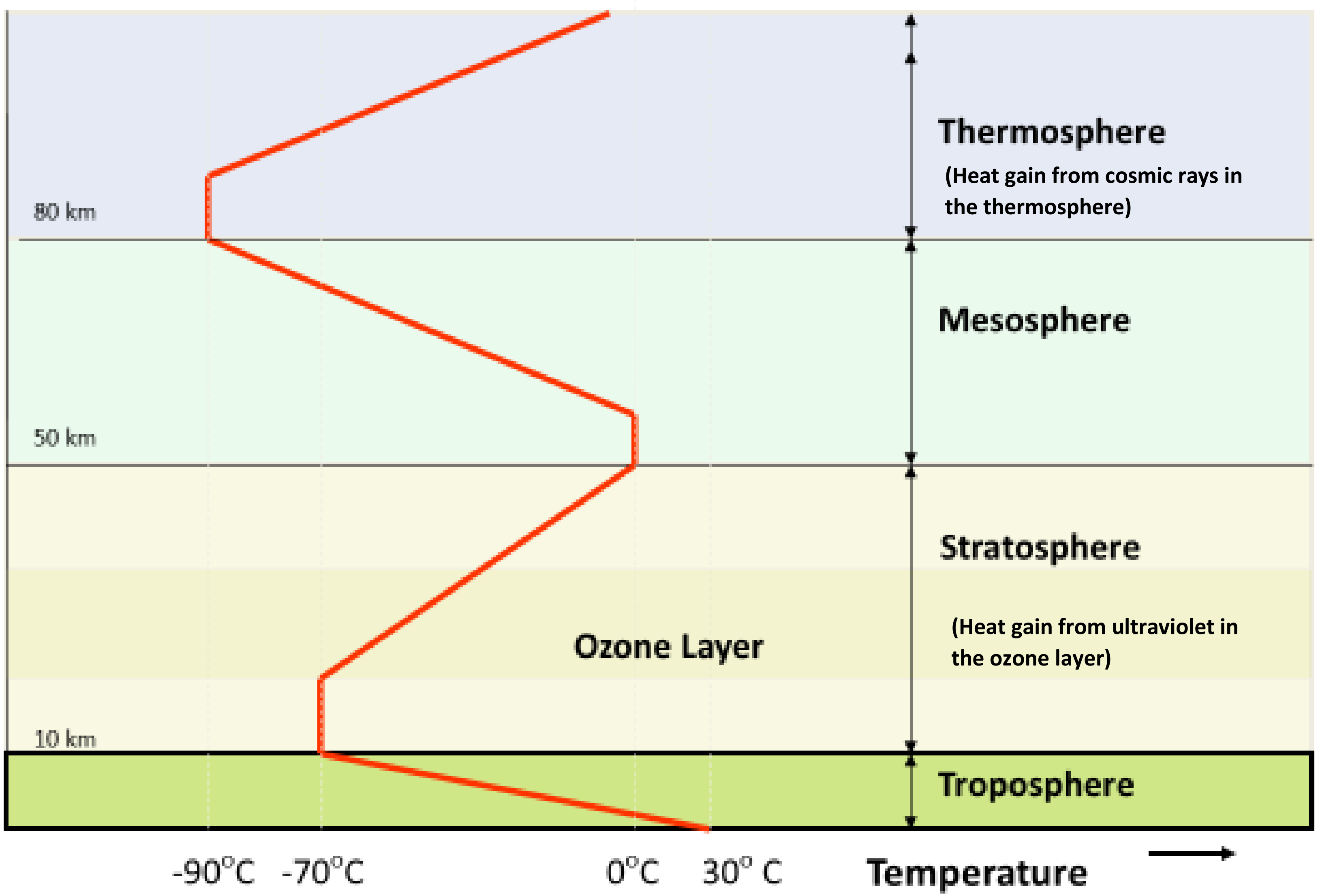
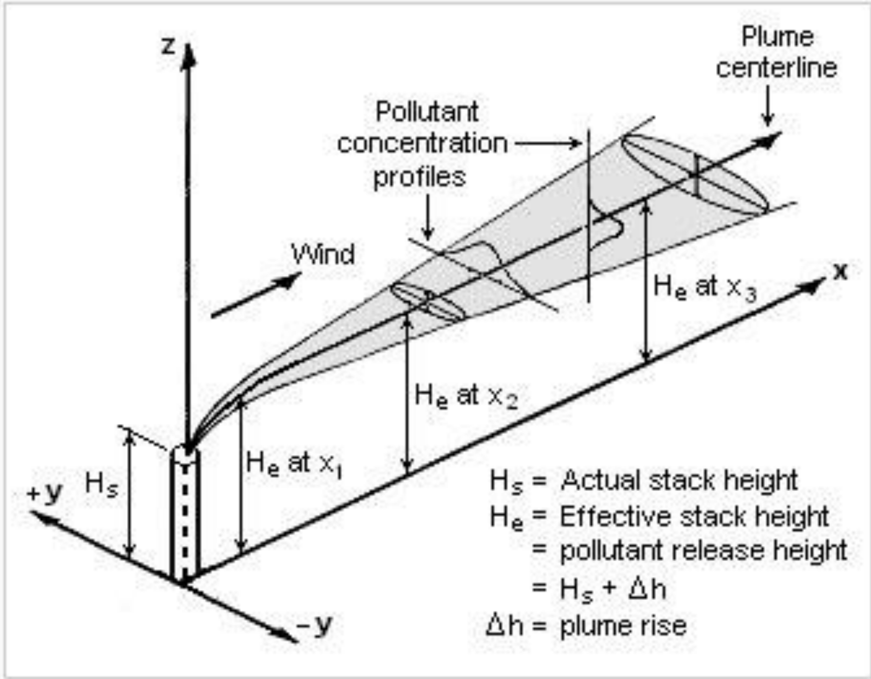
The Atmospheric Temperature Profile



SIMPLIFIED GRAPH OF ATMOSPHERIC TEMPERATURE PROFILE



Visualization of a buoyant Gaussian air pollutant dispersion plume

PD (Photo) U.S. EPA

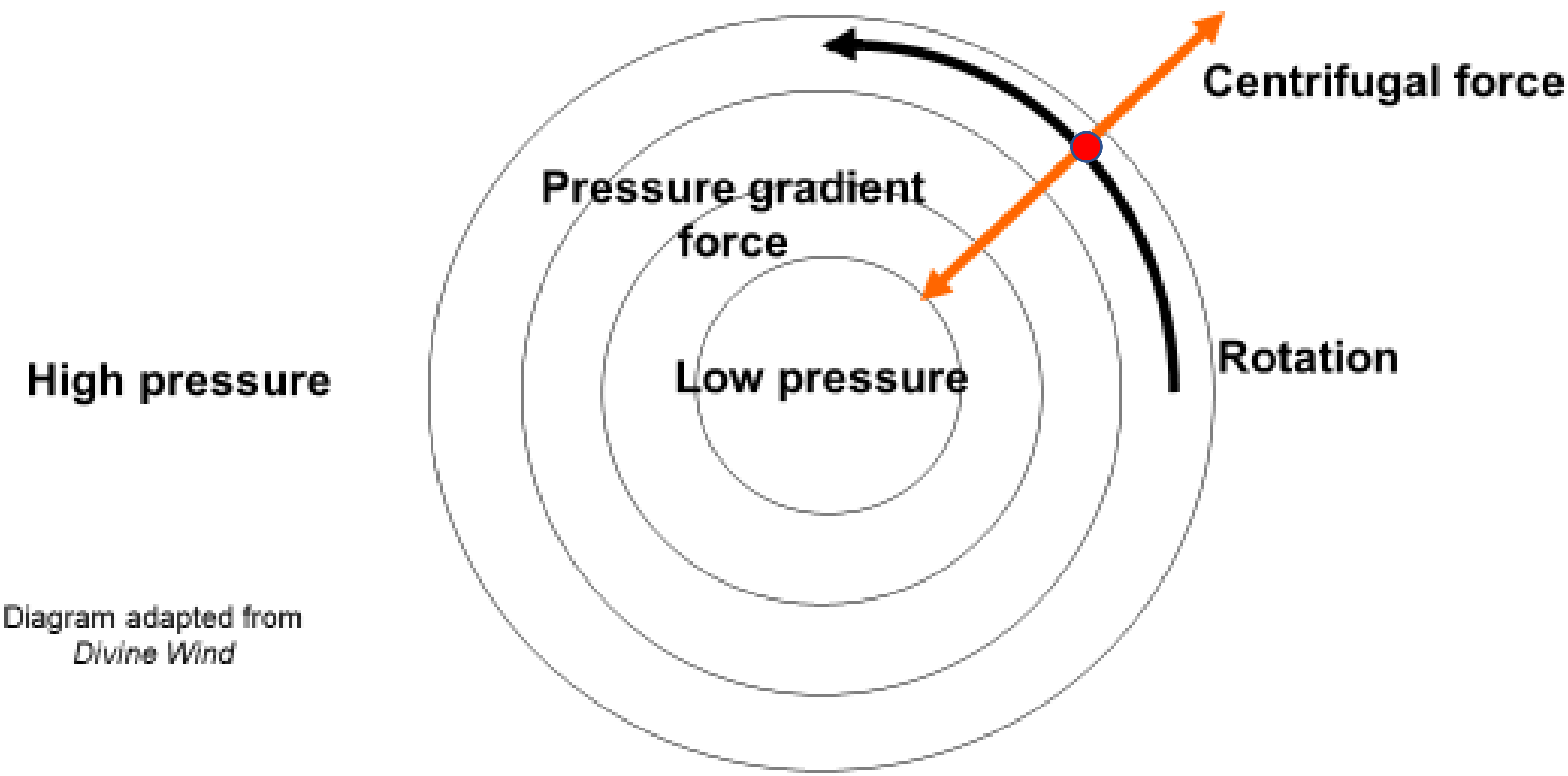
Industrial emissions plume

Non-rotating updrafts tend to entrain the surrounding air and lose vertical momentum.

Rotating updrafts (vortices) lose very little vertical momentum, and hence are much more efficient in terms of convection.

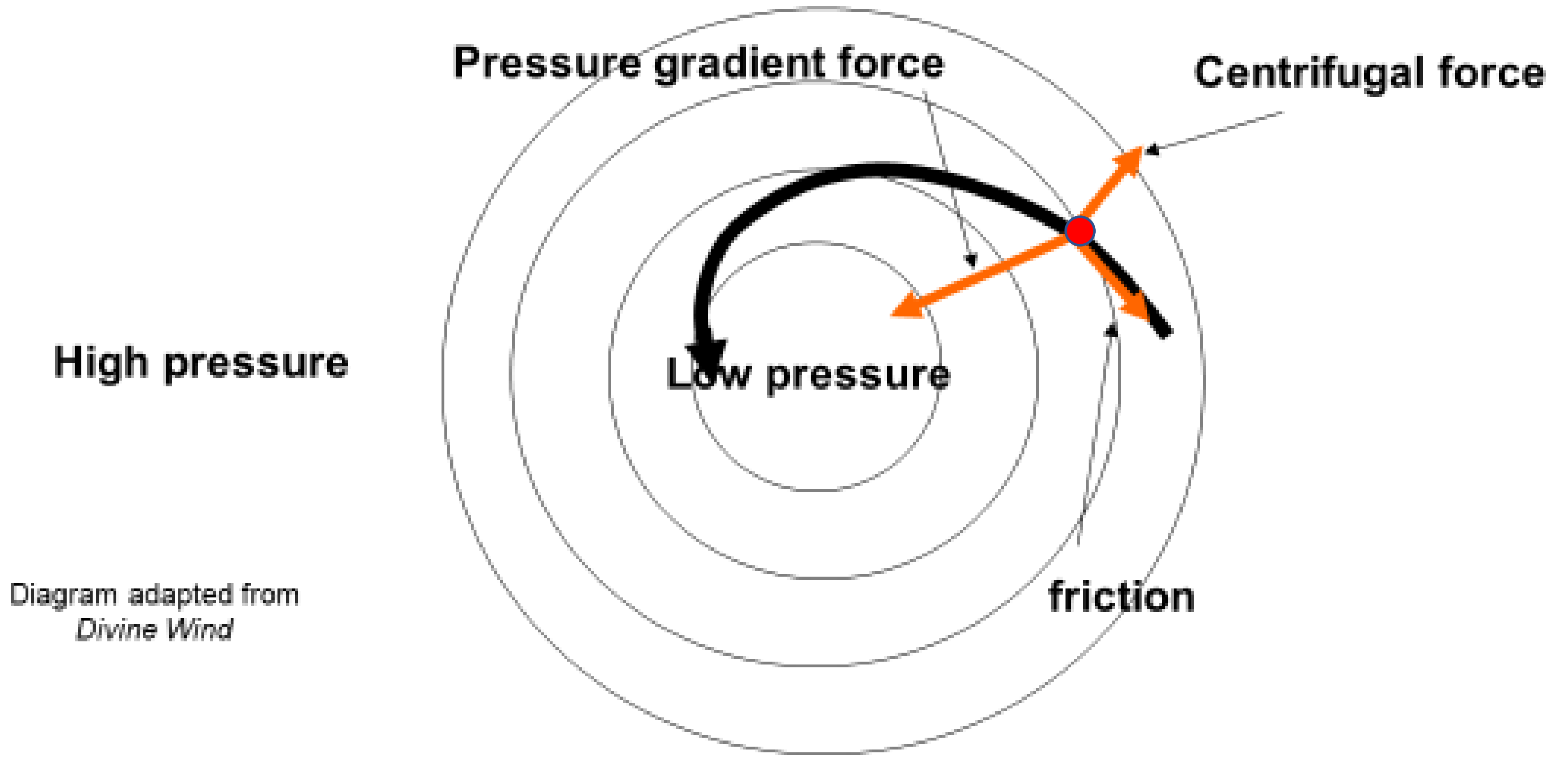
The tornado is a highly effective mechanism through which Nature acts to convey humid boundary layer air to the top of the Troposphere where precipitation is initiated. The "anvil" is formed when it reaches the tropopause (ca. 10 km), the interface with the stratosphere.

Airflow in a vortex at altitude

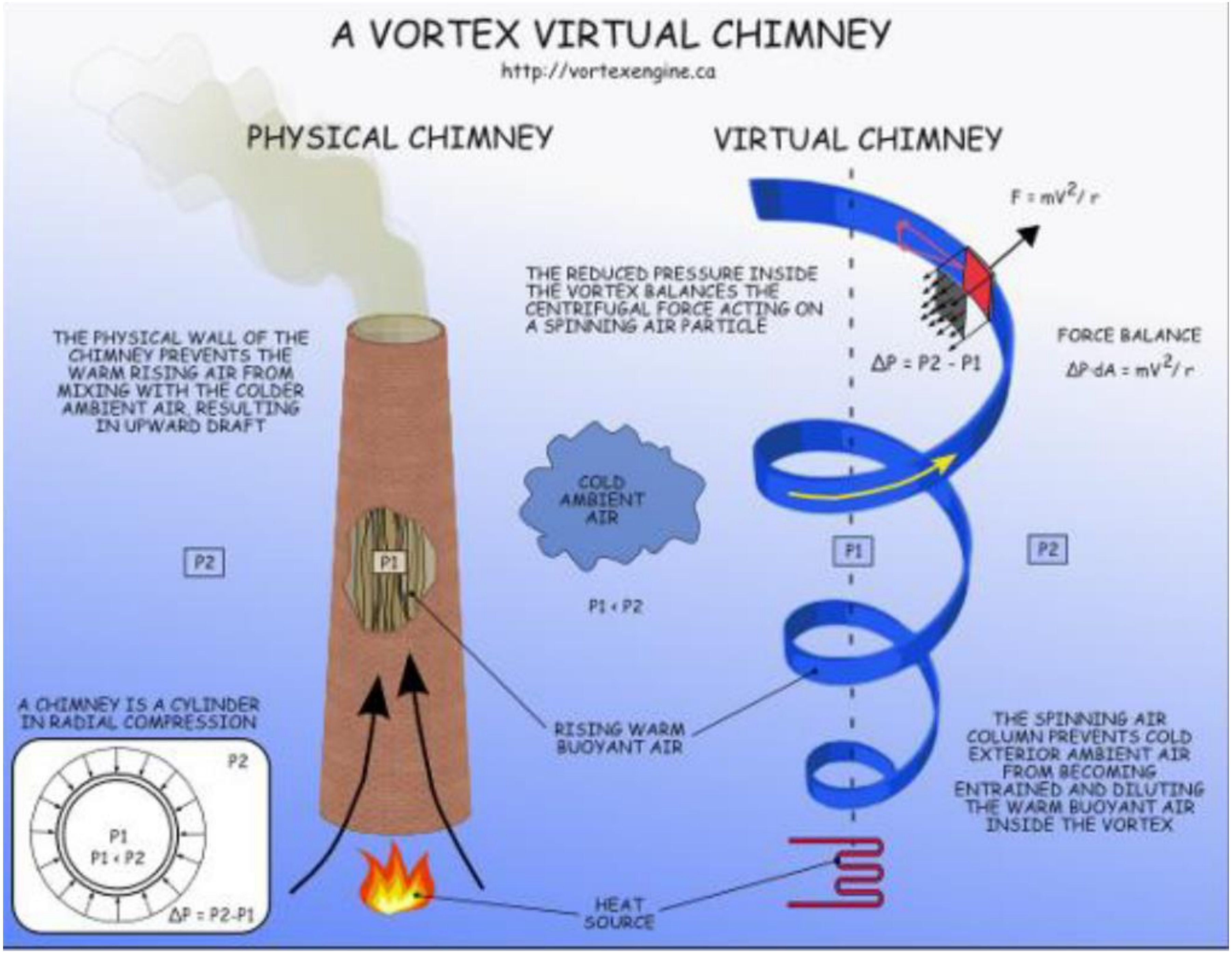


At altitude, the pressure gradient force (inwards) exactly equals the centrifugal force (outwards). Air thus rotates without a significant radial component

Airflow in a vortex near ground level



Within the boundary layer, friction acts to reduce the rotational velocity and hence the centrifugal force. The air is consequently able to spiral towards the low pressure at the vortex centre.


A VORTEX VIRTUAL CHIMNEY
http://vortexengine.ca
PHYSICAL CHIMNEY
VIRTUAL CHIMNEY
THE PHYSICAL WALL OF THE CHIMNEY PREVENTS THE WARM RISING AIR FROM MIXING WITH THE COLDER AMBIENT AIR, RESULTING IN UPWARD DRAFT
THE REDUCED PRESSURE INSIDE THE VORTEX BALANCES THE CENTRIFUGAL FORCE ACTING ON A SPINNING AIR PARTICLE
F = mV²/ r
ΔP = P2 - P1
FORCE BALANCE
ΔP·dA = mV²/ r
COLD AMBIENT AIR
P1 < P2
P2
P1
P1
P2
A CHIMNEY IS A CYLINDER IN RADIAL COMPRESSION
P2
P1
P1 < P2
ΔP = P2-P1
RISING WARM BUOYANT AIR
THE SPINNING AIR COLUMN PREVENTS COLD EXTERIOR AMBIENT AIR FROM BECOMING ENTRAINED AND DILUTING THE WARM BUOYANT AIR INSIDE THE VORTEX
HEAT SOURCE

Positive Feedback Within a Vortex

1. Warm air "rises" towards the centre (the eye) of the centrifugal field as it is less dense. It is also more buoyant in the Earth's gravitational field and hence rises vertically when it reaches the eye.
2. Atmospheric water vapour, which has a mass density about 63% that of air at the same temperature and pressure, is also displaced towards the centre of the centrifugal field and rises vertically once in the eye.
3. Centrifugal force reduces the pressure at the centre of the centrifugal field. Low pressure again means low density and hence high buoyancy. A buoyant gas has inherent potential energy.
4. As the air/vapour mixture progresses to the low-pressure eye, some water vapour condenses, releasing latent heat. **The typical tornado "funnel" is visible because of the condensed water particles.**

Each of the above processes acts to create a strongly buoyant updraft within the eye and hence a self-sustaining natural "chimney" effect.

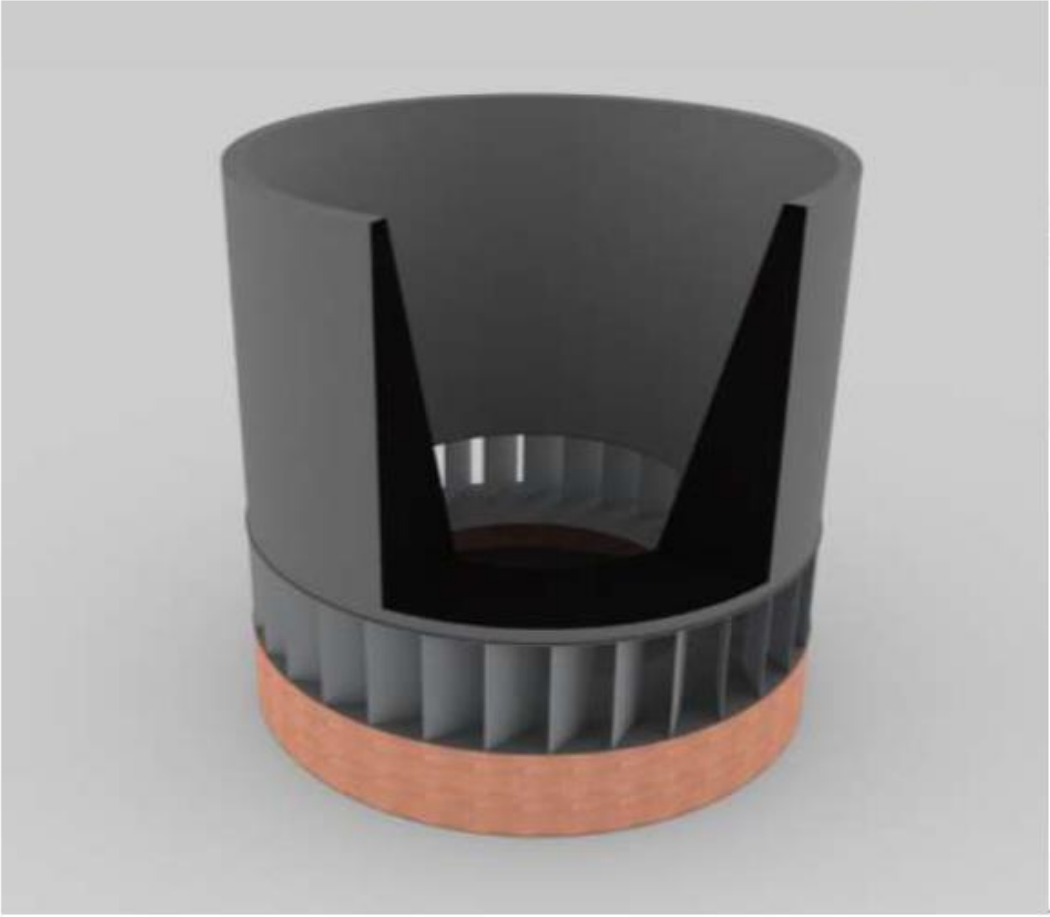
Just as the potential energy of elevated water can be harnessed to drive hydroelectric turbines, so too the potential energy of a warm air/vapour mixture can drive wind turbines.

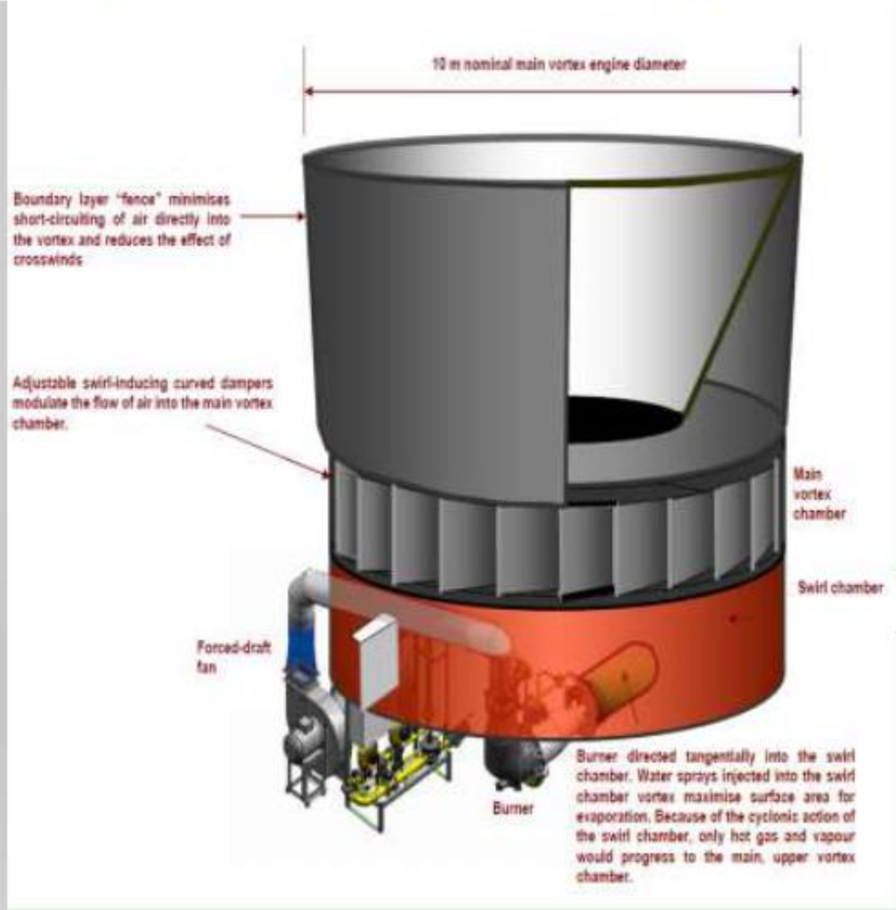
The height to which a buoyancy vortex persists before breakdown to a turbulent plume will depend on:

- Convective Available Potential Energy (CAPE)
- System scale
- Radiation of heat away from the plume

The CAPE of the gas stream is a function of the internal energy of the convecting fluid. In tornadoes, the latent heat of fusion and evaporation of water vapour are important in this regard. Calculation of CAPE is covered at http://tornado.sfsu.edu/geosciences/classes/m201/buoyancy/CAPE_Procedure.html

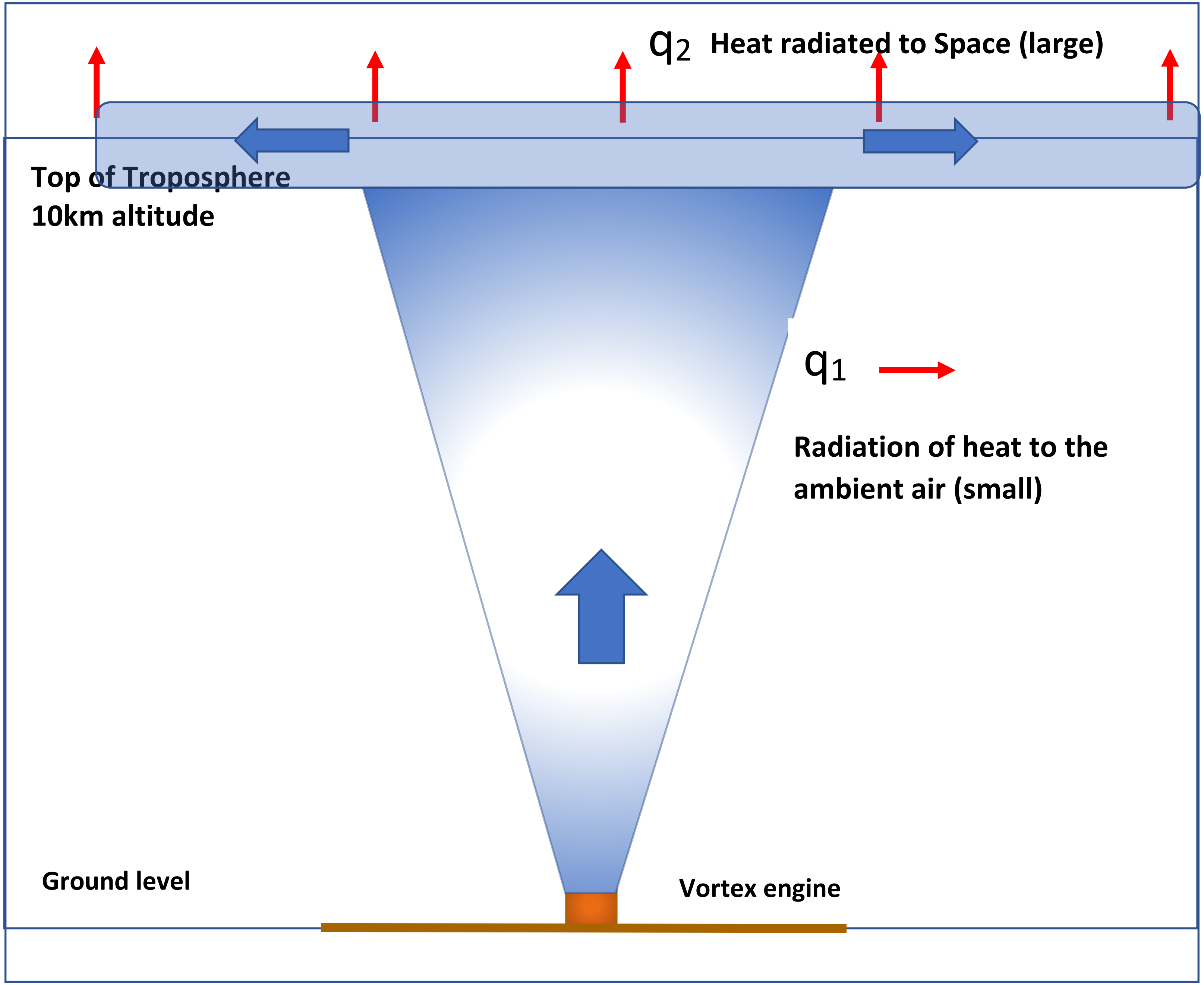
The Vortex Engine (Gas Flaring)



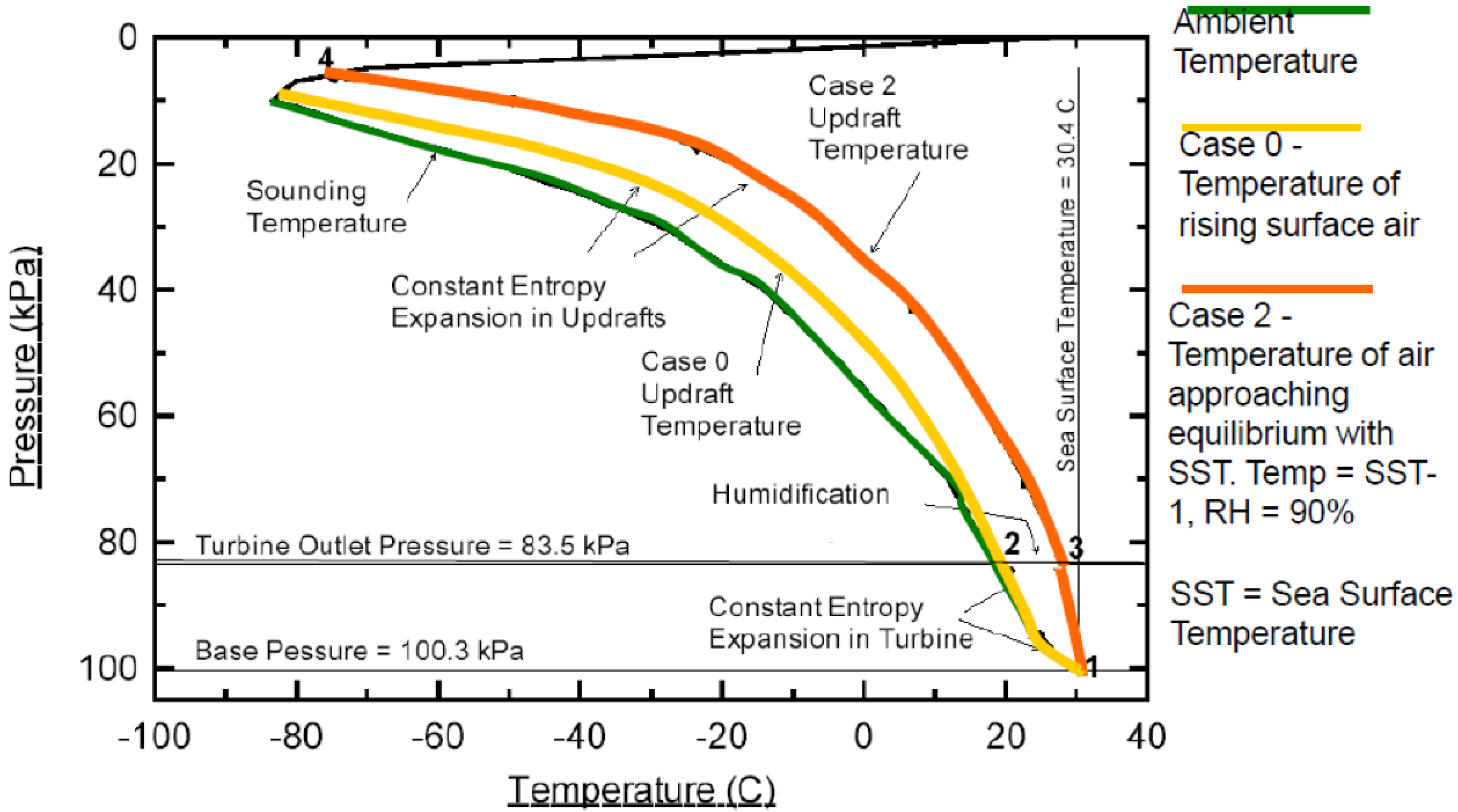


Engine core **Arrangement**

Small scale prototype

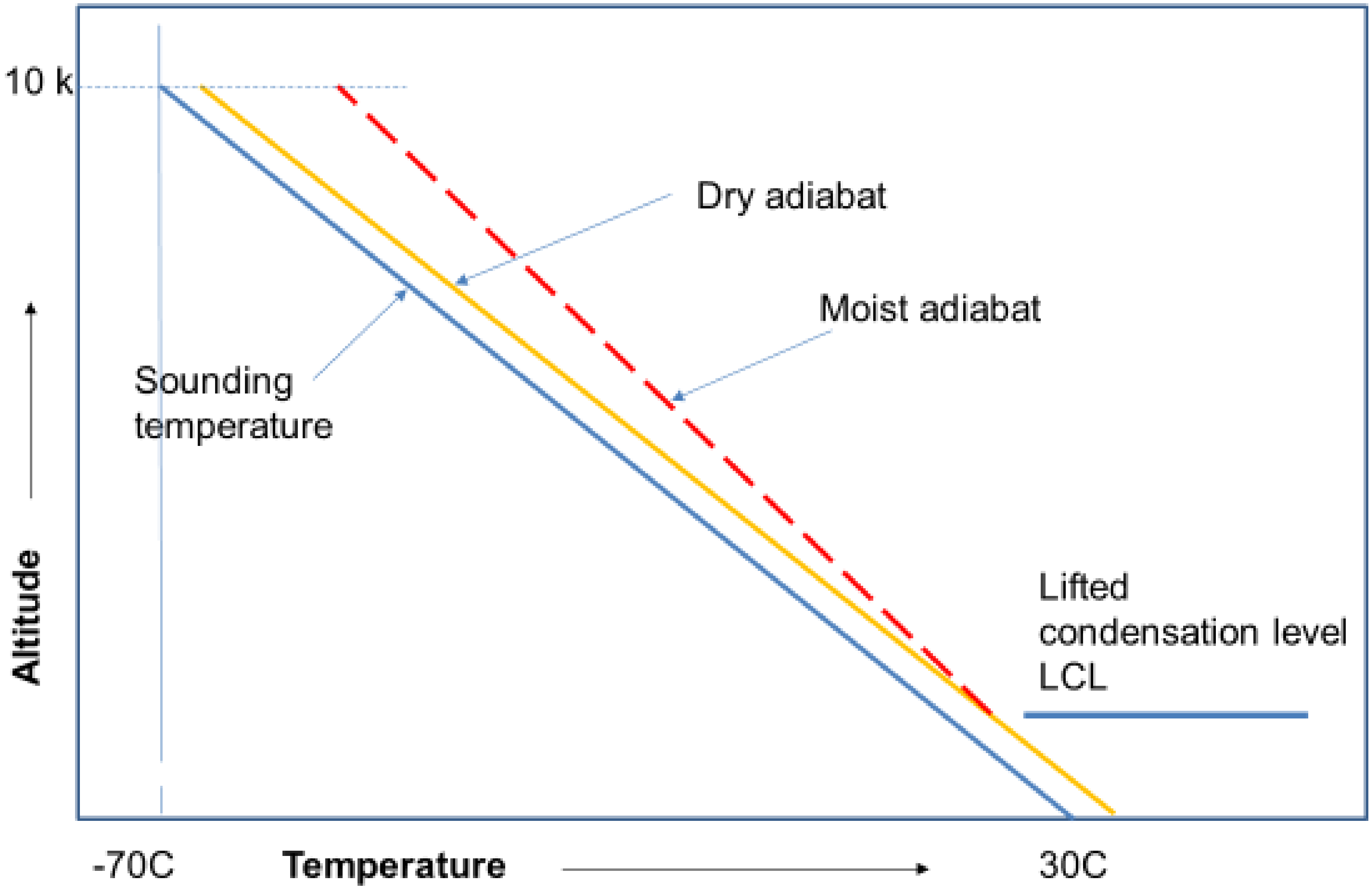

q_2 Heat radiated to Space (large)
Top of Troposphere
10km altitude
q_1
Radiation of heat to the
ambient air (small)
Ground level
Vortex engine

The Release of Latent Heat with Increase in Altitude

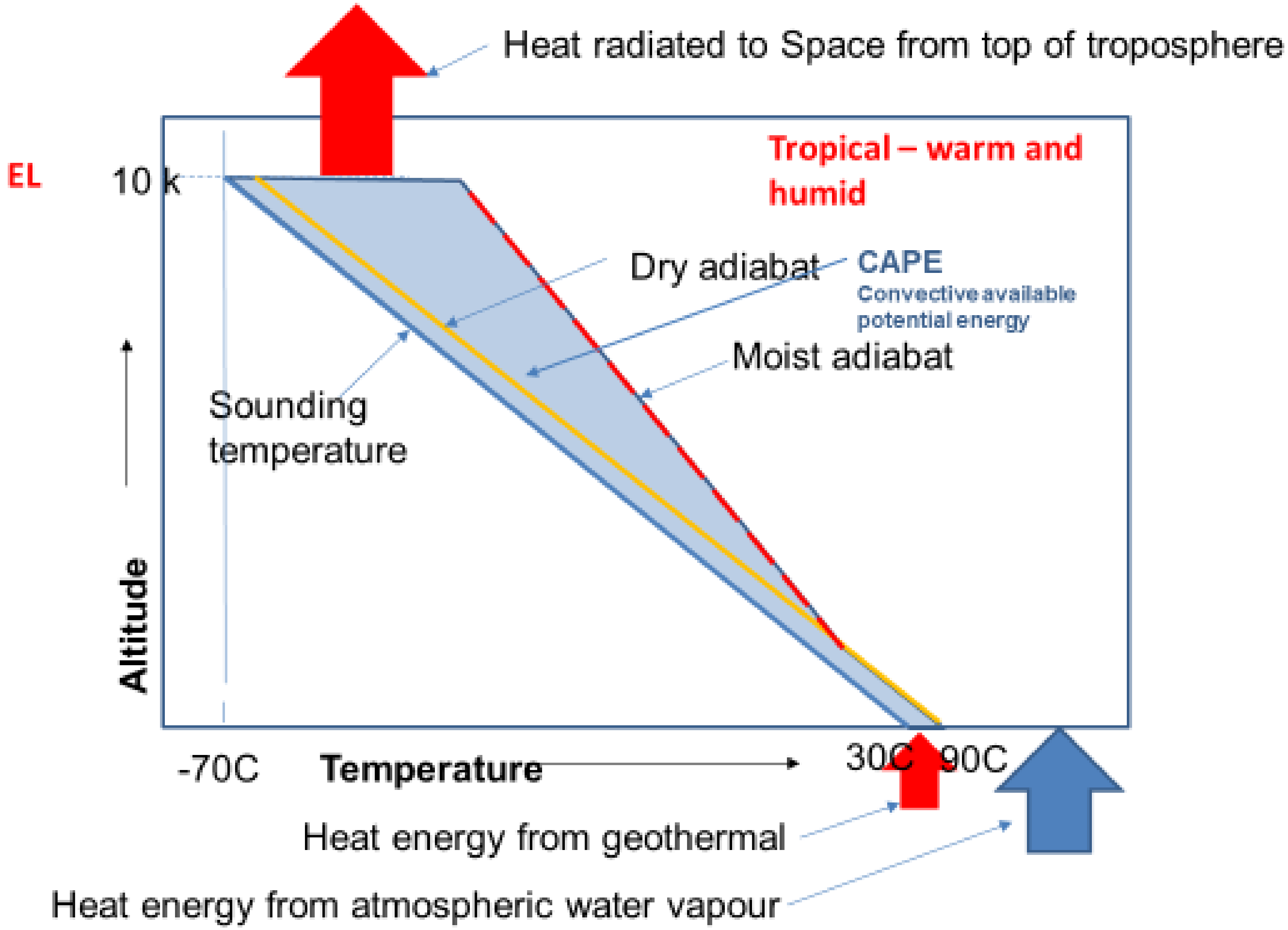


Note: Humidification strongly increases the updraft column buoyancy.

Temperature profiles of updraft vortices within the troposphere



The Vortex Engine can leverage heat transfer by use of the energy of atmospheric water vapour



At a nominal vertical velocity of, say, 20m/s, the time to rise 10km is around 8 minutes.

Note that most of the radiation occurs at the top of the troposphere, where residence time is measured in **hours**. This allows the heat energy to be effectively dumped to Space:

$$q = \varepsilon \sigma (T_h^4 - T_c^4) A_c$$

where

q	=	*heat transfer per unit time (W)*
ε	=	*emissivity*
σ	=	*Stephan-Boltzmann constant*
T_h	=	*hot body absolute temperature (K)*
T_c	=	*cold surroundings absolute temperature (K)*
A_c	=	*area of the object (m^2)*

The emissivity of H_2O and CO_2 are both high, whereas the emissivity of O_2 and N_2 which together make up the majority of gas in the atmosphere, and hence in the updraft stream, are both very low. <u>Hence an updraft within a vortex can approximate to an adiabatic process.</u>

If the vertical velocity of the updraft is relatively low, water vapour may condense and freeze in the form of mid-level clouds.

For an updraft with ΔT between sea level and tropopause of 100C, and 1% water content, around 20% of the available change in enthalpy comes from water, 80% from the air.