



THE ATMOSPHERIC VORTEX ENGINE

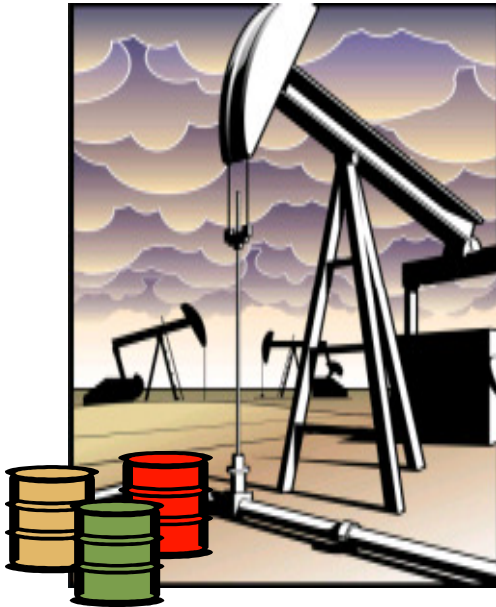
A proposal for the utilization of updraft systems to sustainably generate electrical power, reduce global warming and increase rainfall

Presentation by

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A Comparison of Earth's Stored Energy Resources

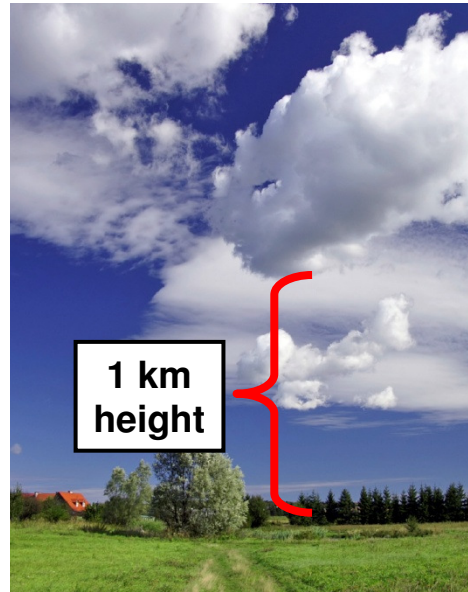
Crude Oil Reserves



$7.3 \times 10^{21} \text{ J}$



Latent heat of water vapor in the bottom kilometer of the atmosphere

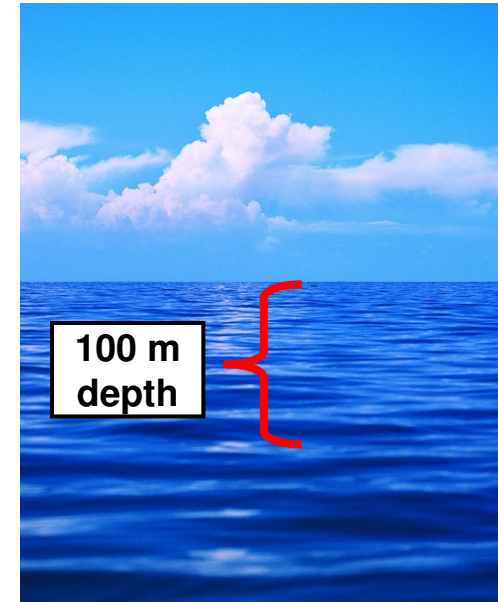


$13 \times 10^{21} \text{ J}$

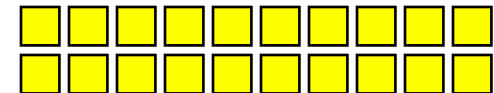


Heat content of tropical ocean water

100 m layer, 3°C



$130 \times 10^{21} \text{ J}$



Replenishment times

10^9 years

10 days

100 days

Eric Michaud

Assumptions / Calculations

Crude Oil Reserves

$$1200 \cdot 10^9 \text{ bbl} \quad [1]$$

$$\times 6100 \cdot 10^6 \frac{J}{\text{bbl}} \quad [2]$$

$$= 7.3 \times 10^{21} J$$

[1] World Crude Oil and Natural Gas Reserves, January 1, 2007, Energy Information Administration

[2] Energy Calculator, Energy Information Administration, <http://www.eia.doe.gov>

Latent heat of water vapor

in the bottom kilometer of the atmosphere

$$10 \frac{\text{kg}}{\text{m}^2} \quad [3]$$

$$\times 2.5 \cdot 10^6 \frac{J}{\text{kg}} \quad [4]$$

$$\times 510 \cdot 10^{12} \text{ m}^2 \quad [5]$$

$$= 13 \times 10^{21} J$$

[3] Assuming 10 kg/m² average moisture content in the bottom 1 km of the atmosphere

[4] Latent heat of water vapour

[5] Surface area of the Earth

Heat content of tropical ocean water

100 m layer, 3°C

$$1000 \frac{\text{kg}}{\text{m}^3} \times 100 \text{ m} \quad [6],[7]$$

$$\times 4190 \frac{J}{\text{kg} \cdot K} \times 3^\circ\text{C} \quad [8],[9]$$

$$\times 510 \cdot 10^{12} \text{ m}^2 \times 20\% \quad [10]$$

$$= 130 \times 10^{21} J$$

[6] density of water

[7] Assuming 100 m depth

[8] sensible heat of water

[9] Assuming 3°C

[10] Assuming the area of Earth's tropical oceans = Area of Earth x 20%

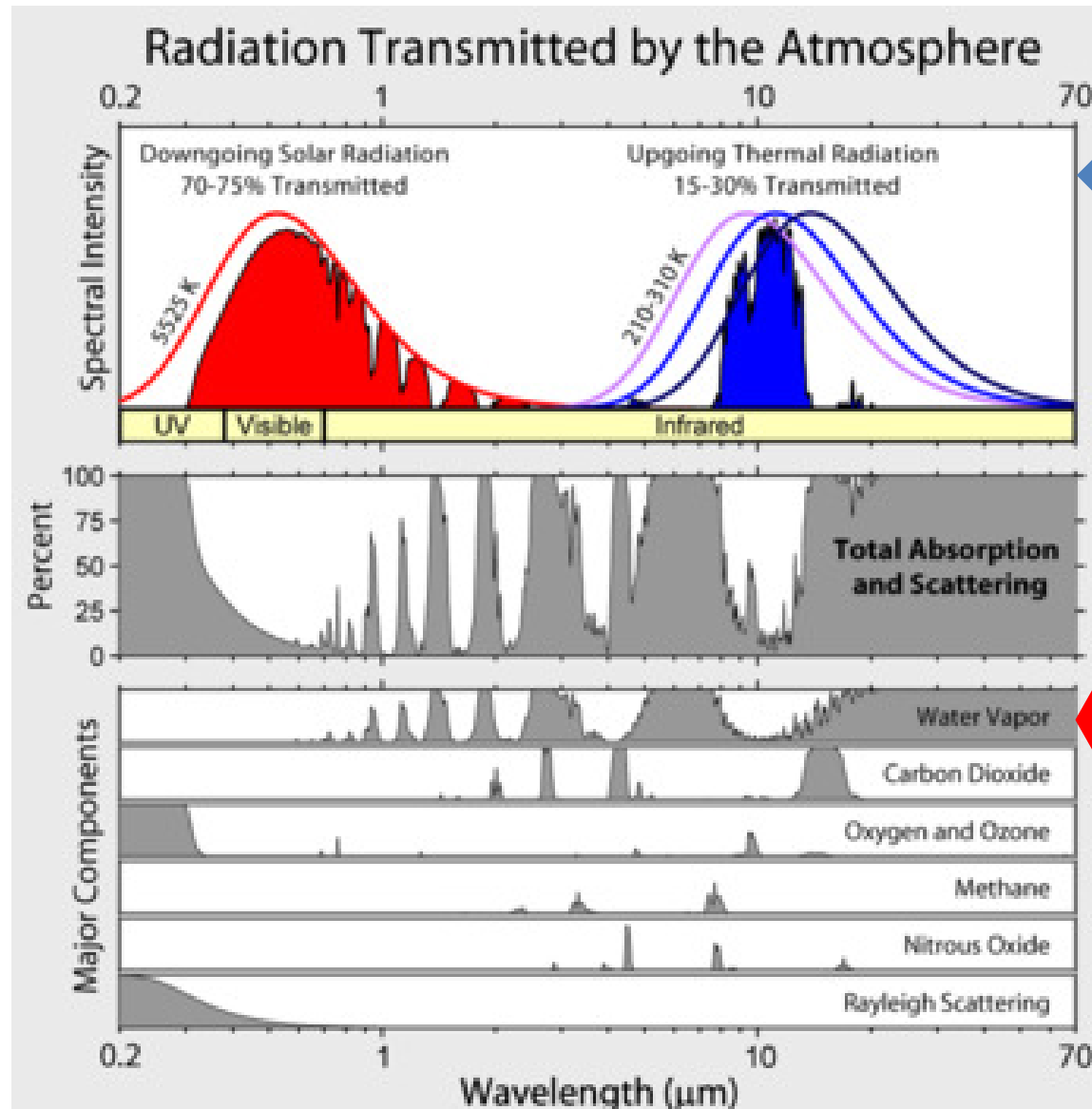
Dissipative Structures

Although the atmospheric and sea energy resources cited above would normally be regarded as low grade and hence not available for power production, it will be argued that the highly non-linear processes within an atmospheric vortex allow the energy to be tapped.

Vortices are, in the words of the Nobel prizewinning chemist Ilya Prigogine, dissipative structures. Dissipative structures are far-from-equilibrium thermodynamic systems that generate order spontaneously by exchanging energy with their external environments. They include:

- physical processes (eg whirlpools and tropical cyclones),
- chemical reactions (eg Rayleigh-Benard cells - convection cells that appear spontaneously in a liquid layer when heat is applied from below), and
- biological systems (eg cells).

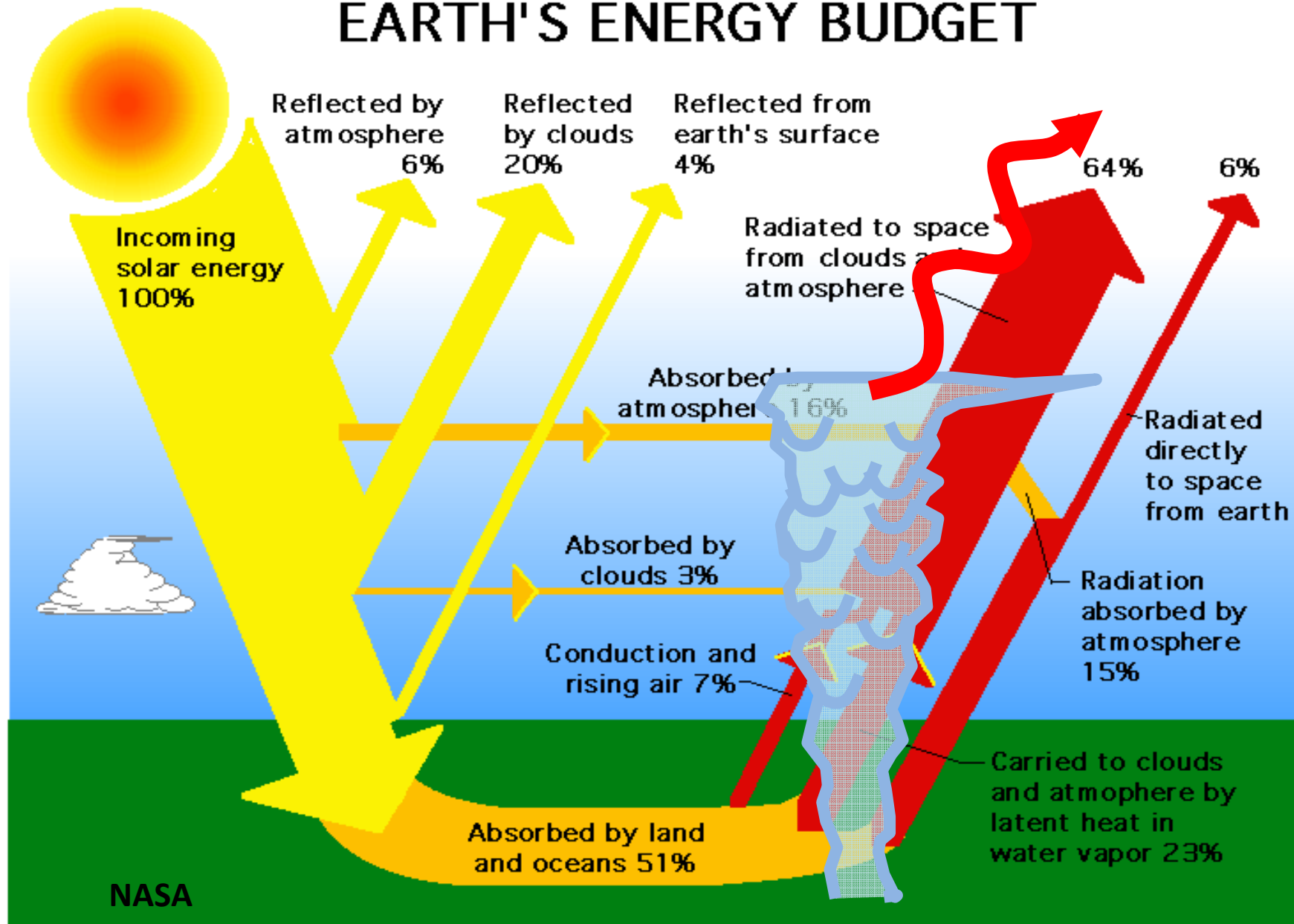
The Greenhouse Effect



The deficit between downgoing and upgoing radiation must be made up for by convection processes

Water vapour is by far the most important greenhouse gas

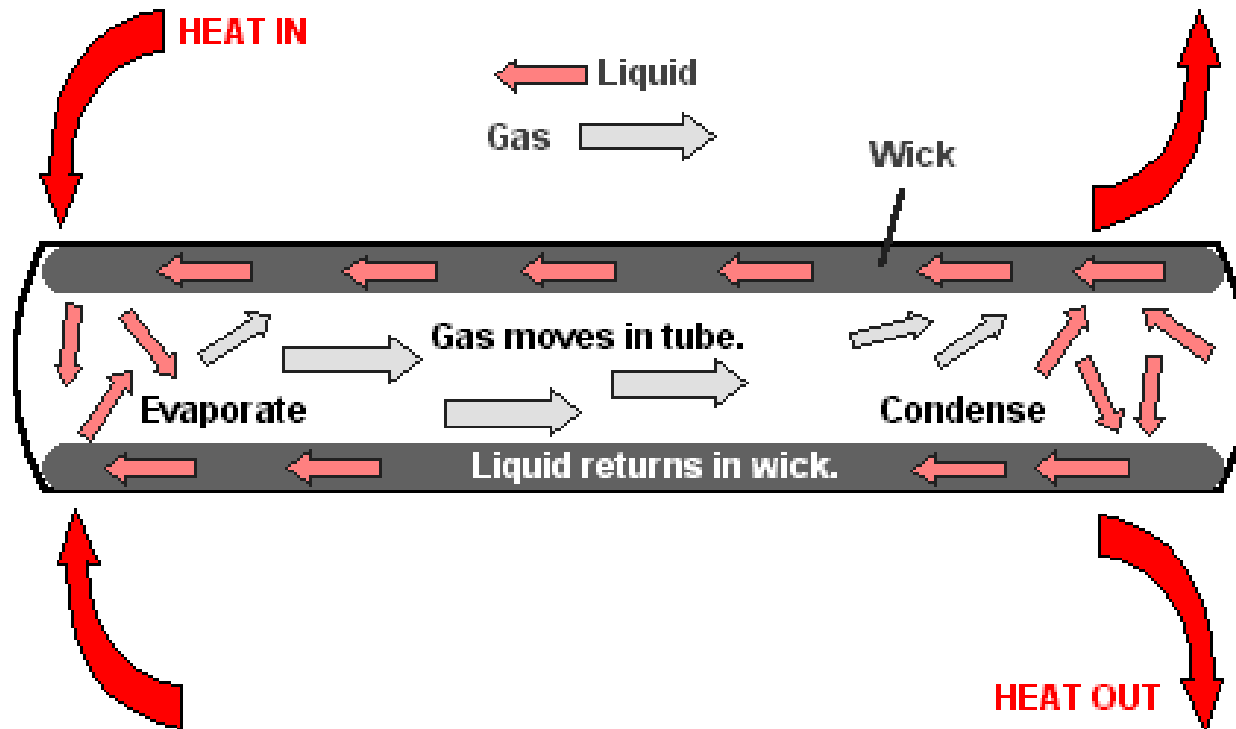
EARTH'S ENERGY BUDGET



Convection of water vapour through the Troposphere provides by far the most effective single way in which Earth's heat can eventually be re-radiated to Space.

The Heat Pipe

From Computer Desktop Encyclopedia
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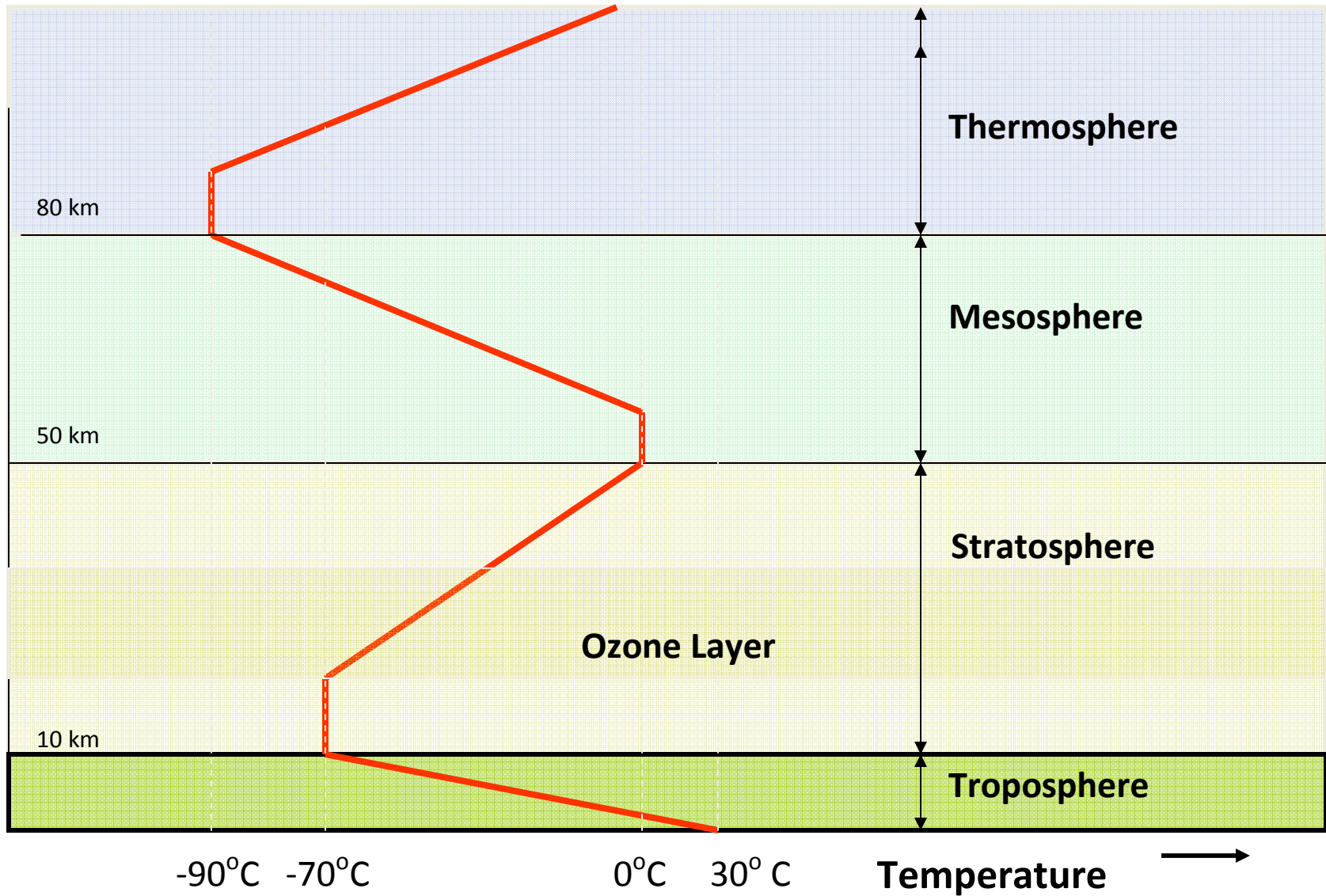


The heat pipe is an extremely efficient system for transmitting heat

The Troposphere - Nature's "Heat Pipe"

Convection processes such as storms, cyclones and tornados are the primary means of effectively pumping heat out of the ocean, into the atmosphere, and lifting it to where it can be re-radiated into space, thereby mitigating the heat build-up that otherwise occurs.

The Atmospheric Temperature Profile



SIMPLIFIED GRAPH OF ATMOSPHERIC TEMPERATURE PROFILE

The Troposphere

“The troposphere is the lowest region of the Earth's atmosphere, where masses of air are very *well mixed* together and the temperature decreases with altitude.”

“The air is heated from the ground up because the surface of the Earth absorbs energy and heats up faster than the air. The heat is mixed through the troposphere because on average the atmosphere in this layer is slightly unstable.”

http://www.windows.ucar.edu/tour/link=/earth/Atmosphere/layers_activity_print.html&edu=high

The proposed vortex engine is a system to enhance the transmission of energy through the troposphere

First, the Vortex Engine's cousin: the Solar Updraft Tower

Solar Chimney



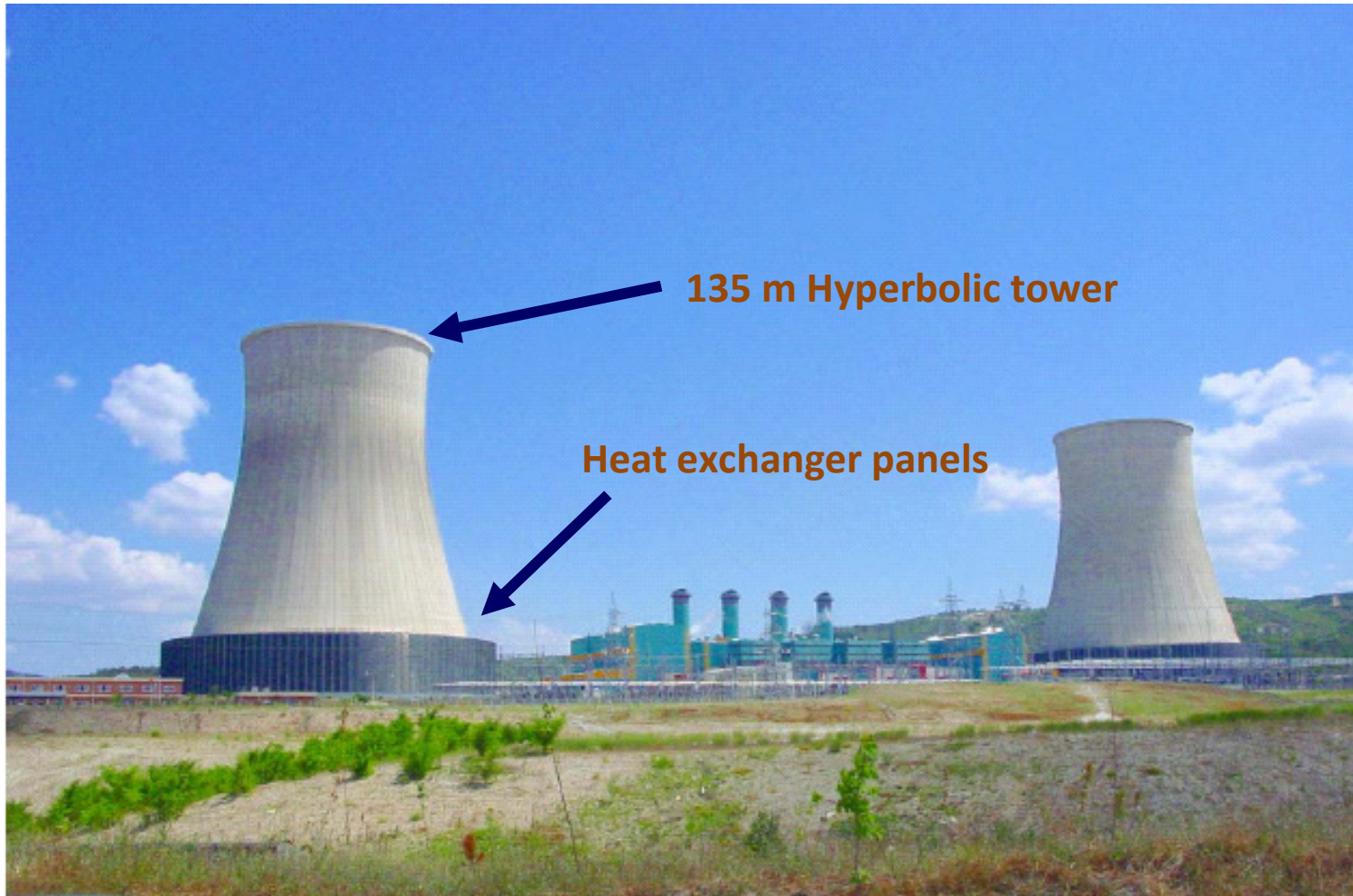
Manzanares
200 m high, 10 m diameter
Collector 0.04 sq. km
50 kw, 130 J/kg, 1 Mg/s
Spain 1982 to 1989



Enviromission
1000 m high, 100 m diameter.
Collector 40 sq km
200 MW, 300 tonne/sec
Australia / US

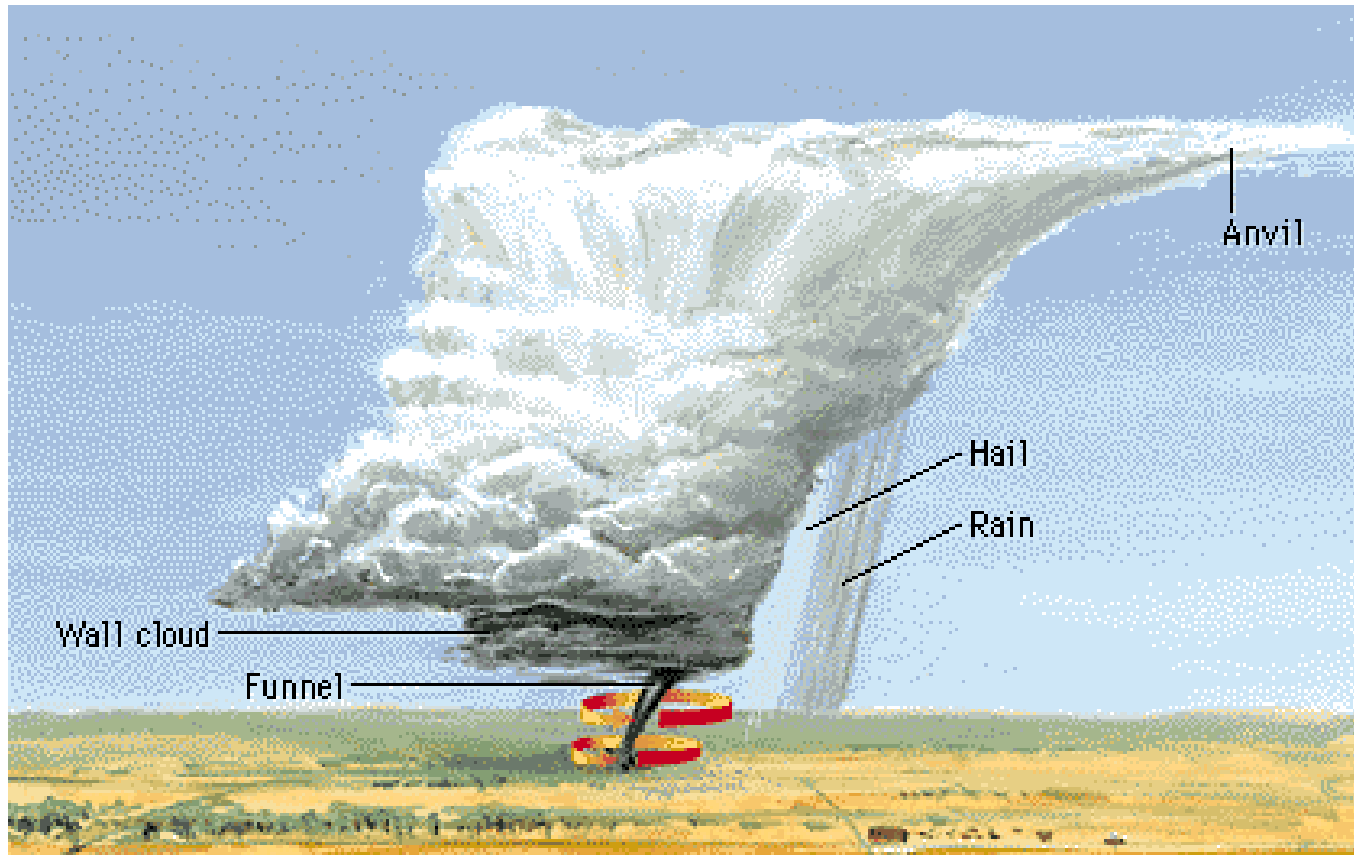
Enviromission in Australia and Solarmission in the US are proposing to build a 200 MWe solar-thermal power station.

1400 MW CCGT Power Station with Dry Cooling Towers



After discussions with Louis Michaud, the cooling tower developer GEA is reportedly considering incorporation of a vortex flow within their design in order to enhance the updraft.

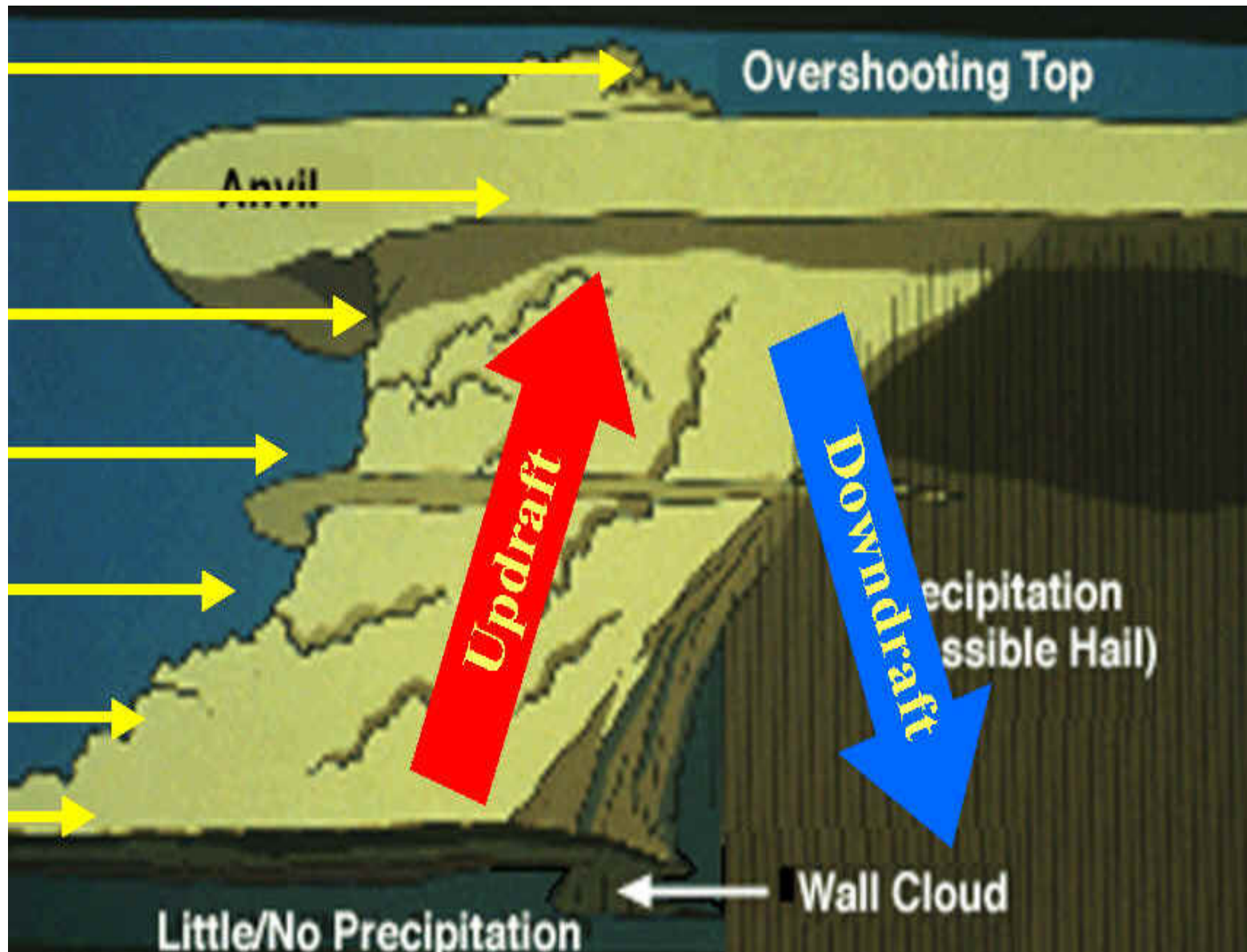
Vortices in Nature



World Book

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, the interface with the stratosphere.

The Supercell

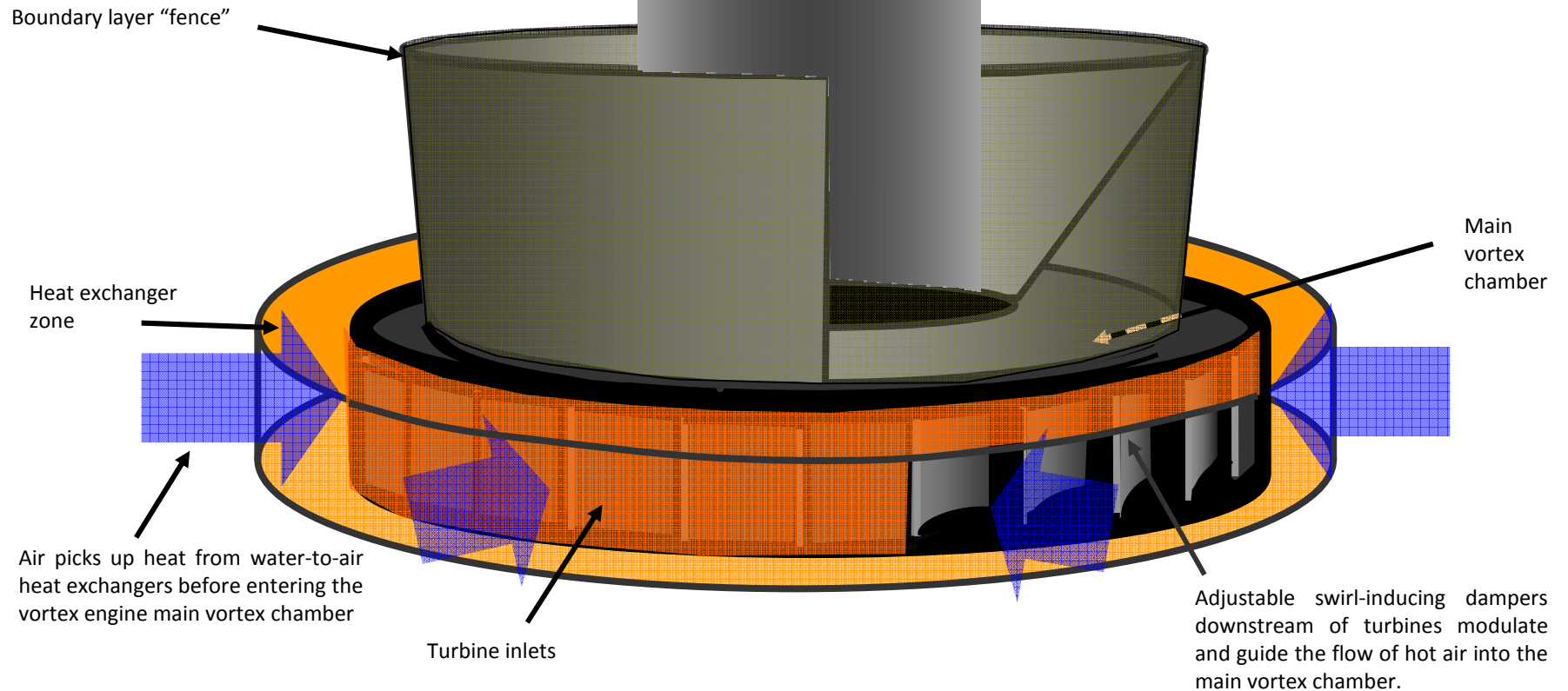


The Supercell



ROGER
EDWARDS

The Vortex Engine



The vortex chimney generated by the vortex engine can be regarded as a natural “worm hole” which is able to link the high and low temperature strata of the troposphere, thereby releasing the energy contained in atmospheric water vapour.

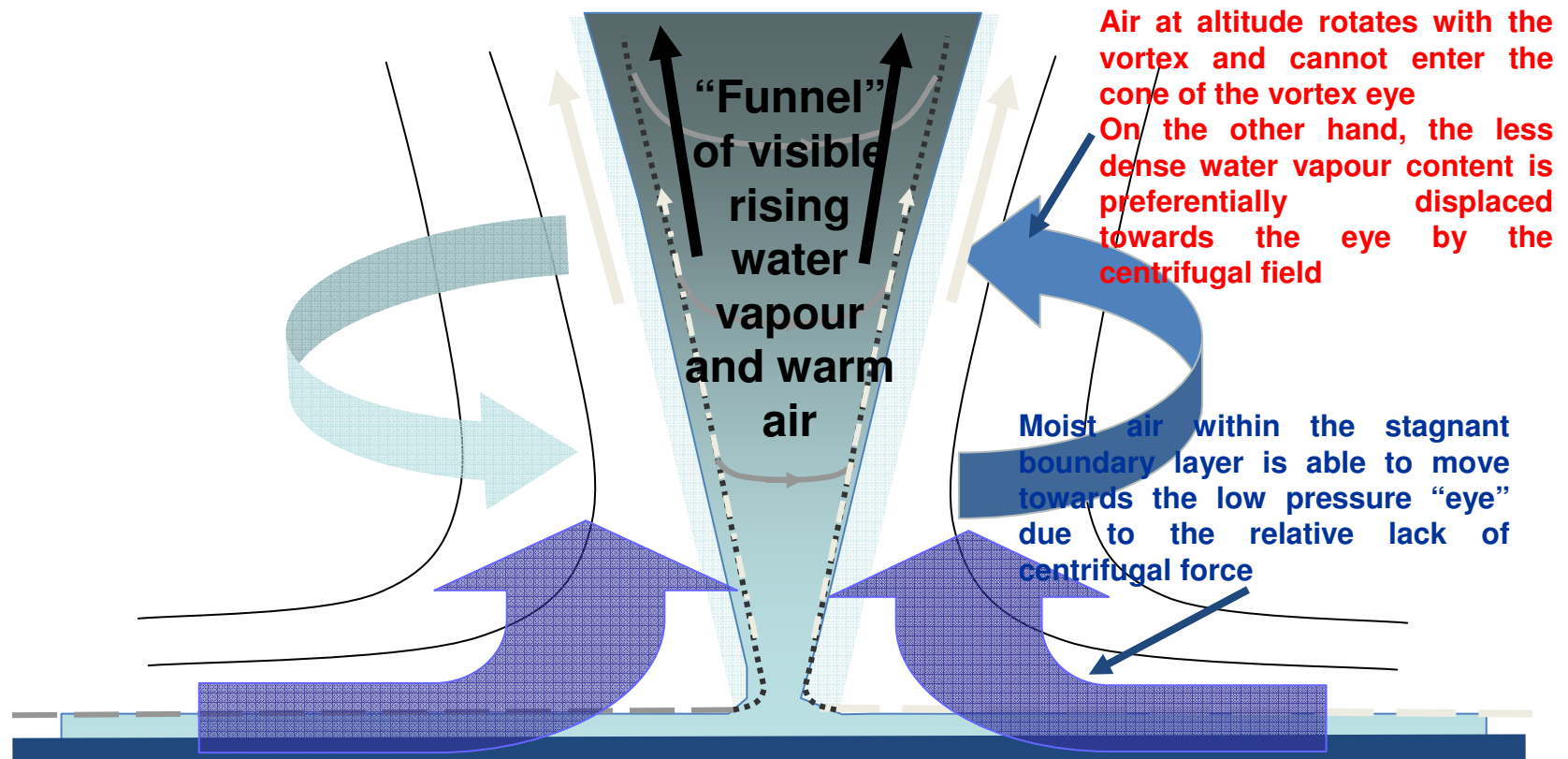
The Positive Feedback Effect Within a Vortex

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 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 used to drive hydroelectric turbines, so too the potential energy of a warm air/vapour mixture can drive wind turbines.

The Power of the Vortex



Diagrammatic representation of the dynamic vortex chimney in a tornado

The vortex naturally concentrates a highly buoyant and high-enthalpy air and water vapour mixture at its centre. It is thus an extremely non-linear system.

Airflow in a Vortex at Altitude

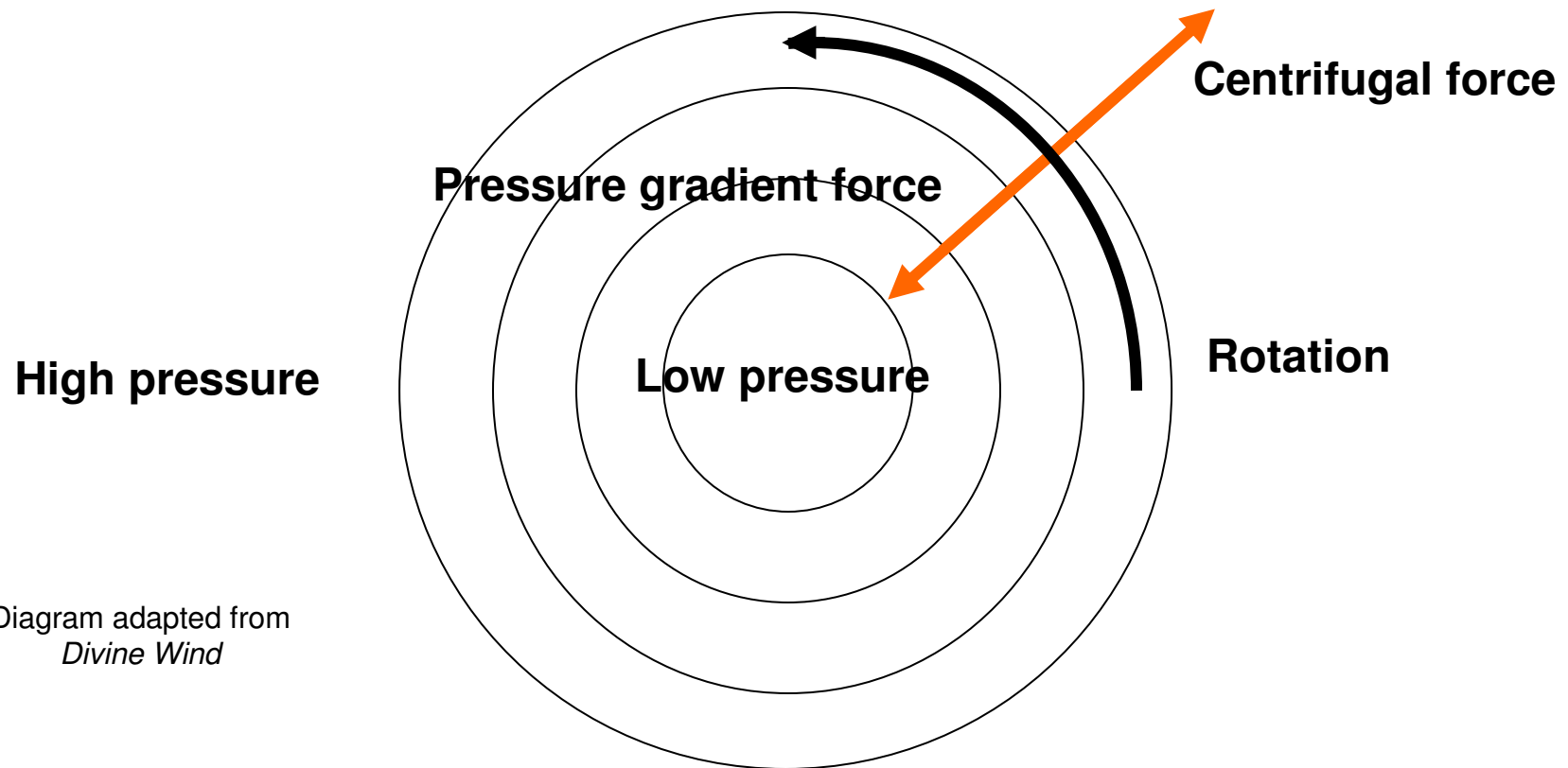
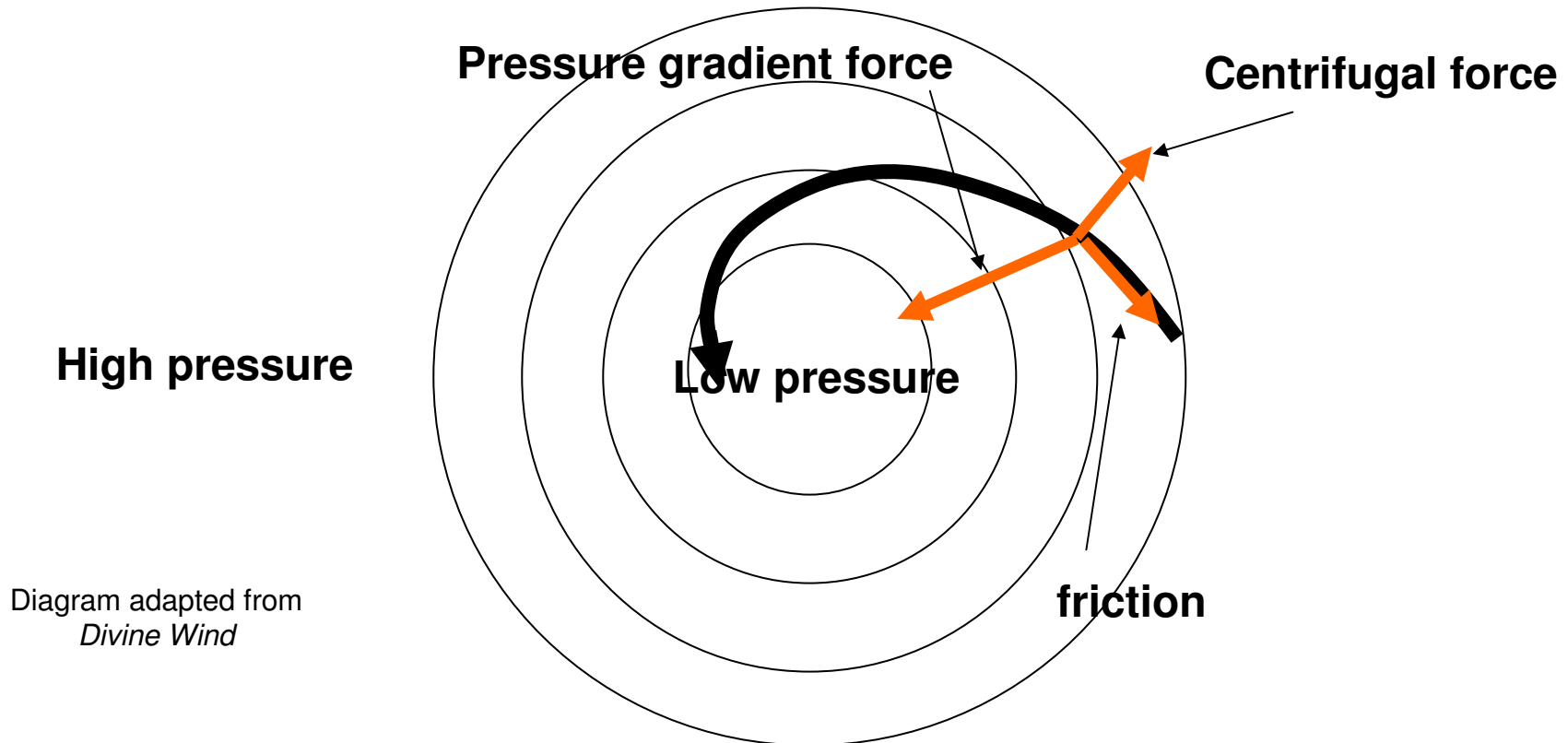


Diagram adapted from
Divine Wind

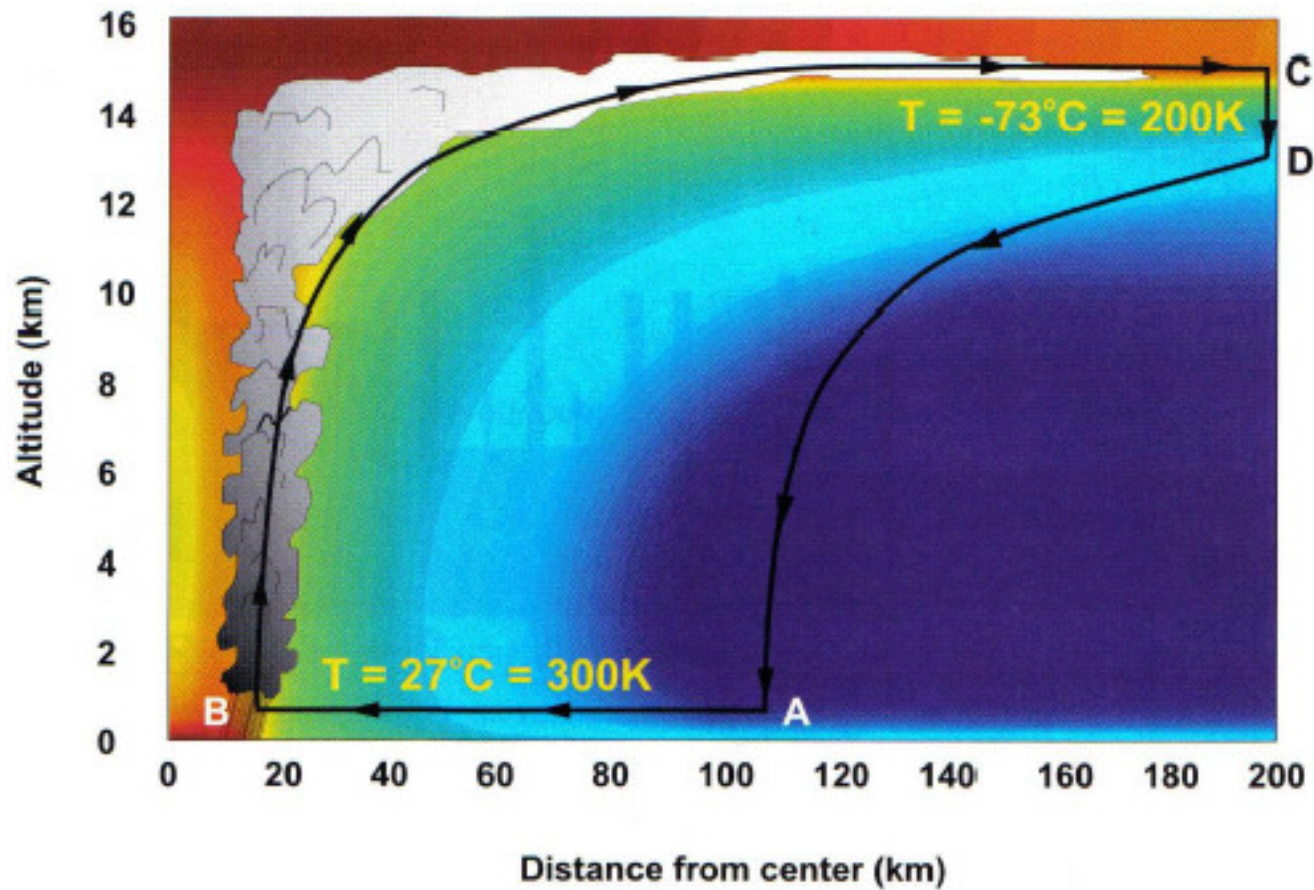
At altitude, the pressure gradient force (inwards) exactly equals the centrifugal force (outwards). Air rotates without a significant radial component

Airflow in a Vortex at 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 Tropical Cyclone seen as a Carnot Cycle



Efficiency

$$n = 1 - T_c / T_h = 1 - 200/300 = 33\%$$

(The colour coding indicates zones of equal entropy)

Geothermal Energy “Priming” of the Vortex Engine

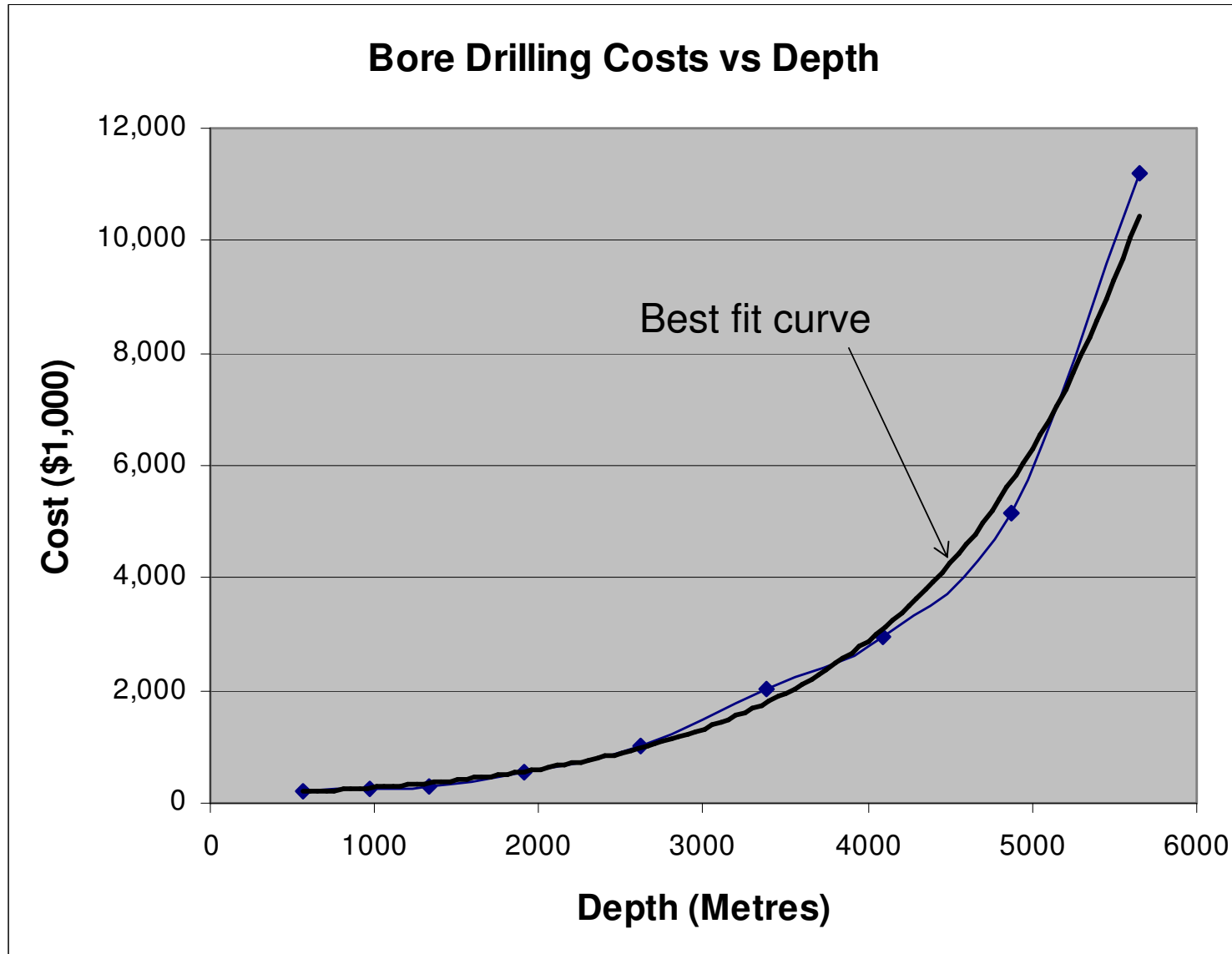
Vortex Engines will have to be located, initially at least, far from population centres. There will be a powerful “not in my back yard” effect.

Geothermal energy is therefore a prime candidate to prime the vortex engine process.

The Atmospheric Vortex Engine can work satisfactorily with *low grade* geothermal energy ($<100^{\circ}\text{C}$), whereas typical Rankine cycle power plant requires temperatures above 200°C .

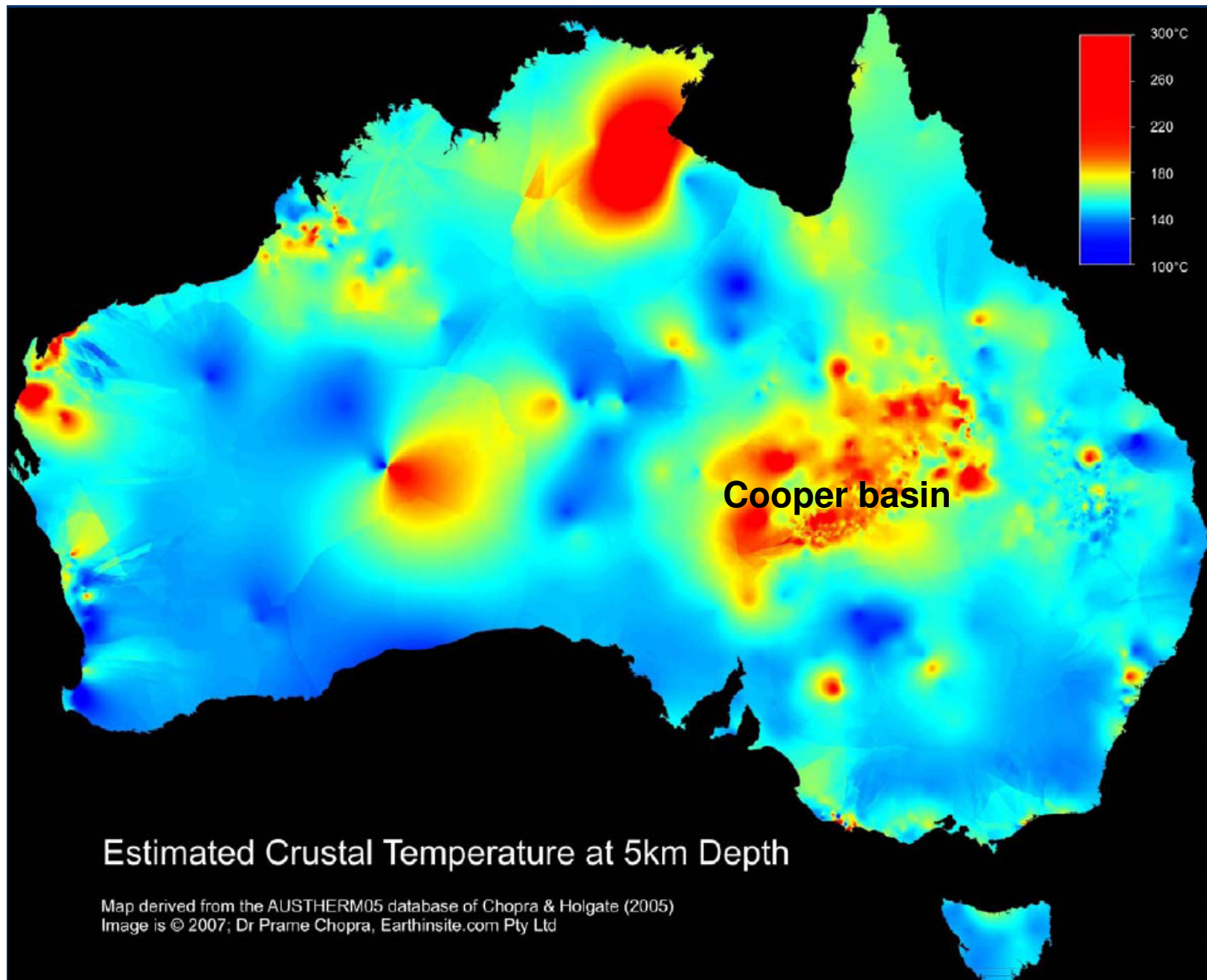
In the best geothermal fields in Australia, depths of 4+ km are required to get over 200°C .

Geothermal Energy Economics



(source: A Comparison of Geothermal with Oil & Gas Well Drilling Costs – MIT)

From the drilling cost graph, it can be seen that because of the power law on the drilling cost curve, the economics are radically improved by using shallower bores. Alternatively an otherwise uneconomic geothermal field can be tapped closer to the end use point, dramatically reducing transmission costs. For instance the Cooper basin field in Australia is about 1000 km from the end use point. Transmission costs are typically in the order of \$1 million per km, hence adding \$1 billion to the cost of a power station.



Atmospheric Water Content

- It has been estimated that only 2% of the atmospheric water content is in the form of clouds. The remaining 98% is in the form of water vapour.
- At 1% average water content, the lowest one kilometre of the atmosphere above the Australian continent contains in the region of 100 billion tonnes of water.

The increasing number and severity of tropical cyclones and tornadoes in some regions is arguably a pointer to Earth's need to dump heat to Space.

That's fine, but we need to learn to control the location, frequency and intensity of the process... hence the need for vortex engine research

Why Won't it Run Away?

The humidity of the surrounding field would be kept below the critical level at which the vortex would be self-sustaining. Only after passing geothermal steam through the vortex engine heat exchangers would the energy level become super-critical. The “boundary layer fence” would act to quarantine the vortex from the surrounding boundary layer except for allowing flow of air through the control dampers and turbines.

What Sort of Power Will Be Produced?

Based on a similar total power to an average tornado (1 GW expended) and an overall system efficiency of around, say, 20%, a power output of 200 MW could be expected per engine.

How much precipitation can be expected?

A 200 MW vortex engine is expected to generate around 20,000 tonne of precipitation per day, assuming 1% atmospheric water content and evaporation losses of around 50% in falling to earth.

If it falls within a radius of 10 km, this would theoretically amount to only about 30 mm per annum. There is some reason to believe this may be amplified by natural processes.

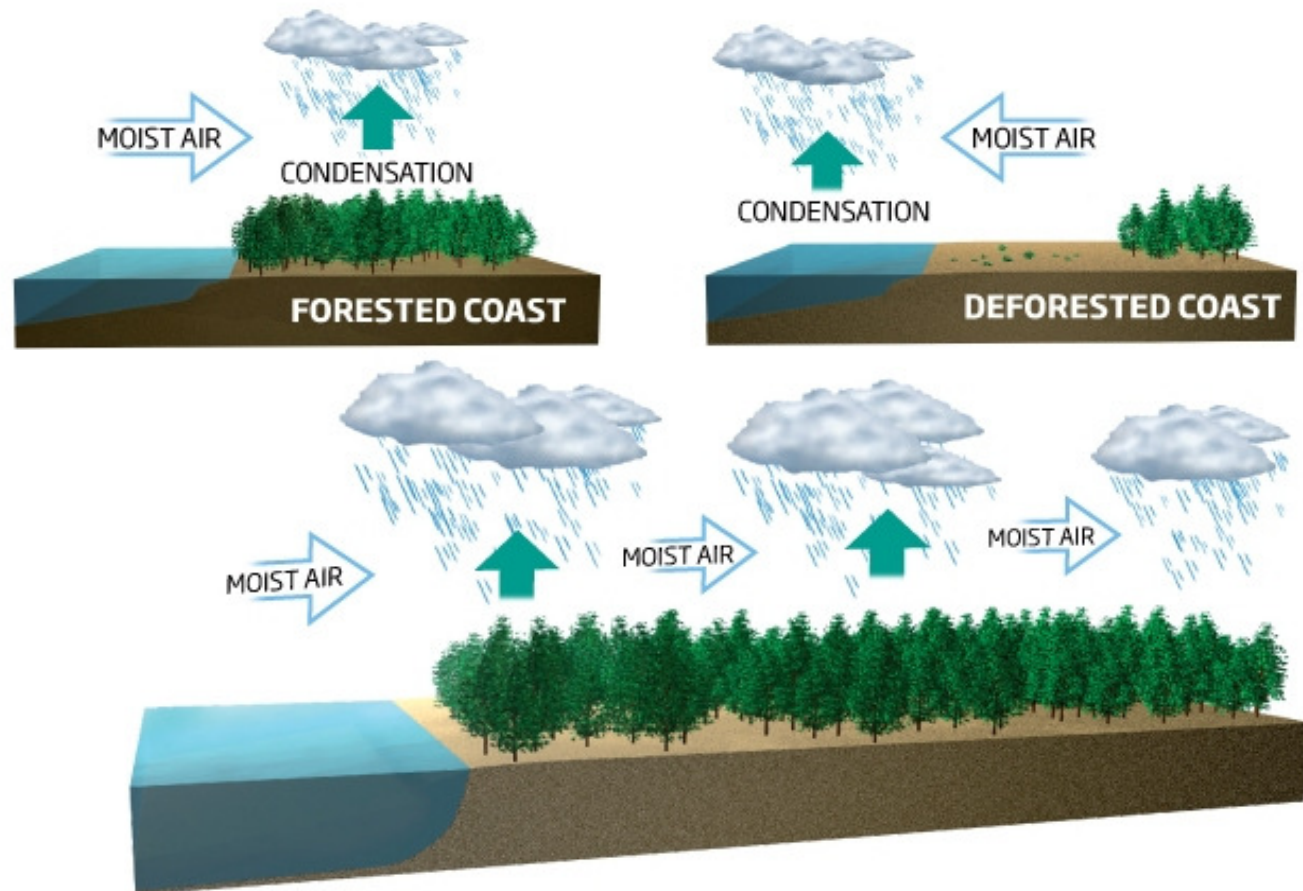
Forest Rainfall Generation

Biotic pump

A controversial theory could explain how large volumes of water reach thousands of kilometres inland

Water vapour over coastal forests condenses to form droplets and clouds. This lowers local air pressure and sucks in moist air from the ocean

If coastal forests are cut, the winds reverse



On a large continent with a forested coast, the rain exported inland helps the forest expand. This process repeats itself, sustaining forest right into the continent's heart

Rainforest Evaporation

“The volumes of water involved in this process can be huge. More moisture typically evaporates from rainforests than from the ocean. The Amazon rainforest, for example, releases 20 trillion litres of moisture every day.”

New Scientist 01 April 2009

A particle of water is recycled many times through the precipitation cycle as it moves inland through a forest such as the Amazon.

Advantages of Convective Vortex Systems

- Reduced CO₂ emissions
- Zero fossil fuel use – instead utilization of stored solar energy within atmospheric water vapour and air
- Increased precipitation over land means increased plant growth and subsequent photosynthesis – hence natural sequestration of CO₂
- Increased heat radiation to space – hence global cooling
- Significantly increased terrestrial Albedo

Will it Work?

‘Nilton Renno, a professor at the department of atmospheric, ocean and space sciences at the University of Michigan, has spent his career studying tornadoes and water spouts. He says there is no reason why Michaud’s vortex engine wouldn’t work.’

“The concept is solid,” says Renno.

...‘Still, Renno is not without reservations. He’s particularly concerned about the ability to control such a powerful monster.’

“‘The amount of energy is huge. Once it gets going it may be too hard to stop,” he says.’

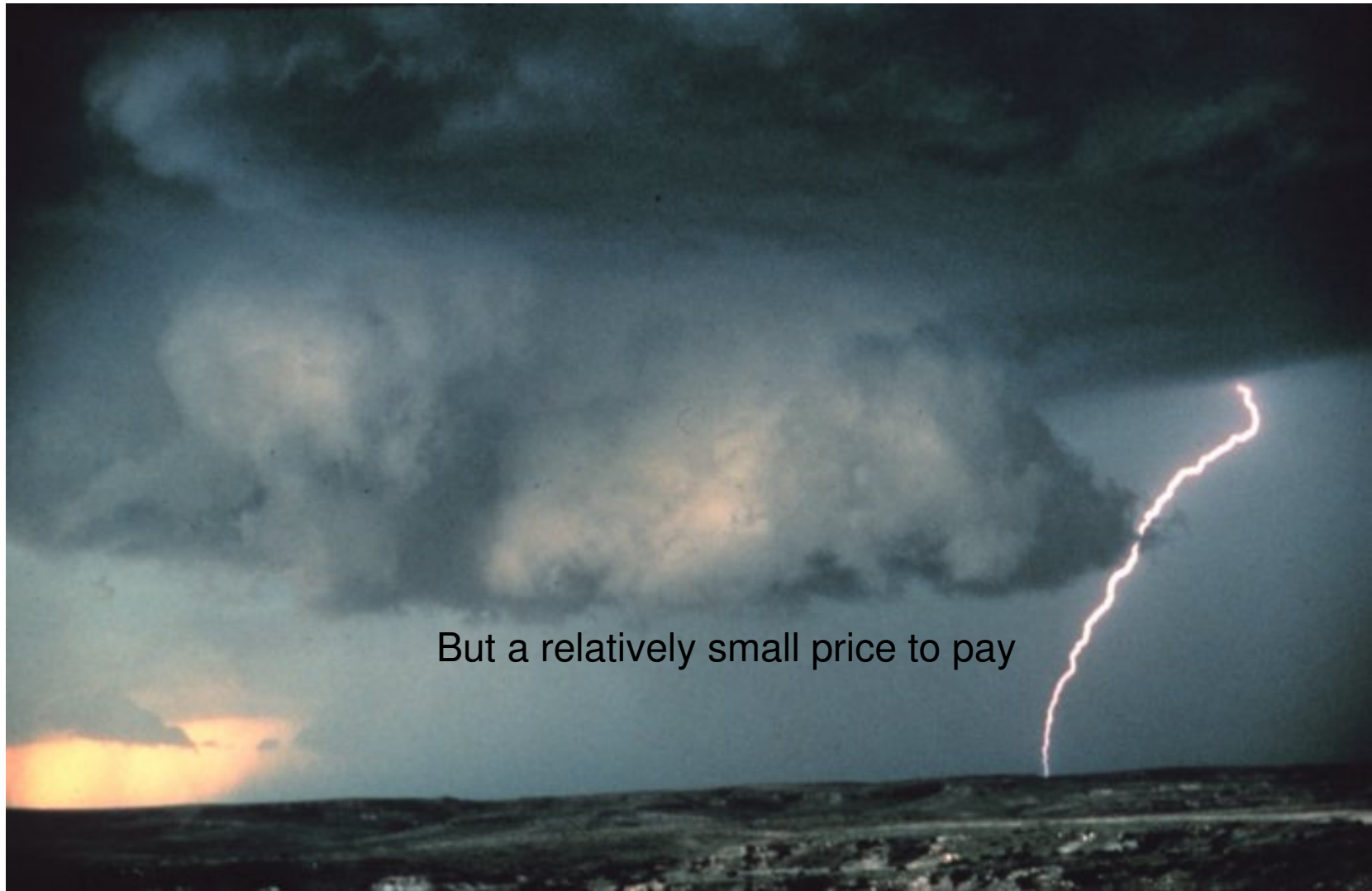
The Toronto Star July 21 2007

This is where research and development engineering is needed...

“What’s necessary at this point is to do proofs of concept,” says professor Kerry Emanuel, the hurricane expert at MIT. “[Michaud’s] idea is pretty simple and elegant. My own feeling is that we ought to be pouring money into all kinds of alternative energy research. There’s almost nothing to lose in trying this...”

ODE Magazine March 2008

Uh Oh... Lightning!



But a relatively small price to pay

Harnessing the vortex principle will not be easy, and the risks are significant.

On the other hand there is a strong argument that research **must be carried out to determine its viability.**

The End