

ATM 241 Climate Dynamics

Lecture 1

Introduction to Climate Dynamics



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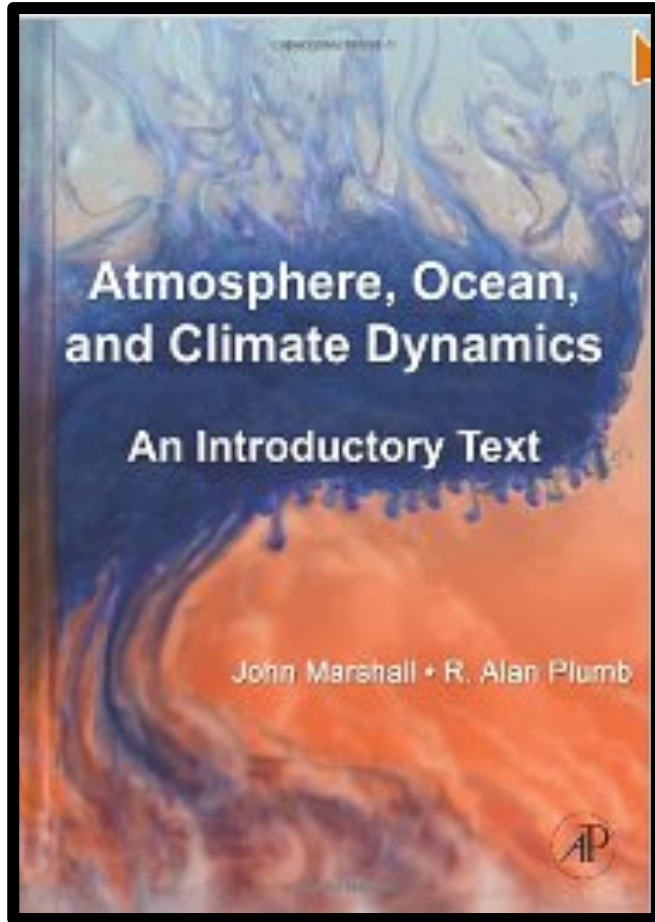
Preface

Climate Dynamics: Outline

Course Goals

- Understand the dynamical behavior of the Earth system
- Focus on global scales, over long time periods
- Understand the drivers of global circulation
- Understand the importance of energy in the climate system
- Understand the importance of moisture in the climate system
- Understand the processes that drive redistribution of energy and moisture
- Understand the implications of a globally interconnected climate system

ATM 241: Primary Textbook



Atmosphere, Ocean and Climate Dynamics: An Introductory Text

John Marshall and R. Alan Plumb (2007)

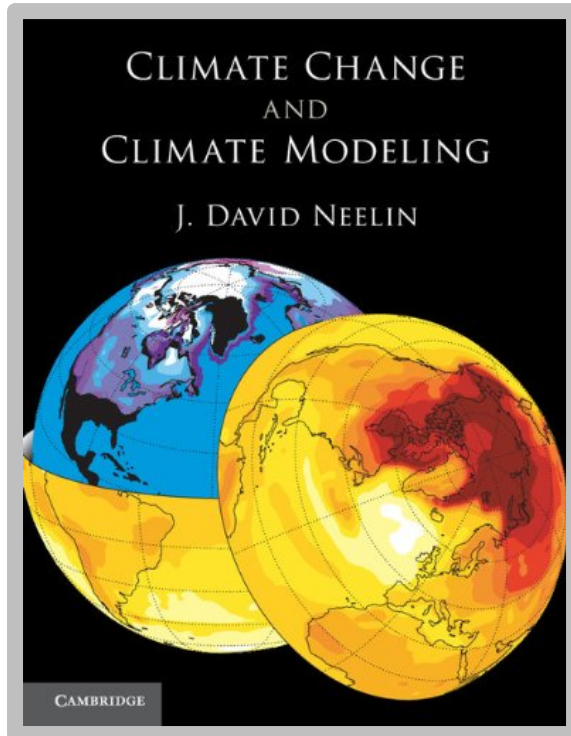
Supporting web page:

<http://marshallplumb.mit.edu/>

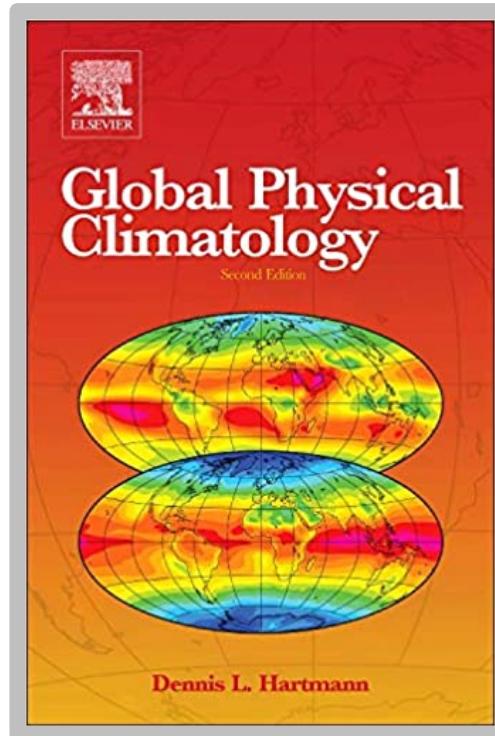
Datasets and plots from IRI/LDEO Climate Data Library:

<http://iridl.ldeo.columbia.edu/>

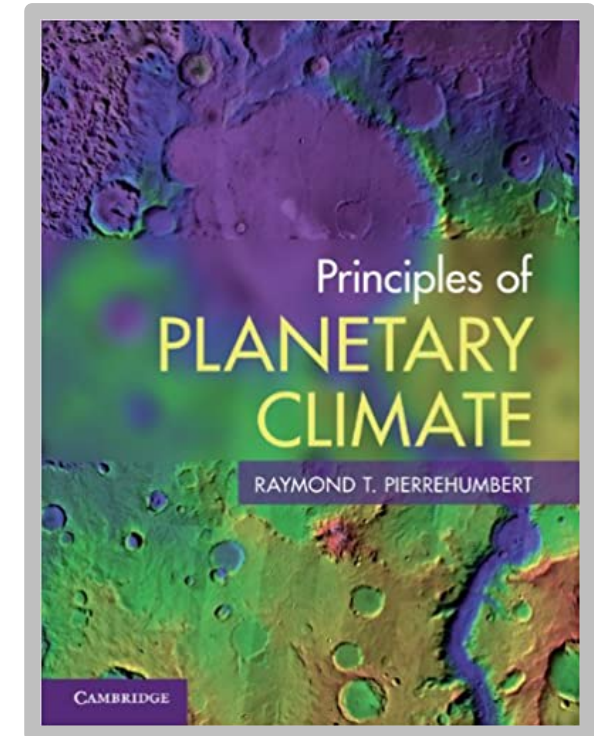
ATM 241: Additional Reading



**Climate Change and
Climate Modeling**
J. David Neelin
(2011)

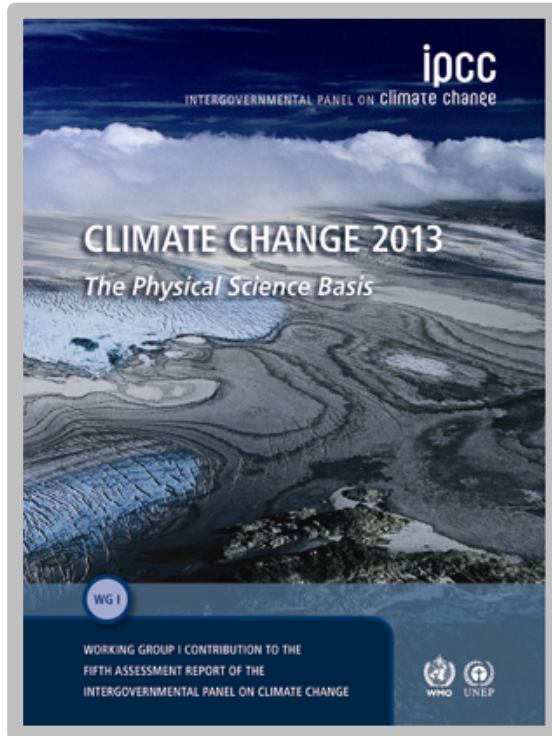


Global Physical Climatology
Dennis L. Hartmann
(2016)



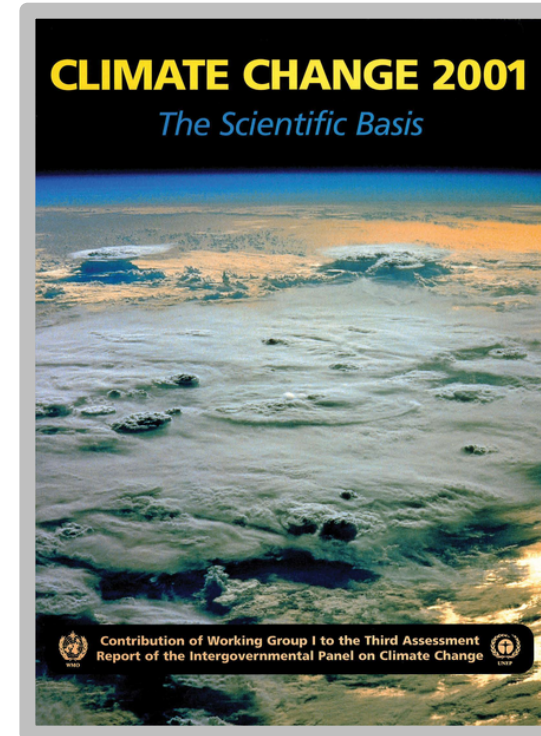
Principles of Planetary Climate
Raymond T. Pierrehumbert
(2010)

ATM 241: Additional Reading



**Climate Change 2013:
The Physical Science Basis**
Intergovernmental Panel
on Climate Change

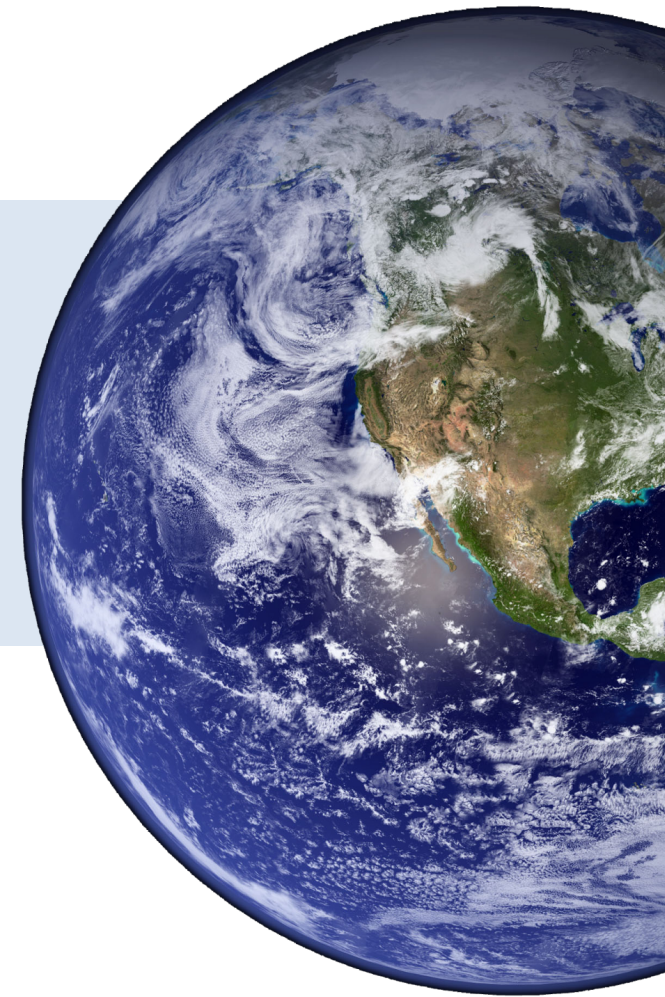
<https://www.ipcc.ch/report/ar5/wg1/>



**Climate Change 2001:
The Scientific Basis**
Intergovernmental Panel
on Climate Change

<https://www.ipcc.ch/report/ar3/wg1/>

The Climate System



In this section...

Definitions

- Climate
- Weather
- Climate dynamics
- Climate experiments
- Climate observations
- Climate models

Questions

- What are the five components of the Earth system?
- Why is it important to understand the Earth system?
- How is the Earth system studied?
- How are climate experiments, observations, and models interconnected?

Climate

How do we define climate?

- **Climate** is the pattern of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods.
- Climate can be contrasted to **weather**, which is the conditions of these variables presently or over short periods.
- **Climate also describes the variability of weather events**, e.g. the probability of a major rainfall event occurring in July in San Francisco, or variations in temperature that typically occur in January in Chicago.

Climate vs Weather

WEATHER CLIMATE

Tells you what to wear each day

**Weather is what
you get**



CLIMATE

Tells you what types of clothes to have in your closet



**Climate is what
you expect**



NOAA National Centers for Environmental Information

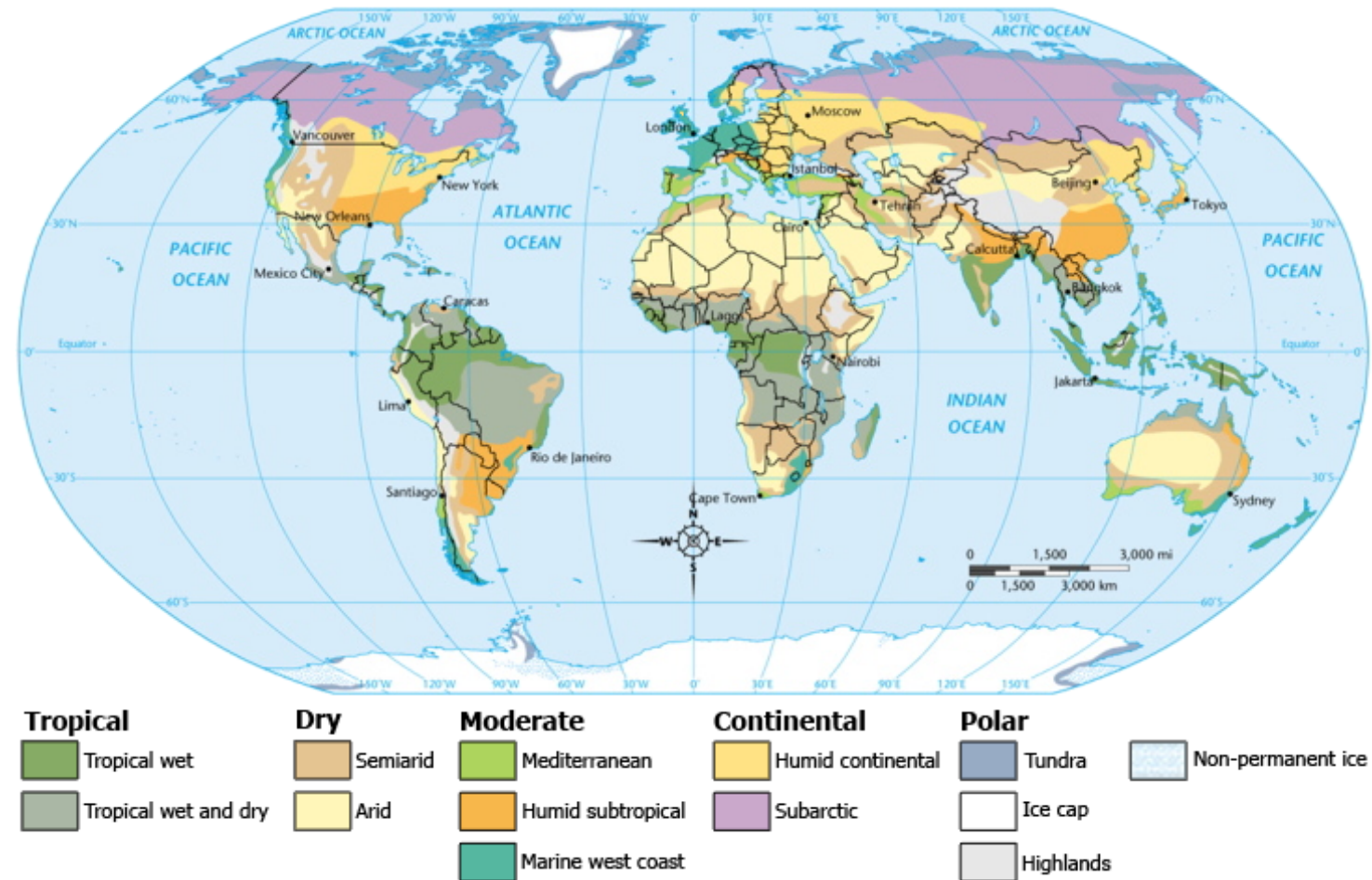
<https://www.ncei.noaa.gov/news/weather-vs-climate>

Climate Dynamics

What is Climate Dynamics?

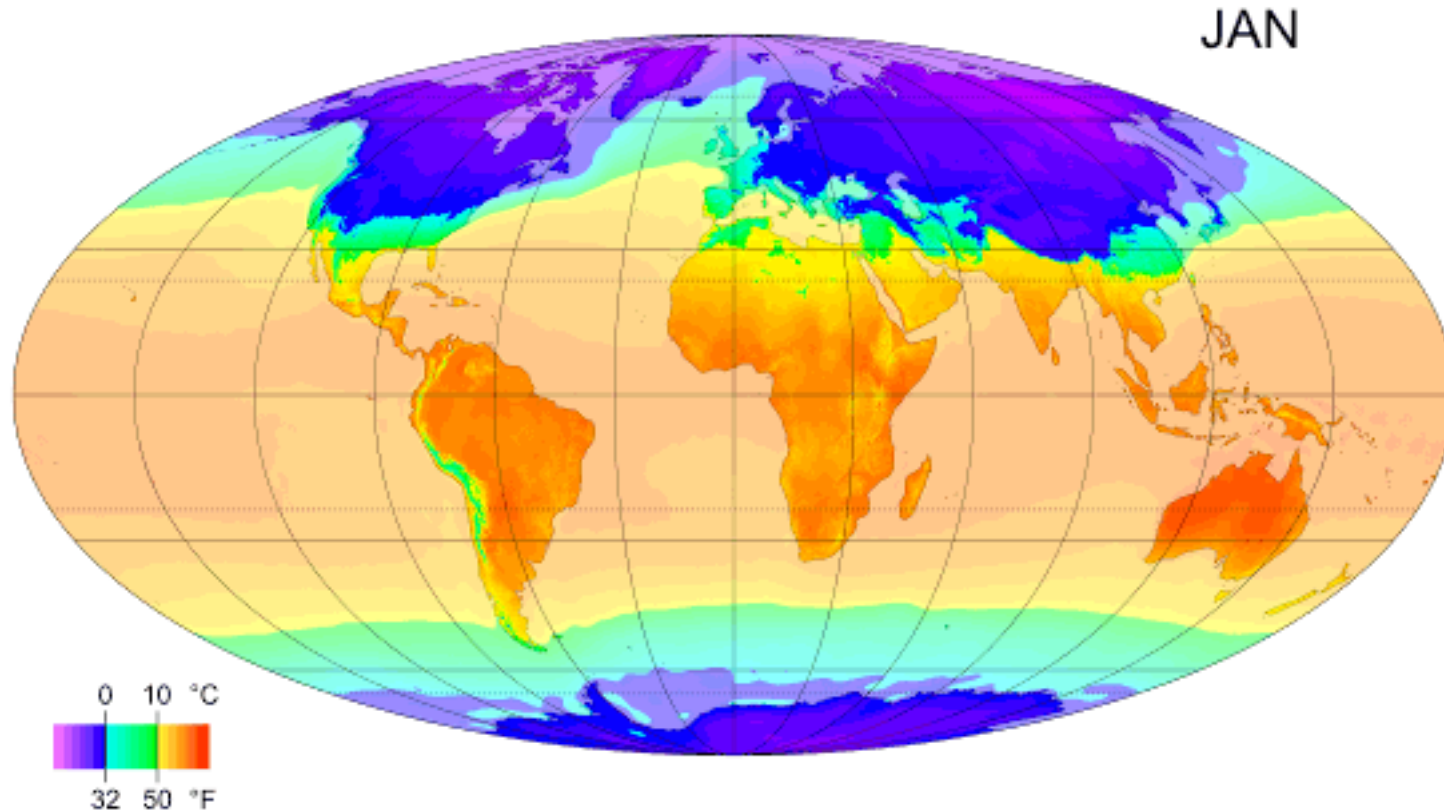
- The field of **climate dynamics** studies the processes that control the Earth system and how it evolves.
- Climate dynamics incorporates the study of **atmospheric** and **oceanic** processes as they occur over long time periods. It also includes the study of interactions between the atmosphere, the oceans, the land surface, the cryosphere, and the biosphere.

The Earth System: Climate Zones



The Earth System: Temperatures

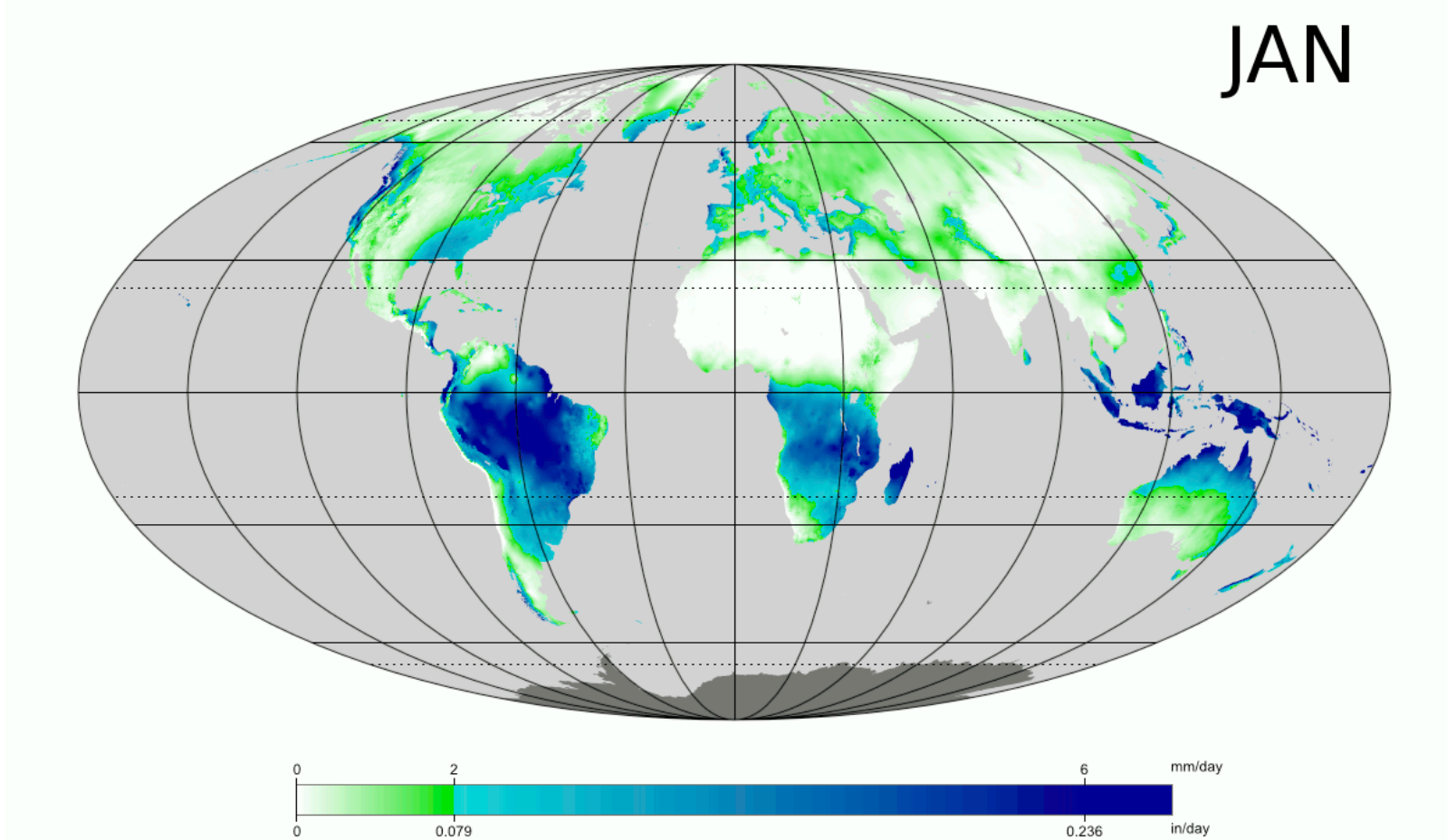
Monthly mean surface temperatures



Author: PZmaps, Wikimedia Commons, Feb 2009

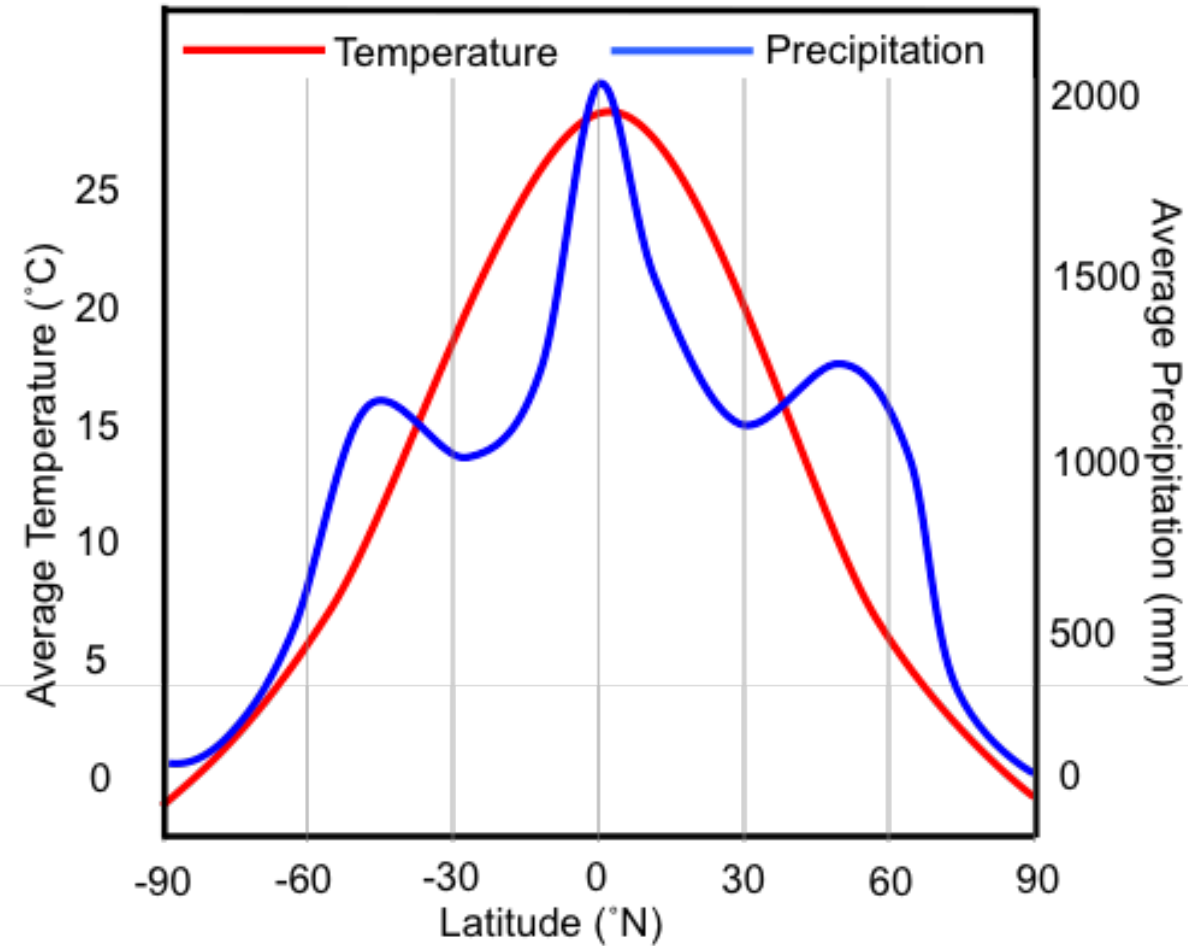
The Earth System: Precipitation

Monthly mean precipitation



Author: PZmaps, Wikimedia Commons, Mar 2009

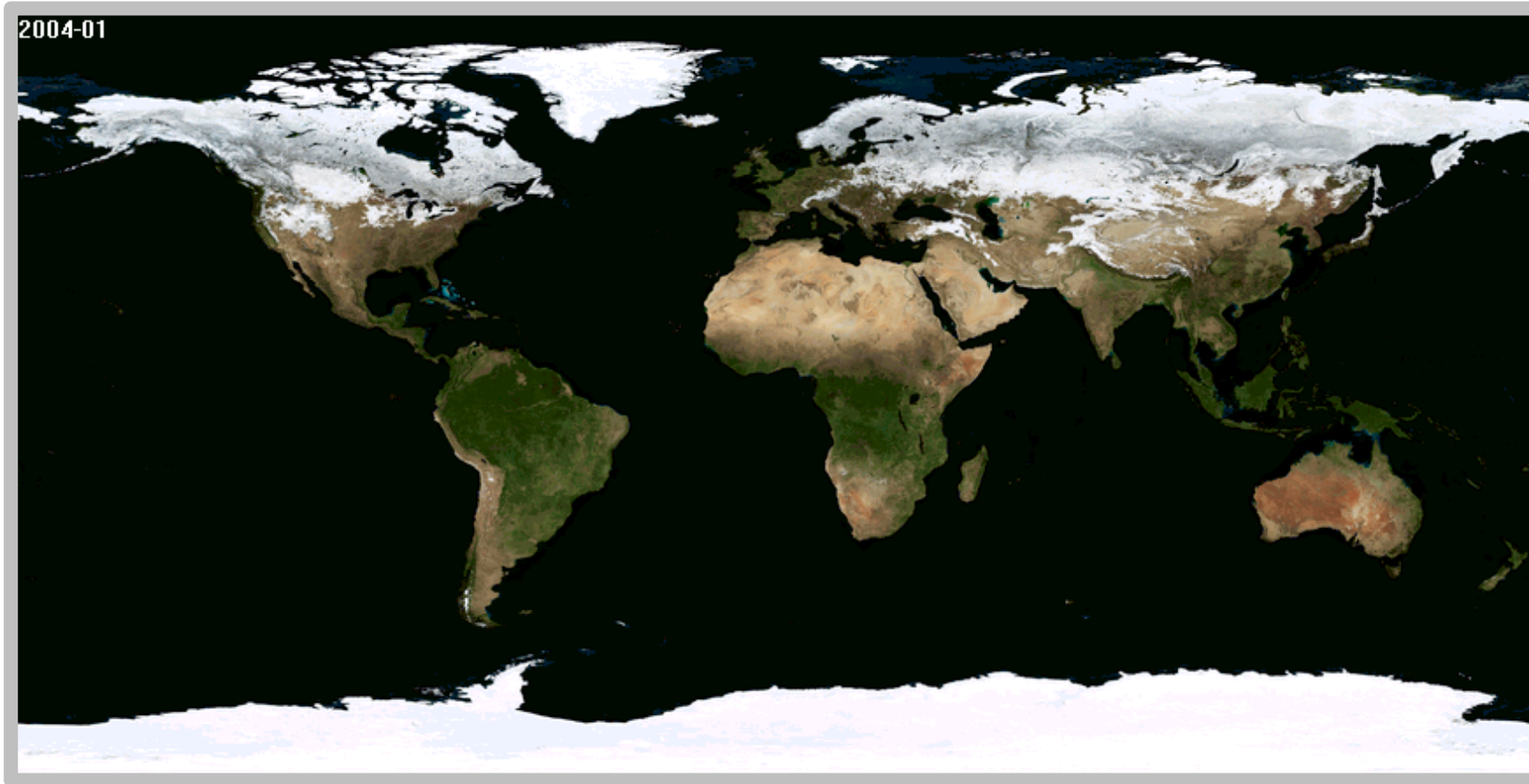
Temperature and Precipitation



https://commons.wikimedia.org/wiki/File:Relationship_between_latitude_vs._temperature_and_precipitation.png

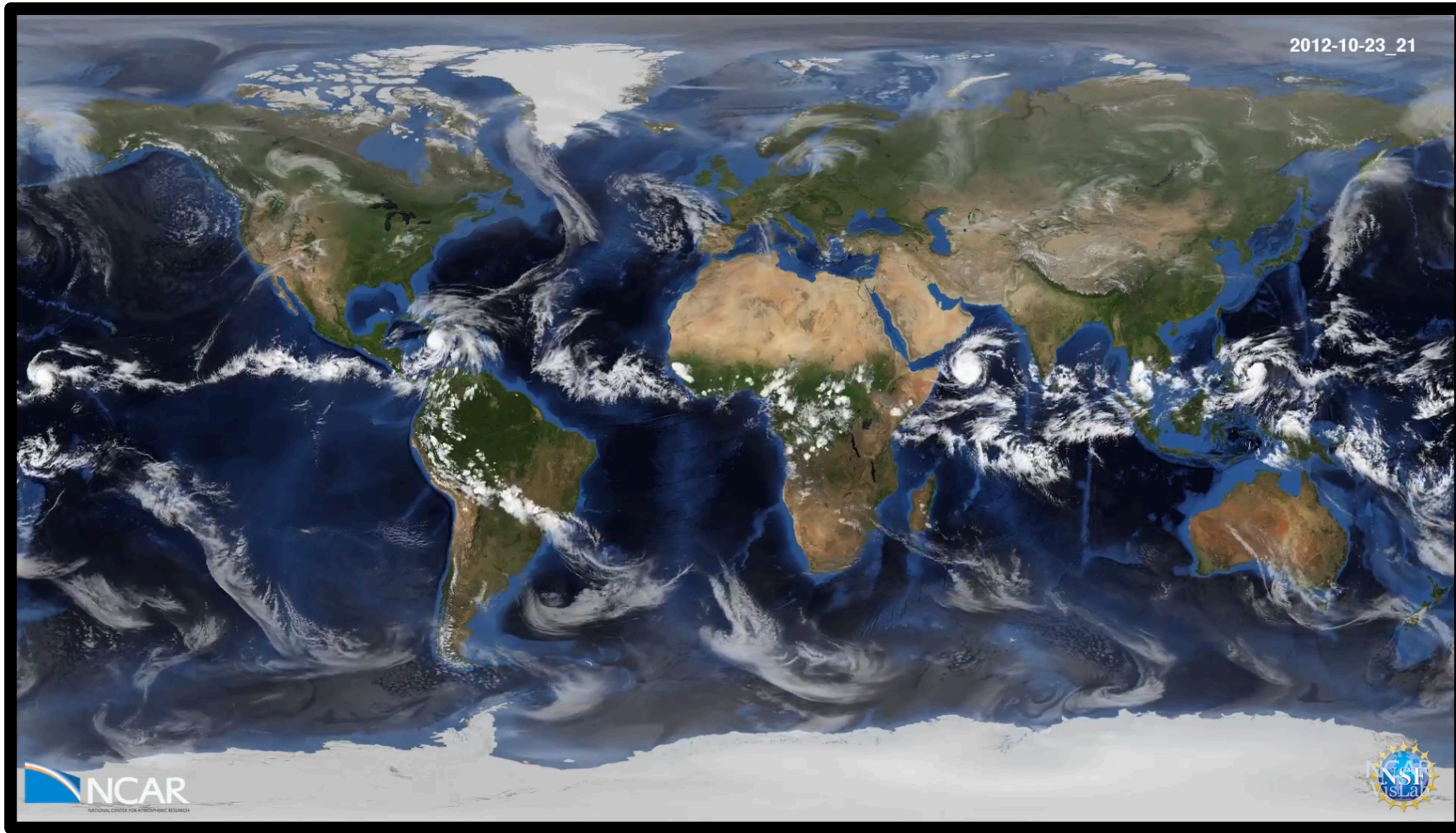
The Earth System: The Land Surface

Satellite Imagery (clouds digitally removed)



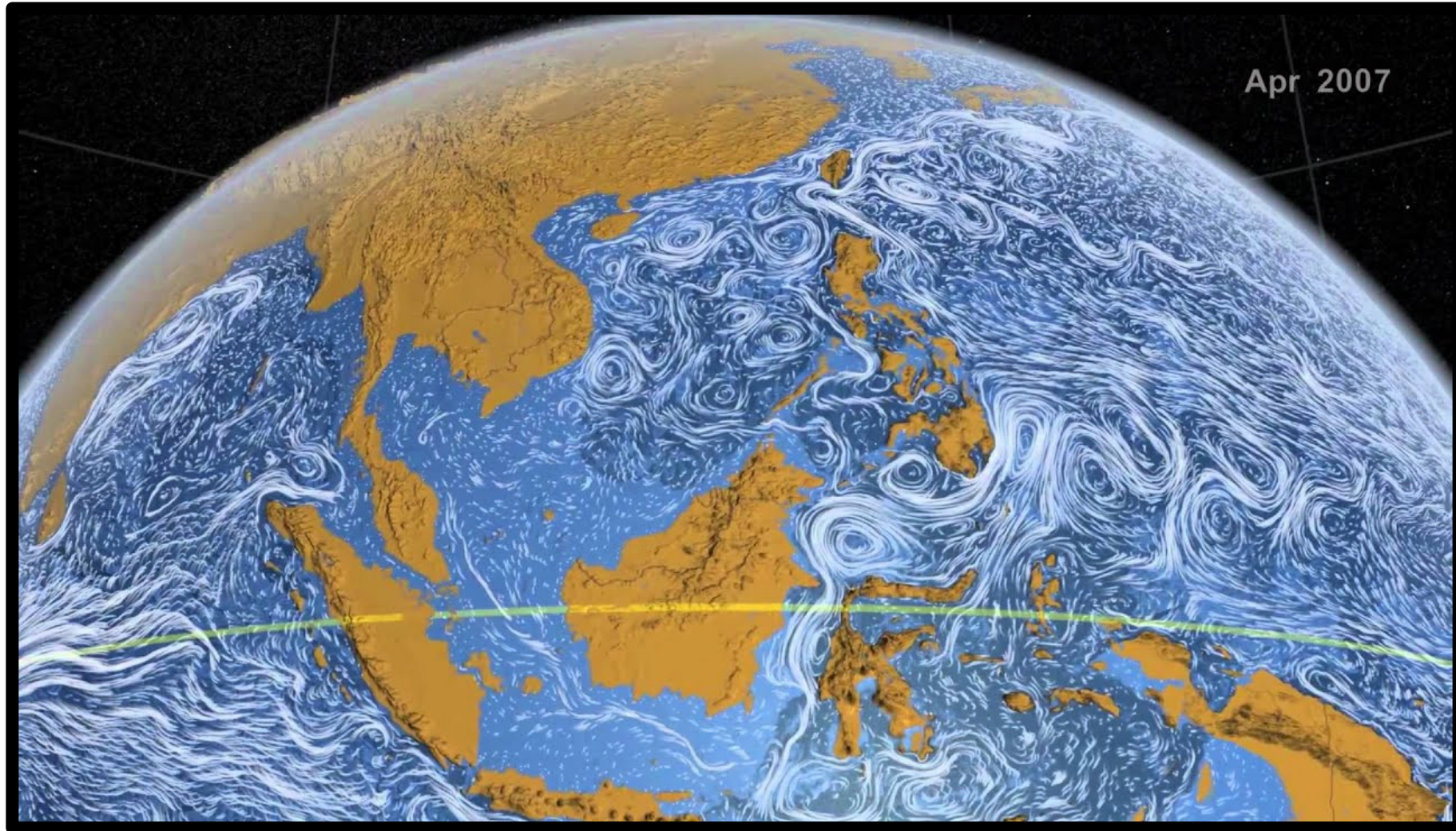
Author: NASA images by Reto Stöckli, 2004

The Earth System: Atmospheric Dynamics



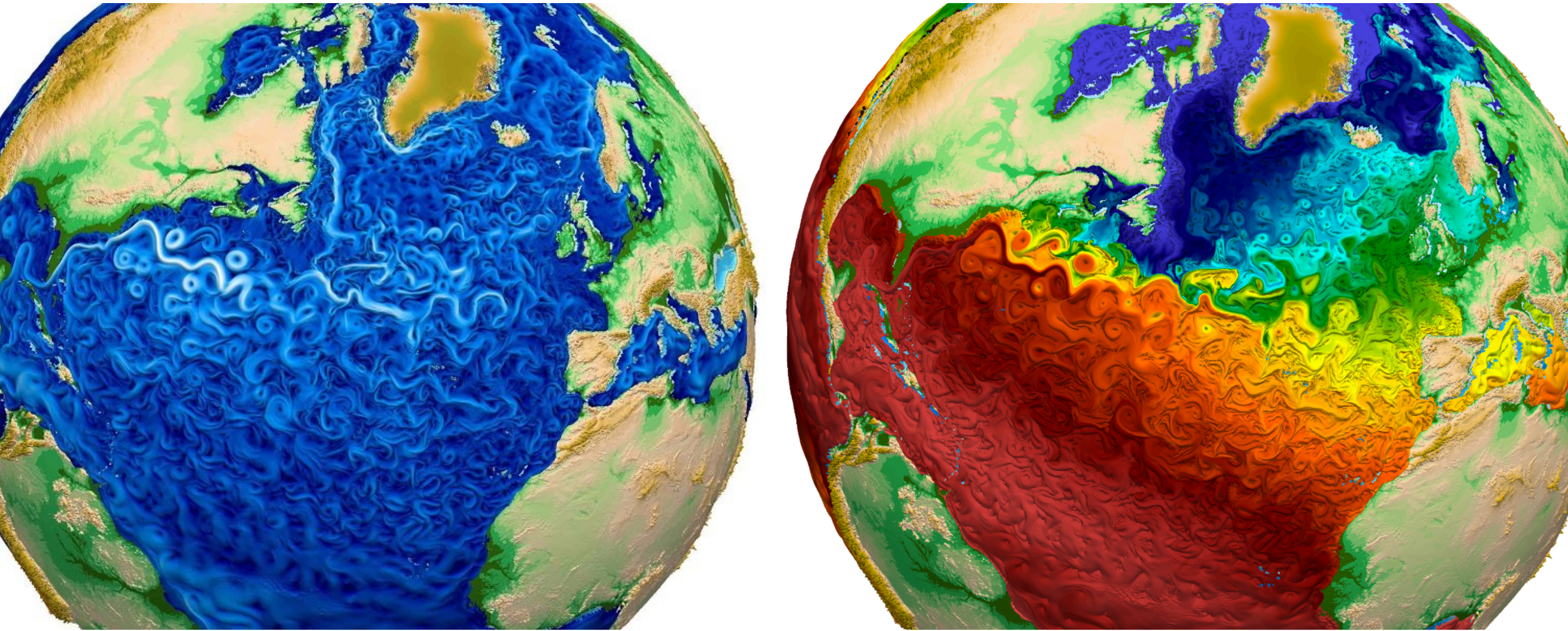
NCAR Simulated Global Weather <https://www.youtube.com/watch?v=UmiB4Ynd9AI>

The Earth System: Ocean Dynamics



NASA Perpetual Ocean <https://www.youtube.com/watch?v=CCmTY0PKGDs>

The Earth System: Ocean Dynamics



US DOE E3SM (left) Simulated ocean current speed and (right) concurrent ocean temperature

More Videos

Global Storm-Resolving and Large-Domain Large-Eddy Simulations with ICON LEM

<https://www.youtube.com/watch?v=ji4nno-fsvw>

NASA Simulated clouds and aerosol

https://www.youtube.com/watch?v=Hv-t_1ofrhU

NASA Global Cloud Modeling with GEOS-5

<https://www.youtube.com/watch?v=mlvLX7YvI88>

NCAR/DOE FV CAM5 Simulation at 0.25 degree global grid spacing

<https://www.youtube.com/watch?v=cNyftYdjt-Q>

US DOE Simulation of the Global Ocean with E3SM

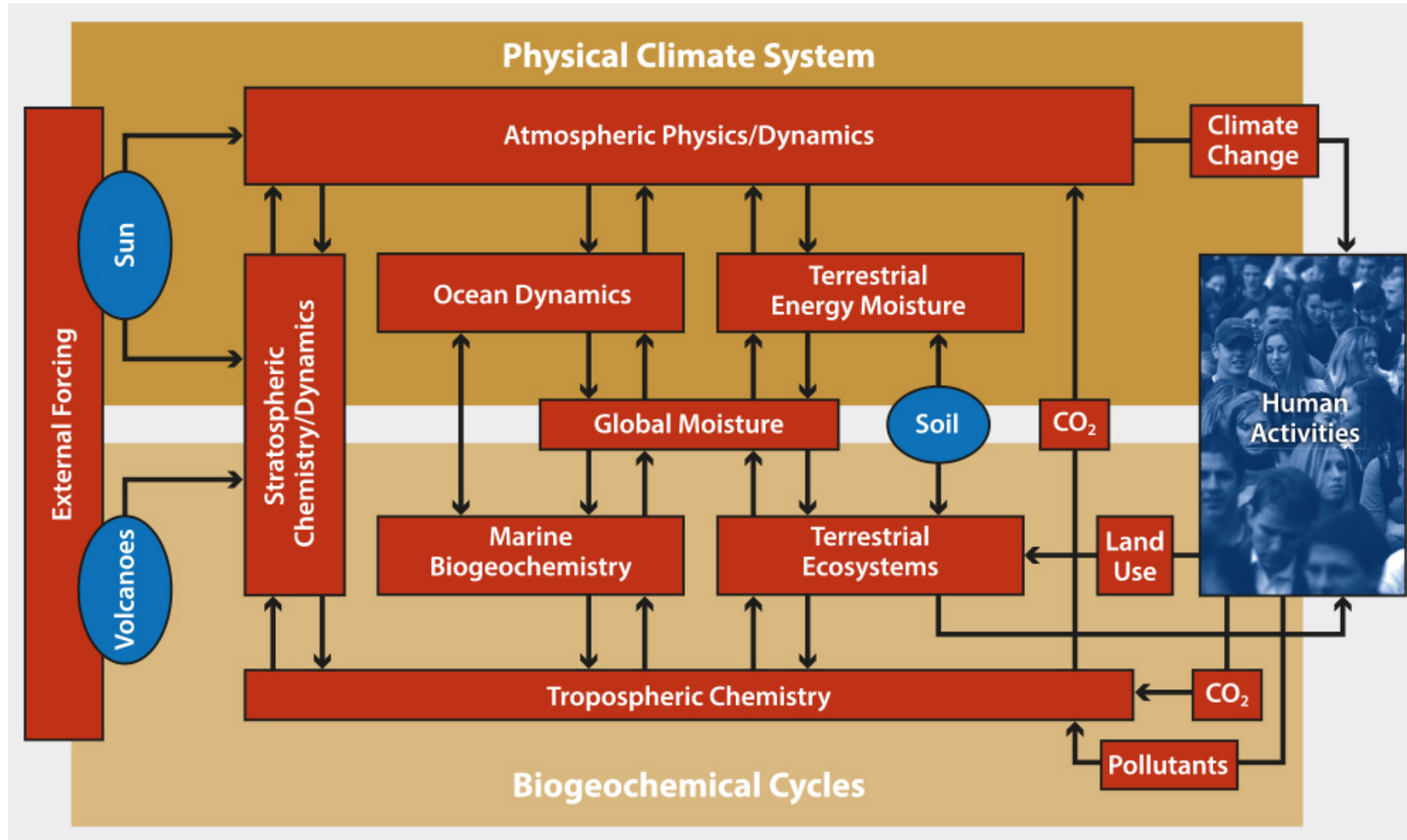
https://www.youtube.com/watch?v=RN_dsLIIIAI

The Earth System

What are the components of the Earth system?

- Atmosphere
 - Hydrosphere (Oceans and Water)
 - Land and Land Surface
 - Cryosphere (Sea and Land Ice)
 - Biosphere
-
- When talking about the **coupled human-Earth system** it is also typical to include **humans (the anthropogenic component)**

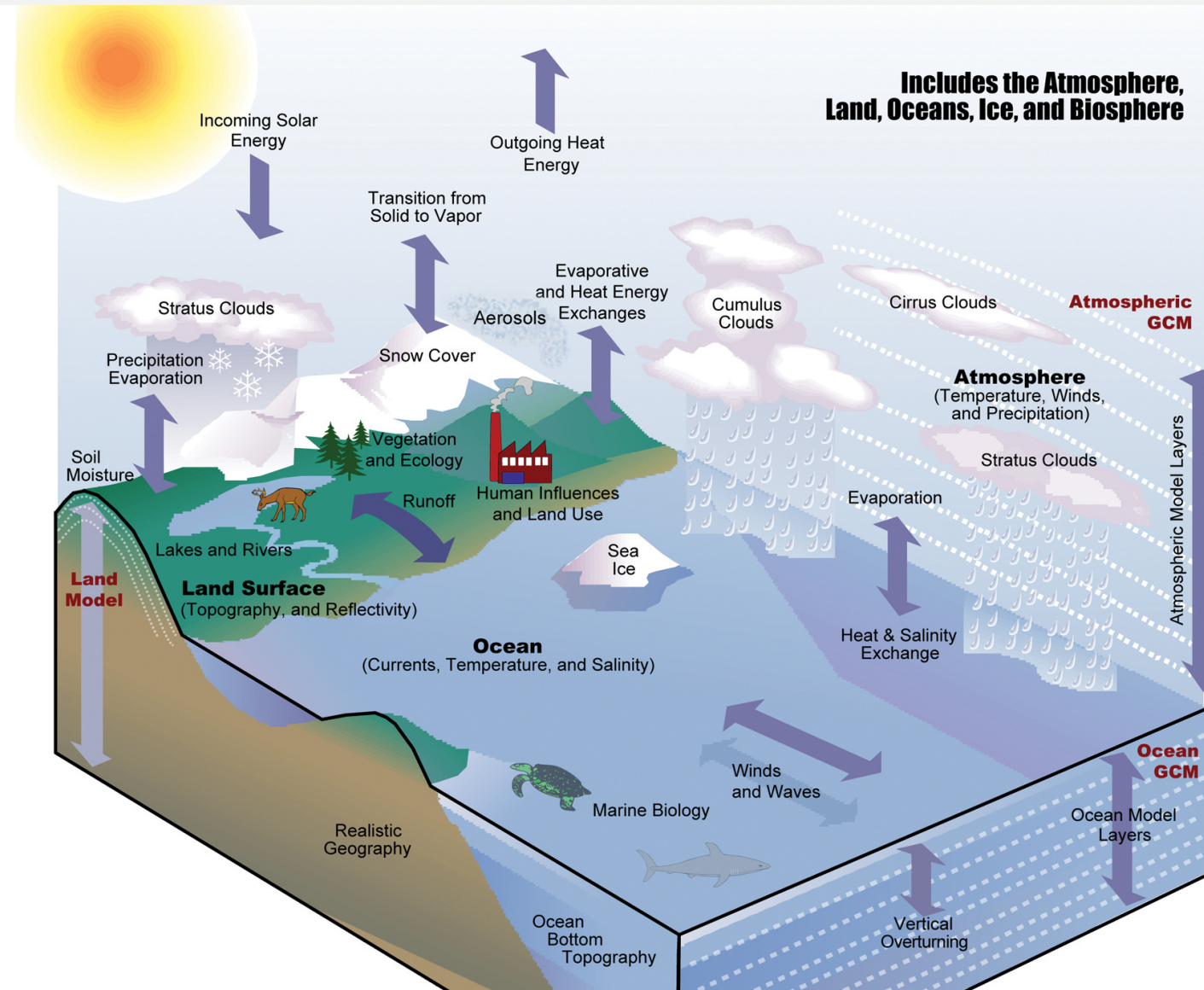
Bretherton Diagram (simplified)



The Bretherton diagram (NASA 1986) is a famous visualization of the interconnectedness of the Earth system.

Processes and Features of the Earth System

...as represented in global Earth system models



Understanding the Earth System

Why is an understanding of the Earth system important?

- Agriculture
- Water availability (Droughts / Floods)
- Ecosystem maintenance
- Weather variability
- Extreme events
 - Tropical cyclones
 - Atmospheric blocking
 - Heat waves / cold spells
 - Atmospheric rivers
 - Extratropical cyclones
 - Wildfires
- Sustainability
- Energy Usage and Planning
- Air Quality
- Sea Level Rise

Claim: An understanding of regional and global climate is one of the most important factors for long-term social and economic planning.

Extreme Events

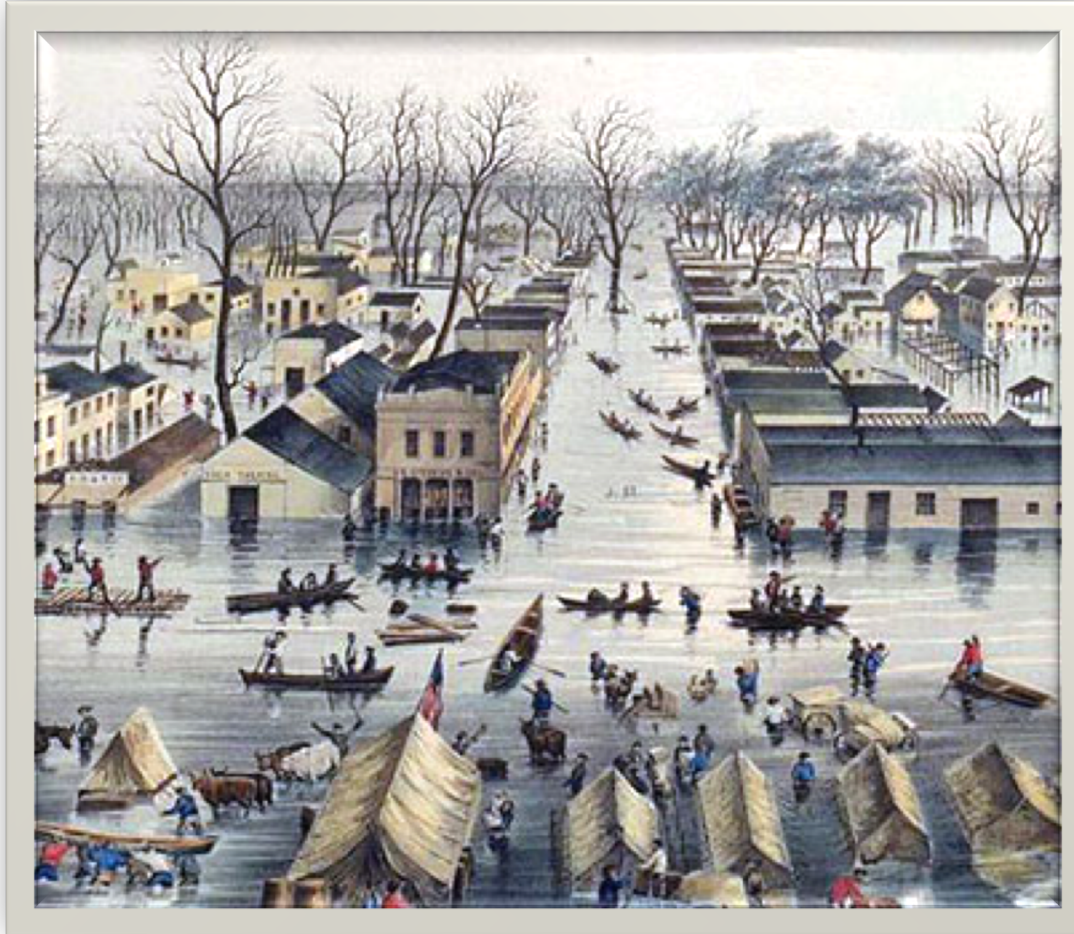
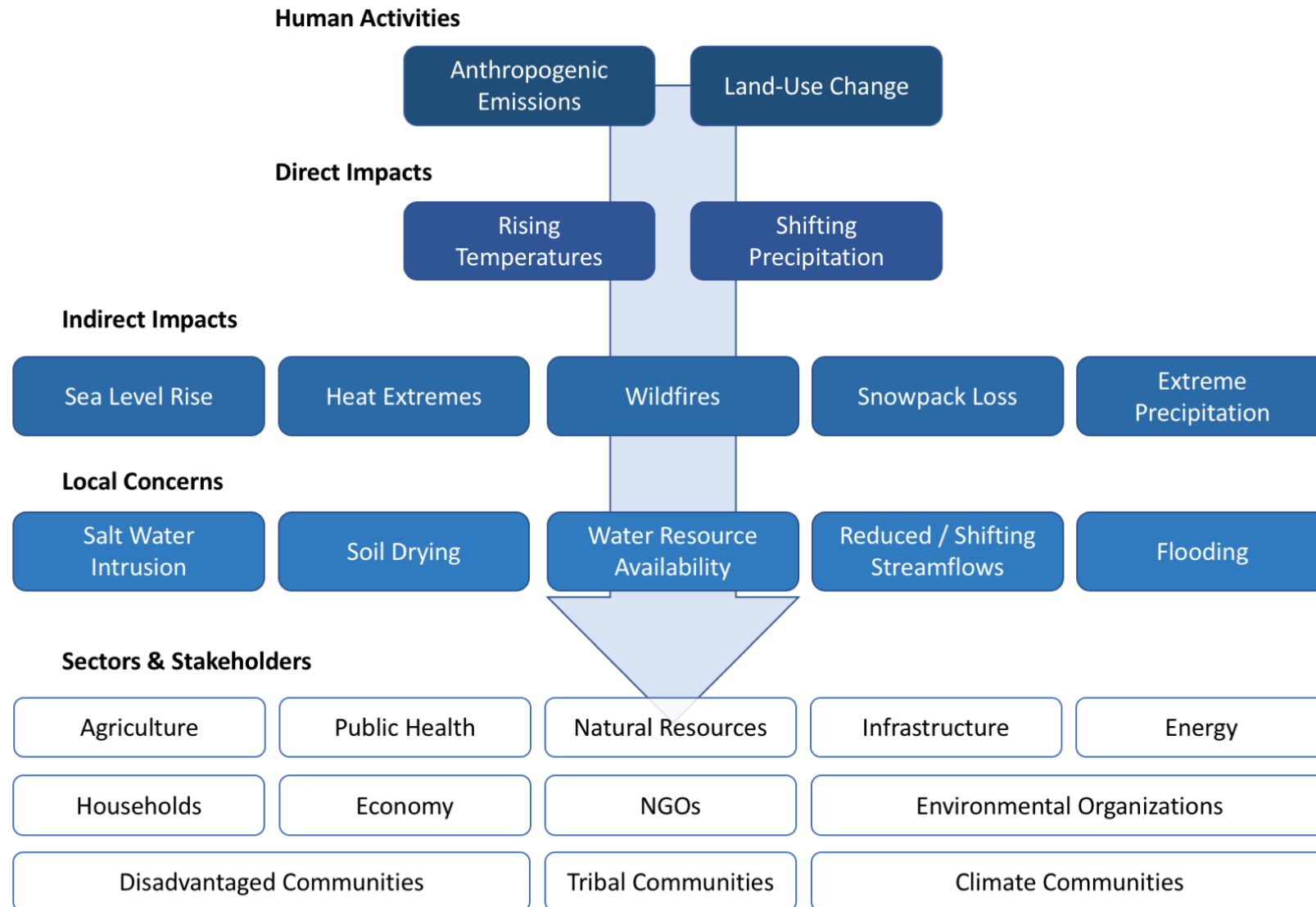


Figure: A depiction of the 1862 floods in Sacramento, California Old Town.

“Those who **do not learn history** are doomed to repeat it.”

“Those who do not **study climate** are doomed to be unprepared for **changing and extreme weather.**”

Understanding the Earth System: Climate Change



Understanding the Earth System: Sea Level Rise

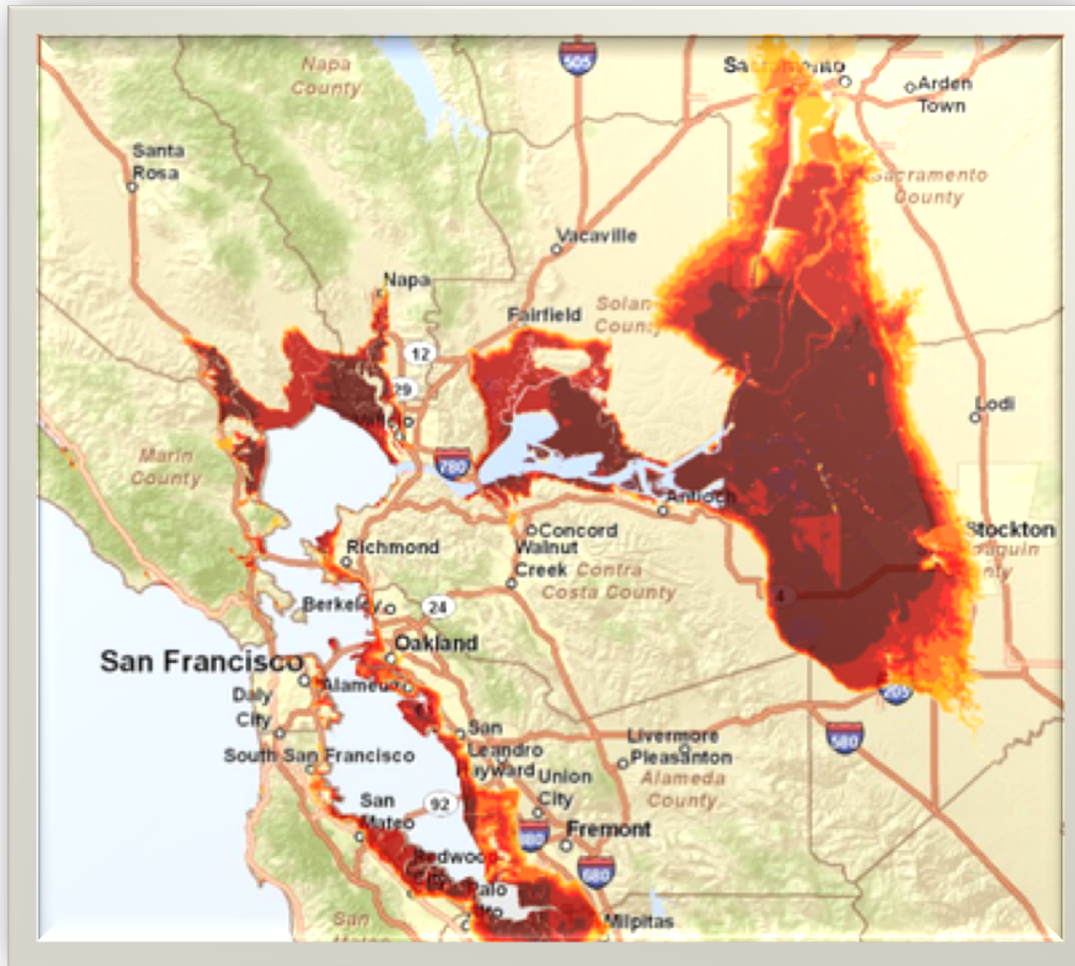


Figure: A map of the San Francisco Bay Area and susceptibility to sea level rise (Weiss and Overpeck 2011).

Dark red: Flooded areas under 3 feet of sea level rise.

Yellow: Flooded areas under 18 feet of sea level rise.

Climate Change and Rising Temperatures

Observed change in average surface temperature 1901–2012

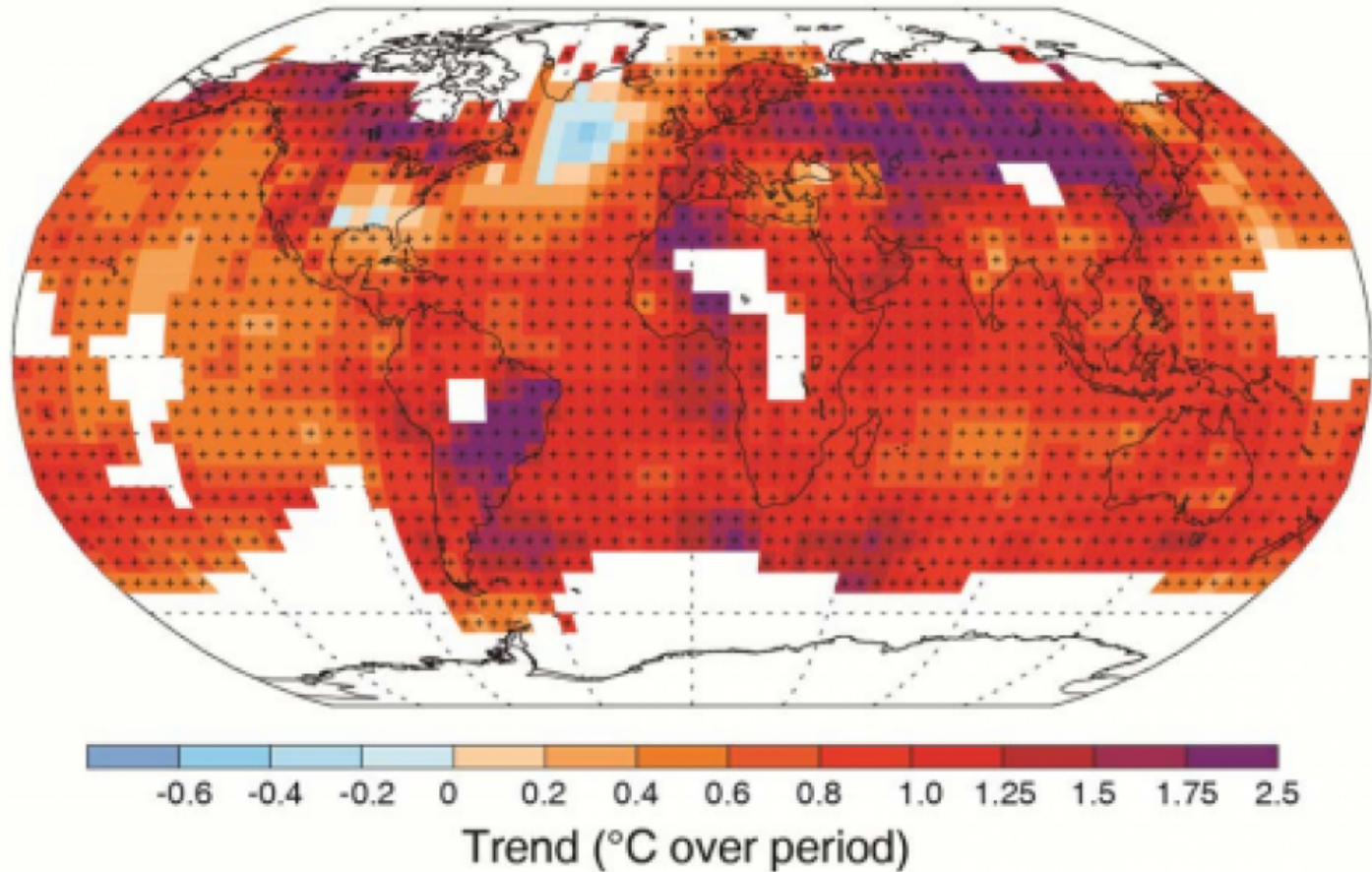


Figure: Global warming trends are indisputable and expected to continue under increases in atmospheric greenhouse gas concentrations.

Understanding the Earth System

How is the Earth system studied and understood?

Three key aspects: Experiments, Observations, Models

Climate Experiments

- Scientific procedures undertaken to test a hypothesis about the climate system.
- Purposeful changes are made to the input variables and outputs observed and quantified.

Climate Observations

- Measurements taken of the climate system in situ or with remote sensing (such as from satellites).
- Datasets that are built upon a global and continuously growing observational network.

Understanding the Earth System

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Climate Experiments

- Understanding the response of atmospheric gases to radiation in a laboratory
- Investigating the effect of organic and inorganic fertilizer on carbon storage

Climate Observations

- Atmospheric carbon dioxide concentration (time series from monitoring stations)
- Mountain snow depth measurements (satellites, flyovers and pillow stations)
- Surface temperature and precipitation (satellites, weather stations)

Understanding the Earth System

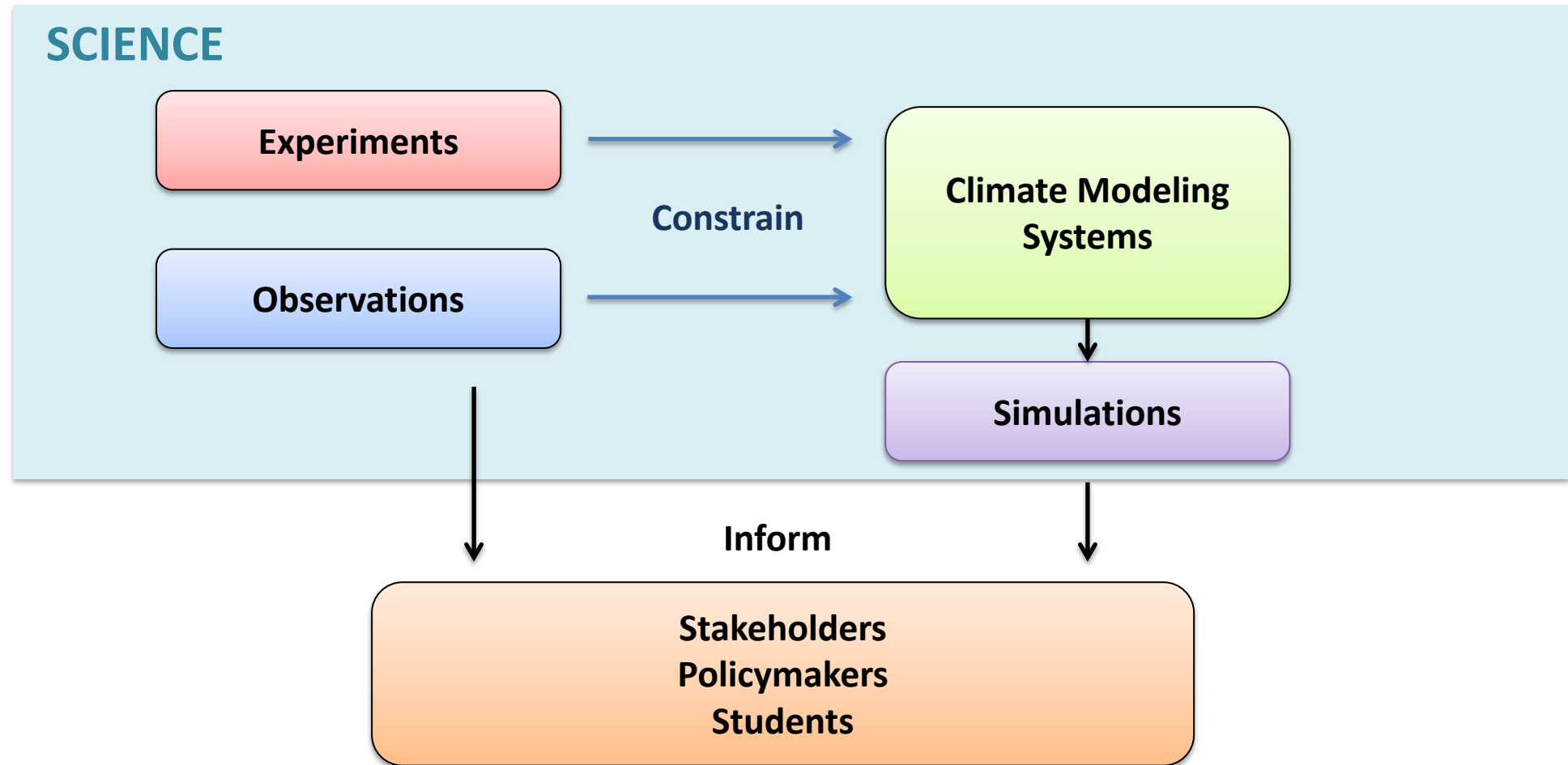
How is the Earth system studied and understood?

Three key aspects: Experiments, Observations, Models

Climate Models

- **Mathematical representations** of the Earth system built using fundamental laws of physics (conservation of mass, conservation of energy, etc.)
- Vary from very simple “back of the envelope” calculations to massive multi-million-line programs run on massive supercomputing systems.
- **Goal:** To understand interdependency and variation in the Earth system, and as a virtual laboratory for experimenting on the Earth.

Understanding the Earth System



Where Next?

Lecture 2: Energy in the Earth system

Lecture 3: The structure of the Earth's atmosphere

Lecture 4: Atmospheric stability and convection

Lecture 5: The general circulation of the Earth's atmosphere

Lecture 6: Subgeographic flow and the boundary layer

Lecture 7: Global structure of the ocean


Lecture 8: The oceanic circulation

Lecture 9: The wind-driven circulation

Lecture 10: Oceanic convection and the thermohaline circulation

Lecture 11: Climate oscillations

Lecture 12: Paleoclimate and climate change



ATM 241 Climate Dynamics

Lecture 1

Introduction to Climate Dynamics



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Thank You!