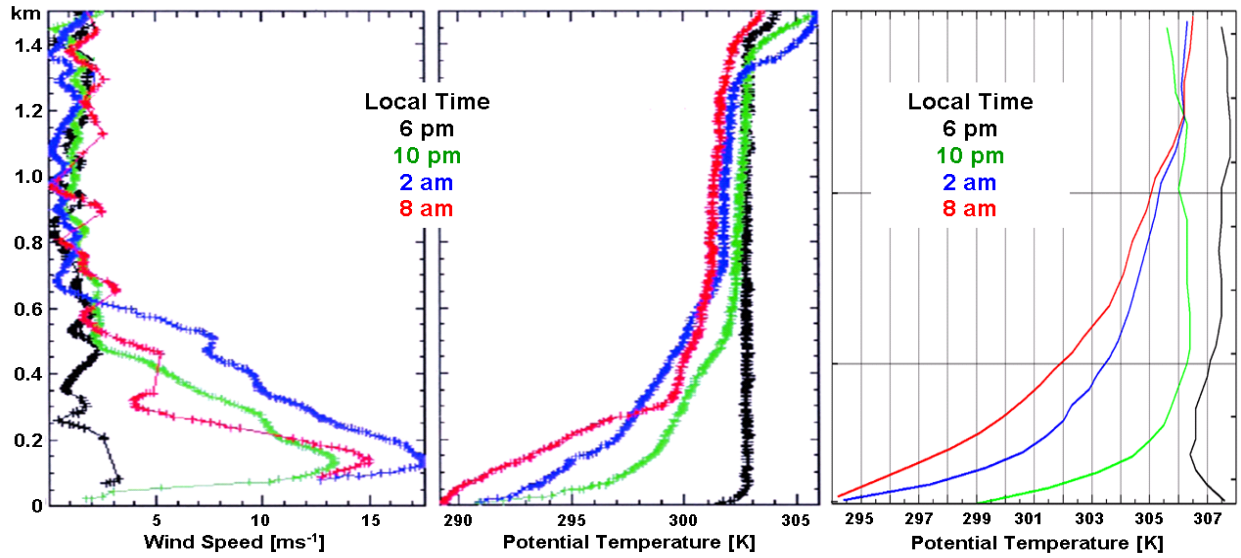
# Thermodynamic Profiling and Wind Energy

Boundary layer temperature and humidity (thermodynamics) and wind speed are closely linked. As shown below, radiosonde measurements show 15 m/sec average wind speed at 100-150 m height during stable conditions and less than 5 m/sec during unstable conditions. Stable conditions occur when potential temperature increases with height (red, blue and green traces, middle and right panels) and unstable conditions occur when potential temperature is constant with height (black). Potential temperature[1] profiles are calculated from temperature and humidity profiles.




*Radiosonde wind speed and potential temperature (left; Poulos et al, 2002); radiometer potential temperature (right).*

At mid-latitudes during clear nighttime conditions, near surface air cools faster than the overlying air, creating surface temperature inversions and stable conditions. During clear daytime conditions, solar heating generates thermals (similar to bubbles rising in boiling water on a stove) resulting in unstable conditions. As seen above, hub height (80-120 m) winds maximize during stable (potential temperature increasing with height) conditions and minimize during neutral or unstable (potential temperature constant or decreasing with height) conditions.

Air pressure differences over distance are fundamental drivers of near surface winds. During stable conditions, near surface air flow is relatively unimpeded compared to unstable conditions with thermal turbulence. For example, Nocturnal Low Level Jets (Karipot et al., 2011) occur during stable conditions.

Radiometer and tower data comparisons demonstrate the accuracy and practicality of radiometric thermodynamic profiling for wind energy forecasting and management (Friedrich et al., 2012).

Major utilities in California and Hawaii recognize the importance of boundary layer thermodynamic profiling for wind energy management and are using radiometer derived

[1] http://en.wikipedia.org/wiki/Potential_temperature

atmospheric stability[2] to forecast hub height wind speed several hours ahead. John Zack, a meteorologist and wind energy prediction expert[3] provides additional perspective:

Monitoring the vertical temperature profile at a wind farm site is an important tool for predicting some types of large power production change events that can't be predicted from wind speed and direction measurements at off-site met tower locations. Off-site measurements are sometimes helpful to predict changes caused by horizontally propagating events but not those associated with changes in the intensity of vertical turbulent mixing, which requires monitoring of the vertical temperature profiles with a sensor such as a radiometer.

New York State is establishing continuous thermodynamic and wind profiling capability to provide essential information for wind energy productivity and use as part of a statewide network[4]. Delivery of Radiometrics MP-3000A thermodynamic profilers for the 17-site network is nearly complete (August, 2016); each site also includes Doppler lidar wind profilers.

## References

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[2] From MP-3000A microwave profilers (www.radiometrics.com)
[3] Meso Inc. (www.meso.com)
[4] New York State Mesonet (www.nysm.org)