High Fidelity Humidity Sensor

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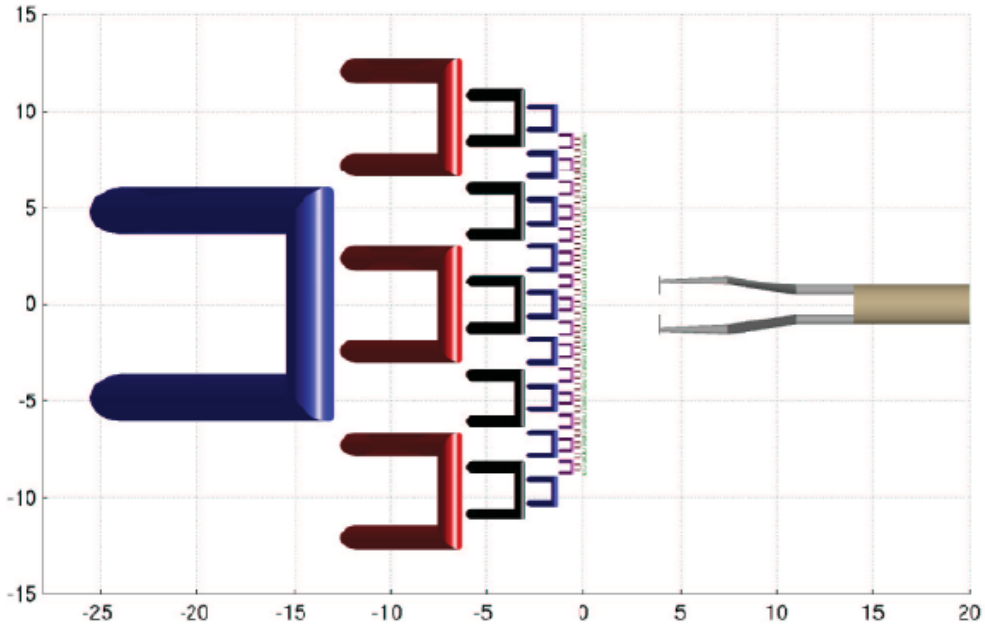
MATERHORN

Team background

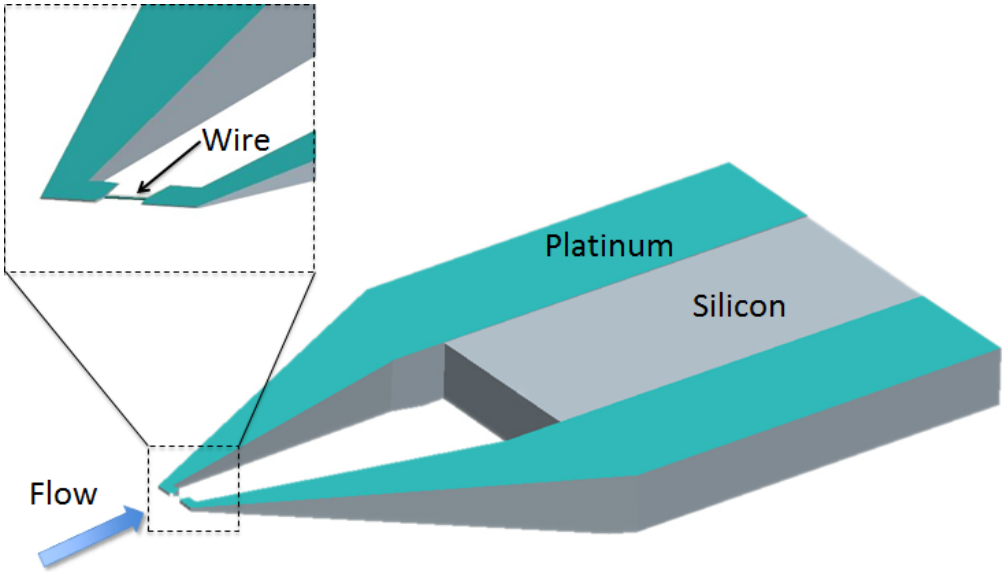
- High Reynolds number laboratory experiments.
- Princeton/ONR Superpipe.
- High Reynolds number Test Facility (HRTF).
- Can reach Reynolds numbers close to those in the ABL.

Team background

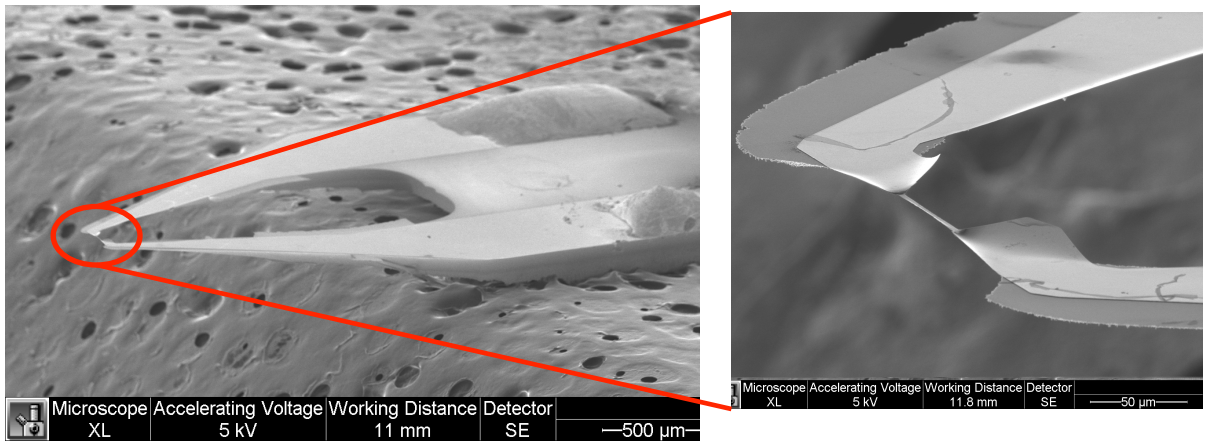
- Kolmogorov scale in these facilities are on the order microns.
- Developing sub-miniature fast response sensors to resolve full spectrum of turbulence



Nano Scale Thermal Anemometry Probe (NSTAP)

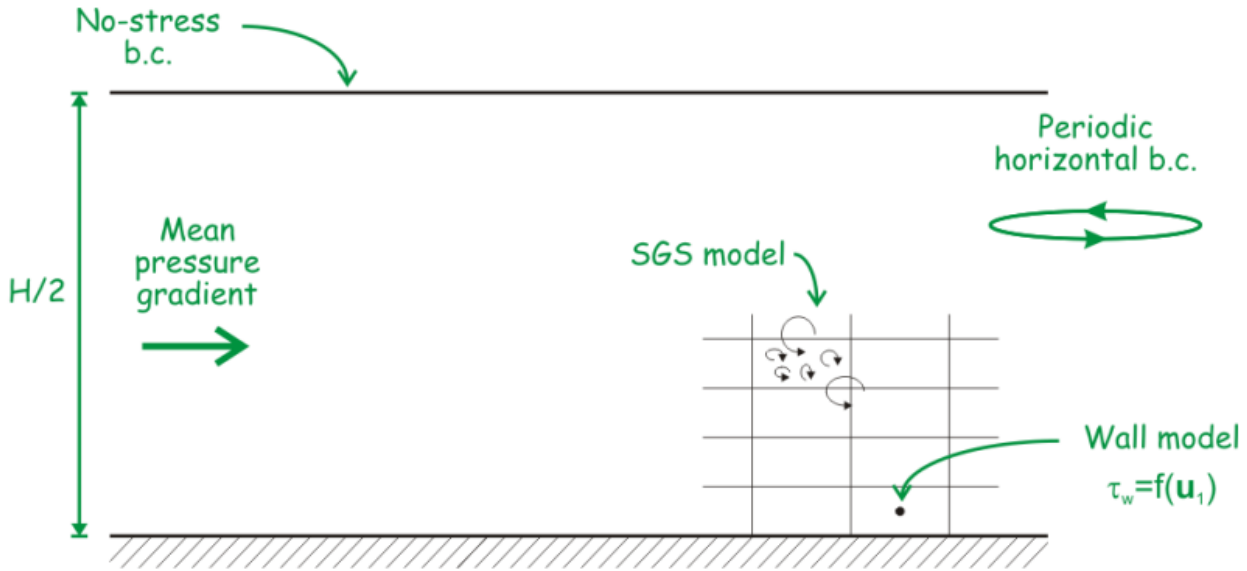


- Hot-wire
- Platinum wire
- Sensing volume of 100nm x 2 µm x 30/60 µm
- Operated with a conven-tional anemometer box (CTA)
- Frequency response >200kHz



Team background

- Based on the results from the high Reynolds number dataset a new formulation for the wall shear stress was developed.
- Working together with Prof. Marc Parlange at EPFL to incorporate this formulation into boundary conditions of LES to be used on heterogeneous surfaces



Atmospheric measurements

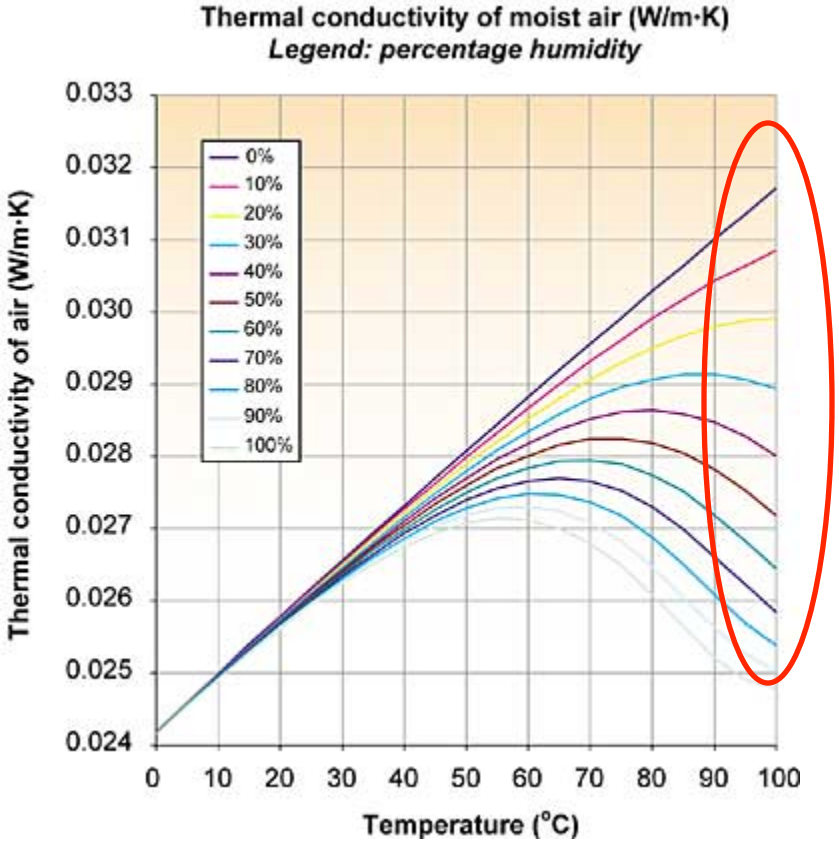
- One of the main fluxes of energy from the surface to the atmosphere is the latent heat flux.
- Poor understanding, partly because of limited measurement techniques.
- Need to measure humidity and surface-normal velocity at the same point and time in space, the flux is their covariance ($\overline{w'q'}$)
- Measuring small scale humidity fluctuations
  - Fast response
  - Small sensor volume
  - Low cost

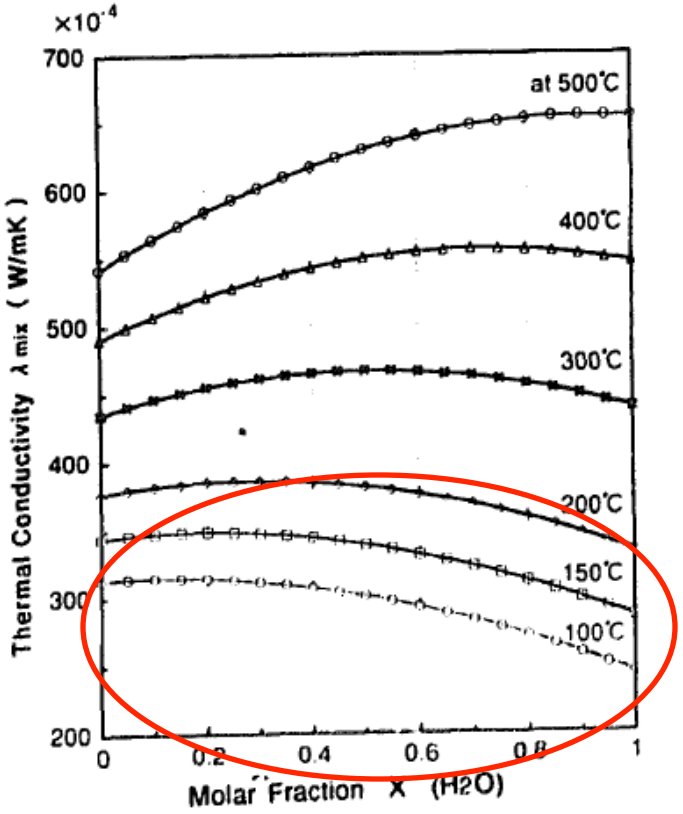
Can use new knowledge to design a better atmospheric probe

- Measure humidity fluctuations
  - Small scale approx. 0.2mm
  - Fast response approx 10kHz
  - Improve measurements of latent heat flux
- Use the same principle as a hot-wire
  - Conductivity is a strong function of humidity.
- Reduce sensitivity to velocity

Can use new knowledge to design a better atmospheric probe

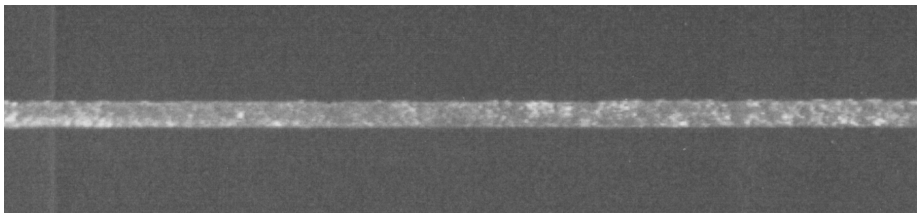
- Use the same principle as a hot-wire
  - Conductivity is a strong function of humidity.
  - Feed constant current measure wire temperature.

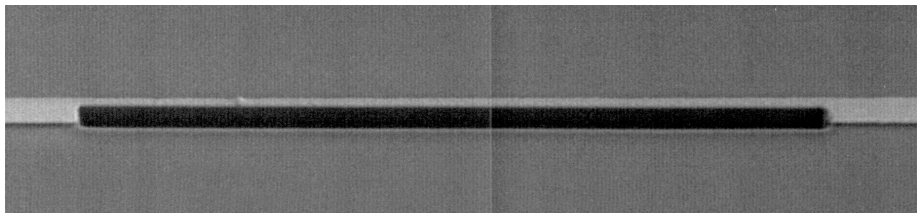




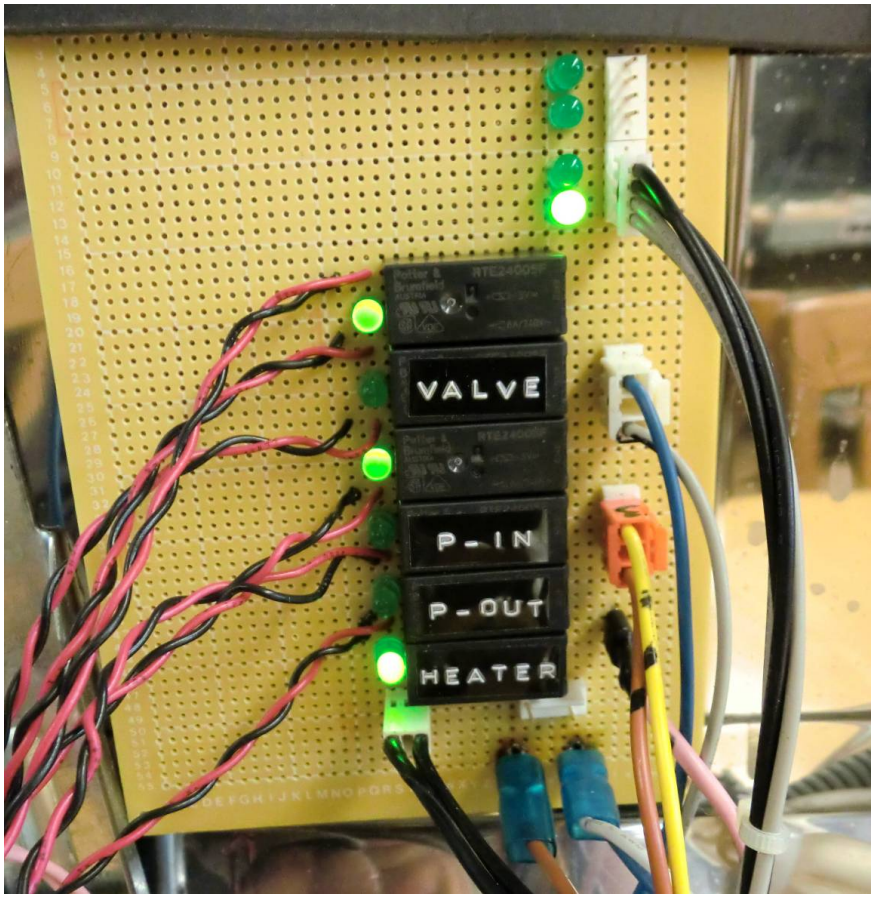
Reducing sensitivity to velocity

- Peclet number is the ratio of convection to conduction.
- $Pe = RePr = \text{convection to the air} / \text{conduction to the air}$
- If we can reduce the Reynolds number so that the Peclet number is below unity, we can separate sensitivity of velocity from that of humidity.

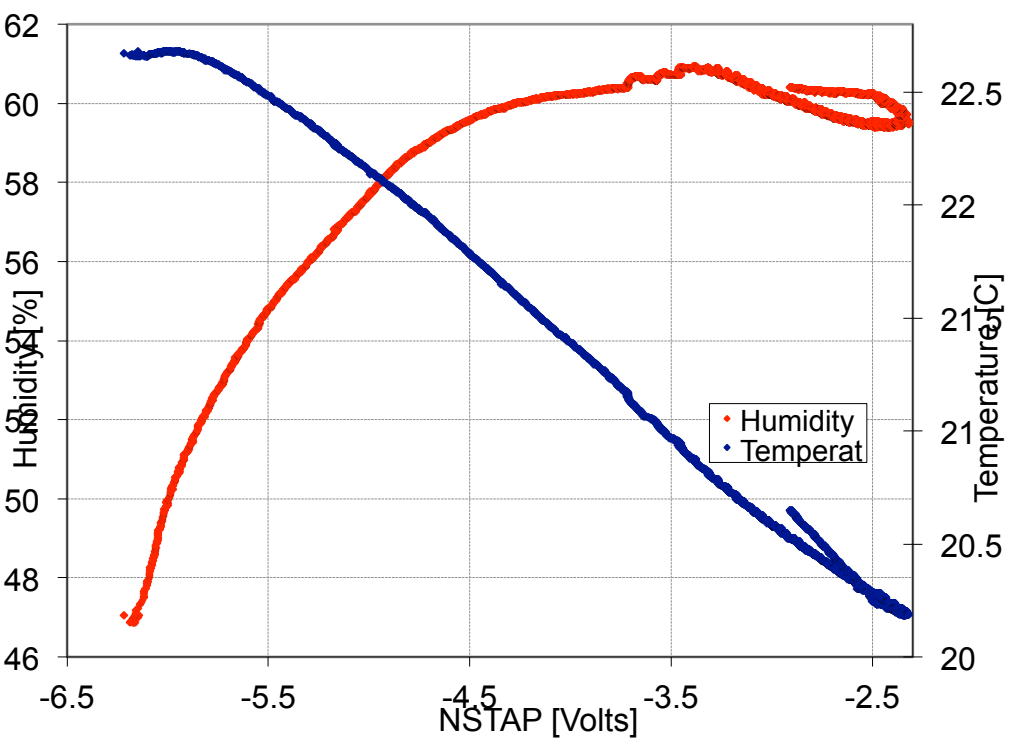




Humidity chamber

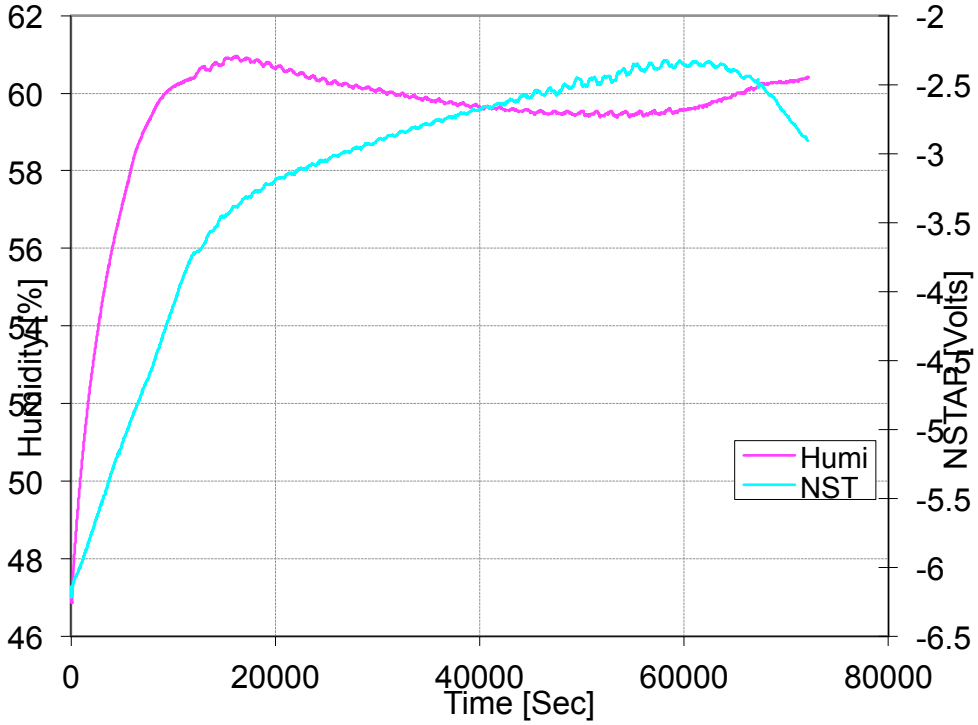


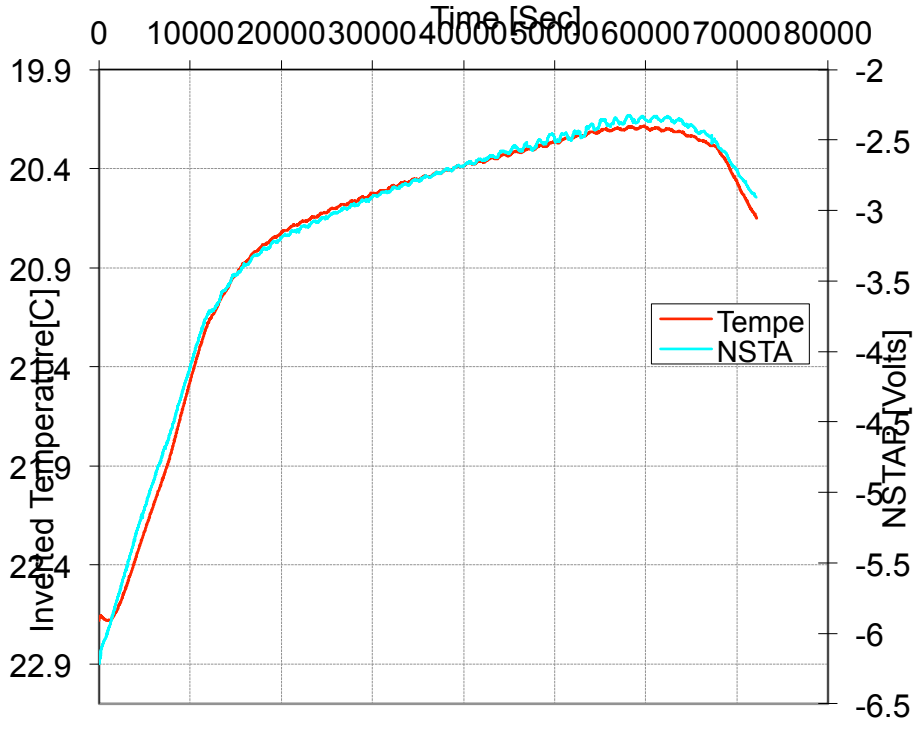
Humidity chamber



Can regulate temperature and humidity independently of each other.

Calibration

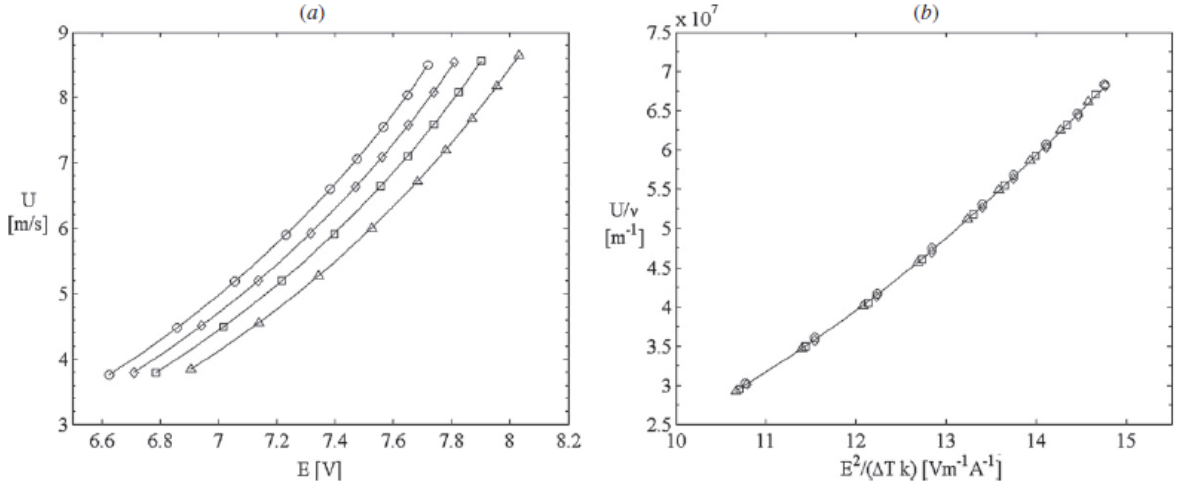




- Sensor is very sensitive to temperature.
- Need to separate the effects of temperature from that of humidity.

Temperature compensation

- Post processing
  - Technique we have developed to correct hot-wire measurements for changes in ambient temperature.
  - Can be rewritten for the case of low Peclet number.



- Active compensation
  - Two wires exposed to temperature, only one to humidity.
  - Automatically balances out temperature changes.

Great complement to Pardyjak's effort

- Eric Pardyjak will have detailed resolved measurements of velocity and temperature.
- Can use the same infrastructure with the addition of these probes.
- Both latent heat flux and sensible heat flux can be measured in detail allowing for a complete overview of the energy budget on the atmospheric side.
- Will be joining for the April campaign.