

Atmospheric Science: An introductory survey

1. Introduction to the atmosphere
2. The Earth system
3. Hydrostatics and thermodynamics
4. Radiative transfer
5. Cloud microphysics
6. Atmospheric chemistry
7. Boundary layer processes
8. Atmospheric dynamics
9. Weather
10. Climate dynamics

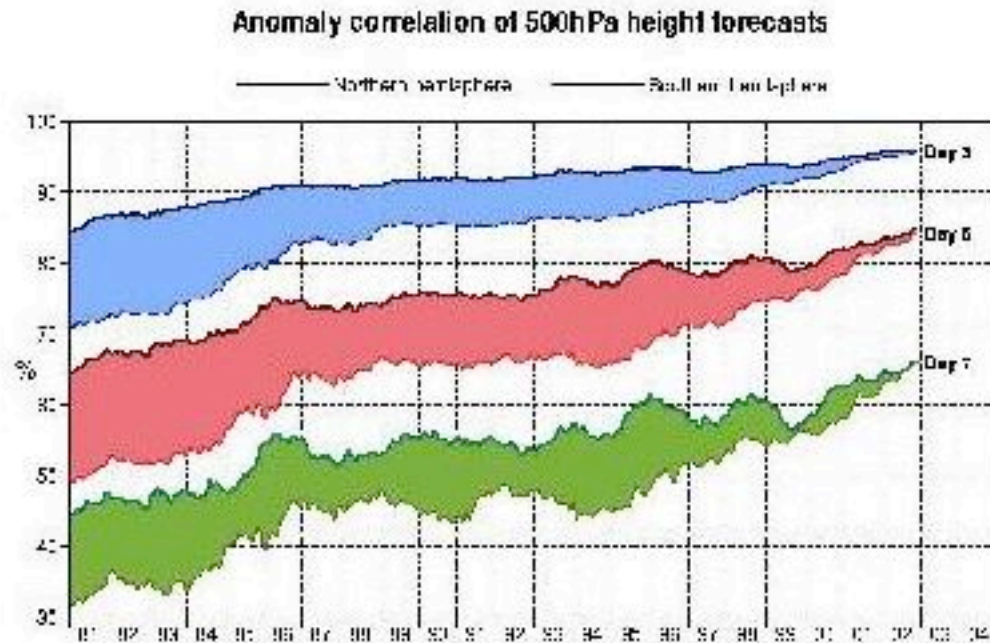
Chapter 1

Introduction and Overview

Big Developments 1977-2003

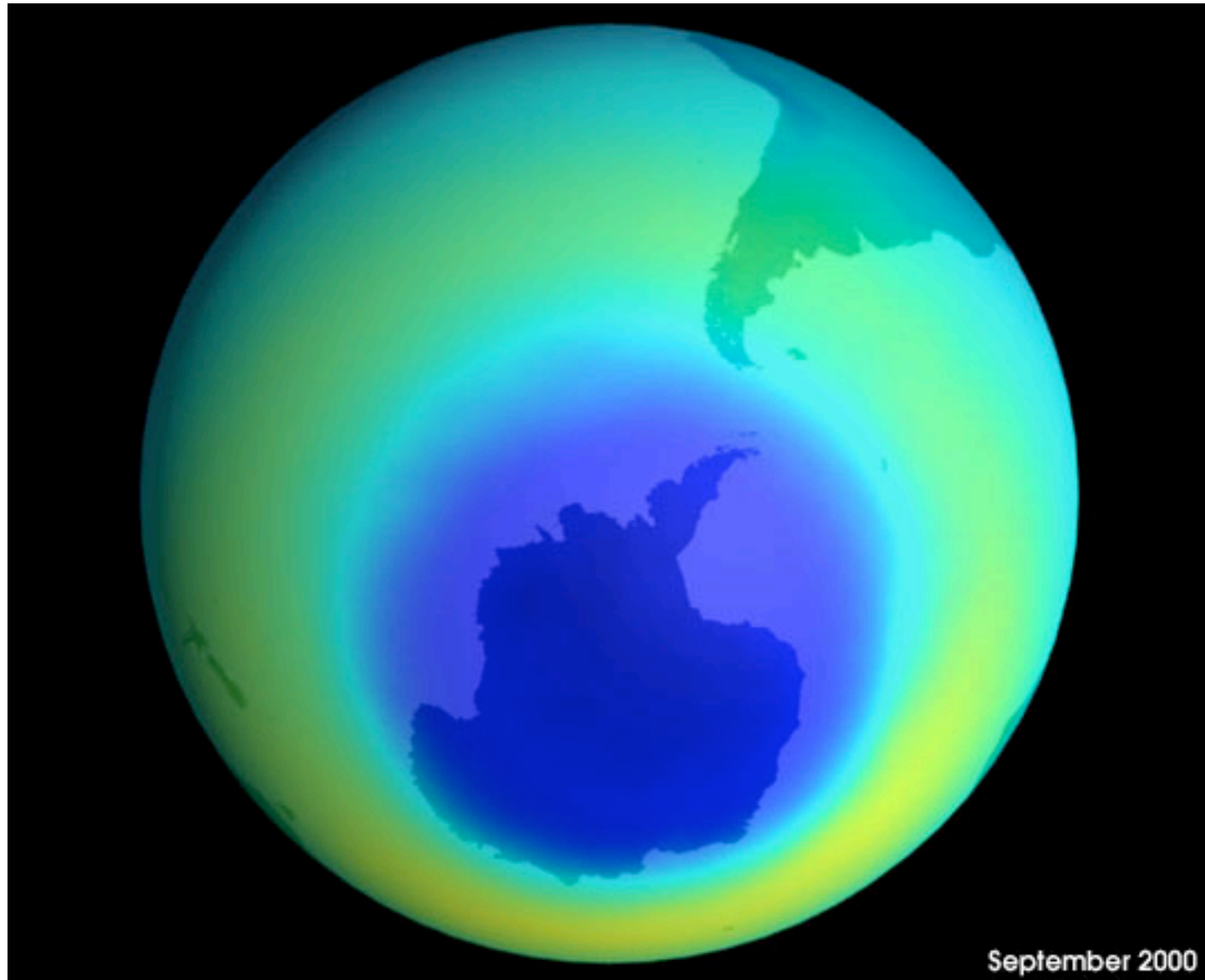
- Progress in weather forecasting
- Acid rain
- Ozone hole
- Recognition of greenhouse warming
- New subfields
 - atmospheric chemistry
 - climate dynamics

Evolution of forecast skill for northern and southern hemispheres 1981-2002

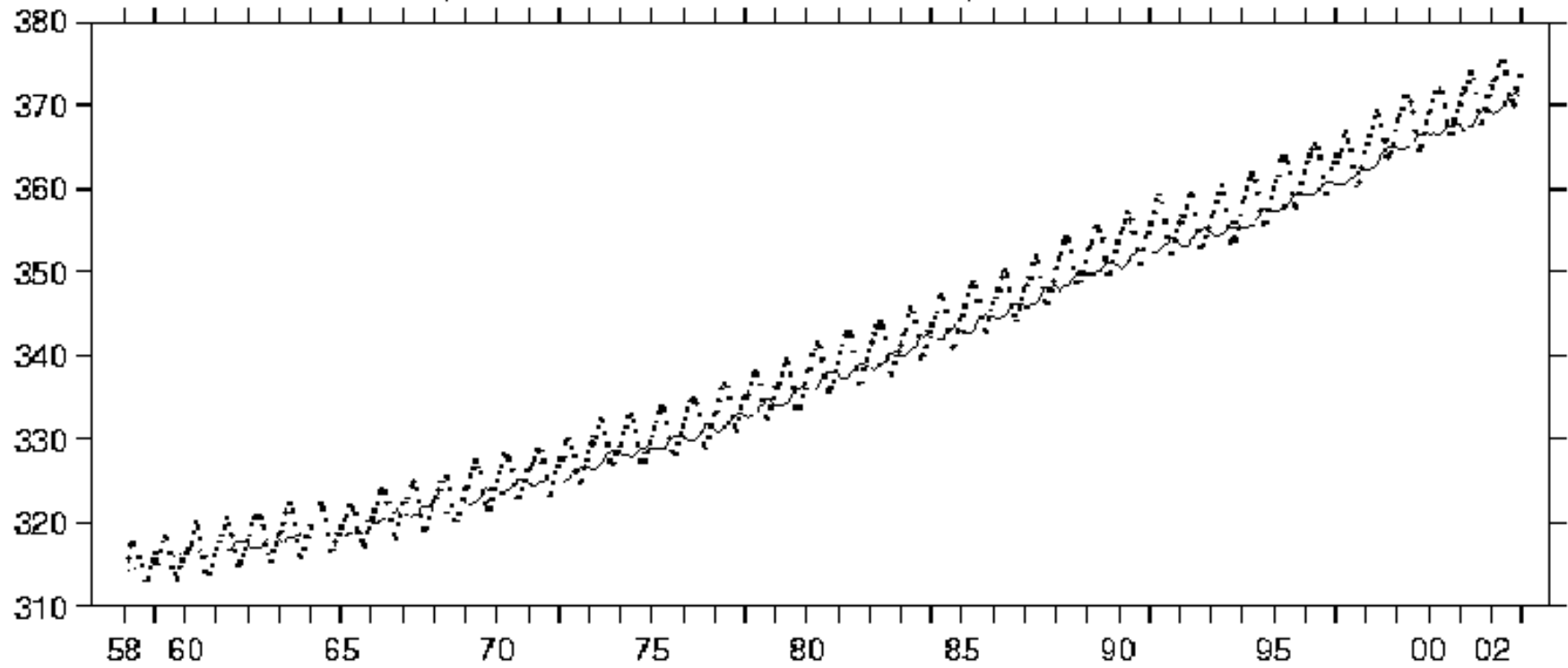




How acid rain affects stonework.
The picture on the left was taken in 1908.
The picture on the right was taken in 1968



Mauna Loa (dots) and South Pole (line) CO₂, 1958–2002



Components of the Earth system

Atmosphere

Oceans

Cryosphere

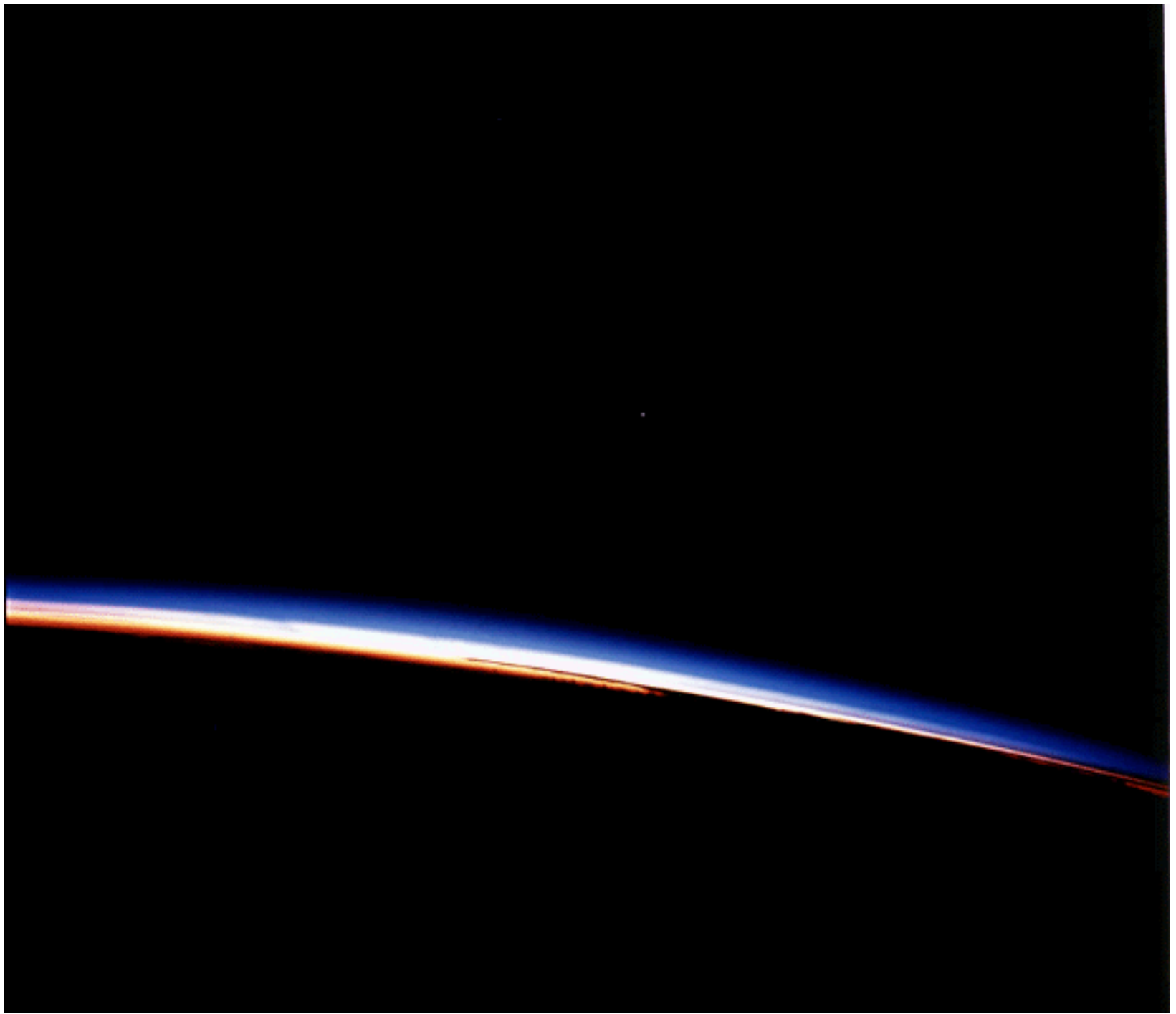
Terrestrial biosphere

Crust and mantle

Overview of the atmosphere

Thinness of the atmosphere





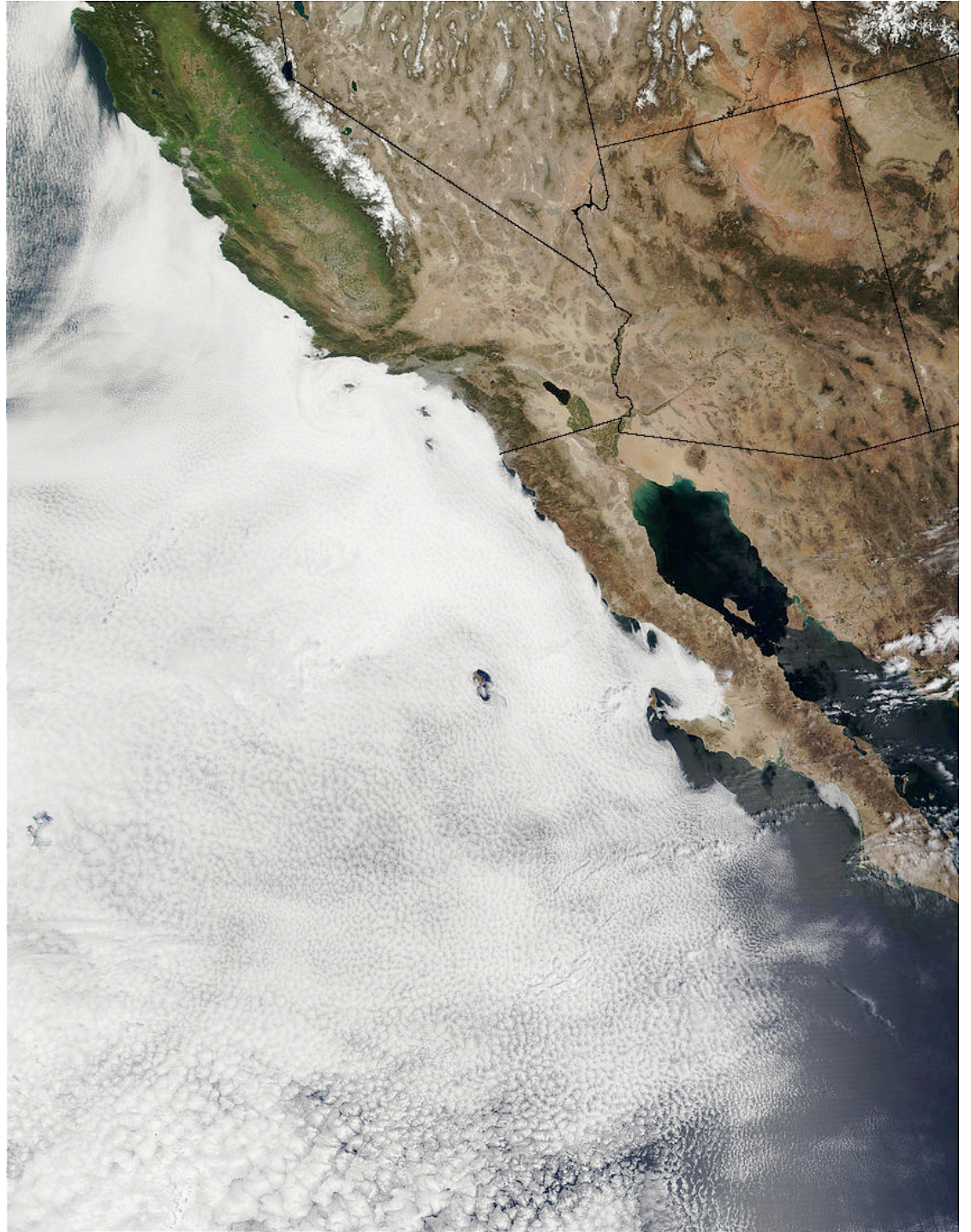




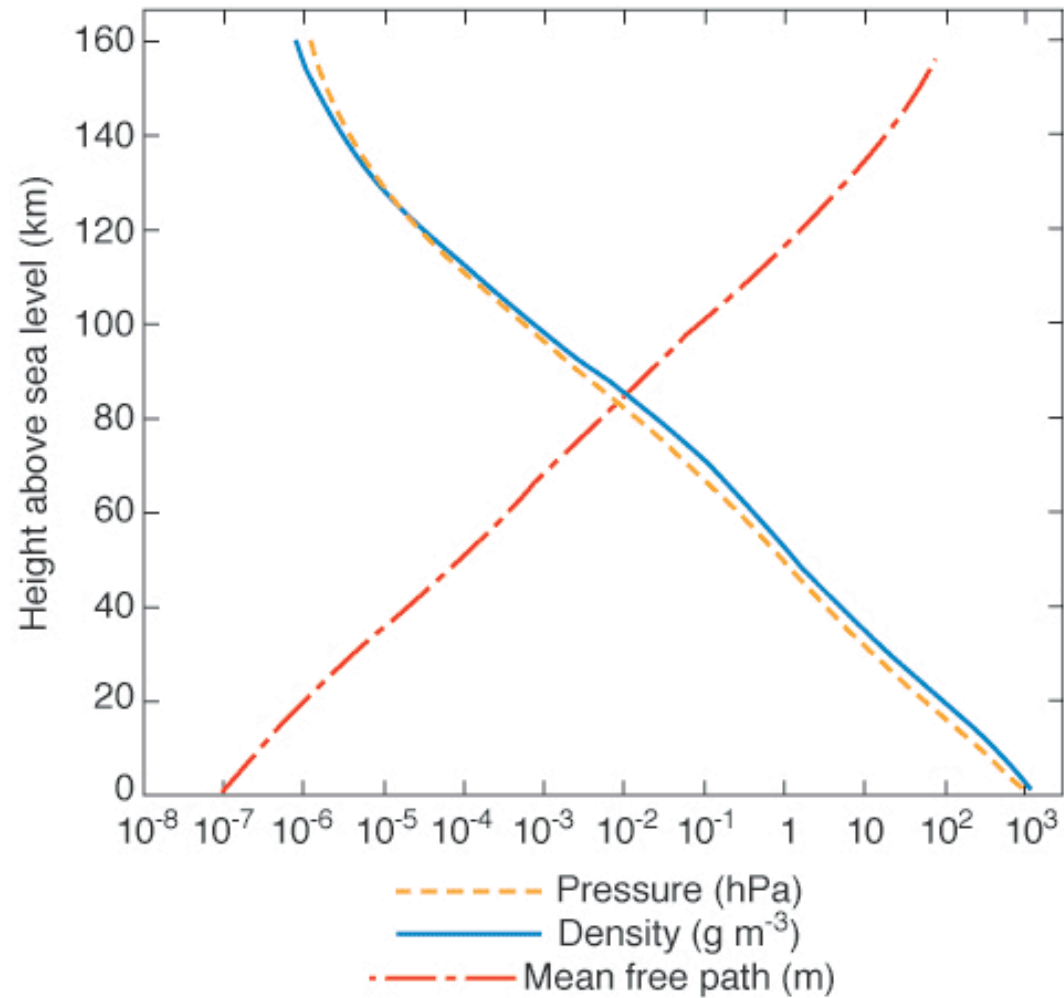
Optical properties

- Energetic radiation absorbed in outer atm.
 - Relatively transparent to solar radiation
 - Relatively opaque to terrestrial radiation
- the greenhouse effect**
- Large regional variations
 - Determined by gases, aerosols, clouds

Importance of clouds



Vertical structure



Vertical dependence of p , ρ

- Exponential decrease with height
- e -folding depth... **scale height**... ~ 7 km
- Pressure due to weight of overlying air
- Gases are compressible..

liquids are incompressible

The Turbopause

- Separates **homosphere** and **heterosphere**
- ~105 km where mean free path $>1\text{m}$
- Fluid motions dominate mixing below
- Molecular motions dominate above

Gaseous constituents

Constituent	Mol. Wt.	Conc. by vol.
Nitrogen (N ₂)	28.013	0.7808
Oxygen (O ₂)	32.000	0.2095
Argon (Ar)	39.95	0.0093
Water vapor (H ₂ O)	18.02	variable
Carbon dioxide (CO ₂)	44.01	380 ppmv
Neon (Ne)	20.18	18
Helium (He)	4.00	5
Methane (CH ₄)	16.	1.75 "
Hydrogen (H ₂)	2.02	0.5 "
Nitrous oxide (N ₂ O)	56.03	0.3 "
Ozone (O ₃)	48.00	0-0.1 "

Minor constituents

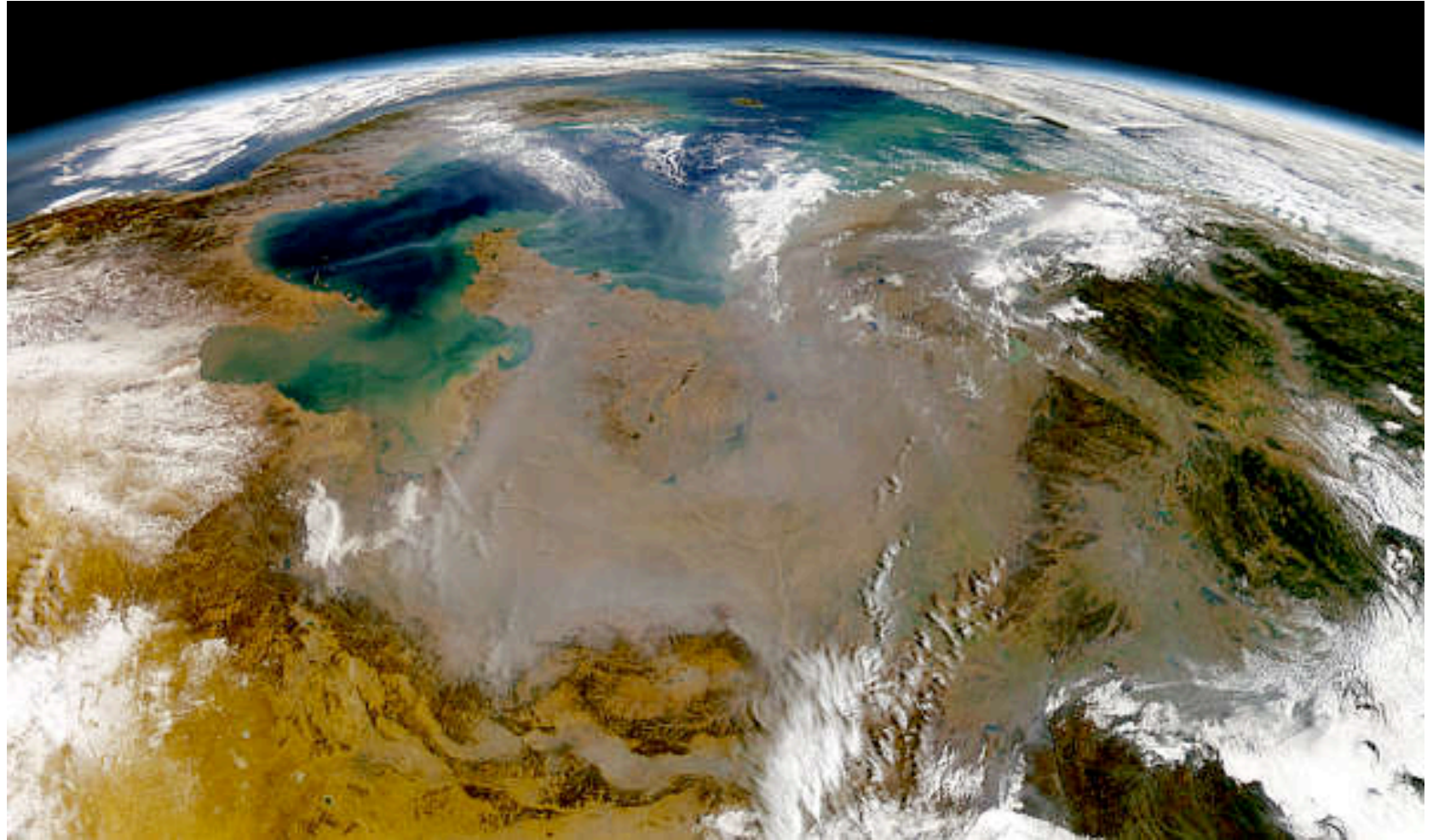
Associated with biogeochemical cycles

- carbon
- nitrogen
- sulfur

OH plays important role as a cleanser

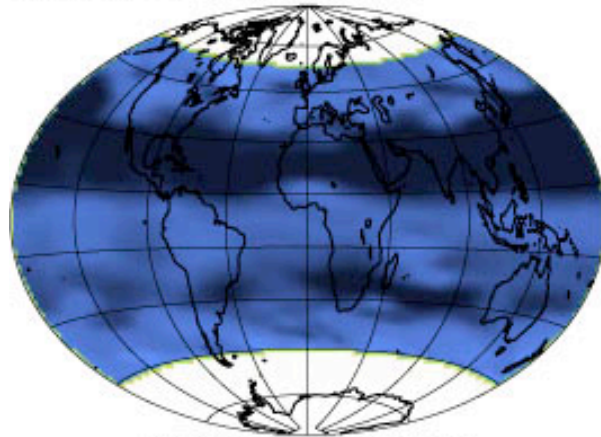
Atmospheric aerosols

- **Sources-** biomass burning, living organisms, industry, volcanoes, windblown dust, gas to particle conversions
- **Sinks-** dry deposition, scavenging by precipitation processes

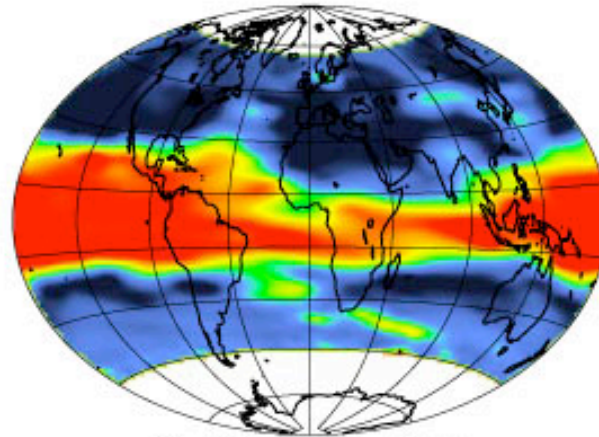


Spread of Pinatubo aerosol

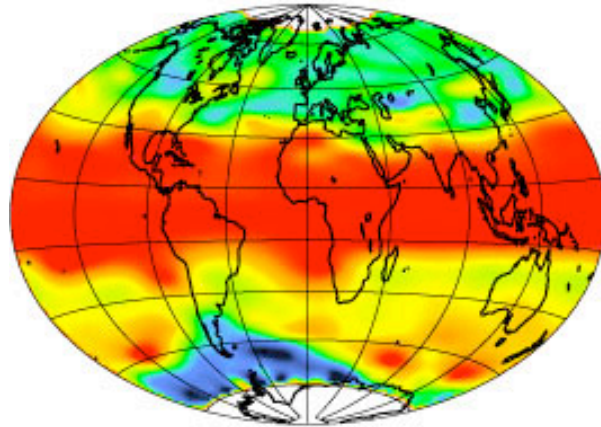
SAGE II 1020 nm Optical Depth



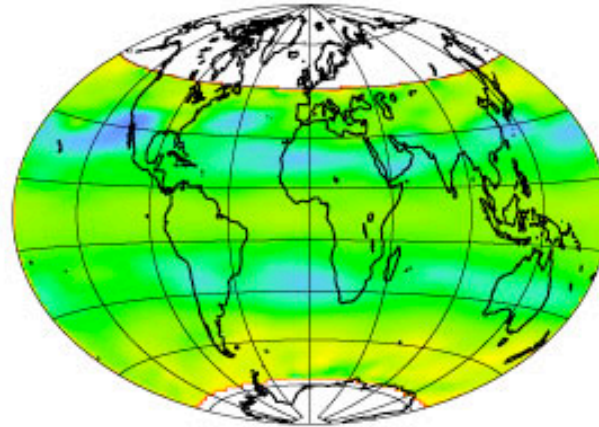
91-April-10 to 91-May-13



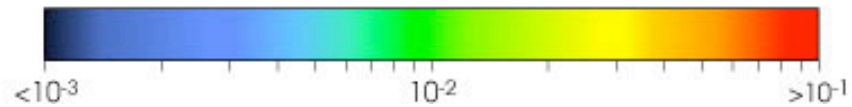
91-June-15 to 91-July-25

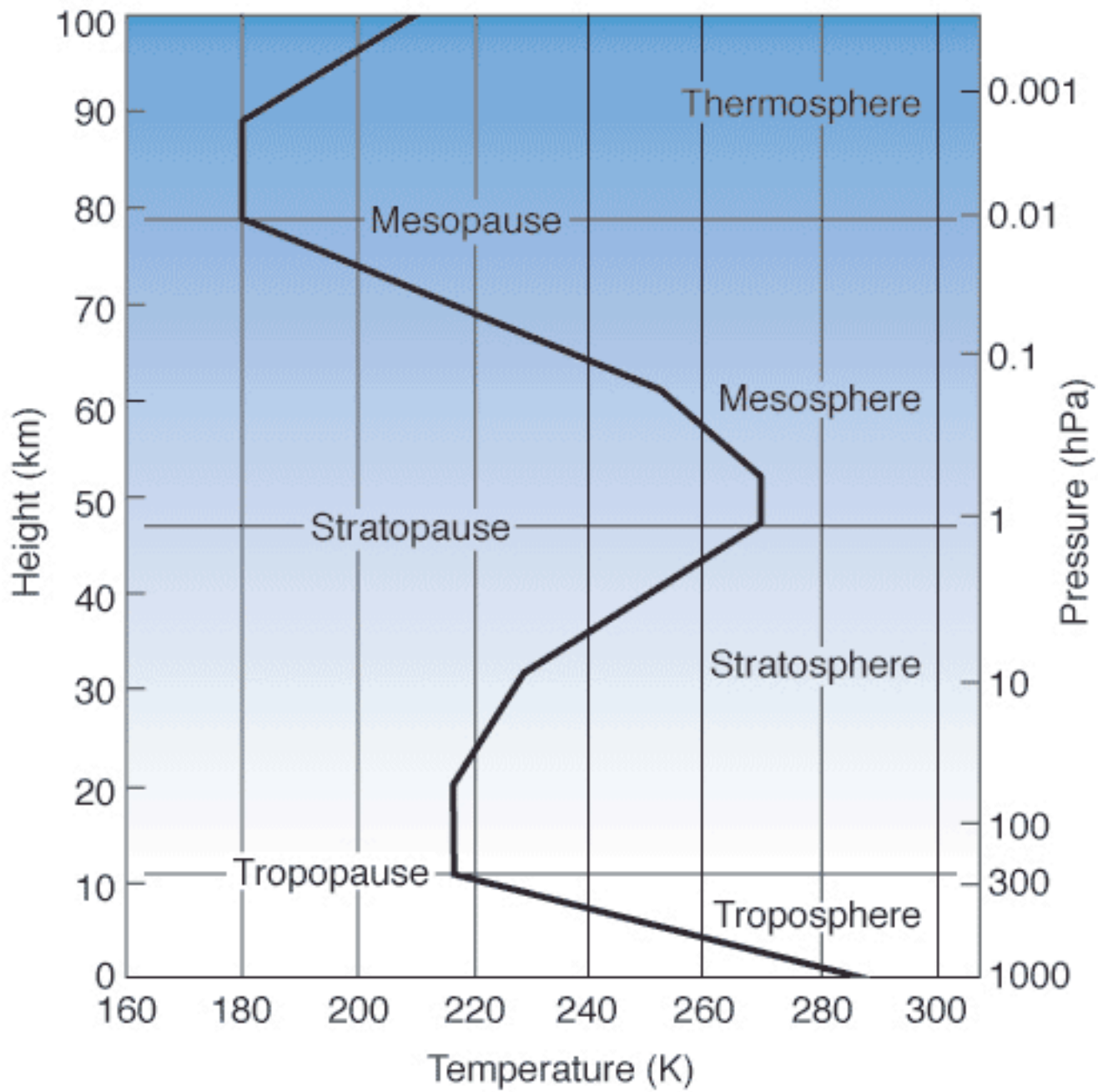


91-August-23 to 91-September-30



93-December-5 to 94-January-16



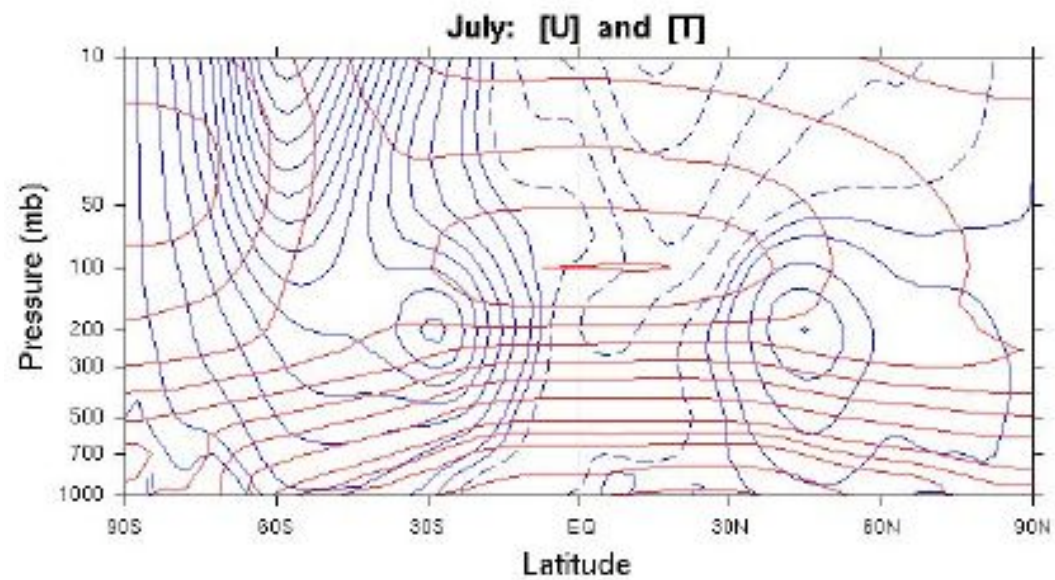
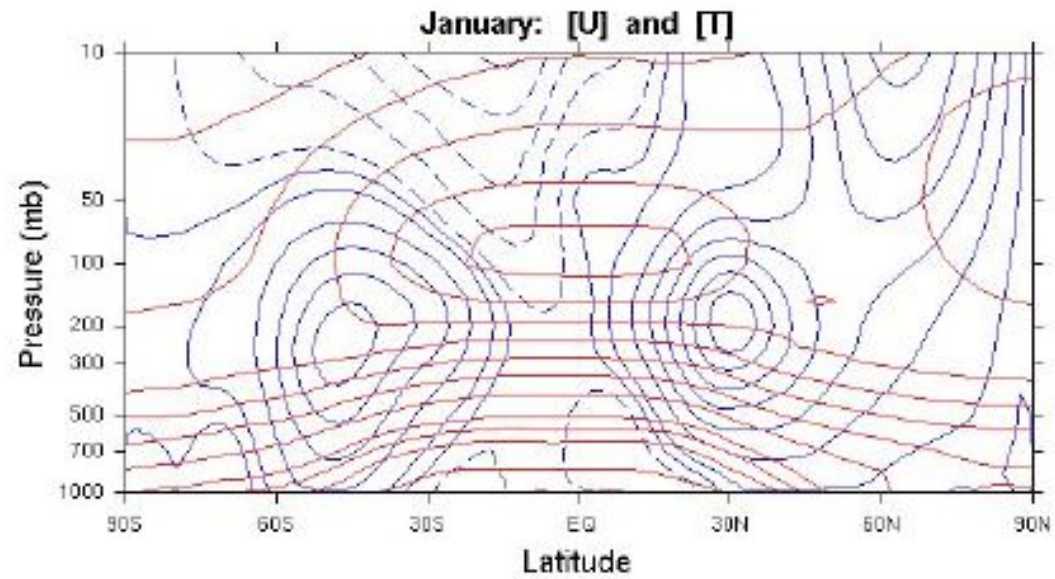


Anvil cloud at tropopause





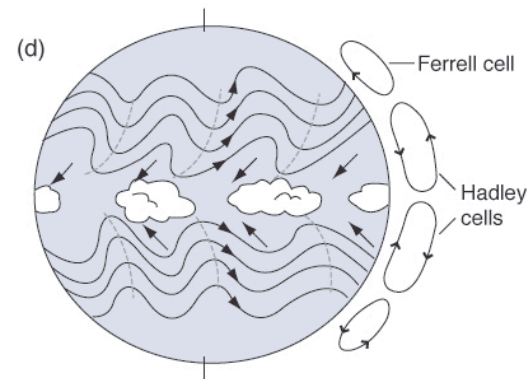
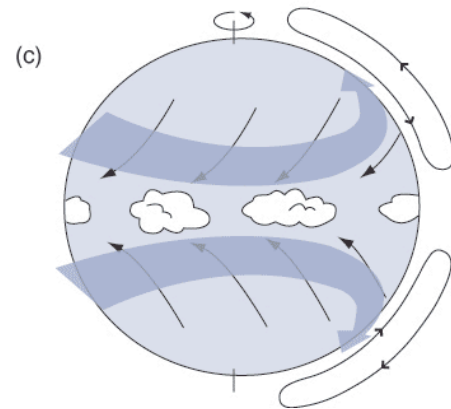
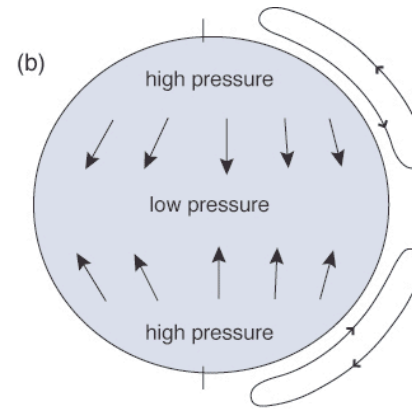
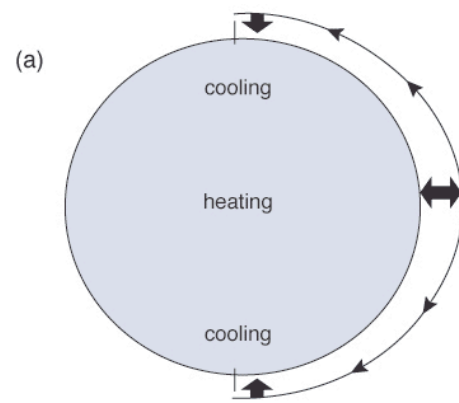
Zonal wind and temperature



Atmospheric motions: sources

- Equator to pole heating gradient
- Convection
 - deep vs. shallow
- Shear instability and boundary effects
 - give rise to turbulence; the ‘energy cascade’

Horizontal heating gradients



Convection

Spontaneous ascent of
buoyant plumes



Shallow convection



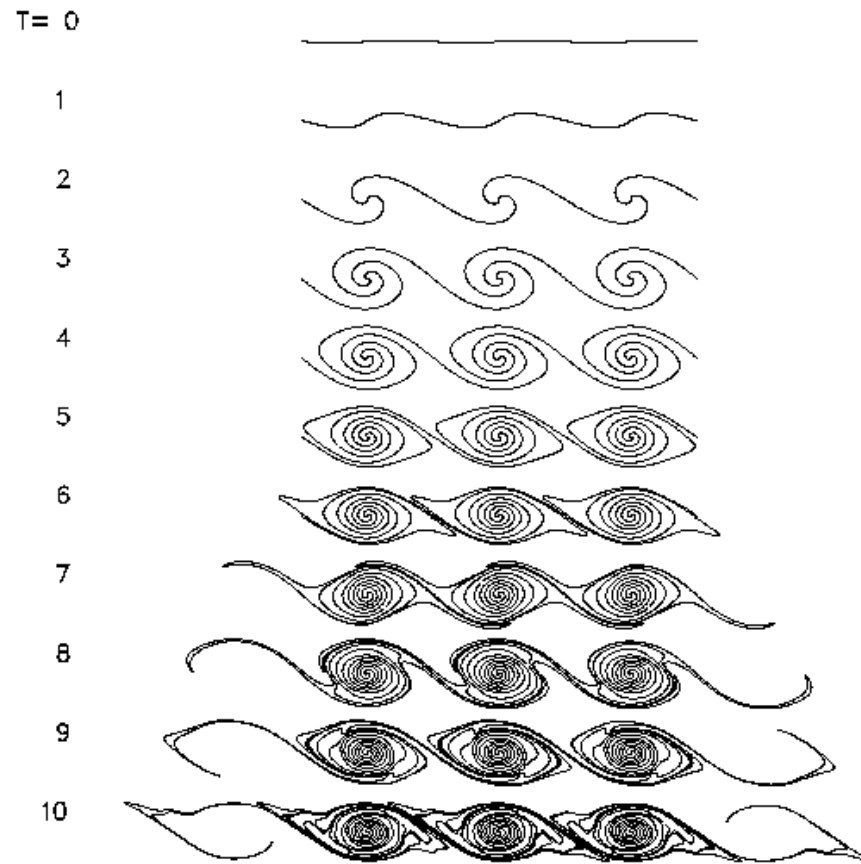
Deep convection



Deep convection



Shear instability



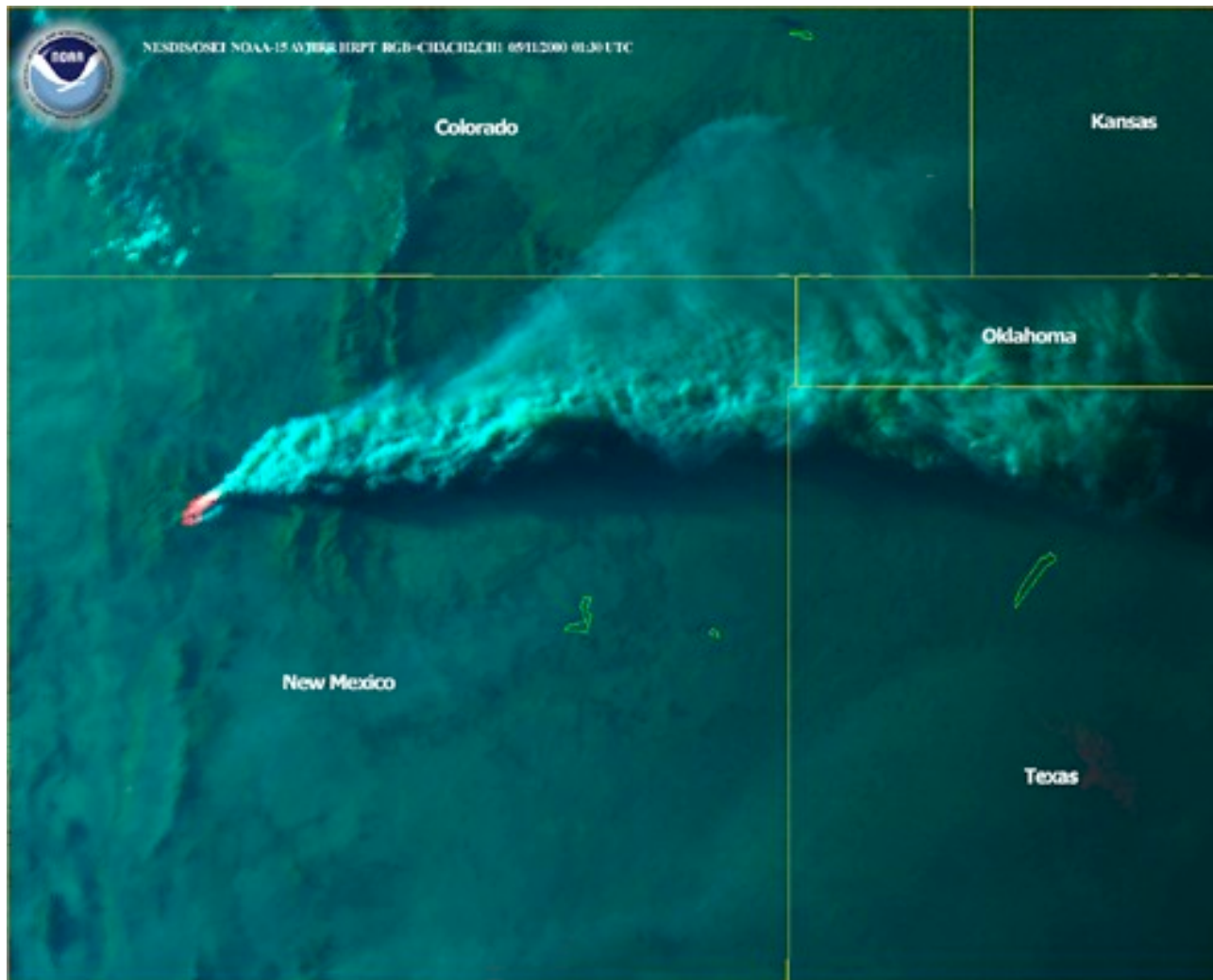


Kelvin-Helmholtz Instability Cloud & Lenticular Cloud above Beartooth Butte



© Rick Dunn
RJDphoto.com

Turbulent diffusion



Weather systems

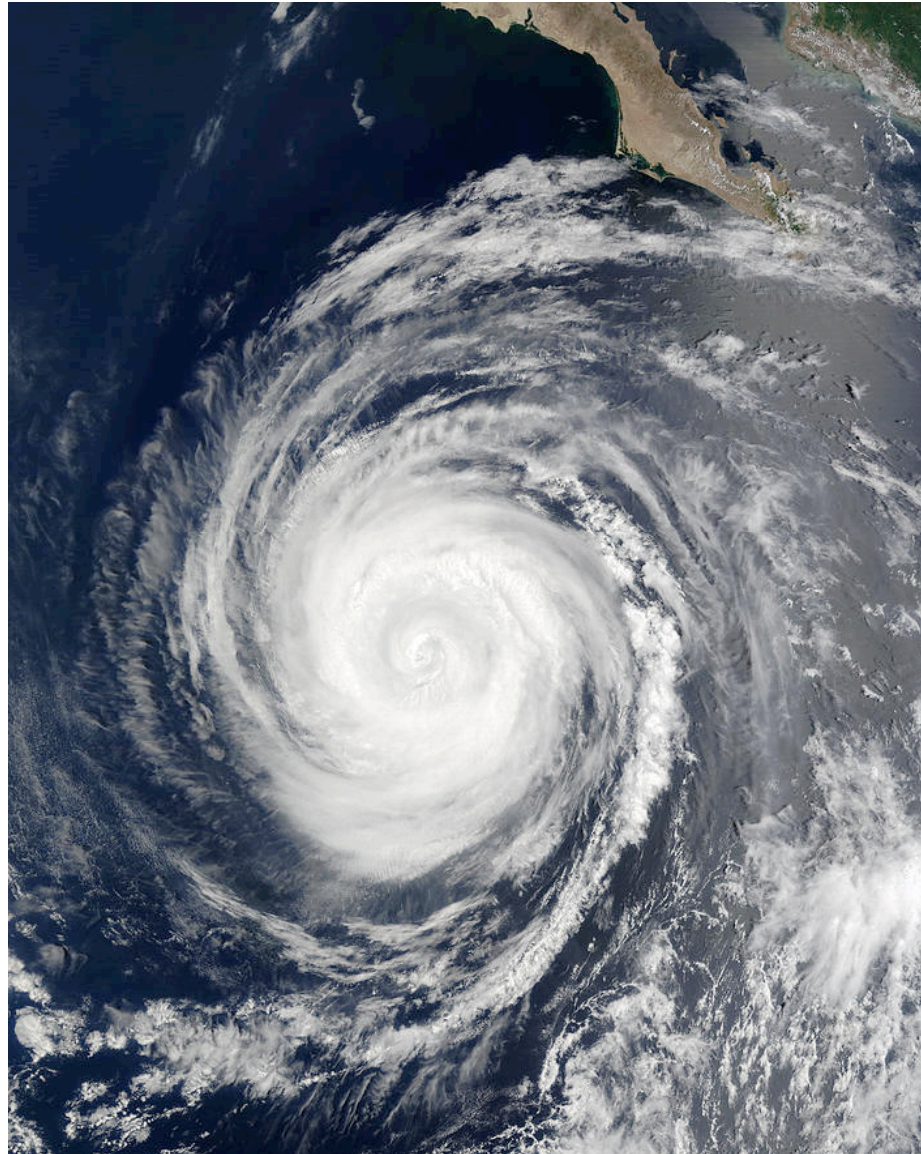
- Baroclinic waves.... extratropical cyclones
fronts
- Tropical cyclones
- Severe convective storms

Extratropical cyclones





Tropical cyclones

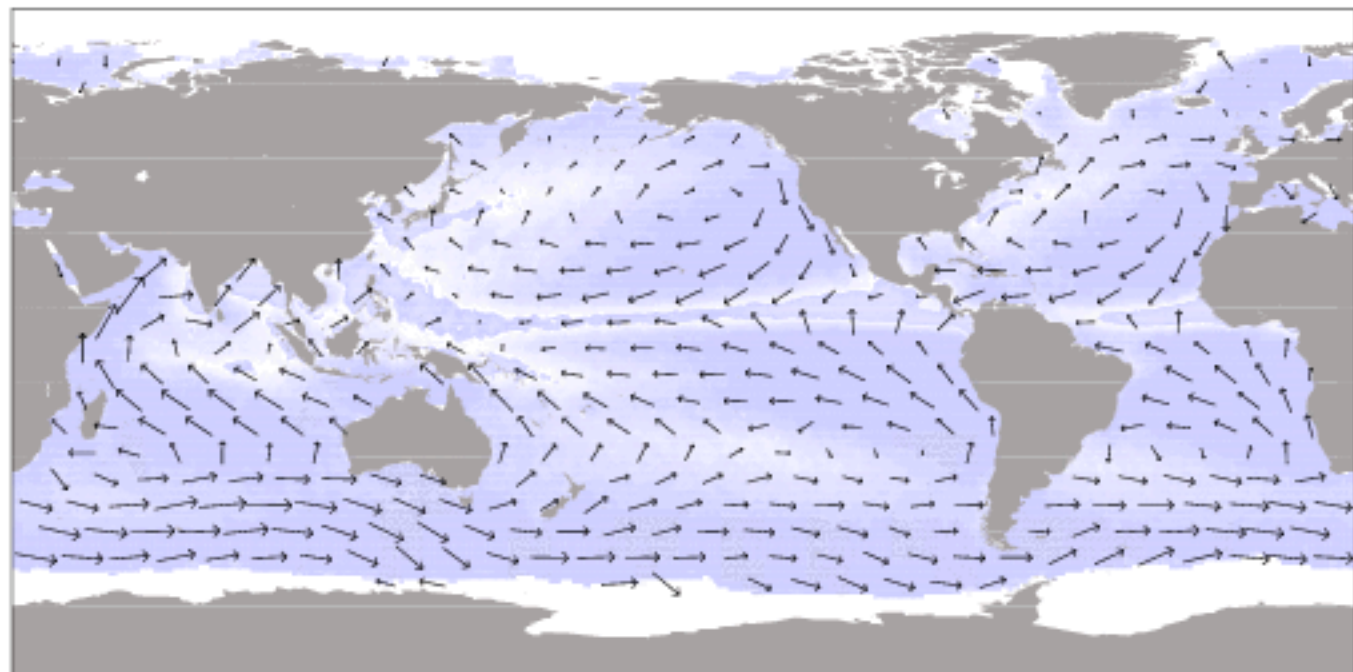
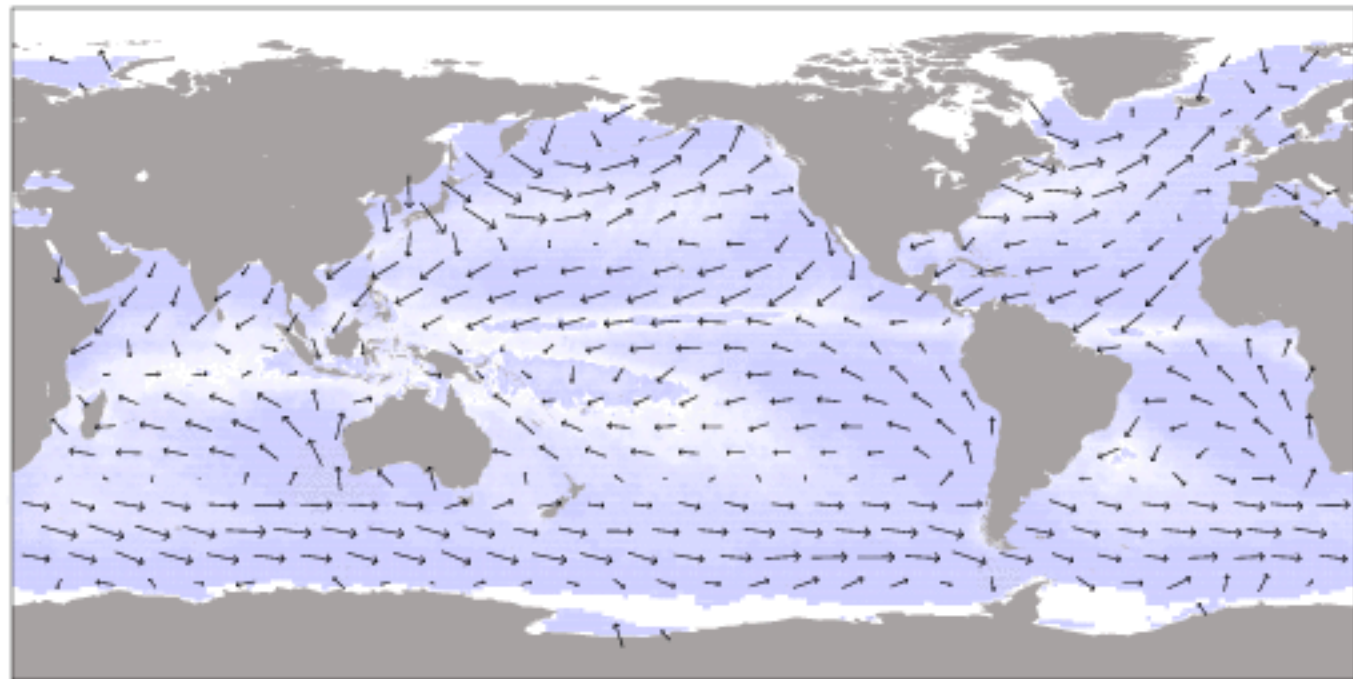


Supercell convective storms



Global wind systems

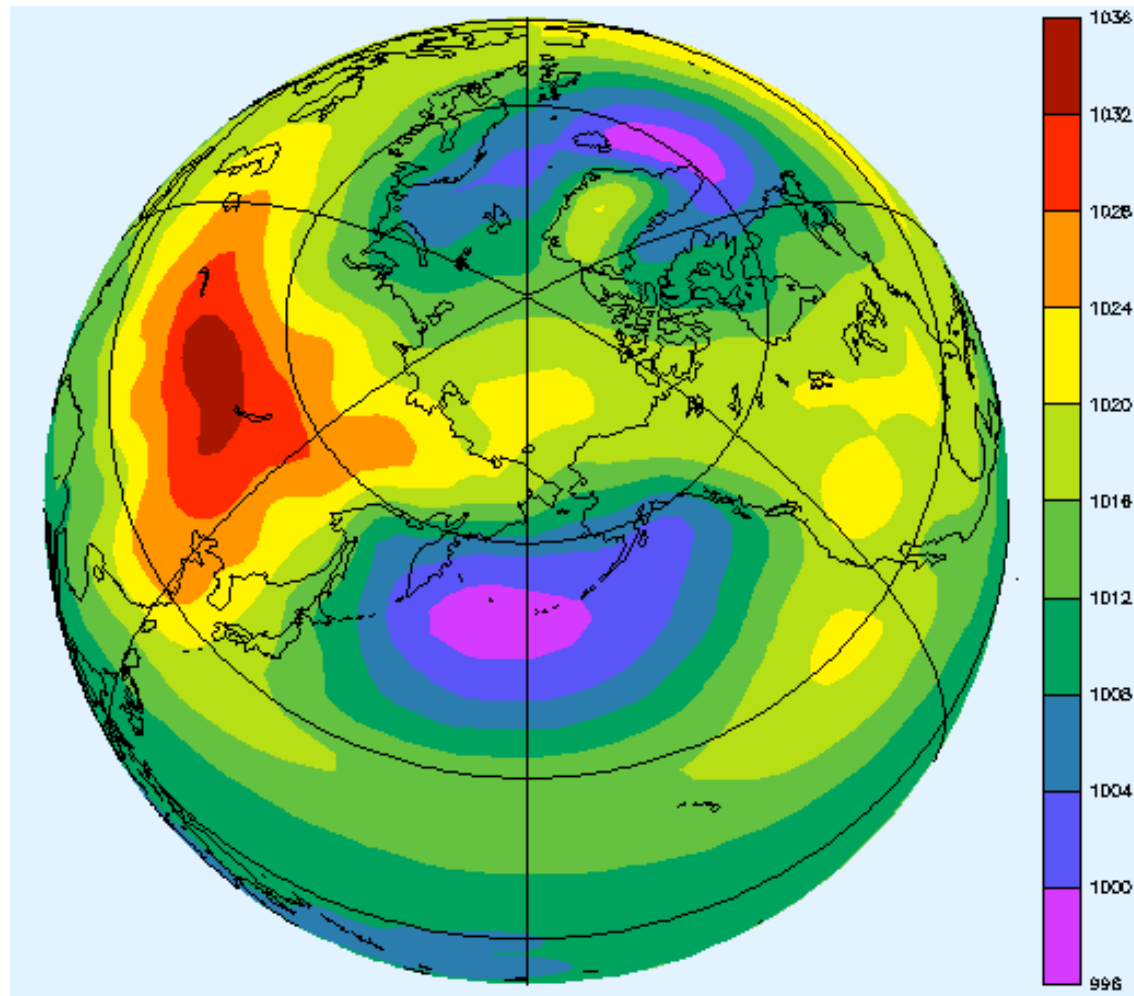
December-January-February and June-July-August 10-m wind and precipitation

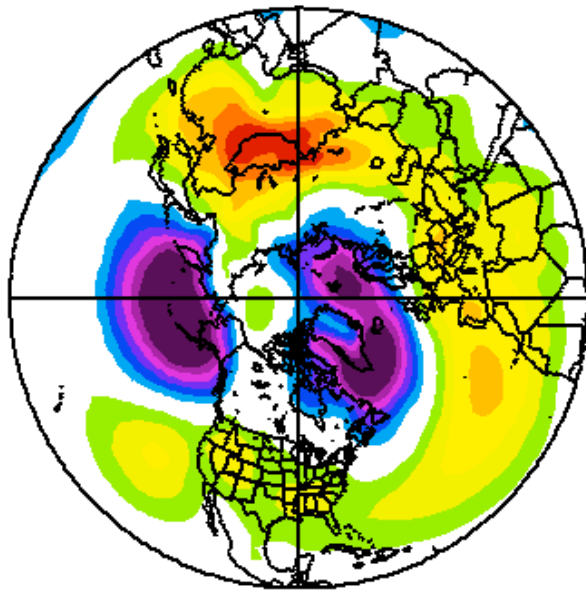


Climatological features

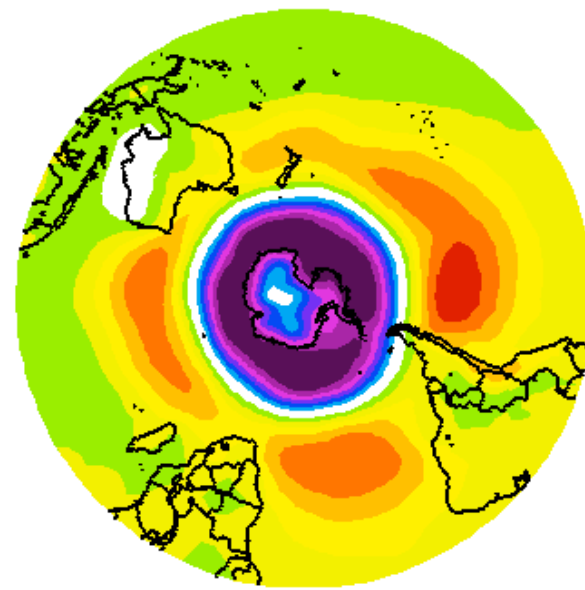
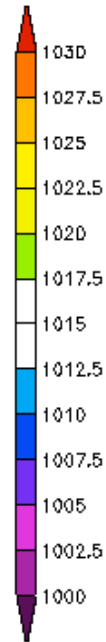
- Tradewind belts (Atlantic, Pacific)
- Intertropical convergence zone
- Monsoons (Indian Ocean sector)
- Westerly wind belts (strongest in winter)
- Subtropical anticyclones (summer)

Jan/Feb sea-level pressure 1958-97

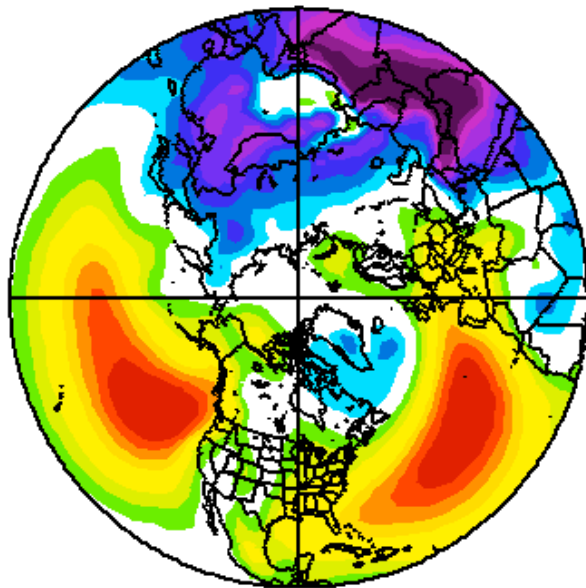
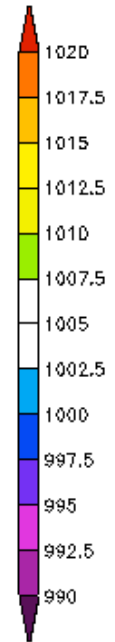




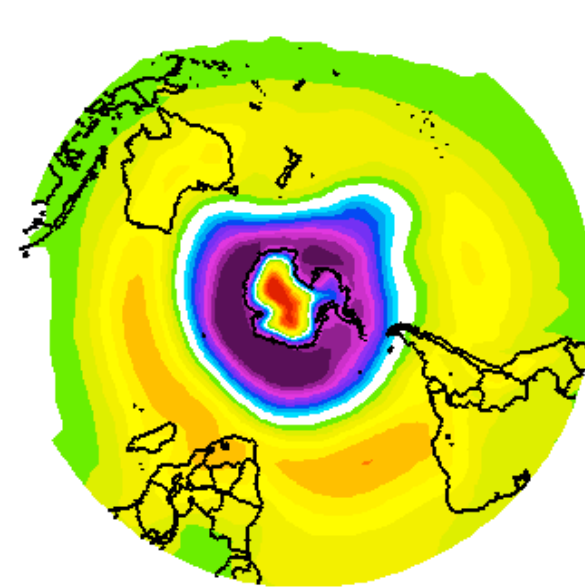
SEA LEVEL PRESSURE (mb) 01-DAY LONG TERM MEAN FOR:
JAN 15



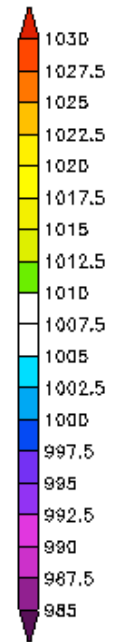
SEA LEVEL PRESSURE (mb) 01-DAY LONG TERM MEAN FOR:
JAN 15



SEA LEVEL PRESSURE (mb) 01-DAY LONG TERM MEAN FOR:
JUL 15

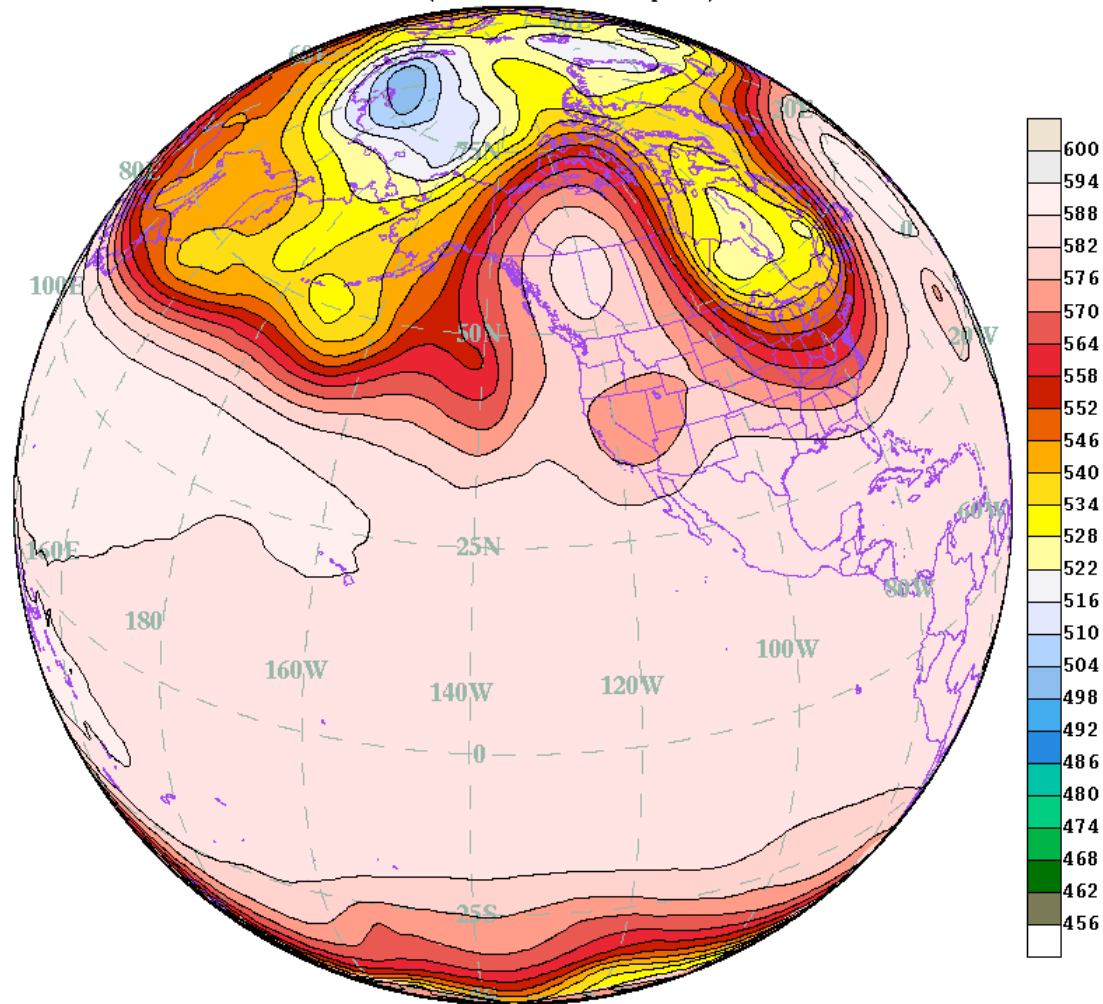


SEA LEVEL PRESSURE (mb) 01-DAY LONG TERM MEAN FOR:
JUL 15

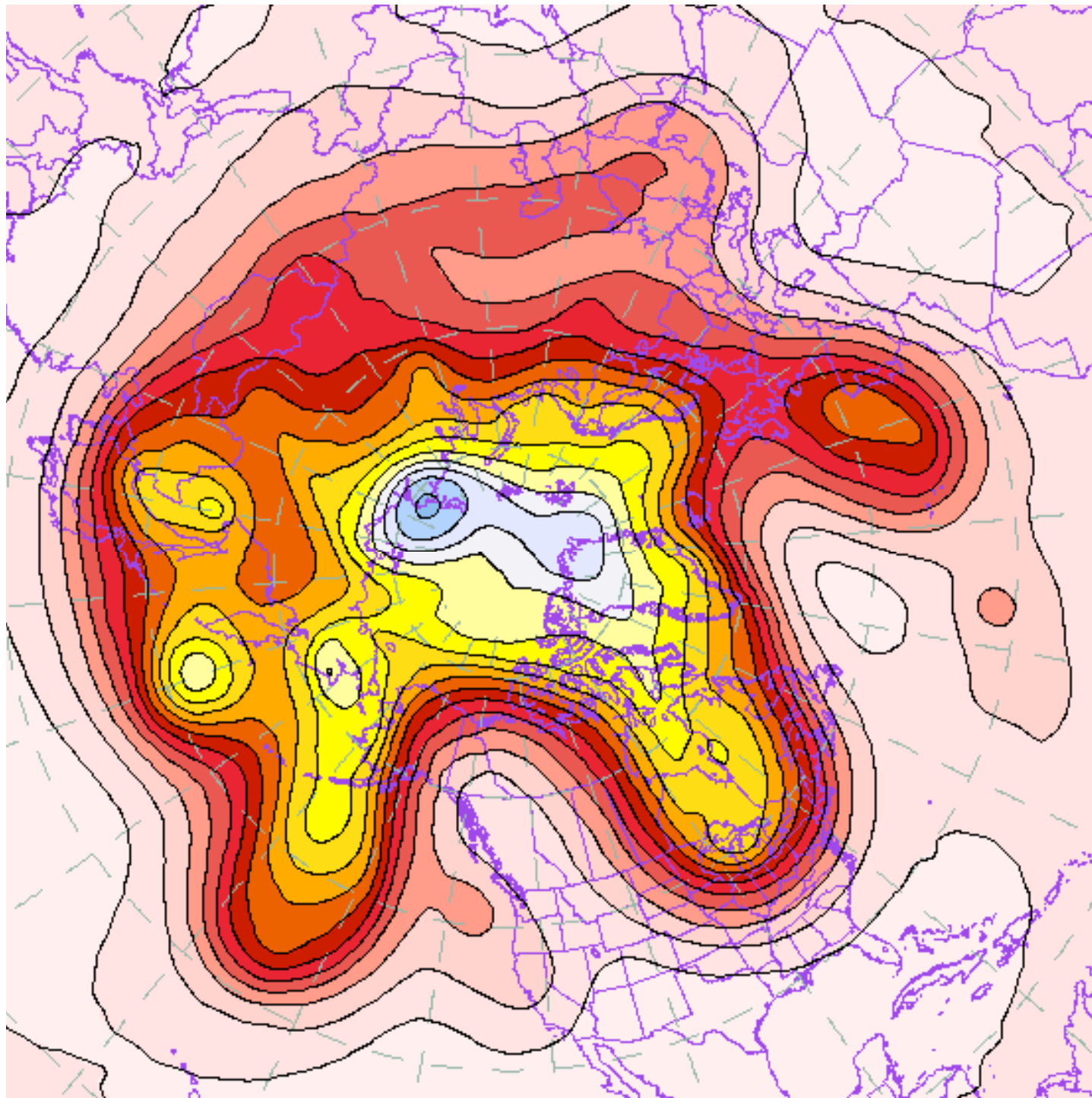


500-hPa height chart

084 Hr Fcst 500 MB Heights (dekameters) valid 12Z Fri 03 Oct 2003
(initialized 00Z Tue 30 Sep 2003)

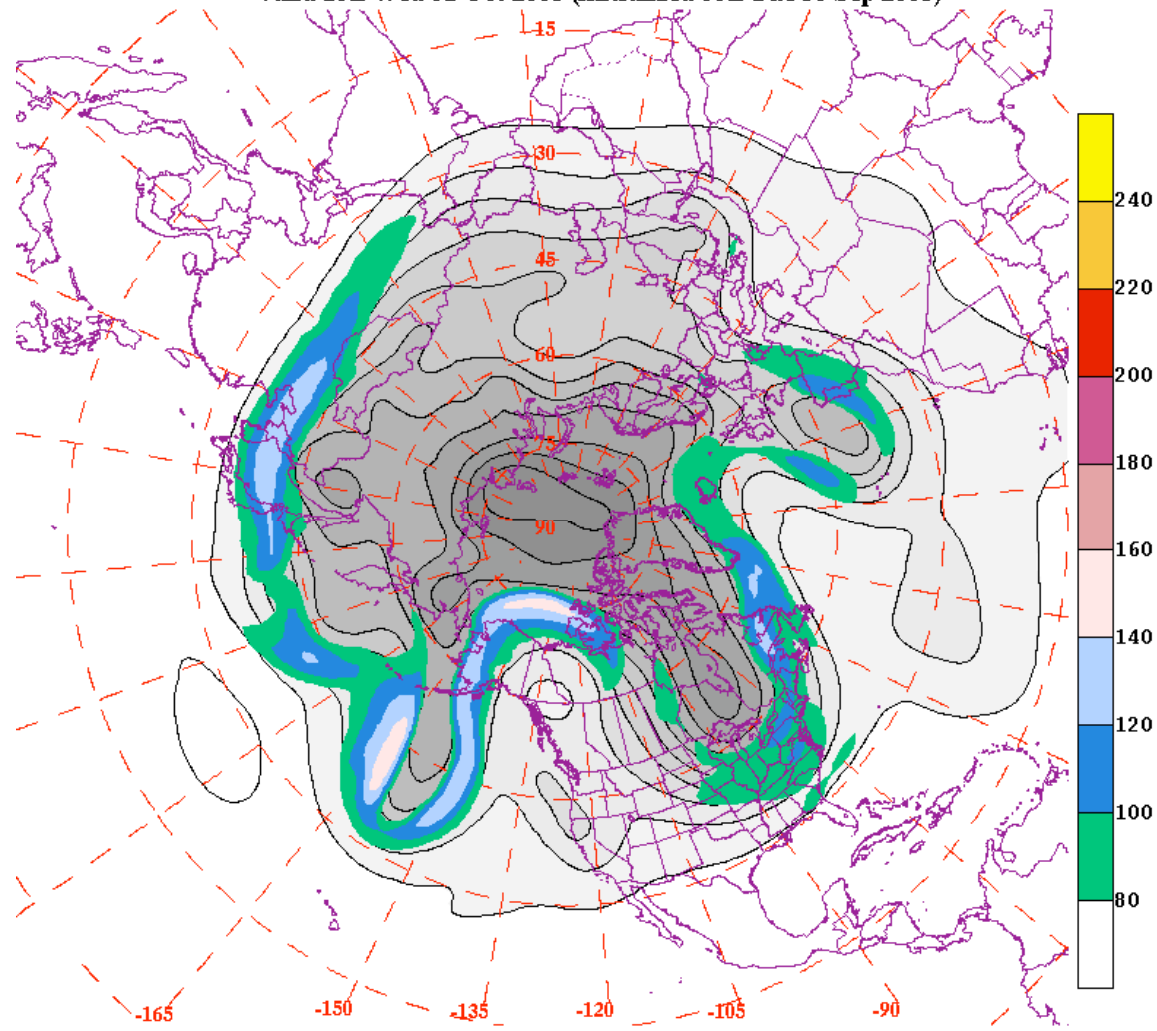


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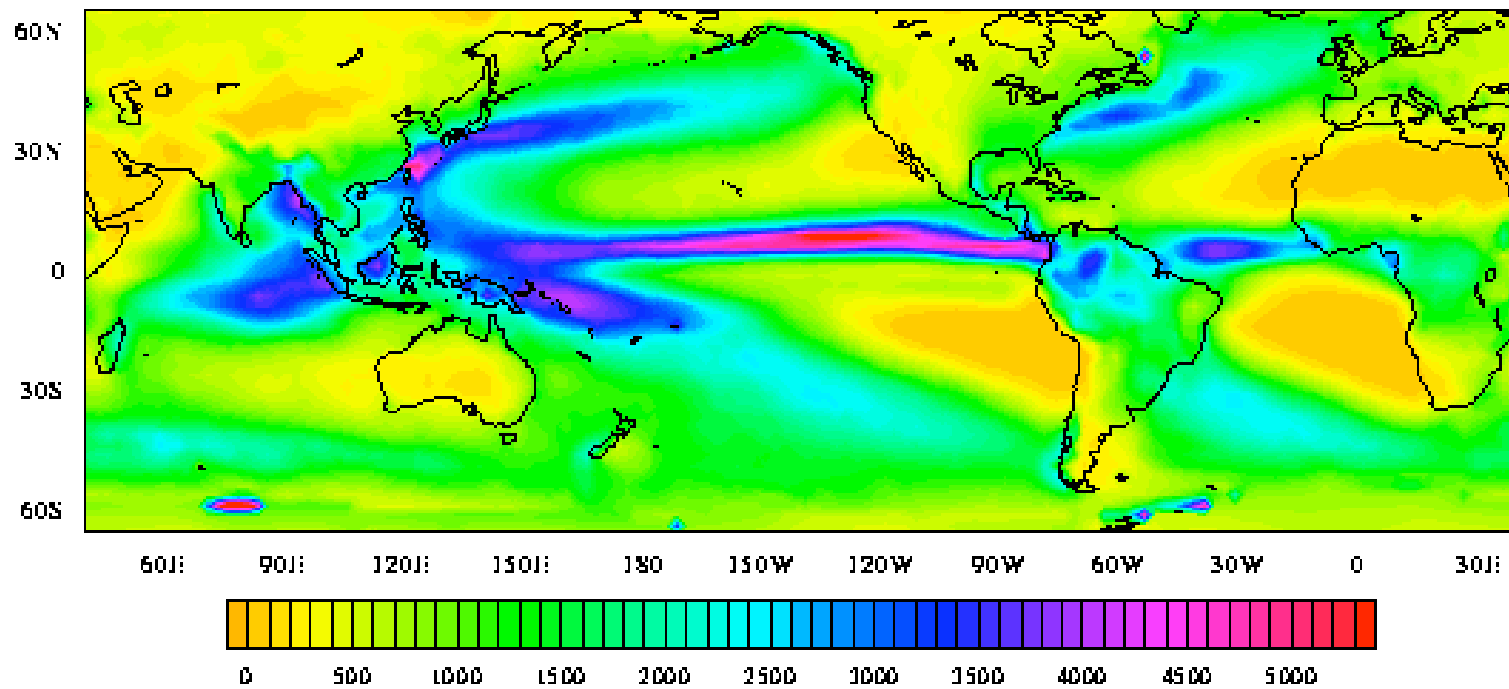
Jet Stream level

042 Hr Fcst 250 MB Heights (dekameters)/Wind Speed (kts)
valid 18Z Wed 01 Oct 2003 (initialized 00Z Tue 30 Sep 2003)



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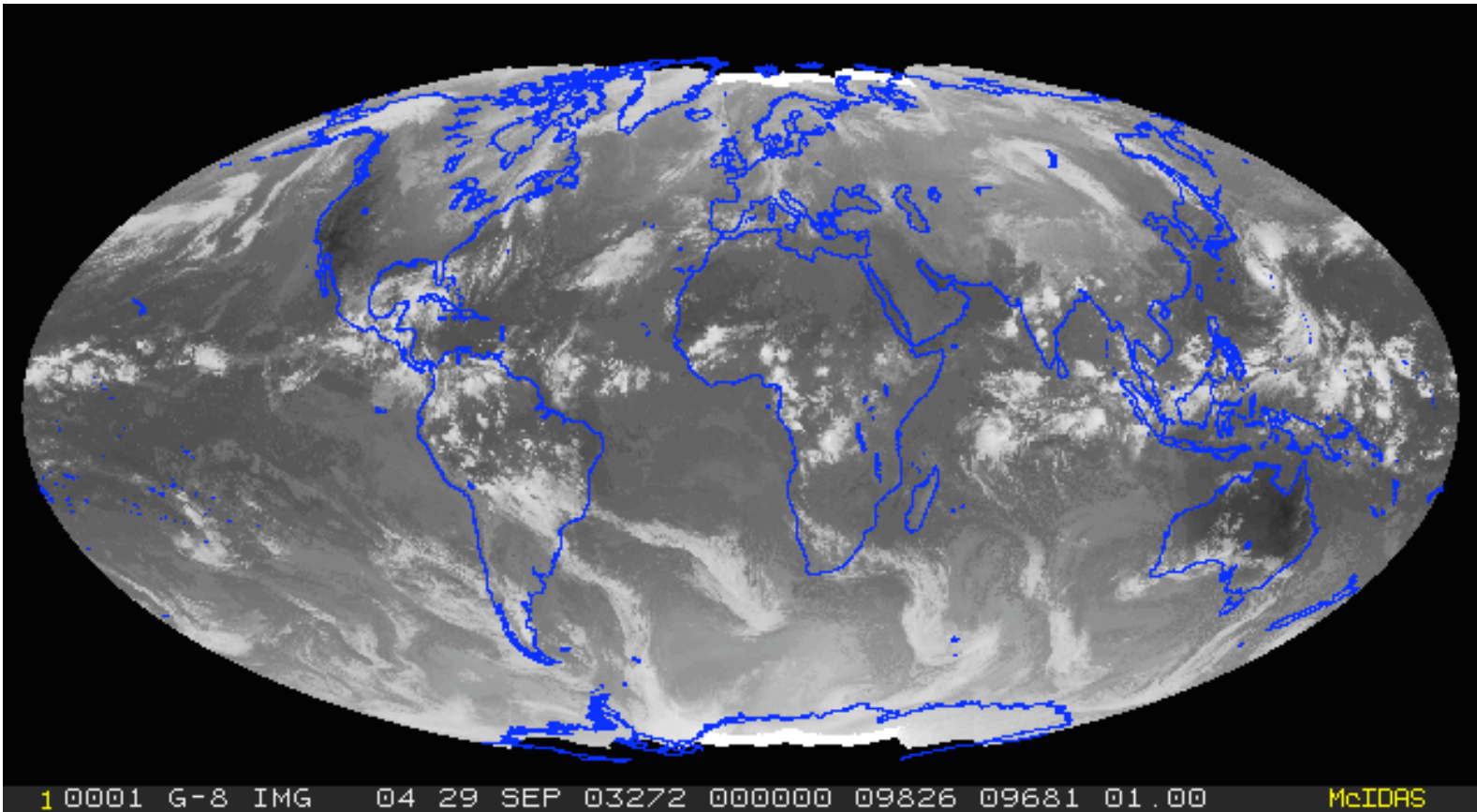
Global rainfall



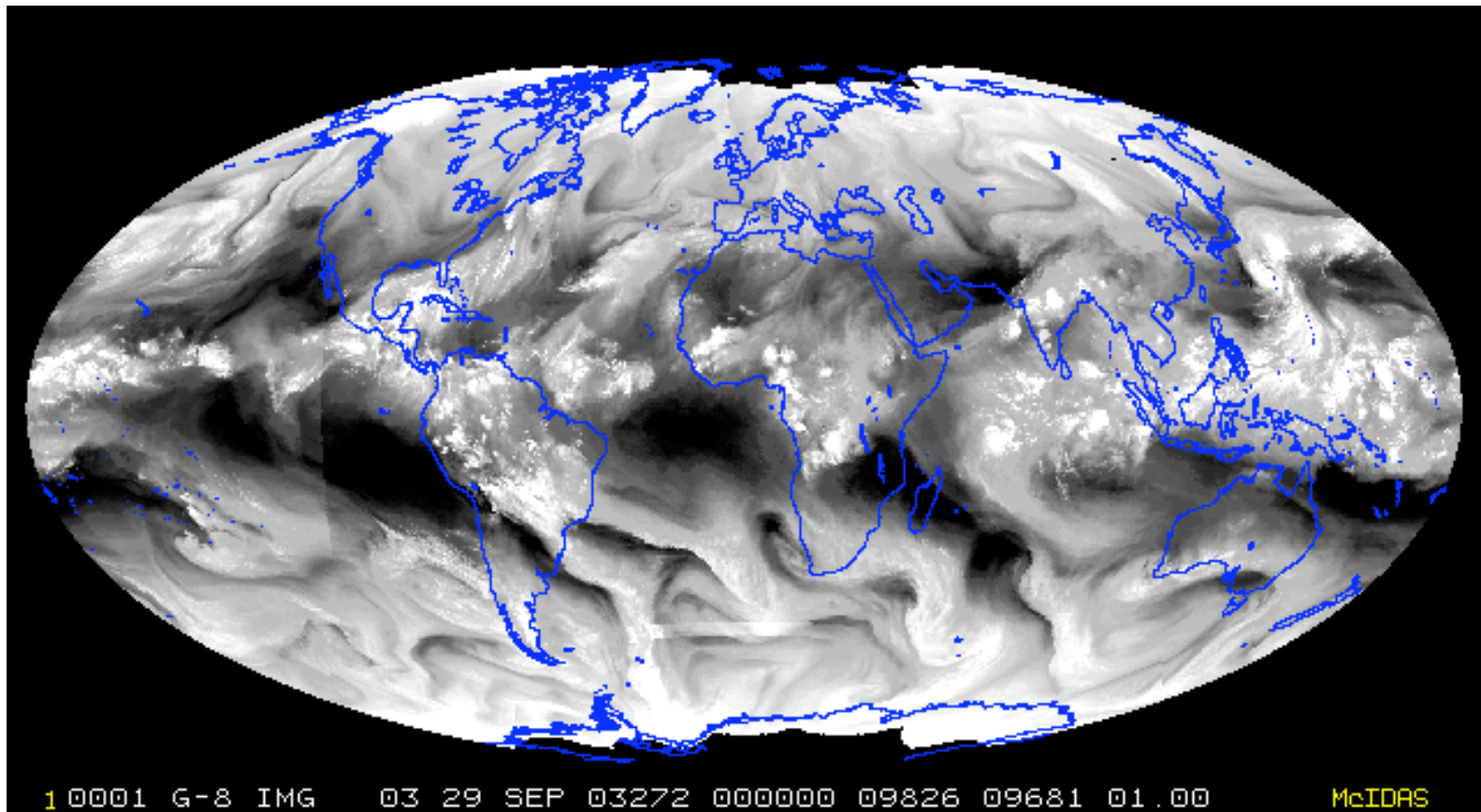
Climatological features

- ITCZ
- Monsoons
- Equatorial and northern subtropical
“dry zones”
- Extratropical “storm tracks”

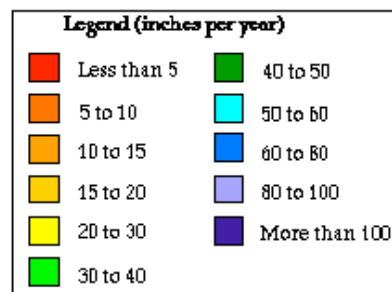
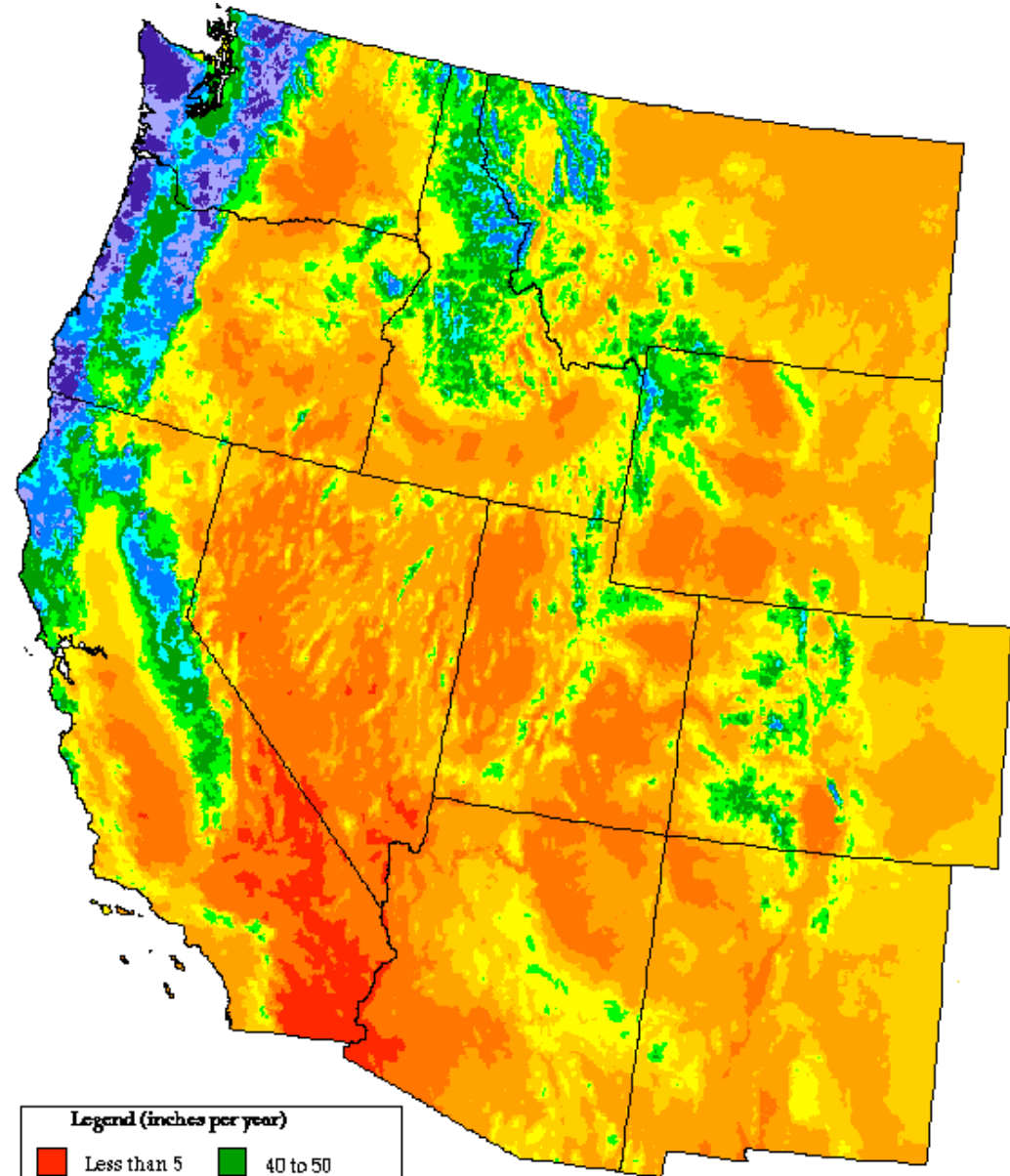
Storm tracks in IR imagery



Water vapor imagery



Terrain effects



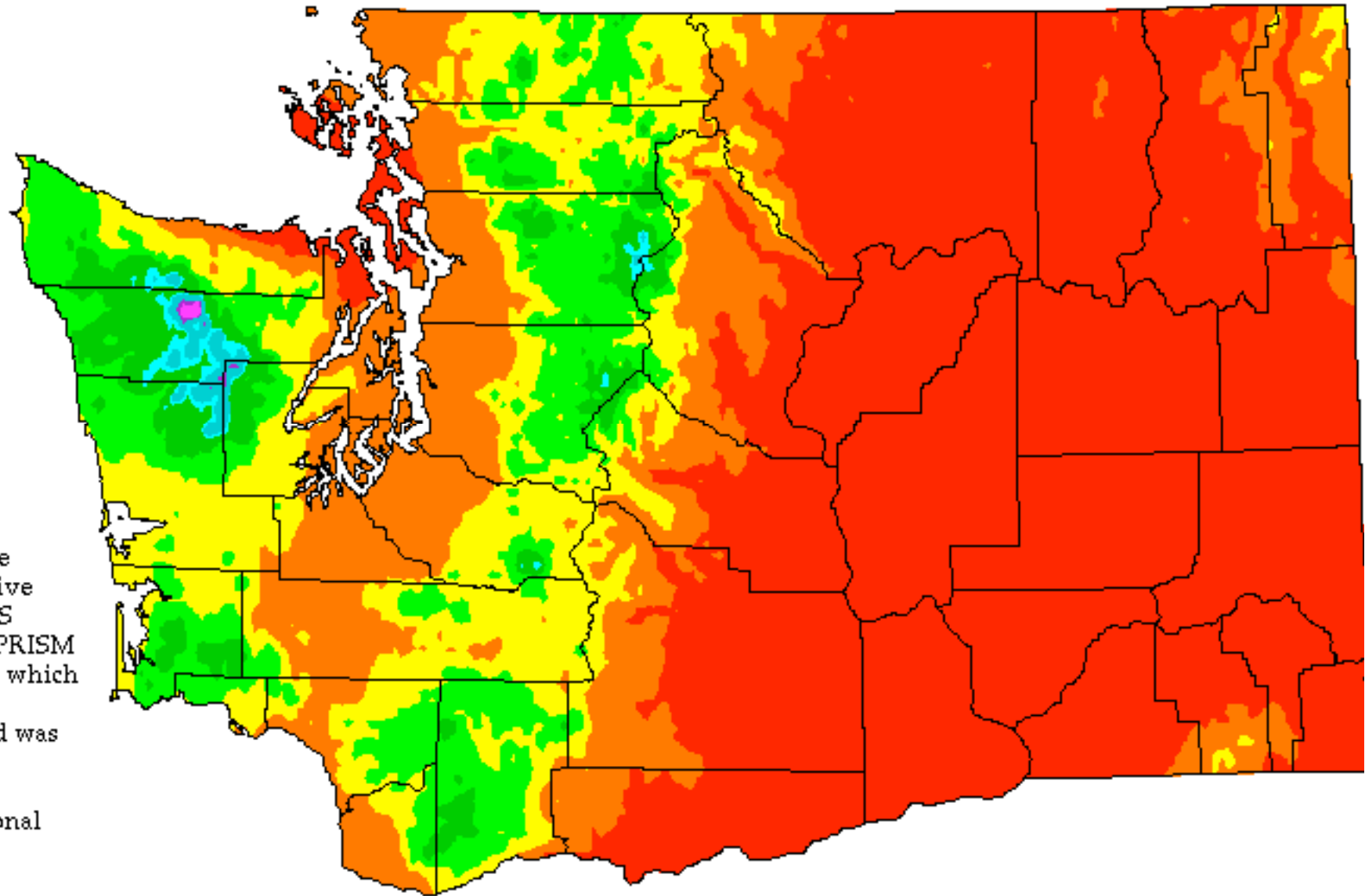
Average Annual Precipitation

Western United States

Period: 1961-1990 Units: inches

Washington

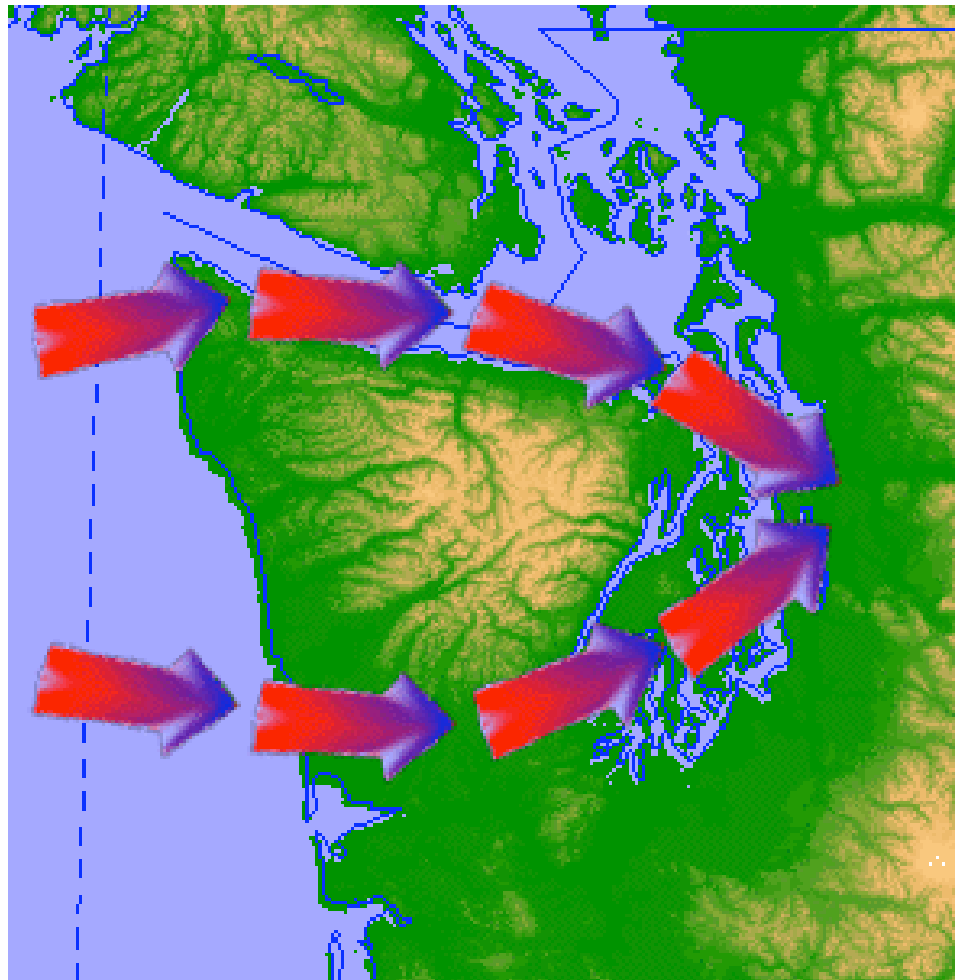
180
210
240
240



annual average
A Cooperative
USDA-NRCS
ly used the PRISM
imates from which
ed grid was
ngitude, and was
ssian filter.
Weisburg,
NRCS National

12/7/97

Puget Sound Convergence Zone



Terrain effects



Von Karman vortex streets



Atmosphere in Earth system

- transparent, mobile, global
- influential in determining “life zones”

