Ocean Oscillations, Blocking High Pressure Systems and Downslope Winds: Explaining The California Drought/Fire Cycle

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Presentation to IEEE Buenaventura Section

11/16/21

Outline

- Time Scales For Climate Change
  - Plate tectonics, Planetary Motion, Solar Insolation, Ocean Oscillations
- The Greenhouse Effect On A Rotating Water Planet
  - Climate Energy Transfer
  - Convective Mass Transport Coupling to Gravity and Rotation
  - Blocking High Pressure Systems And Downslope Winds
  - Ocean Gyres and Ocean Oscillations
- California Rainfall
- Onshore/Offshore Flow In S. California
- Blocking High Pressure Systems
- What About CO_2?
- Future Climate Trends?

The Time Scales For Climate Change

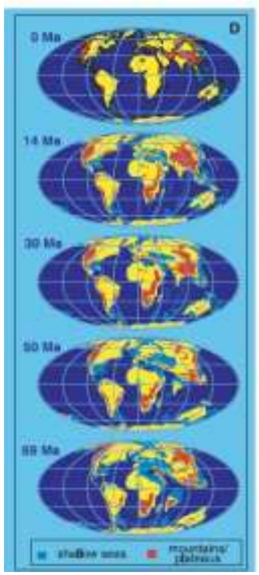
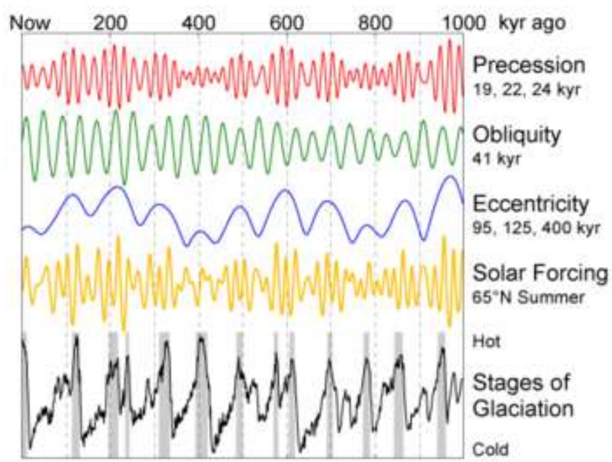
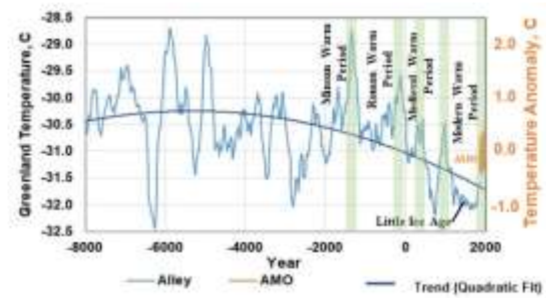


Plate Tectonics



Milankovitch cycles



Medieval warming period

The Time Scales For Climate Change

- The Earth's climate is always changing
- Geological time scales: 1 to 100 million years
  - Plate tectonics, changes in ocean circulation with continental movement
- Milankovitch Cycles: 10,000 to 100,000 Years
  - Planetary perturbations to the Earth's Orbital and Axial Parameters
    - Orbital Eccentricity, Axial Tilt, Precession (wobble) – Ice Ages etc.
- Changes in Solar Output (Sunspots etc.): 100 to 1000 years
  - Climate warming and cooling related to small changes in solar flux
    - Minoan, Roman, Medieval, Modern warming periods
    - Maunder minimum or Little Ice Age
- Quasi-periodic Ocean Oscillations
  - 60 to 70 years:
    - Atlantic Multi-decadal Oscillation (AMO), Pacific Decadal Oscillation (PDO)
  - 3 to 7 Years:
    - El Nino Southern Oscillation (ENSO), Indian Ocean Dipole (IOD)

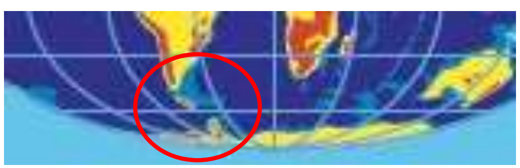
Plate Tectonics

- **Today's continents and oceans have been formed by the breakup of the supercontinent Pangea, starting about 175 million years ago**
- **The oceans are heated by water circulation in the tropics and cooled by circulation near the poles**
- **50 million years of cooling with increased ocean polar circulation**
  - **Temperature reconstruction using $\delta^{18}O$ ocean isotope ratios from ocean sediment cores**

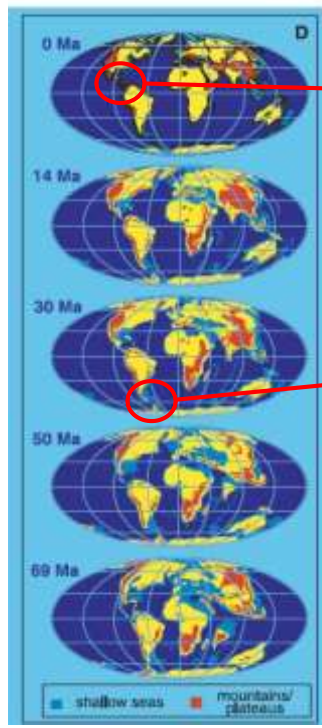
Major Climate Cooling Events

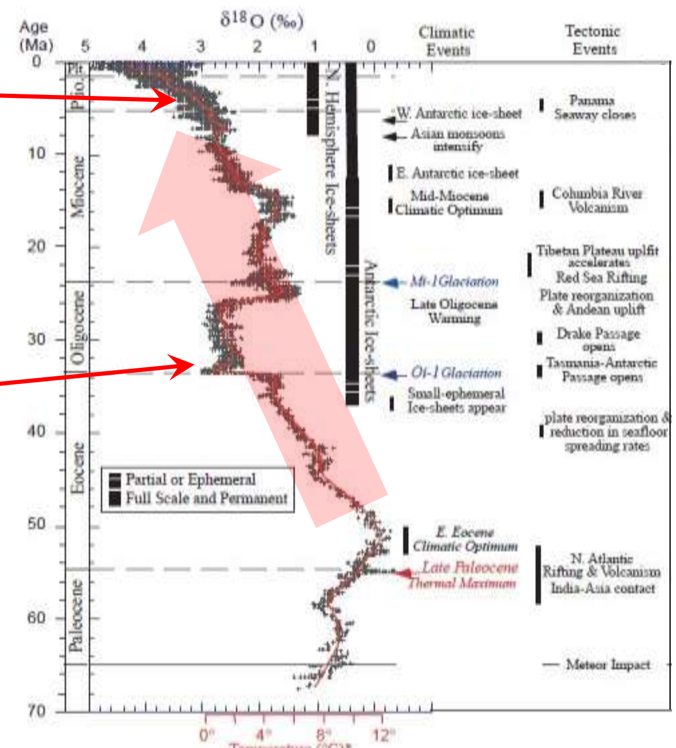
Formation of the Isthmus of Panama

Opening of the Drake Passage and Formation of the Southern Ocean



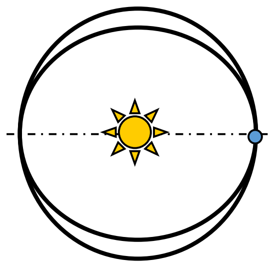
Zachos, J.; M. Pagani, L. Sloan, E. Thomas and K. Billups, Science **292** 686-689 (2001), 'Trends, rhythms and aberrations in the global climate, 65 Ma to present', http://www.gbdgcgl.com/UpLoadFiles/OtherFile/20130727054725.pdf

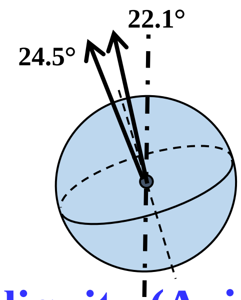


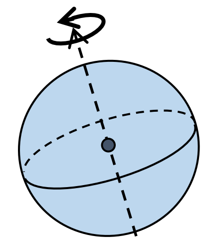


Milankovitch Cycles

- **Planetary perturbations, mainly by Jupiter and Saturn**

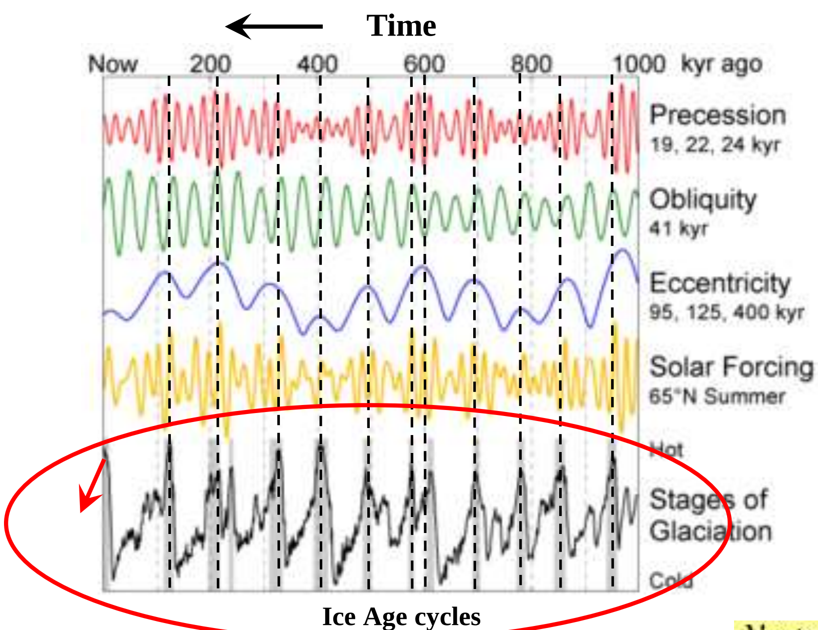


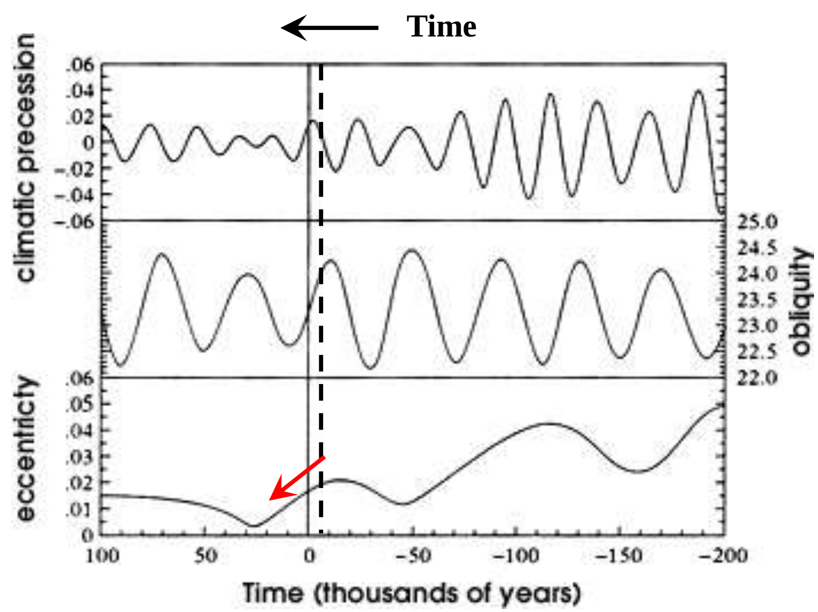




• Eccentricity **• Obliquity (Axial tilt)** **• Precession (Wobble)**

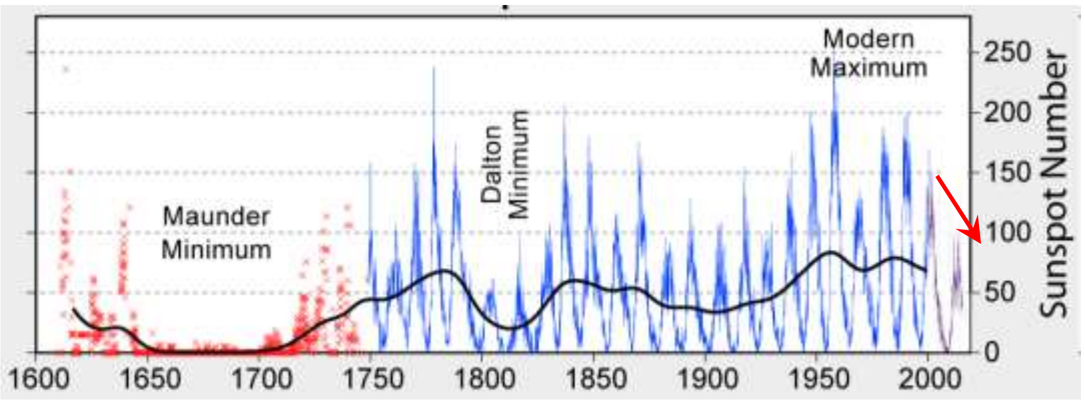
- **There is a nominal 100,000 year Ice Age cycle from orbital eccentricity changes**
- **The earth is starting to cool towards the next Ice Age glaciation**



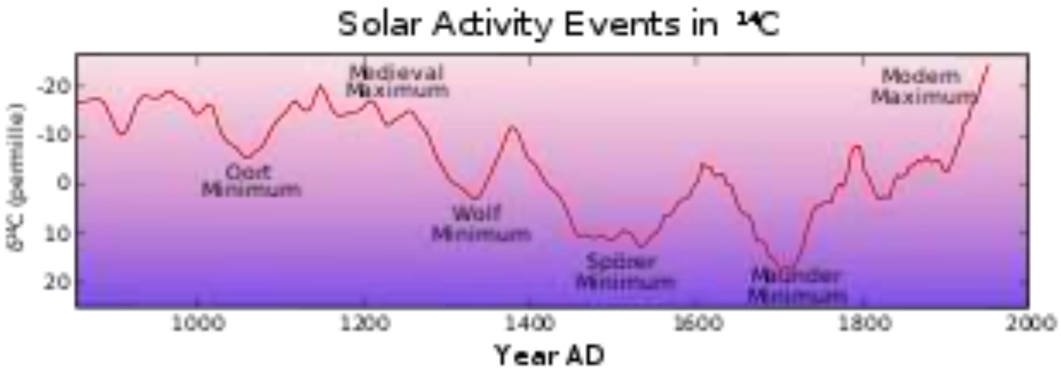


Changes In Solar Flux

- The Sun is a slightly variable star
- 100 to 1000 year flux changes are superimposed on the nominal 11/22 year solar sunspot cycle
- Few sunspots observed during the Maunder minimum/Little Ice Age (LIA)
- Earlier reconstructions from ^{10}Be or ^{14}C isotope data



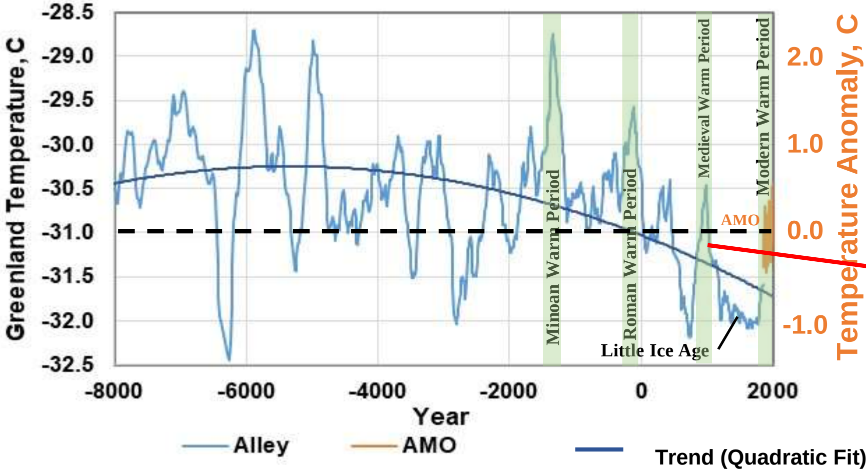
• River Thames, London Bridge, 1677



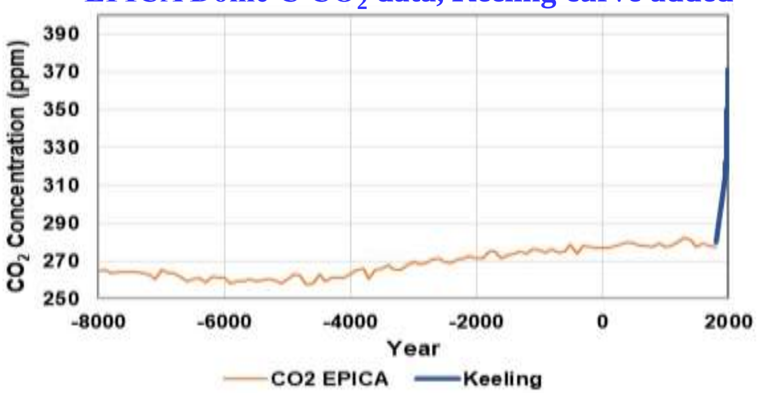
The Earth Has Been Cooling For At Least 6000 Years

- **Climate change caused by Milankovitch cycles with variations in solar flux superimposed**

• GISP ice core data [Alley, 2004] AMO added



• EPICA Dome C CO_2 data, Keeling curve added

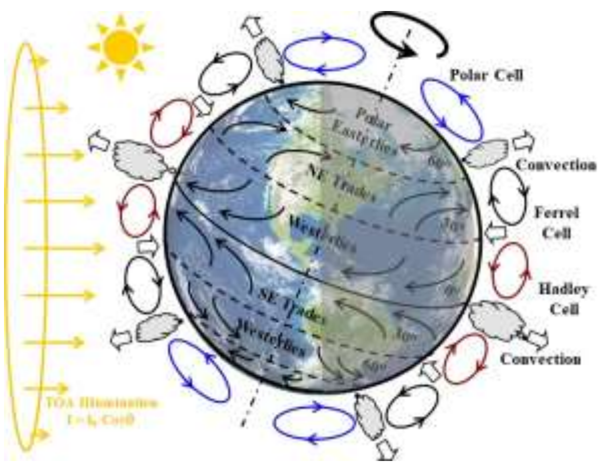


• Ruins of Hvalsey Church, Greenland.

This area was settled and farmed for approximately 500 years during the medieval warm period, 900 to 1400 AD. Estimated population between 6,000 and 10,000 Norsemen. Church records here ended in 1408.

Shepherd, F. J. https://wattsupwiththat.com/2016/01/19/debunking-the-vikings-werent-victims-of-climate-myth/ **Debunking the vikings weren't victims of climate myth**

The Greenhouse Effect On A Rotating Water Planet



‘Effective’ Planetary Emission Temperature

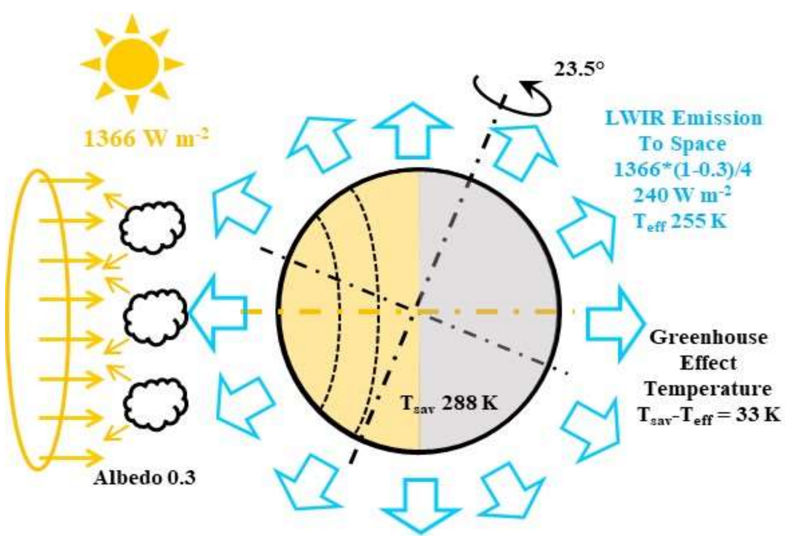
- The earth and the moon are isolated bodies, heated by short wave (SW) electromagnetic radiation from the sun, cooled by long wave IR (LWIR) emission to space.
- Conservation of Energy
  - Planetary average emitted LWIR flux

$$I_{LWIR} = 1366*(1 – Albedo)/4$$

  - ‘Effective’ emission temperature (assume blackbody)

$$T = (I_{LWIR}/\varepsilon\sigma)^{1/4}$$

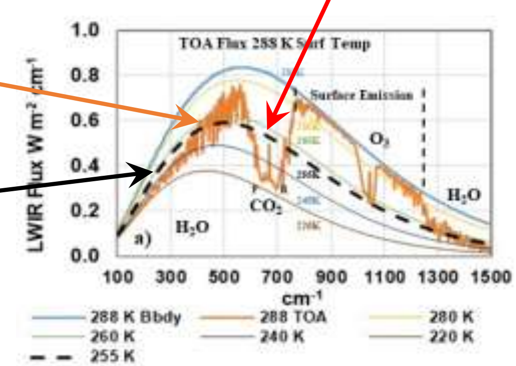
  - For earth, the LWIR flux is 240 ±100 W m^{-2}. This is really a cooling flux that should not be used to define a temperature



	Moon	Earth
Albedo	0.1	0.3
Av. LWIR Flux	308 W m^{-2}	240 W m^{-2}
Eff. Temperature	275 K, 2C	255 K, -18 C

TOA LWIR emission,
288 K surface temperature

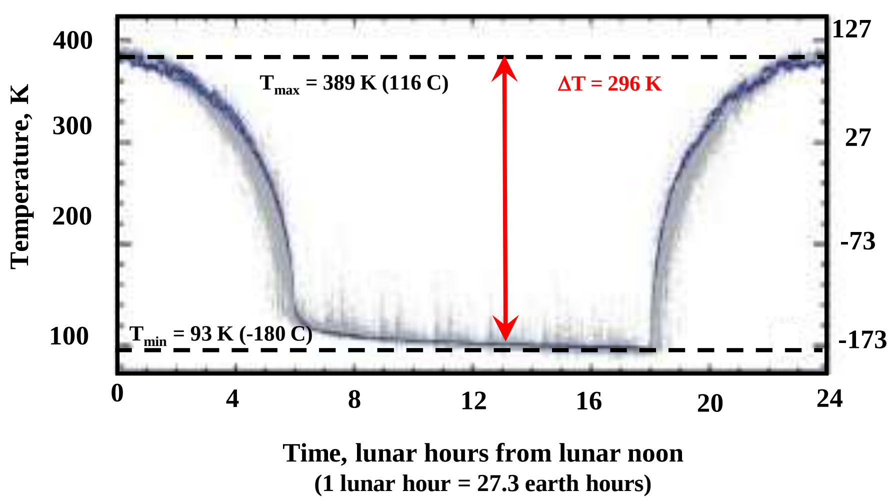
255 K blackbody
emission



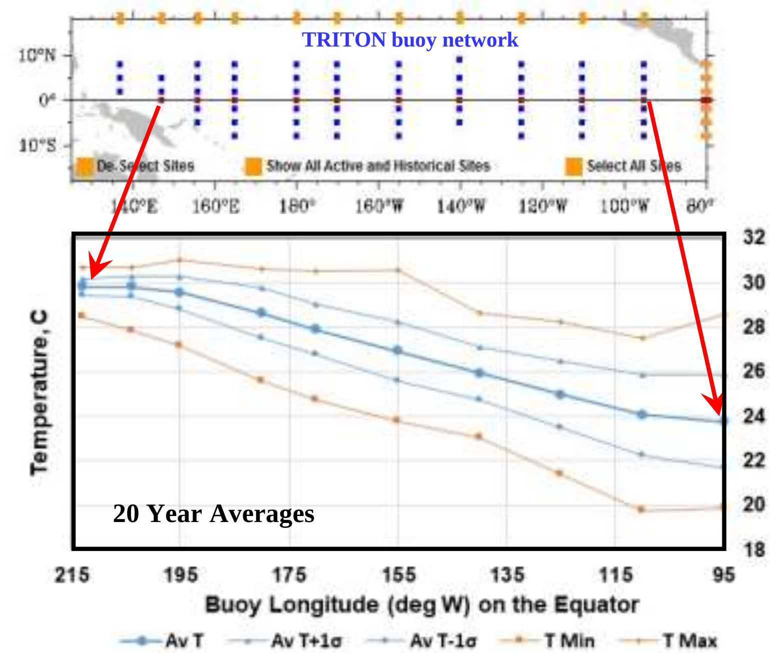
The Greenhouse Effect

- **Why are the temperatures of the earth and the moon so different?**

• Lunar Temperatures at the Equator
116 to -180 C

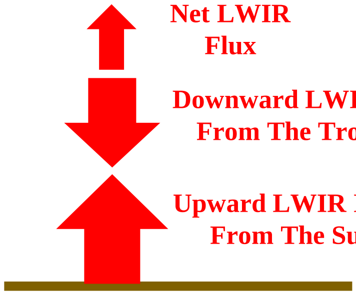


• Equatorial Pacific Ocean Temperatures
East: 24 ±2 C, West 30 ±0.4 C

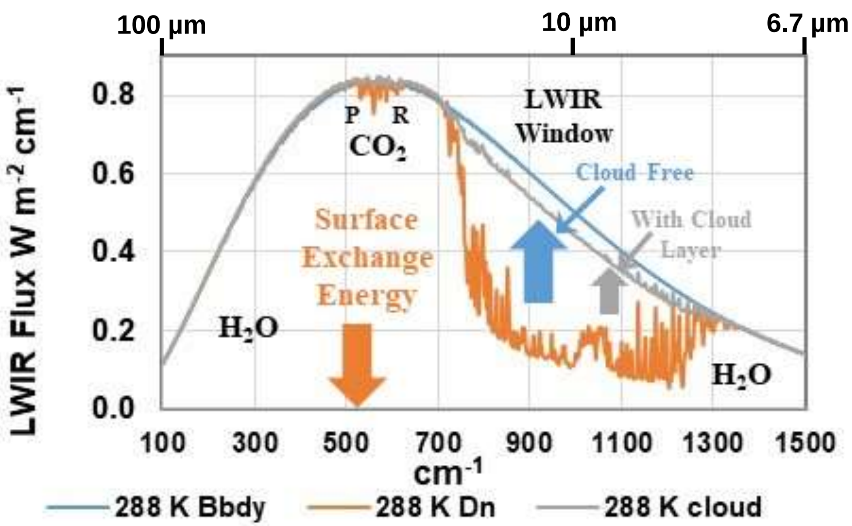


The LWIR Exchange Energy

- The downward LWIR flux from the lower troposphere to the surface partially 'blocks' or 'balances' the upward LWIR flux from the surface
- When surface and surface-air temperatures are similar, the LWIR cooling flux is limited to the LWIR transmission window
  - LWIR cooling flux depends on temperature, humidity and cloud cover
- In order to dissipate the absorbed solar heat, the surface must warm up until the excess heat is removed by moist convection (evapotranspiration)
- Surface temperature is set by the Second Law of Thermodynamics not the First



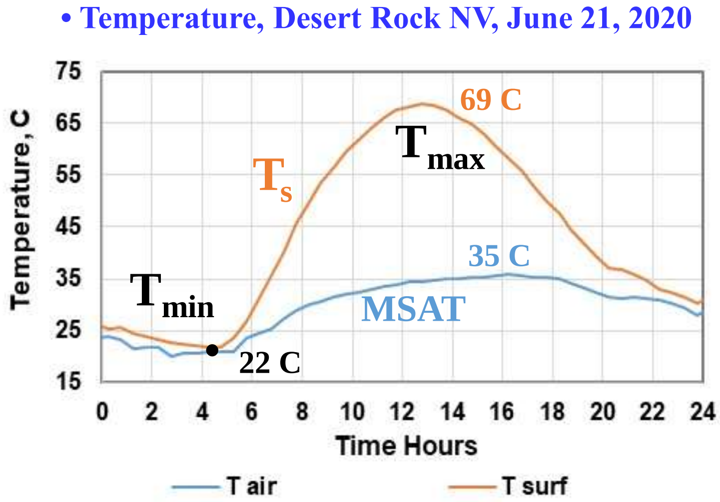
- Surface exchange energy

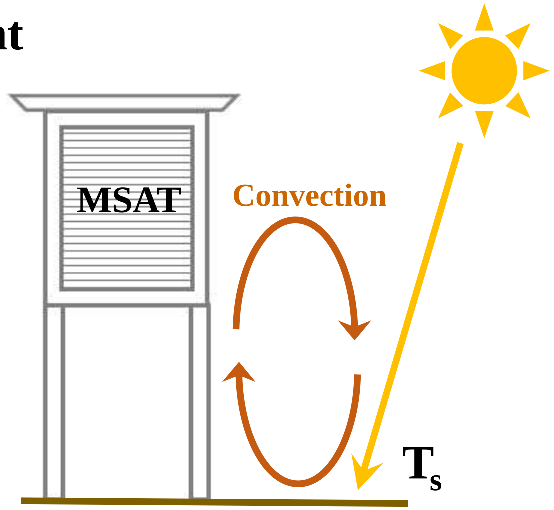


Clark, MODTRAN Calculations, 2020

Surface Temperature Measurement

- The various flux terms interact with the surface - ‘skin’ temperature
- The weather station temperature is measured at eye level above the ground
  - Meteorological surface air temperature (MSAT)
- Surface and surface air temperatures are different





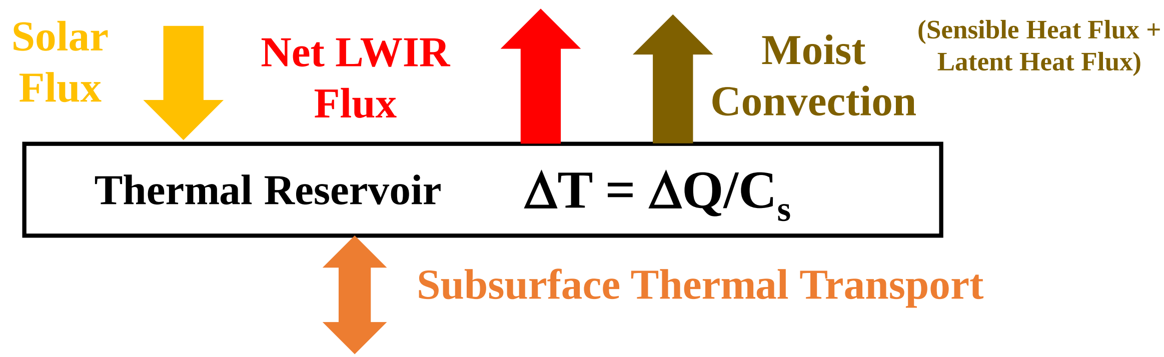
• Cotton Region Shelter

• Six’s Thermometer

• Modern Thermistor Enclosure

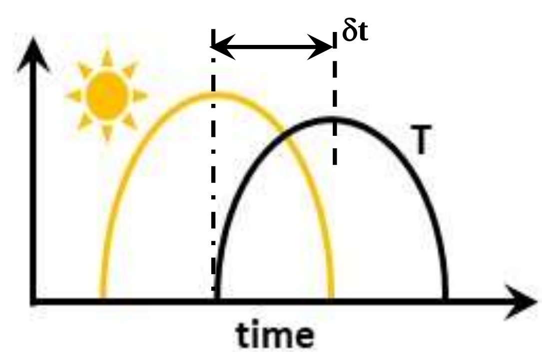
The Calculation Of The Surface Temperature

- **Four main time dependent flux terms interact with the surface reservoir**
  - **These are interactive and should not be separated**
- **The change in temperature is the change in heat content divided by the heat capacity**



- **There are also time delays or phase shifts between the peak solar flux and the surface temperature response**
  - **Clear evidence of non-equilibrium thermal storage**
    - **Described by Fourier in 1824**
  - **Similar to electronic phase shifts in AC circuits**

- **Phase Shift**

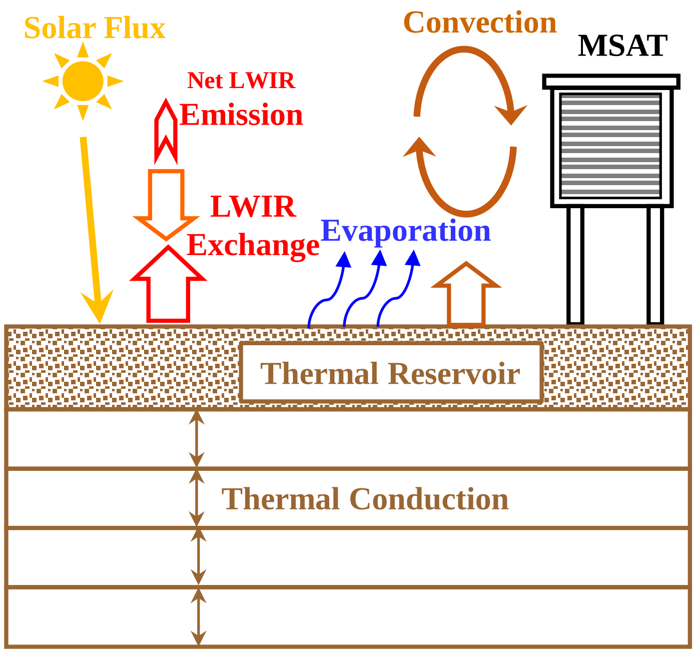


Fourier, B. J. B., Annales de Chimie et de Physique, 27, pp. 136–167 (1824), English translation: http://fourier1824.geologist-1011.mobi/

Land Surface Heating

- All of the flux terms interact with a thin surface reservoir
- Solar heating drives the moist convection during the day
- Some of the solar heat is conducted below the surface and returned later in the day.
- The surface cools more slowly at night by net LWIR emission

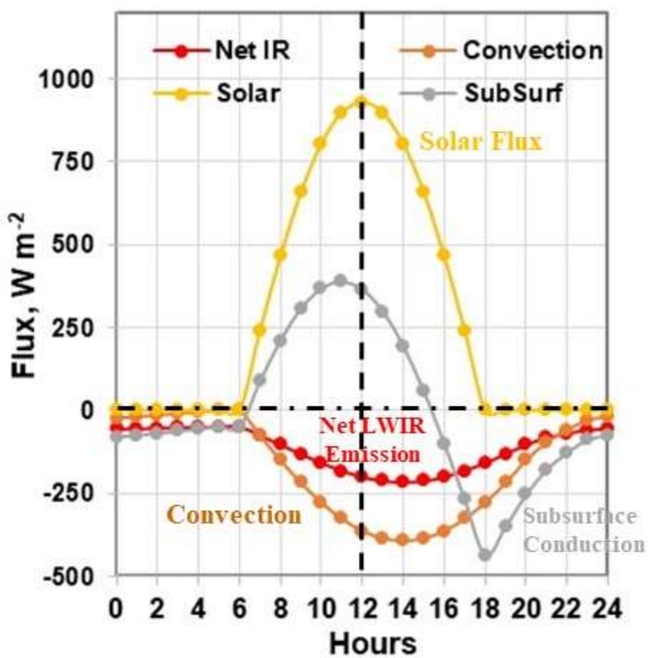
- Land Energy Transfer



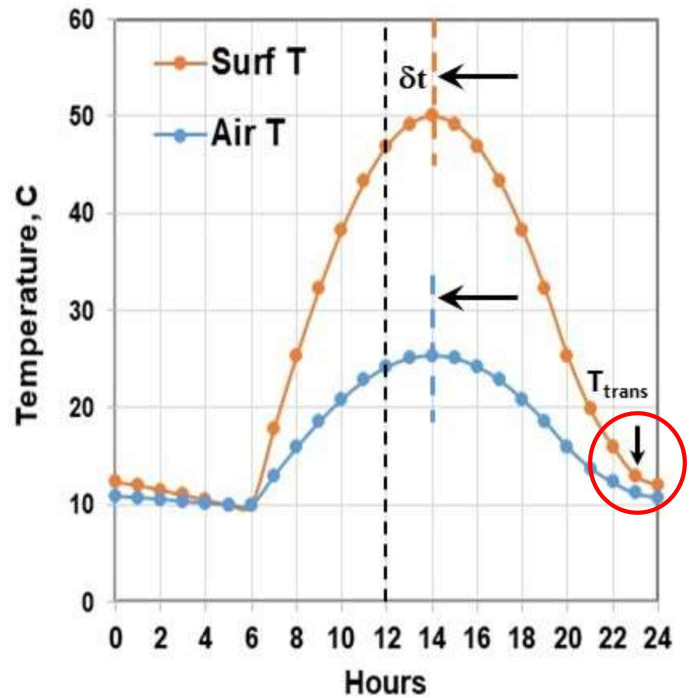
The Convection Transition Temperature

- The convection transition temperature is the evening temperature at which the surface and temperatures (approximately) equalize and convection stops
- It is reset each day by the local weather system
- Almost all of the absorbed solar heat is dissipated within the same diurnal cycle
- There is usually a time delay or phase shift between the peak solar flux at local noon and the peak temperature response

• Diurnal flux terms
(dry surface, summer sun)



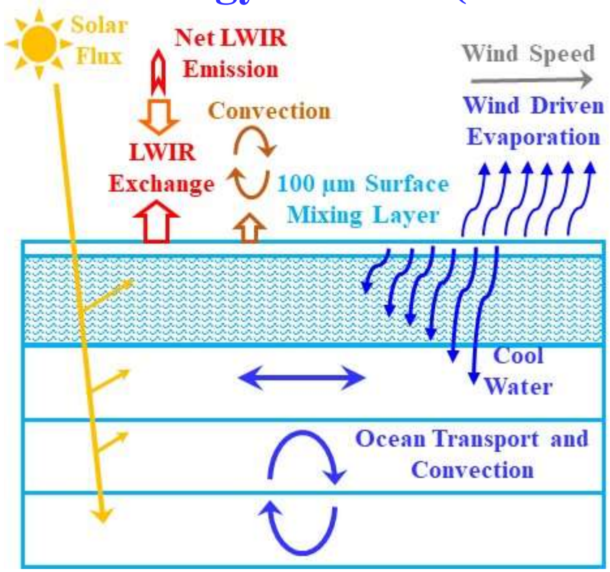
• Surface and surface air temperature



Ocean Heating

- The ocean surface is almost transparent to the solar flux
  - ~50% absorbed within the first 1 meter ocean layer, ~90% in 10 m
  - The bulk ocean heats up until the excess heat is removed by wind driven evaporation (latent heat flux)
- The net LWIR cooling flux, the wind driven latent heat flux and the sensible heat flux are coupled into a thin (100 micron) surface layer
- The cooler surface water sinks and is replaced by warmer water from below
  - The cooling continues at night
  - The surface motion (momentum) is coupled below the surface

• Ocean energy transfer (schematic)



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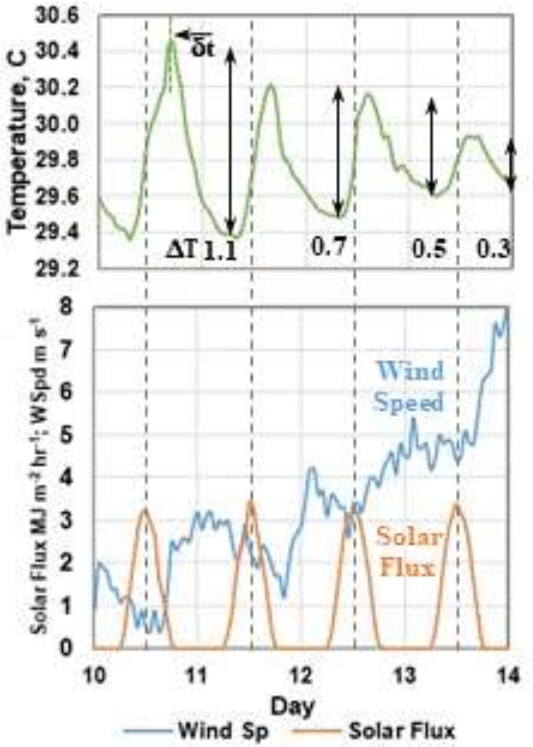
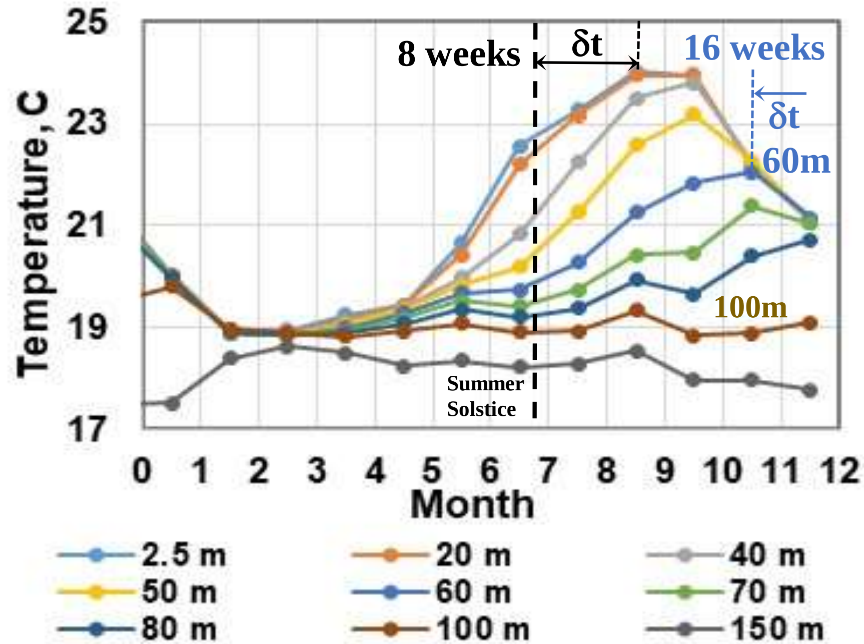
Ocean Temperatures

- **Diurnal temperature rise is small, decreases with increasing wind speed**
  - **Evaporation or latent heat flux increases with wind speed**
- **Heat is stored in the ocean by summer heating and released in winter**
- **Significant phase shifts indicant non-equilibrium thermal transfer**

• TRITON Buoy data July 2010, 165° E, 0° N



• N. Atlantic Ocean, 20° W, 30° N (Argo data) west of Canary Islands



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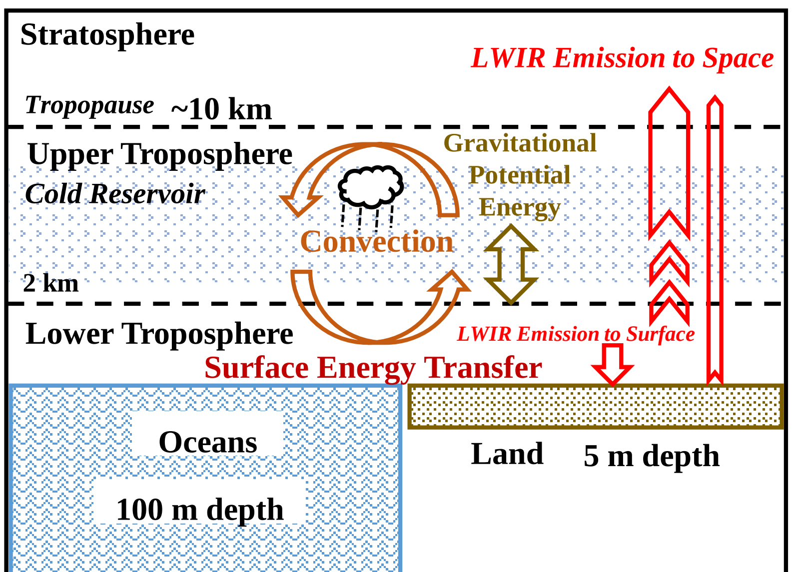
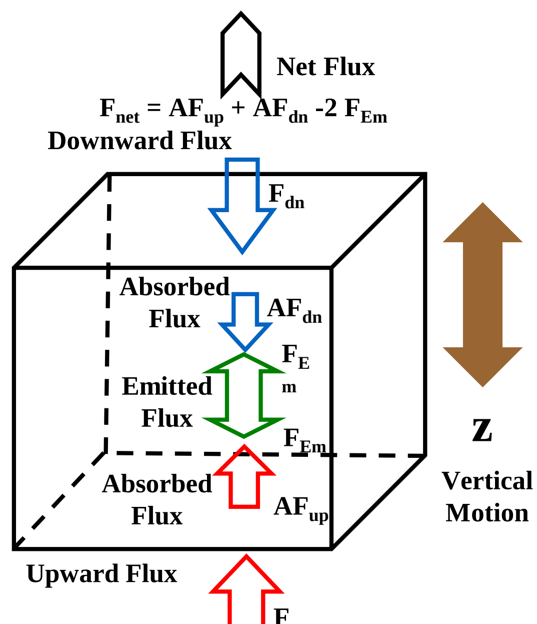
The Tropospheric Heat Engine

- Troposphere divides naturally into two separate thermal reservoirs
  - Lower reservoir, 0 to 2 km
    - Produces almost all of the downward LWIR flux to the surface
  - Upper tropospheric reservoir 2 km to tropopause
    - Cold reservoir cooled by water band LWIR emission to space
  - Heat transported from the surface by moist convection
  - LWIR flux coupled to mass transport through the lapse rate
    - LWIR cooling rate ~ 2 K per day, Lapse rate ~6.5 K per km (3 km hr^{-1} ↑)

- Tropospheric heat engine



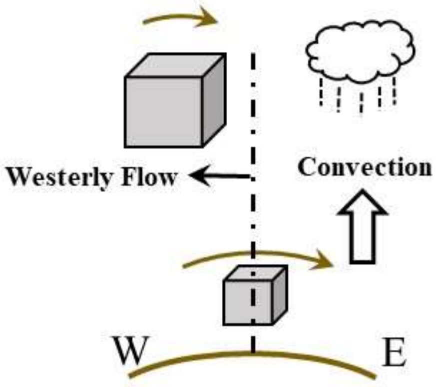
- Air parcel energy transfer



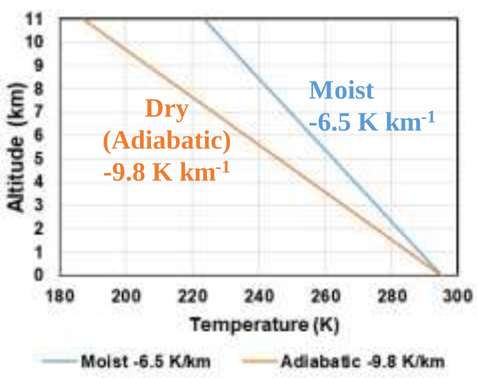
Convection, Rotation and Gravity

- Convection is a mass transport process
- A rising air parcel in the troposphere is coupled to the earth's gravitational field and rotation (angular momentum)
  - The air expands and cools as it rises
    - The tropospheric temperature decrease with altitude (lapse rate)
    - Water vapor condenses above the saturation level (clouds and rain)
    - Latent heat is released, lapse rate is reduced
    - Internal molecular energy is converted to gravitational potential energy
    - Heat is radiated back to space, mainly by the water bands
  - The moment of inertia increases and the angular velocity decreases
    - This produces the trade winds

- Convective coupling



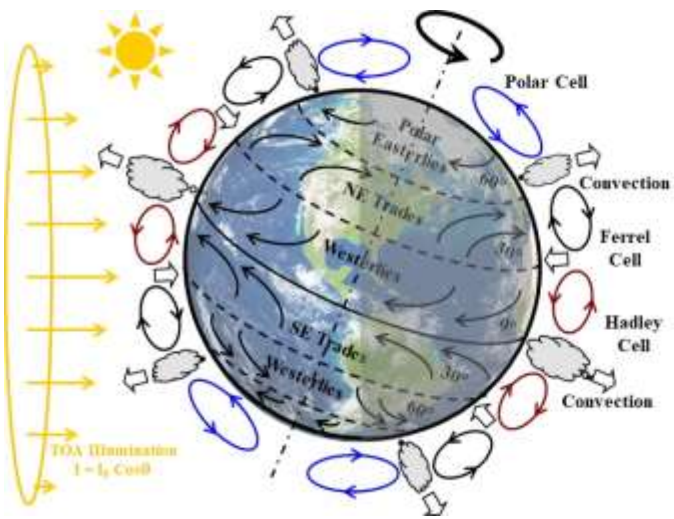
- Tropospheric Lapse Rate



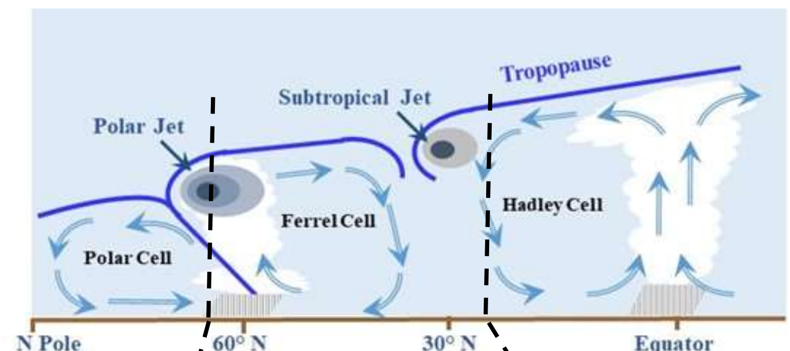
The Earth’s Convective Cell Structure

- **Convection produces the Hadley, Ferrell, Polar cell structure**
- **Downward flow of dry air produces desert conditions near 30° latitudes**
- **Convective flow is coupled to the earth’s rotation (Coriolis effect) to give the Mid latitude cyclone/anticyclone structure**
- **Trade winds drive the ocean gyre circulation**

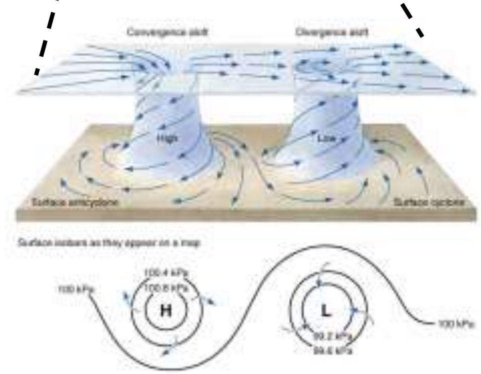
• Convective cell structure and trade winds



• Convective cell structure and jet streams

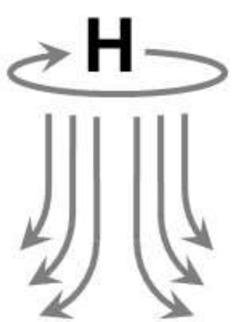


• Mid latitude cyclones and anticyclones

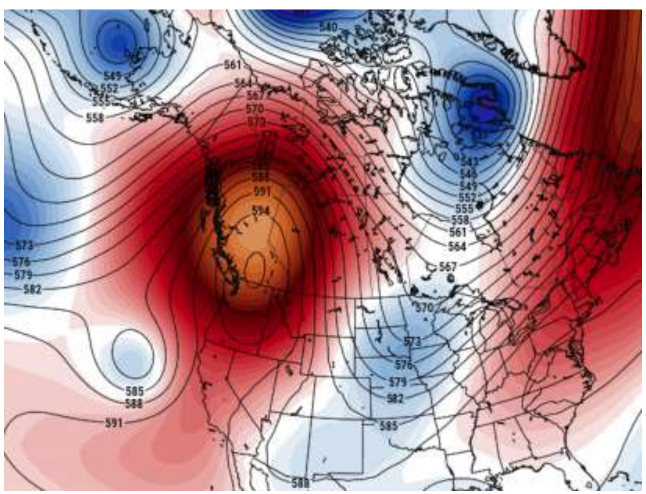


Blocking High Pressure Systems

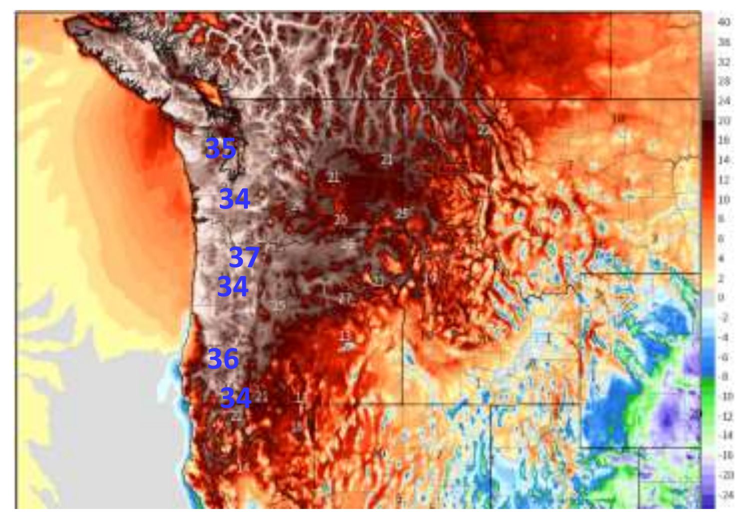
- As dry air descends, the warming rate is 9.8 C per kilometer
  - The heat source is air compression
- Heat accumulates in a stationary blocking high pressure system
- Other weather systems move around the blocking high



• High pressure dome over the Pacific NW,
June 27 th 2021



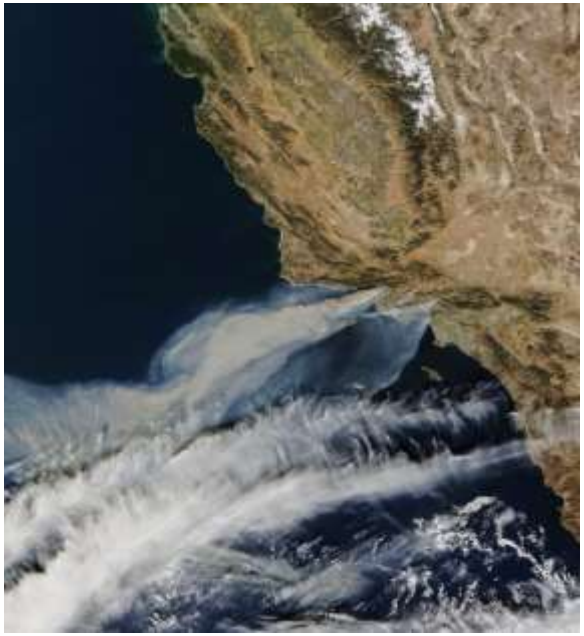
• Overnight temperature drop in Portland OR
June 28 to 29 was 52 F from 116 to 64 F
(29 C from 47 to 18 C)



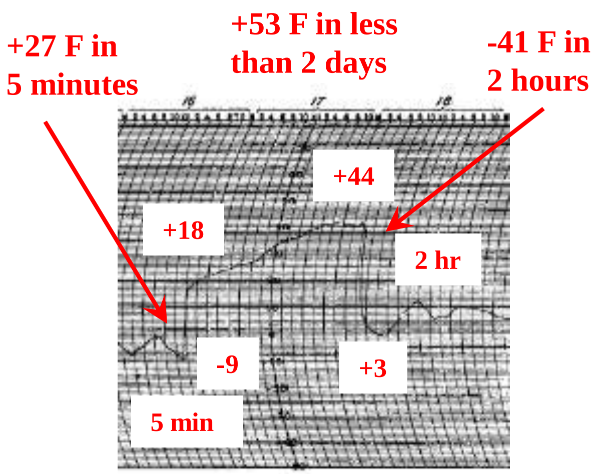
Downslope Winds

- Santa Ana Winds, (S. CA) Diablo Winds (N. CA), Chinook Winds (Rockies), Föen winds (Alps)
- Dry air compressed by downslope flow
  - Can be associated with a blocking high pressure system
  - Rapid changes in temperature

• Thomas fire, Ventura, 12/5/17
Terra Satellite Image

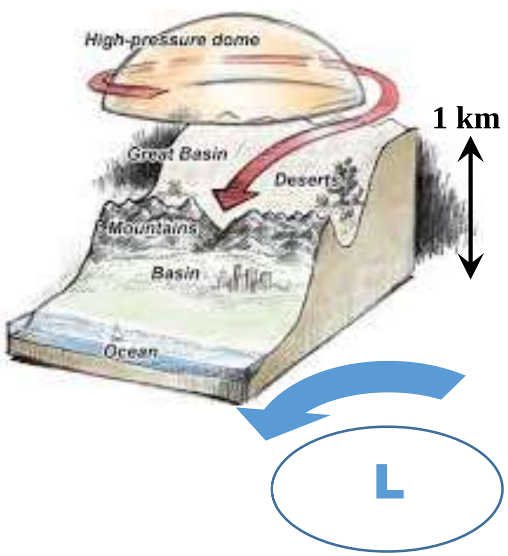


• Chinook Event
Havre, Montana, Dec 16 to 18, 1933



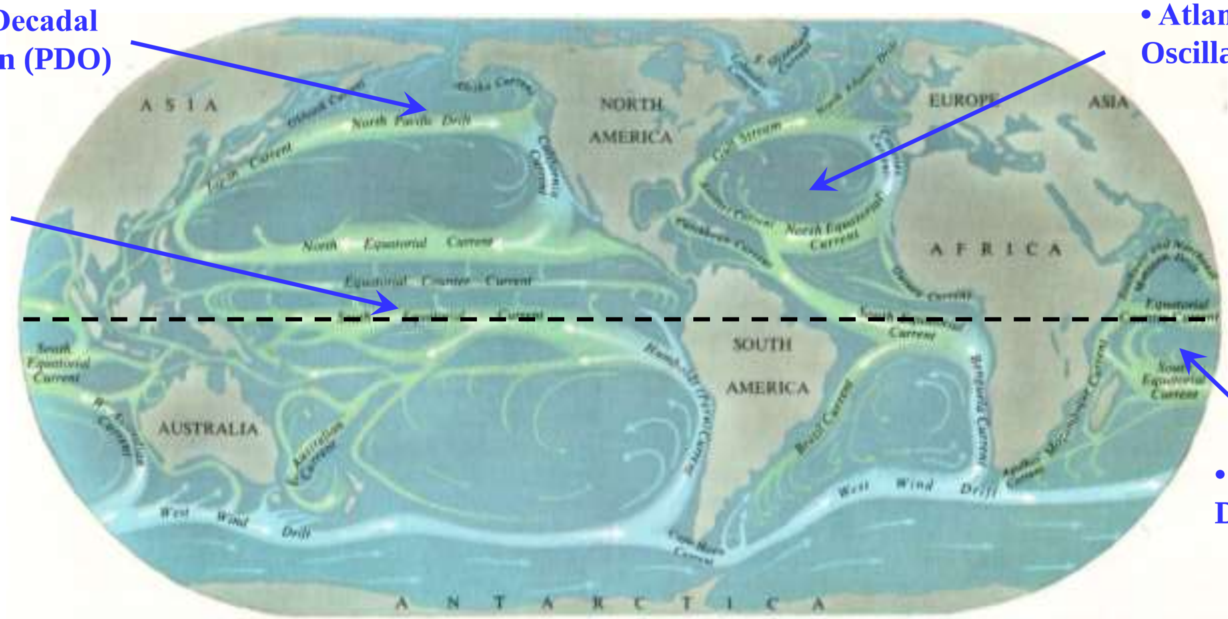
•Thermograph Trace

• Santa Ana Winds



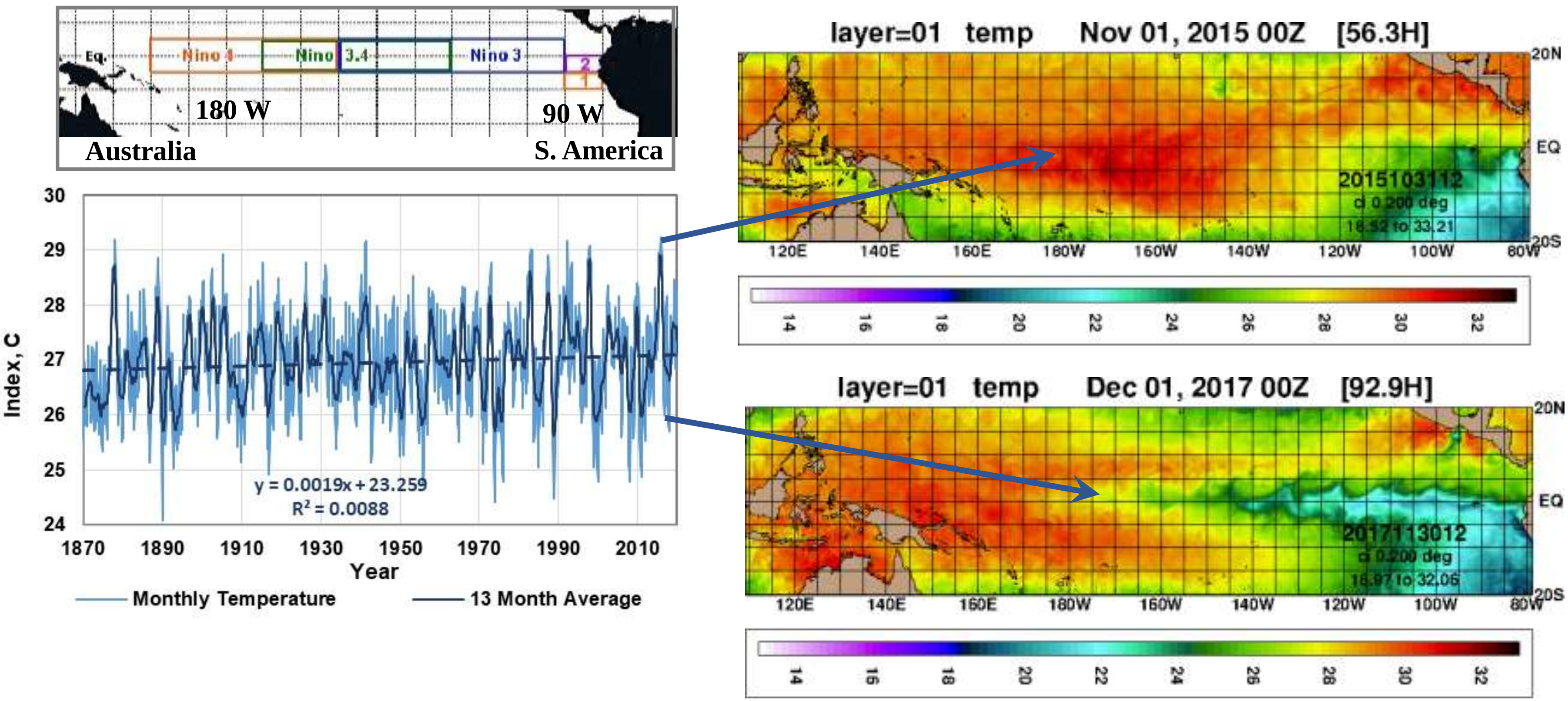
Wind Driven Ocean Gyre Structure

- S. Atlantic, S. Pacific and S. Indian Oceans coupled to S. ocean
- S. Atlantic equatorial current splits off Brazil, part feeds N. Atlantic Gyre
- Pacific equatorial currents are not centered on equator ~ 8° north
- Gyres flow on a spherical earth, area decreases with increasing latitude
- No exact balance between heating and cooling
- Ocean gyre temperatures must fluctuate - randomly
- Major impacts on climate, especially rainfall



El Nino Southern Oscillation (ENSO)

- Temperature of the central equatorial Pacific Ocean
- Short term wind driven oscillation, 3 to 7 year period
- Major climate impacts (rainfall)
- Changes area and location of the Pacific equatorial warm pool
  - Maximum ocean surface temperatures stay near 30 C



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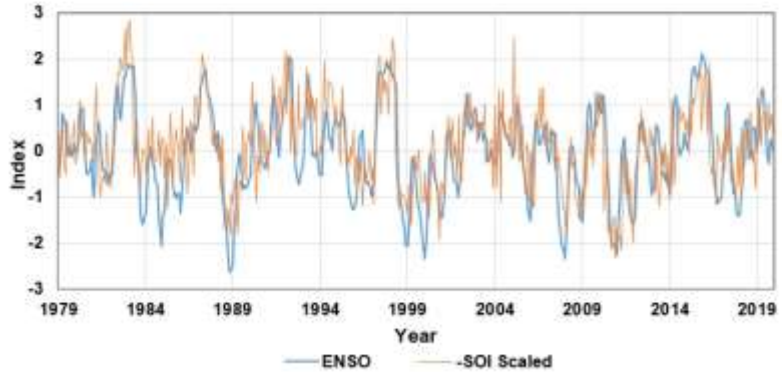
https://www7320.nrlssc.navy.mil/GLBhycomcice1-12/

ENSO, SOI and Tropical Air Temperatures

- **ENSO tracks with the (inverted) Southern Oscillation Index SOI**
- **SOI is the surface air pressure difference between Tahiti and Darwin, Australia (wind speed)**
- **Tropical temperatures in the lower troposphere follow with about a 6 month delay**

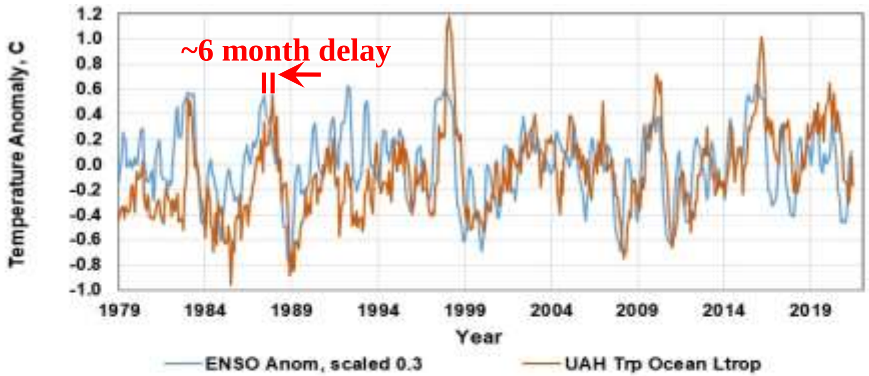
•ENSO and SOI (inverted)



ENSO,
ftp://ftp.coaps.fsu.edu/pub/JMA_SST_Index/jmasst1868-today.filter-5

SOI Index,
ftp://ftp.bom.gov.au/anon/home/ncc/www/sco/soi/soiplaintext.html

•ENSO and UAH lower troposphere tropical temperatures (satellite, microwave sounder)

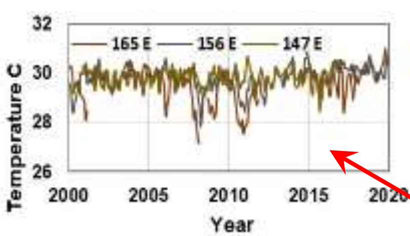


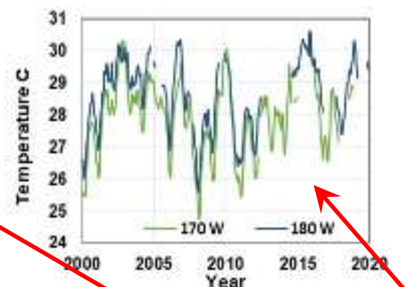
UAH,
https://www.nsstc.uah.edu/data/msu/v6.0/tlt/uahncdc_lt_6.0.txt

20 Year TRITON Network Buoy Data

- Monthly surface temperatures along the equator
- ENSO is a change in the area and location of the Pacific warm pool
- Maximum ocean temperatures do not change significantly

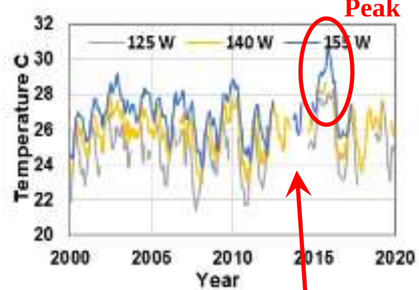
Pacific Warm Pool



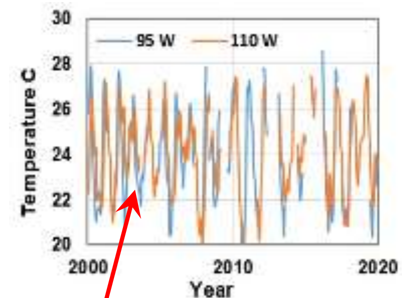


ENSO Region

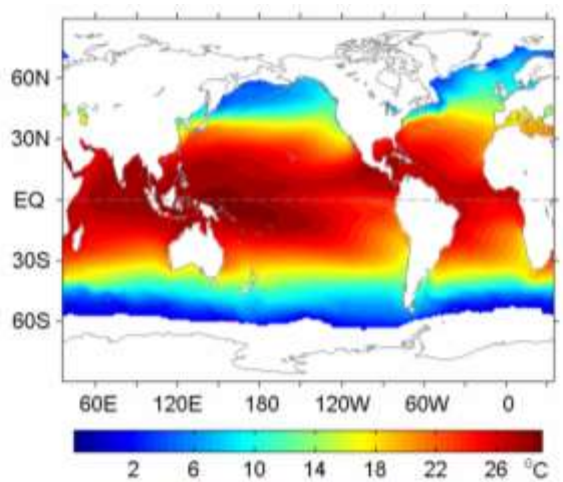
2016 ENSO Peak



Humboldt Current Feed



• Long term (50 yr) average zonal ocean temperatures

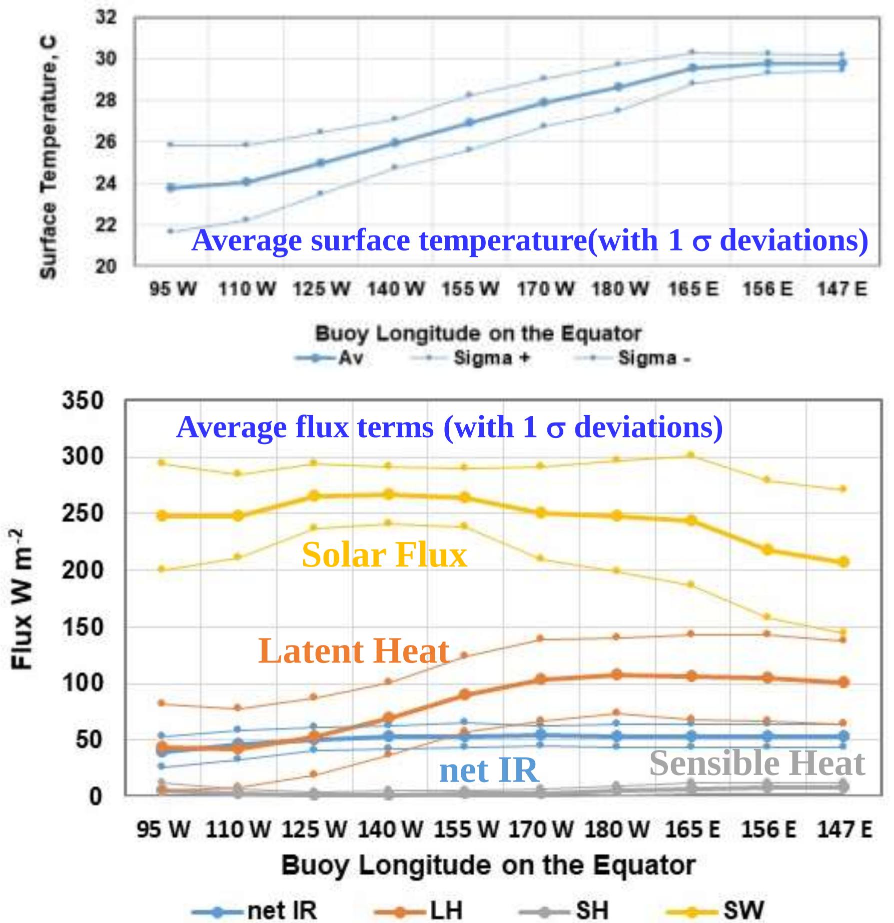


•TRITON buoy locations

TRITON, https://www.pmel.noaa.gov/tao/drupal/disdel/

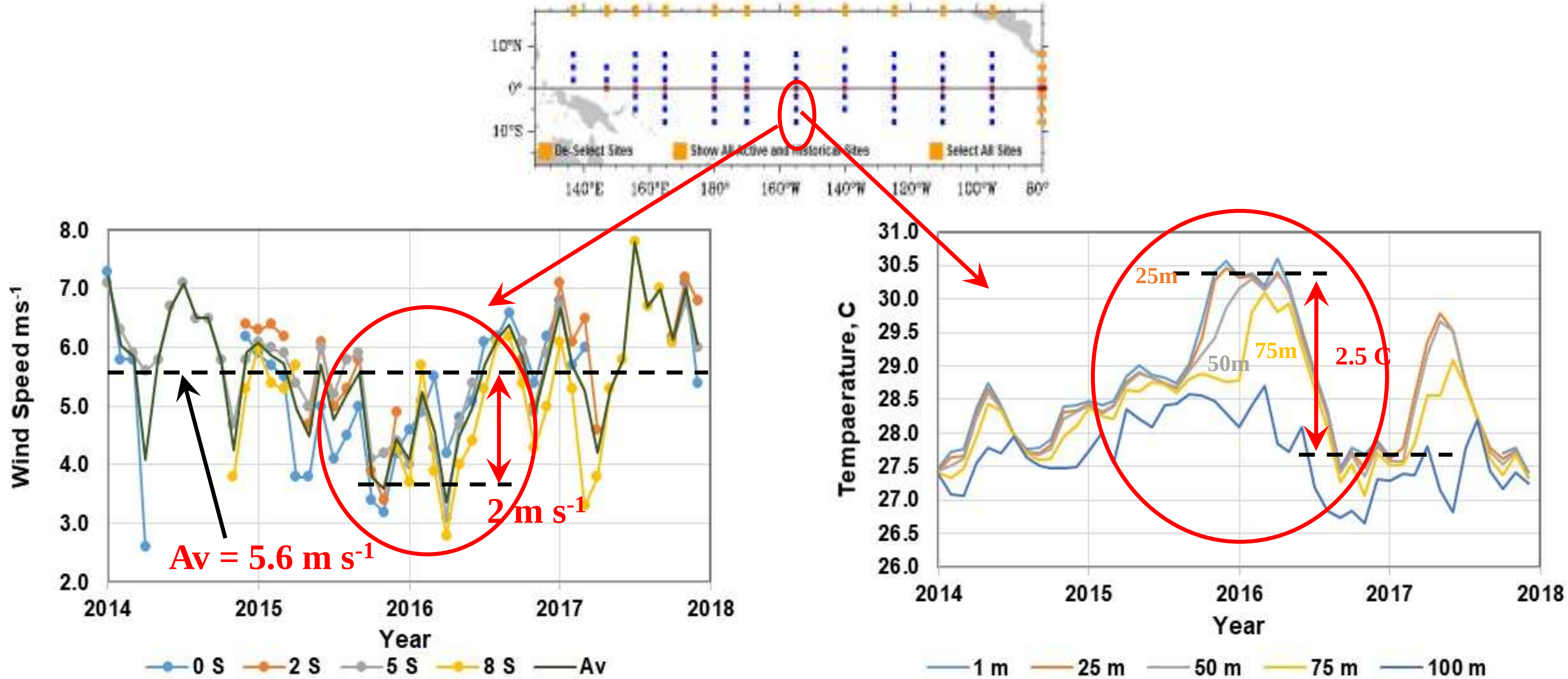
Average Surface Temperature and Flux Terms

- **Solar flux, latent heat, net IR and sensible heat flux (dry convection)**
- **Solar flux decreases by about 50 W m^{-2} E to W (clouds)**
- **Latent heat flux increases by about 60 W m^{-2} E to W**



2016 ENSO Peak, 2014 to 2017 Wind Speed And Temperature Data

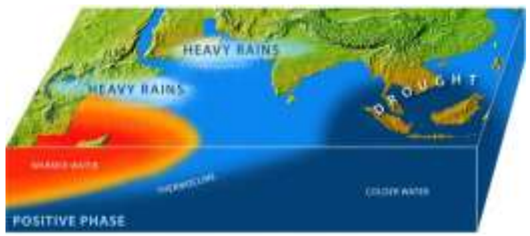
- Monthly average wind speed for the TRITON buoys at 155° W, 0°, 2°, 5° and 8° S
- Monthly average temperatures recorded by the buoy at 155° W, 5° S for depths to 100 m
- Wind speed dropped by 2 m^{-2}, Latent heat flux decreased by ~40 W m^{-2}
- 2.5 C temperature change down to 75 m ($\Delta Q \approx 800$ MJ m^{-2})



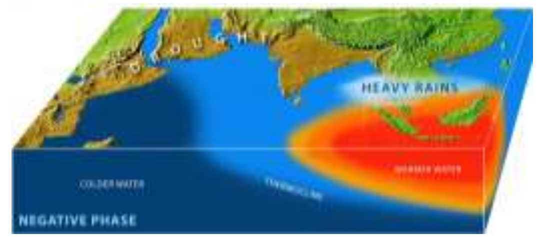
Indian Ocean Dipole, IOD

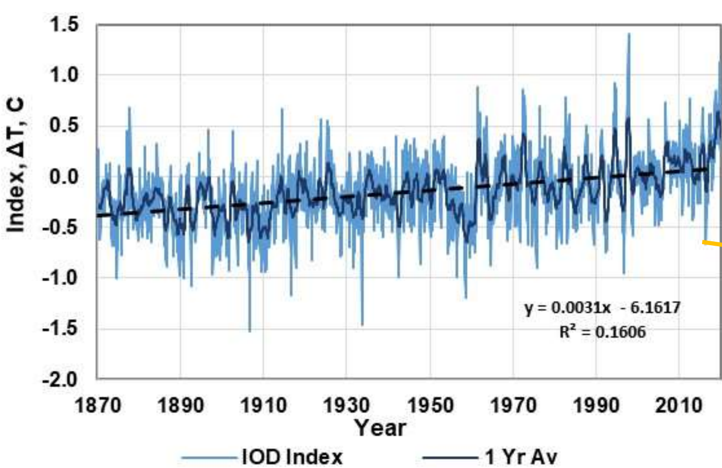
- Short term, 3 to 7 year variation
- Index measured as the East-West temperature difference
- Positive when the W Indian ocean is warmer than the E.
- Major impact on rainfall in E. Africa and Indonesia/Australia
- Indian monsoons may also be effected

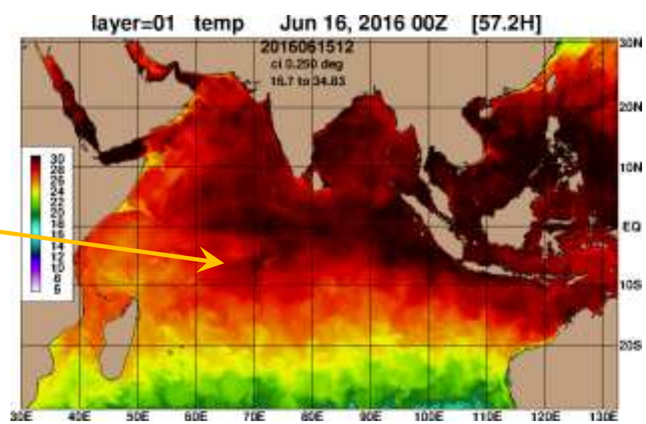
•Positive phase



•Negative phase



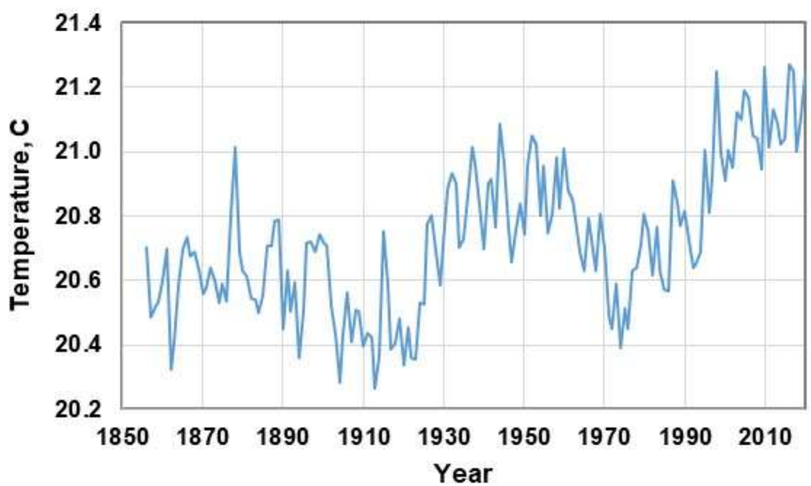




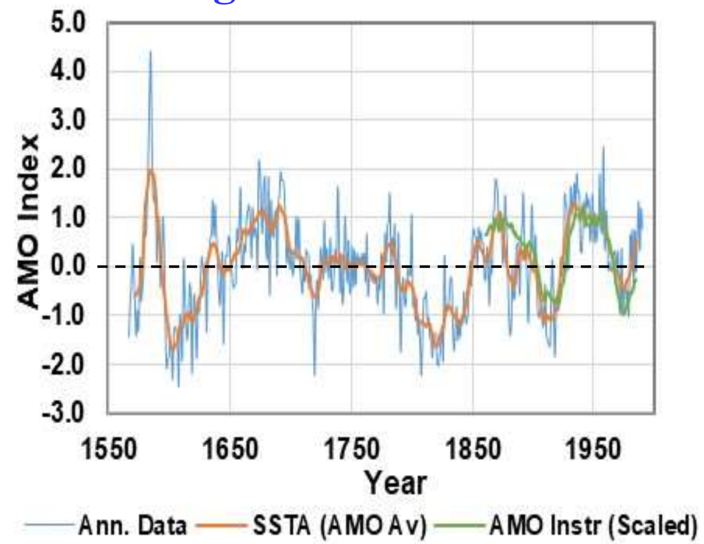
Atlantic Multi-decadal Oscillation (AMO)

- The AMO is the average surface temperature of the N. Atlantic basin 0 to 60° N
- It is a well defined, longer term 60 to 70 year cycle
- It is the dominant contributor to the global average temperature trend
- Weather systems moving onshore from the N. Atlantic Ocean have a wide influence over N. America, W. Europe, parts of Africa
- Related to variations in winter wind speed at higher latitudes in the N. Atlantic

- Annual AMO temperature

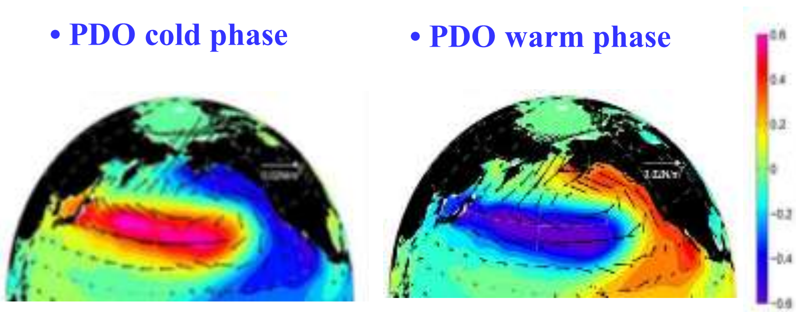


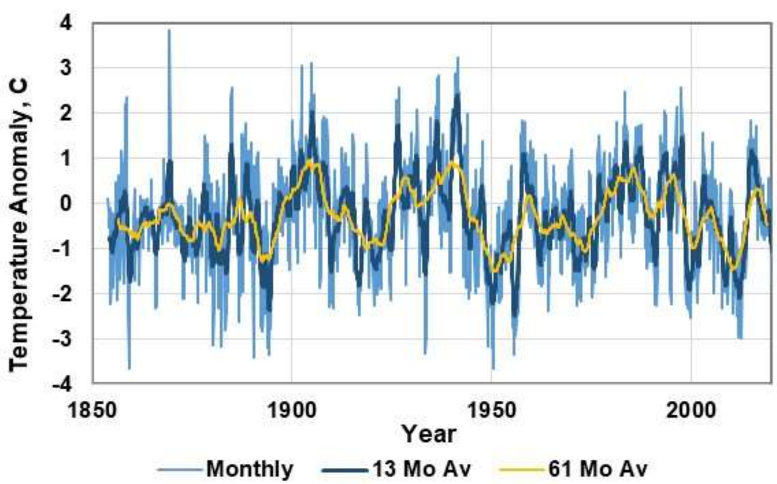
- AMO tree ring reconstruction from 1567

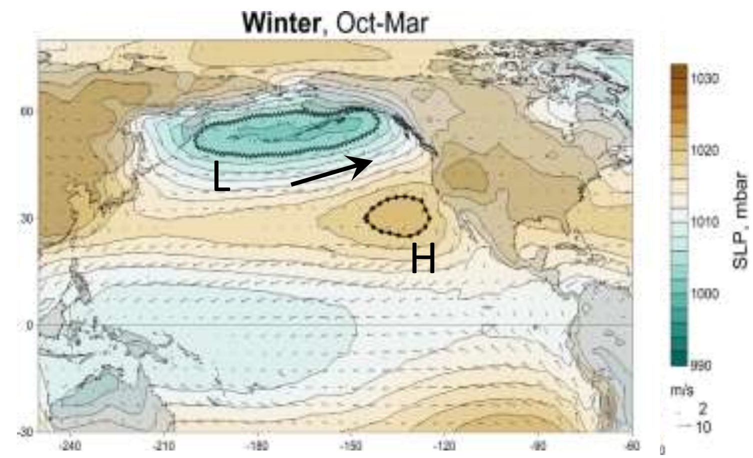


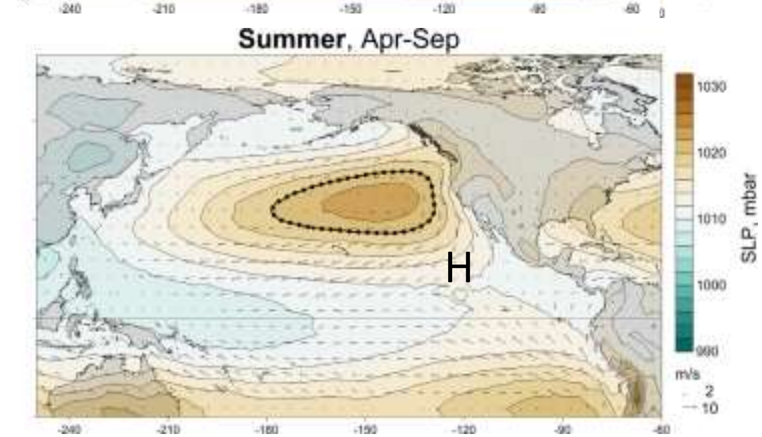
Pacific Decadal Oscillation (PDO)

- Difference in temperature across the N. Pacific Ocean
- 15 to 25 year and 50 to 70 year variations
- Interactions between the Aleutian low and mid latitude westerlies

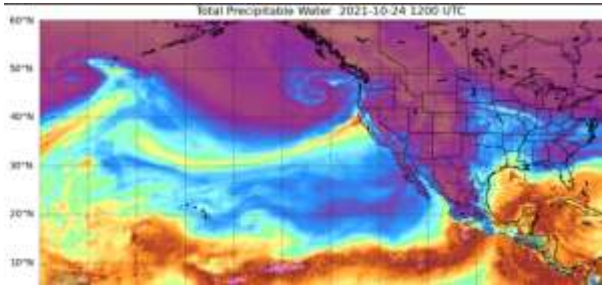








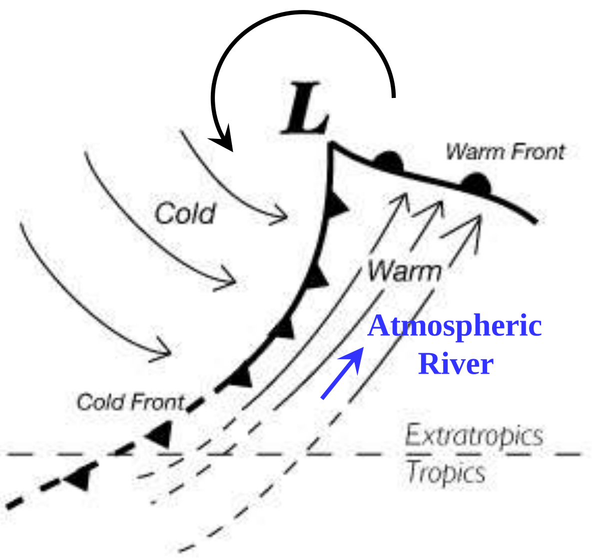
California Rainfall



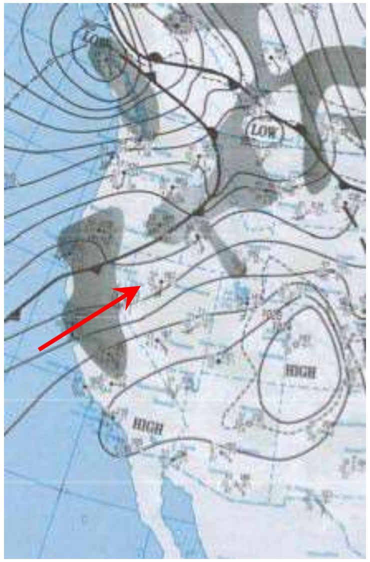
California Rainfall

- California rainfall patterns are produced by complex interactions between the US west coast winter weather systems and the PDO and ENSO
- The PDO warm phase brings more rainfall from the Gulf of Alaska
- Atmospheric river or 'Pineapple Express' – low pressure 'pulls in' moisture from the central Pacific Ocean near Hawaii

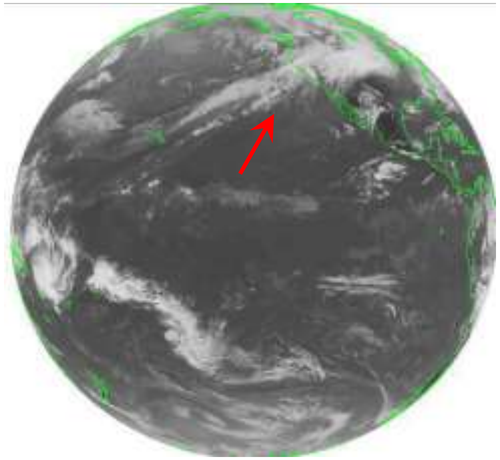
• Low pressure system



• Weather map 1/1/97



• GEOS WEST satellite IR image January 1, 1997



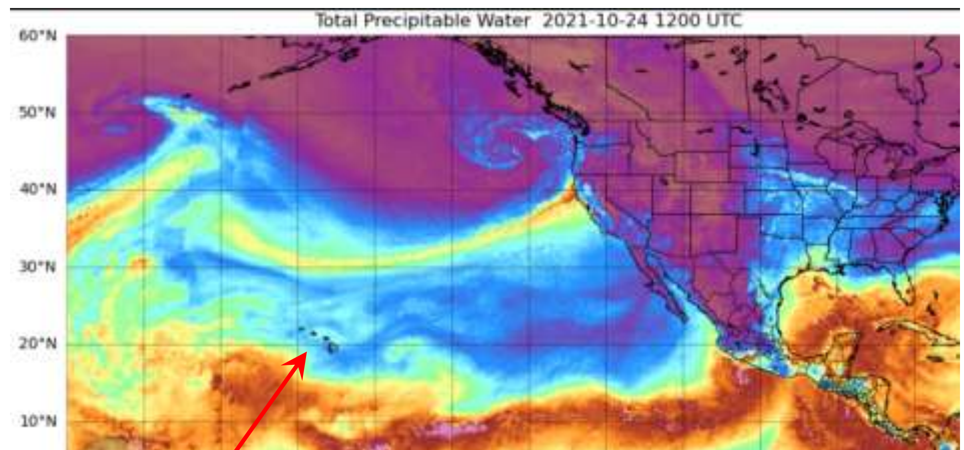
Nothing Much Has Changed in 160 Years

- **Great Sacramento Flood December 1861/January 1862**
- **'Atmospheric River' 2021**

• Sacramento, January 1862

https://en.wikipedia.org/wiki/Great_Flood_of_1862

• 'Unprecedented' atmospheric river, October 24, 2021



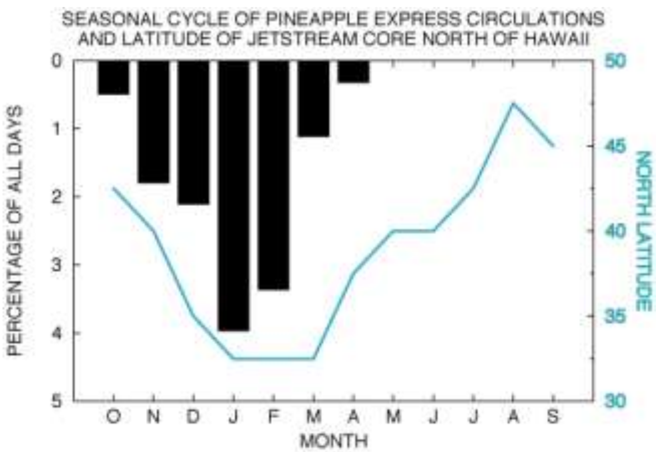
Hawaii 'Pineapple Express'

https://wattsupwiththat.com/2021/10/27/is-california-experiencing-more-weather-whiplash/

‘Pineapple Express’ Variation 1950 to 1999

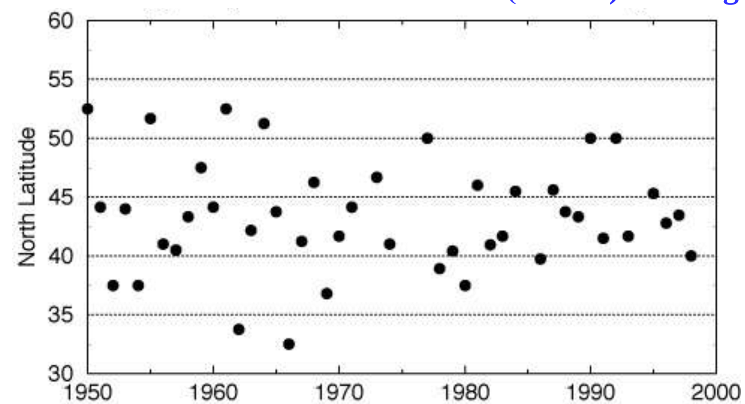
- Rainfall occurs in winter months with a January peak
- Highly variable localized ‘rivers’ mostly north of S. California
- Depends in part on jet stream latitude near Hawaii

• Seasonal cycle and jet stream latitude

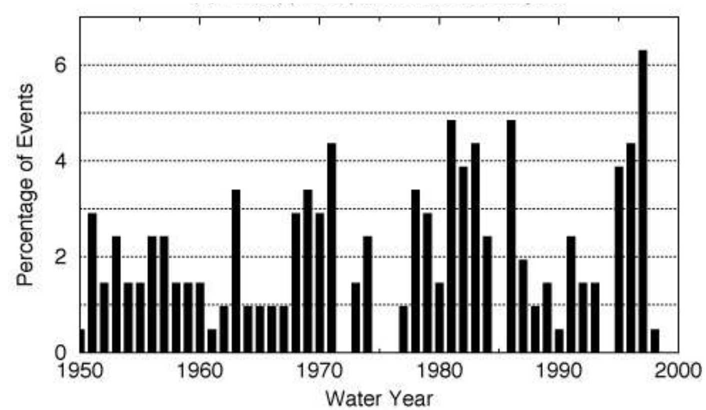


Dettinger, Jan 2004, PIER Report

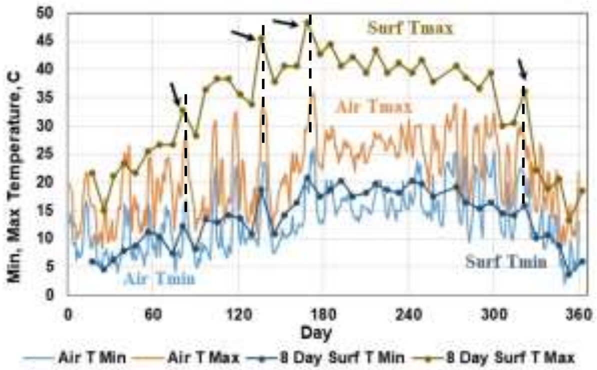
• Annual mean latitudes of west coast (120°W) crossings



• % of days per year with pineapple express events



Onshore/Offshore Flow In S. California: Measurements At Limestone Regional Park, Irvine, 2008



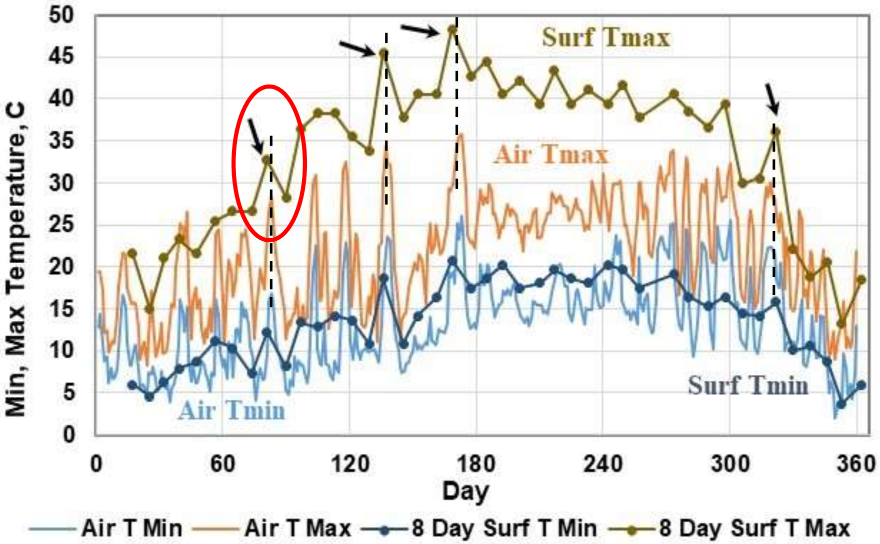
Onshore/offshore flow in S. California

- Data recorded at the Grasslands Site, Limestone Canyon Regional Park
- The temperatures show the onshore/offshore transition
  - Onshore – cooler, higher humidity, higher cloud cover
  - Offshore – warmer, lower humidity, less cloud cover
- The transition to offshore flow shows as temperature ‘spikes’
  - Occurs in both surface and air temperatures

- Measurement site location

R. Clark, Energy and Environment 24(3, 4) 341-359 (2013), https://doi.org/10.1260/0958-305X.24.3-4.341

- Min and max MSAT temperatures and 8 day average satellite surface min/max temperatures for 2008

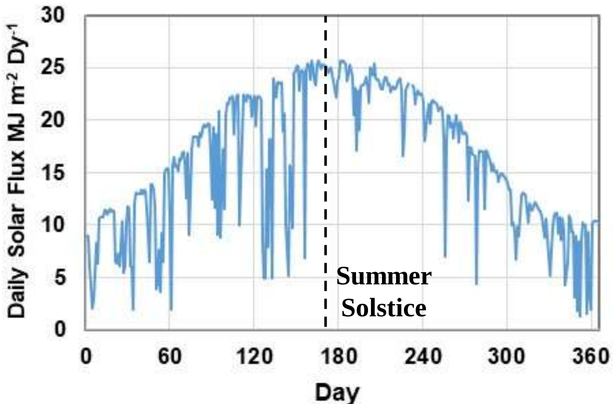


Ventura Photonics
Photonics Solutions

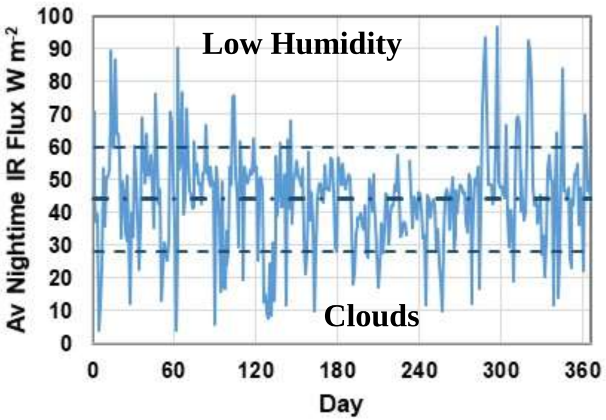
Solar, Net LWIR and Latent Heat Flux

- The solar flux depends on cloud the cover and time of year
- The annual average night time net LWIR flux is 44 ±16 W m^{-2}
- The latent heat flux peaks as the vegetation dries out after winter rains
- The daily temperature rise increases as the latent heat flux decreases

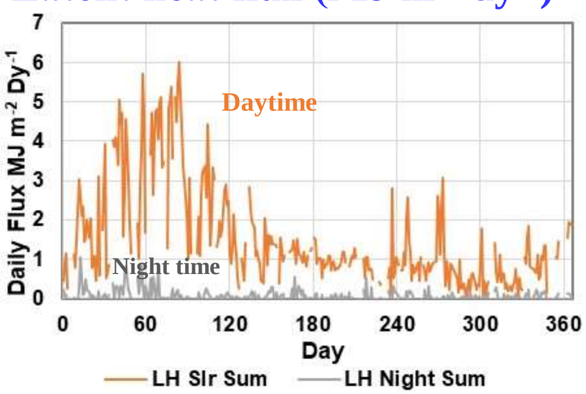
- Daily solar flux (MJ m^{-2} dy^{-1})



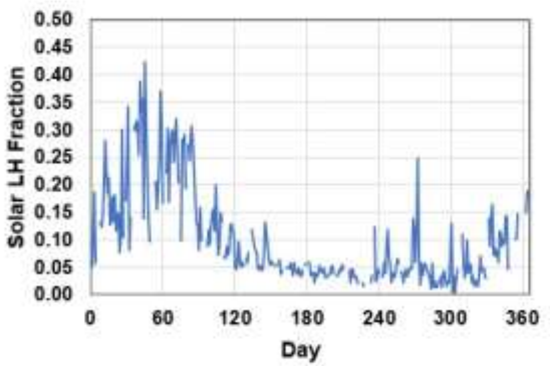
- Average night time net LWIR flux



- Latent heat flux (MJ m^{-2} dy^{-1})

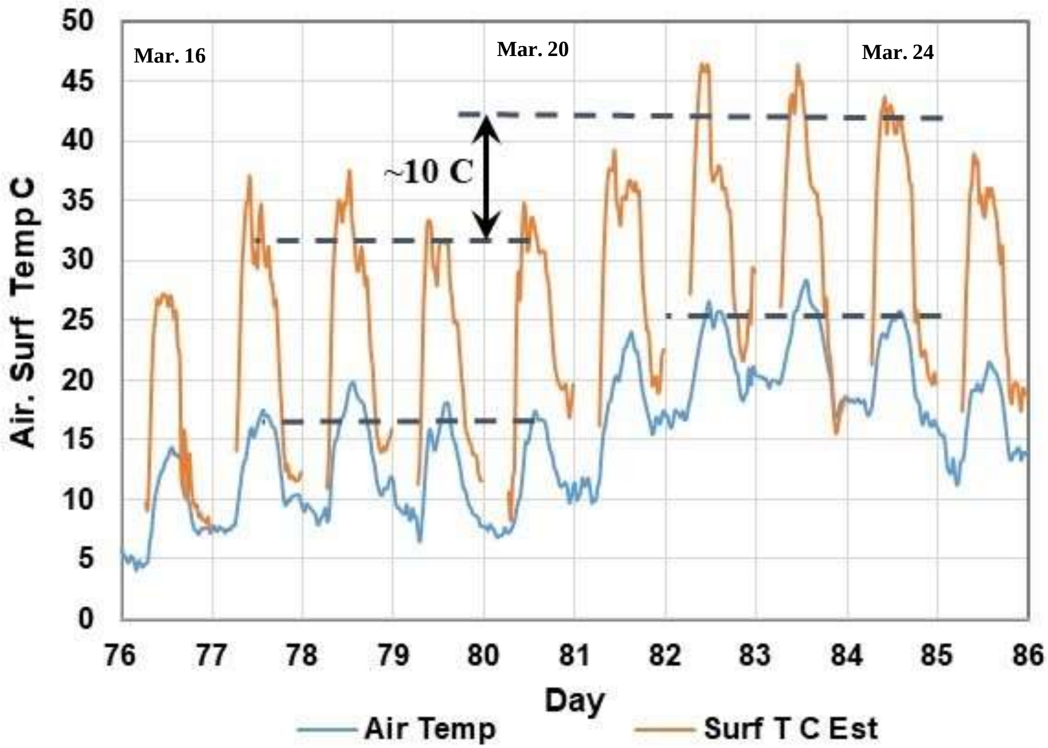


- LH as a fraction of the solar flux



Onshore to Offshore Transition Detail

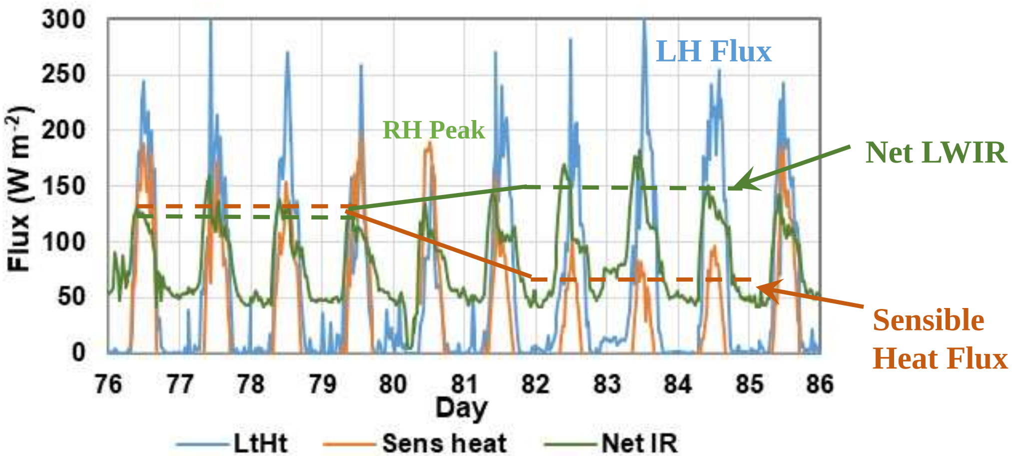
- March 16 to March 25 2008
- Surface temperature estimated from IR flux data
- ~10 C rise in air and surface temperature over 2 days
    - Downslope air compression



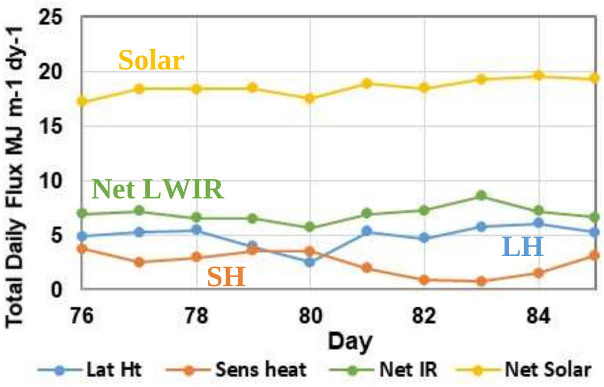
Flux Terms and Relative Humidity

- Solar flux does not change significantly
- Net LWIR flux increases with temperature
- Sensible heat flux (dry convection) decreases
- Latent heat flux changes with RH on Day 80

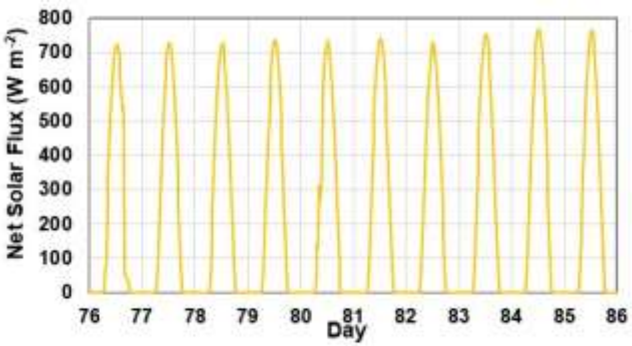
• Cooling flux terms



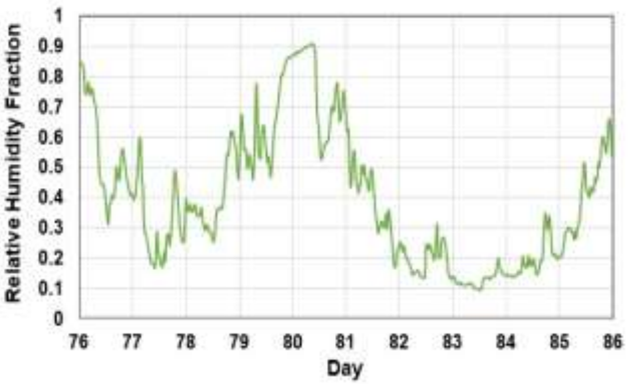
• Total daily flux



• Solar flux

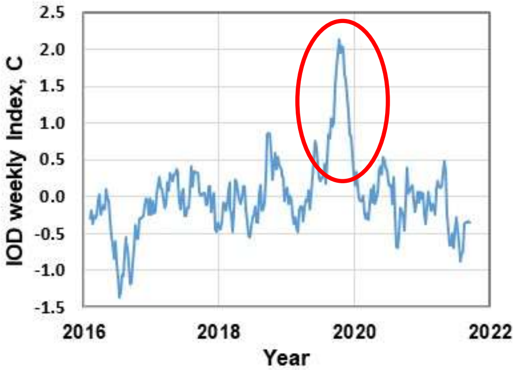


• Relative humidity

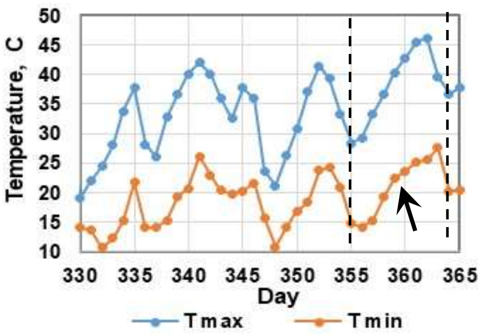


Blocking High Pressure Systems, Woomera, Australia

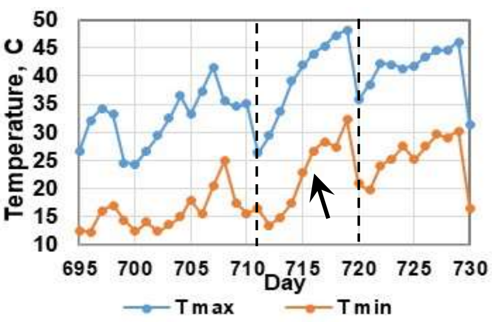
Indian Ocean Dipole



December 2018



December 2019

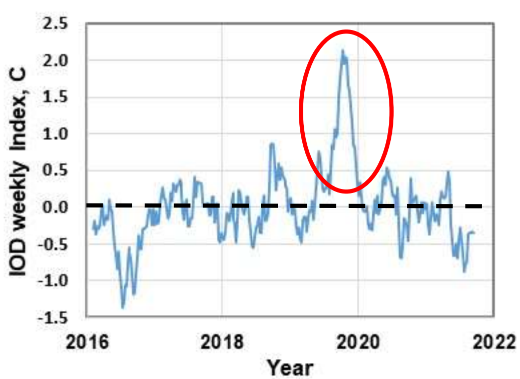


Woomera, S. Australia, 2018 and 2019

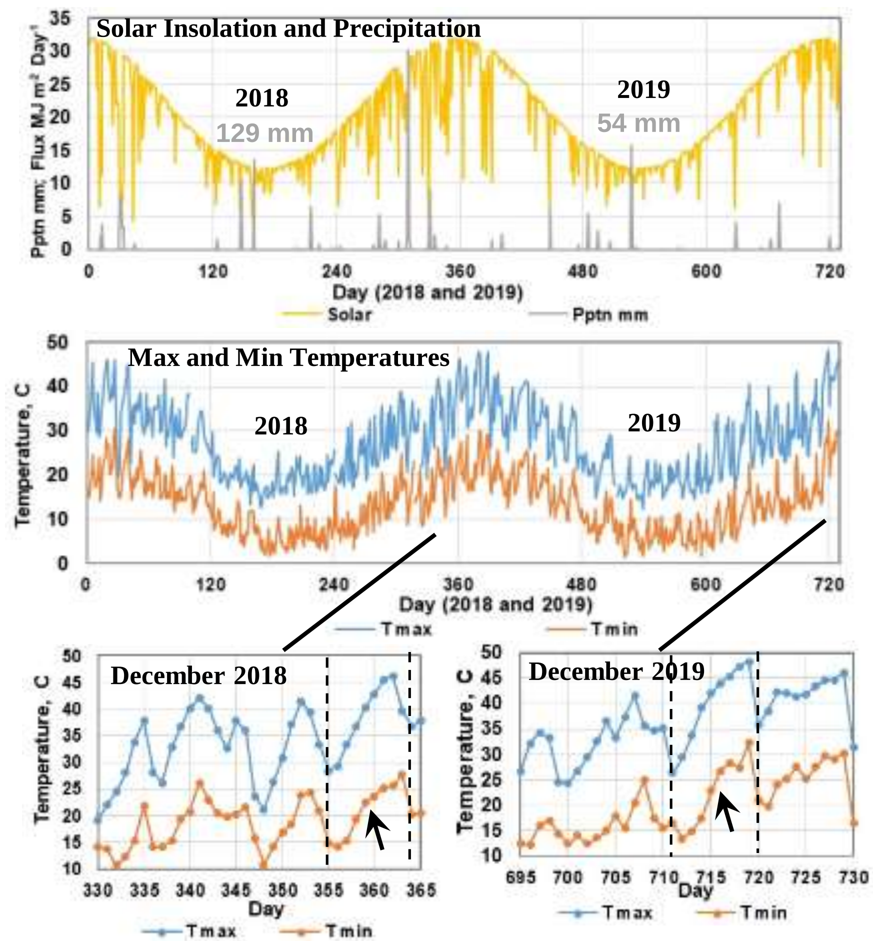
- **Solar insolation, precipitation, min and max MSAT**
- **Blocking high pressure system caused record heat in December 2019**
  - **Related to high positive IOD index**

• Location 31.16° S, 136.81° E

• Indian Ocean Dipole

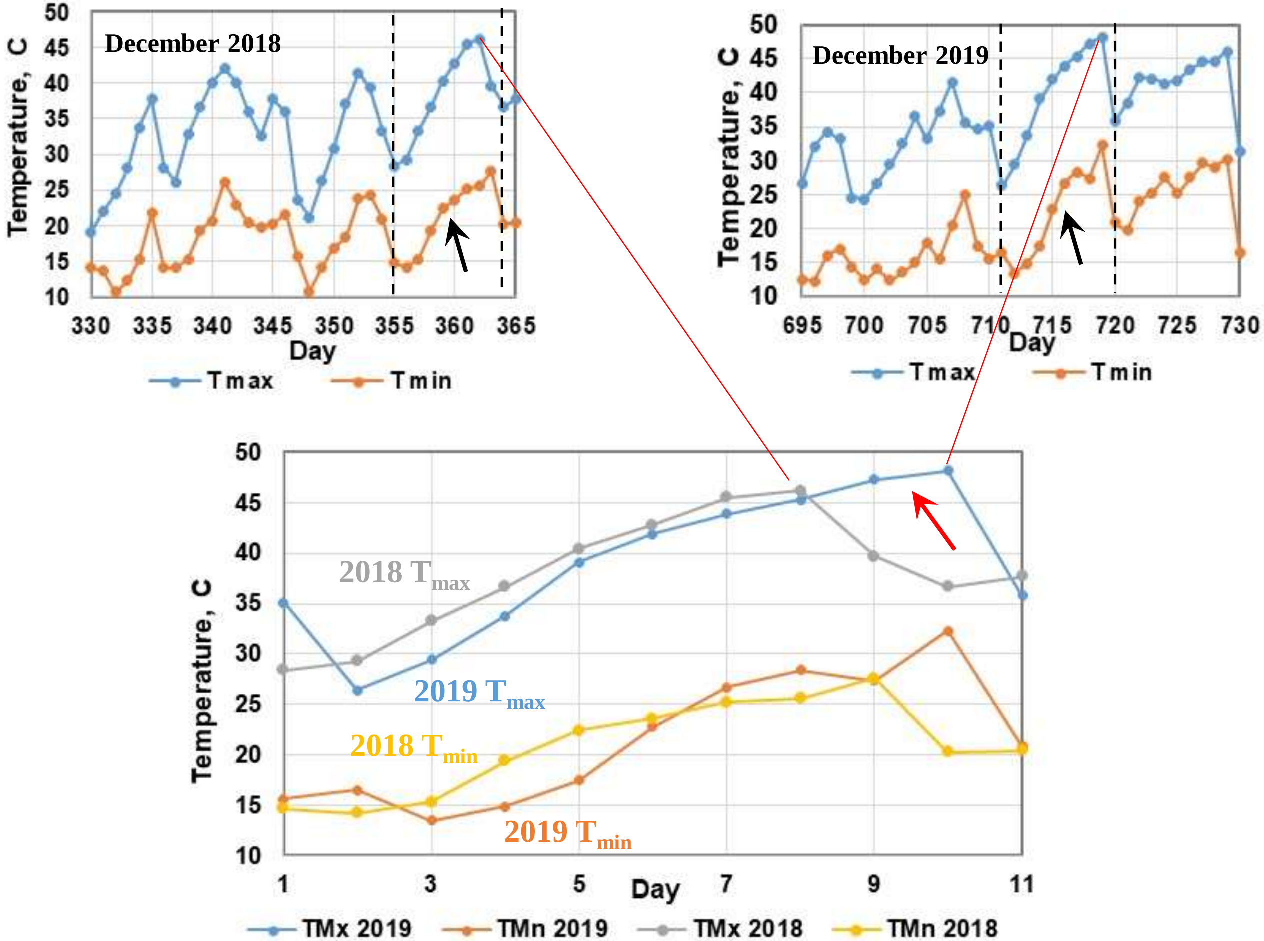


• Station Data



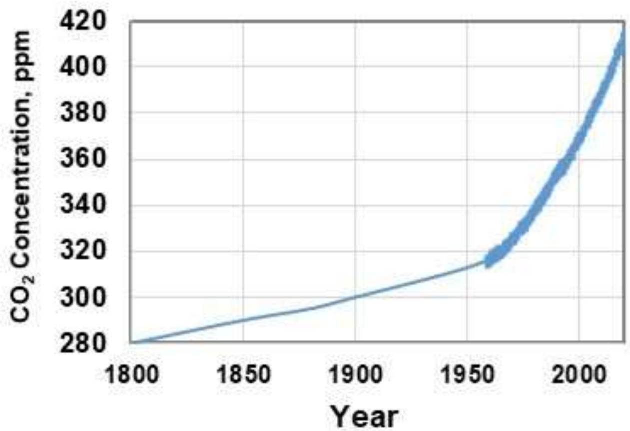
Compare 2018 and 2019 Blocking Highs

- **2018 and 2019 blocking highs overlapped on the same plot**
- **Similar profiles, 2019 blocking high lasts about 2 days longer**

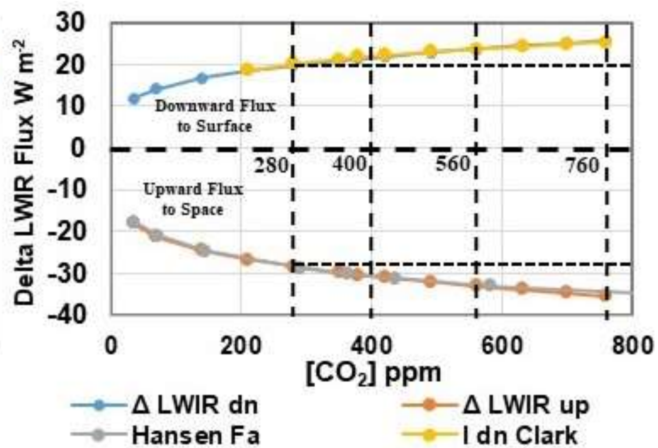


What About CO_2?

• Increase in CO_2 concentration



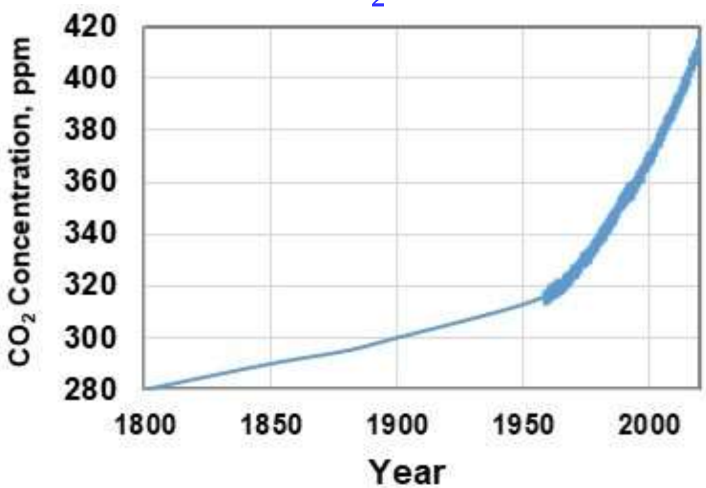
• Change in atmospheric LWIR flux



Changes CO_2 Concentration And LWIR Flux

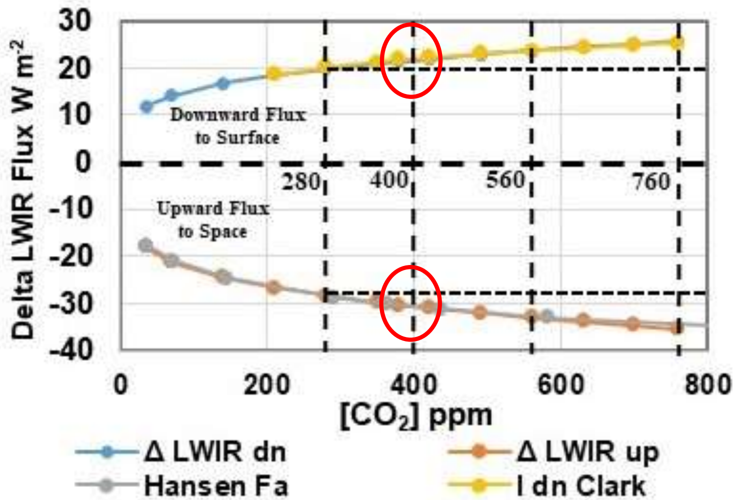
- **~120 parts per million (ppm) increase in atmospheric CO_2 concentration since 1800**
- **~2 W m^{-2} decrease in upward LWIR flux at the top of the atmosphere (TOA)**
  - **Within the CO_2 bands (re-emitted by H_2O)**
- **~2 W m^{-2} increase in downward LWIR flux to the surface**
- **Increases to ~4 W m^{-2} for a 280 ppm 'doubling' of the CO_2 concentration**
- **Present annual increase: ~2.4 ppm per year; ~0.034 W m^{-2} per year**

• Increase in CO_2 concentration



Keeling, https://scripps.ucsd.edu/programs/keelingcurve/

• Change in atmospheric LWIR flux



Harde, H., Int. J. Atmos. Sci.9251034 (2017),. https://doi.org/10.1155/2017/9251034

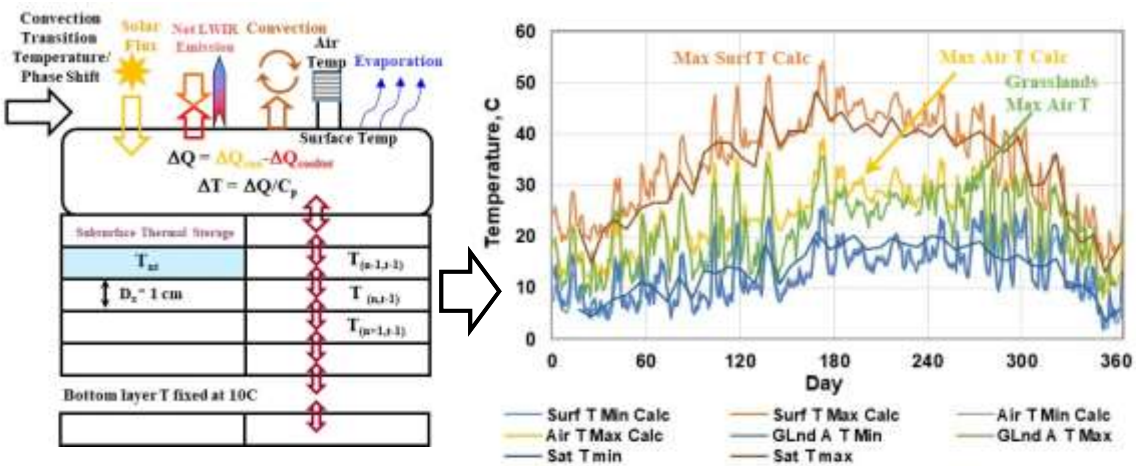
What Is The Change In Surface Temperature From A 120 ppm Increase in CO_2?

- The radiative transfer calculations are reliable
  - HITRAN was funded initially by USAF Geophysics Laboratory
- Need to calculate change in surface temperature
- Engineering calculation
  - 1) Land surface temperature ($\Delta T = \Delta Q/C_s$)
    - Develop a simple thermal reservoir model for Grasslands data
    - Increase the LWIR flux and recalculate the temperatures
  - 2) Ocean Evaporation Analysis
    - Change in LWIR flux is fully coupled to the latent heat flux
    - Calculate the sensitivity of the evaporation the wind speed
- Climate modeling approach
  - Assume *a-priori* that the change in LWIR flux at TOA causes a surface temperature change
  - Radiative forcing in an equilibrium average climate
    - Climate perturbation with forcings, feedbacks and climate sensitivity

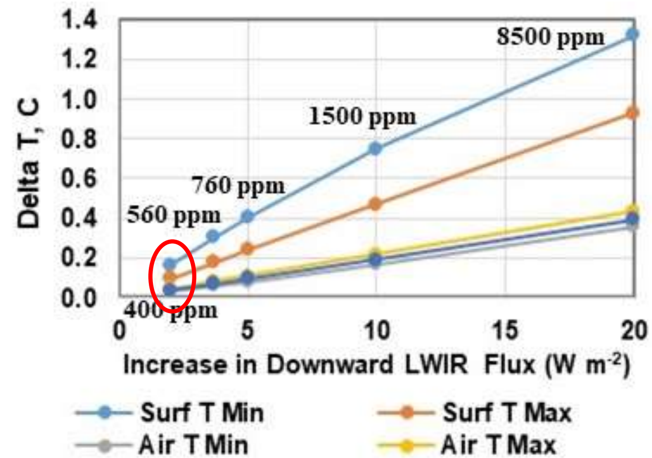
Engineering Analysis 1

- Use a simple thermal model of ‘Grasslands’ data with subsurface conduction
  - Set the daily convection transition temperature to $MSAT_{min}$
- Increase the downward LWIR flux in the model by 2 W m^{-2} and compare the results
- Continue with higher CO_2 concentrations, up to 8500 ppm/20 W m^{-2}

• Grasslands thermal model



• Increase in temperature vs. LWIR flux



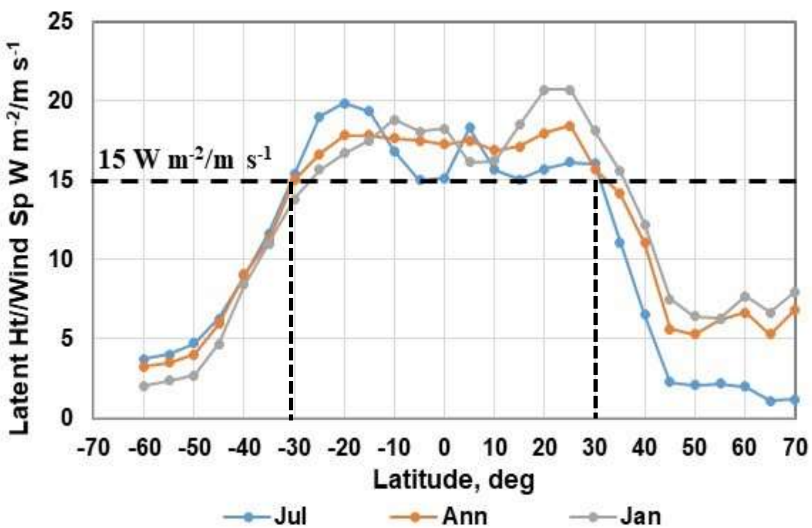
- ~0.17 C increase in annual average minimum surface (skin) temperature
- ~0.05 C increase in annual average min/max air temperature
- ~10,000 ppm CO_2 needed to reach a 1.5 rise in temperature

Engineering Analysis 2

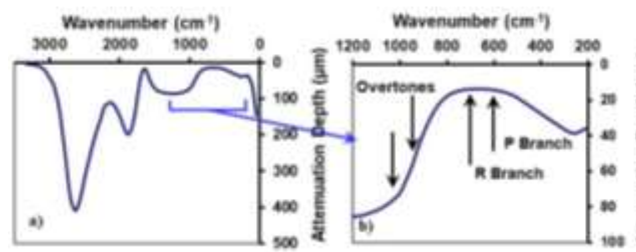
- The penetration depth of the LWIR flux into the ocean surface is < 100 micron
- The LWIR flux is fully coupled to the surface evaporation
  - The sensitivity of the evaporation to the wind speed from Yu et al, 2008
    - 15 W m^{-2}/m s^{-1} over ±30° latitude bands
    - The average Pacific equatorial ocean wind speed is ~5 ±2 m s^{-1}

- Sensitivity of the Latent heat flux to the wind speed

Yu, L., Jin, X. and Weller R. A., *OAFlux Project Technical Report* (OA-2008-01) Jan 2008, https://rda.ucar.edu/datasets/ds260.1/docs/OAFlux_TechReport_3rd_release.pdf



- Penetration depth of LWIR flux into the ocean surface



Hale, G. M. and M. R. Querry, Applied Optics, 12(3) 555-563 (1973), https://doi.org/10.1364/AO.12.000555

200 Years: 120 ppm CO_2 ≡ 2 W m^{-2} ≡ 13 cm s^{-1}

Annual: 2.4 ppm CO_2 ≡ 0.034 W m^{-2} ≡ 2 mm s^{-1}

Category 1 Hurricane
Sustained winds
75 mph, 33.5 m s^{-1}

Equilibrium Climate Model

- Equilibrium Assumption (exact conservation of energy)
    - Exact annual planetary flux balance at top of atmosphere (TOA)
    - Change in LWIR flux at TOA is a perturbation to this equilibrium
        - Now called a 'radiative forcing' (RF)
    - The surface temperature responds to restore the LWIR flux at TOA
    - The forcing is amplified by a 'water vapor feedback'
    - The surface temperature change is a linear function of the forcing

$$\Delta T = \lambda \, RF$$

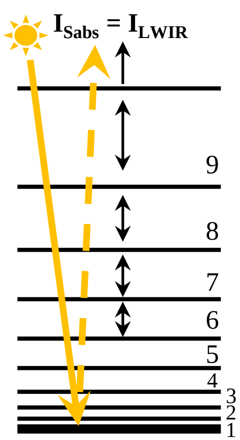
- λ is a 'climate sensitivity constant'
- All of the change in 'global average surface air temperature anomaly' is produced by radiative forcing
- No physics is required, just correlation

When the radiation balance of the Earth is perturbed, the global surface temperature will warm and adjust to a new equilibrium state. *Knutti and Hegerl, 2008*

Knutti, R. and G. C. Hegerl, Nature Geoscience 1 735-743 (2008),. https://www.nature.com/articles/ngeo337

History

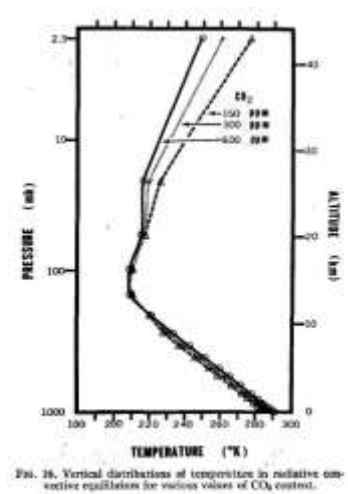
- **The equilibrium assumption started in the nineteenth century (Pouillet, 1836)**
  - **In the 1860s Tyndall proposed that changes in CO_2 concentration could cycle the earth through an Ice Age – no mention of fossil fuel combustion**
  - **An equilibrium temperature change produced by CO_2 was first calculated by Arrhenius in 1896**
  - **'Climate equilibrium' became accepted scientific dogma**
  - **Used in the first 'radiative convective equilibrium' climate model in 1967**
  - **Must create global warming by definition as a mathematical artifact of the initial model assumptions**
  - **New pseudoscience topic: computerized climate fiction**



Exact steady state flux balance at TOA

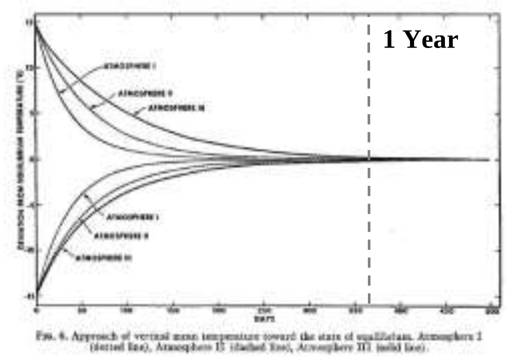
9 or 18 atmospheric layers with fixed RH distribution

Blackbody Surface with zero heat capacity



Manabe and Wetherald J. Atmos. Sci., 24 241-249 (1967)

Model takes a year of step iteration time to reach equilibrium



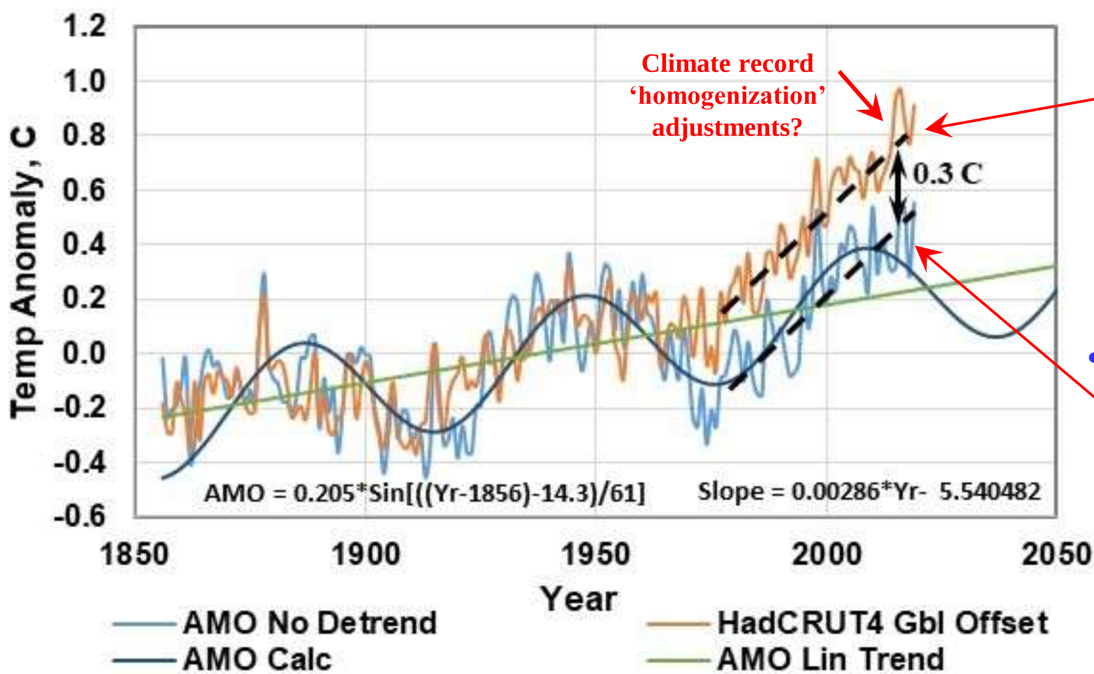
Arrhenius, S., Philos. Trans. 41 237-276 (1896), http://empslocal.ex.ac.uk/people/staff/gv219/classics.d/Arrhenius96.pdf

• Has anyone found the Second Law of Thermodynamics?

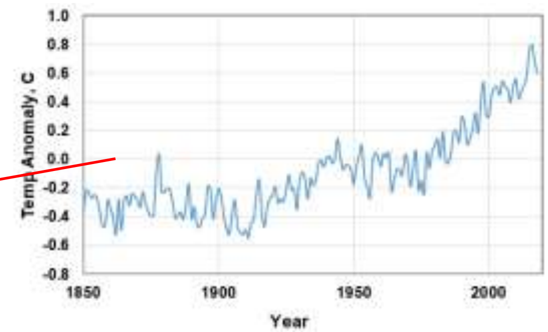
AMO And HadCRUT4 Temperature Series

- HadCRUT4 is the global area weighted average MSAT anomaly
  - The temperatures are processed and 'binned' into latitude/longitude blocks
- The correlation coefficient between AMO and HadCRUT4 is 0.8
- The AMO is coupled to weather station record through the convection transition temperature

- AMO Index and HadCRUT4 Global Climate Record

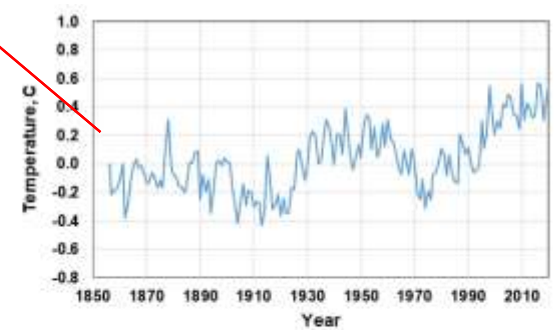


- HadCRUT4 Global Climate Record



https://www.metoffice.gov.uk/hadobs/hadcrut4/data/current/time_series/HadCRUT.4.6.0.0.annual_ns_avg.txt

- Atlantic Multi-decadal Oscillation (AMO)



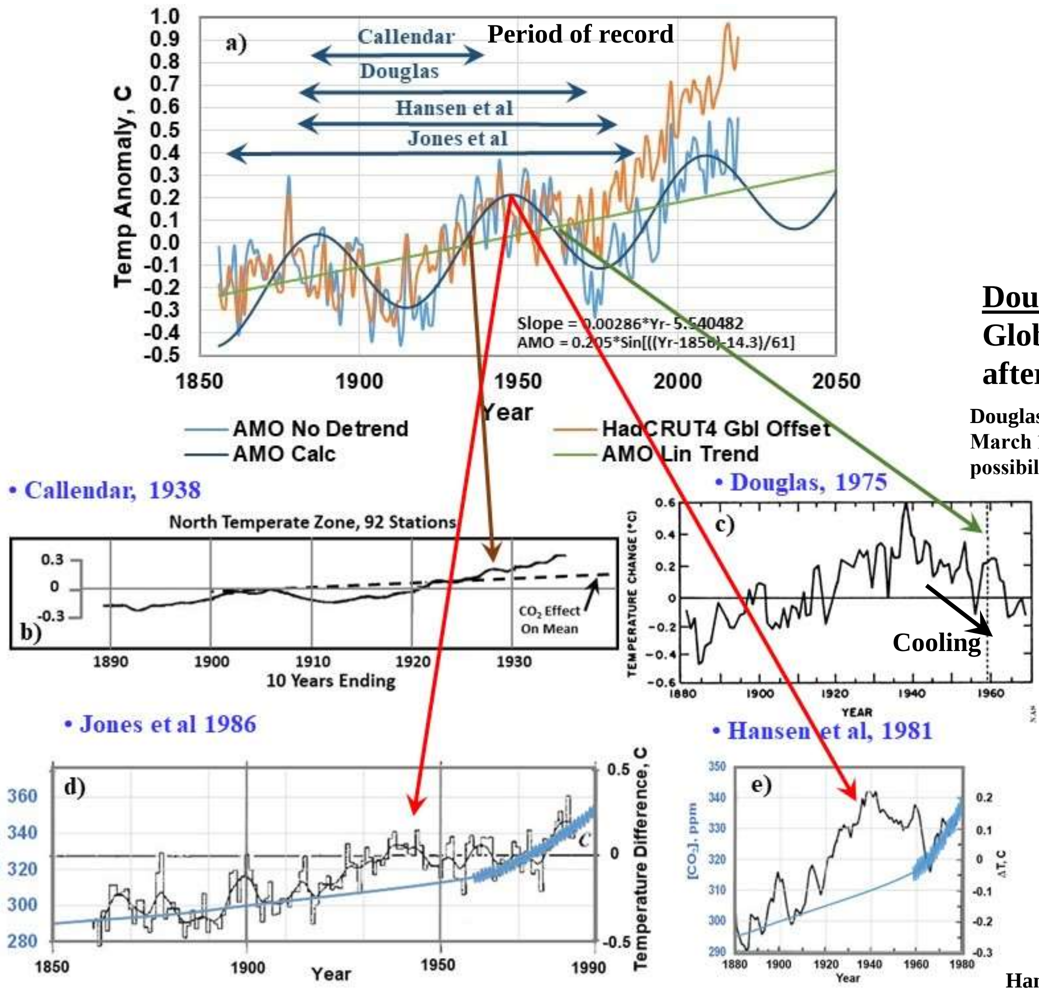
https://www.esrl.noaa.gov/psd/data/correlation/amon.us.long.mean.data

AMO and 'Climate Change'

- **AMO signal used to create warming and cooling by 'cherry picking' the data**

Callendar, 1938
First person to 'detect' CO_2 induced warming in the climate record. He really found the warming phase of the AMO from 1910

Callendar, G. S., <u>J. Roy. Met. Soc.</u> 64 223-240 (1938), 'The artificial production of carbon dioxide and its influence on temperature',



<u>Douglas, 1975</u>
Global cooling scare after the 1940 AMO peak

Douglas, J. H., <u>Science News</u> 107 138-140 March 1, (1975), 'Climate change: chilling possibilities'

Jones et al, 1986
Started the latest global warming scare using the AMO warming phase from ~1975

Jones, P. D.; T. M. Wigley and P. B Wright, <u>Nature</u> 323 (31) 430-434 (1986), 'Global temperature variations between 1861 and 1984'

<u>Hansen, 1981</u>
Ignored the 1940 AMO peak in his claims of global warming

Hansen, J. et al <u>Science</u> 213 957-956 (1981), 'Climate impact of increasing carbon dioxide'

The Climate Sensitivity To A 'CO_2 Doubling'

- This is the 'global average surface temperature' increase produced by a 'doubling' of the CO_2 concentration
- It is based on the correlation between AMO/HadCRUT4 and CO_2
- It is assumed that ocean heating is caused by 'radiative forcing' (CO_2 etc)
- Two pseudoscientific climate sensitivities are defined:
  - Equilibrium Climate Sensitivity, ECS
    - Climate response to RF from a step jump in [CO_2] after ocean equilibration
  - Transient Climate Response, TCR
    - The temperature response to ramp in CO_2 concentration
      - Usually a 1% per year increase

$$ECS = F_{2x}\Delta T/(\Delta F - \Delta Q) \qquad TCR = F_{2x}\Delta T/\Delta F$$

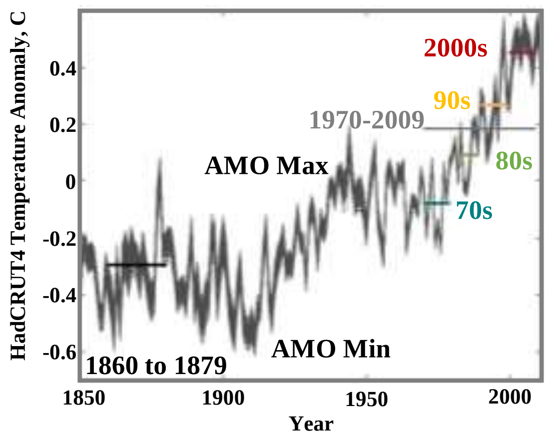
- F_{2x} is the radiative forcing from a CO_2 doubling (3.44 W m^{-2})
- ΔF is the increase in radiative forcing created by the climate modelers for a given CO_2 concentration
- ΔT is (ocean) temperature change
- ΔQ is change in 'earth system heat content', mainly ocean heat uptake
  - (Units are W m^{-2})

Otto et al, Nature Geoscience, 6 (6). 415-416 (2013)
http://eprints.whiterose.ac.uk/76064/7/ngeo1836(1)_with_coversheet.pdf

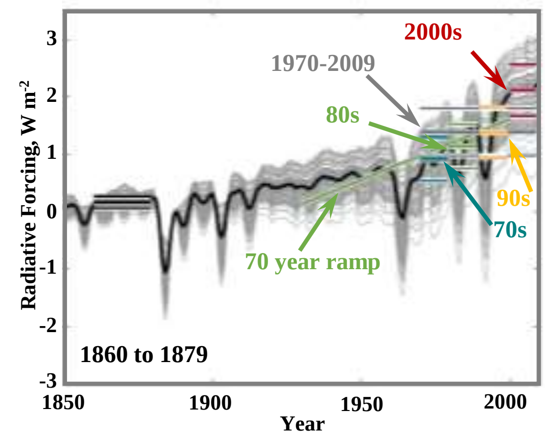
The Determination Of The Climate Sensitivity

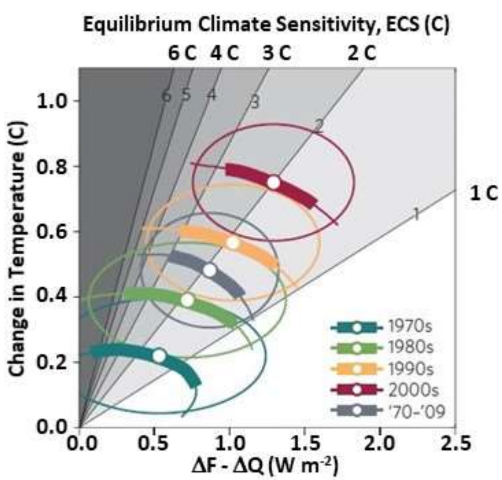
- Determine ‘decadal’ changes in temperatures and forcings
- Plot T vs. [ΔF – ΔQ] for ECS and T vs. ΔF for TCR

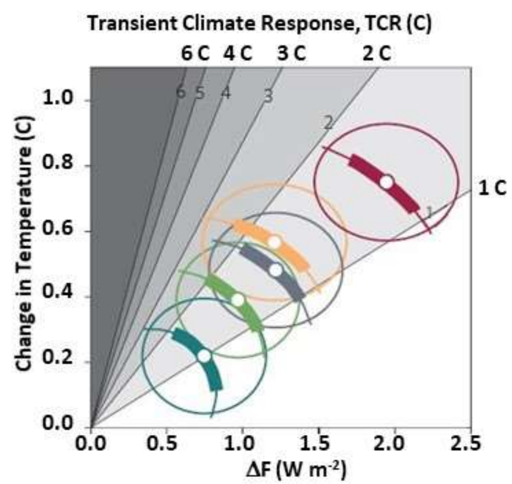
• HadCRUT4 temperature series used by Otto et al.



• Radiative forcing series used by Otto et al.





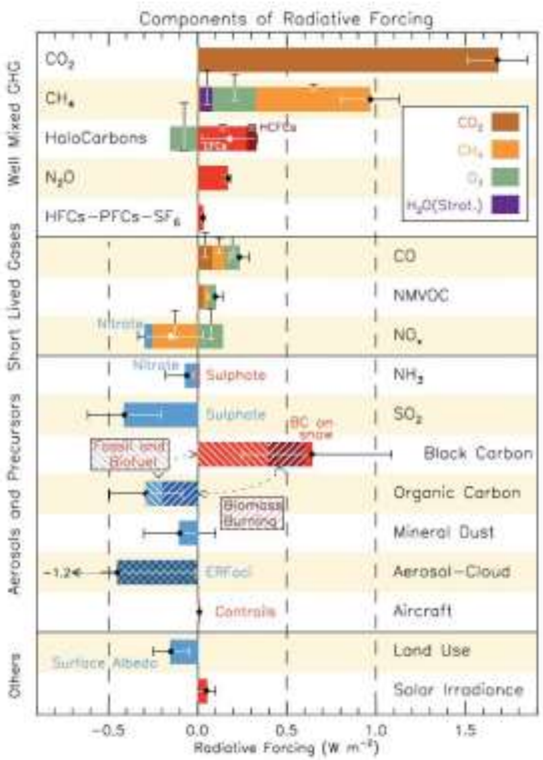


Otto et al, Nature Geoscience, 6 (6). 415-416 (2013)

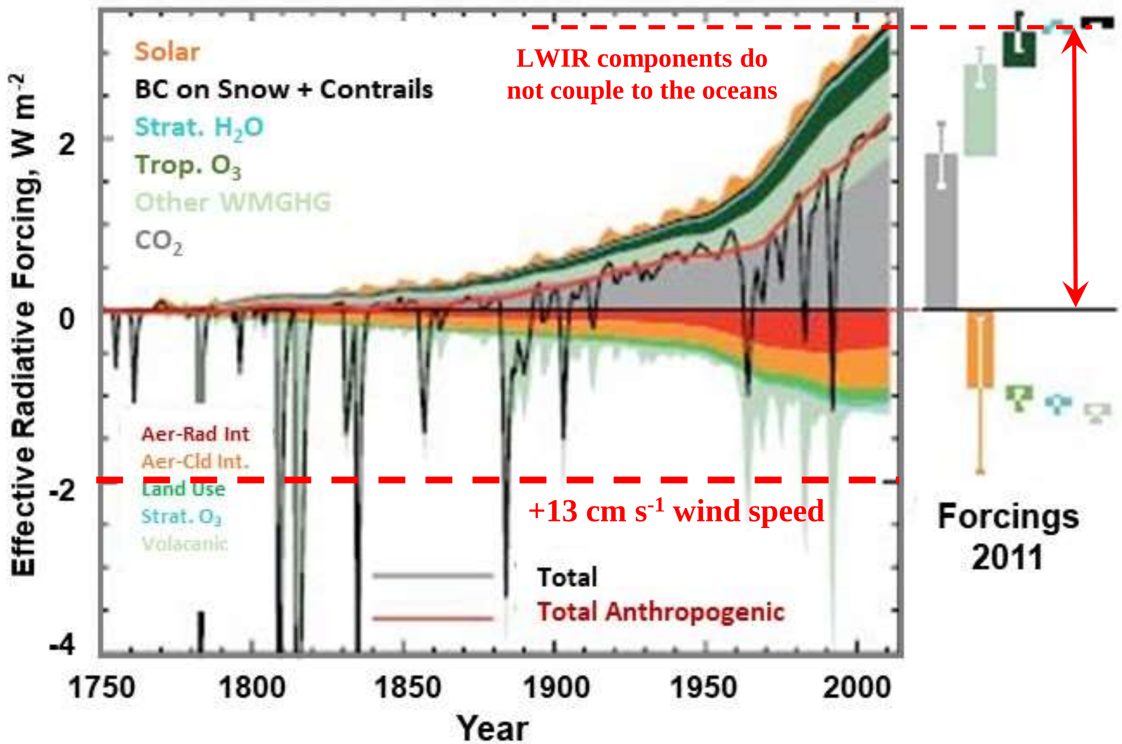
Components Of Radiative Forcing

- The radiative forcing components from IPCC AR5, WGp1
- The LWIR components cannot couple below the ocean surface
- Aerosols are used as empirical 'tuning knobs' to cool the model

• Radiative forcing components [IPCC AR5 2013]



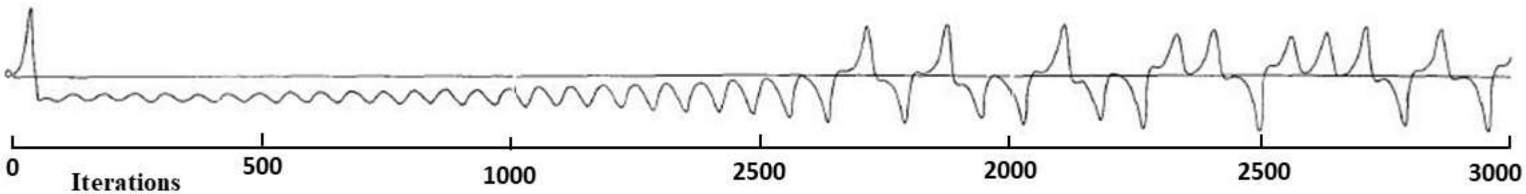
• Time evolution of the radiative forcing components from IPCC AR5 [2013]



IPCC, 2013: Myhre, G., et al In: *Climate Change 2013: The Physical Science Basis.* [Stocker, T.F., et al(eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, Chapter 8, Radiative Forcing 1535 pp, doi:10.1017/CBO9781107415324. http://www.climatechange2013.org/report/full-report/

Lorenz Instabilities

- Lorenz [1963] found instabilities in a simple 3 equation convection model



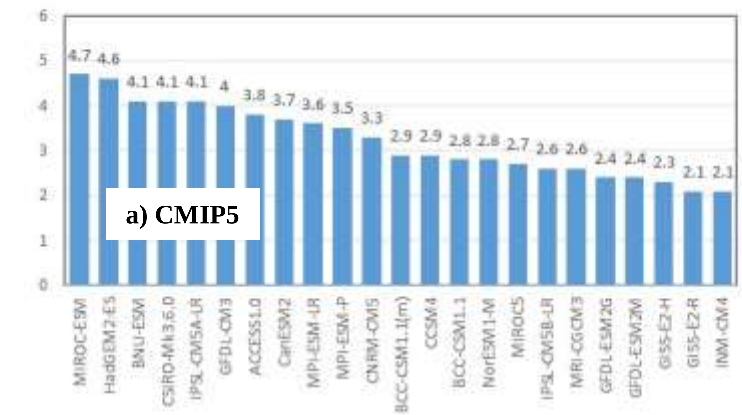
- The solutions to the climate coupled fluid dynamics equations are unstable
- Weather forecasts become unreliable after about 10 days
- Climate models are no exception (6 month limit for ocean oscillations?)
- The climate models are 'tuned' to created the desired outcome
- Usually this involves 'hindcasting' to imitate the historical record
- This is usually the 'global surface air temperature anomaly'
  - Area weighted average of 'homogenized' weather station data with mean subtracted
  - Homogenization adjustments for 'bias' and 'infill' create warming
- Temperature anomaly dominated by AMO

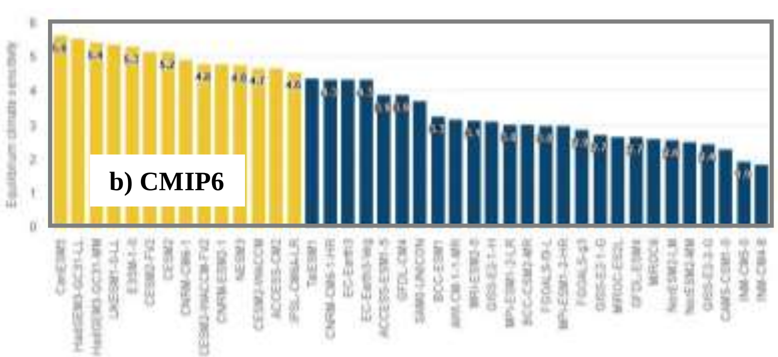
Lorenz, E.N., Journal of the Atmospheric Sciences 20, pp. 130-41 (1963), 'Deterministic non-periodic flow.'
http://eaps4.mit.edu/research/Lorenz/Deterministic_63.pdf

Climate Model ECS and Temperature 'Prediction'

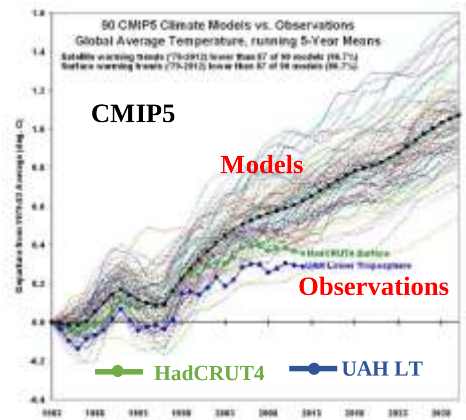
- **ECS for CMIP5 and CMIP6 climate models**
- **Pseudoscience of 'climate sensitivity' used to generate 1.5 or 2 C limit in the Paris climate Accord**

• CMIP5 and CMIP6 climate model ECS
(°C increase in 'equilibrium temperature for 280 ppm 'CO_2 doubling')

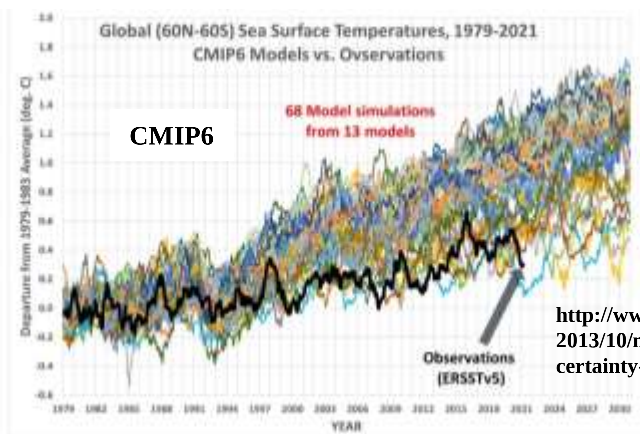




• Models tuned to create non existent warming based on sensitivity to CO_2

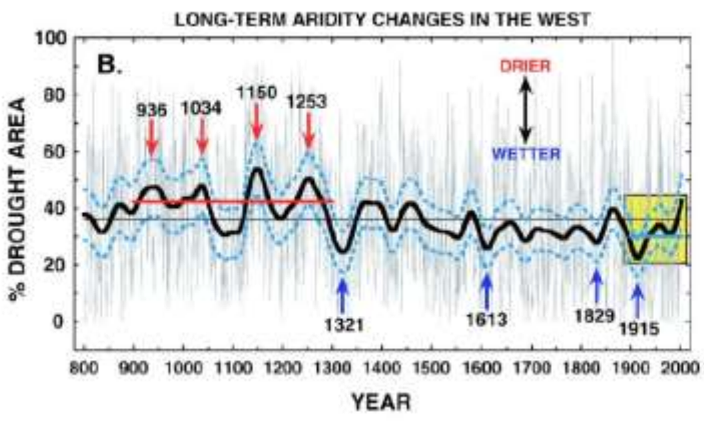


http://www.drroyspencer.com/2021/04/an-earth-day-reminder-global-warming-is-only-50-of-what-models-predict/



http://www.drroyspencer.com/2013/10/maybe-that-ipcc-95-certainty-was-correct-after-all/

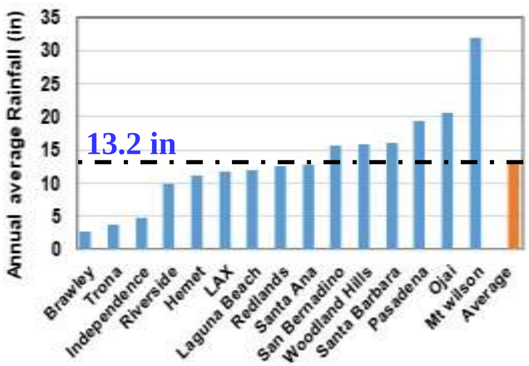
Future Trends?



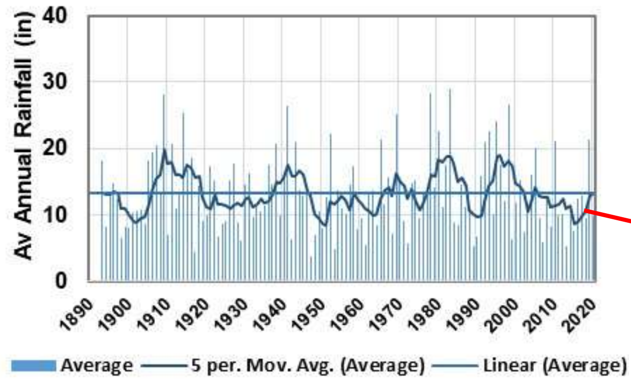
Annual Rainfall Data, Selected Stations

- No Long Term Linear Trend over 120 years
- 5 year averages related to PDO

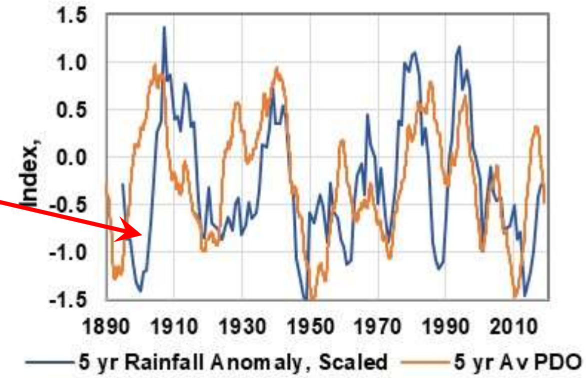
• Long Term Average Annual Rainfall by Station



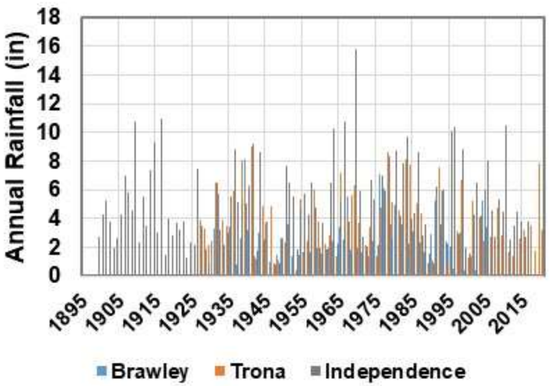
• 15 Station Average Annual Rainfall

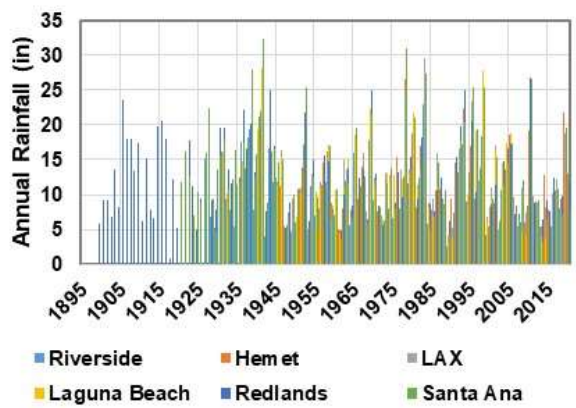


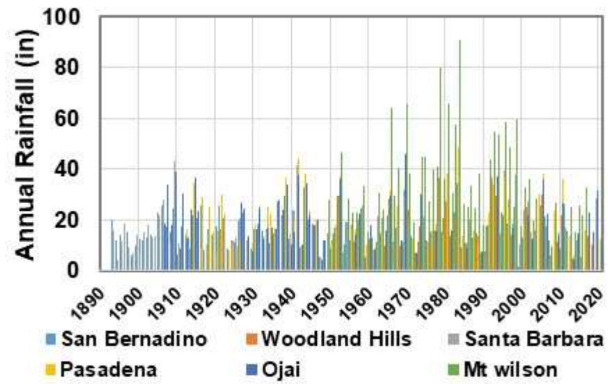
• 5 Year Averages
All station Rainfall and PDO



• Station Data, 15 Stations, Annual Rainfall



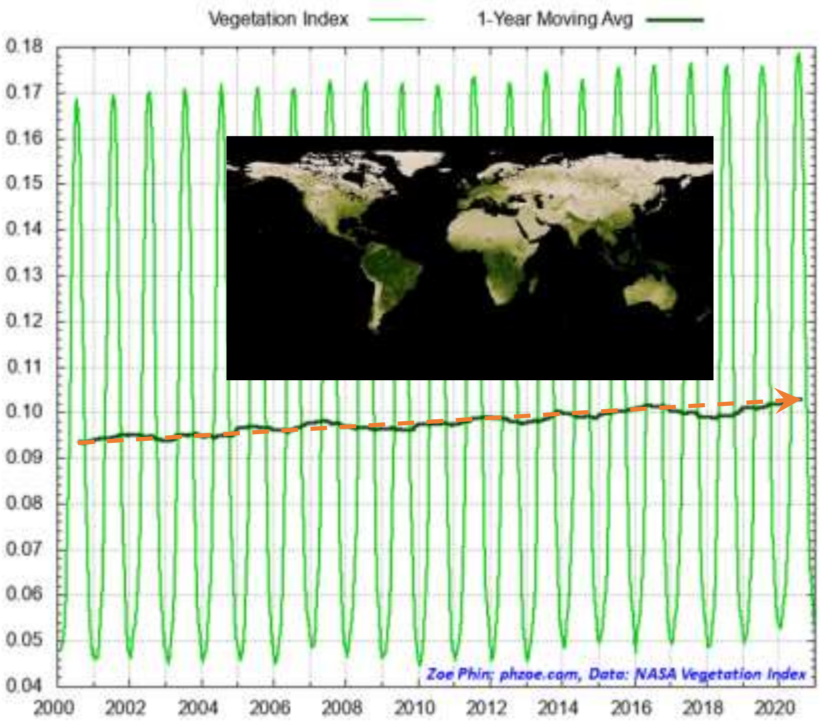




CO_2 Is Also A Good Fertilizer

- **10% increase in vegetation growth observed by NASA**
  - **Sahara desert area reduced by 700,000 km²**
- **More tree and brush growth**
- **Improved drought resistance**
- **More fires??**

• NASA Vegetation Index 10% growth 2000 to 2020



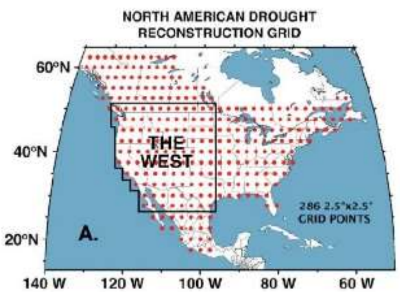
• Effect of CO_2 on plant growth

http://plantsneedco2.org/default.aspx?MenuItemID=103

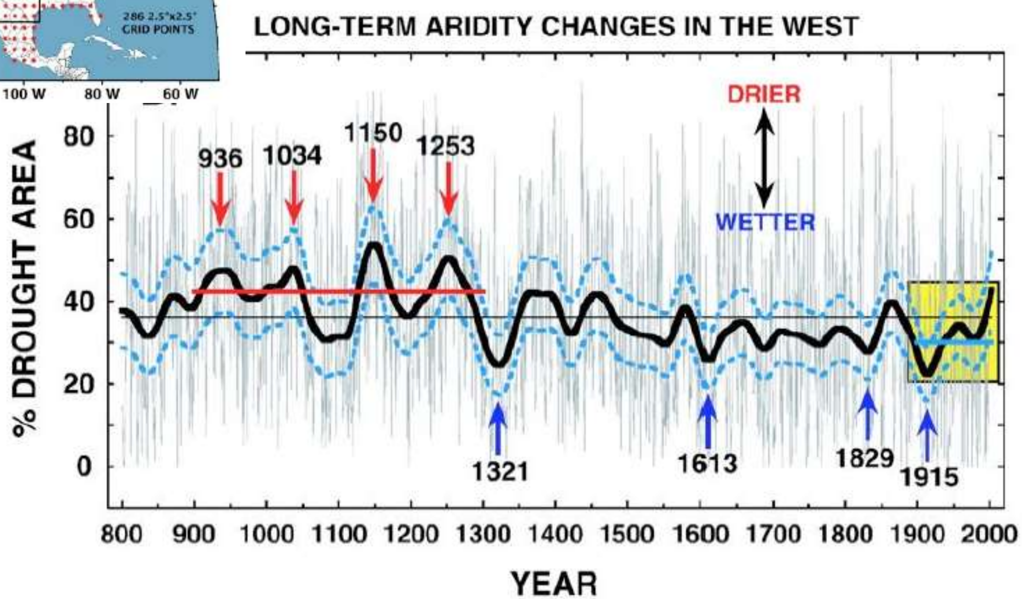
https://wattsupwiththat.com/2021/02/25/nasa-vegetation-index-globe-continues-rapid-greening-trend-sahara-alone-shrinks-700000-sq-km/

Rainfall

- **Western US has experienced 'megadroughts' in the past**
  - **Cliff dwellings abandoned in Mesa Verde in 1200's**
  - **Really just fewer wet years**
- **No long term trends in rainfall for the last 100 years**



• Tree ring reconstruction



Cook, E. R. et al, Earth-Science Reviews 81 93–134 (2007)
https://doi.org/10.1016/j.earscirev.2006.12.002

• Cliff dwellings, Mesa Verde

• Lake Oroville

April 2019

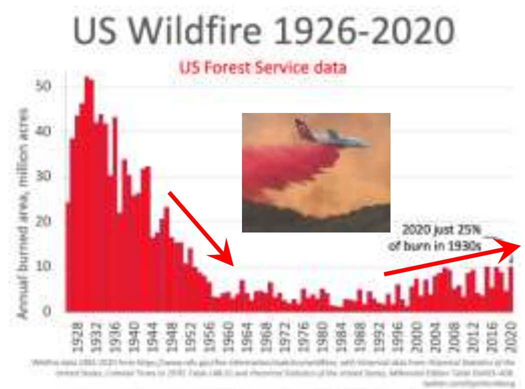
April 2021

Wildfire Data

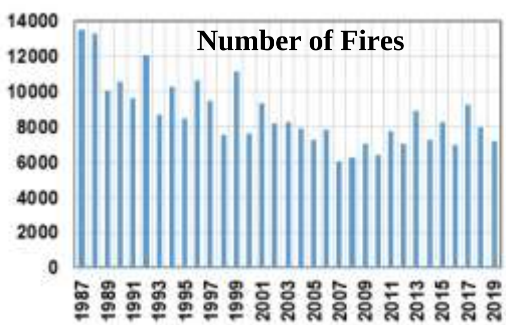
"Of the hundreds of persons who visit the Pacific slope in California every summer to see the mountains, few see more than the immediate foreground and a haze of smoke which even the strongest glass is unable to penetrate." **C. H. Merriam, 1898, Chief, US Biological Survey**

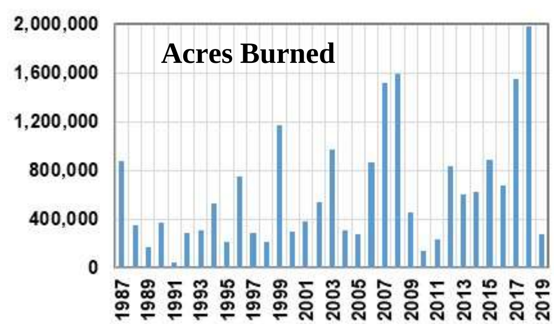
- **California acreage burned before 1800**
    - **4.4 million acres per year**
- **Most fires now caused by human activity**
    - **Only 6% caused by lightning**

• Annual US Area Burned

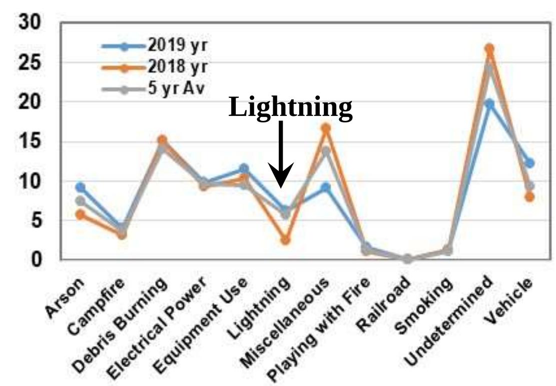


• California Calfire Data 1987-2019





• Causes of California Fires



Note:
Numbers depend on reporting criteria
Data can be 'cherry picked' to create short term trends

Stephens, S. L.; et al. Forest Ecol. Manage. 251 205-216 (2007)
https://farmsandforests.org/Resources/Stephens-et-al.-CA-fire-area-FEM-2007.pdf

https://wattsupwiththat.com/2021/05/13/caught-inconvenient-u-s-wildfire-data-has-been-disappeared-by-national-interagency-fire-center-nifc_fire/

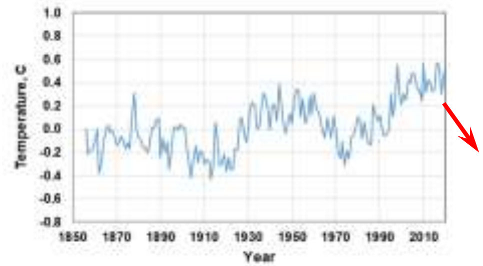
Wildfires

- California population has expanded into wildfire prone areas
- Number and acreage of wildfires has decreased since the 1930s
  - Enhanced fire detection and suppression
- Fire risks are increased by poor forest management
- Intense fires increase flood risks because vegetation is slow to grow back
- Houses in fire prone areas are not usually designed to be fire resistant
- Blocking high pressure systems and downslope winds will continue
- Most fires are caused by human activity

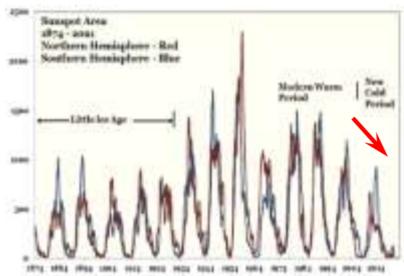
Climate Change

- The AMO has started to cool
- Sunspot activity could remain low

• AMO



• Sunspots



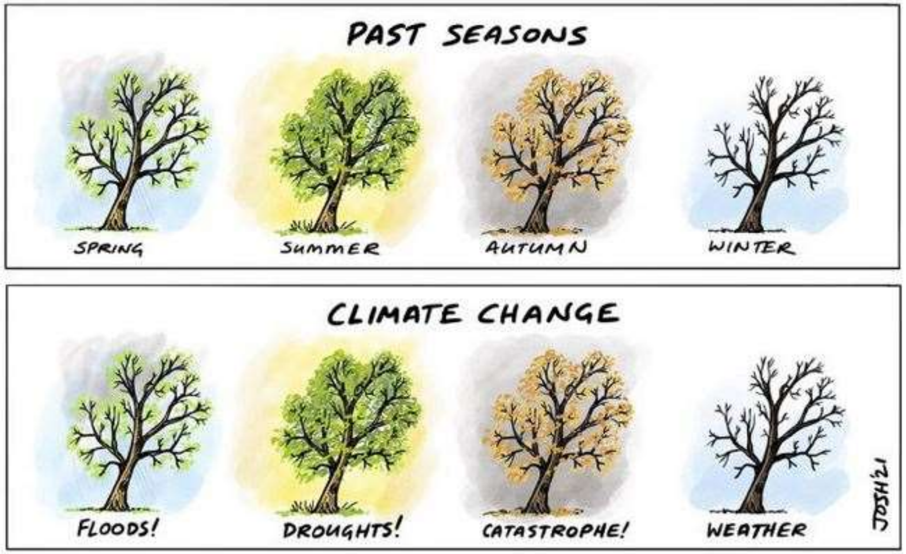
- The Pacific Ocean gyre circulation will continue to change
- California will continue with variable winter rain, droughts and floods
- In the summer, the vegetation will dry out and burn
- There can be no climate change from CO_2
- Eisenhower's warning has come true

> The prospect of domination of the nation's scholars by Federal employment, project allocations, and <u>the power of money is ever present and is gravely to be regarded</u>.
>
> Yet in holding scientific research and discovery in respect, as we should, we must also be alert to the equal and opposite danger that <u>public policy could itself become the captive of a scientific-technological elite</u>.
>
> President Eisenhower, Farewell Speech, 1961

- **The climate modelers will continue to follow the money**

Additional Information

- **Additional information is available on my website research pages:**
  www.VenturaPhotonics.com
- **Climate at a Glance**
  https://climateataglance.com/
- **https://wattsupwiththat.com/**
  (Articles, reference pages, links to other sites)



www.cartoonsbyjosh.com