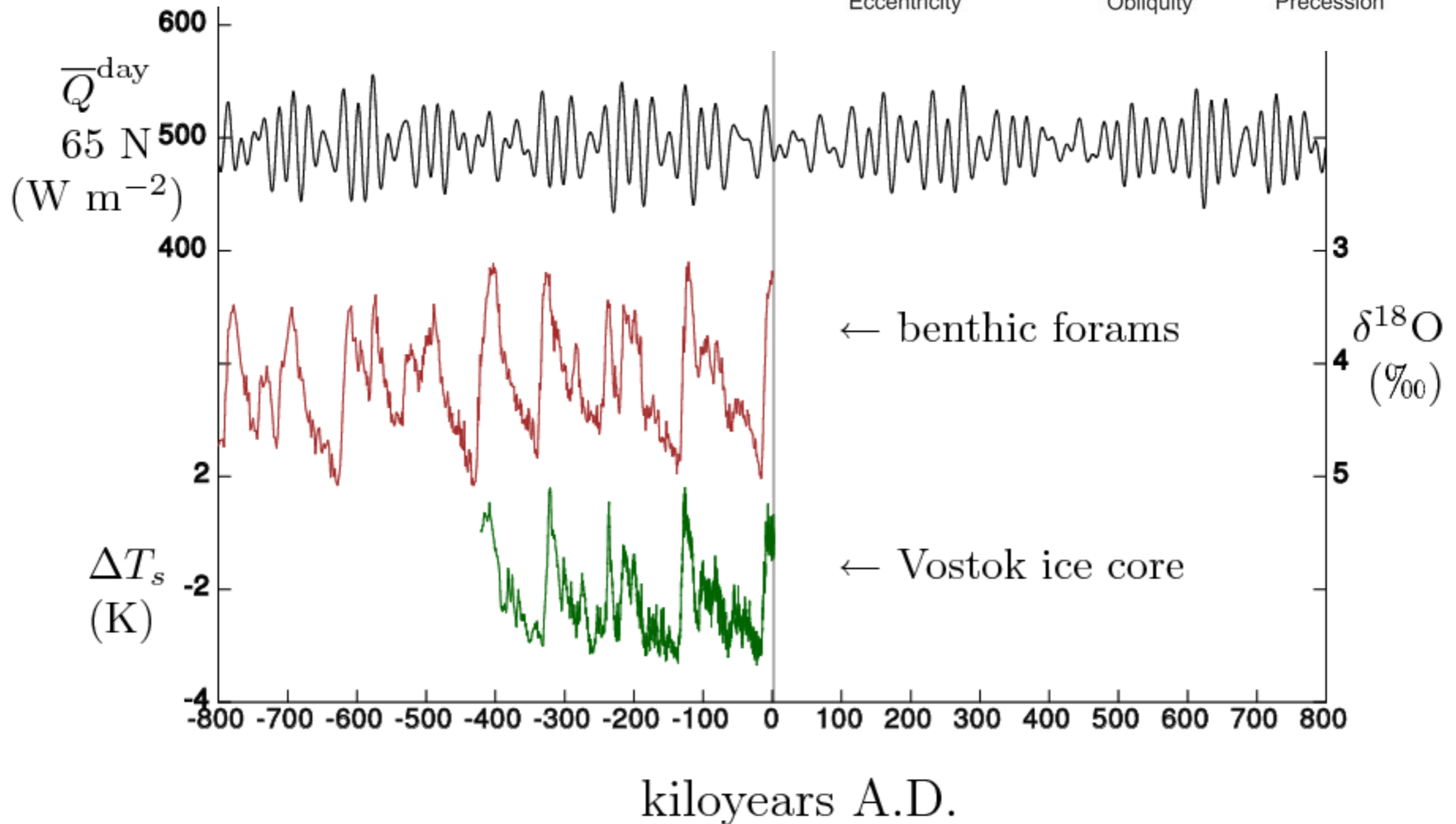
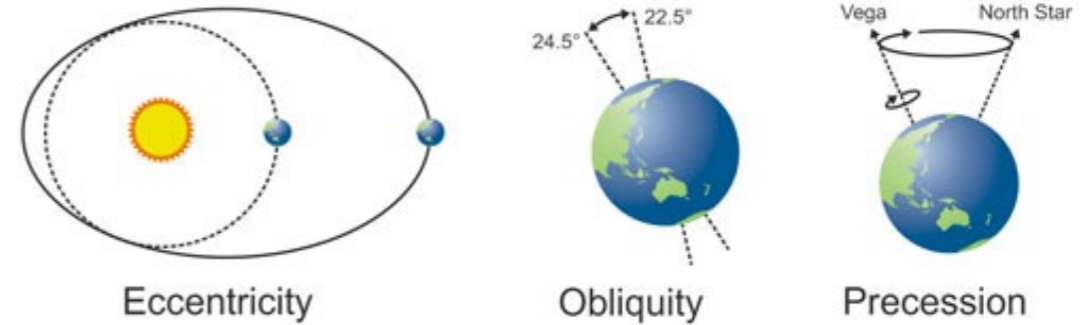
'fit for purpose'

Mondiaal gemiddelde oppervlakte temperatuur afwijkingen t.o.v. preïndustrieel

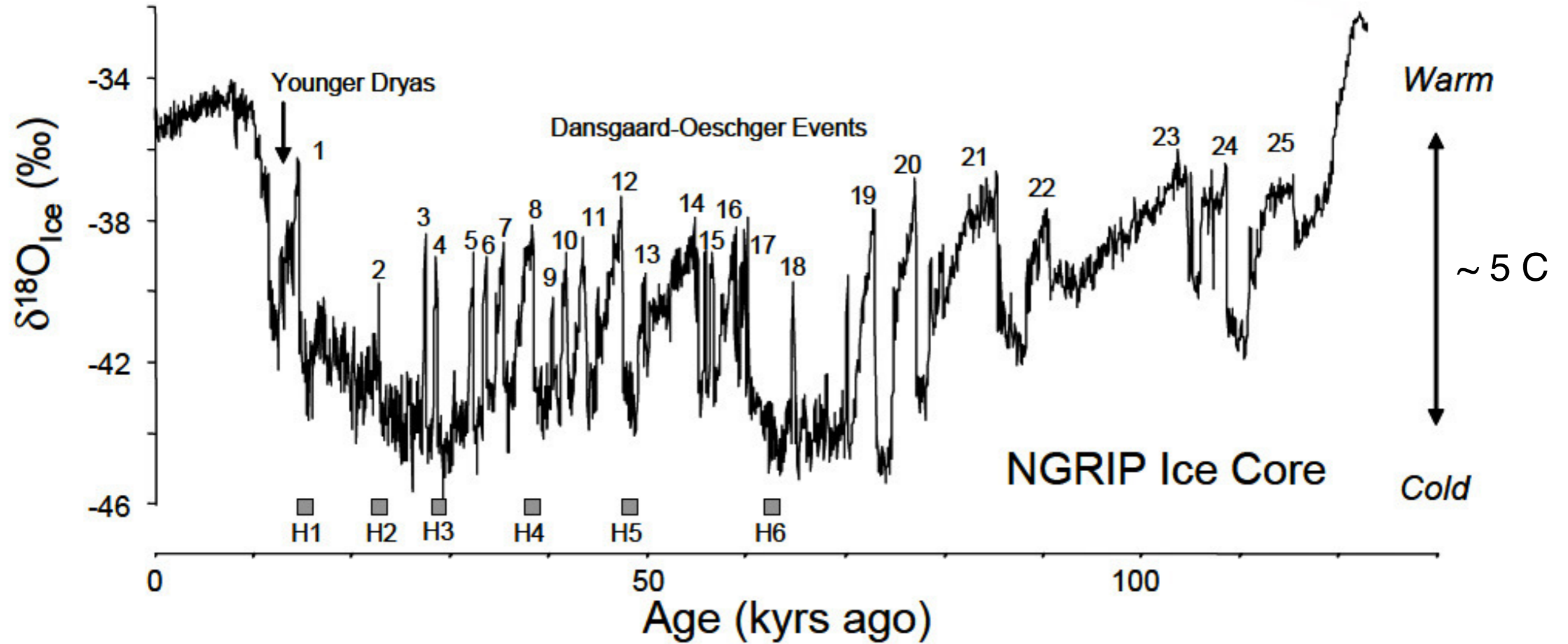
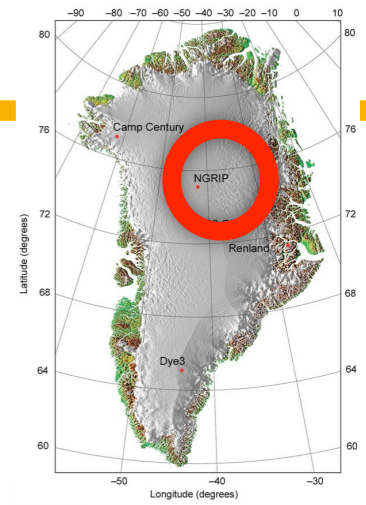


Forcing - Respon

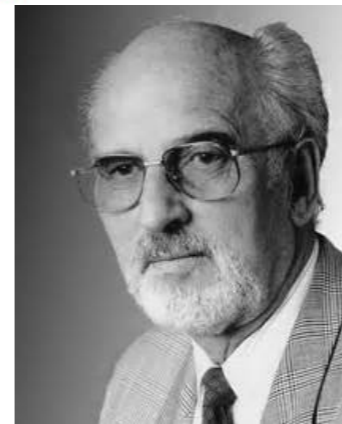
Milankovitch Cycles



Temperatuur op Groenland

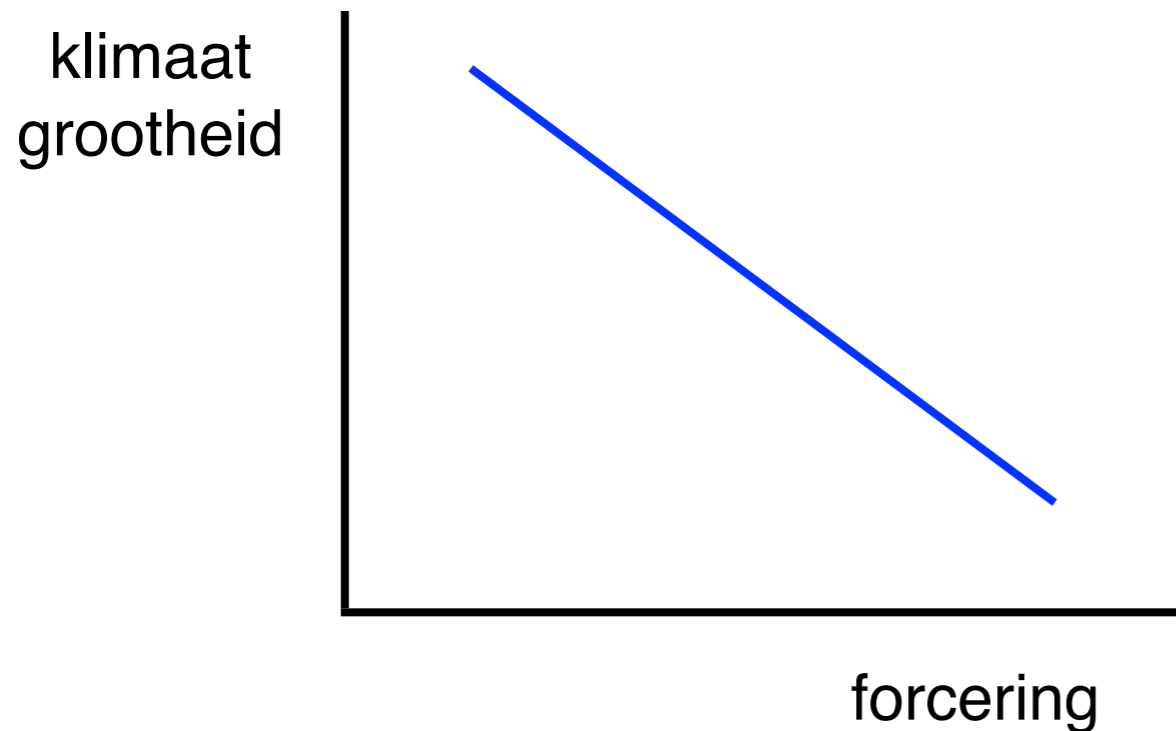


Dansgaard

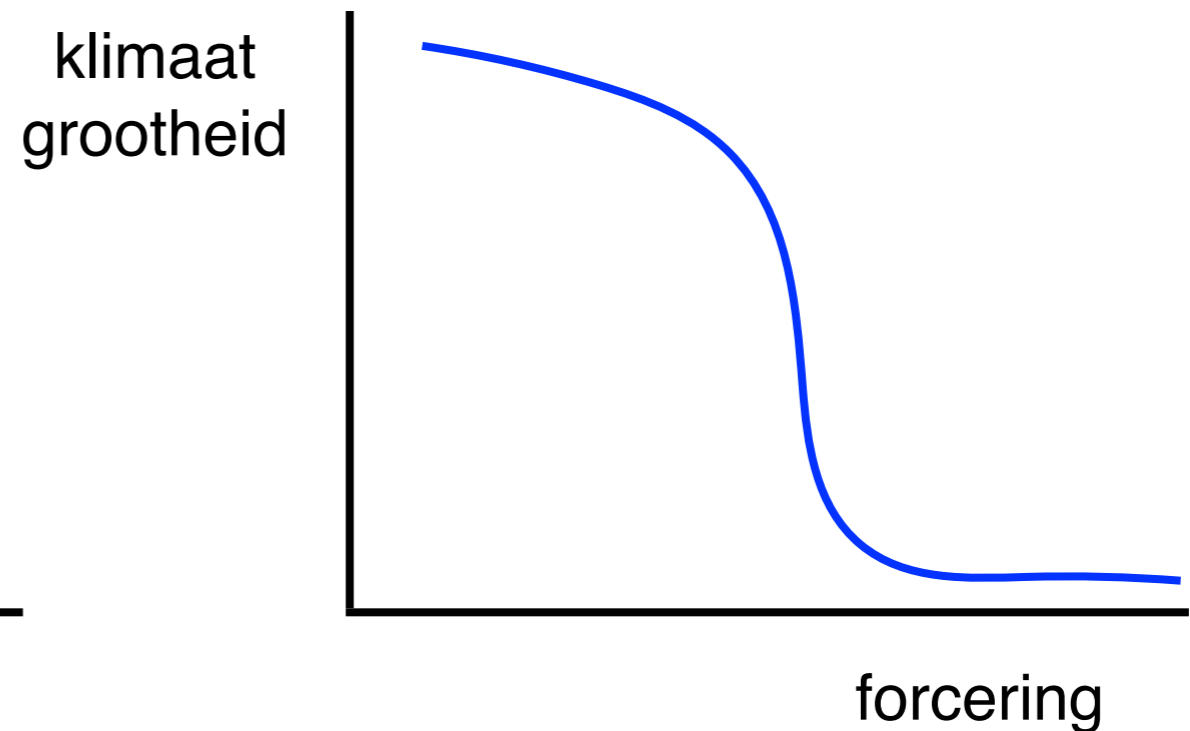


Oeschger

Forcing - respons relaties



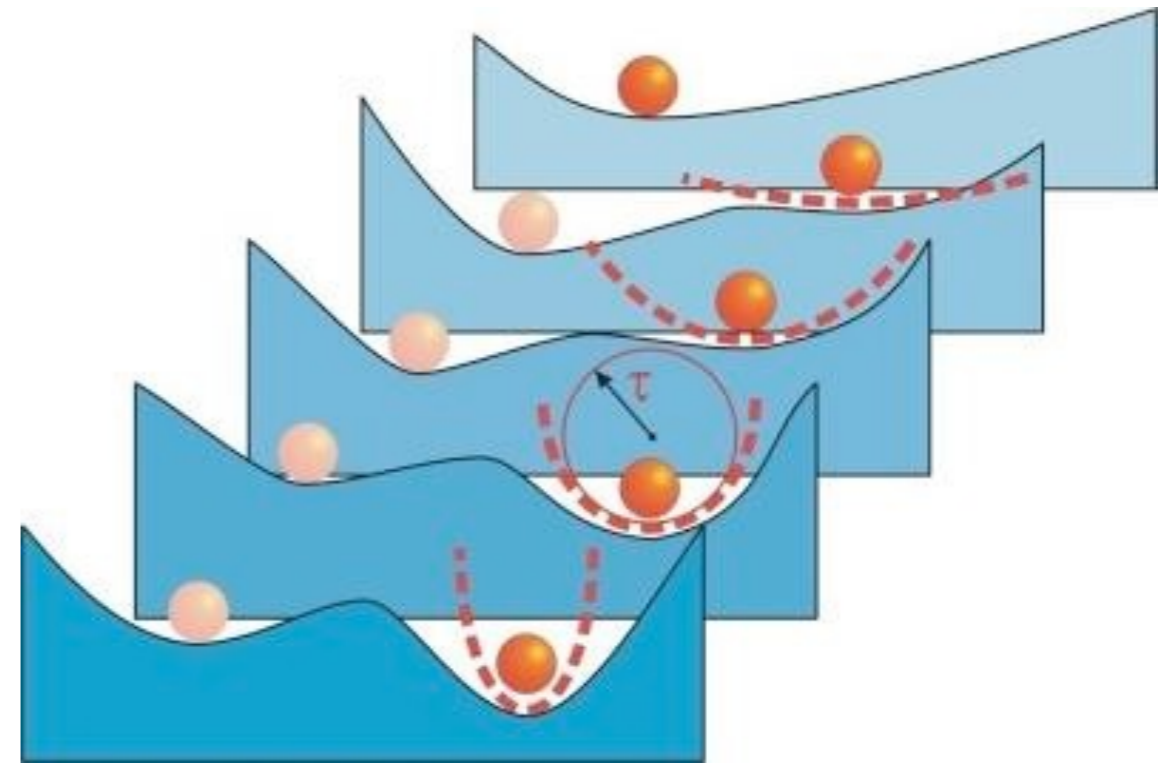
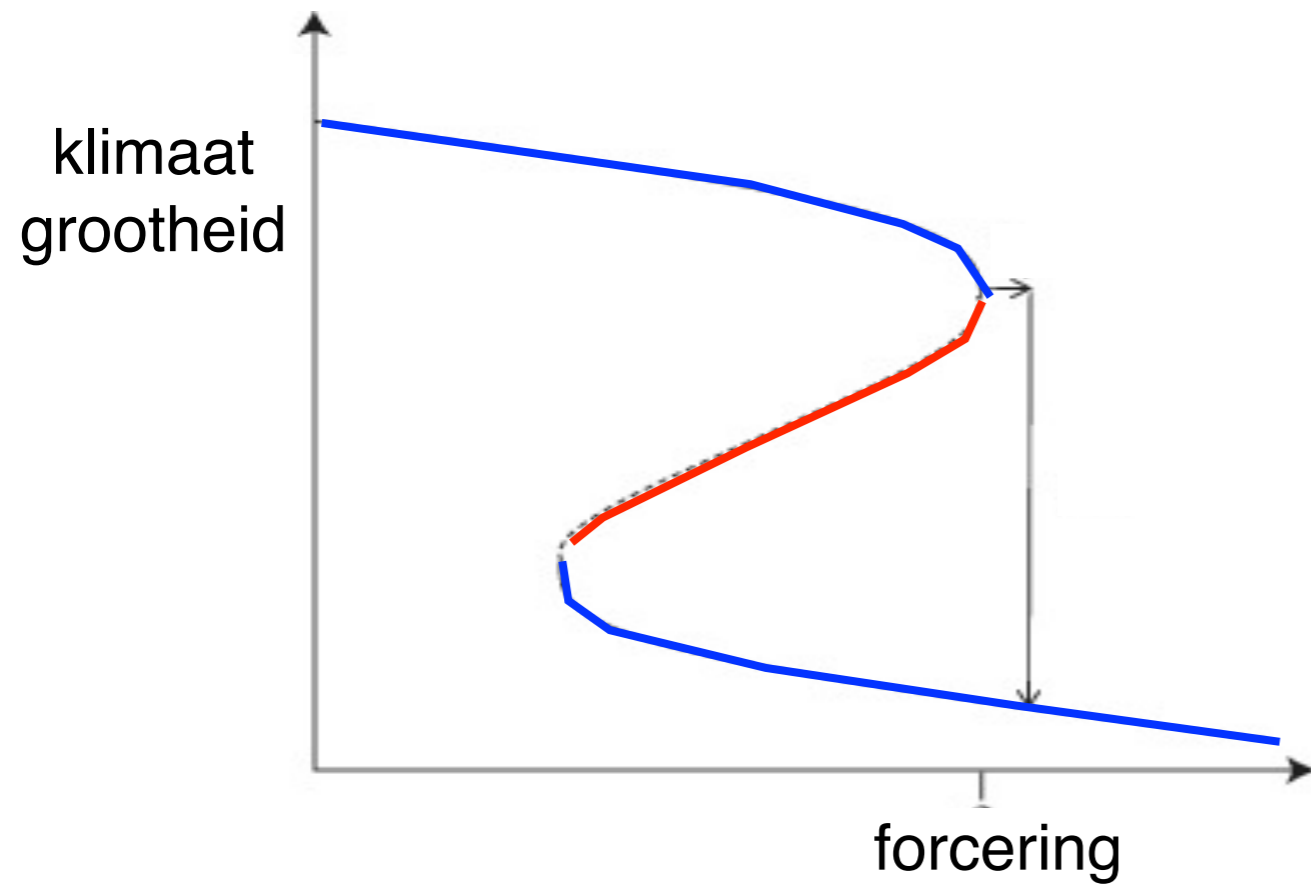
Voorbeeld: diffusie



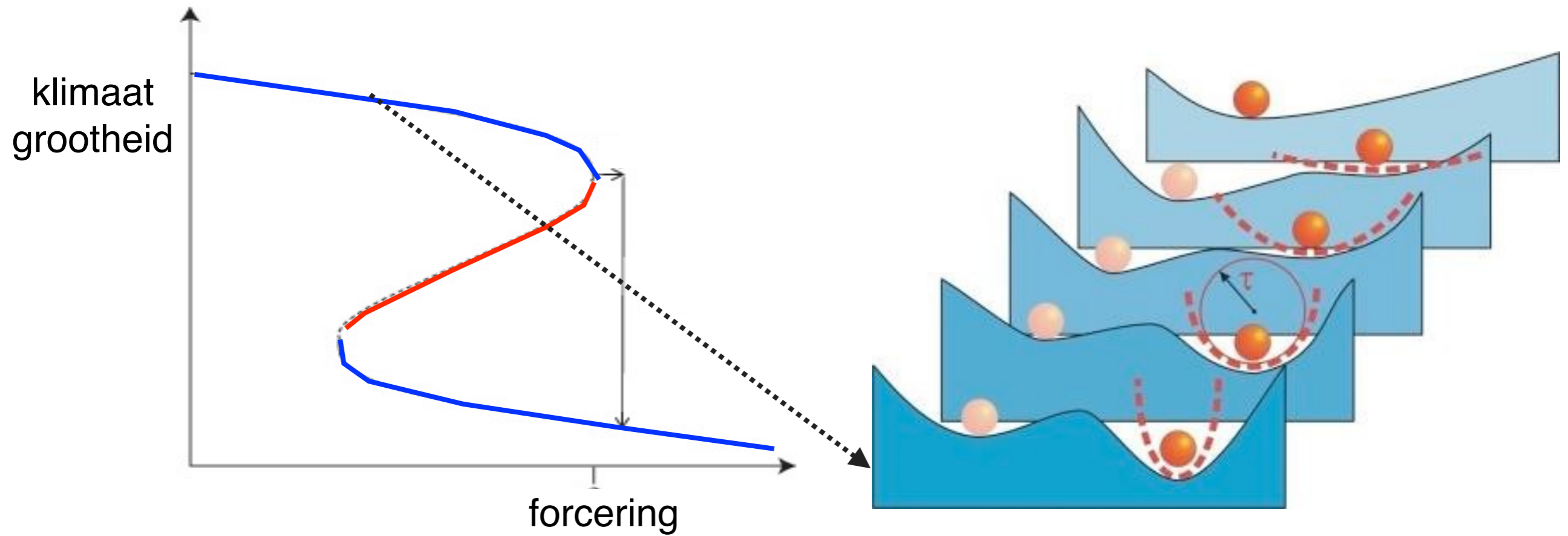
Voorbeeld: straling

Afhankelijk van niet-lineaire processen (advectie, straling) en terugkoppelingen

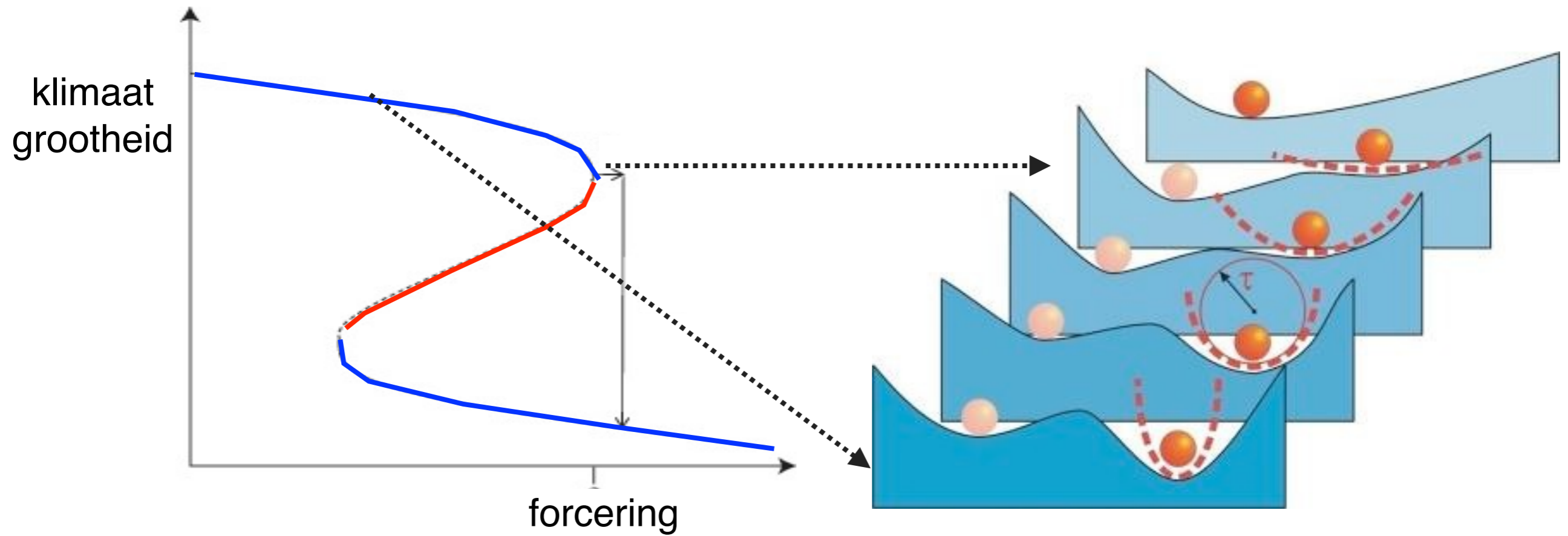
Kritische condities



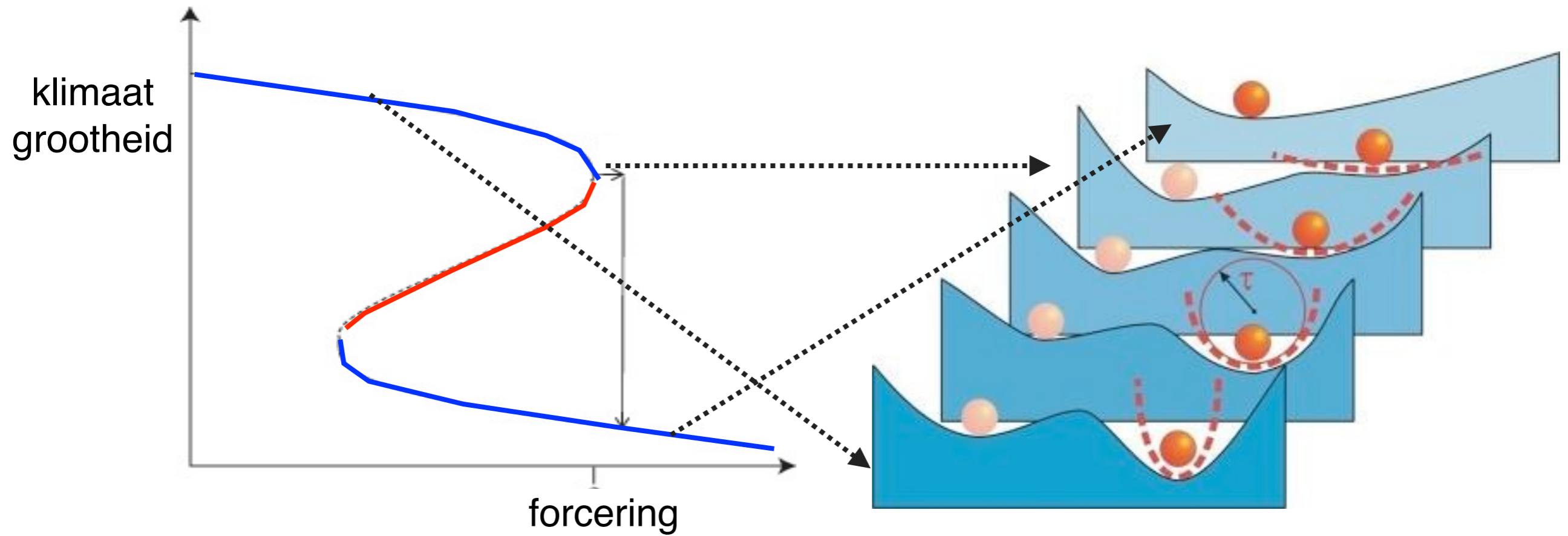
Kritische condities



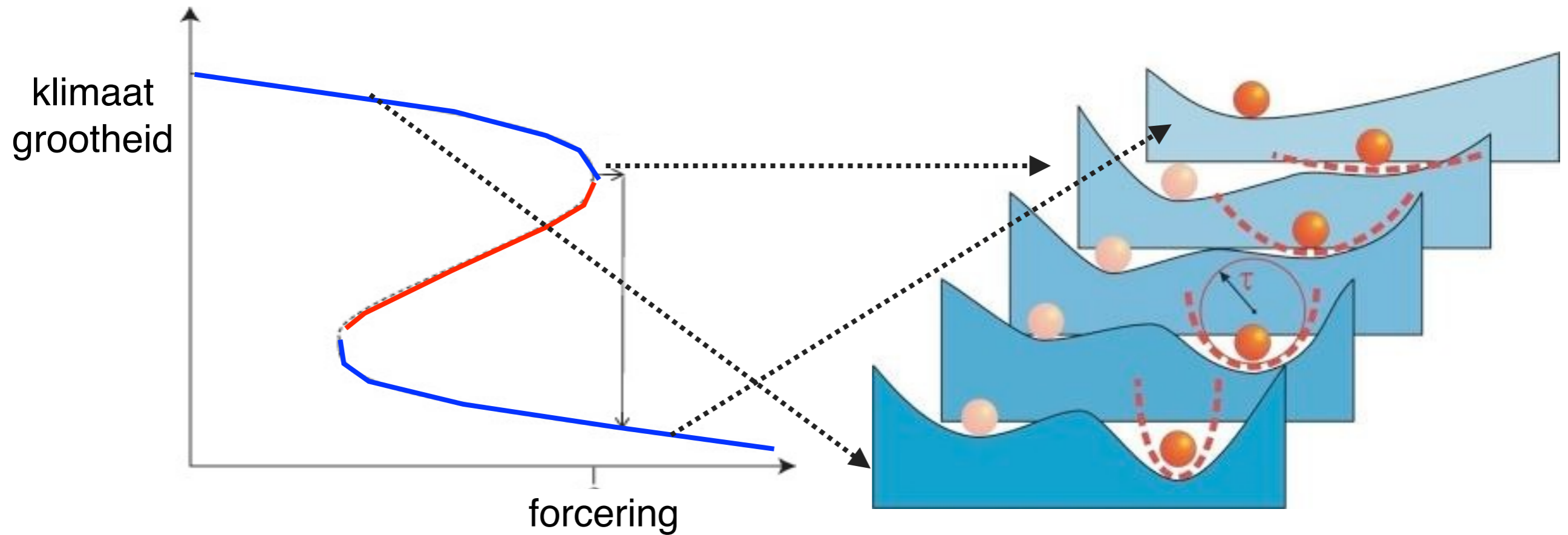
Kritische condities



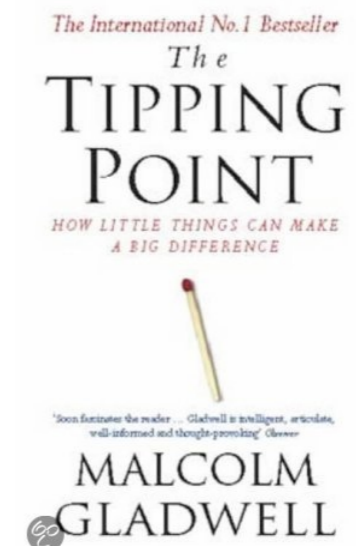
Kritische condities



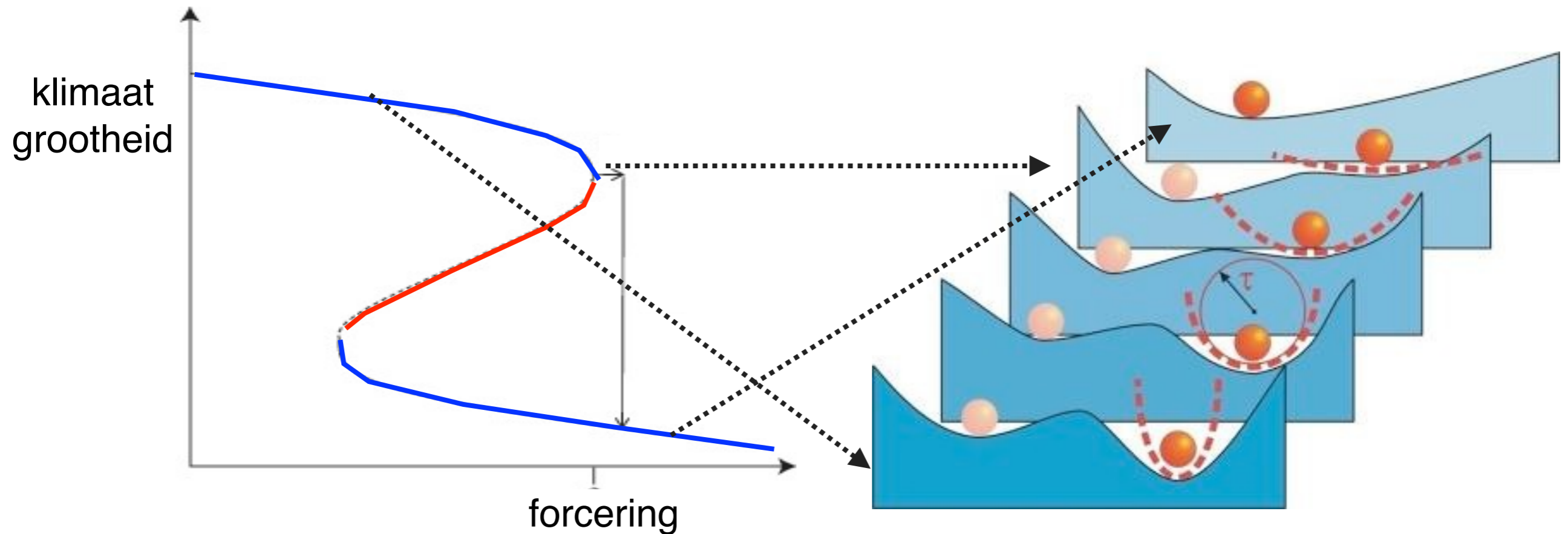
Kritische condities



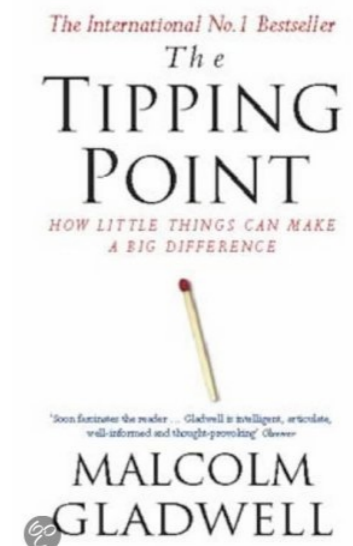
Kantelpunt (Tipping point):
De condities waarbij de toekomstige toestand kwalitatief verandert.



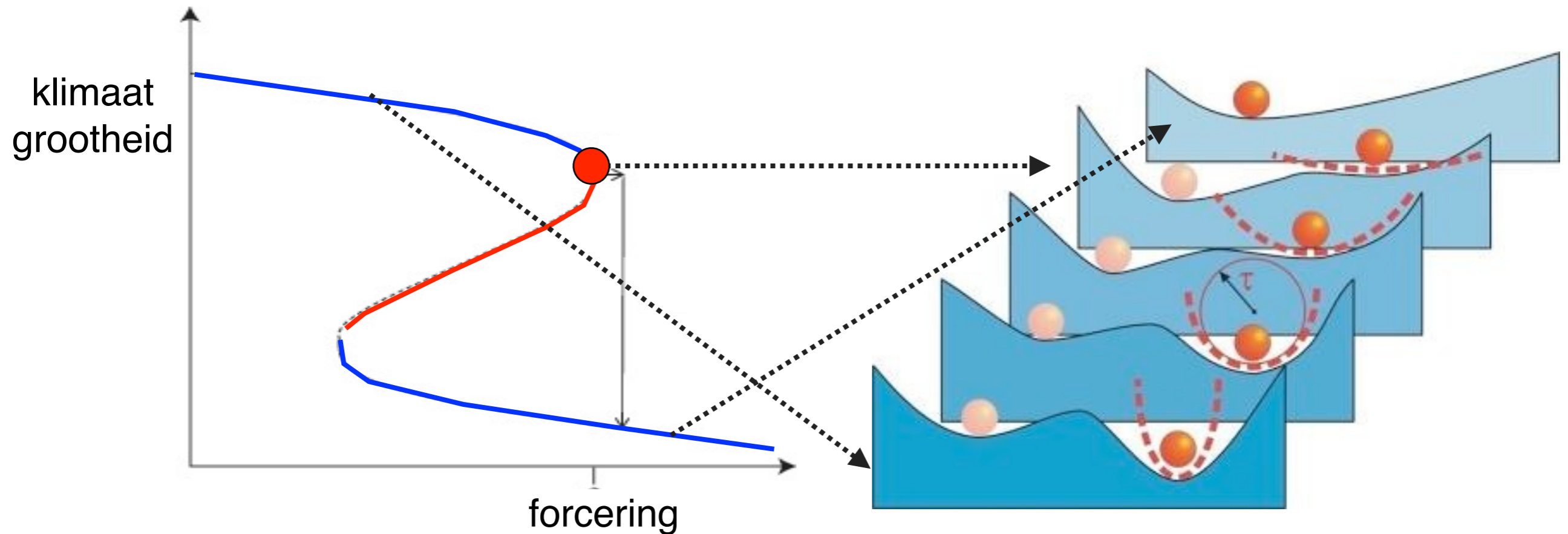
Kritische condities



Kantelpunt (Tipping point):
De condities waarbij de toekomstige toestand kwalitatief verandert.

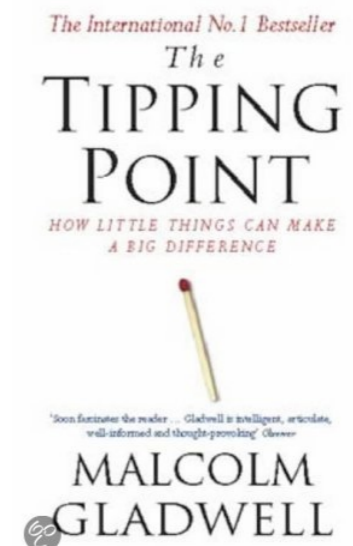


Kritische condities

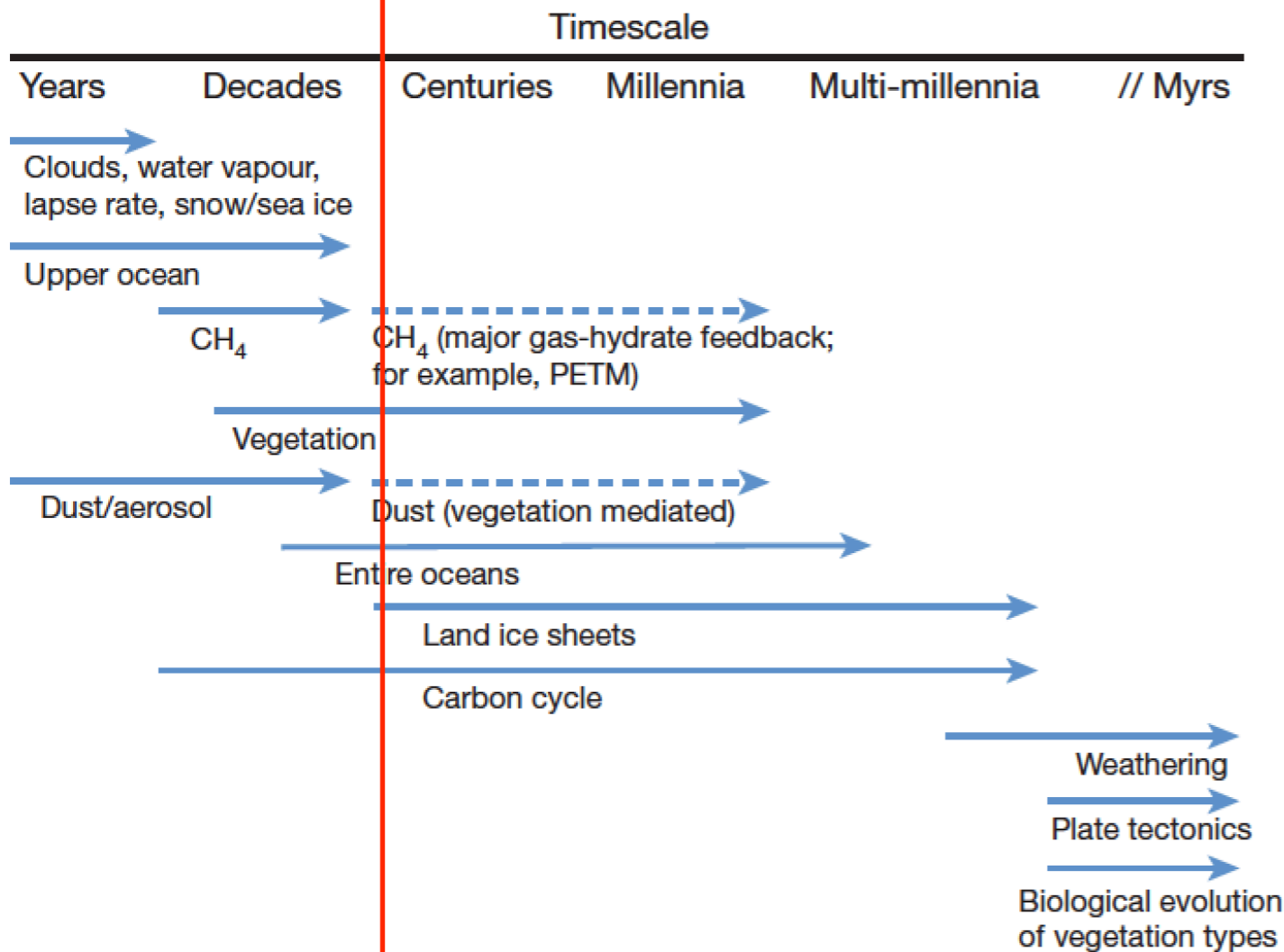


Kantelpunt (Tipping point):

De condities waarbij de toekomstige toestand kwalitatief verandert.



Terugkoppelingen op verschillende tijdschalen



$$\lambda_P = -\frac{1}{S_0} W m^{-2} K^{-1}$$

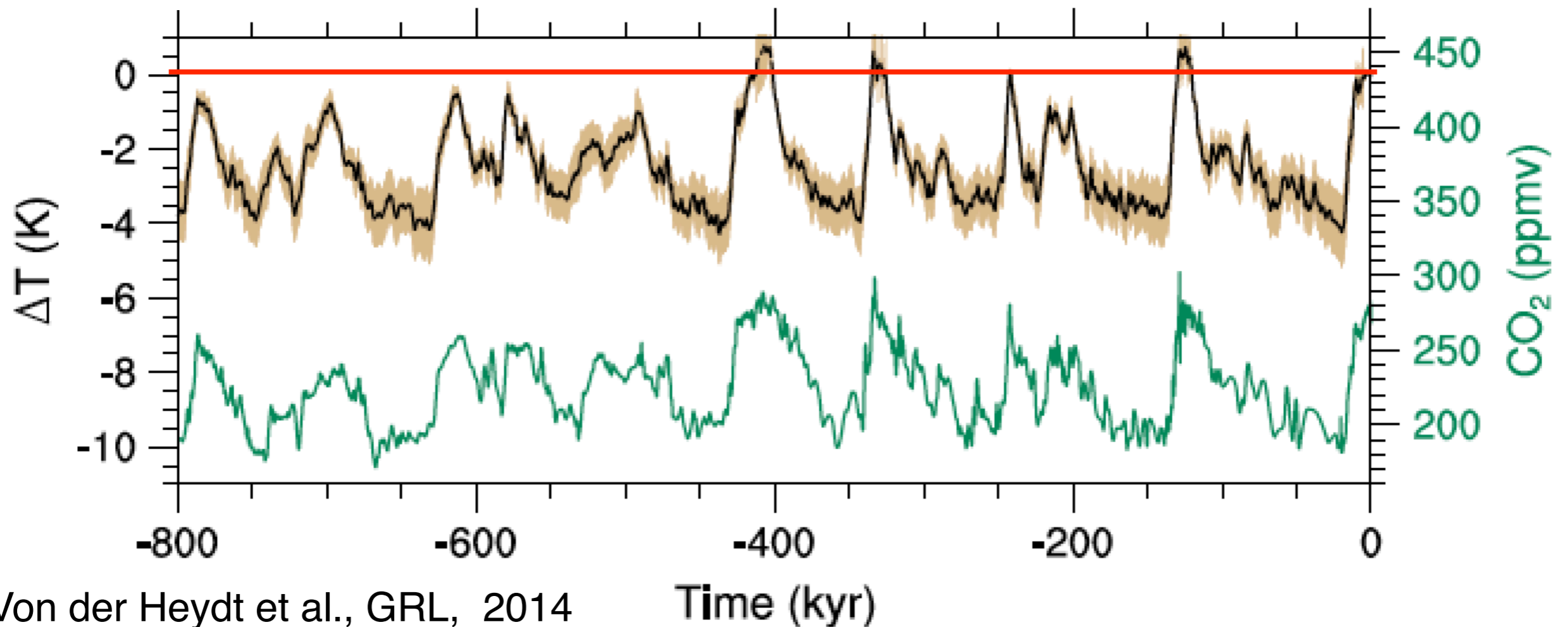
$$S_0 = 0.3 K / (W m^{-2})$$

$$S^a = \frac{\Delta T}{\Delta R} = \frac{-1}{\lambda_P + \sum_{i=1}^N \lambda_i^f}$$

$$S^a = 0.8 \pm 0.4 K / (W / m^2)$$

Charney klimaatgevoeligheid
 'snelle' terugkoppelingen

Mondiaal gemiddelde oppervlakte temperatuur afwijkingen t.o.v. preïndustrieel

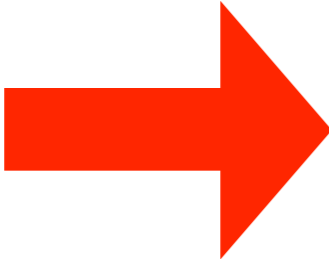


Schatting: $S^p = \frac{\Delta T}{\Delta R} \approx 2 \text{ K}/(W/m^2)$

Was het klimaat in het verleden veel gevoeliger dan nu?

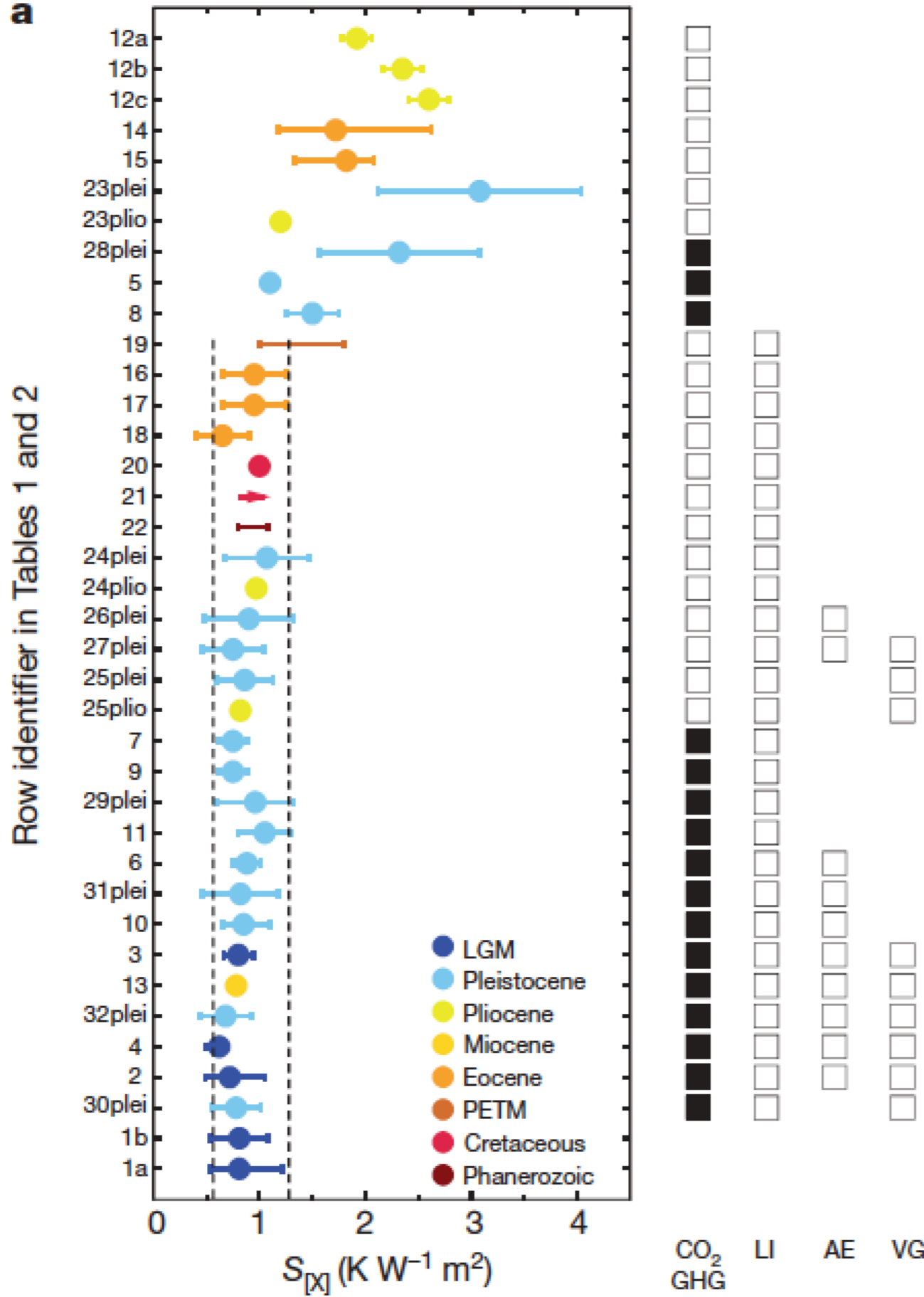
Hoe is Charney gevoeligheid te bepalen via proxy data?

correctie voor de effecten van langzame (tijdschaal > 100 jaar) terugkoppelingen (bijv. landijs-albedo)


$$S^a = S^p \left(1 + \frac{\sum_{j=1}^M \lambda_j^s}{\lambda_p + \sum_{i=1}^N \lambda_i^f} \right)$$

slow

fast

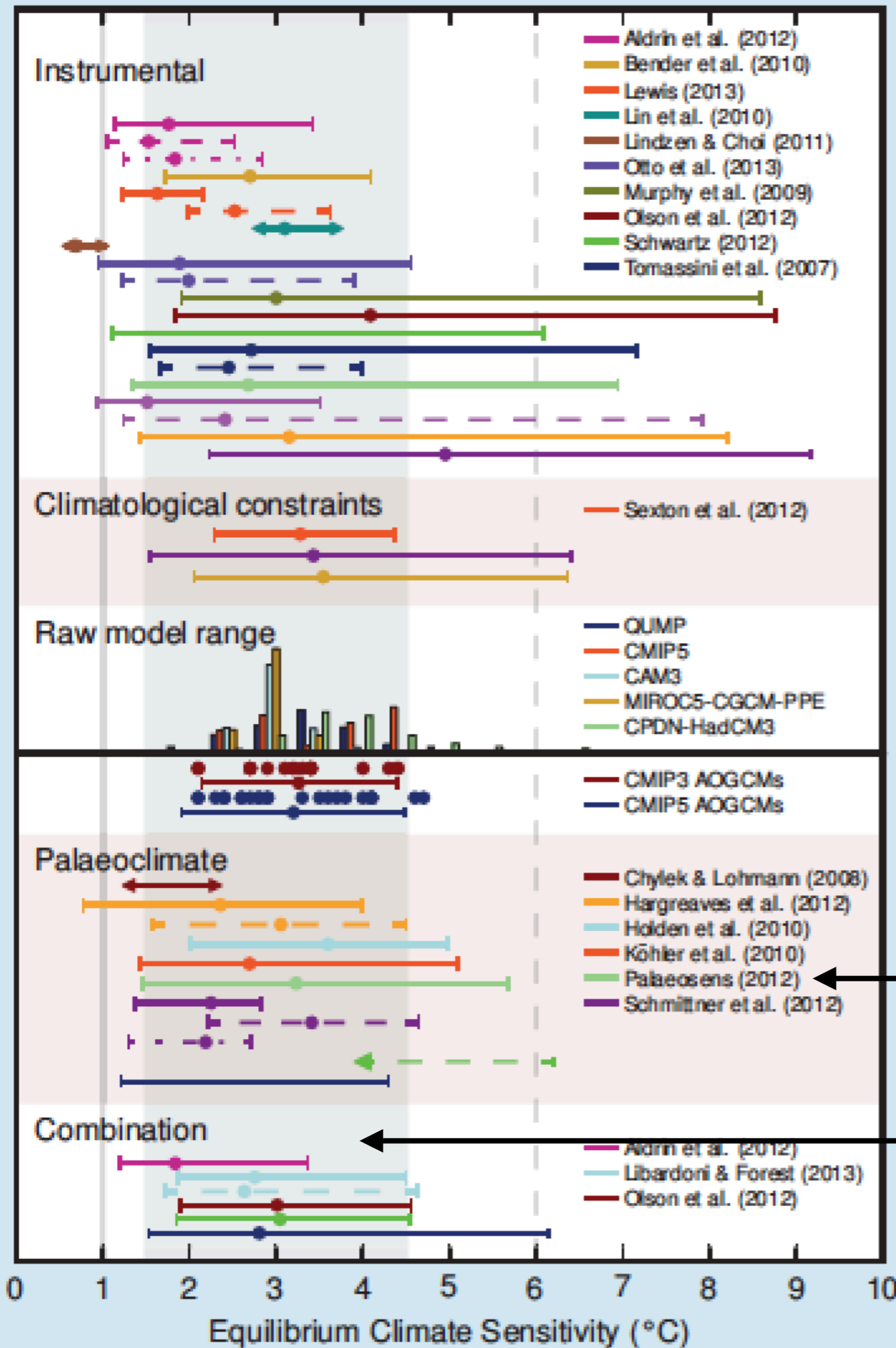


Schattingen van Charney klimaatgevoeligheid mbv proxy data

$$S^a(68\%) = 0.6 - 1.3K/(W/m^2)$$

Charney klimaatgevoeligheid (IPCC-AR5)

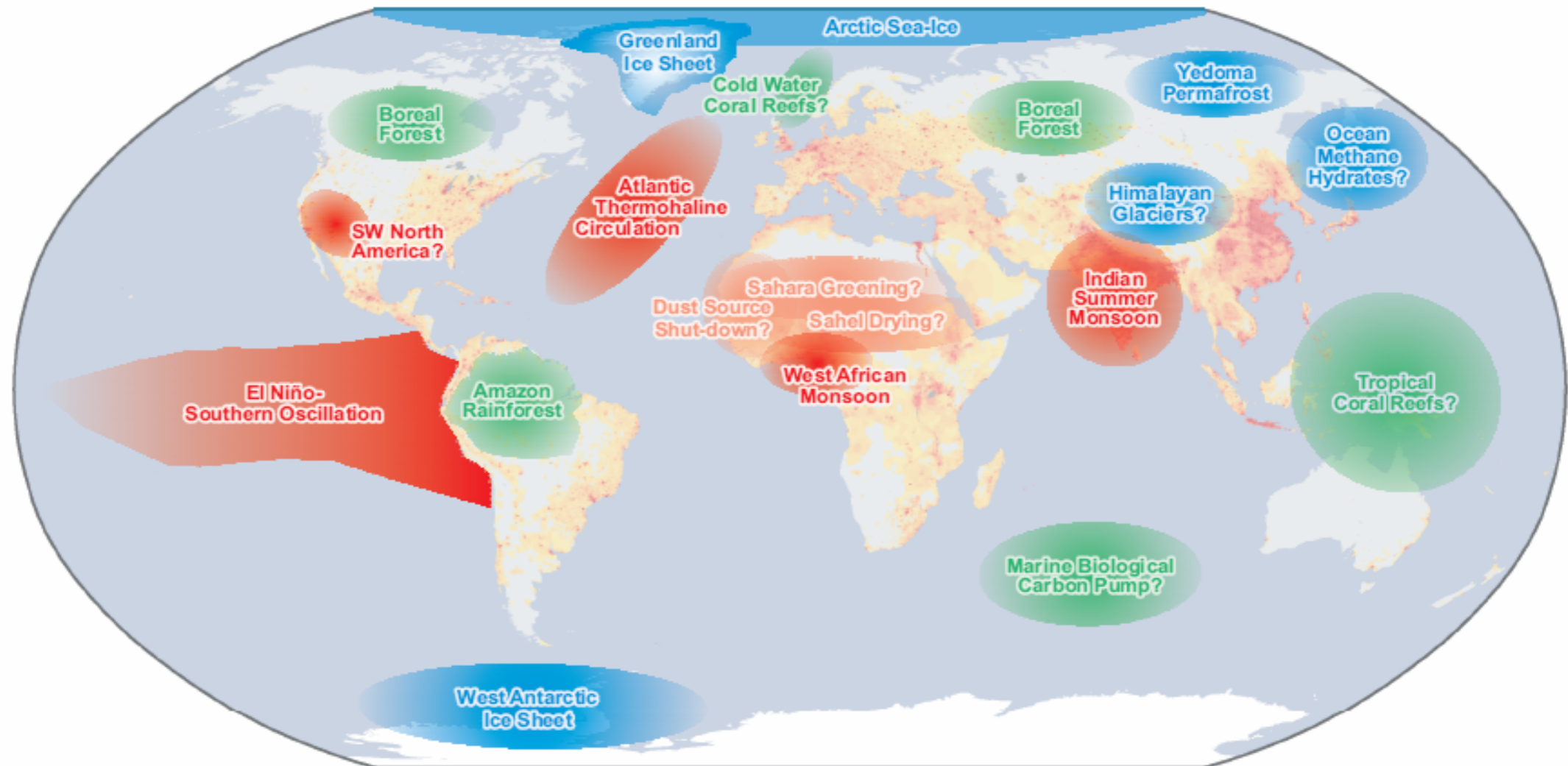
Klimaatmodellen



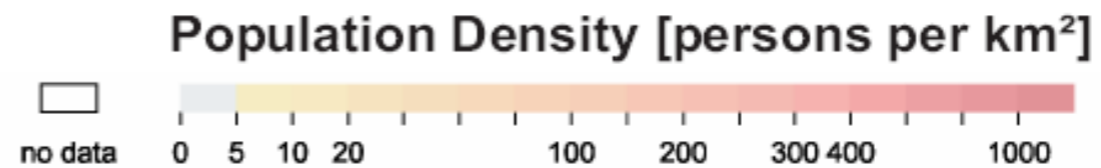
Palaeosense, 2012

‘likely range’
high confidence

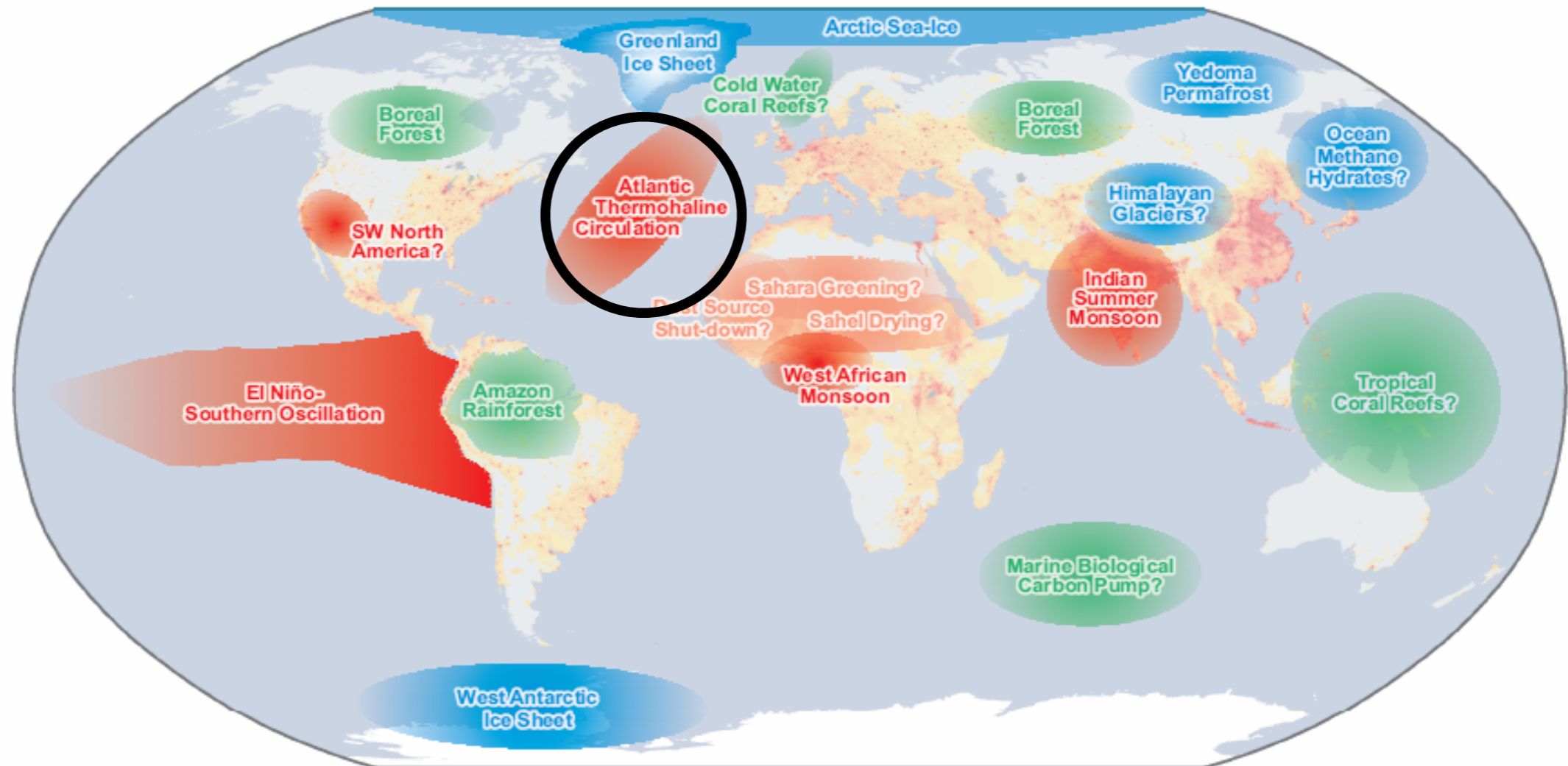
Subsystemen met kritische condities



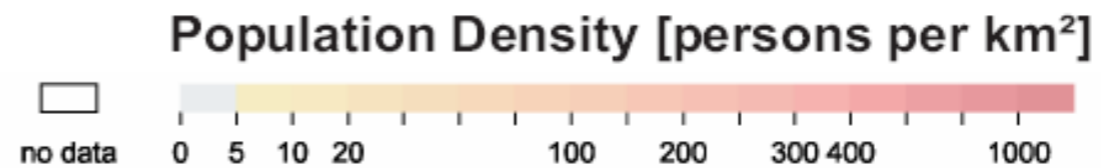
- Melting
- Circulation Change
- Biome Loss



Subsystemen met kritische condities

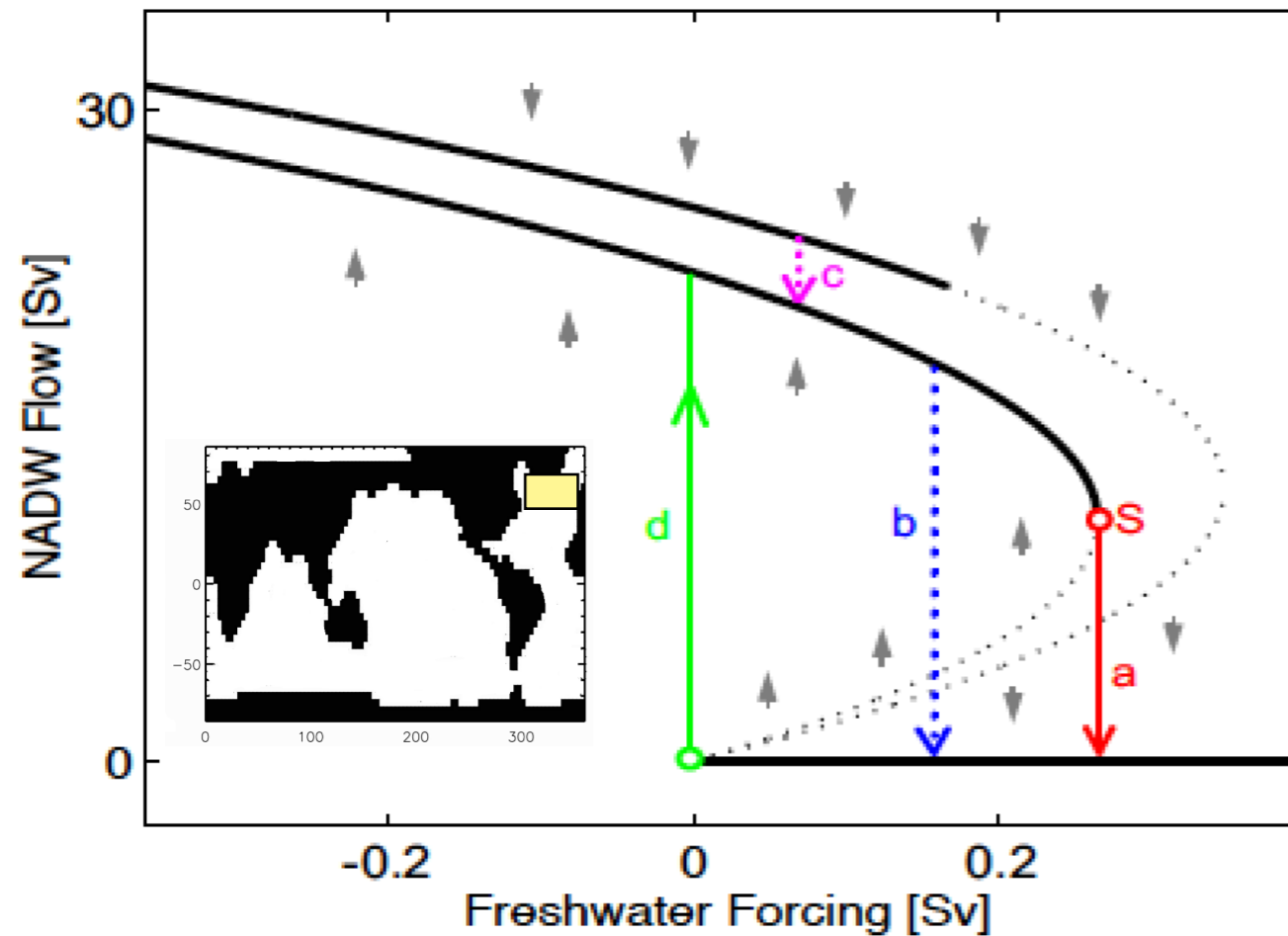


- Melting
- Circulation Change
- Biome Loss



Ineenstorting van de Atlantische Oceaancirculatie (AMOC)

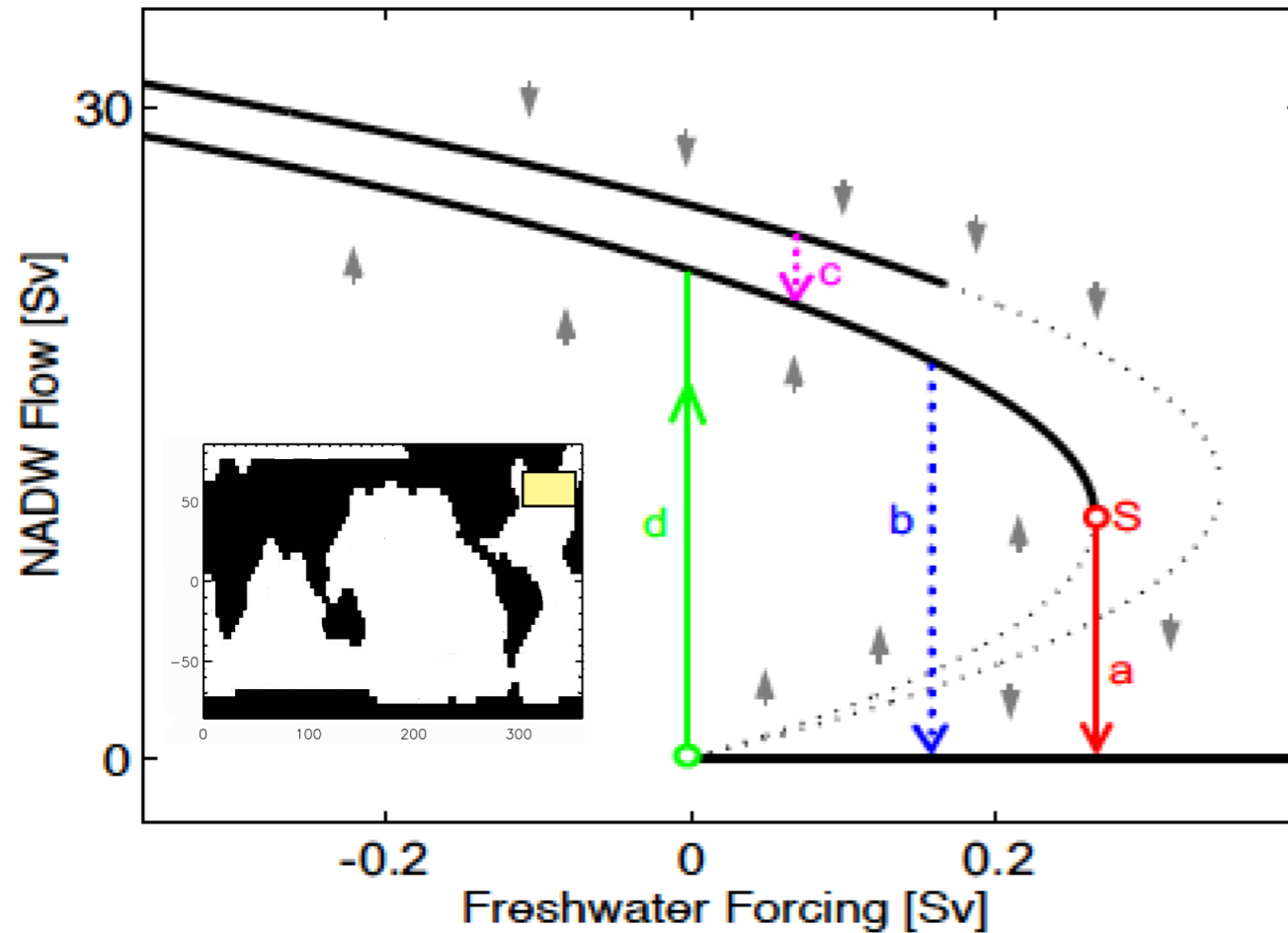
Sterkte circulatie



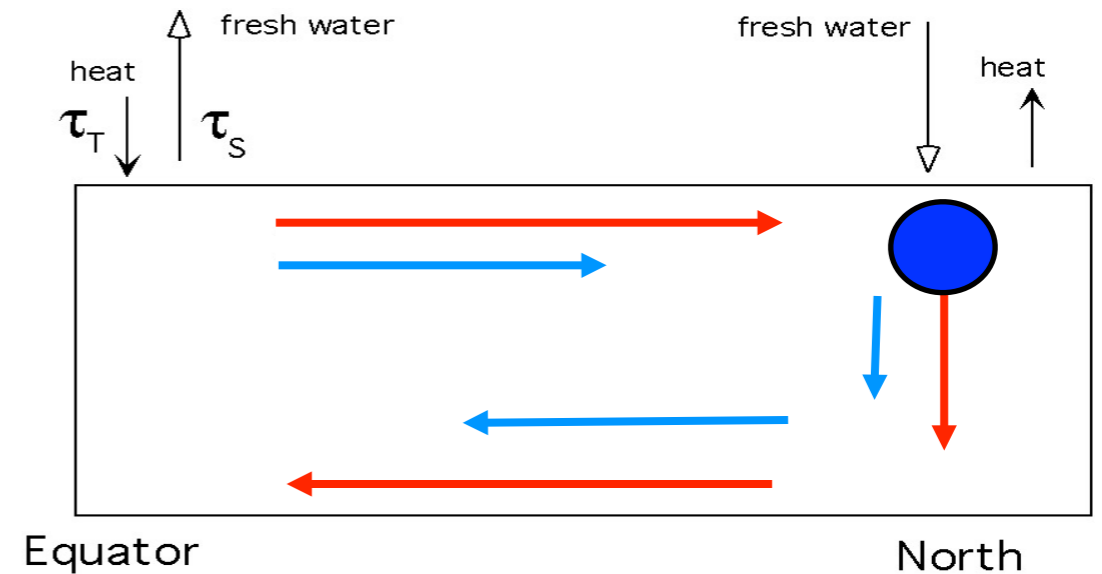
IPCC-AR5: “Although neither possibility can be excluded entirely, it is *unlikely* that the AMOC will collapse beyond the end of the 21st century for the scenarios considered, but a collapse beyond the 21st century for large sustained warming cannot be excluded. There is *low confidence* in assessing the evolution of AMOC beyond the 21st century because of limited number of analyses and equivocal results”.

Ineenstorting van de Atlantische Oceaancirculatie (AMOC)

Sterkte circulatie



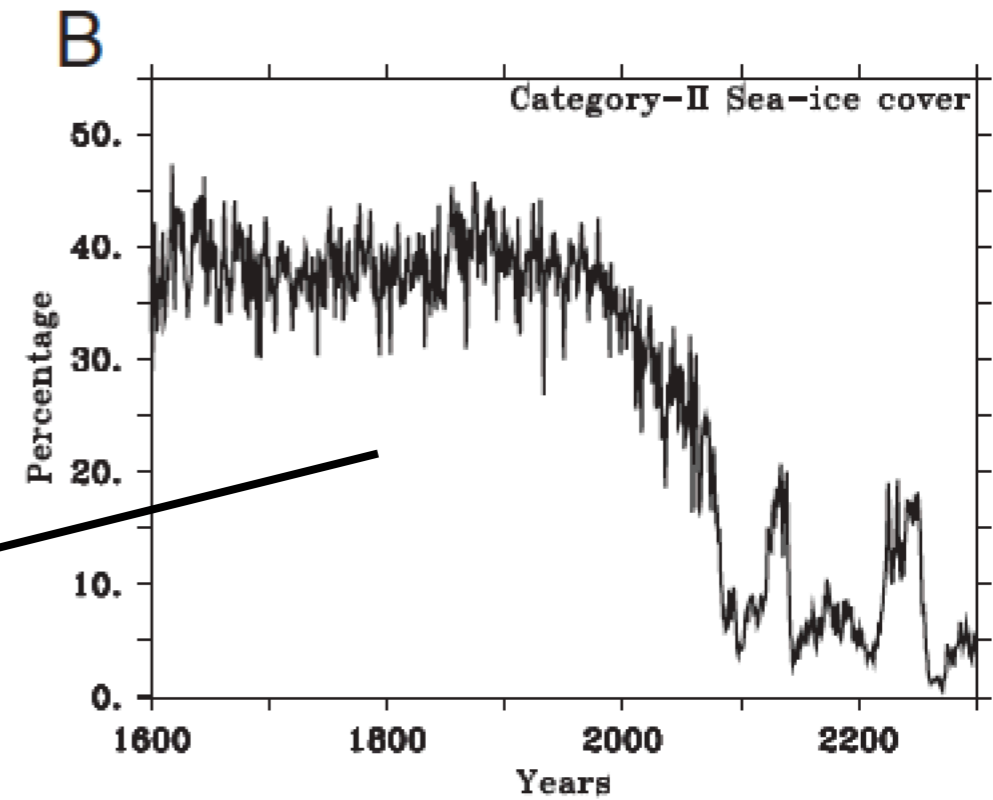
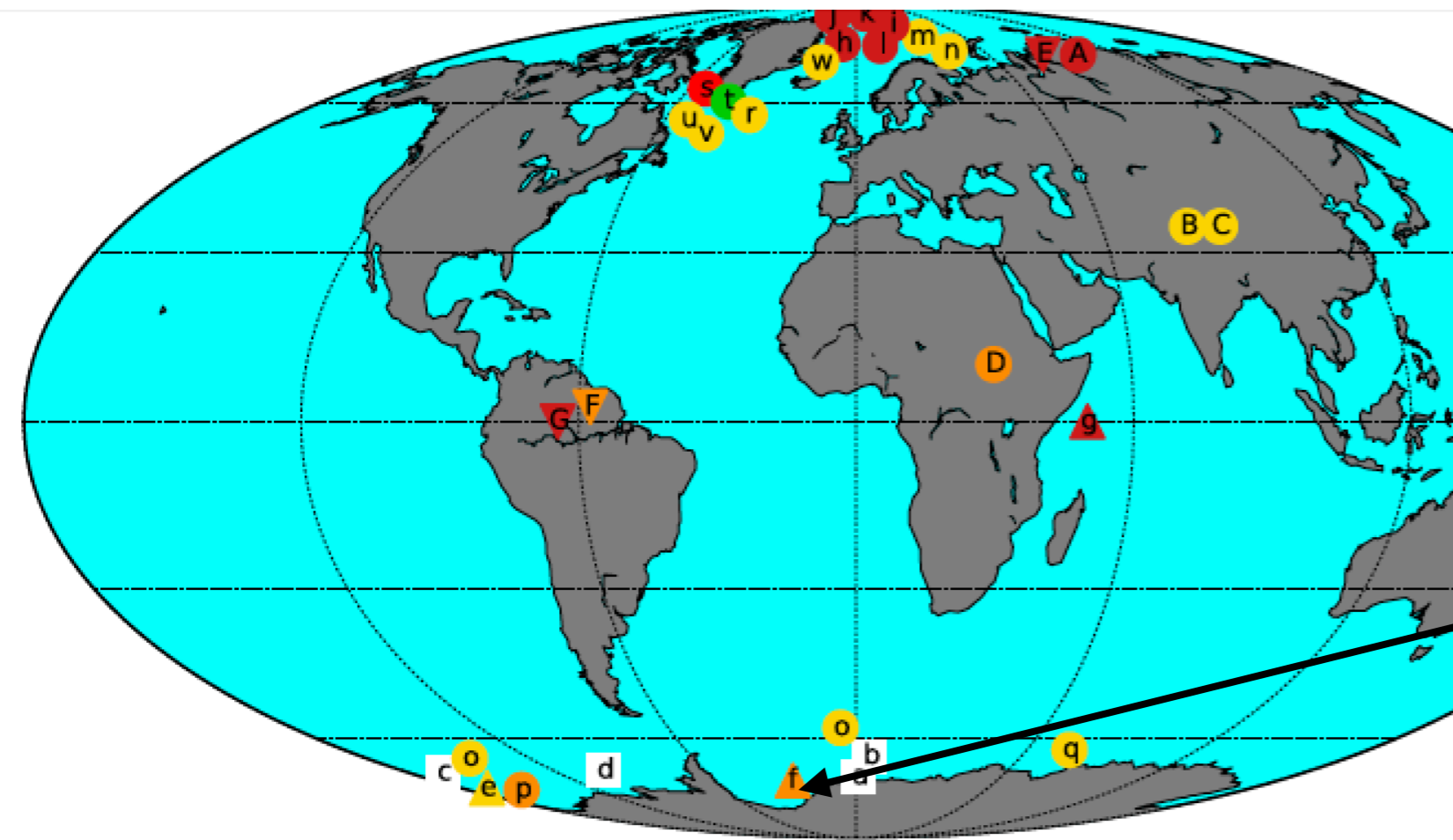
Zout-advectie terugkoppeling



Niet-lineair proces: advection

IPCC-AR5: “Although neither possibility can be excluded entirely, it is *unlikely* that the AMOC will collapse beyond the end of the 21st century for the scenarios considered, but a collapse beyond the 21st century for large sustained warming cannot be excluded. There is *low confidence* in assessing the evolution of AMOC beyond the 21st century because of limited number of analyses and equivocal results”.

CMIP5: kritische condities?



Pre-Industrial

0 1 2 3 4 11

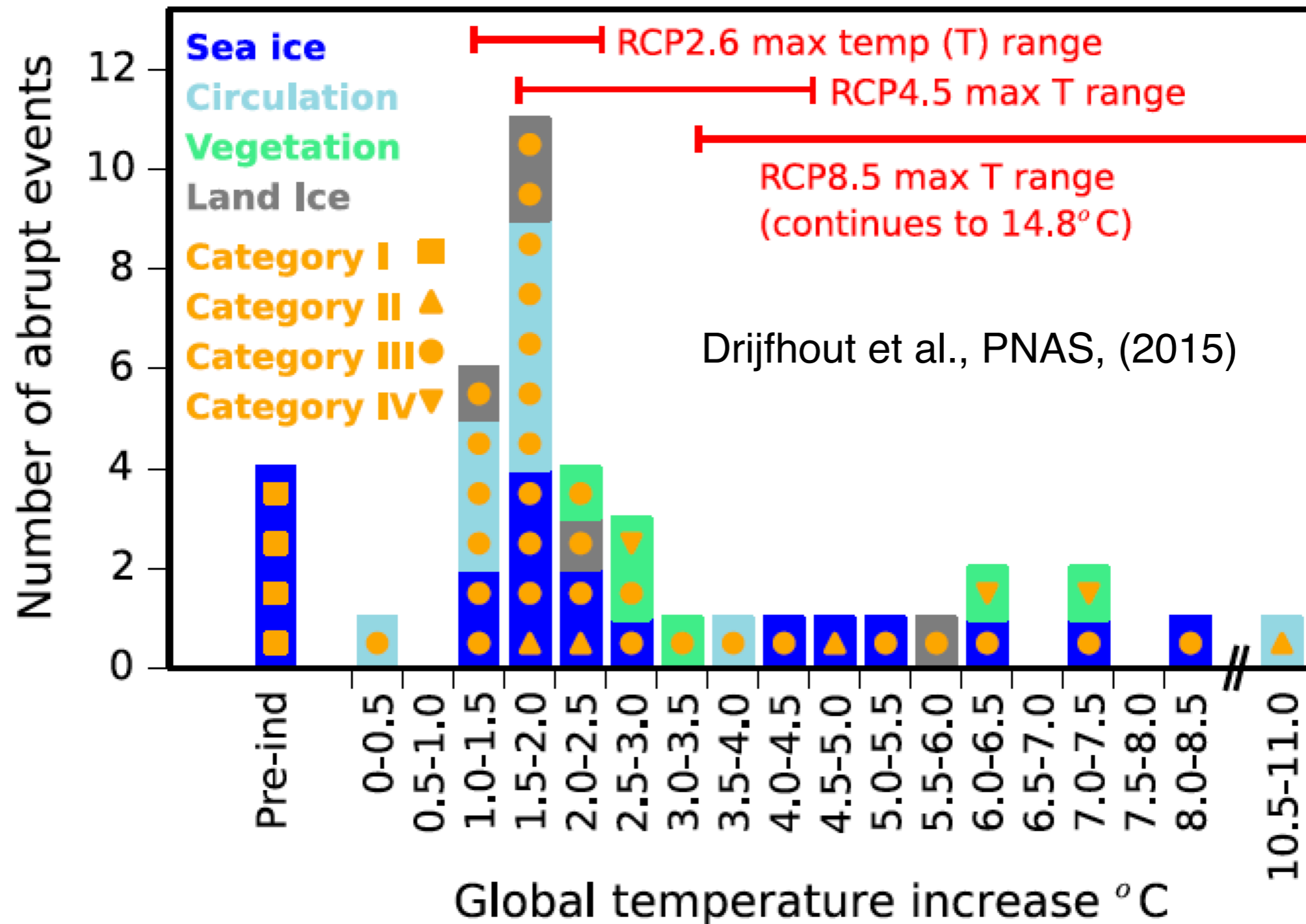
Lowest Global Warming level of abrupt occurrence (K)

Sea ice bimodality: (a):bcc-csm1-1, (b):bcc-csm1-1-m, (c):GFDL-CM3, (d): IPSL-CM5A-LR, (e):GISS-E2-R, (f):GISS-E2-H
 Upwelling change: (g):IPSL-CM5A-LR
 Arctic sea ice collapse: (h):CCSM4, (i):CNRM-CM5, (j):CSIRO-Mk3-6-0, (k):MPI-ESM-LR, (l):HadGEM2-ES
 Abrupt sea ice loss: (m):CanESM2, (n):CMCC-CESM, (o):MRI-CGCM3, (p):FGOALS-g2
 Abrupt sea ice increase: (q):MRI-CGCM3
 Convection collapse: (r):GISS-E2-R, (s):CESM-CAM5, (t):GFDL-ESM2G, (u):MIROC5, (v):CSIRO-Mk3-6-0
 AMOC-induced collapse: (w):FIO-ESM

Permafrost collapse: (A):HadGEM2-ES
 Snow melt: (B):GISS-E2-H, (C):GISS-E2-R
 Vegetation composition change: (D):BNU-ESM
 Forest expansion: (E):HadGEM2-ES
 Forest Dieback: (F):HadGEM2-ES, (G):IPSL-CM5A-LR

Category I Category II Category III Category IV

Snelle veranderingen: relatie met globale opwarming

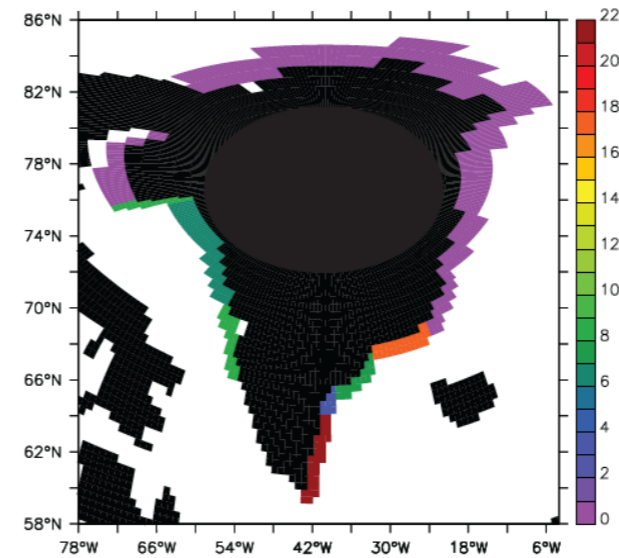
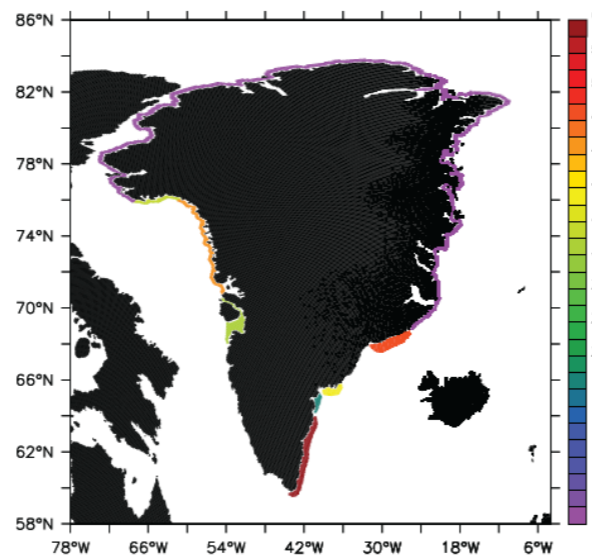


Geen model consistentie voor specifieke transitie

Zijn de CMIP5 modellen hiervoor

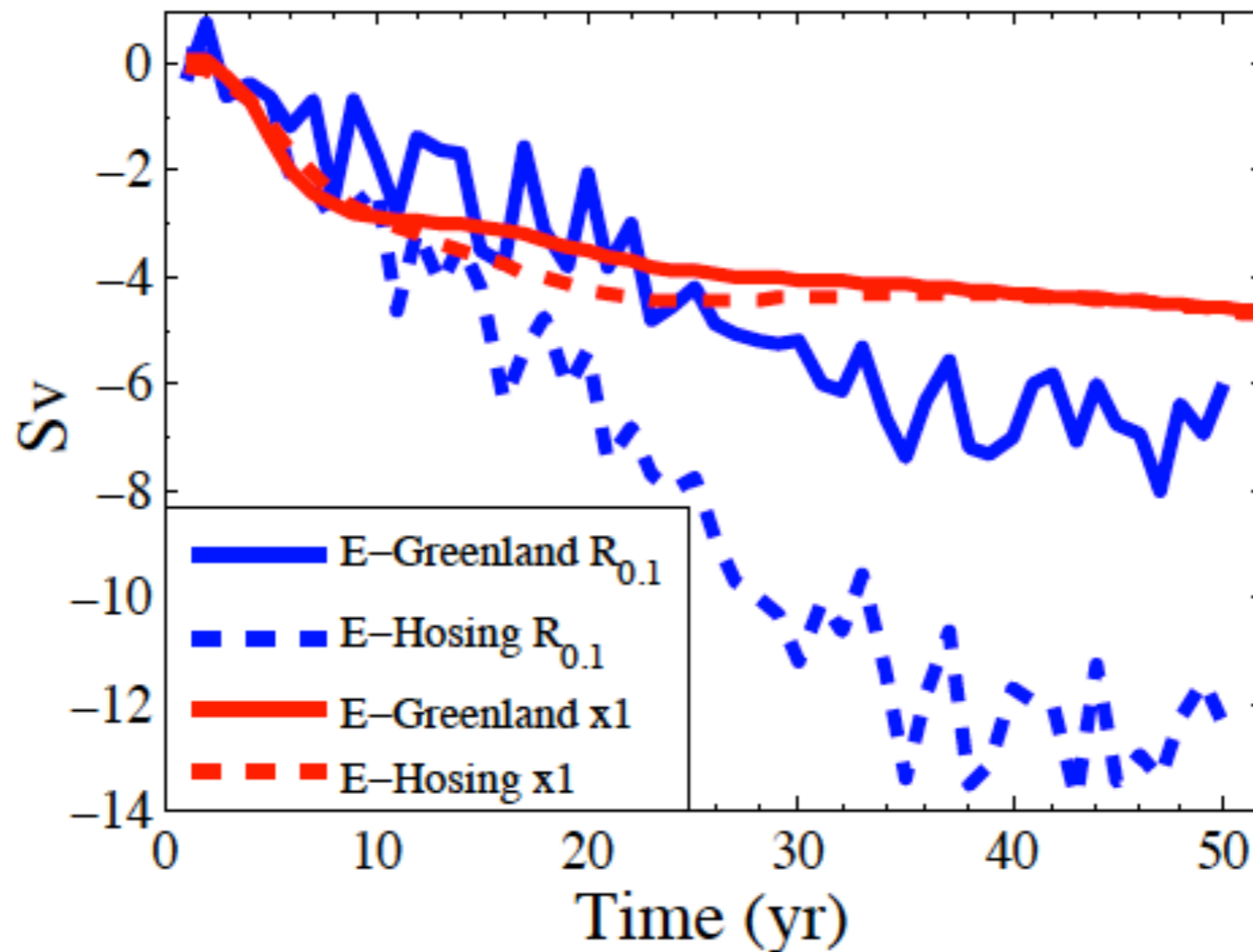
‘fit for purpose’?

zoetwater
verstoring



zoetwater
verstoring

Verstoring
circulatie



CMIP5 oceaan
component

model met
10x hogere resolutie

Conclusies

Mondiale veranderingen in het klimaatsysteem worden bepaald door veranderingen in de forcering en terugkoppelingen in het klimaatsysteem

Regionale veranderingen in het klimaatsysteem kunnen abrupt zijn, een 'point of no return' veroorzaken, en zullen de grootste problemen in adaptatie opleveren

CMIP5 klimaatmodellen zijn goed in staat om Charney gevoeligheid te representeren maar niet geschikt voor een goede representatie van abrupte regionale veranderingen

Conclusies

Mondiale veranderingen in het klimaatsysteem worden bepaald door veranderingen in de forcering en terugkoppelingen in het klimaatsysteem

Regionale veranderingen in het klimaatsysteem kunnen abrupt zijn, een 'point of no return' veroorzaken, en zullen de grootste problemen in adaptatie opleveren

CMIP5 klimaatmodellen zijn goed in staat om Charney gevoeligheid te representeren maar niet geschikt voor een goede representatie van abrupte regionale veranderingen

Er staan ons nog een aantal grote verrassingen te wachten!