Global precipitation changes shaped by natural and anthropogenic forcing

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In response to warming:

How much will it rain?
Theory and Models vs. Observations (at least, Wentz et al)

Where will it rain?
Which is related in part to the SST pattern in the tropical Pacific.

“El Niño like” vs. “La Niña like”
“Weaker Walker” vs. “Ocean Thermostat”

Some lessons from the last millennium
-- primarily from a model simulation of the last millennium

Greenhouse gases vs. Solar-Volcanic
Solar-volcanic (SV) forcing & CO2 concentration (GHG)

Solar
Solar + Volcanic (SV)
Volcanic
CO2

Global (40S-60N) mean temperature & precipitation

°C

Year

FORCING

MODEL RESPONSE

From “ERIK”, an ECHO-G simulation of the last millennium 11-year running means
Global mean **Temperature** in the 20th Century is warmer than in the Medieval Warm Period (MWP) but the **Precipitation rate** is lower.
Global mean precipitation rate versus global mean temperature

- **Solar-Volcanic (SV)**
  - Pre-industrial era (1000-1850): 0.058 mm/day per °C = 2.1% /°C

- **GHG + SV**
  - Industrial era (1850-1990): 0.039 mm/day per °C = 1.4% /°C

Data are decadal mean values from the ERIK forced millennial simulation.
The global tropospheric balance is
Longwave Flux Divergence ≈ Latent Heating

Since $\Delta \text{LW}$ is less for GHG warming than for Solar-volcanic warming, precipitation is less.

See Allan and Ingram 2002, *Nature*
Where will it rain?
We look at the part related to the SST pattern in the tropical Pacific.

“El Niño like” vs. “La Niña like”
“Weaker Walker” vs. “Ocean Thermostat”

Which theory is right?
Both are sound physics.
Which is applicable?
The tropical Pacific in AR4

Weaker Walker $\rightarrow$ El Niño-like

Zebiak-Cane Model Comparison with Fossil Corals from the Central Pacific

Ocean Thermostat ➔ La Niña-like

Mean $dO^{18}$ from Palmyra corals (Cobb et al. 2003)

Mann et al. 2004
20th Century Temperature Trends

Updated from
Cane et al Science 1997
Precipitation Anomaly 1932-1939

OBSERVED

POGA-ML MODEL

GOGA MODEL

OBSERVED

SEA SURFACE TEMPERATURE

Courtesy of Richard Seager
The internal mode of global precipitation

(a) Forced simulation (24.9%)

(b) Control (free) simulation (25.6%)

Spatial structure (upper) and principal component (lower) of the internal (unforced) mode. Based on 11-year running means. The box is the Nino3.4 region.
First remove PC1 of precipitation, the leading internal mode (IM).

(left) The leading SVD mode of the precipitation and SST for the period 1000-1990. Also shown are the 850hPa wind anomalies regressed onto the time expansion coefficient of SST.

(right) As above but for the second SVD mode.

Wind vectors shown are significant above 95% confidence level.

Based on 11-year running means.
Reconstruction and attribution of the global precipitation changes

MWP – LIA
(1100-1200) - (1650-1750)

Present – LIA
(1961-1990) - (1650-1750)

Total precipitation in the forced run.

Reconstructed precipitation = internal (IM) + SV + GHG modes.

The r values (.92, .87) are the correlation coefficients between the reconstructed and total fields.

IM contribution (2%, 11%)
The % values is the fractional variance explained by each mode in the reconstructed fields.

SV mode contribution (98%, 33%)

GHG mode contribution (0%, 56%)
Precipitation regressed onto Solar-volcanic (SV) forcing

Greenhouse Gas (GHG) forcing
The grey curve is the total anomaly.

(a) **Nino 3.4 SST.**

(b) **Zonal SST gradient**: the eastern Pacific (10°S-10°N, 160°-90°W) minus the western Pacific (10°S-10°N, 120°-160°E) SST.

(c) **Walker Cell strength**: the zonal wind at 850 hPa averaged in (10°S-10°N, 120°E-150°W).

(d) **Hadley Cell strength**: differential divergence between 200 hPa and 850 hPa, averaged over (0-360°E, 15°S-0°) for DJF.
Static stability associated with the SV and GHG mode: (T850-T500) regressed onto (top) the SV forced mode (the SVD1 of 1000-1850) and (bottom) the GHG mode (the SVD1 of 1850-1990). Negative values mean reduced (T850-T500) or increase of the atmospheric static stability. The stabilization associated with the GHG mode is much stronger than the SV forced mode.

Solar-Volcanic (SV) mode

Greenhouse gas (GHG) mode

GHG response is more stable, favoring Weaker Walker mechanism
Summary

In many theories for the response to warming, warming is warming, but the type of forcing does matter.

Greenhouse gases vs. Solar-Volcanic

More precip than normal vs. Even more precip
A consequence of global tropospheric energy budget

“El Niño like” vs. “La Niña like”
“Weaker Walker” vs. “Ocean Thermostat”

Favored by static stability differences,
Also see Meehl et al (2003,…) on differences in spatial heating,
DiNezio et al on changes in the thermocline
Net Radiative Cooling Balances
Latent Heating of Troposphere

\[ R = 29 + 12 + 88 - 100 = 29 = LP \]

\[ \Delta R = L \Delta P \]
Total and Reconstructed Global Mean Precipitation

Entire period: SV (CC=0.90, FV=79.6%), GHG (CC=0.01, FV=1.0%), IM (CC=0.16, FV=2.4%)
Preindustrial: SV (CC=0.90, FV=79.8%), GHG (CC=-0.01, FV=-1.4%), IM (CC=0.21, FV=3.7%)
Industrial: SV (CC=0.88, FV=75.1%) GHG (CC=0.62, FV=36.7%), IM (CC=-0.41, FV=-20.2%)
Sea Surface Temperature Anomaly
1932-1939

OBSERVED

Contour interval = 0.2°C

Courtesy of Richard Seager
Precipitation Anomaly 1932-1939

OBSERVED

GOGA MODEL

Contour interval = 2 mm/month

GOGA MODEL = AGCM with Global Sea Surface Temperature Specified

Courtesy of Richard Seager