Hiatus in Global Warming
Paradox and Complexity in Climate Change Science

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The Triplet Paradox

Paradox #1: Why is global temperature constant when CO2 concentration is increasing?
Paradox #2: Why are extreme events increasing when global temperature is constant?
Paradox #3: Why is Arctic warming so rapidly when global temperature is constant?
A Longer Perspective

The present hiatus is an extended period of near record high global temperature
There was an earlier hiatus

“It is certain that Global Mean Surface Temperature has increased since the late 19th century. Each of the past three decades has been significantly warmer than all the previous decades in the instrumental record, and the first decade of the 21st century has been the warmest”. IPCC AR5, Chapter 2, 2013
In 1700, CO2 concentration was 277 ppm; on March 17, 2014, it was 401.34 ppm; industrial civilization has added 124 ppm, of which about 35 ppm, or 28%, was after 1998.

IPCC AR5: CO2 average warming rate, 0.3 W/m² per decade; Implies increase of 0.48 W/m² between 1998 and 2014.
Net warming from all greenhouse gases increased steadily

Climate Cooling: Pinatubo Effect Hiatus

In 1992, Mt. Pinatubo lifted Sulfur Dioxide high into the stratosphere, where it produced aerosol particles that, acting like little mirrors, reflected sunlight back into space. A 2-year hiatus in warming followed.

There were no large volcanic explosions during the hiatus, but the many smaller ones that did occur populated a variable cooling layer in the stratosphere of about 0.1 W/m².

1945-1975 Hiatus Was Caused by Air Pollution

SO2 cooling from N. America and Europe nearly cancelled CO2 warming
To what extent is SO2 cooling from East Asian air pollution contributing to today’s hiatus?

Despite quadrupling of Chinese coal consumption, SO2 controls are working
Less SO2 cooling for the same CO2 emissions

Sunspot Cycle

Decline of Total Solar Irradiance During Long Solar Minimum?
Variation over sunspot cycle typically about 0.1% Peak-to-Trough; 2000-2008 decline about 0.18 W/m²
During 2005-2011, the Earth absorbed 0.56 W/m² more than it let off; where did energy go?

Figure; Courtesy of NASA Goddard Institute of Space Studies
See also: Kopp, G., and J. Lean, Geophysical Research Letters, A new lower value of solar irradiance: Evidence and climate significance
In the *La Nina* phase (above), the trade winds in the tropical Pacific blow westwards, causing warmed surface water to pile up in the Western Pacific off the coast of Asia. The warm water plunges to depth there. At a certain point, the trade winds relax, at which point gravity causes a rush of warm water back across the Pacific until it encounters the west coasts of North and South America. Both the sea surface temperature and the sea surface itself rise across almost the entire tropical Pacific. Since the warm water often arrives at the Americas around Christmas-time, and changes the fish catch, Peruvian fishermen give it the name *El Nino*, for the Christ child. Image: US National Weather Service Jetstream
What happens at the Equator does not stay at the Equator
Progressive Strengthening of Trade Winds During Hiatus

Twice as strong in 2012 as previous record

Progressive Subduction of Warmed Water
Only after the year 2000 was it possible to measure the temperature below the surface comprehensively.
Ocean Heat Content

Volcanoes (yellow) cooled surface layers
Heat plunged to depth following 1998 El Nino, (green)
Effective energy sequestration rate: 0.84 W/m²

Ocean Heat Content (OHC) integrated from 0 to 300 m (grey), 700 m (blue), and total depth (violet)
From the ECMWF ocean reanalysis system, ORAS4, as represented by its ensemble members..

Balmaseda, Trenberth, and Källén, Distinctive Climate Signals in reanalysis of ocean heat content,
El Nino/La Nina and Pacific Decadal Oscillation

The PDO is a 25-30 Year North Pacific Basin-Wide Cycle

Cool phase: *La Nina* bias; warm phase: *El Nino* bias

Monthly Sea Surface Temperature Anomalies in Tropical Central Pacific
United Kingdom Meteorological Office
SST History explains global temperature history

A new phenomenological model prescribes the observed history of sea surface temperature over the central to eastern tropical Pacific in addition to radiative forcing. Even though the sea surface temperature prescription was limited to 8.2% of the global surface, the model reproduced the annual-mean global temperature remarkably well for the period 1970–2012.


Model calculation treats the *El Nino/La Nina* cycle as an externality, unaffected by the advent of anthropogenic global warming.

It allows the impression that the cycles that have ruled seasonal and inter-annual climate for thousands of years have not been changed by the advent of greenhouse warming.

Agreement between this theory and observation would not end the public debate.

Skeptics are likely to say, with some justification, something like: “You have finally taken into account all the effects we told you long ago were missing in your models, and lo and behold, you got a constant temperature profile. Tell us why what we are observing isn’t all natural cycles, tell us why we should go to great expense to change what humans are doing.”
Paradox #2: Extreme Weather Events

Polar jet meanders and blocking associated with La Nina
Subtropical jet strengthening and “pineapple express” events associated with El Nino
Extreme European Summers During Hiatus

Turn Down The Heat! The World at 4C

World Bank-Potsdam Institute for Climate Research

European summer temperatures since 1500
(Barriopedro et al. 2011)
Heat Wave Area Increased During Hiatus

In the 1960s, summertime extremes of more than three standard deviations warmer than the mean of the climate were practically absent, affecting less than 1 percent of the Earth’s surface. The area increased to 4–5 percent by 2006–08, and doubled by 2009–11 to 6–13 percent of the land surface. Now extremely hot outliers typically cover about 10 percent of the land area (Hansen et al. 2012).
Unstable Polar Vortex
Arctic warming is sending wintry weather south

Sea ice and snow melt, lower atmosphere and stratospheric warming affect position of jet stream, cold Arctic air intrudes into midlatitudes

Winter 2009–2010: A case study of an extreme Arctic Oscillation event


Liu, J., et. al., Arctic Sea Ice and Winter Snowfall, PNAS, volume 109, 11, 4074-4079, 2012
Jet Stream, Russian Heat Wave, Pakistani Floods

Slower propagation of meanders (Rossby Waves) in La Nina-like conditions
Longer persistence of extremes over one area


Kaiser, J., Dethloff, K., and Handorf, D., Stratospheric response to Arctic sea ice retreat and associated planetary wave propagation changes, Tellus A 2013, 65, 19375, http://dx.doi.org/10.3402/tellusa.v65i0.19375
Wandering Polar Jet Stream, 2014
Most UK Precipitation Since Record-Keeping Began in 1766
Paradox # 3: Extreme Polar Warming

Flow of heat from equator adds to local solar warming
Temperature changes are amplified by sea ice advance or retreat
Polar Amplification of Climate Warming

Maximum rate 0.42°C/year
A Regime Shift In Progress

ACIA, 2005: Polar Amplification a reality
SWIPA, 2011: Warming accelerated and changed character after 2000

SWIPA: 2005-2010 were the warmest years ever recorded.
Recent warming has been fastest in spring and autumn, whereas
before 2000, it was in winter, consistent with GCMs.
Warming is now faster over the oceans than over land.
Both changes suggest that declines in snow cover (spring) and sea-ice extent (fall)
are accelerating Arctic climate change.

Screen, J.A. and I. Simmonds, The Central Role of Diminishing Sea Ice in Recent Arctic Temperature Amplification,
Major Reduction in Arctic Sea Ice Area.
Rate increased at beginning of hiatus
2012 September
Sea Ice Area
40% Below
1979-2011 Average;
Volume down to 25%

Data provided by the National Snow and Ice Data Center (NSIDC)
Hiatus
Snow and Ice Albedo
Changes Destabilize the Climate In either direction

Percentage of sunlight reflected by Light and dark surfaces
Arctic Region Ice Reflectivity Change, 1979-2011

Albedo decreased from 52% to 48%
Additional solar warming: 6.4 W/m² since 1979; 4.2 W/m² between 2001 and 2011 alone
Averaged over globe, 0.21 W/m², ¼ of increase of CO2 forcing since 1979

Polar Forcing of *El Nino*/*La Nina*

Basic pattern set by seasonal variation of sunlight distribution at poles
Modulated by variable ice and snow albedo warming at poles
Transport in Ferrel Cell accomplished by planetary waves

**Normal and La Nina**
- Warmer Arctic
- Cooler Equatorial SST
- Smaller poleward heat flux
- Stronger tradewinds
- Ocean sequestration
- Variable jet stream
- Mid-latitude blocking events

**El Nino**
- Cooler Arctic
- Warmer Equatorial SST
- Larger poleward heat flux
- Weaker Trade winds
- Ocean sequestration fails
- Smoother jet streams
  - “Pineapple express”
A New “Metastable” Climate State?

A Speculative Scenario
Years of warming thinned the Arctic sea ice, gradually increasing the proportion of one-year ice. One year ice responds sensitively to season and fluctuations in the Arctic warming rate. The extra Arctic warming associated with the 1998 super-El Nino triggered a period of continuing ice retreat, when seasonal regrowth could not make up for the previous year’s loss. Albedo warming became self-sustaining, eventually to exceed greenhouse warming locally: a new configuration of Arctic climate change was created. More, not less, energy of solar origin is now being invested in the climate system than before.

Why is the global temperature constant?
Arctic warming has created a La Nina bias and more persistent ocean sequestration, which carries to depth the extra energy added to the system from both the increase in greenhouse warming and the induced albedo warming. Because of this the ocean surface temperature has grown slowly.

Why are there more extreme weather events?
Heat transport at mid-latitudes requires Rossby waves. When the Arctic warms, they propagate more slowly, leading to more blocking events.

How long can this keep up?
Such a dynamical quasi-equilibrium could conceivably be maintained until the energy added to the climate system from ice and snow retreat stops. About 40% of the 1979 September sea ice area has been lost during the 16 years of the hiatus, 60% remains, so this situation might persist for another 20-30 years.

Circumstantial evidence but no proof