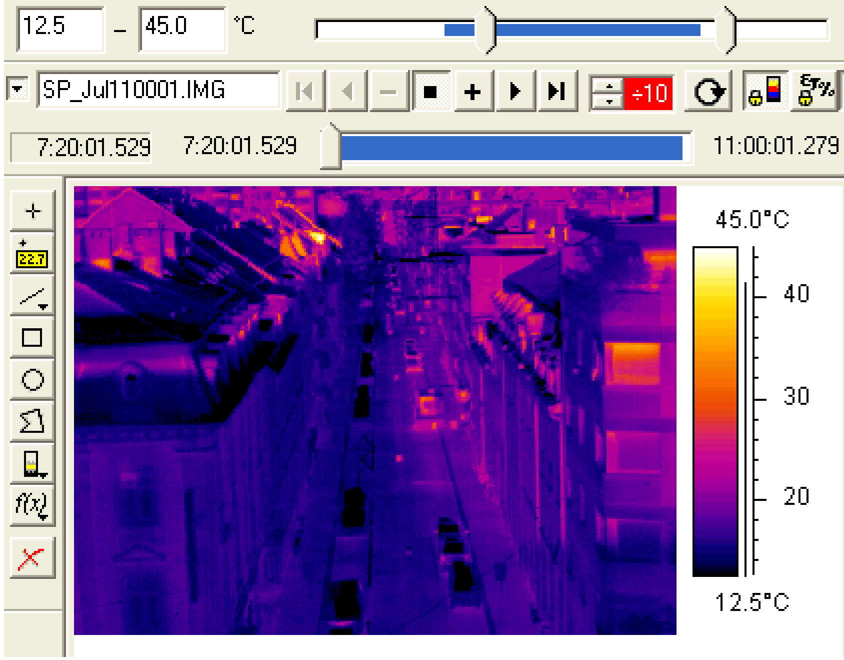
Remote Sensing of Urban Surface Temperatures

James Voogt

University of Western Ontario
London, Ontario, Canada



This work is supported by the Natural Sciences and Engineering Research Council of Canada.

Urban Surfaces:

M. Roth NUS

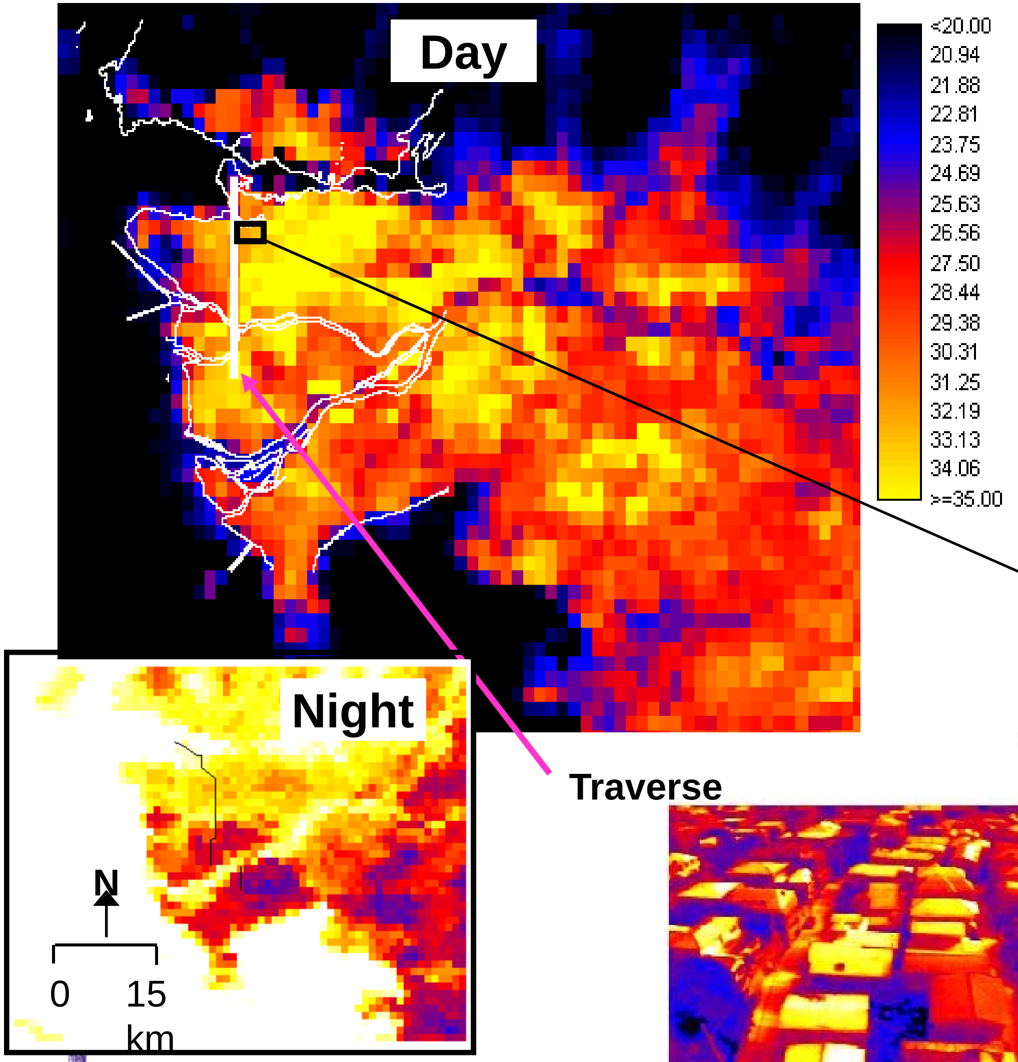
Exhibit strongly three-dimensional surface structure

J. Voogt UWO

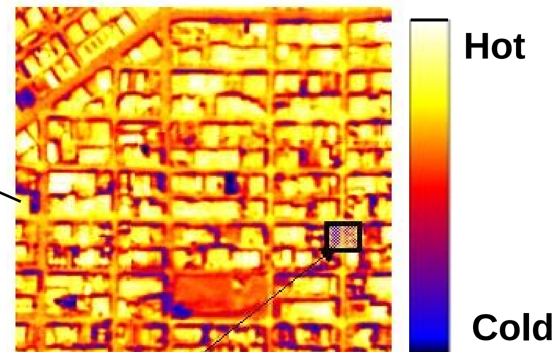
Show microscale variation of surface properties

This is obvious when the spatial resolution is high.

Surface Urban Heat Island



- Large positive values both day and night
- Strong control by surface properties.



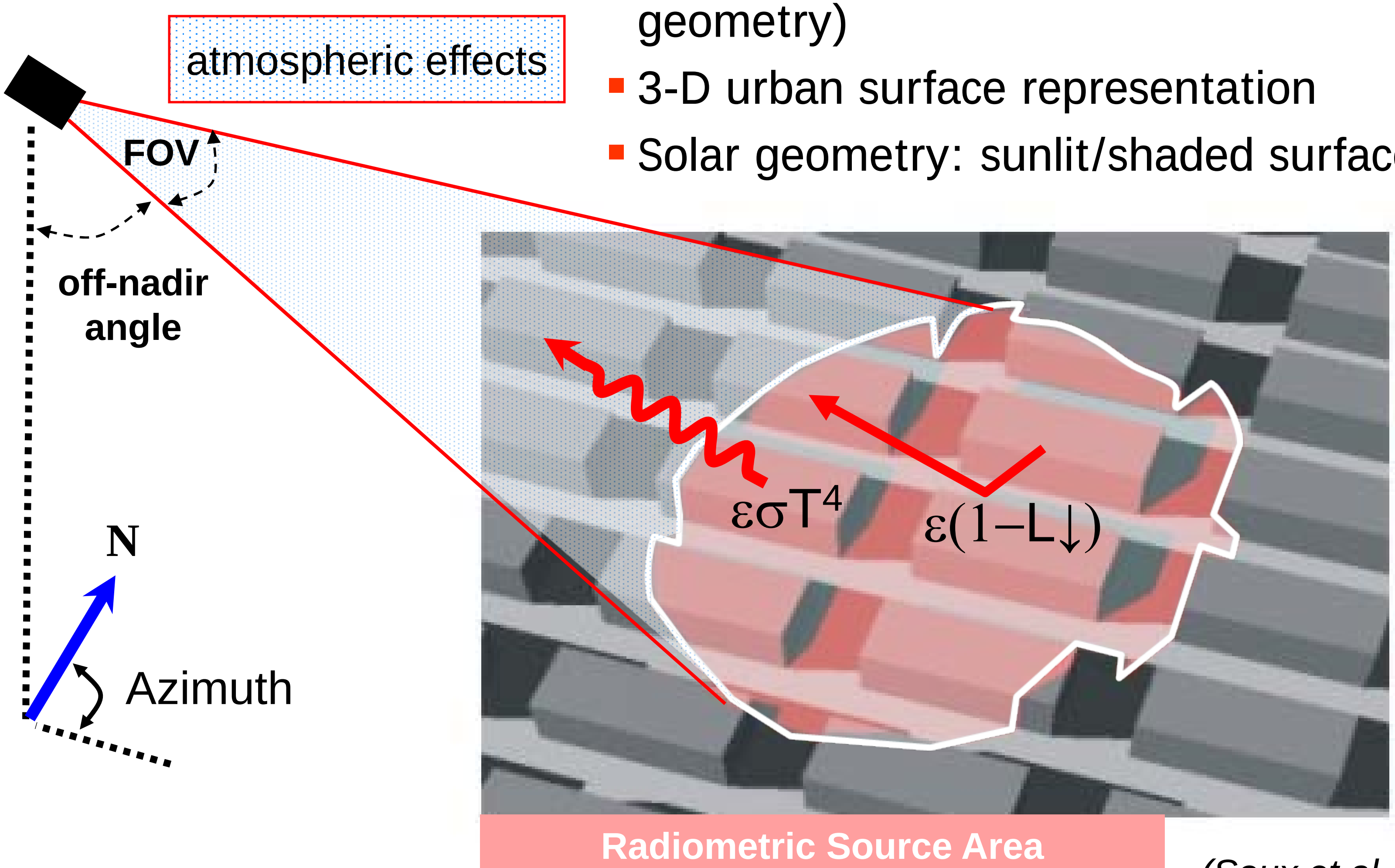
- Surface and atmosphere linked via the energy balance.
- Look at the details within a pixel: surface types and structure

Western

Thermal Remote Sensing of Urban Surfaces

How does the sensor view the surface?

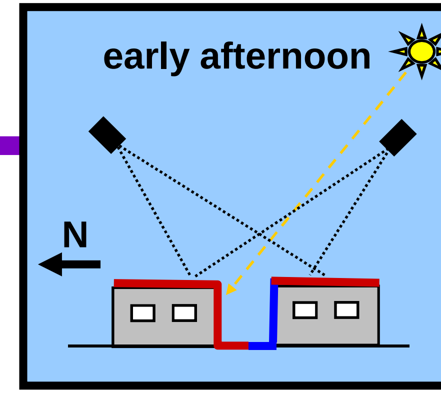
- Sensor characteristics (FOV, viewing geometry)
- 3-D urban surface representation
- Solar geometry: sunlit/shaded surfaces



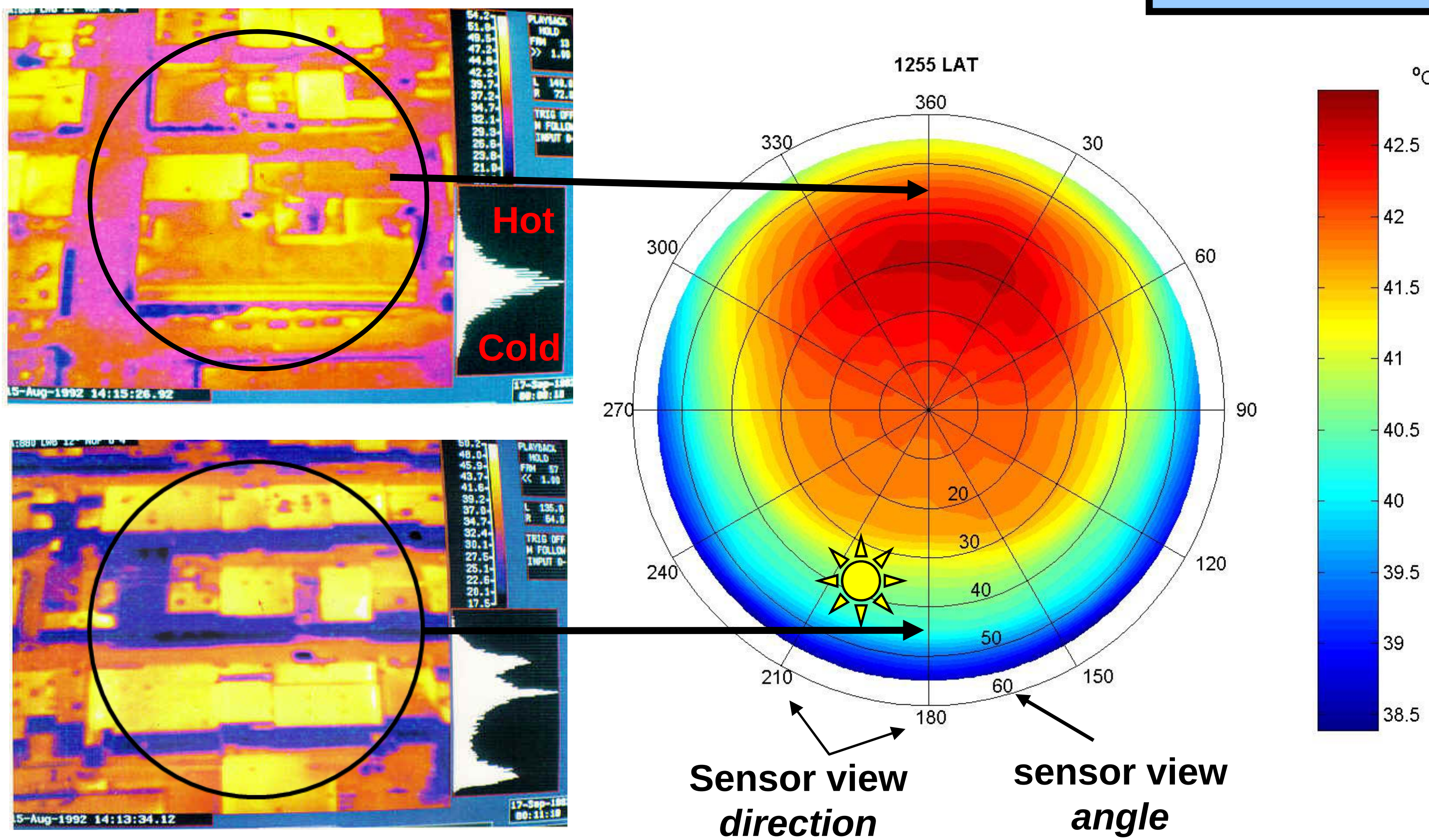
(Soux et al. 2004)

Western

Urban effective thermal anisotropy



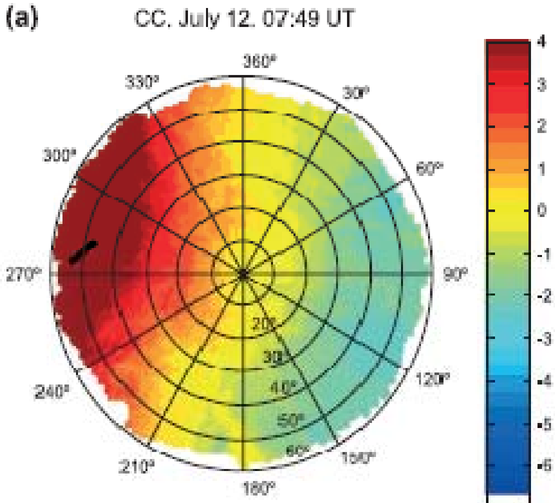
- Three-dimensionally rough urban surfaces create *effective thermal anisotropy* (angular variation in remotely-sensed temperature), visualized on a *polar plot*:



Anisotropy and the SUHI

- How does urban thermal effective anisotropy impact our interpretation of the SUHI?
  - anisotropy means that remotely-determined surface temperature values are potentially dependent on viewing conditions – sensor viewing position, surface structure, and time of day
  - therefore SUHI values will be impacted by those same considerations
- What is known about urban thermal anisotropy?

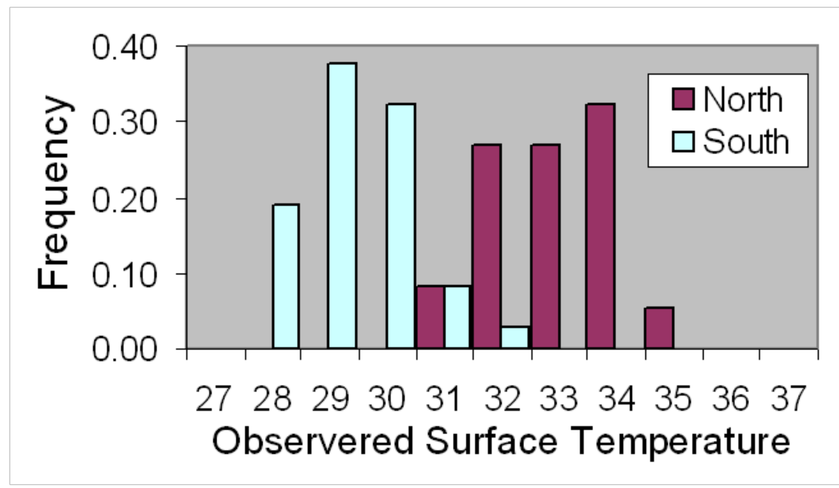
Observed Urban Thermal Anisotropy



Marseille City Centre Morning (Lagourade et al. 2004)

Surface	Anisotropy (°C)
Grass, Crops	0.6 – 1.8
Row crops	13 – 16
Forests	2 – 7
Mountainous Terrain	3 – 10
Urban Areas	*4 – 10*

- is large with respect to natural surfaces
- is complicated and expensive to undertake
- may be spatially and/or temporally limited
- may be difficult to generalize from:
  - specific meteorological conditions
  - microscale surface variability
  - specific morphology of the city



Vancouver: Light Industrial Mid-morning, 45° ONA View Voogt and Oke (1997)

Western

Extending Observations: Use of Models

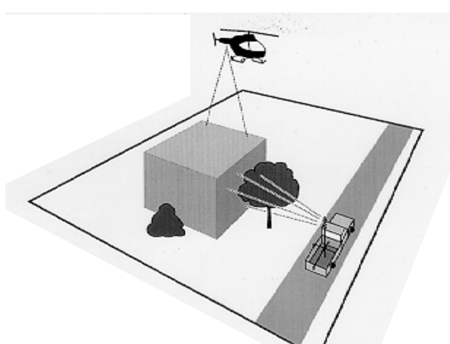
Observed facet surface temperatures

TUF-3D (Krayenhoff & Voogt 2007)

+

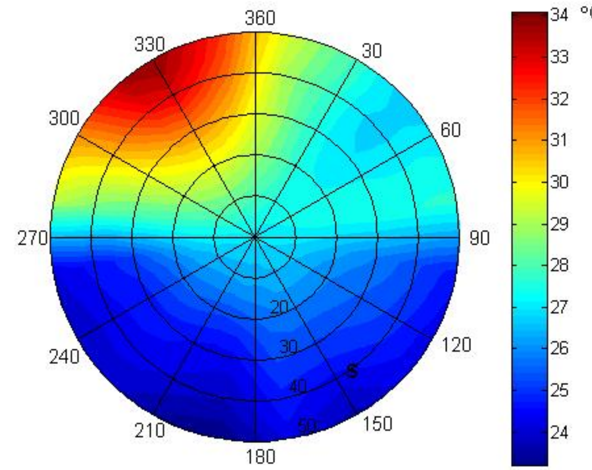
Sensor view model and surface GIS

SUM (Soux et al. 2004)



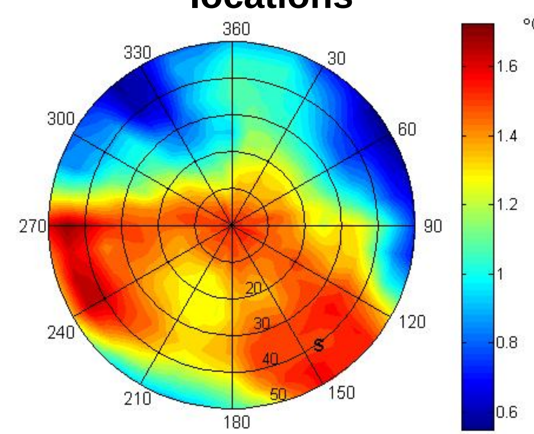
Vancouver Downtown late morning

$\overline{T}_{rad}$ **for sensor view direction**



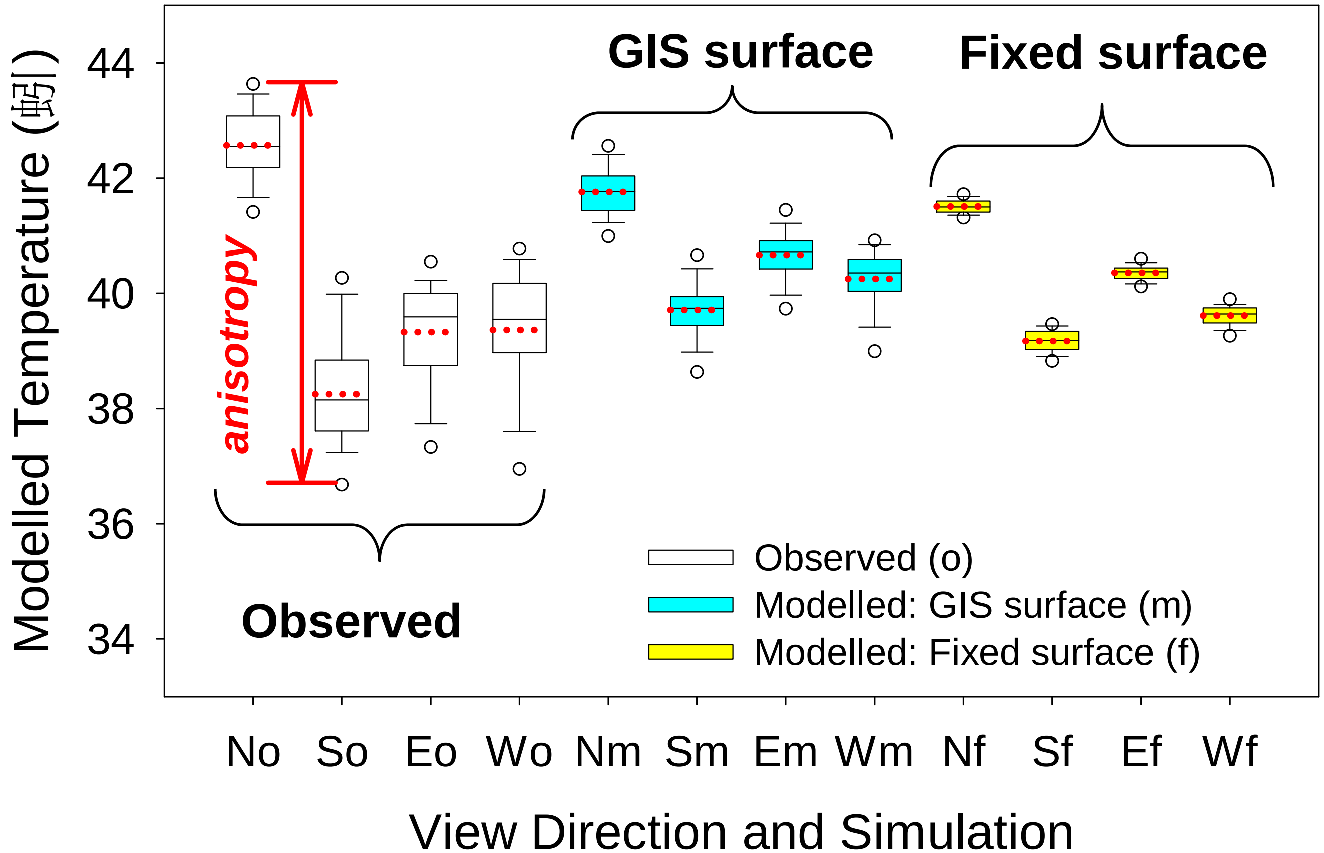
31 different locations

Standard deviation



Western

Model Application: Origins of Anisotropy



Voogt (2008)

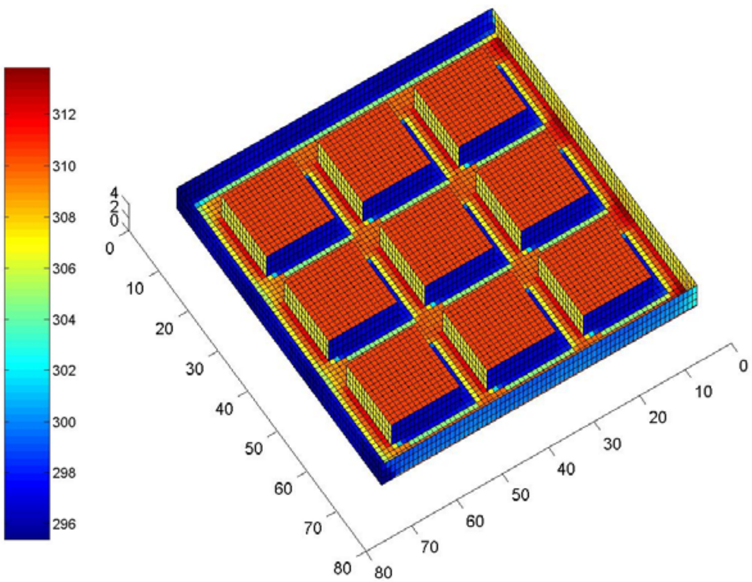
the surface structure only accounts for about 50% of the observed anisotropy

incorporation of microscale temperature variability is important (at the land-use scale)

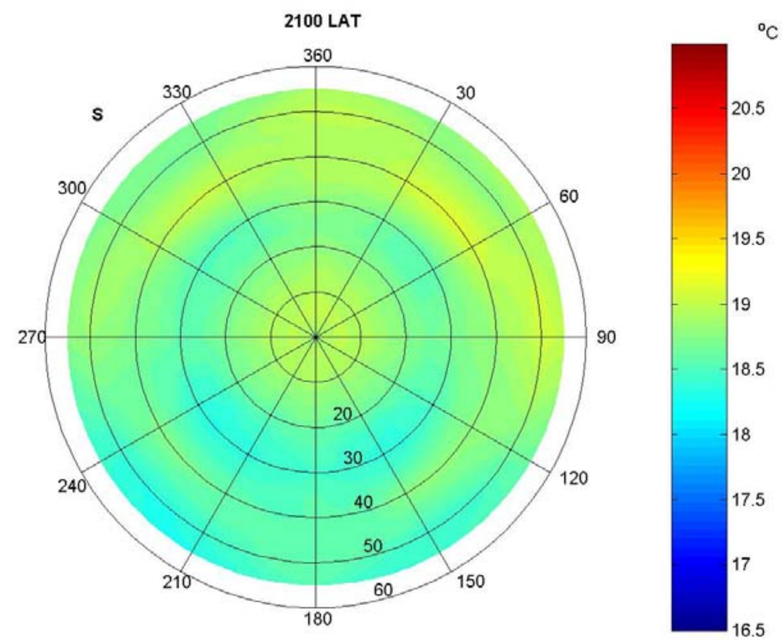
Western

Extending Observations: Coupled Models

Urban surface energy balance model
TUF-3D (Krayenhoff & Voogt 2007)
+
Sensor view model and surface GIS
SUM (Soux et al. 2004)



Hourly visualization of TUF-3D & SUM modelled remotely-sensed brightness temperature August 15, 1992



Vancouver LI: modelled angular variation of brightness temperature
0400 – 2100 local solar time (hourly)

s = sun position

Western

Summary

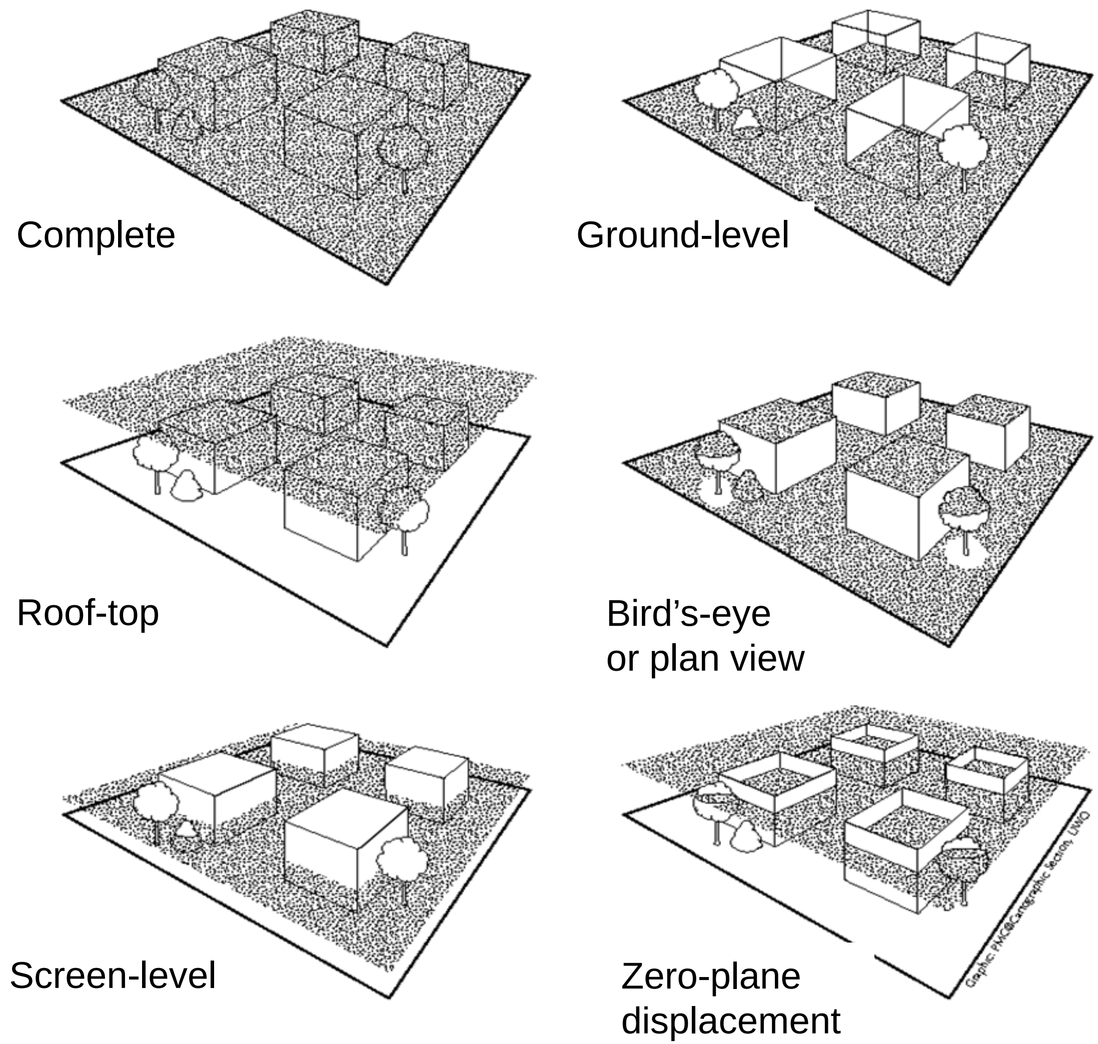
- Urban effective thermal anisotropy (UETA)
  - is large – both relative to other surface types and to other factors in the remote calculation of urban surface temperature (atmospheric correction and surface emissivity)
  - is traditionally not incorporated in SUHI analysis
  - is dependent on both surface structure and variations in material properties.

Anisotropy and the SUHI

- Can we take into account the urban thermal anisotropy when observing the SUHI?

Western

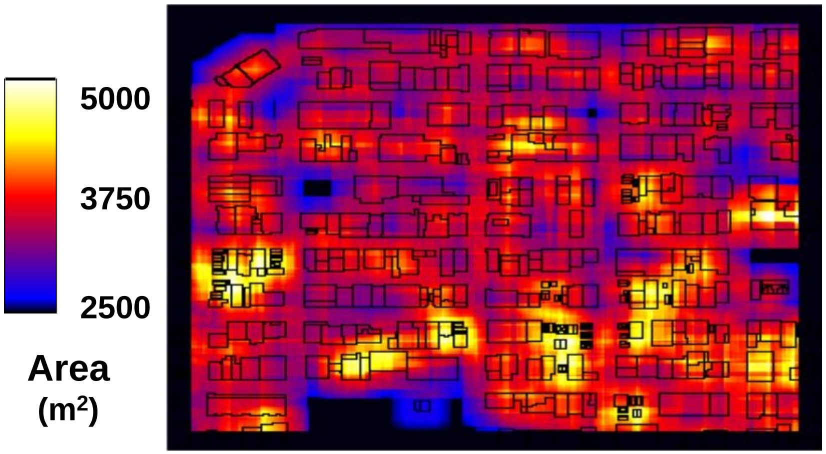
Urban Surfaces: Conceptual Definitions



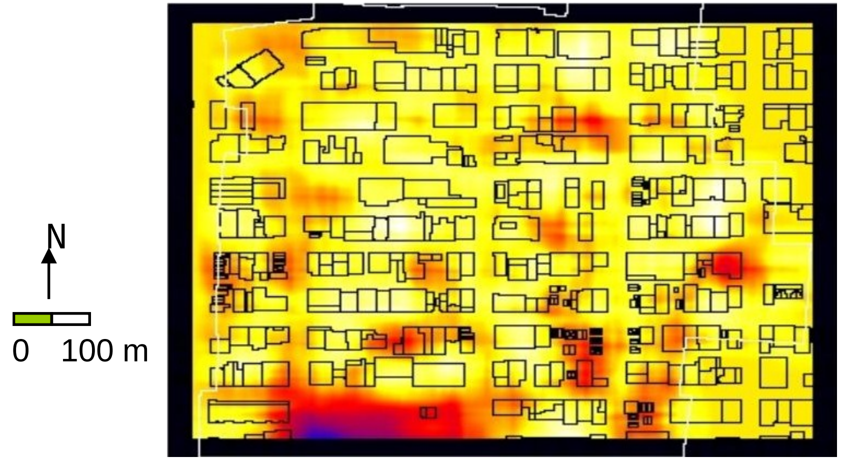
Voogt and Oke (1997)

Western

1. A "complete" surface temperature?

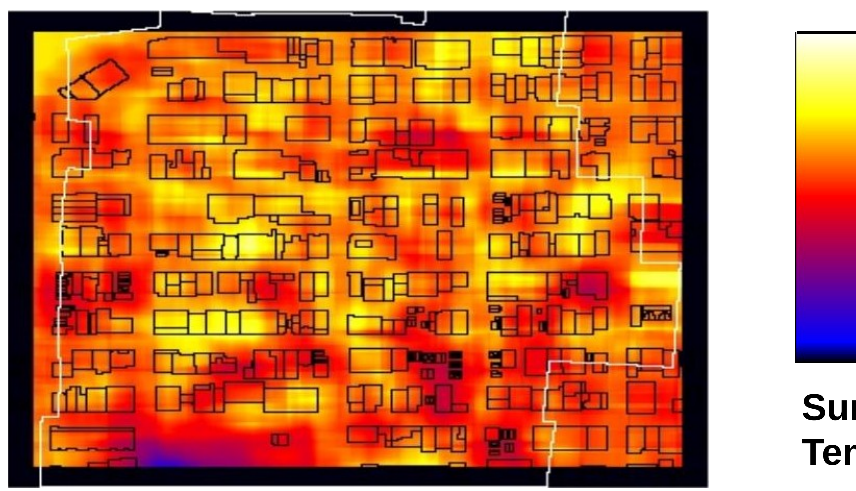


Complete surface area



nadir (plan view) temperature

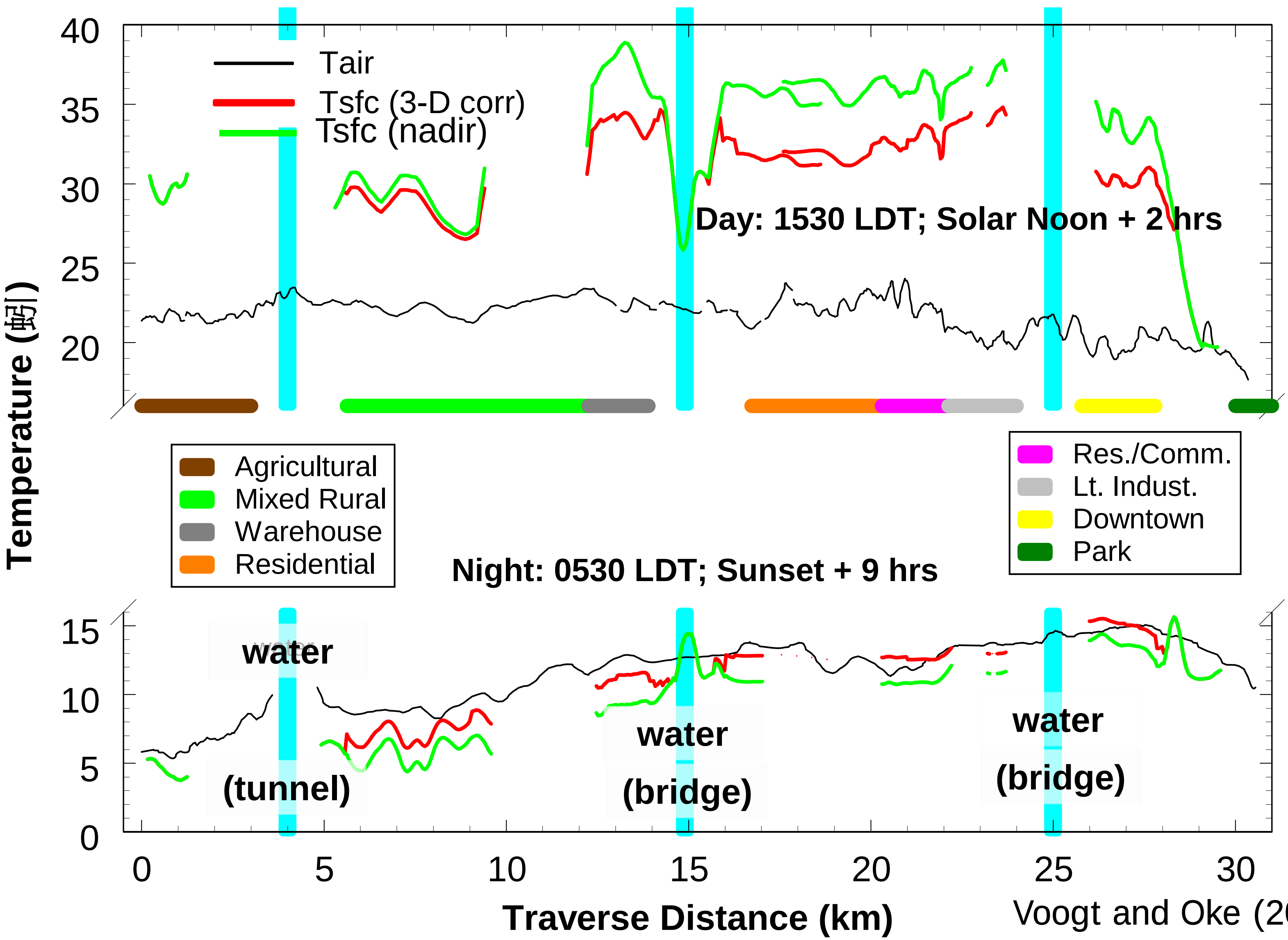
Incorporate building wall and vegetation temperatures from vehicle traverses



Complete surface temperature

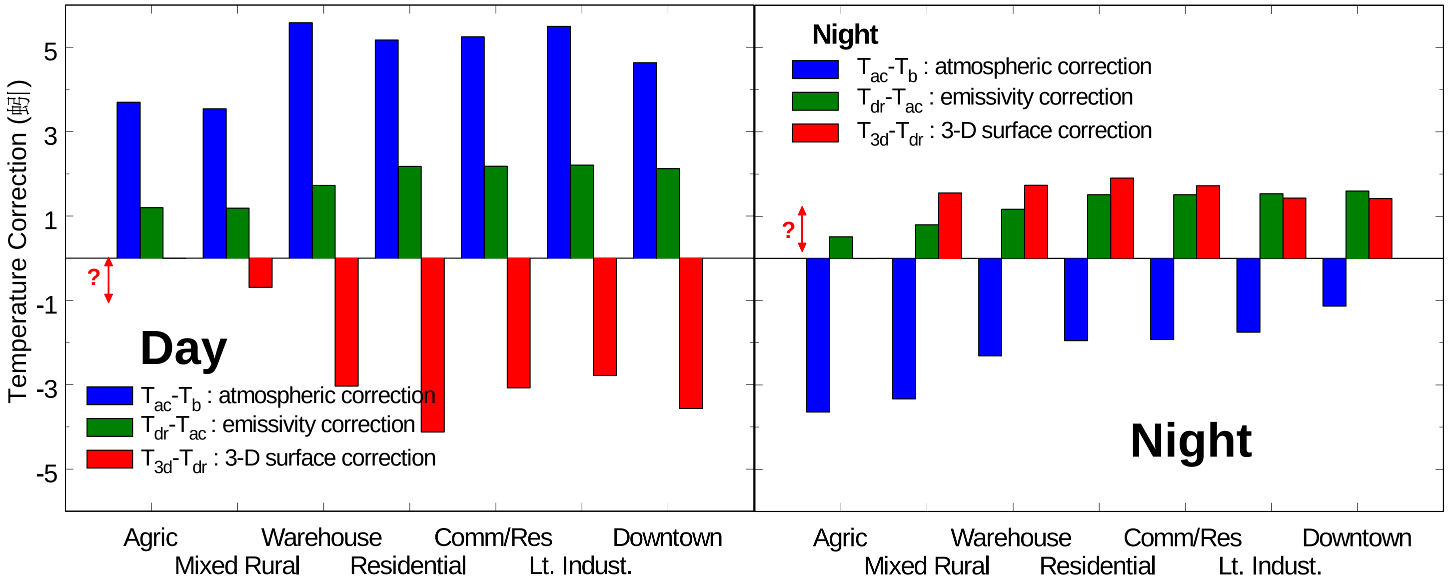
Voogt (2000)

Correction of SUHI using Complete Surface Temperature



Voogt and Oke (2003)

Corrections and SUHI Interpretation



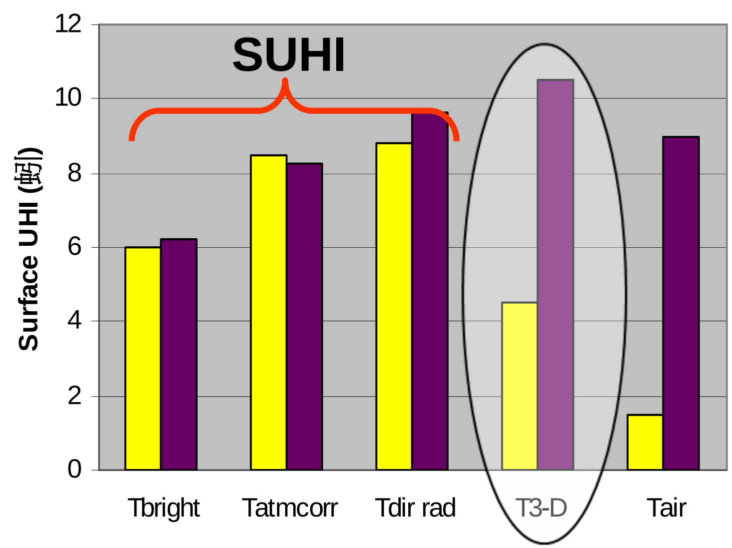
T_{ac}-T_b atmospheric correction

T_{dr}-T_{ac} emissivity correction

T_{3d}-T_{dr} 3-D surface correction

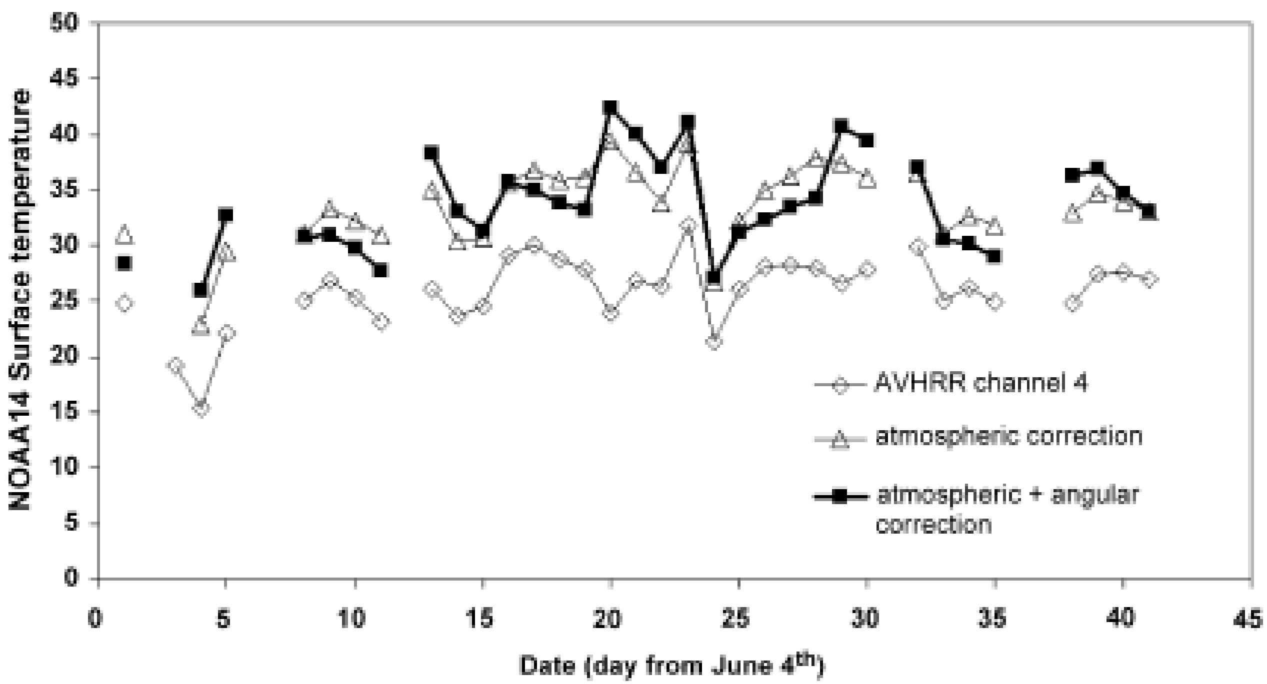
UHI Day

UHI Night

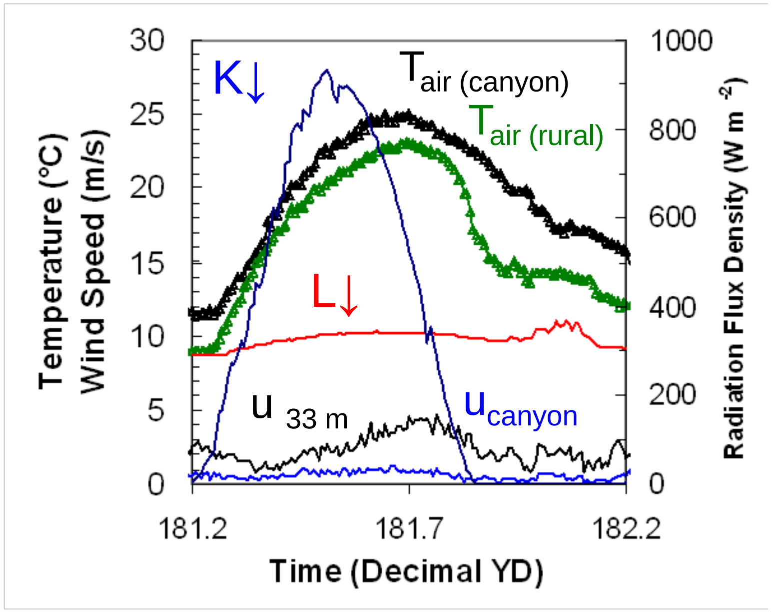


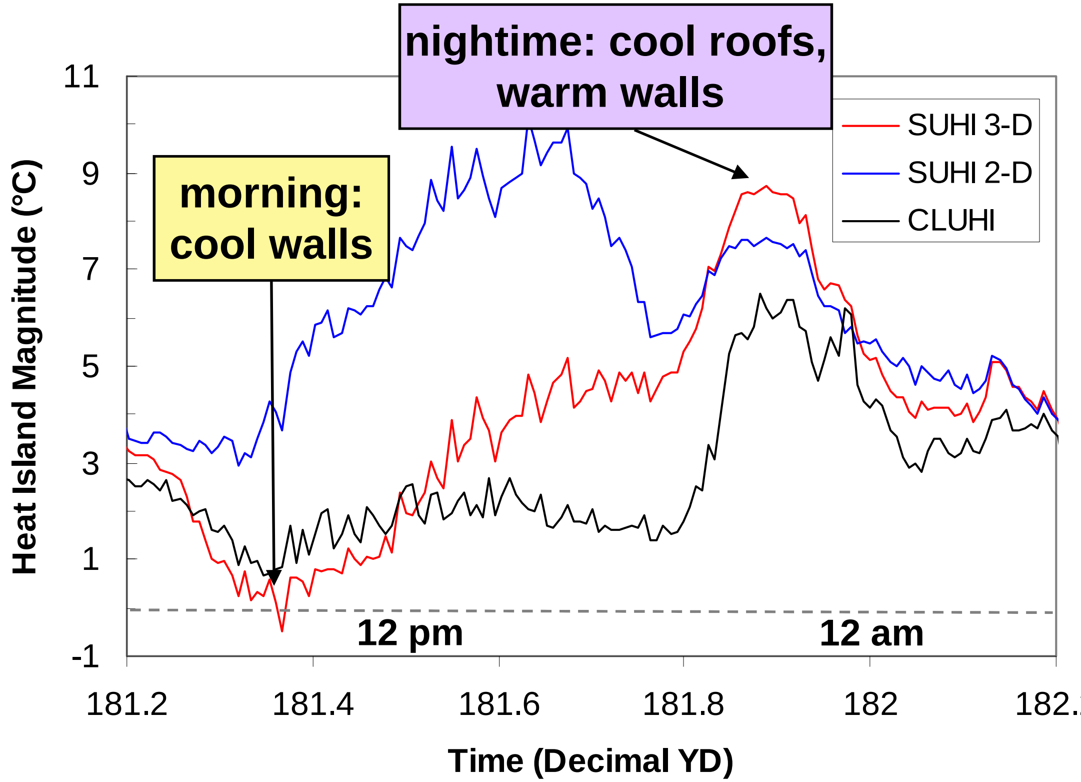
Satellite Time Series

- "directional corrections are significant and should be systematically done for temporal analysis of AVHRR data time series" (Lagouarde *et al*. 2004)
- Corrections of up to $\pm 4^{\circ}$C may be required



2. A slightly different approach





- Ground-based wide FOV sensor that incorporates a view of all surfaces (allows for calculation of SUHI 3-D)
- urban: Basel Sperrstrasse (Dense urban)
- rural: Basel - Lange Erlen (Grassland)

Western

Summary

- Incorporation of 3-D surface structure can change interpretation of SUHI.
  - Daytime: reduces SUHI (from bird's eye view) – cool walls
  - Nighttime: increase of SUHI – warm walls
- No commonly applied method for including UETA impact on SUHI.
- Models provide promise in evaluating general representation of UETA that may be useful for applications (e.g. impact on SUHI interpretation)