AOS 630: Introduction to Atmospheric and Oceanic Physics

Lecture 6   Fall 2021

The First Law of Thermodynamics 2

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Announcements

Please make sure to upload your first Skew-T a week to Canvas.

HW1 is due this Thursday! HW2 will be uploaded that same day.

Last class: Thermodynamic energy

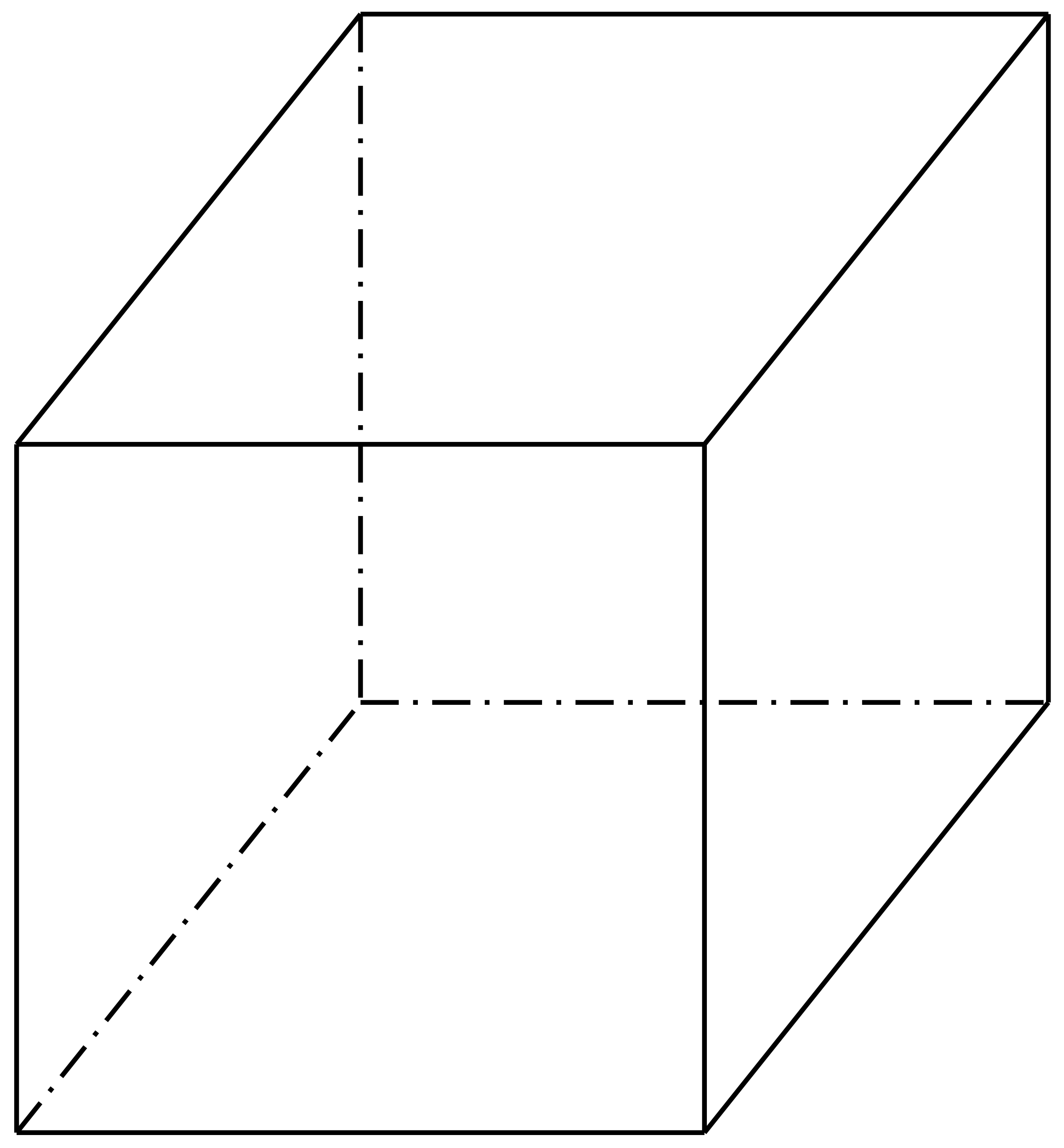
Substituting *de* with $c_v dT$ we get the following

$$c_v dT = \delta q - p d\alpha$$

Where the variables are defined as

$$de = dE/M$$

$$\delta q = \delta Q/M$$



The first law of thermodynamics

Describes the notion of *conservation of energy*.

Also describes the time rate of change of the thermodynamic state

In time-derivative form, we can write as:

$$c_v \frac{dT}{dt} = \dot{Q} - p\frac{d\alpha}{dt}$$

Change in Internal energy

Diabatic heating

Work done by system

$$\dot{Q} \equiv \frac{\delta q}{\delta t}$$

Alternate form for ideal gases

We can use the ideal gas law to write the first law as

$$c_p \frac{dT}{dt} = \dot{Q} + \alpha \frac{dp}{dt}$$

$c_p = c_v + R_d$ Is the specific heat at constant pressure.

We are ignoring the virtual temperature effect.

Today

Continue our discussion of the first law

Types of thermodynamic processes

Isobaric: pressure does not change

Isothermal: temperature does not change

Isochoric: volume does not change

Adiabatic: no heat exchange

Adiabatic processes

When there is no diabatic heating (q=0), the system is *adiabatic*

$$c_p \frac{dT}{dt} = \alpha \frac{dp}{dt} \qquad c_v \frac{dT}{dt} = -p \frac{d\alpha}{dt}$$

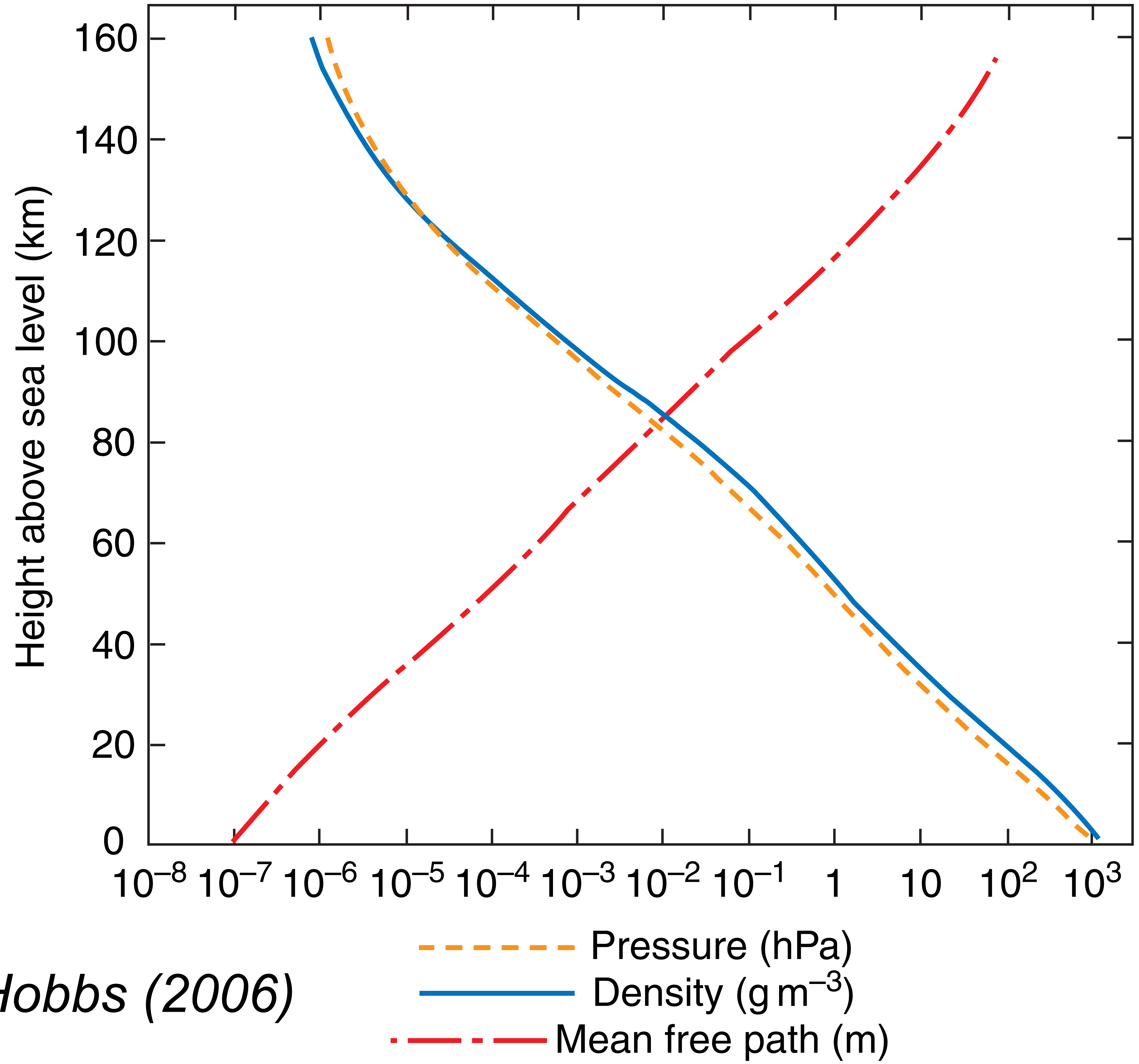
Can use ideal gas law to obtain the following equation

$$c_p \frac{d \ln T}{dt} = R_d \frac{d \ln p}{dt}$$

Adiabatic processes

$$c_p \frac{d \ln T}{dt} = R_d \frac{d \ln p}{dt}$$

For an ideal gas, an increase in pressure increases its temperature. An increase in volume decreases it's temperature



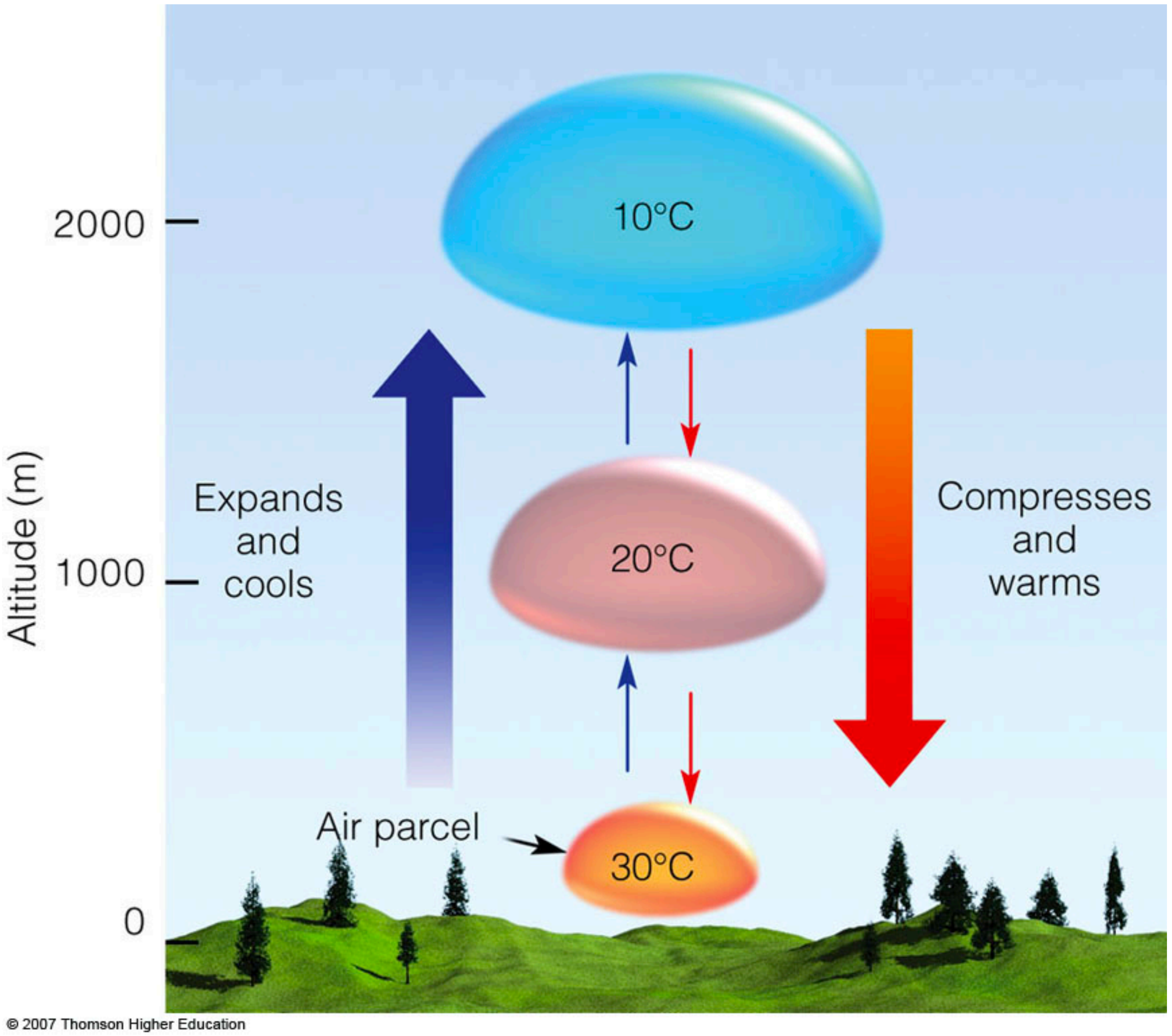
Wallace and Hobbs (2006)

$$c_p \frac{d \ln T}{dt} = R_d \frac{d \ln p}{dt}$$

In the atmosphere, lifting causes parcels to expand and hence cool.

This is because we are moving towards a region of lower pressure, which causes our parcel to expand outward.

The parcel wants to be in the same pressure as its surrounding air.



Adiabatic processes

$$c_p d \ln T = R_d d \ln p$$

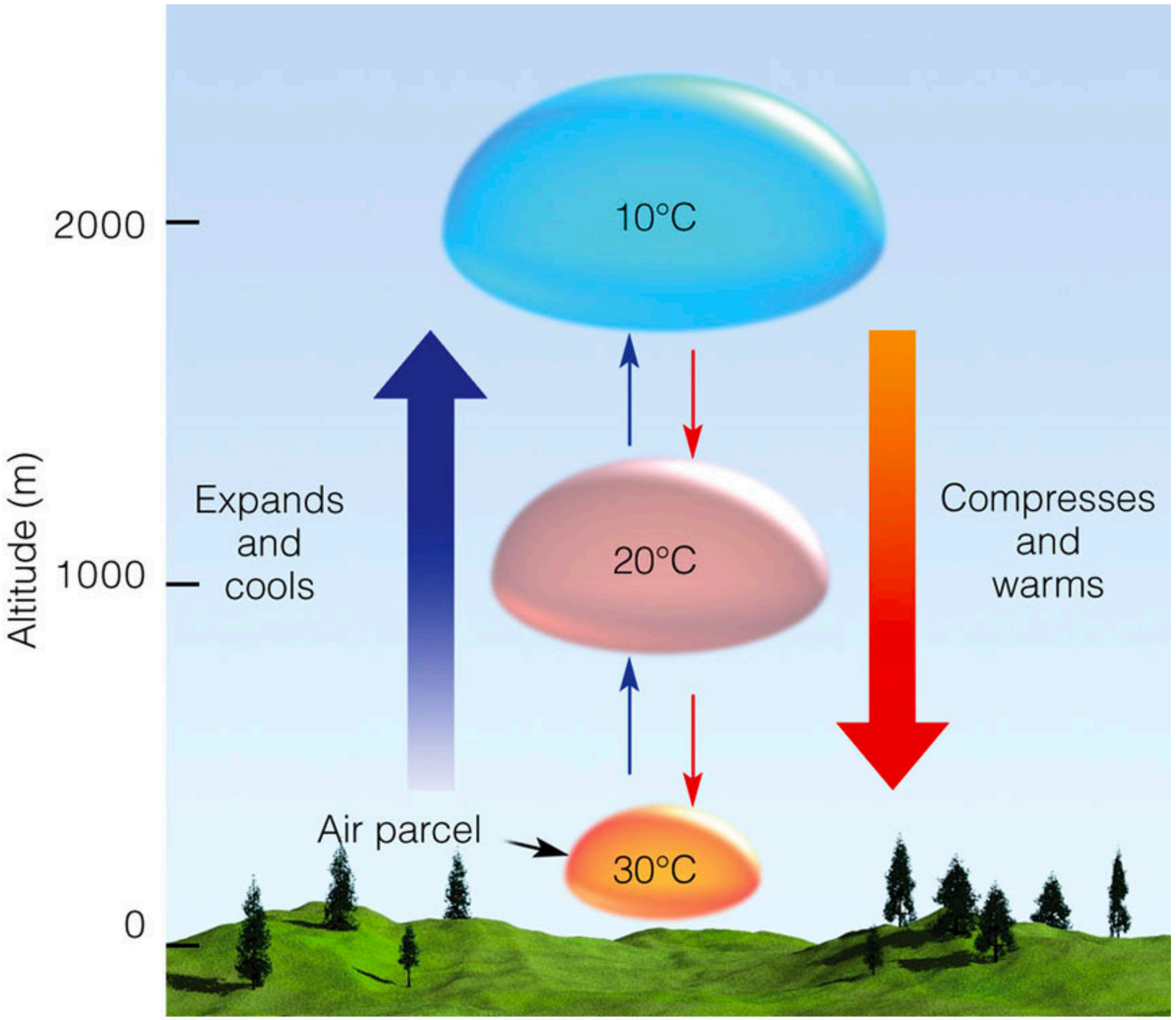
Can solve this equation by integrating

$$T_0 = T \left(\frac{p_0}{p} \right)^{R_d/c_p}$$

When p0 = 1000 hPa

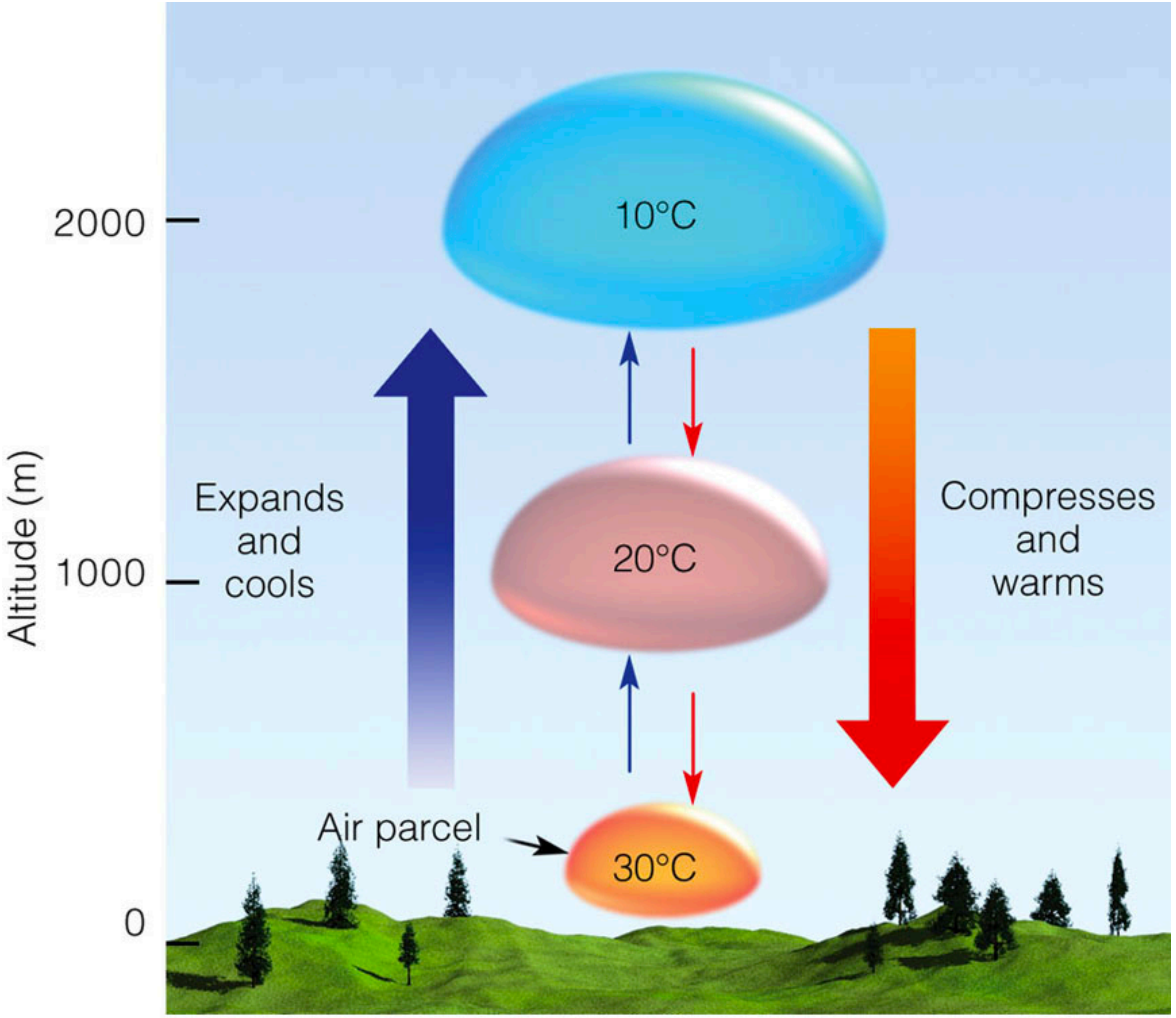
$$T_0 = \theta$$

We refer to as the **potential temperature**

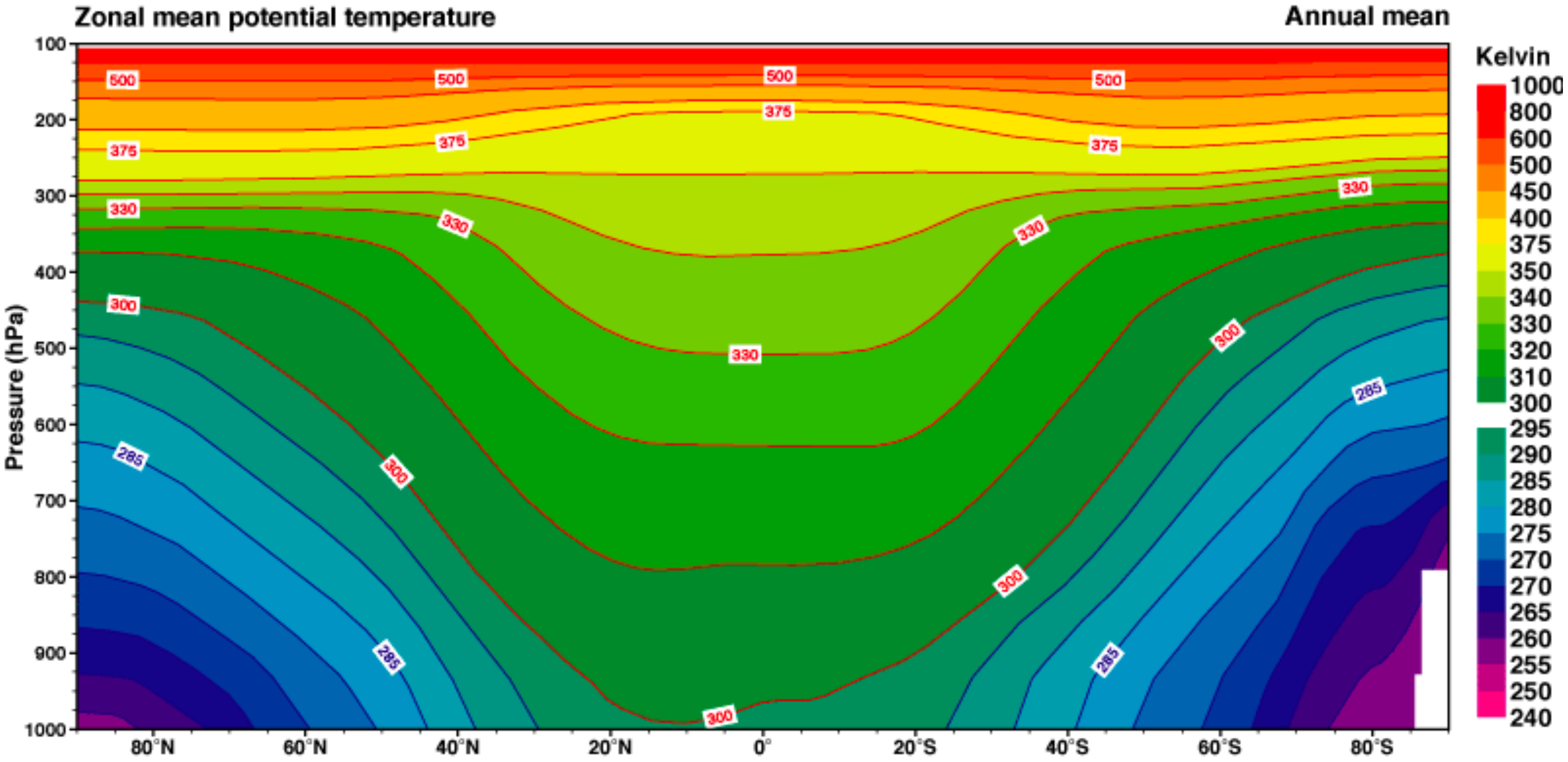


$$\theta = T\left(\frac{p_0}{p}\right)^{R_d/c_p}$$

The temperature a parcel would have if its adiabatically brought back to the surface.



Potential Temperature



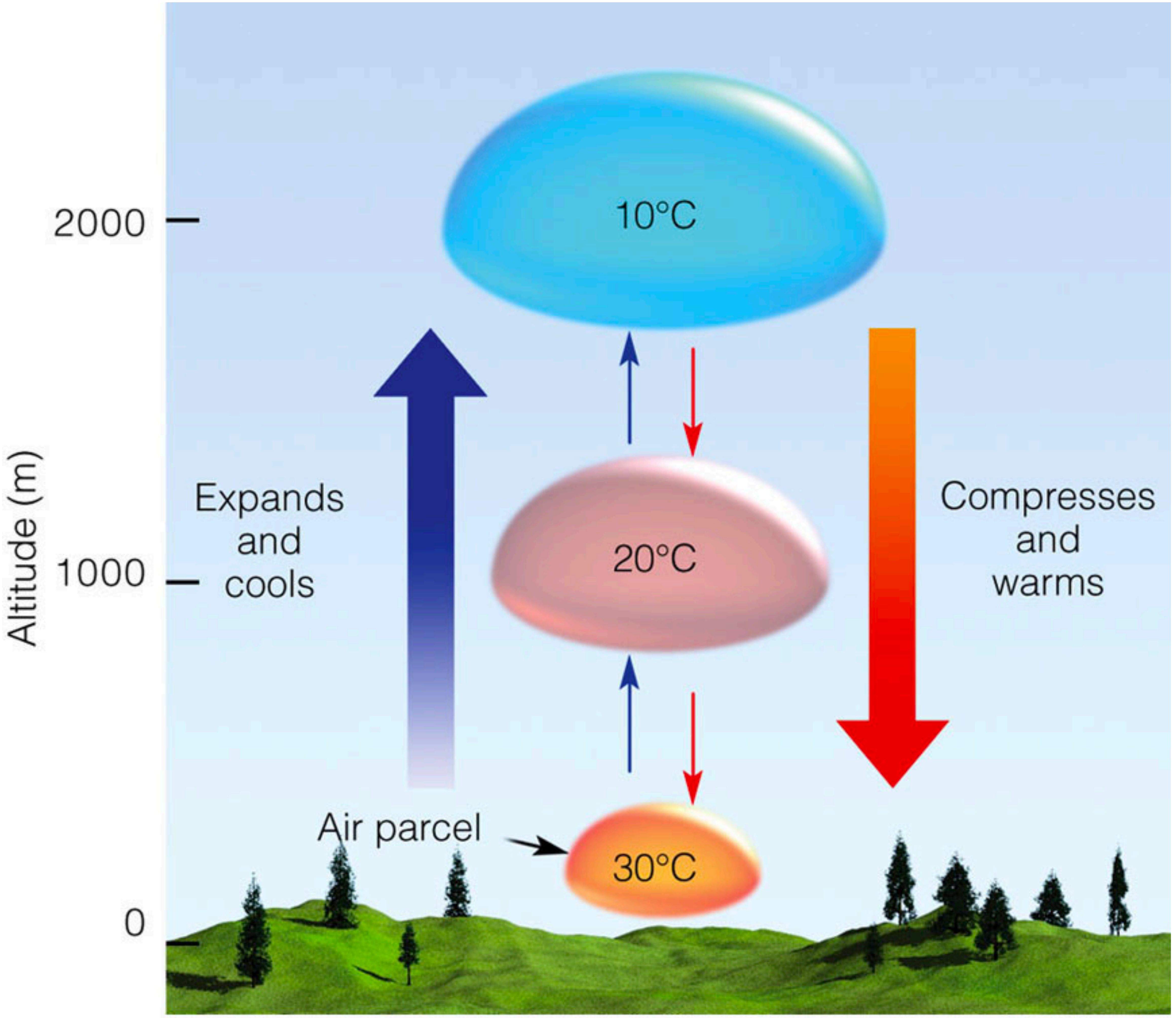
Dry static energy

A similar quantity to potential temperature is the dry static energy

$$s_s = c_p T + \Phi$$

The temperature a parcel would have if its adiabatically brought back to the surface.

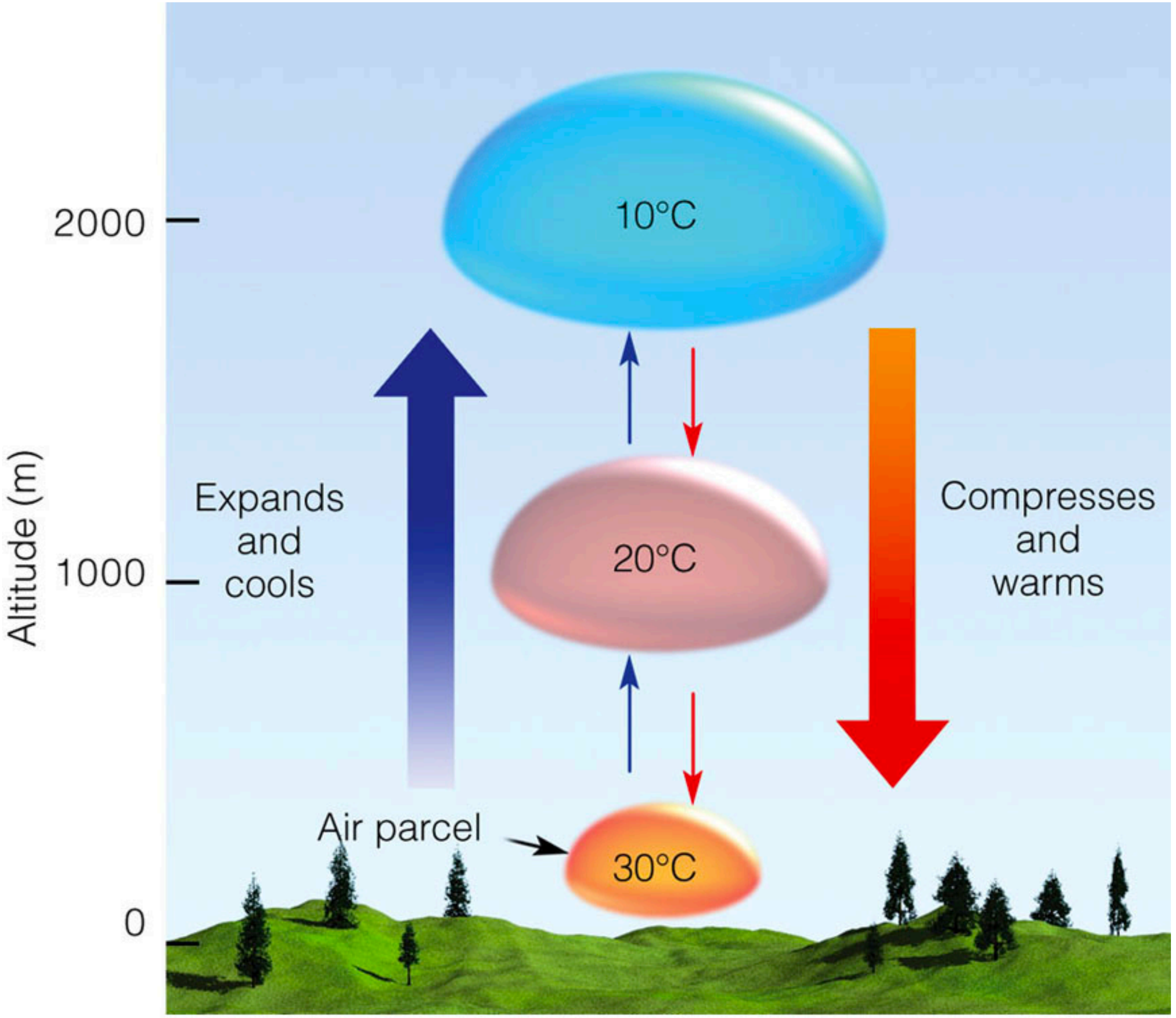
The process needs to also be hydrostatic (vertical acceleration is small)



If a parcel is displaced vertically dry adiabatically, it would cool following the dry adiabatic lapse rate

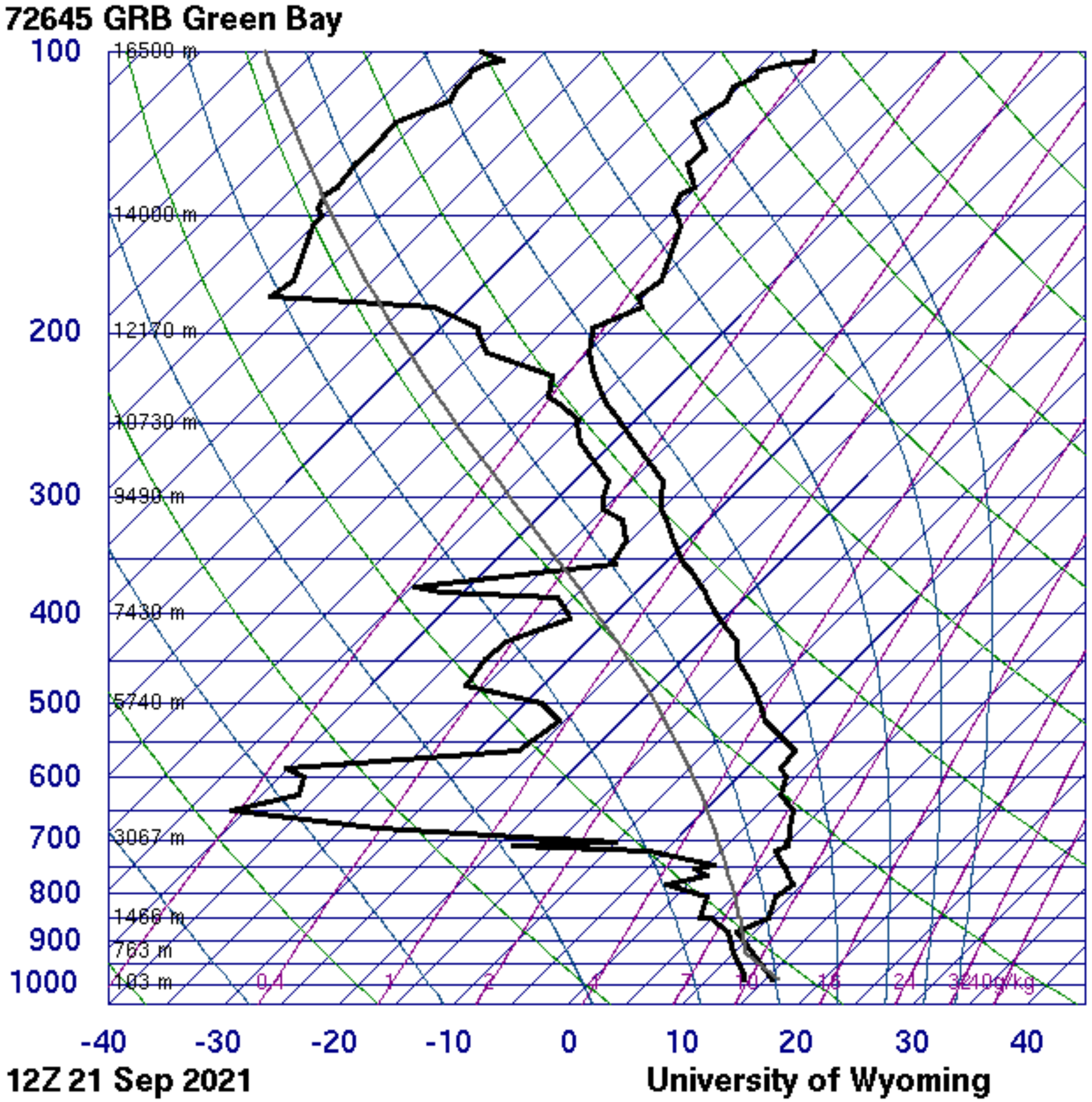
$$\Gamma_d = \frac{g}{c_p}$$

$$\Gamma_d = 9.8 \ \mathbf{K\ km}^{-1}$$

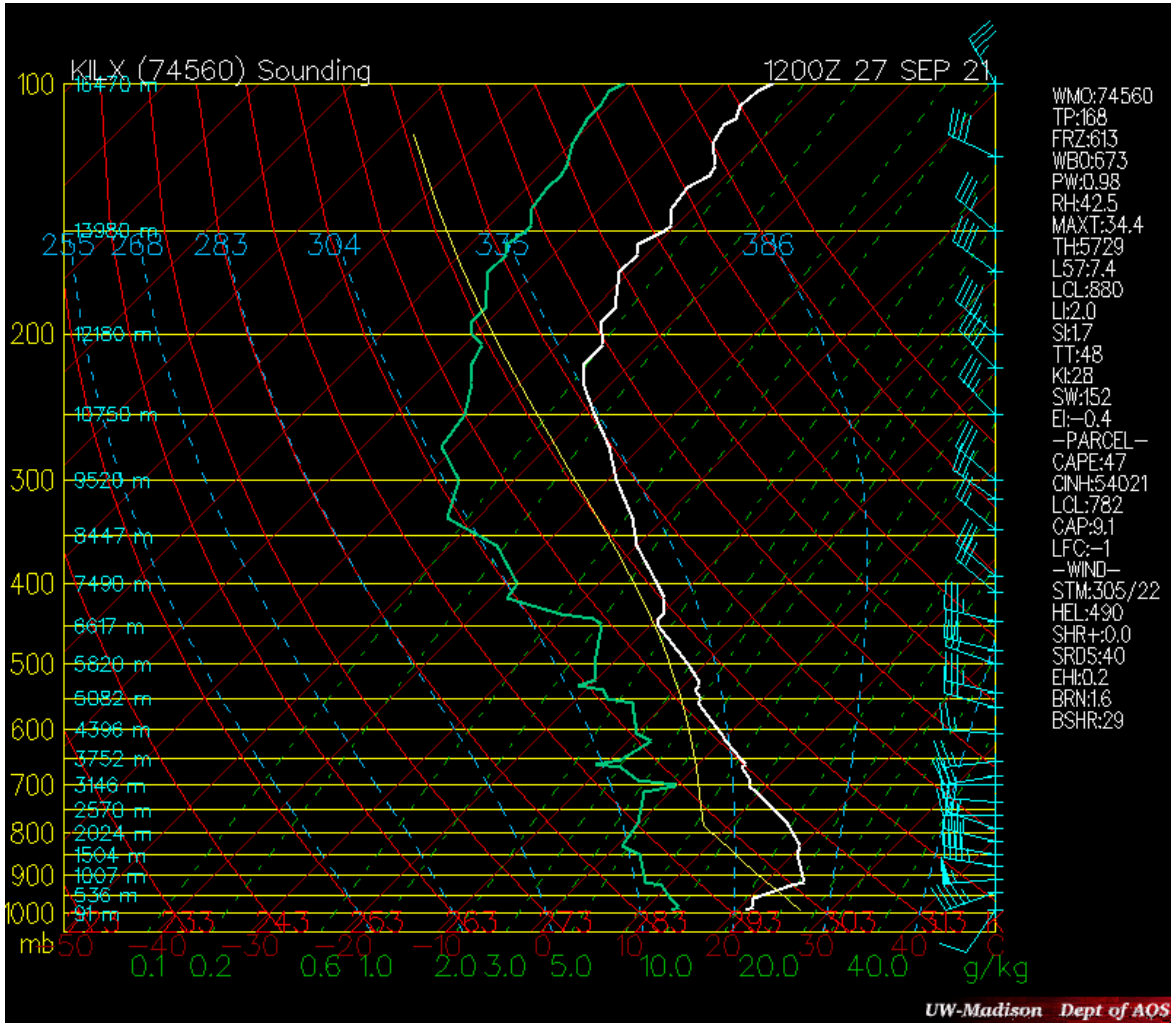


Dry adiabatic lapse rate on a Skew-T

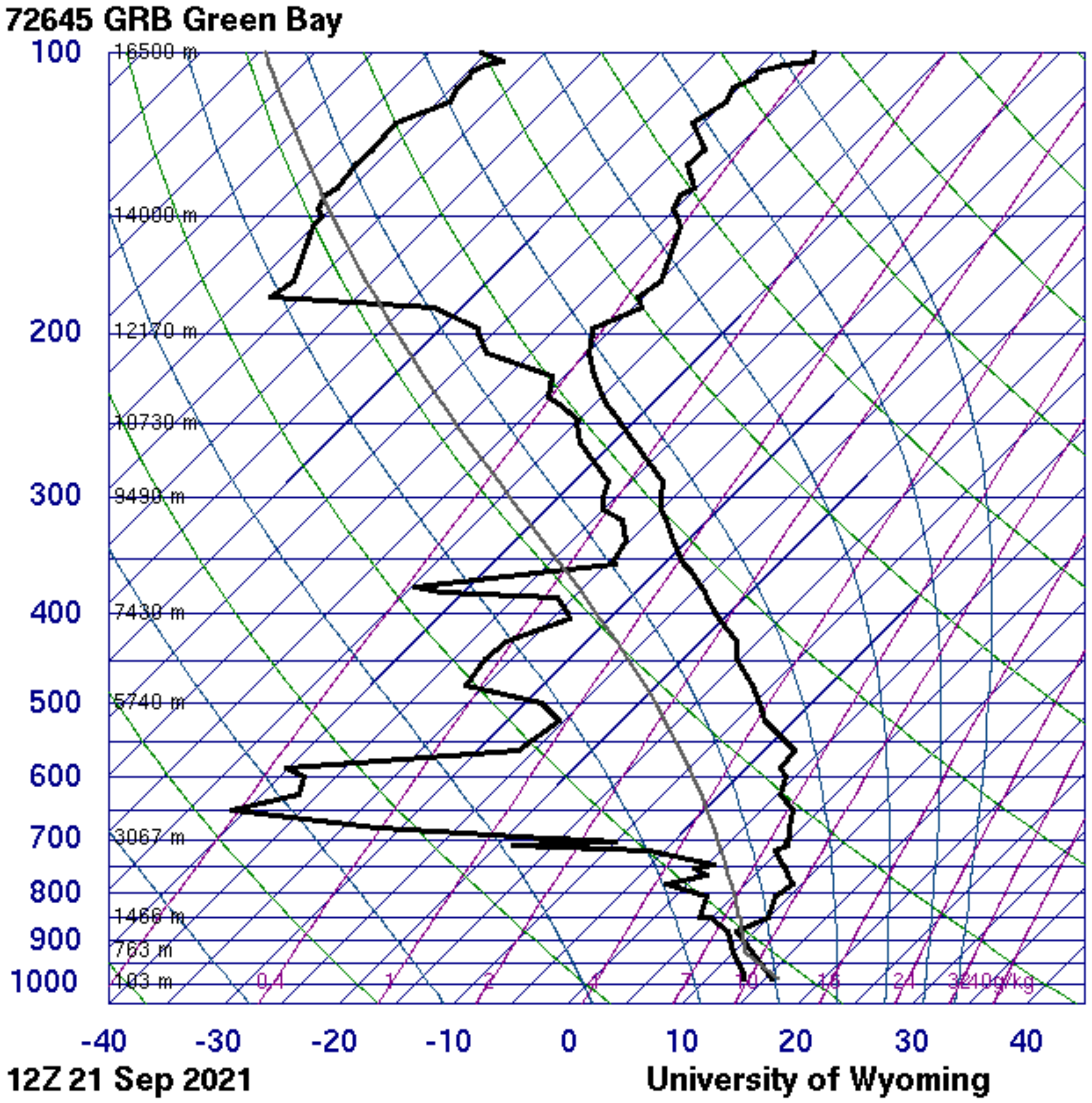
Green line in this diagram



Solid red line in this diagram



Skew-T a week #2



Download a Skew-T from your preferred website.

Pick a parcel at 600 hPa and bring it down adiabatically to the surface.

What will its temperature be and how does that compare to the surface temperature of the sounding?

Discuss your finding.