Session 6: Upper-Air Meteorological Measurements

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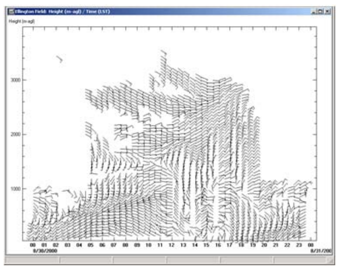
III. Examples



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Sonoma Technology, Inc.

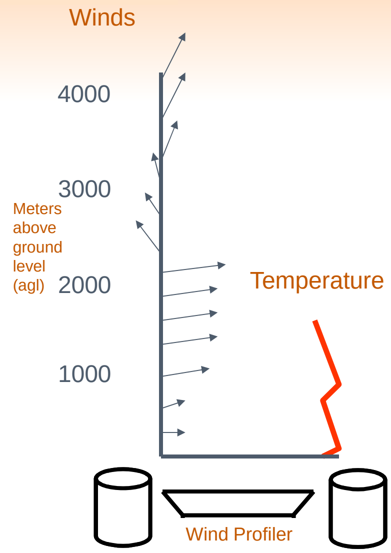
Upper-Air Meteorology

- The PAMS program requires one upper-air meteorological measurement station per PAMS network, with at least four soundings per day of winds and temperature
- These measures of upper-air meteorology are important to PAMS and PM analyses in order to investigate
  - the boundary layer structure and evolution including the spatial and temporal characteristics of mixing height, and
  - PM, ozone, and precursor transport
- Instruments that provide these measurements are rawinsondes: radar wind profilers (RWP) with radio acoustic sounding systems (RASS), and sound detection and ranging (sodar) systems with RASS
- Radar wind profilers with RASS provide hourly averaged vertical profiles of winds, virtual temperature, and related quantities, such as the radar reflectivity structure parameter, which can be used to estimate mixing depth

Upper-Air Meteorological Measurements

Upper-air meteorological data are useful in

- Assessing daily mixing height and mixing height evolution
- Understanding pollutant transport
- Evaluating models



Other Sources of Upper-Air Data

Other sources of upper-air meteorological and air quality data include

- Aircraft instrumented to measure ozone, nitrogen oxides, hydrocarbons, carbonyl compounds, SO_2, CO, meteorological observables, position, and altitude
- Satellite photographs
- Tethersondes and ozonesondes measurements of ozone concentrations as a function of altitude
- Light detection and ranging (Lidar–absorption of light by molecules) ozone measurements as a function of altitude
- Operation meteorological models, such as Eta

Terminology

In this section, we use the terms "depth of the mixed layer," "mixing height," and "mixing depth" synonymously

- Mixing height: the height above the surface through which relatively vigorous mixing will take place due to convection. Mixing heights can have large diurnal and seasonal variations.
- Mixing height can also be the distance between the ground and the inversion base.
  - The location of the inversion base is dependent on the weather conditions that produce the inversion, usually sinking air aloft, or subsidence, with stronger subsidence producing lower inversion bases (hence, higher pollution concentrations).
  - Thus, pollution released at the ground can mix upward until it reaches the inversion base; further upward mixing is strongly inhibited. If the inversion base is close to the ground, pollution is confined to a small volume of air next to the ground, resulting in high pollution concentrations.

Example Screening Criteria: Upper-Air Meteorological Data

- Automated temporal and vertical consistency checks
  - Wind shear – *Look for large changes that may not be real*
  - Hydrostatic (temperature) – *Look for large changes that may not be real*
- Manual data screening tests
  - Meteorological reasonableness checks with climatology and local and regional weather conditions – *Do significant changes in wind or temperature data make physical sense with respect to changes in weather conditions?*
  - Vertical and temporal consistency checks for continuous (hourly) data include comparing adjacent times, heights, and sites – *For example, do changes from hour to hour, from altitude bin to altitude bin, or from site to site make physical sense?*

Upper-Air Data Validation Approach

- Establish dominant (prevailing) weather pattern (i.e., using synoptic weather maps) and changes in weather; for example, the passage of a cold front
- Examine individual profiles
- Attempt to identify the cause of outliers (i.e., meteorological phenomena or instrument problem?)
- Use other supporting data (e.g., surface meteorology and air quality, weather maps, model results, satellite photographs, reflectivity, etc.) to confirm outliers or large changes in time or location

Common Problems Encountered in Upper-Air Meteorological Data (1 of 4)

Rawinsonde systems have the following potential problems:

- **Poor ventilation** may occur if the instrument's air channels become obstructed during operation or due to a manufacturing defect. *The result may be unrepresentative readings of temperature (T) and relative humidity (RH) (thus, dew point temperature) at or near the surface.*
- **Radio frequency (RF) interference** *may occasionally produce erroneous T, dew-point T, and RH measurements, which appear as spikes in the data when plotted in a time series or profile plot.*
- **Uncertainties in the position tracking mechanism** can be caused by factors such as RF interference, downbursts or updrafts, or icing conditions. *The result may be unrealistic changes in the wind speed and direction, especially when the antenna's elevation angle is less than about 10 degrees.*
- **Tracking problems** can occur within rain shafts or updrafts/downdrafts associated with thunderstorms.
- **Icing** can occur when a balloon encounters clouds and precipitation zones where the T is below freezing, causing the balloon to descend. Once the balloon descends below the freezing level, the ice melts and the balloon re-ascends. *The result is unrepresentative wind and thermodynamic data.*

U.S. EPA, 2000

Common Problems Encountered in Upper-Air Meteorological Data (2 of 4)

Sodar wind profiler systems have the following potential problems:

- **Fixed echo reflections** (or "ground clutter"; passive noise sources) occur when nearby obstacles reflect the sodar's transmitted pulse. *Depending on atmospheric conditions, wind speed, background noise, and signal processing techniques, the fixed echoes may reduce the velocity measured along a beam(s), or result in a velocity of zero.*
- **Ambient noise interference** (or active noise sources) can come from road traffic, fans or air conditioners, animals, insects, strong winds, etc. *Loud broad-spectrum noise will decrease the signal-to-noise ratio (SNR) of the sodar and decrease the performance of the system.*
- **Reduced altitude coverage** may be caused by debris in the antenna.
- **Precipitation interference**. During rainfall events, the sodar may measure the fall speed of drops, which will produce unrealistic wind values. Also, the sound of the droplets hitting the antenna can increase ambient noise levels and reduce altitude coverage.

U.S. EPA, 2000

Common Problems Encountered in Upper-Air Meteorological Data (3 of 4)

Radar wind profiler systems have the following potential problems:

- **Interference from migrating birds.** Birds act as large radar targets; signals from birds overwhelm the weaker atmospheric signals. *The result can be biases in wind speed and direction measurements.*
- **Precipitation interference.** During precipitation, the profiler measures the fall speed of rain drops or snowflakes.
- **Ground clutter** occurs when a transmitted signal is reflected off objects such as trees, power lines, or buildings instead of the atmosphere. *Data contaminated by ground clutter can be detected as a wind shift or a decrease in wind speed at affected altitudes.*
- **Velocity folding**, or aliasing, occurs when the magnitude of the radial component of the true air velocity exceeds the maximum velocity that the instrument is capable of measuring. *Folding occurs during very strong winds (>20 m/s) and can be identified and flagged by automatic screening checks.*

U.S. EPA, 2000

Common Problems Encountered in Upper-Air Meteorological Data (4 of 4)

RASS systems have the following potential problems:

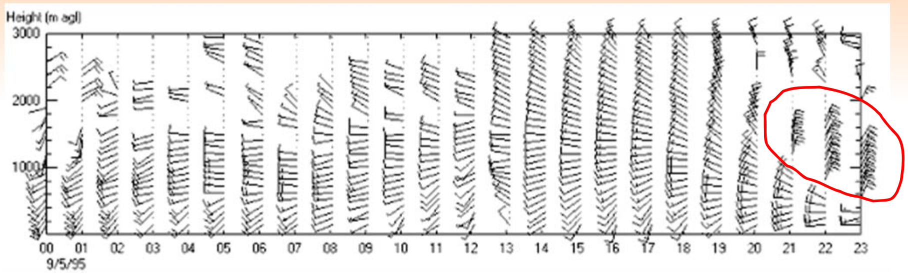
- **Vertical velocity correction.** Vertical motions can affect the RASS virtual temperature (T_v) measurements. T_v is determined by measuring the vertical speed of an upward-propagating sound pulse, which is a combination of the acoustic velocity and the atmospheric vertical velocity. *If the atmospheric vertical velocity is non-zero and no correction is made for the vertical motion, it will bias the T measurement.*
- **Potential cold bias.** *Under certain conditions (possibly associated with site selection), RASS observations may exhibit a bias of -1°C or so.*

U.S. EPA, 2000

Interpreting Upper-Air Meteorological Data Displays

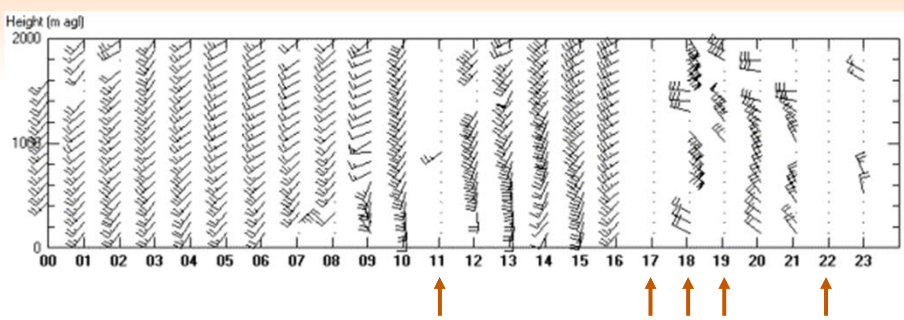
- This figure shows an example key to the wind barbs shown in several figures in this section of the workbook
- The number, size, and often color of tick marks on the bar represent different wind speeds
- The orientation of the barb indicates wind direction (i.e, barb or flag up = wind from the north)

Example Upper-Air Data Validation



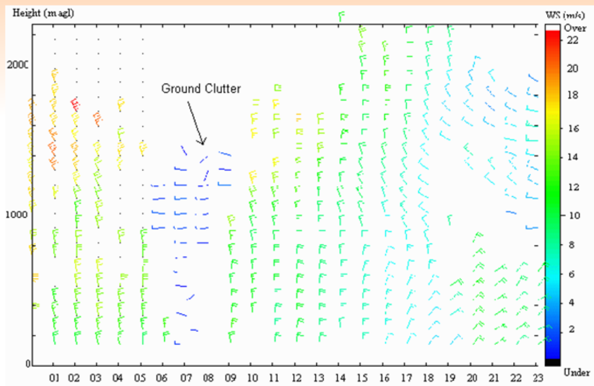
- This example of bird contamination in radar profiler data shows a time series plot of wind speed and direction at various altitudes for a 24-hour period. The orientation of the barb indicates wind direction (barb or flag up = wind from north). A larger number of tails on the barbs indicates increasing wind strength.
- The northerly winds from 2100 and 2300 EST between 500 and 2000 m above ground level (agl) were actually caused by the radar measuring the motion of birds migrating to the south, instead of the northwesterly atmospheric winds. Birds act as large radar "targets," so that signals from birds overwhelm the weaker atmospheric signals.
- Birds generally migrate year-round along preferred flyways, with the peak migrations occurring at night during spring and fall (Gauthreaux, 1991). Additional information about bird contamination of radar wind profiler data can be found in Wilczak et al. (1995).

Example Upper-Air Data Validation



- Another type of natural phenomenon that can invalidate upper-air meteorological data is precipitation. This example shows precipitation interference in radar profiler data. Missing wind data at 1100, 1700–1900, and 2200 EST were caused by precipitation.
- During precipitation, the radar profiler measures the fall speed of rain drops or snowflakes. In this example, the profiler measured strong, downward motion of -3 to -8 m/s (observable in the raw data), which is actually the motion of the rain drops. Missing winds resulted when the radar measured both atmospheric and precipitation motions and the sub-hourly data failed quality control checks (Dye, 1996).

Example Upper-Air Data Validation

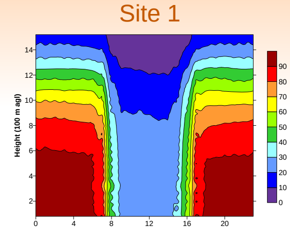


Recurrent and excessive ground clutter can seriously damage data quality. Siting issues are very important. This figure shows an example of ground clutter interference from a radar profiler site. Ground clutter is caused when a transmitted signal is reflected off an object instead of the atmosphere. In this case, the radar signals were reflected off distant trees, which produced the light winds between 0600 and 0800 EST (Dye, 1996).

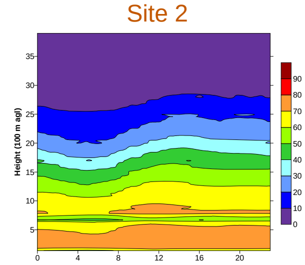
Data Completeness

- RASS Tv data completeness by height and by time of day at two locations (one quarter). The low data completeness at Site 1 during the daytime is due to the RASS's being shut off during business hours to prevent disruption to the nearby businesses.
- In general, data completeness was highest at the lowest altitudes, as is expected because the radar signal returns tend to diminish as the distance from the RWP increases.
- Also, the sound generated by the RASS diminishes quickly with height. At Site 2, data completeness at altitudes above about 600 m agl was lower during the afternoon hours than during the morning and nighttime hours. This may be due to the stronger winds typically observed during the afternoon hours. Stronger winds tend to blow the sound waves out of range more quickly, resulting in less signal detection.

Site 1



Site 2



Summary

For upper-air meteorological data validation,

- Use established screening criteria
- Use validation and visualization tools delivered with the hardware
- Follow EPA guidelines (e.g., http://www.epa.gov/scram001/guidance/guide/mmgrma.pdf)

Appendix:
Suggested Data Quality Objectives for Upper-Air Measurement Systems

Measurement Method	Systematic Difference	Comparability
Radiosonde	p: ±0.5mb T: ±0.2°C RH: ±10% u,v: ±0.5 to 1 ms^{-1}	P (as height): ±24 m T: ±0.6°C T_d: ±3.3°C WS: ±3.1 ms^{-1} WD: ±18° to ±5°[a]
Sodar[b]	u,v: ±1 ms^{-1} WS: ±1 ms^{-1} WD: ±10°	u,v: ±2 ms^{-1} WS: ±2 ms^{-1} WD: ±30°
Radar wind profiler	u,v: ±1 ms^{-1} WS: ±1 ms^{-1} WD: ±10°	u,v: ±2 ms^{-1} WS: ±2 ms^{-1} WD: ±30°
RASS	±1°C	±1.5°C

[a] Over a wind speed range from 3 to 21 ms^{-1}
[b] For wind speeds greater than approximately 2 ms^{-1}

U.S. EPA, 2000