Workshop On Land Cover/Land Use Changes
Cambodia, August 2022

Transformative Change of Land Cover and Land Use in Southeast Asia

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International Science Research Team

The collaborative research science team consists of 63 researchers/scientists

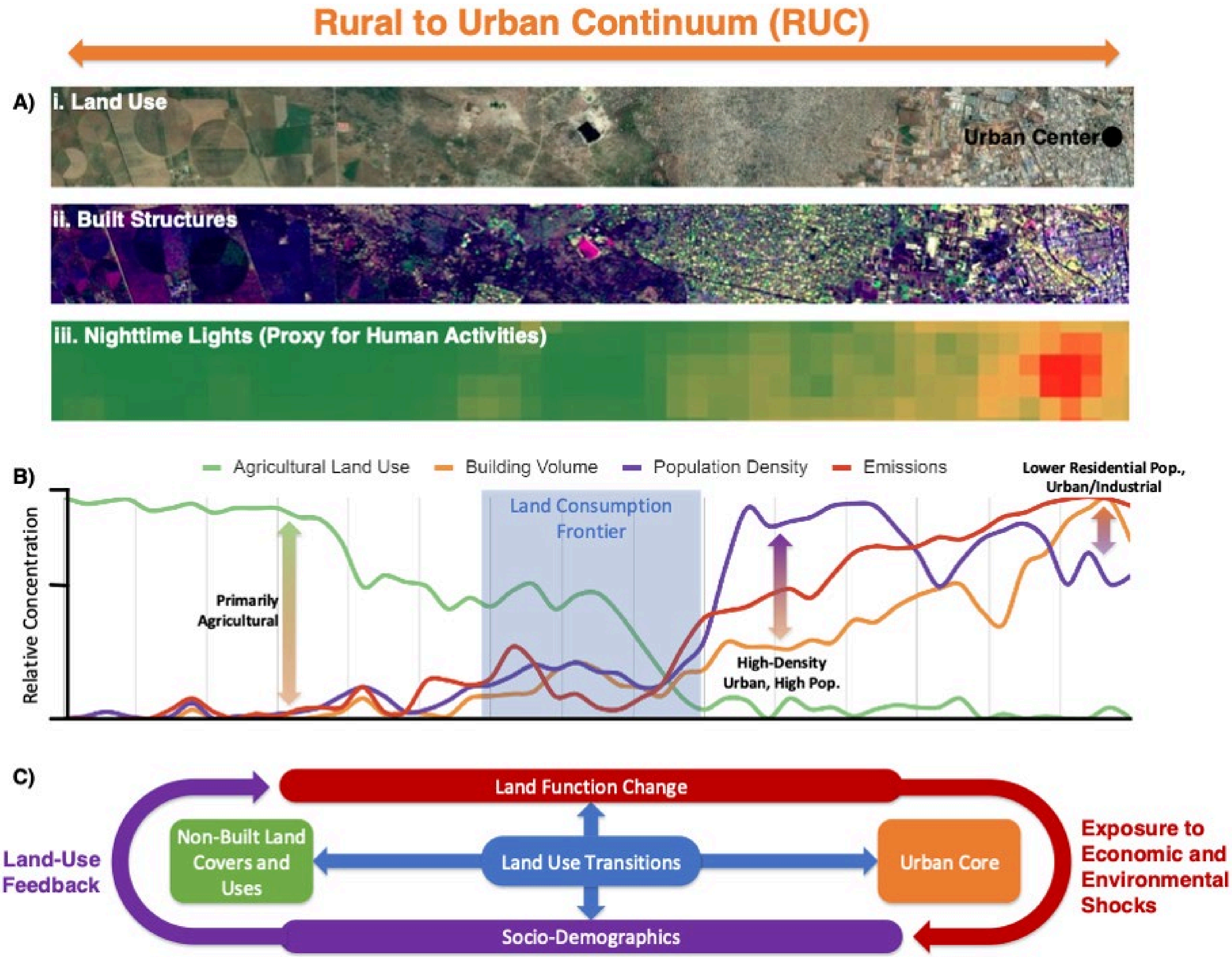
https://lcluc.umd.edu/projects/land-use-status-change-and-impacts-vietnam-cambodia-and-laos

Formulation of Space and Time Gradients

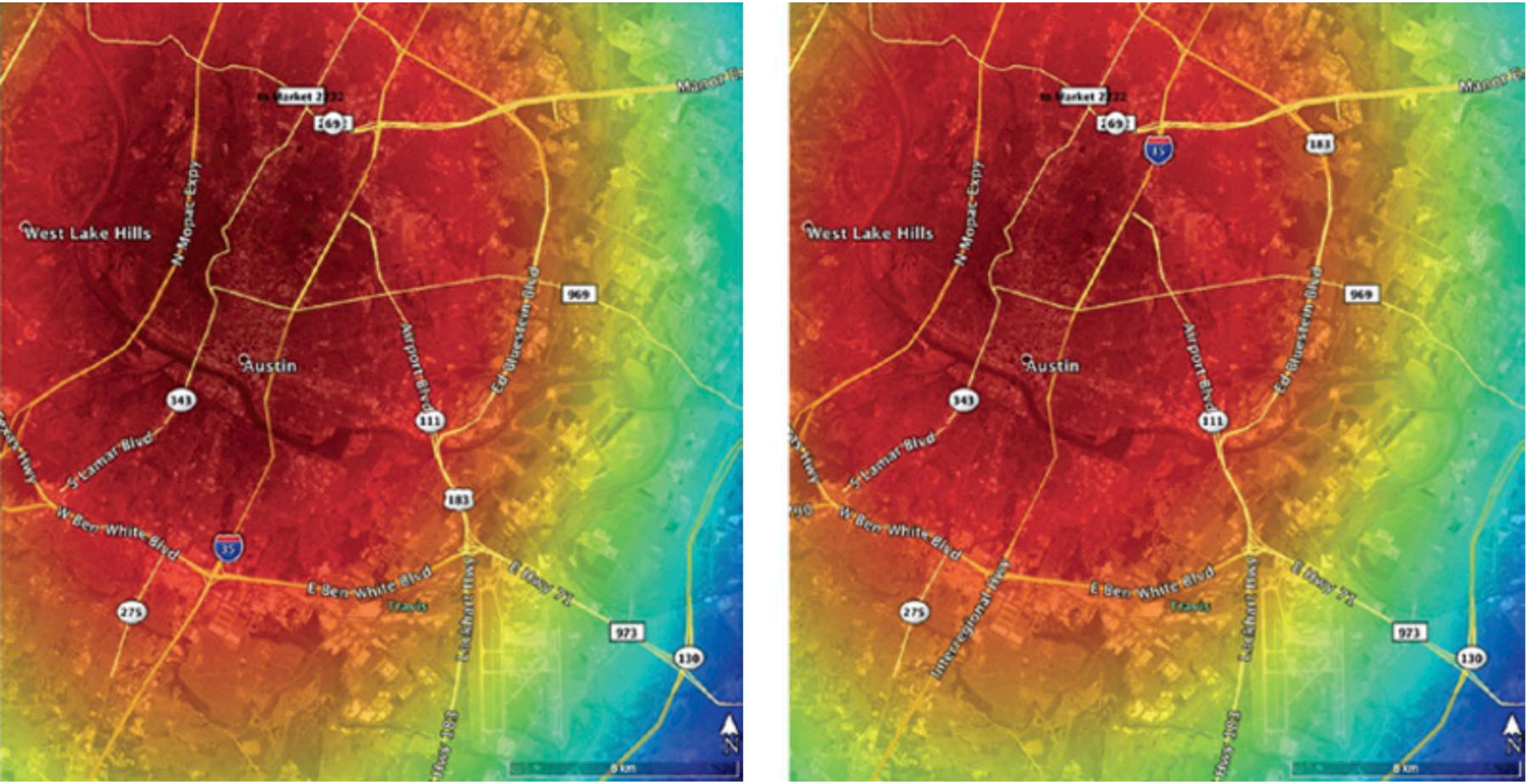
What is a transformative change?

- **Spatial Gradient**: Derivatives in space of 2D and 3D parameters.
- **Temporal Gradient**: Derivatives in time of 2D and 3D parameters.
- **Method**: Derivative of noisy data is a non-linear noise amplifier (ill-posed mathematical problem). The concept of space-time trend (e.g., Şen 2017) resolves the issue and is robust to examine space-time change.
- **Space-Time Change**:
  - Transition: Gradual trend in space and/or time
  - Transformation: Sharp trend in large space and/or time
  - Hot Spot: Abrupt trend change in small space and/or time

Rural Urban Continuum in Space and Time

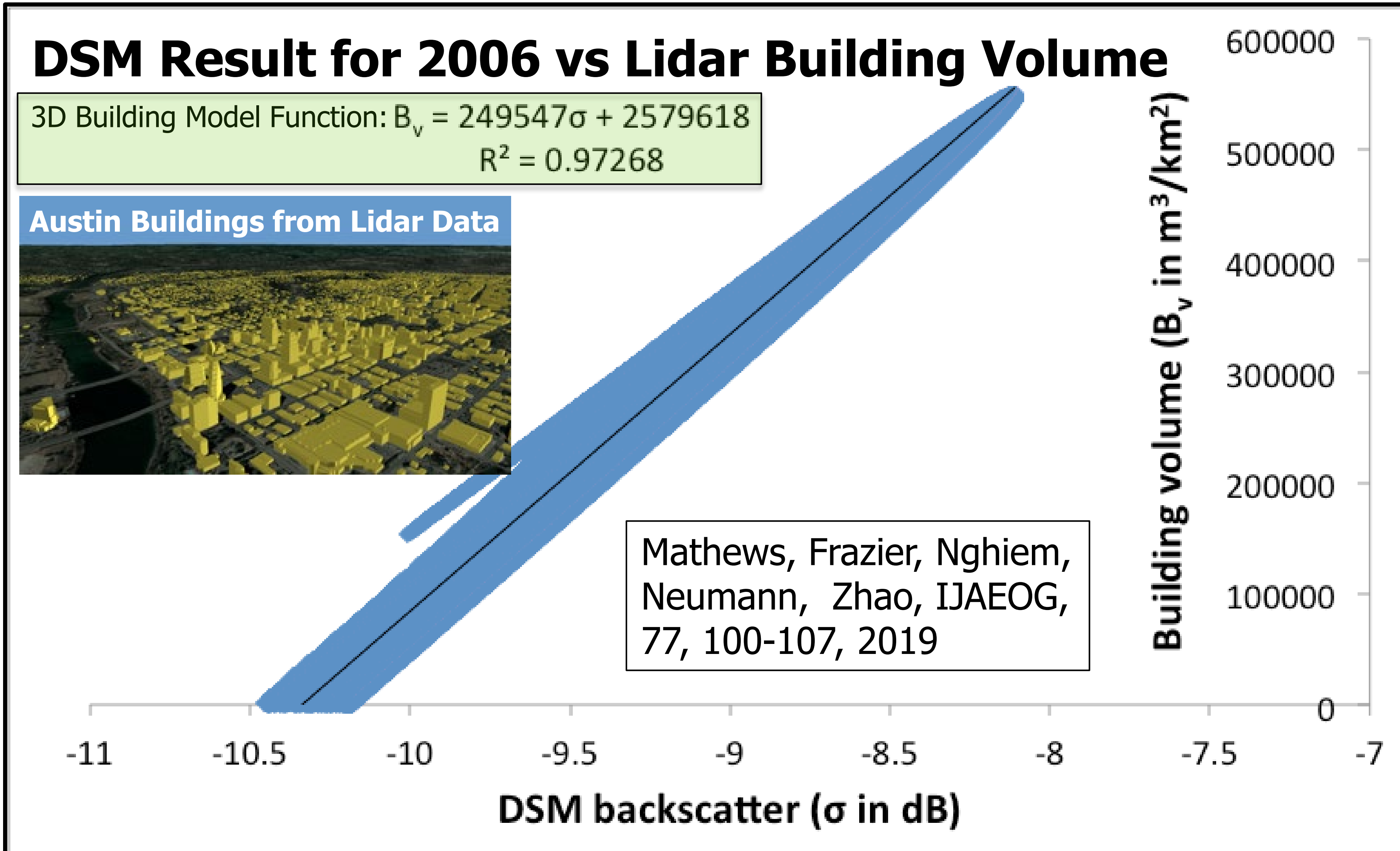


Spatial Trend of Austin, Texas, USA
3D Building Volume



Spatial trend patterns for Austin, Texas in 2006 overlaid on Google Earth base map. (Left) Spatial trend of lidar-derived building volume with the rainbow color scale from 0 to 9 million m^3, and (Right) satellite radar.

Validation of DSM with 3D Buildings



DSM Result for 2000-2009: Austin B_v grew by 9.3%/decade

Validation with 3D Buildings

Validation with seven metropolitan areas distributed across the continental United States: Large differences among cities, located across a variety of ecoregions and environmental conditions.

EXCELLENT VALIDATION FOR 7 CITIES IN 6 STATES and DC

City	Lidar Year	Lidar Area	Pop. (2010)	r^2	r	ρ	τ
Atlanta, GA	2003	79 km^2	420,003	0.76	0.86	0.90	0.73
Austin, TX	2006	390 km^2	720,390	0.97	0.99	0.99	0.91
Buffalo, NY	2004	342 km^2	261,310	0.69	0.83	0.86	0.67
Detroit, MI	2004	347 km^2	713,777	0.81	0.90	0.93	0.78
San Antonio, TX	2003	640 km^2	1,327,407	0.97	0.98	0.97	0.87
Tulsa, OK	2008	1,329 km^2	391,906	0.84	0.92	0.93	0.77
Washington, DC	2008	8,297 km^2	601,723	0.98	0.99	0.98	0.91

r^2: coefficient of determination in linear model; r: Pearson correlation coefficient; ρ: Spearman rank correlation coefficient; τ: Kendall rank correlation coefficient. All correlations significant with p-values < 0.01.

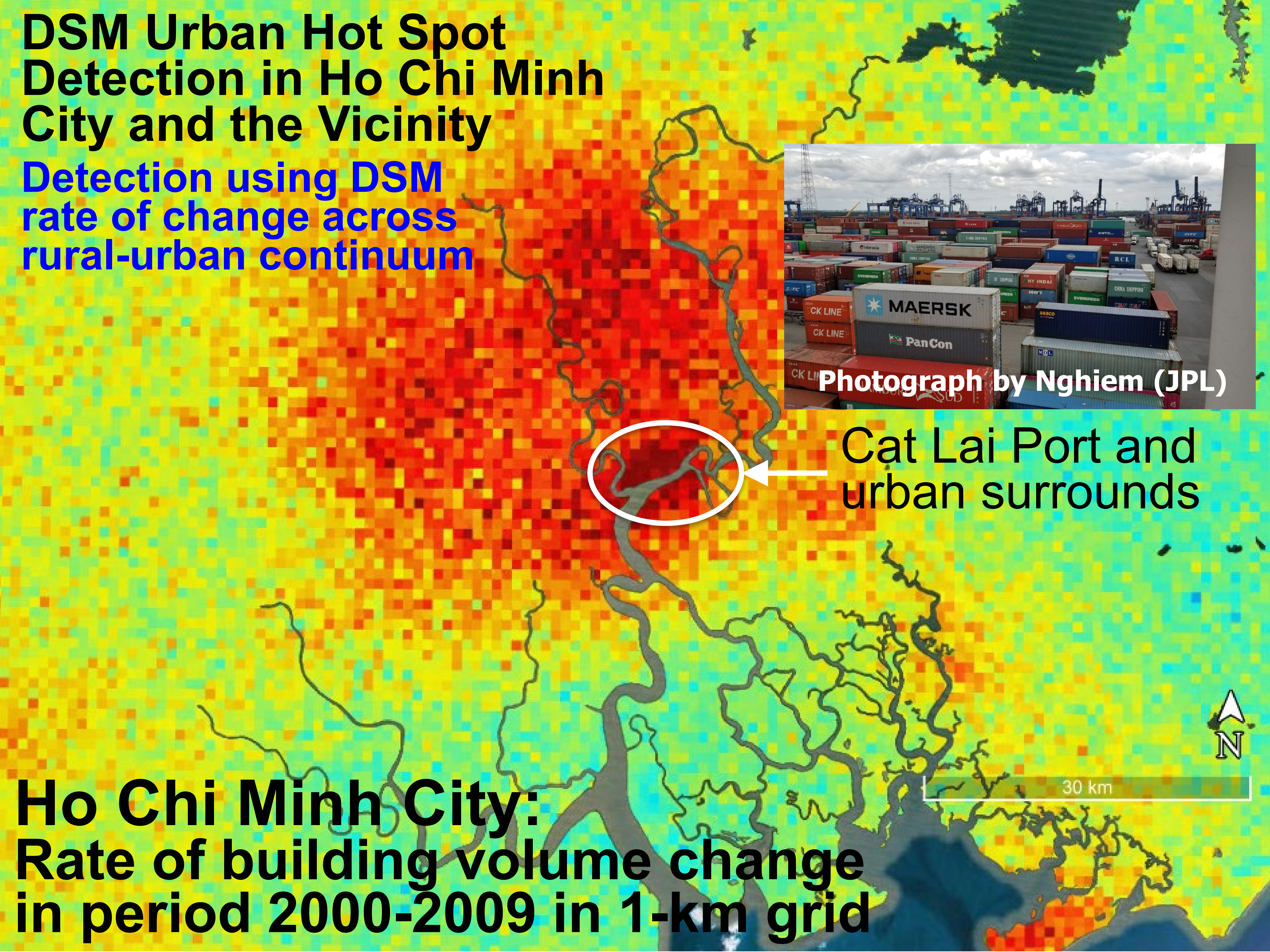
CONVERSION OF NATURAL WETLANDS AND FARM LANDS TO URBAN AREAS DUE TO URBANIZATION OF HCMC

The extreme urbanization of HCMC in 3D (2D lateral expansion + 1D build-up) is observed by satellite radar with the validated and patented Dense Sampling Method (DSM). The rate of change representing 3D building volume change can even capture build-up "hot spot."

Improvement in socioeconiomic status corresponding to the HCMC urbanization is captured by the new 3D DSM results while old 2D method misrepresents it. Thus DSM is a breakthrough overcoming limitations in 2D results.

DSM Urban Hot Spot Detection in Ho Chi Minh City and the Vicinity

Detection using DSM rate of change across rural-urban continuum



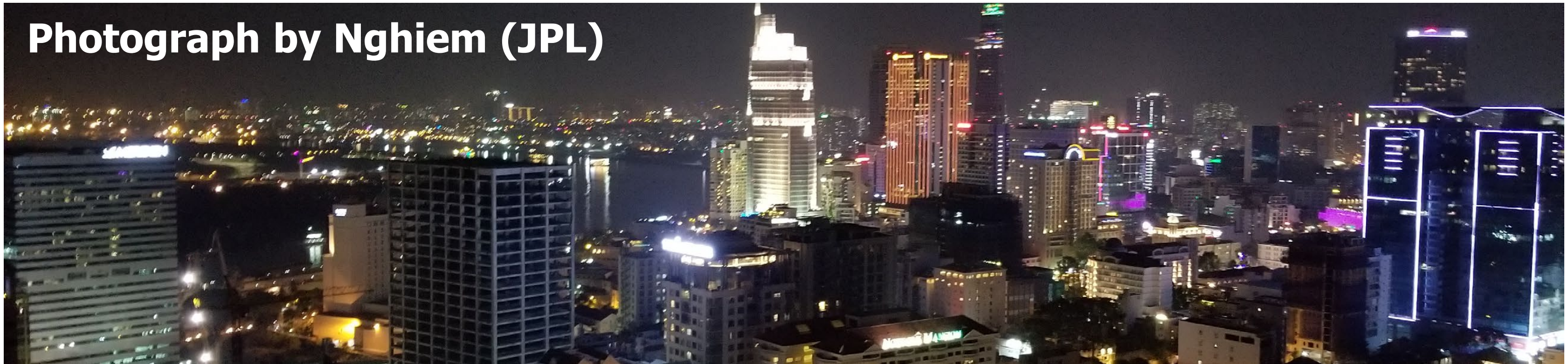
Ho Chi Minh City:

Rate of building volume change in period 2000-2009 in 1-km grid

4D Building Change in Ho Chi Minh City

2D lateral expansion + 1D vertical build-up + 1D decade

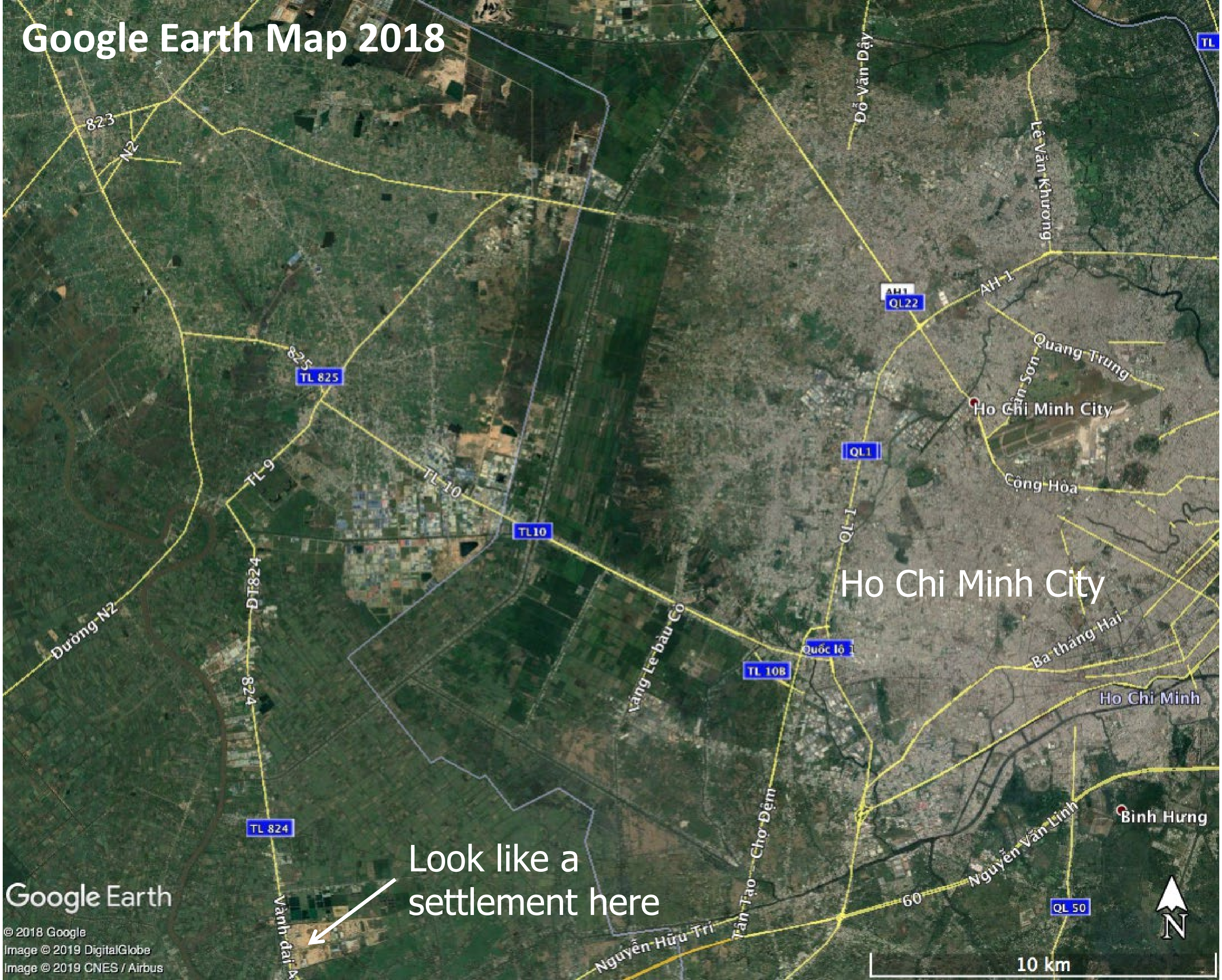
Year	Extent (km^2)	Ratio change from 2000#	Vertical build-up (%) compared to inside 2000
2000	269.58353	1.00000	0.00
2001	351.08442	1.30232	5.59
2002	416.68210	1.54565	11.14
2003	491.58901	1.82351	17.11
2004	573.65858	2.12794	21.25
2005	648.77193	2.40657	25.73
2006	777.61744	2.88451	31.38
2007	861.41044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

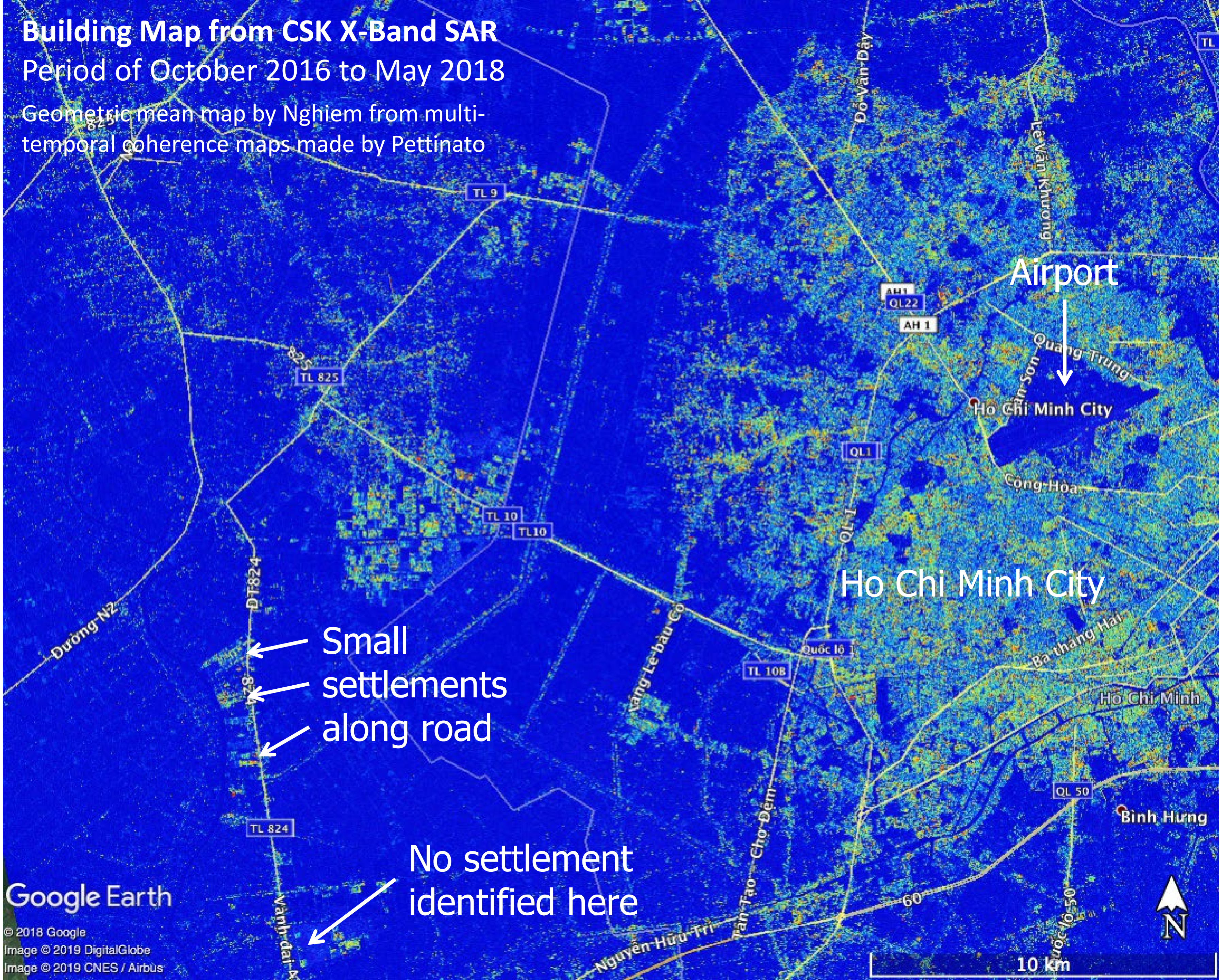

Photograph by Nghiem (JPL)

PUSHING THE ENVELOP: SATELLITE VERY HIGH-RESOLUTION (VHR) SAR TO OBSERVE LAND COVER STATUS

Land cover status of forest, rural, and urban areas (and their change) are observable with satellite synthetic aperture radar (SAR) at X band (3-m resolution) in all weather conditions and all seasons.

New methods using time-series coherent COSMO-SkyMed X-band SAR data from the Italian Space Agency (ASI) can detect existing, new, or destroyed buildings in urban, rural, and natural land. Applicable to LOTUSat.


Google Earth Map 2018
Look like a settlement here
Ho Chi Minh City
823
N2
825
TL 825
TL 9
TL 10
TL10
DT824
824
TL 824
Đường N2
Vành đai 4
Làng Le bàu Cò
TL 10B
Quốc lộ 1
QL1
QL-1
Chợ Đệm
Tân Tạo
Nguyễn Hữu Trí
60
Nguyễn Văn Linh
QL 50
Bình Hưng
Ho Chi Minh
Ba tháng Hai
Cộng Hòa
Ho Chi Minh City
Quang Trung
AH1
QL22
AH-1
Lê Văn Khương
Đỗ Văn Dậy
TL
N
10 km
Google Earth
© 2018 Google
Image © 2019 DigitalGlobe
Image © 2019 CNES / Airbus


Building Map from CSK X-Band SAR
Period of October 2016 to May 2018
Geometric mean map by Nghiem from multi-temporal coherence maps made by Pettinato
Airport
Ho Chi Minh City
Small settlements along road
No settlement identified here
TL 9
TL 825
TL 10
TL10
DT824
TL 824
Đường N2
AH1
QL22
AH 1
QL1
QL 1
Quang Trung
Ho Chi Minh City
Cộng Hòa
Quốc lộ 1
TL 10B
Ba tháng Hai
Hồ Chí Minh
QL 50
Bình Hưng
Đỗ Văn Dậy
Lê Văn Khương
Nguyễn Hữu Trí
Vành đai
60
10 km
N
Google Earth
© 2018 Google
Image © 2019 DigitalGlobe
Image © 2019 CNES / Airbus

3D Building Map in a Core Sector of Ho Chi Minh City

Derived from TerraSAR-X/TanDEM-X SAR

Bangkok: Multi-source Imaging of Infrastructure and Urban Growth with Landsat, Sentine & SRTM

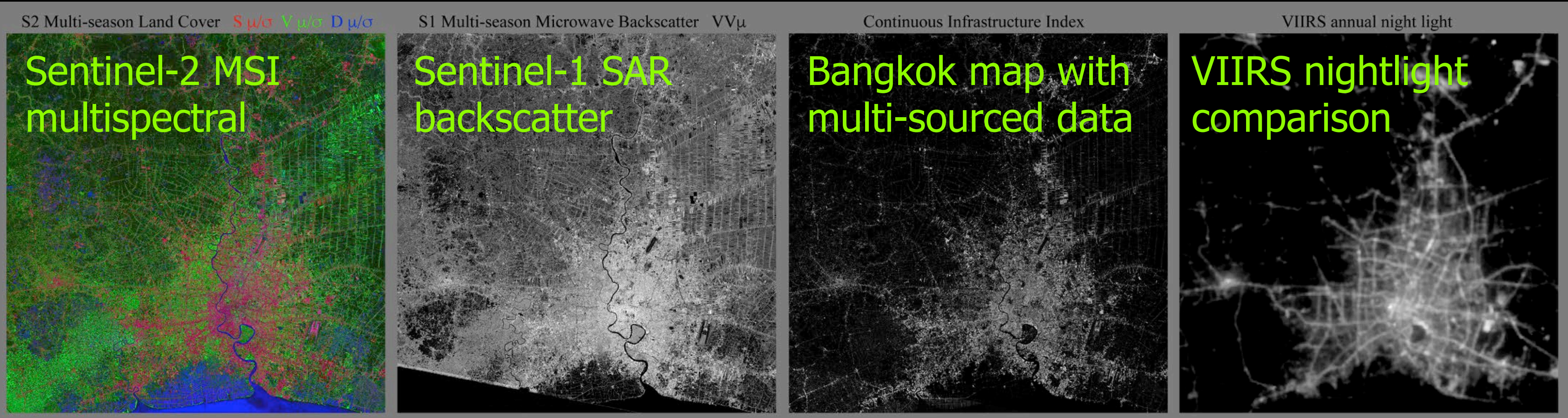
C. Small (Columbia Univ.), S. Nghiem (NASA-JPL), T. Esch (DLR)

Combine multi-season optical land cover fractions with multi-season microwave backscatter to map impervious surface. Continuous Substrate Vegetation Dark land cover fractions from standardized spectral mixture model. Multi-season Substrate moment (Mean/StdDev = μ/σ) distinguishes stable impervious surfaces from variable moisture soils. High density of corner reflectors gives persistent high VV backscatter in multi-season mean VVμ

2015 Sentinel-2 SVD μ/σ + Sentinel-1 VVμ ***2000*** Landsat 7 SVD μ/σ + SRTM VVμ

Continuous Infrastructure Index = $S\mu/\sigma\ VV\mu$

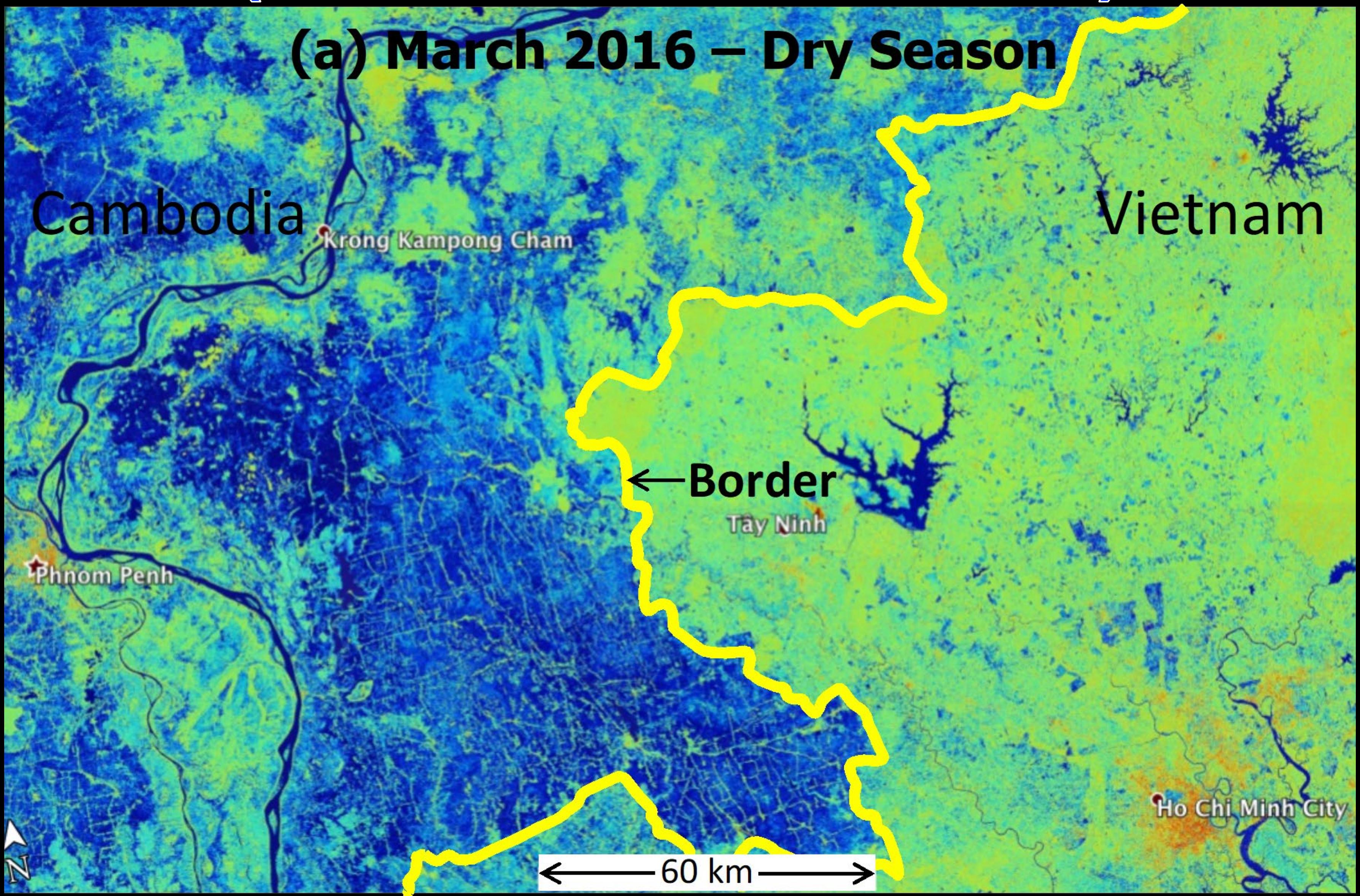
Satellite maps of Bangkok in 2015



DEFORESTATION CONTRAST BETWEEN VIETNAM AND CAMBODIA

- Sentinel-1 SAR can detect and map deforested areas with a high resolution (~10 meters) in all weather conditions and in all seasons.
- Satellite SAR results show a stark contrast with extensive deforestation in Cambodia almost exactly along the Vietnam-Cambodia border.
- With the high-resolution capability, zoom-in image can reveal detailed spatial pattern of deforested areas across the border between Vietnam and Cambodia.

Contrast in Deforestation in Vietnam & Cambodia
(Blue on land with little or no trees)



A clear case of land-use policy reshaping the landscape as Sentinel-1A SAR images show a stark contrast along the Cambodia-Vietnam border.

DEFORESTATION OF MOUNTAINSIDES

- Urbanization and tourist industry demand excessive building materials like soil, san and rocks.
- Mountains are exploited to obtain building materials, consequently causing denudation of mountainsides, which is the worst kind of denudation causing mud flows and landslides.
- Ironically, mud flows and landslide may surge toward new buildings and resort structures, exacerbating properties damage and loss of lives.
- Satellite data can provide a compendium or inventory maps of denudated mountain slides.

DEFORESTATION OF MOUNTAINSIDES

Toc Tien Mountain

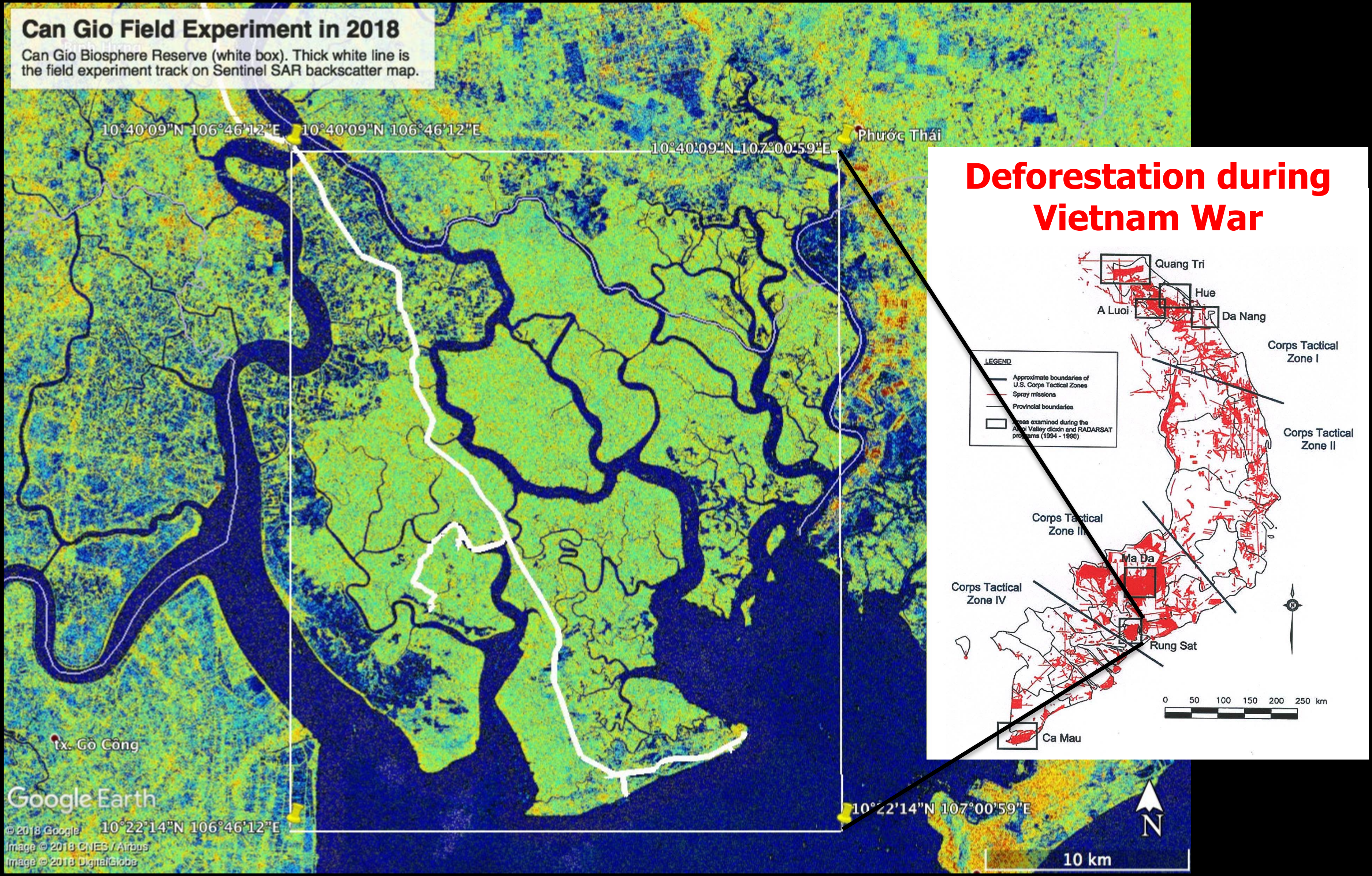
DEFORESTATION OF MOUNTAINSIDES
Toc Tien Mountain – Field validation

DEFORESTATION AND RESTORATION OF MANGROVE FOREST IN CẦN GIỜ WETLAND (A UNESCO BIOSPHERE RESERVE)

- Severe deforestation of Rừng Sát in Cần Giờ, during the Vietnam War, where restoration efforts have been successful.
- However, urbanization has created new pressure on the ecosystem. These changes are observable by Landsat data in 1984-2016.

Wetland Restoration

UNESCO Cần Giờ Biosphere Reserve (Rừng Sác)



Wetland Restoration

UNESCO Cần Giờ Biosphere Reserve (Rừng Sác)

Then | **Now**

Landsat data from the 1970s to 2010s can monitor interdecadal ecosystem change

Completely deforested site with dead tree stumps of Ceriops spp. (Photo by C. P. Weatherspoon).


Google Earth 1984
Cần Giờ
Google Earth
Image Landsat / Copernicus
10 km
N

Google Earth 2016
Biosphere Restoration
Urban Development
Cần Giờ
Google Earth
Image Landsat / Copernicus
10 km
N

TRANSFORMATION OF POOR LAND INTO RICH DRAGON FARMS

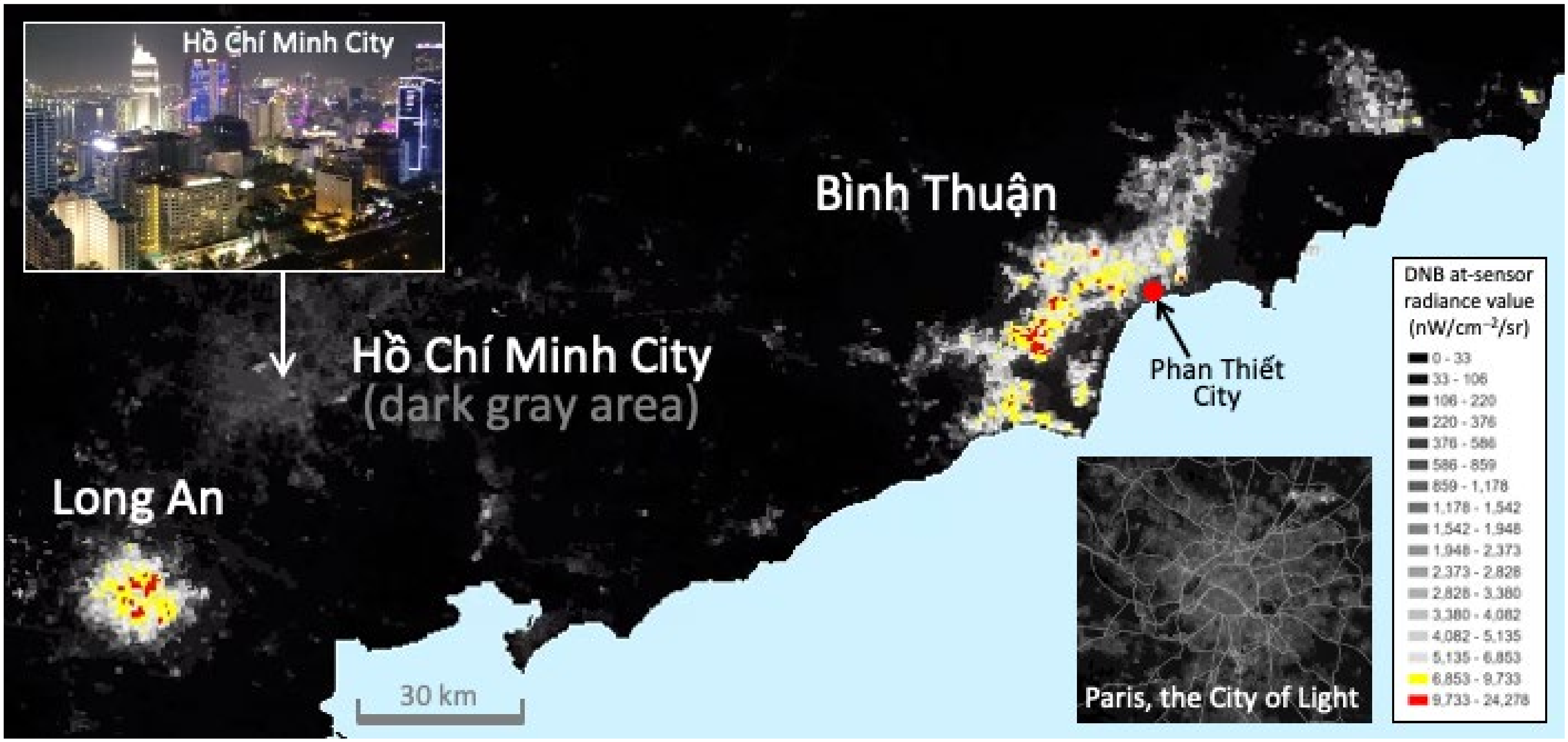
New farming method using nighttime lights has made dragon fruits to be productive leading to extremely extensive conversion of poor land in Bình Thuận (and other places) to rich productive dragon fruit plantations.

However, nighttime lights (NTL) from dragon fruit plantations cause major errors in estimations of fossil fuel CO_2 (FFCO2) because the calculation uses NTL to represent human activities producing CO_2.

This finding has a significant implication on the implementation of UNFCCC Paris Agreement.

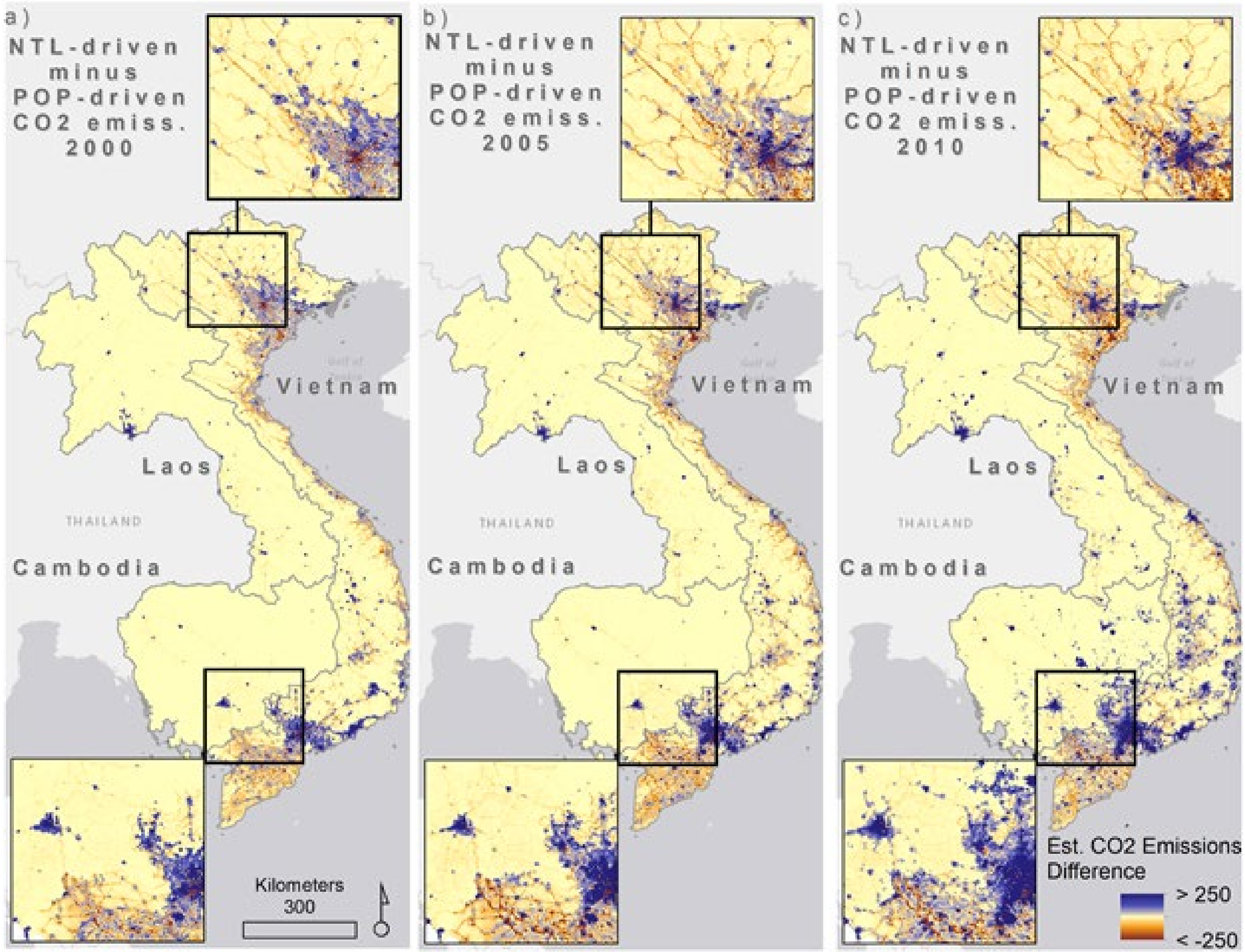
Bình Thuận in Central Vietnam

Dragon Fruit Provinces (Bình Thuận and Long An) are far brighter than Paris, known as the City of Light



Fossil Fuel CO_2 Emission with NT Light

Need to be re-evaluated considering the implication on the implementation of the Paris Agreement under the UNFCCC



Gaughan et al. with Nghiem, Evaluating nighttime lights and population distribution as proxies for disaggregating anthropogenic CO_2 emission in Vietnam, Cambodia and Laos, Environ. Res., Comm., 2019.

SEASONAL TRANSFORMATION BY THE TONLE SAP - MEKONG SYSTEM

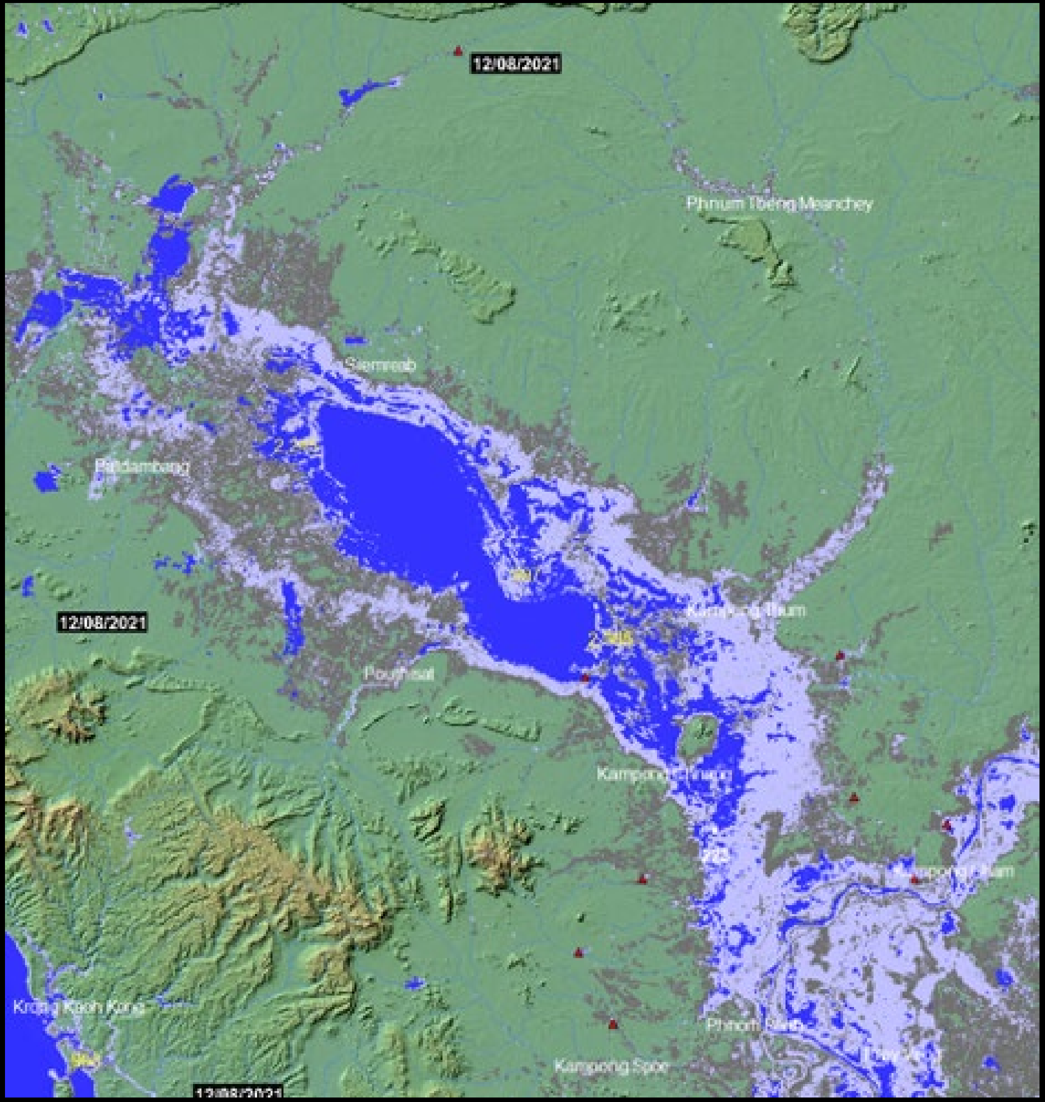
Tonle Sap lake can change its surface area by as much as a factor four between wet and dry seasons.

Tonle Sap Lake is connected to the Mekong River by the Tonle Sap River, the only river that can flow both ways.

The Tonle Sap - Mekong system can be profoundly altered by urbanization, deforestation, and climate change effects.

Using multi-source satellite multispectral and microwave data to observe and quantify the system change.

Water on Land - Tonle Sap Lake Seasonal Transformation



Tonle SAP Surface Water on 8 Dec 2021

MODIS and all other sensors, since 1993

- **Top Layer (Blue): All current surface water mapped by MODIS at 250 m resolution (updated daily)**
- **Middle layer (Light Blue Gray): Mean Annual Flood using MODIS time series data**
- **Bottom Layer (Dark Gray): Maximum Observed Flooding**

Satellite Measurement of River

Two examples on Mekong River

Mekong River Stage by NASA Satellite SMAP

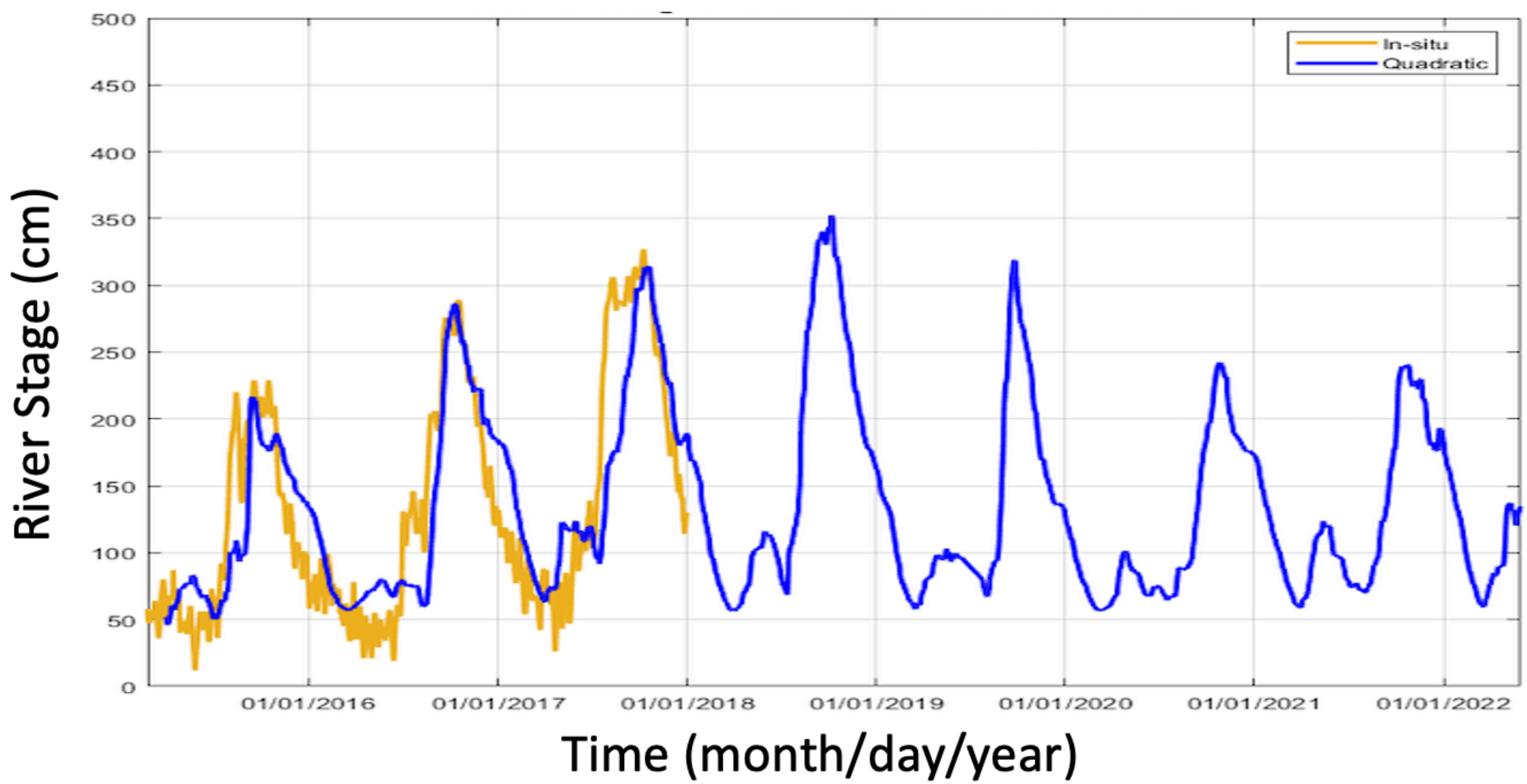
SMAP Measurement of River Stage of Mekong River

Compared to in-situ data at Tân Châu (Tiền Giang) in Vietnam

Mekong River Stage by NASA Satellite SMAP

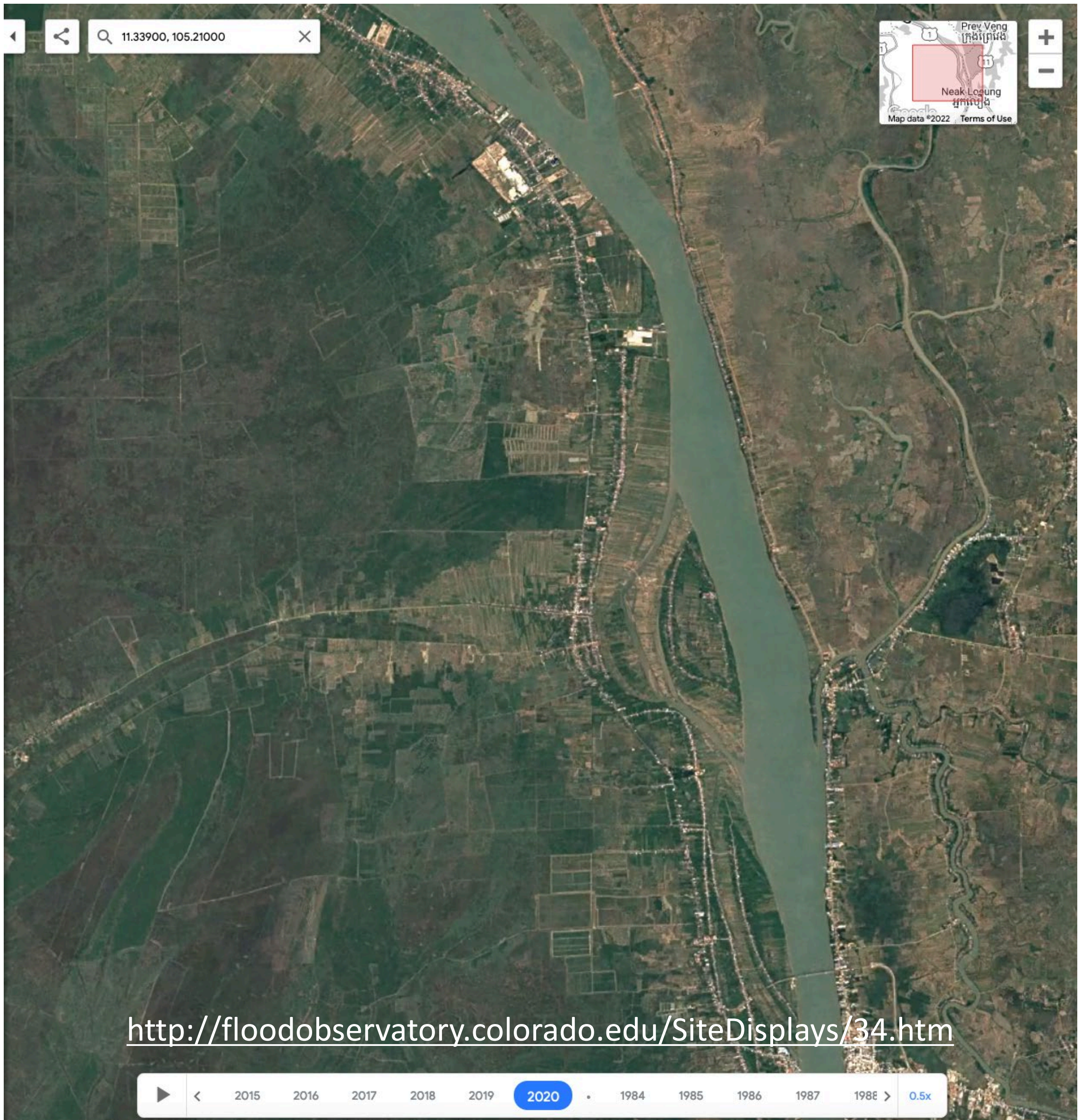
SMAP Measurement of River Stage of Mekong River

Compared to in-situ data at Tân Châu (Tiền Giang) in Vietnam



Mekong River Discharge

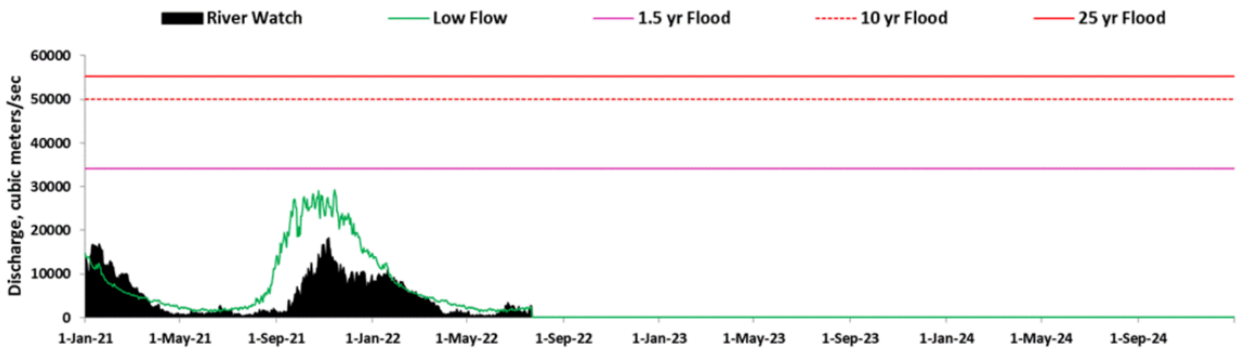
Mekong River in Cambodia (Site ID 34)



http://floodobservatory.colorado.edu/SiteDisplays/34.htm

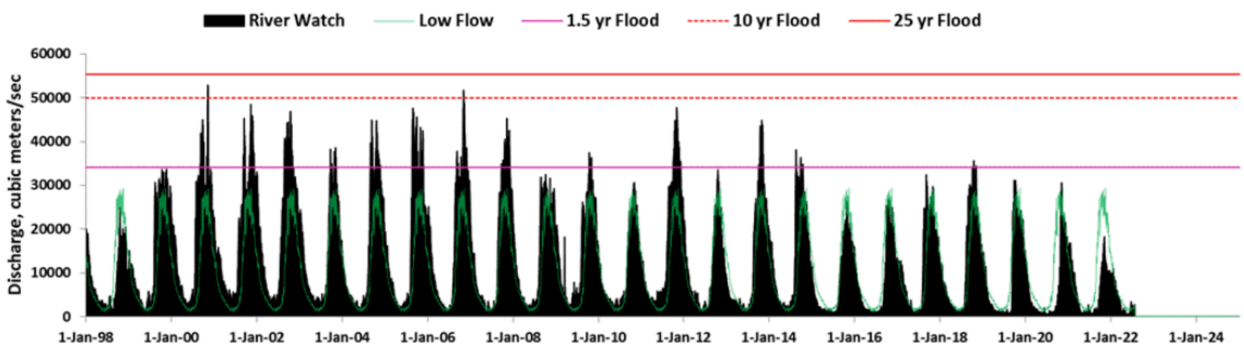
Mekong River Discharge

Mekong River in Cambodia (Site ID 34)

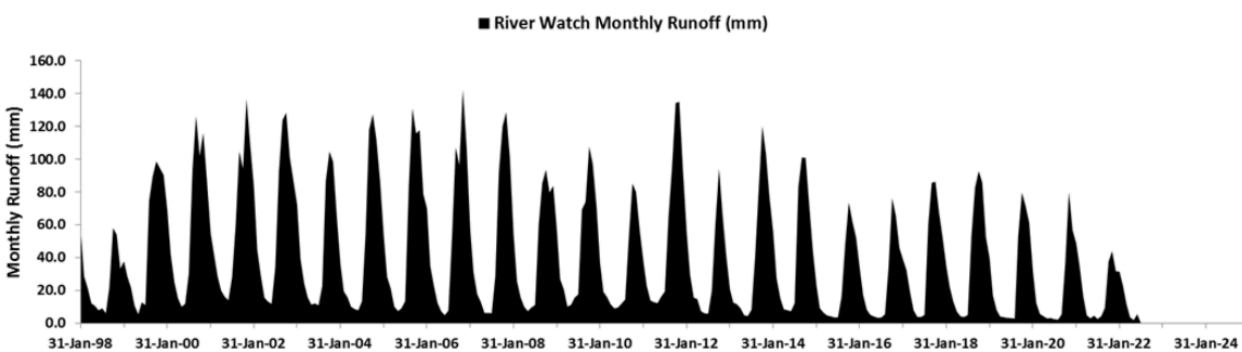


Notes: 7-day forward weighted moving average is applied. Low flow is 20th percentile discharge for this day, 2003-2013.

Geolocation correction, commencing April 1, 2012: **0**



Notes: Log Pearson Type III is used to compute recurrence intervals from 22 years of record (1998-2019)

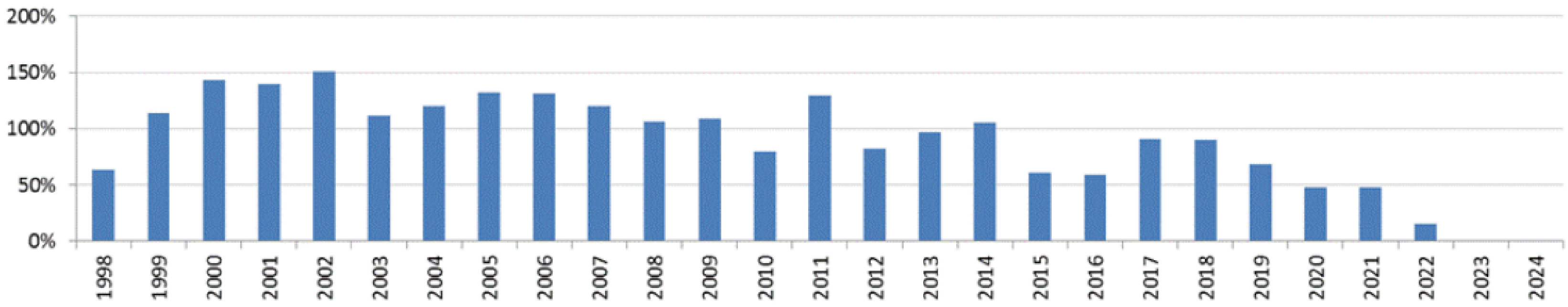


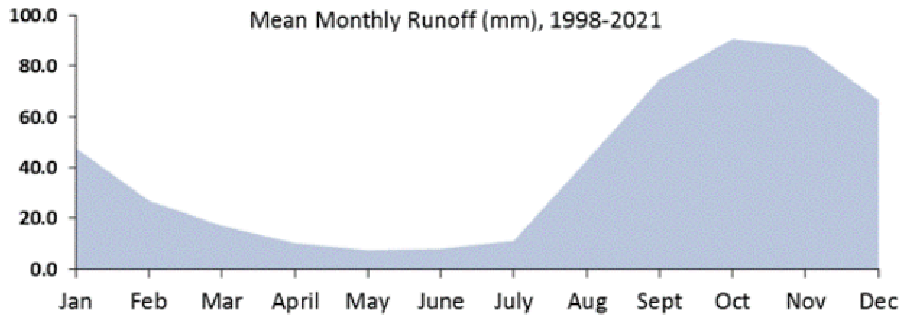
Mekong River Discharge

Mekong River in Cambodia (Site ID 34)

Mean discharge	**12216**	m3/s
Mean Runoff	**507**	mm

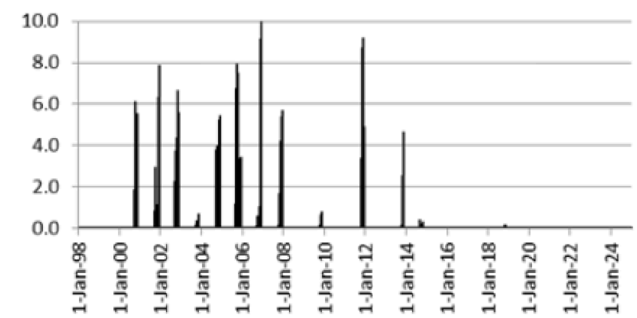
Annual Runoff (percent of mean, 1998-2021)





Major Floods

10 = Flood of Record



Access to Data

Sample Citation: Brakenridge, G. R., Kettner, A. J., Paris, S., Cohen, S., Nghiem, S. V. , River and Reservoir Watch Version 4.5, DFO Flood Observatory, University of Colorado, USA. http://floodobservatory.colorado.edu/ SiteDisplays/ 20.htm (Accessed 20 February 2023).

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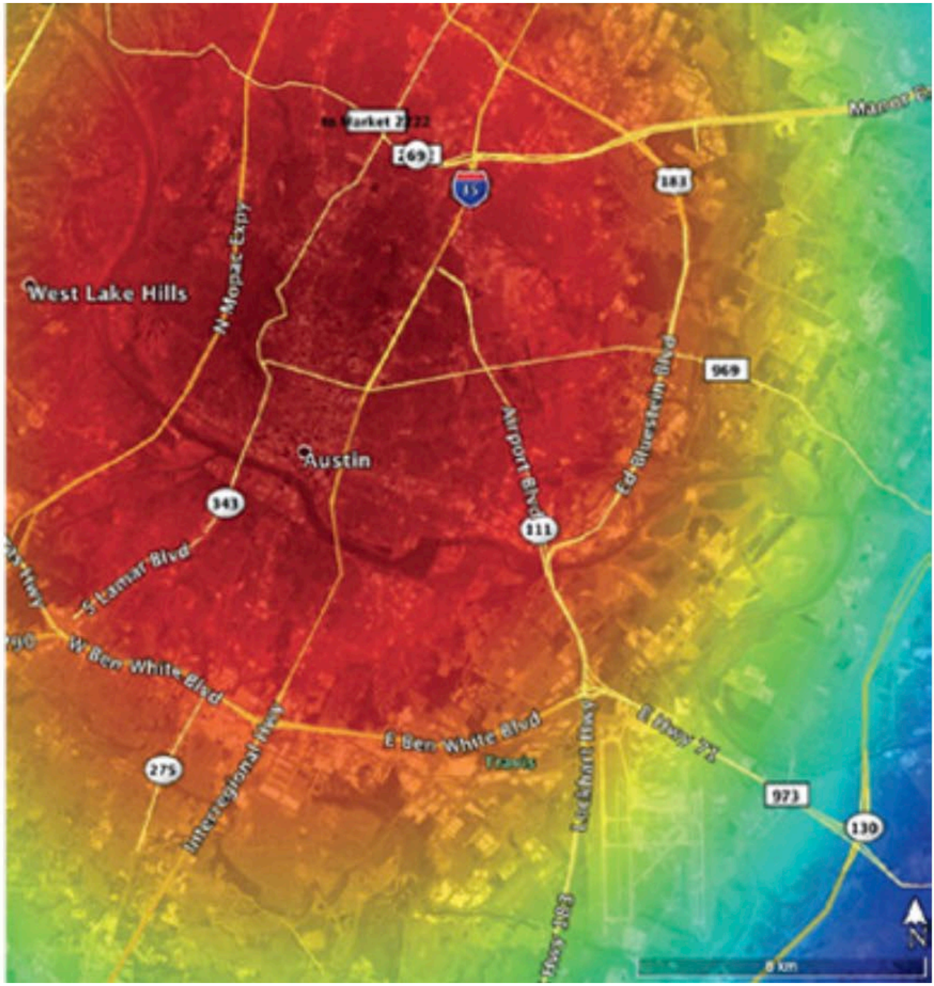
BACK-UP SLIDES

From Nebula down to Earth
Archetype Concept

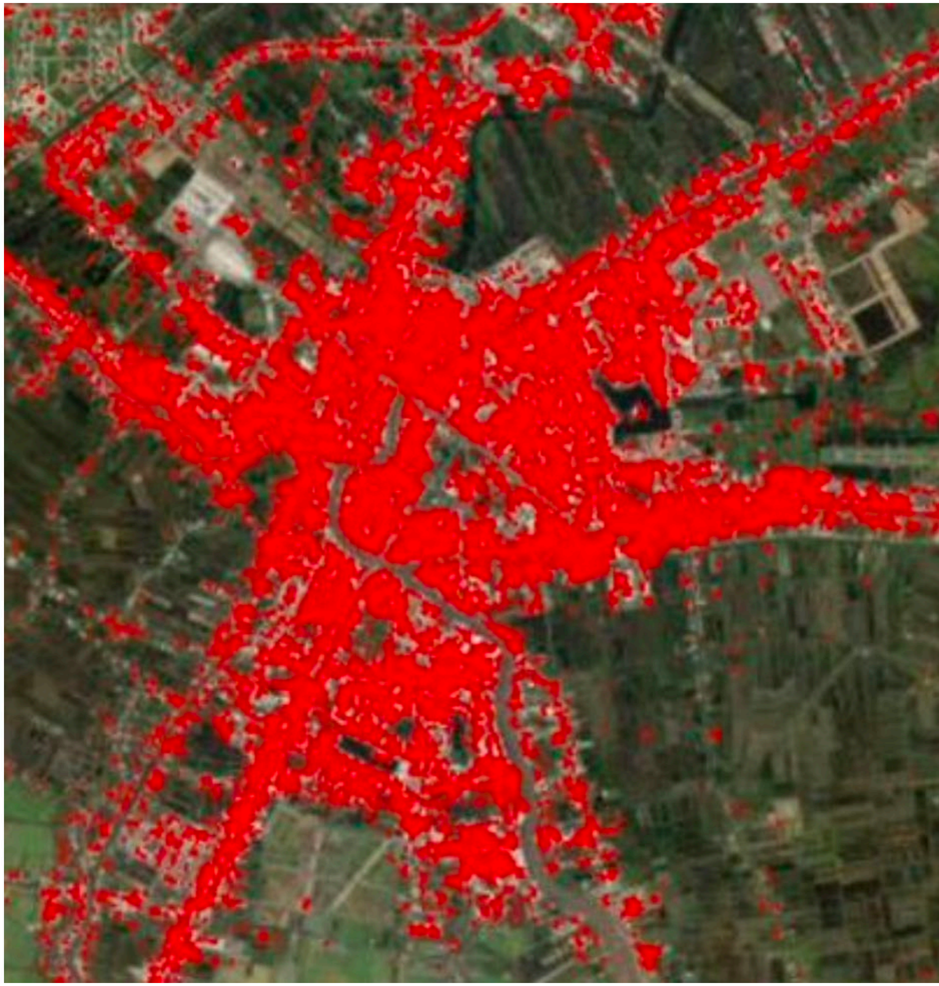
Nebula NGC 6720
Ring Archetype



Austin, Texas, USA
Ring Archetype

From Nebula down to Earth Archetype Concept

Nebula NGC 2070
Tarantula Archetype



Ca Mau, Vietnam
Tarantula Archetype