

Chapter 1 – A Brief Summary of the Atmosphere

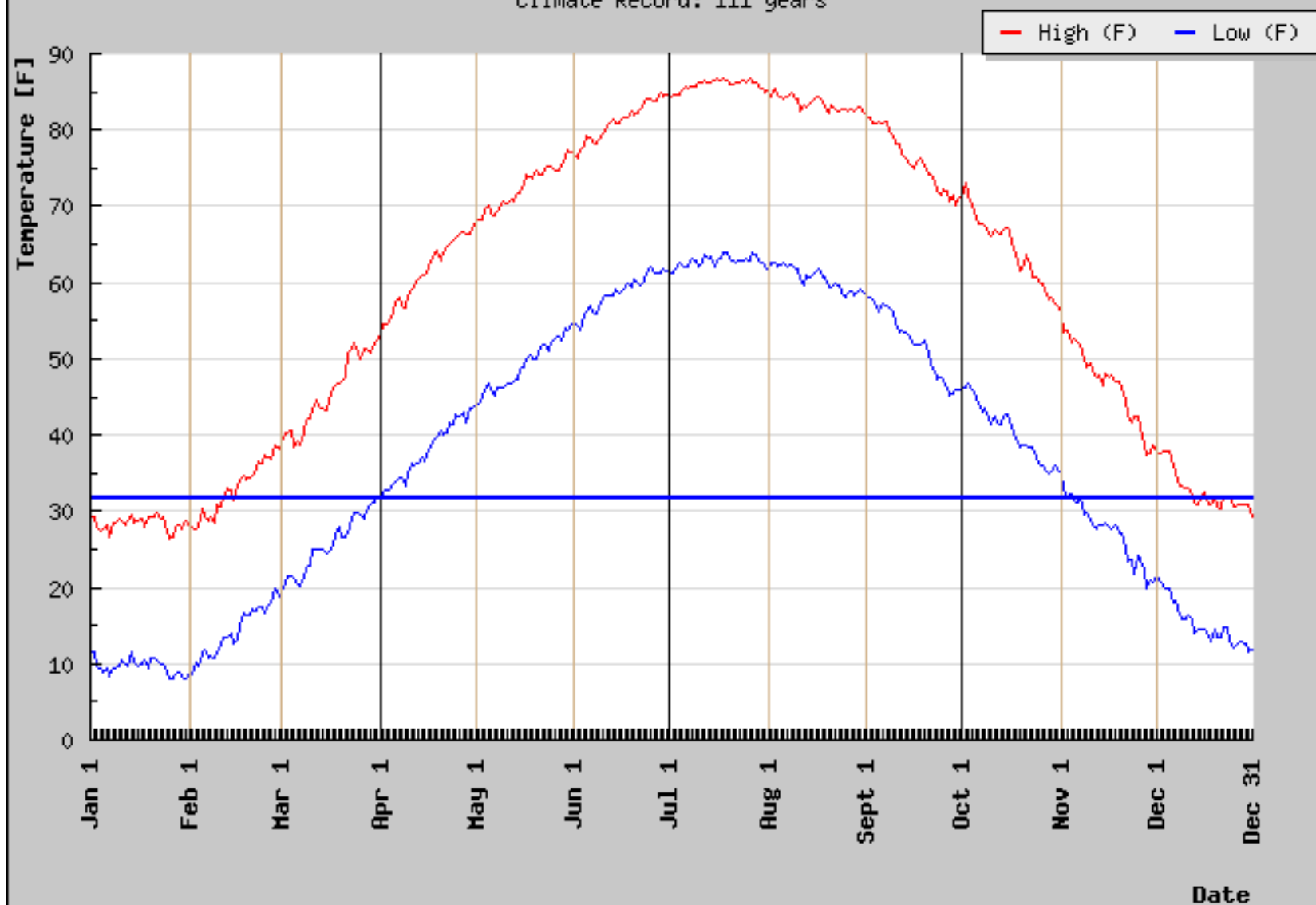
Spring 2024

Atmospheric Science

- Meteorology: Atmospheric Phenomena and their time dependent behavior.
- Climatology: Long-term statistical properties
- Weather: Day to day variation in atmospheric conditions.
- Famous quote: “Climate is what you expect, weather is what you get”.

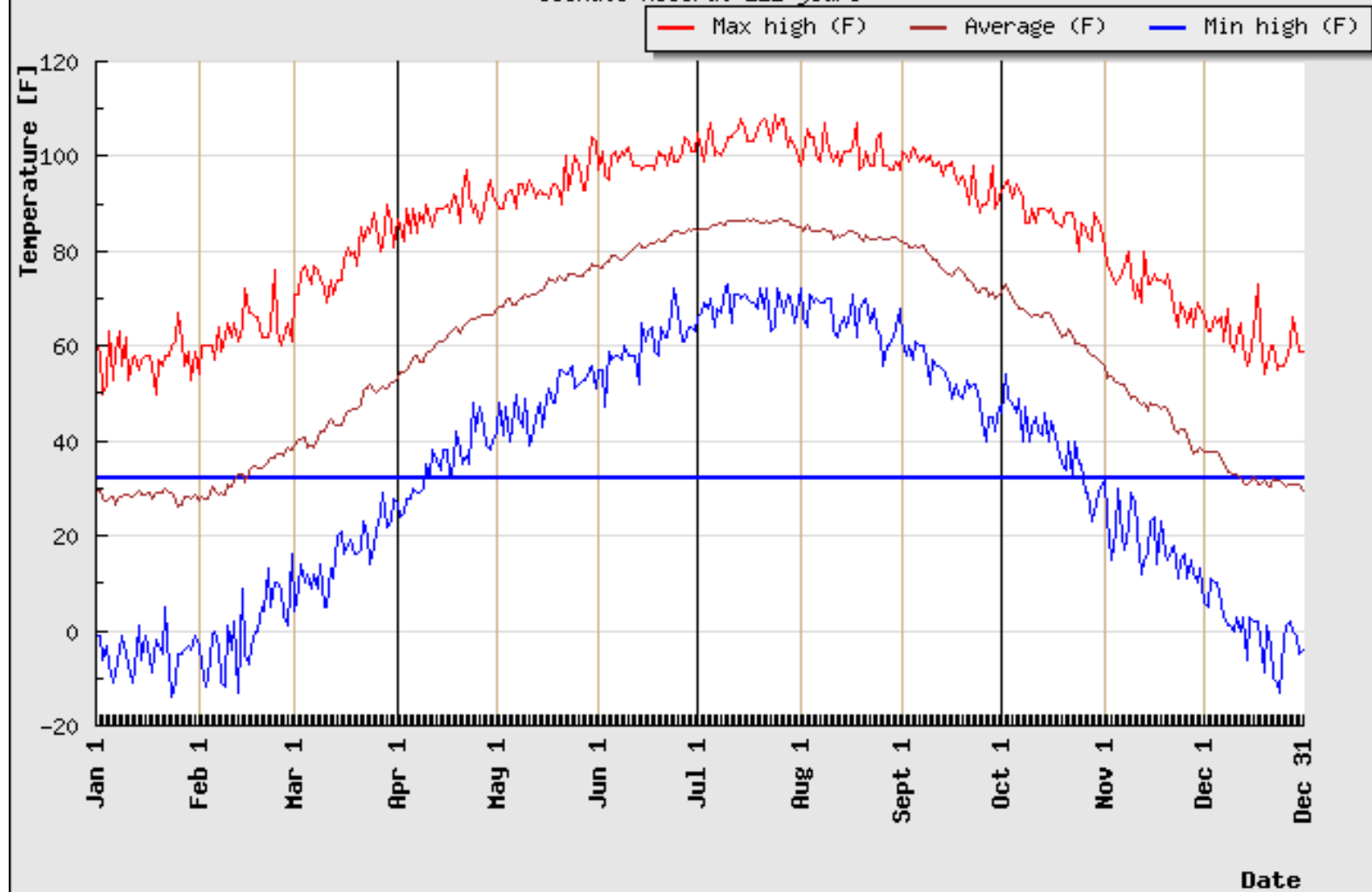
Average Daily High/Lows for Anes

Climate Record: 111 years



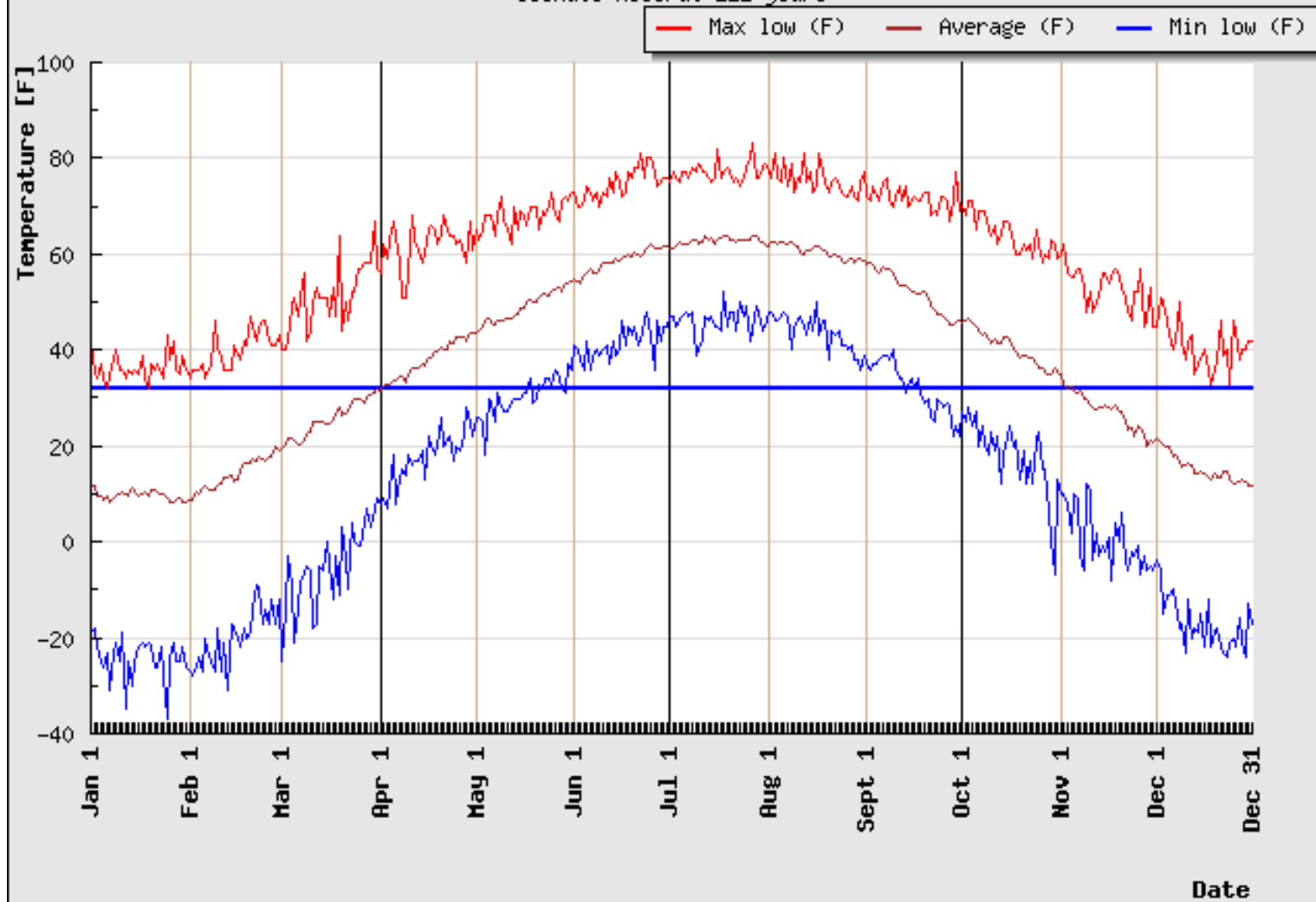
Daily High Temp Extremes for AMES-8-MSM

Climate Record: 111 years



Daily Low Temp Extremes for AMES-8-MSM

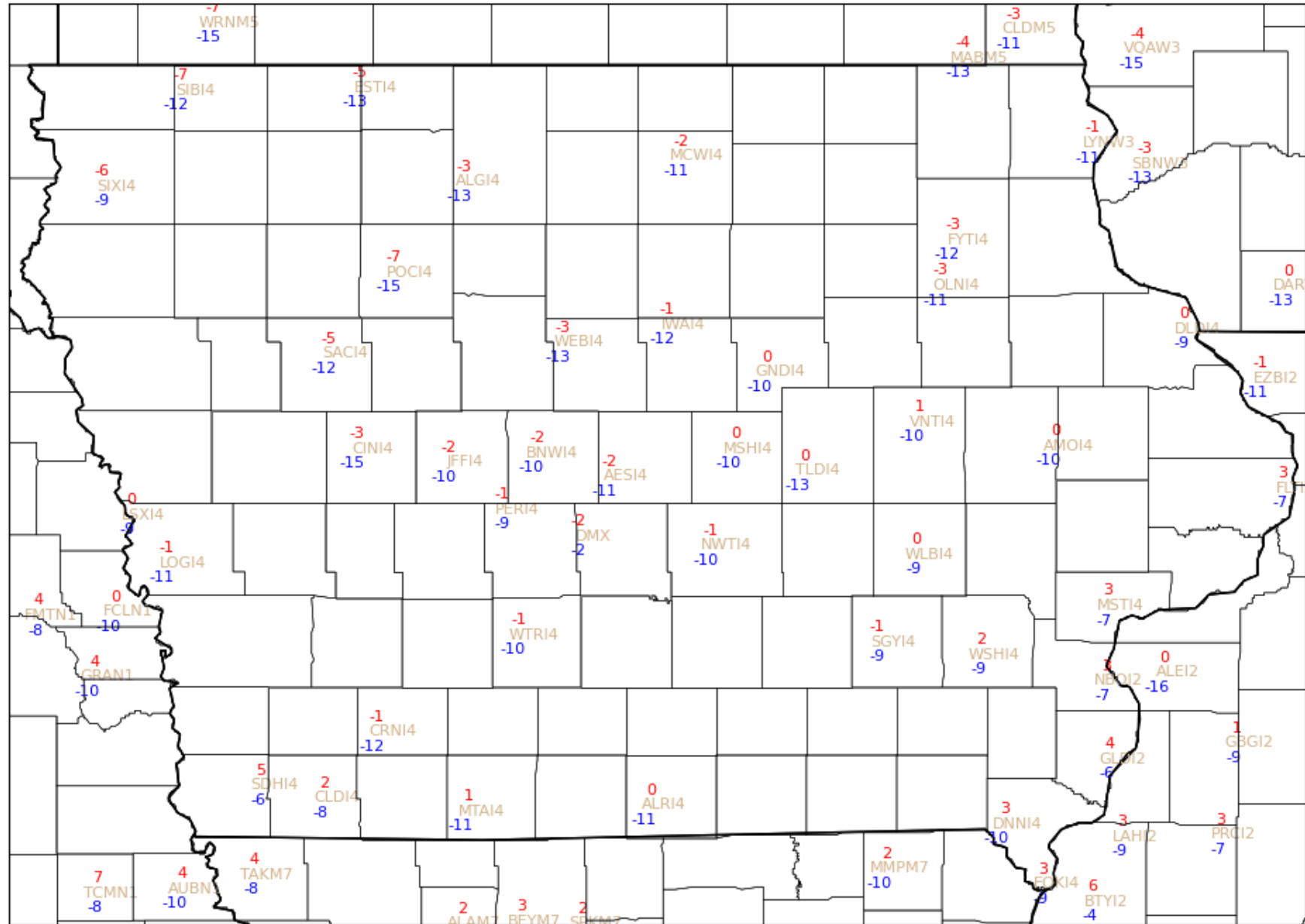
Climate Record: 111 years





24 Dec 2022 NWS COOP 24 Hour High/Low Temperature [° F]

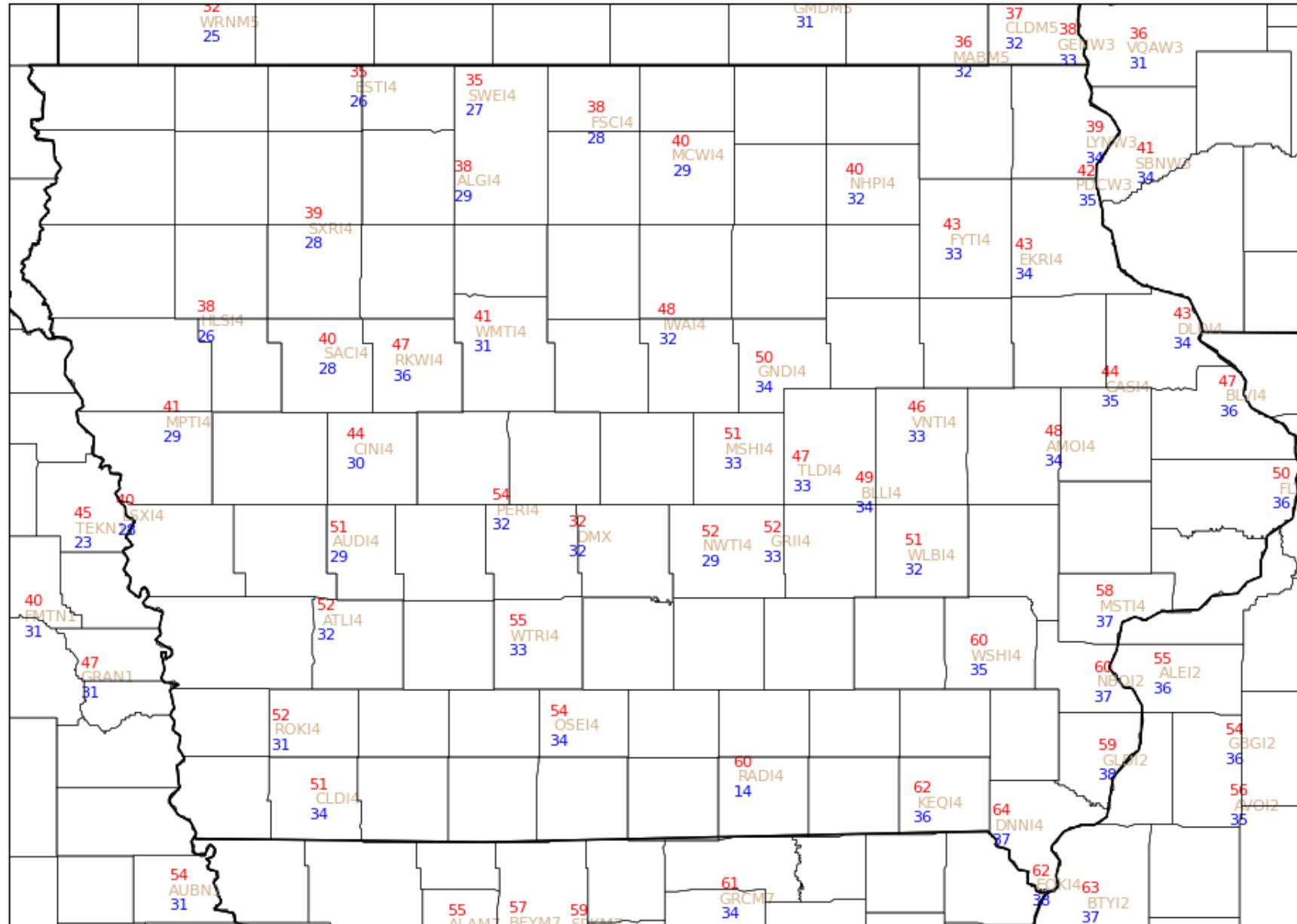
Reports valid between 6 and 9 AM





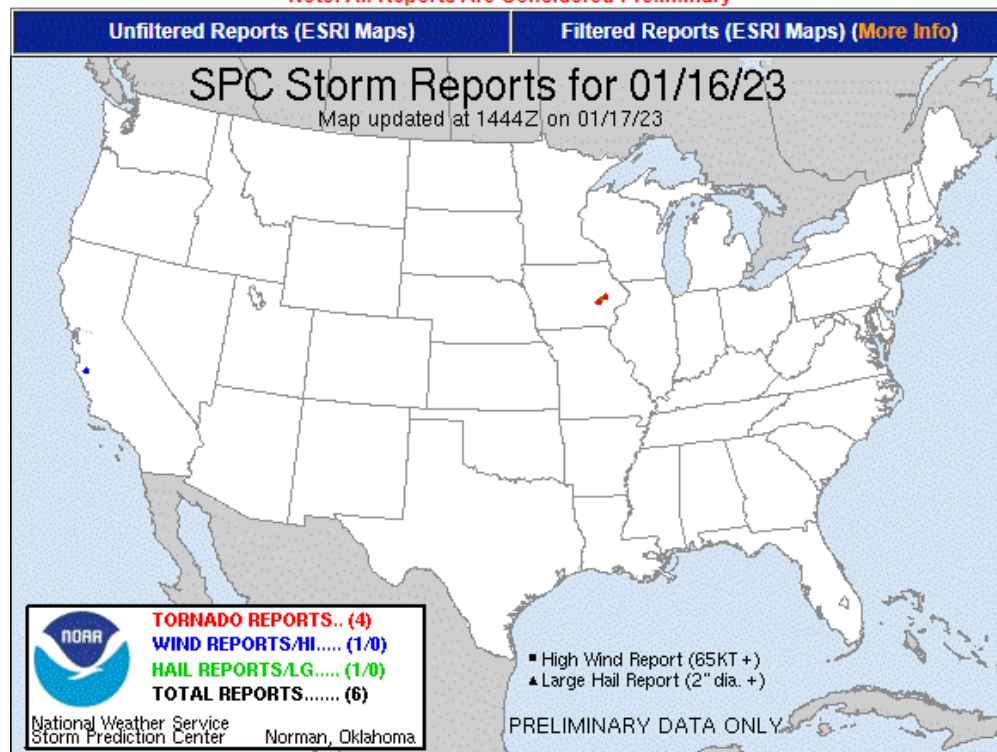
17 Jan 2023 NWS COOP 24 Hour High/Low Temperature [° F]

Reports valid between 6 and 9 AM



[< 230115 Reports](#) [230117 Reports >](#)

Note: All Reports Are Considered Preliminary

**Tornado Reports (CSV) ([Raw Tornado CSV](#))(?)**

Time	Location	County	State	Lat Lon	Comments
2001	1 ENE WILLIAMSBURG	IOWA	IA	4167 9199	BRIEF TORNADO TOUCHDOWN. (DVN)
2003	1 N WILLIAMSBURG	IOWA	IA	4169 9201	SEMI BLOWN OVER AT MILE MARKER 223. WILLIAMSBURG EXIT AND INTERSTATE 80. (DVN)
2003	2 NNE WILLIAMSBURG	IOWA	IA	4170 9199	TORNADO 2 MILES TO THE SOUTHEAST OF SPOTTERS LOCATION. (DVN)
2050	3 NNW ELY	LINN	IA	4192 9160	BRIEF TORNADO. (DVN)

Hail Reports (CSV) ([Raw Hail CSV](#))(?)

Time	Size	Location	County	State	Lat Lon	Comments
2024	100	1 ENE HOMESTEAD	IOWA	IA	4177 9185	NICKEL TO QUARTER SIZE HAIL COVERING THE GROUND. (DVN)

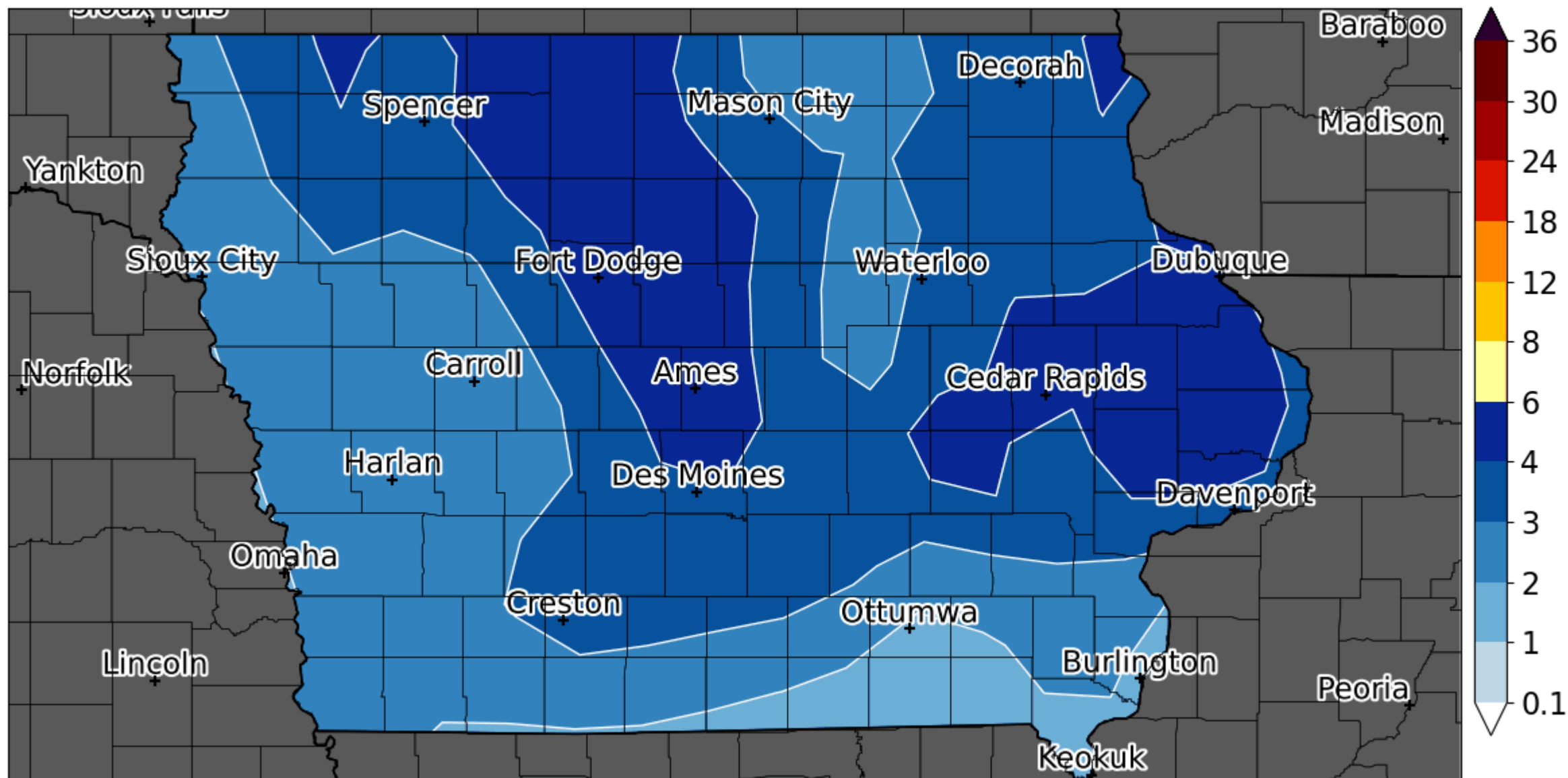
Wind Reports (CSV) ([Raw Wind CSV](#))(?)

Time	Speed	Location	County	State	Lat Lon	Comments
2000	UNK	2 NNW GREENFIELD	MONTEREY	CA	3635 12126	TREE DOWN IN ROADWAY. (MTR)



21-22 December 2022 - IEM Snowfall Total Analysis

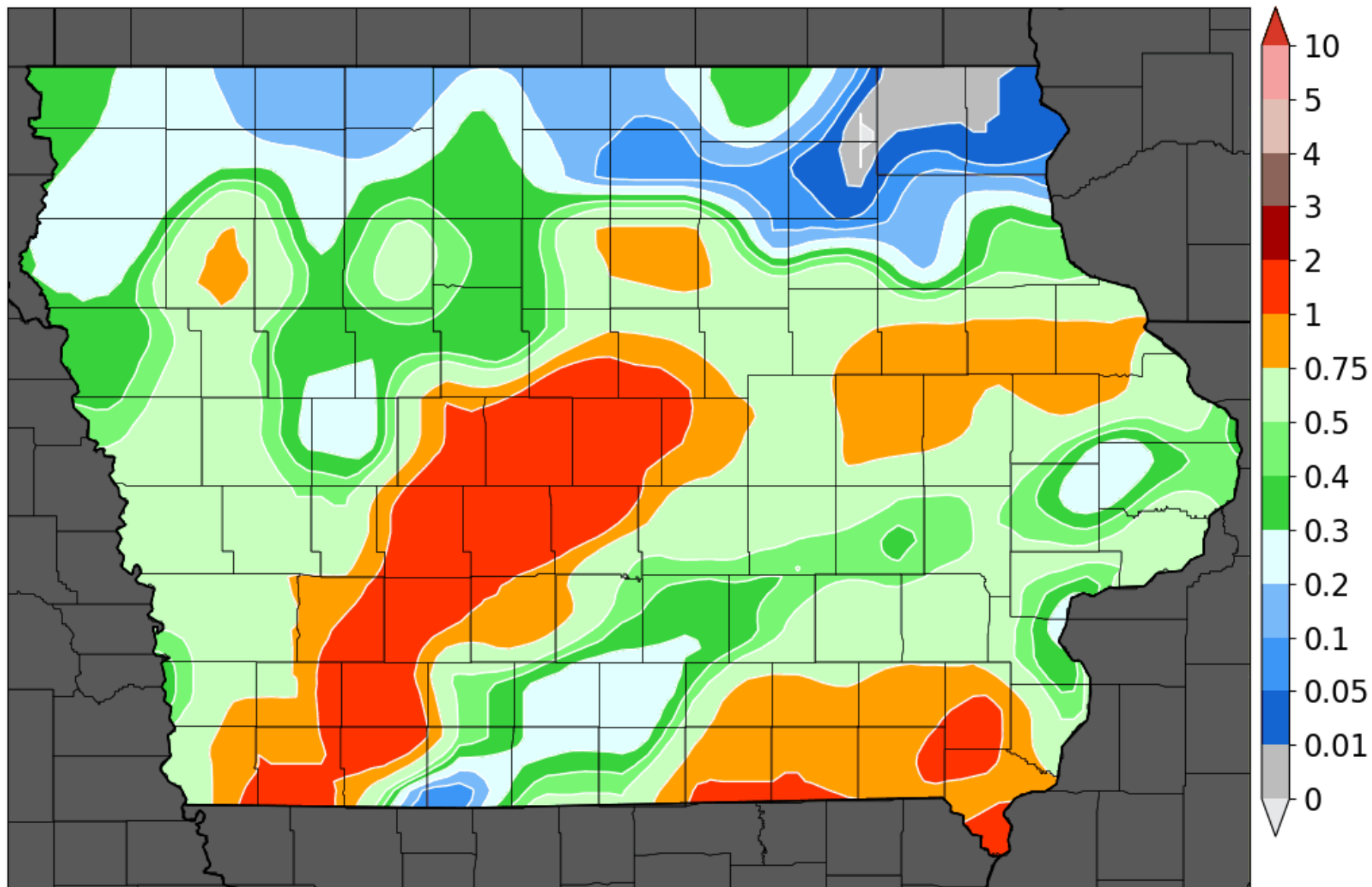
Snowfall totals till 8 AM 23 December 2022 from NWS COOP, LSR, CoCoRaHS Reports; IEM 2022-2023 Winter Storm #8





24 Hour NWS COOP Precipitation [inch]

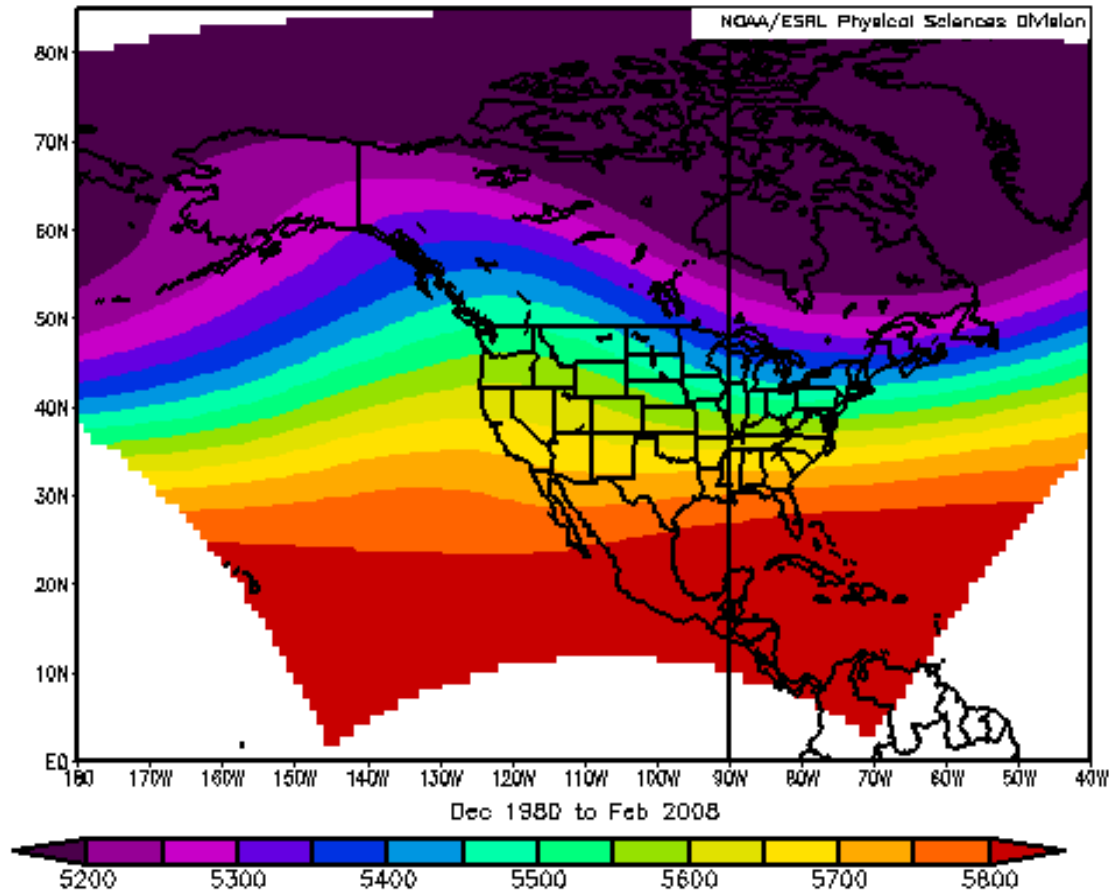
Ending 03 January 2023 at roughly 12Z



Composite 500 mb Heights

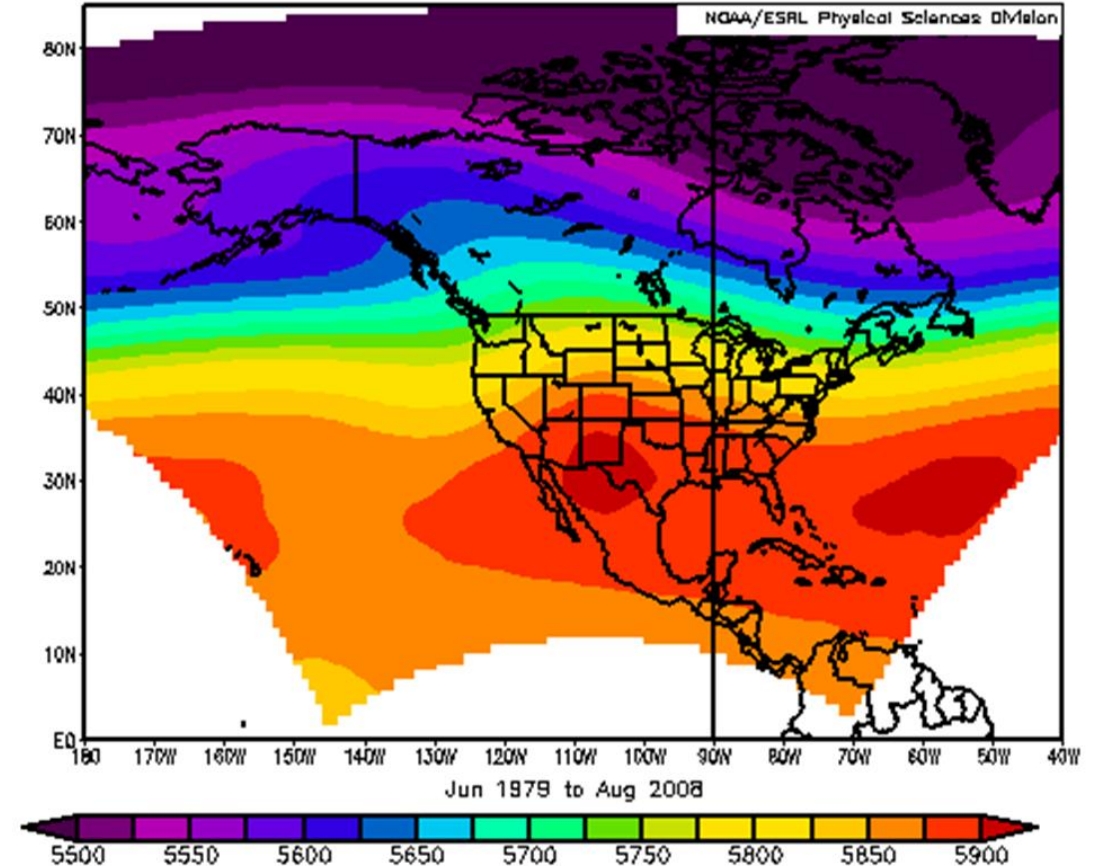
DJF

NCEP North American Regional Reanalysis
Geopotential Height (m) Composite Mean



JJA

NCEP North American Regional Reanalysis
Geopotential Height (m) Composite Mean



Meteorology

- Physical: Atmospheric structure and composition.
 - Radiation, waves, clouds and precipitation formation.
- Synoptic: Description, analysis, and forecasting of large atmospheric motions.
- Dynamic: Description of atmospheric motions and their evolution based upon principles of fluid dynamics.

Earth System

- Atmosphere: Gaseous Constituents.
- Hydrosphere: Total mass of water substance on or above the Earth's surface.
 - Cryosphere
- Biosphere: All animal and plant life.
- Lithosphere: The Earth's crust.

What gases make up the atmosphere?

Atmospheric Concentration

Table 1.1 Fractional concentrations by volume of the major gaseous constituents of the Earth's atmosphere up to an altitude of 105 km, with respect to dry air

Constituent ^a	Molecular weight	Fractional concentration by volume
Nitrogen (N ₂)	28.013	78.08%
Oxygen (O ₂)	32.000	20.95%
Argon (Ar)	39.95	0.93%
Water vapor (H ₂ O)	18.02	0–5%
Carbon dioxide (CO₂)	44.01	380 ppm
Neon (Ne)	20.18	18 ppm
Helium (He)	4.00	5 ppm
Methane (CH₄)	16.04	1.75 ppm
Krypton (Kr)	83.80	1 ppm
Hydrogen (H ₂)	2.02	0.5 ppm
Nitrous oxide (N₂O)	56.03	0.3 ppm
Ozone (O₃)	48.00	0–0.1 ppm

^a So called *greenhouse gases* are indicated by bold-faced type. For more detailed information on minor constituents, see Table 5.1.

Atmospheric Concentration

- By mass
 - Nitrogen: ~ 76%
 - Oxygen: ~ 23 %
 - Argon: ~ 1%
- By volume
 - Nitrogen: ~78%
 - Oxygen: ~21%
 - Argon: ~1%

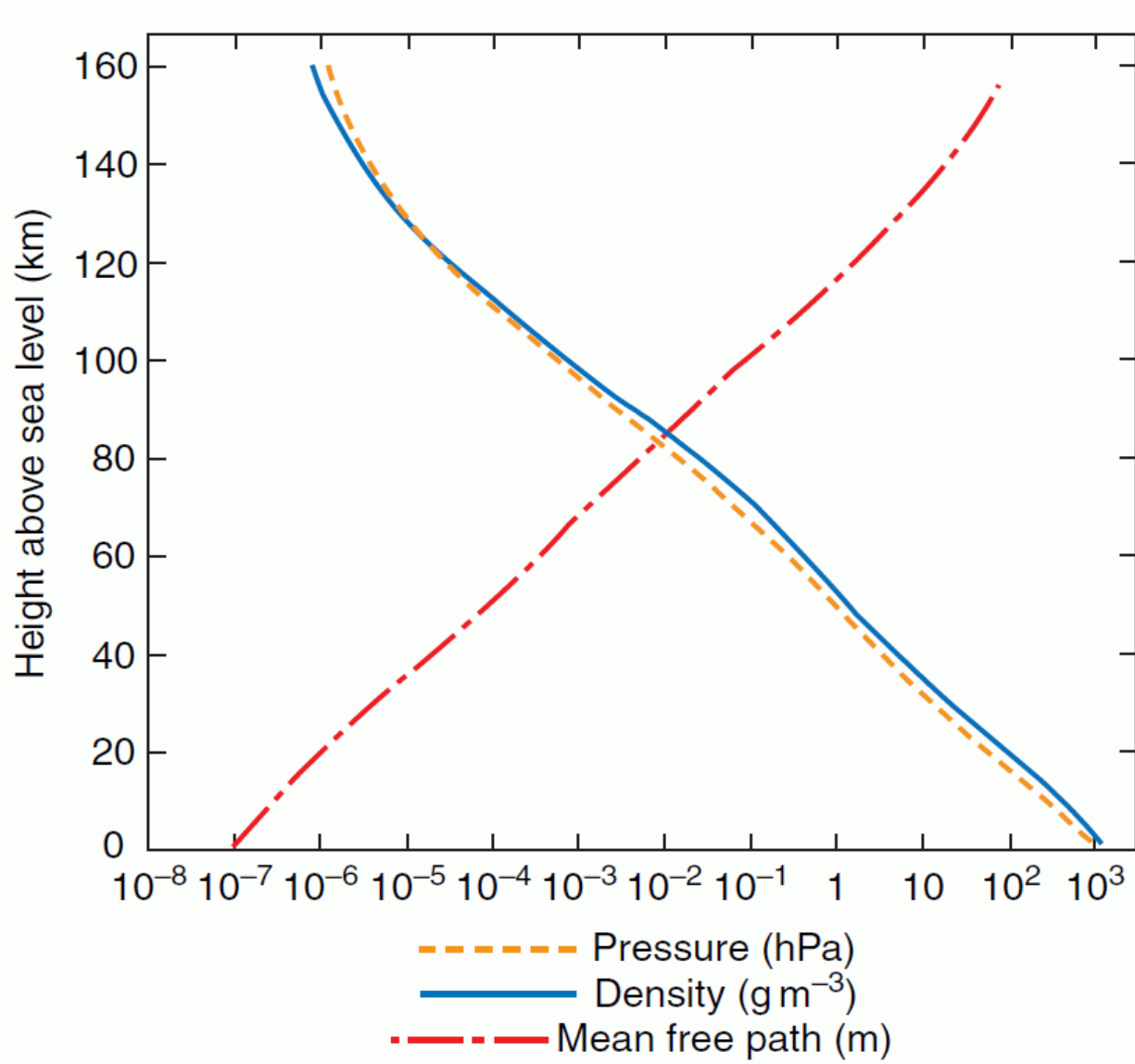
Distribution of Mass

- Gravitational force.
- Pressure = force/area.
 - $1 \text{ N/m}^2 = 1 \text{ Pascal (Pa)}$.
 - $100 \text{ N/m}^2 = 1 \text{ millibar (mb)}$.
- Mean atmospheric pressure
- $M_A g_0 / 4 \pi R_E^2 \approx 9.88 \times 10^4 \text{ N/m}^2 = 988 \text{ mb}$

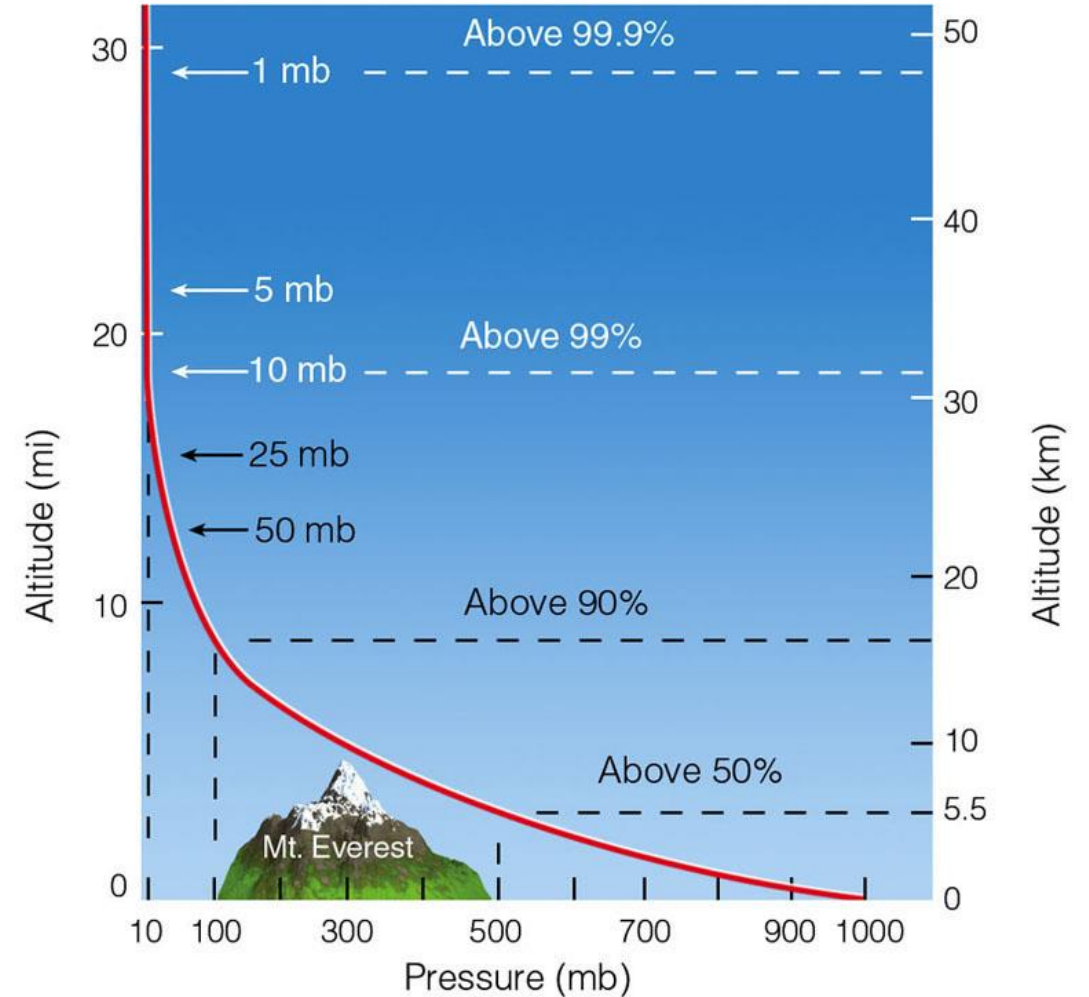
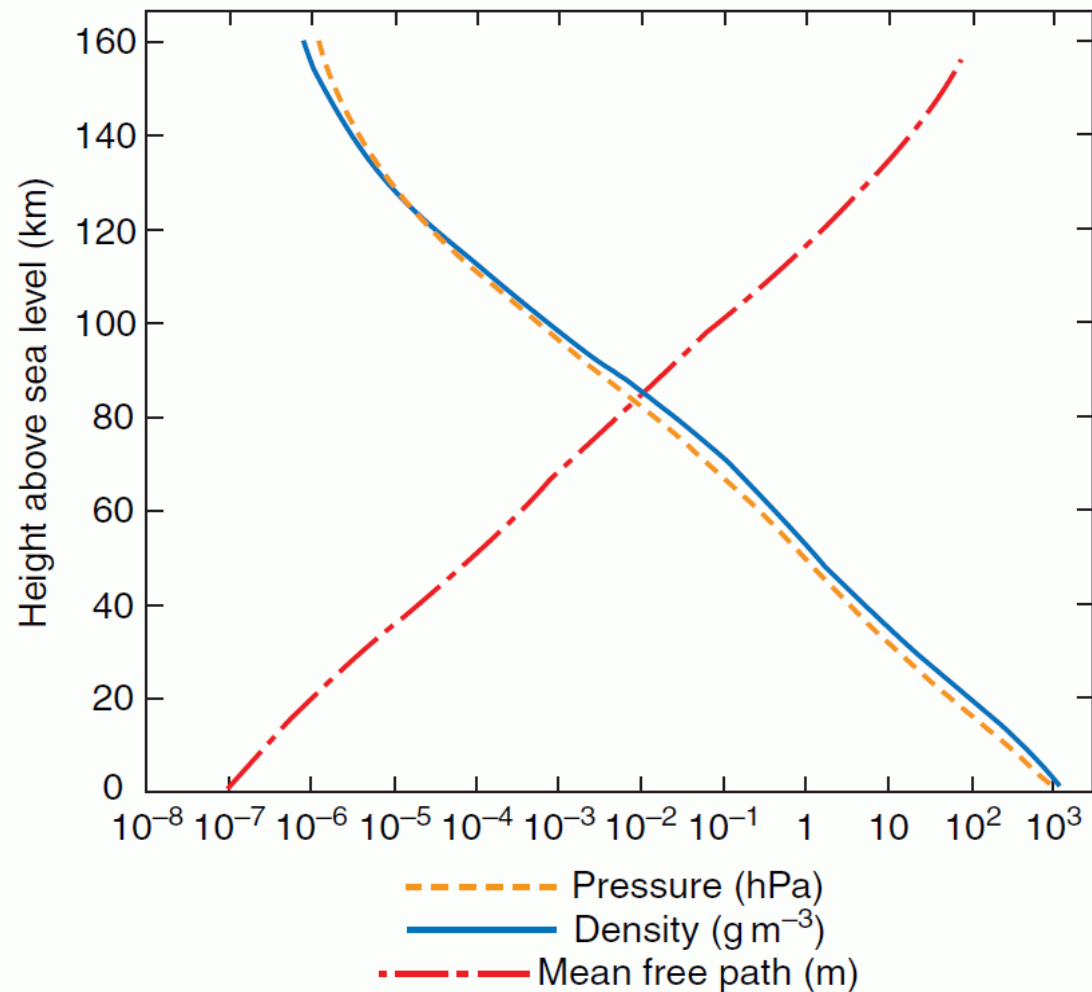
Vertical Profile of Pressure and Density

- Variability in vertical is much larger than the horizontal and temporal variability.
 - What do you expect for the horizontal variability in pressure? How about the temporal variability in pressure?
- In the lowest 100km, the logarithm of pressure drops off nearly linearly with height.
- **Derivation**

Vertical Profile of Pressure and Density



Compare to what you have seen before....



Composition as a function of height

- Molecular diffusion and mixing
- Diffusion
 - Mean molecular weight of mixture gradually decreases with height.
 - Only lightest gases are present at higher levels.
 - Each gas behaves as if it were alone.
 - Density drops of exponentially with height
 - Scale height $\sim 1/M$

Composition continued.

- Rate of diffusion proportional to mean free path (mixing length).
 - Mean free path: average distance a particle must travel before colliding with another particle.
- Turbulent mixing
 - Does not depend on molecular weight.
 - Composition tends to be independent of height.

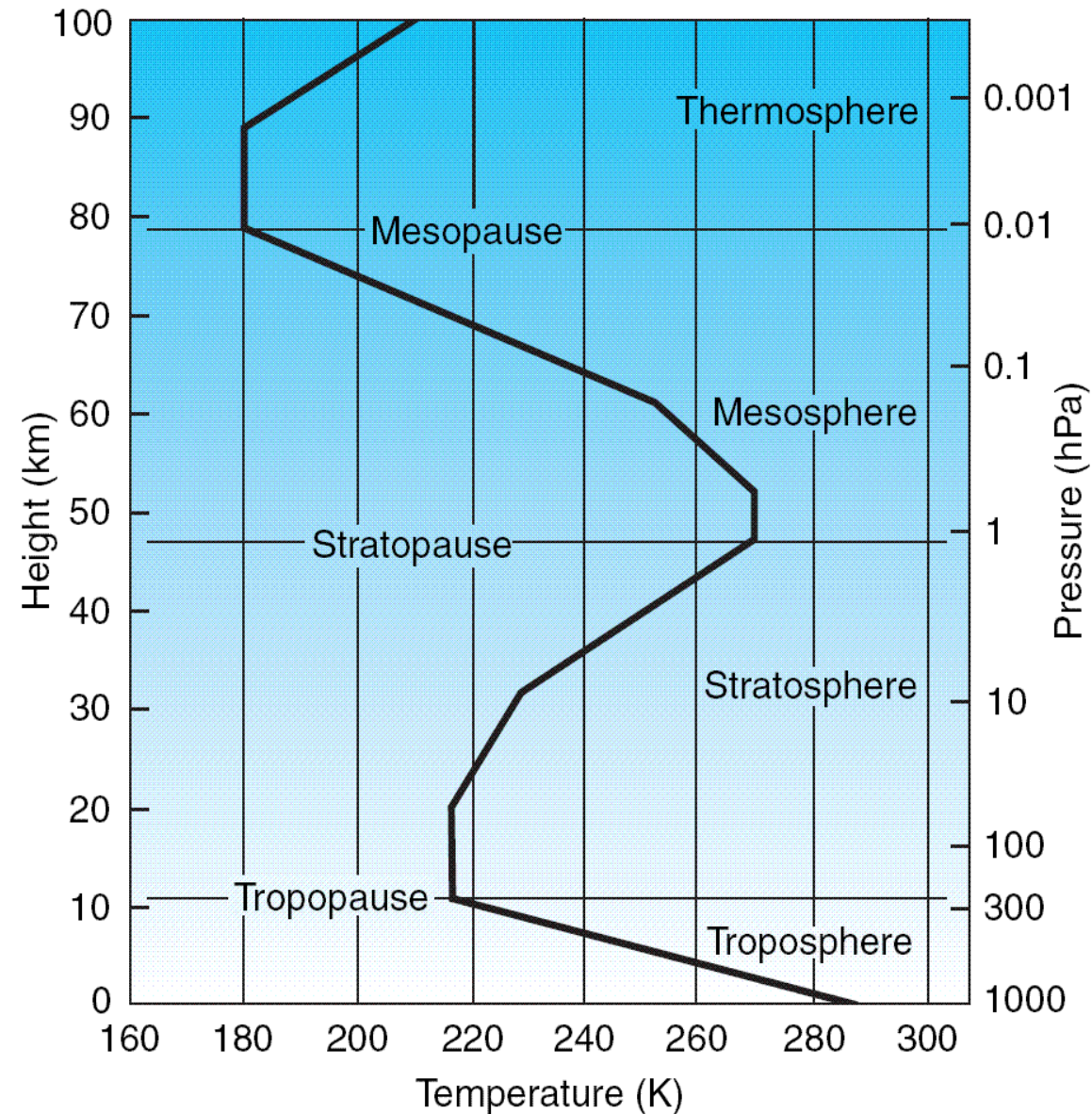
Which one dominates?

- Lower atmosphere: turbulent mixing.
 - Small mean free path.
- Near 100km: diffusion and turbulent mixing.
- Upper atmosphere: diffusion
 - Large mean free path.

Variable Constituents

- Water vapor and ozone are variable in space and time.
- Water vapor
 - Primary source: evaporation from surface.
 - Primary sink: condensation in clouds.
 - Typical lifetime: 1 week.
 - Concentration is largest near the ground.
- Ozone
 - Photochemical reactions between 20km-60km.
 - Destroyed at surface by reacting with plants and dissolving in water.
 - Very stable at 10km-25km with a lifetime on the order of a month.

Temperature Distribution



Troposphere

- Surface-200mb (0-10km).
- 80% of mass.
- Virtually all water vapor, clouds, and precipitation.
- Strong vertical mixing.
- “mean residence time”: few days to a week
 - Rapid vertical mixing and “scavenging” of aerosols by precipitation.

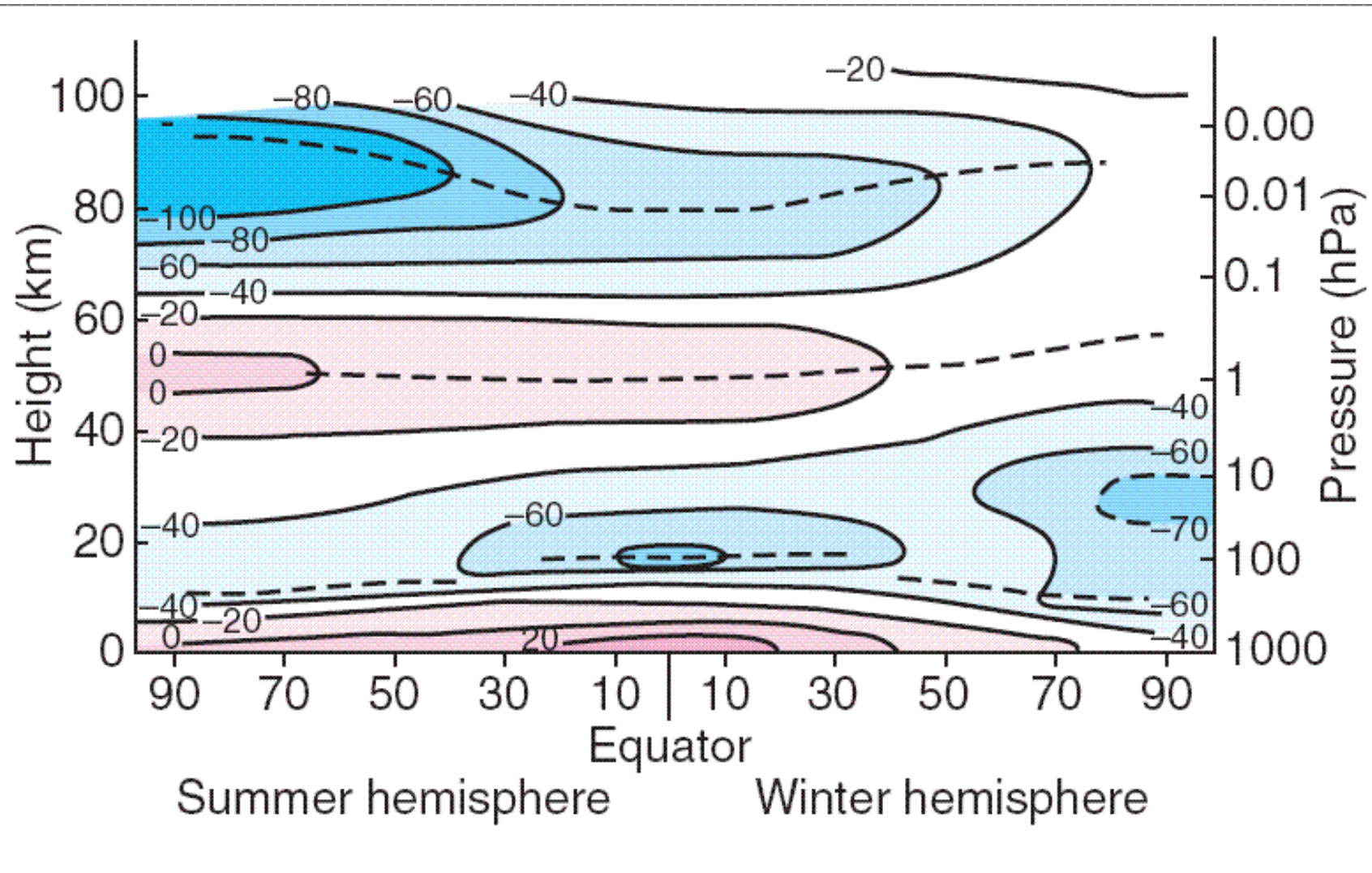
Stratosphere

- 50mb-1mb (20km- ~50km)
- Small vertical mixing.
- Mean residence time : year or longer.
- Together with troposphere accounts for 99.9% of mass.
- Warming with height? Why?

Mesosphere and Thermosphere

- Mesosphere
 - 0.5mb-0.01mb (~55km – 80km)
 - Temperature decreases with height.
- Thermosphere
 - Above 0.0001mb (Above 90km)
 - Temperatures increase with height.
 - Oxygen and Nitrogen atoms absorbed shortwave, high energy radiation.
 - Temperatures range from 500K to as high as 2000K depending on solar activity!!!
 - Temperature a function of average molecular speed
 - Very few molecules

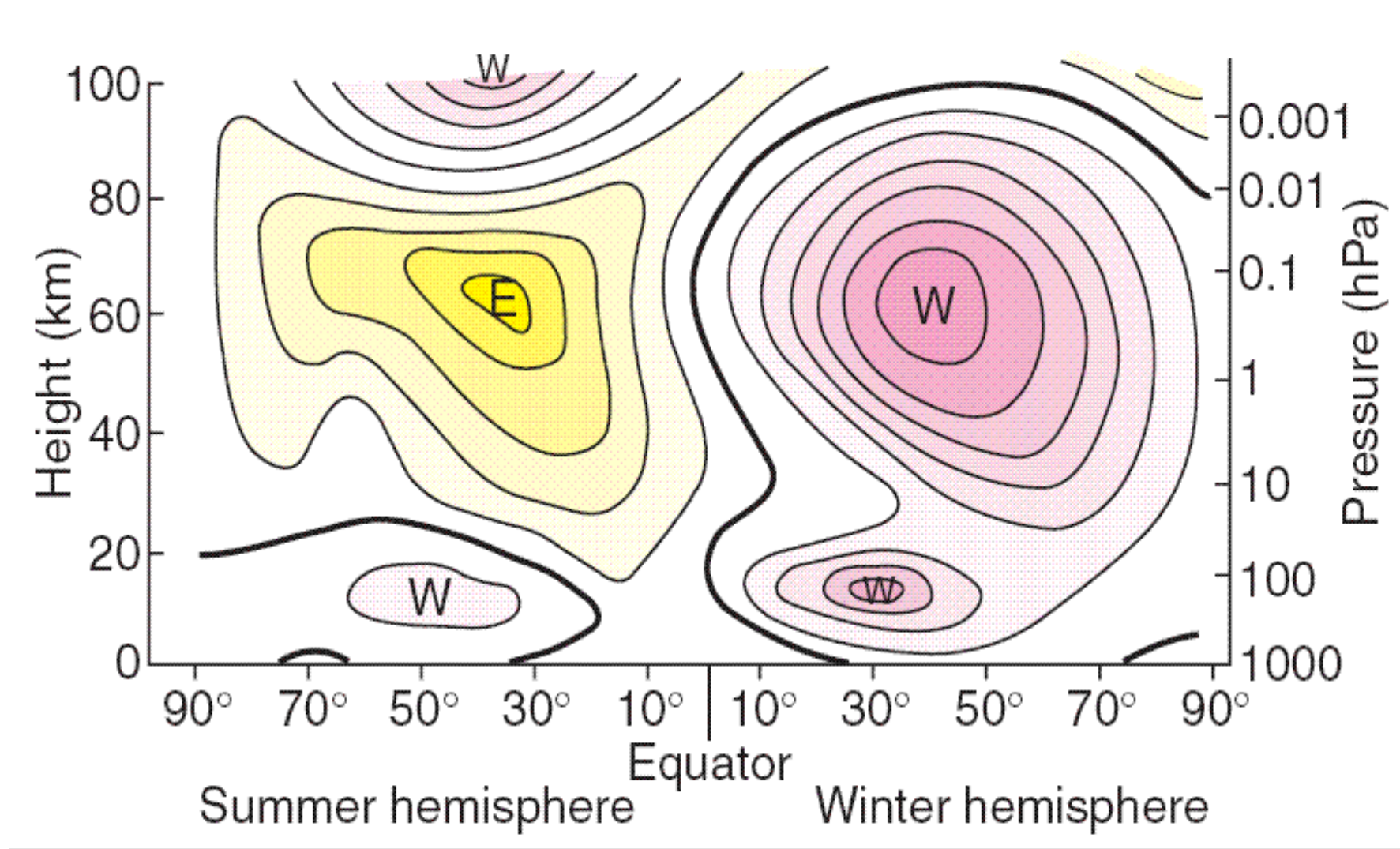
Zonal Average Temperature



Tropospheric Winds at Middle and High Latitudes

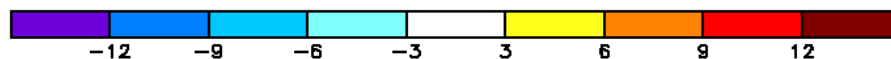
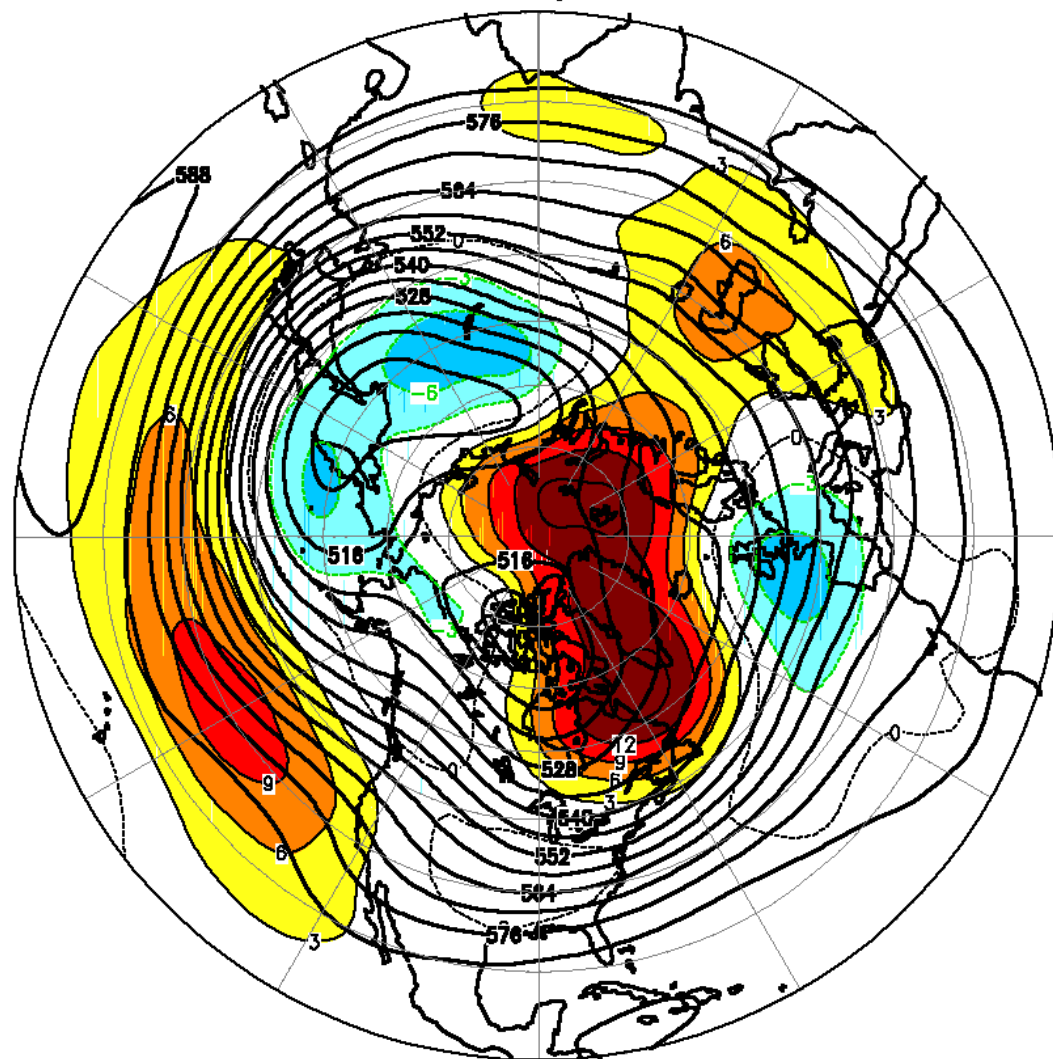
- Winds tend to flow parallel to isobars or height contours with low pressure to the left (Northern hemisphere).
- Wind speed is inversely proportional to spacing of isobars or height contours.
- Geostrophic relationship.

Average Zonal Wind



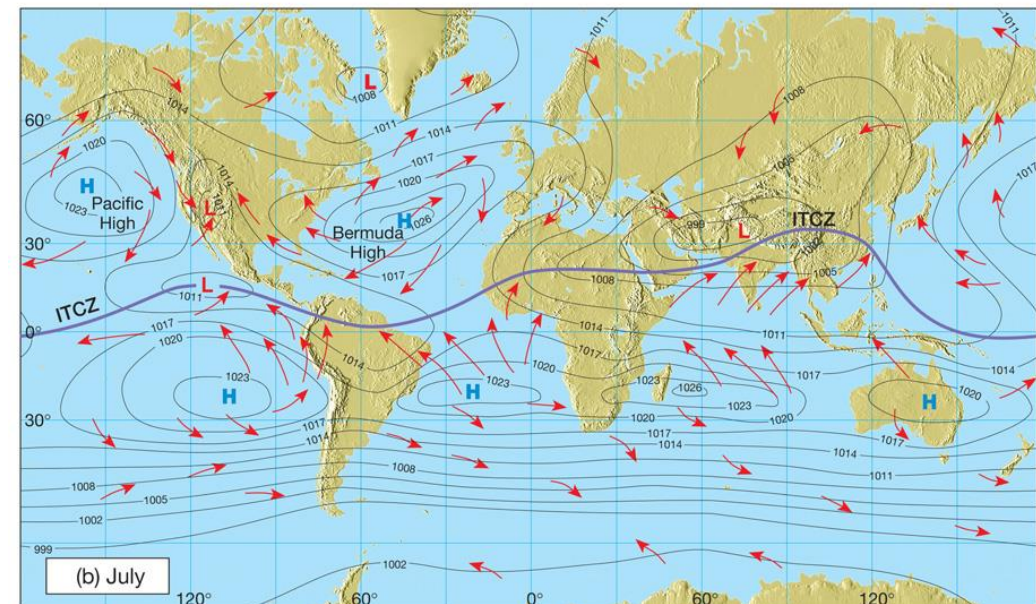
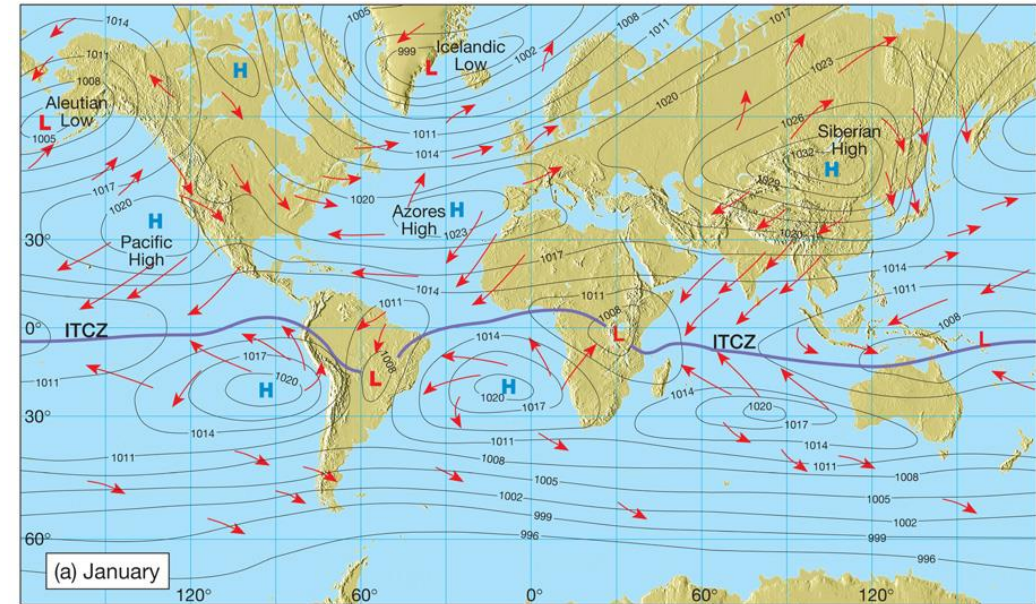
Mean Geopotential Height

500 mb Height and Anomalies
3 Month Mean
Centered: jan2021



CLIMATE PREDICTION CENTER/NCEP

Semi-Permanent Cells

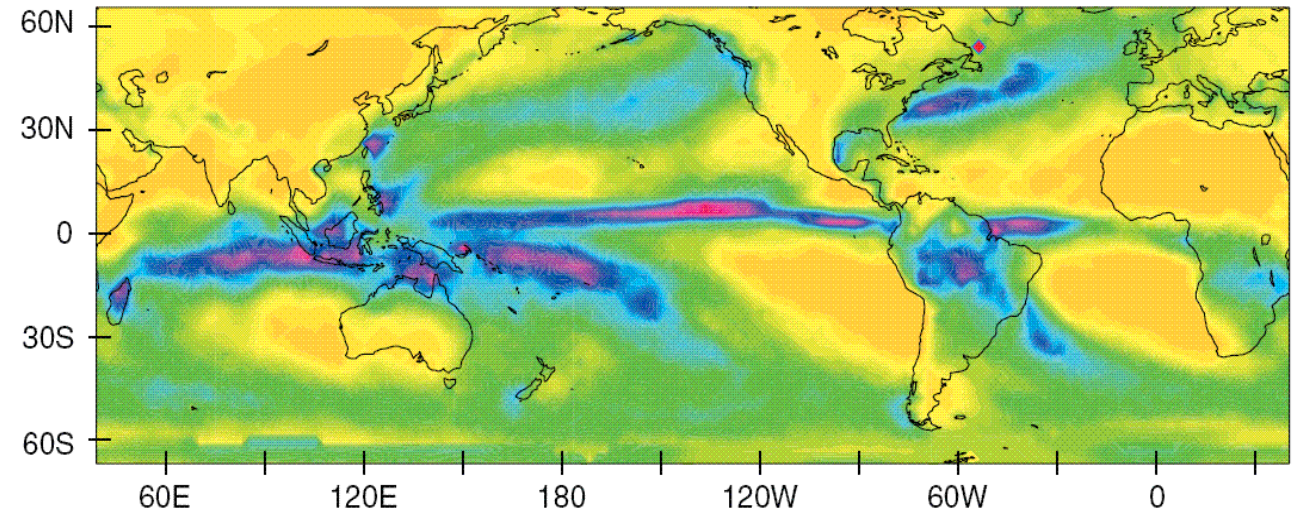


Tropospheric Winds at Low Latitudes

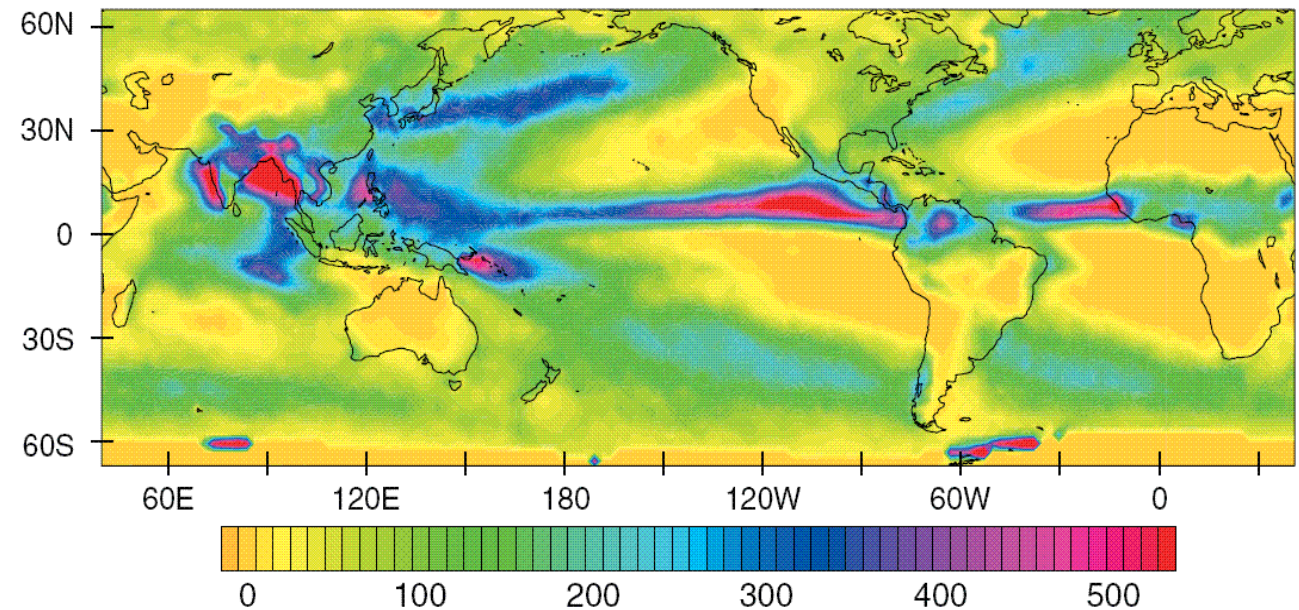
- Not as transient.
- Easterly flow.
- Shift from north-east to south-east with weather systems.
- Tropical cyclones (hurricanes)
- Strongest sustained winds observed anywhere on the earth's surface.
- ITCZ (Inter-Tropical Convergence Zone)

Climatological Mean Precipitation

January



July



Scales in the Atmosphere

- Planetary scale*
 - Horizontal dimensions comparable to scales of major oceans or continents.
 - Global circulation.
- Synoptic scale*
 - Few hundred kilometers.
 - Day to day weather
- Mesoscale*
 - Few 10km – few 100km
 - Jet streams, fronts, lee waves, rain bands squall lines, mid-latitude storms
- Microscale (small scale)
 - Everything smaller than mesoscale. Tornadoes, dust devils, individual storm cells, etc.

Blizzard

- The following conditions are expected to prevail for a period of **3 hours** or longer:
- Sustained wind or frequent gusts of 35mph or greater, **and**
- Considerable falling or blowing snow
 - Frequently reduces visibility to less than $\frac{1}{4}$ mile.