

ASIC200 Climate change Lecture (second class ~1hr to 1hr 15min)
SCIENCE LECTURE PART 2. Jan 23rd, 2014

SECTIONS IN RED (definitely not needed for examination purpose, but still highly recommended for general reading to be informed generally – esp linked to newspaper articles).

Purpose of today's lecture is to get more comfortable with the IPCC SPM report. No requirement to memorize anything, but I should be able to quote something from the report, and you're comfortable speaking intelligently about it. Note: there might be the odd passage that is clearly dependent on a significant amount of additional science background. I'm hoping some will be addressed in these lecture notes, but others you can assume not showing up on exams, etc.

SLIDE 01: Set-up.

PLEASE DO THE FOLLOWING:

1. Attempt to sit down with your “zombie apocalypse” group. This will be your team for today. There is a competition of sorts. No prize - just glory.
2. Write down the name of your team on the white board. Also write down the name of your team on a blank sheet of paper (at the top).

SLIDE 02: Which One is False #1?

1. A paper examining the albedo effects of the vast sheep population in New Zealand has been previously published. In this paper, it noted the sharp decline in sheep numbers in a 2006 foot and mouth outbreak correlated strongly with noticeably lowered reflection measurements.
2. If we were to assume that Spongebob Squarepants is real, various ocean models suggest that he would be in serious trouble in about 50 years or so.
3. Research has shown that cow farts contribute significant positive radiative forcing.
4. One definition of a climate change “tipping point” has been modeled (in a recently published scientific article) to happen as early as 2020 under business as usual emissions scenarios.

SLIDE 03/04: Number 4 is TRUE.

Tipping point has a number of interpretations, but from a media perspective tends to assume a state “of no return.” In the scientific literature, this has been used off and on (most famously by James Hansen who warned in 2007 that a +1C change was subjectively bad, and a +3C was representative of a possible “tipping point.”) These days, the word is used more carefully in science, and sometimes even with a different definition.

For instance, slide 3 highlights a paper:

The projected timing of climate departure from recent variability, Mora, C., et al. *Nature*, 502, 183–187 (10 October 2013) -

<http://www.nature.com/nature/journal/v502/n7470/full/nature12540.html>

This paper defines a tipping point as reach a state when “all” temperatures at a given locale fall outside the current extreme highs. Under this situation, tipping points would occur in different places at different times. 2020 is the earliest modeled for Manokwari, Indonesia. For us in Vancouver, it's apparently closer to 2050).

<http://www.japantimes.co.jp/life/2013/10/10/environment/earths-climate-change-tipping-point-to-start-in-2020-new-model-predicts/#.UuBcpmTTnZs>

Point is: best not to go there – even the most minor plausibility of a tipping point is scary, and based on the IPCC statements presented in these two slides, it's clear that it wouldn't be that difficult to get temperatures previously warned against.

E8: A large fraction of anthropogenic climate change resulting from CO₂ emissions is irreversible on a multi-century to millennial time scale, except in the case of a large net removal of CO₂ from the atmosphere over a sustained period. Surface temperatures will remain approximately constant at elevated levels for many centuries after a complete cessation of net anthropogenic

CO₂ emissions. Due to the long time scales of heat transfer from the ocean surface to depth, ocean warming will continue for centuries. Depending on the scenario, about 15 to 40% of emitted CO₂ will remain in the atmosphere longer than 1,000 years.

E1: Increase of global mean surface temperatures for 2081–2100 relative to 1986–2005 is projected to likely be in the ranges derived from the concentration-driven CMIP5 model simulations, that is, 0.3°C to 1.7°C (RCP2.6), 1.1°C to 2.6°C (RCP4.5), 1.4°C to 3.1°C (RCP6.0), 2.6°C to 4.8°C (RCP8.5). The Arctic region will warm more rapidly than the global mean, and mean warming over land will be larger than over the ocean (very high confidence)

E1: Relative to the average from year 1850 to 1900, global surface temperature change by the end of the 21st century is projected to likely exceed 1.5°C for RCP4.5, RCP6.0 and RCP8.5 (high confidence). Warming is likely to exceed 2°C for RCP6.0 and RCP8.5 (high confidence), more likely than not to exceed 2°C for RCP4.5 (high confidence), but unlikely to exceed 2°C for RCP2.6 (medium confidence). Warming is unlikely to exceed 4°C for RCP2.6, RCP4.5 and RCP6.0 (high confidence) and is about as likely as not to exceed 4°C for RCP8.5 (medium confidence).

Bring up RCP: Representative Concentration Pathways # (where number = positive W/m² radiative forcing value)

Note CMIP5 models that DO NOT consider carbon cycle considerations, that may or may not sequester atmospheric CO₂ (hence the smaller and less confident numbers in the slide 4 IPCC statement).

Slide 4 actually highlights a recent paper:

Spread in model climate sensitivity traced to atmospheric convective mixing, Steven C. Sherwood, SC., Bony, S., and Dufresne J-L., Nature 505, 37–42 (02 January 2014)

<http://www.nature.com/nature/journal/v505/n7481/full/nature12829.html>

This is one of the latest modeling papers that has a better grip on effect of cloud nuances. This paper suggests a final outcome of +4C by 2100.

See <http://www.theguardian.com/science/2014/jan/01/climate-change-models-underestimate-likely-temperature-rise-report-shows> for more

SLIDE 05/06: Number 2 is TRUE!

So basically things aren't looking too good for Spongebob Squarepants and his buddies. The reason being that, all of this carbon dioxide we're pumping into the air is doing some serious shit to the oceans. However in this case, it's less to do with the usual greenhouse effects, but more to do with the ocean's role as a carbon sink. Anyway, it's an interesting and important sidebar to the CO₂ equation, and one that I've looked into a bit more lately as I prep myself for potential topics of discussion in a new course I'm working on.

In essence, the oceans of the world have been changing slowly, not only from a temperature and salinity point of view, but also from a pH point of view. In fact, between the mid 1700s (roughly when the Industrial Revolution started) to present day, the approximate mean ocean pH values have been decreased from 8.25 to 8.14. This is why you hear the term "ocean acidification", although to be technical, the ocean is not actually "acidic" (needs to be less than pH 7.0 for that proper label).

This change might not sound like a lot, but when you consider that the pH scale is a log scale, that .1 difference is akin to a startling 26% increase in H⁺ ions. And how the pH is altered by CO₂ is nicely explained at wikipedia:

When CO₂ dissolves, it reacts with water to form a balance of ionic and non-ionic chemical species : dissolved free carbon dioxide (CO₂ (aq)), carbonic acid (H₂CO₃), bicarbonate (HCO₃⁻) and carbonate (CO₃²⁻). The ratio of these species depends on factors such as seawater temperature and alkalinity.

The overall effect, of course, is that all of this dissolving CO₂ will increase H⁺ concentration in the ocean, leading to the aforementioned change in pH. And although, the irony is that this might actually be a good thing in the greenhouse context, it's not so good for the calcifying organisms that inhabit the waters.

Hmm... "calcifying organisms?" Probably not a term you come across everyday (try working in, "So how's about them calcifying organisms" into your next dinner conversation), but this basically includes organisms like Spongebob, whose delicate structure is primarily made of calcium carbonate and is essentially viable under conditions where the carbonate ion is supersaturated in the water.

However, under the more acidic conditions, chemical equilibrium pushes the oceanic carbonate amounts down, which can result in chemistry that essentially goes: "Hey, where did all the carbonate go in the water? Let's put it back into the water by dissolving the stuff from our shells and skeletons. I'm such a good sponge!"

Obviously, this causes a serious breakdown of these aforementioned structures. In fact, one of the more notable outcomes of this is the current bleaching of coral reefs, which is why we have the silly graphic at the top of the page. (forgot to mention this in class!)

In any event, it's certainly something that merits cause for concern, especially when you consider that the most recent peer reviewed papers suggest a potential drop of a further 0.3 to 0.4 units by 2100 - alarming because this is indicative of a net 100% to 250% increase in H⁺ ions.

As Spongebob once said, "Good people don't rip other people's arms off." - there's a metaphor in there somewhere.

("Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms" Nature 437, p681, 2005)

IPCC statements mentioned:

B5: Ocean acidification is quantified by decreases in pH¹³. The pH of ocean surface water has decreased by 0.1 since the beginning of the industrial era (*high confidence*), corresponding to a 26% increase in hydrogen ion concentration

E7: Earth System Models project a global increase in ocean acidification for all RCP scenarios. The corresponding decrease in surface ocean pH by the end of 21st century is in the range of 0.06 to 0.07 for RCP2.6, 0.14 to 0.15 for RCP4.5, 0.20 to 0.21 for RCP6.0, and 0.30 to 0.32 for RCP8.5

SLIDE 07/08: Number 3 is TRUE! The Methane story.

Cattle paper attempts to measure methane production from cattle. CH₄ is a very strong greenhouse gas. Hence the concern, and (apparently) cattle fart a lot!

Methane Emissions from Cattle, Johnson, KA., Johnson, DE. J Anim. Sci. 1995. 73:2483-2492.

Note that this has been further supported by a more recent paper, which actually suggests that these initial calculations were vastly underestimated.

See Anthropogenic emissions of methane in the United States. Miller, SM., et al. November 25, 2013.

<http://www.pnas.org/content/early/2013/11/20/1314392110.abstract>

"The EPA has also recognized the contribution cow farts are making to Earth's greenhouse gases, stating earlier that globally, livestock are the "largest source of methane from human-related activities," and are the third largest source of methane in the U.S. A 1995 study of methane emissions from cattle found that cows typically lose about 6 percent of their ingested energy as methane, partly a result of their slow digestive process. A single cow can produce between 250 and 500 liters, or about 66 to 132 gallons, of methane a day (the average U.S. vehicle gas tank can hold about 16 gallons of gas)."

Slide 8 brings up the Methane/Permafrost "timebomb." Lots of worry about this in 2011 (when the Copenhagen Diagnosis came out). Essentially this report warned:

"The concentration of methane (CH₄) in the atmosphere increased since 2007 to 1800 parts per billion (ppb) after almost a decade of little change. The causes of the recent increase in have not yet been determined. The spatial distribution of the methane increase shows that an increase in Northern Hemisphere CH₄ emissions has played a role and could dominate the signal (Rigby et al. 2008), but the source of the increase is unknown."

"Between 500 and 10,000 Gt of carbon are thought to be stored under the sea floor in the form methane hydrates (or clathrates), a crystalline structure of methane gas and water molecules (Brook et al. 2008). Another 7.5 to 400 Gt of carbon are stored in the form of methane hydrates trapped in permafrost (Brook et al. 2008). Some have argued that anthropogenic warming could raise the possibility of a catastrophic release of methane from hydrates to the atmosphere. In a recent assessment by the US Climate Change Science Program (CCSP 2008b), it was deemed to be very unlikely that such a release would occur this century, although the same assessment deemed it to be very likely that methane sources from hydrate and wetland emissions would increase as the climate warmed."

Currently, there is no real consensus on whether this is a significant factor (hence the language with the IPCC statements). The paper shown in Slide 8 is one of the more recent papers suggesting that initial worries were greatly over estimated.

Via Permafrost degradation and methane: low risk of biogeochemical climate-warming feedback. Gao, X., et al. *Environ. Res. Lett.* 8 035014
<http://iopscience.iop.org/1748-9326/8/3/035014>
Also see: <http://www.theguardian.com/environment/earth-insight/2013/aug/05/7-facts-need-to-know-arctic-methane-time-bomb>

IPCC statements showcased:

B5: Concentrations of CO₂, CH₄, and N₂O now substantially exceed the highest concentrations recorded in ice cores during the past 800,000 years. The mean rates of increase in atmospheric concentrations over the past century are, with very *high confidence*, unprecedented in the last 22,000 years.

E7: The release of CO₂ or CH₄ to the atmosphere from thawing permafrost carbon stocks over the 21st century is assessed to be in the range of 50 to 250 GtC for RCP8.5 (*low confidence*).

SLIDE 09/10 Number 1 was FALSE!

A few years back, there was a sheep Albedo paper was presented as an april fools joke on a well known climate science website. A take on the concept of albedo/reflection properties of the planet's surface (be it ice, your white t-shirt or millions of sheep), covered in IPCC readings.

Kangaroo sidebar. Australia has investigated use of kangaroos as major livestock (for meat). Basically, the digestive systems of marsupials such as Kangaroos and Wallabies have a very different microbial set up (i.e. the bacteria involved in digestion are different from say, cows). Net effect is that the fecal matter, and "farts" produced from such animals have a much lower amounts of the greenhouse gas methane.

Some research is now looking into this microbial flora in an attempt to see if this type of gut ecosystem can be introduced into cattle (thereby reducing methane amounts from this sector of agriculture – which apparently is quite significant).

TALK about albedo generally (reflective properties of things that can reflect visible light – i.e. white things like snow, white roofs, sheep).

Highlight paper in SLIDE 10: Dead trees (via pine beetle for instance, inadvertently increase albedo – negative radiative forcing).

Radiative Forcing of Natural Forest Disturbances. O'Halloran, TL., et al. *Global Change Biology*. Volume 18, Issue 2, pages 555–565, February 2012
<http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2011.02577.x/abstract>

IPCC statement mentioned:

D3: It is *likely* that there has been an anthropogenic contribution to observed reductions in Northern Hemisphere spring snow cover since 1970.

SLIDE 11: Which One is False #2?

1. Research on the effect of climate change on squirrel sex has been published in peer reviewed journals.
2. Survey evidence has shown that viewers do not statistically become more concerned about global warming after watching the “The Day After Tomorrow” - a big budget action movie about a catastrophic change in thermohaline circulation.
3. In 2011, the state of North Carolina passed a bill that deemed it illegal for the sea level to increase greater than a “projected” 20cm by 2100.

SLIDE 12: Number 1 is true. Yes, squirrel sex is affected. Climate change alters ecological niches. Therefore, organisms will compensate by altering behaviour in terms of where they reside (migration), temporally (i.e. change in temperature, results in change in plant growth, results in change in when mating occurs), the ecological community they interact with (i.e. migration causes organism to encroach on habitat of other organisms).

ALSO bring up the concept of emerging infectious diseases. As climate warms, two primary effects in this regard. Increase movement of water resulting in greater occurrence of water borne diseases (i.e. cholera). Also habitat of many insect vectors (i.e. species of mosquito) can expand into new areas (i.e. malaria).

Brief mention of the Nagoya protocol (UN agreement on biodiversity issues – one central theme was to access economic worth of biodiversity since it often provides services that can have cost benefits).

FINALLY: redistribution of resources like water, arable land, and ask students to think about how folks might react to rapid change. Ask how a developed versus developing country might fair in this regard.

Via: Changing seasonality and phenological responses of free-living male arctic ground squirrels: the importance of sex. [Sheriff MJ, Richter MM, Buck CL, Barnes BM. 2013 Jul 8;368\(1624\)](http://rstb.royalsocietypublishing.org/content/368/1624/20120480.long)
<http://rstb.royalsocietypublishing.org/content/368/1624/20120480.long>

IPCC statement:

D3: Greenhouse gases contributed a global mean surface warming *likely* to be in the range of 0.5°C to 1.3°C over the period 1951 to 2010, with the contributions from other anthropogenic forcings, including the cooling effect of aerosols, *likely* to be in the range of –0.6°C to 0.1°C. The contribution from natural forcings is *likely* to be in the range of –0.1°C to 0.1°C, and from natural internal variability is likely to be in the range of –0.1°C to 0.1°C. Together these assessed contributions are consistent with the observed warming of approximately 0.6°C to 0.7°C over this

period.

SLIDE 13: Number 3 (amazingly) is TRUE!

This story highlights some of the political shenanigans involved in folks working around the science of climate change. Full story can be seen here (worth reading).
<http://www.earthmagazine.org/article/denying-sea-level-rise-how-100-centimeters-divided-state-north-carolina>

IPCC statement

E6: Global mean sea level rise for 2081–2100 relative to 1986–2005 will *likely* be in the ranges of 0.26 to 0.55 m for RCP2.6, 0.32 to 0.63 m for RCP4.5, 0.33 to 0.63 m for RCP6.0, and 0.45 to 0.82 m for RCP8.5 (*medium confidence*). For RCP8.5, the rise by the year 2100 is 0.52 to 0.98 m, with a rate during 2081 to 2100 of 8 to 16 mm yr⁻¹ (*medium confidence*). These ranges are derived from CMIP5 climate projections in combination with process-based models and literature assessment of glacier and ice sheet contributions

SLIDE 14/15/16: Number 2 is FALSE! Turns out watching the movie does correlate with greater concern and worry about climate change.

Slides 14 and 15 highlight parts of the study (not a great study to be honest) that outlines this finding.

Before and After “The Day After Tomorrow.” A U.S. Study of Climate Change Risk Perception. Leiserowitz, AA. Environment. November 2004, Volume 46 Number 9, pp22-37
Access paper at: http://www.upf.edu/pcstacademy/docs/200411_environment1.pdf

Artistic endeavours may alter perceptions. Note the movie is about a catastrophic change to the ocean movement patterns (specifically those concerning the Atlantic Meridional Overturning Circulation (AMOC)).

Note a large movement of ocean water that follows a path can be primarily defined by things like:

- Local climate: which parts get heated, which parts don't.
- Wind patterns (i.e. Gulf Stream) – energy from wind currents move water along.
- Water Salinity (Thermohaline circulation) – as water is evaporated into the atmosphere, the water that remains in the ocean becomes more concentrated in salt. Therefore it becomes more dense, therefore it sinks. Because we're dealing with huge volumes, this is a massive amount of movement of fluid downwards which partially drives this circulation.
- Ocean bed topography: The shape of the sea bed will also obviously effect the movement of water.

See http://en.wikipedia.org/wiki/Thermohaline_circulation

Cool animation from <http://svs.gsfc.nasa.gov/vis/a000000/a003800/a003884/>

IPCC statements:

E4: It is very *likely* that the Atlantic Meridional Overturning Circulation (AMOC) will weaken over the 21st century. Best estimates and ranges for the reduction are 11% (1 to 24%) in RCP2.6 and 34% (12 to 54%) in RCP8.5. It is *likely* that there will be some decline in the AMOC by about 2050, but there may be some decades when the AMOC increases due to large natural internal variability.

E4: It is very *unlikely* that the AMOC will undergo an abrupt transition or collapse in the 21st century for the scenarios considered. There is *low confidence* in assessing the evolution of the AMOC beyond the 21st century because of the limited number of analyses and equivocal results. However, a collapse beyond the 21st century for large sustained warming cannot be excluded.

SLIDE 17: Which One is False #3?

1. Only one academic, out of over 9000 published in recent peer reviewed climate change research (all scientific papers published from November 2012 to December 2013), rejects man made global warming.

2. Calculations suggest that on average, each North American wastes approximately 500kcal of food each day - roughly equivalent to a quarter of the total dietary needs of an average woman.
3. According to the latest data (November 2013) on the prevalence of global warming denial among the US public, 23% of Americans do not believe that global warming is happening. This is up from last year's 17% and also represents a 6 year high.
4. The first convincing model of geoengineering effects suggests that use of sulphates in the atmosphere can inadvertently lead to issues of global inequity.

SLIDE 18/19/20/21

Unfortunately, based on November 2013 stats, climate change denial is at a 6 year high.

Essentially 23% of US folks don't think it's a real thing.

Also: "Nearly half of Americans (47%) believe global warming – if it is happening – is caused mostly by human activities, a decrease of 7 points since Fall 2012, but similar to levels over the past several years. At the same time, 37% of Americans believe that global warming is due mostly to natural changes in the environment. "

See Climate Change in the American Mind. Americans' Global Warming Beliefs and Attitudes in November 2013. Yale Project on Climate Communication.

via <http://environment.yale.edu/climate-communication/article/Climate-Beliefs-November-2013>

Why is there this attitude – lots think it's got something to do with this "global warming pause."

See graph on slide 19.

Except that it still fits the modeling trend – (i.e. 15 year span starting at an extreme year, 1998).

As well, there are a number of other factors that come into play.

These are highlighted in the IPCC statements, but the biggie is (1) deep ocean temperatures, especially noting that net DQ uptake is about 1% for the atmosphere and as much as 60% for the top layer (<700m) of the ocean, and 30% for the layer between 700m and 2000m (i.e. 90% is held in the water) (see graph on slide 20).

Data for graph from http://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/

Also, (SLIDE 21) there may be a conservative bias due to lack of confidence with readings in the poles. Essentially, we talked about issues with trying to settle on a "global mean." Some evidence suggests that if you take more readings into account at the arctic and Antarctic areas, the curves generated would be much more striking.

See Coverage bias in the HadCRUT4 temperature series and its impact on recent temperature trends. Cowtan, K., and Way, RG. Quarterly Journal of the Royal Meteorological Society. Online pub 12 NOV 2013

At <http://onlinelibrary.wiley.com/doi/10.1002/qj.2297/abstract>

IPCC statements.

D1: The observed reduction in surface warming trend over the period 1998 to 2012 as compared to the period 1951 to 2012, is due in roughly equal measure to a reduced trend in radiative forcing and a cooling contribution from natural internal variability, which includes a possible redistribution of heat within the ocean (*medium confidence*). The reduced trend in radiative forcing is primarily due to volcanic eruptions and the timing of the downward phase of the 11-year solar cycle. However, there is *low confidence* in quantifying the role of changes in radiative forcing in causing the reduced warming trend. There is *medium confidence* that natural internal decadal variability causes to a substantial degree the difference between observations and the simulations; the latter are not expected to reproduce the timing of natural internal variability. There may also be a contribution from forcing inadequacies and, in some models, an overestimate of the response to increasing greenhouse gas and other anthropogenic forcing (dominated by the effects of aerosols).

B2: More than 60% of the net energy increase in the climate system is stored in the upper ocean

(0–700 m) during the relatively well-sampled 40-year period from 1971 to 2010, and about 30% is stored in the ocean below 700 m. The increase in upper ocean heat content during this time period estimated from a linear trend is *likely* $17 [15 \text{ to } 19] \times 10^{22} \text{ J}$ ⁷

B2: It is about *as likely as not* that ocean heat content from 0–700 m increased more slowly during 2003 to 2010 than during 1993 to 2002. Ocean heat uptake from 700–2000 m, where interannual variability is smaller, *likely* continued unabated from 1993 to 2009.

Re; next two IPCC statements - Note the difference confidence in statements dependent on the hemisphere you're dealing with (aka a reflection of number of data points you have – more land in the north than the south – similar in concept to weaknesses applied to extreme pole locales as mentioned in SLIDE 21)

B1: It is *virtually certain* that globally the troposphere has warmed since the mid-20th century. More complete observations allow greater confidence in estimates of tropospheric temperature changes in the extratropical Northern Hemisphere than elsewhere. There is *medium confidence* in the rate of warming and its vertical structure in the Northern Hemisphere extra-tropical troposphere and *low confidence* elsewhere.

B1: Confidence in precipitation change averaged over global land areas since 1901 is *low* prior to 1951 and *medium* afterwards. Averaged over the mid-latitude land areas of the Northern Hemisphere, precipitation has increased since 1901 (*medium confidence* before and *high confidence* after 1951). For other latitudes area-averaged long-term positive or negative trends have *low confidence*

SLIDE 22/23: Number 1 is TRUE. The consensus is VERY VERY strong.

Only 1 academic out of 9136 authors rejected man-made global warming. That's quite the consensus – slide 22 highlights the paper from Russian climatologist SV Avakyan.

See:

The Role of Solar Activity in Global Warming. Herald of the Russian Academy of Science. 2013. Vol 83, No. 3, pp275-285

Also: <http://www.jamespowell.org/index.html> (assessed January 22, 14).

SLIDE 23 shows a compelling graphic. You can also state the following:

"Of the 16208 peer reviewed climate change papers published from January 1st, 1991 to December 31st, 2013, only 25 reject human caused climate change."

Pet peeve of internet trolls: "Where is the data?" or "cherry picking results to back a weak claim."

IPCC statement:

D3: It is *extremely likely* that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together. The best estimate of the human-induced contribution to warming is similar to the observed warming over this period. **Word.**

SLIDE 24: Number 4 is TRUE:

Highlight geoengineering (or in this case, climate engineering): see

http://en.wikipedia.org/wiki/Climate_engineering

"Climate engineering, an application of geoengineering, is the deliberate and large-scale intervention in the Earth's climatic system with the aim of reducing global warming.^{[1][2][3]} Climate engineering has two categories of technologies-carbon dioxide removal and solar radiation management."

Paper: Weakened tropical circulation and reduced precipitation in response to geoengineering.

Ferraro, AJ., Highwood, EJ., and Charlton-Perez, AJ. Environ. Res. Lett. Vol 9, (2014) 014001
Via: <http://iopscience.iop.org/1748-9326/9/1/014001/article>

See for easy to read details. To quote:

<http://www.theguardian.com/environment/2014/jan/08/geoengineering-drought-tropics-climate-change-volcano>

“But the new work shows that a leading contender – pumping sulphate particles into the stratosphere to block sunlight – could have side-effects just as serious as the effects of warming itself. Furthermore, the impacts would be different around the world, raising the prospect of conflicts between nations that might benefit and those suffering more damage.”

Nagoya International Treaty (Convention on Biodiversity, 2010) – signed moratorium on all geoengineering projects. Which was why the Haida Gwaii “Iron dump” story had such a ruckus (basically illegal – sort of). Nov 2012. (also broke the London Protocol over toxic dumping in the ocean).

See: <http://www.theglobeandmail.com/news/national/un-expresses-grave-concern-over-bc-sea-experiment/article4900427/>

IPCC statement:

E8: Methods that aim to deliberately alter the climate system to counter climate change, termed geoengineering, have been proposed. Limited evidence precludes a comprehensive quantitative assessment of both Solar Radiation Management (SRM) and Carbon Dioxide Removal (CDR) and their impact on the climate system. CDR methods have biogeochemical and technological limitations to their potential on a global scale. There is insufficient knowledge to quantify how much CO₂ emissions could be partially offset by CDR on a century timescale. Modelling indicates that SRM methods, if realizable, have the potential to substantially offset a global temperature rise, but they would also modify the global water cycle, and would not reduce ocean acidification. If SRM were terminated for any reason, there is *high confidence* that global surface temperatures would rise very rapidly to values consistent with the greenhouse gas forcing. CDR and SRM methods carry side effects and long-term consequences on a global scale.

SO: SLIDE 25: Number 2 was FALSE! Not 500kcal, but 1400kcal per person (that's equivalent to about 70% of the daily dietary needs of the average woman, or 50% of the daily dietary needs of the average woman).

See: The Progressive Increase of Food Waste in America and Its Environmental Impact. Hall, KD, et al. PLOS ONE, November 25, 2009 DOI: 10.1371/journal.pone.0007940

Via <http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0007940>

We're wasteful and we like stuff:

SLIDES 26/27/28: highlight stuff via water bottles: Art piece showing approximate number of water bottles used in the US every 5 minutes (2007 stats). Digital art by Chris Jordan.

See: <http://www.chrisjordan.com/gallery/rtn/#plastic-bottles>

SLIDE 29: To do this, our energy needs are intense – because we're stifling in the clean energy department (solar, etc). Most effort still seems to be concentrated on other sources of fossil fuels. Many of these are energy intensive (mountain top removal, fracking, oil sands, etc). Less political will to focus on cleaner types of energy source (many of which have issues themselves – solar, nuclear, wind, wave, etc))

Graphic from Pembina Institute. Op-Ed at <http://www.pembina.org/op-ed/2515>

IPCC statement:

E8: Limiting the warming caused by anthropogenic CO₂ emissions alone with a probability of >33%, >50%, and >66% to less than 2°C since the period 1861–1880²², will require cumulative CO₂ emissions from all anthropogenic sources to stay between 0 and about 1570 GtC (5760 GtCO₂), 0 and about 1210 GtC (4440 GtCO₂), and 0 and about 1000 GtC (3670 GtCO₂) since that period, respectively²³. These upper amounts are reduced to about 900 GtC (3300 GtCO₂), 820 GtC (3010 GtCO₂), and 790 GtC (2900 GtCO₂), respectively, when accounting for non-CO₂ forcings as in RCP2.6. An amount of 515 [445 to 585] GtC (1890 [1630 to 2150] GtCO₂), was already emitted by 2011.

SLIDE 30: Ecofootprint data for the average Vancouverite: 7.71 Gha per person (~4 earth equivalence) 2008 numbers – Canada roughly the same at 2010 numbers.

This number is tough to get (also saw 2006 numbers published in a 2013 paper for 4.75Gha/person). NOTE the number is hard to pin down via literature, so maybe I can say something like “It seems *very likely* that the current average ecofootprint for a Vancouverite is between 5.0kGa and 8.0Gha”

SLIDE 31: Things that make you go hmmm...

In conclusion:

IF YOU THINK ABOUT IT

SCIENCE, IN A WAY, HAS ALREADY PROVIDED US WITH THE KNOWLEDGE TO “FIX” CLIMATE CHANGE.

WE KNOW WHAT IS “AT FAULT.”

WE KNOW WHAT SHOULD BE “CHANGED.”

WE KNOW WHAT “MIGHT HAPPEN” IF WE DON’T CHANGE.

WE EVEN HAVE BENCHMARKS TO AIM FOR.

SO WHY IS THIS SO DIFFICULT?