# Measurement and Improved Understanding of Mixing and Vertical Transport and the Evaluation of these Processes in Mesoscale Models

## Outline

1. Research interests and staff

2. Pre-VTMX experiments, instruments and goals

3. Mesoscale modeling: past experience

4. Our planned efforts for VTMX

# Staff and Research Interests

- Evaluate the role of terrain induced-circulations and transient mesoscale flows in controlling the location and intensity of mixing and vertical transport within stable layers and transition boundary layers. *(**Dave Parsons and Steve Cohn**)*

- Evaluate and improve our ability to observe mixing and vertical transport events using remote sensing techniques (***William Brown and Steve Cohn***)

- Verify and improve mesoscale model predictions of mixing and vertical transport under conditions of interest to VTMX (***Dave Parsons***)

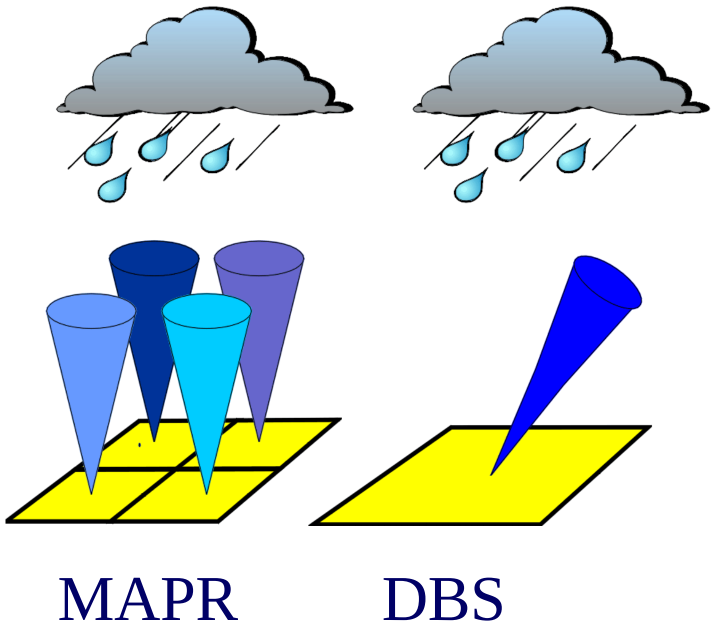
- Examine the vertical profile of turbulent kinetic energy within transition boundary layers through collaboration with other VTMX investigators (***Tom Horst***)

# Overall goals for MAPR

- Rapid measurement of the three-dimensional wind
- Estimates of turbulent intensity
- Detection of three-dimensional winds and heat flux from applying spaced antenna techniques to radio acoustic sounding system (RASS)
- Incorporation of multiple wavelengths and FDI processing to detect and monitor the evolution of fine-scale refractivity layers

# MAPR (with clutter screen) at NOAA's 300m BAO tower

# MAPR compared with conventional DBS profilers




- **MAPR uses Spaced Antenna techniques to measure wind. Atmospheric echoes are essentially tracked as they move over four vertically pointing antenna.**

- **Conventional DBS (Doppler Beam Swinging) profilers use a single antenna pointed in 3 or 5 orthogonal directions. The wind is derived from the Doppler shift of the echoes in each direction.**

# MAPR compared with conventional DBS profilers

**Advantages**

- **MAPR can make a much faster wind measurement because:**

  **The antenna is not pointed in a series of different directions, thus -**

  **assumes uniform wind field over much smaller volume so requires less averaging**

  **⇒ MAPR can make a wind measurement in 1 - 5 minutes**

  – **(DBS Profilers require 10 – 30 minutes)**
- **MAPR provides continuous vertical measurements**
- **MAPR does not need mechanical phase switches to steer the antenna**

**Disadvantages**

- **MAPR requires 4 antennas and receivers**
- **Data analysis more sophisticated**
- **Less sensitivity so more powerful transmitter required**

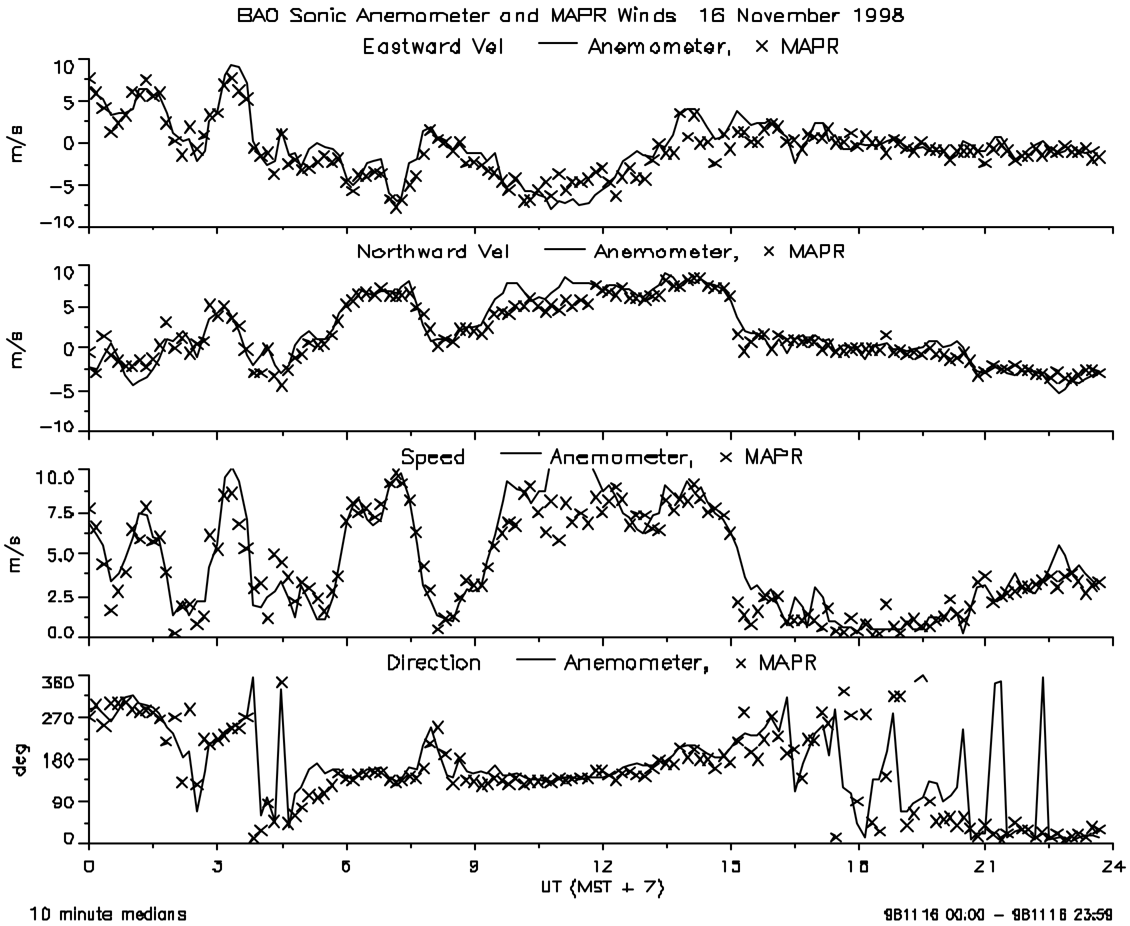
# Relevant pre-VTMX experiments

1. Front Range winter 1998-1999 experiment:
   - *Technical motivation:* Advanced profiling techniques need better verification
   - *Atmospheric motivation:* Examination of terrain induced flows in the lower atmosphere (updrafts with frontal cold surges, down-slope wind storms, diurnal cycle, etc.)
   - *Primary instruments:* A Multiple Antenna Profiler (MAPR) was placed along the 100 m Boulder Observatory instrumented tower. (also surface sensors, 445 Mhz profiler, ceilometer)

# Some results from our Front Range Experiment

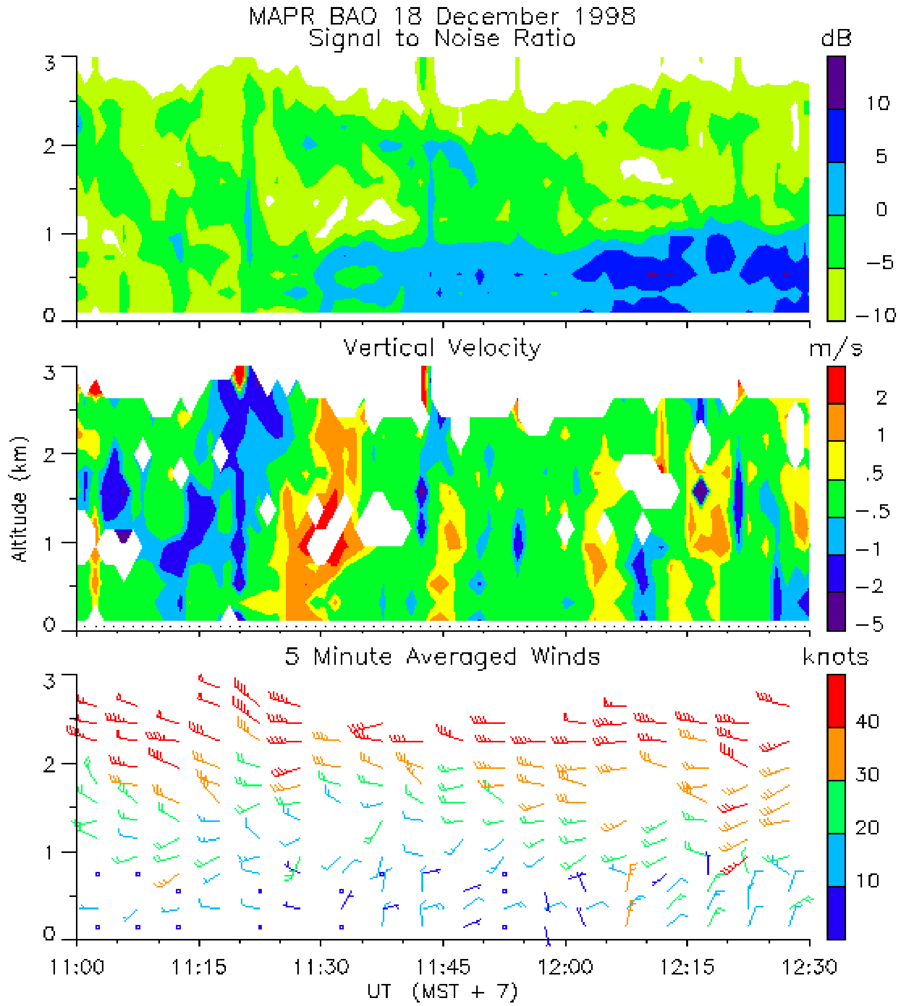
- Verification of the technique for rapid and continuous measurement of the three-dimensional wind field
- Organized vertical transport well detected, even weak nocturnal fronts have strong vertical ascent
- *Turbulence:* Statistics of vertical motion are promising. For mixing estimates, when turbulent intensity is high, events are well captured, but weak events over estimated.

# MAPR wind measurements (×) compared with anemometer measurements (line) on 300 meter BAO tower.

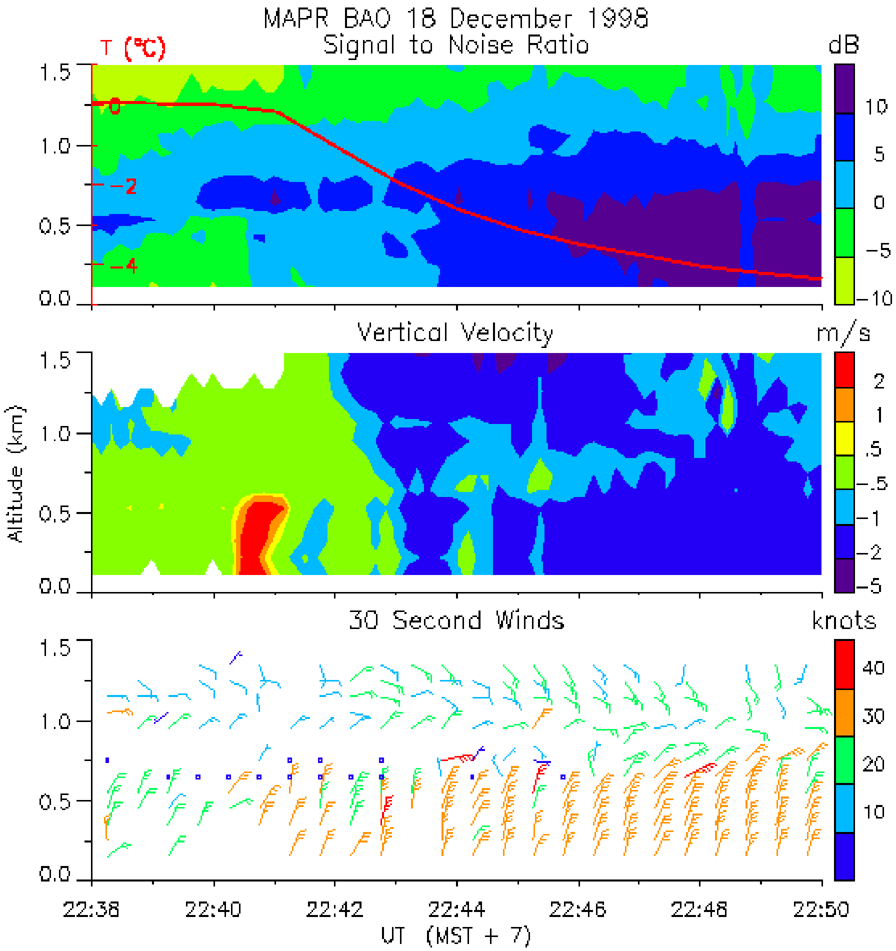


# Cold Front Observations

- MAPR observations of a cold front at Erie, Colorado. The upper panel indicates echo strength, the middle panel vertical motion, and the lower winds.
- Note the strong downdraft, followed by a strong updraft at the leading edge of the front. The periodic up and down motions, which follow, suggests gravity waves. The frontal passage at the surface was weak.



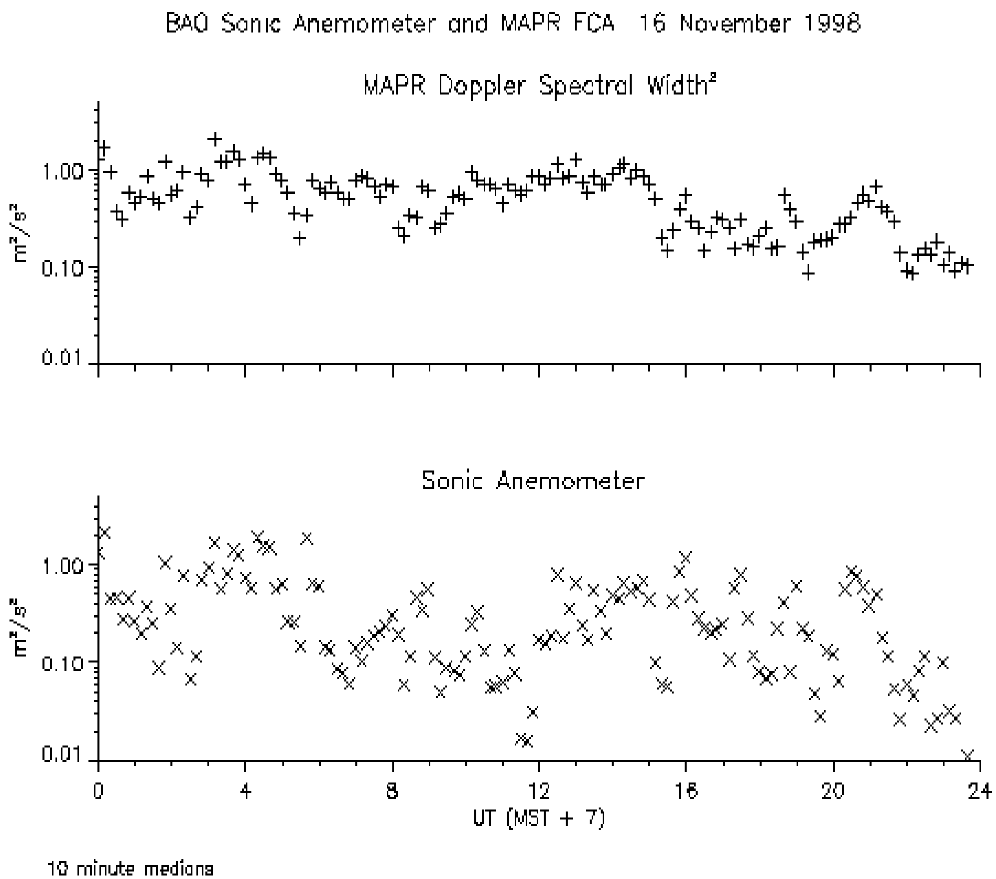
# Arctic Front Observations




**MAPR observations of an Arctic front following the previous cold front. The red line (upper panel) indicates surface temperature. The surface frontal passage is more pronounced in this case. The blue regions in the upper and middle panels correspond to snow. Note the brief, strong but shallow updraft (red region, middle panel) ahead of the front. MAPR has the unique capability to obtain rapid continuous measurements in situations such as these.**

# Turbulence Measurement

**MAPR can also estimate turbulent intensity.  This analysis is still being developed, but this example shows that the Doppler spectral width of MAPR echoes is related to velocity variance as measured by a sonic anemometer on the BAO tower.**



# Other pre-VTMX experiments

2. NAURU99: Several aircraft/MAPR comparisons were conducted to examine the ability to estimate turbulence intensity. Initial tests with RASS wind finding. (DOE ARM)
3. CASES99: Conventional wind profilers, surface flux sites and sounding systems. Stable boundary layers over flat terrain. (NSF)
4. Return to BAO tower for winter tests: Continuation of work on turbulence detection, RASS winds/fluxes, and hardware upgrades, clutter and bird removal. Lidar comparisons (VTMX)

# A Few Points on Mesoscale Modeling

- The Salt Lake City basin is complex: lake breezes, blocking of westerly flow by the steep Wasatch Range, canyon drainage flows, diurnally varying terrain flows, terrain extensions that are favorable for the generation of eddies and convergence zones (i.e., Meridian peak area), upstream orography. This fact argues the need for distributed observations and a modeling approach.
- We will undertake simulations likely with the Penn. State/NCAR Mesoscale model (MM5), where we have experience with four dimensional data assimilation and detailed comparisons with observations.
- Factors other than PBL parameterizations (cloud cover, resolution of terrain, surface properties) can strongly impact the ability to represent stable, winter boundary layers.

# Instruments for VTMX

- E-BLISS (Enhanced-Boundary Layer Integrated Sounding System)
  - MAPR
    - Increased transmitted power (from 460W to 2-3 kW) to allow for increased vertical resolution (>40 m)
    - We hope to implement FDI-multiple wavelength (resolve separate layers within the radar volume)
    - Operation in RASS mode possible
  - Doppler SODAR
  - Surface site with radiation
  - TAOS (Tethered Atmospheric Observing System) 8 level system for heights below 1 km
  - Rawinsonde launches if needed
  - Possibly a high resolution lidar back scatter lidar (SABL)

# Siting requirements

- Typical profiler requirements (no nearby trees, no planes, trains, automobiles and powerlines)
- Within the basin but near the Wasatch slope (several kms away)
- Near the LANL volume imaging lidar and/or Doppler lidar system and near chemistry
- Invited TRIAD (high resolution acoustic device to participate)
- Over 10 km from the UMASS TEP and not near home due to RASS/SODAR noise

# Mesoscale modeling efforts

- MM5 is a widely used non-hydrostatic mesoscale model
- Nested to high resolution over the basin (~5 km) for VTMX.
- Boundary layer scheme selected based on pre-VTMX sensitivity tests.
- Coarse grid simulations will likely be available in real-time.
- Prefer to run on a daily basis but with a 36 h forecast to avoid spin-up problems.