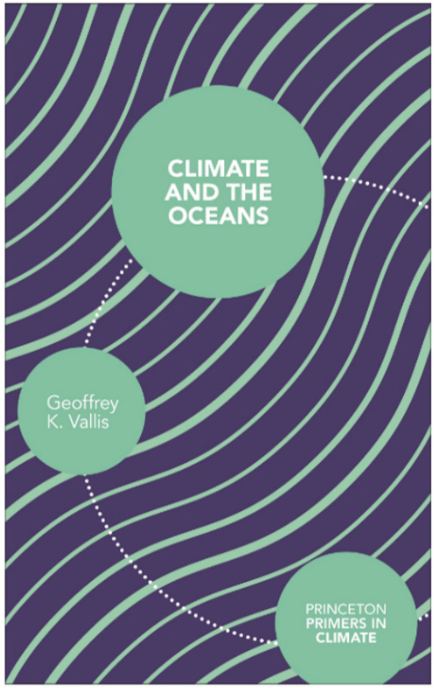
Climate and the Oceans: Ocean Dynamics and Circulation

AOSC 680

Ross Salawitch

Class Web Sites:
http://www2.atmos.umd.edu/~rjs/class/fall2022
https://umd.instructure.com/courses/1327017



Lecture 17

3 November 2022

Copyright © 2022 University of Maryland.
This material may not be reproduced or redistributed, in whole or in part, without written permission from Ross Salawitch.

Class Schedule

11/03	Ocean Dynamics and Circulation	Chapters 3 & 4 of *Climate and the Oceans*	AT 17	**Shaun** Lecture 17 Instructor Video		Schlesinger and Ramankutty, *Nature*, 1994 Canty et al., 2013 AMOC Variability	
11/08	Oceans Role in Climate & Climate Variability	Chapters 5 & 6 of *Climate and the Oceans*	AT 18	**Rachel** Lecture 18			
11/10	Global Warming and the Ocean	Chapters 7 of *Climate and the Oceans*	AT 19	**Alisha** Lecture 19			
11/15	Tips on Writing a Good Paper	To Be Determined	AT 20	Ross Lecture 20			
11/17	Introduction to Ecosystems and the Cryosphere	Chapters 1 & 2 of *Climate and Ecosystems* and Chapter 1 of *The Crysophere*	AT 21	Ross Lecture 21			
11/22	Cryosphere	Reading to be determined from *The Cryosphere*	AT 22	**Natalia** Lecture 22			
11/29	Ecosystems	Reading to be determined from *Climate and Ecosystems*	AT 23	**Yixin** Lecture 23			
12/02	T.B.D.	T.B.D.	No AT	Student Presentations 1 and 2	Each Presentation is 18 minutes, with 5 mins for discussion. 2 x 23 = 46 minutes Paper is due on the next class meeting after the discussion.		
12/06	T.B.D.	T.B.D.	No AT	Student Presentations 3, 4, & 5	Each Presentation is 18 minutes, with 5 mins for discussion. 3 x 23 = 70 minutes Paper is due on the next class meeting after the discussion.		
12/08	T.B.D.	T.B.D.	No AT	Student Presentations 6, 7 & 8	Each Presentation is 18 minutes, with 5 mins for discussion. 3 x 23 = 70 minutes Paper is due on the next class meeting after the discussion.		

Copyright © 2022 University of Maryland.
This material may not be reproduced or redistributed, in whole or in part, without written permission from Ross Salawitch.

AMOC: Atlantic Meridional Overturning Circulation

NATURE · VOL 367 · 24 FEBRUARY 1994

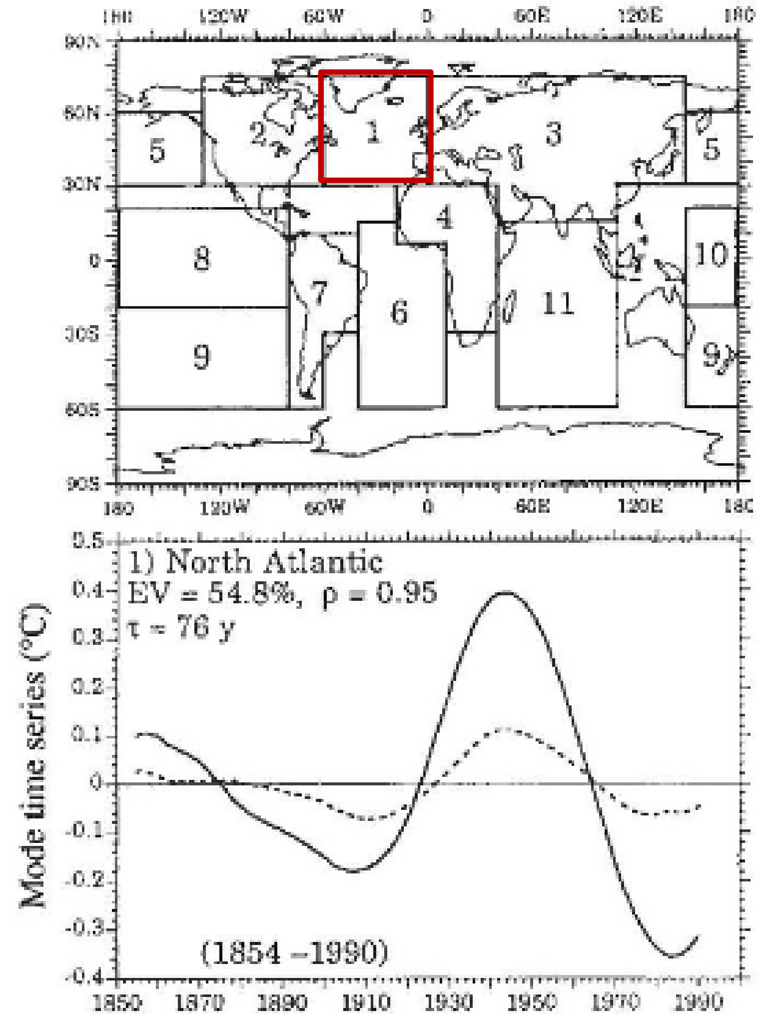
LETTERS TO NATURE

An oscillation in the global climate system of period 65–70 years

Michael E. Schlesinger & Navin Ramankutty

Department of Atmospheric Sciences,
University of Illinois at Urbana-Champaign,
105 South Gregory Avenue, Urbana, Illinois 61801, USA

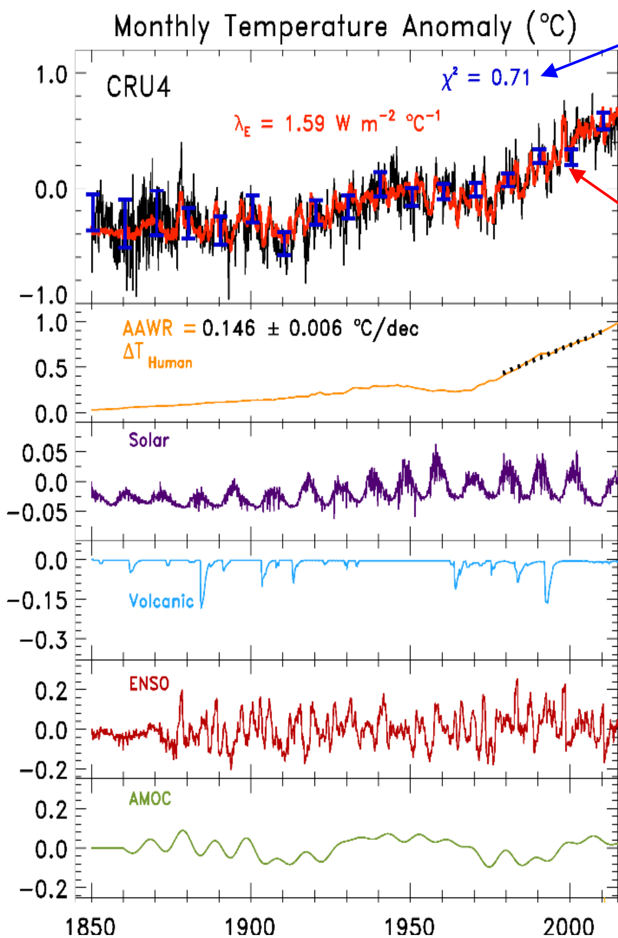
In addition to the well-known warming of ~0.5 °C since the middle of the nineteenth century, global-mean surface temperature records[1–4] display substantial variability on timescales of a century or less. Accurate prediction of future temperature change requires an understanding of the causes of this variability; possibilities include external factors, such as increasing greenhouse-gas concentrations[5–7] and anthropogenic sulphate aerosols[8–10], and internal factors, both predictable (such as El Niño[11]) and unpredictable (noise[12,13]). Here we apply singular spectrum analysis[14–20] to four global-mean temperature records[1–4], and identify a temperature oscillation with a period of 65–70 years. Singular spectrum analysis of the surface temperature records for 11 geographical regions shows that the 65–70-year oscillation is the statistical result of 50–88-year oscillations for the North Atlantic Ocean and its bounding Northern Hemisphere continents. These oscillations have obscured the greenhouse warming signal in the North Atlantic and North America. Comparison with previous observations and model simulations suggests that the oscillation arises from predictable internal variability of the ocean–atmosphere system.



https://www.nature.com/articles/367723a0

Copyright © 2022 University of Maryland.
This material may not be reproduced or redistributed, in whole or in part, without written permission from Ross Salawitch.

AMOC: Atlantic Meridional Overturning Circulation & Volcanic Cooling



$$\chi^2 = \frac{1}{\left(N_{YEARS} - N_{FITTING\ PARAMETERS} - 1\right)} \times \sum_{j=1}^{N_{YEARS}} \frac{1}{\langle \sigma_{OBS\,j} \rangle^2} \left(\langle \Delta T_{OBS\,j} \rangle - \langle \Delta T_{EM\text{-}GC\,j} \rangle \right)^2$$

where $\langle\ \rangle$ denotes annual average

$$\Delta T_{MDL\,i} = (1+\gamma)\left(\frac{GHG\ RF_i + LUC\ RF_i + Aerosol\ RF_i}{\lambda_p}\right) + C_0 + C_1 \times SOD_{i-6} + C_2 \times TSI_{i-1} + C_3 \times ENSO_{i-2} + C_4 \times AMOC_i - \left(\frac{Q_{OCEAN_i}}{\lambda_p}\right)$$

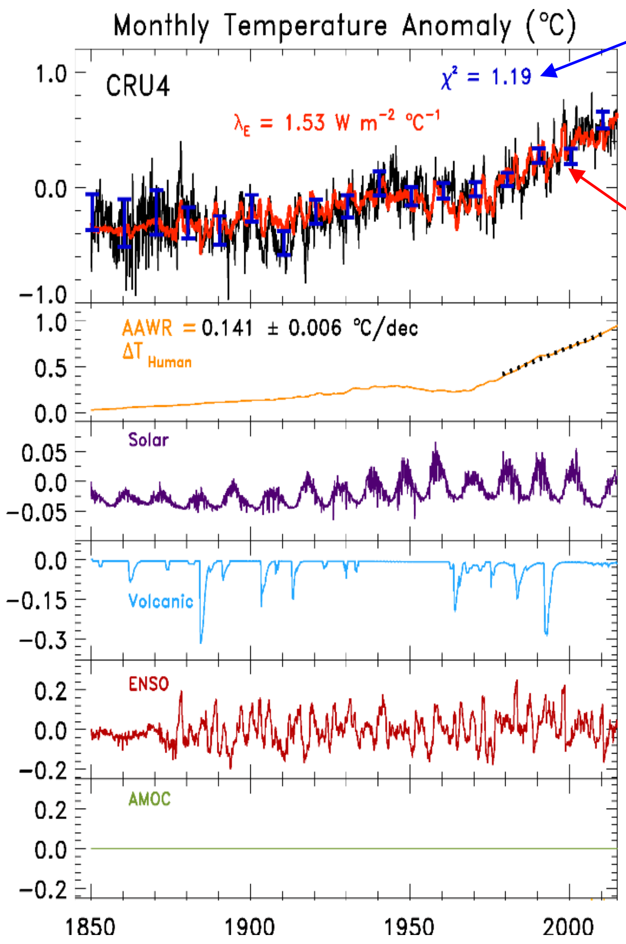
where:

- i denotes month
- $\lambda_p = 3.2\ \mathrm{W\,m^{-2}\,{}^\circ C^{-1}}$
- $1+\gamma = \{1 - \lambda_\Sigma/\lambda_p\}^{-1}$
- GHG RF = RF due to all anthropogenic GHGs
- LUC RF = RF due to Land Use Change
- Aerosol RF = RF due to Tropospheric Aerosols
- SOD = Stratospheric Optical Depth
- TSI = Total Solar Irradiance
- ENSO = El Niño Southern Oscillation
- AMOC = Atlantic Meridional Overturning Circulation
- Q_{OCEAN} = Ocean heat export = $\kappa(1+\gamma)\{\Delta T_{MDL\,i} - \Delta T_{OCEAN\ SURFACE\,i}\}$

Canty et al., ACP, 2013: https://acp.copernicus.org/articles/13/3997/2013
Hope et al., Earth's Future, 2020: https://www.essoar.org/doi/10.1002/essoar.10504179.1

Copyright © 2022 University of Maryland.
This material may not be reproduced or redistributed, in whole or in part, without written permission from Ross Salawitch.

AMOC: Atlantic Meridional Overturning Circulation & Volcanic Cooling



$$\chi^2 = \frac{1}{\left(N_{YEARS} - N_{FITTING\ PARAMETERS} - 1\right)} \times \sum_{j=1}^{N_{YEARS}} \frac{1}{\left\langle \sigma_{OBS\,j} \right\rangle^2} \left(\left\langle \Delta T_{OBS\,j} \right\rangle - \left\langle \Delta T_{EM\text{-}GC\,j} \right\rangle \right)^2$$

where $\langle\ \rangle$ denotes annual average

$$\Delta T_{MDL\,i} = (1+\gamma)\left(\frac{GHG\ RF_i + LUC\ RF_i + Aerosol\ RF_i}{\lambda_p}\right) + C_0 + C_1 \times SOD_{i-6} + C_2 \times TSI_{i-1} + C_3 \times ENSO_{i-2} + \cancel{C_4 \times AMOC_i} - \left(\frac{Q_{OCEAN\,i}}{\lambda_p}\right)$$

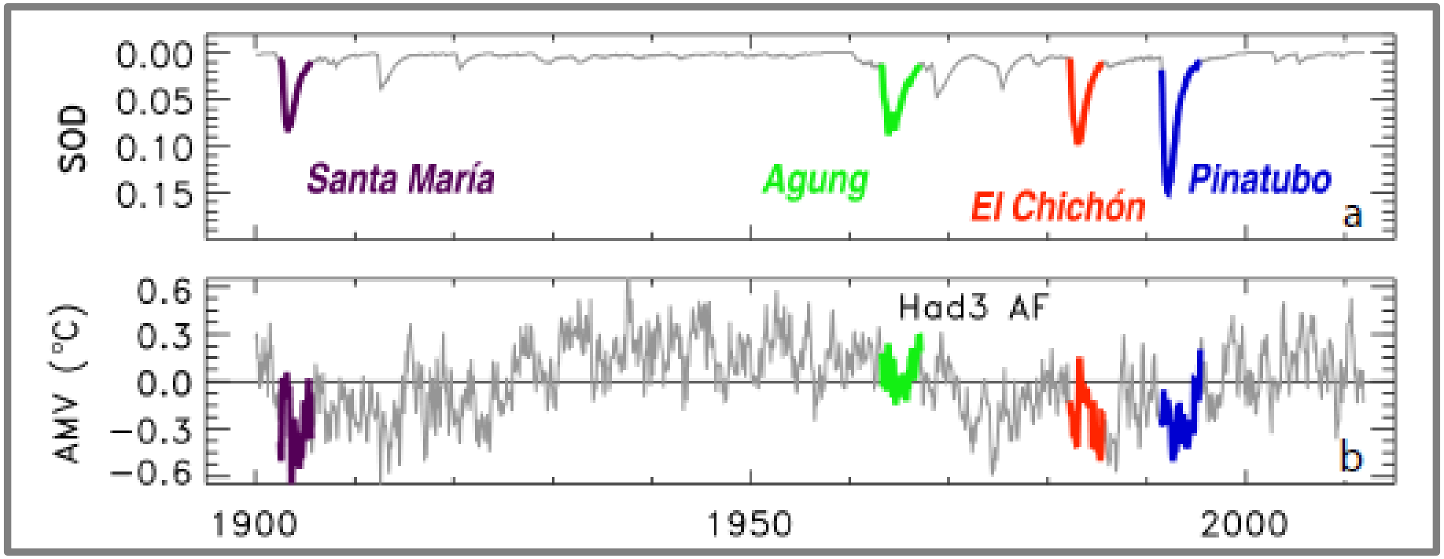
where:

- i denotes month
- $\lambda_p = 3.2\ \mathrm{W\,m^{-2}\,°C^{-1}}$
- $1+\gamma = \{1 - \lambda_\Sigma/\lambda_p\}^{-1}$
- GHG RF = RF due to all anthropogenic GHGs
- LUC RF = RF due to Land Use Change
- Aerosol RF = RF due to Tropospheric Aerosols
- SOD = Stratospheric Optical Depth
- TSI = Total Solar Irradiance
- ENSO = El Niño Southern Oscillation
- ~~AMOC = Atlantic Meridional Overturning Circulation~~
- Q_{OCEAN} = Ocean heat export = $\kappa(1+\gamma)\{\Delta T_{MDL\,i} - \Delta T_{OCEAN\ SURFACE\,i}\}$

Canty et al., ACP, 2013: https://acp.copernicus.org/articles/13/3997/2013
Hope et al., Earth's Future, 2020: https://www.essoar.org/doi/10.1002/essoar.10504179.1

Copyright © 2022 University of Maryland.
This material may not be reproduced or redistributed, in whole or in part, without written permission from Ross Salawitch.

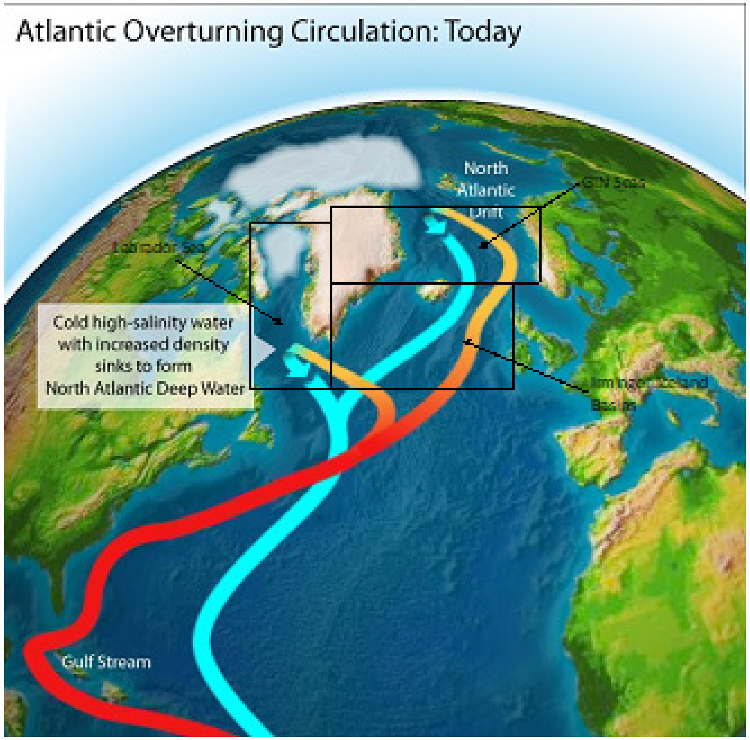
AMOC: Atlantic Meridional Overturning Circulation & Volcanic Cooling



Canty et al., ACP, 2013: https://acp.copernicus.org/articles/13/3997/2013

Copyright © 2022 University of Maryland.
This material may not be reproduced or redistributed, in whole or in part, without written permission from Ross Salawitch.

AMOC: Atlantic Meridional Overturning Circulation: Driver of Long-Term Variability ?!?



- Low-frequency ocean heat transport variability by AMOC driven primarily driven by strong northwesterly winds off eastern North America that initially cool and densify Labrador Sea waters, increasing the sinking in that region.
- This increased sinking strengthens AMOC, which leads to an increased OHT.
- The strengthened AMOC and OHT carry more warm water northwards into the Labrador Sea, causing a reduction in sinking, and hence a weakening of AMOC and OHT.

https://pcc.uw.edu/blog/research/mechanisms-of-low-frequency-variability-in-north-atlantic-ocean-heat-transport-and-amoc/
Oldenburg et al., J. Climate, 2021: https://journals.ametsoc.org/view/journals/clim/34/12/JCLI-D-20-0614.1.xml

See also: https://www.gfdl.noaa.gov/research_highlight/a-simple-conceptual-model-for-the-self-sustained-multidecadal-amoc-variability/

Copyright © 2022 University of Maryland.
This material may not be reproduced or redistributed, in whole or in part, without written permission from Ross Salawitch.