Weather & Climate

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What is Weather?

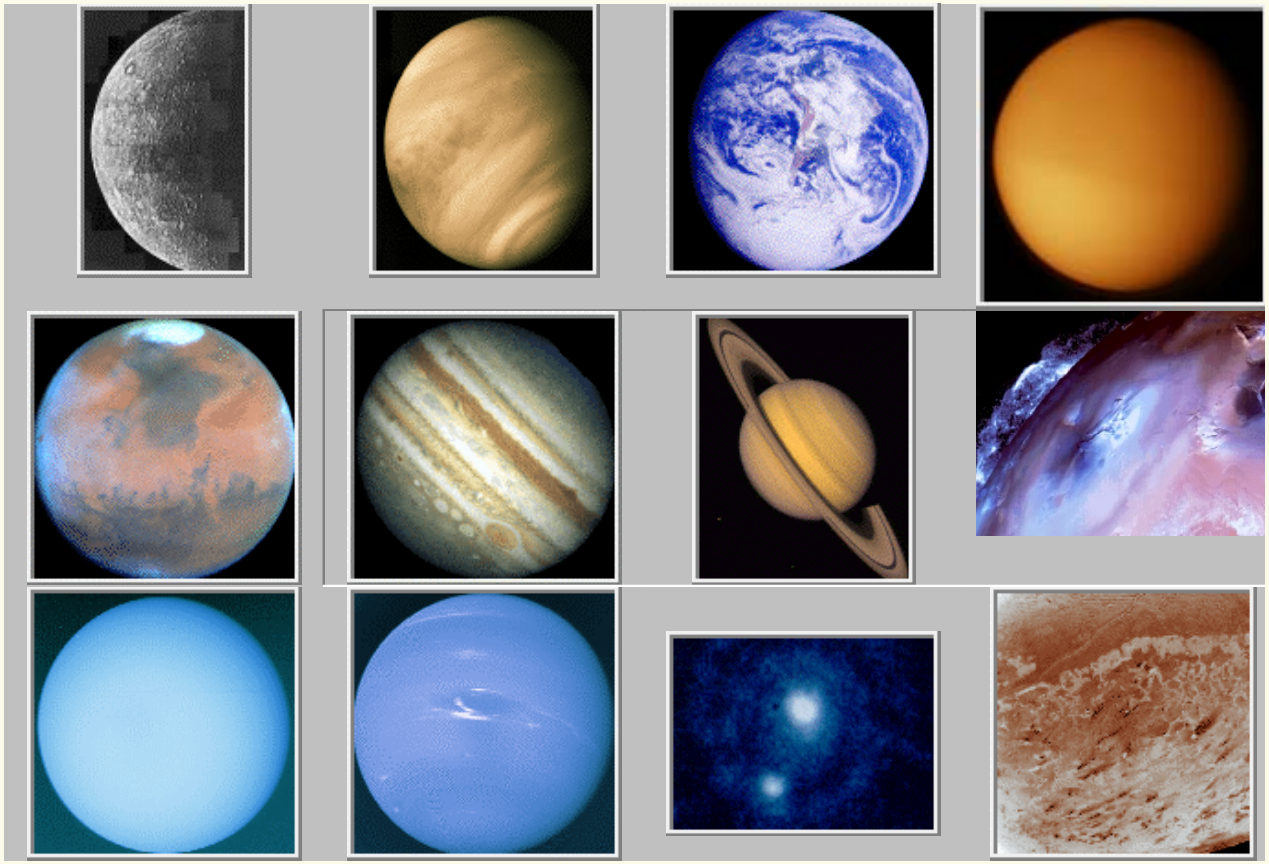
- ✓ Webster's New Collegiate Dictionary: *"state of the atmosphere with respect to heat or cold, wetness or dryness, calm or storm, clearness or cloudiness"*

- ✓ GLOBE: *"By weather we mean what is happening in the atmosphere today, tomorrow, or even next week."*

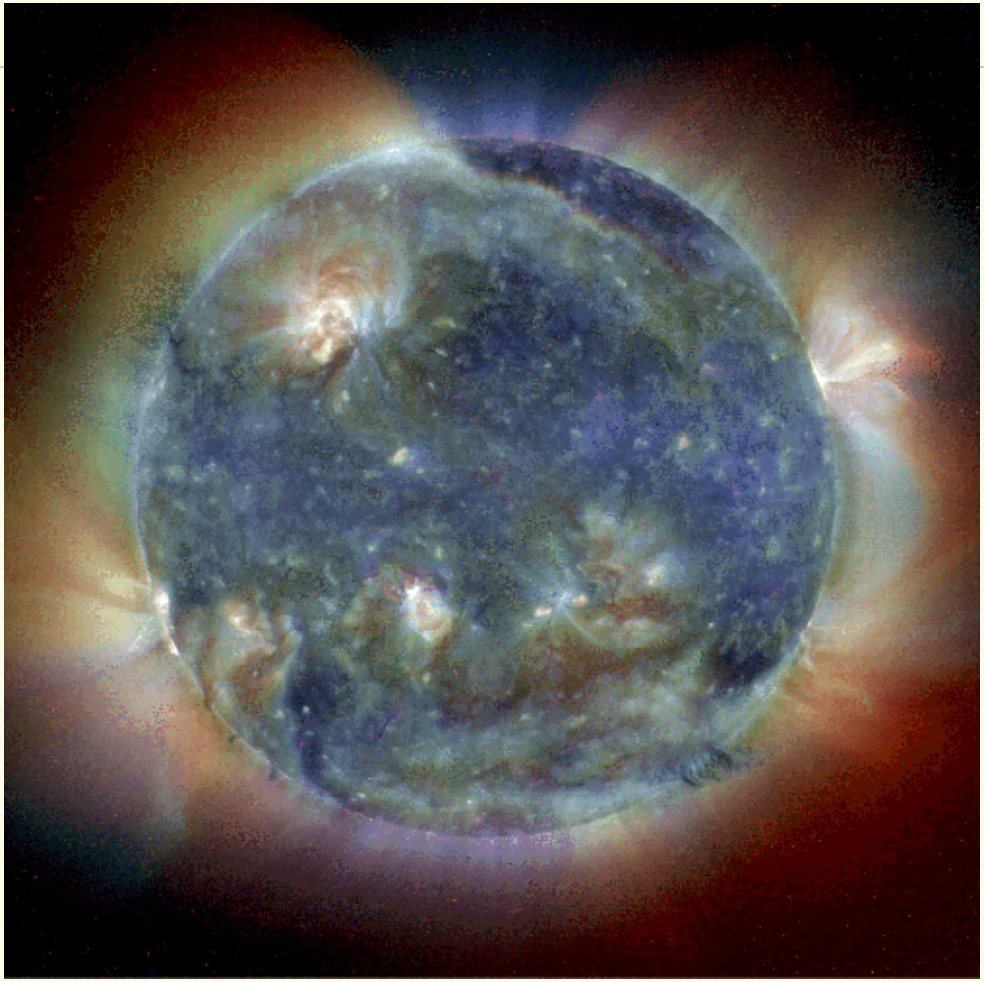
Ingredients for Making Weather

- **A nice, thick atmosphere**
- **A variable energy source (*for heating and cooling changes*)**
- **A condensate (on earth it is water; on other planets methane, ammonia, carbon dioxide and other compounds)**

Weather, Weather Everywhere!

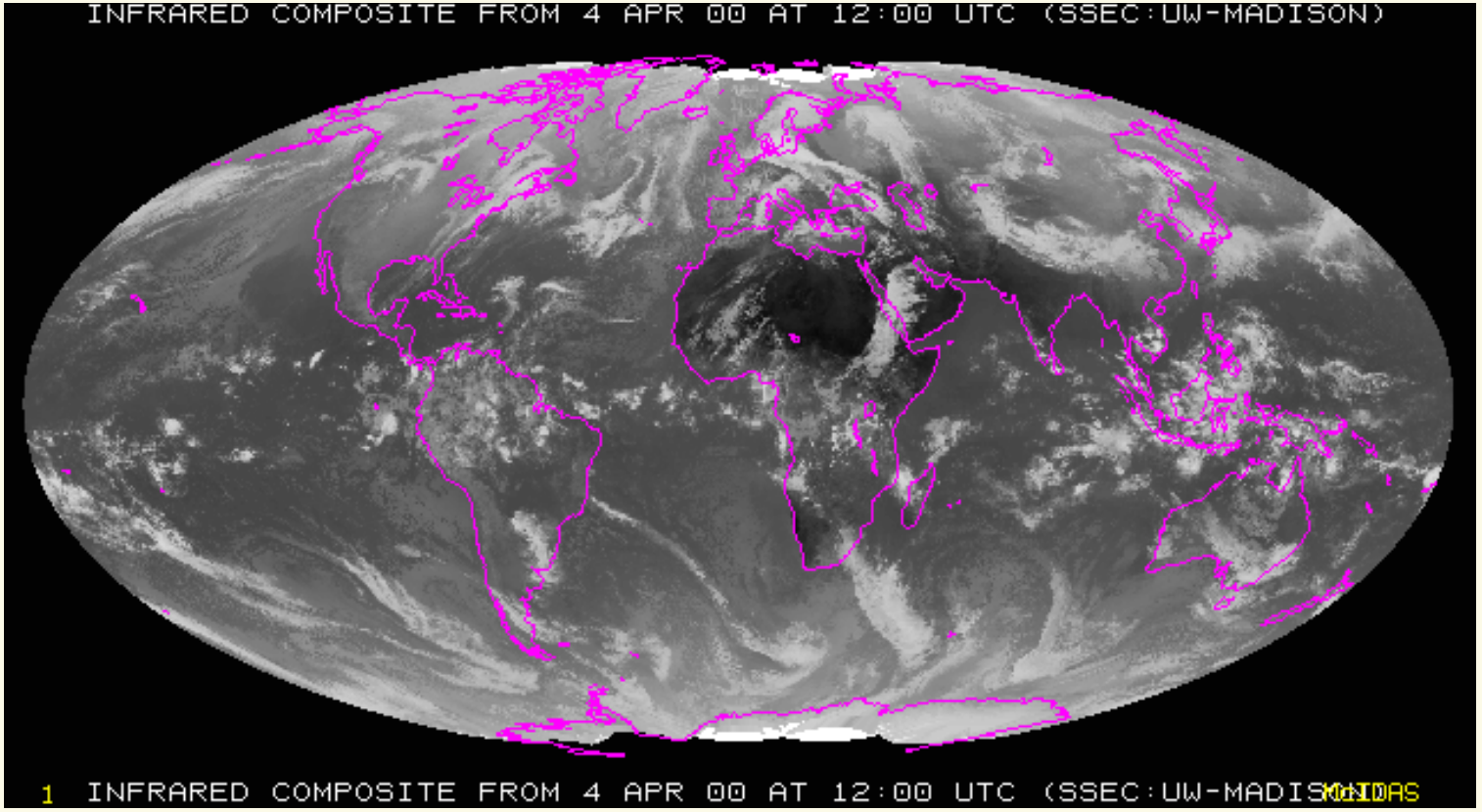


Weather, Even on the Sun!

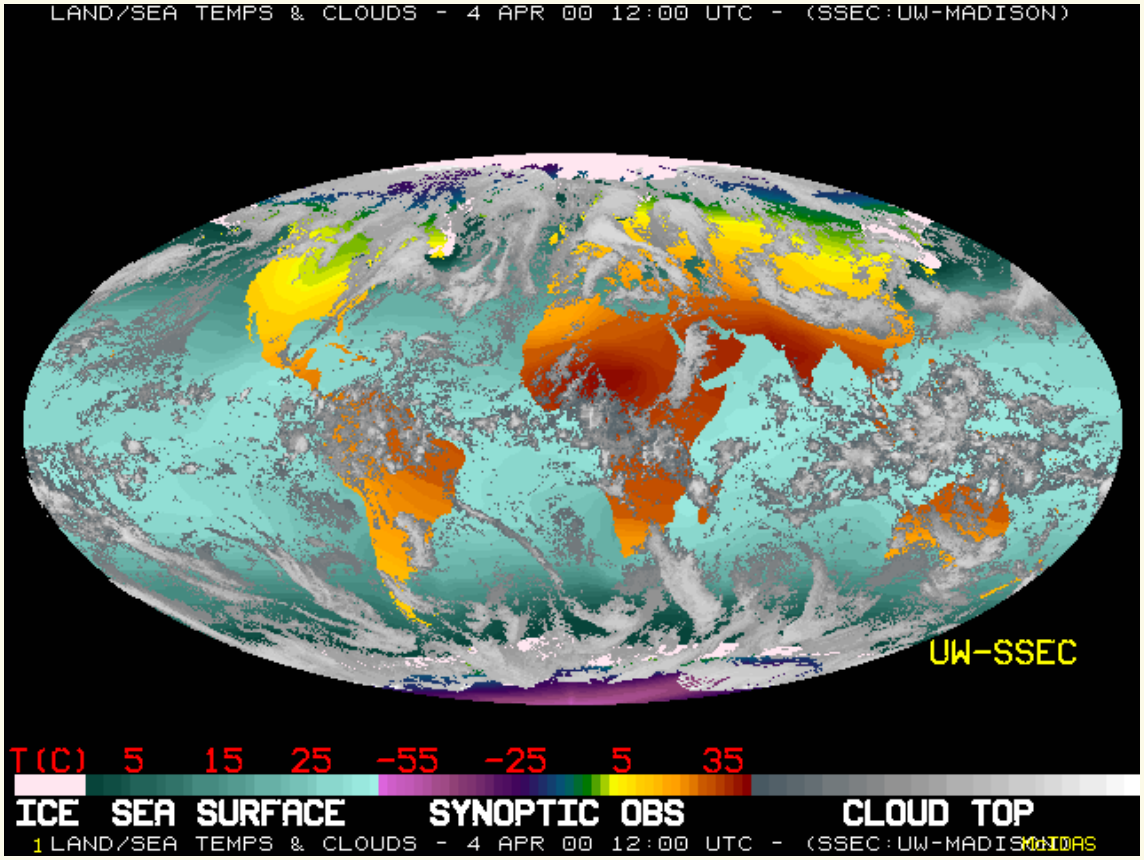


Weather on Earth: Global clouds and surface temperatures

Infrared mosaic of the earth that shows thermal contrasts and clouds

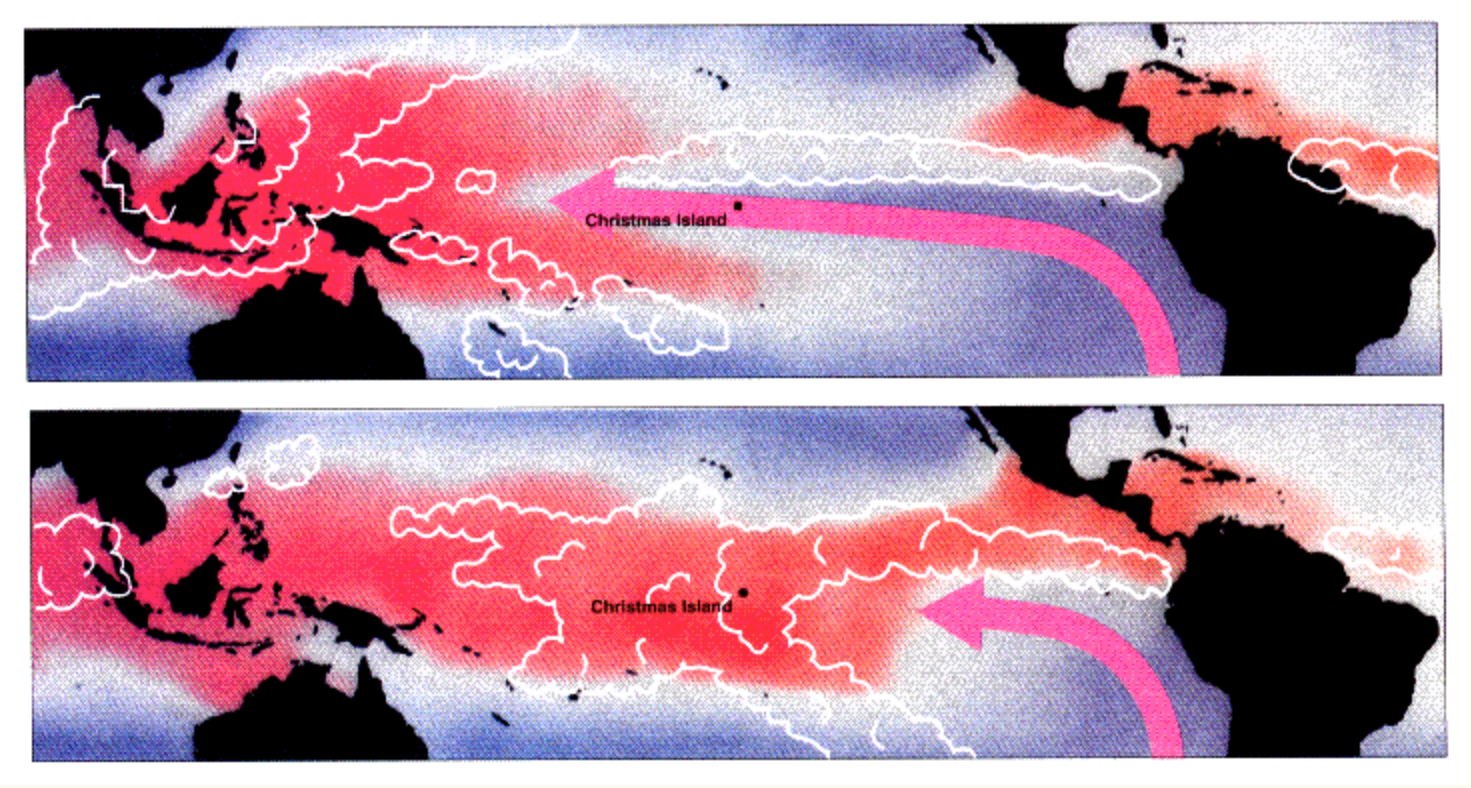


Weather on Earth: The Oceans affect it!

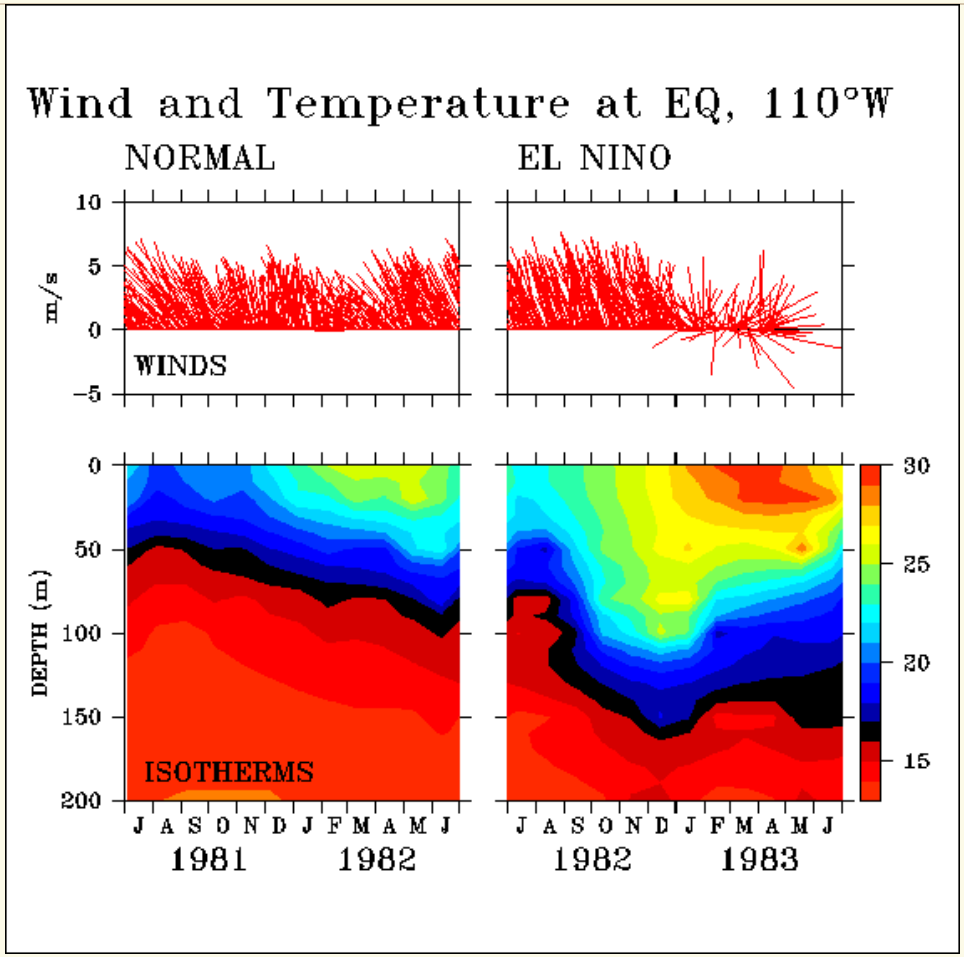


The Oceans: El Nino Phenomenon

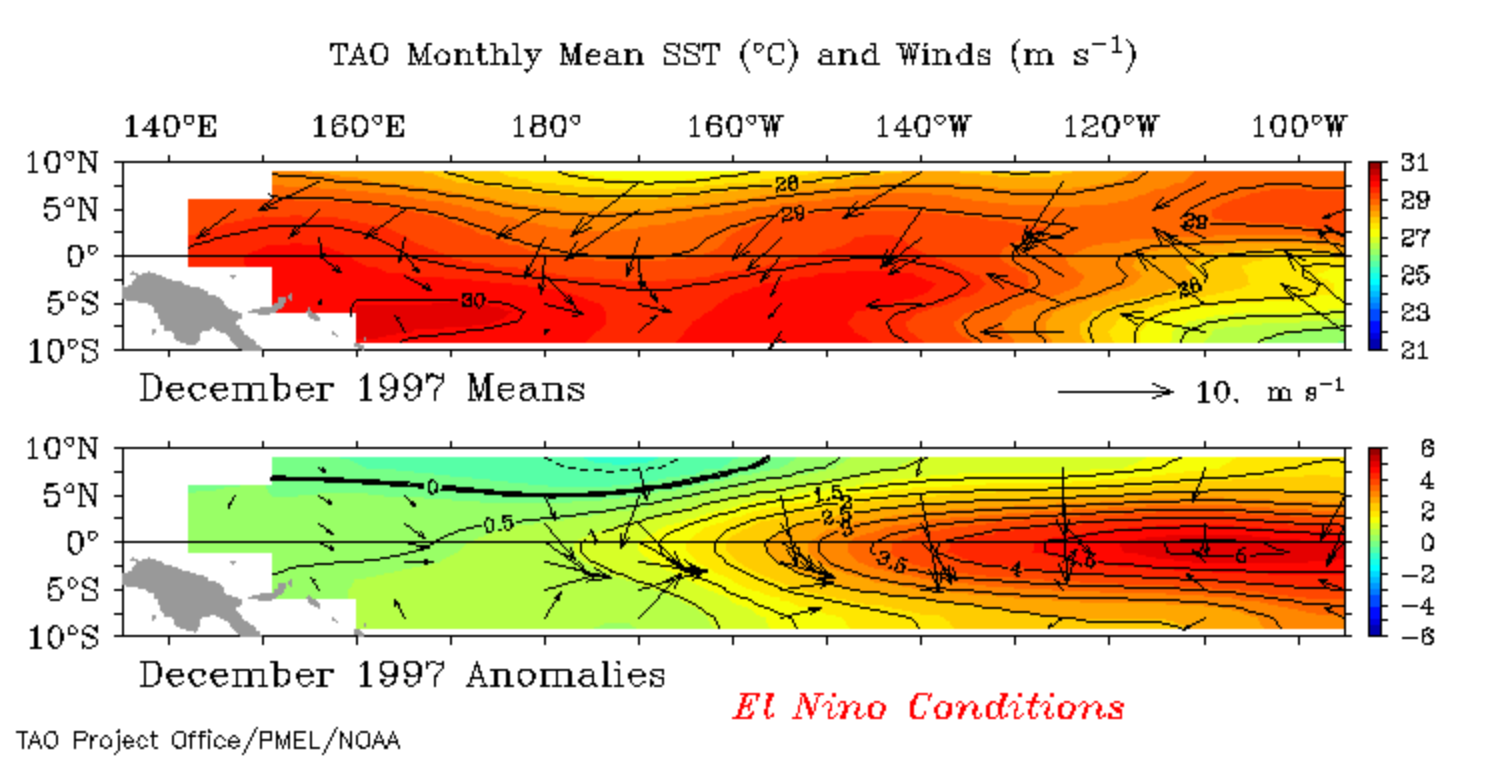
Warming of the S. American equatorial coastal sea surface temperatures that reduces the fishing due to lowering of nutrients



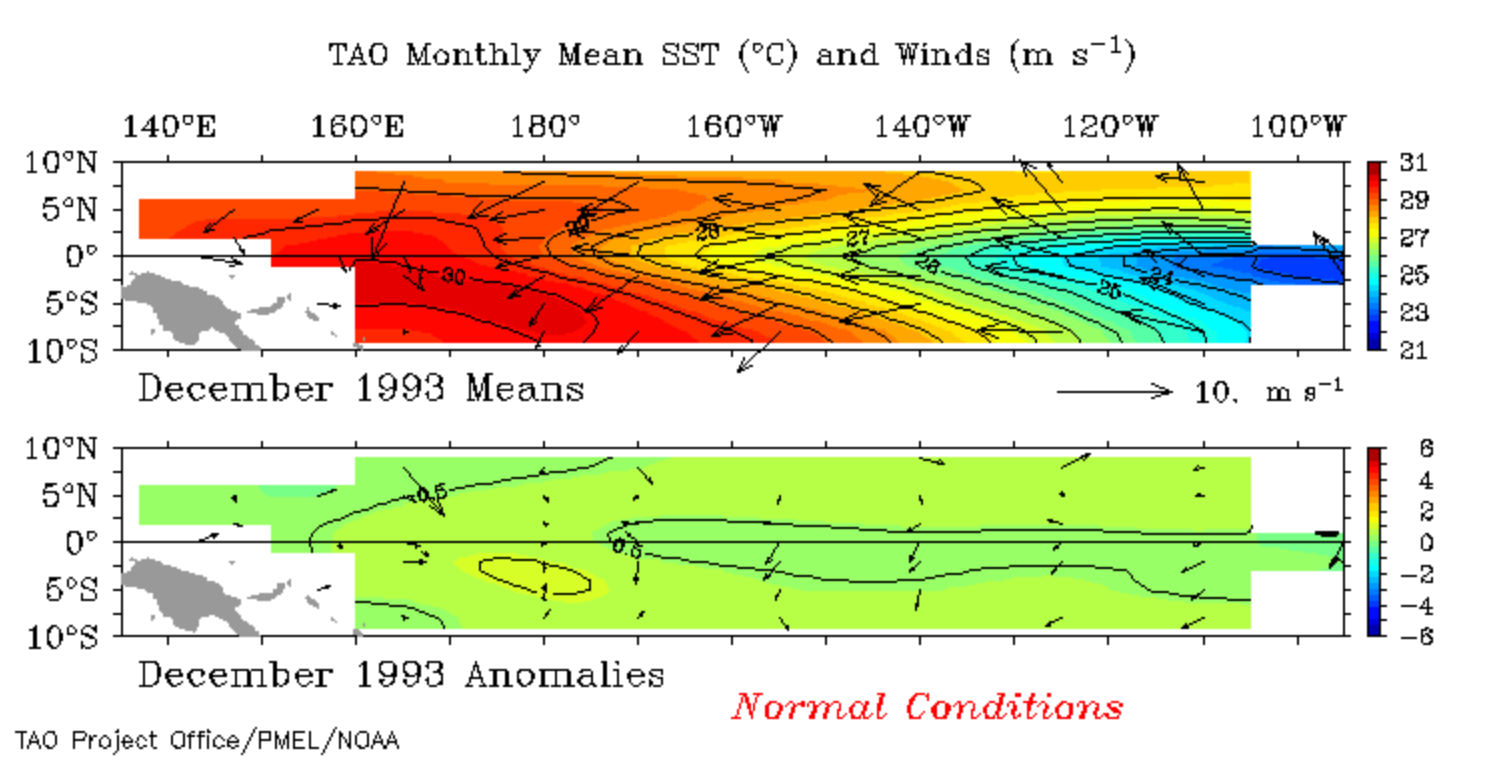
El Nino: Decrease in surface winds causes warm water to pile up near the eastern pacific equatorial ocean surface



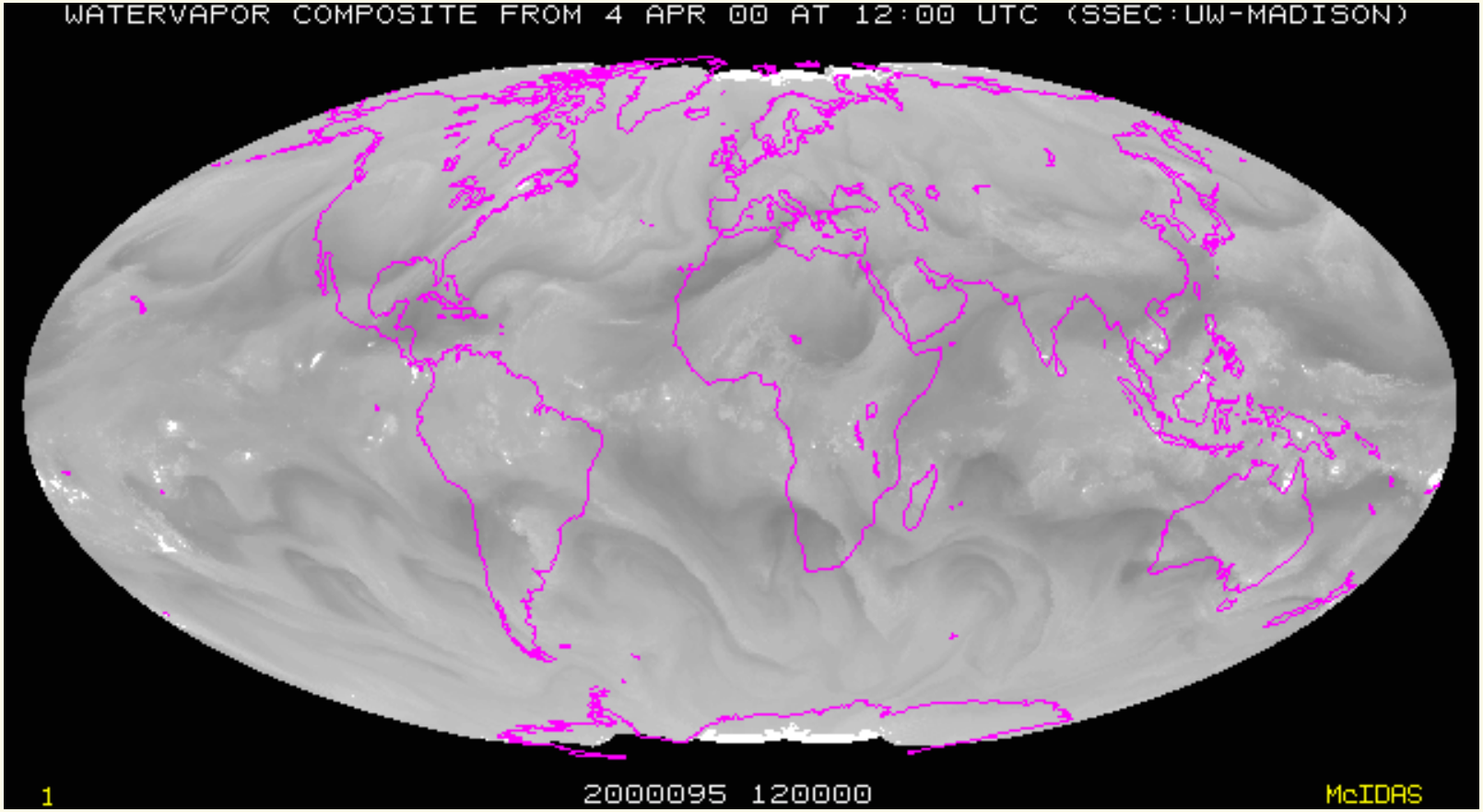
Equatorial Conditions in an El Nino Year



Equatorial Sea Surface Temperatures in a "Normal" Year



Global Distribution of Moisture: Non-uniform horizontal and vertical distribution of moisture is both an effect and cause of weather

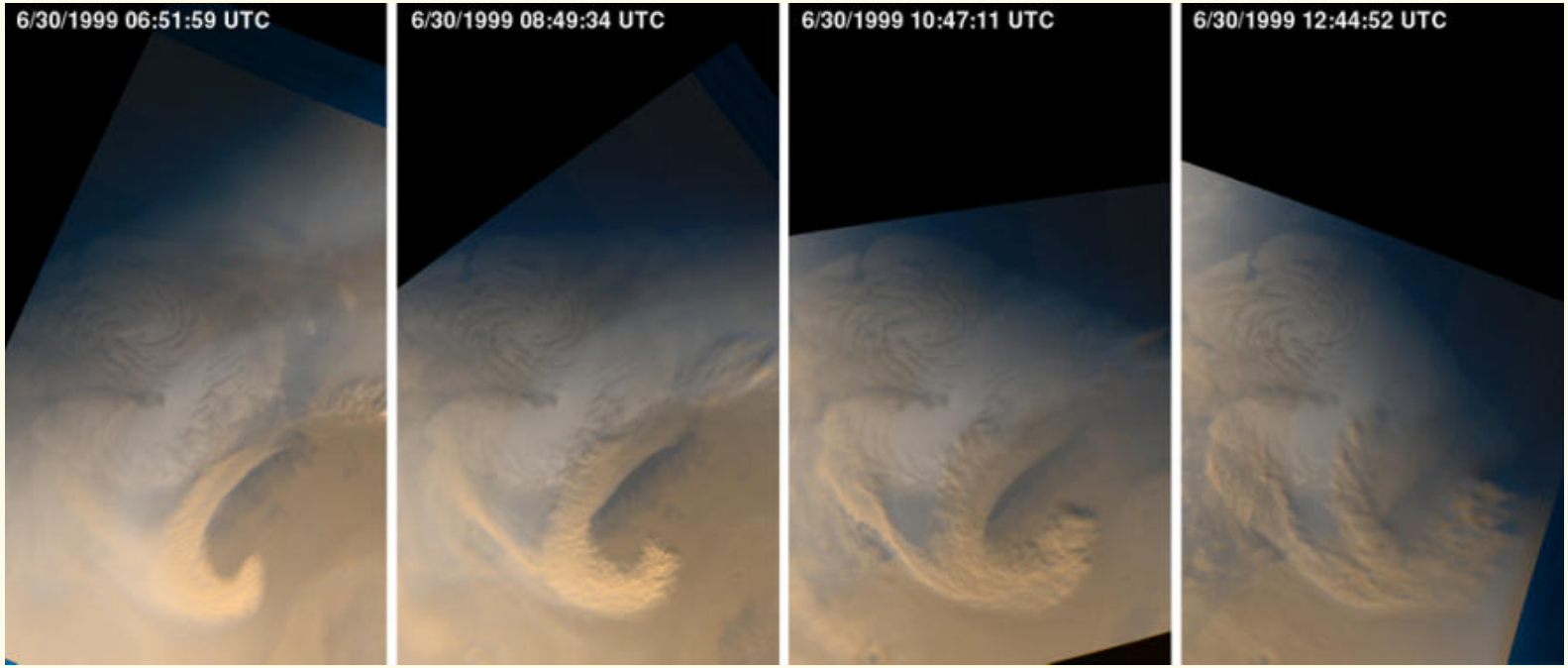


What are Storms and what causes them?

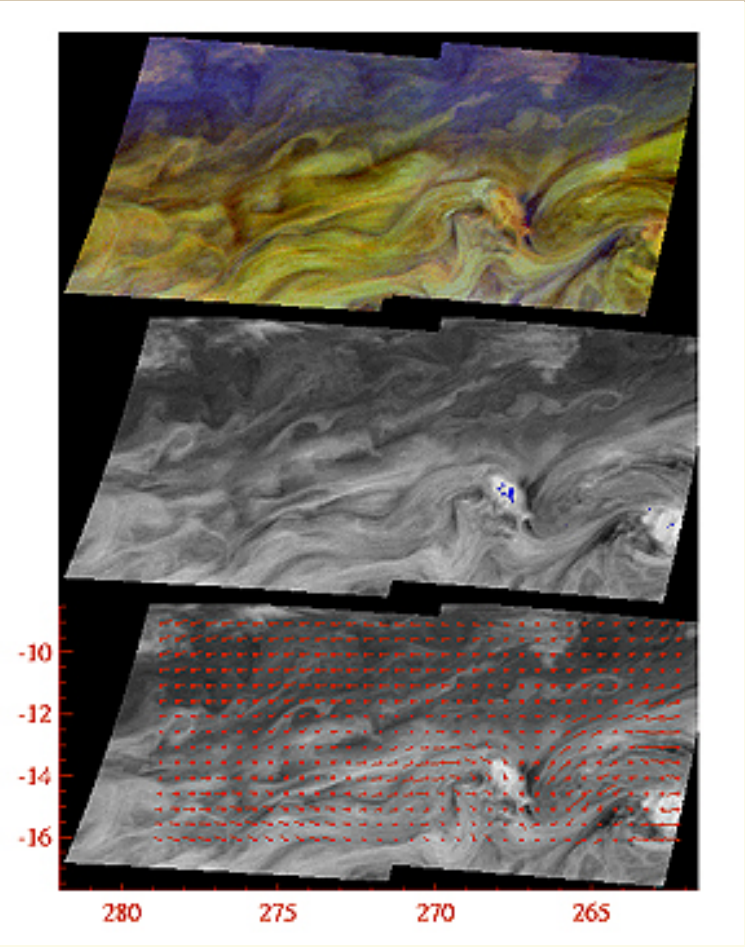
- According to Webster's Collegiate Dictionary:

"a disturbance of the atmosphere marked by wind and usually by rain, snow, hail, sleet, or thunder and lightning"

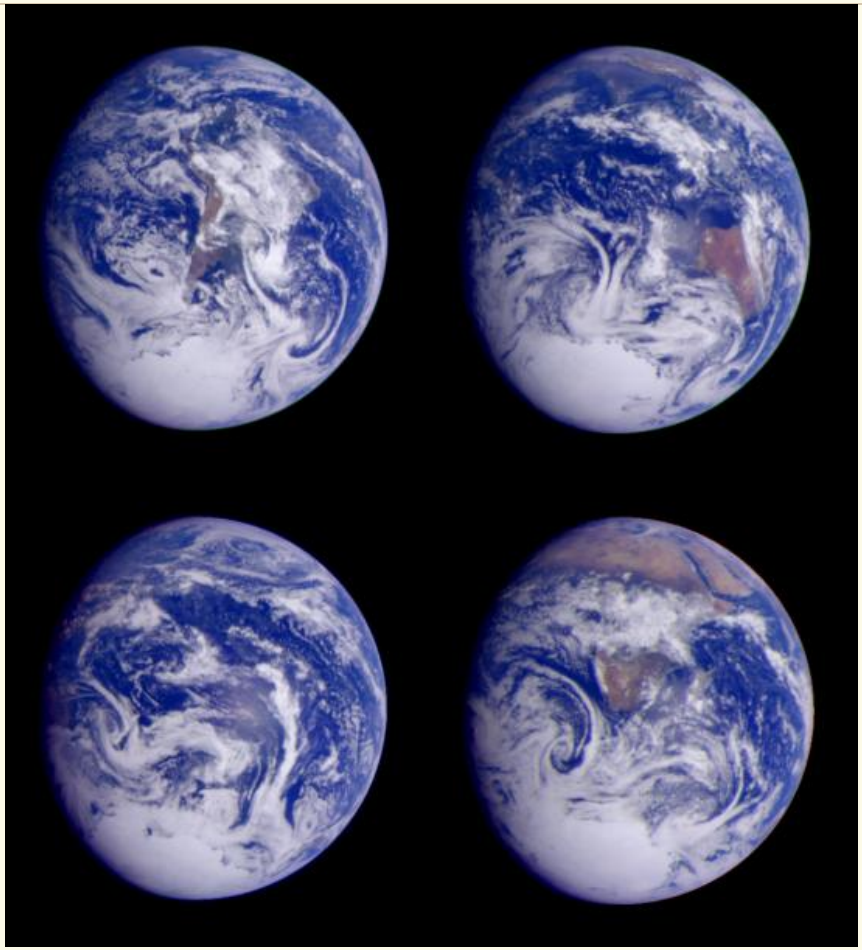
Storms occur on Mars



And on Jupiter...



And viewing Earth from space, storm systems appear to be beautiful!



Weather: Atmospheric Heat Engine

- Weather is a consequence of the atmospheric heat engine: The sun provides the fuel, the top of the atmosphere acts as a radiator, and the atmosphere and oceans do the work, resulting in winds and storms.

What Changes Weather?

Temperature is one aspect of weather. What changes temperature?

- Heating

  Sun is the primary source of energy (for inner planets). Energy absorbed from the sun by the earth (surface-atmosphere-oceans) is the fuel for the atmospheric heat engine.

- Cooling

  Loss of energy, Phase Change, Mixing

- Change in atmospheric composition

  Absorption of energy by constituents

Heating & Cooling - Transfer of Energy

- Heating or cooling take place when energy is transferred to or from the earth, atmosphere, and oceans.

- Three ways through which this can happen:
  - *Radiation*
  - *Convection*
  - *Conduction*

Radiation

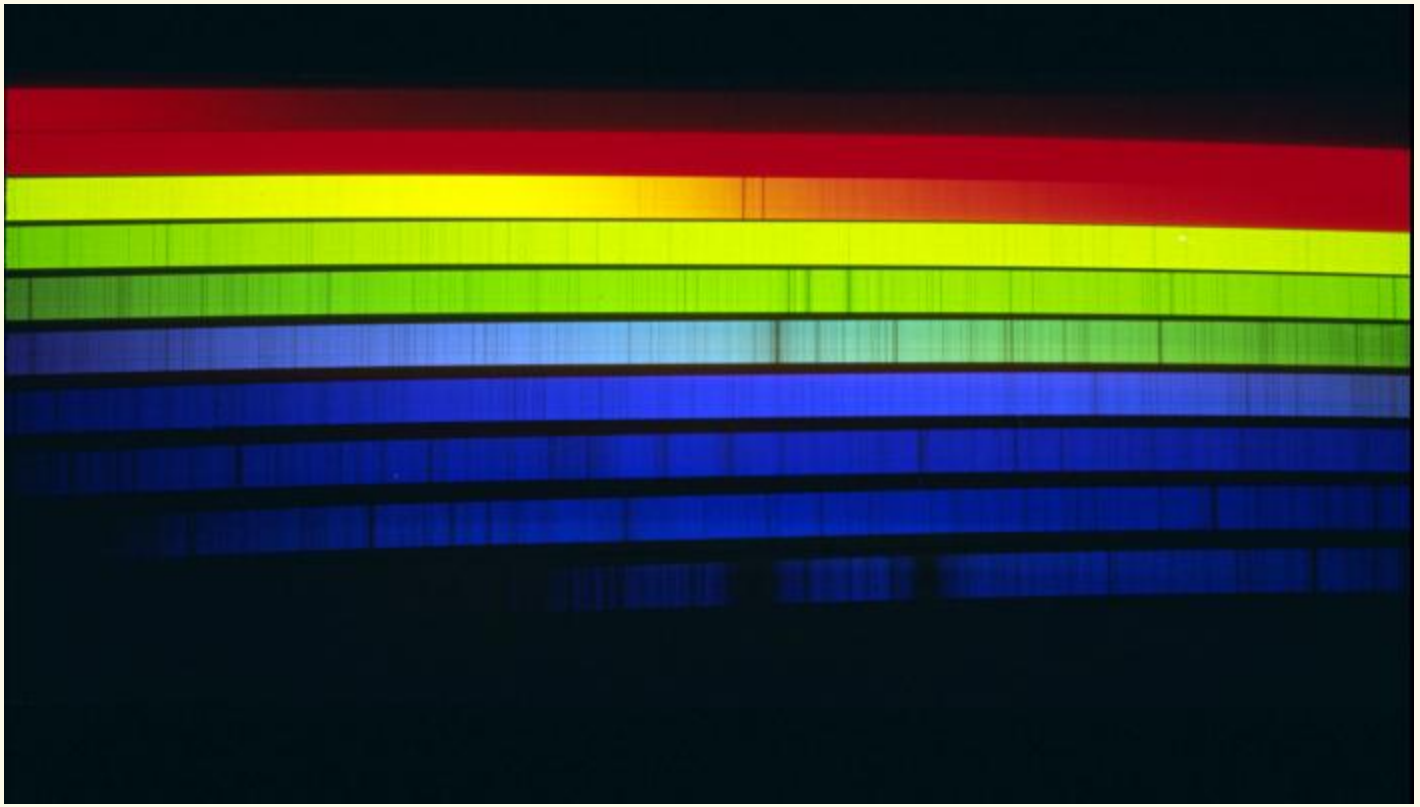
- Every object emits (and absorbs) electromagnetic radiation, whose spectrum is determined by its temperature and emissivity. Most of the the Sun's energy arrives at earth through electromagnetic radiation. This can occur through space and does not need any intervening medium.

Examples:

Cooling on clear cloudless nights
Warm nights with cloudy skies
Greenhouse Effect

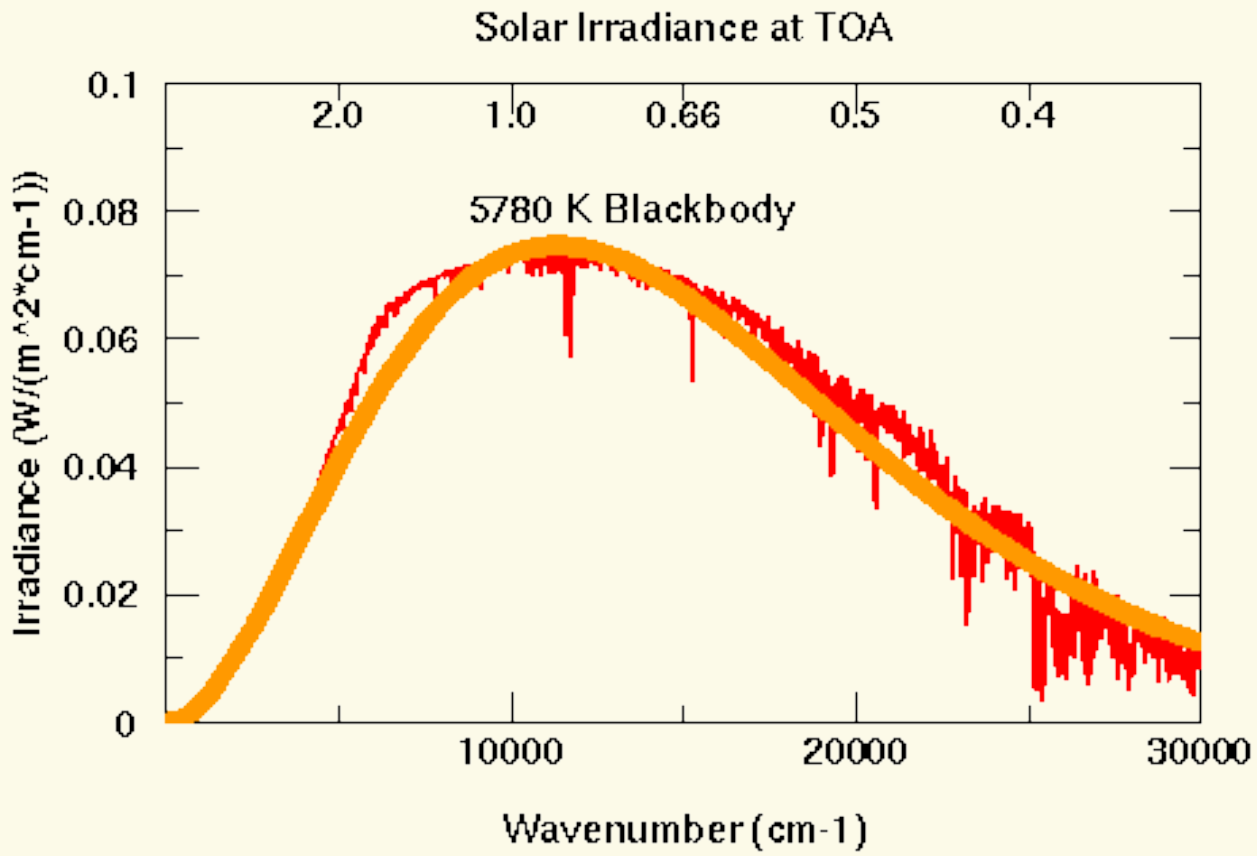
The Solar (Visible) Spectrum:

Fraunhoffer Lines (absorption lines) characteristic of different elements seen as dark vertical lines

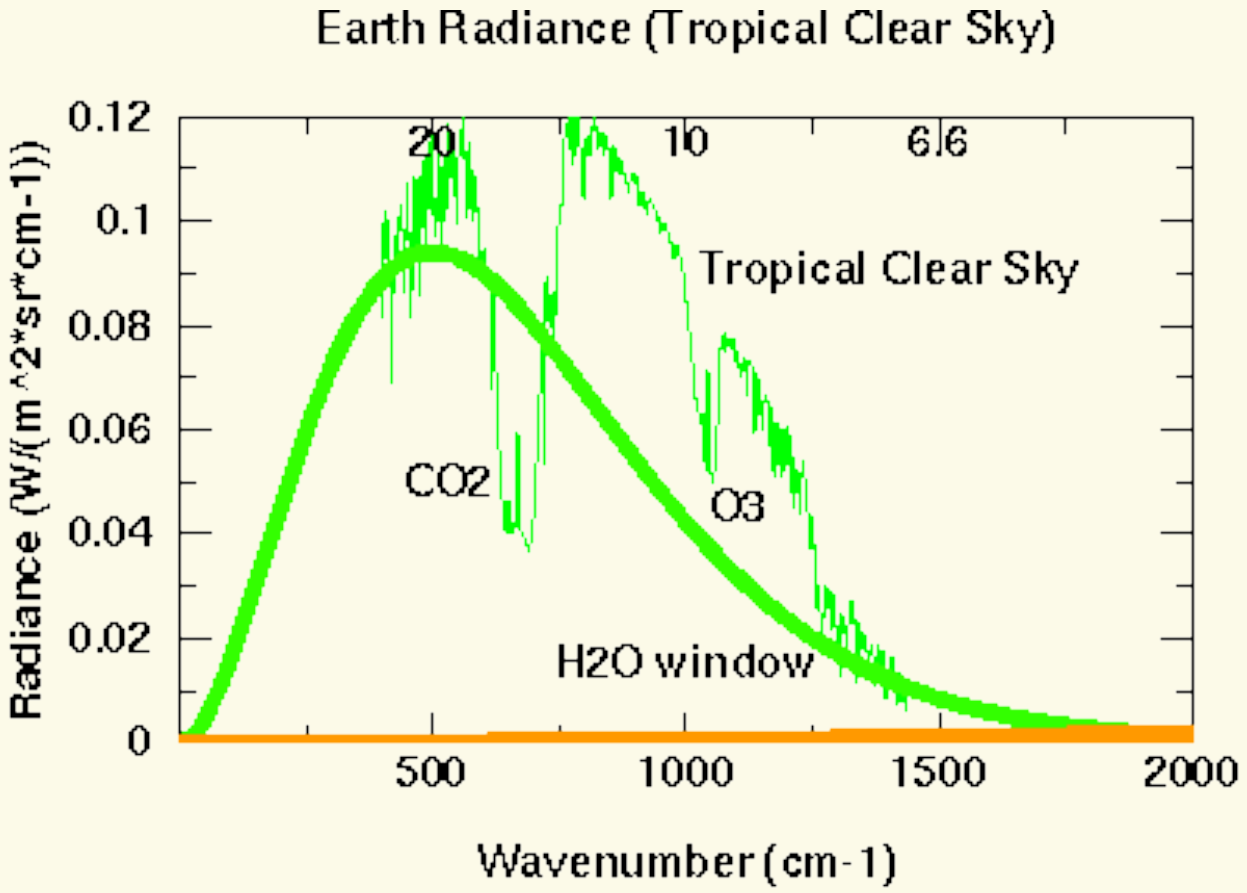


Solar Radiation Spectrum

http://climate.gsfc.nasa.gov/~cahalan/Radiation/

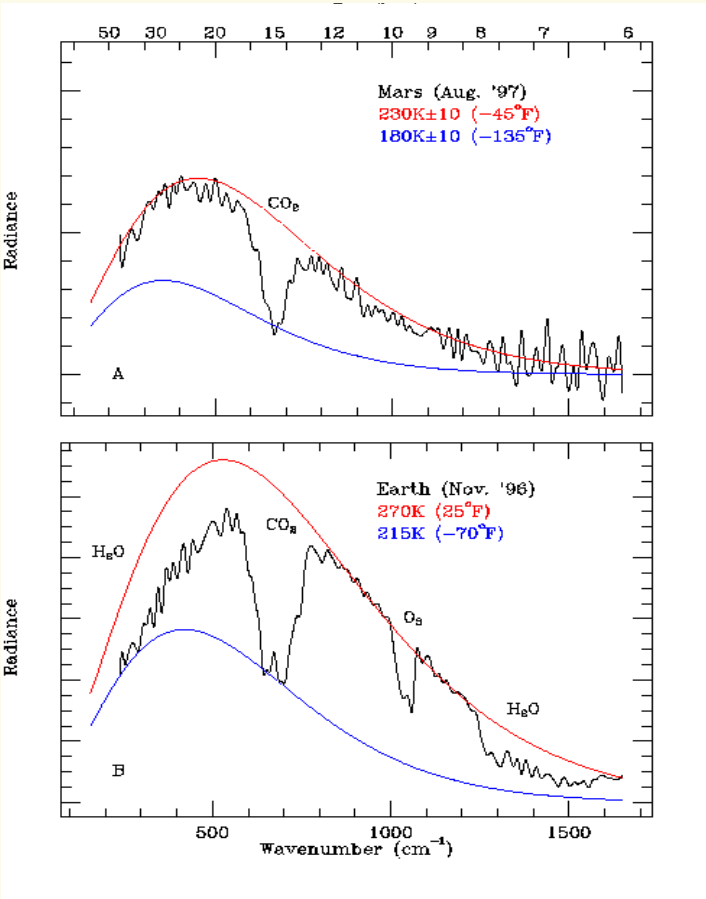


Earth Radiation Spectrum

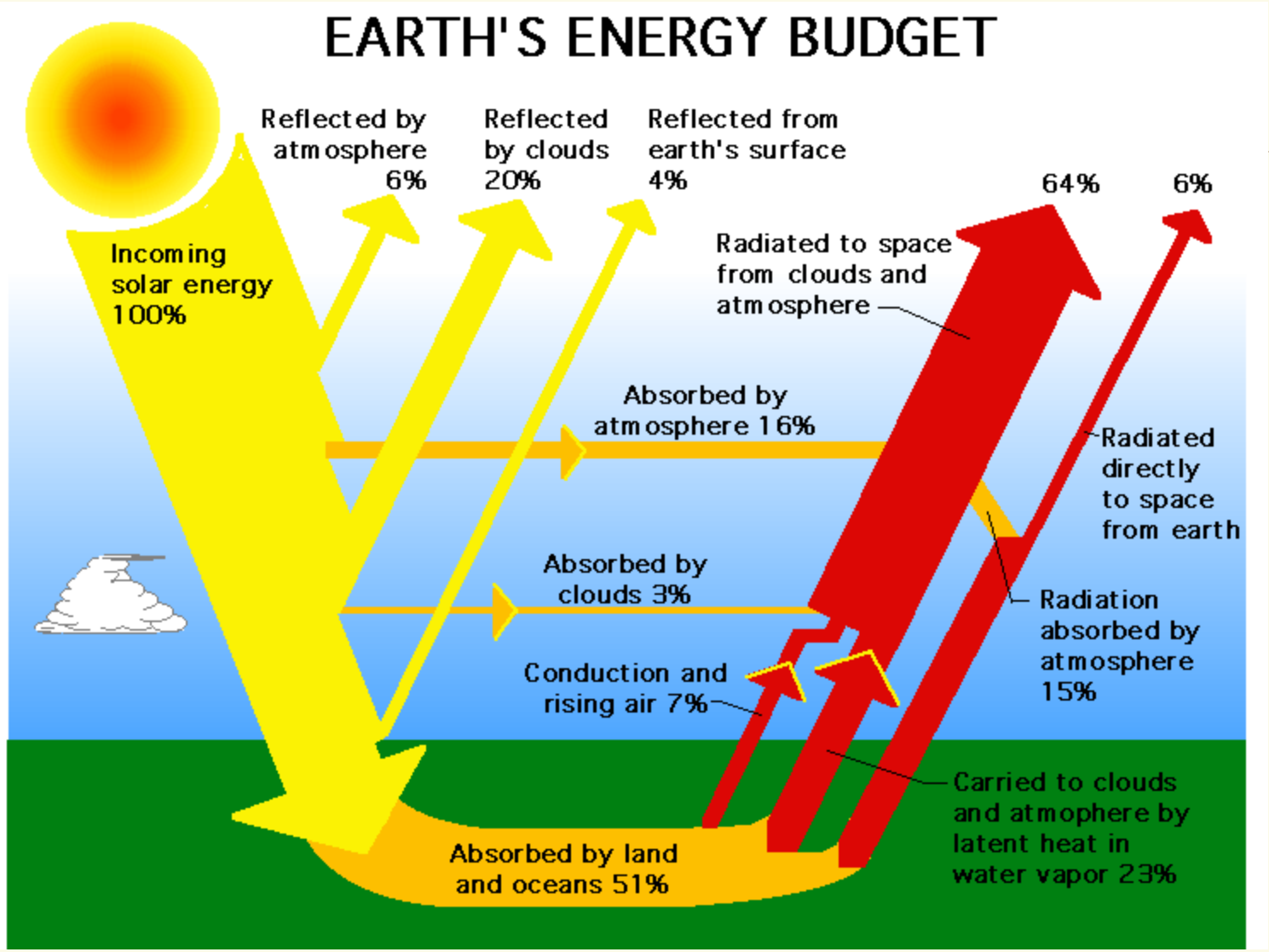


Earth & Mars Radiation Spectra

http://emma.la.asu.edu/TESCruise/marscruise.html



- ✓ Earth and Mars spectra show similarities due to CO_2 and differences in H_2O and O_3 abundances. Colored lines show Black Body temperature curves for different temperatures.


EARTH'S ENERGY BUDGET
Reflected by atmosphere 6%
Reflected by clouds 20%
Reflected from earth's surface 4%
64%
6%
Incoming solar energy 100%
Radiated to space from clouds and atmosphere
Absorbed by atmosphere 16%
Radiated directly to space from earth
Absorbed by clouds 3%
Radiation absorbed by atmosphere 15%
Conduction and rising air 7%
Carried to clouds and atmophere by latent heat in water vapor 23%
Absorbed by land and oceans 51%

Greenhouse Effect - *Caused by* the *selective absorption of radiation in the infrared and transparency to visible radiation.*

- Certain materials absorb (and emit) radiation at selected wavelengths.
- Carbon dioxide, Water vapor, Methane, Ozone have characteristic absorption bands
- Snow is reflective in the visible spectrum but absorbs some infrared wavelengths (important on Triton!)

Convection

- The transfer of energy by physical movement of matter. A process governed by properties of the material that is moved and of the material through which it moves.

- Examples:
  - *Localized cooling or heating*
  - *A pot of boiling water*
  - *Volcanic eruptions*
  - *Thunderstorms*

Conduction

- The transfer of energy between a bulk material or across surfaces through physical contact. A process governed by the conductivity of the material.

  Conduction is relatively less important than transfer of energy through radiation or convection in determining weather, but can be occasionally significant.

  - *Heat loss through contact with wind (wind chill)*
  - *Frost depth in sub-freezing weather*

What Changes Weather?

Moisture affects the buoyancy and heating or cooling of the atmosphere.

- Humidity- Water exists in three forms - vapor, solid and liquid. Phase changes are accomplished by heat exchange
  - Evaporation
    - Oceans, Lakes, Rivers
  - Condensation
    - Clouds, frost
  - Precipitation
    - Rain, snow and other forms

What Changes Weather?

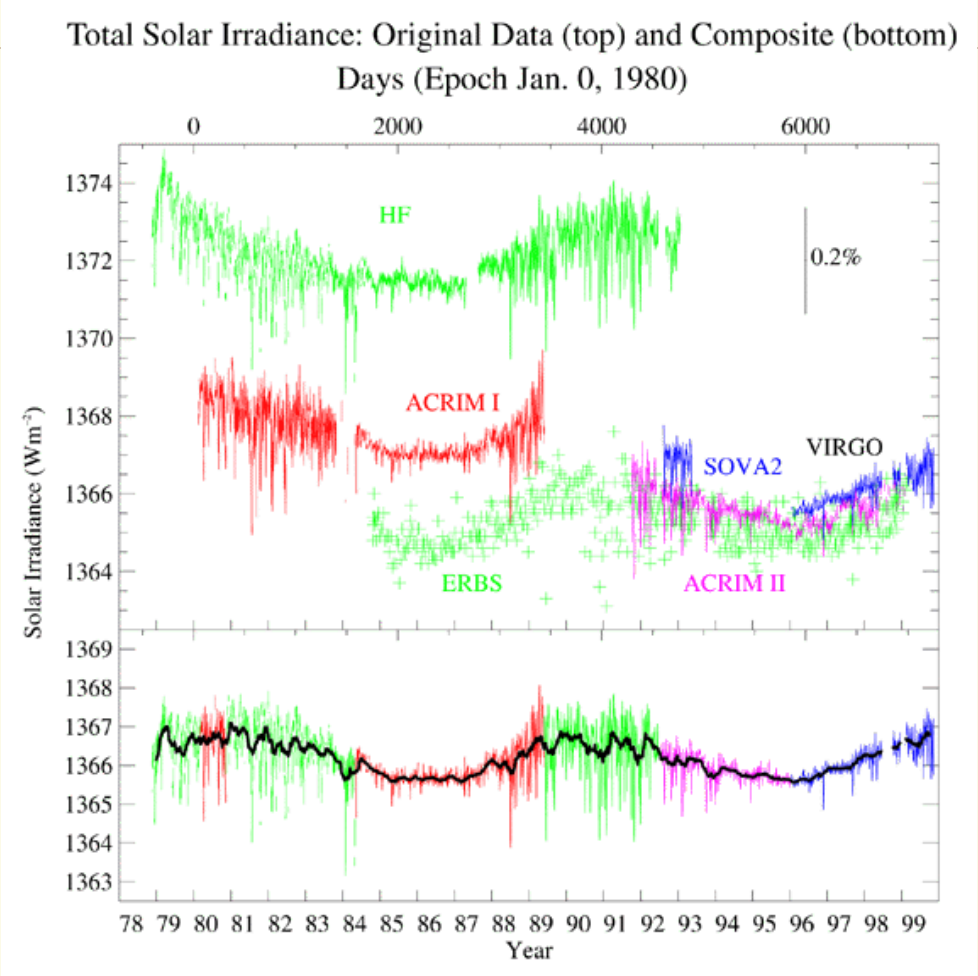
Wind is the result of atmospheric pressure changes, and can impact local and regional weather

- Winds can change weather locally and regionally. They depend on air masses and density variations in the atmosphere.
- Examples:
  - *Monsoon Circulation*
  - *Sea and Land Breezes*
  - *Density Winds*
  - *Foehn (Mountain Winds)*

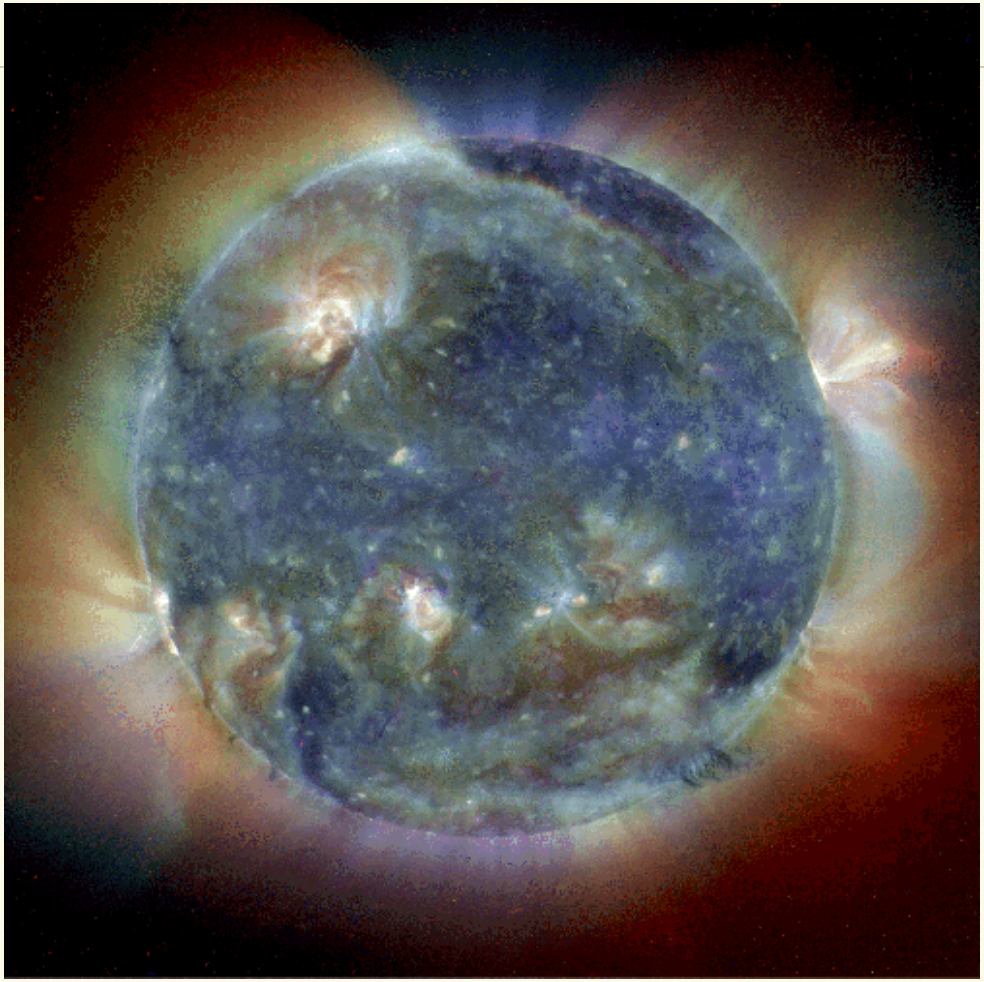
Recipe for Weather Change

- Changes in Heating/Cooling
  - Insolation changes due to earth-sun geometry
  - Diurnal changes (due to rotation)
- Changes in Surface Properties
  - deforestation, urbanization, topography
- Changes in atmospheric composition
  - change in amount of greenhouse gases

Changes in the Solar Irradiance (SOHO Data)



Weather on the Sun affects its radiation output!



Weather on Mars

- **Mars Pressure Change movie** http://mars3.jpl.nasa.gov:80/ops/pressmov.html
- **Mars Cyclone Movie** http://mars3.jpl.nasa.gov:80/mgs/msss/camera/images/8_10_99_releases/moc2_172/index.html
- **Mars Today** http://www-mgcm.arc.nasa.gov/

Climate… what is it?

- According to Webster's Collegiate Dictionary: *"the average course or condition of the weather at a place over a period of years as exhibited by temperature, wind velocity, and precipitation."*

- GLOBE: *"By climate we mean weather over time"*

Weather can be the Climate!

- If the weather is the same every day, the climate and weather are the same!

  It **never** rains in California (or so the song says), so weather ≡ climate

  On Venus, the weather does not change much each day, hence weather ≡ climate!

Summary of Key Concepts

- Weather over time IS climate
- To better understand the climate, we must develop a better understanding of weather and the factors that control it.
- Climate over a very long period (thousands and millions of years) can be very different.

Summary of Key Concepts

- Study of past climates requires a good knowledge of past physical conditions.
- Earth's orbit, surface, atmospheric composition have changed since the beginning through complex processes such as continental drift, subduction, asteroid impacts, and more recently, human activity.

Key Concepts (continued):

- Weather is global (e.g. CFCs in Antarctic)
- Weather is a result of physical processes
- If we understand the Physics, we can predict the weather
- In order to be able to predict weather, we need good global observations

Worst Case Scenario for Climate Change (Global Warming)

- Venus provides a good warning for adding too much carbon dioxide (or other greenhouse gases) to the atmosphere (millions of years).
- In the long run (a few billion years), Earth's days are numbered. We are impacted by the aging of the sun, and when it goes, the earth follows!