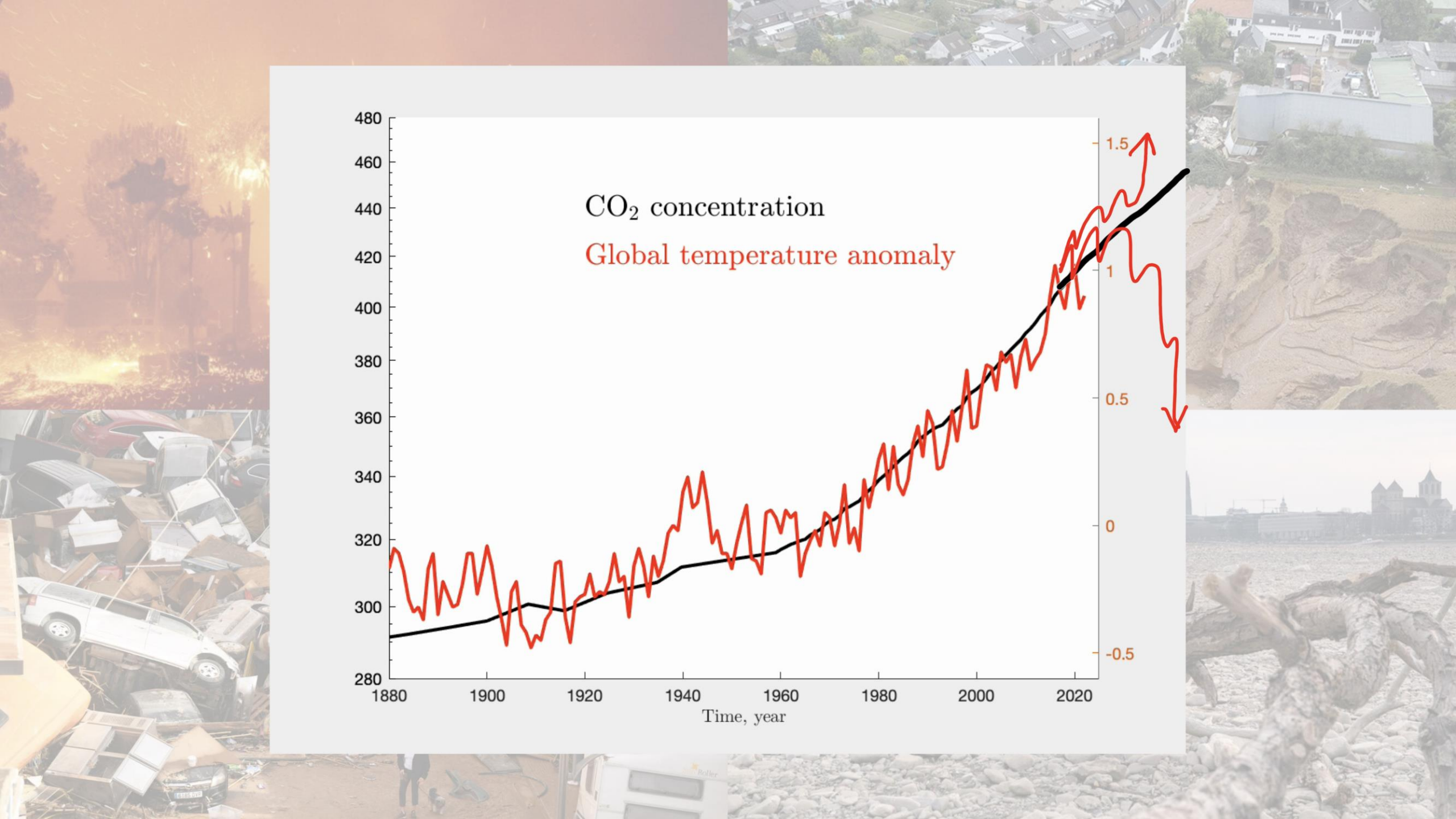
Videnskabelig basis for Tipping points i klimaet

Peter Ditlevsen, Niels Bohr Institute, Københavns Universitet

UNIVERSITY OF COPENHAGEN
TiPES TIPPING POINTS IN THE EARTH SYSTEM
CriticalEarth
European Commission
Horizon 2020
European Union funding
for Research & Innovation

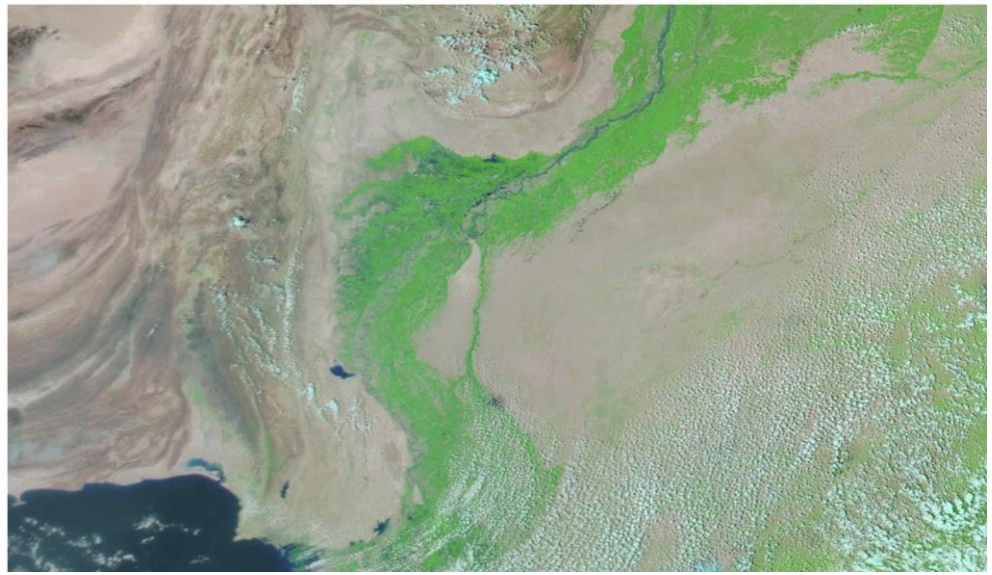

CO_2 concentration
Global temperature anomaly
480
460
440
420
400
380
360
340
320
300
280
1.5
1
0.5
0
-0.5
1880
1900
1920
1940
1960
1980
2000
2020
Time, year


Los Angeles, Jan. 2025

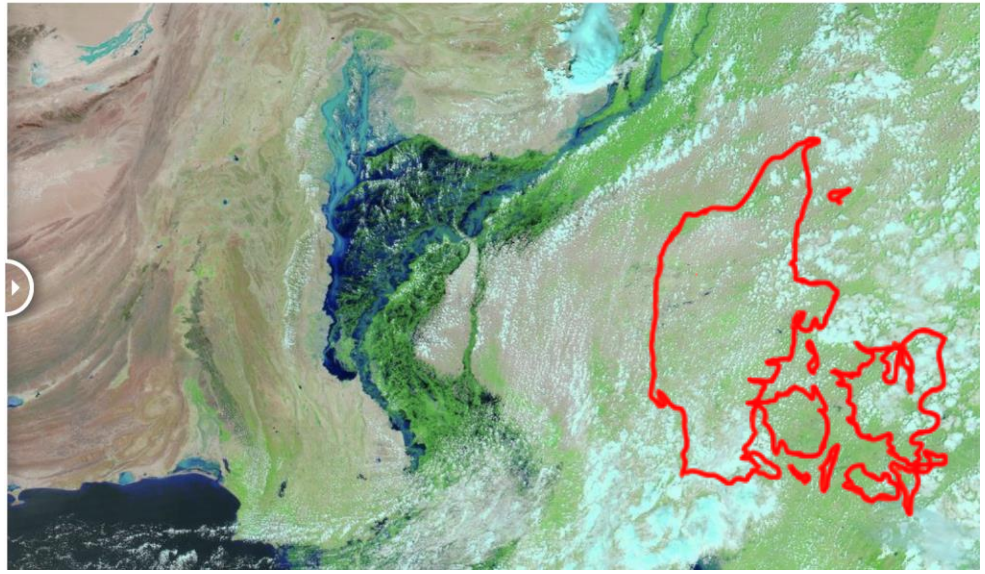

Erftstadt, Germany, July. 2021


Valencia, Oct. 2024
HERSOL
INMO HABITAT


Rhine, Köln, Oct. 2024

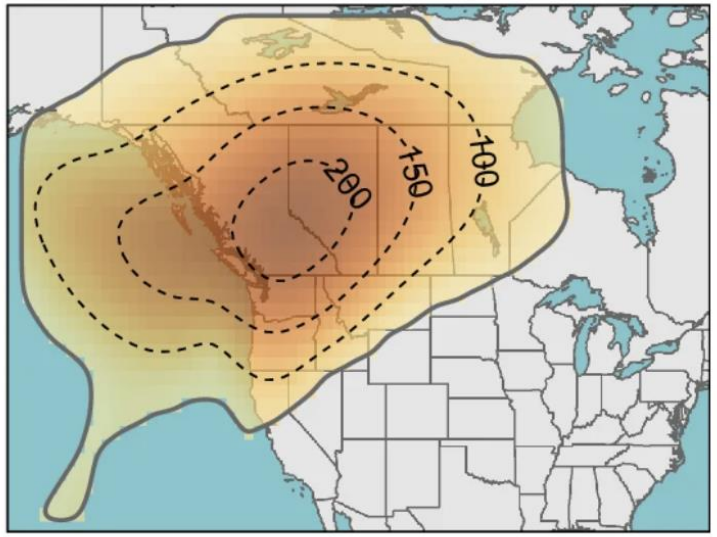


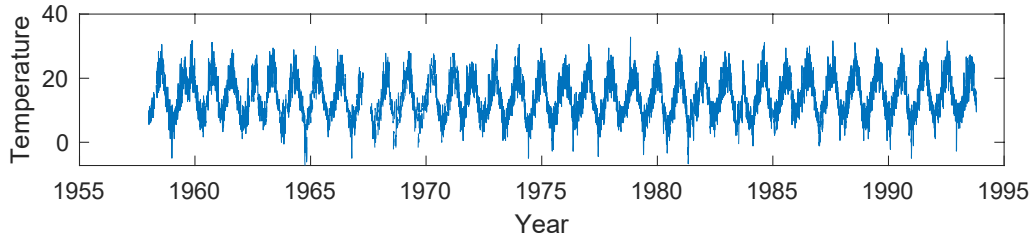
August 21, 2022

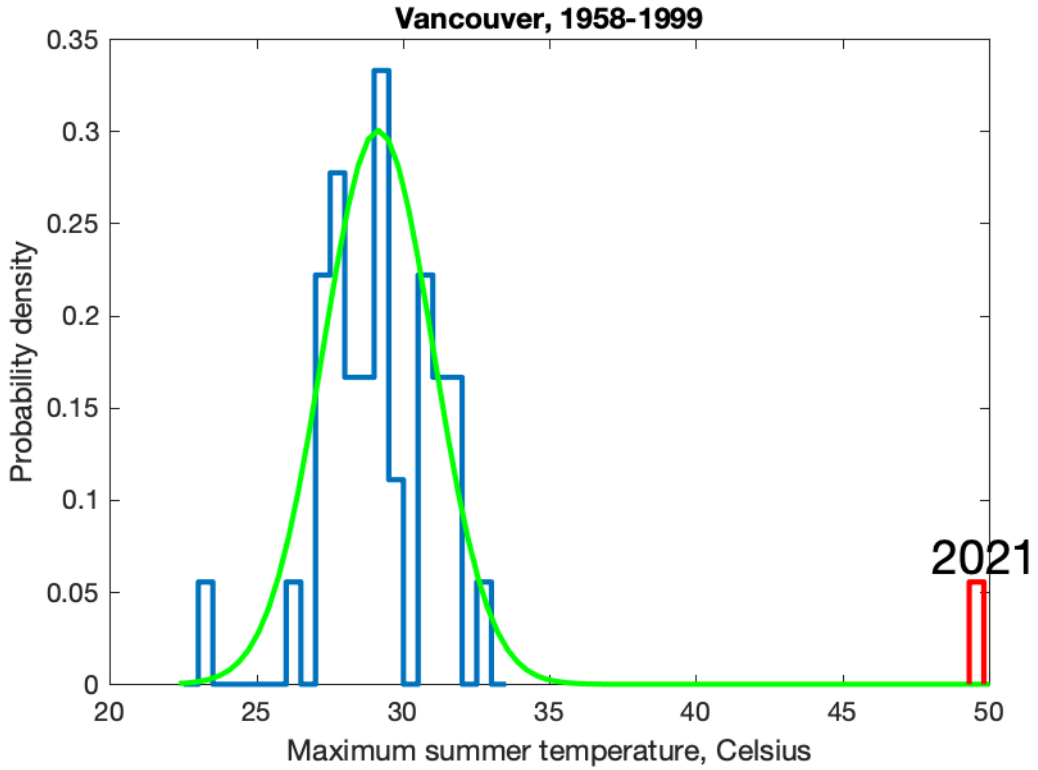


August 22, 2022

Jun 29, 2021


-200
-150
-100


Temperature
40
20
0
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year


Vancouver, 1958-1999
Probability density
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
20
25
30
35
40
45
50
Maximum summer temperature, Celsius
2021

Skybrud i Danmark – Statistik og Overblik

Definition

Et **skybrud** defineres af DMI som regn, hvor der falder mindst **15 mm på 30 minutter**.

Historisk Udvikling

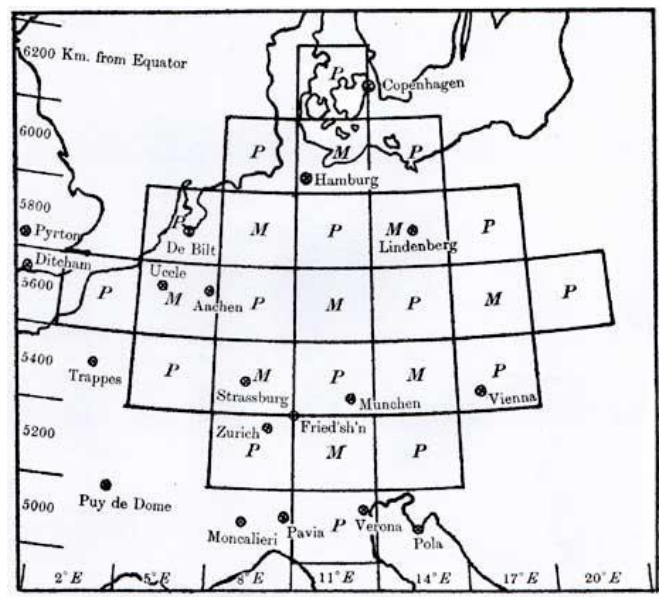
- **Skybrud er blevet hyppigere** de seneste årtier, især pga. klimaforandringer.
- Før 1950 var skybrud sjældne, og der findes kun få systematiske målinger.
- Fra ca. 1970 og frem har DMI detaljerede data.

Statistik – Udvikling og Antal

1. Antal registrerede skybrud pr. år (ca.-tal fra DMI):

Årti	Skybrud pr. år (gennemsnit)
1950-1970	0-2
1970-1990	2-5
1990-2010	5-10
2010-2023	10-20

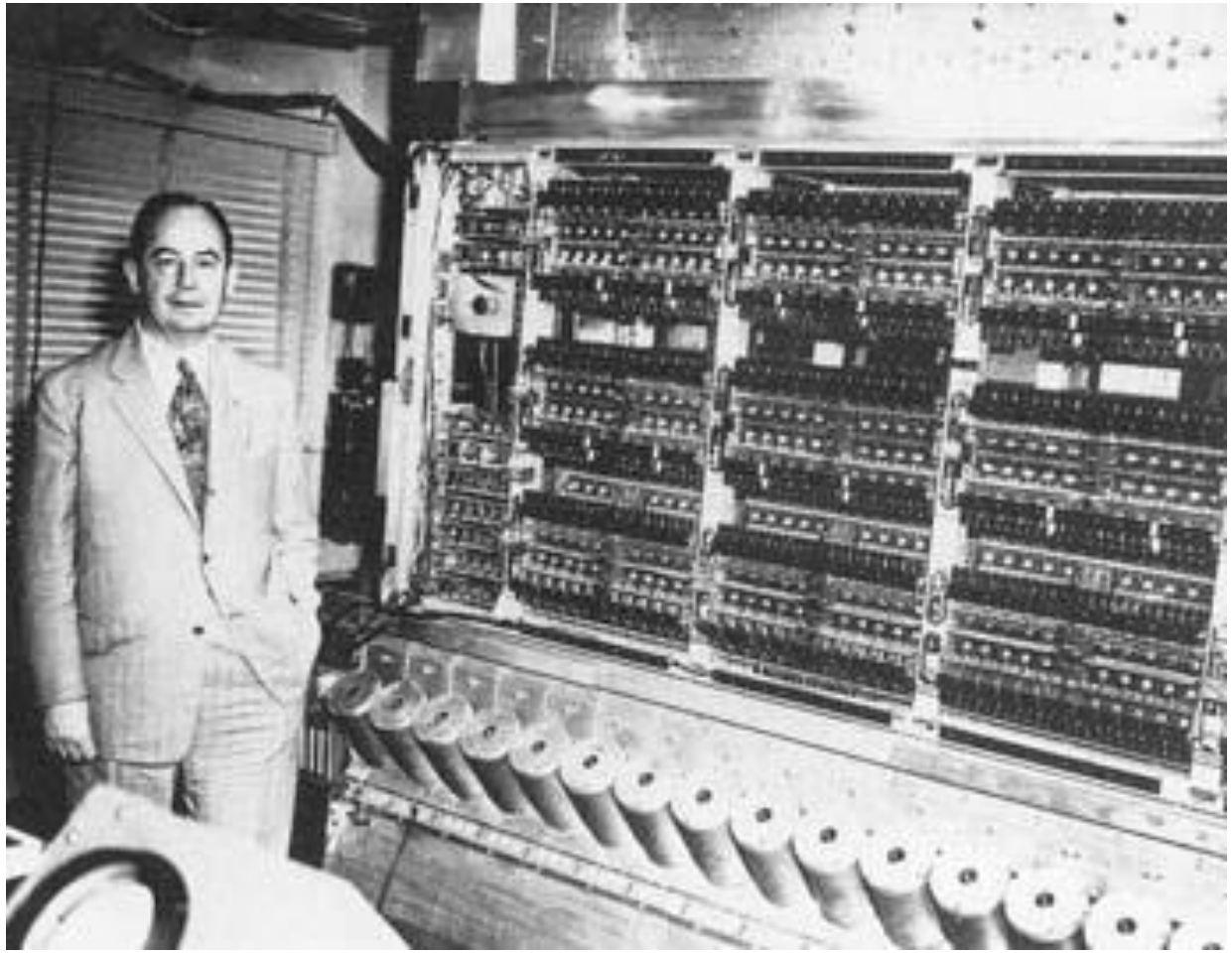
- **2011:** Rekordår med **32 registrerede skybrud**.
- **2014:** 25 registrerede skybrud.
- **2023:** 18 registrerede skybrud.

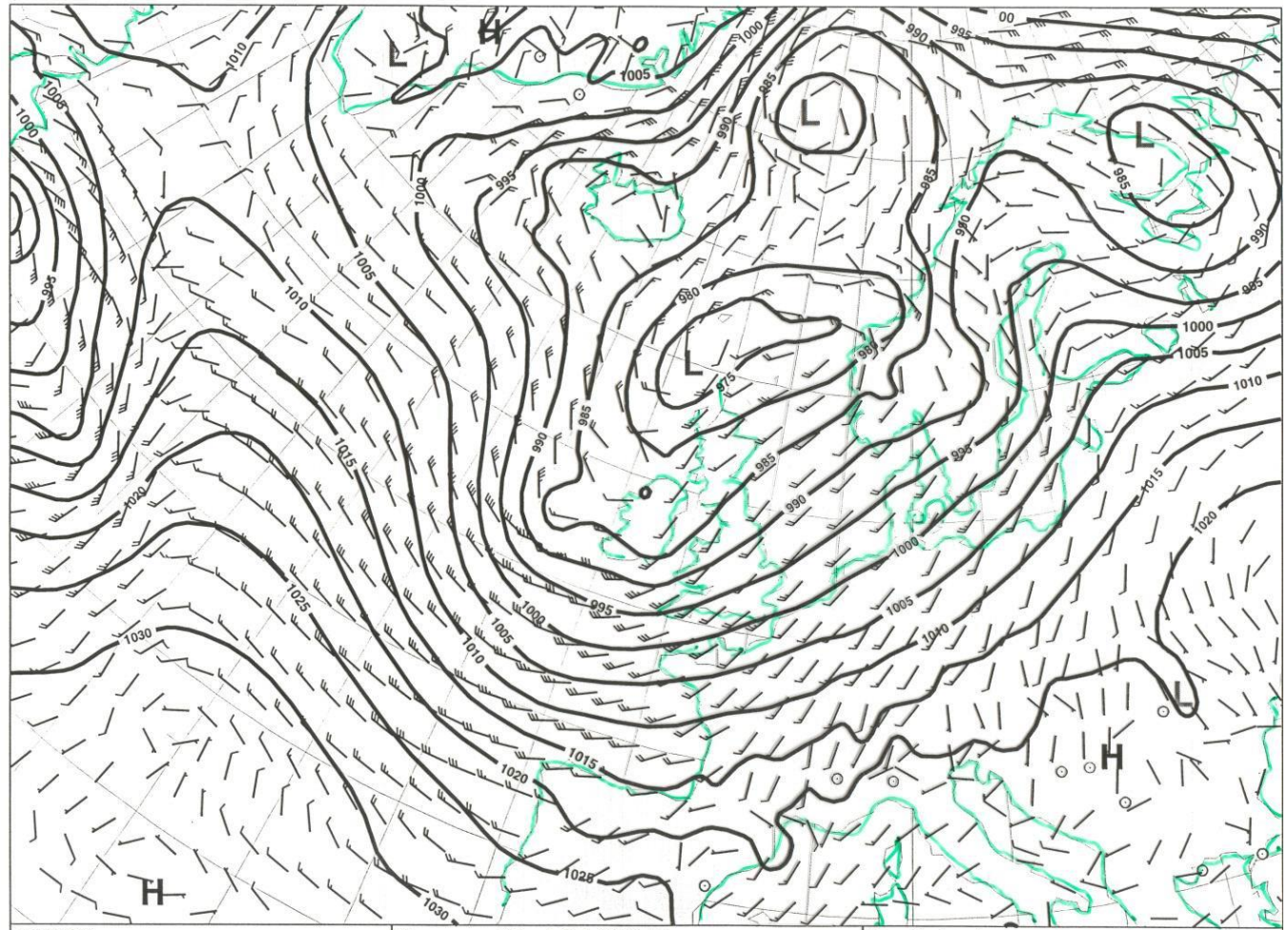


MAP OF POINTS FOR PRESSURE (*P*) AND MOMENTUM (*M*) USED IN THE EXAMPLE of Ch. 9.

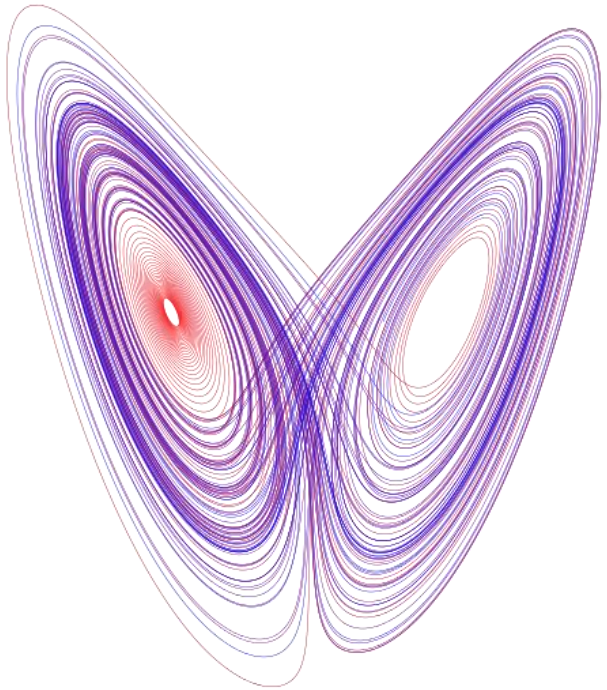
Forecast Factory

Artist's impression: Francois Schuiten.





ECMWF PROGNOSE + 024	Beregne : Man 4 Feb 2002 12 z Gælde de: Tir 5 Feb 2002 12 z	Overfladetryk 10m Vind m/s



Deterministic Nonperiodic Flow[1]

EDWARD N. LORENZ

Massachusetts Institute of Technology

(Manuscript received 18 November 1962, in revised form 7 January 1963)

ABSTRACT

Finite systems of deterministic ordinary nonlinear differential equations may be designed to represent forced dissipative hydrodynamic flow. Solutions of these equations can be identified with trajectories in phase space. For those systems with bounded solutions, it is found that nonperiodic solutions are ordinarily unstable with respect to small modifications, so that slightly differing initial states can evolve into considerably different states. Systems with bounded solutions are shown to possess bounded numerical solutions.

A simple system representing cellular convection is solved numerically. All of the solutions are found to be unstable, and almost all of them are nonperiodic.

The feasibility of very-long-range weather prediction is examined in the light of these results.

$$
\begin{aligned}
\dot{x} &= \sigma x + \sigma y \\
\dot{y} &= \rho x - y - xz \\
\dot{z} &= xy - \beta z
\end{aligned}
$$

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$$
\begin{aligned}
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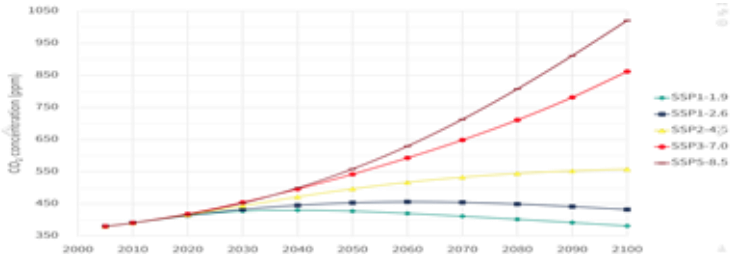
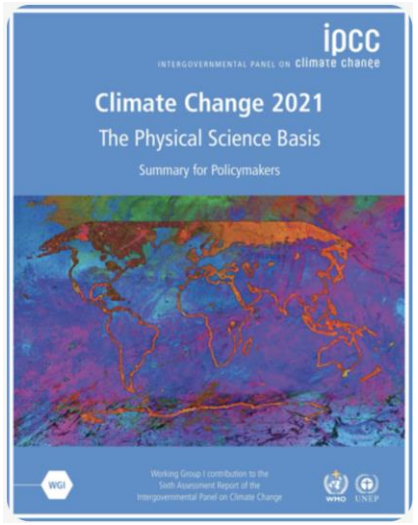
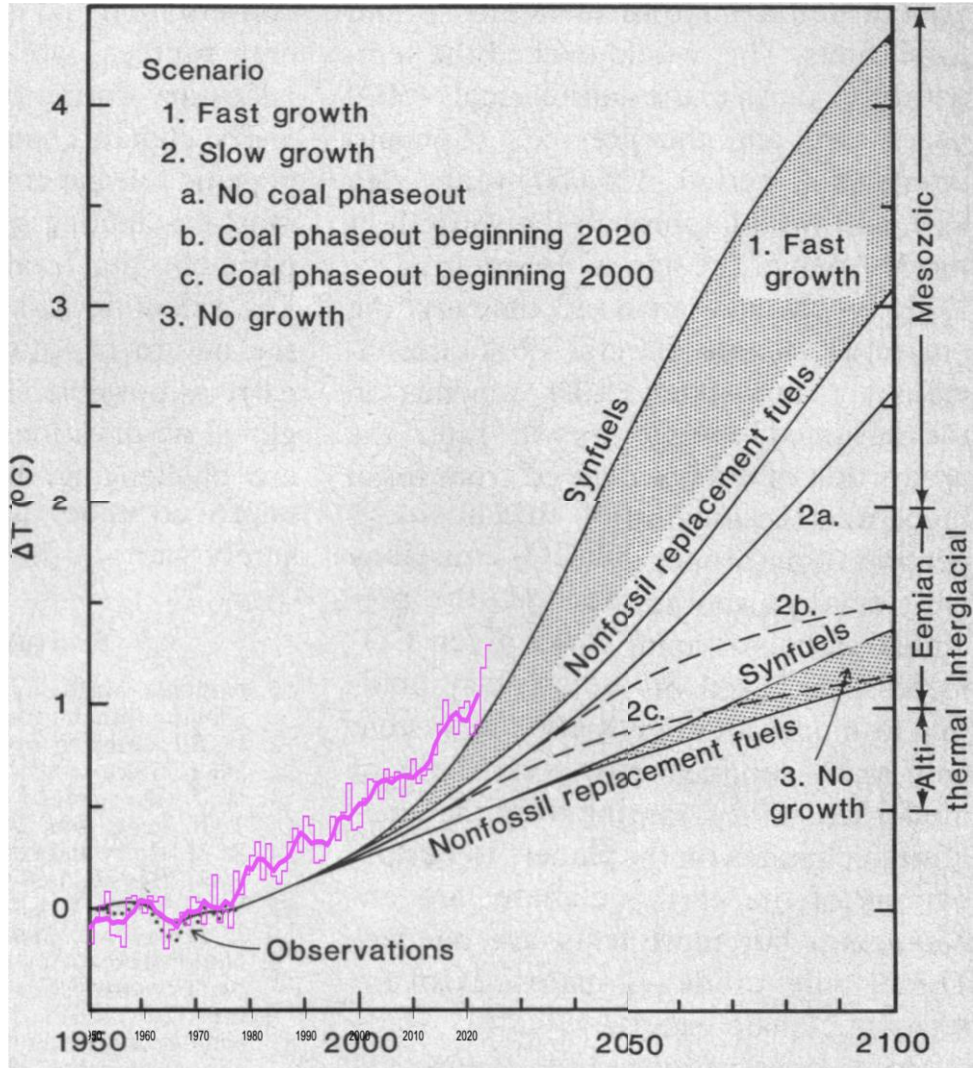




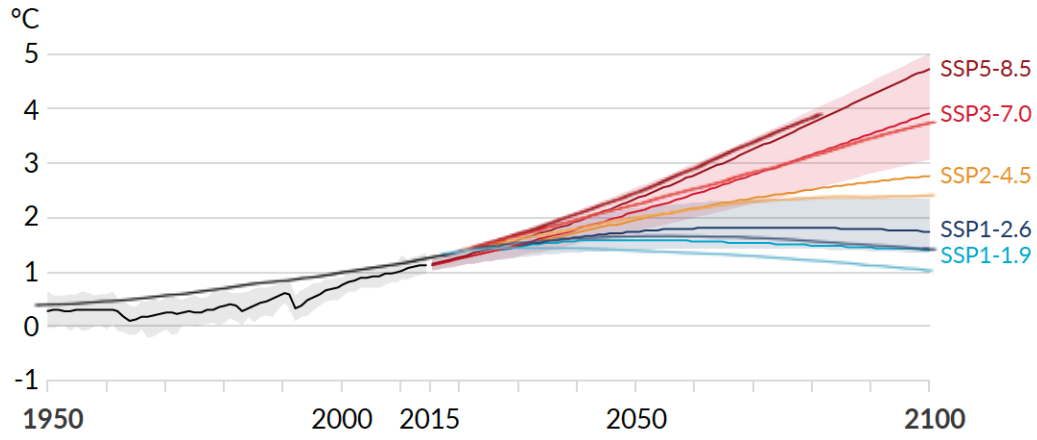
28 August 1981, Volume 213, Number 4511 SCIENCE

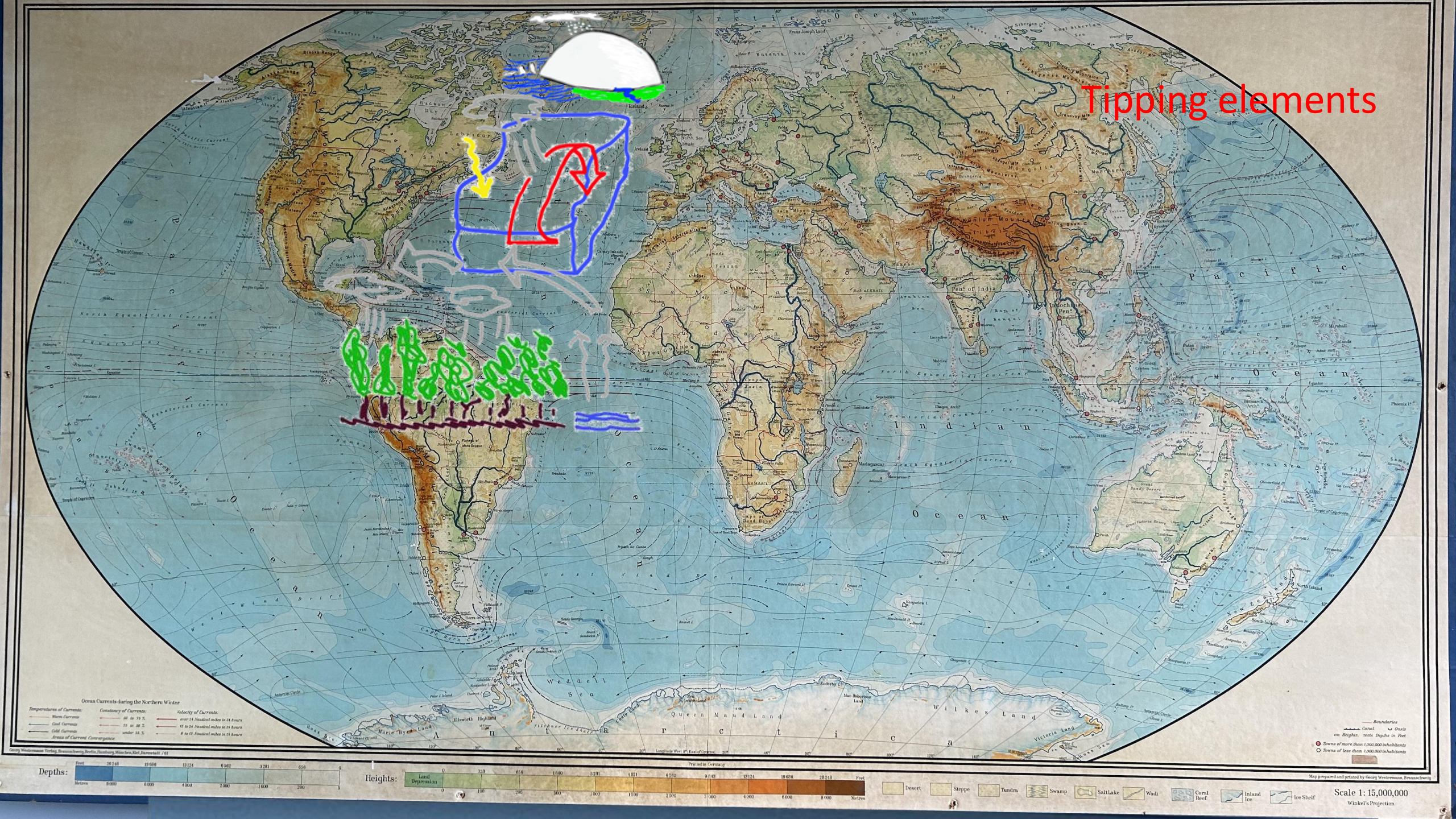
Climate Impact of Increasing Atmospheric Carbon Dioxide

J. Hansen, D. Johnson, A. Lacis, S. Lebedeff
P. Lee, D. Rind, G. Russell



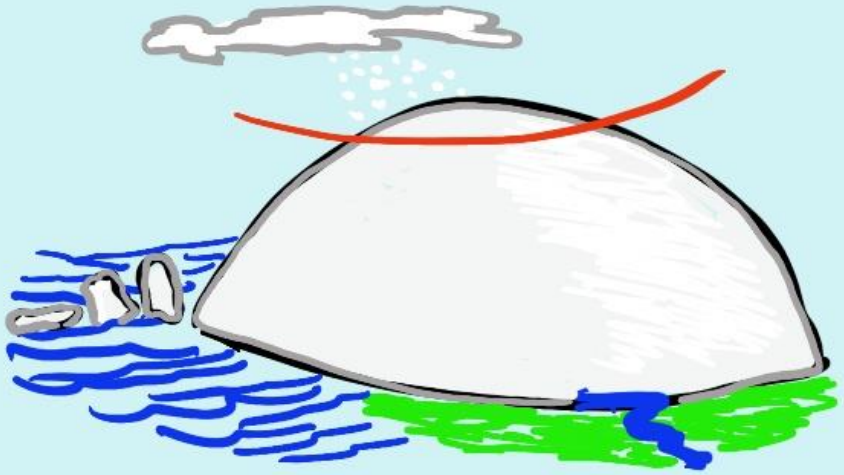
a) Global surface temperature change relative to 1850-1900

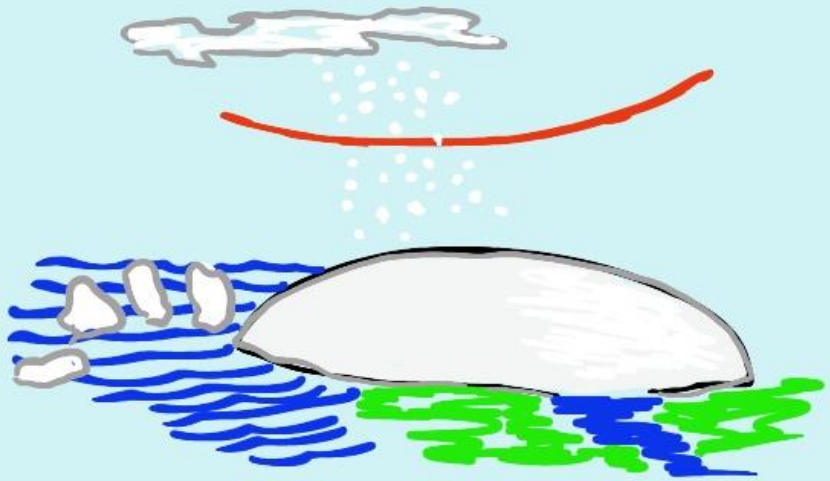


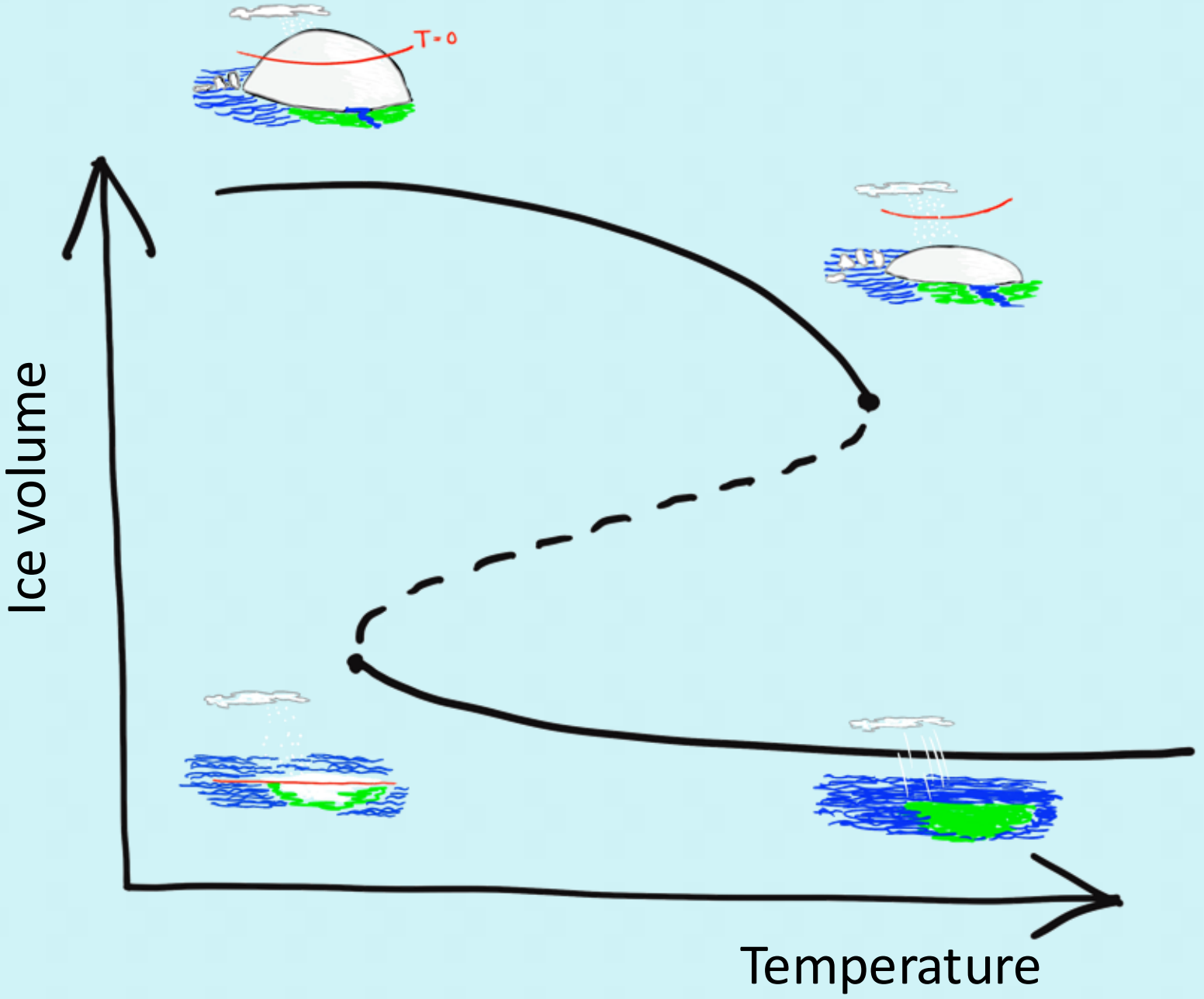

Tipping elements

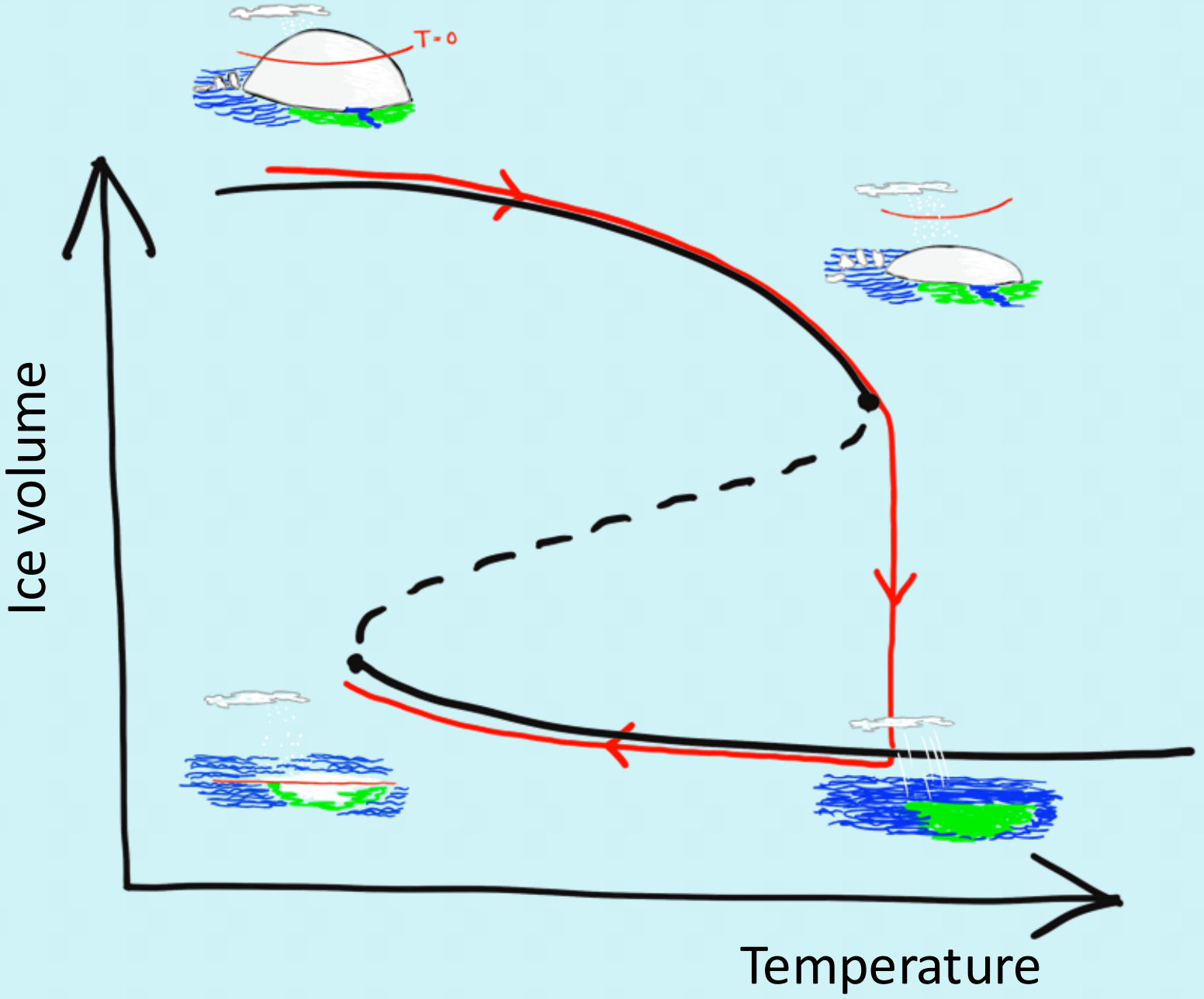

T = 0

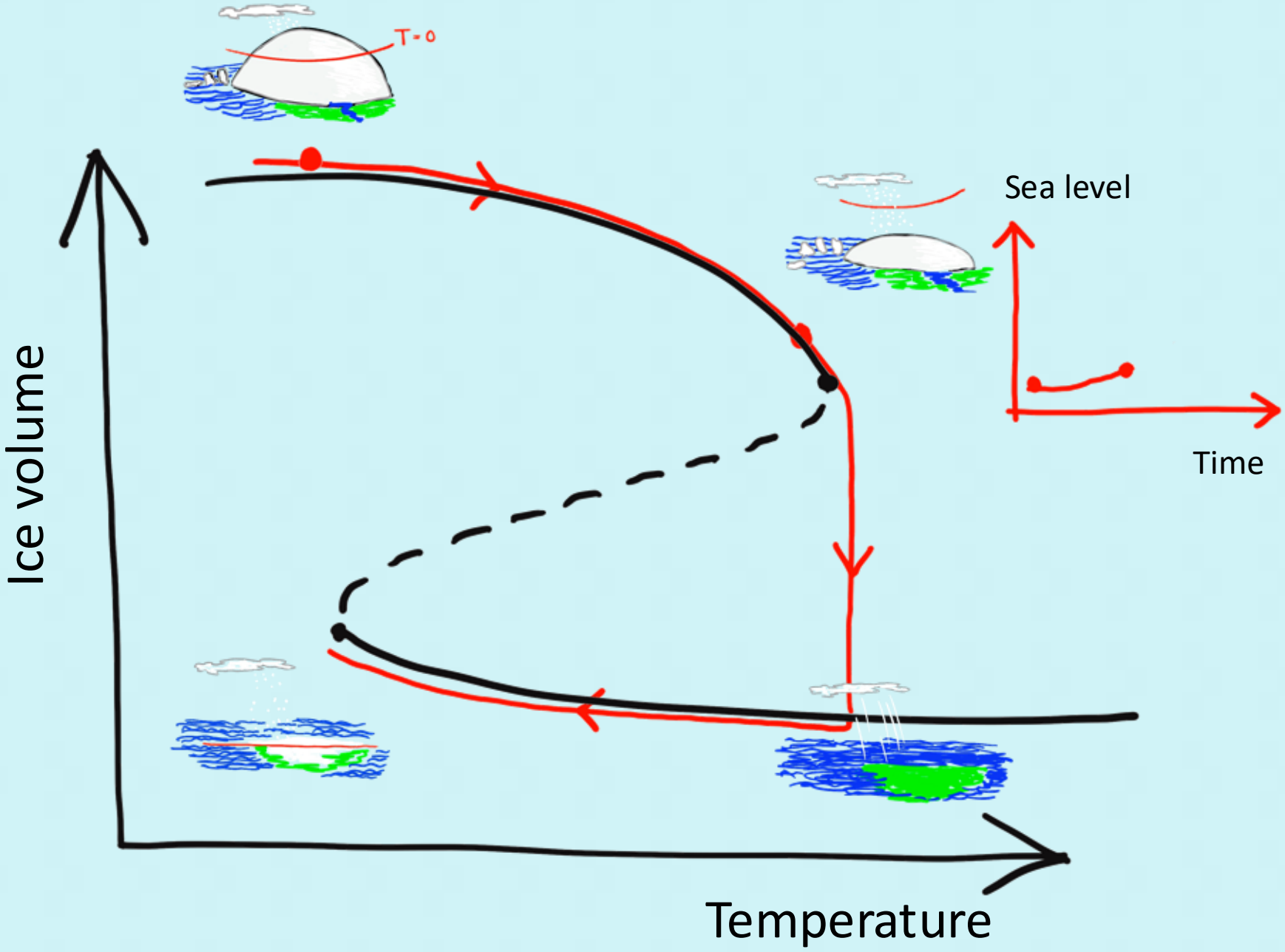

T = 0

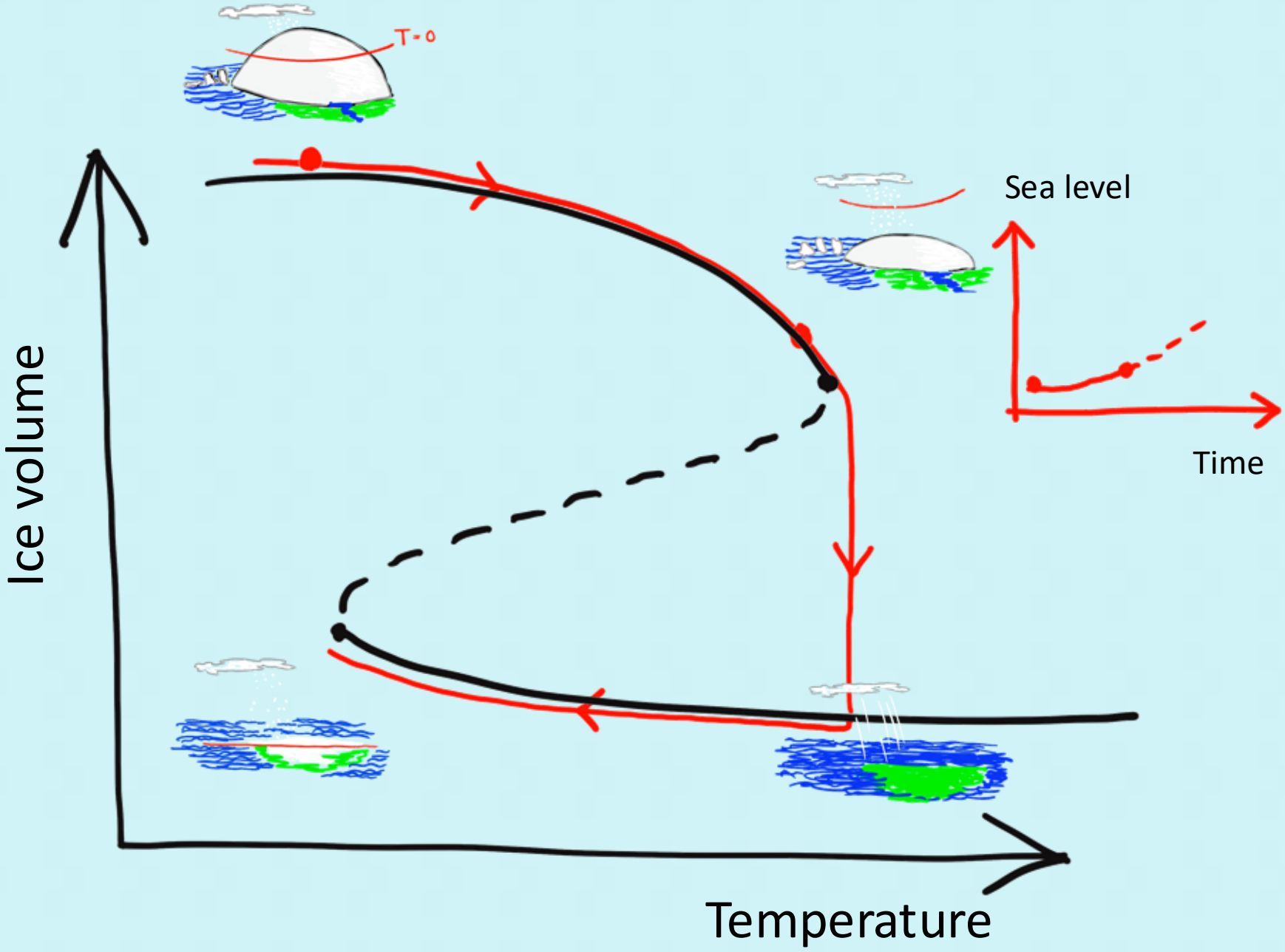


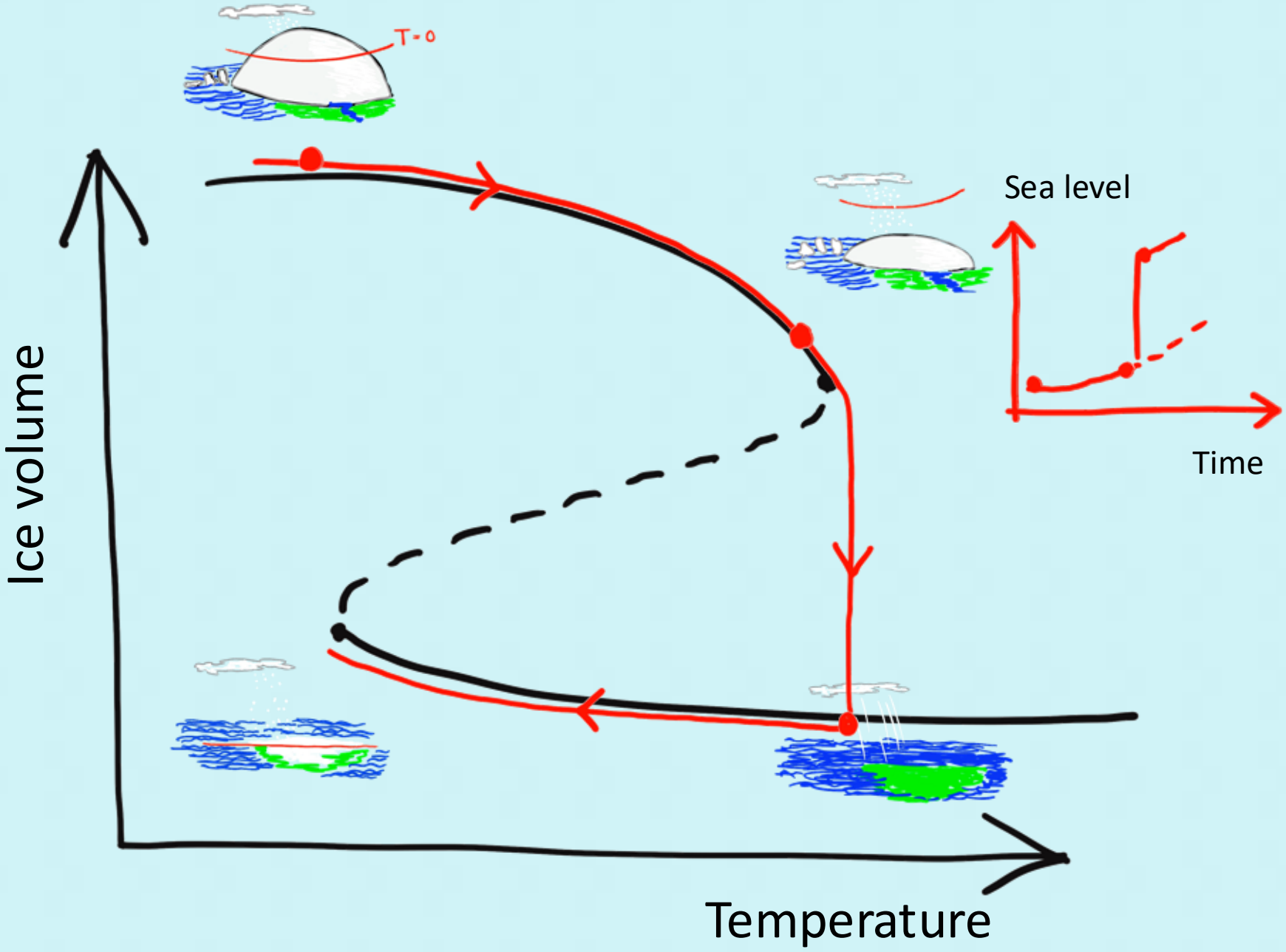


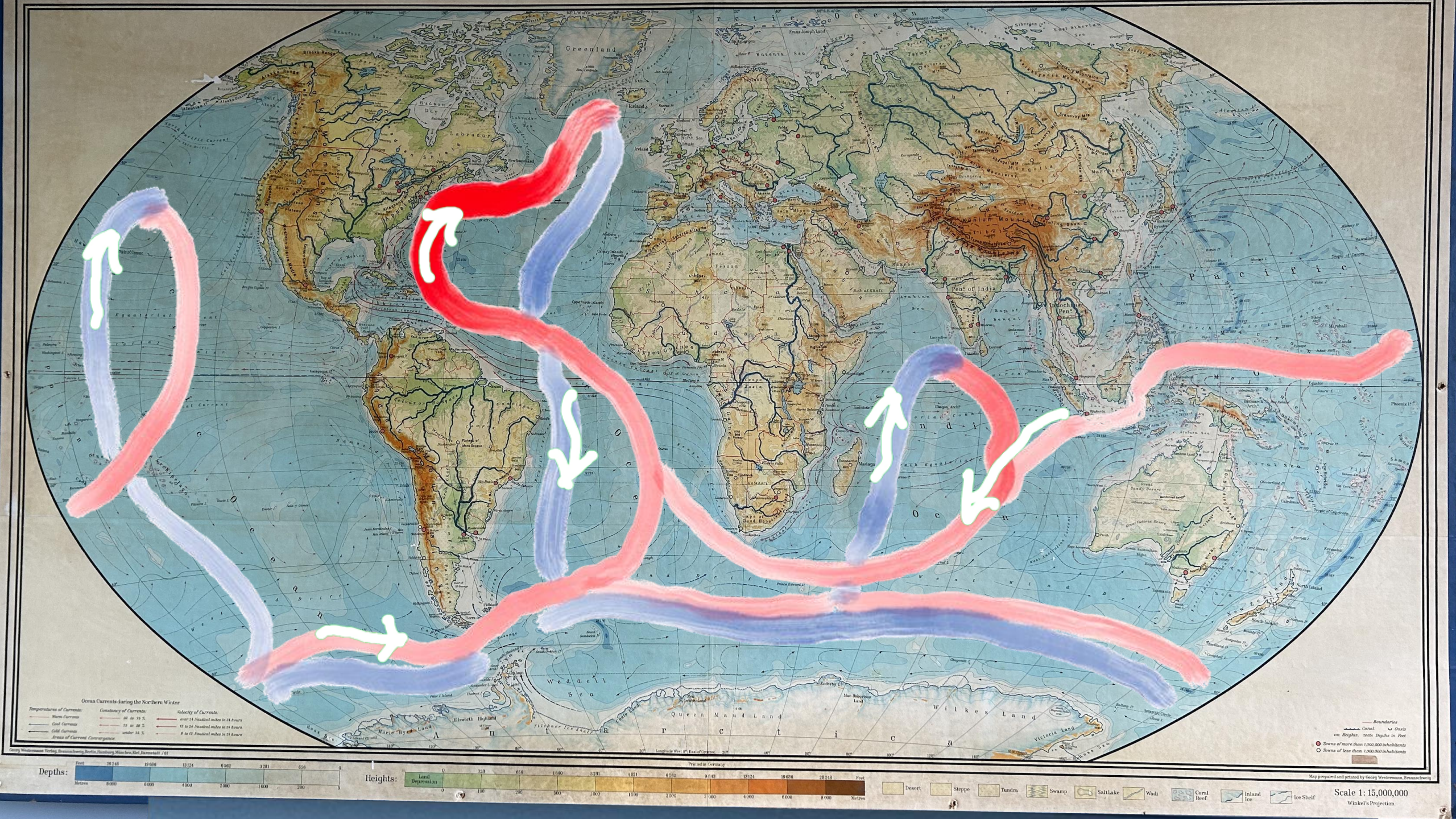

T-0
Ice volume
Temperature

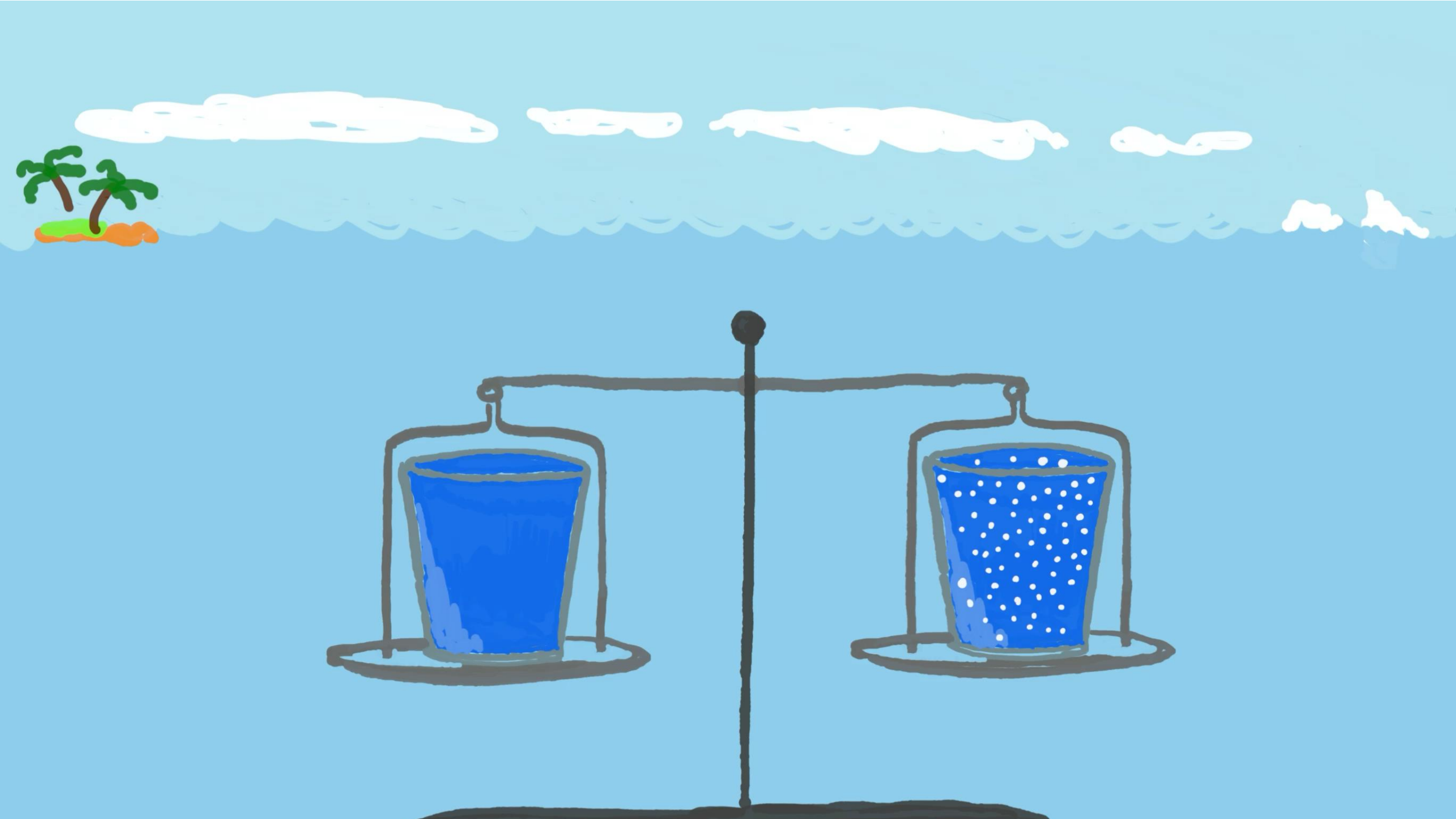

T-0
Ice volume
Temperature

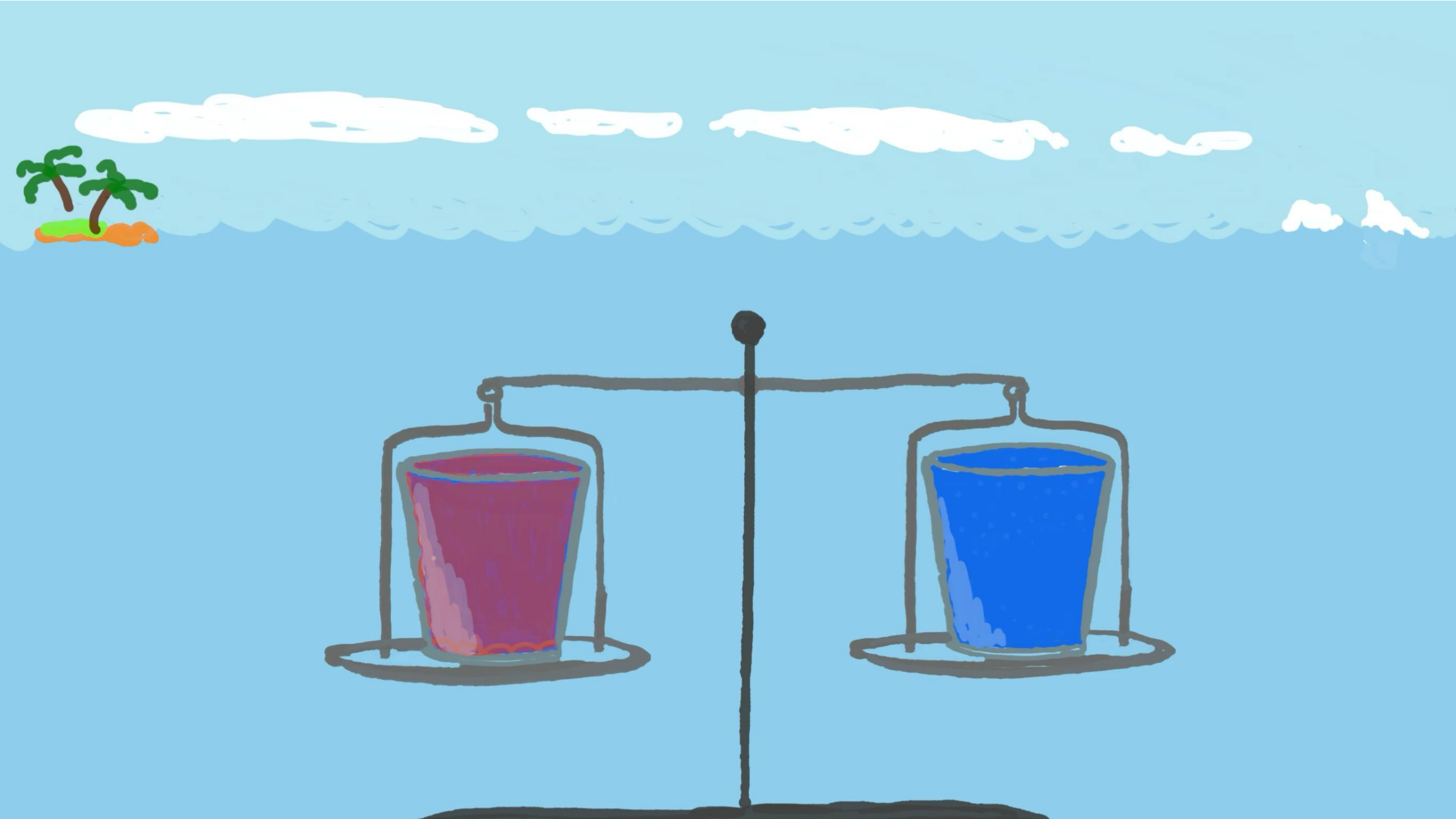

T-0
Sea level
Time
Ice volume
Temperature

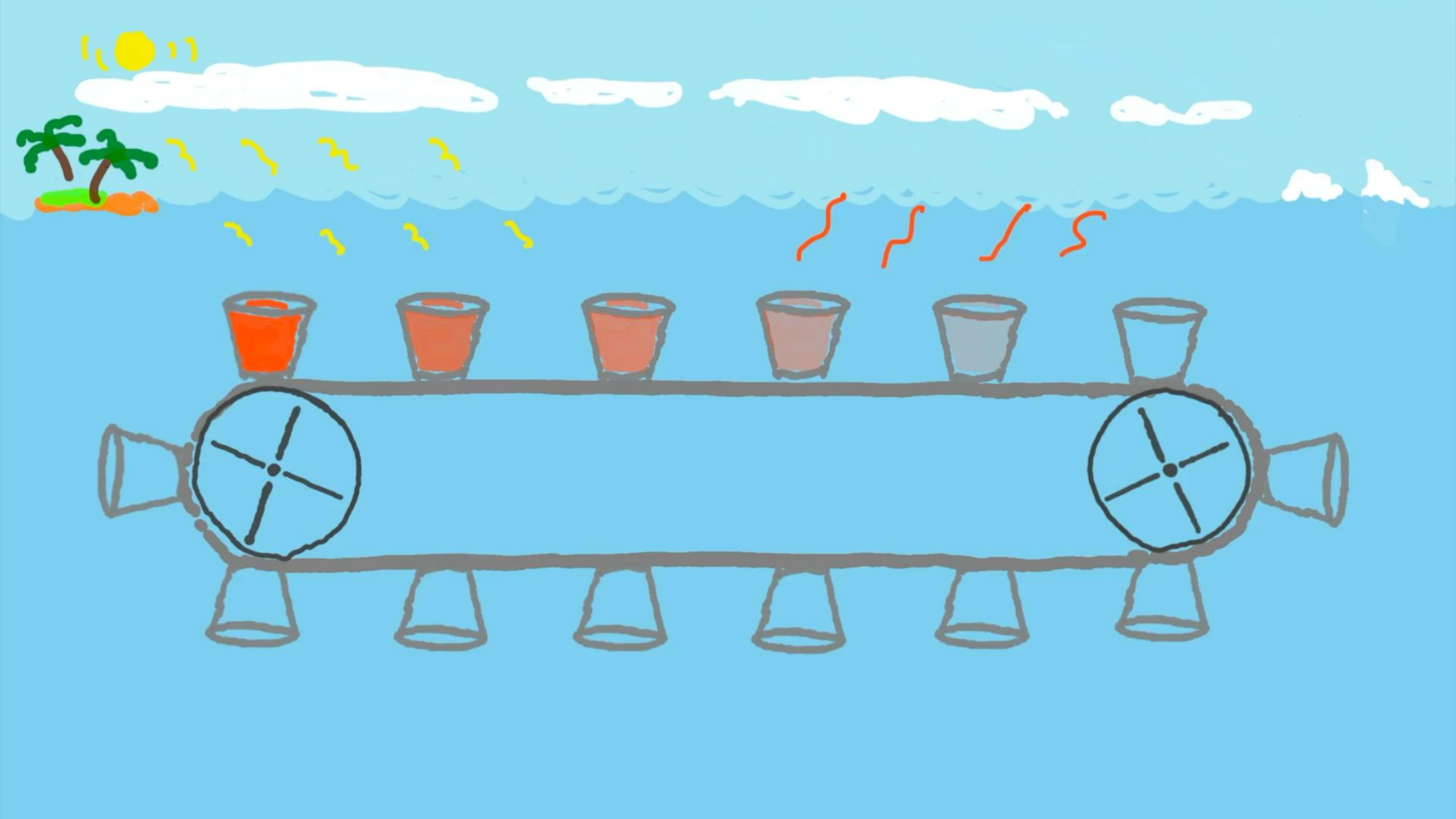

T-0
Sea level
Time
Ice volume
Temperature

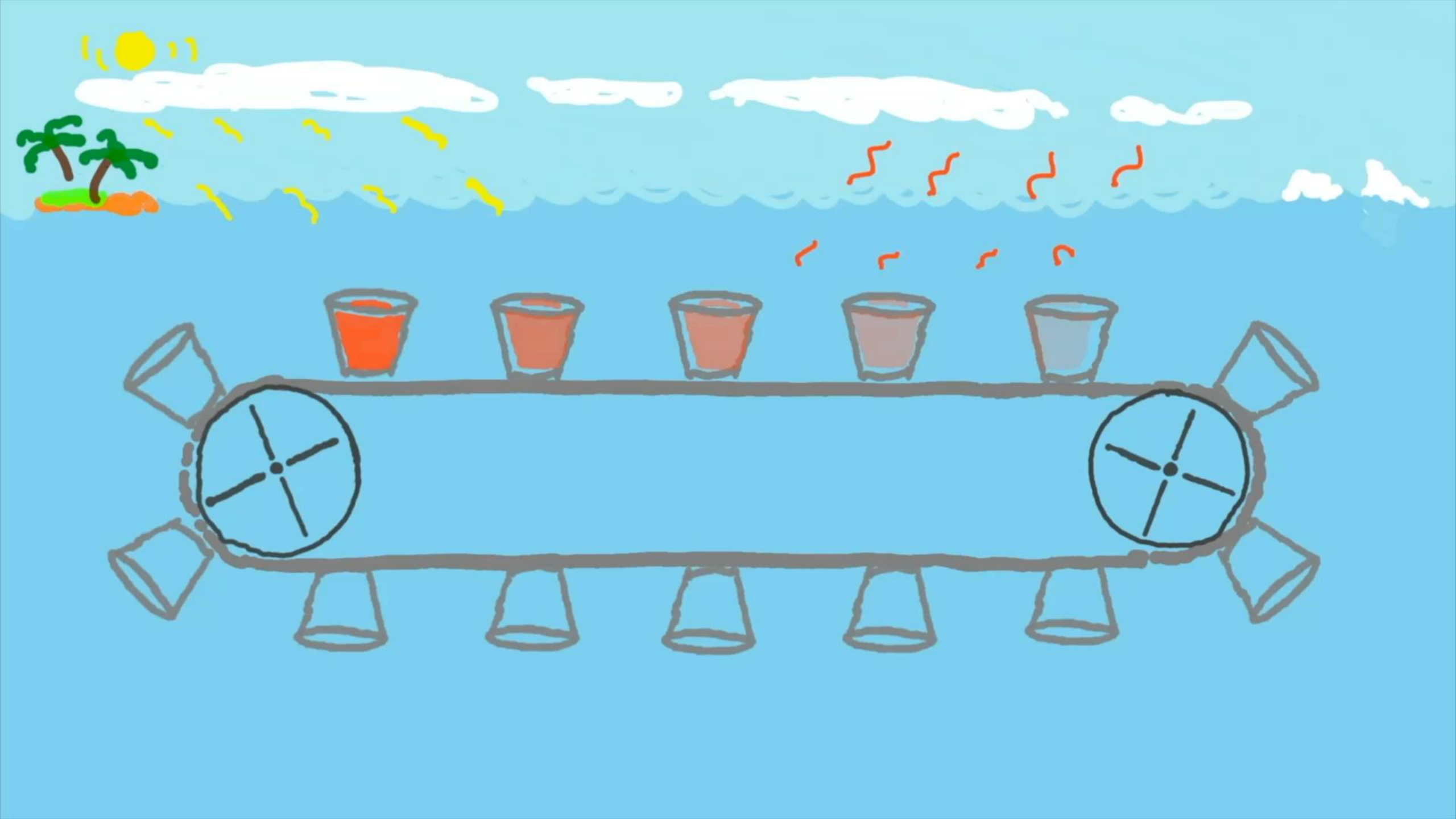

T-0
Sea level
Time
Ice volume
Temperature

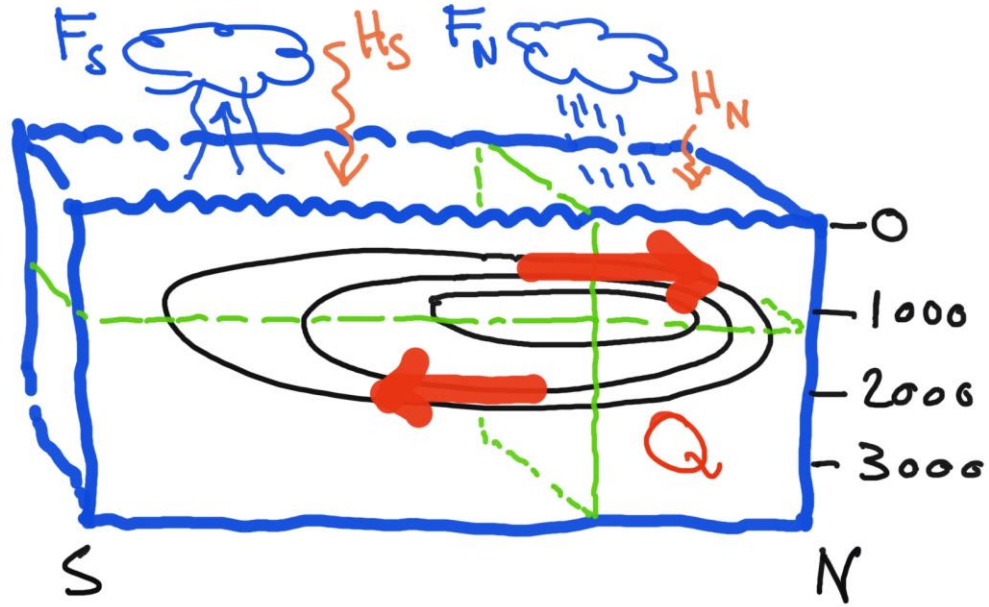

Ocean Currents during the Northern Winter
Temperatures of Currents:
Warm Currents
Cold Currents
Cold Currents
Areas of Current Convergence
Constancy of Currents:
50 to 75 %
75 to 90 %
under 25 %
Velocity of Currents:
over 24 Nautical miles in 24 hours
12 to 24 Nautical miles in 24 hours
6 to 12 Nautical miles in 24 hours
Depths:
Feet
Metres
Heights:
Land Depression
Metres
Desert
Steppe
Tundra
Swamp
Salt Lake
Wadi
Coral Reef
Inland Ice
Ice Shelf
Boundaries
Canal
Oasis
Towns of more than 1,000,000 inhabitants
Towns of less than 1,000,000 inhabitants
Scale 1: 15,000,000
Winkel's Projection
Printed in Germany
Map prepared and printed by Georg Westermann, Braunschweig
Georg Westermann Verlag, Braunschweig, Berlin, Hamburg, München, Kiel, Darmstadt / 61

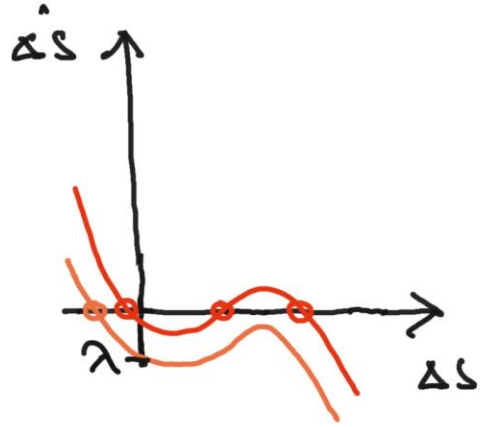












$$\dot{\Delta s} = -A\,\Delta s^3 + B\,\Delta s + \lambda$$

density:

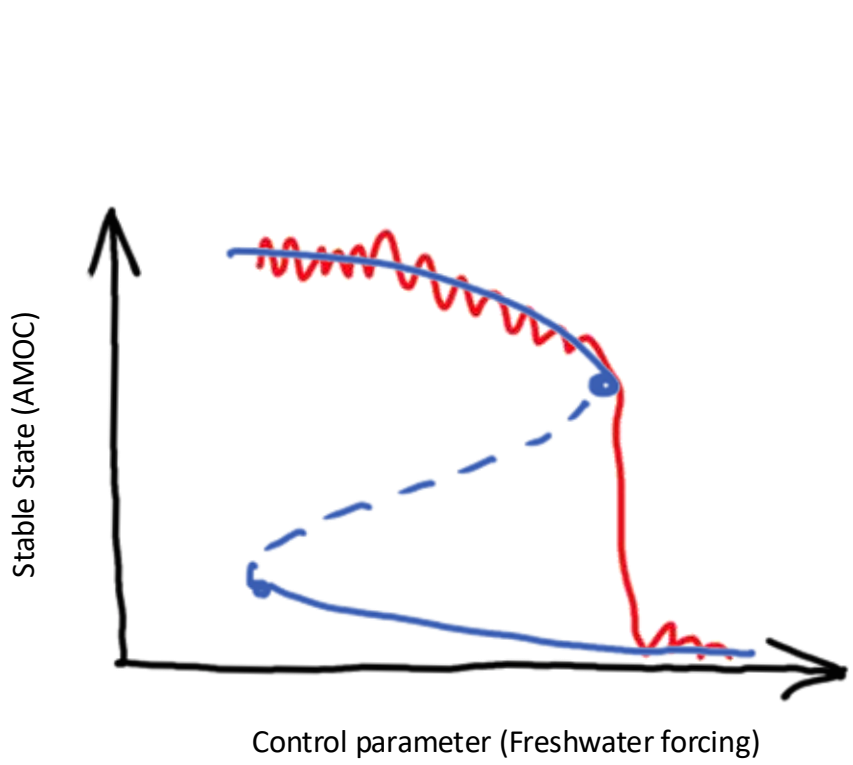
$$\rho(T,S) = \rho_0 - \alpha(T - T_0) + \beta(S - S_0)$$

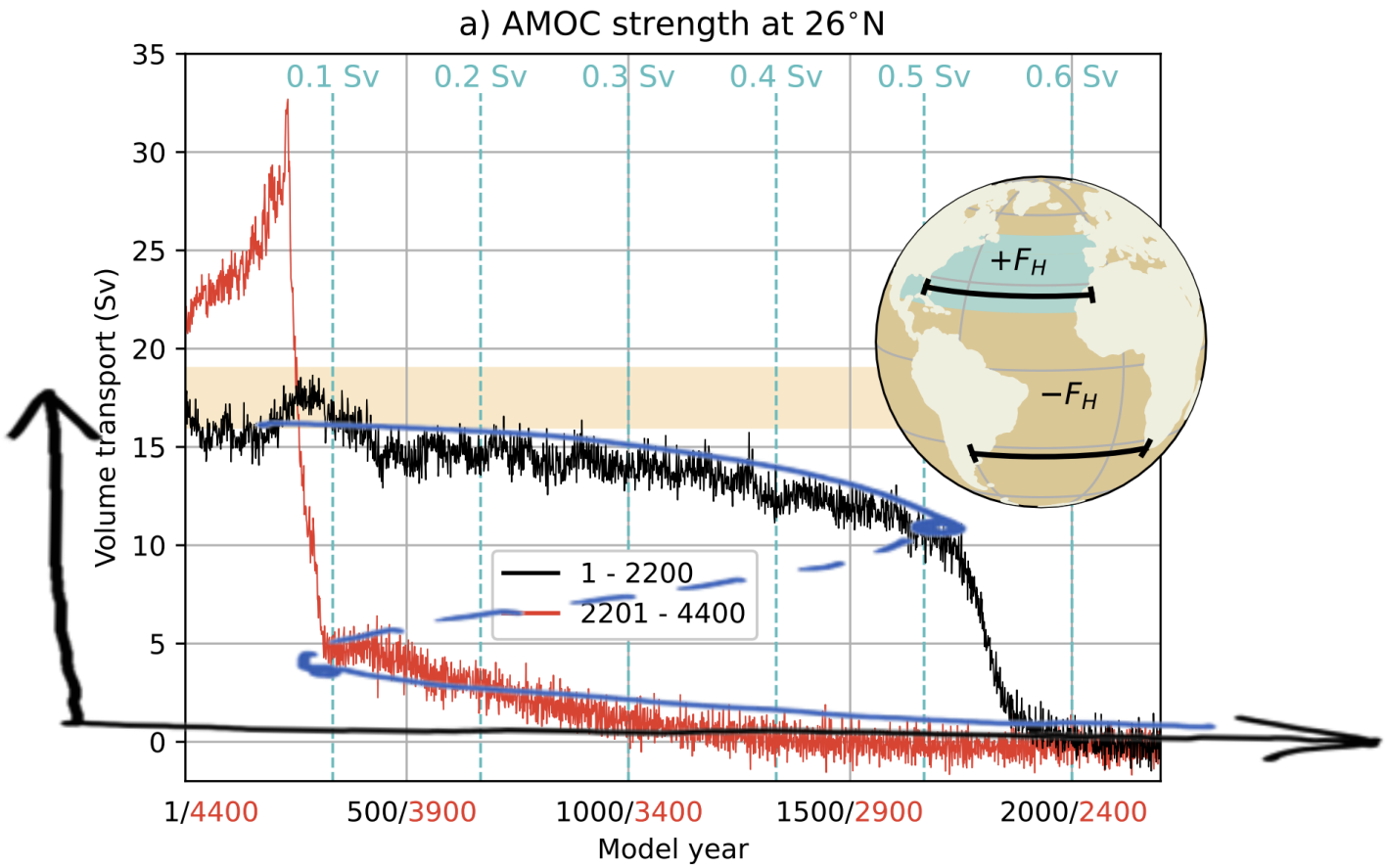
$$\Delta\rho = -\alpha\,\Delta T + \beta\,\Delta S$$

$$\Delta T = T_S - T_N$$

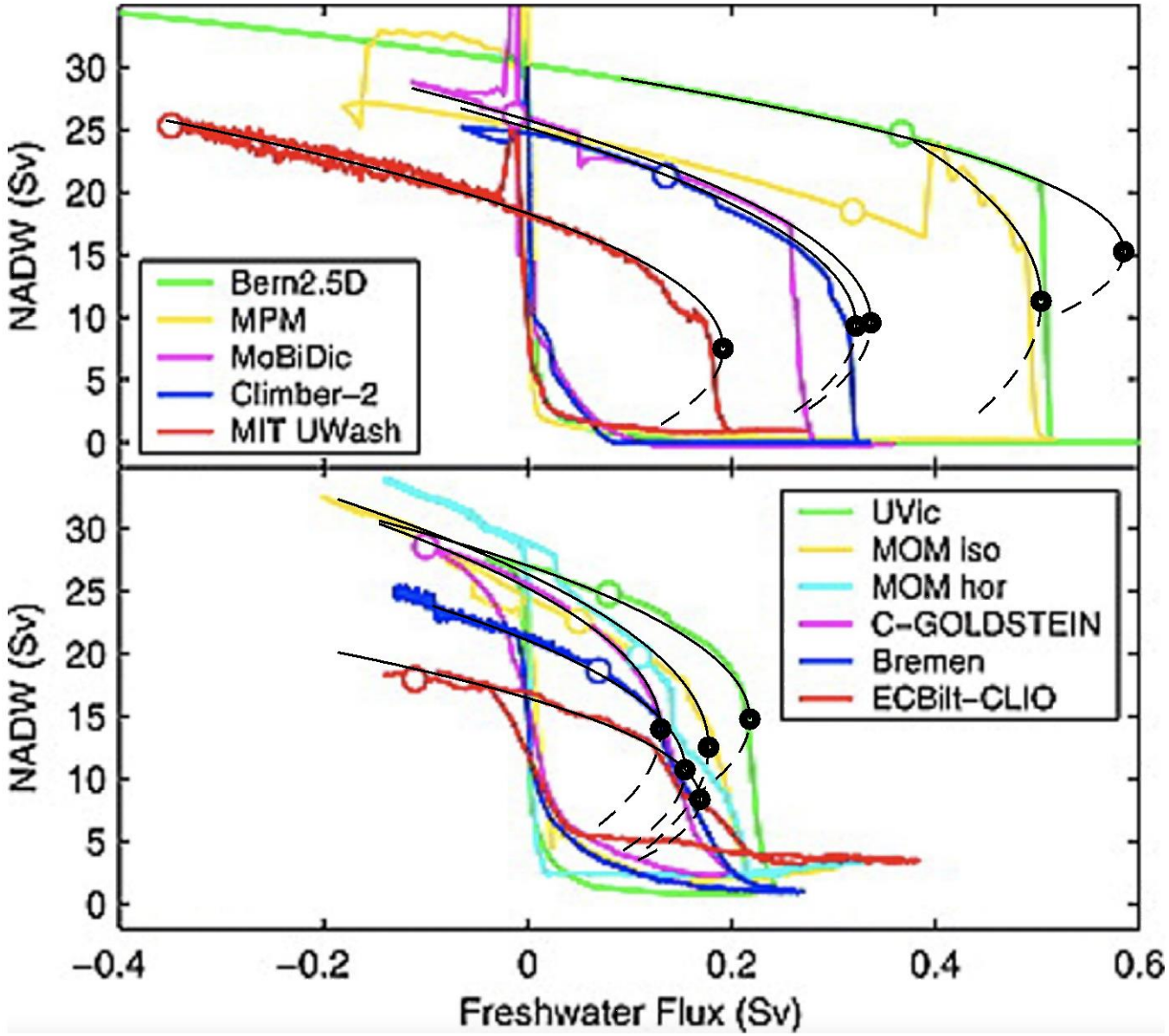
$$\Delta S = S_S - S_N$$

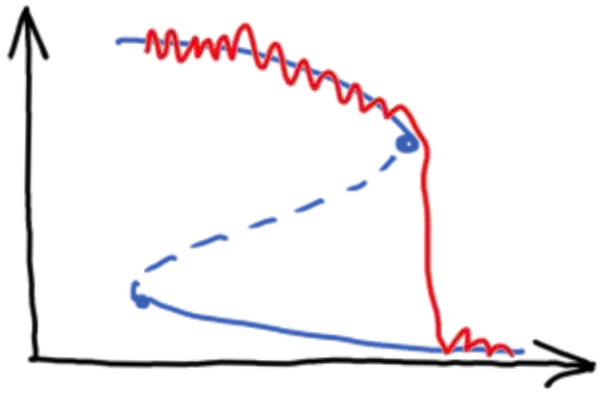
$$Q(\Delta\rho) \sim (\Delta\rho)^2$$

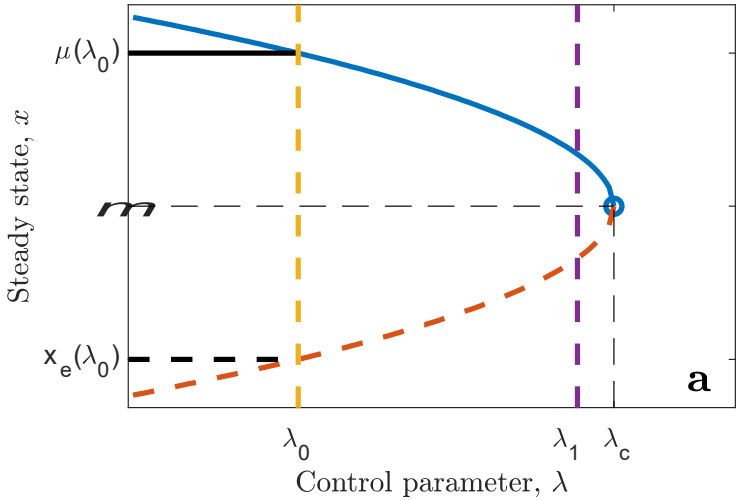


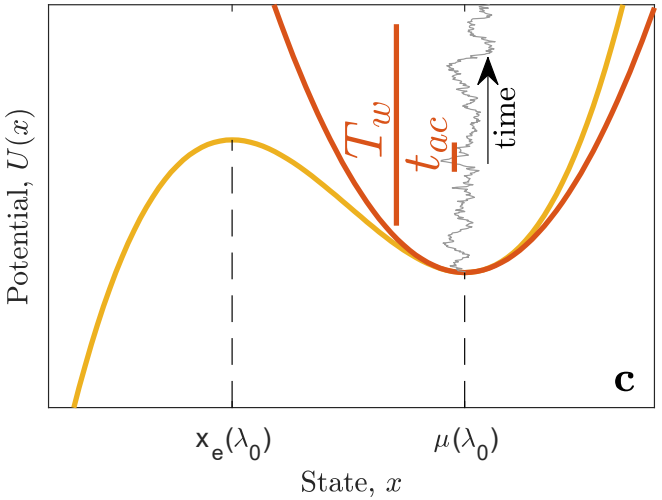


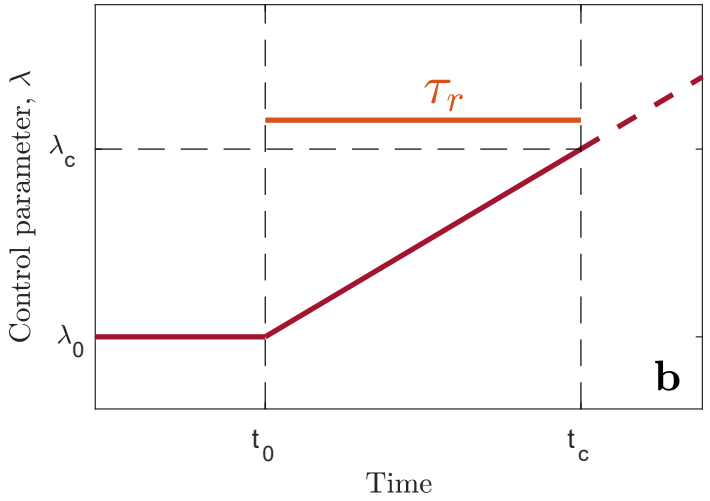
van Westen and Dijkstra, 2023

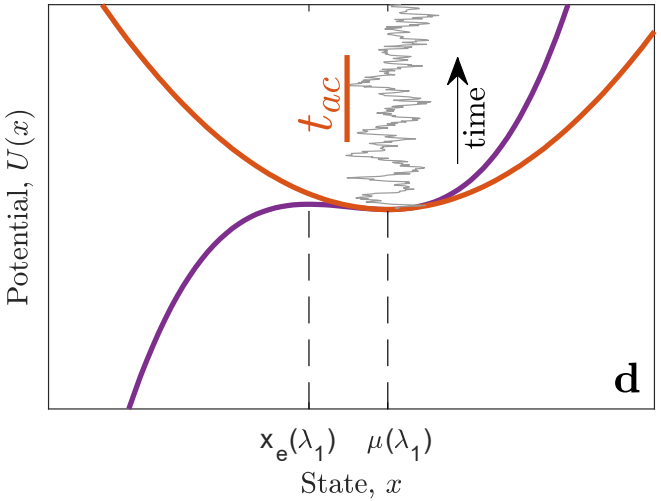

NADW (Sv)
30
25
20
15
10
5
0
Bern2.5D
MPM
MoBiDic
Climber–2
MIT UWash
UVic
MOM Iso
MOM hor
C–GOLDSTEIN
Bremen
ECBilt–CLIO
–0.4
–0.2
0
0.2
0.4
0.6
Freshwater Flux (Sv)




$\mu(\lambda_0)$
$x_e(\lambda_0)$
Steady state, x
λ_0
λ_1
λ_c
Control parameter, λ
a


T_w
t_{ac}
time
Potential, $U(x)$
$x_e(\lambda_0)$
$\mu(\lambda_0)$
State, x
c

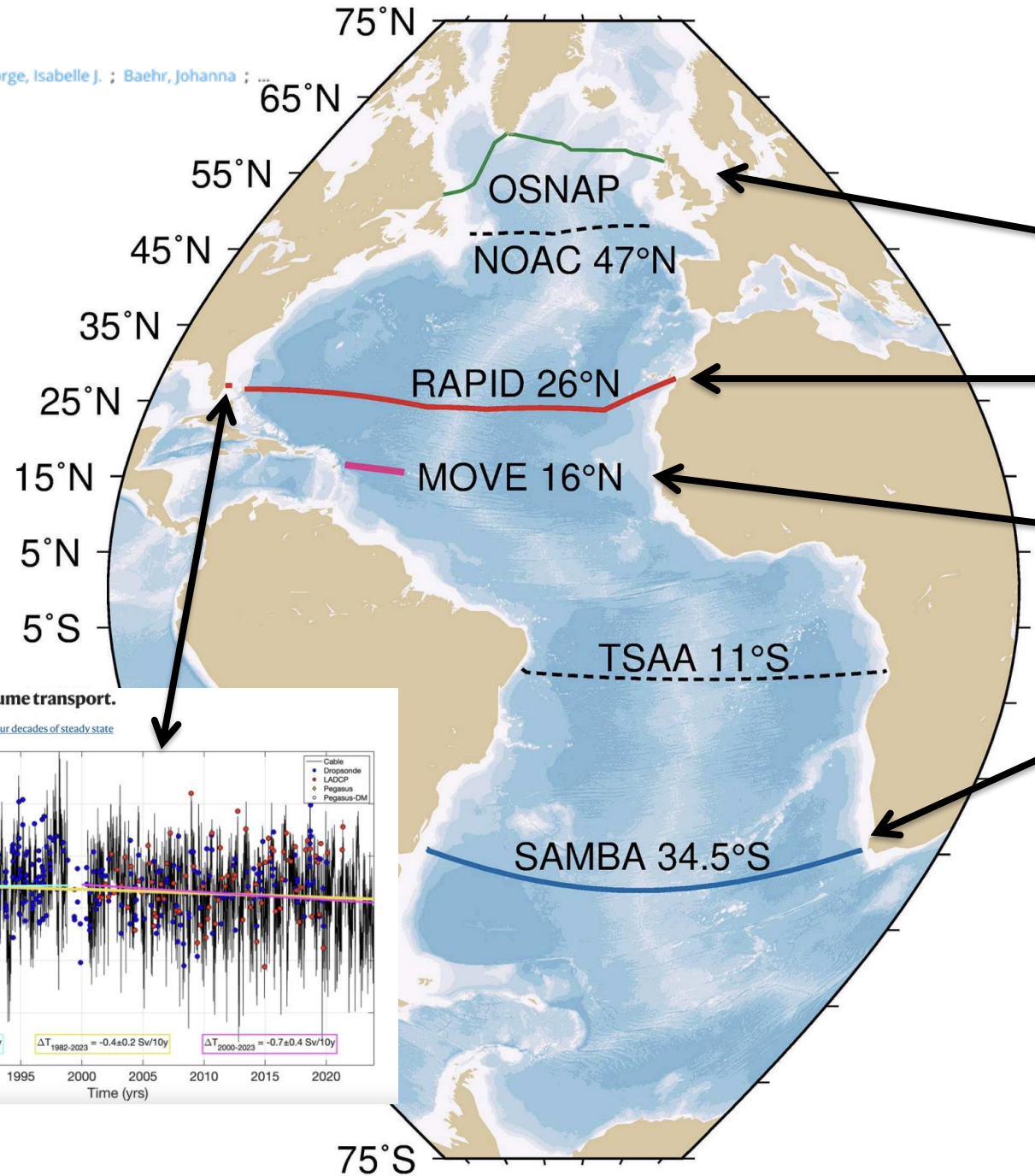

τ_r
λ_c
λ_0
Control parameter, λ
t_0
t_c
Time
b


t_{ac}
time
Potential, $U(x)$
$x_e(\lambda_1)$
$\mu(\lambda_1)$
State, x
d

Atlantic Meridional Overturning Circulation: Observed Transport and Variability

2019

By Frajka-Williams, Eleanor ; Ansorge, Isabelle J. ; Baehr, Johanna ; ...



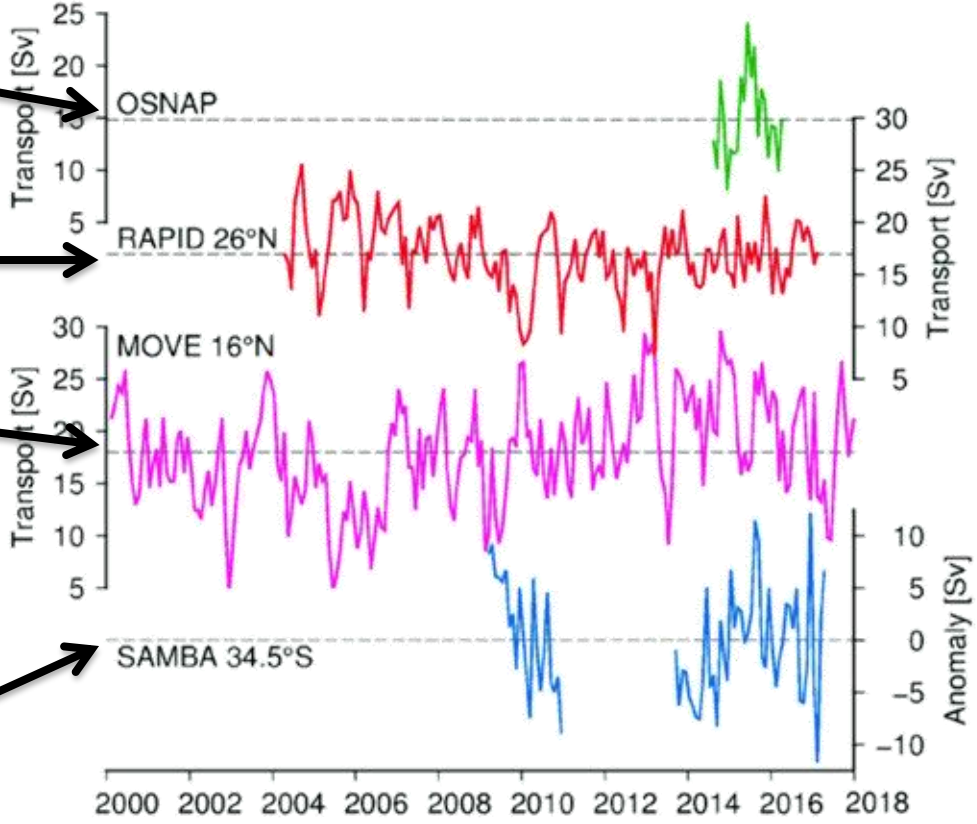
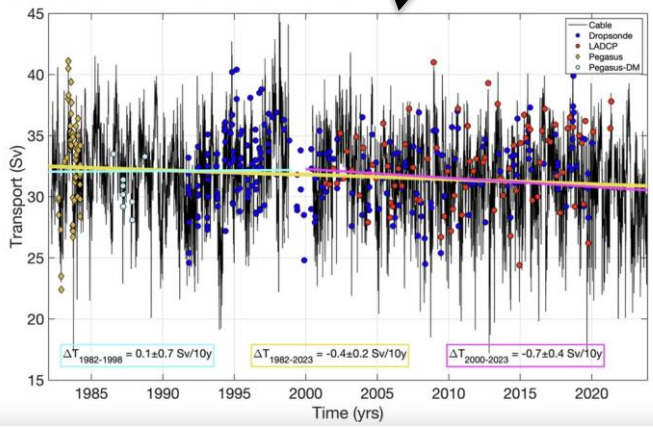
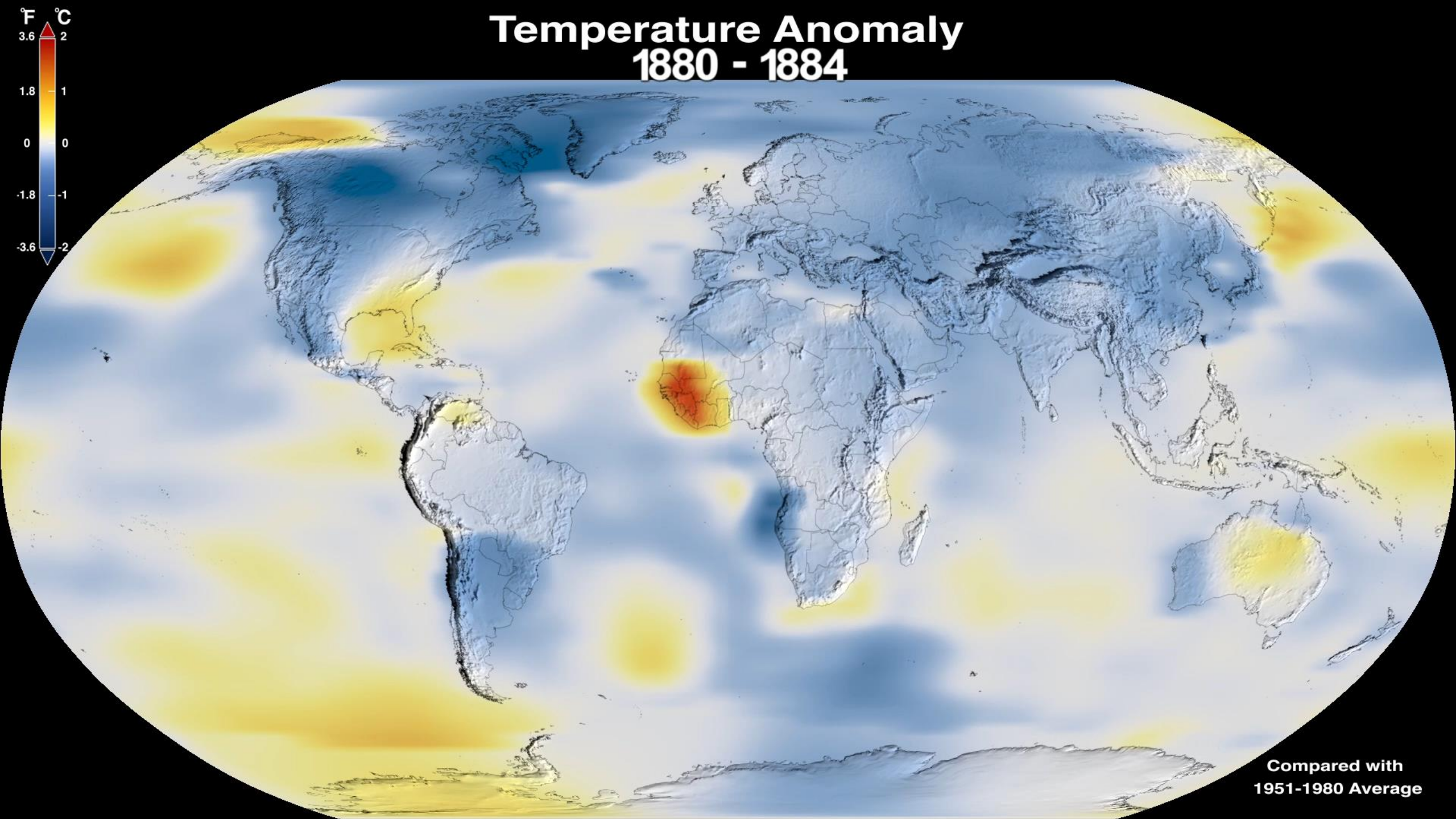


Fig. 2: The Florida Current volume transport.

From: Florida Current transport observations reveal four decades of steady state

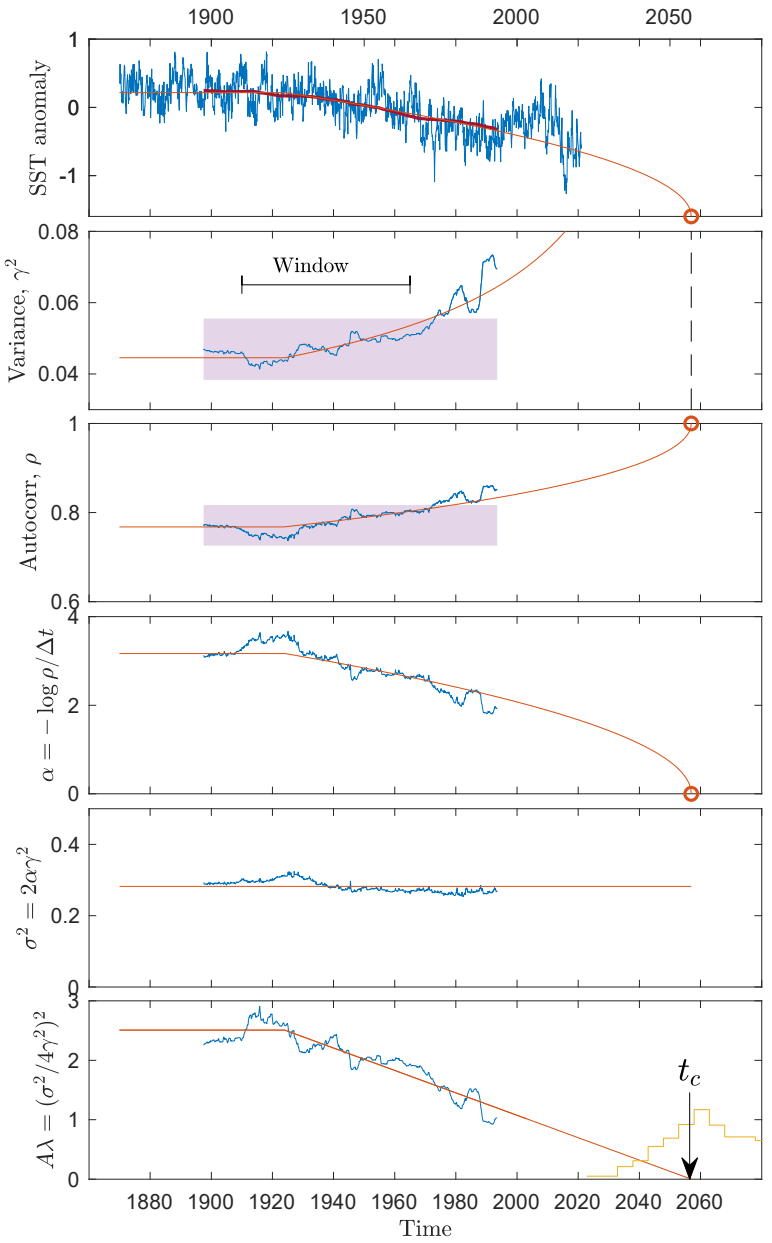



Temperature Anomaly
1880 - 1884
°F °C
3.6 2
1.8 1
0 0
-1.8 -1
-3.6 -2
Compared with
1951-1980 Average

Warning of a forthcoming collapse of the Atlantic meridional overturning circulation

Peter Ditlevsen ✉ & Susanne Ditlevsen ✉

Nature Communications **14**, Article number: 4254 (2023) | Cite this article



Warning of a forthcomin
meridional overturning

Peter Ditlevsen & Susanne Ditlevsen

Nature Communications **14**, Article number: 4

576k Accesses | **157** Citations | **8240** Altr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TO BLOCK CHINA
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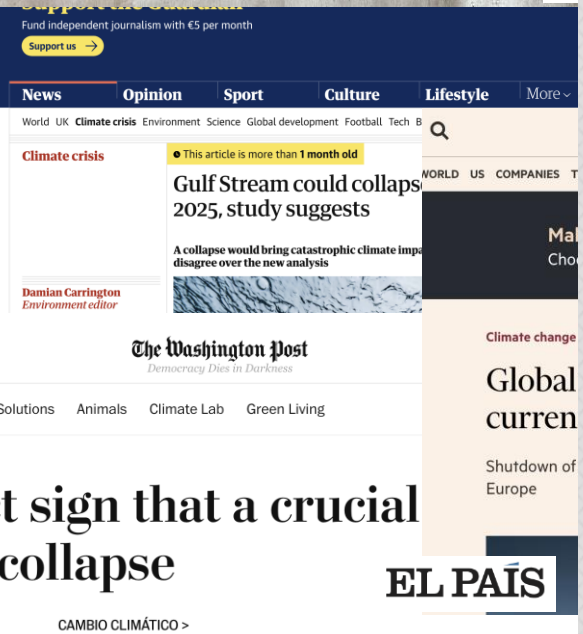
INTERNATIONAL EDITION | THURSDAY,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2025, study suggests
A collapse would bring catastrophic climate impa
disagree over the new analysis
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Environment editor
The Washington Post
Democracy Dies in Darkness
Solutions Animals Climate Lab Green Living
Climate change
Global
curren
Shutdown of
Europe

t sign that a crucial
collapse

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JULY 25, 2023

Post

expert reaction to paper warning of a collapse of the Atlantic meridional overturning circulation

A paper published in *Nature Communications* warns of a forthcoming collapse of the Atlantic Meridional Overturning Circulation (AMOC).

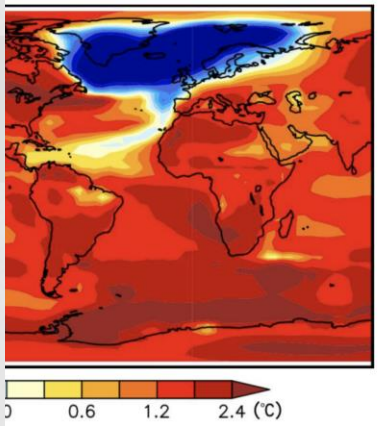
Prof Andrew Watson FRS, Royal Society Research Professor at the Global Systems Institute, University of Exeter, said:

"This study highlights that the North Atlantic circulation is showing signs of instability, which might indicate that a collapse of the overturning could occur,

Climate Scientists
uncil of Ministers

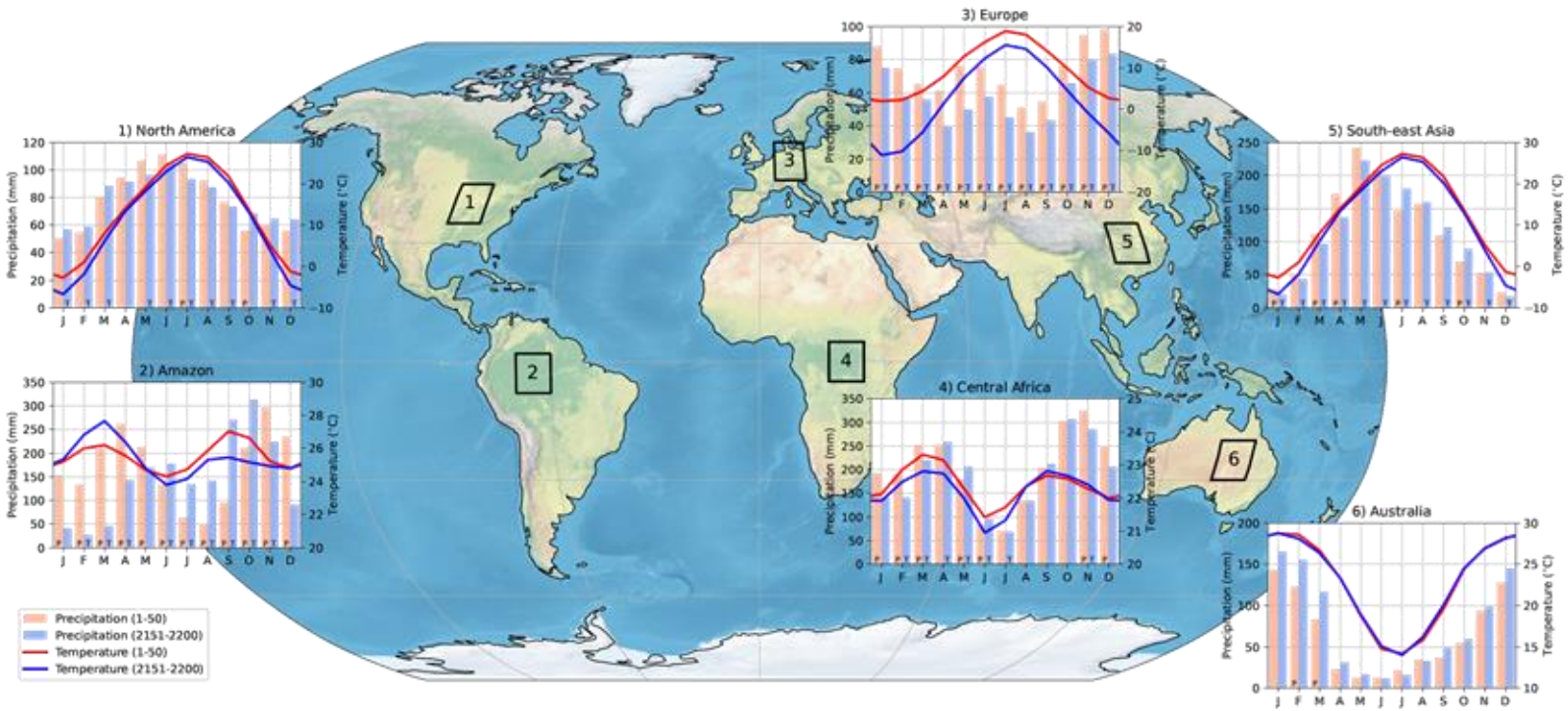
October 2024

in the field of climate research and feel it is
uncil of Ministers to the serious risk of a
c. A string of scientific studies in the past few
greatly underestimated. Such an ocean
nd irreversible impacts especially for Nordic
d.


0 0.6 1.2 2.4 (°C)

n idealised future CO2 doubling scenario
collapsed. Source: Science[1].


lfstrømmens mulige kollaps



Westen et al., 2023