Change is in the Air: Global Climate Change from a New York Perspective

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Photo Credit: Barbara Sacks, Elmsford, NY
Global Average Temperature

A World of Agreement: Temperatures are Rising

Global Temperature Anomaly (°C)

1.0 –

0.5 –

0.0 –

-0.5 –

-1.0 –


NASA Goddard Institute for Space Studies
Berkeley Earth
Japanese Meteorological Agency
NOAA National Climatic Data Center
Met Office Hadley Centre/Climatic Research Unit
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Climate vs. Weather

WEATHER

CLIMATE
In the beautiful Midwest, windchill temperatures are reaching minus 60 degrees, the coldest ever recorded. In coming days, expected to get even colder. People can’t last outside even for minutes. What the hell is going on with Global Warming? Please come back fast, we need you!

lustnoah @lustnoah · Jan 30
You do understand the earth has naturally heated and cooled its climate for thousands of years
Then

Rainbow Formed

Winter sports enthusiasts found the cold weather to their liking, as the ice made skating and hockey in evidence. and put the toboggan slide in excellent shape. Hardy souls ventured out upon Cayuga's surface, for the continued cold has frozen the lake for a long distance from shore. Vapor rising from the ice indicated a certain buoyancy; beneath本文的图片是另一个表格的内容。其中包含了一些数据，显示了温差和平均温度。表格如下：

<table>
<thead>
<tr>
<th>Date</th>
<th>Max Temperature</th>
<th>Min Temperature</th>
<th>Avg Temperature</th>
</tr>
</thead>
<tbody>
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<td>-14</td>
<td>-2.5</td>
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<td>37</td>
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<td>49</td>
<td>36</td>
<td>42.5</td>
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<td>2019-02-05</td>
<td>61</td>
<td>42</td>
<td>51.5</td>
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<tr>
<td>2019-02-06</td>
<td>52</td>
<td>27</td>
<td>39.5</td>
</tr>
</tbody>
</table>

Now

**Cornell to Stay Open Amid Wind Chill in Minus 20s, Drawing Icy Response from Students**

By Nicholas Bogel-Burroughs

Ithacans will be lucky if thermometers crack zero by 10 a.m. on Thursday. The wind chill will make it feel 20 to 30 degrees colder than that. Exposed skin could become frostbitten in just 10 minutes.

Cornell plans to remain open on Thursday, administrators said, shrugging off a last-minute email blast from dozens of students, a petition signed by thousands more encouraging the University to cancel classes and a wind chill warning from the National Weather Service.

Rick Burgess, the vice president of infrastructure, properties and planning, said in an interview Wednesday night that he and other administrators expected to keep Cornell open.
The Laws

Law 1: Anything with a temperature above 0 K (absolute zero) emits heat (electromagnetic radiation)

\[ I = \sigma T^4 \]

Law 2: To maintain a stable temperature heat received must equal heat emitted.
The Real Picture

1. Incoming Sunlight

2. Earth absorbs Sunlight and Radiates it as "heat"

3. GHG redirect some "heat" back to Earth

4. Remaining "heat" lost to space
The Greenhouse Gases are VERY Selective

- Sunlight has wavelengths < 4.0 μm shortwave radiation
- Earth radiates at wavelengths >4.0 μm longwave radiation
- Atmosphere gases such as H₂O, CO₂, CH₄, N₂O, O₃, CFCs absorb ONLY longwave radiation
For a Stable Climate

NEED TO HAVE BALANCE
Energy Balance

\[ \text{IN (Deposits)} = \text{OUT (Withdraws)} \]

Incoming solar radiation = Reflected solar radiation

Outgoing radiation
Human Factors Affecting the Climate System

- Increases in greenhouse gases
  - For instance Carbon Dioxide and Methane
- Changes in aerosol concentrations
- Deforestation
- Other land use changes
  - Urbanization
What causes these increases

CO₂ emissions per year in billions of metric tons of carbon.

- Total
- Fossil Fuel
- Deforestation
- Cement

zFacts.com

1750 1800 1850 1900 1950 2000 2050
GHG Changes

Carbon Dioxide (CO₂)
Methane (CH₄)
Nitrous Oxide (N₂O)
Feedback Mechanisms

• Climate system response to imbalances in radiative forcings can bring about feedbacks.

• Feedbacks can be positive, enhancing any initial warming (or cooling), or negative, damping out any initial climatic change.

• Unfortunately, many of the feedbacks which have been identified are positive.
Ice-albedo feedback

- Warming leads to the melting of ice and snow.
- Ice has a much higher albedo.
- Less snow cover means more solar energy is absorbed.
- More warming, and hence more ice melting, etc.
The ice albedo feedback leads to more warming in the polar regions compared to the rest of the globe.
Feedback Examples

Carbon Dioxide Increases
Atmosphere and Ocean warms

Ability to dissolve CO$_2$ decreases

More CO$_2$ will stay in the atmosphere

More warming
Oceans Acidify with more CO$_2$
Feedback Examples

Atmosphere and Ocean warms

More atmospheric water vapor = GHG
More high thin clouds
More trapped long wave radiation

Warming!

Also MORE rain!
Frequency of Heavy Rain

Almost Doubled in last 50 year in Northeast
Annual Temperature Northeast U.S.
New York Winter Temperature

Average Winter Temperature (°F)

5-year Period

Very Cold Nights (NY)
New York Summer Temperature

![Bar chart showing average summer temperatures for different 5-year periods from 1895-99 to 2005-09. The x-axis represents the 5-year periods, and the y-axis represents average summer temperature in degrees Fahrenheit. The chart shows a general increase in temperature over time.](image-url)
Very Hot Days (NY)

Observed Number of Very Hot Days

Number of Days with Maximum Temperature Above 95°F

5-year Period

New York
Very Hot Nights (NY)

Number of Days with Minimum Temperature Above 70°F

New York

5-year Period

Annual Precipitation Northeast U.S.
So What Does the FUTURE Hold?
What About the Future

You Are Here
Natural vs. Human

- Observations
- Natural and Human Factors
- Natural Factors Only
So What Exactly is a Climate Model?
Total distance: 384.7 mi
Total Time: 6 hrs 18 min

Via I-390 S
7 hrs 14 mins / 390.83 miles

38.7 miles | 7 hrs 12 min

Driving directions to Washington, DC
Distance: 382.46 miles — Time: 6:48 h

US-15 S
385 mi, 6 hours 52 mins
Fundamental Physical Equations

**Drive Time Model**

\[ \text{time} = \frac{\text{distance}}{\text{speed}} \]

**Climate Model**

Conservation of momentum:
\[ \frac{\partial \mathbf{V}}{\partial t} = - (\mathbf{V} \cdot \nabla) \mathbf{V} - \frac{1}{\rho} \nabla p - \mathbf{g} - 2\Omega \times \mathbf{V} + \nabla \cdot (k_s \nabla \mathbf{V}) - \mathbf{F}_d \]

Conservation of energy:
\[ \rho c_s \frac{\partial T}{\partial t} = -\rho c_s (\mathbf{V} \cdot \nabla) T - \nabla \cdot \tilde{K} + \nabla \cdot (k_s \nabla T) + C + S \]

Conservation of mass:
\[ \frac{\partial \rho}{\partial t} = - (\mathbf{V} \cdot \nabla) \rho - \rho (\nabla \cdot \mathbf{V}) \]

Conservation of H$_2$O (vapor, liquid, solid):
\[ \frac{\partial q}{\partial t} = - (\mathbf{V} \cdot \nabla) q + \nabla \cdot (k_s \nabla q) + S_q + E \]

Equation of state:
\[ p = \rho R_a T \]
Parameterizations

**Drive Time Model**

\[
\bar{V} = 55 \text{ mph}
\]

\[
\bar{V} = 65 \text{ mph}
\]

\[
\bar{V} = 75 \text{ mph}
\]

**Climate Model**

\[C = 0 \text{ if RH < 90%} \]

\[C = 5 \times (\text{RH}-90\%) \text{ if } 90\% < \text{RH} < 110\% \]

\[C = 100 \text{ if RH > 110} \]
Man vs Dog

Drive Time Model

Climate Model
What About the Future

(a)

RCP 2.6
Change in average surface temperature (1986–2005 to 2081–2100)

RCP 8.5

(°C)
What About the Future

(b) Change in average precipitation (1986–2005 to 2081–2100)
Future Temperatures in Aurora NY

[Graph showing temperature trends from 1950 to 2090]
Future Temperatures in NY

Central New York
Future Precipitation in NY

Percent Change

-12 -9 -6 -3 0 3 6 9 12
Last Spring - First Fall 32° F

2040-2069

2070-2099

2040-2069

2070-2099

Temperature Range: 6 to 30
2040-2069 High Emission

Spring Precip

Summer Precip

Fall Precip

Winter Precip

[Maps showing precipitation patterns for different seasons and regions]
Summer Potential Evap High Emission

2040-2069

2070-2099

NRCC
Adaptation

- Change in land use, relocation
- Emergency & business continuity planning
- Upgrades or hardening of building and infrastructure
- Residential programs promoting adaptation

Health programs

Mitigation

- Energy conservation and efficiency
- Renewable energy
- Sustainable transportation, improved fuel efficiency
- Capture and use of landfill and digester gas

- Seal Buildings
- Green Infrastructure
- Water and Energy Conservation
- Smart Growth

Carbon sinks

- 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.
Any Questions??