

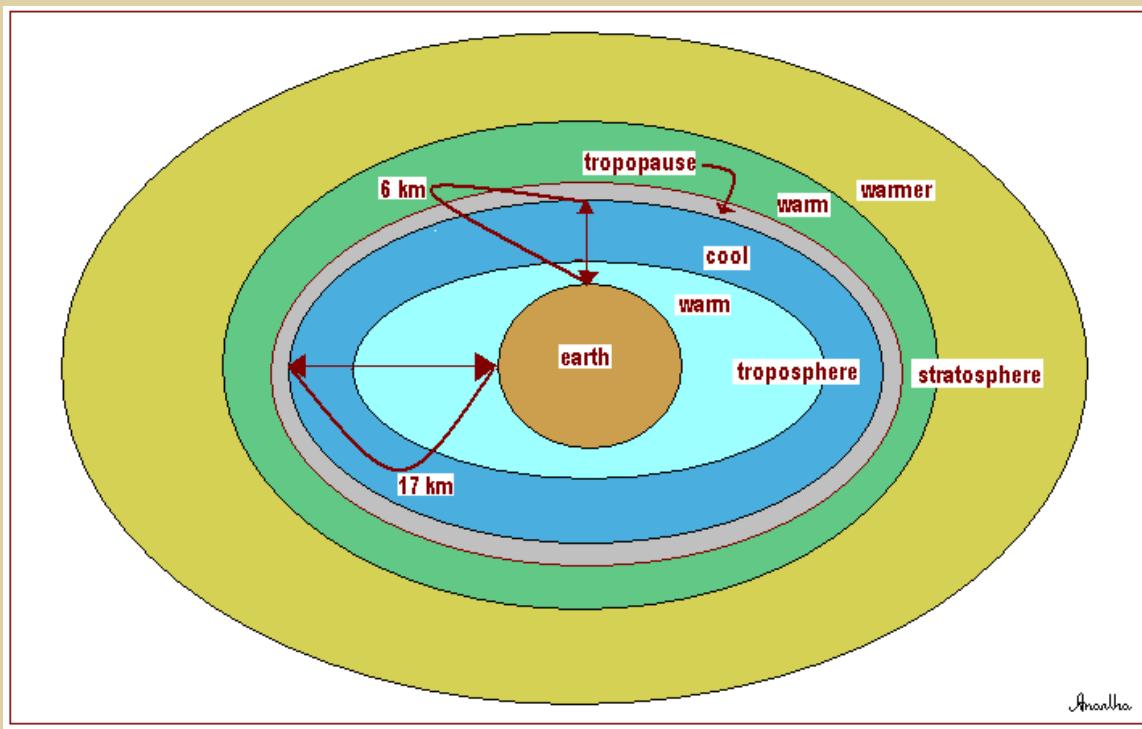
# Windmills 9 km up in sky!

Harnessing wind power high up in the *tropopause* may prove the answer to the world's energy crisis, says S.Ananthanaryanan.

Groups working in the US, Netherlands and Canada are readying to set up wind farms nine kilometers up in the sky. This is where we have the so called *jet stream*, or corridors of high velocity winds, which high altitude aircraft make use of while flying eastwards.

## Structure of atmosphere

The earth's atmosphere broadly consists of two parts – the troposphere and the stratosphere. The troposphere is the lower of the two - from six to seventeen km up from the ground. This, lower part of the atmosphere is where the air gets cooler as one goes higher and where all the phenomena of *weather*, like rainfall and storms, take place. When one goes beyond this height, the air begins to absorb the ultra violet radiation from the sun and gets warmer as the altitude increases.



This condition, of warm air being above and cool air being below is a stable state. The air thus remains in *strata* and the region is called the *stratosphere*. In the troposphere, where the air is cooler as one goes higher, the cool air is at high altitudes and tries to descend, while warm air near the ground tries to rise. This leads to convection currents, the rain cycle and all else.

The boundary area, where the ‘cooling with height’ changes to ‘warming’, is called the **tropopause**. The tropopause is at about seventeen km at the equator and about six km at the poles. We can see that this is the surface of the lowest temperature, as things begin to warm up when we go higher. The actual temperature is around -50°C

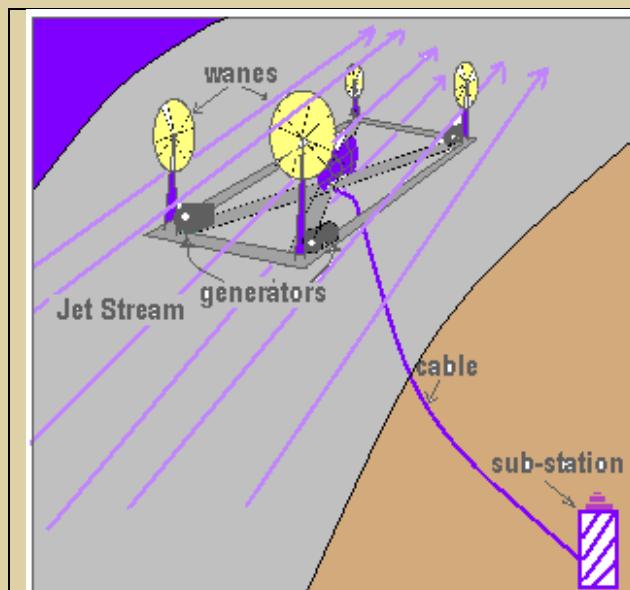
### Jet streams

Winds are caused by 2 reasons – by differences in pressure and by the rotation of the earth. At the place where two air masses at different temperatures meet, the cool air, at higher pressure, will flow towards the warm. Typically, the poles are cooler than the tropics and winds tend to move away from the poles. The air from the across the equator also moves towards the tropics and then on towards the poles. Now air at the equator and tropics is also rotating from west to east along with the earth, and when it moves towards the poles, it must move in smaller circles. The air-stream hence swings to the east and this leads to formation of vortices and cyclones. For this and other reasons, masses of air with different densities collect around the mid-latitudes.

It is hence at midlatitudes that masses of air at different temperatures meet. But the rotation of the earth again prevents the air from flowing directly from one mass to the other, and drives it **along the boundary** between the 2 air masses. These are the corridors of wind, which constitute the **jet stream**. The jet stream is strongest at the tropopause and is made use of aircraft, like ships use ocean currents. The same stream is now seen as a source of energy for power generation.

### Wind farms

The idea first came to Bryan Roberts, an engineer in Australia, who worked out how to extract energy using a fleet of whirring “gyromills” at more than four kilometres above the ground. Compared to the slow winds near ground level, the jet stream is a torrent, which can reach a speed of 500 kilometres per hour. The power available in the jet streams is over a thousand times more than can be collected from windy hilltops.



The whole concept is challenging, as it involves getting the massive windmills ideally seven to nine km up, with anchoring wires to help the windmills stay aloft, like a kite, and then to keep a high tension power cable connected, for getting the power down for use. One design being considered by a group in California has four rotary blades mounted on an ‘H’ shaped frame, connected to the ground by the power line. The prototypes are planned to take off like helicopters, powered through the electric cable, and once in the jet stream, they would stay there like giant kites, anchored against the wind by stay wires..

"If we were able to tap 1% of the wind energy at high altitude, that would be enough to supply all of the world's energy needs," says David Shepard, president of the group working in Coronado, California.

---