Climate Change, Air Pollution, and Health: Co-Benefits and Cross-Benefits

Kirk R. Smith
Professor, University of California Berkeley
Visiting Scholar
International Institute of Applied Systems Analysis

Center for Climate Change and Sustainable Energy Policy and
Department of Environmental Sciences and Policy
Central European University, Budapest
May 5, 2014
Map

- A brief summary of the IPCC process
- Brief results from WG I -- Climate Science
- WGII -- Impacts
- Ch 11 -- Health Impacts
- Co-Benefits
- Cross-Benefits
TIMELINE 5th ASSESSMENT REPORT (AR5)

1. **Experts & governments scope report**
   - During 2009

2. **IPCC approves outline**
   - October 2009

3. **Governments & organisations nominate authors**
   - By March 2010

4. **Informal drafting and review**
   - 2011

5. **Global expert & government review**
   - 2012/13

6. **Authors prepare 2nd order draft**
   - 2012/13

7. **Global expert review**
   - 2012

8. **Authors prepare 1st order draft**
   - 2011/12

9. **Authors prepare final draft**
   - 2013

10. **Government review of SPM**
    - 2013

11. **IPCC approves report**
    - 2013/14

12. **Publication of report**
    - September 2013 (WG I)
    - March/April 2014 (WGII / III)
    - October 2014 (Synthesis Report)
$\text{CO}_2$ levels now higher than any time in last 400,000 years

Update: passed 400 ppm this year (2013)

Petit et al. 1999; Keeling and Whorf 2000
Warming at the surface of the Earth – about 0.8 degrees C since pre-industrial era
Evidence of warming – more record high maximum temperatures (in red) than record low minimum temperatures (in blue)
Climate models that exclude greenhouse emissions do not match recent warming; models that incorporate both natural and anthropogenic forcings fit well with the temperature record.
### Summary for Policy Makers, WGI AR5

The situation up to the present

<table>
<thead>
<tr>
<th>Phenomenon and direction of trend</th>
<th>Assessment that changes occurred (typically since 1950 unless otherwise indicated)</th>
<th>Assessment of a human contribution to observed changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warmer and/or fewer cold days and nights over most land areas</td>
<td>Very likely (2.6)</td>
<td>Very likely (10.6)</td>
</tr>
<tr>
<td>Warmer and/or more frequent hot days and nights over most land areas</td>
<td>Very likely (2.6)</td>
<td>Very likely (10.6)</td>
</tr>
<tr>
<td>Warm spells/heat waves. Frequency and/or duration increases over most land areas</td>
<td>Medium confidence on a global scale. Likely in large parts of Europe, Asia and Australia (2.6)</td>
<td>Likely (10.6)</td>
</tr>
<tr>
<td>Heavy precipitation events. Increase in the frequency, intensity, and/or amount of heavy precipitation</td>
<td>Likely more land areas with increases than decreases (2.6)</td>
<td>Medium confidence (7.6, 10.6)</td>
</tr>
<tr>
<td>Phenomenon and direction of trend</td>
<td>Early 21st century</td>
<td>Late 21st century</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>--------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Warmer and/or fewer cold days and nights over most land areas</td>
<td>Likely (11.3)</td>
<td>Virtually certain (12.4)</td>
</tr>
<tr>
<td>Warmer and/or more frequent hot days and nights over most land areas</td>
<td>Likely (11.3)</td>
<td>Virtually certain (12.4)</td>
</tr>
<tr>
<td>Warm spells/heat waves. Frequency and/or duration increases over most land areas</td>
<td>Not formally assessed (11.3)</td>
<td>Very likely (12.4)</td>
</tr>
<tr>
<td>Heavy precipitation events. Increase in the frequency, intensity, and/or amount of heavy precipitation</td>
<td>Likely over many land areas (11.3)</td>
<td><strong>Very likely</strong> over most of the mid-latitude land masses and over wet tropical regions (12.4)</td>
</tr>
</tbody>
</table>

The future
### Summary for Policy Makers, WGI AR5. cont.

<table>
<thead>
<tr>
<th>Phenomenon and direction of trend</th>
<th>Assessment that changes occurred (typically since 1950 unless otherwise indicated)</th>
<th>Assessment of a human contribution to observed changes</th>
</tr>
</thead>
</table>
| Increases in intensity and/or duration of drought | Low confidence on a global scale  
Likely changes in some regions\(^a\)  
Medium confidence in some regions  
Likely in many regions, since 1970\(^a\) | Low confidence |
| Increase in intense tropical cyclone activity | Low confidence in long term (centennial) changes  
Virtually certain in North Atlantic since 1970\(^a\) | Low confidence\(^i\)  
More likely than not |
| Increased incidence and/or magnitude of extreme high sea level | Likely (since 1970)  
Likely (late 20th century)  
Likely \(\^k\)  
More likely than not \(\^k\) | Likely\(^k\)  
More likely than not \(\^k\) |

The situation up the present
### Summary for Policy Makers, WGI AR5. cont.

<table>
<thead>
<tr>
<th>Phenomenon and direction of trend</th>
<th>Early 21st century</th>
<th>Late 21st century</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increases in intensity and/or duration of drought</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increases in intense tropical cyclone activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased incidence and/or magnitude of extreme high sea level</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Likelihood of further changes

<table>
<thead>
<tr>
<th>Phenomenon and direction of trend</th>
<th>Early 21st century</th>
<th>Late 21st century</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increases in intensity and/or duration of drought</td>
<td>Low confidence³</td>
<td>Likely (medium confidence) on a regional to global scale⁹</td>
</tr>
<tr>
<td>Increases in intense tropical cyclone activity</td>
<td>Low confidence³</td>
<td>More likely than not in the Western North Pacific and North Atlantic⁸</td>
</tr>
<tr>
<td>Increased incidence and/or magnitude of extreme high sea level</td>
<td>Likely⁴</td>
<td>Very likely⁴</td>
</tr>
</tbody>
</table>

The future
E.3 Atmosphere: Air Quality

• The range in projections of air quality (ozone and PM2.5 in near-surface air) is driven primarily by emissions (including CH₄), rather than by physical climate change (medium confidence). There is high confidence that globally, warming decreases background surface ozone. High CH₄ levels (as in RCP8.5) can offset this decrease, raising background surface ozone by year 2100 on average by about 8 ppb (25% of current levels) relative to scenarios with small CH₄ changes (as in RCP4.5 and RCP6.0) (high confidence).  \{11.3\}

• Observational and modelling evidence indicates that, all else being equal, locally higher surface temperatures in polluted regions will trigger regional feedbacks in chemistry and local emissions that will increase peak levels of ozone and PM2.5 (medium confidence). For PM2.5, climate change may alter natural aerosol sources as well as removal by precipitation, but no confidence level is attached to the overall impact of climate change on PM2.5 distributions.  \{11.3\}
Black carbon?

“While removal of black carbon aerosol could also counter warming associated with sulphate removal, uncertainties are too large to constrain the net sign of the global temperature response to black carbon emission reductions, which depends on reduction of co-emitted (reflective) aerosols and on aerosol indirect effects.”

SPM, WGI
Temperature projections for four concentration pathways, median (yellow) and uncertainty bound (gray), 2010 – 2300.

High end warming – assumes no restriction on use of fossil fuels, climate does not stabilize below about +12 degrees warming

Nature Climate Change 2012;2:248
IPCC WG1
Rate makes a big difference
Rate of change over the next 100 years a hundred times greater than experienced previously (RCP 8.5). Even the RCP2.6 scenario warms ten times faster than the PETM.

Palaeo-Eocene Thermal Maximum: caused by volcanoes, methane releases, peat fires

Source: Kump, Scientific American July 2011
Introducing the idea of climate velocity – a critical test of the limits of adaptation to global heating.

Summary for Policy Makers Fig 3, WG1
Percent simulated yield change as a function of local temperature change, with 95% confidence interval, according to absence or presence of adaptation. Figure 7.5, WG1

Rapid warming amplifies fall in maize and wheat yields in the tropics
And now highlights from the executive summary of Chapter 11: Health Impacts, Adaptation, and Co-benefits of Working Group 2
WG2: *Impacts, Adaptation, and Vulnerability*

- 308 authors from 70 countries
- 50492 review comments (3 rounds)
- 30 chapters in two volumes
- Vol 1 sections:
  - Natural and managed ecosystems
  - Settlement sand infrastructure
  - Health, well-being, and security
  - Adaptation
  - Risks, vulnerabilities, and opportunities
- Vol 2: ten regional chapters
Chapter 11: Expert Team

- Kirk R. Smith (USA), Alistair Woodward (New Zealand)

- Lead Authors: Diarmid Campbell-Lendrum (WHO), Dave Chadee (Trinidad and Tobago), Yasushi Honda (Japan), Qiyong Liu (China), Jane Olwoch (South Africa), Boris Revich (Russian Federation), Rainer Sauerborn (Sweden)

- Contributing Authors: Clara Aranda (Mexico), Helen Berry (Australia), Colin Butler (Australia), Zoe Chafe (USA), Lara Cushing (USA), Kristie Ebi (USA), Tord Kjellstrom (New Zealand), Sari Kovats (UK), Graeme Lindsay (New Zealand), Erin Lipp (USA), Tony McMichael (Australia), Virginia Murray (UK), Osman Sankoh (Sierra Leone), Marie O’Neill (USA), Seth B. Shonkoff (USA), Joan Sutherland (Trinidad and Tobago), Shelby Yamamoto (Germany)

- Review Editors: Ulisses Confalonieri (Brazil), Andrew Haines (UK)

- Volunteer Chapter Scientists: Zoë Chafe (USA), Joachim Rocklov (Sweden)
Chapter 11 Conclusions

• Until mid-century climate change will act mainly by exacerbating health problems that already exist [*very high confidence*].

• New conditions may emerge under climate change [*low confidence*] and existing diseases (e.g. food-borne infections) may extend their range into areas that are presently unaffected [*high confidence*].

• But the largest risks will apply in populations that are currently most affected by climate-related diseases.
In recent decades, climate change has contributed to levels of ill-health (likely) though the present worldwide burden of ill-health from climate change is relatively small compared with other stressors on health and is not well quantified.

Rising temperatures have increased the risk of heat-related death and illness (likely).

Local changes in temperature and rainfall have altered distribution of some water-borne illnesses and disease vectors, and reduced food production for some vulnerable populations [medium confidence].
If climate change continues as projected across the RCP scenarios until mid-century, the major increases of ill-health compared to no climate change will occur through:

- greater risk of injury, disease, and death due to more intense heat waves and fires [very high confidence];
- increased risk of under-nutrition resulting from diminished food production in poor regions [high confidence];
- consequences for health of lost work capacity and reduced labor productivity in vulnerable populations [high confidence];
- increased risks of food- and water-borne diseases [very high confidence] and vector-borne diseases [medium confidence];

There will also be some health benefits

- modest improvements in cold-related mortality and morbidity in some areas due to fewer cold extremes [low confidence],
- Increased food production in some areas, and
- reduced capacity of disease-carrying vectors due to exceedance of thermal thresholds [medium confidence].

These positive effects will be out-weighed, worldwide, by the magnitude and severity of the negative effects of climate change [high confidence].
• Impacts on health will be reduced, but not eliminated, in populations that benefit from rapid social and economic development [high confidence], particularly among the poorest and least healthy groups [very high confidence].

• Climate change is an impediment to continued health improvements in many parts of the world.

• If economic growth does not benefit the poor, the health effects of climate change will be exacerbated.
Some parts of the world already exceed the international standard for safe work activity during the hottest months of the year. The capacity of the human body to thermoregulate may be exceeded on a regular basis, particularly during manual labour, in parts of the world during this century.

In RCP8.5, by 2100 some of the world’s land area will be experiencing 4-7 degree higher temperatures due to anthropogenic climate change.

If this occurs, the combination of high temperatures and high humidity will compromise normal human activities, including growing food or working outdoors, raising doubt about the habitability of some areas, for parts of the year [high confidence].
### Table 1 | The four RCPs

<table>
<thead>
<tr>
<th>Name</th>
<th>Radiative forcing</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCP8.5</td>
<td>&gt; 8.5 W m⁻²</td>
</tr>
<tr>
<td>RCP6.0</td>
<td>~ 6 W m⁻² at steady state</td>
</tr>
<tr>
<td>RCP4.5</td>
<td>~ 4.5 W m⁻²</td>
</tr>
<tr>
<td>RCP2.6</td>
<td>Peak at ~ 3 W m⁻² at the end of the century</td>
</tr>
</tbody>
</table>

### Table TS.5. Best estimate, likely ranges and very likely lower bounds of global mean equilibrium surface temperature increase (°C) over pre-industrial temperatures for different levels of CO₂-equivalent radiative forcing, as derived from the climate sensitivity.

Max temps committed but not yet reached by 2100

<table>
<thead>
<tr>
<th>Equilibrium CO₂-eq (ppm)</th>
<th>Temperature Increase (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Best Estimate</td>
</tr>
<tr>
<td>350</td>
<td>1.0</td>
</tr>
<tr>
<td>450</td>
<td>2.1</td>
</tr>
<tr>
<td>550</td>
<td>2.9</td>
</tr>
<tr>
<td>650</td>
<td>3.6</td>
</tr>
<tr>
<td>750</td>
<td>4.3</td>
</tr>
<tr>
<td>1000</td>
<td>5.5</td>
</tr>
<tr>
<td>1200</td>
<td>6.3</td>
</tr>
</tbody>
</table>
What most people consider with heat stress

Who died?
The vulnerable – mainly the old and others who should have been protected, but were not
Wet Bulb Globe Temperature = Function of
• temperature,
• humidity,
• wind speed, and
• radiative energy, e.g., sunlight

No epidemiology needed
Basic thermodynamics and
Human physiology from exposure chamber studies
The science is 60 years old – US military research in the 1950s and much since
Refers to healthy workers – not the most vulnerable
Here is what happens at 3 degrees

What about 6 or 9 degrees?

Hyatt, Lernke, Kellstrom, 2010
Approximate 9-deg world

Places where people cannot work outdoors

Sherwood & Huber, PNAS, 2010
What is coming?

• Few places exist on Earth now where people cannot work outdoors nearly every day of the year with appropriate work practices
• More and more of such places with global warming if nothing is done
• When in major populated areas will it be possible only to work outdoors in winter or at night?
• Then only in the winter at night?
• Then what?
Ch 11, cont.

• The most effective adaptation measures for health in the near-term are programs that implement basic public health measures such as provision of clean water and sanitation, secure essential health care including vaccination and child health services, increase capacity for disaster preparedness and response, and alleviate poverty [very high confidence].
Co-benefits

The positive effects that a policy or measure aimed at one objective might have on other objectives, irrespective of the net effect on overall social welfare.

Examples include benefits in other sectors, such as health, urban development, transport, employment, and agriculture, of climate mitigation and adaption efforts. Another term used is “ancillary benefits”
There are opportunities to achieve co-benefits from actions that reduce emissions of CAPs and at the same time improve health. Among others, these include:

- reducing local emissions of health-damaging and climate-altering air pollutants from energy systems, through improved energy efficiency, and a shift to cleaner energy sources [very high confidence];
- providing access to reproductive health services (including modern family planning) to improve child and maternal health through birth spacing and reduce population growth, energy use, and consequent CAP emissions over time [medium confidence];
- shifting consumption away from animal products, especially from ruminant sources, in high-meat-consumption societies toward less CAP-intensive healthy diets [medium confidence];
- designing transport systems that promote active transport and reduce use of motorized vehicles, leading to lower emissions of CAPs and better health through improved air quality and greater physical activity [high confidence].
Global DALYs 2010: Top 20 Risk Factors

- High blood pressure
- Tobacco smoking, including second-hand smoke
- Alcohol use
- Household air pollution from solid fuels
- Diet low in fruits
- High body-mass index
- High fasting plasma glucose
- Childhood underweight
- Ambient particulate matter pollution
- Physical inactivity and low physical activity
- Diet high in sodium
- Diet low in nuts and seeds
- Iron deficiency
- Suboptimal breastfeeding
- High total cholesterol
- Diet low in whole grains
- Diet low in vegetables
- Diet low in seafood omega-3 fatty acids
- Drug use
- Occupational risk factors for injuries

Disability-adjusted life-years (%)

- 0
- 2
- 4
- 6
- 8
How (and where) to reduce carbon emissions and improve health in a cost-effective fashion

IPCC, WG2, chapter 11
Population growth and global greenhouse emissions – high, medium and low UN population projections, applying the B2 emissions scenario, 2000-2100.

O’Neill et al. Lancet 2012
Reproductive health services and climate change

- Several hundred million women have restricted access to reproductive health services and wish to limit their families.
- Satisfying unmet demand for contraception would reduce fertility by about 0.5 births per woman (world-wide), equivalent to shifting from the UN medium growth projection to the low growth future.
- Such a shift would lower CO\textsubscript{2} emissions by about 40% by 2100, and bring large health gains.

O’Neill et al. PNAS 2010;107:17521
Health benefits associated with wider birth spacing

Figure 1  Under-five mortality by birth interval (17 DHS surveys).
Temperature projections for four concentration pathways, median (yellow) and uncertainty bound (gray), 2010 – 2300.

Political appeal of co-benefits: no discernible impact of lowered emissions until around 2050

Nature Climate Change 2012;2:248
Cross-benefits?

• Good for health, but not for climate
• Reduce sulfur emissions from fossil fuel combustion
<table>
<thead>
<tr>
<th>Emitted Compound</th>
<th>Resulting Atmospheric Drivers and Responses</th>
<th>Emission-based Radiative Forcing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Well-Mixed Greenhouse Gases</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂</td>
<td>CO₂</td>
<td></td>
</tr>
<tr>
<td>CH₄</td>
<td>CO₂, H₂O&lt;sup&gt;str&lt;/sup&gt;, O₃, CH₄</td>
<td></td>
</tr>
<tr>
<td>Halo-carbons</td>
<td>O₃, CFCs, HCFCs</td>
<td></td>
</tr>
<tr>
<td>N₂O</td>
<td>N₂O</td>
<td></td>
</tr>
<tr>
<td><strong>Short Lived Gases</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>CO₂, CH₄, O₃</td>
<td></td>
</tr>
<tr>
<td>NMVOC</td>
<td>CO₂, CH₄, O₃</td>
<td></td>
</tr>
<tr>
<td>NO&lt;sub&gt;x&lt;/sub&gt;</td>
<td>Nitrate, CH₄, O₃</td>
<td></td>
</tr>
<tr>
<td><strong>Aerosols</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral Dust, Sulphate, Nitrate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic Carbon, Black Carbon</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Cloud Adjustments due to Aerosols*
Cross-benefits?

• Good for health, but not for climate
• Reduce sulfur emissions from fossil fuel combustion
• Some development uses of energy such as
• Household fuels for clean cooking
  – Making the available clean – very difficult
  – Making the clean available – needs to be pursued as well
Indian Energy Ladder

Very Low Income 200 million
Low Income 400 million
Middle Income 400 million
High Income 200 million

Decreasing Household Air Pollution

How do we help people move into this realm?

Non-solid fuels

Solid Fuels

Wood

Crop Waste Dung

Solid Fuels

Liquefied Petroleum Gas
Biogas

Smith/Pillarisetti, 2014
Indian Energy Ladder

- Wood
- Solid Fuels
- Non-solid fuels
- Biogas
- Liquefied Petrol. Gas
- Natural Gas
- Electricity

Income Levels:
- Very Low Income: 200 million
- Low Income: 400 million
- Middle Income: 400 million
- High Income: 200 million

Decreasing Household Air Pollution

- Crop Waste
- Dung

Increasing Prosperity and Development
The three eras: bottom lines

- The present: very difficult to assign a significant burden of disease to human-caused climate change to date
- Up to 2050: Growing health impacts can be expected if adaptation measures are not taken, but could be greatly reduced if they are
- After 2050: risk in the higher emissions scenarios of exceeding conceivable adaptation potentials and thus leading to major impacts on health, particularly among the poor.
- Unfortunately, however, to wait until 2050 to take mitigation action will not be enough – need to work now – we must always act some 50 years ahead.
Caveats

• Climate models do not handle the extreme scenarios well – few try and they do not agree
• Currently, these high temperature scenarios are low probability (although not that low)
• But definitely high consequence and we are doing little to reduce their probability
• But at least they are far off in the future – 2100+
• Or are they?
2100 – is it even the future?

Yui Honda, Granddaughter of Yasushi Honda, IPCC Author

Born Oct 26, 2012
Japanese girl babies have the longest life expectancy on Earth

87.4 years

They are among the very first members of Earth’s 22C Club

Twenty-second Century Club
When girl babies will live to see 2100

Before 2022 baby Chinese girls will live to see 2100

Well before 2030, baby Indian girls too
CLIMATE SUMMIT

What if it's a big hoax and we create a better world for nothing?

- Energy independence
- Preserve rainforests
- Sustainability
- Green jobs
- Livable cities
- Renewables
- Clean water, air
- Healthy children
- Etc. etc.
Thank you

IPCC website has a tremendous amount of useful material including summaries, full reports, ppt figures, press releases, review comments/responses, databases of literature cited, full copies of gray literature reports, etc.

JUST GOOGLE: IPCC