Wind Field Observations with a Monostatic and Bistatic C-band Doppler Radar Network

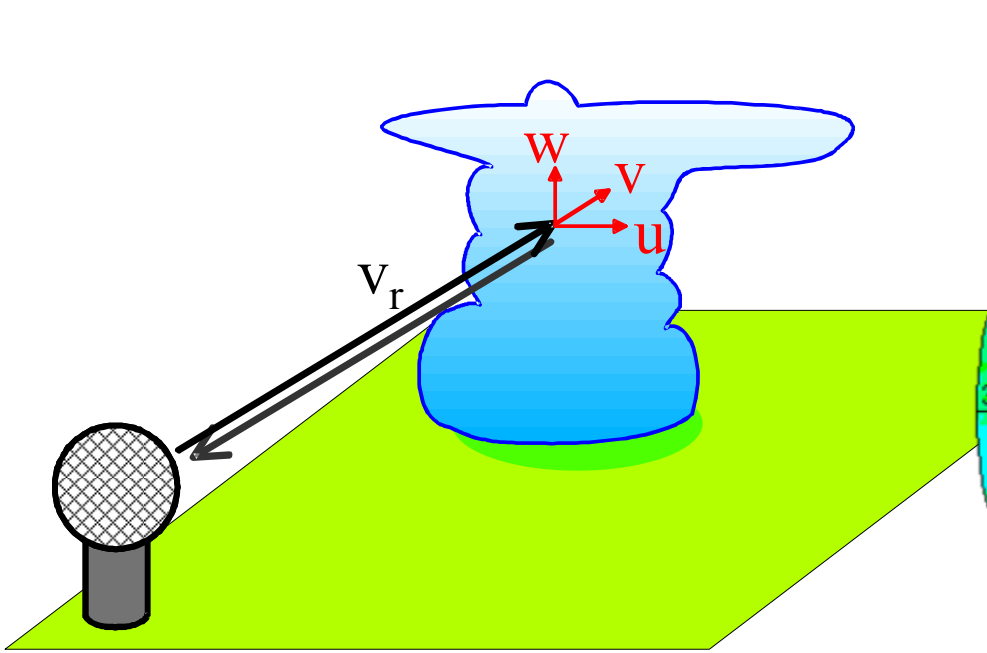
Martin Hagen

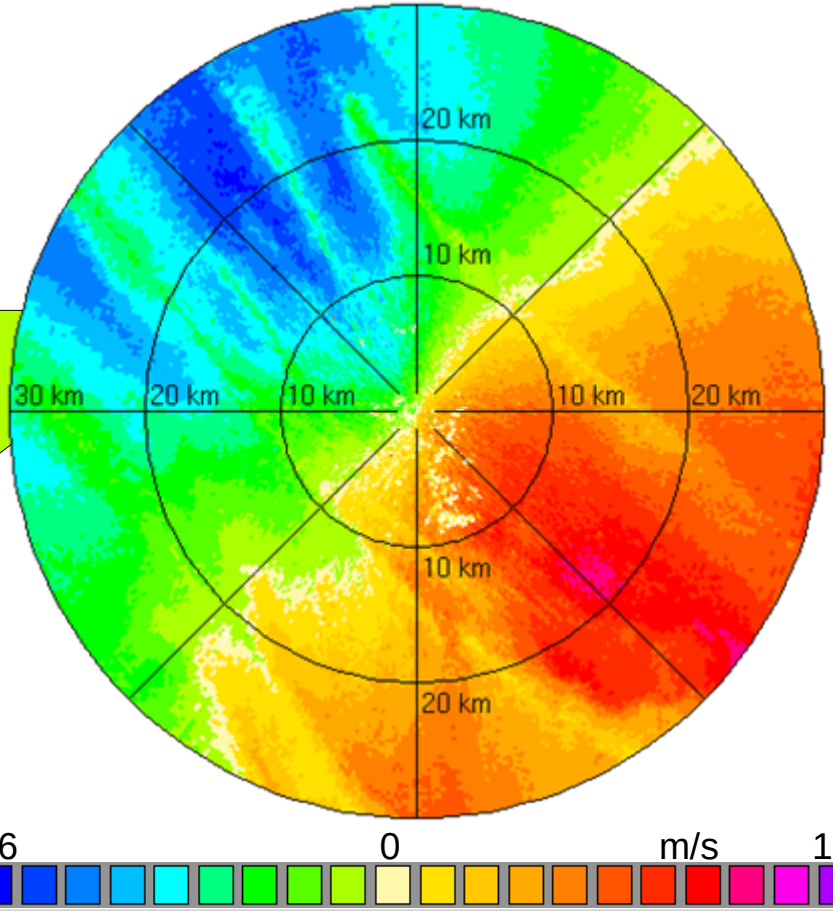
Institut für Physik der Atmosphäre, DLR Oberpfaffenhofen

Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Wind field and Doppler radar

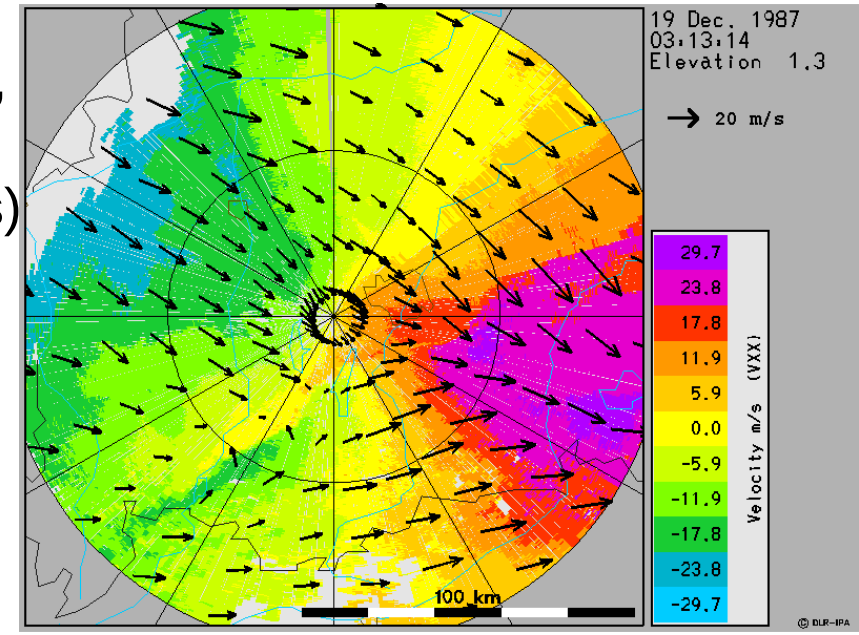
- Doppler radar (and lidar) can only measure one component (the radial one) of the 3-dimensional wind vector





Wind field and Doppler radar

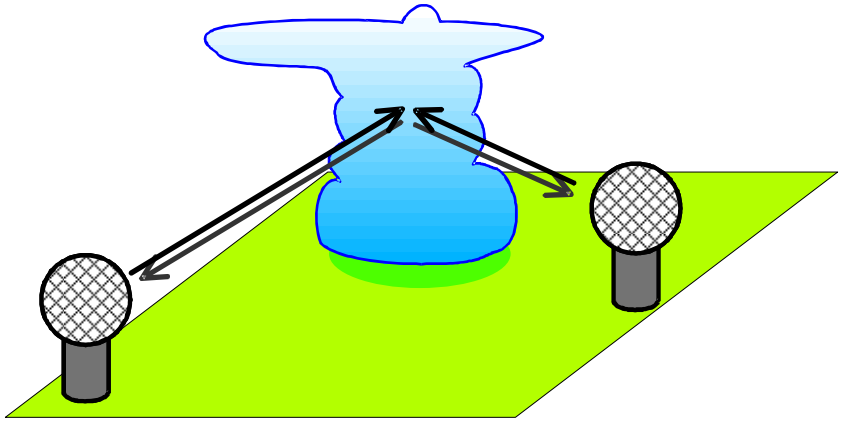
- Estimation of the 3-dimensional
  - single Doppler wind field techniques (VAD, VVP, UWT, ...) make assumptions about the wind field (linear, homogeneous, constant) within a region (dimension of several kilometres)



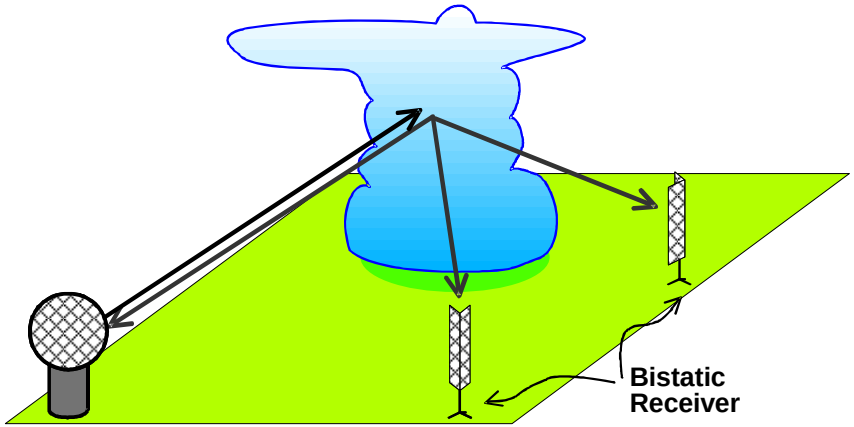
  - requires more than one radar (or lidar)
  - vertical air motion can not be retrieved, it will be estimated by vertical integration of convergences of the horizontal wind field (3d-var, 4d-var techniques)

Monostatic and Bistatic Doppler Radar Network

- Monostatic radar network: same antenna for transmit and receive

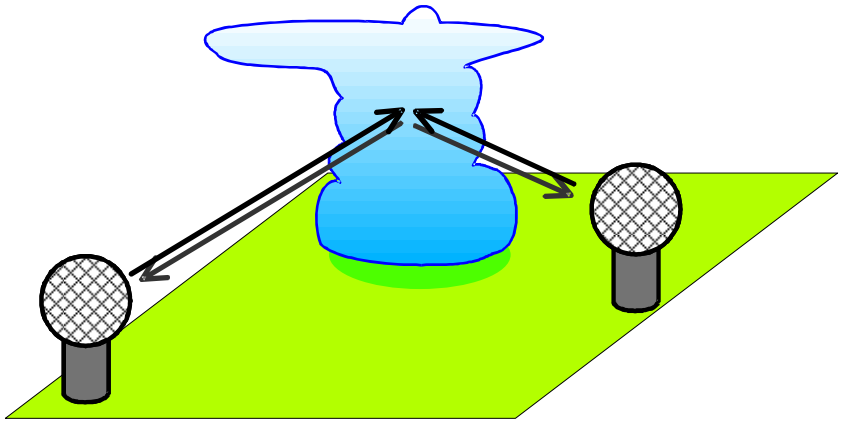


- Bistatic radar network: different antennas for transmit and receive



Monostatic Doppler Radar Network

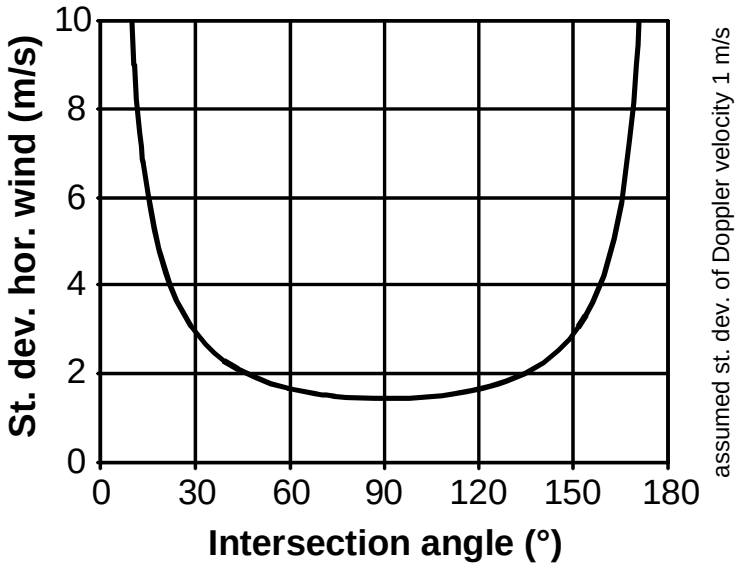
- Monostatic radar network: same antenna for transmit and receive

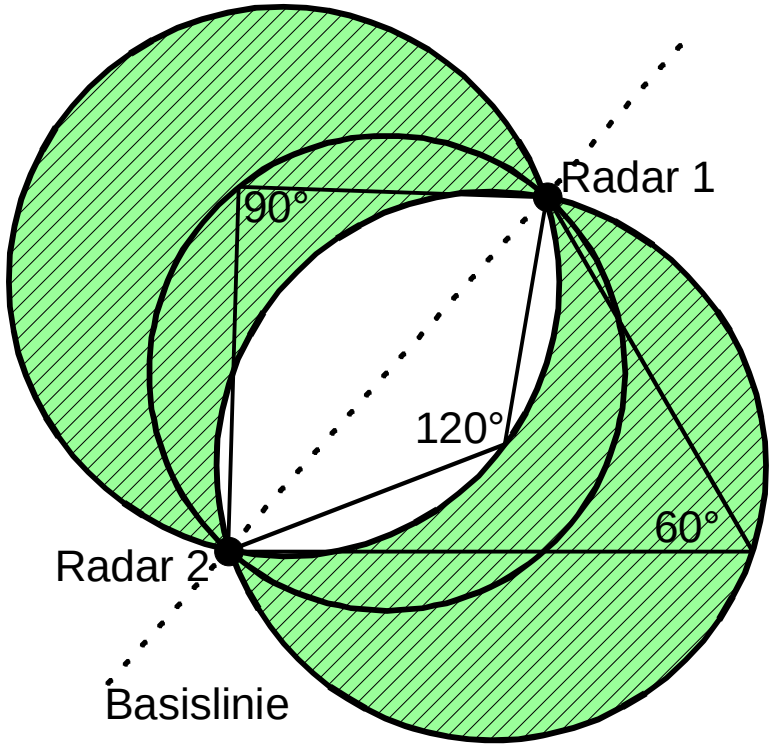


- minimum 2, better more radars (or lidars) are required
  - synchronized scanning
  - short distance (20 – 40 km) between radars to cover low-level wind field features close to the airport (operational networks: distance 100 - 200 km)

Monostatic Doppler radar network

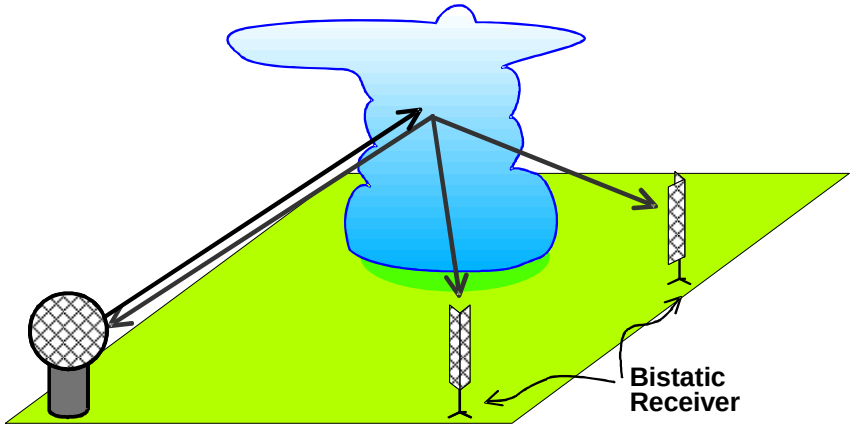
- Estimation of horizontal wind vector with measurements from two Doppler radars
- Highest accuracy if intersection angle $\gamma = 90°$
- Sufficient accuracy for $30° < \gamma < 150°$





Monostatic and Bistatic Doppler Radar Network

- Bistatic radar network: different antennas for transmit and receive

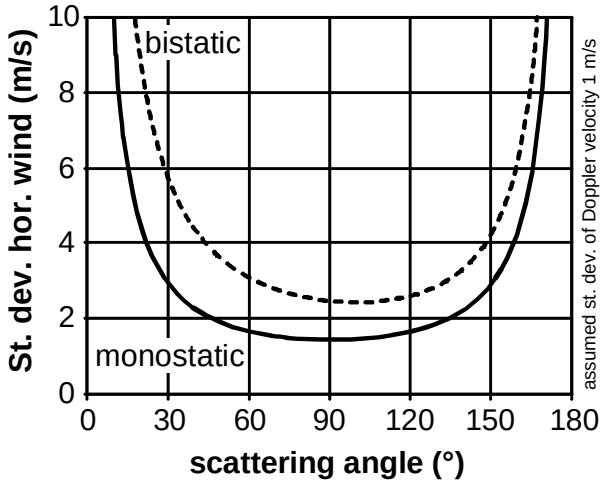


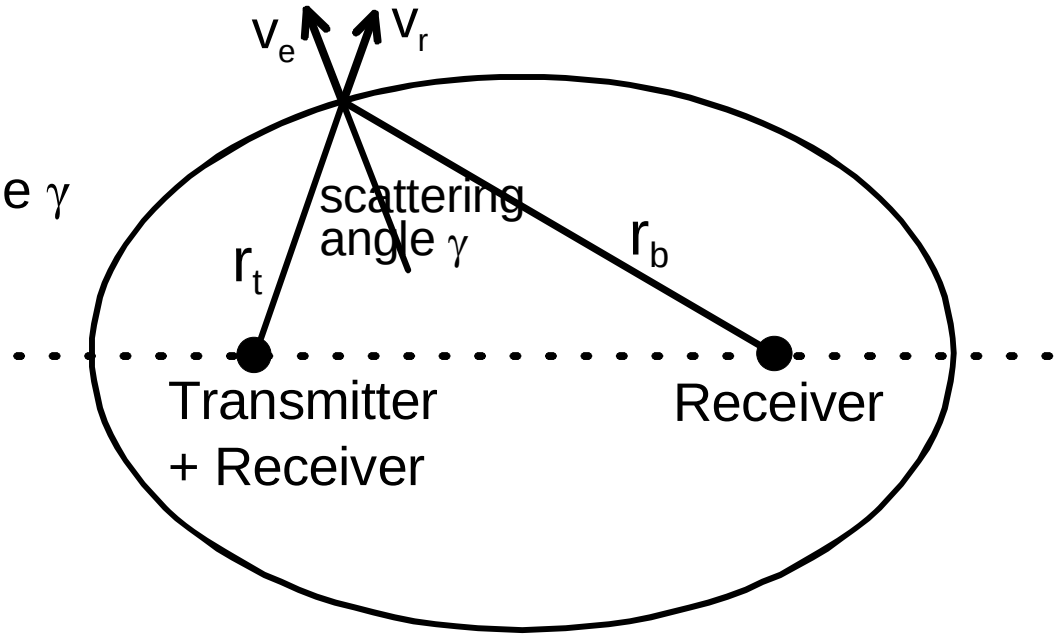
- Bistatic radar network uses one active (transmit and receive) radar and several passive receivers
  - measurements are synchronized in time and space
  - bistatic receivers are cheap (0.1 vs. 1.5 M€)
  - distance between receivers – radar: 20 – 40 km

Bistatic Doppler radar network

- Horizontal wind composed from
  - radial Doppler velocity measured by radar (v_r),
  - (elliptical) Doppler velocity measured by bistatic receiver (v_e).

- accuracy is reduced since intersection angle between v_e and v_r = ½ scattering angle γ

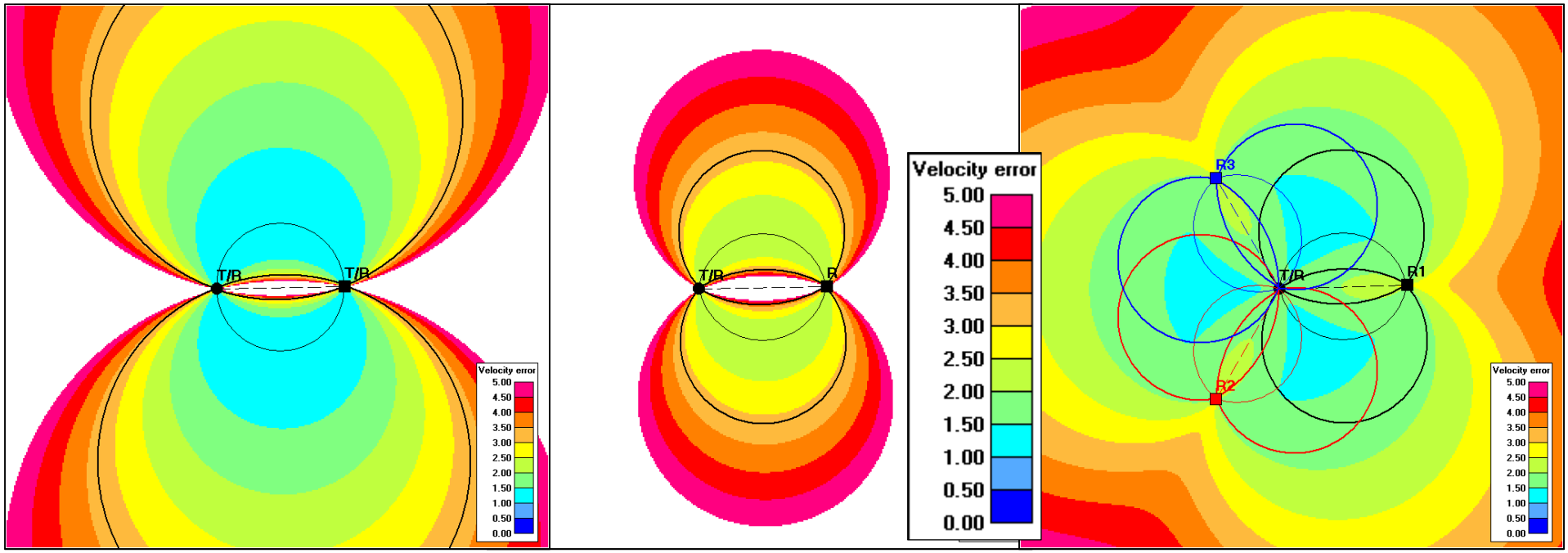




Monostatic versus bistatic Doppler radar network

- Reduced accuracy and areal coverage can easily be compensated by a larger number of receivers

monostatic 2 radars | bistatic 1 radar 1 receiver | bistatic 1 radar 3 receivers



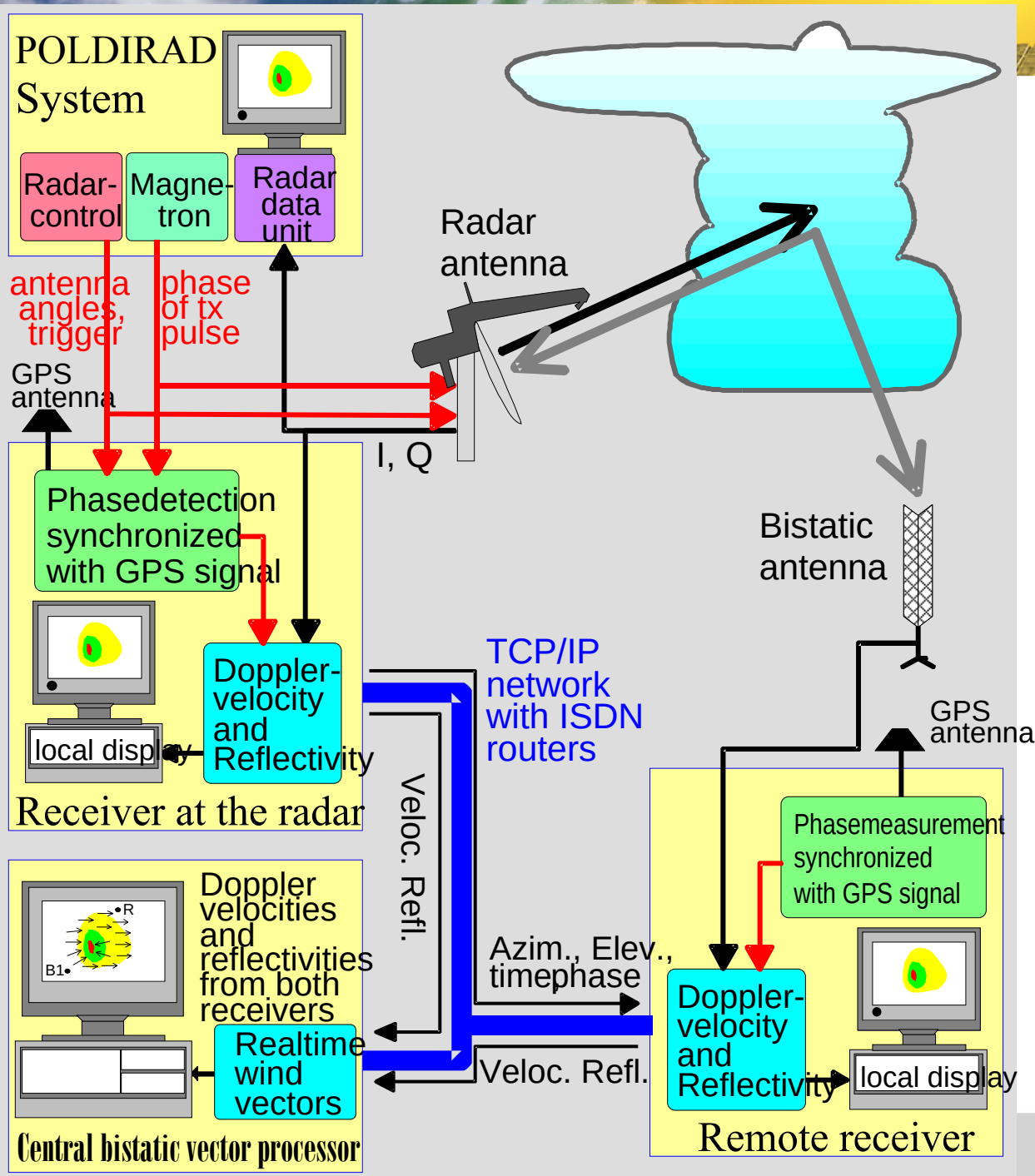
Bistatic Doppler radar network

- first trials 1993: NCAR / Univ. of Oklahoma
  - challenge: synchronization of oscillator at radar and remote site for accurate phase estimation

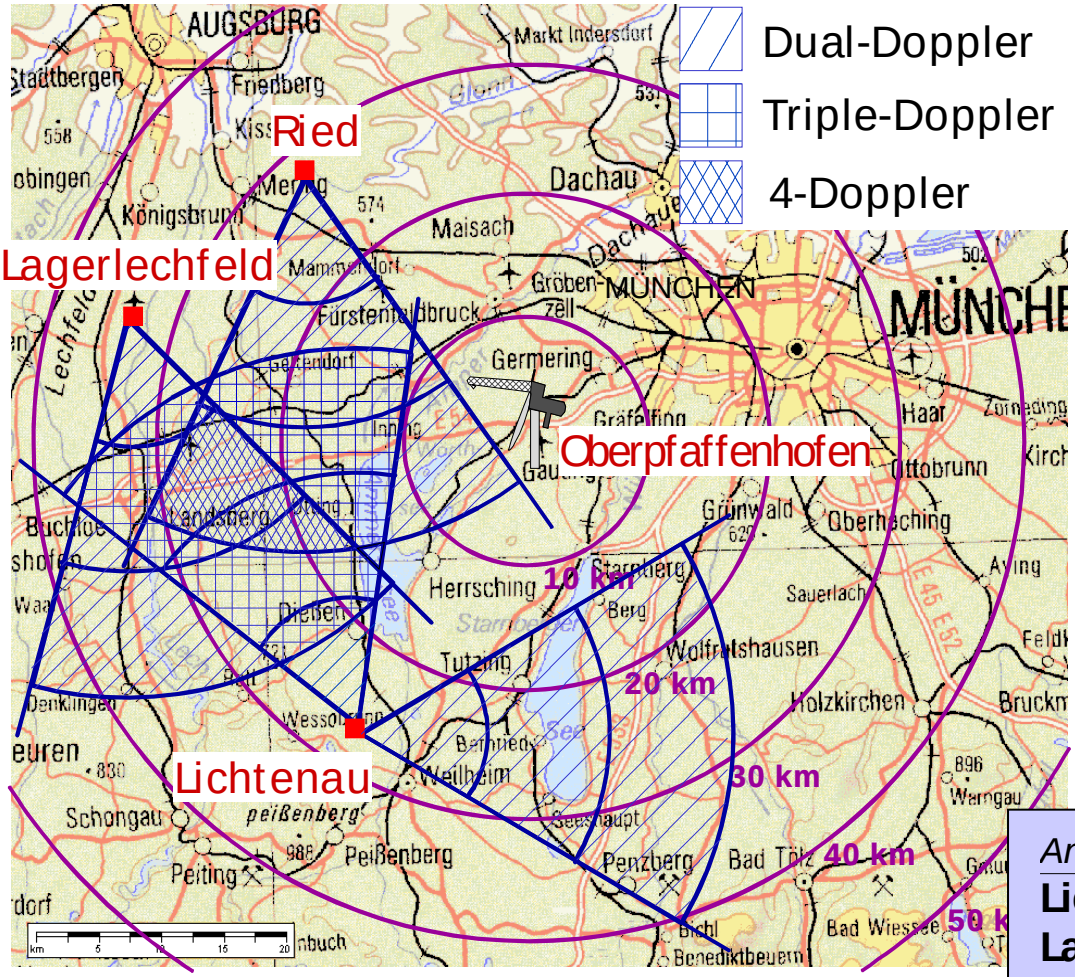
- available systems for research:
  - McGill University Montreal (1996 – 2002 ?)
    first permanent installation, klystron transmitter
  - NCAR S-Pol radar field campaigns
    e.g. IMPROVE I at Pacific coast (2001)
  - NICT Japan, Okinawa (2003 ?)
    C-band, klystron transmitter, GPM ground validation site
  - DLR Oberpfaffenhofen (1998 – 2005; 2010 -)
    first C-band system with magnetron transmitter

Overview of DLR bistatic radar net

- Radar POLDIRAD
- Bistatic receiver at radar
- Remote bistatic receiver
- Hub: central processor and communication

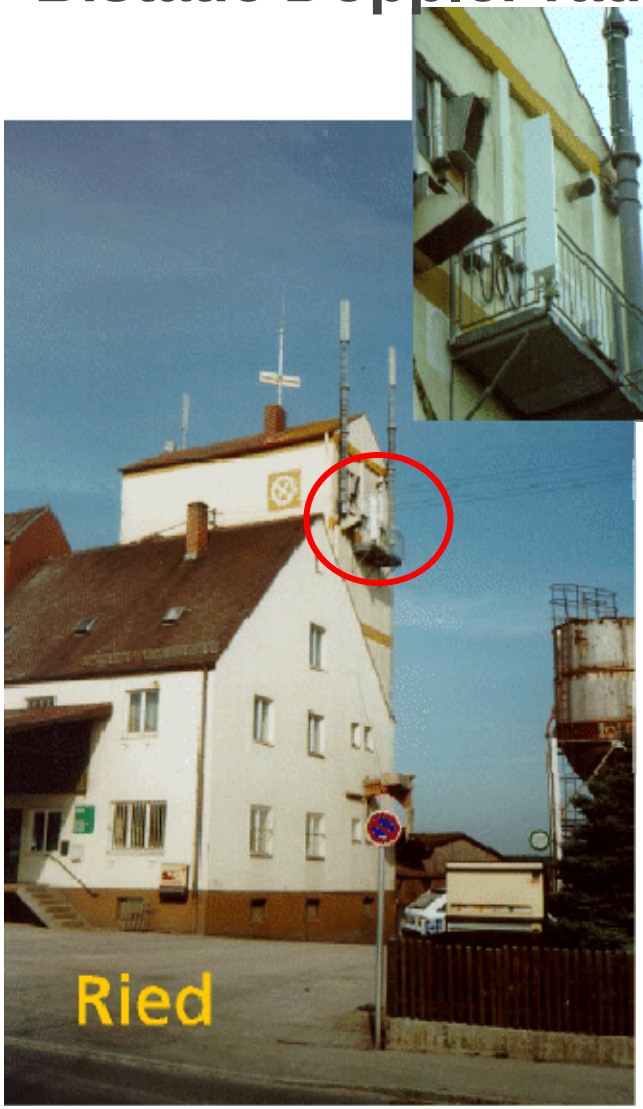


Bistatic Doppler radar network at DLR Oberpfaffenhofen

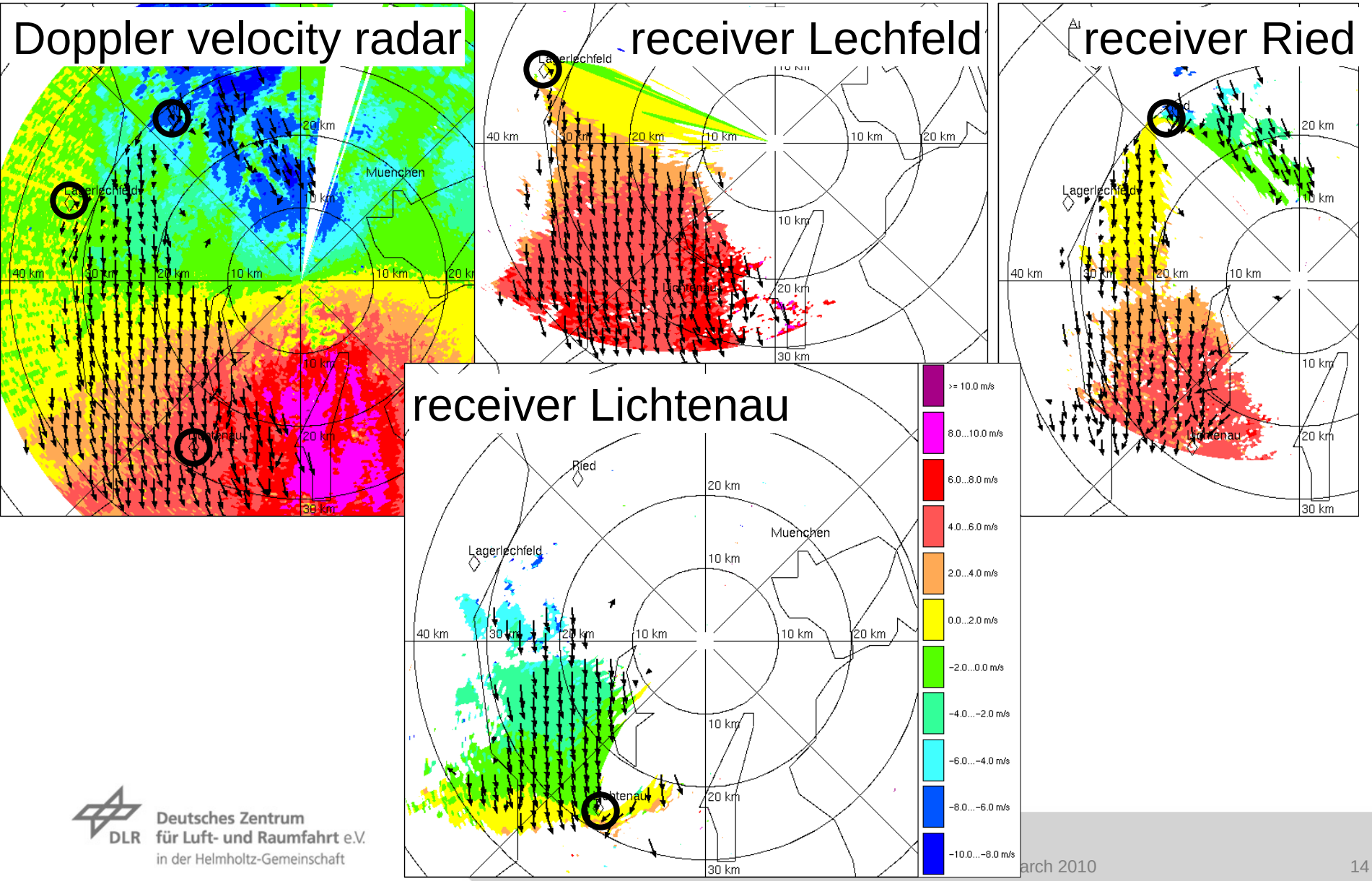


Antenna aperture	**Horizontal**	**Vertical**
Lichtenau	60°	8°, 22°
Lagerlechfeld	60°	8°, 22°
Ried	60°	8°

Bistatic Doppler radar network at DLR Oberpfaffenhofen



DLR bistatic Doppler radar network wind synthesis



Observation of thunderstorm outflow

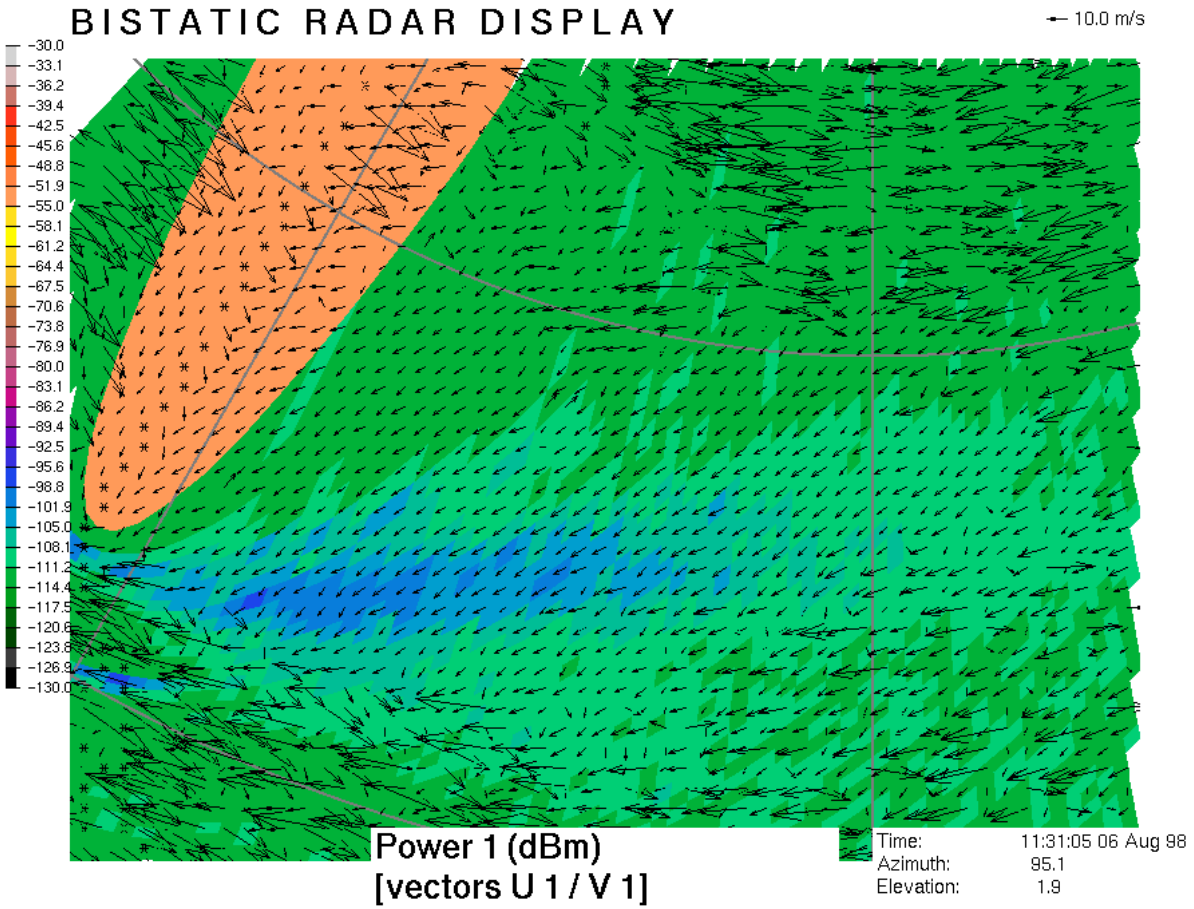
9 July 2002

1557 UTC

Elevation 5.4°

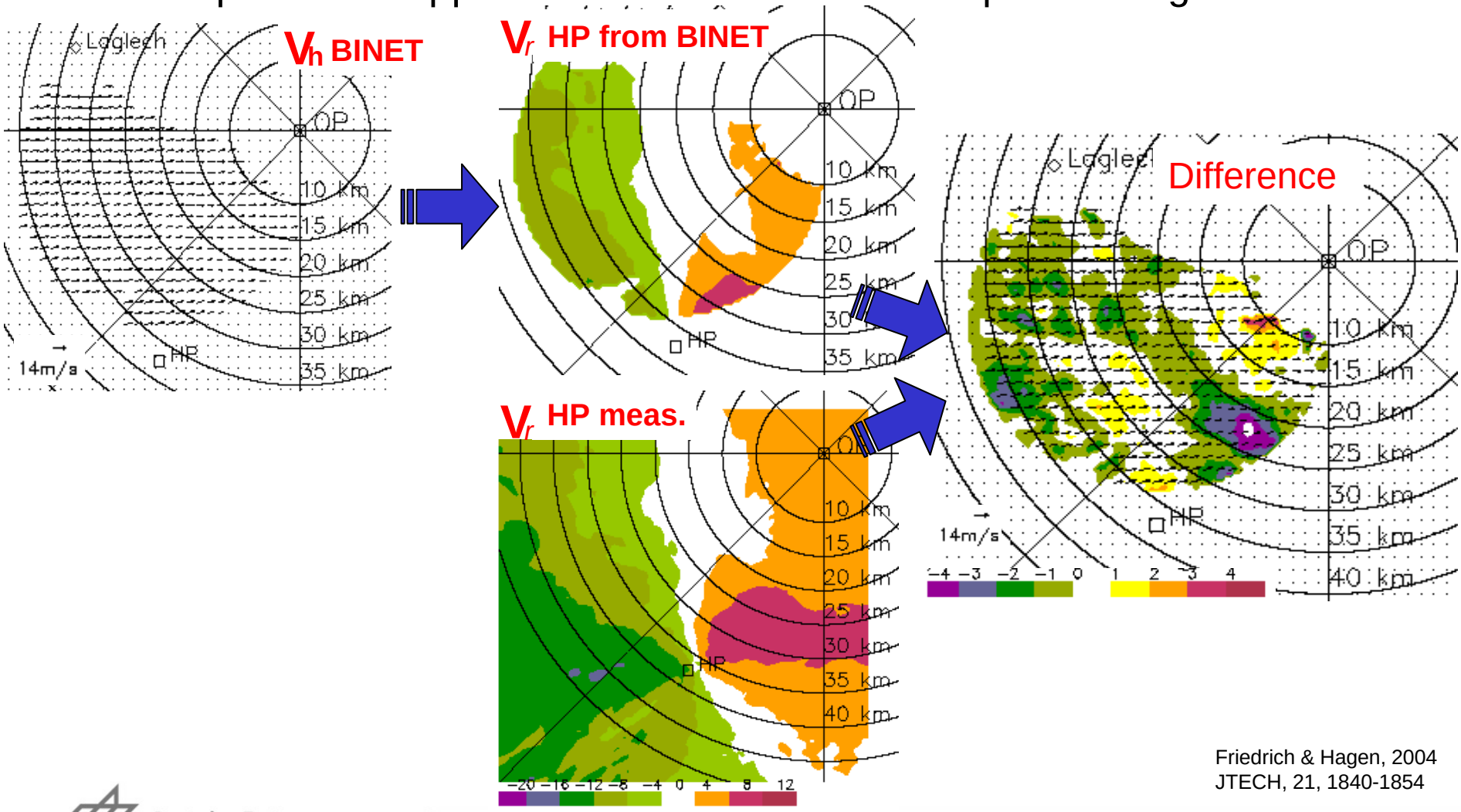
Observations in clear-air echoes

- Clear-air echoes give good radar coverage at short distances (~50 km) during summer (insects)
- Minimum detectable signal of bistatic receivers is less than for monostatic radars due to reduced antenna gain ~10 vs. 45 dB



Evaluation of bistatic Doppler wind field

- Independent Doppler measurements at Hohenpeißenberg

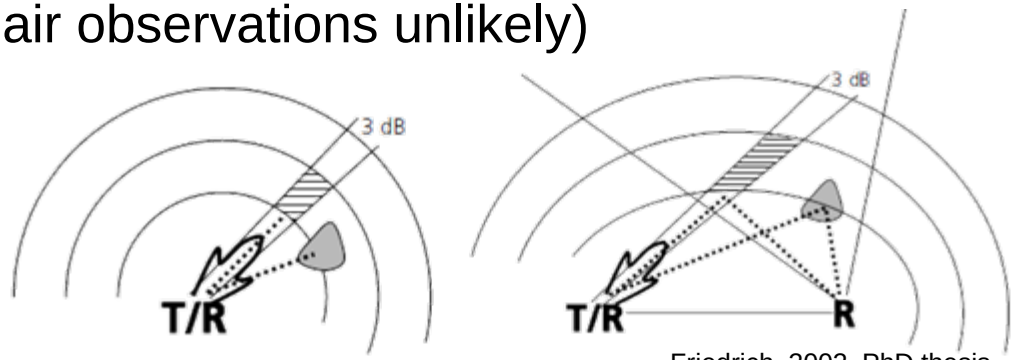


Friedrich & Hagen, 2004
JTECH, 21, 1840-1854

Conclusion Bistatic Doppler radar network

- Advantages:
  - Low costs for a multiple Doppler radar system
  - high resolution (pulse volume) wind field estimates
  - temporal synchronized measurements

- Disadvantages:
  - reduced sensitivity (clear-air observations unlikely)
  - contamination by side-lobes of radar
  - Production and support of systems stopped



Friedrich, 2002, PhD thesis