Water vapour transport to the stratosphere driven by thunderstorm activity

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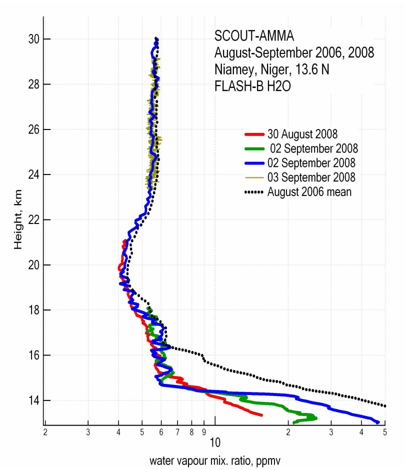
Thunderstorm Effects on the Atmosphere-Ionosphere System

Outline

Water in the stratosphere



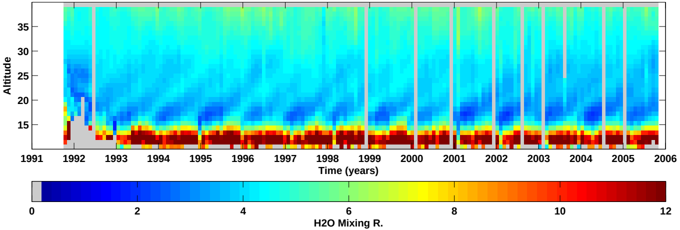
Methane oxidation, triggered by UV

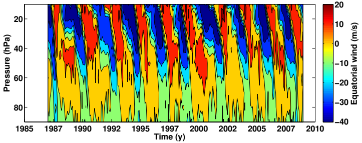
$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$$

Water transport

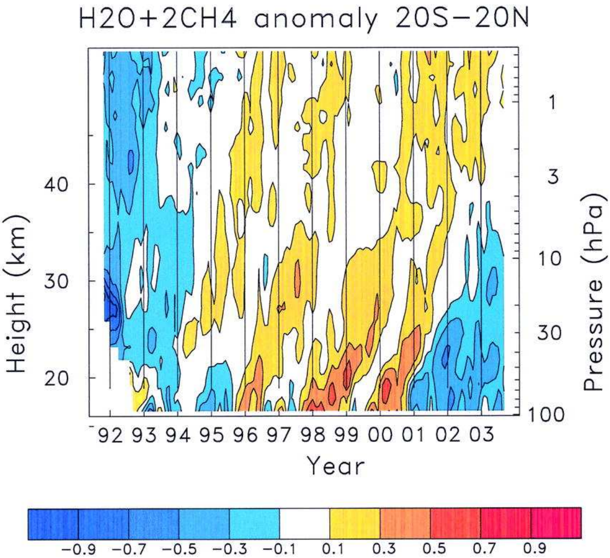
Tropopause 16 km

(Plot from Pommereau and Khaykin)

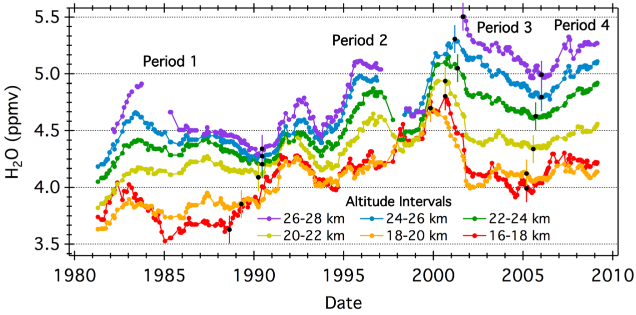




UARS HALOE 2.5- 11 μ m

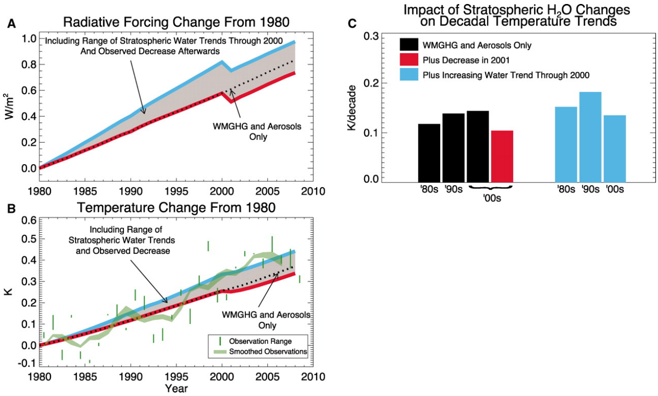

H2O+2CH4 anomaly 20S–20N
Height (km)
40
30
20
Pressure (hPa)
1
3
10
30
100
92 93 94 95 96 97 98 99 00 01 02 03
Year
−0.9 −0.7 −0.5 −0.3 −0.1 0.1 0.3 0.5 0.7 0.9

Randel (2006)



Hurst et al. JGR (2011)

Why is water interesting?



Solomon et. al (2010)

What controls the stratospheric water content?

Dehydration at the tropopause

Correlation between tropopause temperature and stratospheric water: 0.81 Fueglistaler (2005)

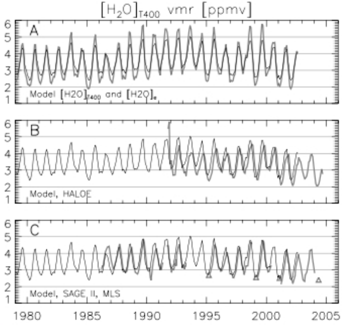


Figure 1. Tropical mean (30°S to 30°N) water vapor mixing ratios in the lowermost stratosphere at 400 K ($[H_2O]_{T400}$). (a) Model results (black) and model results for $[H_2O]_e$ (grey). (b) Model results (black) and HALOE

(Anti) correlation between residual vertical velocity and stratospheric water -0.66. Castanheira (2012 in review ACPD)

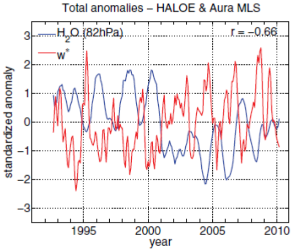
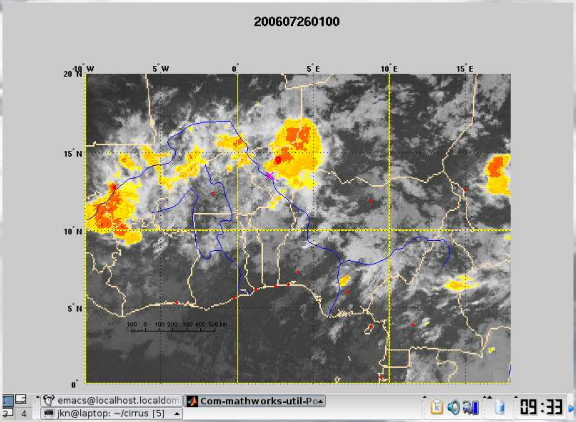
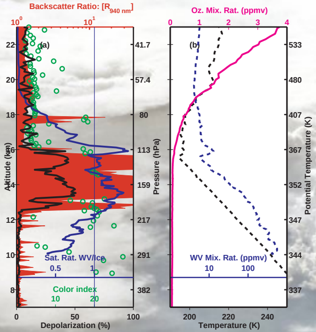


Fig. 13. Time series of mean residual vertical velocity, ($\overline{w}^*$), in the tropics (22.5° S–22.5° N) and the near-global (50° S–50° N) water vapour anomalies at 82-hPa. The water vapour data were derived from the HALOE and Aura MLS instruments. Both time series were smoothed by a 5-month running mean and normalized by their respective standard deviations. The time series of the residual vertical velocity leads the water vapour by 5 months. This means that time series of the vertical velocity was shifted five months to the left in the plot.

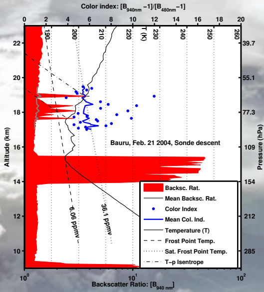
Hydration from overshooting convection



Tropical Stratospheric Clouds

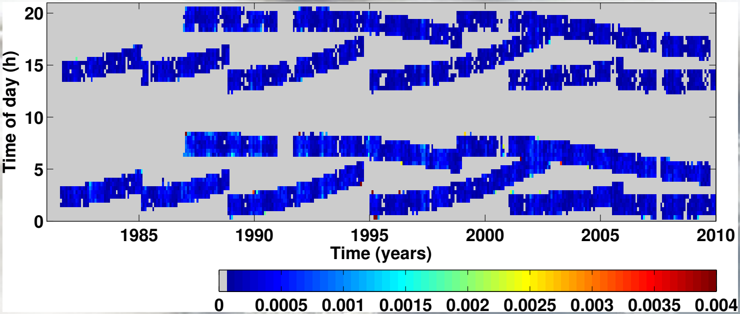


Khaykin et al. (2009)

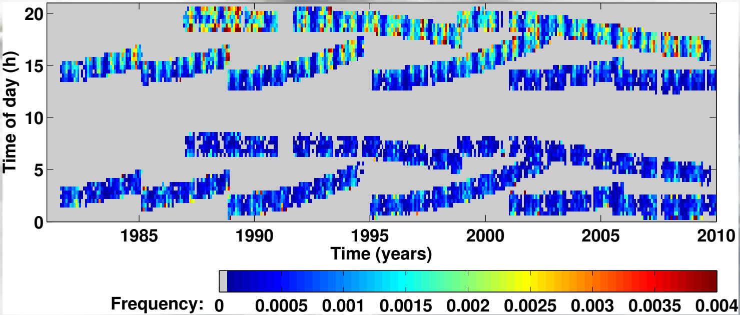


Nielsen et al. (2007)

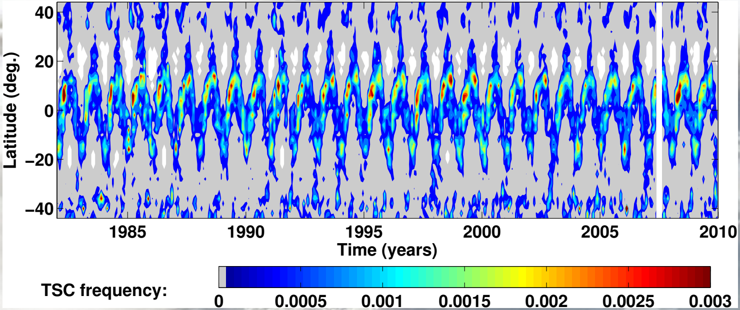
Intensity of clouds with $T_B < 200$ K (OCEAN!)



Intensity of clouds with $T_B < 200$ K (LAND!)



Intensity of clouds with $T_B < T_{\mathrm{tropopause}}$ (LAND!)

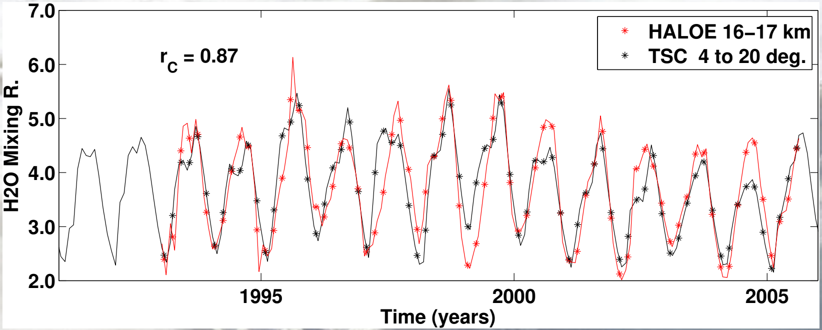


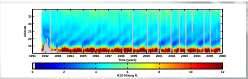
Model

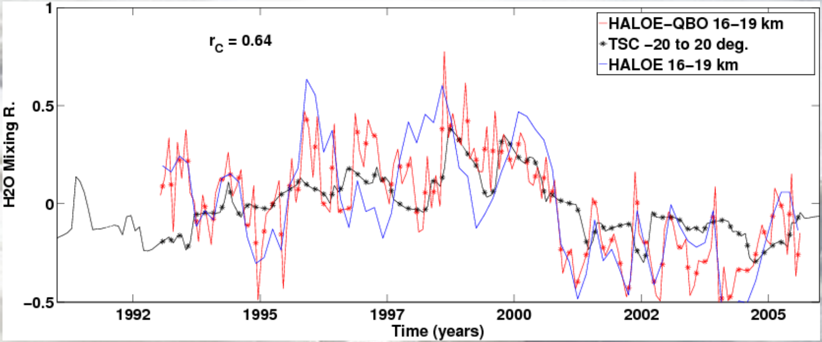
$$\dot{x} = -k(x - a) + cd(t) \tag{1}$$

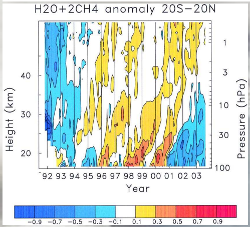
x = Water Vapour Mixing Ratio
d = Tropical Stratospheric Cloud -frequency
a = Mixing ratio of slow ascending air.

Phenomenological relation

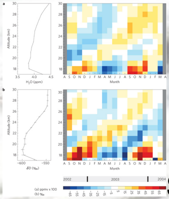




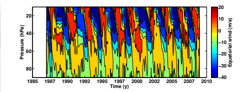

r_C = 0.64
HALOE–QBO 16–19 km
TSC –20 to 20 deg.
HALOE 16–19 km
H2O Mixing R.
1
0.5
0
–0.5
1992
1995
1997
2000
2002
2005
Time (years)


H2O+2CH4 anomaly 20S–20N
Height (km)
40
30
20
Pressure (hPa)
1
3
10
30
100
92 93 94 95 96 97 98 99 00 01 02 03
Year
–0.9 –0.7 –0.5 –0.3 –0.1 0.1 0.3 0.5 0.7 0.9

Ideas and perspectives

Isotopes 

Steinwagner (2010)



Explain QBO! ← Lightening data / Shumann resonances / PATMOS-x

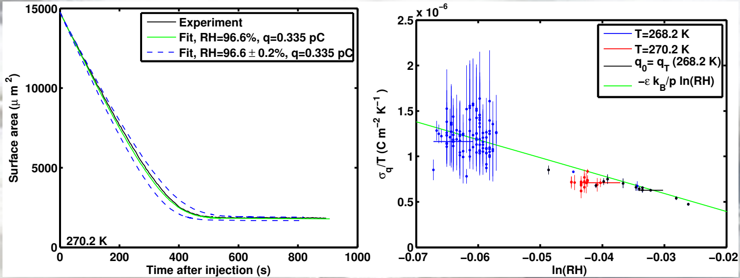
Explain stratospheric water SWOOSH, 2 decades, (SAGE,HALOE,MLS) (Rosenlof)

Characterize thunderstorms with GNSS RO data. (Biondi 2011)

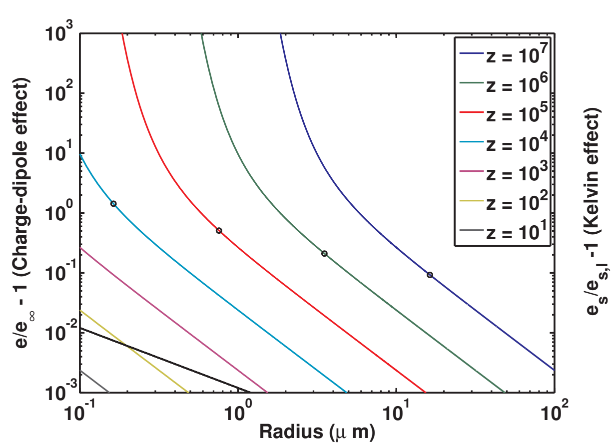
Conclusions

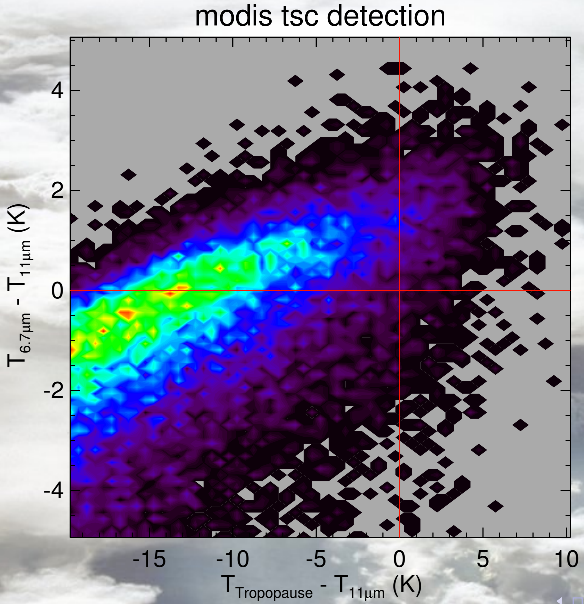
- Tropical stratospheric clouds correlate well with stratospheric Water Vapour Mixing Ratio
- Still a lot to do

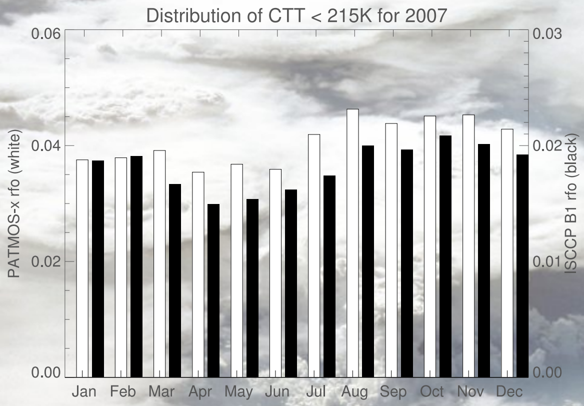
lunch

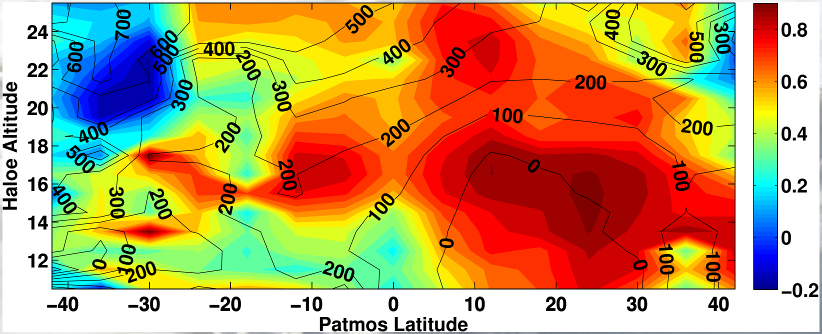


$$\mathrm{RH_w} = \exp\left(-\frac{|\vec{p}\sigma_\mathrm{q}|}{\varepsilon_0 k_\mathrm{B} T}\right) . \qquad (2)$$

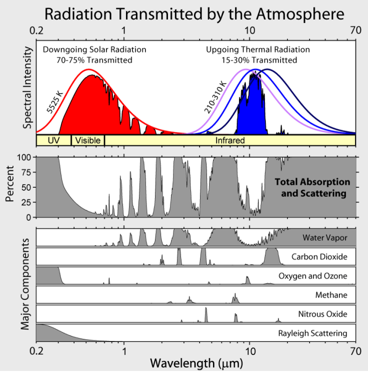

z = 10^7
z = 10^6
z = 10^5
z = 10^4
z = 10^3
z = 10^2
z = 10^1
e/e∞ - 1 (Charge-dipole effect)
e_s/e_s,l -1 (Kelvin effect)
Radius (μ m)
10^-1
10^0
10^1
10^2
10^-3
10^-2
10^-1
10^0
10^1
10^2
10^3

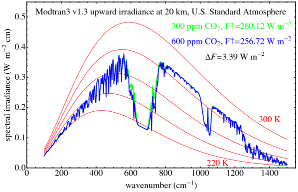

modis tsc detection
4
2
0
-2
-4
$T_{6.7\mu m} - T_{11\mu m}$ (K)
-15
-10
-5
0
5
10
$T_{Tropopause} - T_{11\mu m}$ (K)

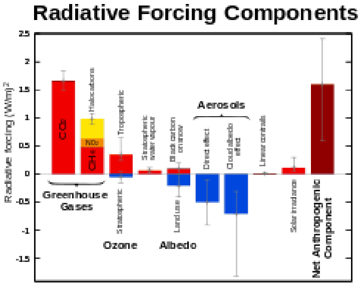

Distribution of CTT < 215K for 2007
0.06
0.04
0.02
0.00
0.03
0.02
0.01
0.00
PATMOS-x rfo (white)
ISCCP B1 rfo (black)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Haloe Altitude
Patmos Latitude
24
22
20
18
16
14
12
−40
−30
−20
−10
0
10
20
30
40
0.8
0.6
0.4
0.2
0
−0.2

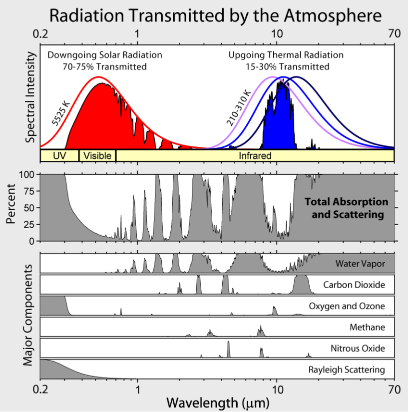

Map
Traffic
Ireland
Nederland
Deutschland
Polska
France
Bay of Biscay
Celtic Sea
Portugal
España
Italia
Hrvatska
România
Tyrrhenian Sea
Mediterranean Sea
Tunisia
Morocco
Algeria
Libya
Western Sahara
Mauritania
Mali
Niger
Chad
Sudan
Senegal
The Gambia
Guinea-Bissau
Guinea
Sierra Leone
Liberia
Côte d'Ivoire
Burkina Faso
Ghana
Togo
Benin
Nigeria
Cameroon
Central African Republic
South Sudan
Gulf of Guinea
Equatorial Guinea
Gabon
Congo
Democratic Republic of the Congo
Uganda
Rwanda
Burundi
Angola
Zambia
Zimbabwe
Namibia
Botswana
Swaziland
Lesotho
South Africa
South Atlantic Ocean
Paraiba
Pernambuco
500 mi
Map data ©2011 Basarsoft, Europa Technologies, Geocentre Consulting, ORION-ME, Tele Atlas, Transnavicom - Terms of Use


Radiation Transmitted by the Atmosphere
0.2
1
10
70
Spectral Intensity
Downgoing Solar Radiation
70-75% Transmitted
Upgoing Thermal Radiation
15-30% Transmitted
5525 K
210-310 K
UV
Visible
Infrared
Percent
100
75
50
25
0
Total Absorption and Scattering
Major Components
Water Vapor
Carbon Dioxide
Oxygen and Ozone
Methane
Nitrous Oxide
Rayleigh Scattering
Wavelength (μm)

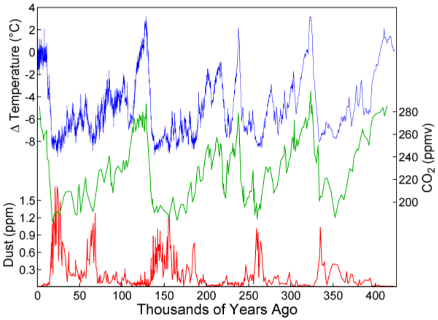

Modtran3 v1.3 upward irradiance at 20 km, U.S. Standard Atmosphere
300 ppm CO_2, F↑=260.12 W m^{-2}
600 ppm CO_2, F↑=256.72 W m^{-2}
ΔF=3.39 W m^{-2}
300 K
220 K
spectral irradiance (W m^{-2} cm)
0.0
0.1
0.2
0.3
0.4
0.5
0
200
400
600
800
1000
1200
1400
wavenumber (cm^{-1})

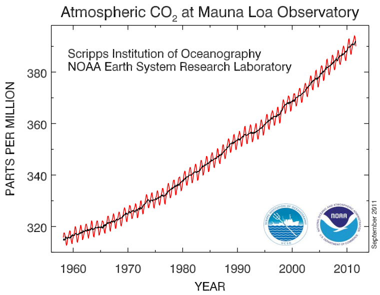

Radiative Forcing Components
Radiative forcing (W/m)^2
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Greenhouse Gases
Aerosols
Ozone
Albedo
Net Anthropogenic Component

(Wikipedia)

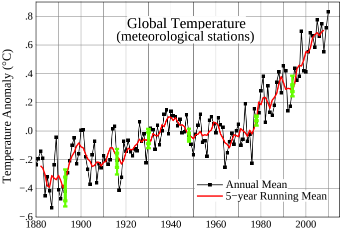


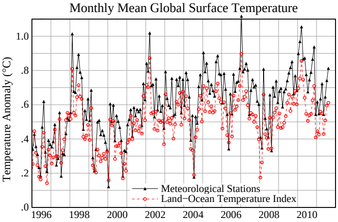
UARS HALOE 2.5- 11 μm

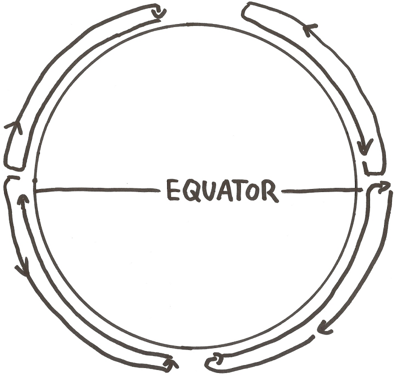

Δ Temperature (°C)
4
2
0
-2
-4
-6
-8
Dust (ppm)
1.5
1.2
0.9
0.6
0.3
280
260
240
220
200
CO2 (ppmv)
0
50
100
150
200
250
300
350
400
Thousands of Years Ago


Atmospheric CO2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
380
360
340
320
1960
1970
1980
1990
2000
2010
YEAR
September 2011

CO_2 forcing + natural variability







Earth with stratosphere