Bringing Peace to the Climate Wars

Peter L. Ward
U.S. Geological Survey retired
Science Is Never Settled
peward@Wyoming.com
Jackson, Wyoming

WhyClimateChanges.com
Arizona Geological Society January 2, 2018
Scientific discovery does not start with someone running down the hall shouting "Eureka!"

Isaac Asimov
Scientific discovery does not start with someone running down the hall shouting "Eureka!" Rather, advances go more like someone saying to himself, "Hmm, that's odd."

Isaac Asimov
Scientific discovery does not start with someone running down the hall shouting "Eureka!"
Rather, advances go more like someone saying to himself, "Hmm, that’s odd."

1. Volcanoes rule!

Isaac Asimov
Scientific discovery does not start with someone running down the hall shouting "Eureka!" Rather, advances go more like someone saying to himself, "Hmm, that's odd."

1. Volcanoes rule!

2. Where's the heat?

Isaac Asimov
Scientific discovery does not start with someone running down the hall shouting "Eureka!" Rather, advances go more like someone saying to himself, "Hmm, that’s odd.”

1. Volcanoes rule!  
2. Where’s the heat?  
3. Heat flows by resonance.

Isaac Asimov
Scientific discovery does not start with someone running down the hall shouting "Eureka!" Rather, advances go more like someone saying to himself, "Hmm, that’s odd."

1. Volcanoes rule!
2. Where’s the heat?
3. Heat flows by resonance.

These three conclusions redefine the climate wars in important ways, providing an opportunity, with a little humility on all sides, for all of us to work together for the benefit of humanity.
What causes the sudden changes in fossils and sediments?
What causes the sudden changes in fossils and sediments?
The enigma: Volcanism ended the last ice age
The enigma: Volcanism ended the last ice age

"Hmm, that’s odd.”
Basaltic volcanism ended the last ice age

- Bølling warming
  - 12,000 to 9500 years before present

White Et al. 1997
Zielinski et al. 1996
Basaltic volcanism ended the last ice age

Zielinski et al., 1996

White et al., 1997

Bølling warming

Cosmogenic $^3$He exposure ages

Licciardi et al., 2007

Last glacial maximum

12,000 to 9500
Basaltic volcanism ended the last ice age

12 of 13 best dated tuyas were active during this time
Bárðarbunga 2014
Aerially extensive flood-basaltic eruptions
Occur in rift zones

Aerially extensive flood-basaltic eruptions

Bárðarbunga 2014
Occur in rift zones

Chlorine and bromine deplete ozone, warming Earth **GLOBALLY** many degrees within years
Occur in rift zones

Chlorine and bromine deplete ozone, warming Earth **GLOBALLY** many degrees within years

Aerially extensive flood-basaltic eruptions

Bárðarbunga 2014
Occur in rift zones

Chlorine and bromine deplete ozone, warming Earth GLOBALLY many degrees within years

Amount of global warming is determined by the duration and aerial extent
Occur in rift zones

Chlorine and bromine deplete ozone, warming Earth GLOBALLY many degrees within years

Amount of global warming is determined by the duration and aerial extent
Occur in rift zones

Chlorine and bromine deplete ozone, warming Earth GLOBALLY many degrees within years

Amount of global warming is determined by the duration and aerial extent
Occur in rift zones

Chlorine and bromine deplete ozone, warming Earth GLOBALLY many degrees within years

Aerially extensive flood-basaltic eruptions

Amount of global warming is determined by the duration and aerial extent

Occur above subduction zones

Form aerosols cooling Earth GLOBALLY ~0.5°C for ~3 years

Aerosol forming explosive eruptions

Bárðarbunga 2014 versus Pinatubo 1991
Occur in rift zones

Chlorine and bromine deplete ozone, warming Earth globally many degrees within years

Aerially extensive flood-basaltic eruptions

Amount of global warming is determined by the duration and aerial extent

Occur above subduction zones

Form aerosols cooling Earth globally ~0.5°C for ~3 years

Aerosol forming explosive eruptions

Krakatoa 1883

Gleckler et al., 2006
Occur in rift zones

Chlorine and bromine deplete ozone, warming Earth **GLOBALLY** many degrees within years

Aerially extensive flood-basaltic eruptions

**versus**

Occur above subduction zones

Form aerosols cooling Earth **GLOBALLY** ~0.5°C for ~3 years

Amount of global warming is determined by the duration and aerial extent
Occur in rift zones

Chlorine and bromine deplete ozone, warming Earth GLOBALLY many degrees within years

Aerially extensive flood-basaltic eruptions

Amount of global warming is determined by the duration and aerial extent

Occur above subduction zones

Form aerosols cooling Earth GLOBALLY ~0.5°C for ~3 years

Aerosol forming explosive eruptions

Amount of global cooling is determined by the number of eruptions per century

Krakatoa 1883

Bárðarbunga 2014

Pinatubo 1991

Gleckler et al., 2006

Gregory et al., 2006
Human-caused global warming
Human-caused global warming

Molina & Rowland 1974

Chlorine from CFCs
Ozone depletion

Annual mean temperature anomaly (°C)


Year

Temperature

Total column ozone (DU) (seven year running mean)

1 0.5 0 0

0 0.5 1

305 315 325 335

0 0.5 1

2.5 3 3.5 4

Chlorine (ppb)

Molina & Rowland 1974
Human-caused global warming

- Molina & Rowland 1974
- Antarctic ozone hole discovered 1985
- Chlorine from CFCs
- Ozone depletion

Graph showing annual mean temperature anomaly (°C) and total column ozone (DU) from 1945 to 2015.
Human-caused global warming

- Molina & Rowland 1974
- Antarctic ozone hole discovered 1985
- Chlorine from CFCs
- Ozone depletion

Graph shows annual mean temperature anomaly (°C) from 1945 to 2015.
Human-caused global warming

- Antarctic ozone hole discovered 1985
- Molina & Rowland 1974
- Chlorine from CFCs
- Ozone depletion
- 1993
Human-caused global warming

- Chlorine from CFCs.
- Ozone depletion.
- Temperature.
Increasing CFCs caused increasing warming from 1970 to 1998. The Montreal protocol stopped the increases, but ozone remained depleted.
The effects of ozone depletion and of aerosols
The effects of ozone depletion and of aerosols
The effects of ozone depletion and of aerosols

**NORMAL CONDITIONS**
- UV-C keeps atmosphere warm
- UV-B keeps ozone layer warm
- UV-A & sunlight keeps Earth warm

**GLOBAL WARMING**
- Volcanoes release Chlorine & Bromine
- Depleting ozone
- Cooling ozone layer & warming Earth

**GLOBAL COOLING**
- Explosive volcanoes also eject Sulfur Dioxide into stratosphere
- Forming aerosols that reflect & disperse sunlight causing net cooling of Earth
The effects of ozone depletion and of aerosols

**NORMAL CONDITIONS**
- **UV-C** keeps atmosphere warm
- **UV-B** keeps ozone layer warm
- **UV-A** & sunlight keeps Earth warm

**GLOBAL WARMING**
- Volcanoes release **Chlorine & Bromine**
- Depleting ozone
- Cooling ozone layer & warming Earth

**GLOBAL COOLING**
- Explosive volcanoes also eject **Sulfur Dioxide** into stratosphere
- Forming aerosols that reflect & disperse sunlight causing net cooling of Earth

**GLOBAL WARMING**
- **CFCs** in polar stratospheric clouds (PSCs) release chlorine
- Depleting ozone
- Cooling ozone layer & warming Earth
Changes in temperature trends
Major cooling when there is major subduction

Veizer et al. 1999

Cogné & Humler 2006

Ward 2009
Major cooling when there is major subduction

Ocean crust production
Onset Antarctic glaciation
Izu-Bonin-Mariana, Aleutians, southern Rocky Mountains, Sierra Madre Occidental
Ocean temperature
Eruptions

Veizer et al. 1999
Cogné & Humler 2006
Ward 2009
Major cooling when there is major subduction

- Ocean temperature
- Ocean crust production
- More glaciers
- Less glaciers
- Cumulative Number of Major Eruptions
- Million Years Before Present
- Himalayan mountain building 23-16 Ma
- Izu-Bonin-Mariana, Aleutians, southern Rocky Mountains, Sierra Madre Occidental
- Onset Antarctic glaciation

Veizer et al. 1999
Cogné & Humler 2006
Ward 2009
Major cooling when there is major subduction

Ocean crust production

Izu-Bonin-Mariana, Aleutians, southern Rocky Mountains, Sierra Madre Occidental

Himalayan mountain building 23-16 Ma

Mid-miocene climate optimum

Onset Antarctic glaciation

Ocean temperature

Veizer et al. 1999

Cogné & Humler 2006

Ward 2009
Major cooling when there is major subduction

Veizer et al. 1999

Cogné & Humler 2006

Ward 2009
Stack of 57 globally distributed deep sea $\delta^{18}$O records

Lisiecki et al. 2005
Erratic sequences of rapid warming followed by slower cooling
Dansgaard-Oeschger events observed in Greenland ice
Erratic sequences of rapid warming followed by slower cooling
Dansgaard-Oeschger events observed in Greenland ice
Erratic sequences of rapid warming followed by slower cooling

Dansgaard-Oeschger events observed in Greenland ice

Footprints
Sudden warming
Slow cooling
Erratic sequences
Holocene temperatures and volcanism

Oxygen isotopes GISP2

Years before 2000

Warmer

Cooler

11000 10000 9000 8000 7000 6000 5000 4000 3000 2000 1000 0

-34

-34.5

-35

-35.5

-36

-36.5

9665 8829 7765 6842

Holmsa Fires, Tungnaahauk, Craters of the Moon

9665 8160

Krafta, Iceland ??

850

Great Bjorsa Lava

5352 5181 4933

Peak glaciation Alaska Finland

3640 3271

Santorini 3627-3600

2050

Mycenean-Shang Warm Period

968

Eldgjia Medieval Warm Period

227

Lowest Little Ice Age

85

Bandubunga

700 800

Craters of Moon, Roman Warm Period

0
Eocene Green River Formation in Wyoming

53 to 48 million years ago

- Oil shale
- Trona
- Dolostone

Surdam, 2013
Eocene Green River Formation in Wyoming

53 to 48 million years ago

Mud Lake
Florida
Oil shale

oil shale
trona
dolostone

Surdam, 2013
Eocene Green River Formation in Wyoming

53 to 48 million years ago

- Lake Magadi, Kenya, Trona
- Mud Lake, Florida, Oil shale

oil shale, trona, dolostone

Surdam, 2013
Paleozoic brachiopod habitat temperatures
Examples of flood basalts and large igneous provinces
Extrusion of basaltic magma reached a peak 56 million years ago during the rifting of the Greenland-Norwegian Sea.
Extrusion of basaltic magma reached a peak 56 million years ago during the rifting of the Greenland-Norwegian Sea.

Paleocene-Eocene Thermal Maximum

Associated with end of time units

Ages of effusive flood basalts

Ages of mass extinctions
Extrusion of basaltic magma reached a peak 56 million years ago during the rifting of the Greenland-Norwegian Sea.

Associated with end of time units:
- Paleocene-Eocene Thermal Maximum
- Ages of effusive flood basalts
- Ages of mass extinctions
- Paleocene-Eocene Thermal Maximum
- Central Atlantic Magmatic Province
- Siberian Traps
- Emeishan
- Frasnian
- Guadalupian
- Permian
- Triassic
- Pliensbachian
- Jurassic
- Valanginian
- Aptian
- Cenomanian
- Turonian
- Paleocene
- Early Oligocene
- Early Miocene

Storey et al. 2007
Courtillot and Renne 2003
Extrusion of basaltic magma reached a peak 56 million years ago during the rifting of the Greenland-Norwegian Sea.

Ages of effusive flood basalts

Ages of mass extinctions

Typically end geologic eras, periods, and epochs

Storey et al. 2007

Courtillot and Renne 2003
Large Igneous Provinces punctuate the geologic time scale

- Siberian basalts
- Deccan basalts
- Madagascar
- Kerguelen
- Jurassic ice age
- Kola-Dnieper
- Hirnation
- Katian?
Large Igneous Provinces punctuate the geologic time scale

<table>
<thead>
<tr>
<th>Geological Society of America Time Scale</th>
<th>Ages of LIPs from Ernst 2014</th>
</tr>
</thead>
</table>

### CENOZOIC
- **Pleistocene**
  - Deccan basalts
- **Miocene**
  - Madagascar
  - Kerguelen
  - Parana
- **Eocene**
  - Columbia
- **Oligocene**
  - Ethiopia
- **Paleocene**
  - Columbia
- **Eocene**
  - Kola-Dnieper
- **Kazanian**
  - Hirnation
- **Kazanian**
  - Katian?
- **Triassic**
  - Kalkarindji
- **Jurassic**
  - CAMP

### MESOZOIC
- **Triassic**
  - Siberian basalts
- **Eocene**
  - Kerguelen
- **Kazanian**
  - Kaledonides
- **Triassic**
  - Kalkarindji
- **Jurassic**
  - Siberian basalts
  - Karoo
- **Kazanian**
  - Hirnation
- **Kazanian**
  - Katian?
- **Triassic**
  - Kalkarindji

### PALEOZOIC
- **Triassic**
  - Siberian basalts
  - Karoo
- **Kazanian**
  - Hirnation
- **Kazanian**
  - Katian?
- **Triassic**
  - Kalkarindji

### PRECAMBRIAN
- **Snowball Earth**
- **Guibei**
- **Umkondo**
- **Mackenzie**

17 largest out of >200 LIPS
Large Igneous Provinces punctuate the geologic time scale

<table>
<thead>
<tr>
<th>PETM</th>
<th>Deccan basalts</th>
<th>Siberian basalts</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAMP</td>
<td>Madagascar</td>
<td>Emeishan basalts</td>
</tr>
<tr>
<td></td>
<td>Kerguelen</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Parana</td>
<td>Karoo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kola-Dnieper</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hirnation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Katian?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kalkarindji</td>
</tr>
</tbody>
</table>

Only 104 ages since 540 Ma

Geological Society of America Time Scale

Ages of LIPs from Ernst 2014

17 largest out of >200 LIPS
Large Igneous Provinces punctuate the geologic time scale

The balance of effusive and explosive volcanism explains climate change in detail

Only 104 ages since 540 Ma

Siberian basalts
Deccan basalts
Emeishan basalts
Parana
Jurassic ice age
Karoo
Kerguelen
Madagascar
Columbia
Ethiopia

Snowball Earth
Guibei
Umkondo
Mackenzie

17 largest out of >200 LIPS
Late Proterozoic  650 Ma

Snowball Earth

Little sub-aerial rifting
Siberian basalts
What IS heat?
Energy absorbed by greenhouse gases

- Water
- Carbon dioxide
- Oxygen
- Ozone
- Methane

Radiation brightness

Frequency in terahertz

Sun 5770K
At the top of Earth’s atmosphere
Visible
Ultra-violet

Infrared

Percent absorption
Energy absorbed by greenhouse gases

- **Radiation brightness**
  - Earth 288K
  - Sun 5770K
  - At the top of Earth’s atmosphere

- **Frequency in terahertz**
  - Infrared
  - Visible
  - Ultraviolet

- **Percent absorption**
  - Water
  - Carbon dioxide
  - Oxygen
  - Ozone
  - Methane
Energy absorbed by greenhouse gases

Radiation brightness

Earth 288K

Sun 5770K
At the top of Earth’s atmosphere

Visible
Ultra-violet

Infrared

Frequency in terahertz

Percent absorption

Water
Carbon dioxide
Oxygen
Ozone

Methane
Energy absorbed by greenhouse gases

- **Radiation brightness**
  - Earth 288K
  - Sun 5770K
  - At the top of Earth's atmosphere

- **Frequency in terahertz**
  - Infrared
  - Visible
  - Ultraviolet

- **Energy of oscillation (eV)**
  - Water: 0.08 eV
  - Carbon dioxide: 0.3 eV
  - Oxygen: 4 eV
  - Ozone: 4 eV
  - Methane: 4 eV

- **Percent absorption**

- **E = hν**

- 48 times more energy
Energy absorbed by greenhouse gases

- Energy of ultraviolet radiation reaching Earth when ozone is depleted is at least 48 times “hotter” than energy absorbed by greenhouse gases.

\[ E = h \nu \]

- Percent absorption
  - Water
  - Carbon dioxide
  - Oxygen
  - Ozone
  - Methane

- Energy of oscillation (eV)
  - Methane: 4 eV
  - Oxygen: 0.3 eV
  - Carbon dioxide: 0.08 eV

- Frequency in terahertz

- Radiation brightness

- Energy absorbed by greenhouse gases

- Sun 5770K At the top of Earth’s atmosphere

Infrared

Visible

Ultra-violet

Visible

Energy of oscillation (eV)
Energy absorbed by greenhouse gases

Energy of oscillation (eV)

- Water: 0.08 eV
- Carbon dioxide: 0.3 eV
- Oxygen: 0.3 eV
- Ozone: 0.3 eV
- Methane: 4 eV

48 times more energy

Energy of ultraviolet radiation reaching Earth when ozone is depleted is at least 48 times “hotter” than energy absorbed by greenhouse gases

"Hmm, that’s odd."
But we cannot see radiation. We see its effects.
But we cannot see radiation. We see its effects.

We cannot see frequency. We see the effects of frequency.
But we cannot see radiation. We see its effects.

We cannot see frequency. We see the effects of frequency.

Frequency of oscillation of all the bonds holding matter together.
But we cannot see radiation. We see its effects.

We cannot see frequency. We see the effects of frequency.

Frequency of oscillation of all the bonds holding matter together
Planck’s empirical law (1900) describing observed radiation

\[ B_\nu(T) = h\nu \left(\frac{2\nu^2}{c^2}\right) \frac{1}{e^{\frac{h\nu}{k_b T}} - 1} \]
Planck’s empirical law (1900) describing observed radiation

Heat is a broad spectrum of frequencies

\[ B_\nu(T) = h\nu \left( \frac{2\nu^2}{c^2} \right) \left( \frac{1}{e^{h\nu/k_BT}} - 1 \right) \]
Electromagnetic radiation is a broad continuum of frequencies.

Planck's law (1900)
Planck’s law (1900)

Electromagnetic radiation is a broad continuum of frequencies.
Planck's law (1900)

Electromagnetic radiation is a broad continuum of frequencies

A light bulb emits a broad range of frequencies (heat) just to produce a narrow range of visible light

Less than 16% Frequencies absorbed by carbon dioxide
Electromagnetic radiation is a broad continuum of frequencies

Planck’s law (1900)

A light bulb emits a broad range of frequencies (heat) just to produce a narrow range of visible light.

LEDs emit a narrow range of visible frequencies without emitting heat.
Electromagnetic radiation is a broad continuum of frequencies

Planck’s law (1900)

Greenhouse gases simply do not absorb a broad enough range of frequencies, that we perceive as heat, to be a significant cause of global warming.

Greenhouse-warming theory appears to be mistaken.
How does heat travel through matter and through air and space?
Waves

Aristotle 340 BC
Descartes 1630

Democritus 410 BC
Alhazen 1000

Huygens 1678
Hooke 1680
Fresnel 1814

Newton 1670

Young 1803
Faraday 1830
Maxwell 1865

Planck 1900

Wave particle duality

Einstein 1905
Bohr 1912

Compton 1922
de Broglie 1924

Particles

Einstein 1905
Heat IS
Heat IS waves
Heat IS waves
particles
Heat IS waves
Heat IS particles
Heat IS frequencies
Heat IS a broad spectrum of frequencies
The Planck-Einstein Relation

\[ E = h \nu \]
The Planck-Einstein Relation

$$E = h \nu$$
The Planck-Einstein Relation

\[ E = h \nu \]

"Hmm, that's odd."
Each frequency causing resonance is how we perceive the world
Each frequency causing resonance is how we perceive the world.
Each frequency causing resonance is how we perceive the world.
Each frequency causing resonance is how we perceive the world.
Each frequency causing resonance is how we perceive the world.

Sympathetic oscillations

Cochlea

KUAZ 89.1 MHz

white light coming in

green light

green surface
Each frequency causing resonance is how we perceive the world.
Each frequency causing resonance is how we perceive the world.
Volcanoes Rule
WhyClimateChanges.com

Where is the heat?
WhyClimateChanges.com
Heat flows by resonance

WhyClimateChanges.com
WHAT REALLY CAUSES GLOBAL WARMING?
Greenhouse Gases or Ozone Depletion?

PETER LANGDON WARD, PHD
Implications

We can burn fossil fuels without overheating Earth
Implications

We can burn fossil fuels without overheating Earth
But we must minimize air pollution
Implications

We can burn fossil fuels without overheating Earth
But we must minimize air pollution
We need to help the ozone layer recover
We can burn fossil fuels without overheating Earth
But we must minimize air pollution
We need to help the ozone layer recover
We need to help people understand:
Implications

We can burn fossil fuels without overheating Earth
But we must minimize air pollution
We need to help the ozone layer recover
We need to help people understand:
  1. That greenhouse-warming theory is a scientific mistake,
We can burn fossil fuels without overheating Earth
But we must minimize air pollution
We need to help the ozone layer recover
We need to help people understand:
  1. That greenhouse-warming theory is a scientific mistake,
  2. That science is self-correcting,
Implications

We can burn fossil fuels without overheating Earth
But we must minimize air pollution
We need to help the ozone layer recover
We need to help people understand:
  1. That greenhouse-warming theory is a scientific mistake,
  2. That science is self-correcting,
  3. That science is never settled,
Implications

We can burn fossil fuels without overheating Earth
But we must minimize air pollution
We need to help the ozone layer recover
We need to help people understand:
  1. That greenhouse-warming theory is a scientific mistake,
  2. That science is self-correcting,
  3. That science is never settled,
  4. That science is still the most logical and valuable way to inform good public policy in our increasingly technological world.
Implications

We can burn fossil fuels without overheating Earth
But we must minimize air pollution
We need to help the ozone layer recover
We need to help people understand:
1. That greenhouse-warming theory is a scientific mistake,
2. That science is self-correcting,
3. That science is never settled,
4. That science is still the most logical and valuable way to inform good public policy in our increasingly technological world.