Wind vector field determination with a bistatic multiple-Doppler radar network in Oberpfaffenhofen

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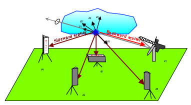
Motivation

The knowledge of the spatial and temporal distribution of the 3D wind vector field is essential in meteorological research and operational meteorology, e.g. for data assimilation, nowcasting and the understanding of transport processes.

A bistatic multiple-Doppler radar network can provide a horizontal wind field within an area of 40 km x 40 km. The optimal experimental setup, a quantitative assessment to other wind measuring systems and a case study is presented on behalf of the bistatic multiple-Doppler radar network in Oberpfaffenhofen (OP) and on measurements within a thunderstorm.

With a variational method combining the equation of continuity and measured horizontal wind fields a 3D wind field can be retrieved. The critical point is the vertical integration of the equation of continuity. Different methods for the vertical integration are presented.

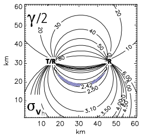
Principle & Network Setup



Monostatic Doppler radar (backward scattering) + one bistatic Doppler radar (sideward scattering) ⇒ Horizontal wind field

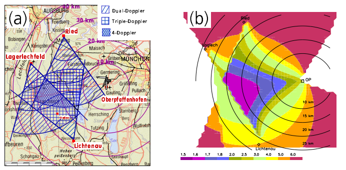
Bistatic area within a scattering angle γ of $40° - 140°$ provides:

- $150\ \mathrm{m} \leq a_b \leq 500\ \mathrm{m}$
- $2\ \mathrm{ms}^{-1} \leq \sigma_{\mathbf{V_h}} \leq 4\ \mathrm{ms}^{-1}$
- $20° \leq \sphericalangle \mathbf{V_t V_e} \leq 70°$
- $-5\ \mathrm{dBZ} \leq Z_{min} \leq 15\ \mathrm{dBZ}$



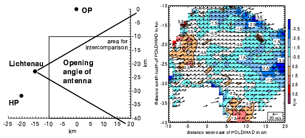
a_b - Resolution volume length
$\sigma_{\mathbf{V_h}}$ - Standard dev. of hor. wind
$\sphericalangle \mathbf{V_t V_e}$ - Intersection angle
Z_{min} - Min. det. equiv. refl. factor

Bistatic Multiple-Doppler Radar Network at DLR



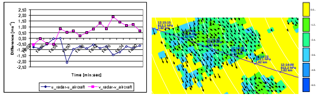
The network consists of POLDIRAD at OP and three bistatic Doppler radars (a). The investigation area is restricted by the horizontal opening angle of the bistatic antennas. At Fig. (b), $\sigma_{\mathbf{V_h}}$ *normalized by* $\sigma_{\mathbf{V_t}}$ *at ground is presented assuming* $\sigma_{\mathbf{V_t}} = \sigma_{\mathbf{V_e}}$.

Intercomparison with
Mono. Dual-Doppler



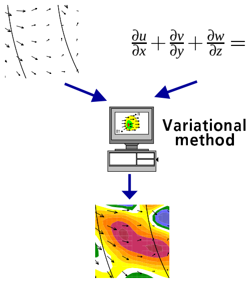
$\mathbf{V_h}$ *measured by the bistatic radar at Lichtenau (right, arrows) on 21 August 1998 1534 UTC at 1.5 km MSL underlaid by the difference of* $\mathbf{V_h}$ *between dual-Doppler monostatic (HP, OP) and bistatic (Lichtenau, OP) analysis.*

Flight Measurments



Intercomparison of horizontal wind between in situ aircraft and bistatic radar measurements on 11 April 2001 (left). Flight track, $\mathbf{V_h}$ *of the bistatic radar underlaid by the respective v-component is presented on the right figure.*

3D Wind Retrieval



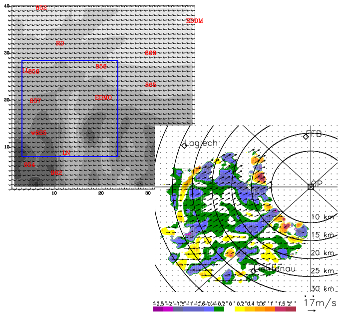
$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = -\frac{\partial(ln\rho)}{\partial z} w$$

Variational method

Methods for vertical integration

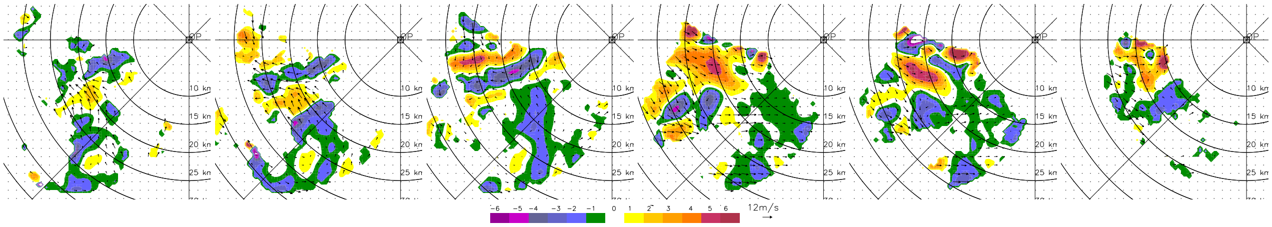
- *Simple upward integration (SUPI):* $w_\uparrow$
- *Simple downward integration (SIDO):* $w_\downarrow$
- *Averaged up- and downward integration (AVUDI):* $w = 0.5(w_\uparrow + w_\downarrow)$
- *Weighted up- and downward integration (WUDI):* $w = (1 - z/z_{top})w_\uparrow + (z/z_{top})w_\downarrow$

Numerical Model versus Radar Measurement



Horizontal wind field at 0700 UTC on 26 April 2001 at 850 m MSL simulated with the mesoscale model MM5 (upper). The blue box marks the area where radar measurements are available. Lower figure, horizontal wind field measured by the bistatic radar at 0641 UTC underlaid by the retrieved vertical velocity.

Case Study



Temporal development of a thunderstorm crossing the investigation area on 3 May 2000 and monitored by the bistatic radar at Lagerlechfeld. The horizontal wind field (arrows) is underlayed by the vertical velocity (ms^{-1}) at 1401 UTC, 1411 UTC 1421 UTC at 1.8 km MSL and at 1454 UTC, 1504 UTC 1514 UTC at 3.5 km MSL (from left to right). High wind shear occurs not only within each level but also with SE wind near the ground and a NW-SW flow at higher altitudes.

Analysis

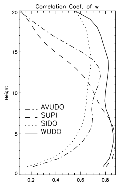
- On intercomparison

Although the horizontal wind is measured simultaneously with a bistatic Doppler radar, the nonsimultaneous nature of the data acquisition (radar scanning) and the spatial interpolation to a uniform grid can lead to uncertainties. Furthermore, for an intercomparision the different spacial and temporal resolution has to be considered.

A quantitative assessment between mesoscale model simulation and measurements shows the occurrence of small scale processes observed by the bistatic radar which can hardly be simulated. The understanding of short timescale mixing processes and complex structure of the atmosphere can be used to improve the parameterization in mesoscale models. Furthermore, measured wind fields can be assimilated into numerical models to achieve a more realistic simulation.

- On vertical integration

An idealized case of a convective cell is chosen to quantify different vertical integration methods. Herein, the horizontal wind field of a Meso-NH simulation is used as input data for the variational method model. The retrieved vertical wind is compared to the model output.



Bias and correlation coefficient over the whole domain of simulated and retrieved vertical velocity using different integration methods.

	Bias (ms^{-1})	*CC*
SUPI	*-0.9*	*0.41*
SIDO	*0.1*	*0.59*
AVUDI	*-0.02*	*0.55*
WUDI	*-0.03*	*0.80*

Conclusion

- Bistatic antennas should point into the bistatic area to achieve good spatial resolution, reasonable $\sigma_{\mathbf{V_h}}$ and reasonable signal-to-noise power ratio.
- Comparisons to other wind measuring system show a difference in speed between 1-2 ms^{-1} and in direction of ±5°.
- For the 3D wind retrieval with a variational method, the weighted up- and downward integration works much better than the traditional up- or/and downward integration.
- The 3D wind field of a bistatic Doppler radar helps to understand the meteorological processes much better, because a simultaneous measurement can show high wind gradients and high wind shear more accurate than time and space interpolated wind fields of monostatic dual–Doppler systems.

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