Neighborhood Scale Modeling

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Objectives for Neighborhood Scale Modeling

- Develop air quality grid models for risk assessments at neighborhood scales
- Develop urban canopy parameterizations for air quality grid modeling with CMAQ
- Create sub-grid pollutant concentration variability fields using PDFs
- Link to human population exposure models

Design Issues

- Scale-dependent model parameterizations in momentum, TKE, surface energy balance, vertical mixing for air quality simulations
- Many area, point, and line sources within urban canopy
- Near-source transport, and horizontal and vertical dispersion constrained by urban canopy characteristics

Why use a UCP?

- Want to improve urban simulations for ~1 km
- Parameterized roughness may not adequately account for heterogeneities in urban areas
- UCP allows for more specific treatment of urban contributions to dynamics and thermodynamics

- Ultimately want to run CMAQ to simulate photochemical pollutant species on that scale

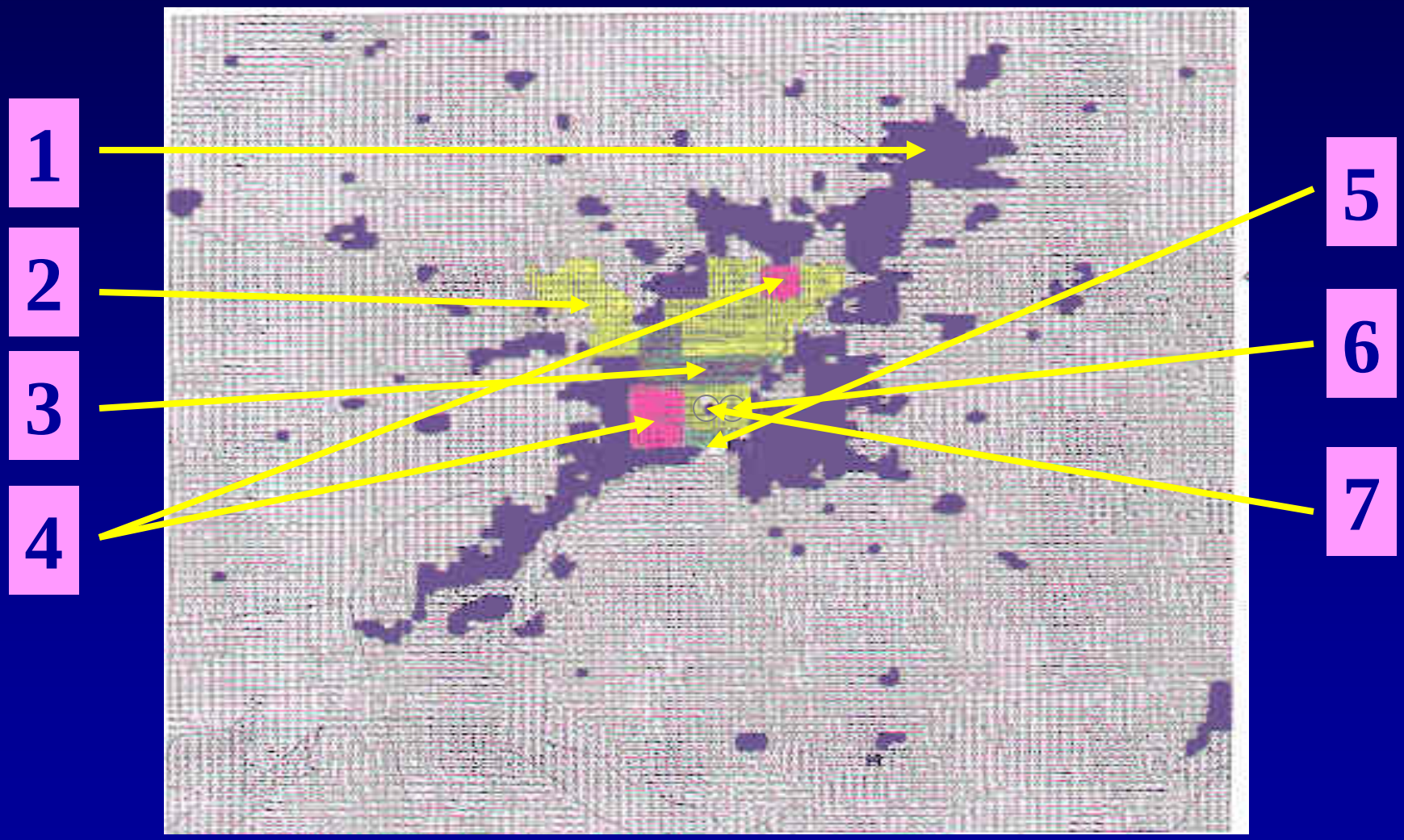
About the UCP

- Based on Brown and Williams “drag approach”
- Applied in 1.3-km MM5 simulations
- Directly impacts grid cells with non-zero urban
- Drag and TKE effects due to urban structures
- Anthropogenic heat as time-varying function
- Extinction of radiation in city canyons
- Roof top contribution under development

Implementing the UCP in MM5

- 40 layers: 12 in lowest 100 m
  - Typical setup has 30 layers, 3 in lowest 100 m
- Updates U, V, TKE in Gayno-Seaman PBL
- Energy modifications in RRTM, solve, slab
- Uses fractional land use categories
- Added new “urban zones” definitions

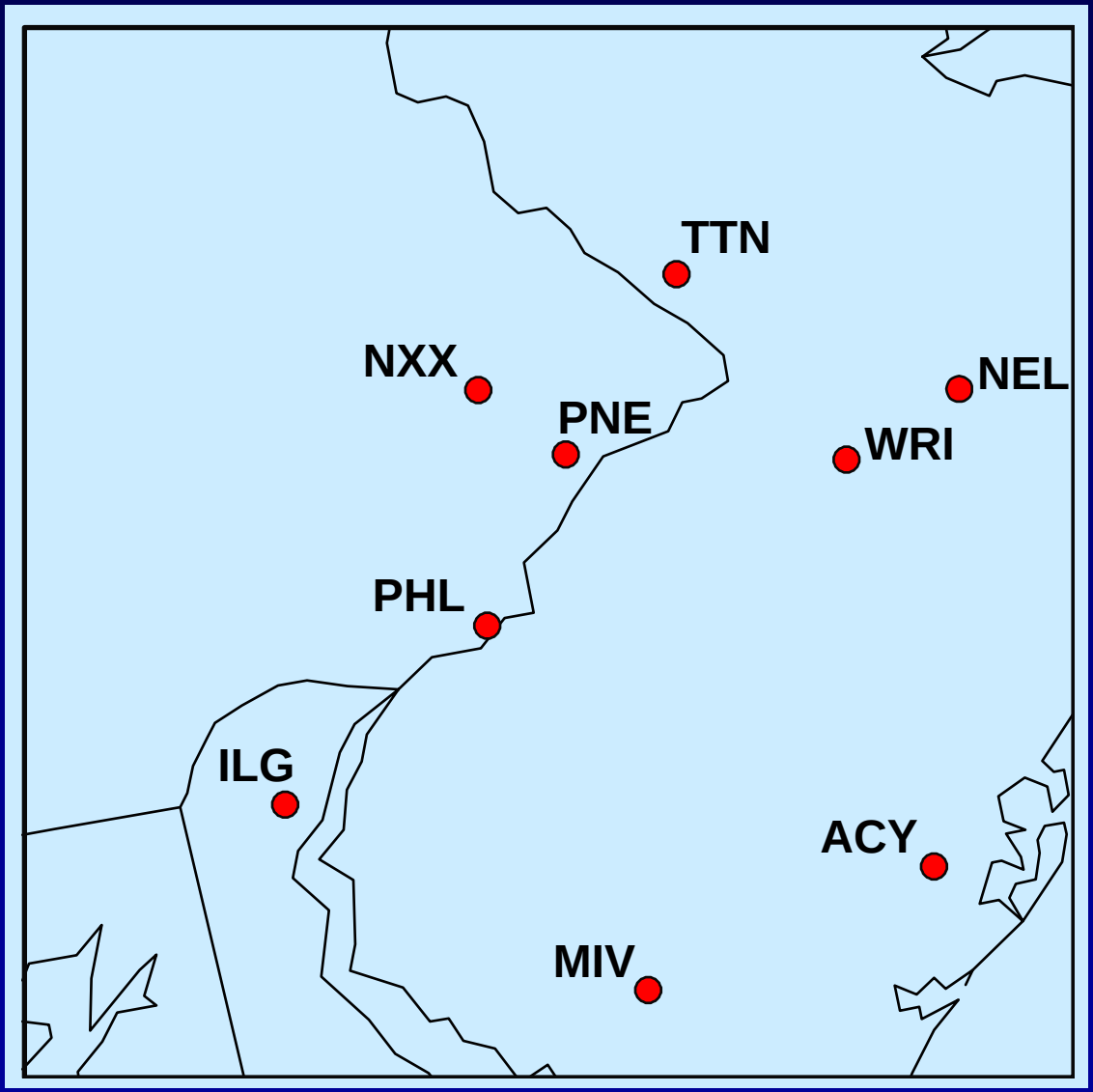
Pseudo-Morphology for Philadelphia



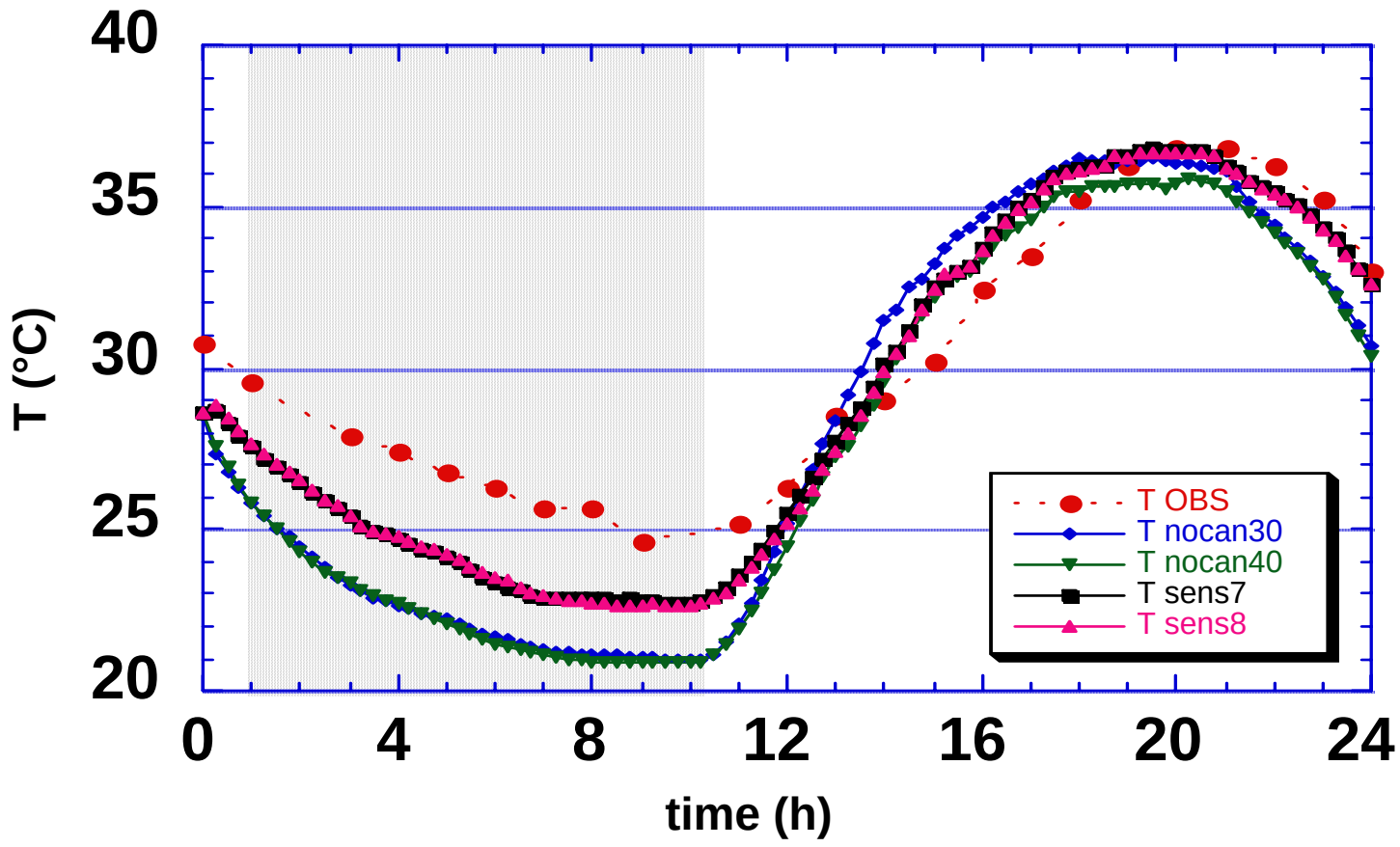
Preliminary Results

- Four experiments here…
  - Initialized 00 UTC 14 July 1995 from 4-km, 30-layer
  - "nocan30": 30-layer, no UCP
  - "nocan40": 40-layer, no UCP
  - "sens7": 7 urban categories (e.g., morphology)
  - "sens8": 1 urban category (wgt'd avg morphology)

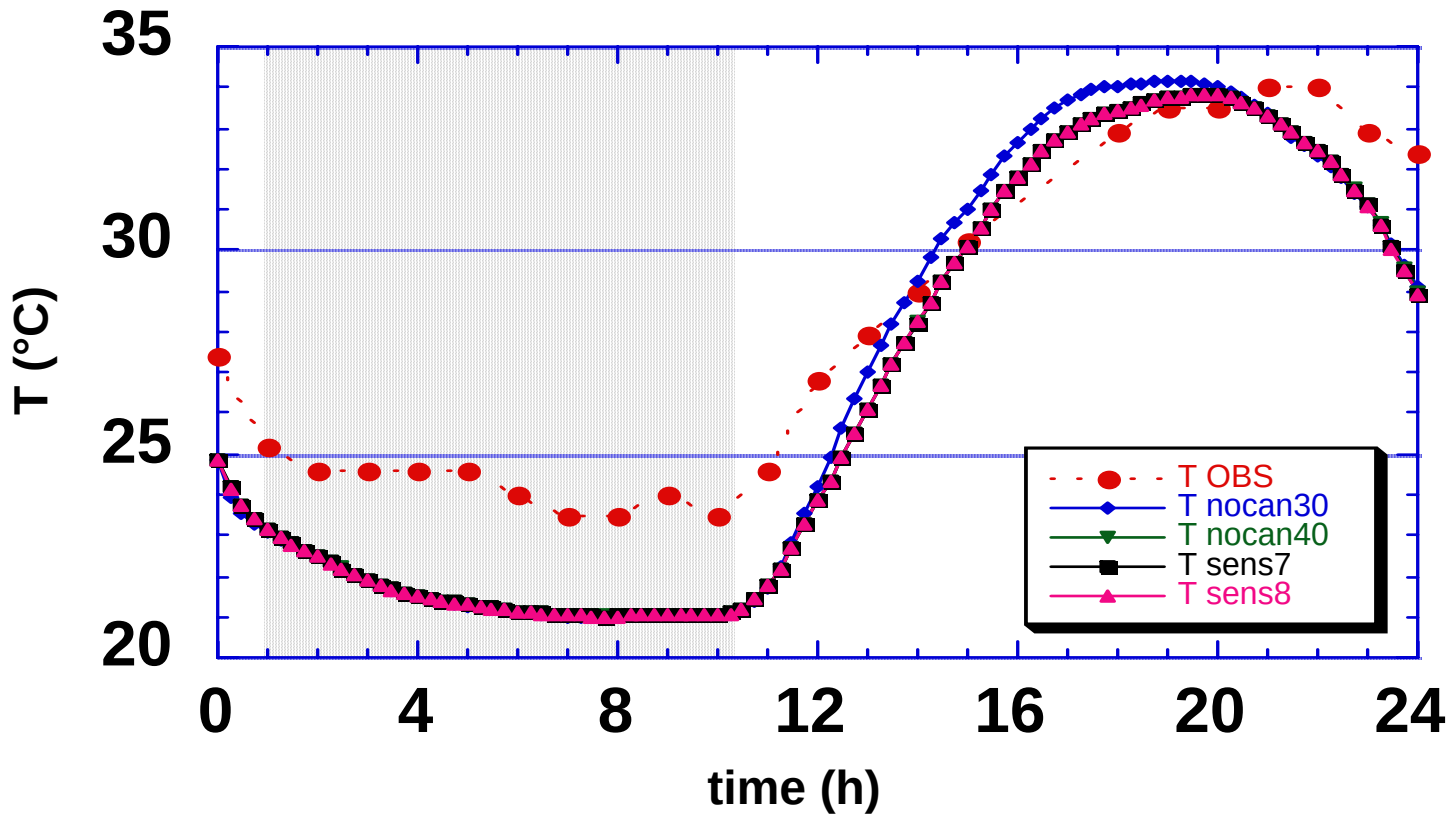
Surface Observations



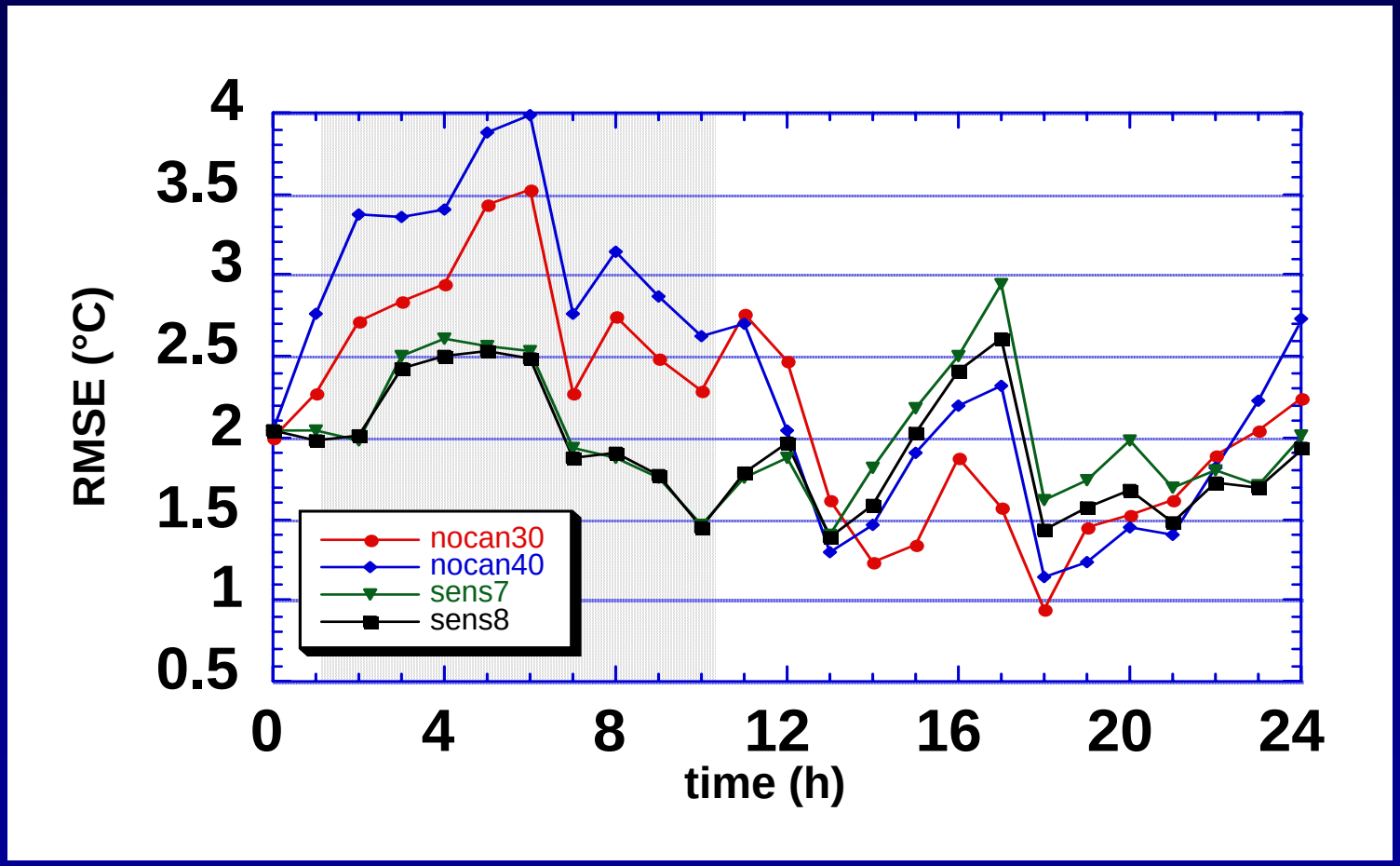
PHL Temperature — 14 July 1995



MIV Temperature — 14 July 1995



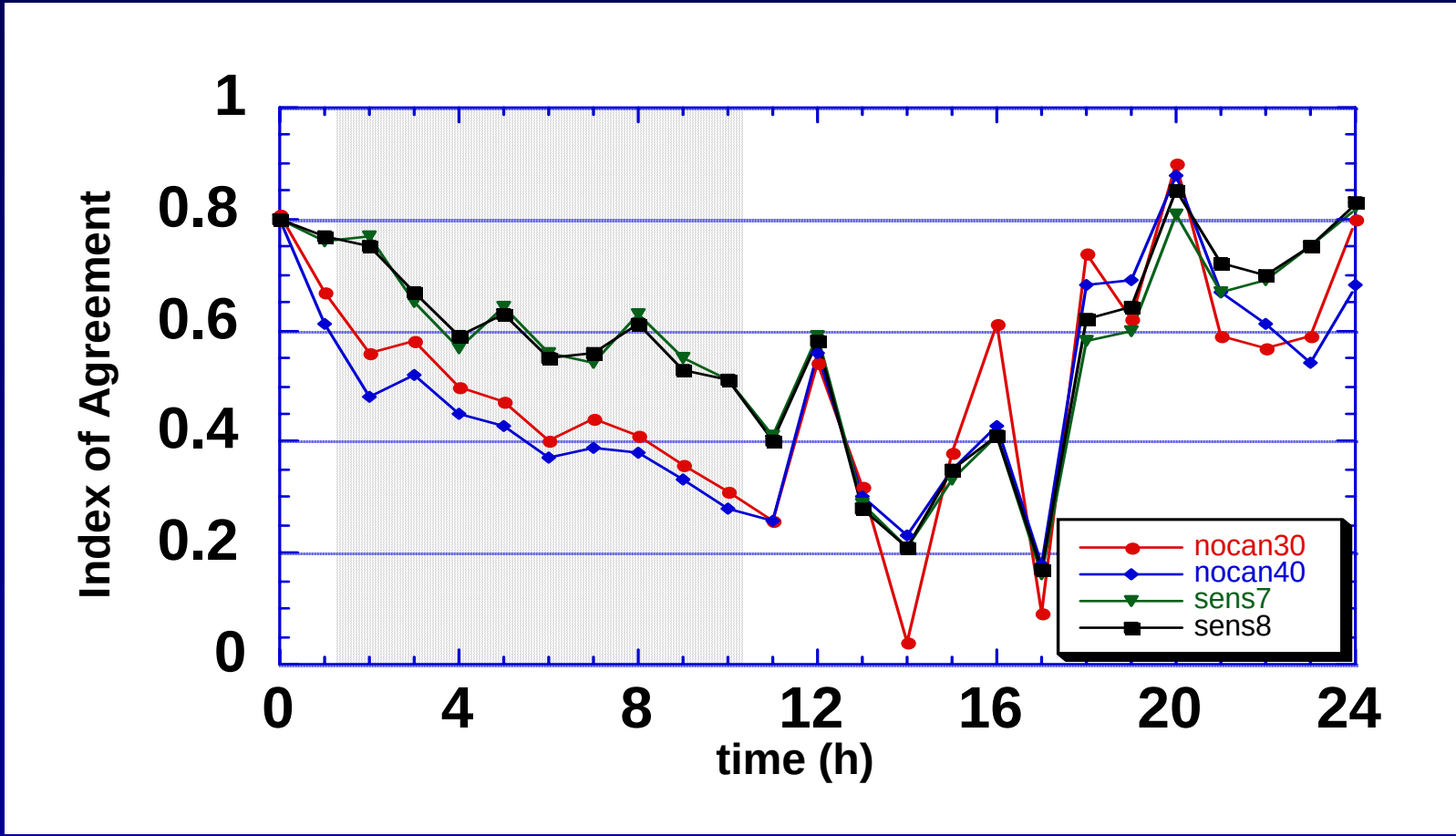
RMSE — Temperature



sens8: 1.93 nocan30: 2.17

sens7: 2.01 nocan40: 2.41

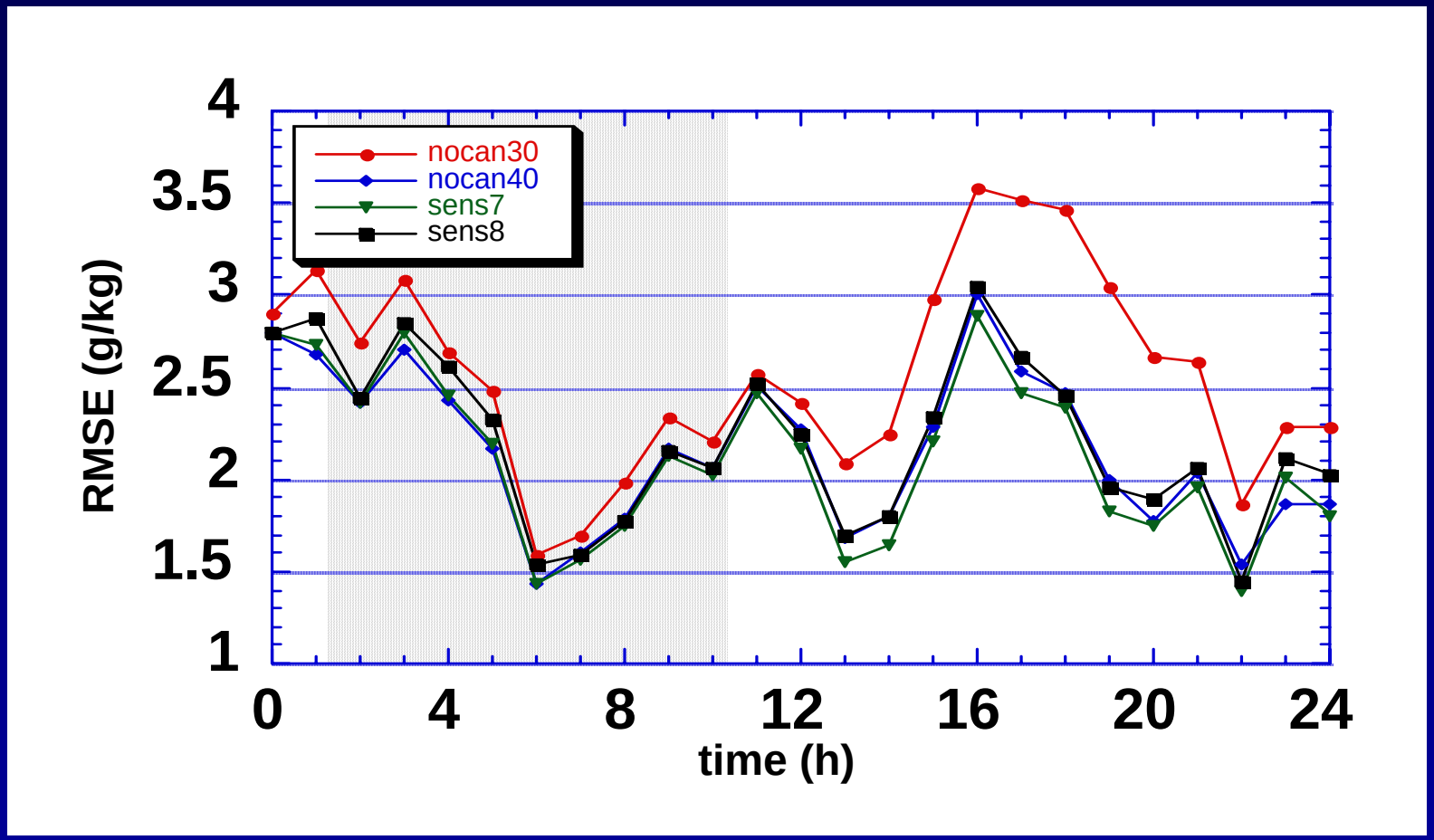
Index of Agreement — Temperature



sens8: 0.58 nocan30: 0.50

sens7: 0.57 nocan40: 0.48

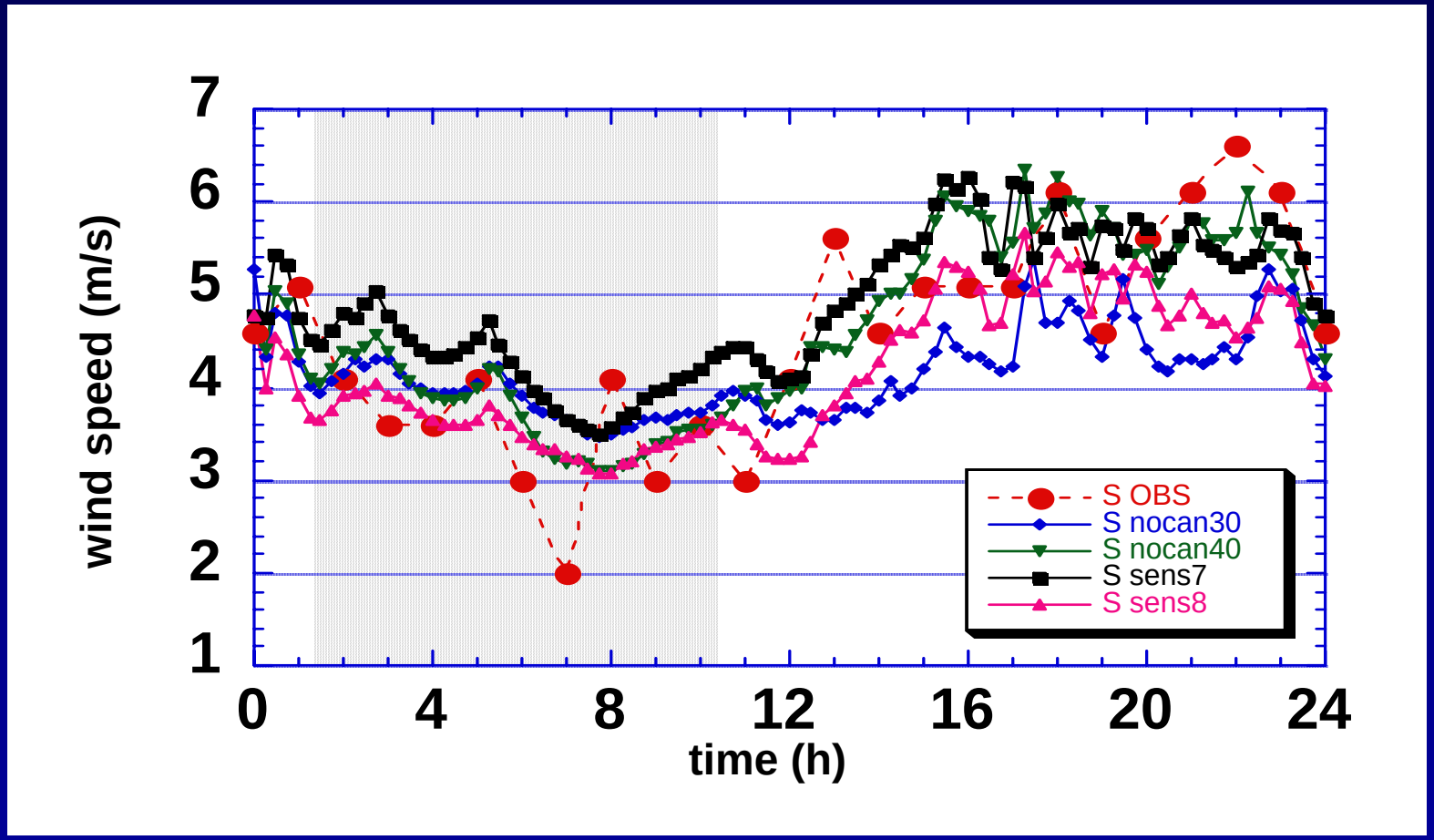
RMSE — Moisture



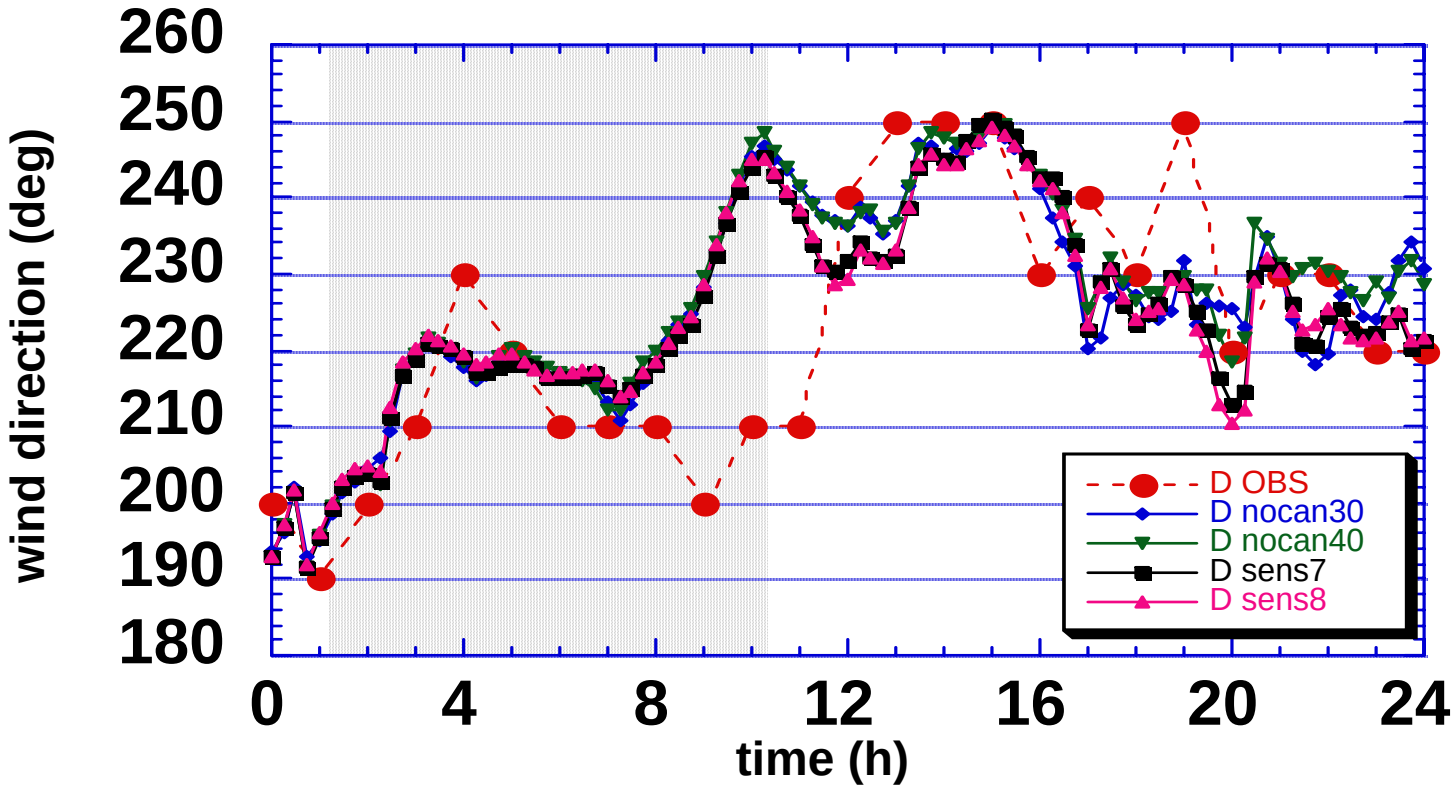
sens7: 2.11 sens8: 2.21

nocan40: 2.16 nocan30: 2.58

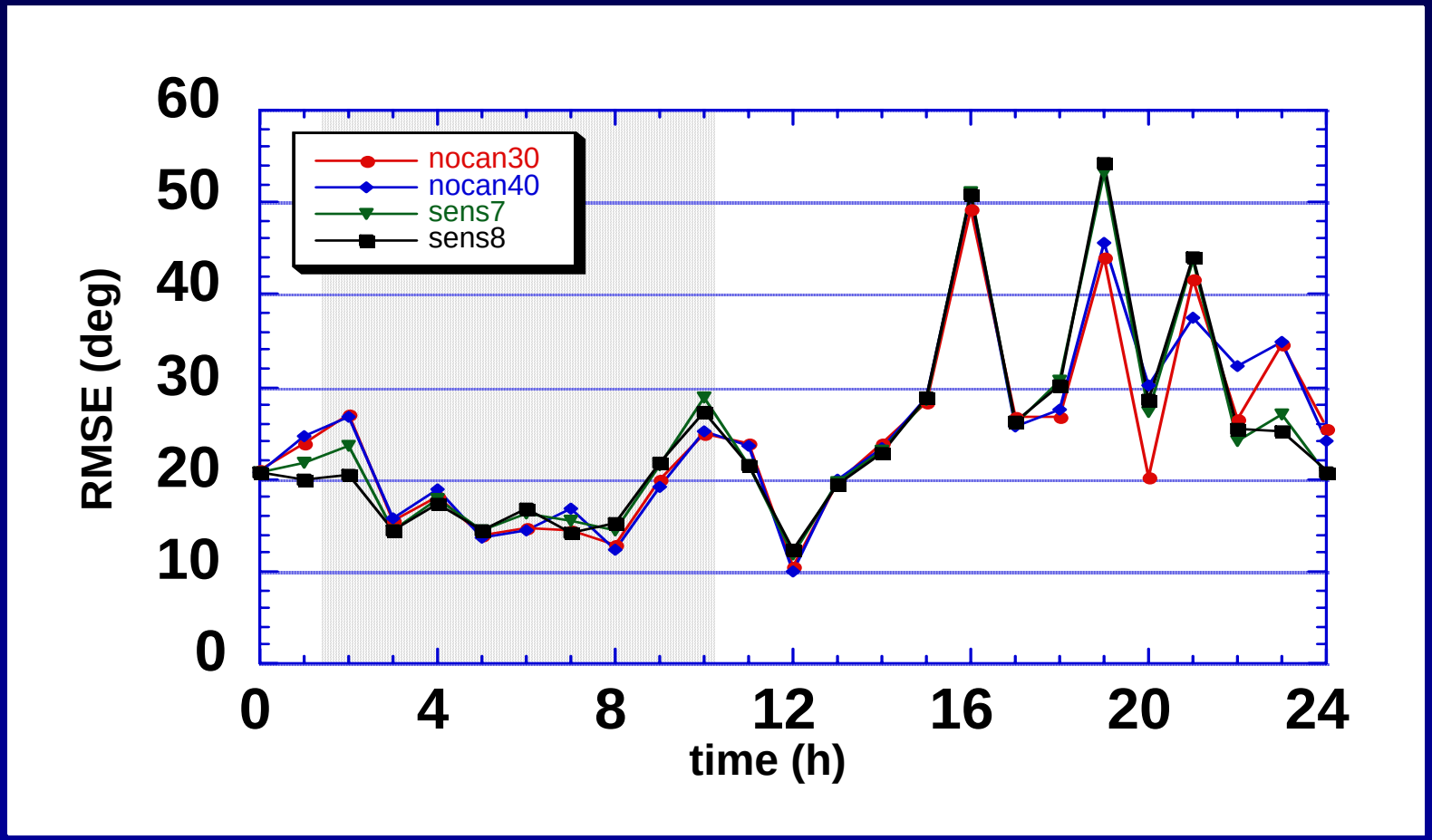
WRI Wind Speed — 14 July 1995



WRI Wind Direction — 14 July 1995

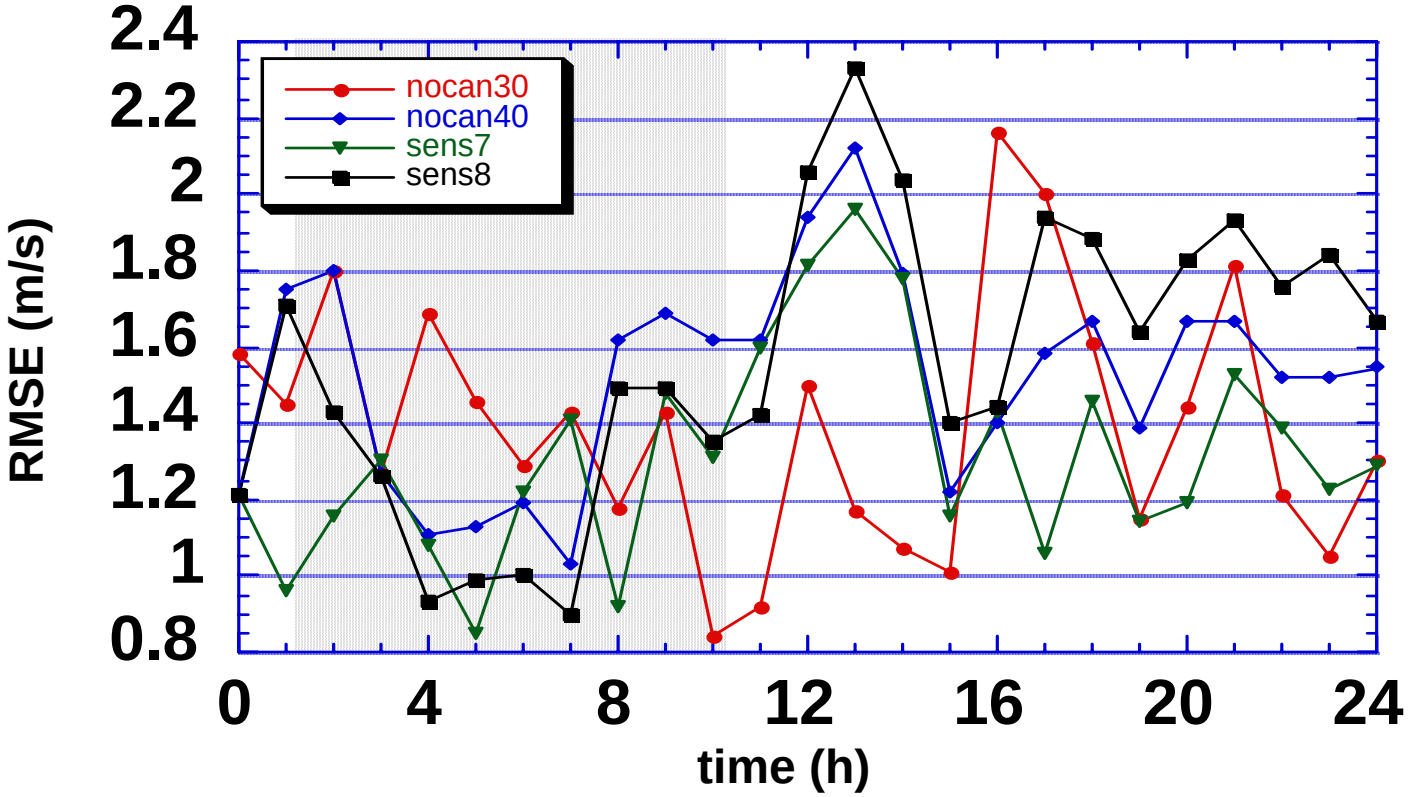


RMSE — Wind Direction



All Expts: 24.3 - 24.8

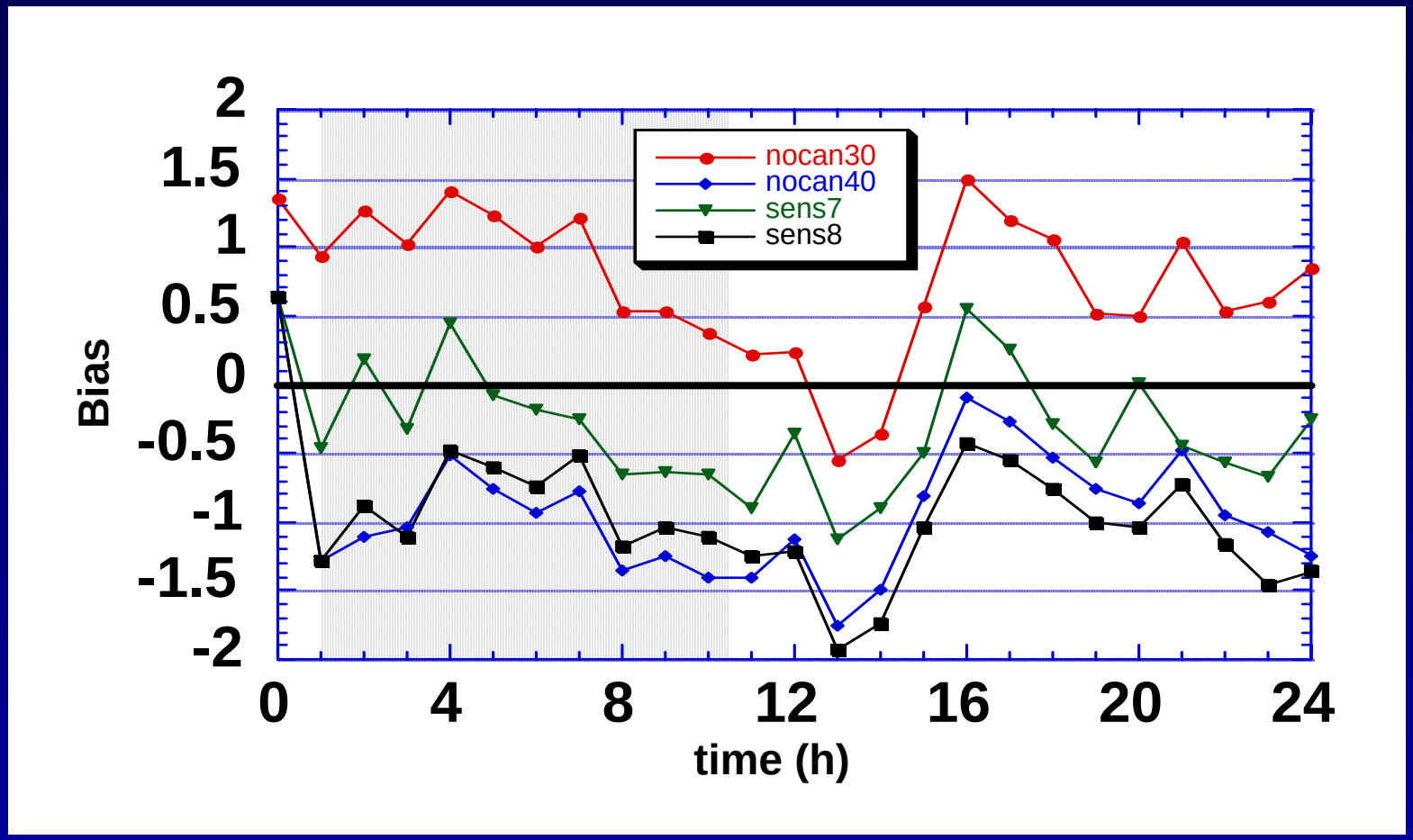
RMSE — Wind Speed



sens7: 1.32 nocan40: 1.52

nocan30: 1.39 sens8: 1.56

Bias — Wind Speed



sens7: -0.31 nocan40: -0.91

nocan30: +0.75 sens8: -0.96

Summary of UCP

- UCP at 1.3-km tends to produce desired effects
  - Changes to wind, TKE, temperature
- UCP tends to be superior to 40-layer run w/o UCP and 30-layer run w/o UCP (standard set-up)
- UCP with morphology tends to be superior to UCP with homogeneous city…esp. wind speed

- …must evaluate more days before concluding!

Advanced UCP

- Extend drag approach to all roughness elements inside canopy (buildings and vegetation)
- Couple drag approach to urban soil model (SM2-U from French SUB-MESO)
- Use actual urban morphology database

Advanced UCP Considerations

- Momentum sources:
  - Horizontal and vertical surfaces of buildings
  - Vegetation
- TKE sources:
  - Horizontal and vertical surfaces of buildings
  - Vegetation
  - Sensible heat fluxes
- Heat and humidity sources:
  - Buildings and vegetative surfaces
  - Anthropogenic contributions

Urban Canopy Parameters

- Mean and std dev of building, vegetation height
- Roof and vegetation area density
- Building and vegetation plan area density
- Frontal area density of buildings
- Surface area of walls
- Plan area fraction of vegetation, roof tops, water, and paved surfaces

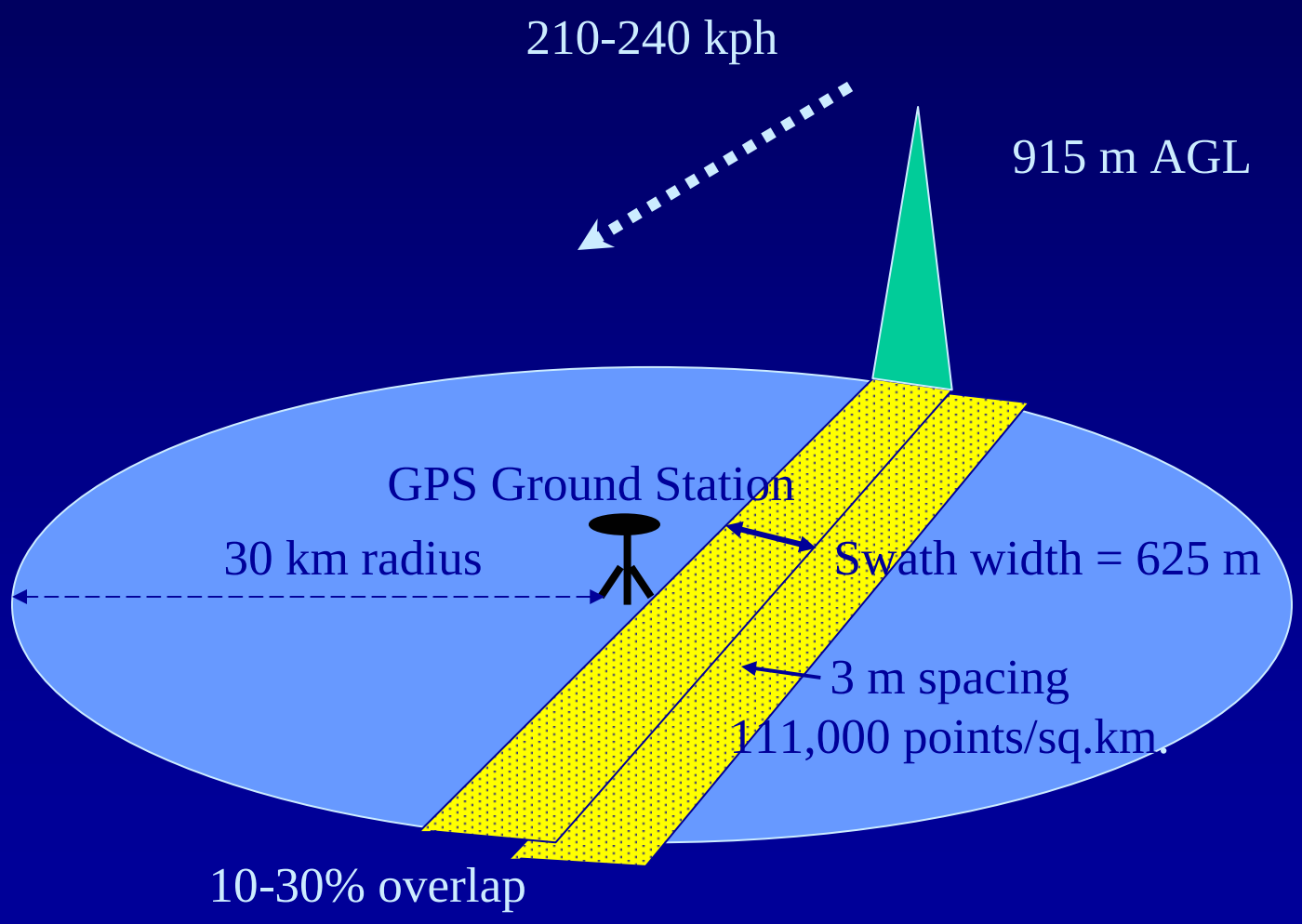
Urban Canopy Parameters (cont.)

- Ratio of building height to width
- Mean orientation of streets
- Sky view factor
- Roughness length
- Displacement height
- Material type of building surfaces
- Percent impervious area directly connected to draining system

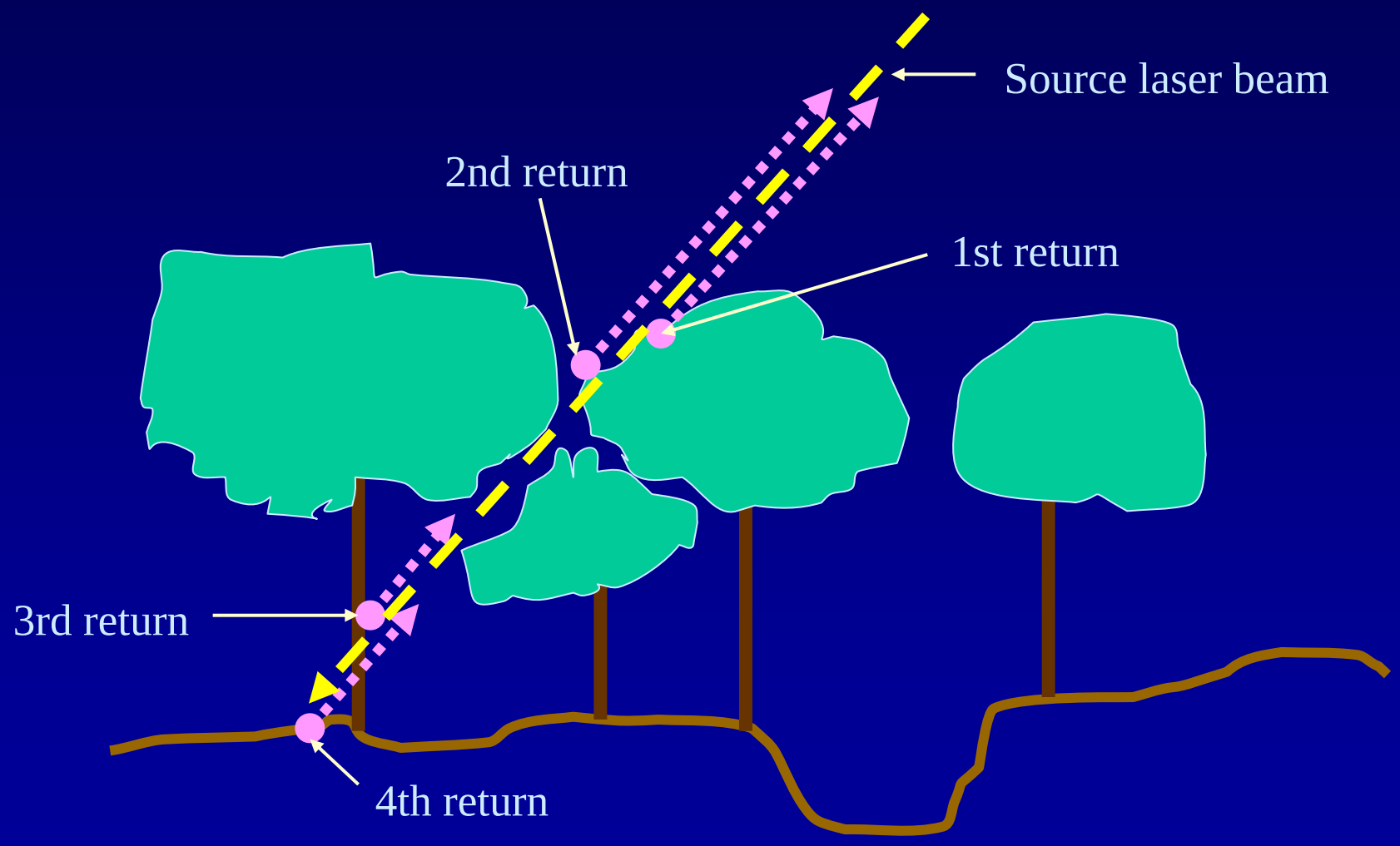
Obtaining Urban Morphology from Lidar Mapping

- Very high data density: 100,000's points/km^2
- High accuracy: 15-30 cm RMSE in open areas
- Flexible: independent of sun angle, cloud cover
- "Multi-Return" allows mapping in canopy gaps
- Rapid collection of elevation data

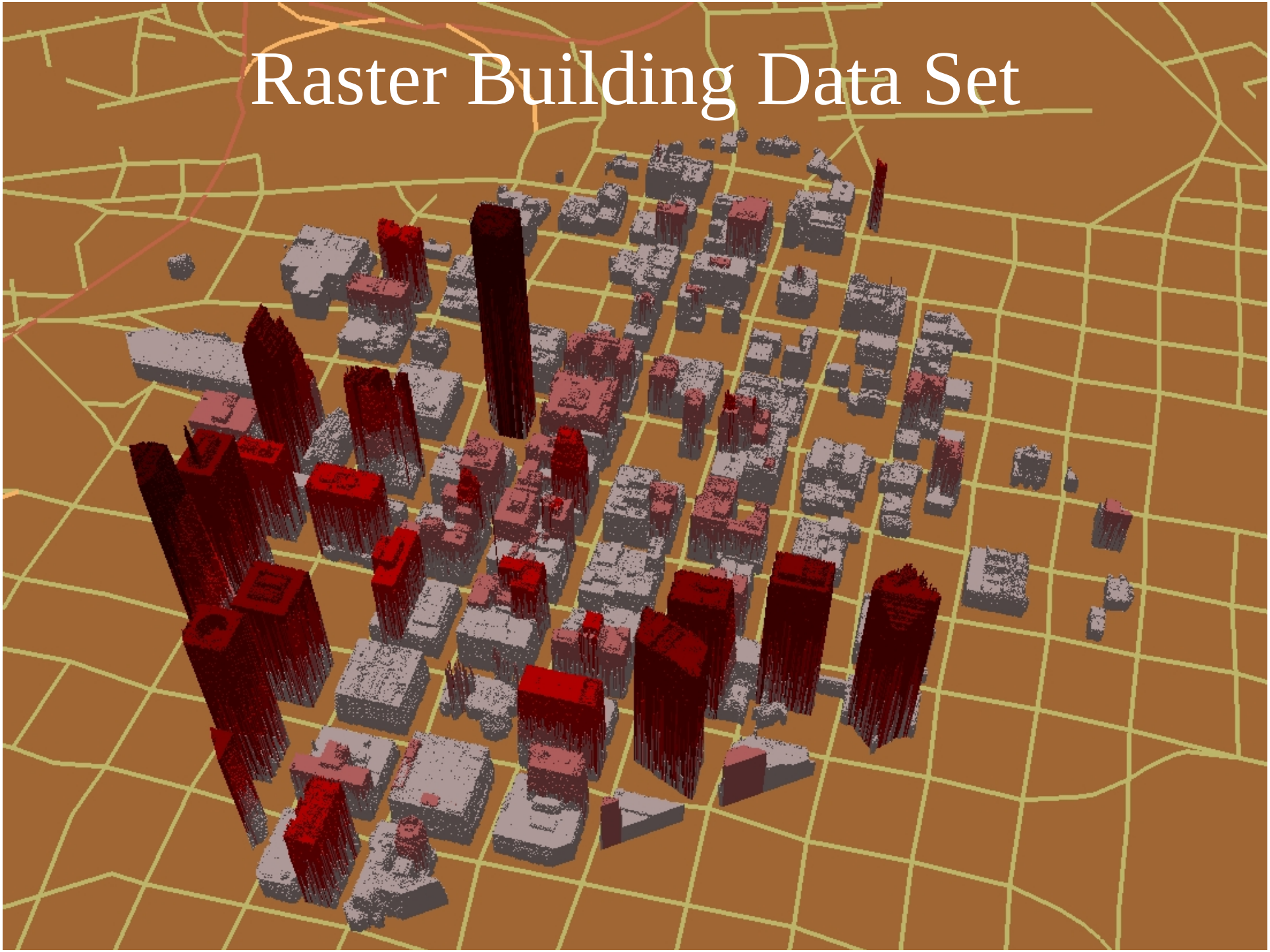
Typical Flight with LIDAR



Multiple Returns



Raster Building Data Set



Defining Morphology for MM5

- Where full data coverage…
  - GIS processing of raster and vector data
  - Distinguish roof tops from vegetation canopy
- In data-void areas…
  - Extrapolate based on co-relationships between building histogram and land use

Next Steps

- Complete development and evaluation of UCP for Philadelphia for additional days
- Evaluate 1.3-km CMAQ…modifications?
- Continue development of advanced UCP and apply to Houston with morphology database
- Explore sub-grid variability with PDFs
- Explore linkages to human population exposure models