Overview of Climate Change Science (AR4-WG1—Chapter 1)

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Learning Outcomes

1. Explain Earth Science Limitations
   - Scientific Progress
   - Methods in Environmental and Earth Sciences
2. Describe the Progress in Climate Change Science
   - Building Hypotheses Linking Greenhouse Gases and Climate
   - Compiling Temperature Records
   - Advances in Climate Science Processes
   - Progress in Climate Models
3. Summarize the IPCC Assessments and Categories of Uncertainty
   - History of IPCC
   - Treatment of Uncertainties

How is Scientific Progress Made?

- Role of Hypothesis Testing
- Science as Inherently Self-Correcting
- Ordinary Science and Paradigm Shifts

(See AR4 WG1 C01:95)

How to Gauge Competing Claims

- Can they be proven false?
- Have they been rigorously tested?
- Do they appear in peer reviewed literature?
- Do they build on existing records, where appropriate?
- How are uncertainties considered?

Earth Sciences and Controlled Experiments

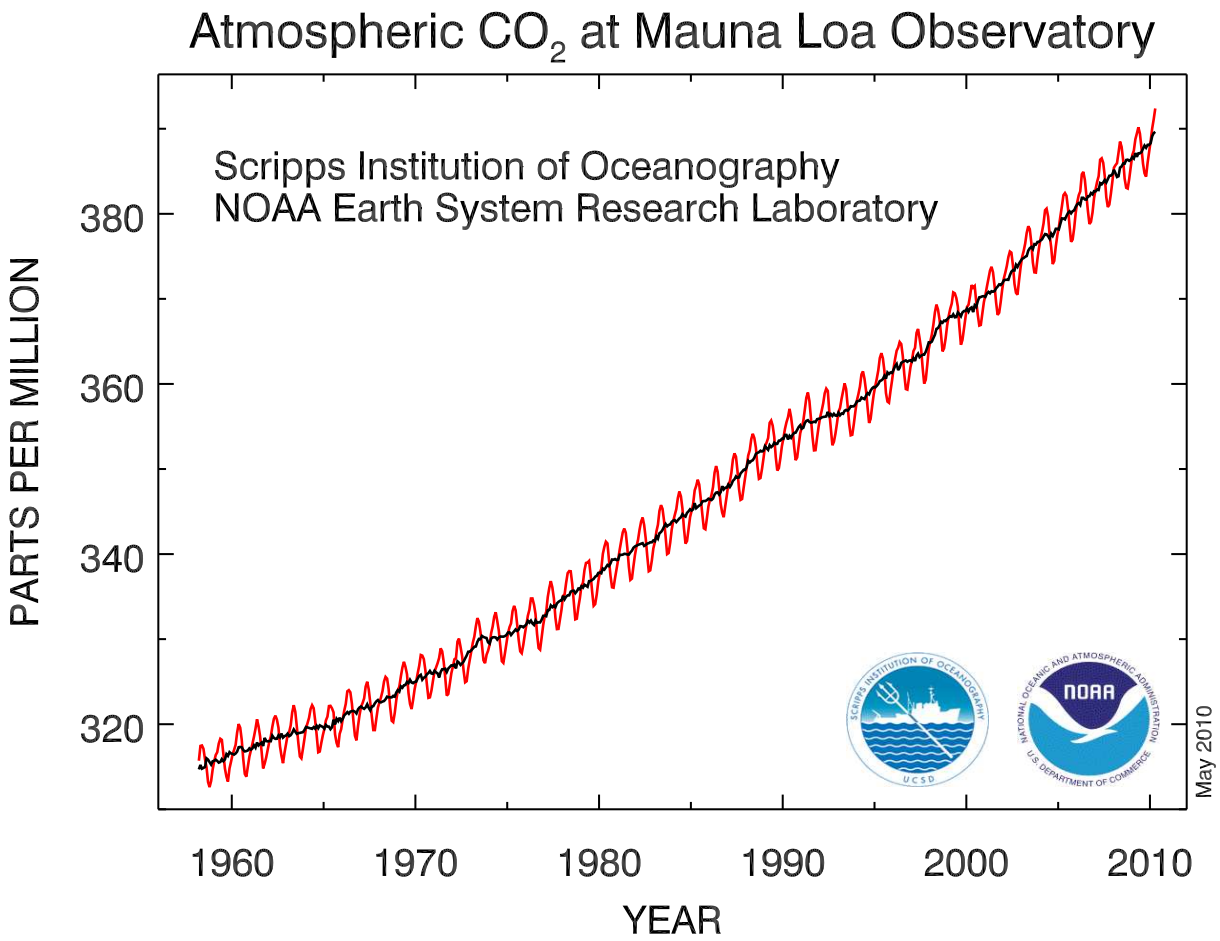
- N of 1 (no capacity to repeat, replicate, to test various scenarios)
- Numerous studies have tested various sub-component of the climate system
  - Mt. Pinatubo eruption provided data to test particular aspect of global climate models.
  - In the 1970s data suggested the Earth was cooling and was associated with increase in carbon dioxide concentrations – however, it was later acknowledged the cooling was due to aerosols which remain in the atmosphere for longer than carbon dioxide, the interpretation was revised.[1]
- We can only understand the Earth's Climate within a whole-Earth, system-scale that incorporates the full complexity of interacting processes and feedback

[1] These results were widely publicized in the popular literature, which has continued to cause confusion or used for political goals.

Hypotheses about Greenhouse Gases and Climate

- Tyndall (1861) found that water and carbon dioxide absorbed infrared light in the lab and might explain climate changes hypothesized by geologists.
- Arrhenius (1886) suggested that concentration changes of 40% greenhouse gases could explain glacier advances and retreats.
- Callendar (1938) used coupled equations to predict that a doubling of carbon dioxide would increase the Earth's temperature by 2° C.

Carbon Dioxide Record from Mona Loa



Compiling Temperature Records

In spite of a network of assimilated records starting in Italy in 1653, there remain numerous obstacles for their use:

- Access to the data in usable forms
- Quality control to remove or edit erroneous data
- Methods to ensure fidelity of data
- Area averaging in the presence of substantial gaps

Complied Temperature Records

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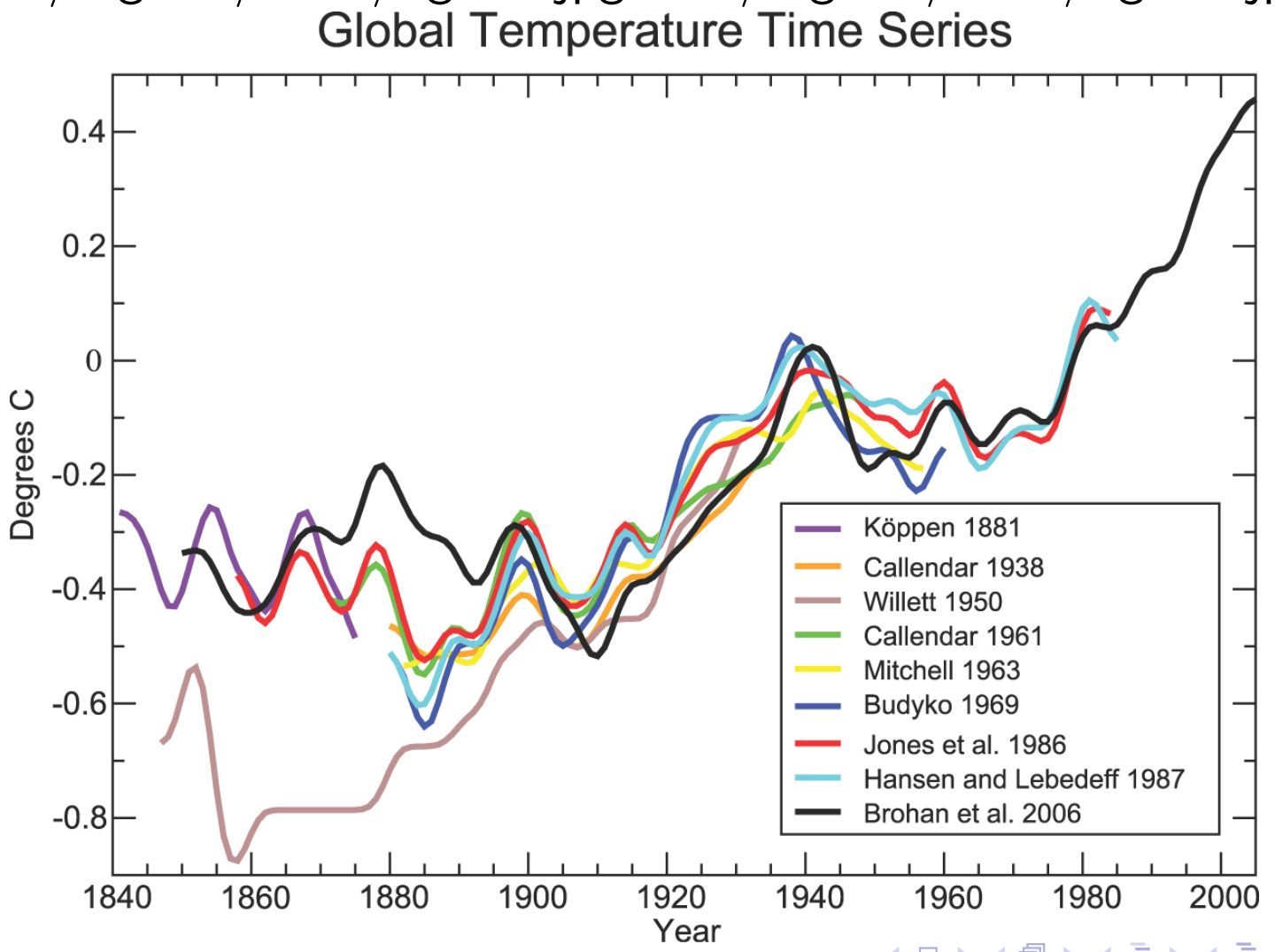

Greenhouse Gas Players

By the 1970s, other gases were identified as greenhouse gases

- Methane
- Nitrous Oxide
- CFCs

Cooling Effects

Aerosols (small particles in the atmosphere) also had an impact, e.g. sulfate aerosols have a cooling effect by reflecting the suns light away from the Earth.

Paleoclimates: Observations from the 19th and 20th Century

- Paleozoic Era (600-252 Mya): Warmer and Colder Conditions
- Tertiary Period (65-2.5 Mya): (Mostly) Warmer Conditions
- Quaternary Period (2.5 Mya - present): Oscillations between Glacier advances and retreats

Astronomical Forcing: Milankovitch (1941)

- 100k year cycle
- 23k year cycle
- Align with glacier advances and retreats
- Forcing is not very strong (maybe?)[2]

[2] Recent evidence suggest the cycles may be strong enough with more sophisticated models (See Abe-Ouchi, Nature v500:7461.)

Increased Resolutions: Abrupt Changes in Climate

- Marine Sediment Cores
- Ice Cores
- Lacustrine Sediment Cores
- Cave Stalagmites
- Quaternary Period (2.5 Mya - present): Oscillations between Glacier advances and retreats

Increased Resolutions: Abrupt Changes in Climate

In the context of slow ocean and continent plate arrangements and orogeny (via tectonics), various factors can drive abrupt climate change.

- Ocean Current Changes
- Volcanism
- Astroids

Solar Radiation: More Research Needed

Change in Solar radiation could cause surface temperature changes on the ford of a few 0.1s $^{\circ}$ C (AR5).
Although some evidence exists that sun spots may have declined and could play a role in climate patterns, the TAR concluded that the influence was not great – but AR4 concludes that a range of processes in the upper troposphere need more research to evaluate the role of solar irridiance variation on climate change.

Biogeochemistry and Radiative Forcing

Indirect and feedback on greenhouse gasses that may mitigate or aggregate climate change.

- Soot Aerosols
- Plant fixation and soil carbon storage
- Methane-hydrates

Ocean-Atmospheric Coupling

Indirect effects and feedbacks on ocean-atmospheric coupling may mitigate or aggregate climate change.

- Merdidional Overturning circulation (MOC—aka thermohaline circulation)
- Role of ENSO (El Niño-Southern Oscillation)
- NOA (North Atlantic Oscillation)

Increase in Resolution, Complexity, and Processor Speeds

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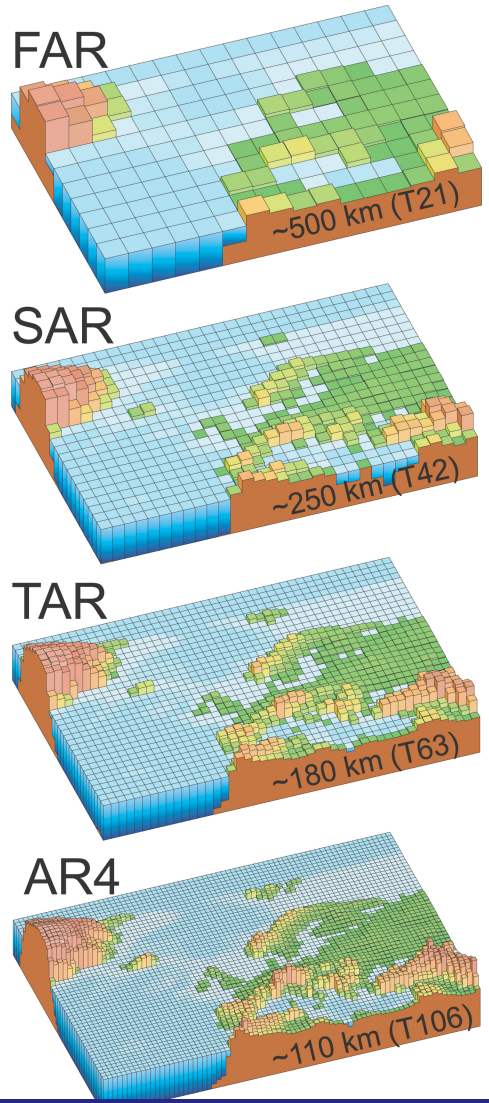

Progress in Climate Models

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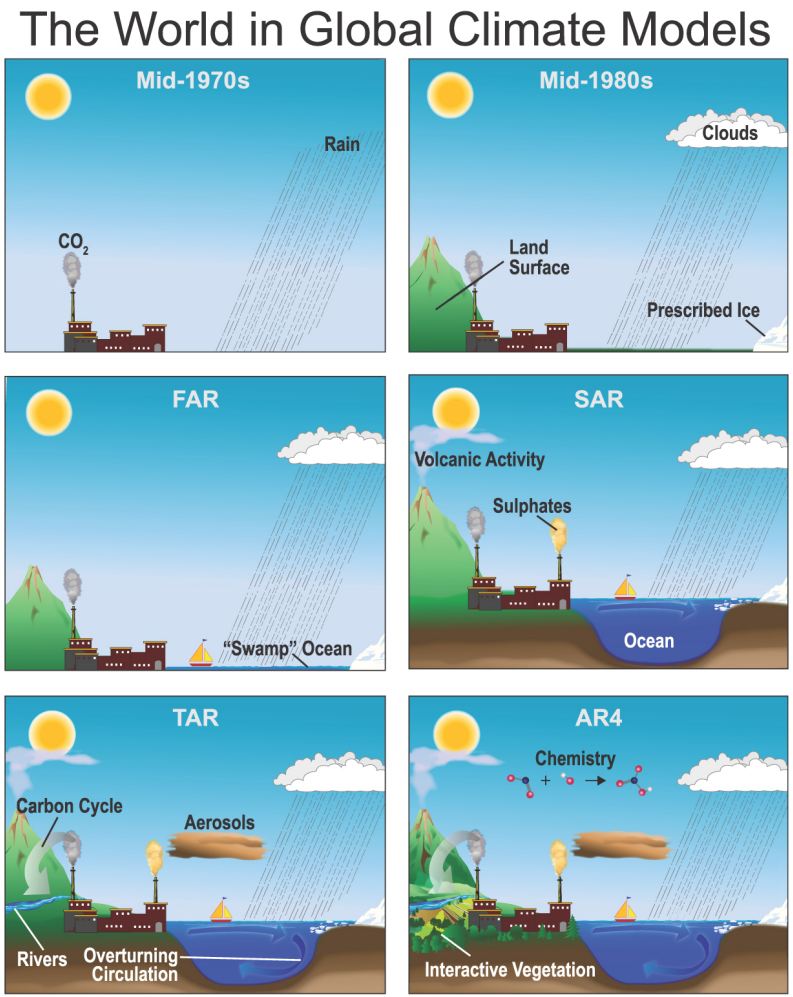

Climate Change Predication Improvements

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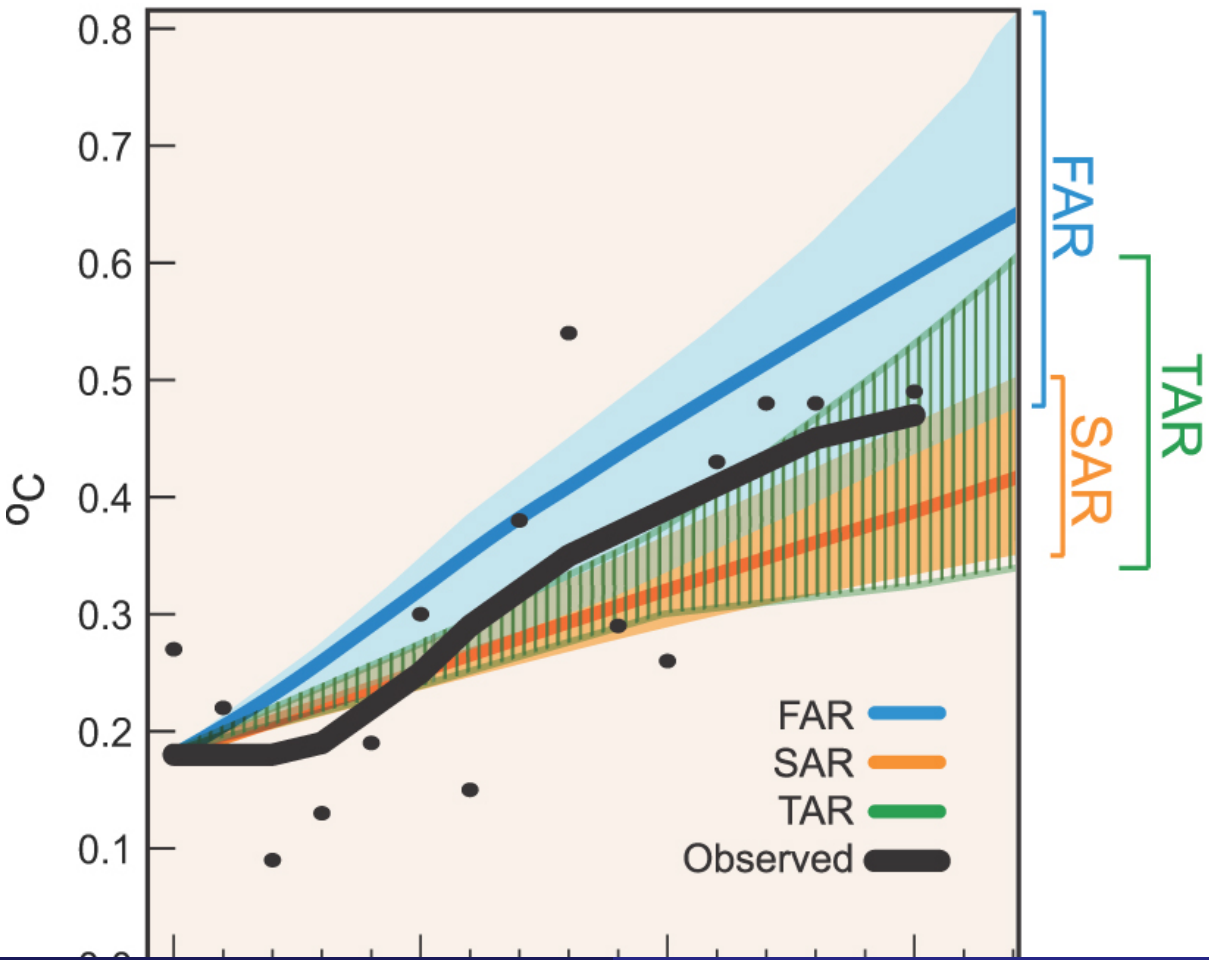

IPCC Assessment

Established in 1988 by the WMO and UNEP to accomplish the following goals:

- Identification of uncertainties and gaps in our present knowledge with regard to climate changes and its potential impacts, and preparation of a plan of action over the short-term in filling these gaps;
- Identification of information needed to evaluate policy implications of climate change and response strategies;
- Review of current and planned national/international policies related to the greenhouse gas issue; and
- Scientific and environmental assessments of all aspects of the greenhouse gas issue and the transfer of these assessments and other relevant information to governments and intergovernmental organizations to be taken into account in their policies on social and economic development and environmental programs.

IPCC Assessment

IPCC has three Working Groups and a Task Force.

Working Group I (WGI) assesses the scientific aspects of the climate system and climate change.

WGII assess the vulnerability and adaptation of socioeconomic and natural systems to climate change.

WGIII assess the mitigation options for limiting greenhouse gas emissions.

Task Force is responsible for the IPCC National Greenhouse Gas Inventories Programme

IPCC Assessments

IPCC has published five assessment reports

- FAR 1990
- SAR 1995
- TAR 2001
- AR4 2007
- AR5 2013
- AR6 2021

Treatment of Uncertainties

AR4 distinguished between two distinct concepts:

- Confidence—to gauge scientific understanding.
- Likelihood—to gauge a specific outcome or result.

(See AR4 WQ1 C01:120-121)