HONR 229L: Climate Change: Science, Economics, and Governance

Discussion #10: Climate Models: Perspective of a Social Scientist

Ross Salawitch & Laura McBride

rjs@atmos.umd.edu       mcbridel@terpmail.umd.edu

Class Web Site: http://www.atmos.umd.edu/~rjs/class/honr229L

ELMS Page: https://myelms.umd.edu/courses/1249026

2 October 2018
One student wrote:

The oceans have four important roles with respect to Earth's climate. They:

1. are deeply intertwined with the atmosphere
2. have a large heat capacity which alters the change in atmospheric temperature
3. redistribute heat through internal circulation
4. affect the atmosphere through the interactions between atmospheric and oceanic circulation.
AT 9, Q2. In a few sentences, explain:

a) what is meant by an El Niño event (i.e., physically what happens in the ocean & where in the ocean does this happen)?

b) what are the weather related consequences associated with an El Niño event ?

One student wrote: An El Niño event occurs every 3 to 7 years, when trade winds slacken in the Pacific Ocean. Under normal conditions, trade winds move warm surface water from Peru to Australia, resulting in a nutrient-rich upwelling of cold water underneath off the coast of Peru. This results in great fishing for Peruvians and lets the cool air warm as it travels to Australia and drops some rain on their coast.

However, when the surface water is not moved and remains stagnant the upwelling does not occur, and the warm air instead causes rain to fall just off the coast of Peru and leaves Australia in drought. Although this event occurs in the Pacific Ocean, it can cause droughts and floods all over the globe.

Another student: The weather-related consequences associated with an El Niño event consist of droughts that may lead to forest fires such as in Asia, and floods. The events can also have negative effects on fishing because of the warm upper waters preventing nutrients from reaching the lower cooler levels that pelagic fish survive in.

Note from instructor: When an El Niño happens, globally averaged surface temperature can rise by as much as a few 10ths of a degree C (i.e., several decades’ worth of human induced warming).
La Niña conditions

El Niño conditions

Warming of Eastern Pacific, with consequences for global climate


Copyright © 2018 University of Maryland. This material may not be reproduced or redistributed, in whole or in part, without written permission from Ross Salawitch.
**Key model output parameter #1:**
Climate Feedback Parameter, $\lambda$, units $W \ m^{-2} \ \circ C^{-1}$

\[
\Delta T_{\text{MDL},i} = \frac{(1+ \text{Feedback}) \ (\text{GHG RF}_i + \text{Aerosol RF}_i)}{\lambda_p} + C_0 + C_1 \times \text{SOD}_{i-6} + C_2 \times \text{TSI}_{i-1} + C_3 \times \text{ENSO}_{i-2} + C_4 \times \text{AMOC}_i - Q_{\text{OCEAN},i} / \lambda_p
\]

where

$\lambda_p = 3.2 \ W \ m^{-2} / \circ C$

Aerosol RF = total RF due to anthropogenic aerosols
SOD = Stratospheric optical depth
TSI = Total solar irradiance
ENSO = El Niño Southern Oscillation
AMOC = Atlantic Meridional Overturning Circ.
PDO = Pacific Decadal Oscillation

$Q_{\text{OCEAN}} = \text{Ocean heat export} = \kappa (1+\gamma) \ {\{(\text{GHG RF}_{i-72}) + (\text{Aerosol RF}_{i-72})\}}$

**Fig 2.4, updated: Salawitch et al., Paris Climate Agreement: Beacon of Hope, 2017.**
AT 9, Q3.

a) if the abundance of CO$_2$ were to double and no feedbacks were to occur, how would global surface temperature respond?

b) if the abundance of CO$_2$ were to double and feedbacks were to occur, according to our present understanding of how they actually operate, how would global surface temperature respond?

Table 5.1: Estimates of global average temperature changes under different assumptions about changes in greenhouse gases and clouds

<table>
<thead>
<tr>
<th>Greenhouse gases</th>
<th>Clouds</th>
<th>Change (in °C) from current average global surface temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>As now</td>
<td>As now</td>
<td>0</td>
</tr>
<tr>
<td>None</td>
<td>As now</td>
<td>-32</td>
</tr>
<tr>
<td>None</td>
<td>None</td>
<td>-21</td>
</tr>
<tr>
<td>As now</td>
<td>None</td>
<td>4</td>
</tr>
<tr>
<td>As now</td>
<td>As now but +3% high cloud</td>
<td>0.3</td>
</tr>
<tr>
<td>As now</td>
<td>As now but +3% low cloud</td>
<td>-1.0</td>
</tr>
<tr>
<td>Doubled CO$_2$ concentration otherwise as now</td>
<td>As now (no additional cloud feedback)</td>
<td>1.2</td>
</tr>
<tr>
<td>Doubled CO$_2$ concentration + best estimate of feedbacks</td>
<td>Cloud feedback included</td>
<td>3</td>
</tr>
</tbody>
</table>
AT 9, Q3.

a) if the abundance of CO₂ were to double and no feedbacks were to occur, how would global surface temperature respond?

b) if the abundance of CO₂ were to double and feedbacks were to occur, according to our present understanding of how they actually operate, how would global surface temperature respond?

A student wrote: A proper understanding of feedbacks is very important for accurately projecting climate change. The predicted global surface temperature increase with feedbacks is over twice the magnitude of the increase without feedbacks. *Feedbacks may also be useful for determining how quickly warming can be slowed or reversed if emissions are reduced*; one must consider factors other than the breakdown or sequestration of greenhouse gases, such as restoration of the albedo effect.

Instructor adds: The factor of $3 \degree C / 1.2 \degree C = 2.5 \degree C$ enhancement in direct warming due to rising CO₂ is, as I have tried to emphasize in class, *quite uncertain* and therefore incredibly important for the achievement of accurate climate change projections.
Q4. Describe, in a few sentences, how climate models are validated and note whether or not you are convinced, based on the material in the reading, that climate models have been properly validated.

Another student stated: Climate models are validated through tests to see if each model is good, there are three main ways. The first is running simulated time for a number of years and comparing that climate to current climate. The second way is, comparing against simulations of past climates when distributions were very different from the present. A third way is to use the models to predict effects of large perturbations on the climate, for instance, volcanic eruptions. I am not entirely convinced that climate models have been properly validated because what we know is that climate models can only predict trends and not events. As a result, the accuracy and coverage of data available for past periods, as the author states are limited. However, they do appear as reliable guides for climate change predictions. All in all, I believe that in order to truly state whether or not I am convinced I would have to conduct more research on climate models.

One student concluded: Though the models don't line up completely perfectly with the observed temperatures in figures 5.21 and 5.23, they follow the same general trends, suggesting that they could also project general trends for longer-term future climate.
Discussion for next Tuesday to be led by Christine Johnson:

Impacts of climate change with a focus on four topics:

1. Longer and more damaging wildfire seasons
2. Ocean Acidification
3. Sea Level Rise
4. Infectious Disease

Readings for Tuesday all web-based material

Students will be asked to explore 2 of these 4 topics, and address in a short essay:

a) How does climate change impact the chosen topic area (i.e., described the underlying science) ?

b) If human society does not reduce our emissions of greenhouse gases, what will be the consequences for society ?
Climate Models: Perspective of a Social Scientist

Nathan Pereyra

4 October 2018
What does this graph serve as a representation of, and why did Nate Silver use it to open this chapter of his book?

How a "signal" can be blocked by data, making it hard to determine what the results are. He chose to use this as an easy to understand metaphor for the difficulty of modeling climate change.
What are the two findings from the IPCC Report published in 1990 that Nate Silver describes as being absolutely certain?

- There is a natural greenhouse effect that warms the Earth
  - What is the mean temperature of the earth?
    - 15° Celsius
  - What would the Earth’s temperature be without the Greenhouse Effect?
    - Earth would be at a temperature of 0° Fahrenheit
    - This equates to about -18° Celsius

![Table 5.1](image-url)
The second finding is

- As the concentration of greenhouse gases increase, the greenhouse effect and global temperatures increase alongside the gases
  - How does this statement relate to the material we have learned prior?
  - Carbon dioxide, Methane, Chlorofluorocarbons, and nitrous oxide have all increased over the last century
  - Water vapor is the largest greenhouse gas, and as the Earth warms, atmospheric water vapor rises, trapping heat, leading to the creation of more water vapor
What are the three prongs of the critiques made in the Armstrong and Green paper in regards to the IPCC forecasts?

1. Agreement among forecasters does not equate to accurate forecasting
   People are often wrong, and agreement among people does not mean that they are right

2. The complexity of the issue of climate change makes forecasting nearly impossible and not worth the effort
   With how many variables are in play, nothing will turn out to be correct

3. Forecasts don’t adequately account for uncertainty inherent to climate change
   There is a lot of uncertainty in play, and scientists may be overconfident in their predictions
Figure 2.1 Four possible futures for the three most important anthropogenic GHGs

Some of the most outspoken critics on climate change are often TV weathermen. Why do you think this is?

• The two features of meteorology that led to improvements in forecasting weather
  1. Frequent Reality Check - It is easy to see what the actual weather is and learn from it
  2. A strong understanding on the physics of weather – Often easier to understand the physics of weather than the physics of climate change, as it takes less time to gather results

TV meteorologists may criticize climate change or ignore due to the politicized nature of it, and do not wish to impact ratings by supporting/denying that it exists, and that humans are the primary driver of it.

Climatology also may not have been a part of meteorologists’ educations, so they may have not felt qualified to talk about the topic
Explain the three types of uncertainty with climate change

1. Initial condition – effects on forecast warming diminishes over time
2. Structural Uncertainty – The dynamics of the global climate system, which may slightly increase over time.
3. Scenario Uncertainty – how will the abundance of greenhouse gases in the atmosphere chance over time

However, if the models are not accurately depicting climate feedback correctly, then the error in the models will grow over time. This is why some consider the large climate models used by scientists to be “wrong”
Snowfall in 2 hours in October 2011
Based on this figure,

Define anomaly:

The deviation, plus or minus, relative to the average surface temperature of Earth from 1951 to 1980

State something remarkable/interesting you notice about the data plot
What do the three line from this figure represent?

The top line is upper end of the IPCC’s range, and the bottom line the lower end
The graph represents the actual global temperatures

From this graph, what conclusions can you draw based on the actual temperatures and the forecasted outcome by the IPCC

- IPCC originally forecast about 2 to 3°C warming per century, whereas data from 1990 through 2011 suggest a warming of 1.5°C per century
- The next IPCC forecast was for 1.8°C warming per century

Based on the fact that the model was not that accurate, what grade would you give it if you were a climate scientist?
FIGURE 12-8: GLOBAL ANNUAL SULFUR EMISSIONS, 1900–2005
SO₂ emissions, by world region (in million tonnes)

Annual sulphur dioxide (SO₂) emissions in million tonnes

Source: Clio Infra; Klimont. et al (2013)

OurWorldInData.org/air-pollution/ • CC BY-SA

Copyright © 2018 University of Maryland.
This material may not be reproduced or redistributed, in whole or in part, without written permission from Ross Salawitch.
Emissions of air pollutants, United States
Annual emissions of various air pollutants, indexed to emission levels in the first year of data. Values in 1970 or 1990 are normalised to 100; values below 100 therefore indicate a decline in emissions. Volatile organic compounds (VOCs) do not include methane emissions.
Compare and contrast simple models used for climate change versus complex models used for the same thing

Simple models only focus on small/narrow aspects of the climate, and none of them focus on creating forecasts with the weather in mind, so the regional climates are ignored by simple models.

Complex models on the other hand factor in many of the aspects used in simple models into one model, and include regional climates as well to provide for a more accurate representation of the global climate and what is predicted to occur in the future.
Temperature record better simulated by adding complexity to model:

- Global Warming estimate nearly same
- Estimate of volcanic cooling drops by nearly a factor of two

Global Warming = 0.12 °C/dec over past 30 yr

An admonition like “the more complex you make the model the worse the forecast gets” is equivalent to saying “never add too much salt to the recipe”... If you want to be good at forecasting, you have to trust your own taste buds.

Page 389, The Signal and the Noise

Canty et al., ACP, 2013
Why is this graph not an accurate representation of climate change over time?
What are your thoughts as to the predictions made by Armstrong and Green in regards to this image?
This change is due to:

- a large ENSO event that started in late 2015
- tendency of climate system to be in a strong La Nina state during the early 2000s
- a relatively small value of total solar irradiance during the middle part of the time series
- a slight bias in the data, due to closure of some observing stations in the Arctic that is now being corrected in some datasets (not the data in the book, or at GISS)

Any 10 year period of time may not match the long term data, such as an decline in global temperature over that 10 years, but still increasing over time. This then allows climate deniers to say that humans don’t cause climate change, as they look at small pieces, not the big picture.
Climate Models: Perspective of a Social Scientist

Last Word: Ross Salawitch

4 October 2018
Climate Projections Are Driven by Future Levels of GHGs

- Future abundances of CO$_2$, CH$_4$, N$_2$O & minor GHGs provided, for use as input to climate models
- Scenarios are called Representative Concentration Pathways (RCPs); number represents increase in RF of climate (units of W m$^{-2}$ ) that will occur at end of this century

Today, CO$_2$ is at about 410 ppm, which means 410 out of every million molecules of air are CO$_2$ (rather than N$_2$, O$_2$, argon, etc)  

https://www.co2.earth

Fig 2.1, Salawitch et al., Paris Climate Agreement: Beacon of Hope, 2017.
Color Bar: Probability a particular future ΔT will occur, based on the assumption that whatever value of climate feedback needed to fit past climate will persist into future

**EM-GC:** Empirical Model of Global Climate (i.e., Univ of Md model)

**CRU:** Climate Research Unit, East Anglia, United Kingdom

**IPCC:** Intergovernmental Panel on Climate Change

After Fig 2.20, Salawitch et al., Paris Climate Agreement: Beacon of Hope, 2017.
Colors appear for combinations of Aerosol RF$_{2011}$ & climate feedback for which $\chi^2 \leq 2$ can be obtained

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

where $\langle \rangle$ denotes annual average

After Fig 2.16, 2.18, & 2.20, Salawitch et al., Paris Climate Agreement: Beacon of Hope, 2017.
EM-GC Probabilistic Forecast, RCP 8.5

Probability ↑ in GMST stays below
1.5°C: 0 %
2.0°C: 1 %

After Fig 2.17 & 2.19, Salawitch et al.,
Probability ↑ in GMST stays below
1.5°C: 21%
2.0°C: 65%

After Fig 2.17 & 2.19, Salawitch et al.,

Copyright © 2018 University of Maryland.
This material may not be reproduced or redistributed, in whole or in part, without written permission from Ross Salawitch.
EM-GC Forecast: Blended CH₄ & RCP 4.5 CO₂ etc.

After Fig 4.12. Salawitch et al.,
EM-GC Probabilistic Forecast, RCP 2.6

Probability ↑ in GMST stays below
1.5°C: 80 %
2.0°C: 98 %