Bias estimation of Doppler radar radial wind observations

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Motivation
Measurement principle

Doppler radar radial wind:

• is determined from the phase difference between the back-scattered returns from successive radar pulses.

• has a cosine form as a function of azimuth angle, if the wind field is uniform.

  • amplitude of the cosine defines the wind speed
  • phase of the cosine defines the wind direction.
A conceptual example of the behaviour of the radial wind bias

Obs: 17 m/s from 190°
True: 15 m/s from 180°

• The bias statistic calculated by summing up the individual OmT values is zero.
Behaviour of the radial wind bias

• Non-zero bias statistic is obtained when
  • wind field is not uniform
  • there is no back-scattering in all azimuth directions
  • the radar is unable to measure all azimuth directions due to obstacles
  • the radar measurement is contaminated by non-meteorological echoes like birds, ground clutter etc.
Bias estimation method (1)

• Wind direction varies from day to day and from radar to radar.
• No unique reference, such as $u$ and $v$.
• To make observations comparable, an arbitrary reference direction is chosen.
Bias estimation method (2)

- Rotation angle $\Delta \Phi$: difference between the reference and the model wind direction.
- Azimuth angle corresponding to observation is rotated by adding $\Delta \Phi$ to it.
- With the rotation, nominal wind direction is the same for all observations.
Bias estimation method (3)

- Calculate an azimuth bin average.
- By least-squares fitting
  \[ v_r = v_h \cos(\delta - \Phi) \]
  to the bin averaged observations, estimates for horizontal wind speed and direction are obtained.
Demonstration of the bias estimation method

• One-month data set (January 2002), ca 533 000 superobservations and their model counterparts.
• Unambiguous velocity interval $\pm 48$ m/s.
• Raw observations are averaged to superobservations with 10 km resolution in range and 1.7° in azimuth.
• Model counterparts are calculated from HIRLAM model with 9 km horizontal resolution.
• The reference wind direction used in the rotation is 180°.
WMO requirements for upper air wind measurements

- The wind speed bias must be less than 1 m/s and the wind direction bias must be less than 5° for wind speeds less than 15 m/s and less than 2.5° for higher winds.
Verification for the whole data set

- Amplitudes are nearly the same. The obtained wind speed bias is 0.03 m/s.
- Phase difference indicates systematic difference in the wind direction. The obtained wind direction bias is 4°.
An intercomparison of the bias estimates with radiosonde wind bias
Summary

• The introduced method enables estimation of the bias in wind speed and direction for Doppler radar radial wind observations.

• The bias in Doppler radar winds is within the limits of the WMO requirements above the altitude of 1.5 km.

• Bias estimation method is useful for example in model validation.