2nd EARSeL SIG LU/LC and NASA LCLUC Joint Workshop
Charles University, Prague, Czech Republic

Land-Cover / Land-Use Change Program

Synergistic Use of Multi-Satellite Sensors for Mapping and Monitoring LCLUC across Multi-Scales in the Time-Space Continuum

Key Note Presentation by Son V. Nghiem
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Including results from the following authors/researchers:
C. Small and G. Yetman, Columbia University; G. Neumann and D. Nguyen, JPL, T. Esch, DLR; W. Salas and N. Torbick, AGS; T. Le Toan, CESBIO; D. Hoekman, Wageningen University; C. Huang, University of Maryland; M. Lang, US Fish & Wildlife Service, J. Jones, US Geological Survey; I. Creed, University of Western Ontario; M. Masetti and S. Stevenazzi, University of Milan; A. Sorichetta, Southampton University; C. Linard, Unicersity of Namur; and A. Methews, Oklahoma State University

Session 3: Challenges of Land Cover and Land Use Monitoring with Dense Time Series of EO Data – 7 May 2016

Challenges in Mapping and Monitoring LCLUC

- LCLUC sciences across multiple scales in time and in space
- Require mapping across spatial dimension and monitoring across temporal dimension
- Require multiple satellite sensors with different spatial and temporal resolution and coverage + ancillary
- Time-space continuum paradigm to address rural-urban transformation

Multi-Sensors in Mapping and Monitoring LCLUC

- **Optical/multi-spectral:** AVHRR, OLS, MODIS, VIIRS; **High resolution:** Landsat, Sentinel, LISS-I/II, AVNIR, Spot, WorldView …
- **Active microwave radars:** SRTM, Sentinel, SIR-C/X, Envisat, ERS, ALOS, RADARSAT, TanDEM-X, Scatterometers …
- **Passive microwave radiometers:** SSM/I, SSMIS, AMSRE, AMSR2, TMI, …
- **Others Sat.:** SCIAMACHY, GOME, OCO-2, …
- **Others:** Airborne, tower, surface sensors, …

Multi-Datasets in Mapping and Monitoring LCLUC

- **Sensory data (L0, L1): Reflectance, backscatter, brightness temperature – Calibration, accuracy, stability, geolocation**
- **LCLUC parameter/product (L2-L4): Urban extent, building height, impervious surface, vegetation cover, surface water – Algorithms, models, validation, uncertainty**
- **Data policy: Free, open, accessible, long-term archives, latency, documentation, format/software.**

Synergy in Mapping and Monitoring LCLUC

- **Different sensor types:** Sensitive to different LCLUC parameters – optical multispectral for surface types, temperature, vegetation; radars for surface water and physical infrastructures – 3D capability
- **Multi-scales in time and in space:** 1m-10s km, narrow-1000s km swath, sub-daily-yearly, month-decade – Diversity
- **Multi-disciplinary science and applic-ations:** Physical to human dimensions

Approaches in LCLUC Science and Applications

- **Cross-scale in time and in space:** **Sectorial, systematic, and holistic methods**
- **Discrete:**
  - **Relevant to boundaries in time/space**
  - **Dependent on specific definitions**
  - **Dependent on specific thresholds**
- **Continuous:**
  - **Relevant to rural-urban transformation**
  - **Continuum in time and in space**
  - **Gradient in space and rate in time**
- **Hybrid: e.g., Intra-urban continuum**

SPECIFIC EXAMPLES

NASA Multi-source Land Imaging Science (MuSLI) & InterDisciplinary Science (IDS) Research in Collaboration with European and other Research Institutes and Agencies

Multi-source Imaging of Infrastructure and Urban Growth using Landsat, Sentinel and SRTM

C. Small, G. Yetman
Columbia University USA

S. Nghiem, G. Newman
NASA/JPL USA

EU Collaborators: T. Esch & Team *DLR Germany*

Objectives

Develop, calibrate and validate a continuous optical+microwave index to map the continuum of human settlements worldwide.

Apply the index to Landsat+SRTM circa 2000 and Landsat+Sentinel circa 2015 to map changes in spatial structure of settlement networks.

Quantify spatiotemporal co-evolution of settlement networks and other complementary land cover networks.

Funded by NASA LCLUC grant 14- LCLUC14-003 to

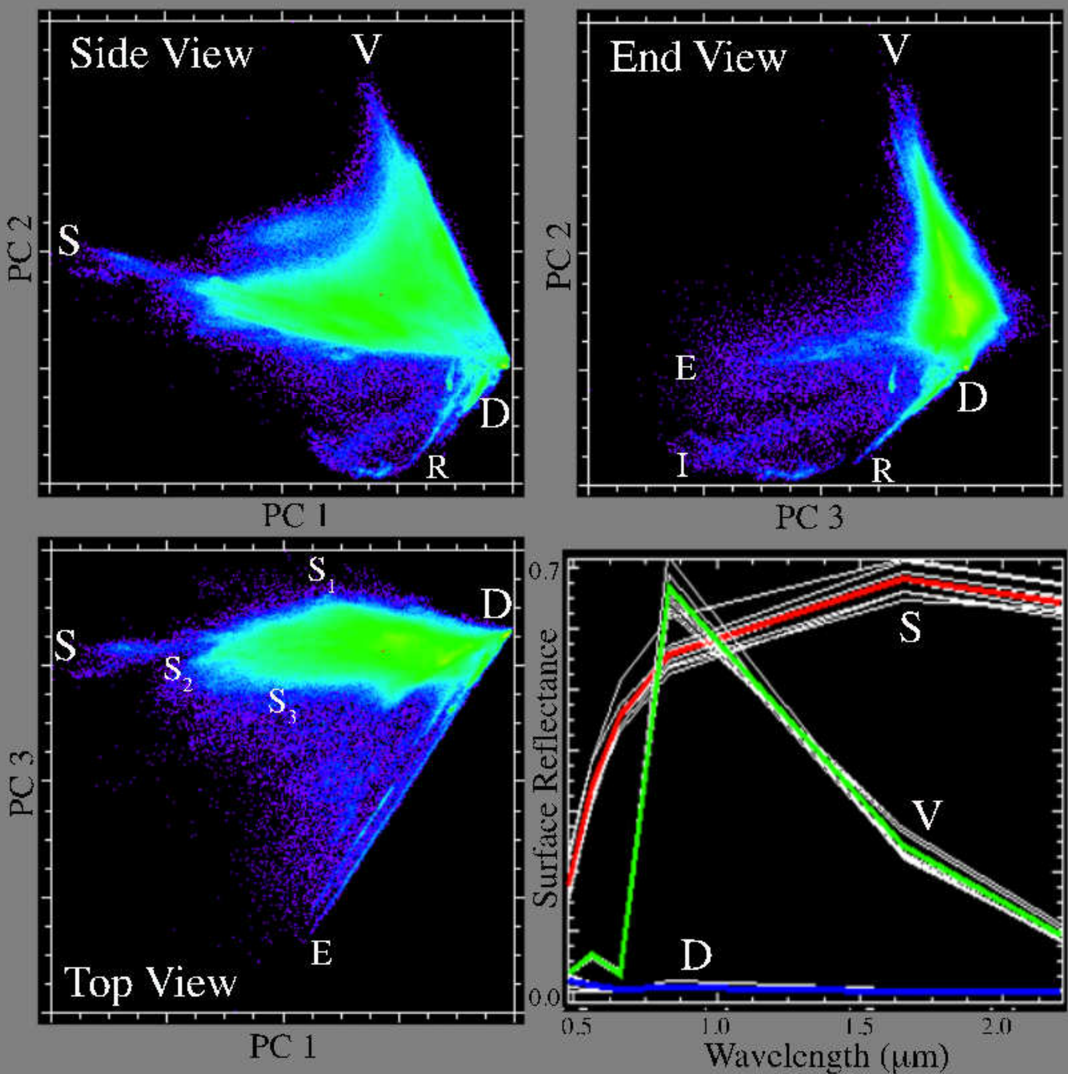
Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE

NASA JPL
Jet Propulsion Laboratory
California Institute of Technology

The Global Spectral Mixing Space

Spectrally, most land surfaces are composed of a few common reflectances:

Susbstrate, Vegetation and Dark surfaces



Substrate

The Rock - Soil continuum

Plane of Substrates D $S_1 S_2$ S_3

High albedo (when dry)

SWIR bright

Vegetation

Similar spectral features:

Vis - Chlorophyll Absorptive

NIR - Mesophyll Reflective

SWIR - H_2O, Lignin,Absorptive

Dark surfaces:

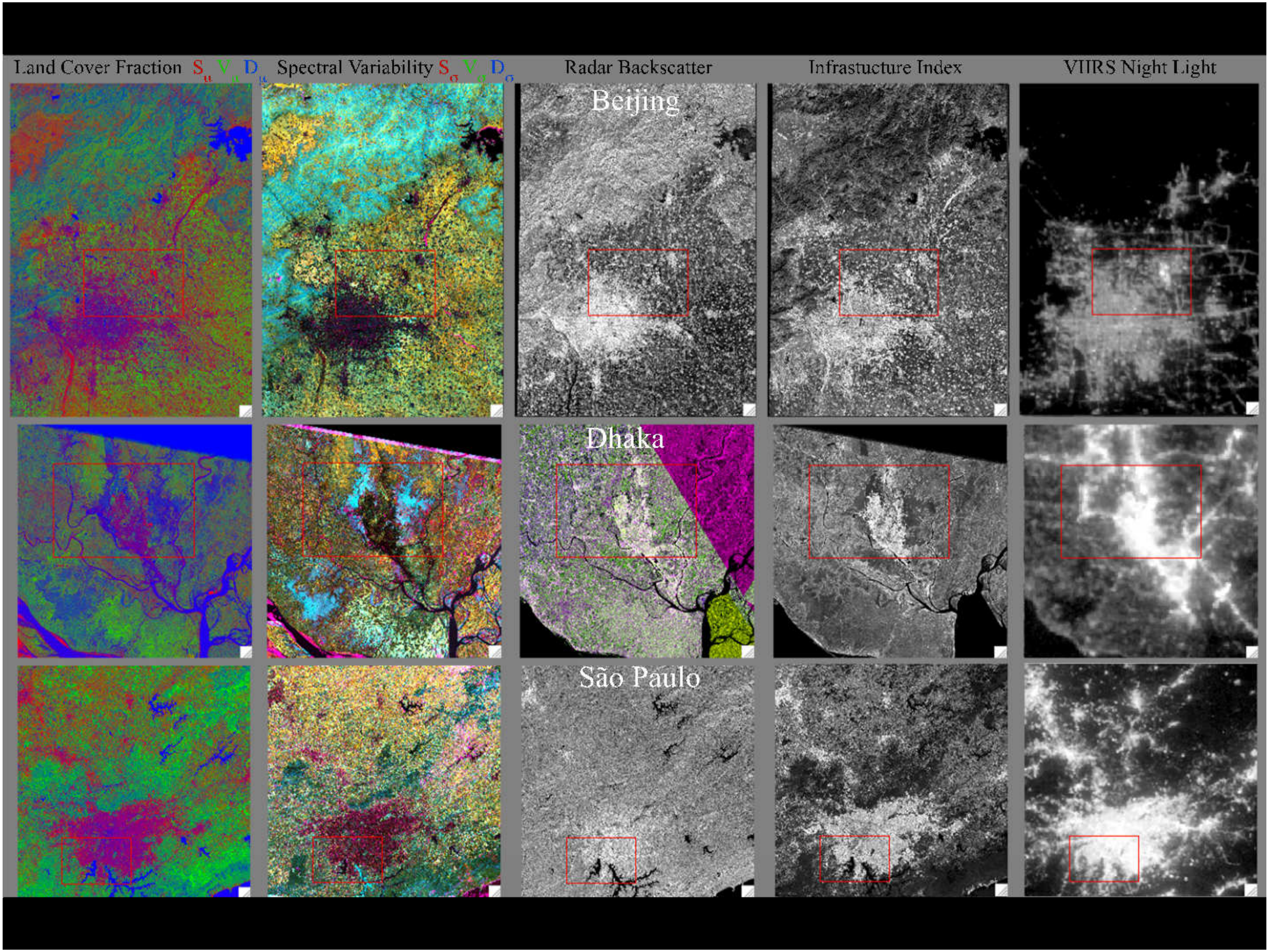
Transmissive: e.g. clear water

Absorptive: dark rocks & soils

Non-illuminated: shadow

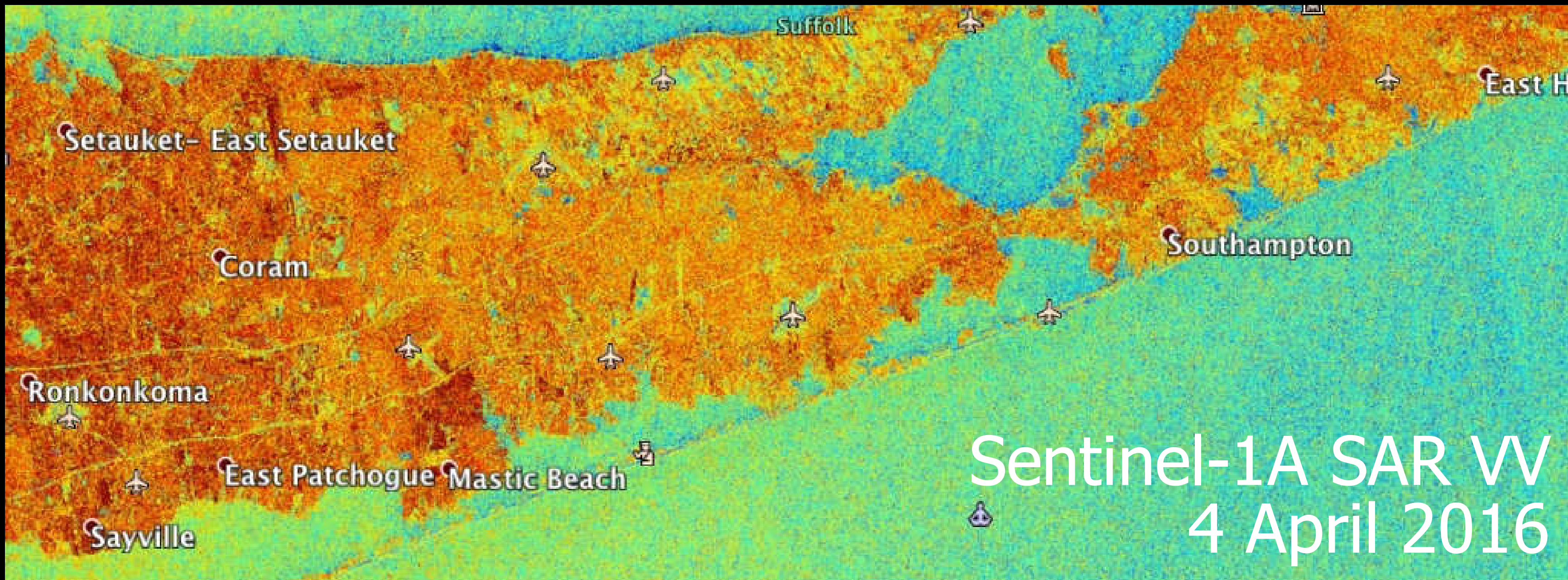
Other Stuff

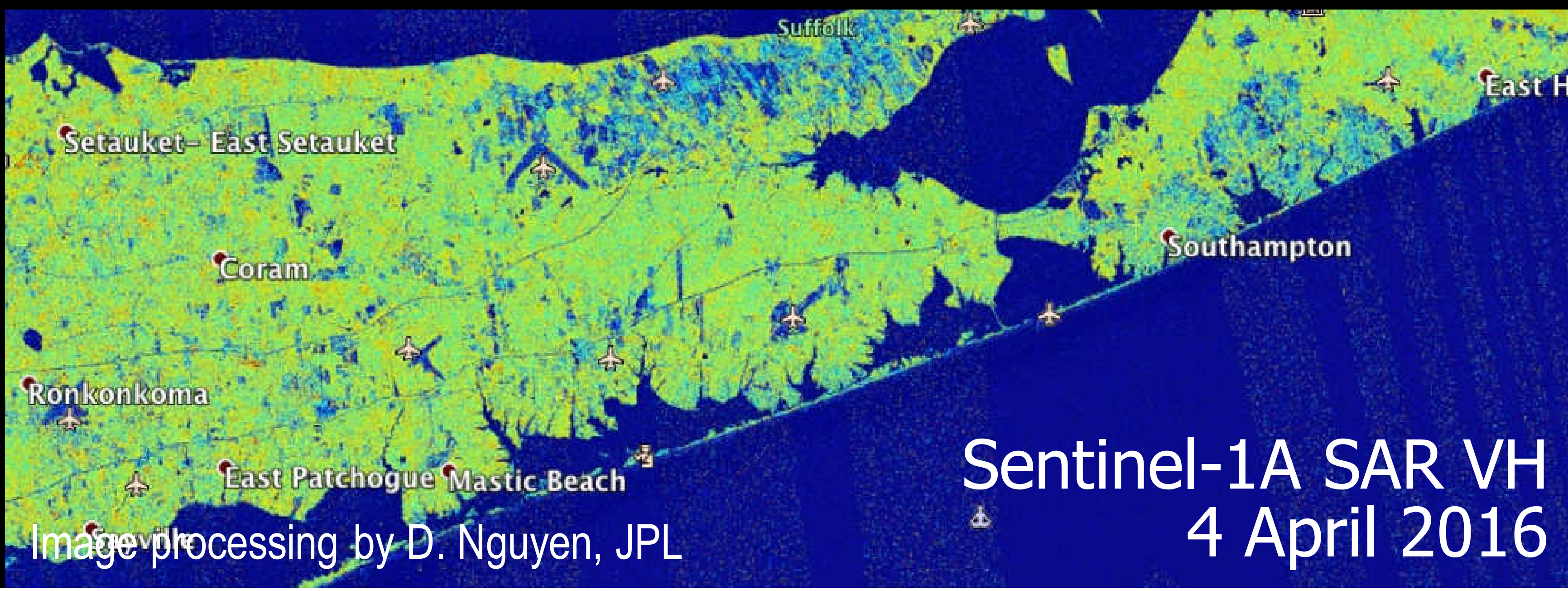
Evaporites, **I**ce/snow **R**eefs



Land Cover Fraction S_μ V_μ D_μ
Spectral Variability S_σ V_σ D_σ
Radar Backscatter
Infrastucture Index
VIIRS Night Light
Beijing
Dhaka
São Paulo

Polarization Diversity



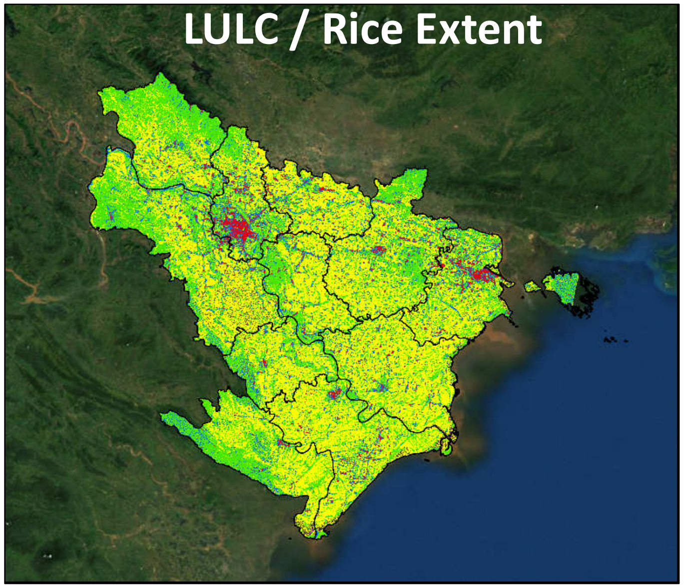


Operational algorithms and products for near real time maps of rice extent and rice crop growth stage using multi-source remote sensing

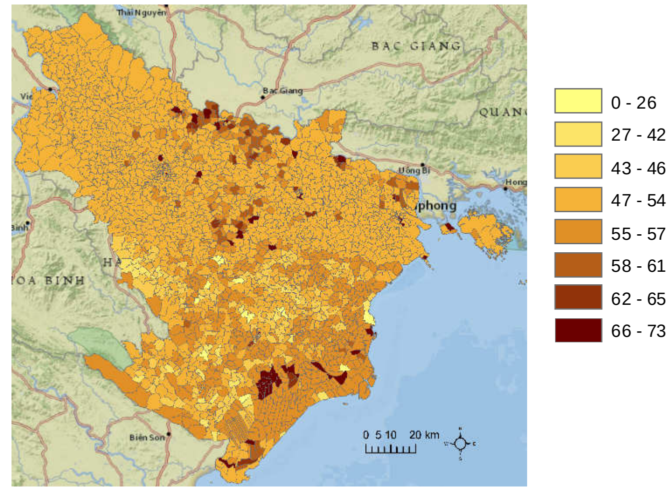
PI: W. Salas, N. Torbick, AGS
Thuy Le Toan CESBIO, Dirk Hoekman

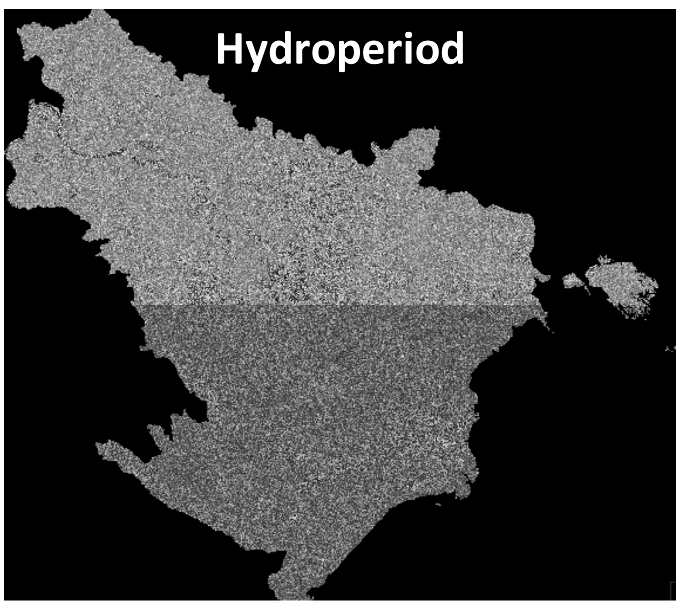
- PALSAR-2, Sentinel-1, Landsat 8 fusion high LULC accuracy
  - Multitemporal required for mapping rice attributes
  - Suite of parameters: extent, hydroperiod, intensity, calendar
- RRD GHG footprint characterized and uncertainty reduced with EO compared to IPCC Tier 1 approach
- Tuning, evaluating, and scaling products for new regions and select hot spots this upcoming year
- Open source tools, tech transfer, Decision Support Tools
  - Transition research to operational domain
  - github.com/Applied-GeoSolutions

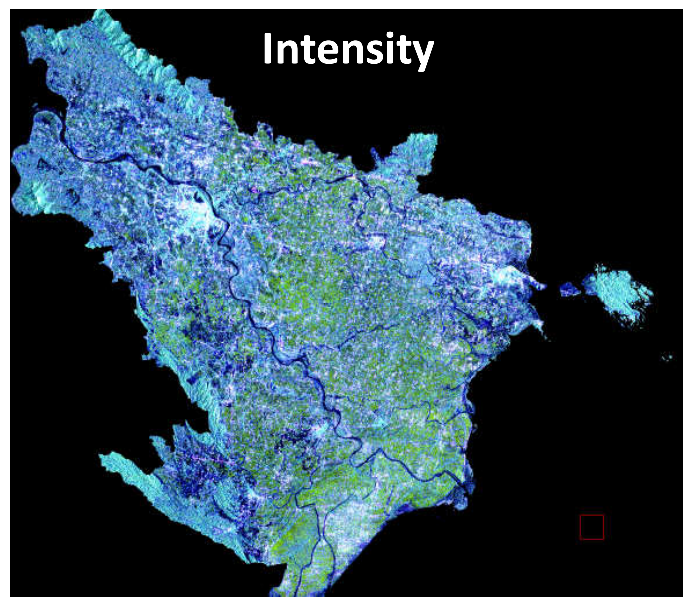
Driving DeNitrification-DeComposition Model with Earth Observations for GHG Assessment - Red River Delta



Crop calendar (1st crop planting DOY)

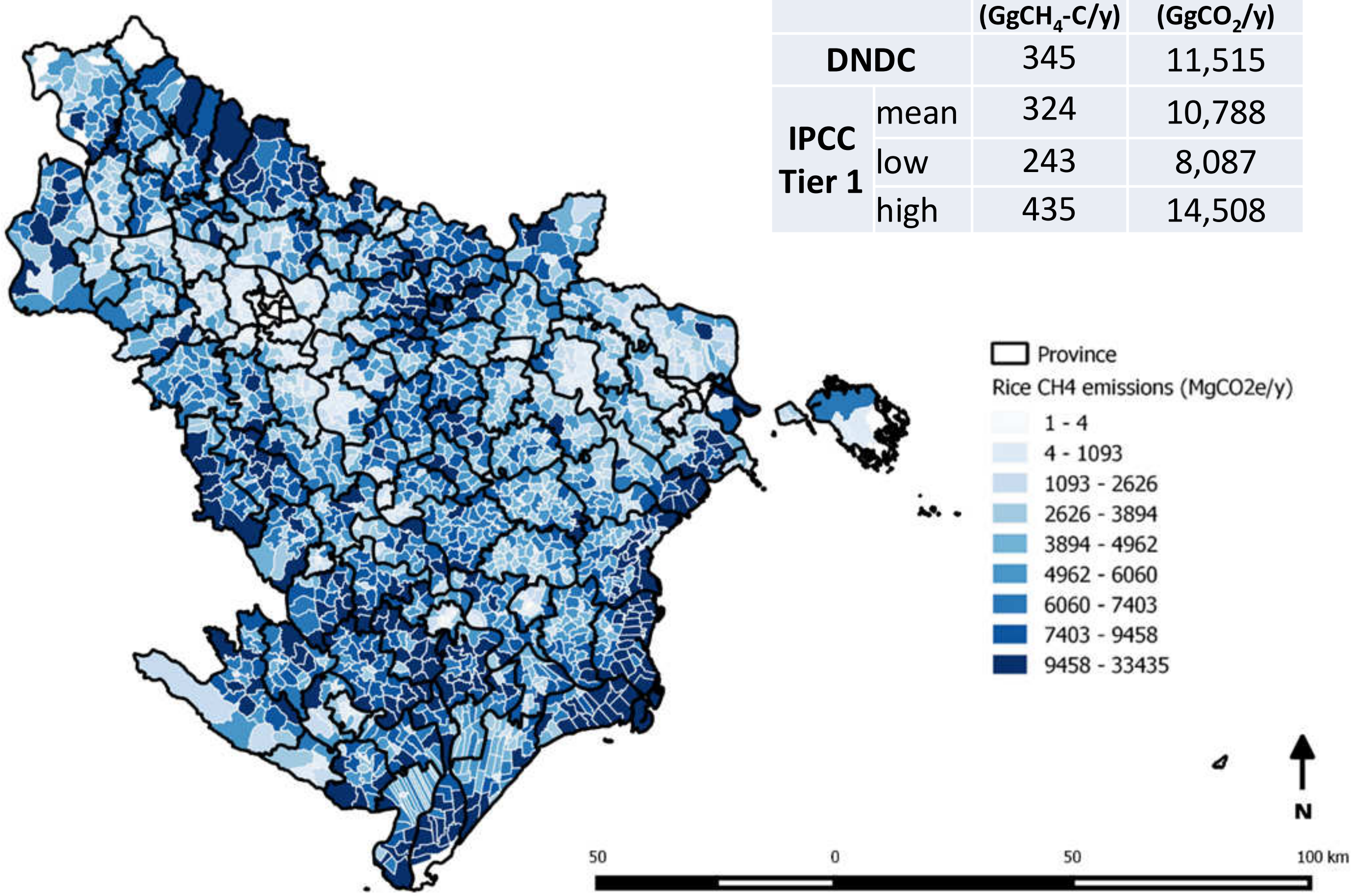






RRD 2015 Rice CH_4 Emissions

		CH_4	CH_4 GWP
		($GgCH_4$-C/y)	**($GgCO_2$/y)**
DNDC		345	11,515
IPCC Tier 1	mean	324	10,788
	low	243	8,087
	high	435	14,508



Commune-level rice GHG emissions for DNDC and comparison to IPCC Tier 1 approach.

Towards Near Daily Monitoring of Inundated Areas over North America through Multi-Source Fusion of Optical and Radar Data

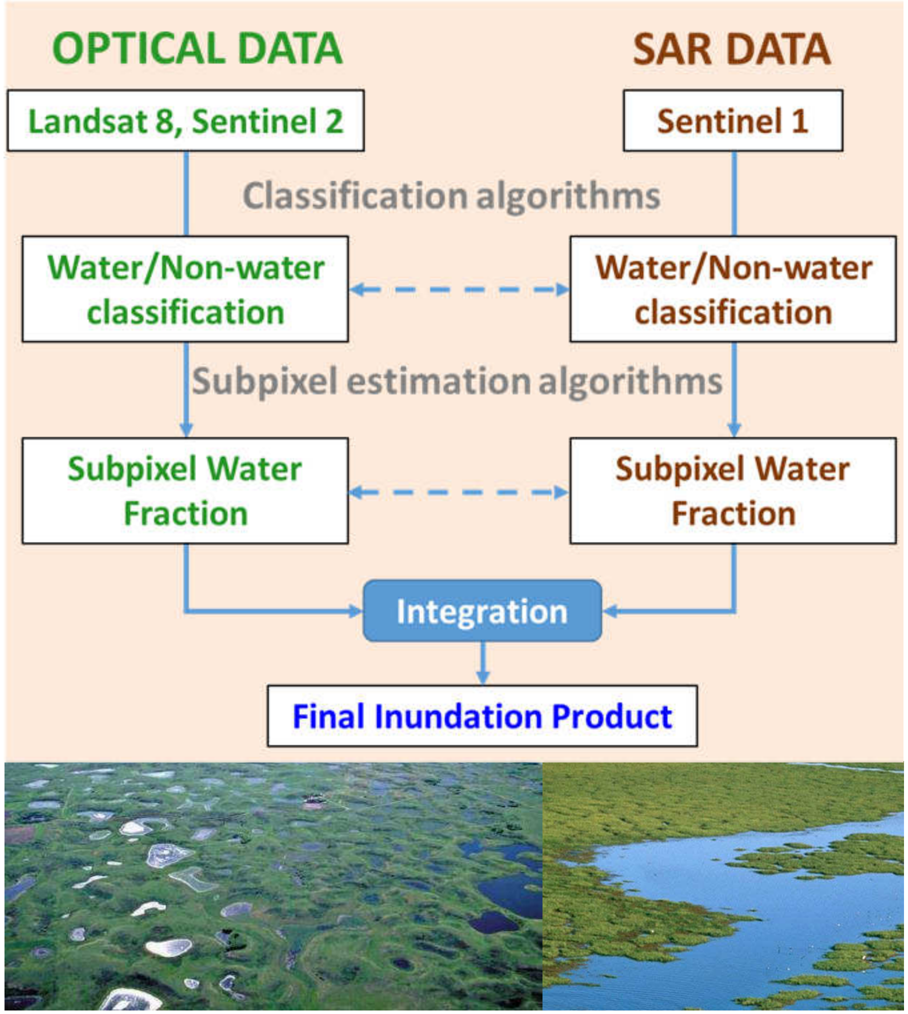
PI: Chengquan Huang, University of Maryland

Co-Is: Megan Lang, US Fish and Wildlife Service National Wetland Inventory

John Jones, US Geological Survey

International Collaborators: Irena Creed, University of Western Ontario, and many others

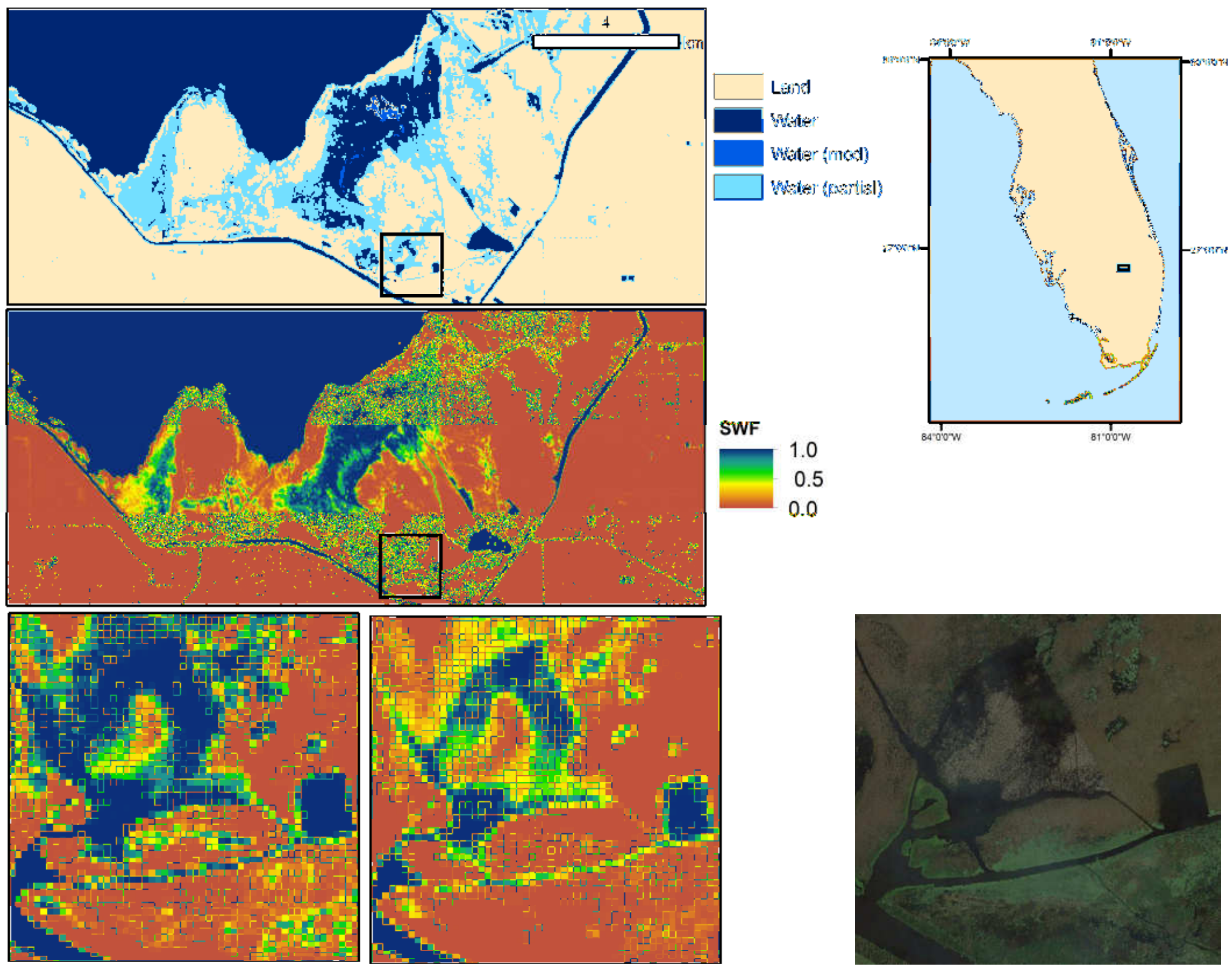
- Goals
  - develop automated inundation mapping algorithms
  - generate near daily inundation products
- Geographic area
  - US and southern Canada
- Data used
  - Landsat 8, Sentinel 2, Sentinel 1
- Advantage of using MuSLI approach
  - Capture rapid changes in surface inundation
- Up-to-date progress
  - Data exploration
  - Initial algorithm development



Iterative, Self-Training Approach for Subpixel Inundation Mapping Using Optical Data (Landsat 8, Sentinel-2)

Initial Classification
2014-03-23

SWF (final pass)

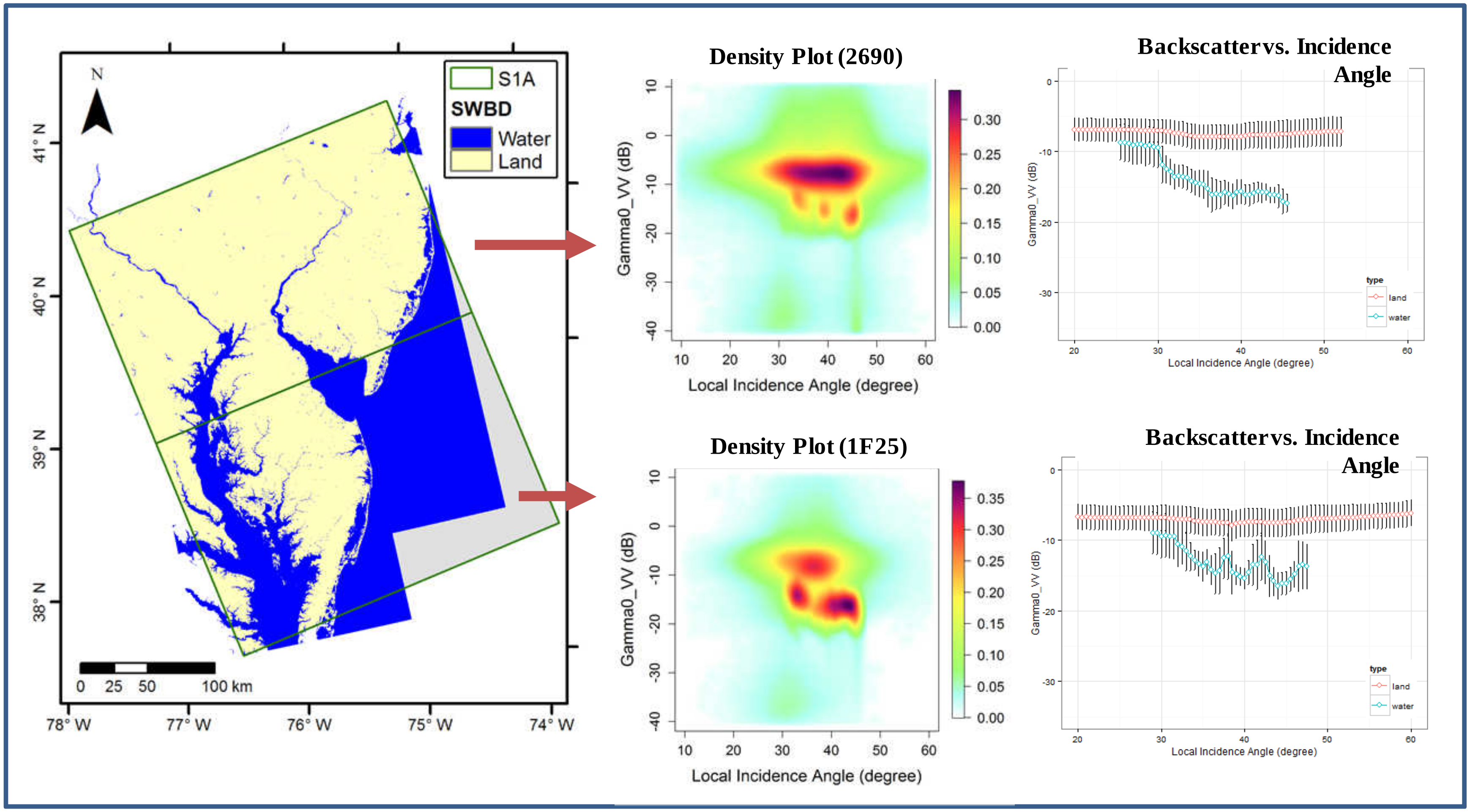


1st pass

final pass

2014-02-17

Local Incidence Angle Based Method for Separating Surface Inundation from Land Using Sentinel-1 Radar Data



NASA InterDisciplinary Research in Earth Science (NASA IDS)

GLOBAL MEGA URBANIZATION AND IMPACTS IN THE 2000s

PI: S. V. Nghiem (NASA/JPL)

Co-Is and Collaborators: 30 Institutions/Agencies in U.S., Italy, Germany, Belgium, and U.K.

Using 14 satellites from international space agencies

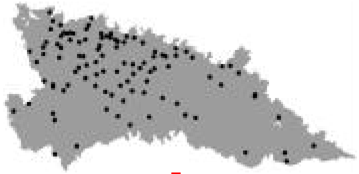
http://urban.jpl.nasa.gov

Jet Propulsion Laboratory
California Institute of Technology
Lamont-Doherty Earth Observatory of Columbia University
The City University of New York
Università degli Studi di Milano
Dipartimento di Scienze della Terra "Ardito Desio"
Goddard Space Flight Center
ASU
Purdue University
The World Bank
Carnegie Institution for Science
IFAC
Chapman University
Schmid College of Science and Technology
Center of Excellence in Earth Systems Modeling & Observations
arpa
Emilia Romagna
iah aih
Italian Chapter
University of Southampton
Geography and Environment
world pop
ULB
Université Libre de Bruxelles
LMU|LA
Center for Urban Resilience
SDSU

Lombardy, Italy: Groundwater Vulnerability Assessment in the Shallow Aquifer (2006/118/EC)

Training points

Urban area



Rural area

+

Natural predictors (not time-dependent)

- ✓ Groundwater depth
- ✓ Groundwater velocity
- ✓ Hydraulic conductivity of the vadose zone
- ✓ Soil protective capacity

Anthropogenic predictors (time dependent)

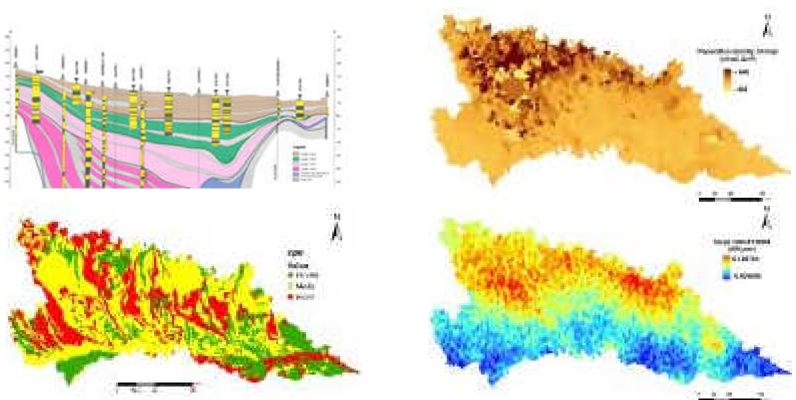
- ✓ Population density change

or

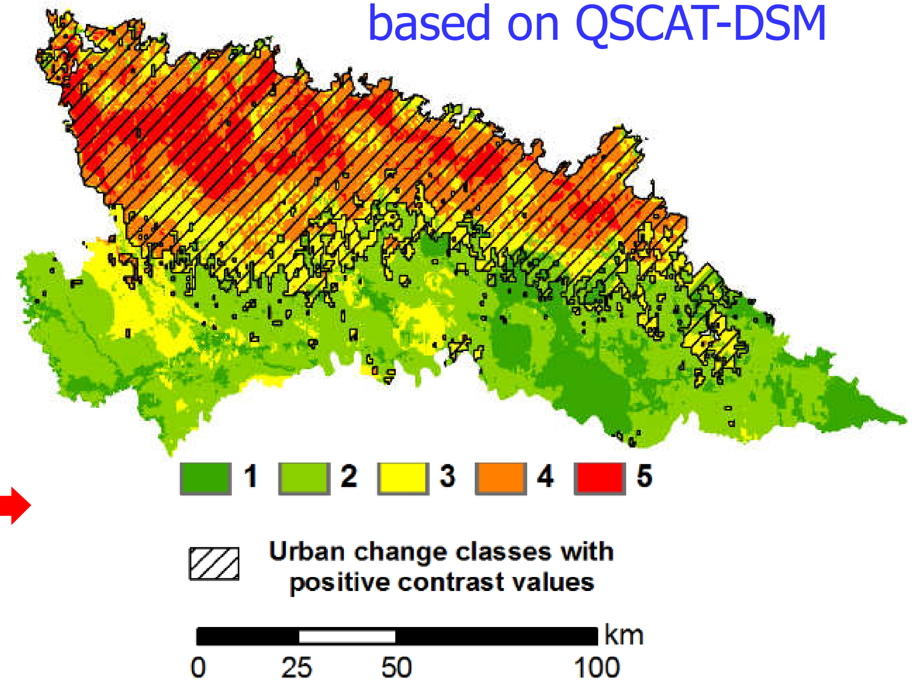
- ✓ Land cover change (QSCAT-DSM slope)

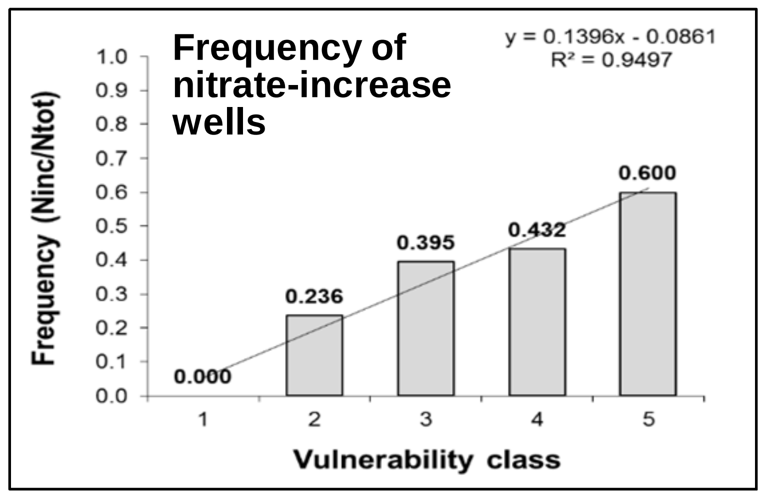
or

- ✓ Urban change (DUSAF data set)

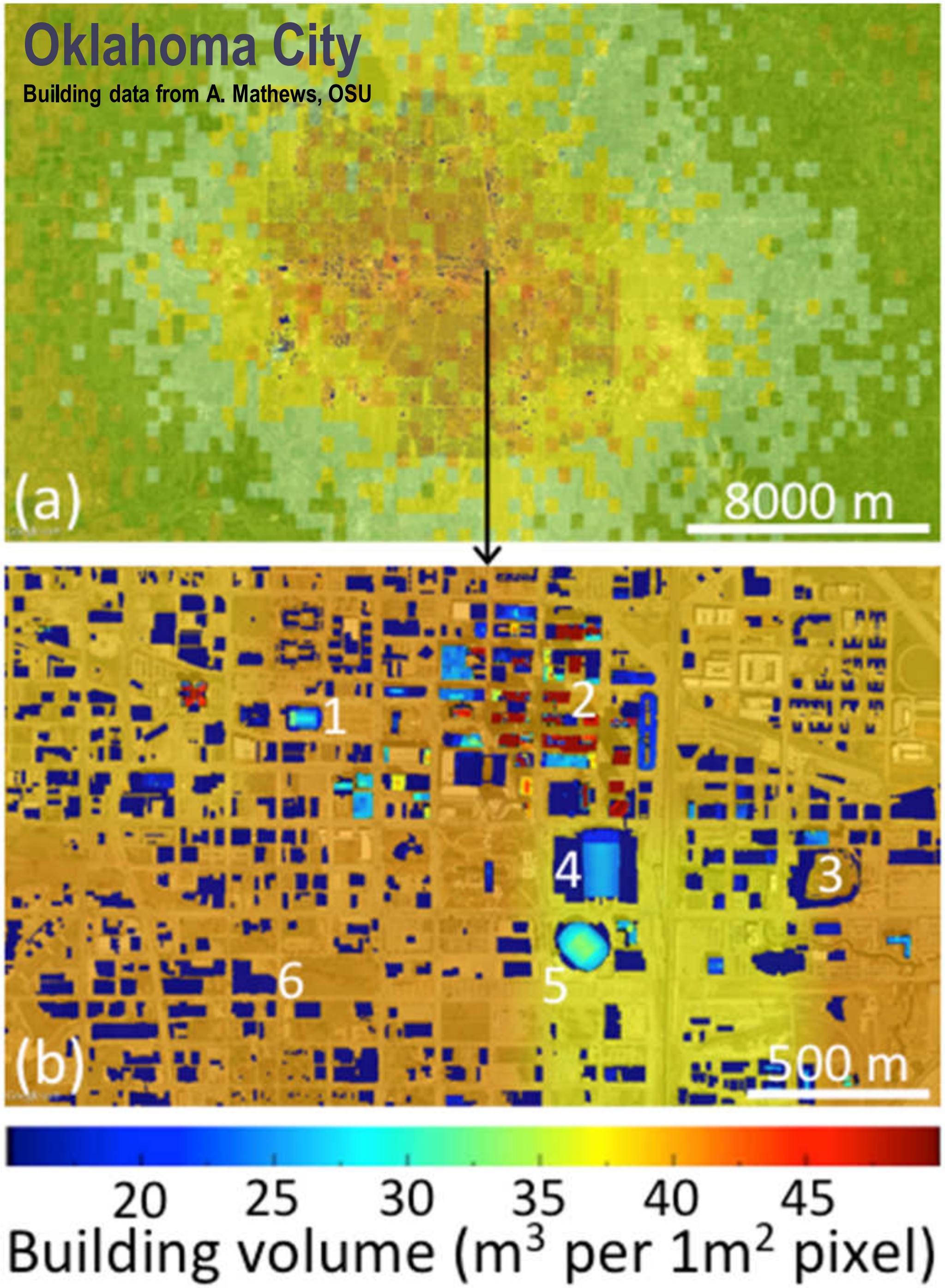


Groundwater vulnerability maps based on QSCAT-DSM



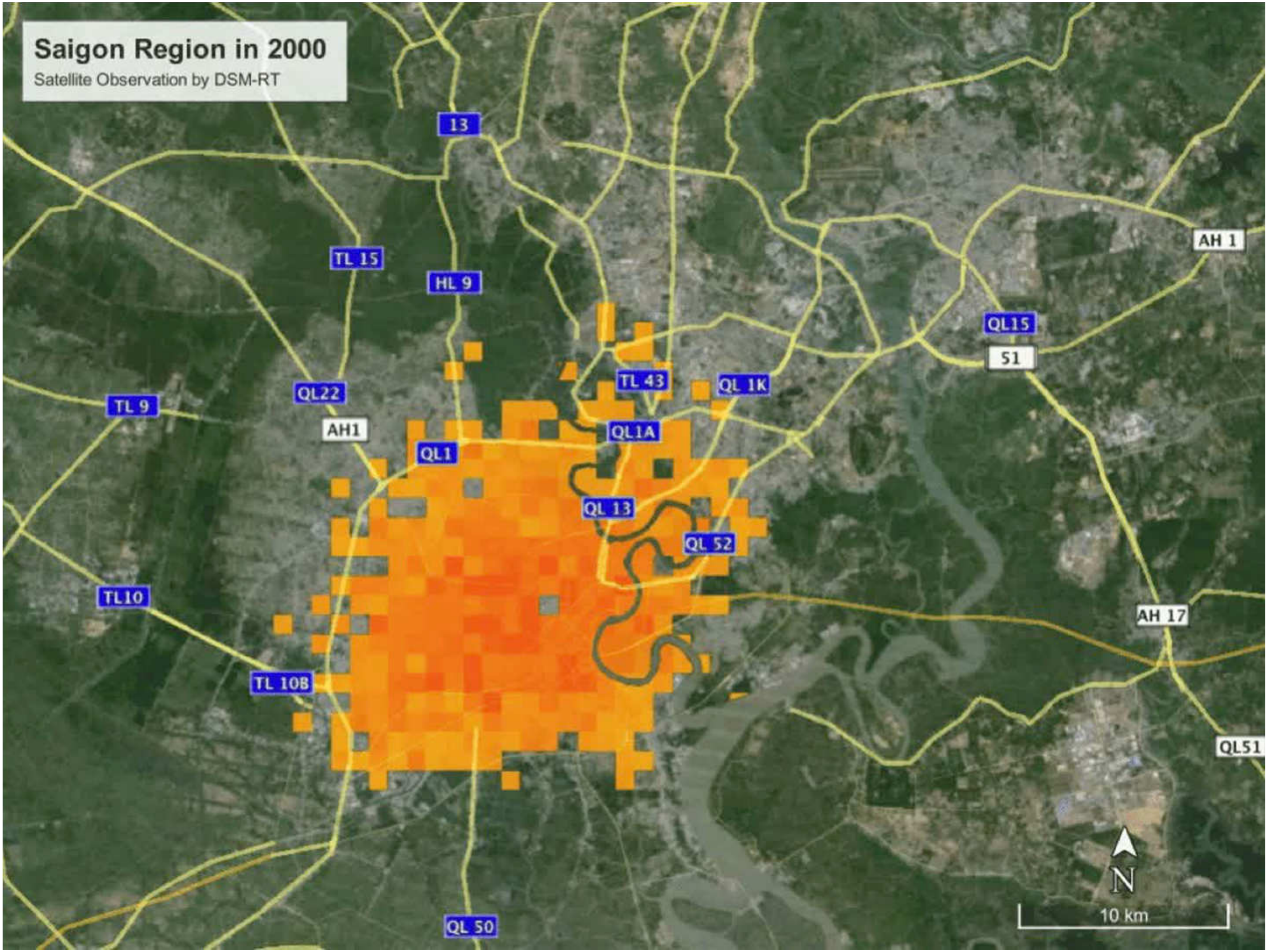


Stevennazi, Masetti, Nghiem, Sorichetta, HJ, 2015



Dense sampling method to measure 3D vertical and lateral infrastructure is demonstrated and validated:

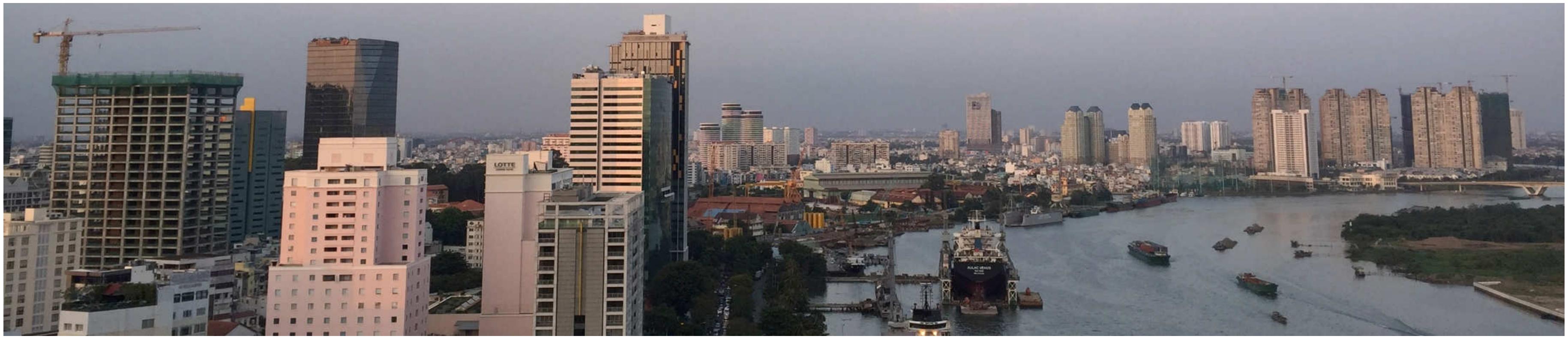
- NASA ESPCoR: OSU & JPL, 4 grad students
- Declassified Lidar data + building footprint at 1-meter resolution
- Almost identical patterns between DSM and 3D building volume with R^2 larger than 0.9



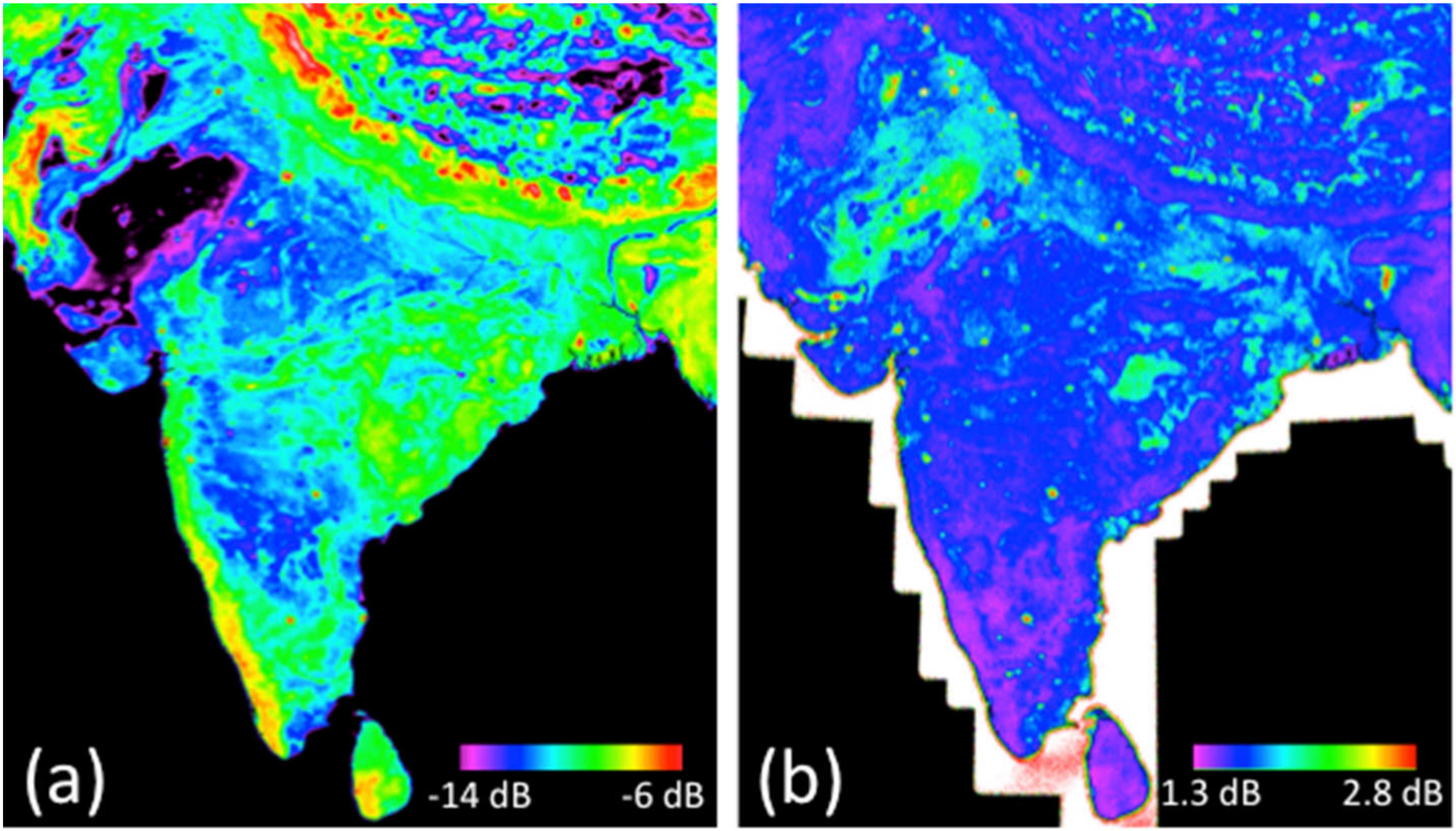
Saigon Region in 2000
Satellite Observation by DSM-RT
13
TL 15
HL 9
AH 1
QL15
51
TL 43
QL 1K
QL22
TL 9
AH1
QL1A
QL1
QL 13
QL 52
TL10
AH 17
TL 10B
QL51
N
10 km
QL 50

Saigon Regional Change in 2000-2009

Year	Extent (km^2)	Ratio change from 2000#	Vertical build-up (%) compared to inside 2000
2000	269.58353	1.00000	0.00
2001	351.08442	1.30232	5.59
2002	416.68210	1.54565	11.14
2003	491.58901	1.82351	17.11
2004	573.65858	2.12794	21.25
2005	648.77193	2.40657	25.73
2006	777.61744	2.88451	31.38
2007	861.41044	3.19534	37.58
2008	997.09949	3.69865	46.52
2009	1081.9193	4.01330	53.58



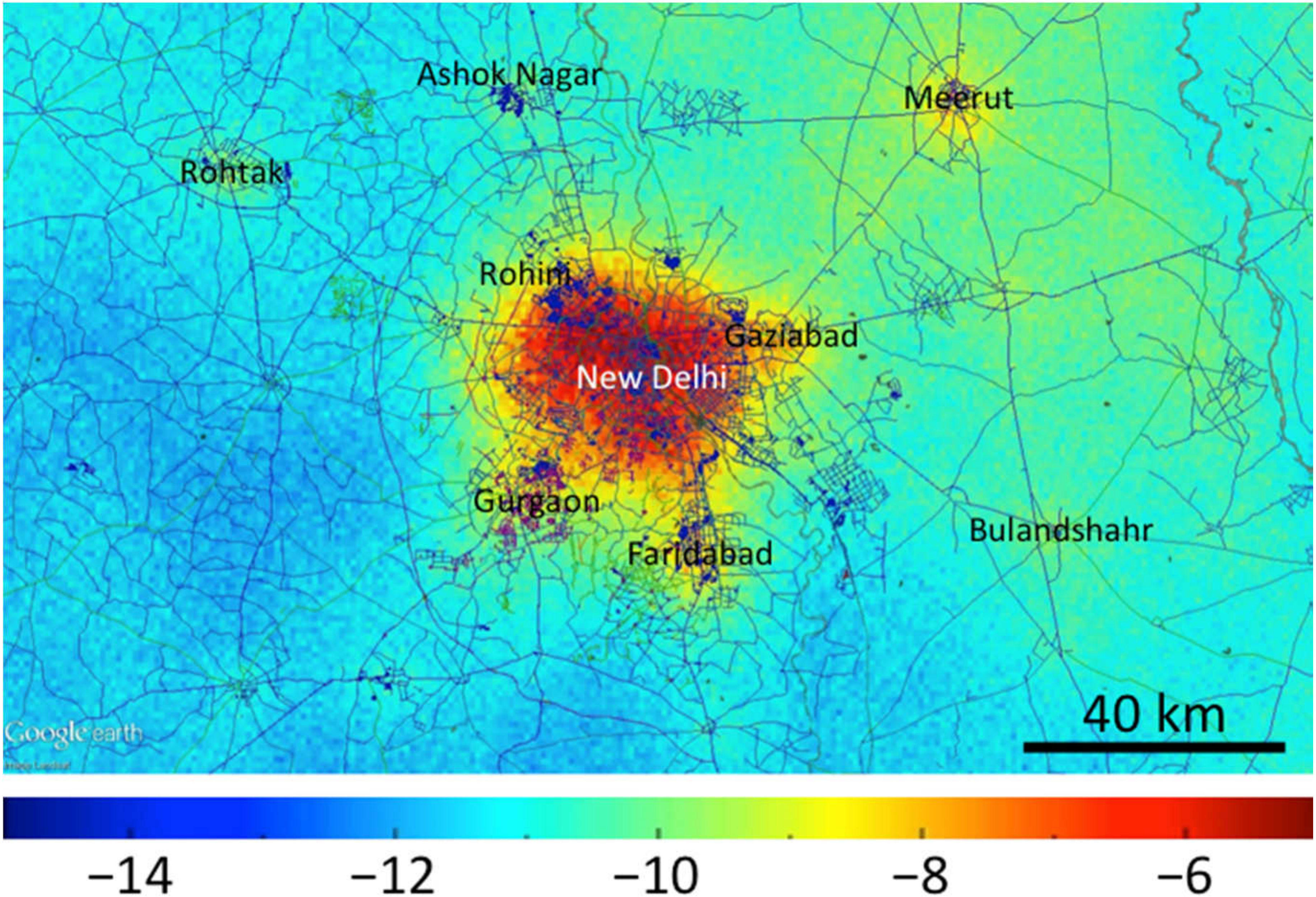
DSM Decadal Continuums over the Indian Subcontinent



Intensity

Variability

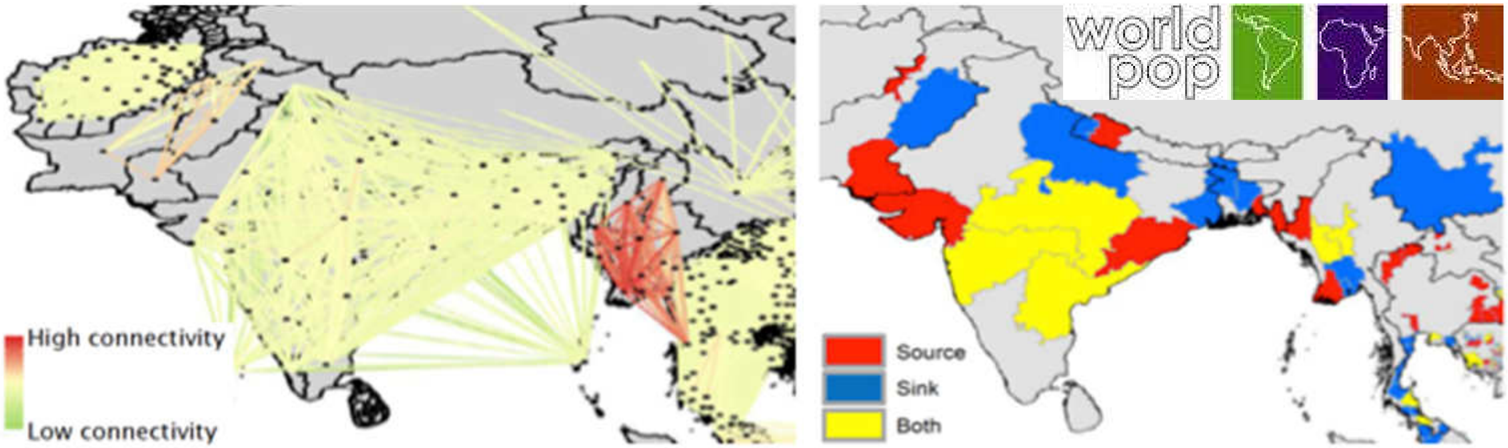
DSM Y-Intercept Continuum with OSM Road Network and SRTM Water Bodies



Vector-Borne Diseases (Malaria, Zika) over the Indian Subcontinent

Malaria Study (Courtesy of A. Sorichetta et al., ASTMH 2014)

Anopheles



(a) Connectivity from migration data (b) Malaria source and sink

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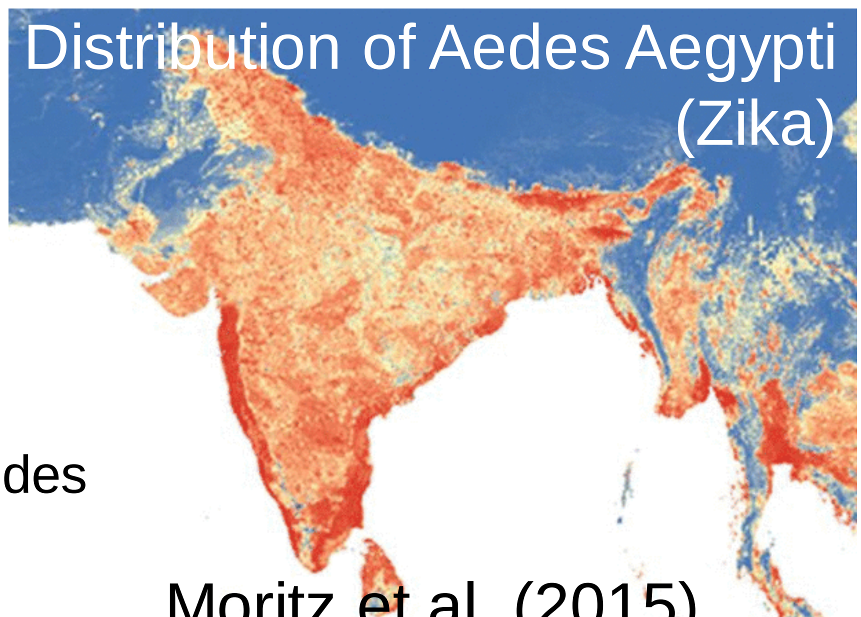
Aedes



Moritz et al. (2015)

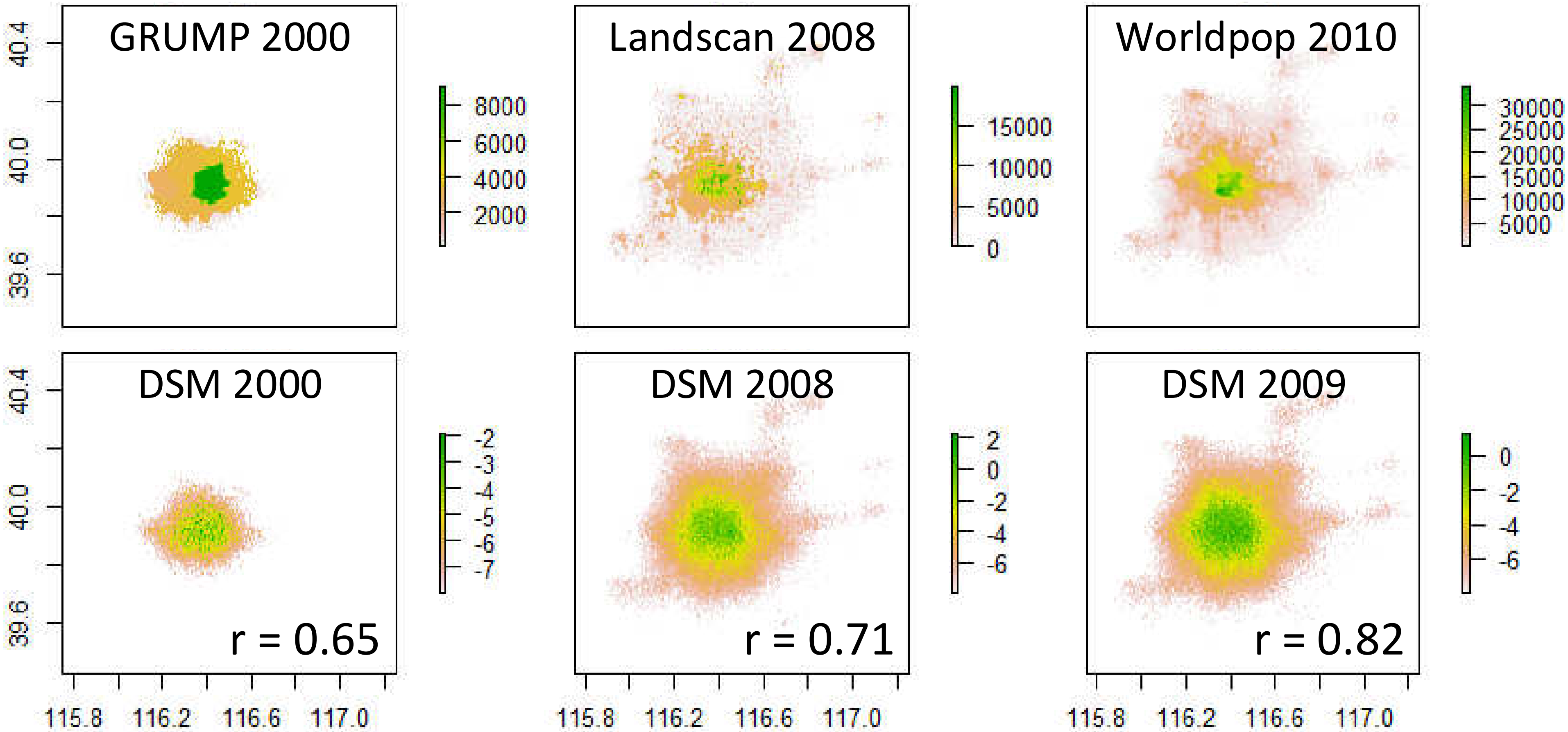
Require layer of rural/urban/peri-urban as a **continuum of built-up density rather than binary.**

Population Distribution and Dynamics

Census data partitioned in discrete boundaries

Distributed ambient population by Landscan

Distributed ambient population by Worldpop



DSM rural-urban continuum in 2000

DSM rural-urban continuum in 2008

DSM rural-urban continuum in 2009

Enabling assessment of spatial gradient and rate of change to characterize rural-urban transformation

Summary

- Challenges in LCLUC science & appl.
- Multi-sensors in LCLUC observations
- Multi-datasets/products for LCLUC
- Synergy for LCLUC mapping/monitor
- Approaches in LCLUC science & appl.
- Specific examples from NASA MuSLI and NASA IDS projects in collabor-ation with European and others institutions and agencies