

LCLUC Meeting, Maryland, April 2014

# Mega Urban Changes and Impacts in the Decade of the 2000s

Interdisciplinary Research in Earth Science (IDS)  
Authors and Contributors from IDS Science Team

Presentation by Son V. Nghiem (PI)

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# Interdisciplinary Science Team

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# Objective and Approach

- **Objective:** Investigate impacts of global urban changes on the environment during the rapid growth of large cities (mega-urbanization) in the decade of the 2000s, including:  
Physical factors: urban heat island, urban dome, emission, pollutions in the atmosphere and water systems.  
Demographic factors: population distribution, population dynamics and changes in livelihoods such as housing, living arrangements, and socioeconomic status.
- **Approach:** Four components
  1. Satellite observations: >15 satellites
  2. Surface networks: meteorological, hydrological, chemical
  3. Socioeconomics and demography data
  4. Modeling: Gas, Aerosol, Transport, Radiation, General Circulation, Mesoscale, and Ocean Model (GATOR-GCMOM).
- **Field Campaign:** POPLEX Field Campaign, Italy, May 2014.

# Dense Sampling Method

(Patent US 8,401,793 B2, 3/19/2013)

**Enable global urban observations without gaps**

$$P_{Ri} = \frac{P_{Ti}\lambda^2}{(4\pi)^3 R^4} \iint_A dx dy G(\phi_i, x, y) \sigma_0(\phi_i, t_i, x, y)$$

$$P_{Ri} = \frac{P_{Ti}\lambda^2}{(4\pi)^3 R^4} \bar{\sigma}_0(\phi_i, t_i) \iint_A dx dy G(\phi_i, x, y)$$

$$\bar{\sigma}_0(\phi_i, t_i) = \frac{1}{\Gamma_A} \iint_A dx dy G(\phi_i, x, y) \sigma_0(\phi_i, t_i, x, y)$$

# Dense Sampling Method

(Patent US 8,401,793 B2, 3/19/2013)

**Enable global urban observations without gaps**

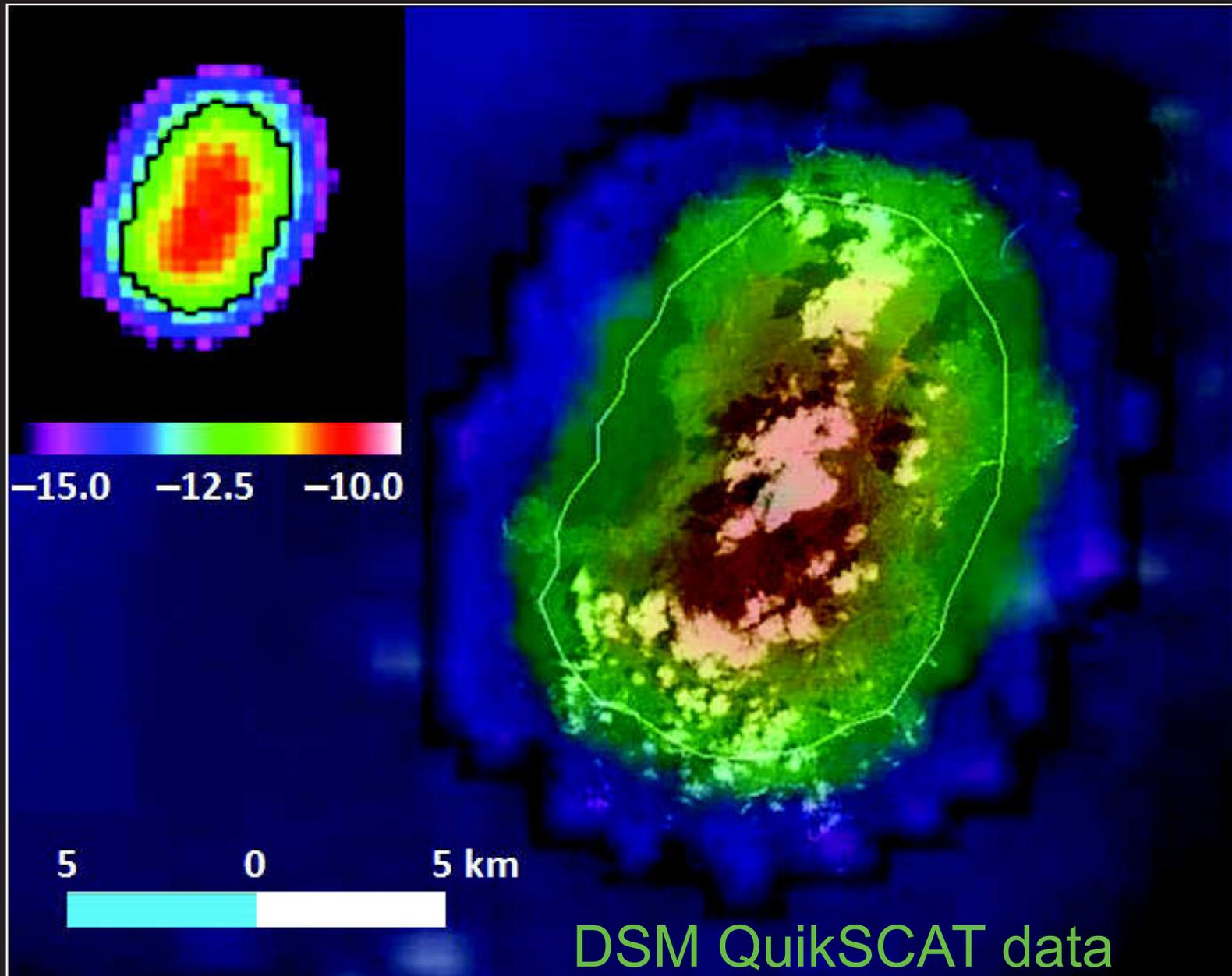
$$\bar{\sigma}_0 = \frac{1}{N} \sum_{i=1}^N \bar{\sigma}_0(\phi_i, t_i) = \frac{1}{N\Gamma_A} \sum_{i=1}^N \iint_A dx dy G(\phi_i, x, y) \sigma_0(\phi_i, t_i, x, y)$$

$$\sigma_0(\phi_i, t_i, x, y) = \bar{\sigma}_0(x, y) + \varepsilon(\phi_i, t_i, x, y)$$

$$\bar{\sigma}_{0M} = \frac{1}{\Gamma_A} \iint_A dx dy \left[ \sum_{i=1}^N \frac{G(\phi_i, x, y)}{N} \right] \bar{\sigma}_0(x, y)$$

$$\mathcal{R} = \frac{1}{\Gamma_A} \iint_A dx dy \sum_{i=1}^N \left[ \frac{G(\phi_i, x, y)}{N} \varepsilon(\phi_i, t_i, x, y) \right]$$

# Verification - Príncipe Island



# Procedure to Obtain Global Urban Extent, Type, Change

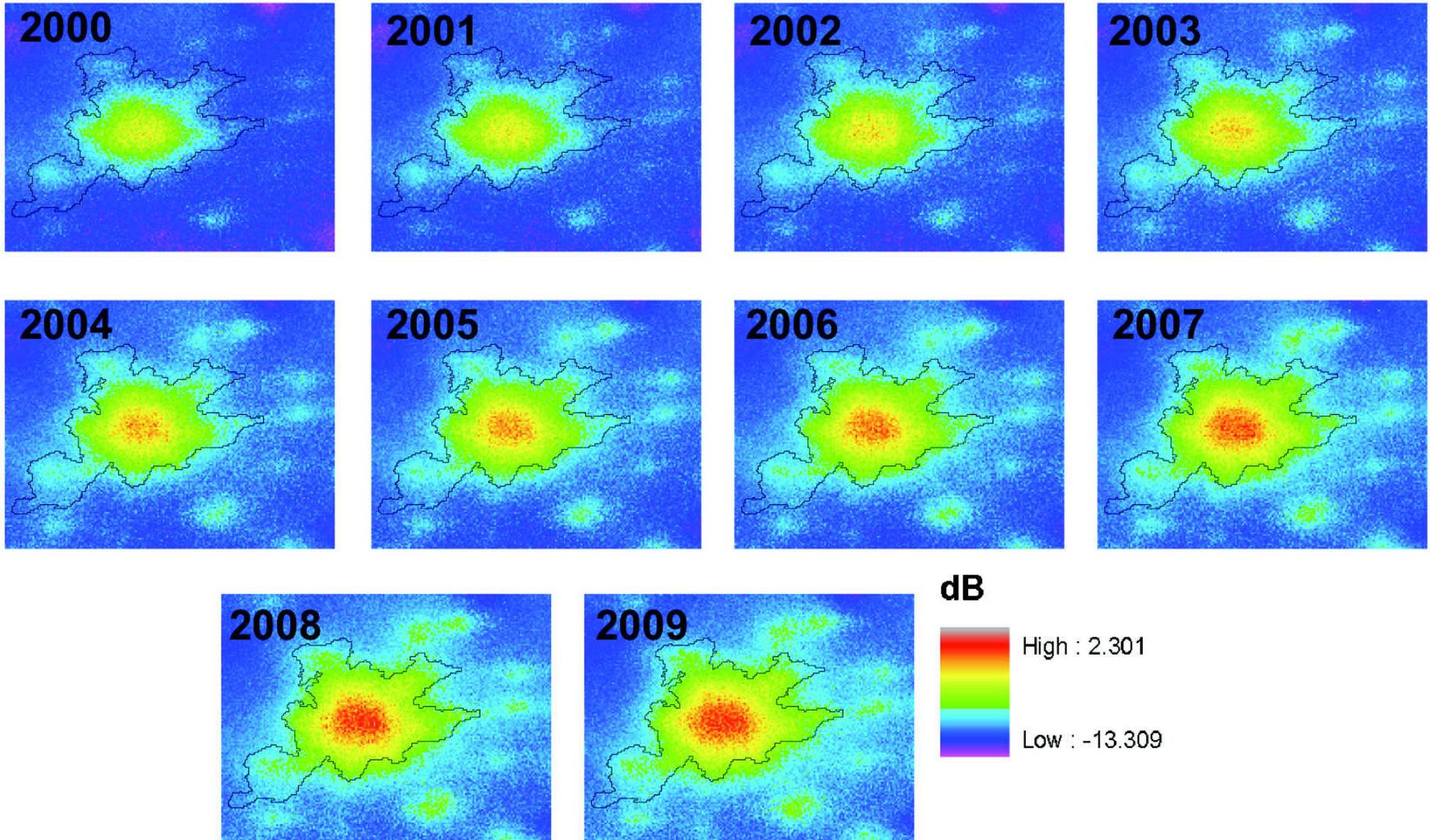
- Use the DECADE of NASA QuikSCAT satellite scatterometer collected GLOBALLY
- Apply the Dense Sampling Method for high-resolution data processing over land regions
- Classification using training urban data from multiple sources, using both mean and variation
- Verification in regions where census/demographic data are available (e.g. Dallas-Ft Worth)
- Obtain urban extent, and typology (commercial/industrial core, residential, rural), and change

**Enable Development of ATLAS of Global Urban Change**

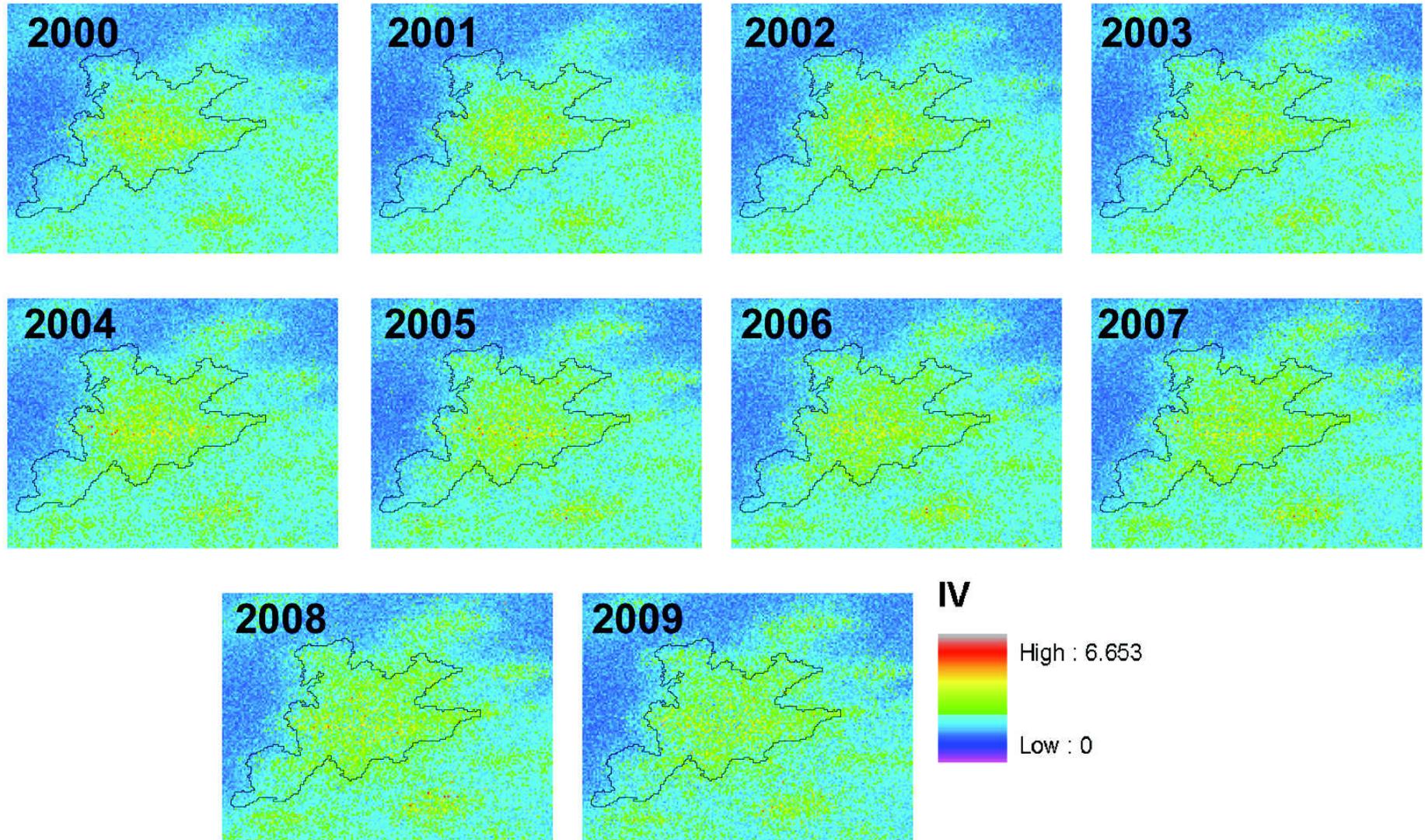
# DSM: All Mega Cities Worldwide

Rank	Megacity	Country	Continent	Population	DSM Latitude (°)		DSM Longitude (°)	
1	<a href="#">Tokyo</a>	 <a href="#">Japan</a>	<a href="#">Asia</a>	34,800,000	33.8	37.9	137.5	142.3
2	<a href="#">Guangzhou</a>	 <a href="#">China</a>	<a href="#">Asia</a>	31,700,000	21.0	25.0	111.2	115.5
3	<a href="#">Shanghai</a>	 <a href="#">China</a>	<a href="#">Asia</a>	28,900,000	30.4	31.9	120.4	122.6
4	<a href="#">Jakarta</a>	 <a href="#">Indonesia</a>	<a href="#">Asia</a>	26,400,000	-6.8	-5.6	106.1	107.5
5	<a href="#">Seoul</a>	 <a href="#">South Korea</a>	<a href="#">Asia</a>	25,800,000	37.0	38.0	126.3	127.8
6	<a href="#">Delhi</a>	 <a href="#">India</a>	<a href="#">Asia</a>	24,000,000	28.2	29.1	76.6	77.7
7	<a href="#">Mexico City</a>	 <a href="#">Mexico</a>	<a href="#">North America</a>	23,800,000	18.4	20.5	-99.9	-98.1
8	<a href="#">Karachi</a>	 <a href="#">Pakistan</a>	<a href="#">Asia</a>	22,700,000	24.4	25.2	66.5	67.6
9	<a href="#">Manila</a>	 <a href="#">Philippines</a>	<a href="#">Asia</a>	22,200,000	14.0	15.2	120.6	121.5
10	<a href="#">New York City</a>	 <a href="#">United States</a>	<a href="#">North America</a>	21,600,000	39.9	41.5	-76.1	-71.6
11	<a href="#">São Paulo</a>	 <a href="#">Brazil</a>	<a href="#">South America</a>	21,500,000	-24.2	-22.9	-47.6	-45.5
12	<a href="#">Mumbai</a>	 <a href="#">India</a>	<a href="#">Asia</a>	21,400,000	18.5	19.7	72.6	73.4
13	<a href="#">Beijing</a>	 <a href="#">China</a>	<a href="#">Asia</a>	19,300,000	39.2	40.7	115.5	117.3
14	<a href="#">Los Angeles</a>	 <a href="#">United States</a>	<a href="#">North America</a>	17,200,000	32.8	34.9	-120.0	-116.2
15	<a href="#">Osaka</a>	 <a href="#">Japan</a>	<a href="#">Asia</a>	16,800,000	33.8	35.4	134.2	136.4
16	<a href="#">Moscow</a>	 <a href="#">Russia</a>	<a href="#">Europe</a>	16,500,000	55.3	56.2	36.9	38.4
17	<a href="#">Dhaka</a>	 <a href="#">Bangladesh</a>	<a href="#">Asia</a>	16,300,000	23.4	24.1	90.1	90.7
18	<a href="#">Cairo</a>	 <a href="#">Egypt</a>	<a href="#">Africa</a>	16,100,000	29.7	30.4	30.8	31.7
19	<a href="#">Kolkata</a>	 <a href="#">India</a>	<a href="#">Asia</a>	16,000,000	21.9	23.3	87.7	88.8
20	<a href="#">London</a>	 <a href="#">United Kingdom</a>	<a href="#">Europe</a>	15,500,000	51.0	52.0	-1.1	1.0
21	<a href="#">Buenos Aires</a>	 <a href="#">Argentina</a>	<a href="#">South America</a>	14,500,000	-35.4	-33.9	-59.5	-57.2
21	<a href="#">Bangkok</a>	 <a href="#">Thailand</a>	<a href="#">Asia</a>	14,500,000	13.0	14.8	99.7	101.3
23	<a href="#">Istanbul</a>	 <a href="#">Turkey</a>	<a href="#">Europe/Asia</a>	13,800,000	40.4	41.6	27.9	30.2
24	<a href="#">Lagos</a>	 <a href="#">Nigeria</a>	<a href="#">Africa</a>	13,200,000	6.0	7.3	2.7	4.2
25	<a href="#">Tehran</a>	 <a href="#">Iran</a>	<a href="#">Asia</a>	13,200,000	35.3	36.1	50.8	51.9
26	<a href="#">Rio de Janeiro</a>	 <a href="#">Brazil</a>	<a href="#">South America</a>	12,900,000	-23.4	-22.3	-44.2	-42.4
27	<a href="#">Shenzhen</a>	 <a href="#">China</a>	<a href="#">Asia</a>	11,700,000	21.5	24.0	112.4	115.0
28	<a href="#">Paris</a>	 <a href="#">France</a>	<a href="#">Europe</a>	10,700,000	48.5	49.2	1.7	2.9
29	<a href="#">Tianjin</a>	 <a href="#">China</a>	<a href="#">Asia</a>	10,600,000	38.6	39.6	116.6	118.0

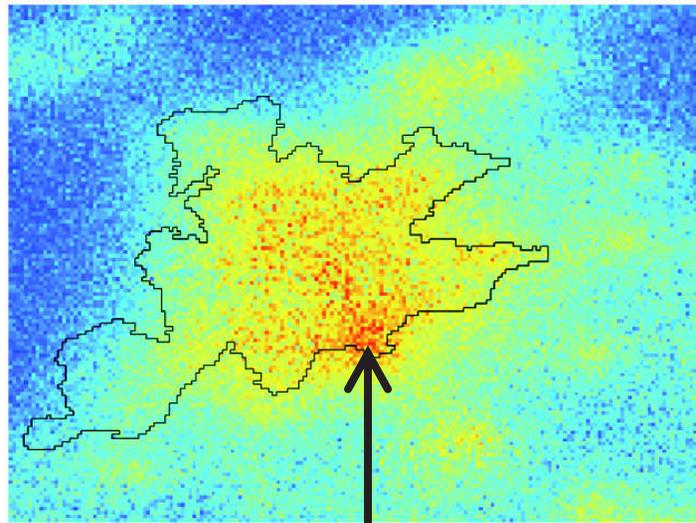
# Beijing DSM Backscatter



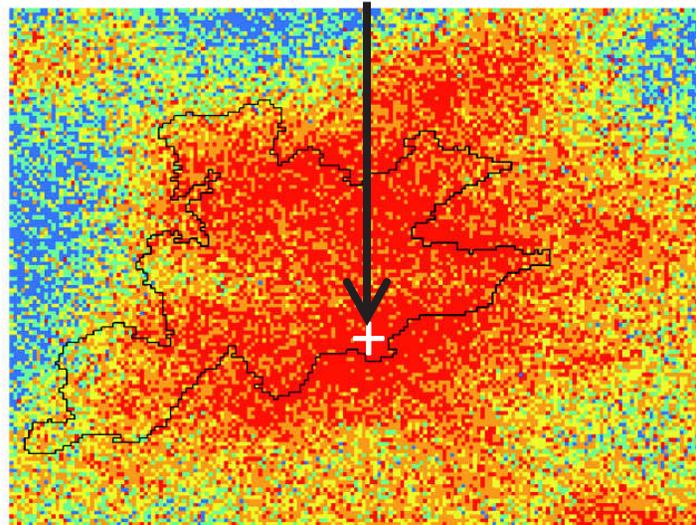
# Beijing DSM Index of Variability



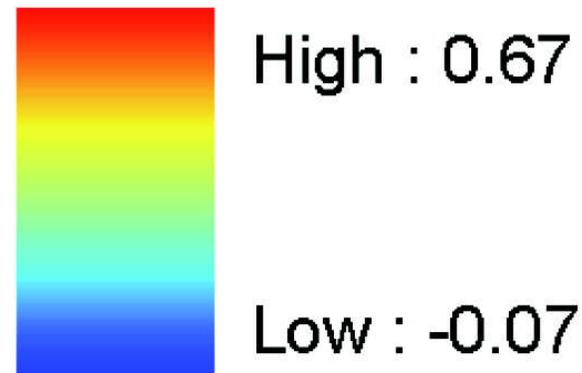
# Rate of Change – DSM 2000-09



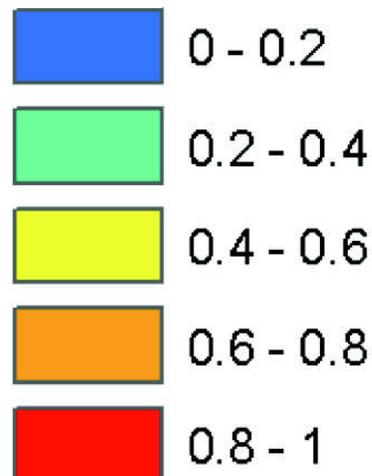
High intensification



## SLOPE (Trend)



## R<sup>2</sup>



# Very Significant Build-up in an Area in Southeast Beijing

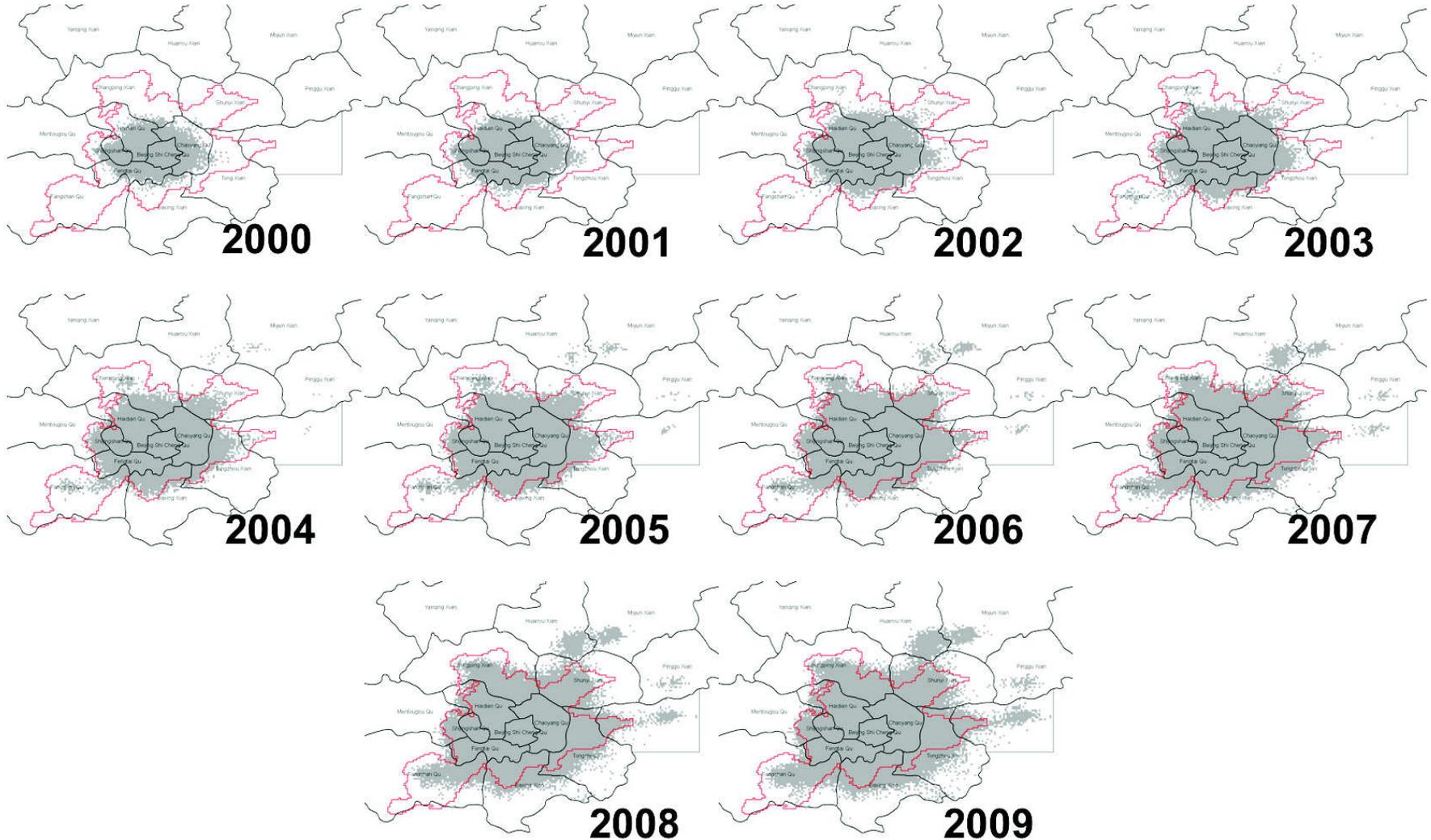
Center of image is located around 39°46'40" N and 116°31'29" E  
(marked by the white plus in the 2000-2009 DSM R<sup>2</sup> images)



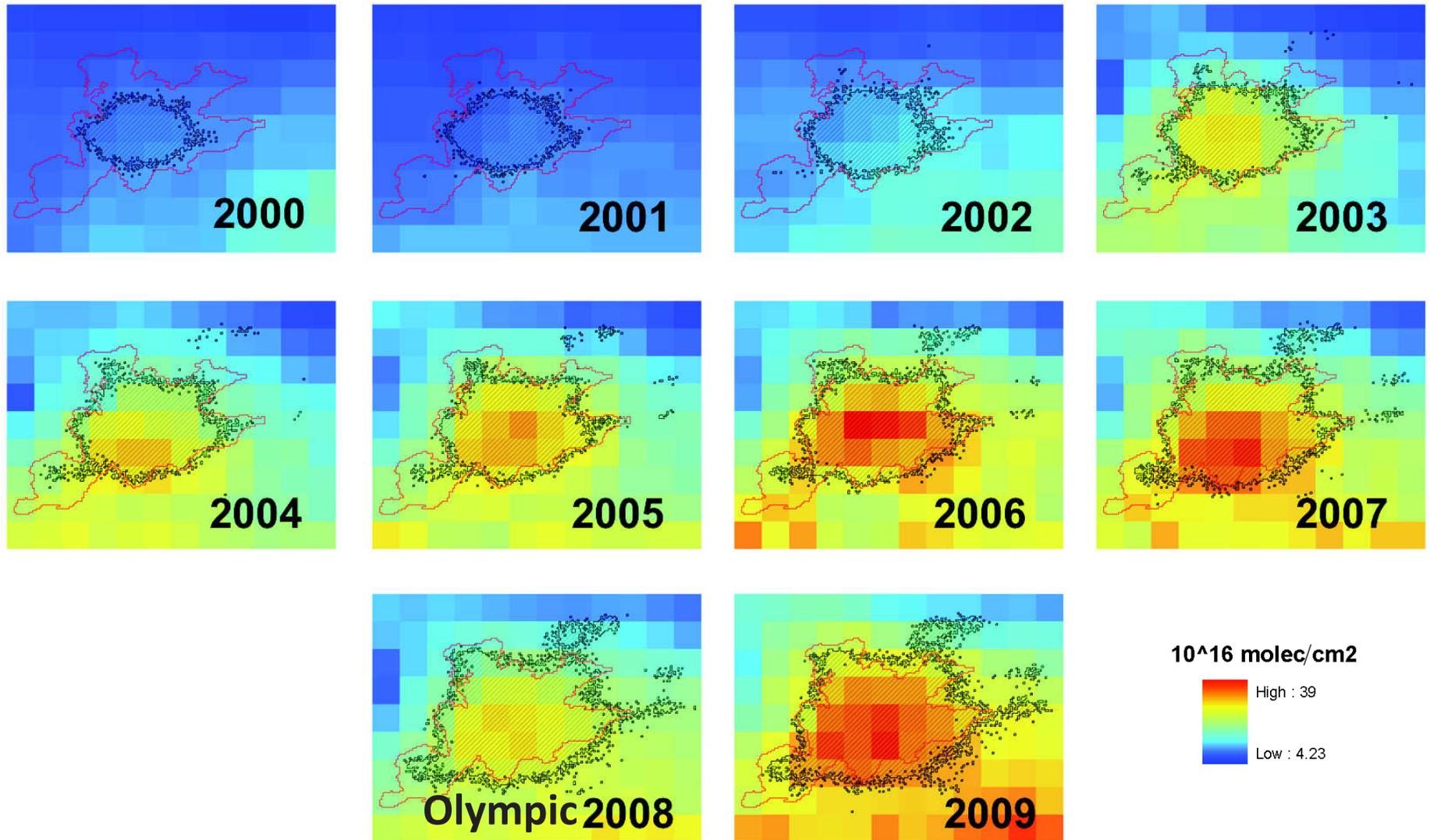
Images from Google Earth Pro 5.1

Paper in preparation

# Beijing Urban Extent from DSM

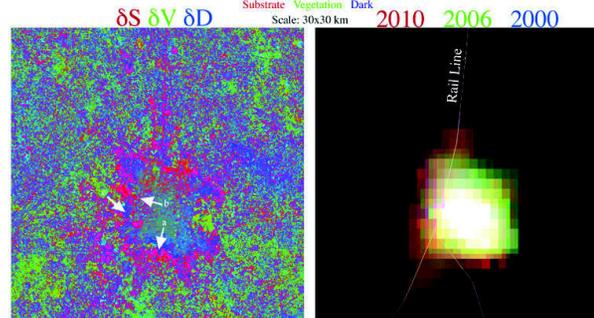
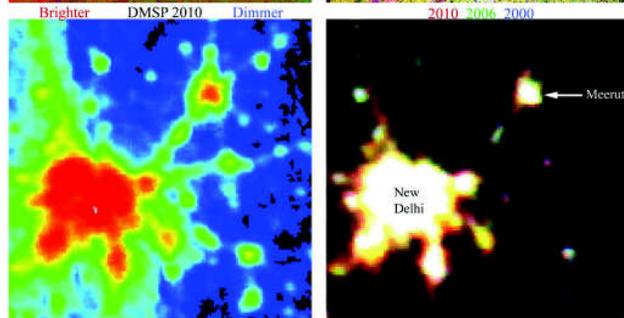
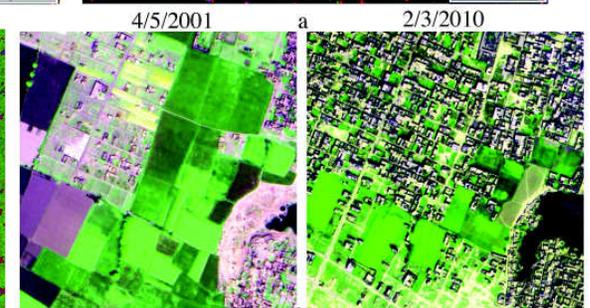
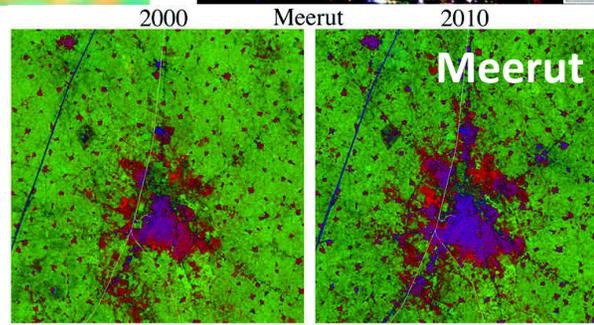
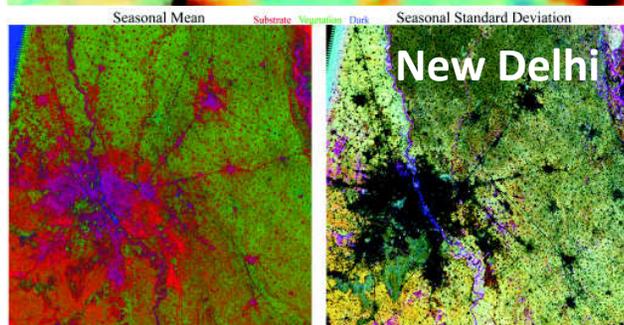
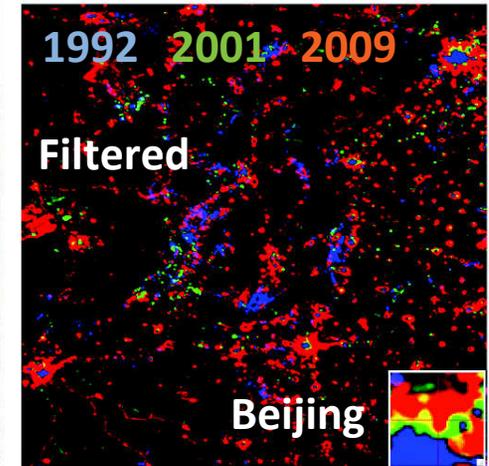
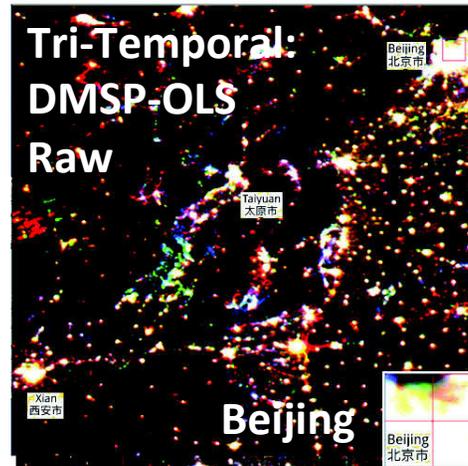
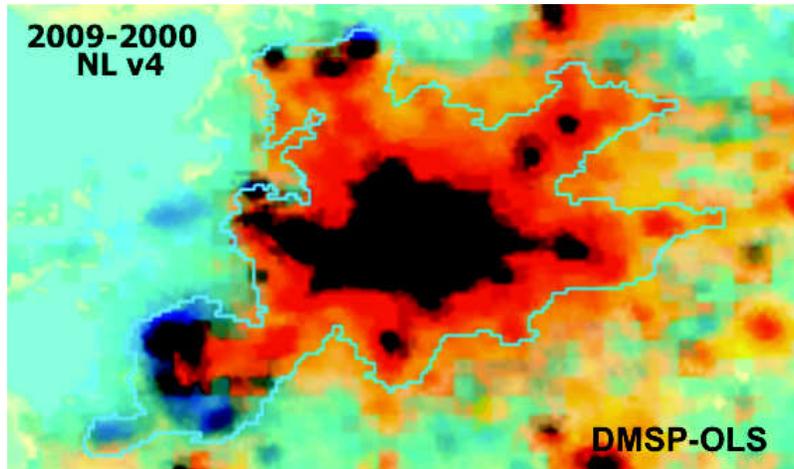


# Beijing Urban Change and NO<sub>2</sub>



Paper in preparation

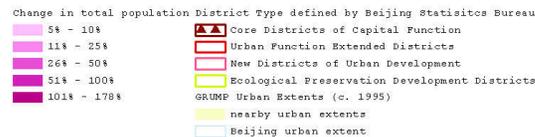
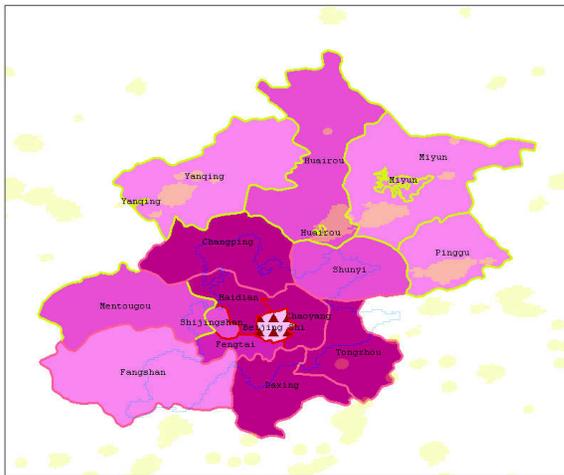
# Increase Information Content with Multiple Satellite Data



See poster by  
Small et al.,  
LCLUC, 2014

# Demography – Population Change in 2000-2010

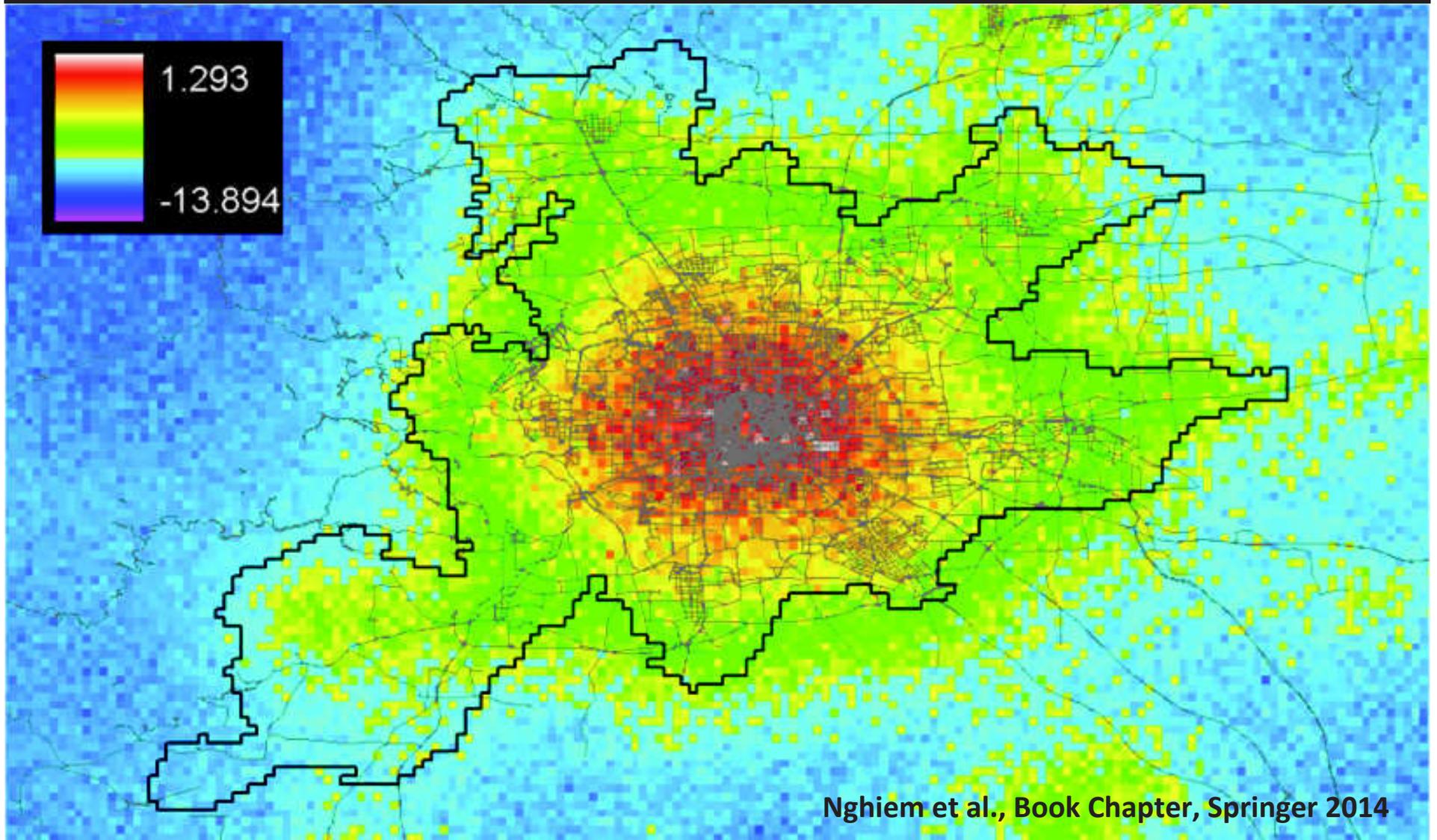
Beijing Total Population Change, 2000-2010



**Beijing total  
population  
change**

- Highest rate of total population growth in districts called "New Districts of Urban Development" surrounding the city proper.
- Growth rate of migrant population is much higher than the growth rate of native population.
- Growth of native urban population is slow, and probably is an indicator of strict "Hukou" registration system.

# Infrastructure – Road Network



Beijing DSM with road network (grey) and Night-Light urban extent (black).

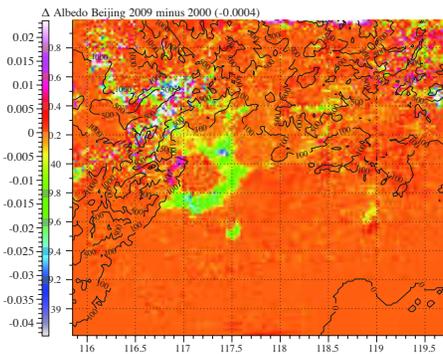
# Modeling – GATOR-GCMOM from global circulation to urban scale

- **GATOR-GCMOM is used to simulate the global, regional, and urban climate and air pollution health impacts resulting from urbanization. The goal is to investigate effects on climate and air quality of annual changes in the extent of urbanization over regions of mega urbanization in Asia and to compare with other regions in the 2000s.**
- **This model nests climate, meteorological, gas, aerosol, and radiative parameters simultaneously from the global through urban scale. simulates meteorology and its feedback among gases, aerosol particles, cloud hydrometeor particles, surfaces, and radiation. Gas processes include emissions, photochemistry, gas-to-particle conversion, gas-to-hydrometeor conversion and exchange, gas-ocean exchange, advection, convection, molecular diffusion, turbulent diffusion, and dry deposition.**
- **At the land surface, each subgrid soil class is divided into vegetated and bare soil. Snow can accumulate on both soil and vegetation. For bare and vegetated soil, the surface energy balance equation accounts for latent heat, sensible heat, solar, thermal-IR, and energy fluxes.**
- **Oceans are represented in 3-D for some calculations and 2-D for others. A 2-D time-dependent mixed-layer ocean dynamics model driven by surface wind stress is used to solve for mixed-layer velocities, heights, and horizontal energy transport in each cell. The scheme conserves potential enstrophy, vorticity, energy, and mass and predicts gyres and major currents. Air ocean exchange, vertical diffusion, 3-D ocean equilibrium chemistry and pH are solved among the Na-Cl-Mg-Ca-K-H-O-Li-Sr-C-S-N-Br-F-B-Si-P system.**

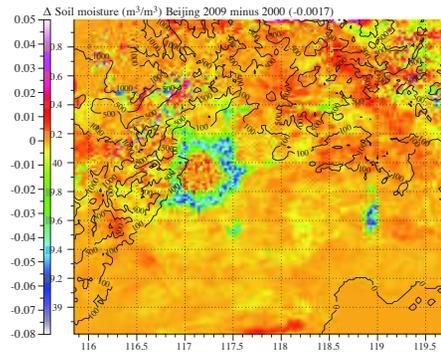
# Modeling – GATOR-GCMOM

## Mega urbanization impacts in 2000s

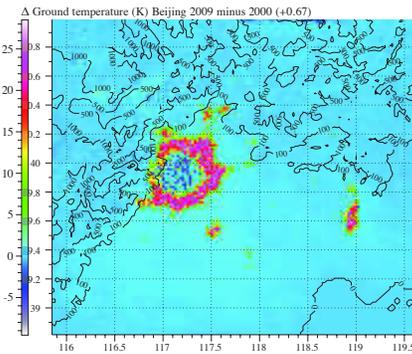
### Quantifying changes in 2000-2009



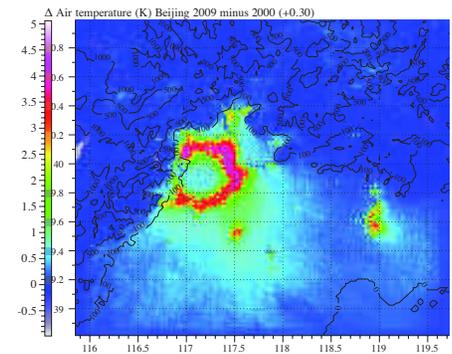
**Albedo Change**



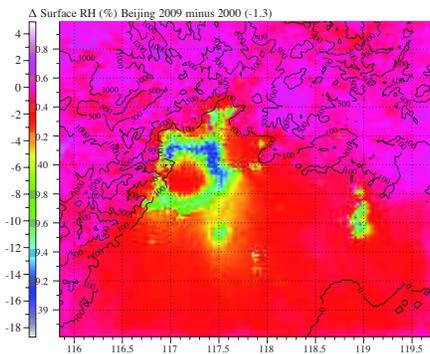
**Soil Moisture Change**



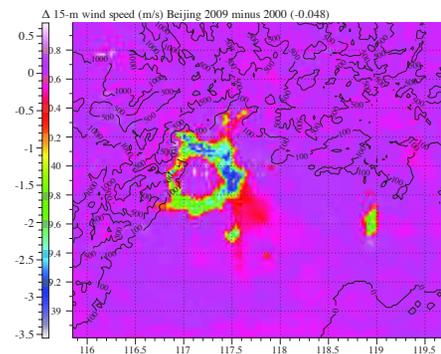
**Ground Temperature**



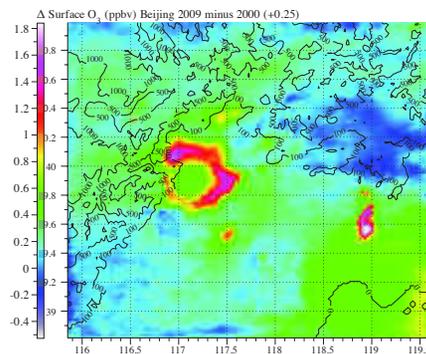
**Surface Air Temperature**



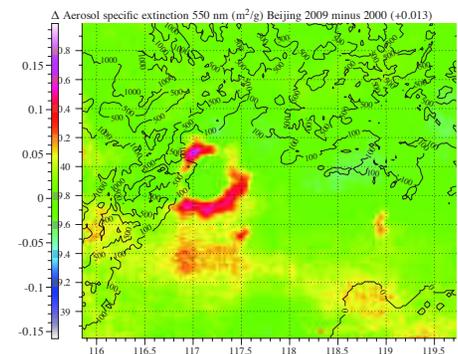
**Surface Rel. Humidity**



**15-m Wind Speed**



**Surface Ozone**



**Aerosol Spc. Extinction**

Model results from Jacobson

# **Model – GATOR-GCMOM**

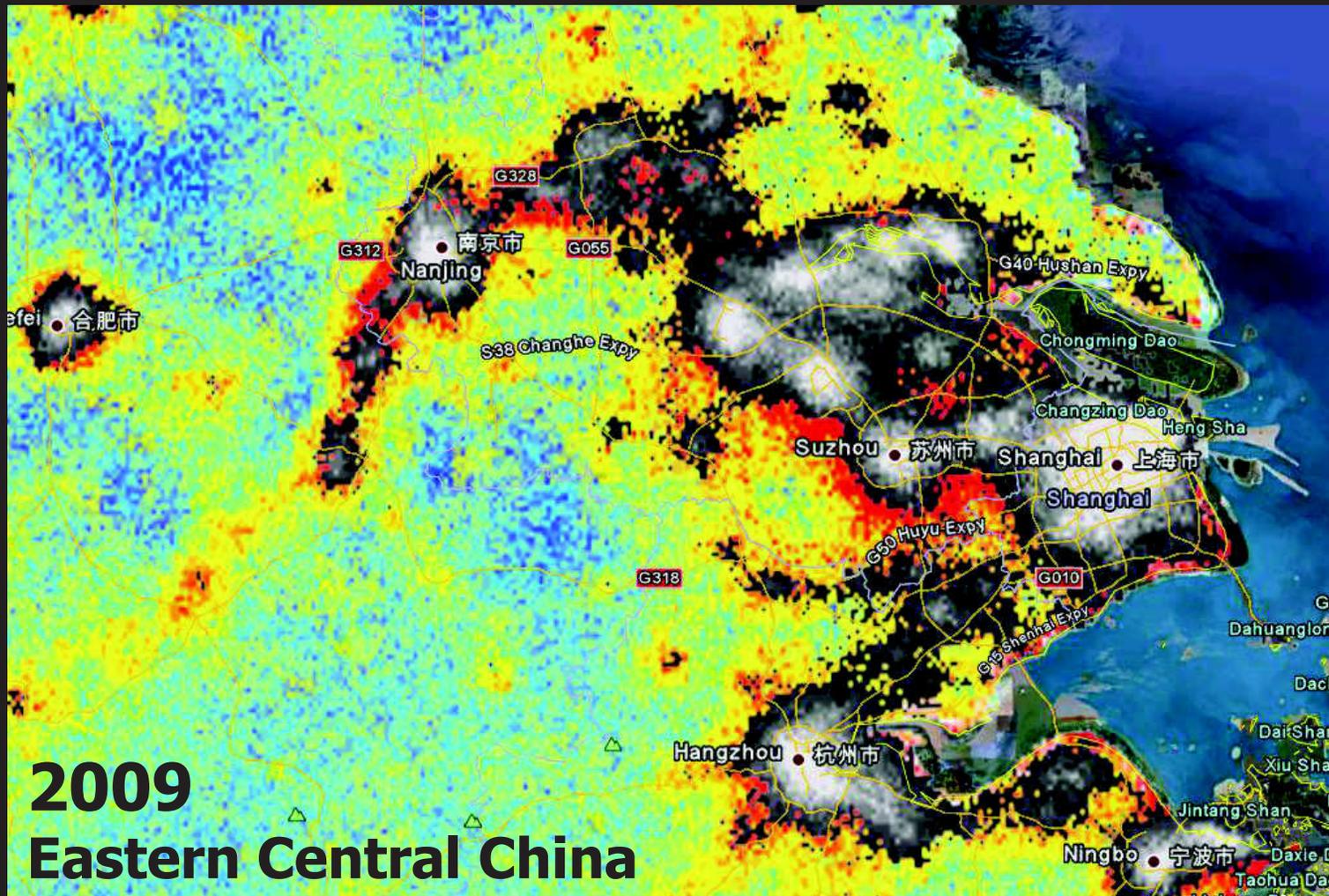
## **Mega urbanization impacts in 2000s**

### **“Ring Around the Beijing”**

- **Increasing urban heat**
- **Drier soil condition**
- **More air stagnation**
- **Worse smog condition**
- **More ozone pollution**
- **More pollutant mixing upward**

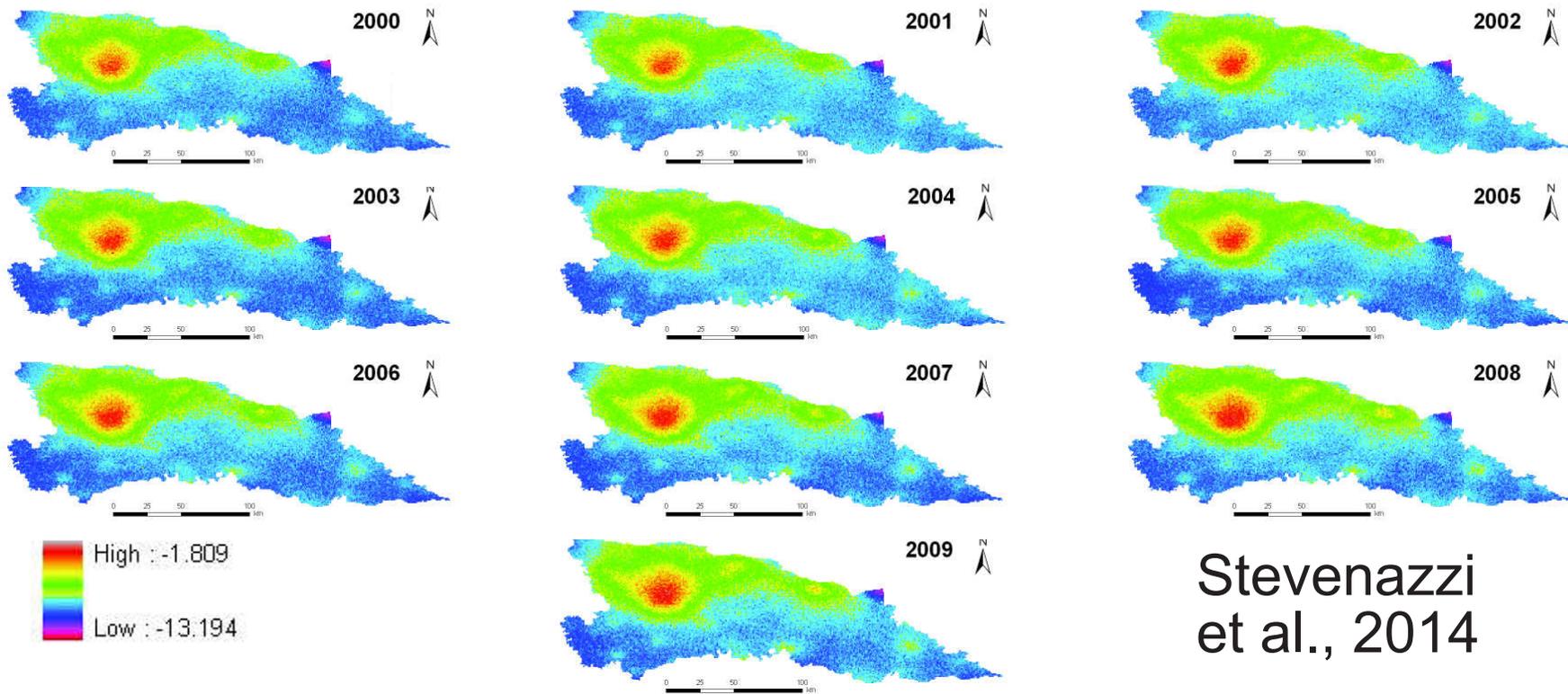
# Formation of Mega-Agglomeration Challenging the Westphalian System

Changes between 2000 and 2009



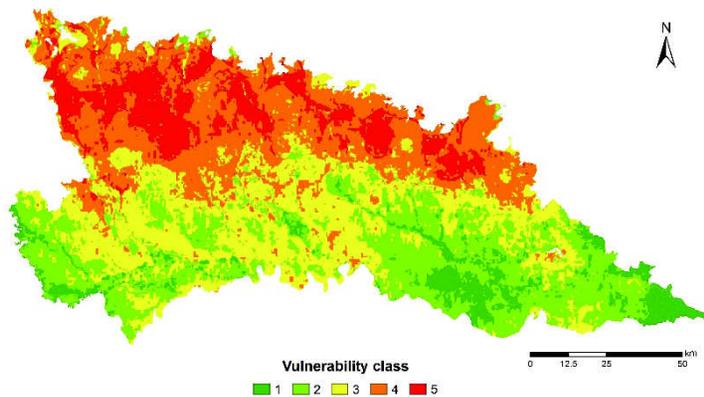
Paper in preparation

# DSM Assessment of Ground-Water Contamination



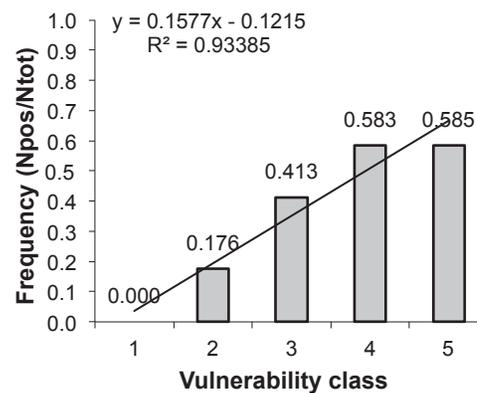
Stevenazzi  
et al., 2014

Slope QSCAT-DSM

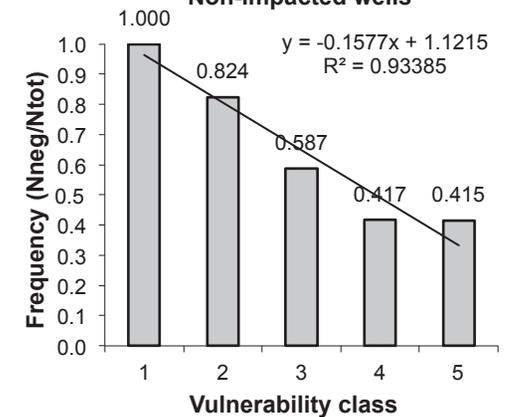


## Nitrate Monitoring Wells

Impacted wells



Non-impacted wells



# POPLEX Field Campaign

## 2-17 May 2014, Italy

### 22 participants, 14 institutions, 5 countries, 12 satellites, many in-situ networks



#### The Po Plain Experiment (POPLEX) Field Campaign Effects of urban sprawl on environmental matrices in northern Italy

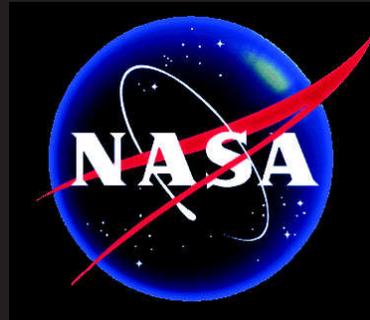
The "Dipartimento di Scienze della Terra" of "Universitàegli Studi di Milano," together with the "NASA Jet Propulsion Laboratory" under the InterDisciplinary Science (IDS) research on Mega Urban Changes and Impacts supported by the NASA Land-Cover / Land-Use Change (LCLUC) Program, in collaboration with "Universitàegli Studi di Padova", "Universitàegli Studi Alma Mater di Bologna" and "University of Southampton", under the Patronage of Italian Chapter of International Association of Hydrogeologists, organize a field campaign, including science-team working meetings in conjunction with field surveys and measurements in the Po Plain territory in Northern Italy to investigate effects of urban sprawl on environmental matrices in the area.

The Environmental European Agency reports that the urban-area expansion rate in several eastern and western European countries had increased by over three times with respect to the growth rate of their population. At present, urban sprawl can be considered as one of the most significant land-use transformation affecting Europe. At the same time, it is the one causing major effects on the different environmental matrices as well as on multiple social and economic aspects. Northern Italy is one of the most populated areas in Europe and most of its cities registered an urban sprawl pattern in the 2000s. From this point of view, northern Italy represents a pertinent "pilot area" to identify environmental impacts due to urban sprawl. The focus of the campaign will be to conduct the most effective investigation, by closely coordinating the field campaign through interactive technical discussion meetings of the science team for each zone of the Po Plain. This is to identify and understand the influence of urban characteristics and its change on important environmental topics such as: (a) groundwater resources and management, (b) air quality assessment, and (c) temperature assessment.

It is well recognized in general that groundwater contamination, air pollution and air temperature are impacted by land use type and variation. Nevertheless, it is extremely important to have a temporally and spatially consistent dataset delineating the urban extension through time in order to investigate the potential relationships between the change in urban area extent and the change in groundwater contamination, air pollution and air temperature. Even in the data-rich European and North American countries, such information are collected only at fixed period of time and are often either/both spatially or/and temporally limited and inconsistent.

Innovative processing and use of satellite data have allowed a successful development of a spatially and temporally consistent dataset delineating urban extension and thus to monitor the annual degree of urban changes, in each pixel of a 1-km grid, for the decade of 2000s. Moreover, the massive amount of high-quality satellite data products enables qualitative evaluations of environmental changes over large

# Contact



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