PH458

Case Study: Climate Science

Dr. Ioannis Votsis
LAK3.01 (Lakatos Building)
Office hours: Tuesdays 15:00-16:00
i.votsis@lse.ac.uk
www.votsis.org

Introduction

Climate science: Its components

- The study of the Earth's climate and its effects on humans through a number of scientific disciplines or parts thereof.

  * atmospheric science
  * decision theory
  * ecology
  * economics
  * glaciology
  * oceanography
  * paleoclimatology
  * …

Philosophy of climate science

- The study of the epistemological, metaphysical, logical and ethical dimensions of climate science.

- It seeks to answer questions like:

  * How should we define climate and climate change?

  * Are the methods used to gather evidence in climate science and the inferences drawn warranted?

  * What's the best way to model climate decisions under the specific conditions of uncertainty we face?

Climate vs. weather

- It has become customary to distinguish between climate and weather.

- *Weather* refers to things like atmospheric conditions over short time-intervals.

  Example: Temperature and humidity in Tokyo today.

- *Climate* refers to things like atmospheric (but also oceanic and land) conditions over longer time-intervals.

  Example: Historical patterns of the freezing-over of rivers.

Climate variables

- To determine the latter, various climate variables are being tracked. They include:

  * atmospheric pressure
  * carbon dioxide levels
  * glacier size and movement
  * humidity levels
  * methane levels
  * ozone levels
  * sea-ice level
  * sea-surface and subsurface salinity
  * temperature levels
  * wind speed and direction
  * ...

Detection and attribution

- We have relatively good data of air temperatures since 1750. The rest we reconstruct via proxies.

  Proxy data: ice cores, ocean sediments and tree rings.

- The proxies create further uncertainty as the data is often sparse, inexact & far removed from the variable in question.

- Two central questions can be asked:

  (1) **Detection**: Does the rise in temp indicate climate change?

  (2) **Attribution**: If so, is that change mainly anthropogenic?

Findings and Actions

What is the IPCC?

- What does the acronym stand for?

  Intergovernmental Panel on Climate Change.

- It was set up in 1988 by the World Meteorological Organisation and the UN Environment Programme.

- To do what?

  To offer policymakers evidence-based appraisals of climate change, its impacts, future risks, adaptation and mitigation.

- Reports cover all relevant scientific areas and contain contributions by thousands of experts.

The fourth IPCC assessment report 2007

- Working Group 1 (The Physical Science Basis):

  "Human-induced warming of the climate system is widespread... It is **likely** that there has been a **substantial anthropogenic contribution** to surface temperature increases in every continent except Antarctica since the middle of the 20th century... **Surface temperature extremes** have **likely been affected by anthropogenic forcing**... There is **evidence of anthropogenic influence** in **other parts** of the climate system [e.g. reduction of arctic sea ice]... Analyses of **palaeoclimate data** have **increased confidence in the role of external influences on climate**... Estimates of the climate sensitivity are now better constrained by observations" (pp. 665-6) [boldness added].

The fifth IPCC assessment report 2014

- The latest assessment report reinforces the findings of the previous one. According to the Synthesis Report:

  "The **evidence for human influence** on the climate system has **grown** since AR4. Human influence has been **detected in warming** of the **atmosphere** and the **ocean**, in **changes in the global water cycle**, in **reductions in snow and ice**, and in **global mean sea level rise**; and it is **extremely likely** to have been the **dominant cause** of the observed warming since the mid-20th century. In recent decades, changes in climate have caused impacts on natural and human systems **on all continents and across the oceans**" (p. 47) [boldness added].

The Paris agreement

- The Paris climate agreement was negotiated in 2015. It builds on the UN Framework Convention on Climate Change.

  “[The agreement] brings **all nations** into a **common cause** to undertake ambitious efforts to **combat climate change** and **adapt to its effects**, with enhanced support to **assist developing countries** to do so... [its] central aim is to **strengthen the global response** to the threat of climate change by keeping a global temperature rise this century **well below 2 degrees Celsius** above pre-industrial levels and to **pursue efforts to limit** the temperature increase even further to **1.5 degrees Celsius**” [boldness added].

  http://unfccc.int/paris_agreement/items/9485.php

Recently in the news

- To date, 170 of the 197 parties to the convention have ratified the agreement.
- In June, the US government announced that it intends to withdraw from the agreement.
- Meanwhile:

  "Global emissions of CO_2 in 2017 are projected to rise for the first time in four years, dashing hopes that a peak might soon be reached".

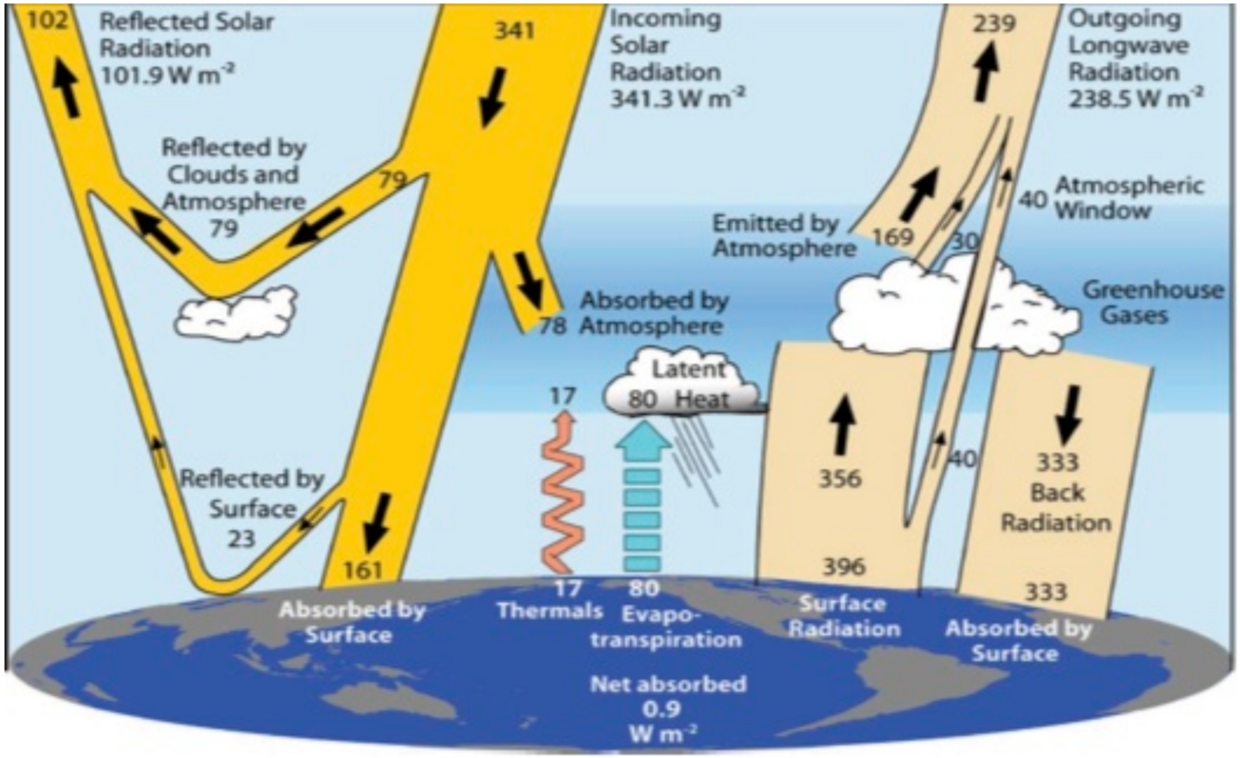
  http://www.bbc.co.uk/news/science-environment-41941265

Climate Modeling

What are they?

- A climate model is intended to represent a number of features of a climate system in a dynamical way.

Example: The energy-balance model treats the Earth as a flat surface where incoming-outgoing radiation is equal.



The devil's in the details

- Such models attempt to include as much relevant detail as possible from as many relevant sciences as possible.

  Examples: Earth divided into grid cells of a given resolution and climatic processes are flows (e.g. heat) between cells.

- These processes are described by equations that form the central part of a global circulation model (GCM).

- Crucially, solving these equations cannot be done with analytical methods. Supercomputers are used instead.

- Working through a model thus means running simulations.

Climate Modeling: UKCP09

A little description

- What does it stand for?

  United Kingdom Climate Projections

- It was put in place in 2009, led by DEFRA and uses Met Office methods, combining input from 30 organisations.

- To do what?

  To provide organisations with future climate projections, including potential impacts and adaptation options.

Some qualifications

"The results are called 'projections' rather than 'predictions' because the results are conditional on certain assumptions that cannot be quantified, such as the likelihood that an assumed pathway of future emissions of greenhouse gases will turn out to be correct".

"... the limits of our current ability to understand and model the climate system lead to some climate variables being predictable with greater confidence than others. For example, there is relatively high confidence in projections of temperature, and less confidence in variables such as summer precipitation or cloudiness".

http://ukclimateprojections.metoffice.gov.uk/21679

Model outputs and policy

- Frigg et al. (2013) examine the UKCP09 methodology.
- They claim that all climate models have systematic errors and urge caution over using their outputs for policy-making.

  "This casts doubt on our ability, today, to make trustworthy, high-resolution predictions out to the end of this century" (p. 887).

  NB: Frigg et al. do *not* deny climate change. Moreover, they admit that some of their warnings are voiced w/in UKCP09.

Some specific limitations

- The UKCP09 employs HadCM3 to model the earth's oceans, surface and atmosphere. Frigg et al. list some limitations:

  (1) Fluids are treated in a discrete way and mapped onto a relatively coarse grid, e.g. typical resolution about 300km.

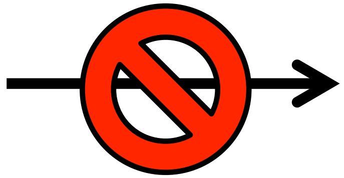
  (2) Computational limitations simulating 10000s variables over next 100 years so ocean model idealised – 'slab ocean'.

  (3) Because of uncertainty, a selection of values falling in between the min and max of parameters are used.

  (4) Still, we cannot run simulations on all so we focus only on those that have the greatest influence, e.g. atmospheric.

More general concerns

- On their view, it's senseless to talk about how informative a model is *if it is not at least close* to the future target system.

inputs close now  outputs close in the future

- Moreover, they are alarmed by the tension found in the literature concerning the proxy assumption.

Model outputs compared to other models (proxies for truth).

"the literature... exhibits a certain degree of schizophrenia. On the one hand, the method is illustrated and advertised as delivering trustworthy results; on the other hand, disclaimers that effectively undermine the crucial assumptions are also included..." (p. 894).

Decision-Theory: A primer

Decision theory

- Roughly speaking, this is the study of making decisions under uncertainty on the basis of evaluated consequences.

  NB: The standard approach goes back to von Neumann and Morgenstern (1944).

- We may speak of two versions of decision theory:

  Normative: Modelling how we ought to make decisions.

  Descriptive: Modelling how we actually make decisions.

  NB: Our focus here is normative decision theory.

Decision theory: Tables

- The content of a decision-theoretic analyses of a particular problem can be given in tabular form.

STATES / ACTIONS	S_1	S_2	S_3
A_1	$O_{1,1} = A_1(S_1)$	$O_{1,2} = A_1(S_2)$	$O_{1,3} = A_1(S_3)$
A_2	$O_{2,1} = A_2(S_1)$	$O_{2,2} = A_2(S_2)$	$O_{2,3} = A_2(S_3)$

- Such analyses are meant to offer a clear way to determine the best course of action.

- What is the best course of action? Roughly, the one that leads to best outcome!

Expected utility

- But the outcomes have a certain probability of occurring. Thus, the utility of each outcome is weighted accordingly.

- Summing up all these probability-weighted utilities of outcomes is called the *expected utility* (EU) *of an action*.

- In the case at hand, if we wanted to calculate the EU of A_1.

  $EU(A_1) = P(O_{1,1}) \times u(O_{1,1}) + P(O_{1,2}) \times u(O_{1,2}) + P(O_{1,3}) \times u(O_{1,3})$

- ***Maximising expected utility***: The best course of action is the one that leads to the highest expected utility.

Expected utility: Example

STATES ACTIONS	*Rain*	*~ Rain*
T: Umbrella	15	3
L: ~Umbrella	0	18

- Suppose that *P*(*Rain*) = 0.1. Hence, *P*(*~ Rain*)= 0.9.
- Then: $EU(T) = 0.1 \times 15 + 0.9 \times 3 = 4.2$ and
  $EU(L) = 0.1 \times 0 + 0.9 \times 18 = \mathbf{16.2}$
- What is the best course of action? To *not* take an umbrella since that maximises our expected utility: EU(*L*) > EU(*T*).

Decision-Making in Climate Science

The inadequacy of the standard model

- According to Bradley and Steele (2015), using the standard model is inadequate in the case of climate science.
- That's because the standard model considers uncertainty only at the level of the states of the world.
- Instead, they think that in many climate decisions, there is also uncertainty about what are:

  (1) the available actions
  (2) the outcomes of given actions
  (3) the (ethical) value we assign to the outcomes

- If they're right, we need richer decision-theoretic models.

Uncertainty regarding available actions

- Here, we consider only the first kind of uncertainty.

- Bradley and Steele claim that there is uncertainty about which actions are or will become available.

  Example: Future technologies, e.g. fusion, may severely distort the accuracy of current decision-making.

  “The IPCC (2014a) ARC-5 WGIII report, for instance, acknowledges that mitigation costs are greatly dependent on future technological options, in particular, options for enhanced energy efficiency and reduced carbon intensity of energy production” (p. 803).

The End