Using Non-Specular Radar Meteor Echoes to Monitor Lower Thermosphere Wind Profiles-

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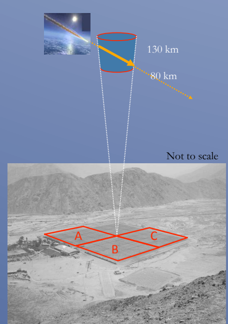
ABSTRACT

We present a new method of measuring lower thermospheric wind velocity profiles by tracking non-specular meteor echoes in time. This approach relies on having a radar following plasma irregularities as they are dragged by the neutral wind. This requires a VHF radar with interferometric capability able to point close to perpendicular to the geomagnetic field. Using a small sample of data from the Jicamarca Radio Observatory, we calculated wind speeds and directions between 90 and 110\, km with a range resolution of a few hundred meters. The measurements taken show speeds reaching 150m/s and sometimes changing by as much as 100m/s over a 6km altitude range. With some refinement of the data collection and analysis techniques, we expect that one could obtain high resolution images of lower thermospheric winds as they change in both altitude and time. We will discuss these results, the physics underlying these measurements, and the limitations.

Overview

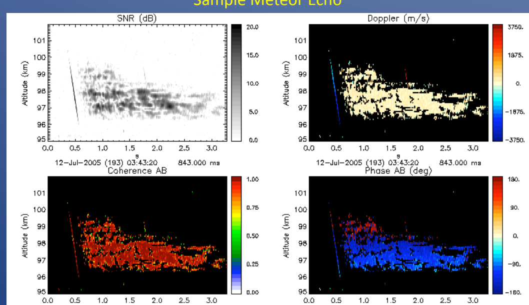
- Background:
  - Observations of Specular Meteor trails by Large (HPLA) Radars
  - Winds in the MLT
- Method: Use Phase interferometry from Trails
- Result: Accurate Wind measurements with km and time resolution.



JRO 50MHz Radar

- Antenna:
  - 300m x 300m
  - 18,432 dipoles
  - Peak power: 2 MW
  - Frequency: 50 MHz
- *A truely High-Power Large-Aperture Radar (HPLA)*
- **Interferometer**

Sample Meteor Echo



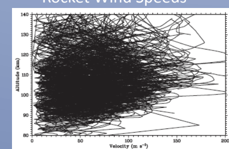
Background: HPLA Meteor Radar Science

- Meteor enters Atmosphere (130 km altitude)
- Heating, ablation & ionization create plasma trail
- Reflections from leading edge of plasma form head echoes
- Trail cools and expands
- Diffusion begins
- Waves and Turbulence develop:
  - In a limited range of altitudes
  - Reflections from plasma waves creates non-specular trails

Thermospheric Wind Measurments

- Importance:
  - Detect Tides and Gravity Waves
  - Circulation Modeling of MLT
- Methods:
  - Specular Meteor Radars
  - Optical (Lidar, Fabry-Perot) measurements
  - 400 Rocket launches to measure

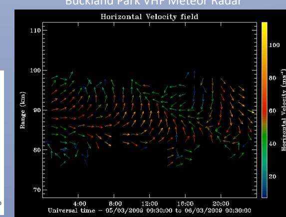
Rocket Wind Speeds



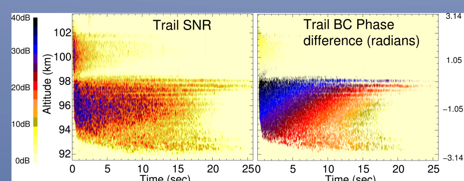
Larsen, M. F. , J. Geophys. Res., 2002

Specular Meteor Radar Winds

Buckland Park VHF Meteor Radar

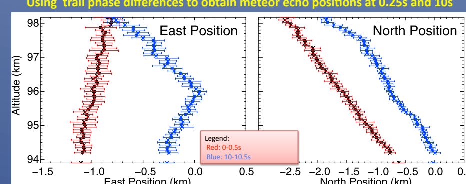


Determining Winds from HPLA data: An example



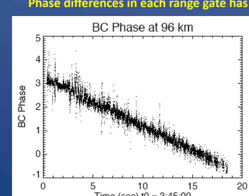
Caption: Long trail from July 12, '05 data set. The SNR (left) in dB and the phase difference (right) between the B and C quarters of the antenna array

Using trail phase differences to obtain meteor echo positions at 0.25s and 10s



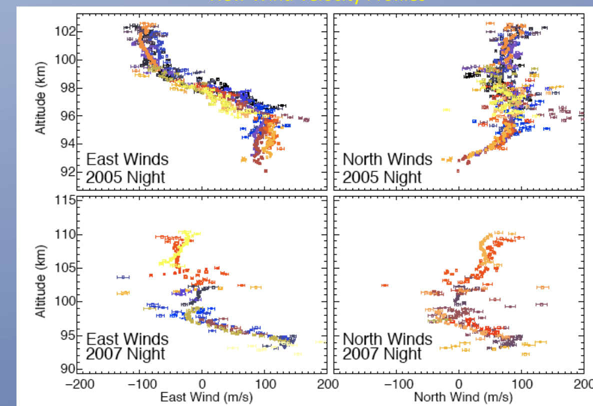
Caption: East-west and north-south trail positions vs. altitude at 0s–0.5s (red) and again at 10s–10.5s (blue). Phase data in these intervals were treated as statistical samples and converted to 3-D positions. The central point at altitude corresponds to the mean position, while the horizontal bars give the standard deviation.

Phase differences in each range gate has a distinct slope: Gives the wind speed



Caption: Difference between the B and C phase angles in radians at 96 km altitude.

New Wind Velocity Profiles



Horizontal wind velocities vs. altitude from 2 data sets. The zonal (east) and meridional (north) meteor winds from the time interval (top) 0342 to 0401 from July 12, '05, and (bottom) 0401 to 0437 July 17, '07. Each trail was assigned a distinct color. Much of the '07 data set had a channel receiver timing offset which added a large systematic error to the BC phase data, making only the longest duration trails useful. We used all data where the error in the slope was less than 10 m/s.

Discussion and Conclusions

- New Tool to Monitor Winds
  - Measures average positions of turbulent trail
  - Consistent from meteor to meteor
  - East-West (⊥***B***) more accurate than North-South (|| ***B***)
  - Meteor dust may play role
  - Shows high winds and strong sheers (like rocket data)
- High Spatial and Time Resolution
  - JRO resolution: 150m
  - Near dawn (+/- 4 hours):
    - Useful meteor every ~30s
    - generate a profile every 5-10 min
  - At other times, less frequent meteor echoes
  - Night better than day
- Low and Mid-latitudes
- *GRL* VOL. 36, L09817, 2009
- *Physics Today*, Physics Update, May 2009
- Needs further validation (Rocket study)

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