3. Describe the marketing ideas behind the term ‘sound science’. How has this term and approach been used to stall policy action?
Solutions Proposal

• ~250 word (half page) paragraph proposal supported by scientific evidence. i.e. Provide a strong argument that your solution addresses a global change problem.

• Statements in your proposal based on the literature should be cited.

• Literature review of 4 peer reviewed papers related to the global change topic.
Climate Change I: Lines of Evidence
Everything you ever wanted to know about climate change science

www.realclimate.org
Anthropogenic Greenhouse Gas Emissions

- **CO₂ (fossil fuel use)**: 56.6%
- **CO₂ (deforestation, decay of biomass, etc)**: 17.3%
- **CH₄**: 14.3%
- **N₂O**: 7.9%
- **F-gases**: 1.1%
- **CO₂ (other)**: 2.8%
Global totals, anthropogenic emissions, for year 2000
USA – CO₂ emissions from fossil fuel combustion (2005)

Relative Contribution by Fuel Type

<table>
<thead>
<tr>
<th>Category</th>
<th>Natural Gas</th>
<th>Petroleum</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity Generation</td>
<td>Natural Gas</td>
<td>Petroleum</td>
<td>Coal</td>
</tr>
</tbody>
</table>

US EPA
Atmospheric CO₂ at Mauna Loa Observatory

1974-2007 NOAA/ESRL

CONCENTRATION (parts per million)

YEAR


CONCENTRATION (parts per million)

YEAR
Line of evidence #1: Physics

“if the quantity of carbonic acid increases in geometric progression, the augmentation of the temperature will increase nearly in arithmetic progression”

- Svante Arrhenius, 1896
Line of evidence #1: Physics

The Greenhouse Effect

- Sun
- Solar radiation
- Reflected heat
- Radiated heat
- Re-radiated heat
- Increasing greenhouse gases absorb & re-radiate heat
- Carbon dioxide & other gases
- Earth
Line of evidence #1: Physics

Line of evidence #1: Physics
Line of evidence #2: Paleoclimate

Atmospheric CO₂ at Mauna Loa Observatory

1974-2007 NOAA/ESRL
Where do these data come from?
Paleoclimate to 5 million years

Five Million Years of Climate Change From Sediment Cores

Equivalent \( \Delta T \) (°C)

\( \delta^{18}O \) Benthic Carbonate (per mil)

Millions of Years Ago

41 kyr cycle
100 kyr cycle
Paleoclimate to 65 million years

65 Million Years of Climate Change
Paleoclimate to 65 million years

Paleocene-Eocene Thermal Maximum

- Global temperature rise of 6°C over 20,000 years
- Mass extinction of benthic forams (*protozoa – single celled organisms*) and terrestrial mammals
- Carbonate dissolved in oceans (ocean acidification)
Line of evidence #3: Observations

Atmospheric CO\textsubscript{2} at Mauna Loa Observatory

1974-2007 NOAA/ESRL

CONCENTRATION (parts per million)

YEAR

Photosynthesis selects for lighter $^{12}$C isotope, so decreasing $^{13}$C in atmospheric CO$_2$ is caused by burning of photosynthetic material (i.e. plants and fossil fuels)
Line of evidence #3: Observations

Global average observed warming is 0.85 °C (1.5 °F) since 1880.
Temperature rise continues

2014: Record high global temperature

No need to consult your local weather, I made a detailed map for you:
Line of evidence #3: Observations

Observations of global rise in sea level

Blue/green/yellow: tide gauges

red: satellite (since 1993)
Line of evidence #3: Observations
Line of evidence #3: Observations

(b) Arctic summer sea ice extent

Red/orange: Satellite records
Line of Evidence #4: Models
Logic connecting emissions to projected climate changes

The most uncertainty in climate projections comes from how much we will continue to emit.
# Modeling groups in IPCC AR4

<table>
<thead>
<tr>
<th>Originating Group(s)</th>
<th>Country</th>
<th>CMIP3 I.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing Climate Center</td>
<td>China</td>
<td>BCC-CM1</td>
</tr>
<tr>
<td>Bjerknes Centre for Climate Research</td>
<td>Norway</td>
<td>BCCR-BCM2.0</td>
</tr>
<tr>
<td>National Center for Atmospheric Research</td>
<td>USA</td>
<td>CCSM3</td>
</tr>
<tr>
<td>Canadian Centre for Climate Modelling &amp; Analysis</td>
<td>Canada</td>
<td>CGCM3.1(T47)</td>
</tr>
<tr>
<td>Canadian Centre for Climate Modelling &amp; Analysis</td>
<td>Canada</td>
<td>CGCM3.1(T63)</td>
</tr>
<tr>
<td>Météo-France / Centre National de Recherches Météorologiques</td>
<td>France</td>
<td>CNRM-CM3</td>
</tr>
<tr>
<td>CSIRO Atmospheric Research</td>
<td>Australia</td>
<td>CSIRO-Mk3.0</td>
</tr>
<tr>
<td>CSIRO Atmospheric Research</td>
<td>Australia</td>
<td>CSIRO-Mk3.5</td>
</tr>
<tr>
<td>Max Planck Institute for Meteorology</td>
<td>Germany</td>
<td>ECHAM5/MPI-OM</td>
</tr>
<tr>
<td>Meteorological Institute of the University of Bonn, Meteorological Research Institute of KMA, and Model and Data group.</td>
<td>Germany / Korea</td>
<td>ECHO-G</td>
</tr>
<tr>
<td>LASG / Institute of Atmospheric Physics</td>
<td>China</td>
<td>FGOALS-g1.0</td>
</tr>
<tr>
<td>US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory</td>
<td>USA</td>
<td>GFDL-CM2.0</td>
</tr>
<tr>
<td>US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory</td>
<td>USA</td>
<td>GFDL-CM2.1</td>
</tr>
<tr>
<td>NASA / Goddard Institute for Space Studies</td>
<td>USA</td>
<td>GISS-A0M</td>
</tr>
<tr>
<td>NASA / Goddard Institute for Space Studies</td>
<td>USA</td>
<td>GISS-EH</td>
</tr>
<tr>
<td>NASA / Goddard Institute for Space Studies</td>
<td>USA</td>
<td>GISS-ER</td>
</tr>
<tr>
<td>Instituto Nazionale di Geofisica e Vulcanologia</td>
<td>Italy</td>
<td>INGV-SXG</td>
</tr>
<tr>
<td>Institute for Numerical Mathematics</td>
<td>Russia</td>
<td>INM-CM3.0</td>
</tr>
<tr>
<td>Institut Pierre Simon Laplace</td>
<td>France</td>
<td>IPSL-CM4</td>
</tr>
<tr>
<td>Center for Climate System Research (The University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC)</td>
<td>Japan</td>
<td>MIROC3.2(hires)</td>
</tr>
<tr>
<td>Center for Climate System Research (The University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC)</td>
<td>Japan</td>
<td>MIROC3.2(medres)</td>
</tr>
<tr>
<td>Meteorological Research Institute</td>
<td>Japan</td>
<td>MRI-CGCM2.3.2</td>
</tr>
<tr>
<td>National Center for Atmospheric Research</td>
<td>USA</td>
<td>PCM</td>
</tr>
<tr>
<td>Hadley Centre for Climate Prediction and Research / Met Office</td>
<td>UK</td>
<td>UKMO-HadCM3</td>
</tr>
<tr>
<td>Hadley Centre for Climate Prediction and Research / Met Office</td>
<td>UK</td>
<td>UKMO-HadGEM1</td>
</tr>
</tbody>
</table>
Summary of lines of evidence

1. Increasing atmospheric CO$_2$, N$_2$O and CH$_4$ cause surface warming by absorbing and re-radiating heat from the earth’s surface

2. Current magnitudes and rates of greenhouse gas accumulation are unprecedented in paleo-climate history

3. We have observed increasing temperatures and temperature-associated processes (sea ice melt, glacier melt, sea level rise)

4. Models cannot account for temperature trends unless they include human influence
Small Groups Discussion

• Go through remaining questions from Smoke, Mirrors & Hot Air