CAN GLOBAL TEMPERATURE RISE BE LIMITED TO 2 DEGREES?

WHAT DO WE NEED TO KNOW AND HOW WELL DO WE NEED TO KNOW IT?

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Santa Fe, NM, February 5-10, 2017

www.ecd.bnl.gov/steve
GEDANKEN EXPERIMENT

• Turn off all fossil fuel combustion.
• Turn off emissions of carbon dioxide.
• Turn off emissions of aerosols and aerosol precursors.
• What happens?

Stop Cold Turkey!

GREAT WARMING EFFECT
Despite extensive research, climate sensitivity remains *highly uncertain*. 
Greenhouse gas forcing dominates positive forcing.
Aerosol forcing dominates negative forcing.
Uncertainty in aerosol forcing dominates total uncertainty in forcing.
Uncertainty is an uncomfortable position...

But certainty is an absurd one.

– Voltaire
ECS vs $F - N$ is straight line on log-log plot; slope = $-1$. 
$\Delta T_s$ over 20th century, 0.78 K; net TOA flux $N$, 0.51 W m$^{-2}$. Dashed lines account for uncertainties in $\Delta T_s$ and $N$. Models are consistent with observations despite widely differing $F$ and ECS.
TWO COMPARTMENT ENERGY BALANCE MODEL

Two Resistor–Capacitor circuit as analog to climate system

Flow of heat into large, deep compartment (current into large capacitor) acts in parallel to emitted longwave radiation (current through primary resistor) to decrease temperature (voltage) of upper compartment, until deep compartment (large capacitor) fills up.

Same model used to interpret GCM results by Gregory 02; Held et al., 10.
### Key Properties of the Climate System

**“Rule of Fives”**

<table>
<thead>
<tr>
<th>Component of Climate System</th>
<th>Time Constant, yr</th>
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<tbody>
<tr>
<td>Deep Ocean</td>
<td>500</td>
</tr>
<tr>
<td>Upper Ocean and Troposphere</td>
<td>5</td>
</tr>
<tr>
<td>Atmospheric Carbon Dioxide</td>
<td>50</td>
</tr>
<tr>
<td>Tropospheric Aerosols</td>
<td>1 week = 1/50</td>
</tr>
<tr>
<td>Atmospheric Fraction of Emitted CO$_2$</td>
<td>0.5</td>
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</table>
EMPIRICAL DETERMINATION OF CO$_2$ PARAMETERS

Data: Le Quéré et al., 2016; NOAA
If aerosol forcing magnitude is low, climate sensitivity is low, and vice versa.

Cessation of negative aerosol forcing results in positive step-function increase in forcing.
Committed future increase in global temperature depends strongly on climate sensitivity or, equivalently, current aerosol forcing.

If climate sensitivity is high, as required for aerosol forcing at the large end of the IPCC range, then 2 K target maximum would be exceeded even for immediate cessation of fossil fuel combustion.
MAXIMUM COMMITTED WARMING AND ALLOWABLE CO₂ EMISSIONS

Dependence on climate sensitivity or aerosol forcing

Strong dependence on climate sensitivity or, equivalently, current aerosol forcing. Might need to go “cold turkey” within 20 years, or possibly too late to avoid 2 K.
PROPOSITION FOR DISCUSSION
Climate Sensitivity is (remains) the single greatest source of uncertainty in determining allowable future greenhouse gas emissions consonant with not exceeding a given target increase in GMST.

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**Equilibrium climate sensitivity, K**

- Maximum global mean temperature increase following abrupt cessation of fossil fuel combustion

**Aerosol forcing, W m⁻²**

- **IPCC AR5 Aerosol forcing range**
- **2 K Target**

**Maximum incremental CO₂ forcing and emissions not to exceed 2 K above preindustrial**

**Divide by 10 Pg yr⁻¹ to get years**