Weather and Climate

Maryland Master Naturalist

Engaging the Community Outdoors

A training program for volunteers who want to learn and share knowledge of the natural world in Maryland

UNIVERSITY OF MARYLAND EXTENSION

Solutions in your community

www.masternaturalist.umd.edu

Why is there Weather?

Why is there Weather?

- Weather begins with Energy from the sun
- 1360w/m^2 arrives at the Earth
- 68 LED light bulbs every square meter
- Or a small space heater every square meter
- At 39N about 53 bulbs in summer
- In winter only 31 about 60% power

We're Special

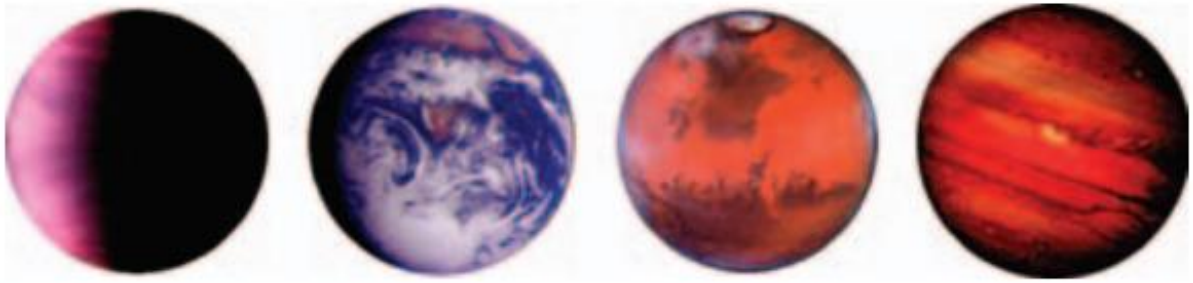


Fig. 2.36 Venus, Earth, Mars, and Jupiter from space. Venus and Jupiter are cloud covered. Not shown to scale. [Photographs courtesy of NASA.]

Table 2.5 Astronomical and atmospheric data for Earth and neighboring planets[a]

Parameter	Venus	Earth	Mars	Jupiter
Radius (km × 10^3)	6,051	6,371	3390	66,911
Gravity (m s^{-2})	8.87	9.80	3.71	24.79
Distance from sun (AU)	0.72	1.000	1.524	5.20
Length of year (Earth years)	0.615	1.000	1.88	11.86
Length of day (Earth days)	117	1.000	1.027	0.41
Orbital eccentricity	0.0067	0.0167	0.093	0.049
Orbital obliquity	2.36	23.45	25.19	3.13
Dominant constituent (% by volume)	CO_2 (96.5)	N_2 (78.1)	CO_2 (95.3)	H_2 (90)
Secondary constituent (% by volume)	N_2 (3.5)	O_2 (21)	N_2 (2.7)	He (10)
Surface pressure (hPa)	92,000	997	8[b]	>>10^6
Surface temperature (K)	737	288	210	
Diurnal temperature range (K)	~0	10	40	

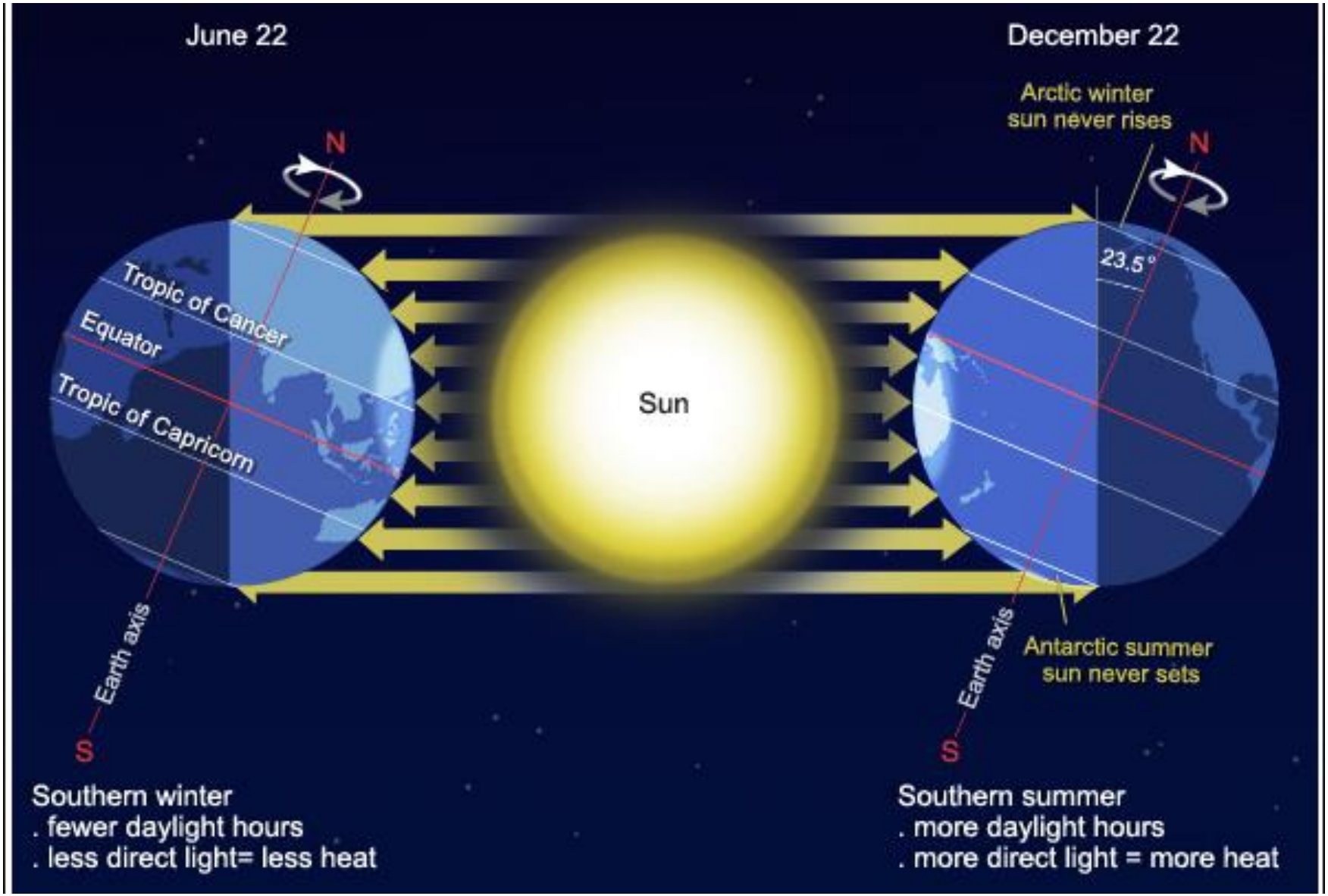
[a] Based on *Planetary Fact Sheets* on NASA Web site; Mars surface data based on records at the Viking 1 Lander site.
[b] Varies seasonally from 7.0 hPa during the austral winter, when Mars is farthest from the sun, to 9.0 hPa during the austral summer.

Constituents

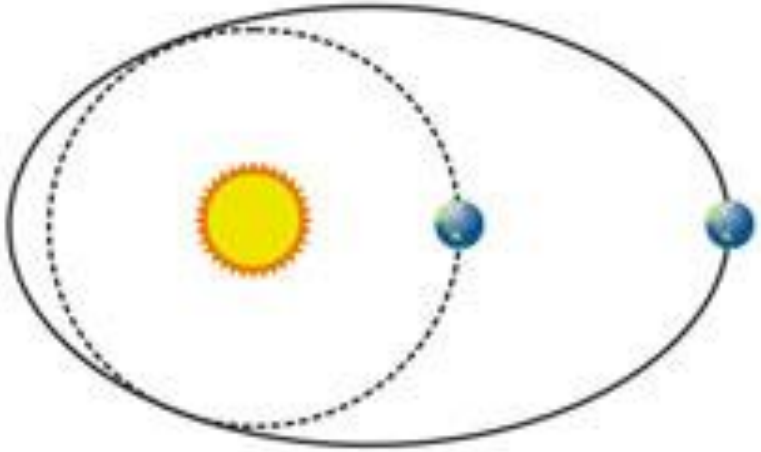
Gas	Chemical formula	Fraction of volume of air occupied by the species[a]	Residence time (or lifetime)[b]	Major sources
Nitrogen	N_2	78.084%	1.6×10^7 years	Biological
Oxygen	O_2	20.946%	3000–4000 years	Biological
Argon	Ar	0.934%	—	Radiogenic
Carbon dioxide	CO_2	379 ppmv[c]	3–4 years[d]	Biological, oceanic, combustion (concentration increasing)
Neon	Ne	18.18 ppmv	—	Volcanic (?)
Helium	He	5.24 ppmv	—	Radiogenic
Methane[e]	CH_4	1.7 ppmv	9 years	Biological, anthropogenic
Hydrogen	H_2	0.56 ppmv	~2 years	Biological, anthropogenic
Nitrous oxide	N_2O	0.31 ppmv	150 years	Biological, anthropogenic
Carbon monoxide	CO	40–200 ppbv	~60 days	Photochemical, combustion, anthropogenic
Ozone	O_3	10–100 ppbv	Days–weeks	Photochemical

Why are there Seasons?

Why Seasons?


June 22
December 22
Arctic winter
sun never rises
N
N
23.5°
Tropic of Cancer
Equator
Tropic of Capricorn
Sun
Earth axis
Earth axis
Antarctic summer
sun never sets
S
S
Southern winter
. fewer daylight hours
. less direct light= less heat
Southern summer
. more daylight hours
. more direct light = more heat

Milankovitch Cycles



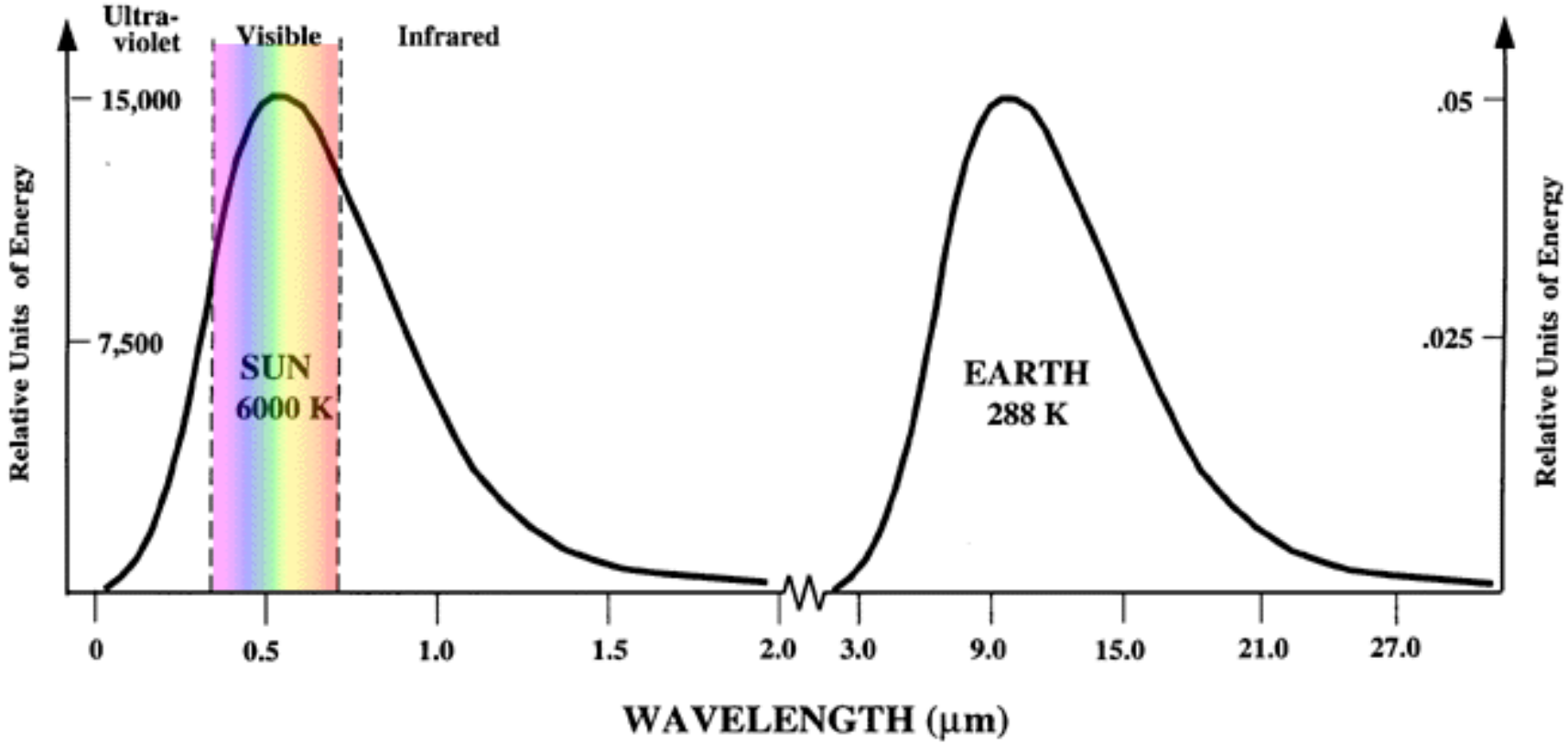
Eccentricity

Obliquity

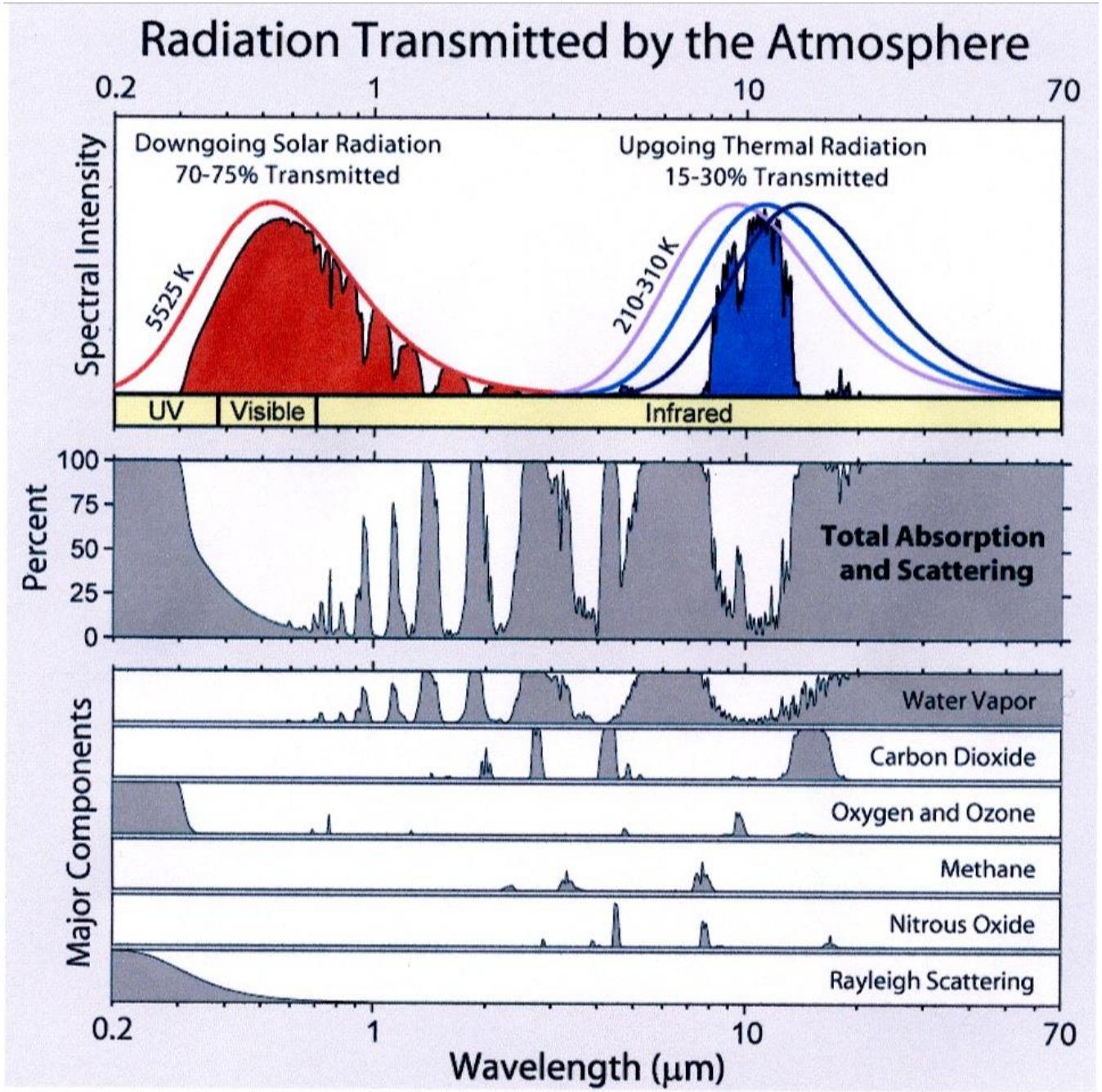
Precession

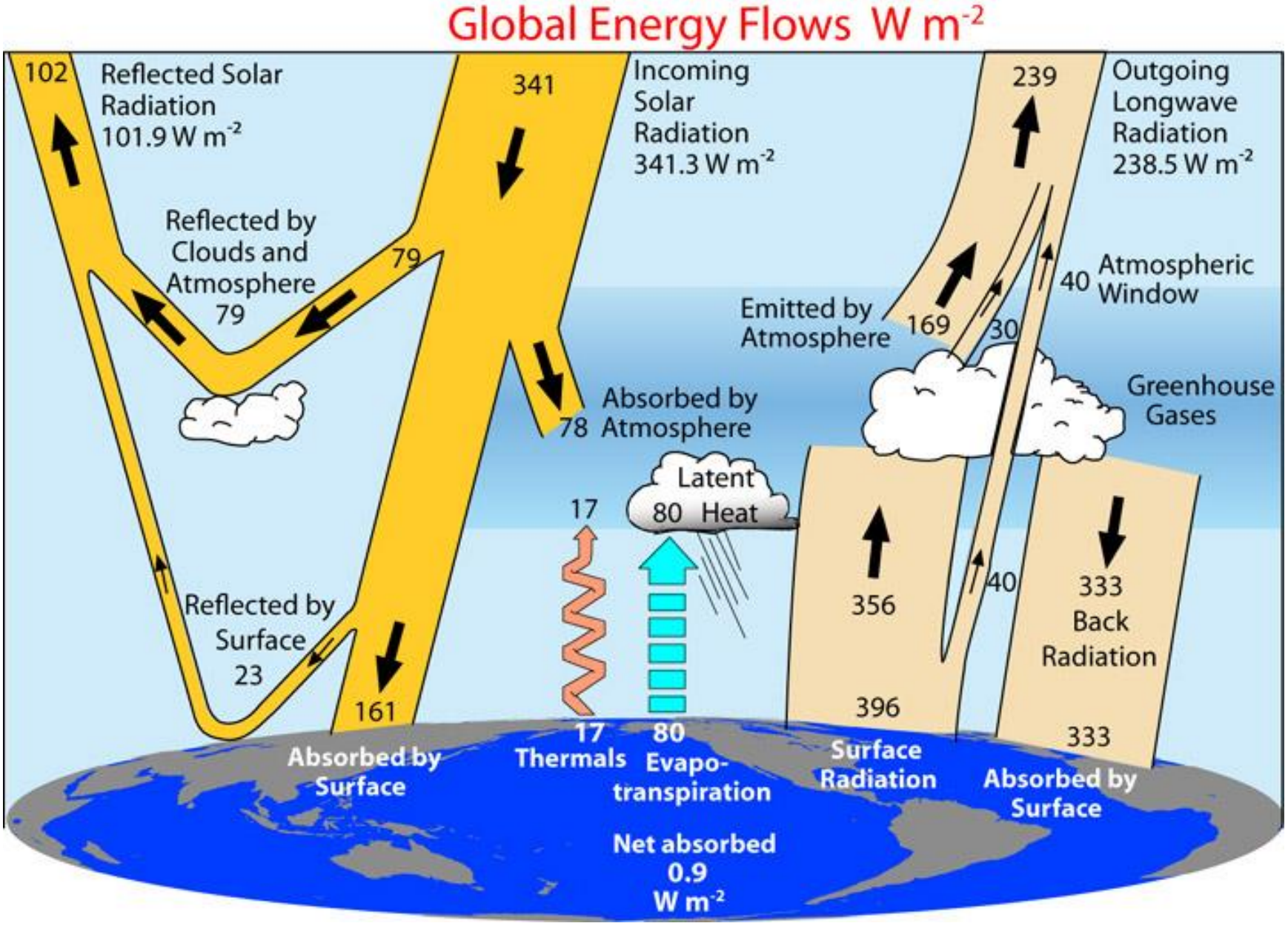
- Precession 26,000 years
- Obliquity 41,0000 years
- Eccentricity 100,000 years

Earth and Sun Emission Spectrum

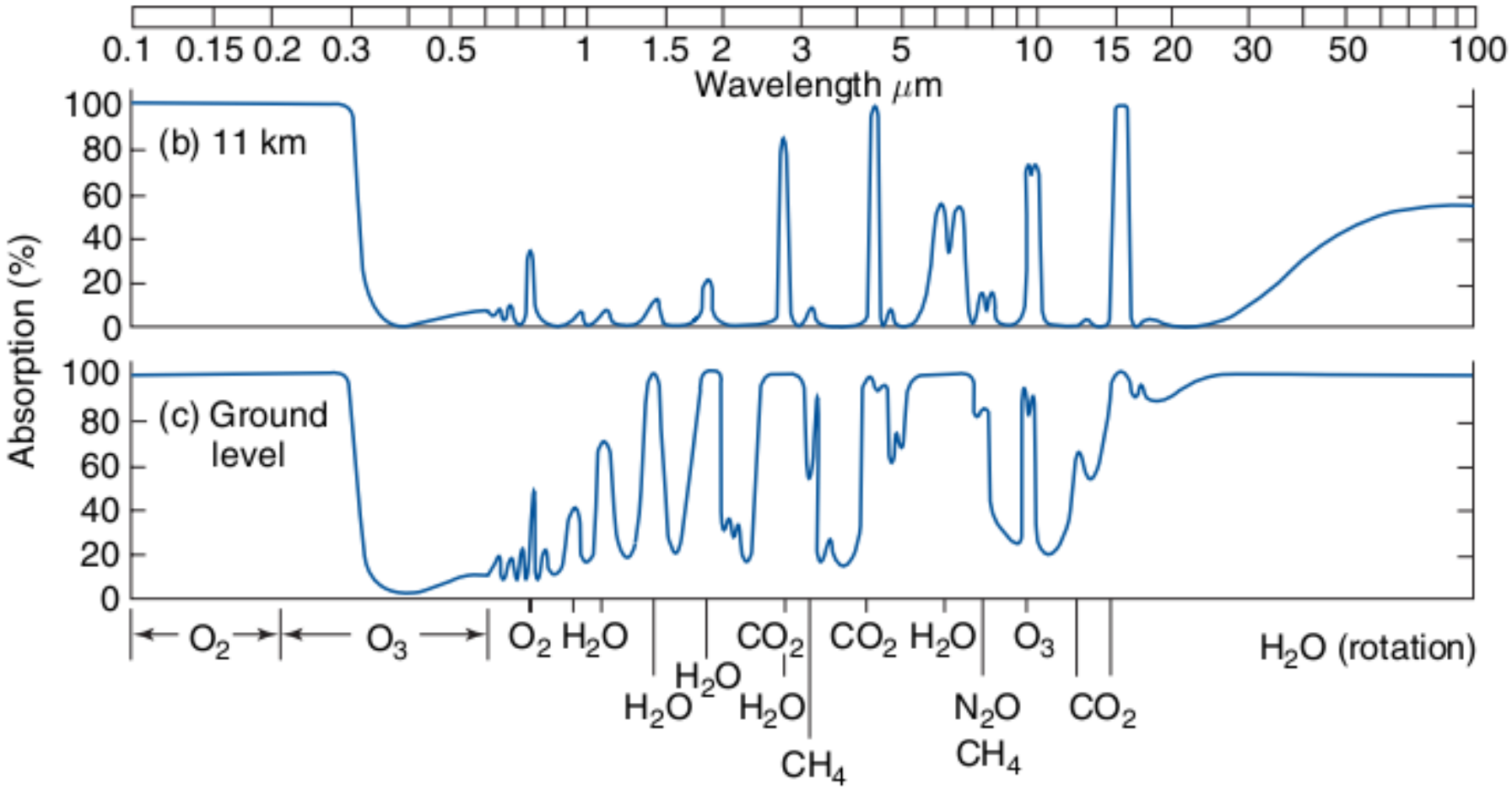


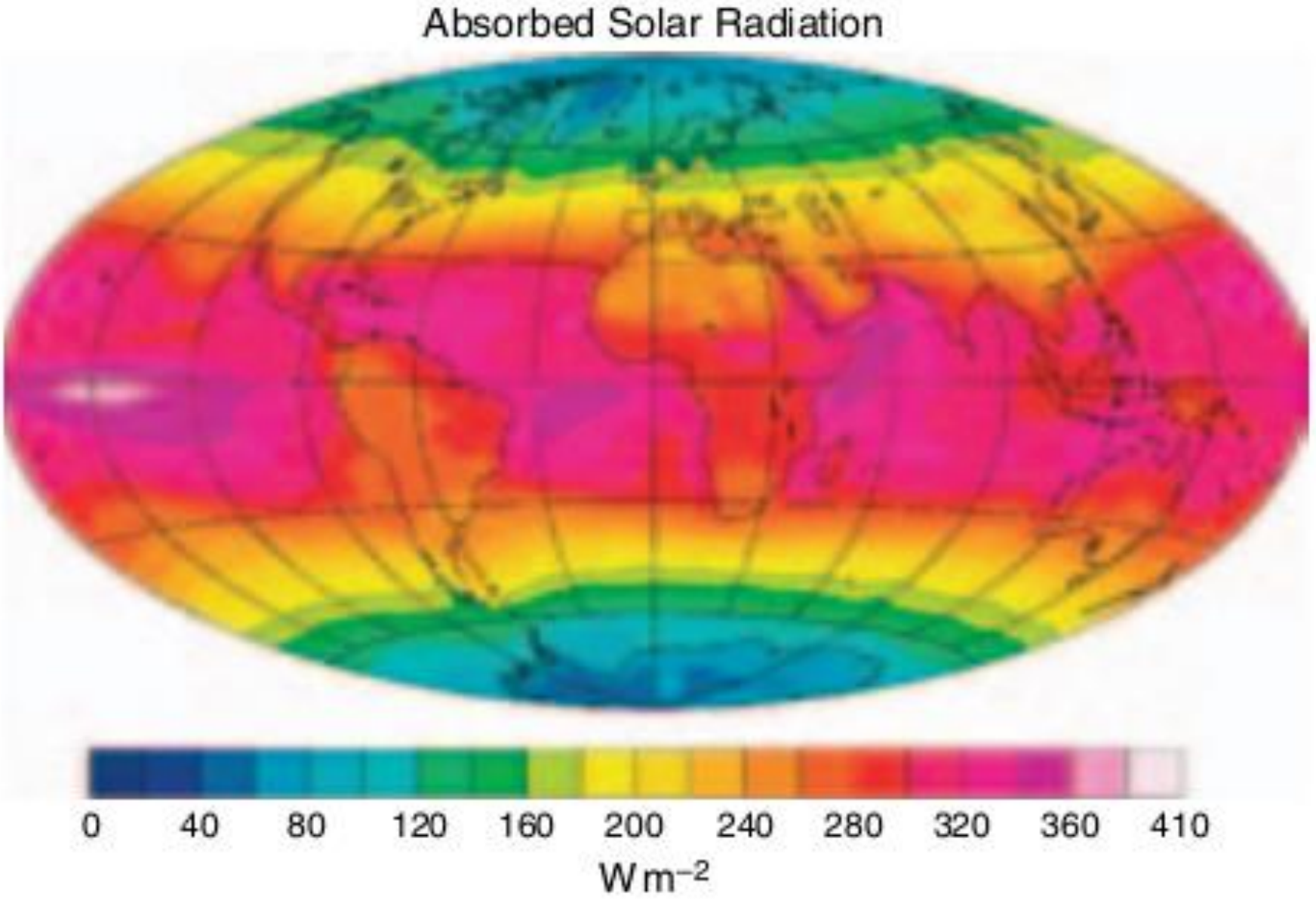
Comparison of the emission spectra of the sun and the earth. Note the huge disparity in the amount of energy emitted by the sun (left-hand scale) and the earth (right-hand scale).

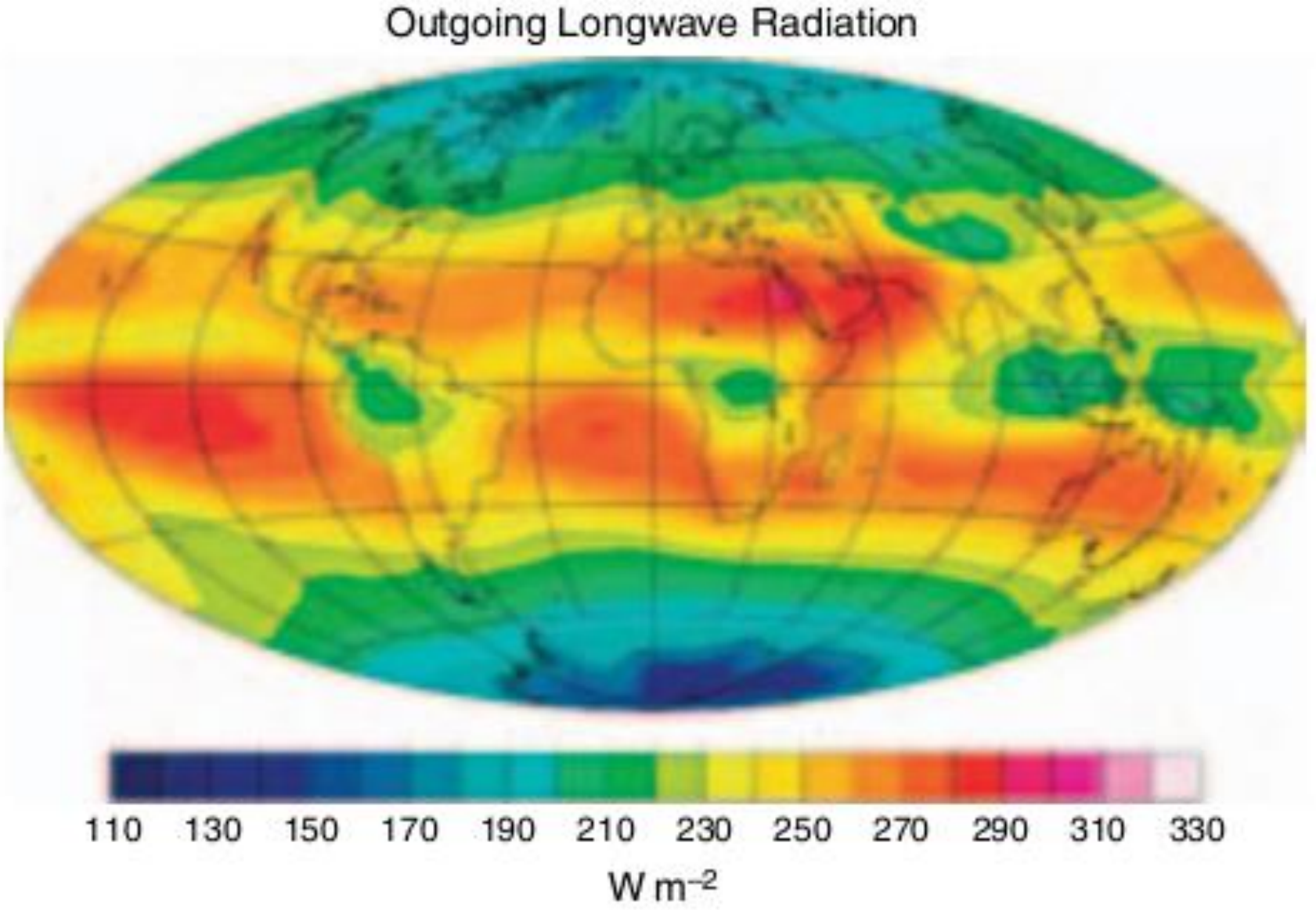

Radiation Transmitted by the Atmosphere
0.2
1
10
70
Spectral Intensity
Downgoing Solar Radiation
70-75% Transmitted
Upgoing Thermal Radiation
15-30% Transmitted
5525 K
210-310 K
UV
Visible
Infrared
Percent
100
75
50
25
0
Total Absorption and Scattering
Major Components
Water Vapor
Carbon Dioxide
Oxygen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

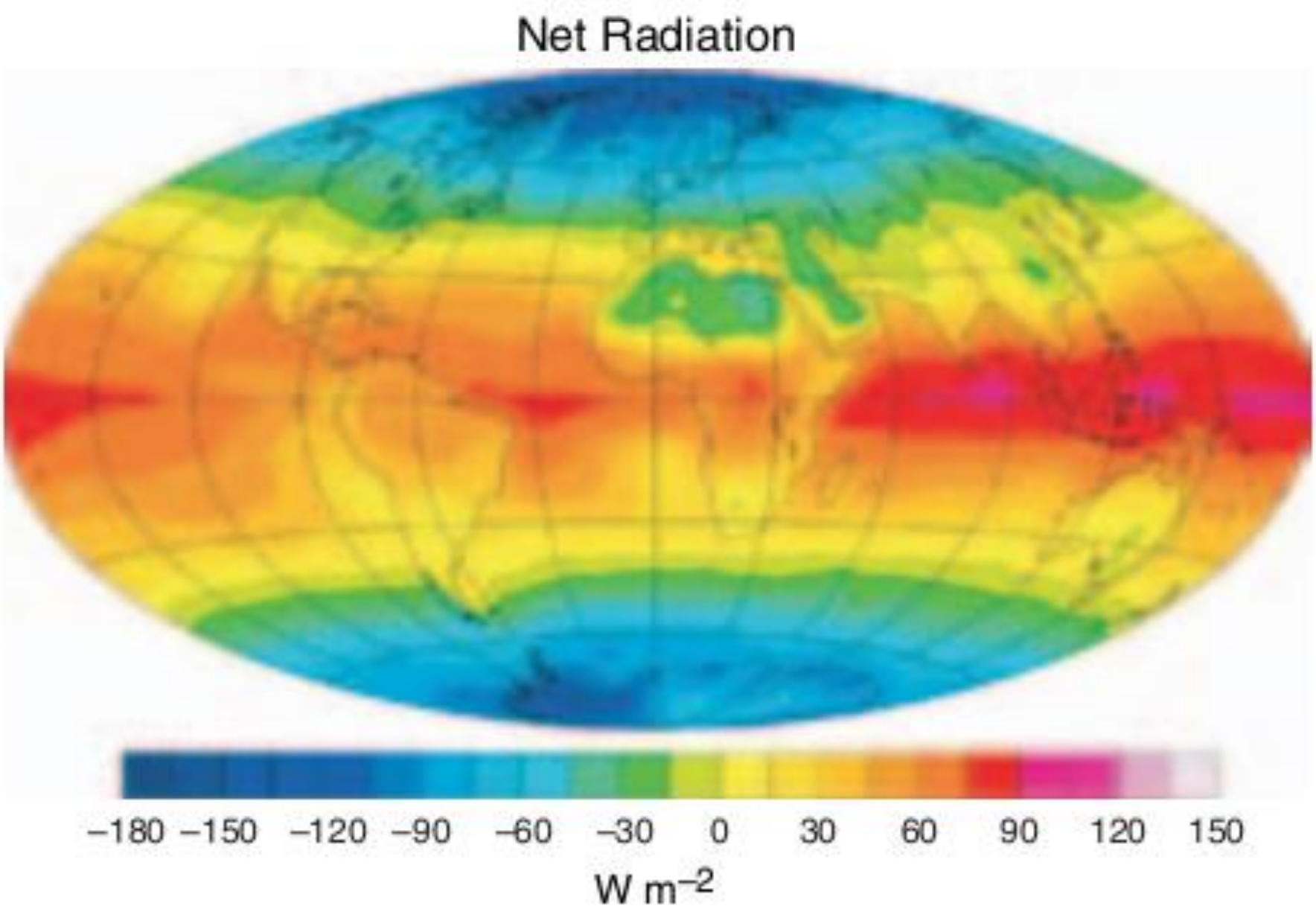

Global Energy Flows W m-2
102
Reflected Solar Radiation 101.9 W m-2
341
Incoming Solar Radiation 341.3 W m-2
239
Outgoing Longwave Radiation 238.5 W m-2
Reflected by Clouds and Atmosphere 79
79
40 Atmospheric Window
Emitted by Atmosphere 169
30
Greenhouse Gases
Absorbed by 78 Atmosphere
Latent 80 Heat
17
356
40
333 Back Radiation
Reflected by Surface 23
161
396
333
17 Thermals
80 Evapo-transpiration
Absorbed by Surface
Surface Radiation
Absorbed by Surface
Net absorbed 0.9 W m-2

Absorption in the Atmosphere

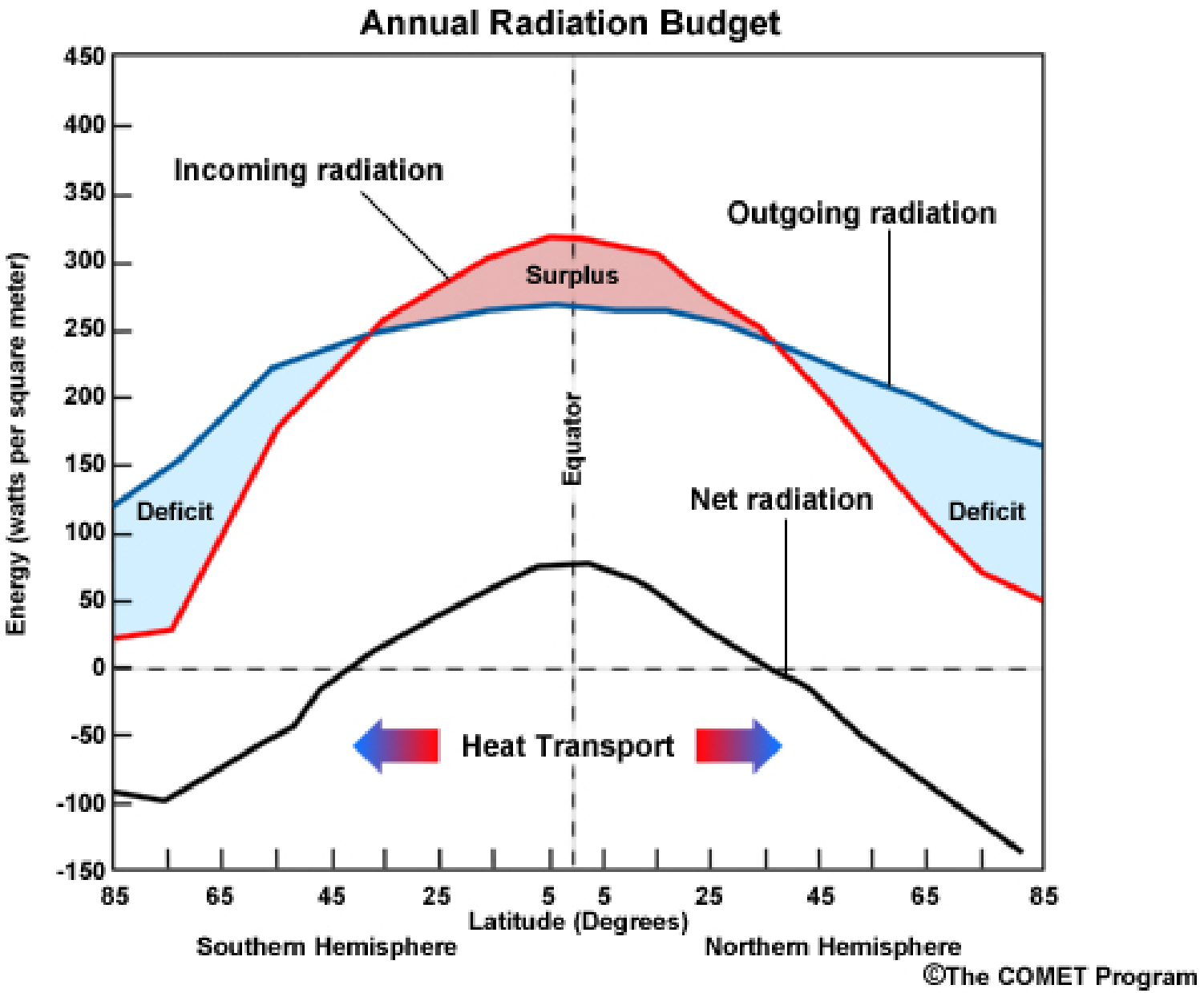


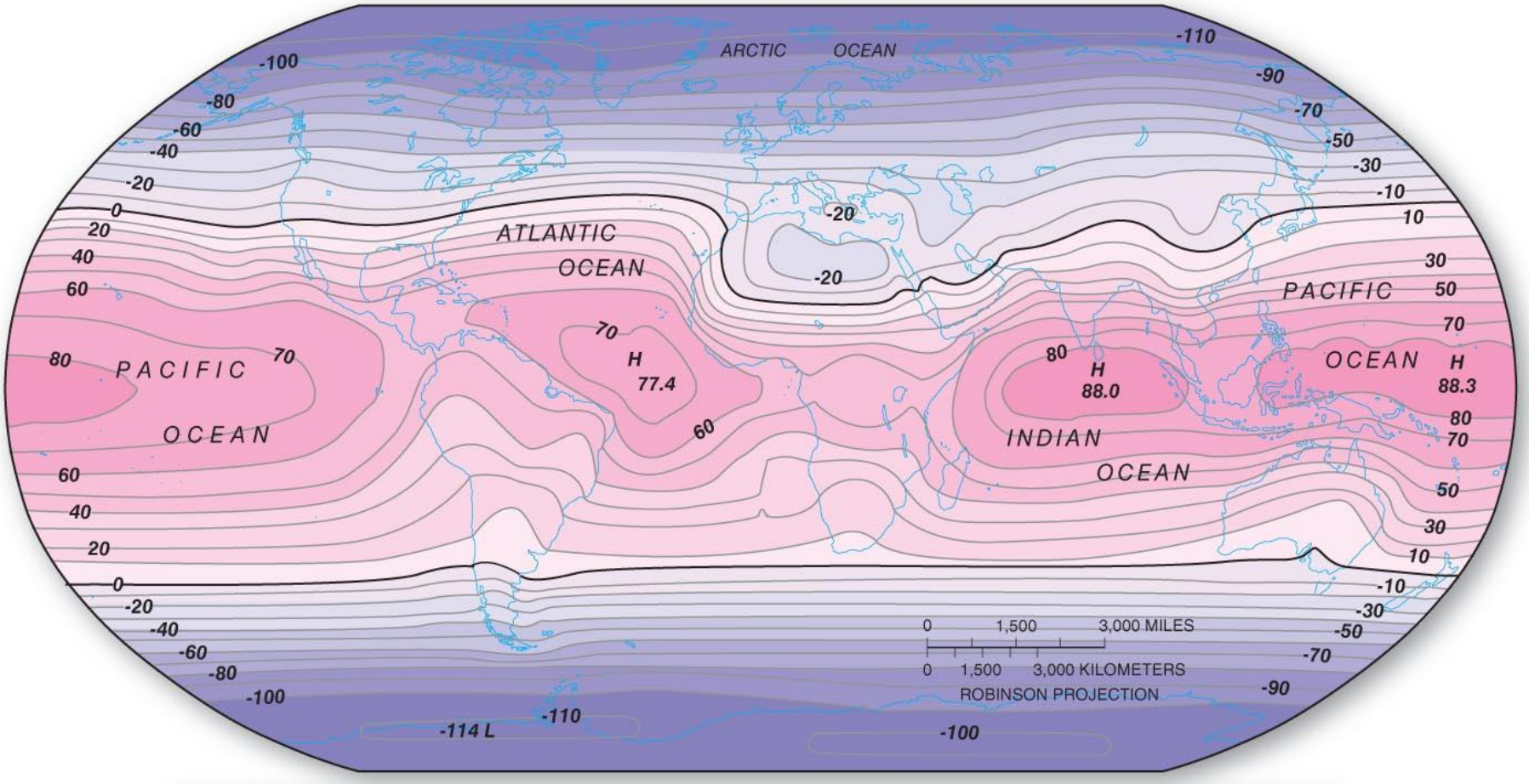

Absorbed Solar Radiation
0
40
80
120
160
200
240
280
320
360
410
W m⁻²


Outgoing Longwave Radiation
110 130 150 170 190 210 230 250 270 290 310 330
W m⁻²

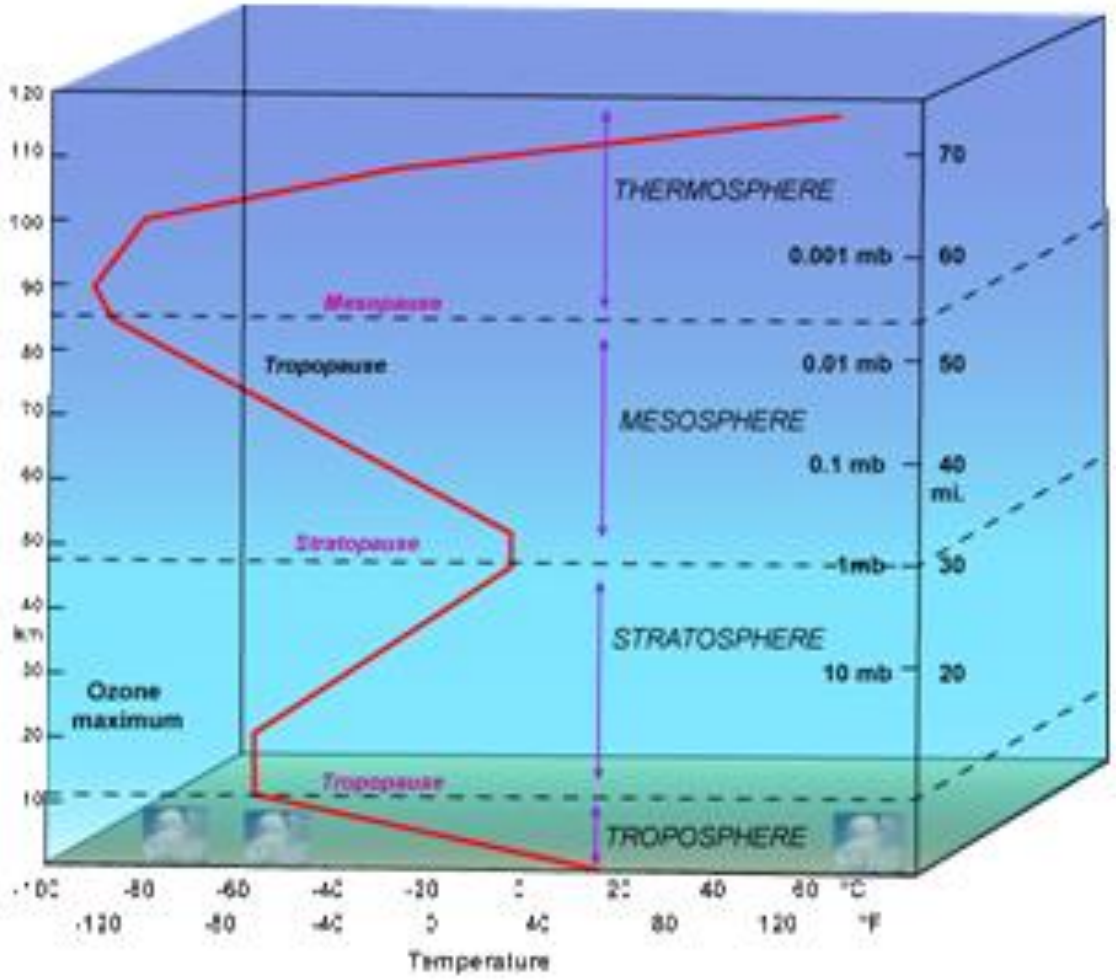

Net Radiation
−180 −150 −120 −90 −60 −30 0 30 60 90 120 150
W m−2

b

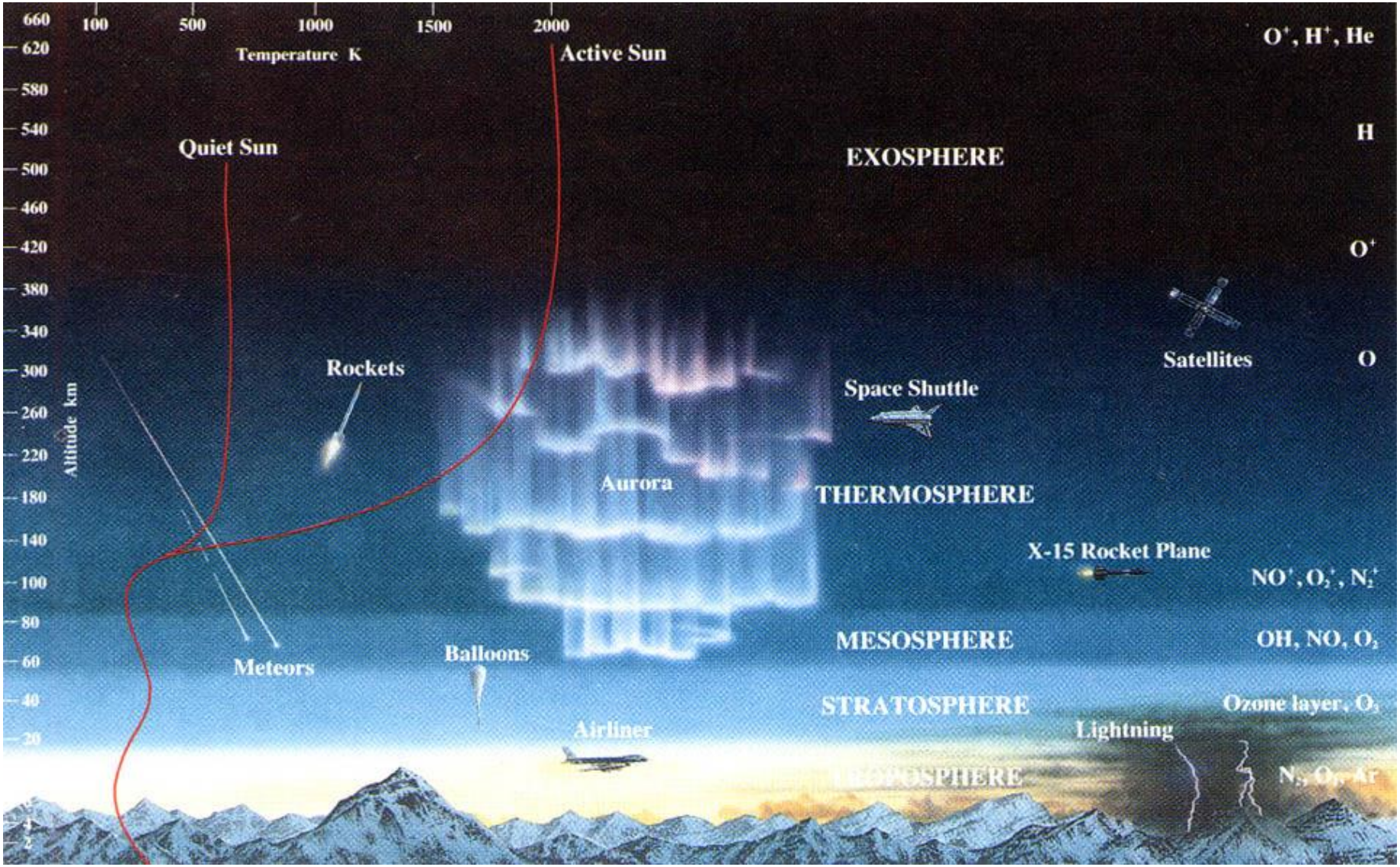

Annual Radiation Budget
Incoming radiation
Outgoing radiation
Surplus
Deficit
Deficit
Equator
Net radiation
Heat Transport
Energy (watts per square meter)
450
400
350
300
250
200
150
100
50
0
-50
-100
-150
85
65
45
25
5
5
25
45
65
85
Latitude (Degrees)
Southern Hemisphere
Northern Hemisphere
©The COMET Program



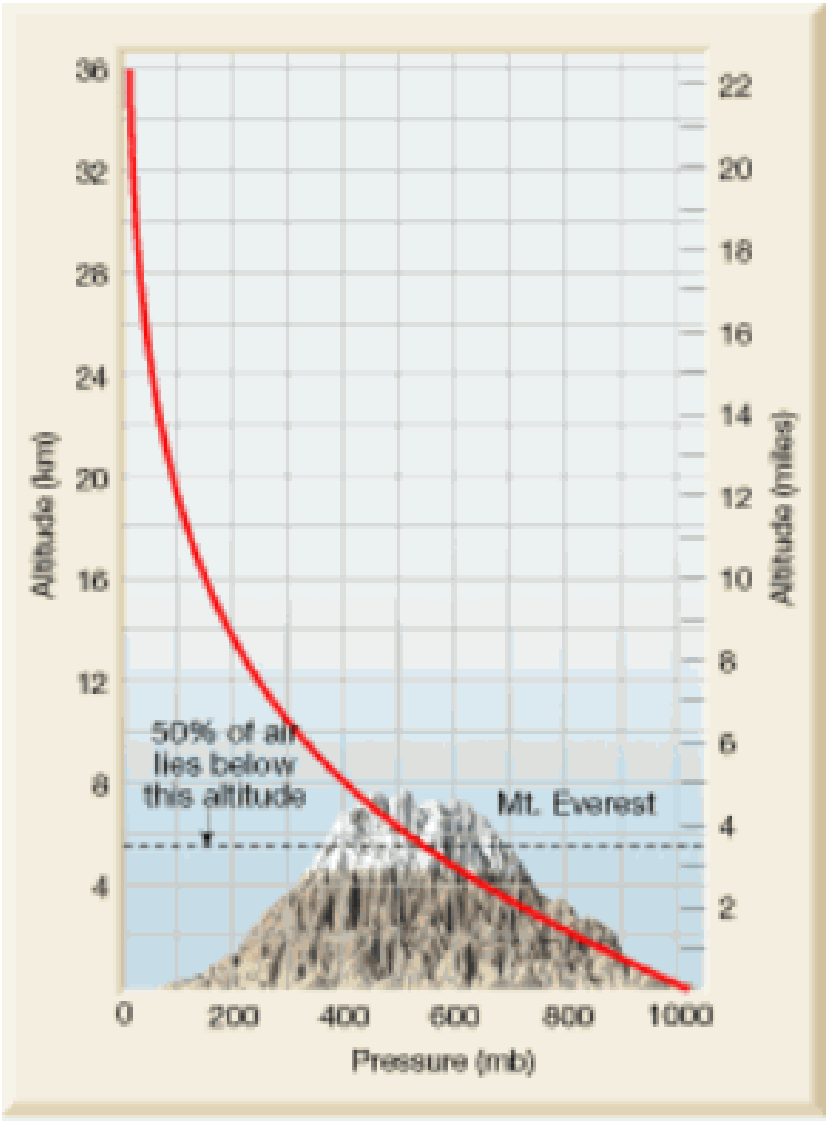
Layers of the Atmosphere



Layers continued



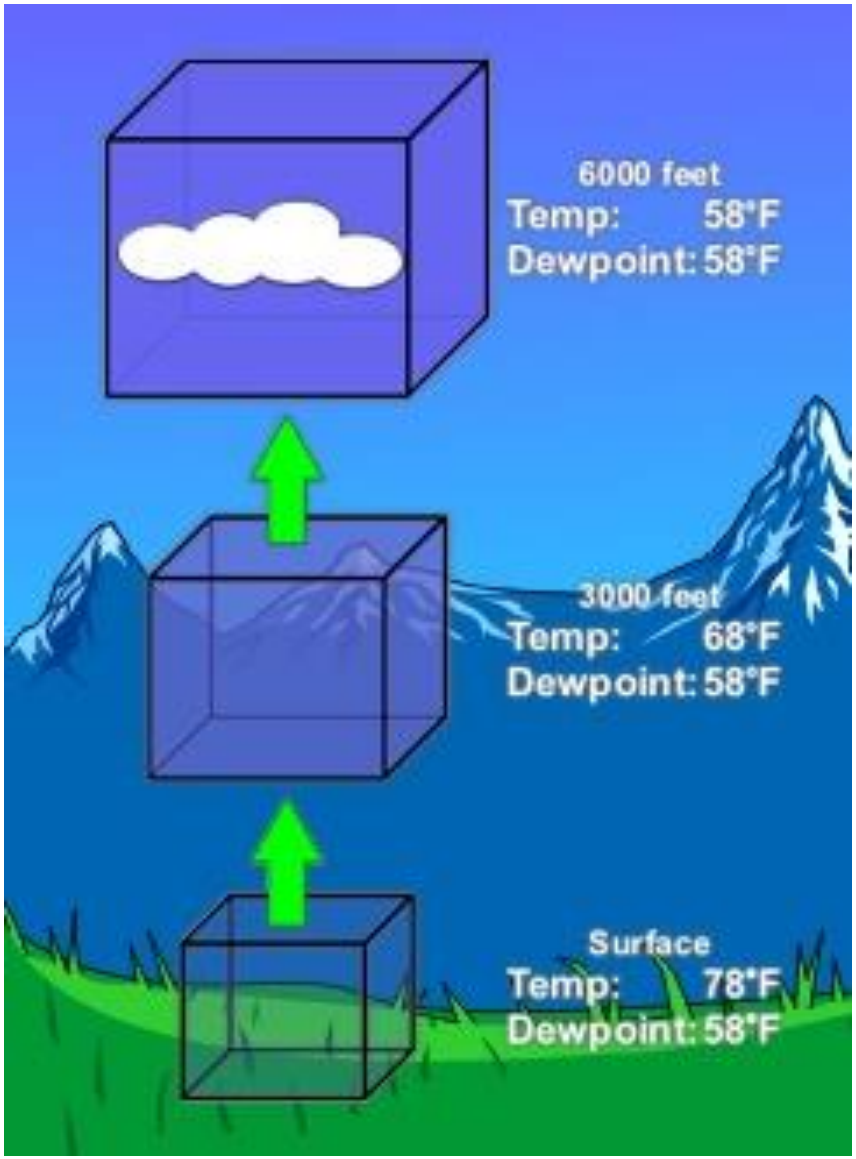
Pressure Versus Altitude

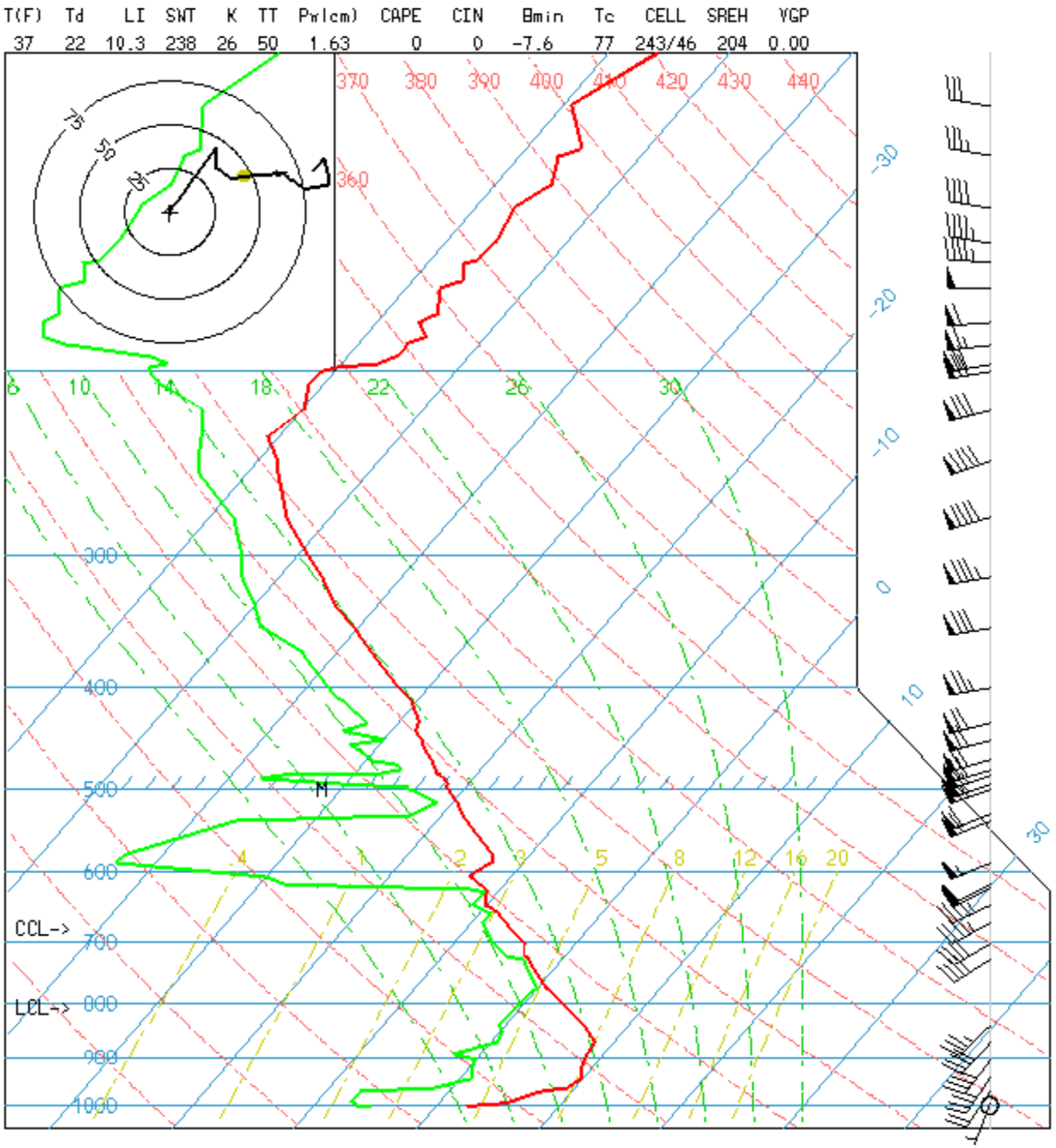


Dennis Tasa

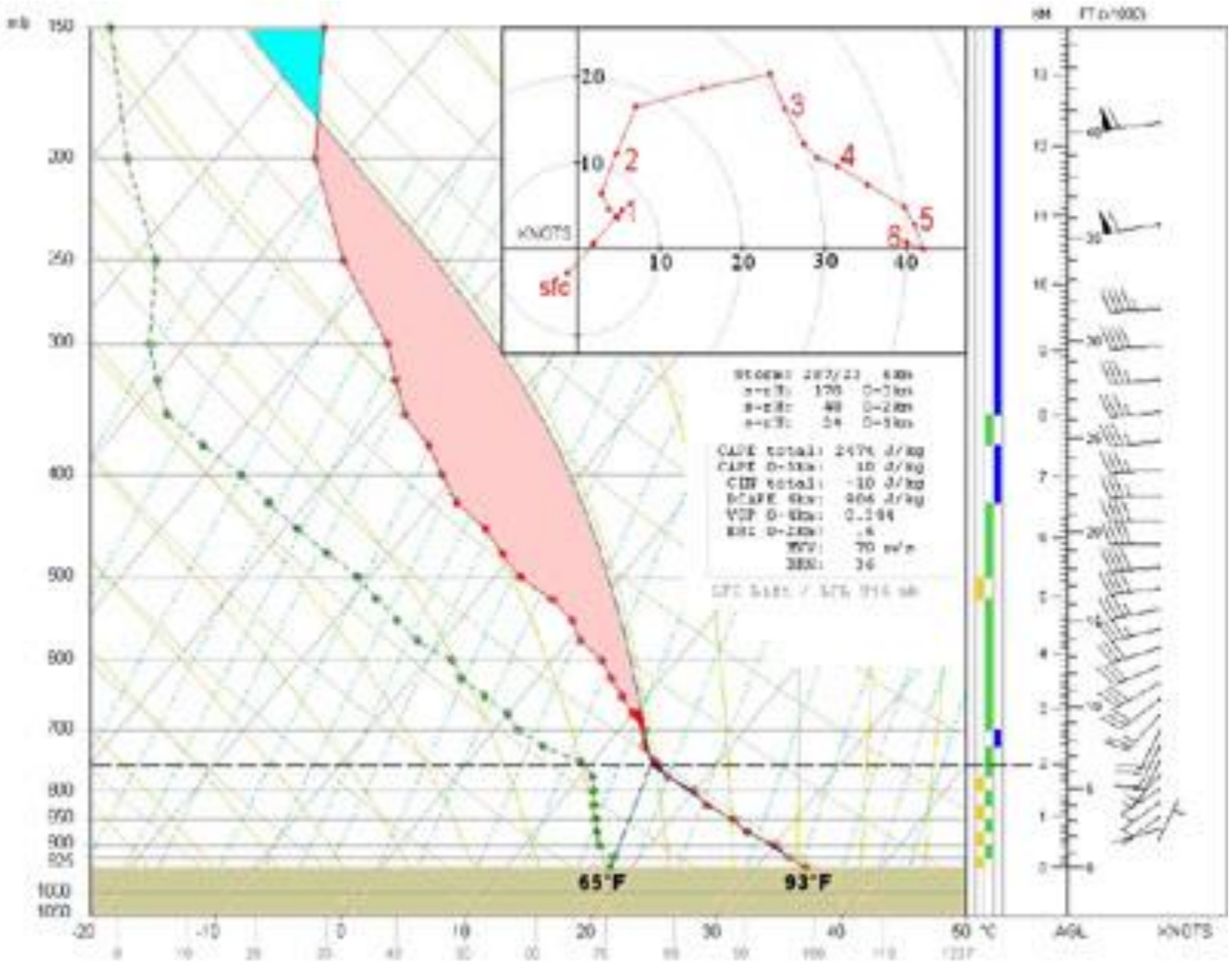
Standard Atmosphere			
Altitude (ft)	Pressure (in. Hg)	Temp. (°C)	Temp. (°F)
0	29.92	15.0	59.0
1,000	28.86	13.0	55.4
2,000	27.82	11.0	51.9
3,000	26.82	9.1	48.3
4,000	25.84	7.1	44.7
5,000	24.89	5.1	41.2
6,000	23.98	3.1	37.6
7,000	23.09	1.1	34.0
8,000	22.22	-0.9	30.5
9,000	21.38	-2.8	26.9
10,000	20.57	-4.8	23.3
11,000	19.79	-6.8	19.8
12,000	19.02	-8.8	16.2
13,000	18.29	-10.8	12.6
14,000	17.57	-12.7	9.1
15,000	16.88	-14.7	5.5
16,000	16.21	-16.7	1.9
17,000	15.56	-18.7	-1.6
18,000	14.94	-20.7	-5.2
19,000	14.33	-22.6	-8.8
20,000	13.74	-24.6	-12.3

Adiabatic process

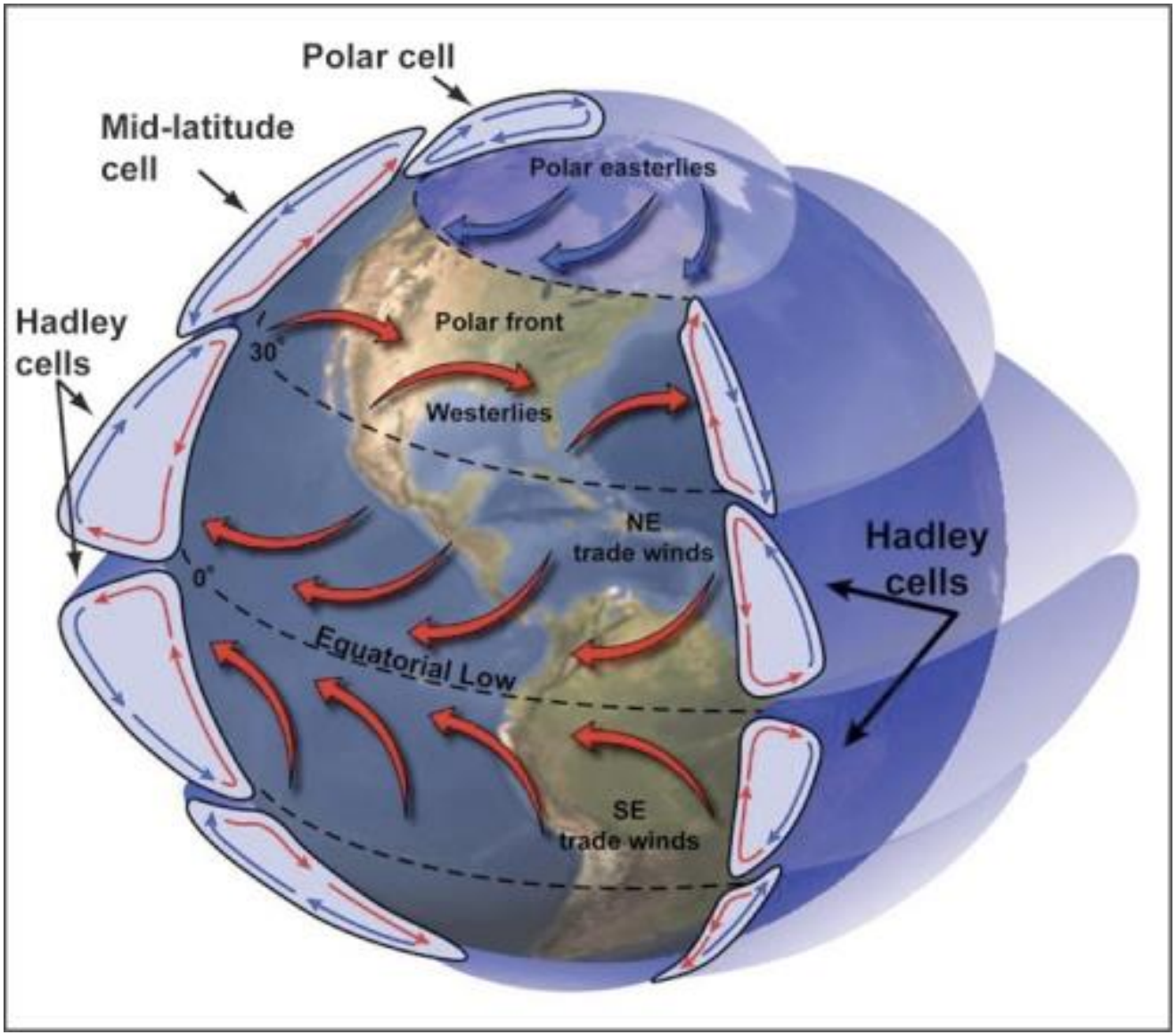



T(F) Td LI SWT K TT Pw(cm) CAPE CIN Bmin Tc CELL SREH VGP
37 22 10.3 238 26 50 1.63 0 0 -7.6 77 243/46 204 0.00
370 380 390 400 410 420 430 440
360
6 10 14 18 22 26 30
300
400
500
600
700
800
900
1000
-30 -20 -10 0 10 30
-4 -1 2 5 8 12 16 20
CCL->
LCL->
SKEW-T/LOG-P VALID 1200 UTC 02/19/2014 KIAD
Lat = 38.93 , Lon = -77.45

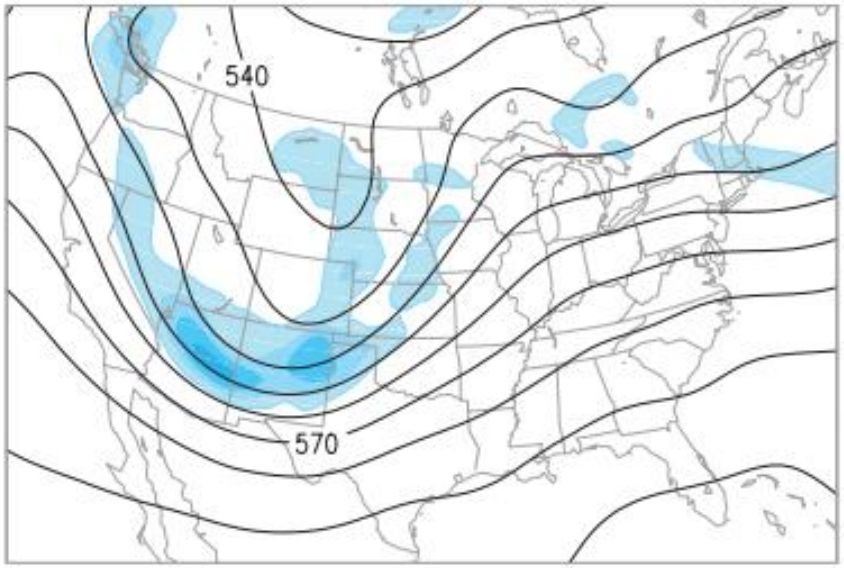
CAPE

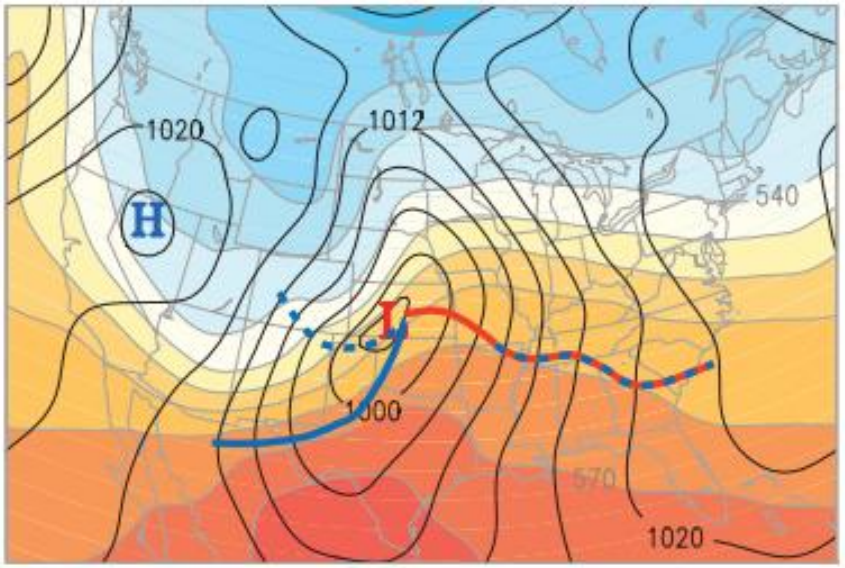


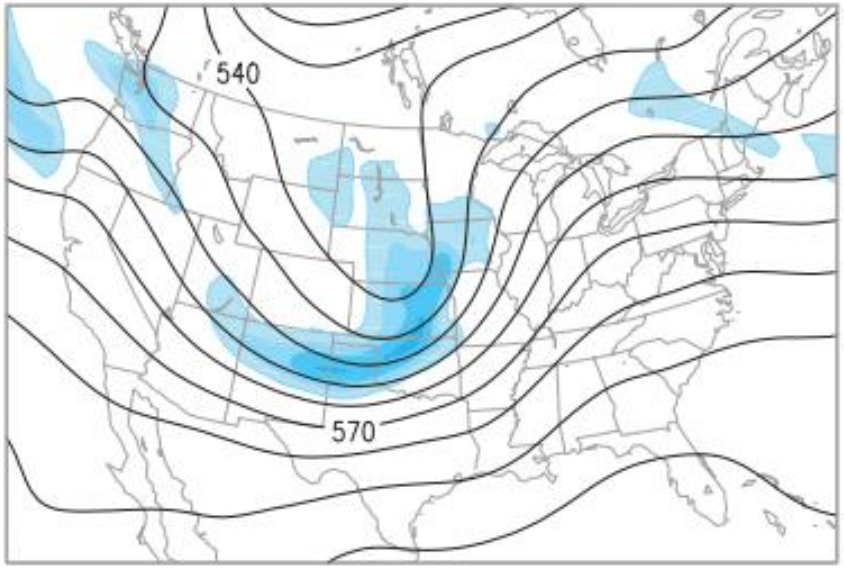
Global Circulation

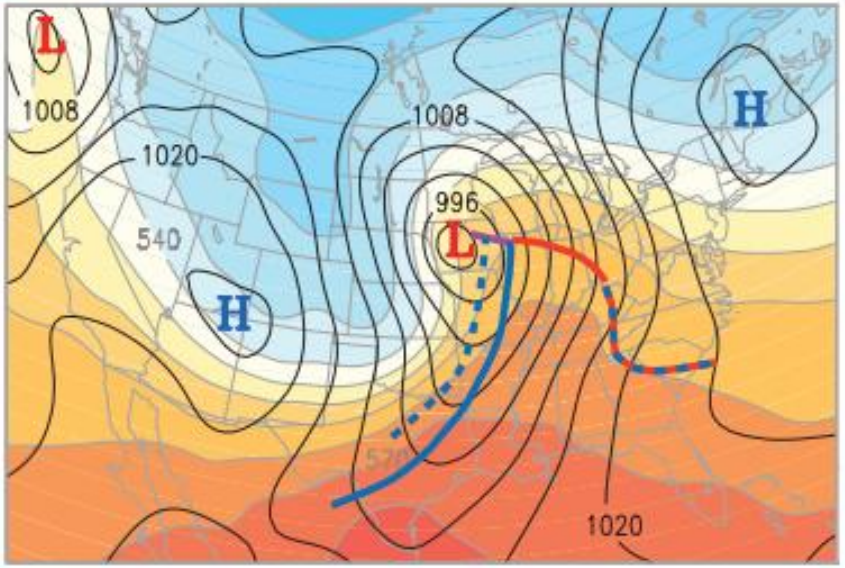


Frontal Systems

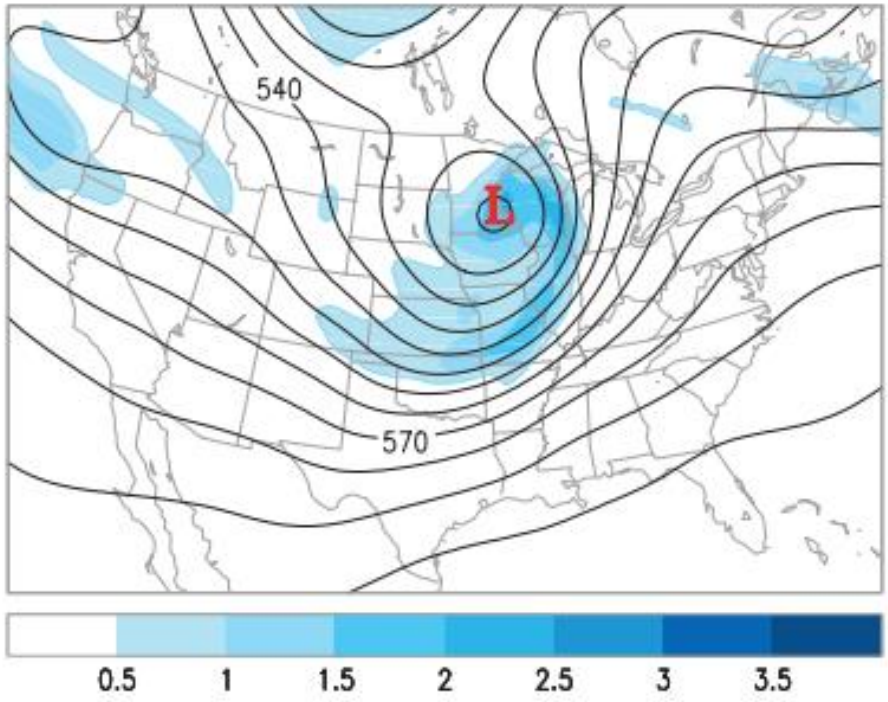


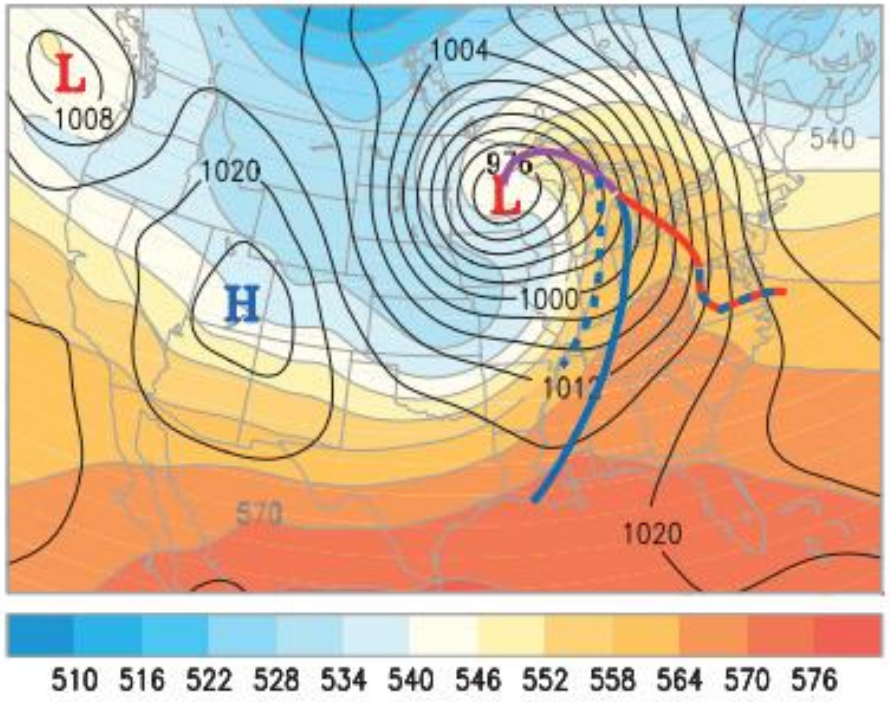




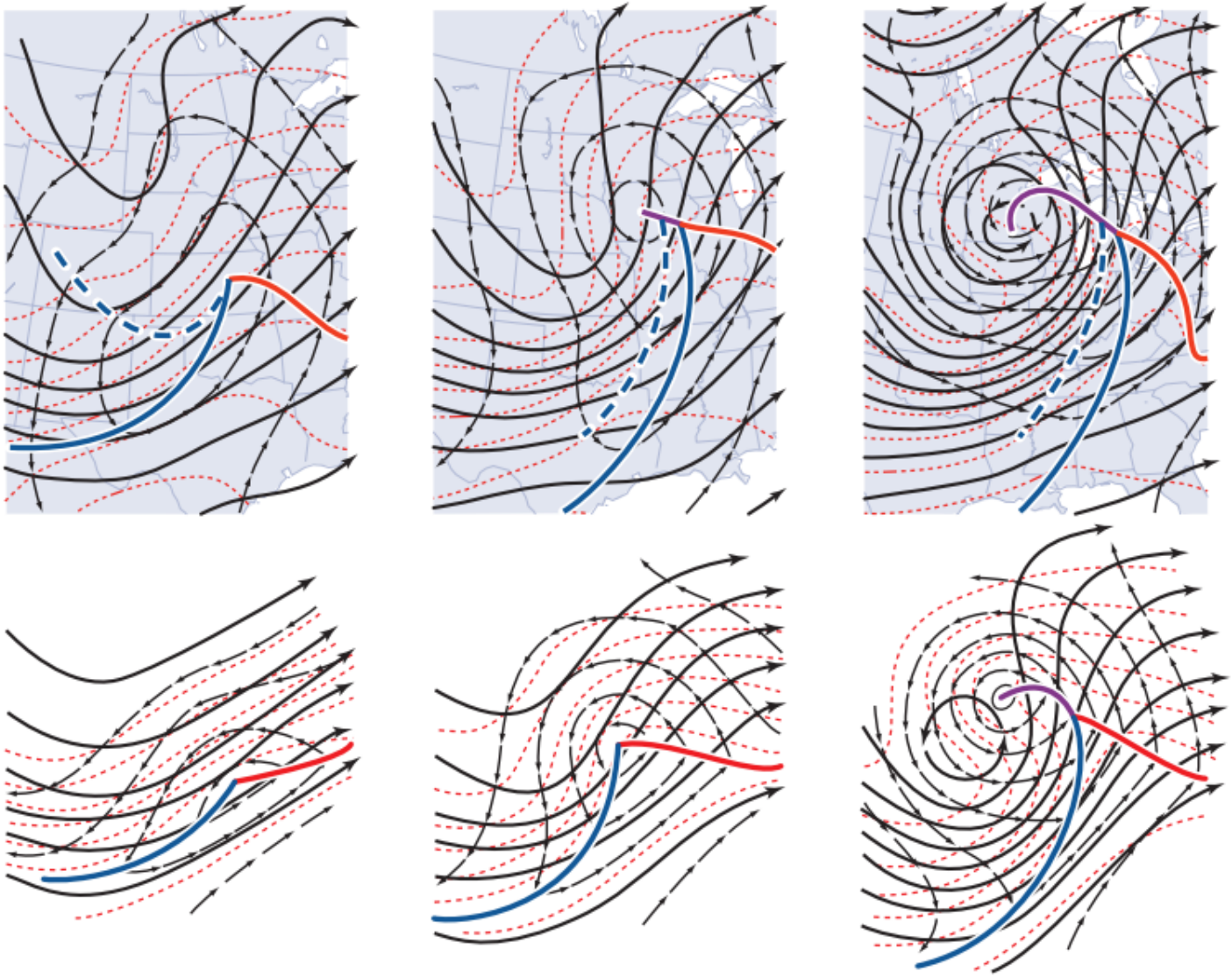


Frontal Systems

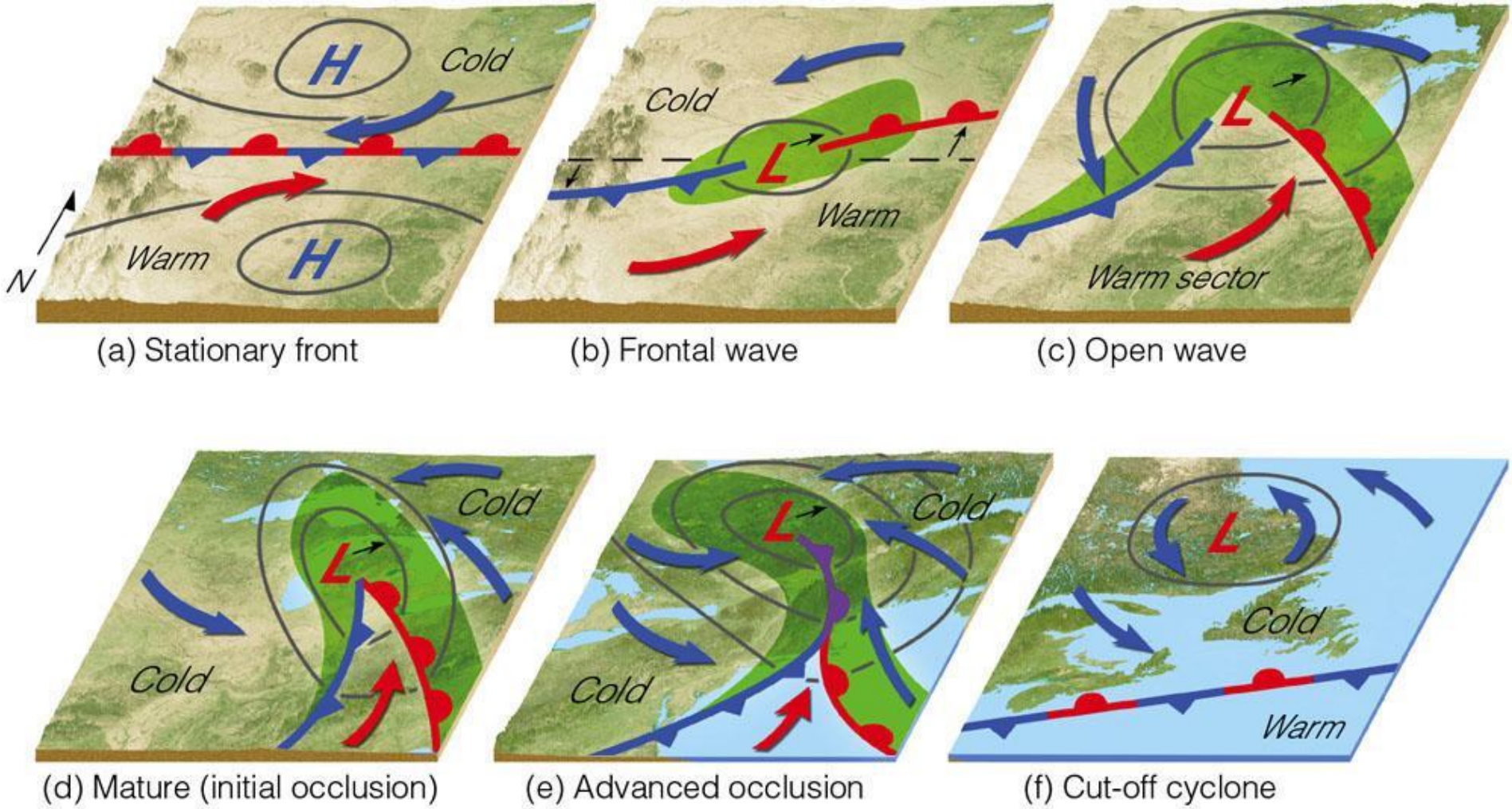




Another Look



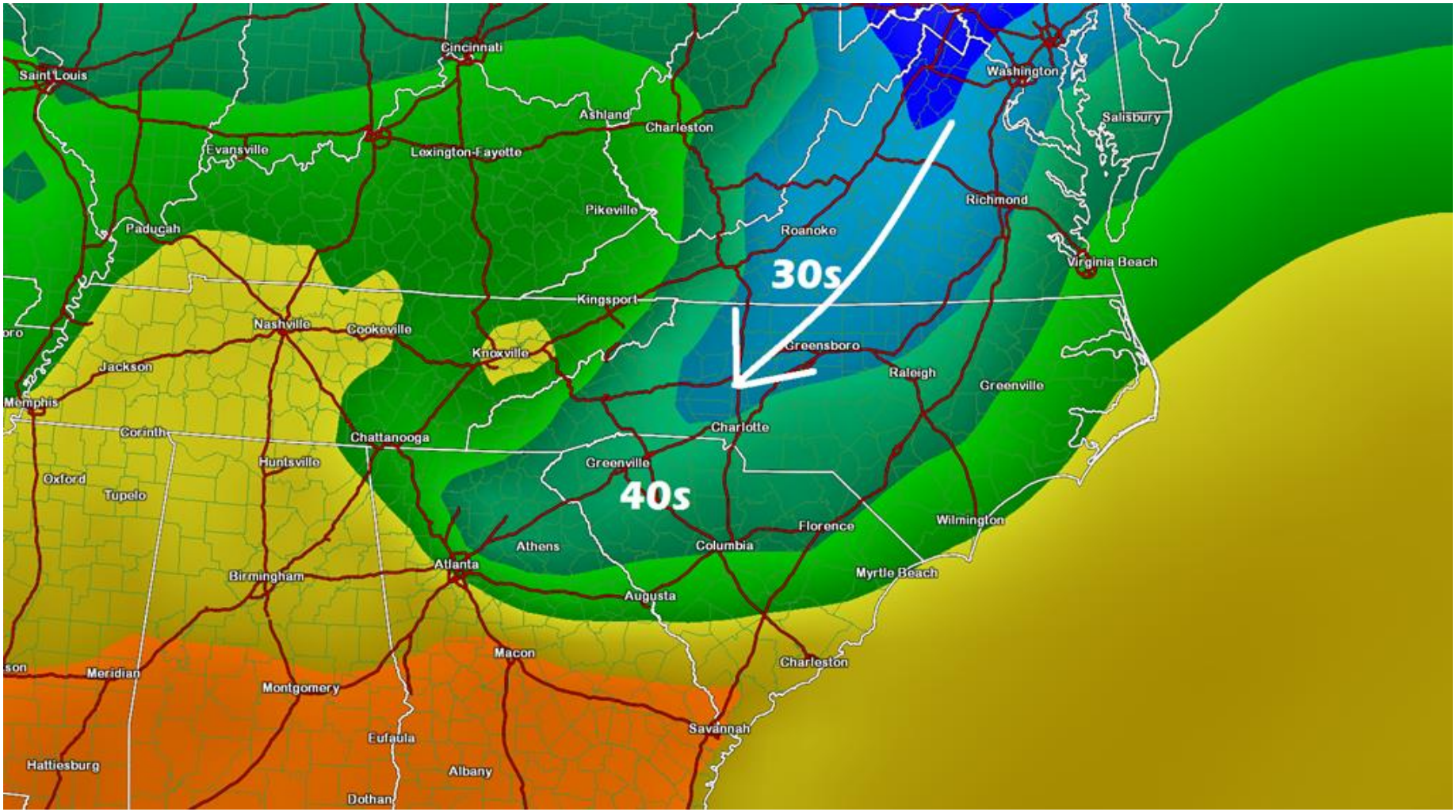
Baroclinic Wave Development



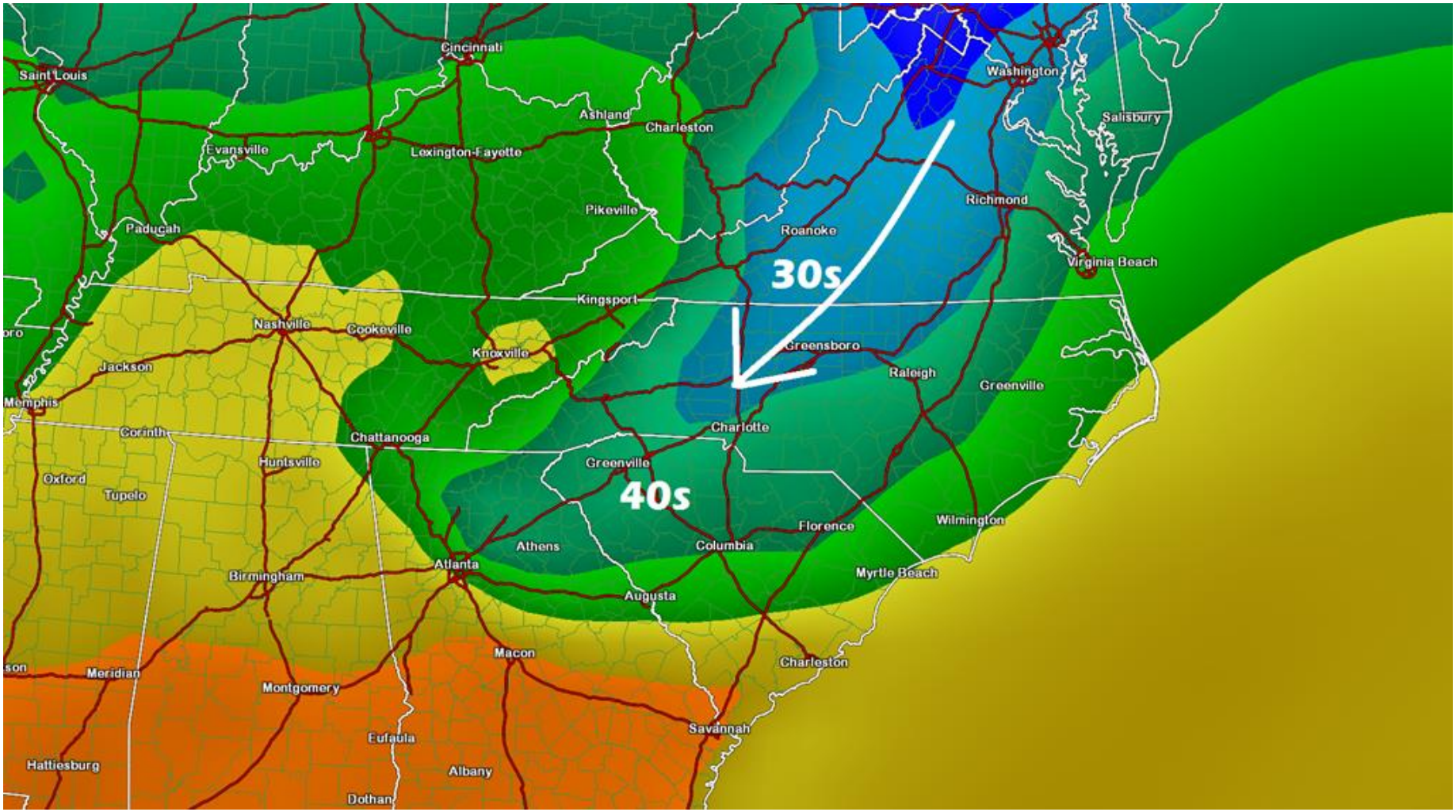
(a) Stationary front (b) Frontal wave (c) Open wave

(d) Mature (initial occlusion) (e) Advanced occlusion (f) Cut-off cyclone

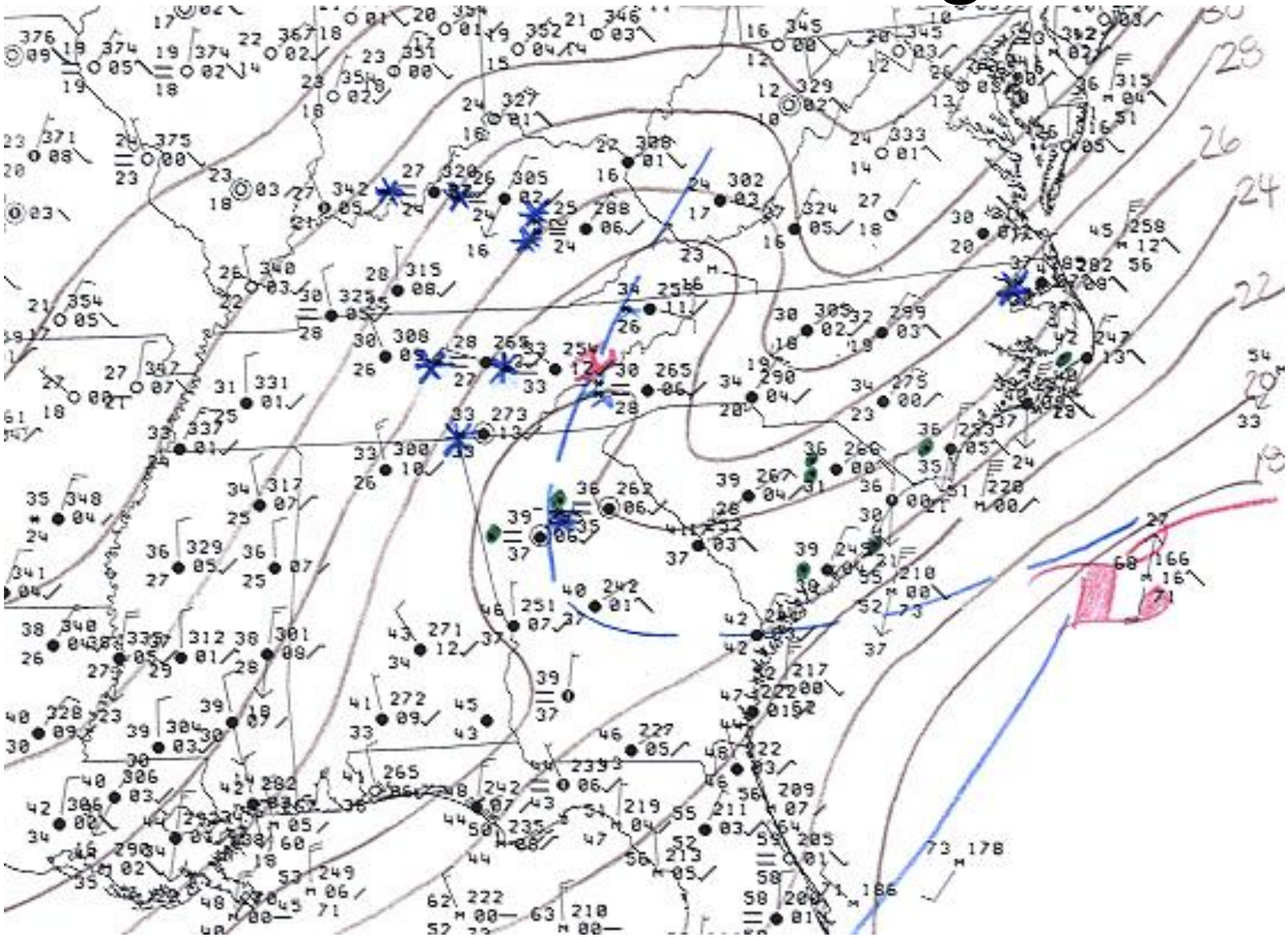
Cold air Damming



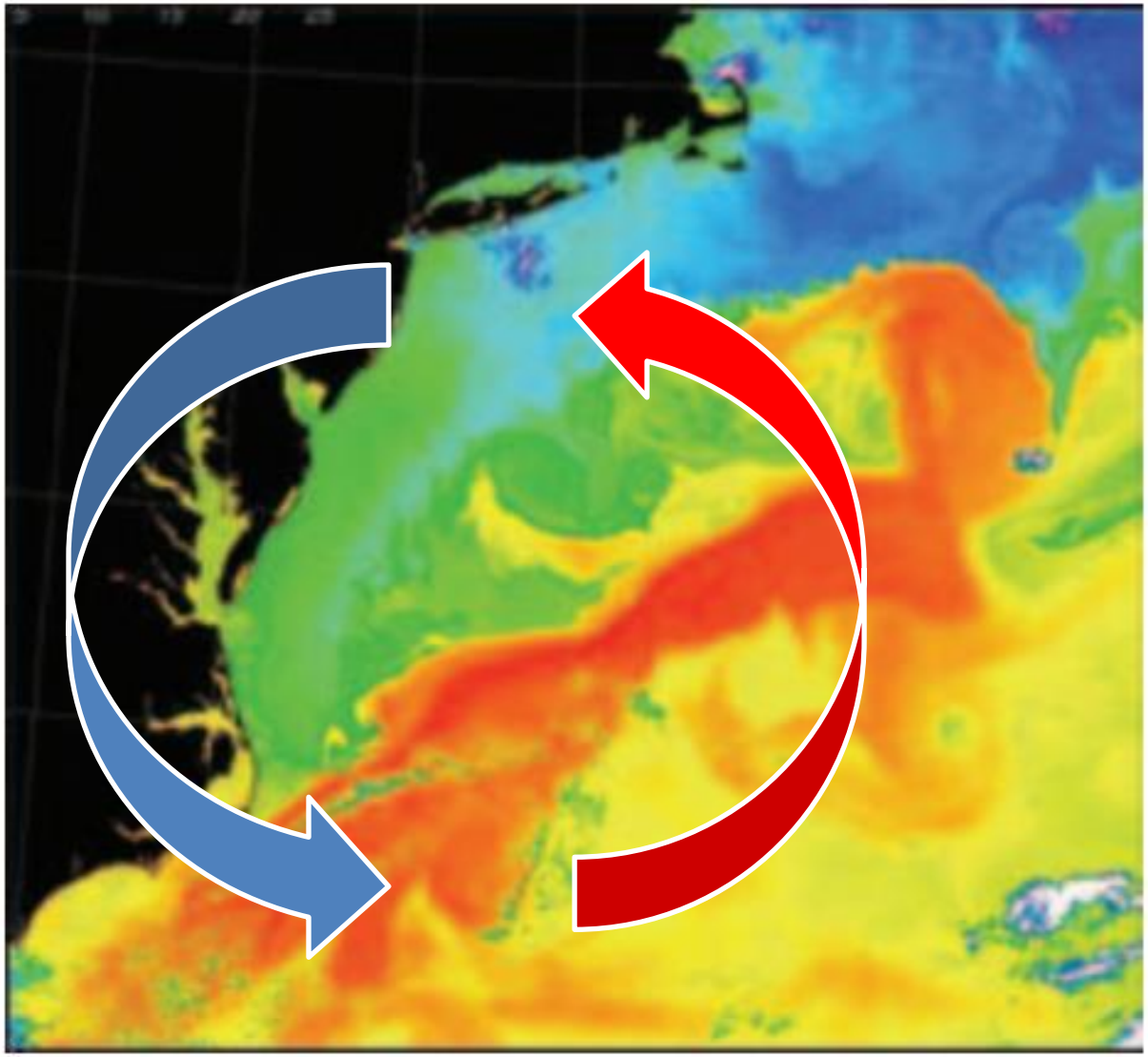
Cold air Damming

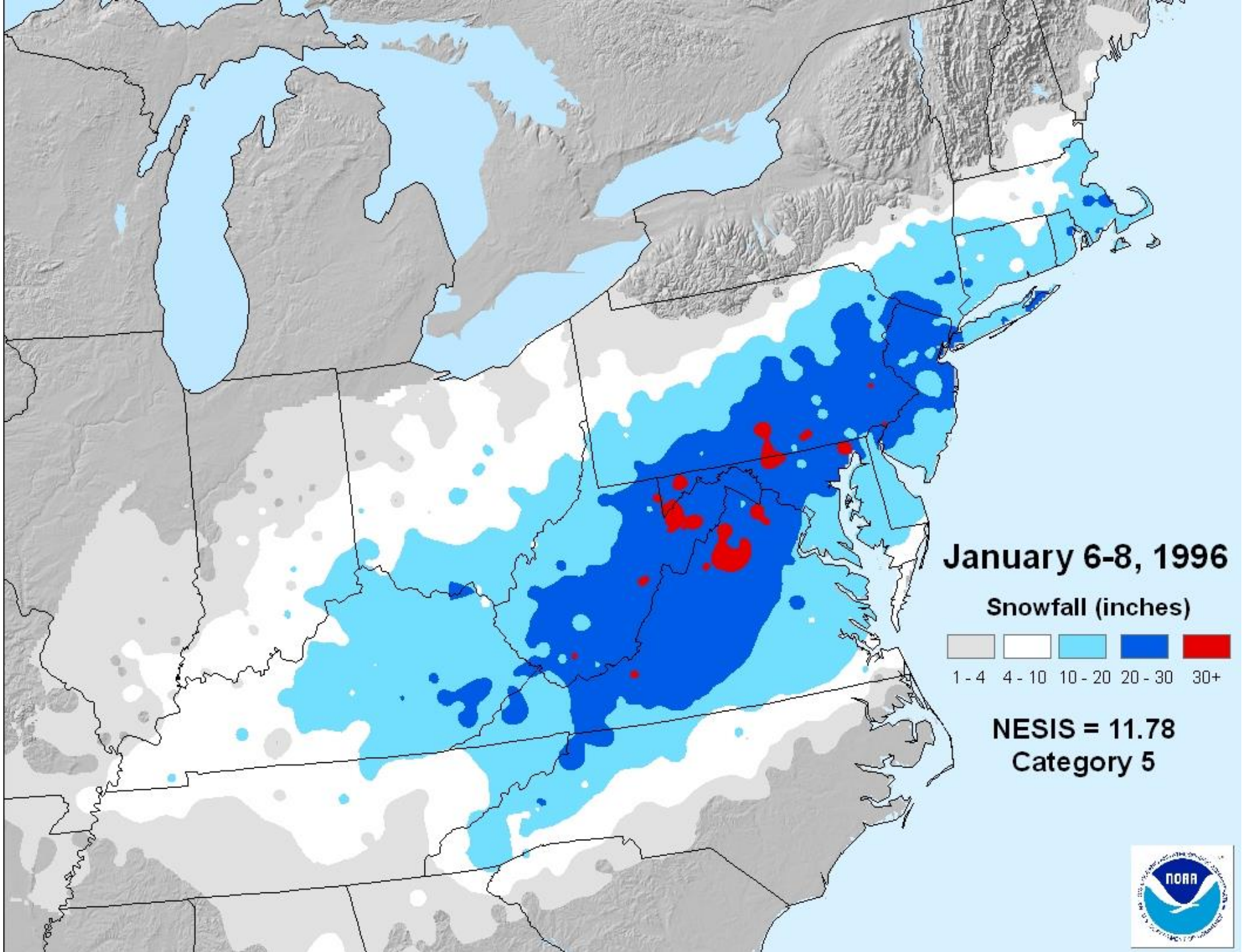


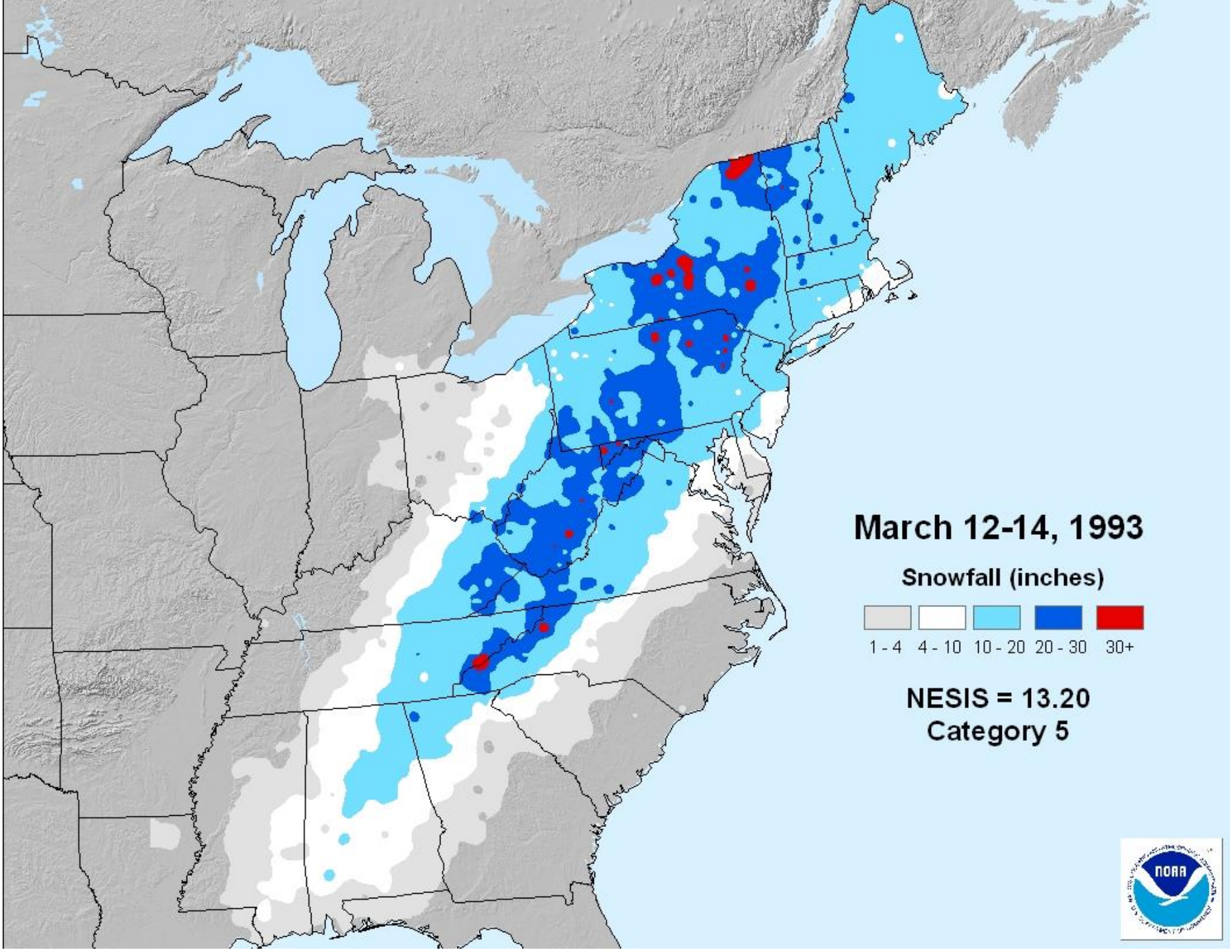
Cold Air Damming

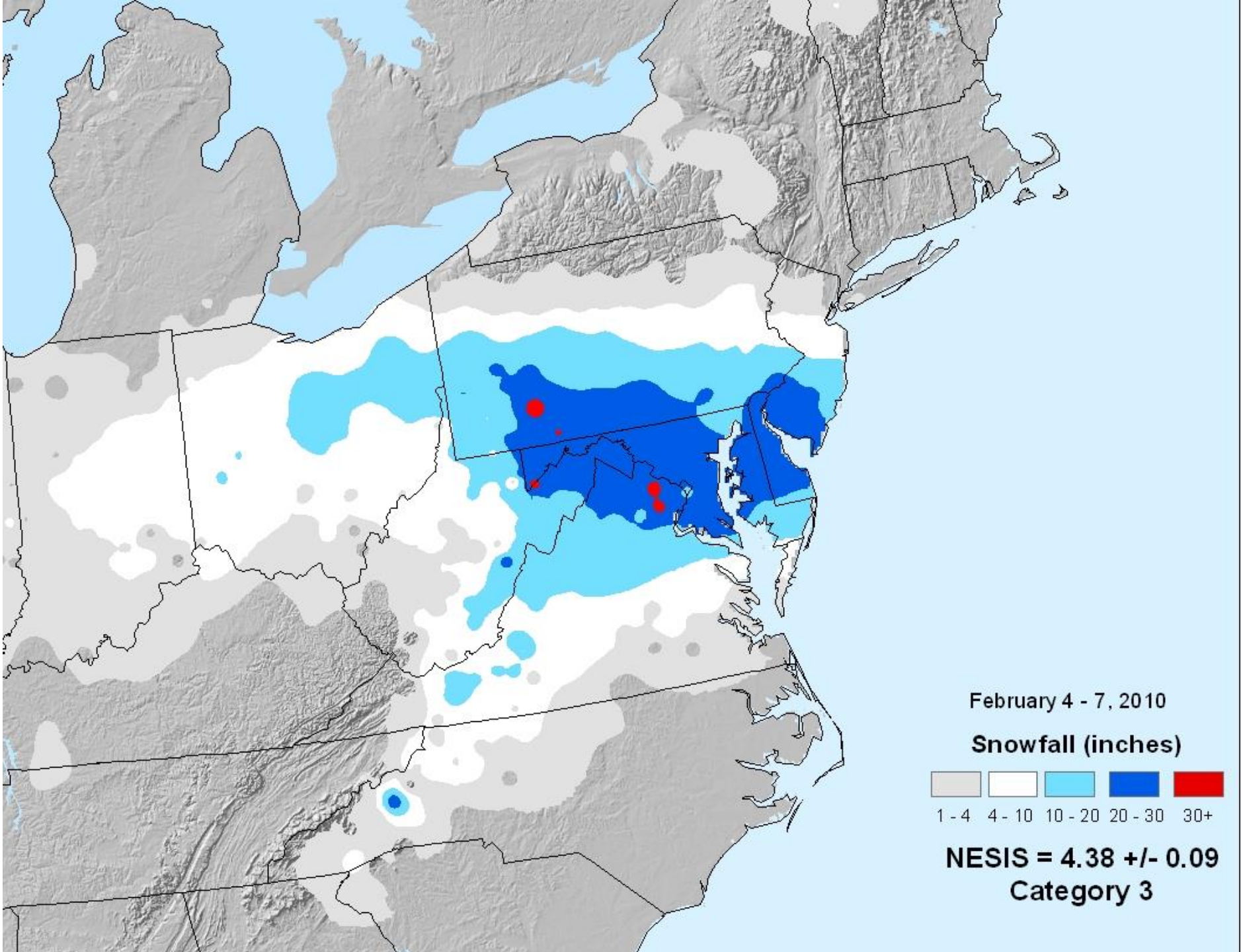


The Gulf Stream

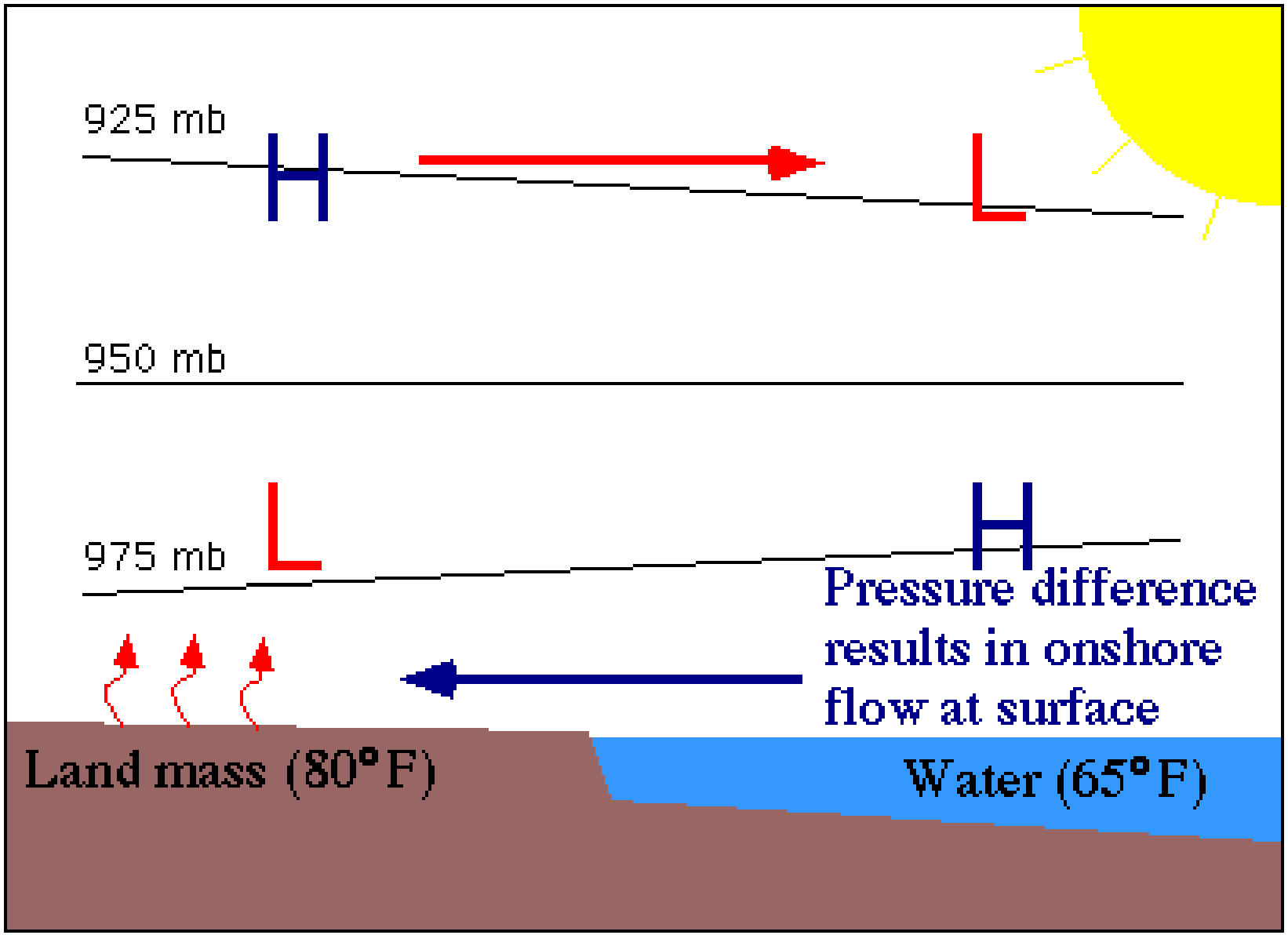



January 6-8, 1996
Snowfall (inches)
1 - 4
4 - 10
10 - 20
20 - 30
30+
NESIS = 11.78
Category 5
NOAA

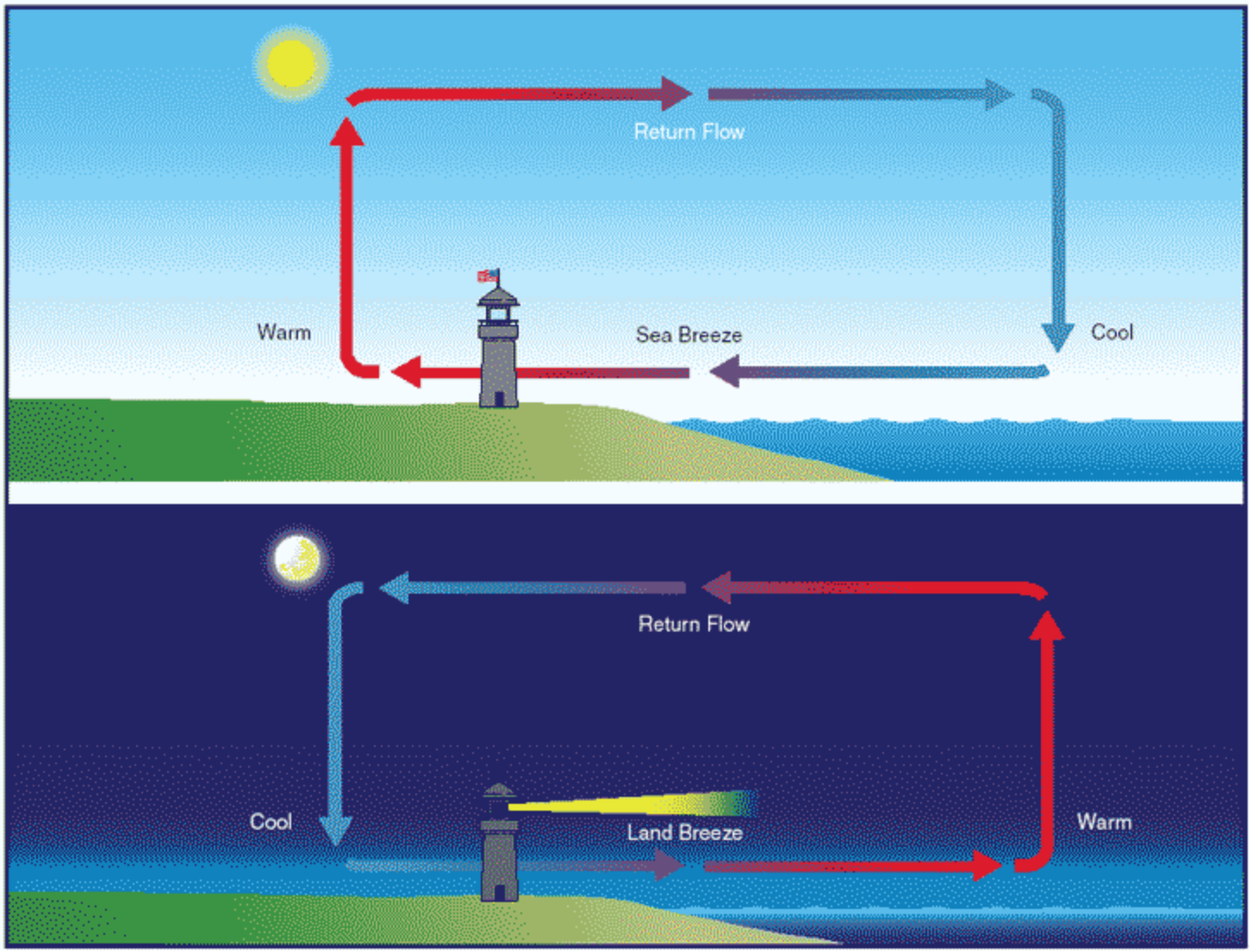

March 12-14, 1993
Snowfall (inches)
1 - 4
4 - 10
10 - 20
20 - 30
30+
NESIS = 13.20
Category 5
NOAA


February 4 - 7, 2010
Snowfall (inches)
1 - 4
4 - 10
10 - 20
20 - 30
30+
NESIS = 4.38 +/- 0.09
Category 3

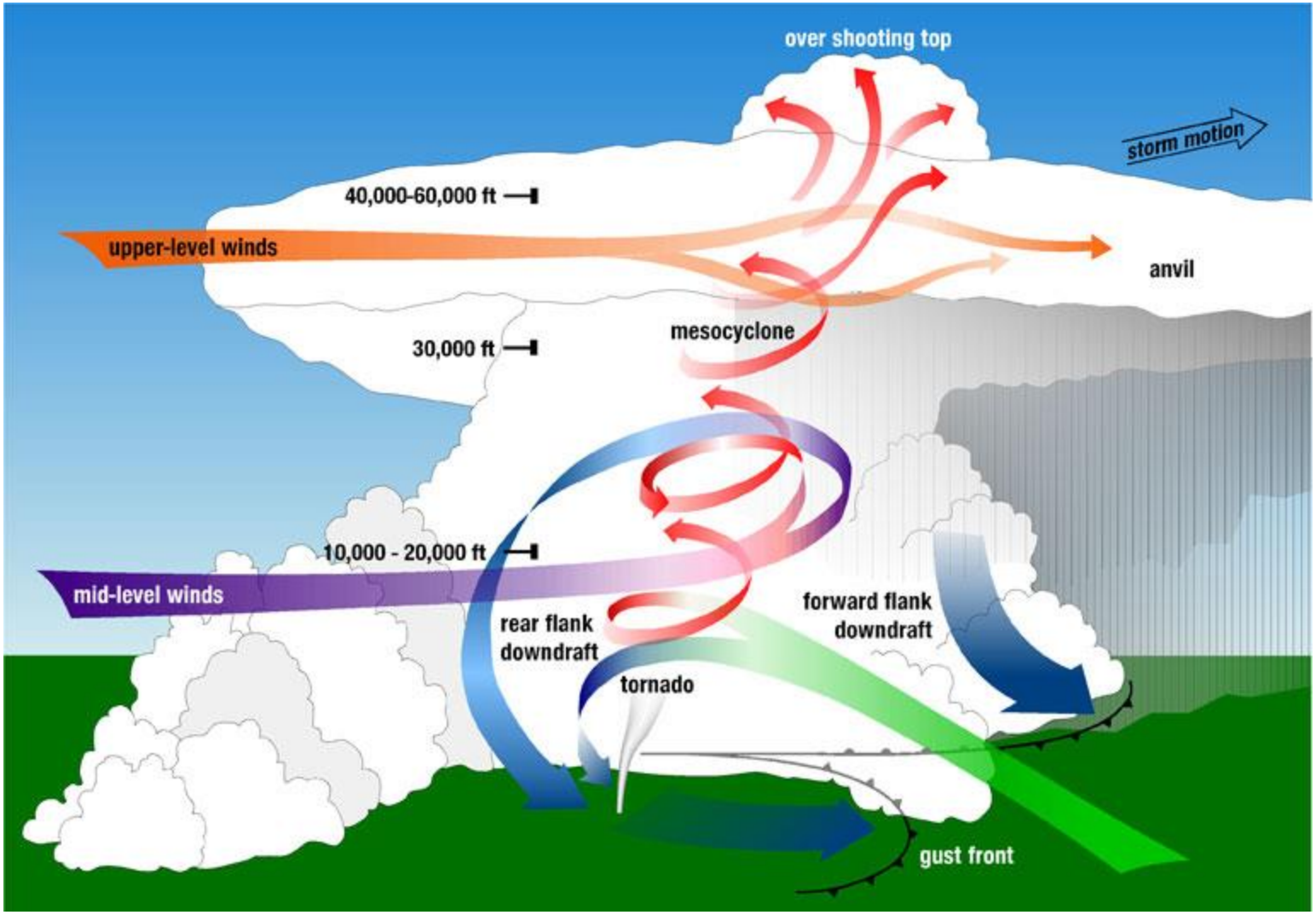
Sea Breeze


925 mb
H
L
950 mb
975 mb
L
H
Pressure difference
results in onshore
flow at surface
Land mass (80°F)
Water (65°F)

Bay Breeze


Return Flow
Warm
Sea Breeze
Cool
Return Flow
Cool
Land Breeze
Warm

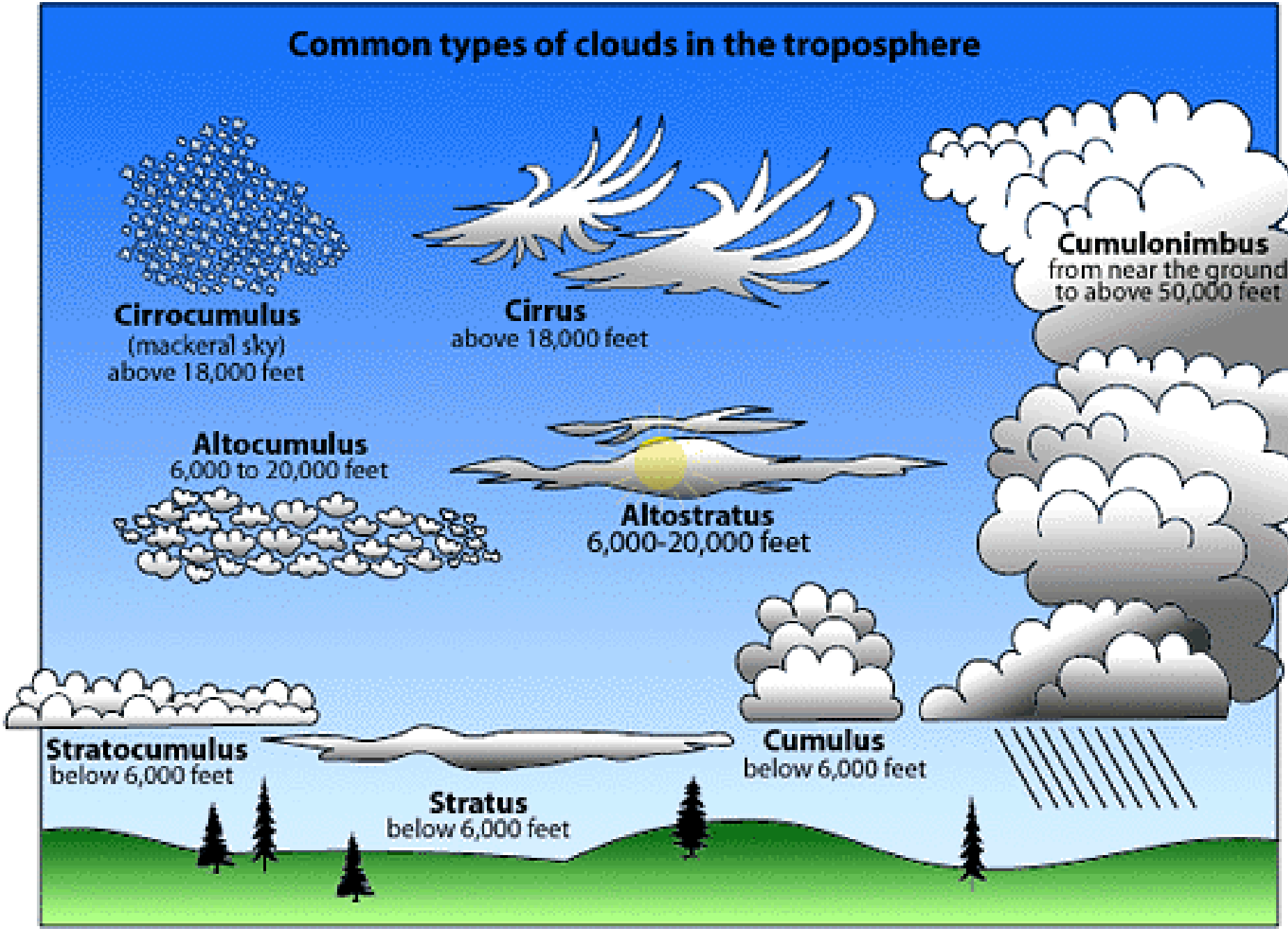
Thunderstorms, Hail, Tornadoes



Lightning

Clouds

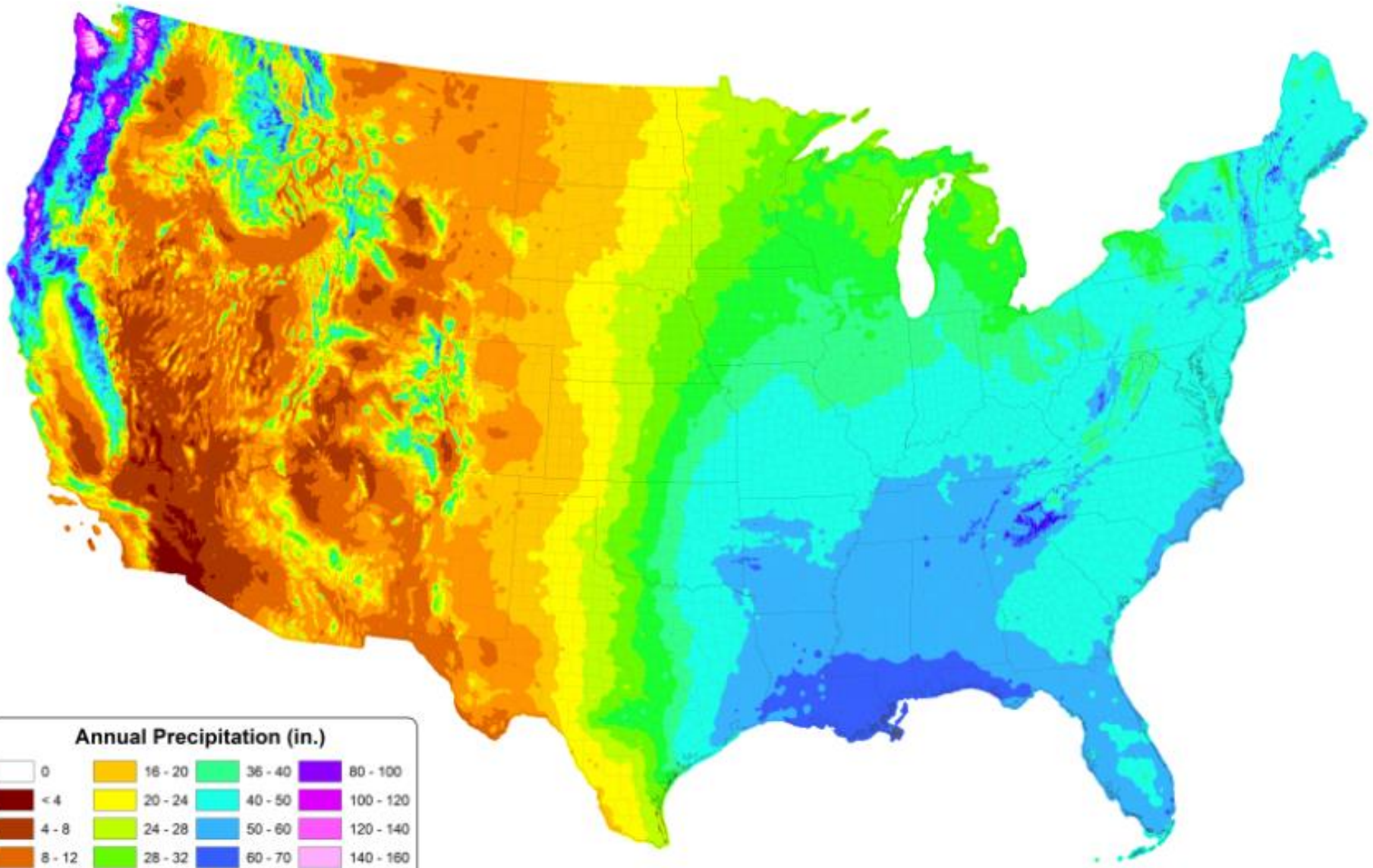
- Cumulus – cumulo means pile or heap in Latin
- Stratus- Strato means layer
- Nimbus – Latin for rain
- Cirrus – ringlet or curl of hair in Latin
- Prefixes can include: Alto, congestus, uncinus, towering


Common types of clouds in the troposphere
Cirrocumulus
(mackeral sky)
above 18,000 feet
Cirrus
above 18,000 feet
Cumulonimbus
from near the ground
to above 50,000 feet
Altocumulus
6,000 to 20,000 feet
Altostratus
6,000-20,000 feet
Stratocumulus
below 6,000 feet
Cumulus
below 6,000 feet
Stratus
below 6,000 feet

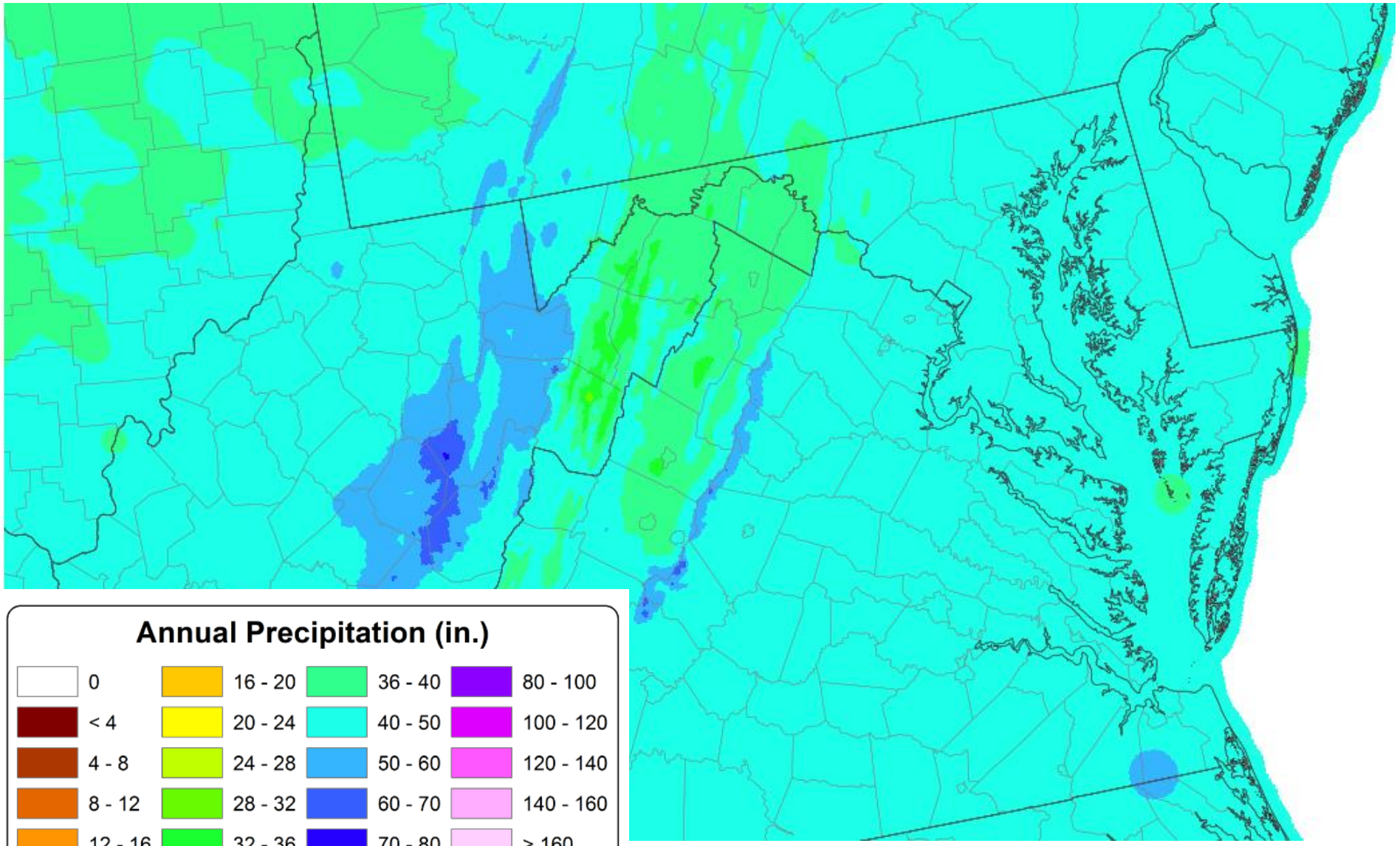
What is Climate?

30-yr Normal Precipitation: Annual

Period: 1981-2010

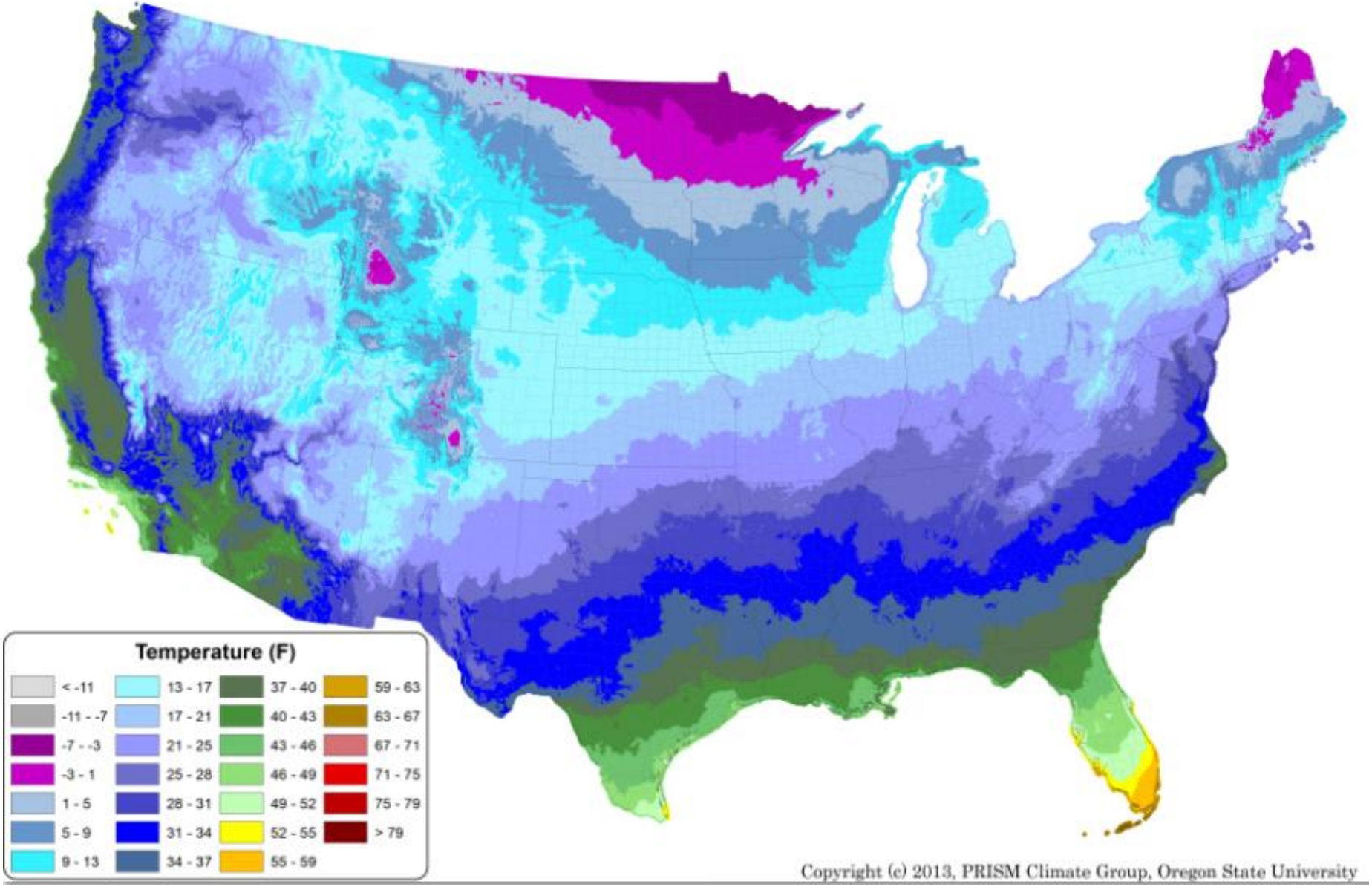


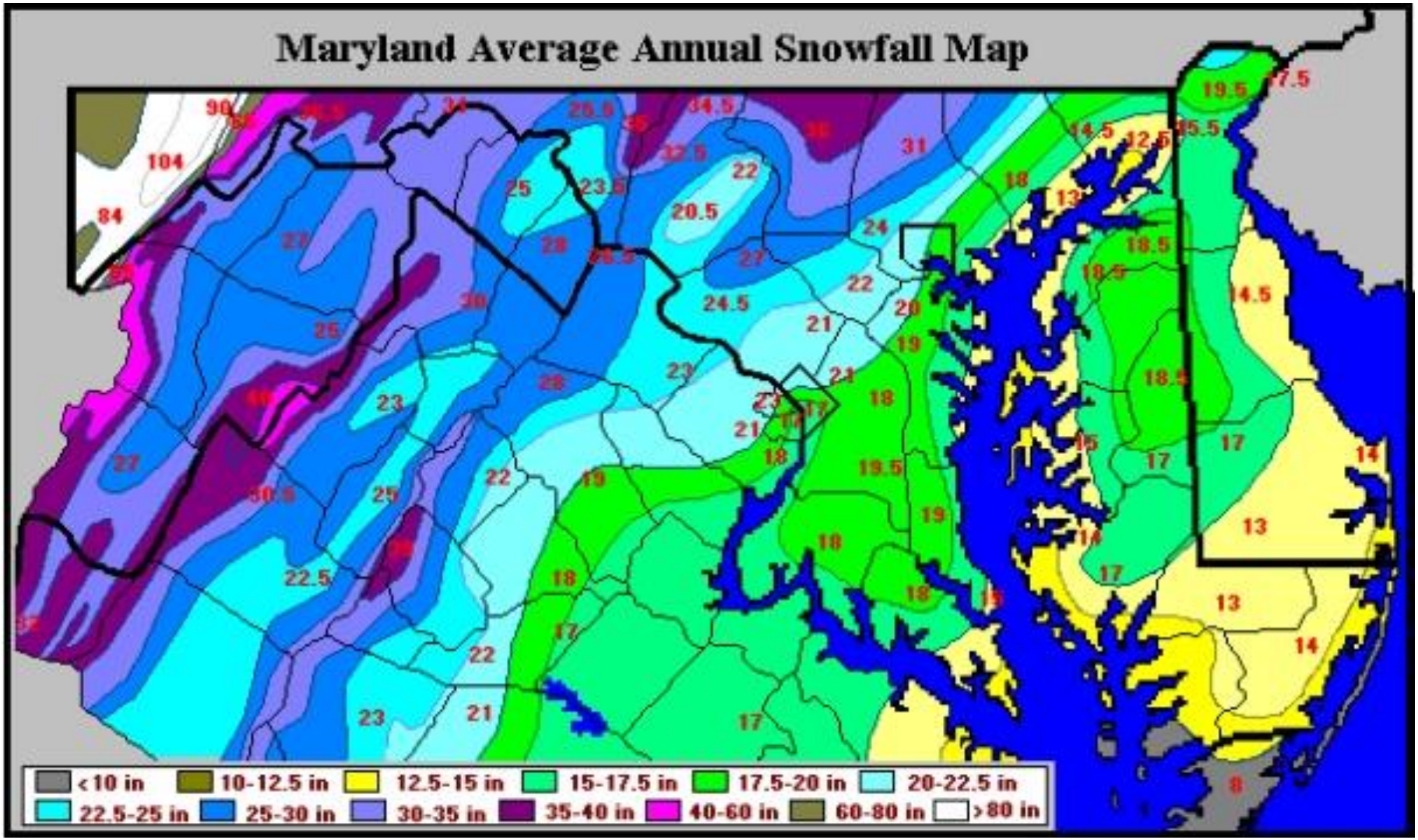
30 year Normal Maryland Precipitation



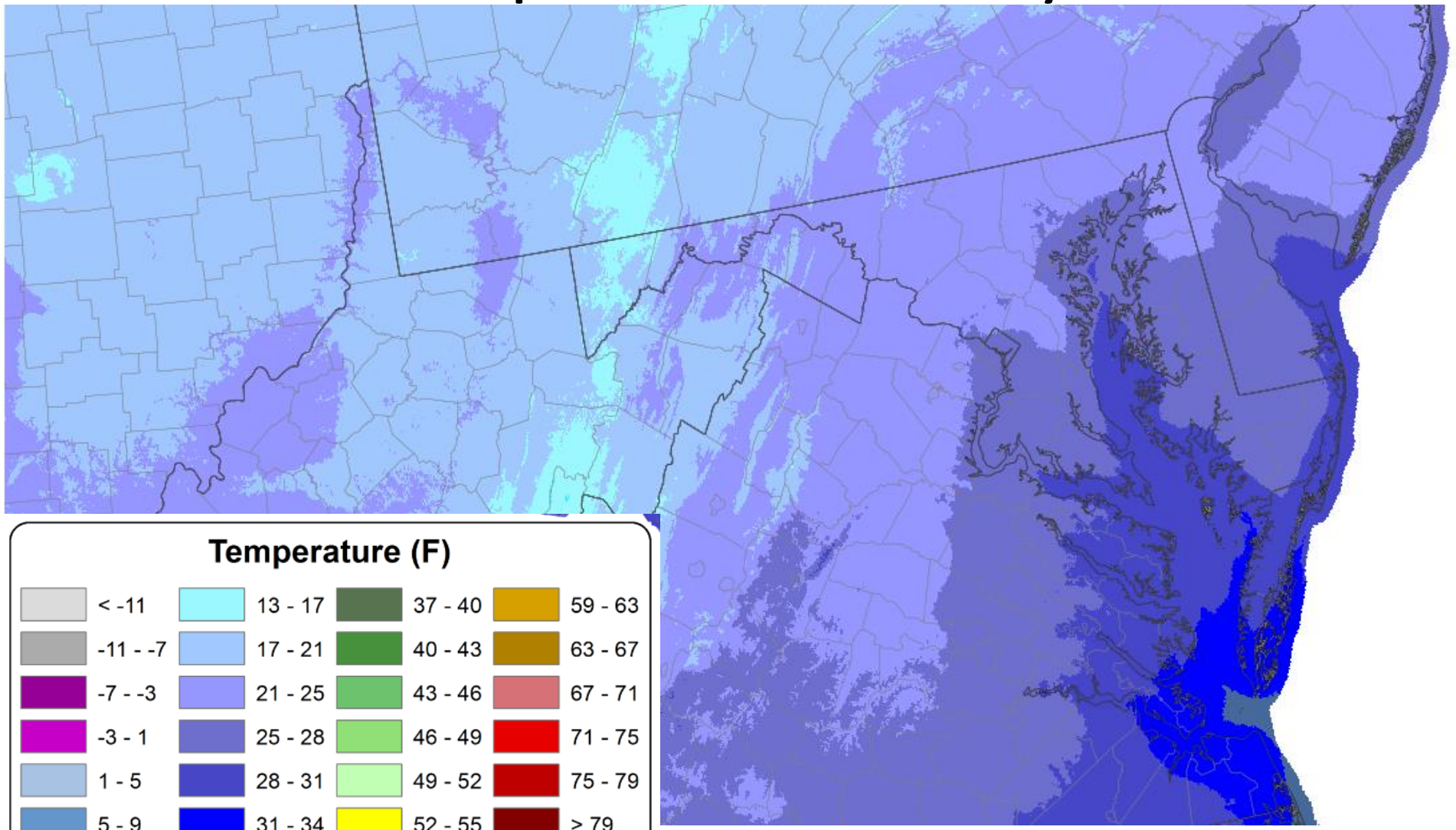
30 yr Normal Min Temperature: January

Period: 1981-2010



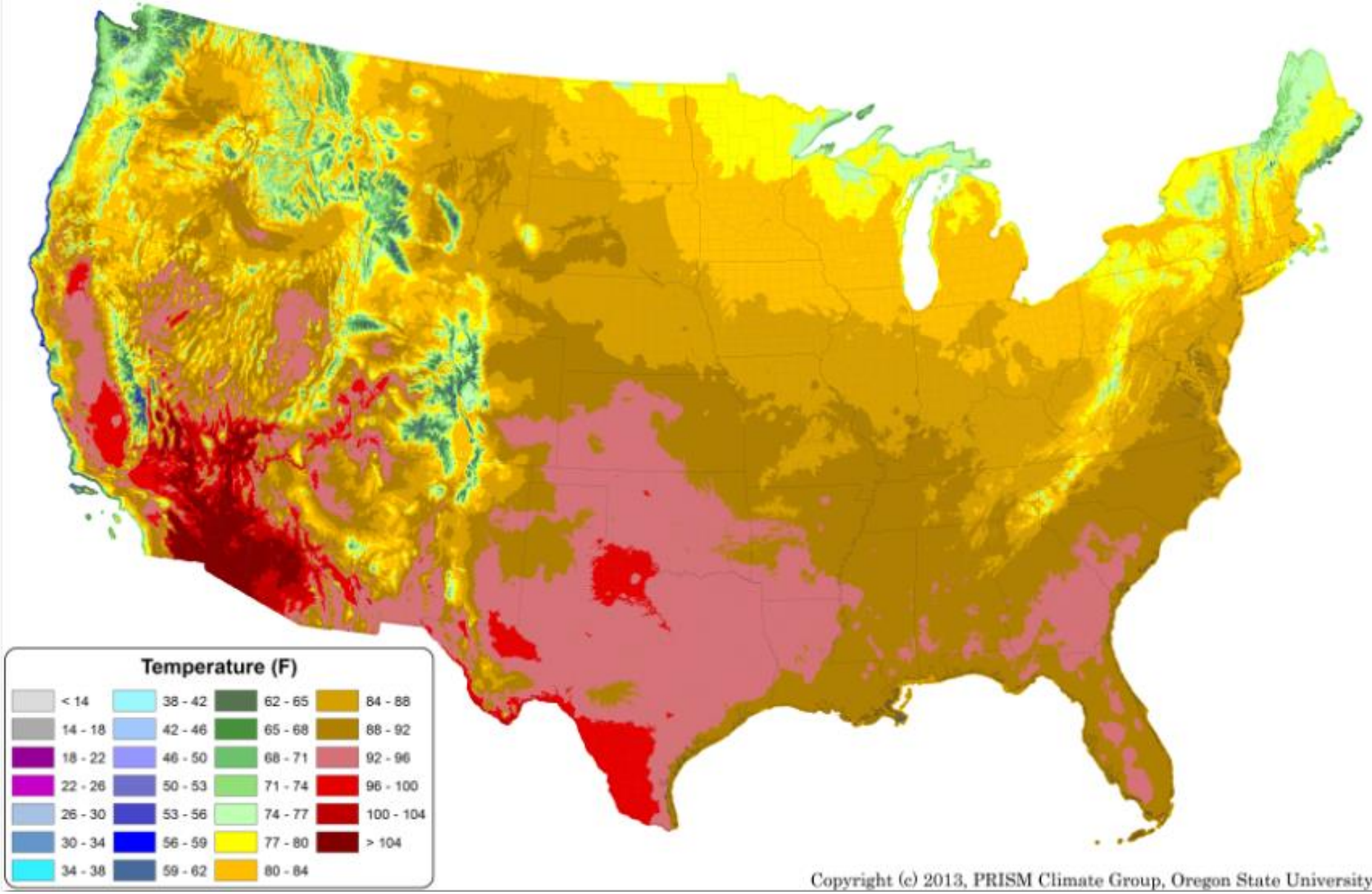

Maryland Average Annual Snowfall Map
< 10 in
10-12.5 in
12.5-15 in
15-17.5 in
17.5-20 in
20-22.5 in
22.5-25 in
25-30 in
30-35 in
35-40 in
40-60 in
60-80 in
>80 in

30 year Normal Maryland Minimum Temperature January

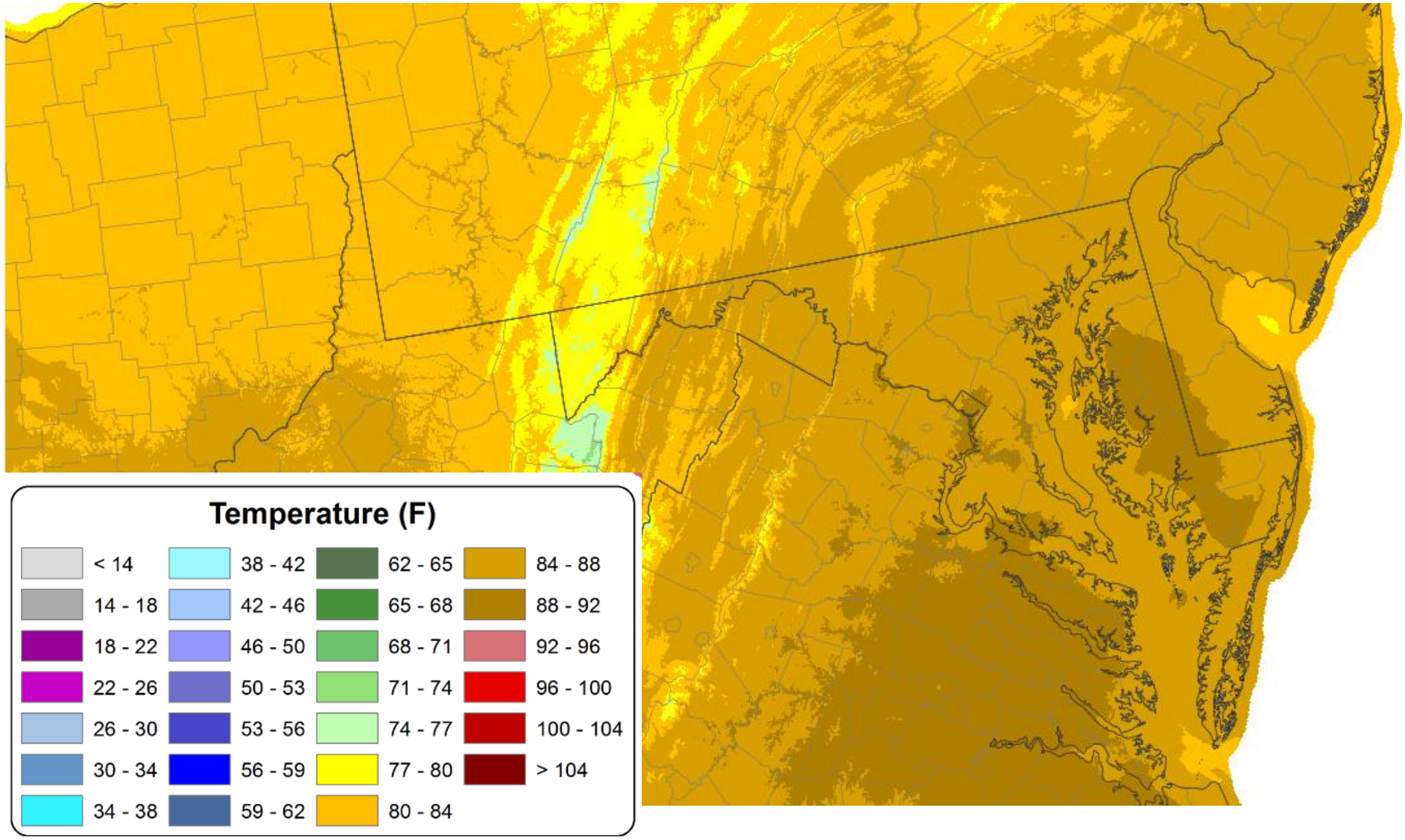


30 yr Normal Max Temperature: July

Period: 1981-2010

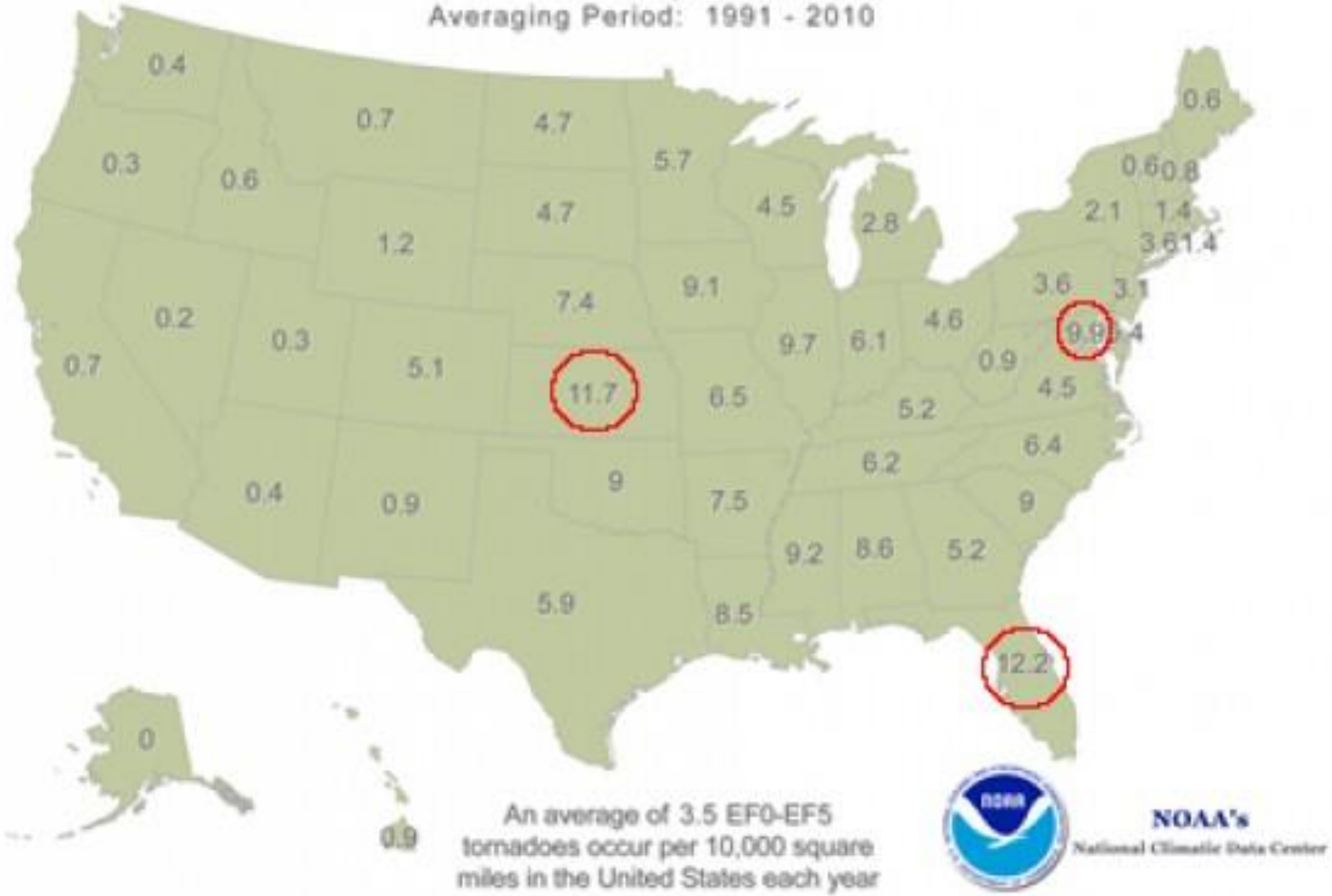


30 year Normal Maryland Maximum Temperature July



Average Annual Number of EF0-EF5 Tornadoes

Per 10,000 Square Miles
Averaging Period: 1991 - 2010

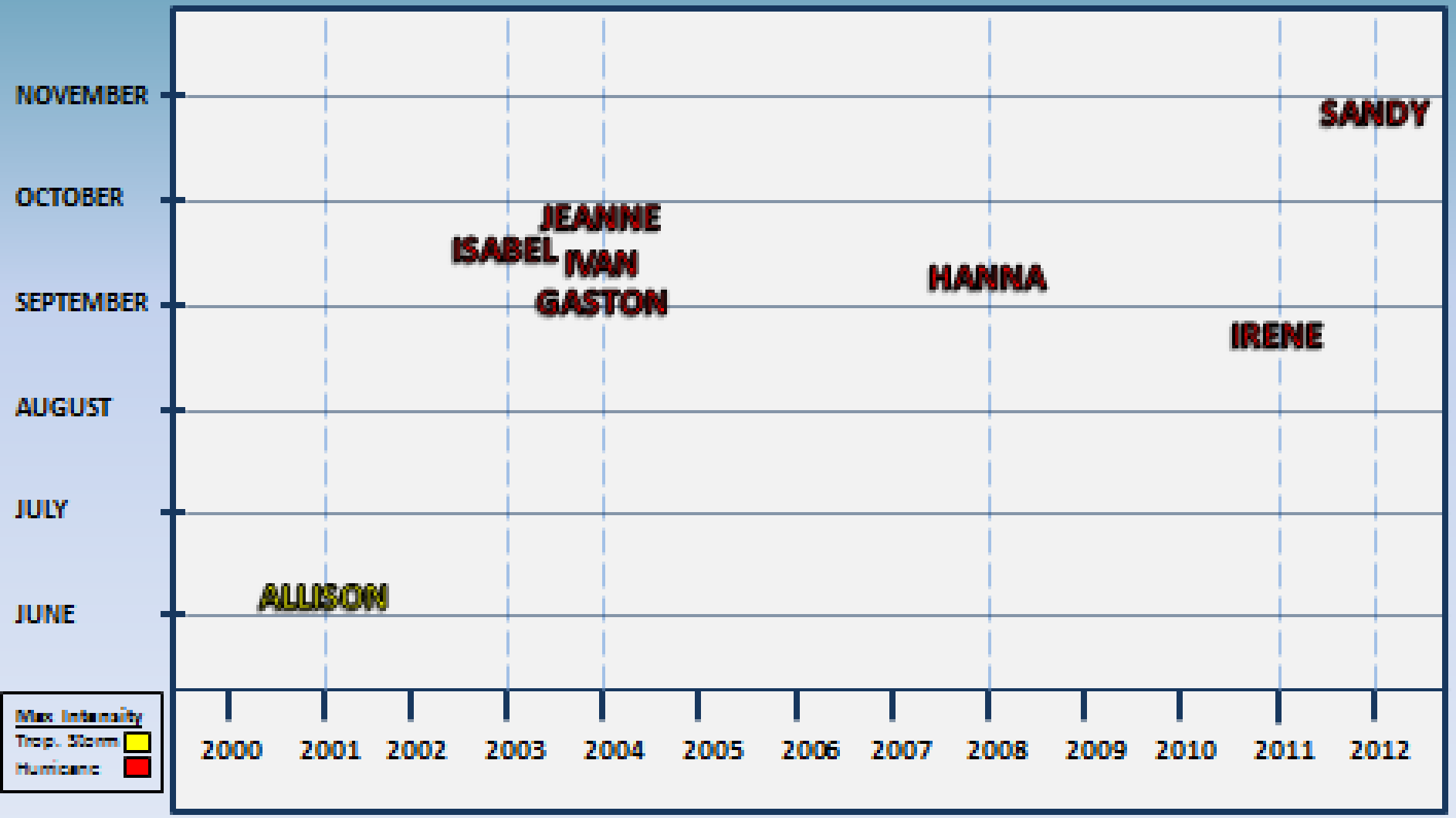


An average of 3.5 EF0-EF5 tornadoes occur per 10,000 square miles in the United States each year

NOAA's National Climatic Data Center

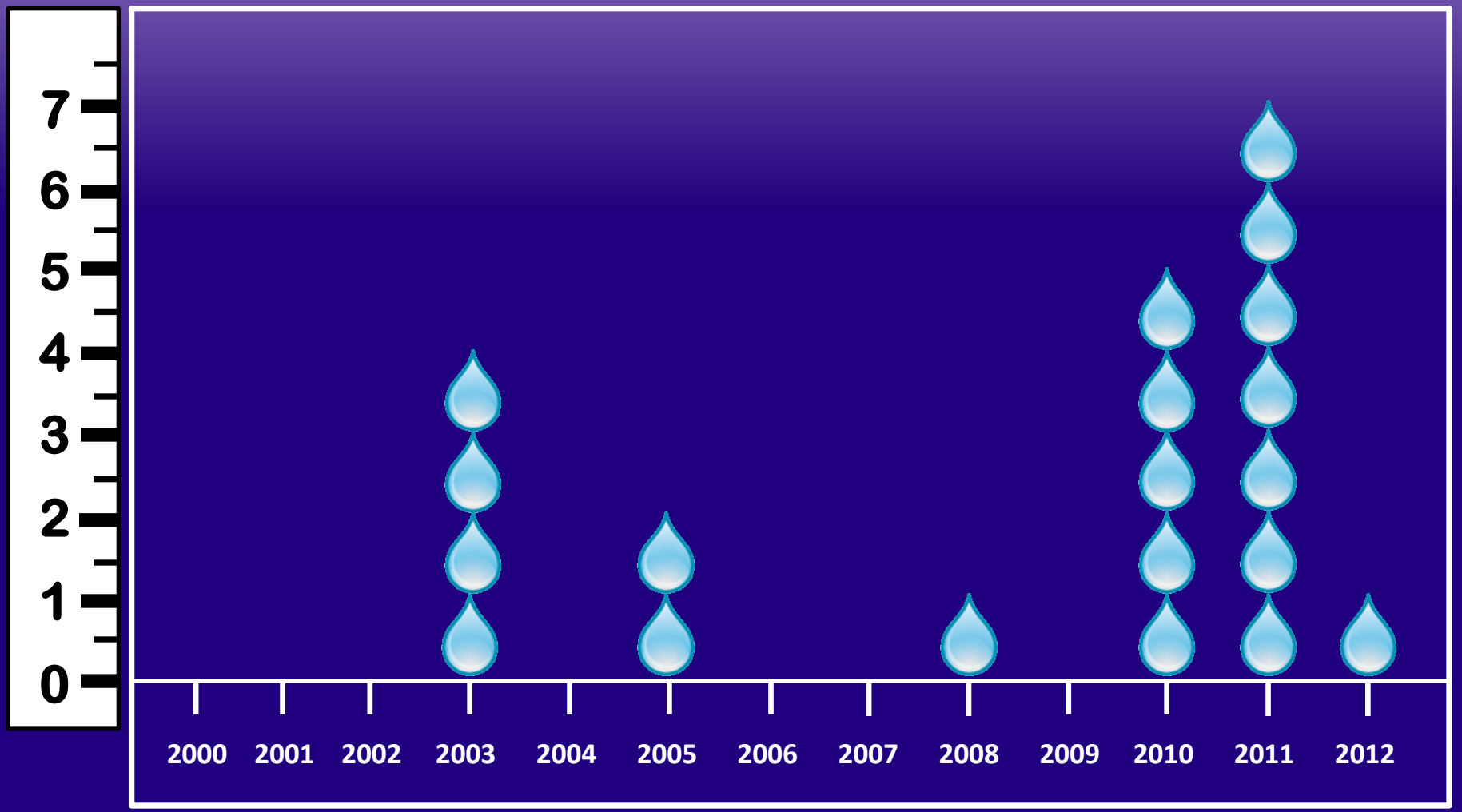
Maryland Tropical Cyclones 2000-2012

From National Hurricane Center Annual Reviews and Best Track Data



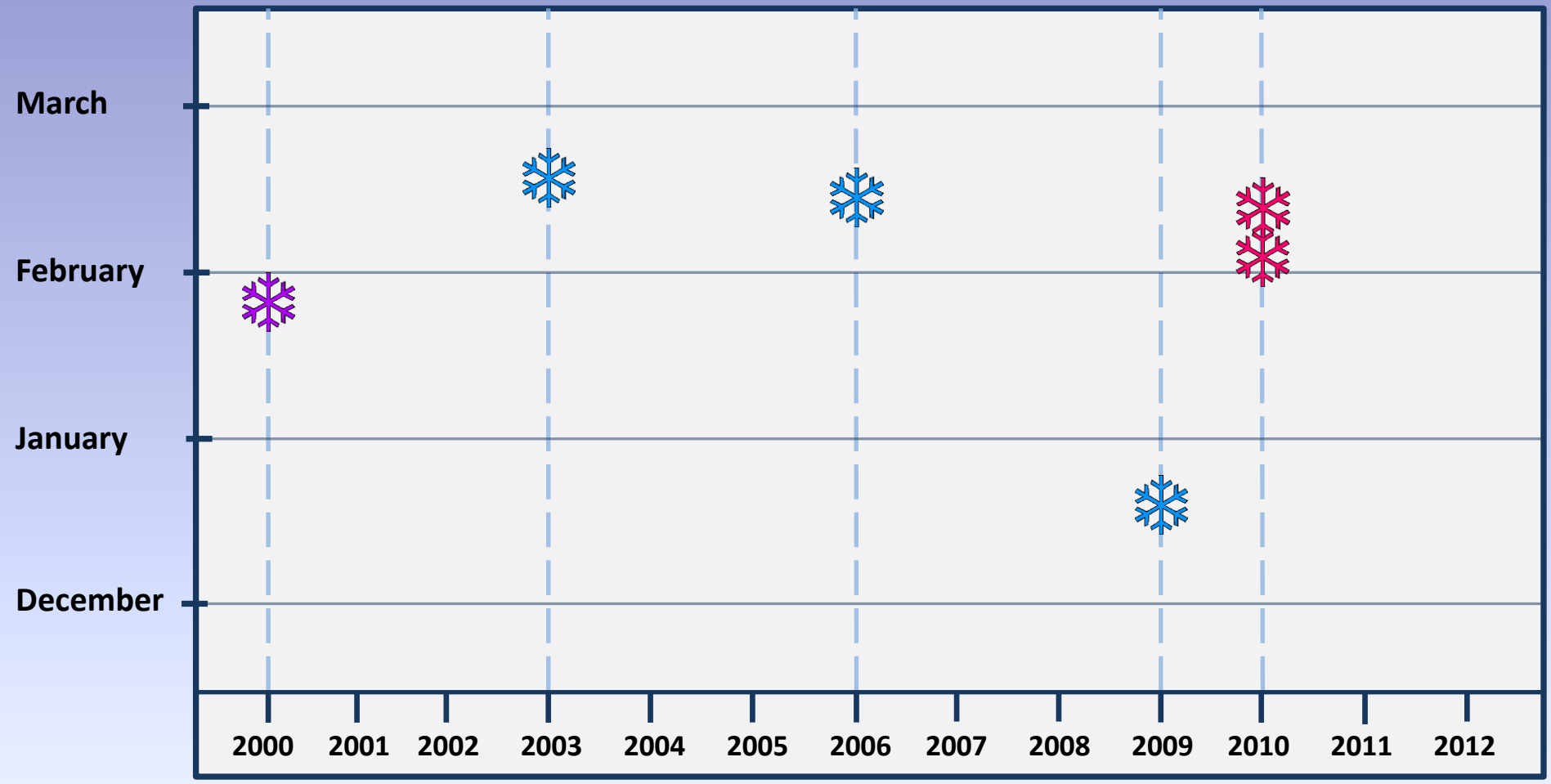
Maryland Floods 2000-2012

Days above flood stage from USGS river gauge data on the Potomac River



Maryland Nor' Easters 2000-2012

From NOAA NESIS/RSI and NWS Baltimore/Washington storm reports

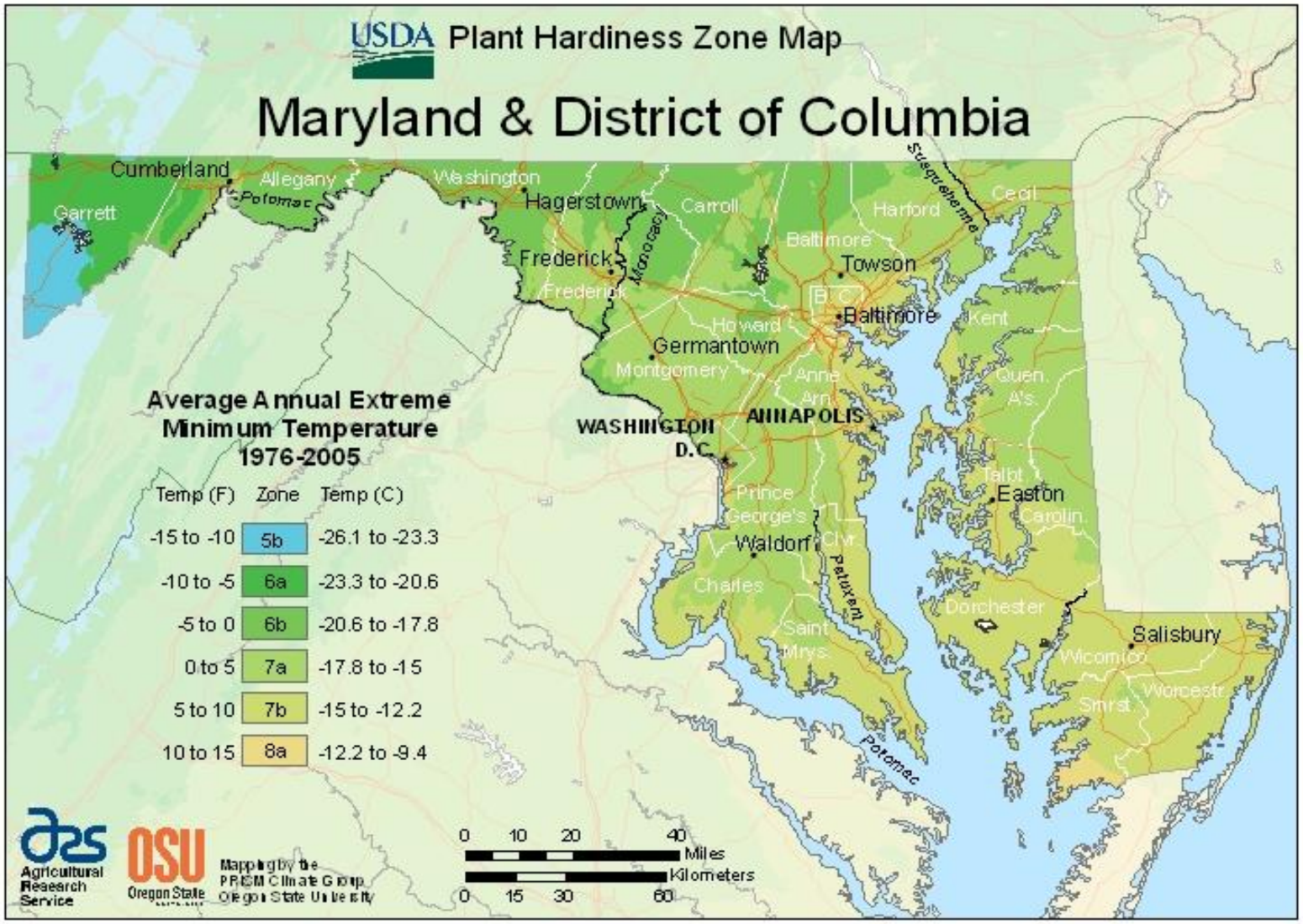


1. Coastal storm with heavy Snow > 10" over majority of MD

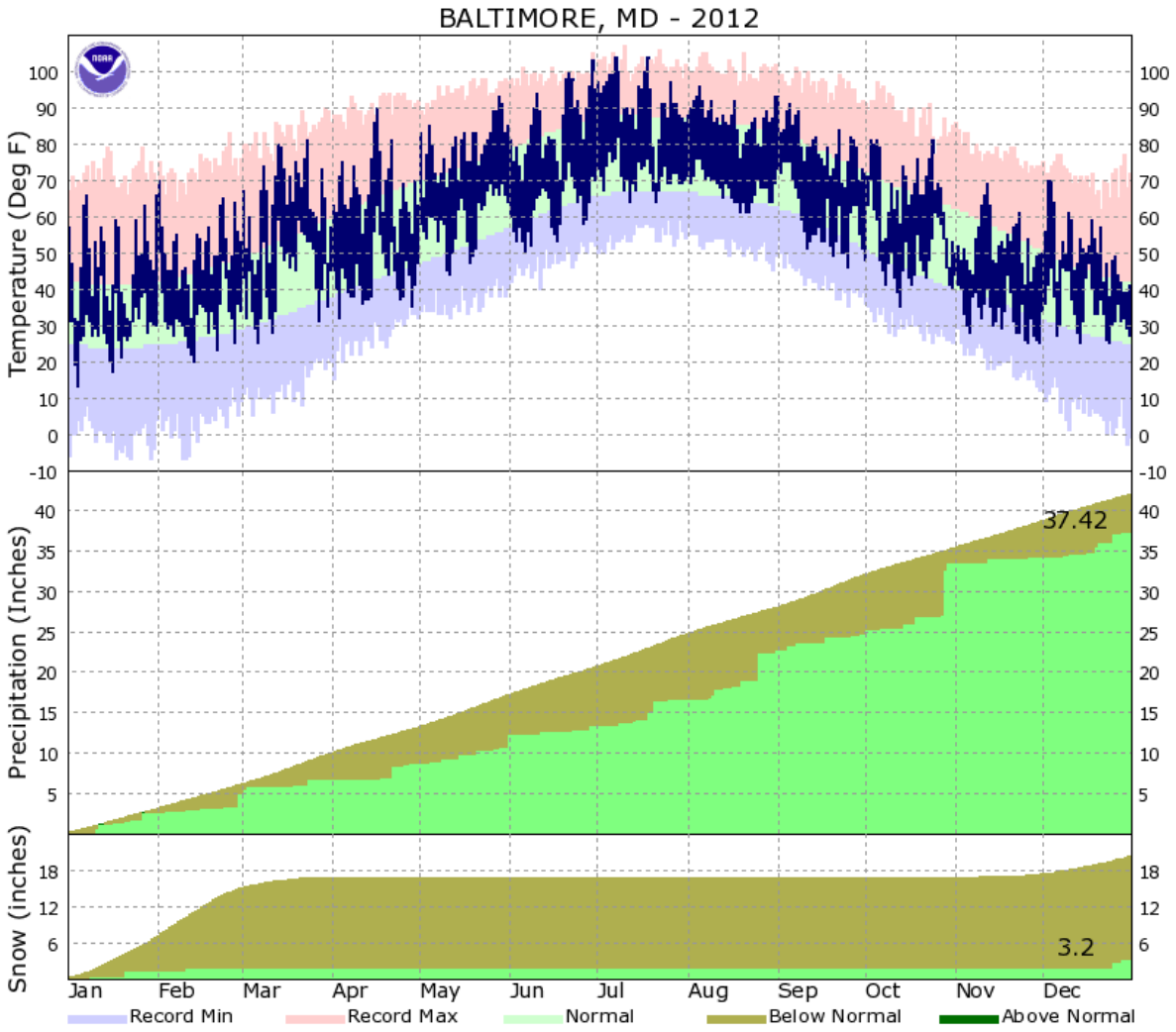
2. (1) + widespread strong winds near blizzard conditions

3. (2) + NWS blizzard conditions reported in low terrain

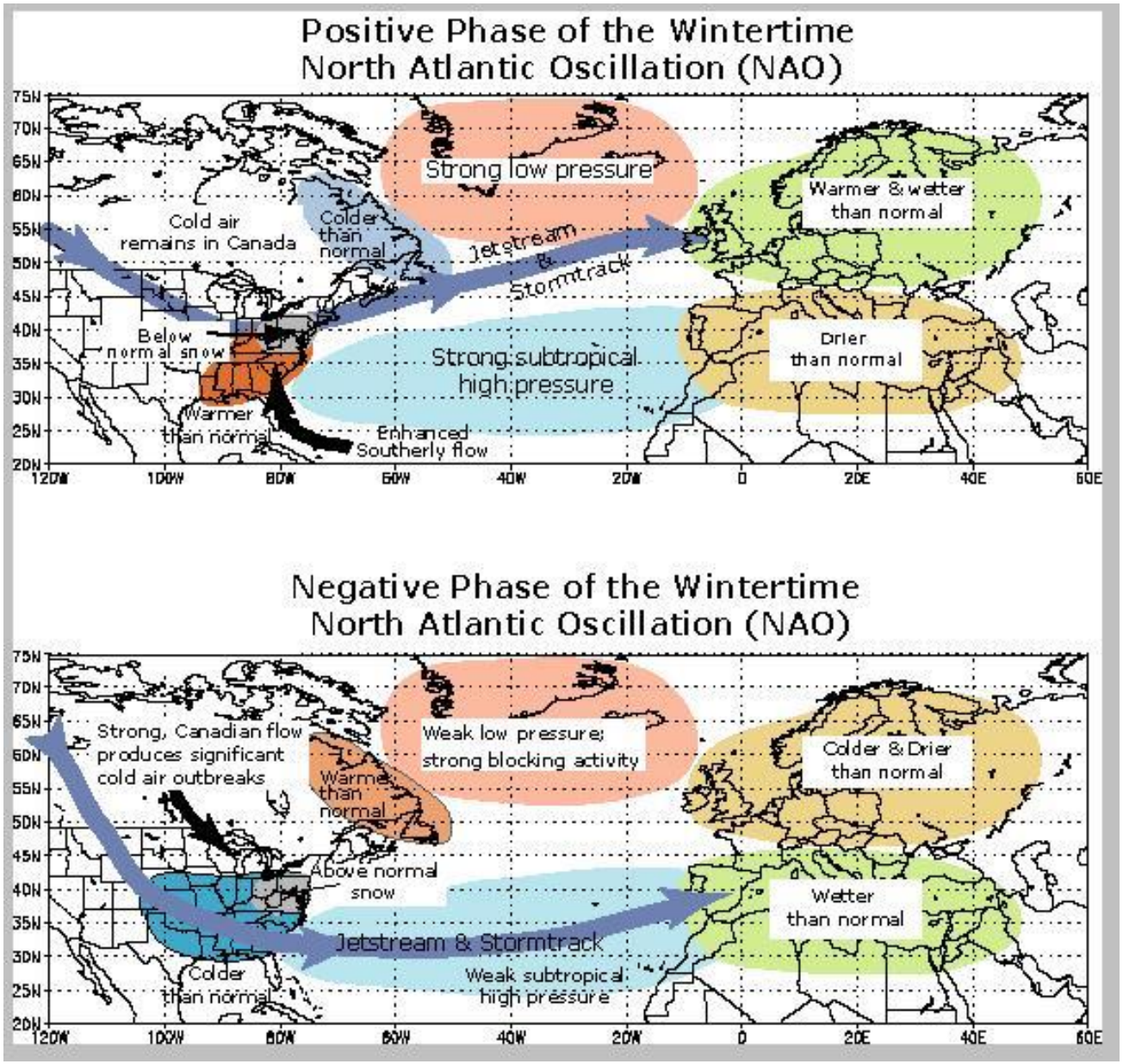
Maryland Climate Zones



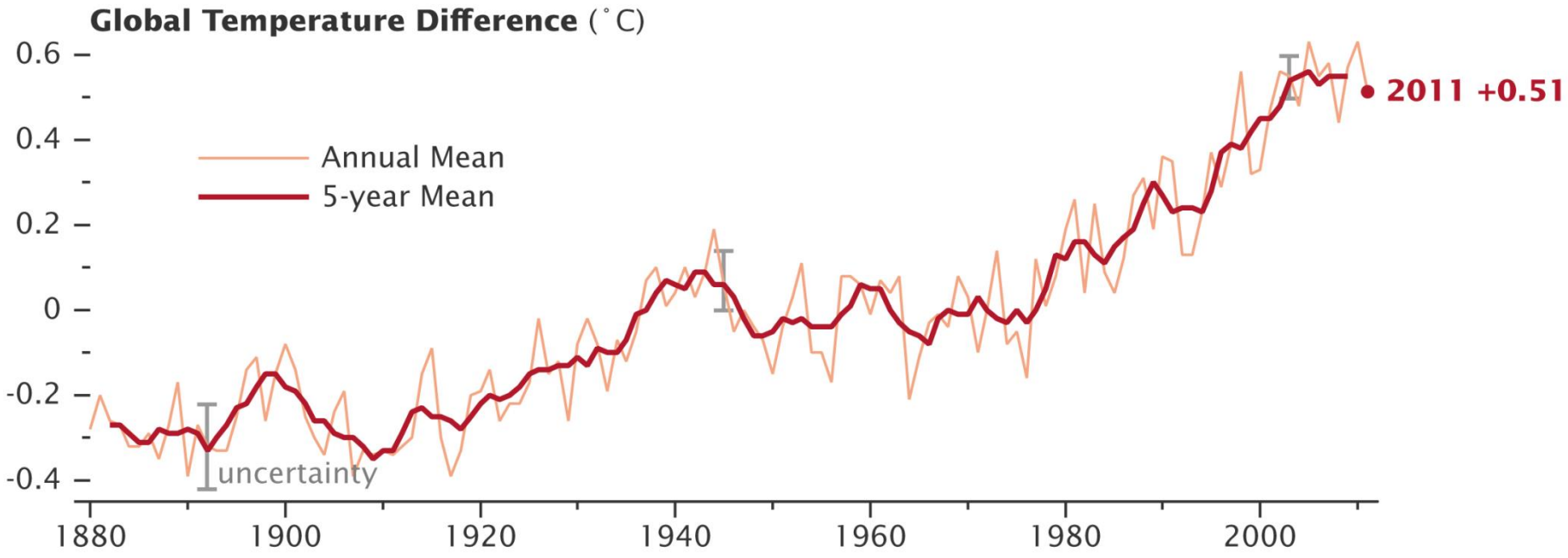
Climate Versus Weather



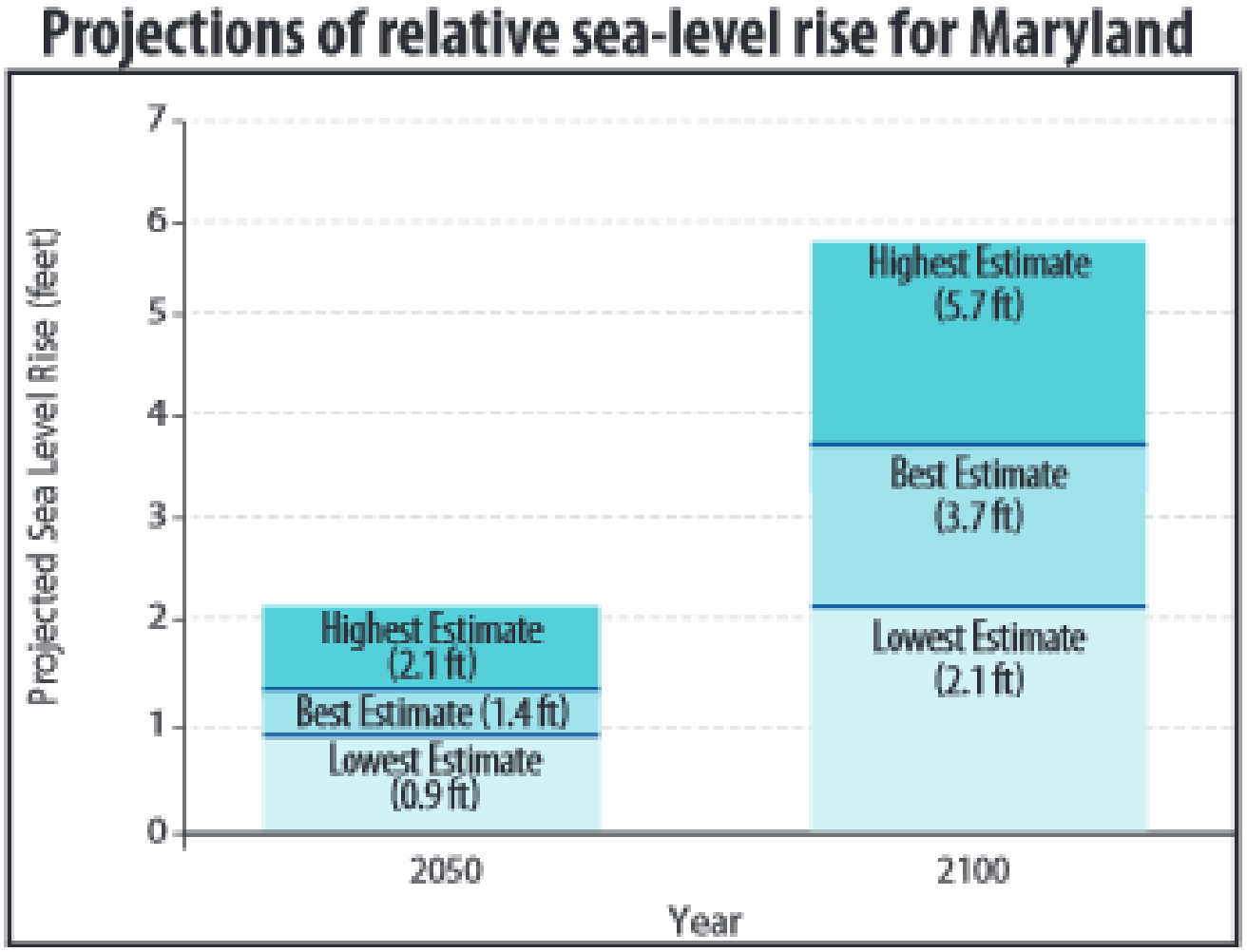
North Atlantic Oscillation



Climate change

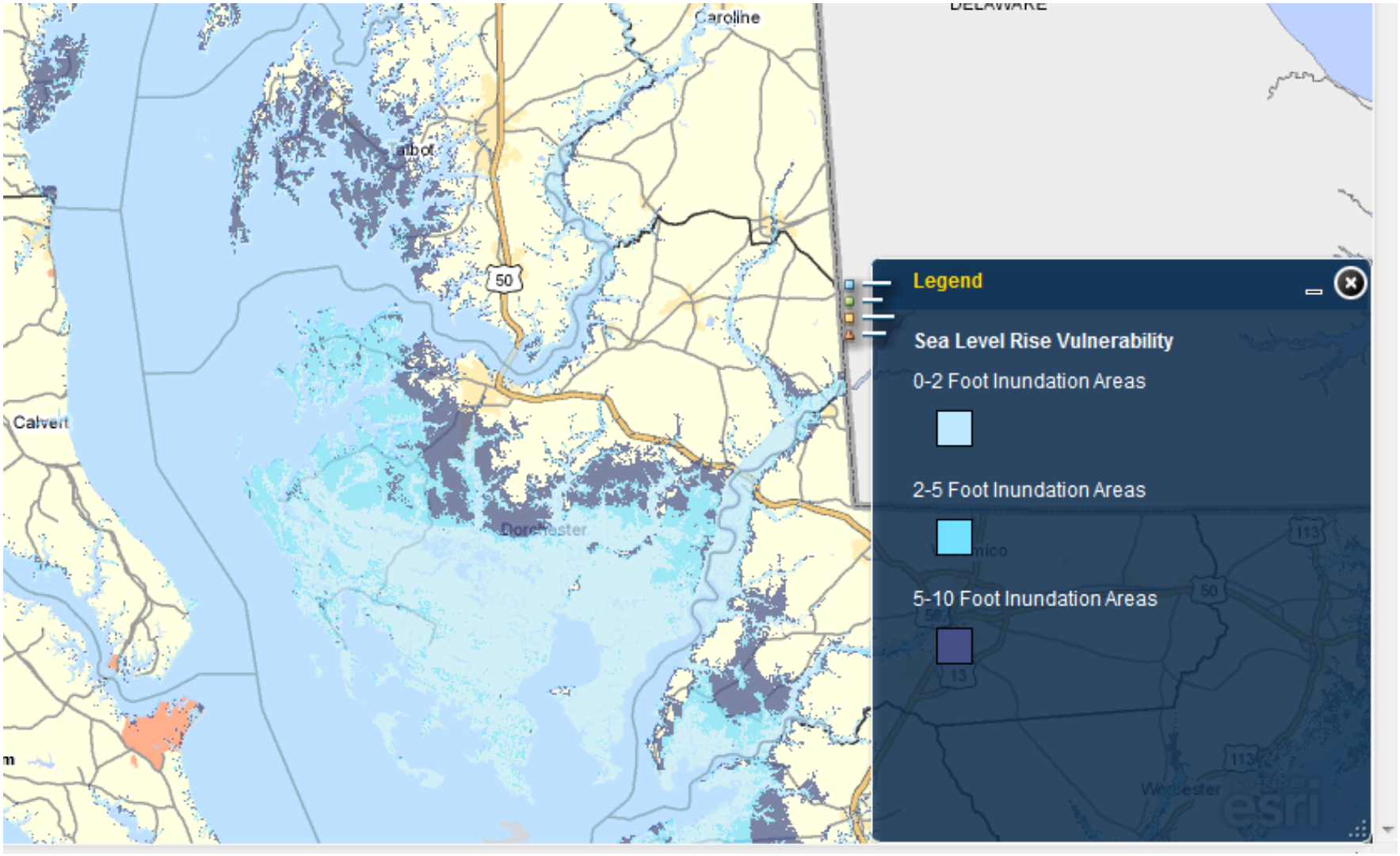


Climate change



Source: Boesch et al., 2013

Vulnerable areas



Is That True?

- Red Sky at night sailors delight, red sky in morning sailor take warning
- Mackerel in the sky three days dry

Questions

- Why is the sky blue at noon?
- Why is the sky red at sunset?
- What about the Nor'East enhances Nor'Easters?
- What is the most significant climate change impact to the Coastal Plain of Maryland?