Recent Developments in Climate Science

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Outline

- Past
- Present
- Future
Past
Paleoclimate

• How can we reconstruct past climate?
• How did climate change in the past?
• Why did it change?
Paleoclimate Reconstructions

Foraminifera (Zooplankton)

Surface (planktonic)

Some like it hot (tropical species)
Some like it cold (polar species)

Sea Floor (benthic)

Pollen from lake sediments can be used to reconstruct past vegetation

Isotopes give infos on temperature and sea level
Bubbles in the ice contain ancient air

CO₂, CH₄ measurements and temperatures (isotopes)
Ice Age Cycles

Caused by changes in Earth's orbit around the sun

CO$_2$ is high when Earth is warm, low when cold

Temperature changes more at poles, less in tropics

Sea level high when warm, low when cold

lines: proxy data based reconstructions
shading: model simulations

LGM
Last Glacial Maximum
Surface Temperature Reconstructions from the Last Glacial Maximum 20,000 years ago

$\Delta T = -4^\circ C = -7^\circ F$

Large Ice Sheets over Canada and N. Europe

Sea Level 120 m lower
From Newport 1/2 h longer drive to beach
Global Surface Temperature

Temperature Anomaly [°C]

Year (BC / AD)

-20000 -16000 -12000 -8000 -4000 0 4000

Holocene

Last Glacial Maximum

Shakun et al
Marcott et al
A1B
HadCRUT4

2100
Last Deglaciation: $\text{CO}_2$ increases first, then global temperature.

Also: without $\text{CO}_2$ increases models cannot reproduce deglacial warming (not shown).

Shakun et al. (2012) Nature
Lessons from the Past

• CO$_2$ is an important control on global climate
• Climate changes are not uniform
  • small in tropics and over oceans
  • large at higher latitudes and over land
Present

- How is climate changing?
- What is the role of humans?
Atmosphere & Oceans warming

- Water vapor increasing
- Snow and ice cover decreases
- Sea level rises

IPCC 2014
The magenta line shows the median ice extent for September from 1979 to 2000.

glaciers shrinking worldwide

Muir Glacier, SE Alaska
USGS & NPS photographs
What are the causes?
We have put lots of carbon in the atmosphere.

And we continue to do so.

Some is taken up by land and ocean but about half stays in atmosphere.
CO₂ has increased in the atmosphere and is entering the ocean where it leads to acidification (drop in pH). It is a greenhouse gas and causes warming.

Other greenhouse gases have increased too.
What about the sun?
No! Solar variability has not increased during the past 30 years. Plus the changes are small.

Satellite measurements of solar radiation on surface perpendicular to sun’s rays for average on Earth’s surface divide by 4 (ratio area sphere over disc)

Could the ocean be the culprit?
No! The ocean is warming.
Models including human effects reproduce observed warming.

Models including natural effects only do not reproduce observed warming.
Lessons from the Present

• Earth’s atmosphere and oceans are warming

• Snow and ice is melting

• Sea level is rising

• Human greenhouse gas (mainly CO$_2$) emissions are the main reason
The Future

• How may climate change?
• What will be the impacts?
We still have a choice between moderate (RCP2.6) and large (RCP8.5) climate changes.
Annual mean temperature change

RCP85: 2016-2035

RCP85: 2081-2100

RCP26: 2016-2035

RCP26: 2081-2100

pessimistic scenario

optimistic scenario

°C

-2 -1.5 -1 -0.5 0 0.5 1 1.5 2 3 4 5 7 9 11
Precipitation

RCP8.5

Wet get wetter
dry get dryer
Soil Moisture

RCP8.5

(mm)
Sea level will continue to rise
Sea level will continue to rise for centuries

- 2-7 m for high emission scenarios
- < 1 m for low emission scenarios
Outcomes

“Key regionally consequential risks in the Northwest include impacts of warming on watersheds where snowmelt is important, coastal consequences of sea level rise combined with other stressors, and the cumulative effects of fire, insects, and disease on forest ecosystems.”
Together with decreasing snow pack this will lead to reduced summer stream flow with impacts on e.g. agriculture.
For 2.2°F global warming
Projected Sea Level Rise for Newport, Oregon

Projection, 45°N
Other Ocean Impacts

- Acidification and
- increased frequency of hypoxia
- may adversely affect marine ecosystems and fisheries.
Lessons from the Future

• Future warming can be moderate or extreme depending on future emissions.

• We still have the choice to avoid worst case scenarios.

• This is where your work is important!
Thank You!