Atmosphere

Lecture 2

ME EN 415
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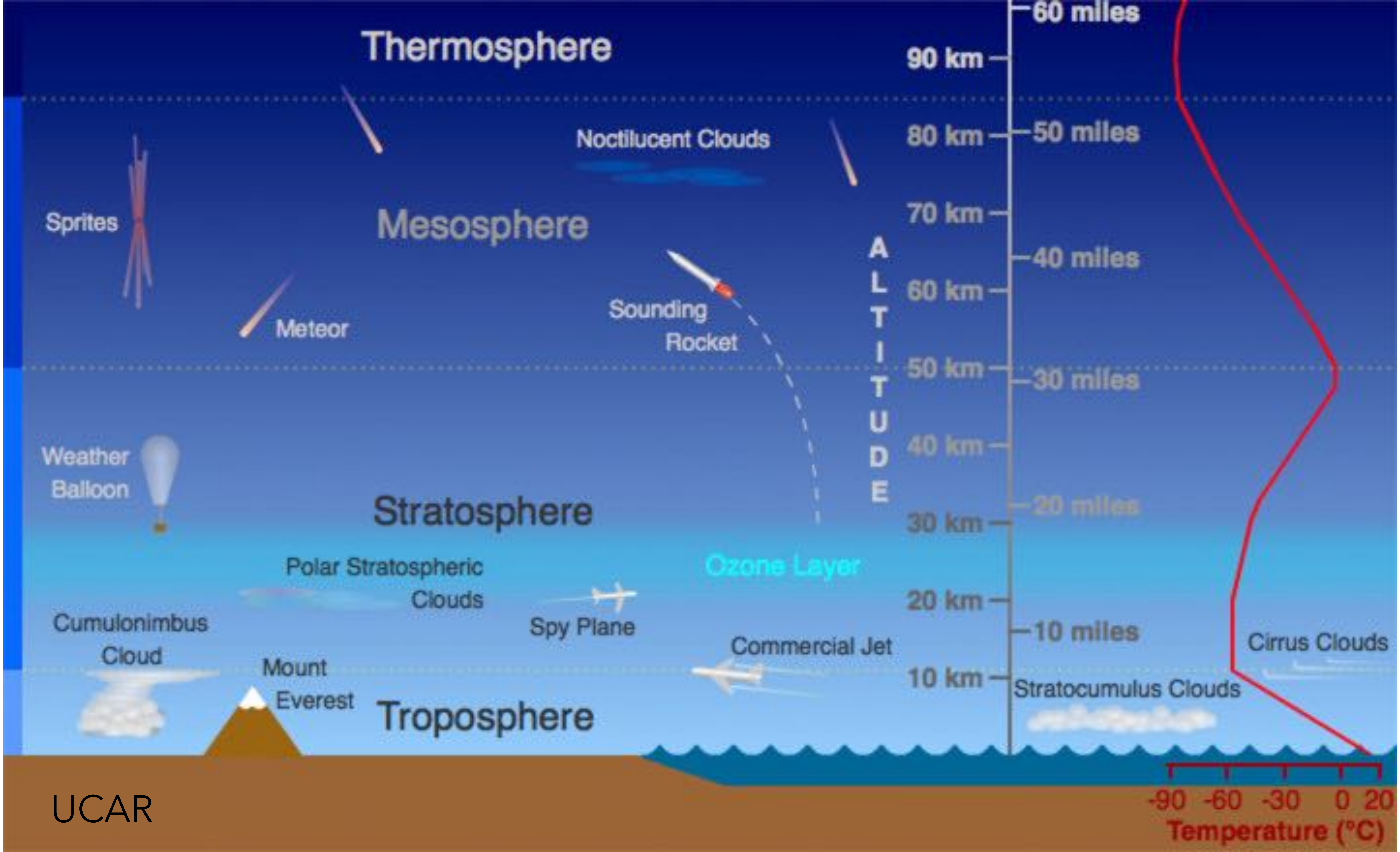


Thermosphere
Mesosphere
Stratosphere
Troposphere
Noctilucent Clouds
Sprites
Meteor
Sounding Rocket
Weather Balloon
Polar Stratospheric Clouds
Ozone Layer
Spy Plane
Cumulonimbus Cloud
Mount Everest
Commercial Jet
Cirrus Clouds
Stratocumulus Clouds
ALTITUDE
90 km
80 km
70 km
60 km
50 km
40 km
30 km
20 km
10 km
60 miles
50 miles
40 miles
30 miles
20 miles
10 miles
-90 -60 -30 0 20
Temperature (°C)

UCAR

Altitude

Geometric Altitude: geometric distance from sea level

Absolute Altitude: geometric height from center of Earth

Pressure Altitude: corresponding alt. in standard atm. w/ same pressure.

Geopotential Altitude: an equivalent altitude using a constant g

Altimeters

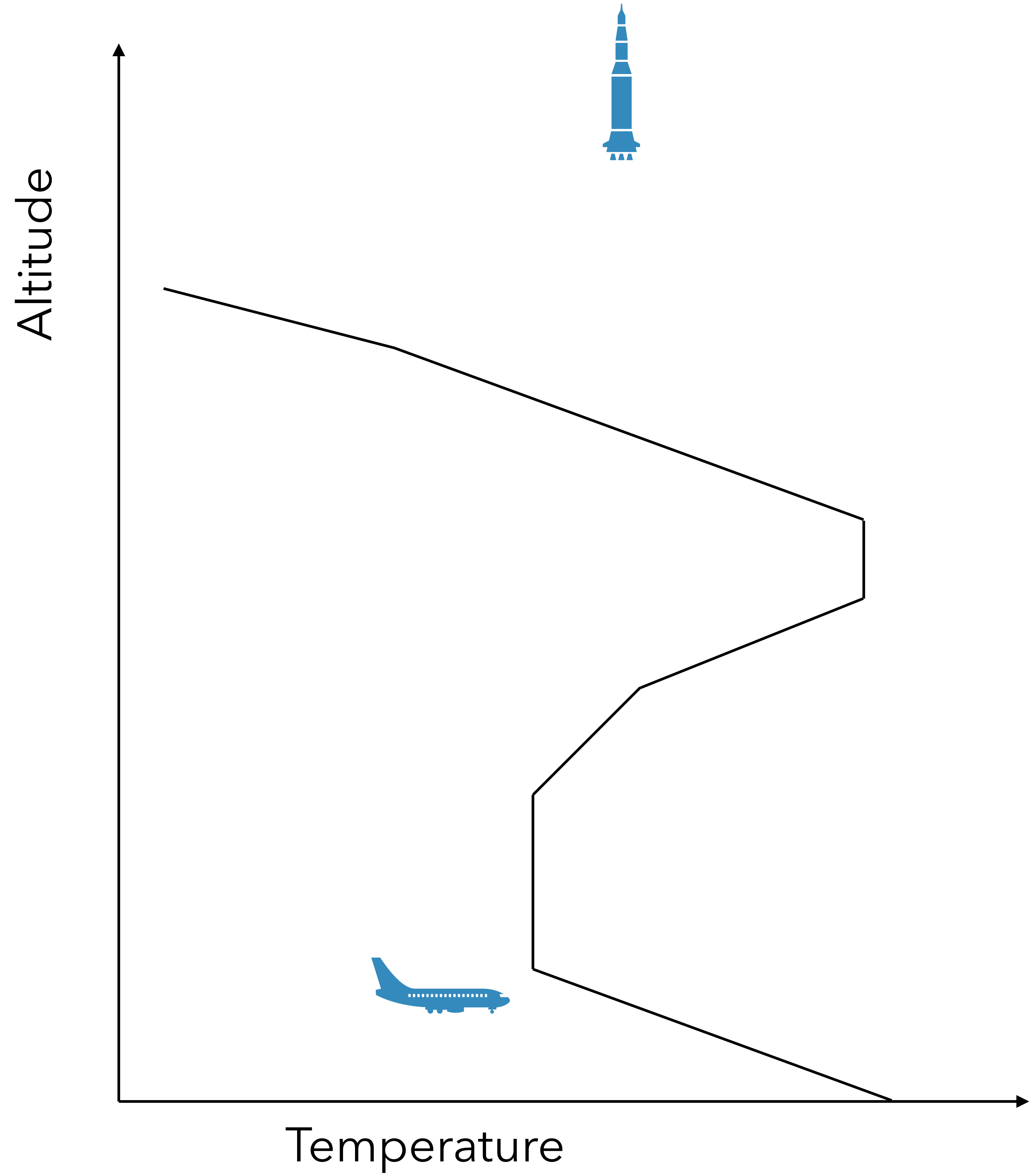
Pressure (barometric) altimeter.

Radar altimeter

GPS

International Standard Atmosphere

Geopotential Altitude (km)	Temperature Gradient (K/km)
0	-6.5
11	0.0
20	+1.0
32	+2.8
47	0.0
51	-2.8
71	-2.0
84.8520	

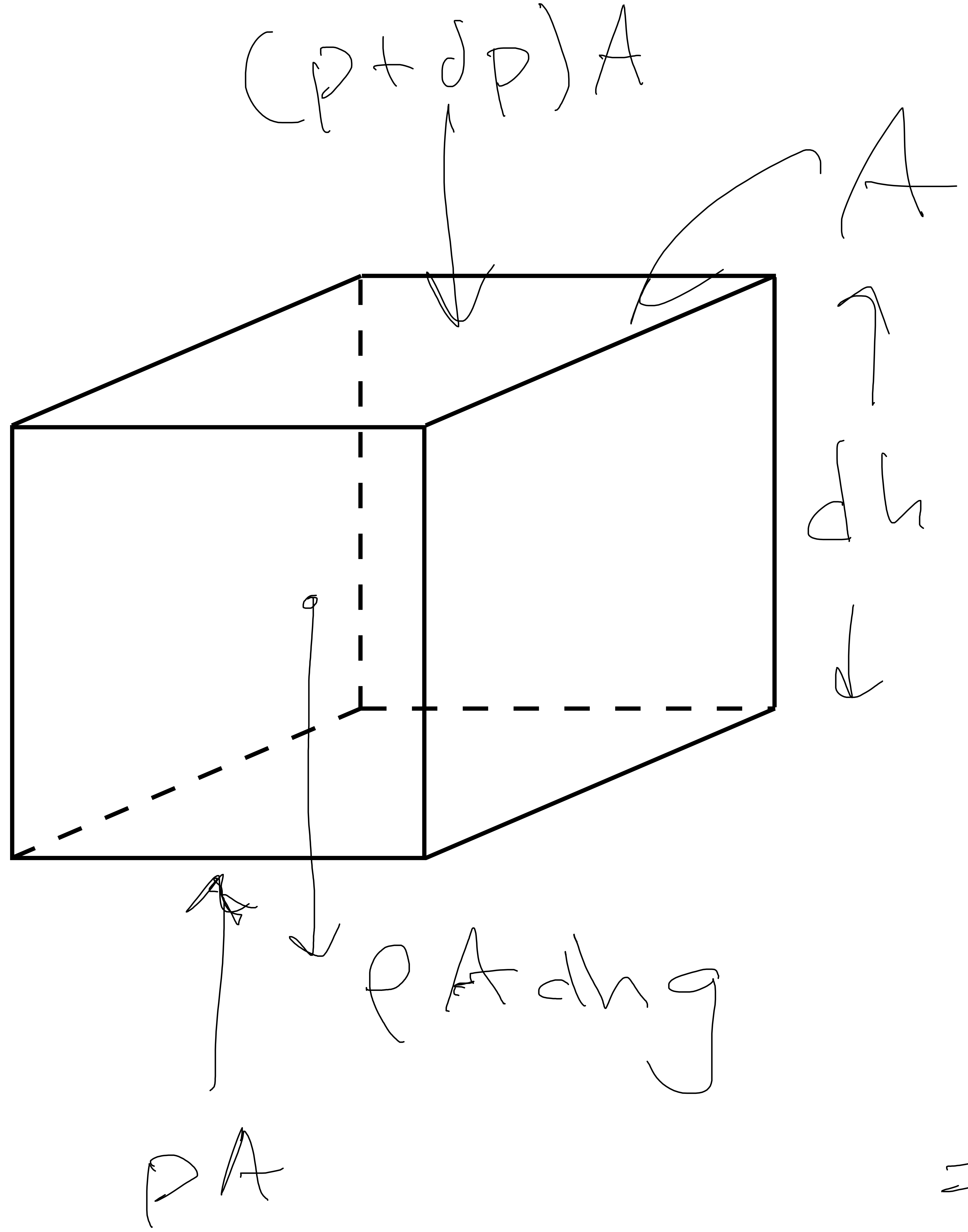


Sea Level Properties

$$R = 287.053 \ \frac{J}{kg \cdot K}$$

T_{SL}	288.15 K
P_{SL}	$1.01325 \times 10^5 \text{ Pa}$
μ_{SL}	$1.79 \times 10^{-5} \text{ kg/m-s}$
g	9.80665 m/s^2

Hydrostatics



$$\cancel{p}\cancel{A} = \rho \cancel{A}\, dh\, g + (\cancel{p}+dp)\cancel{A}$$

$$\Rightarrow dp = -\rho g\, dh$$

$$P = \rho R T$$

$$\Rightarrow dP = -\frac{P}{RT} g\, dh$$

$$\Rightarrow \frac{dP}{P} = \frac{-g}{RT} dh$$

Isothermal Layers

$$\int_{P_1}^{P} \frac{dP}{P} = \frac{-g}{RT} \int_{h_1}^{h} dh$$

$$\ln P \Big|_{P_1}^{P} = \frac{-g}{RT}(h - h_1)$$

$$\ln\left(\frac{P}{P_1}\right) = \quad ''$$

$$\boxed{\frac{P}{P_1} = e^{\frac{-g}{RT}(h-h_1)}}$$

Gradient Layers

$$\frac{dP}{P} = \frac{-g}{RT}\,dh$$

$$a = \frac{T - T_1}{h - h_1}$$

$$\Rightarrow T = T_1 + a(h - h_1)$$

$$dT = a\,dh$$

$$\int \frac{dP}{P} = \frac{-g}{Ra}\int \frac{dT}{T}$$

$$\ln P\Big|_{P_1}^{P} = \frac{-g}{Ra}\ln T\Big|_{T_1}^{T}$$

$$\ln\left(\frac{P}{P_1}\right) = \frac{-g}{Ra}\ln\left(\frac{T}{T_1}\right)$$

$$\Rightarrow \boxed{\frac{P}{P_1} = \left(\frac{T}{T_1}\right)^{\frac{-g}{Ra}}}$$

Curve Fit

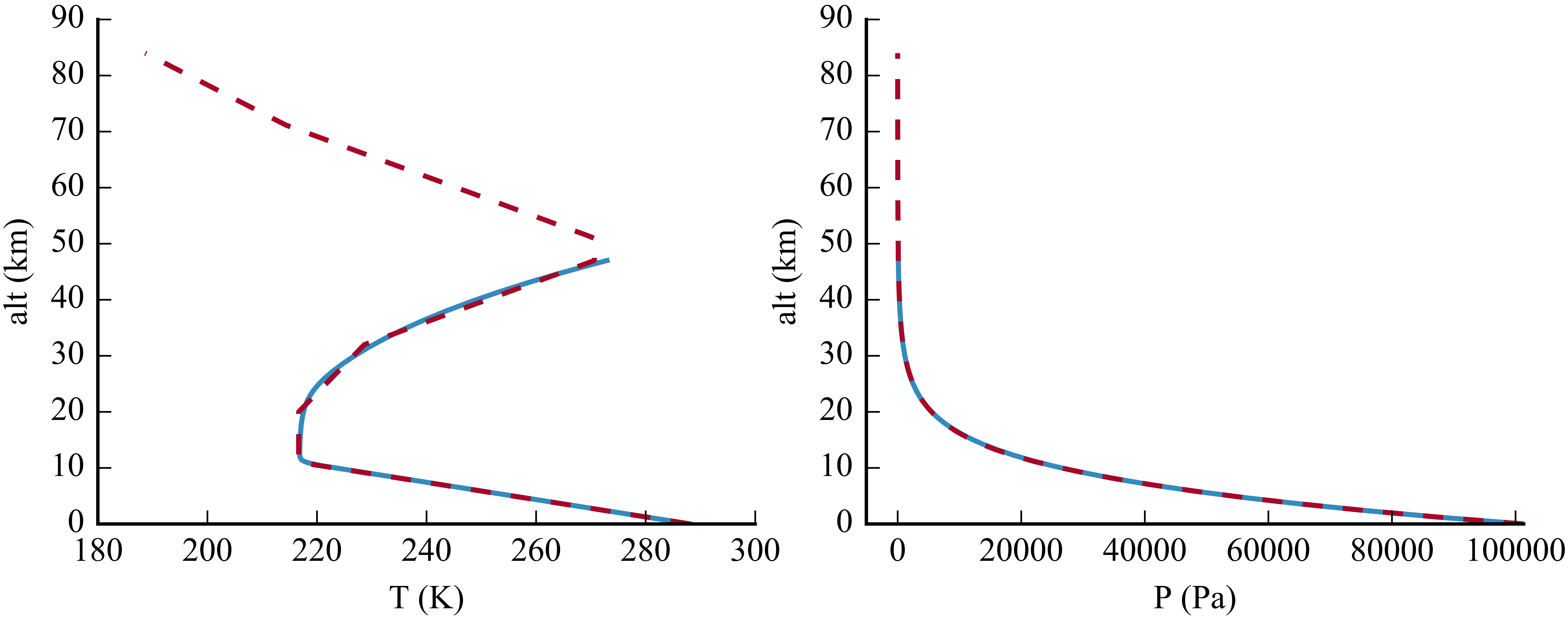
$$T(h) = T_{SL} - 71.5 + 2.0 \ln \left[1 + \exp(35.75 - 3.25h) + \exp(-3.0 + 0.0003h^3)\right]$$

$$P(h) = P_{SL} \exp \left(-0.118h - \frac{0.0015h^2}{1 - 0.018h + 0.0011h^2}\right)$$

(h in km, T in K)

applicable for altitudes below 47 km

modified slightly from: Mark Drela, Flight Vehicle Aerodynamics


90
80
70
60
50
40
30
20
10
0
alt (km)
180
200
220
240
260
280
300
T (K)
90
80
70
60
50
40
30
20
10
0
alt (km)
0
20000
40000
60000
80000
100000
P (Pa)

Upper Atmosphere

NRLMSISE-00 (up to 1000 km)

Upper Atmosphere

NRLMSISE-00 (up to 1000 km)

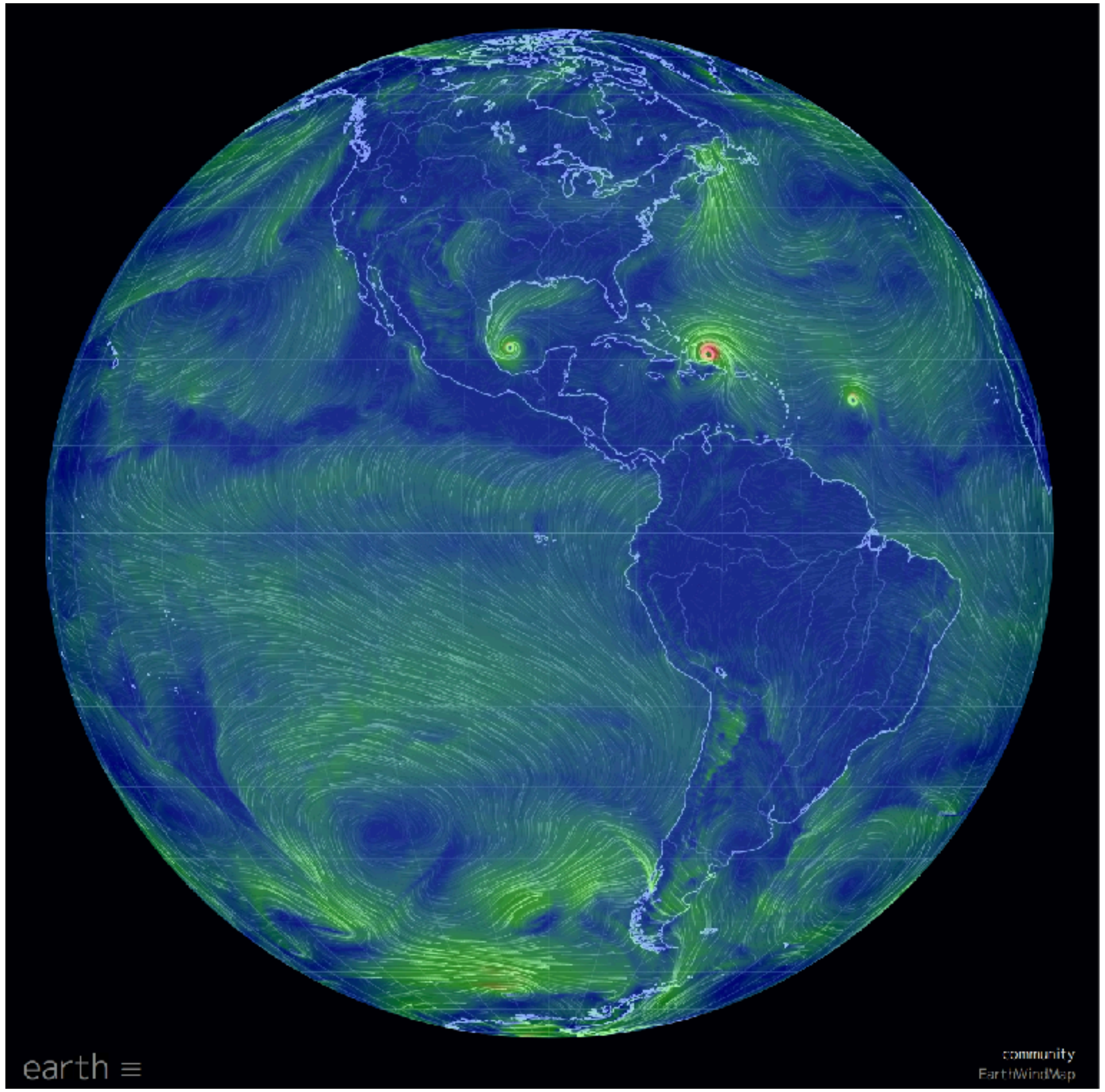
or for a simple approximation during atmospheric entry:

$$\frac{P}{P_{SL}} = \exp^{-\frac{gh}{RT_m}}$$ (reasonable up to 140 km)

Create Your Own

$$P, T, \rho = \mathrm{atmosphere}(h)$$

More Comprehensive Databases



ERA Interim dataset

https://earth.nullschool.net