Invest to Save Budget

EVALUATION OF DISPERSION MODEL PARAMETERS BY DUAL DOPPLER LIDARS OVER WEST LONDON, U.K.

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Met Office

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ISB 52 Project Team

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Aims

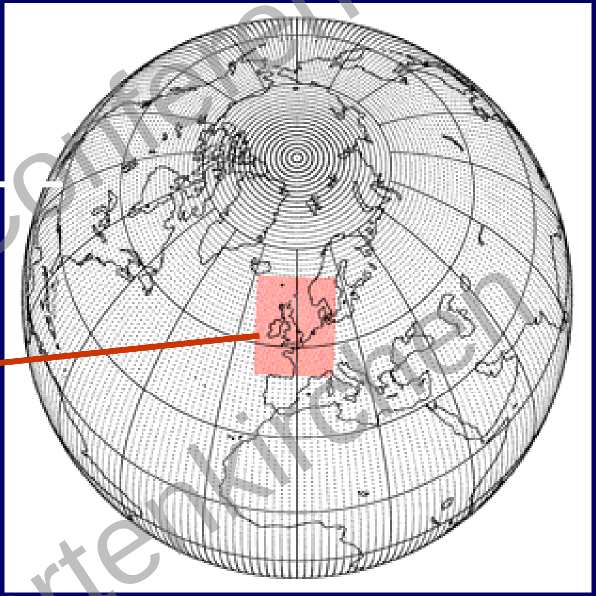
- Improve the forecasting of air quality from dispersion models.
- Use lidar data to measure dispersion model parameters used in meteorological pre-processing.
- Evaluate NAME/Unified Model, ADMS and other models using the lidar results.
- Following COST 715, investigate rural-urban differences

Work programme

- Upgrade the lidar systems with more powerful TEA lasers, new data processing software, better SNR.
- Deploy two scanning pulsed Doppler lidar systems simultaneously at an urban site.
- Prove the dual lidar concept.
- Obtain new urban and rural data sets.
- Develop suitable algorithms.
- Improve model parameters.
- Develop new visualisation software (DAViS).

Unified Model

- Global: 60 km
- (Regional)
- Mesoscale: 12 km



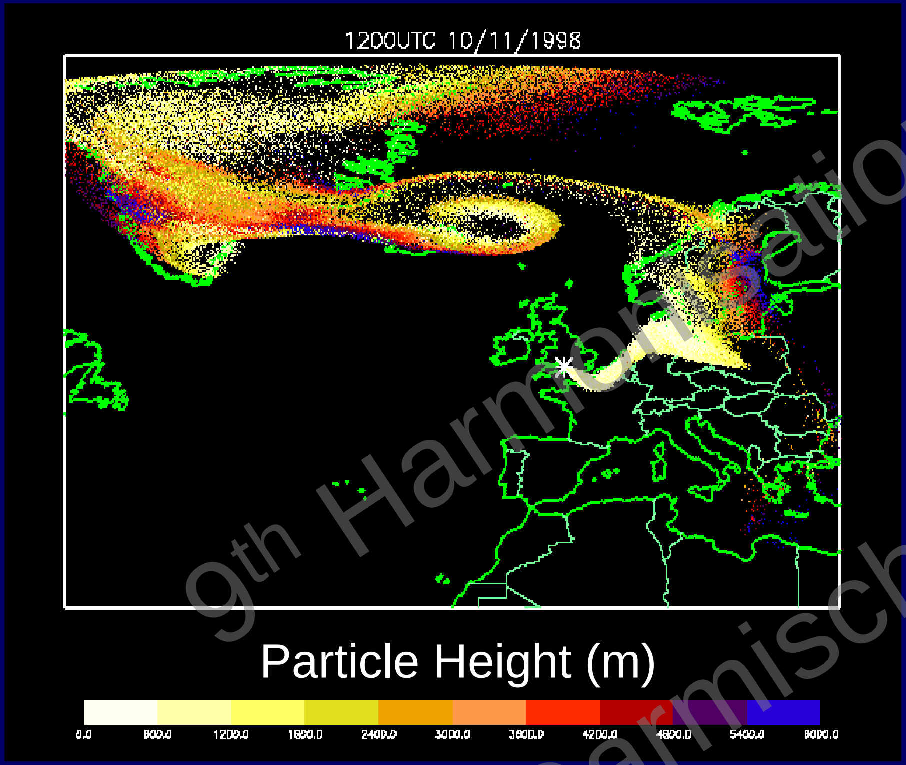
…operational weather forecasting model

…38 levels

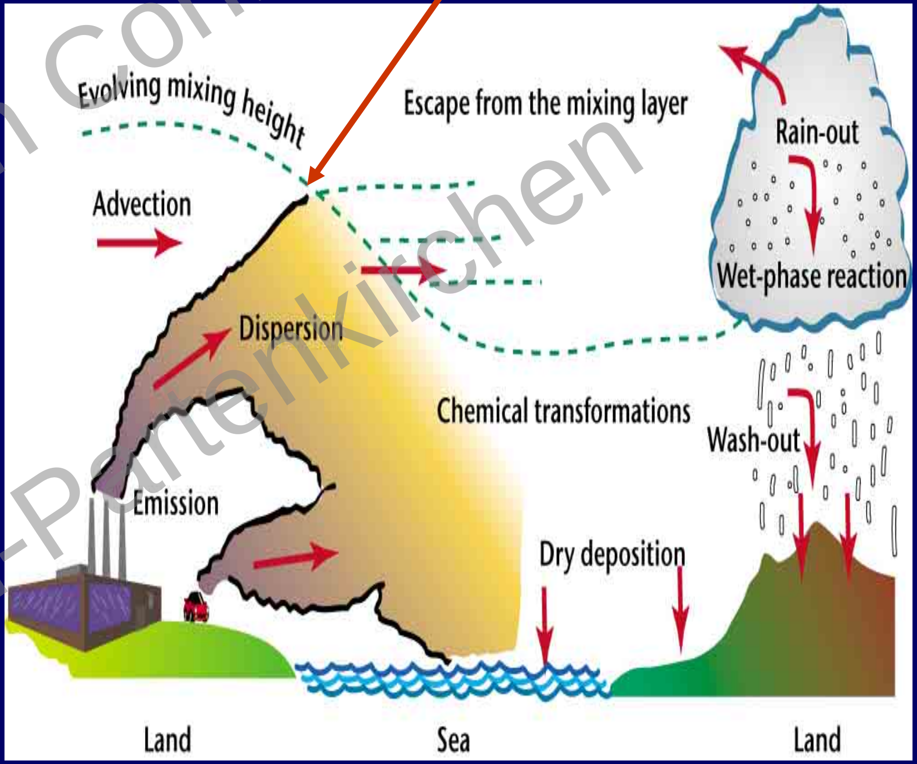
…output data from daily runs stored

NAME Dispersion Model

Concentration forecasts are sensitive to the Mixing Height



Example of Lagrangian Plume
Continuous Release 4 Days



Emission, Rise, Dispersion,
Reaction & Deposition

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Modelling pollution

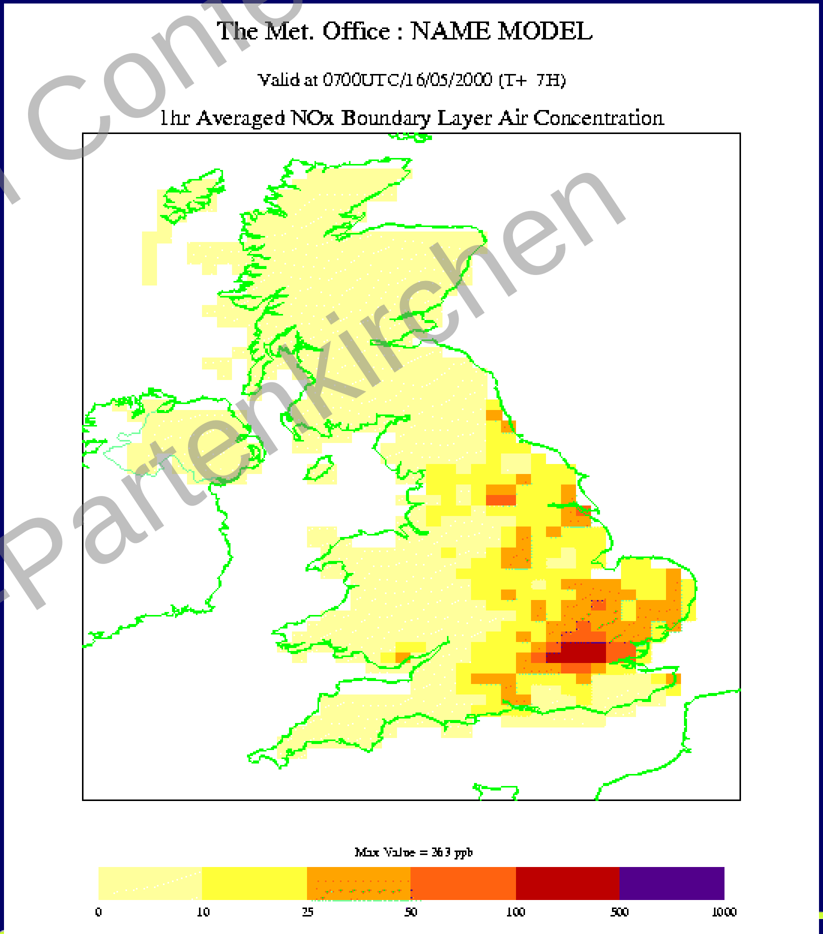
- Large number of Lagrangian particles are released into the model atmosphere.
- Particles advected by mean wind.
- Turbulence by random walk techniques.
  – Velocity variances after Kansas/Minnesota
  See Helen Webster's paper!
- Plume rise and mixing height use NWP profiles.

Parameters in NAME

- NAME uses UM variables and calculates dispersion parameters
  - Boundary Layer Depth: Parcel ascent or Ri
  - Calculates turbulence (velocity variances)
  - Calculates integral timescale & eddy diffusivity

Air Quality forecasts

- NAME model
- Forecasts twice daily
- CO, NO_x, SO_2, PM_{10}
- PM_{10} includes European primary and secondary aerosols
- O_3 at NETCEN via trajectory/met data
- Dissemination on Web



Important Dispersion Parameters for Urban Air Quality Forecasts

- Mixing height – if too shallow, makes forecast too high.
- Stability - if too stable for urban boundary layer, could under-estimate turbulence, makes forecast too high. Depends on urban heat flux.
- Wind field – controls the advection of pollutants across the city and through the urban canopy.
- COST 715 Reports and Workshops have studied these parameters in an urban setting; essential for improving air quality models.

Pulsed Doppler Lidar

$$\Delta f = 2u \cos\theta / \lambda$$

- Powerful 10.6µm pulse is back-scattered by atmospheric aerosol & cloud droplets
- Range from time of flight: 112 metre “gates”
- Doppler shift along beam: “radial velocity”
- Maximum Range depends on back-scatter: 5-10 km
- Scan: vertical elevation; direction (azimuth)
- Velocity from centre of spectrum of observed

Lidar measurements

- A challenge was to understand the nature of the lidar measurement, and how to use it, as the beam is scanned through elevation & azimuth.
- The 'signal' is a line of sight average along a 112 metre long part of the beam volume.
- Measures radial velocity (at centre of spectrum of returned Doppler Velocities).
- Measures back-scatter signal intensity, and calculates SNR (signal to noise ratio).
- Sample rate up to 50 Hz; usually 10 Hz.

Dispersion Model parameters from lidar (Table)

- Mixing height h – RHI scans: SNR or back-scatter data.
- Profiles of mean velocity & direction u,v,w – VAD scan
- Turbulence σ_u σ_v σ_w – multiple RHI or Dual scans
- Friction Velocity u_* – Reynolds stresses using u' v' w'
- Eddy dissipation rate ε –spectral slope
- Lagrangian integral timescale τ and lengthscale L_i
- Sensible heat flux H – indirectly – Gal Chen et al. 1992
- Convective velocity scale w_* – Angevine et al 1994; Hojstrup 1982

Dual lidars 1.7km apart at RAF Northolt, West London, July 2004.

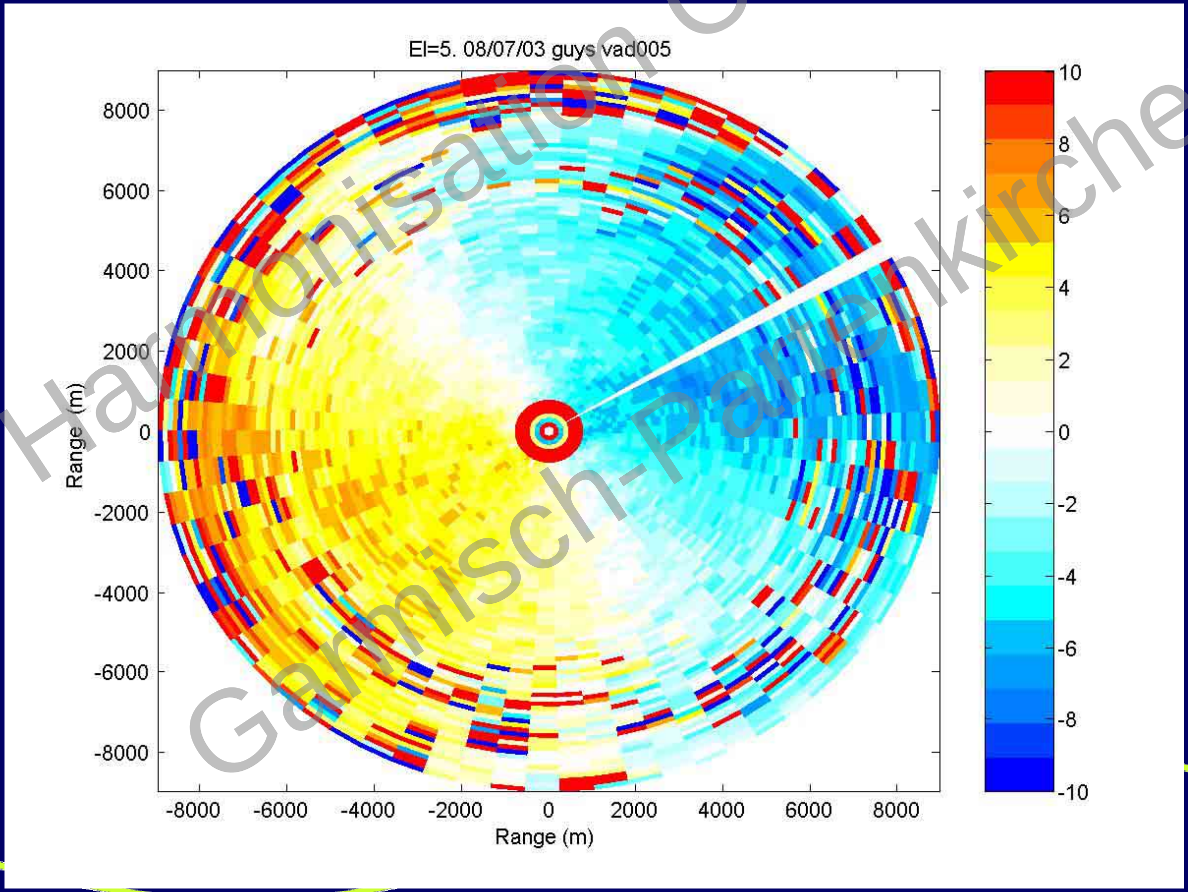
Lidar • Beamcross •

Lidar Velocity Azimuth Display VAD

- Plot radial velocity as beam sweeps out inverted cone. Shows mean wind direction.

velocity

Range



Range

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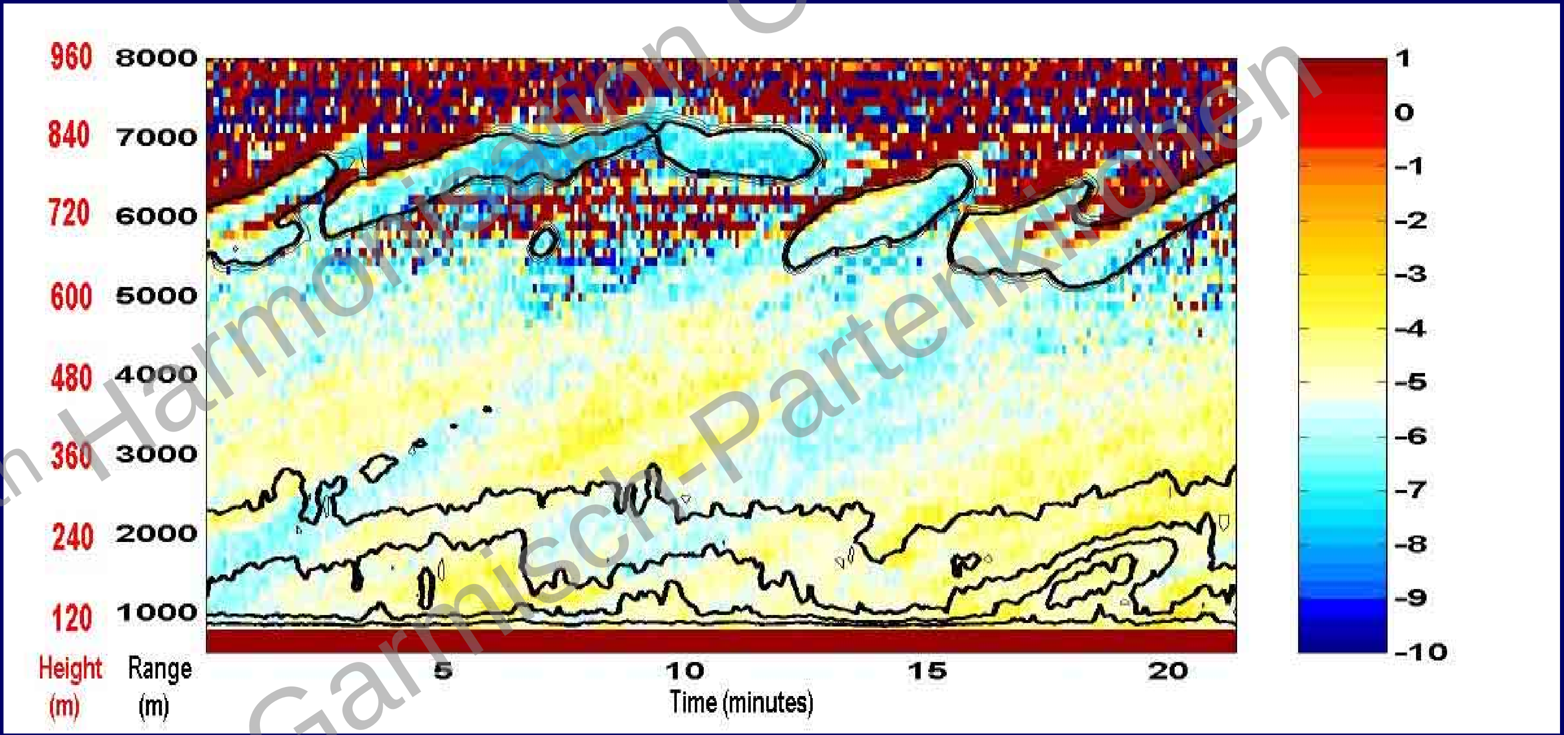
Lidar Fixed Stand and Stare

- Fixed stand and stare:, observe changing flow moving through the beam; sample data for 10-20 minutes; derive statistics.

Height



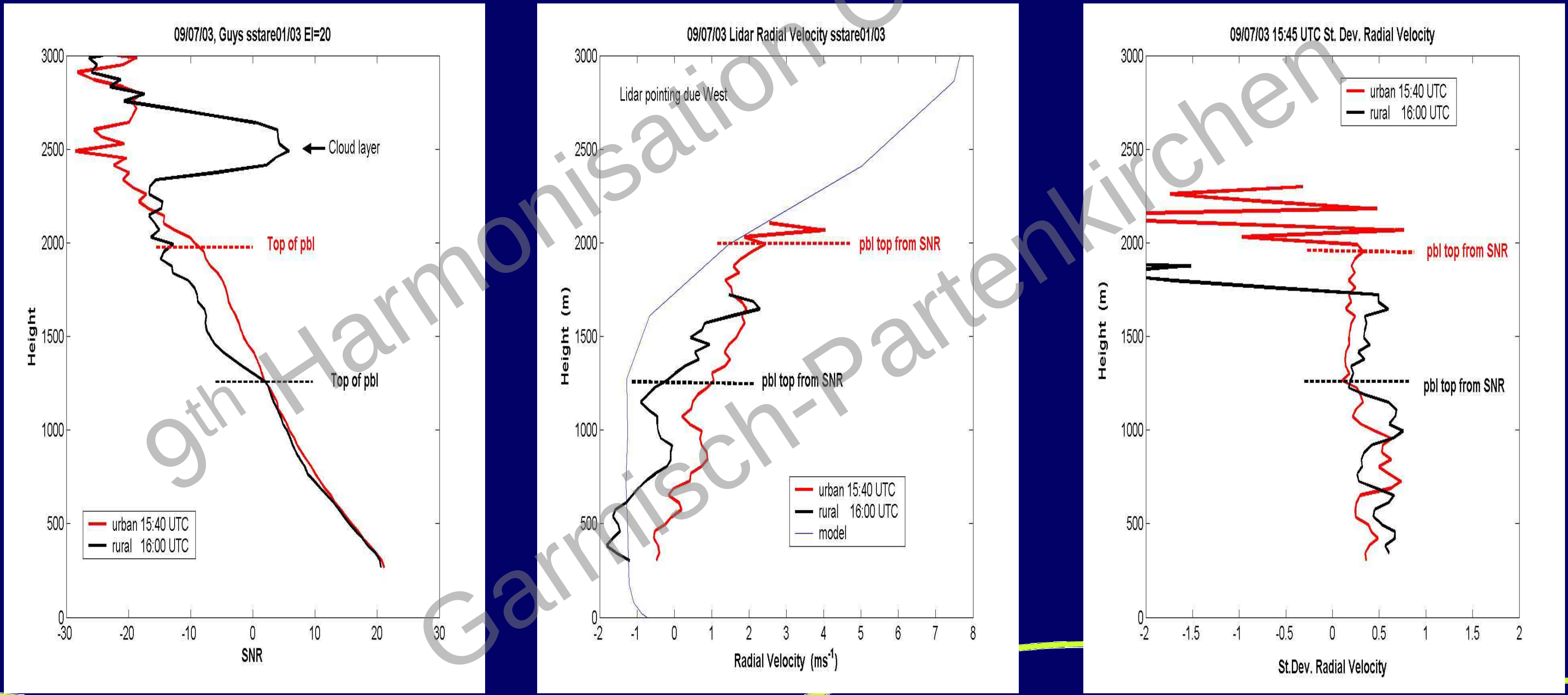
Time

velocity

Stand and Stare Profiles: 9/07/03
Lidar pointing West

Urban 15:40 UTC ——— Rural 16:00 UTC ———

SNR dB | Radial velocity | SD Radial velocity



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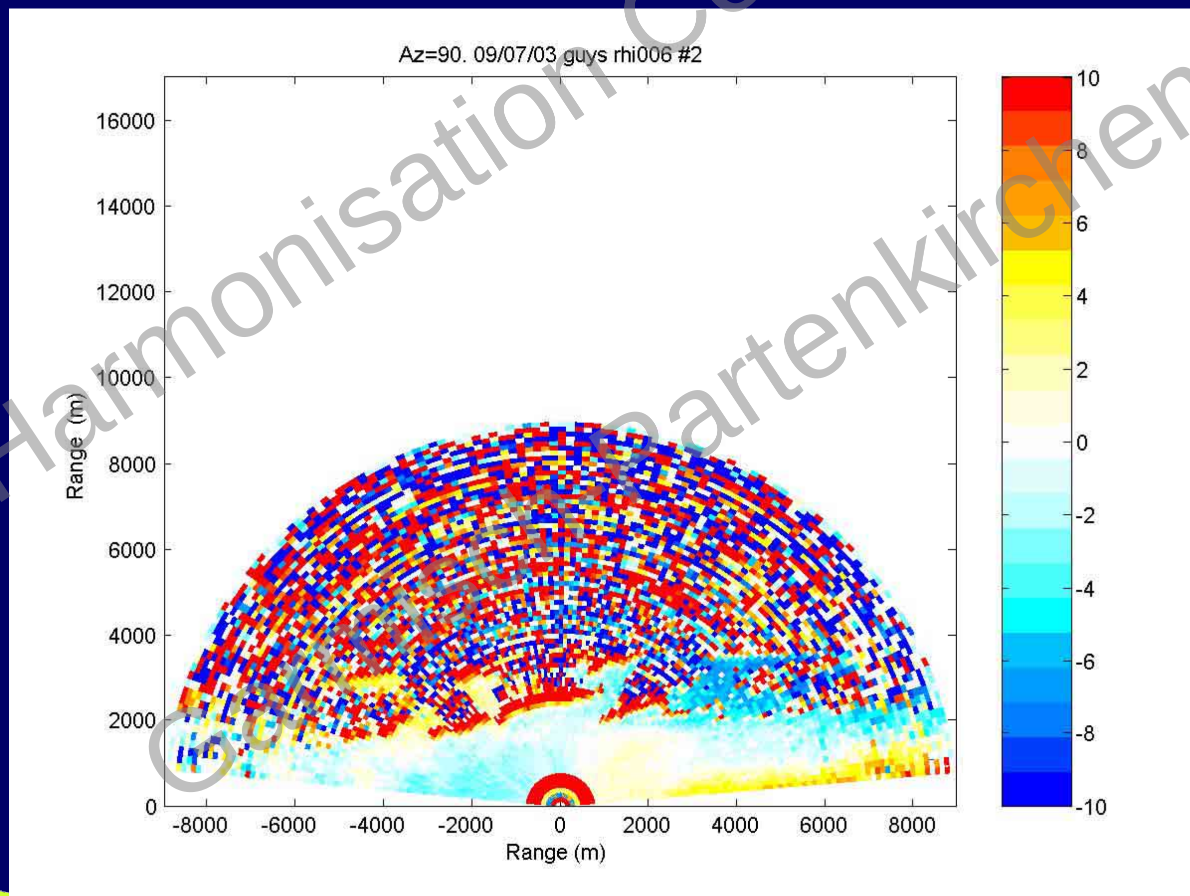
Lidar Range Height Indicator RHI 6

- Plot radial velocity as beam sweeps vertical semicircle over the instrument, from rural SW to urban NE.

Range



Range velocity

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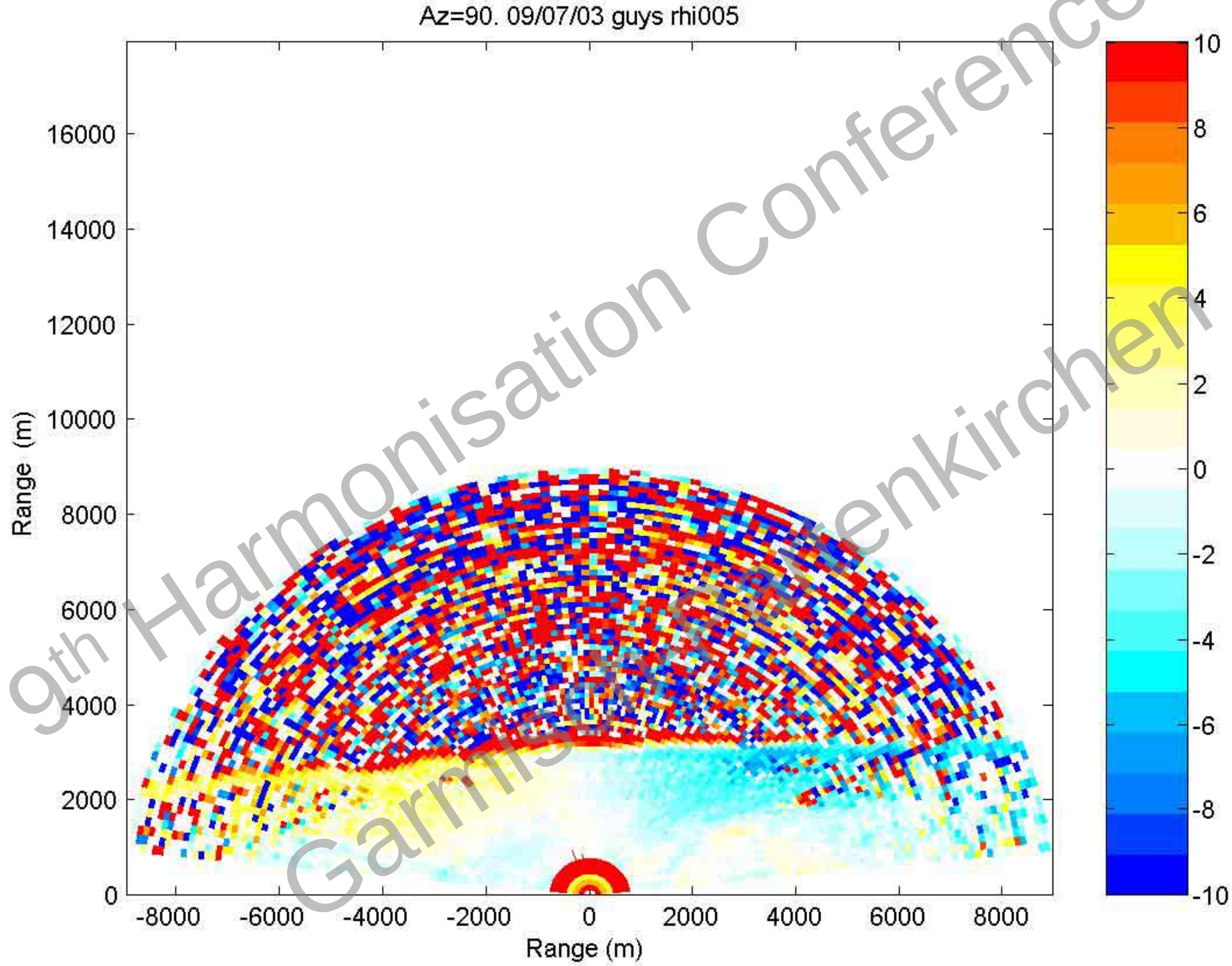
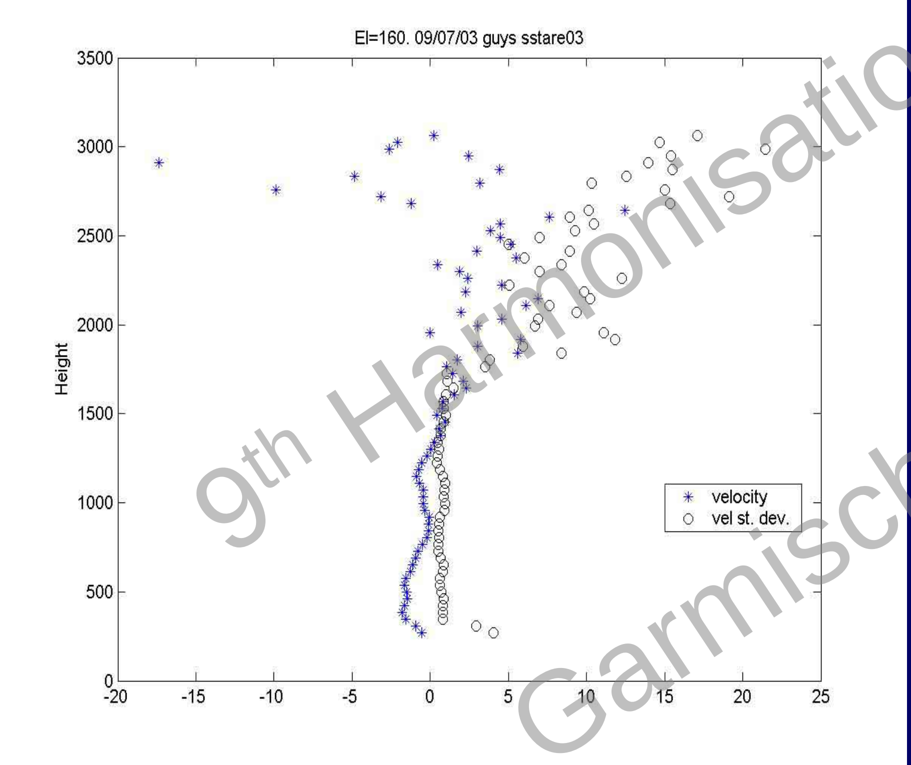
Rural-Urban transition RHI 5

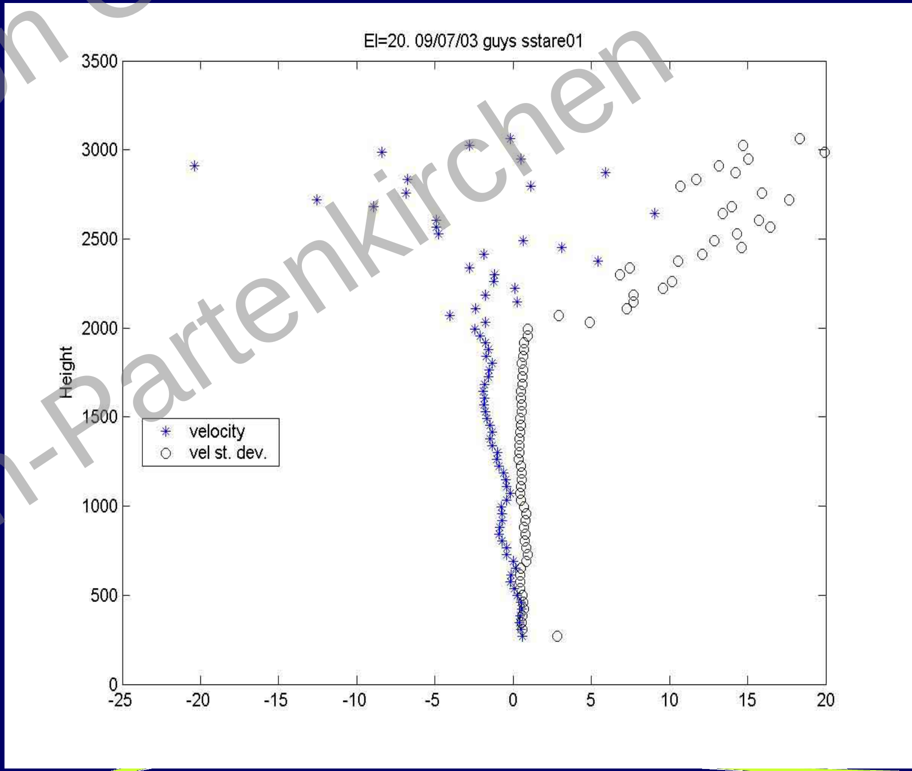


Profiles of Mean Velocity & Standard Deviation 9/07/03

Rural view



Urban view



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Rural-Urban Difference

- RHI scans on 9 July 04 revealed an upward slope on going from the rural to urban conditions.
- Profiles of velocity & variance show a similar increase in the mixed layer
- Plan to investigate this further using a high resolution mesoscale model simulation with urban and surface tiling schemes.

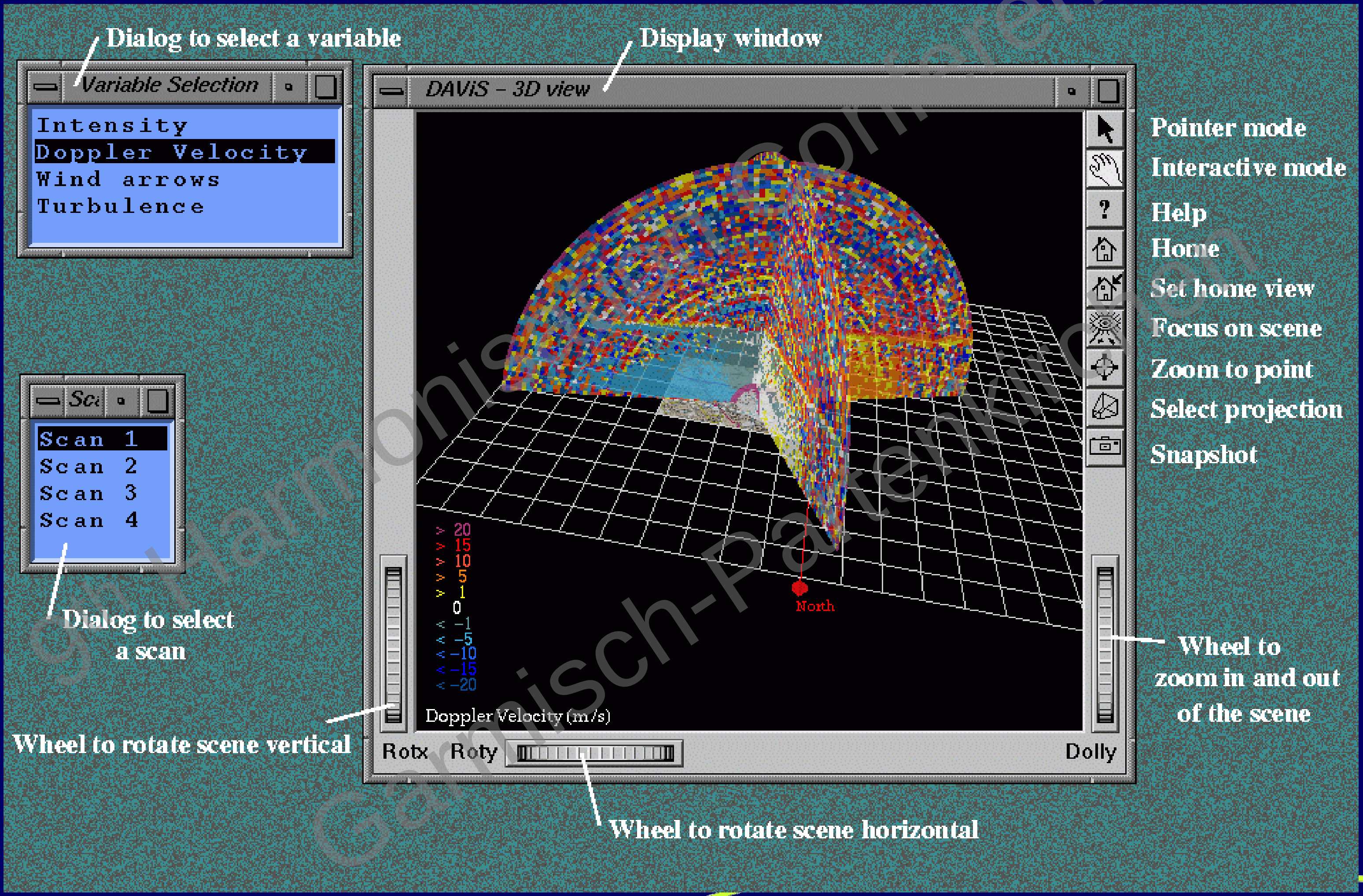
Mixing Height

- From RHI scans, where velocities break down into random colours for each range gate
- From change of gradient in SNR profile
- From decay or discontinuity in back-scatter signal intensity
- By scanning, can be mapped as a contoured surface, exposing urban and rural aspects
- By stand and stare, get some idea of dynamical behaviour and irregularities

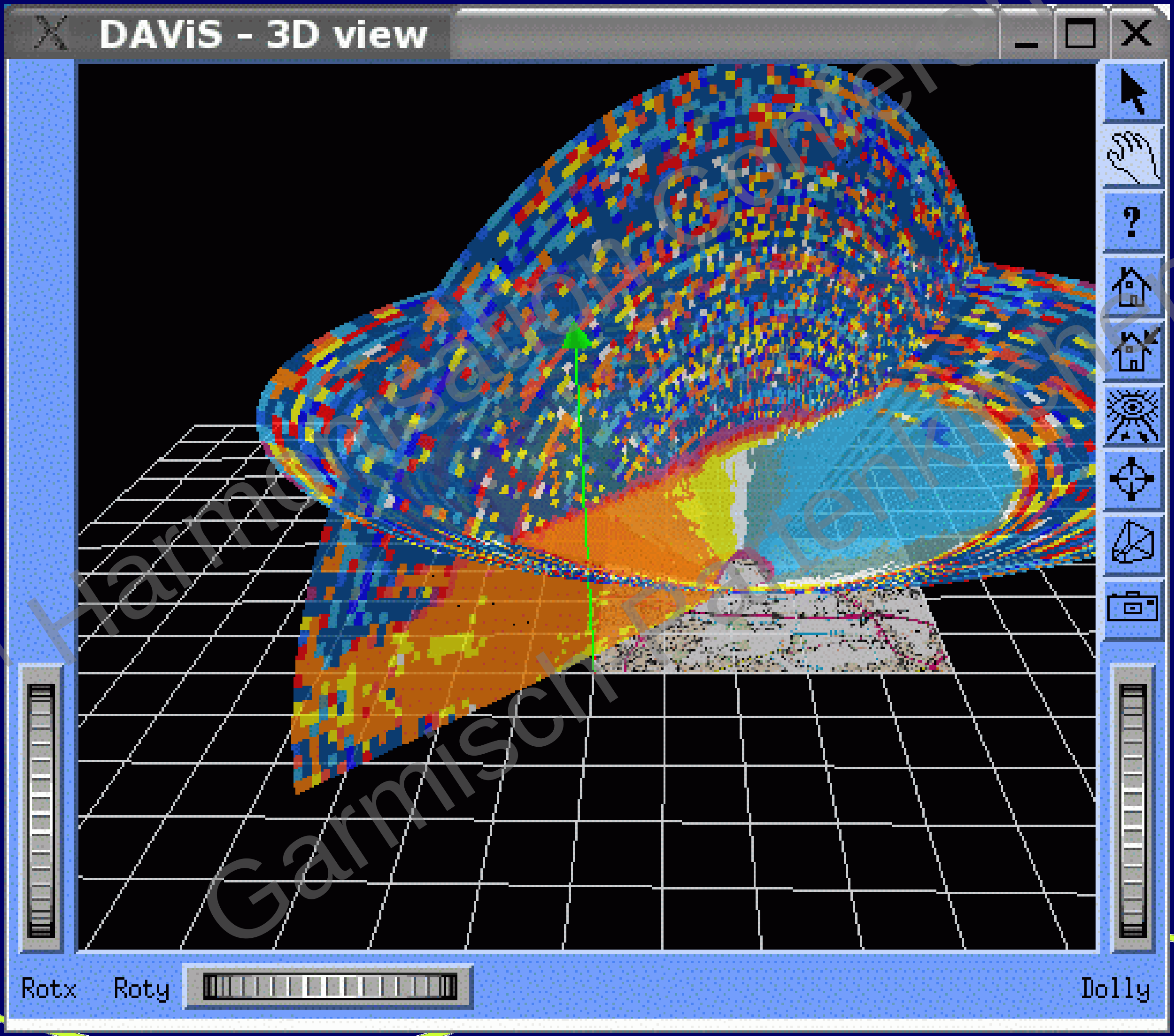
Dual Doppler Lidar

- Two lidars placed 1.7km apart and operated together e.g. opposite ends of runway
- Beams aligned to intersect at a sample volume above the ground
- Fewer assumptions needed when deriving flow with two components being measured
- Also operated in back-to-back mode to scan out over rural and urban areas

DAViS Visualisation Software Tool



DAViS Visualisation Tool: PPI & RHI



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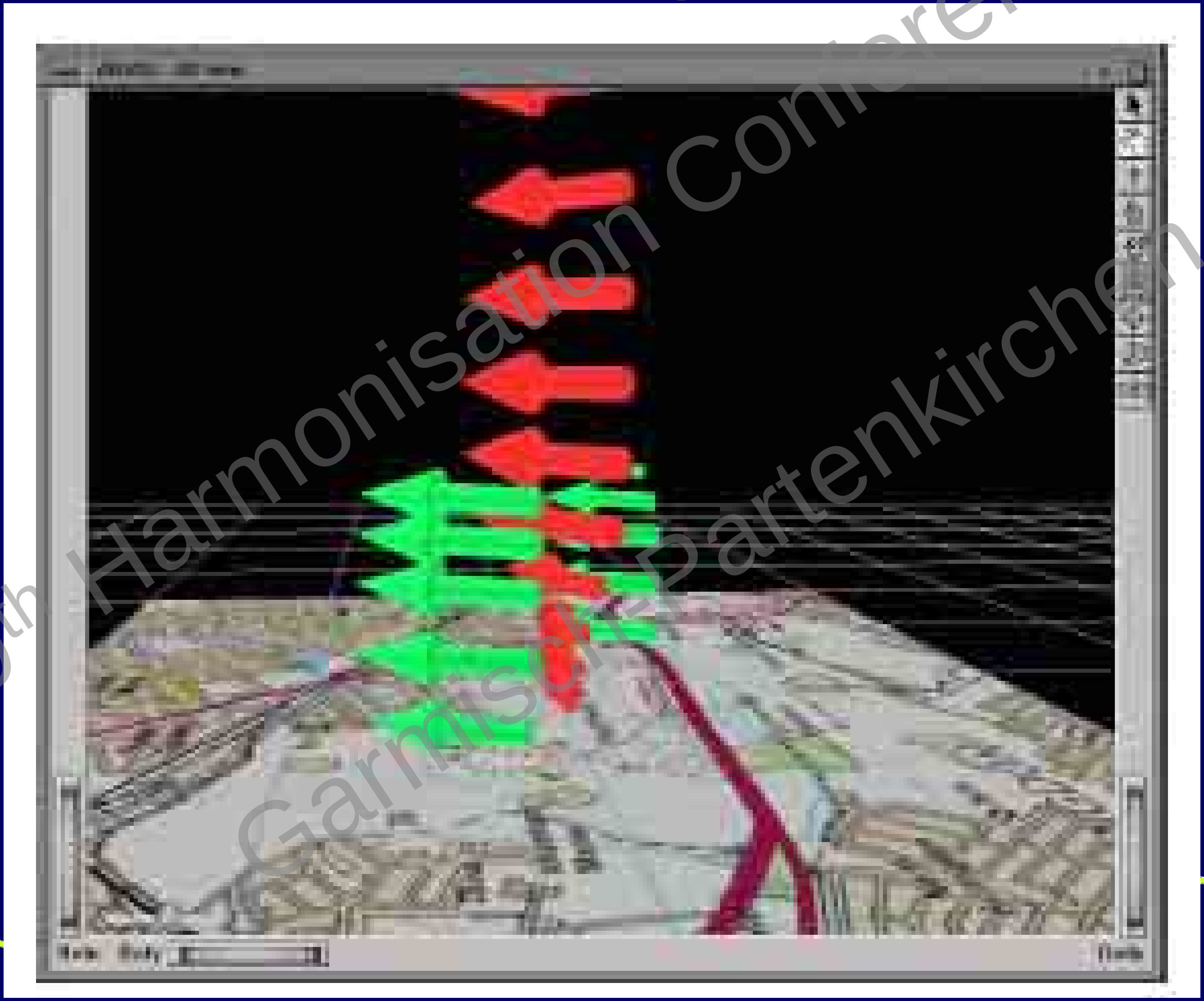
Using DAViS to compare model and lidar wind profiles



Conclusions

- Scanning pulsed Doppler lidar is a powerful tool for studying rural & urban dispersion model parameters.
- Demonstrated the Dual lidar concept by intersecting two beams sampling one volume and analysing first results: error analysis is sensitive to beam geometry.
- Identified those dispersion model parameters derivable in principle from the lidar data.
- Currently analysing results and comparing with model data.
- DAViS visualisation software tool developed.
- Funding of a joint project for further field measurements?

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References

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  - www.aqf.QinetiQ.com
- Collier et al. (in preparation)
  Dual Doppler lidar measurements for improving dispersion models
  Submitted to BAMS (2004).
- NAME Model
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