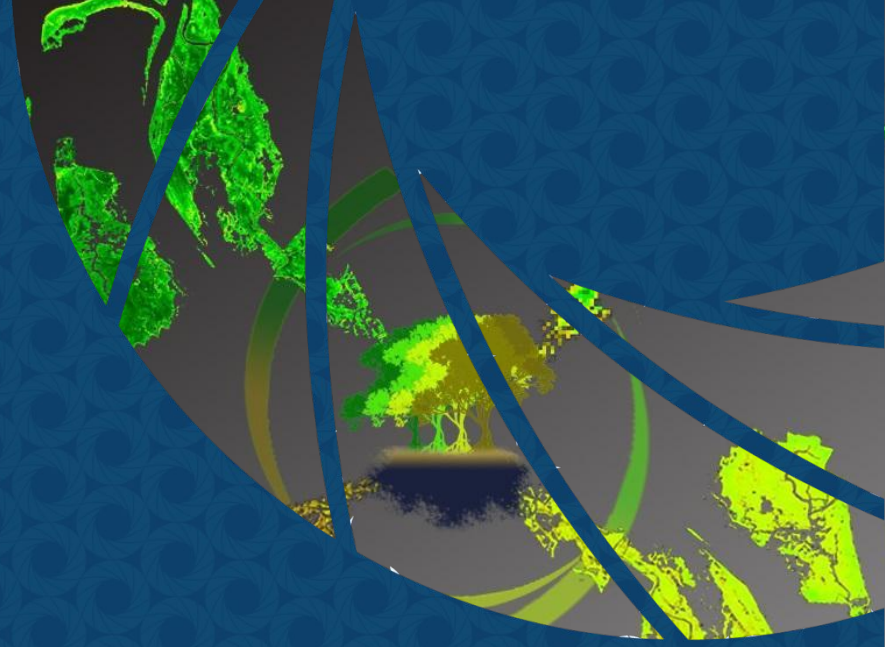


National Aeronautics and Space Administration

EASTERN INDIA ECOLOGICAL FORECASTING

A Multi-Sensor Approach to Enhance the Prediction of Mangrove Biophysical Characteristics in Bhitarkanika Wildlife Sanctuary and Chilika Lagoon, Odisha, India

Abhishek Kumar (Project Lead)

Roger Bledsoe

Caren Remillard

María José Rivera

Jessica Staley

Patricia Stupp

Study Area

Bhitarkanika

Latitude: 20.71°N

Longitude: 86.86°E

Mangrove Types: Dense, Closed & Open

Total Mangrove Species: 55

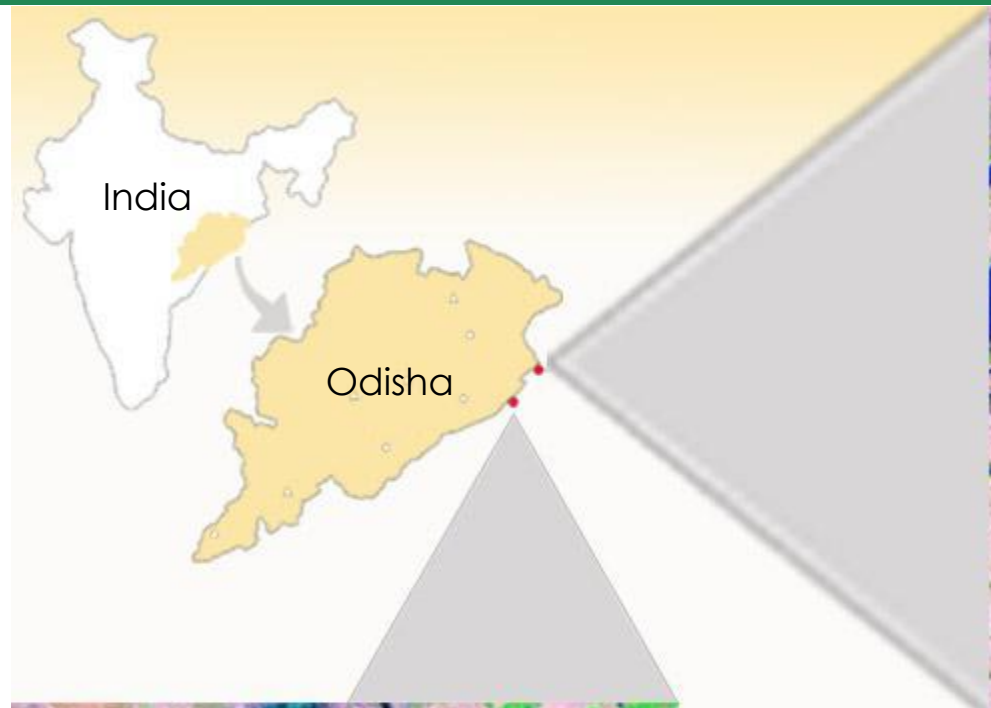
Mangrove Area: 145 km^2

Chilika

Latitude: 19.84° N

Longitude: 85.47° E

Mangrove Types: Open, Small patches



0 kilometers 15

Red polygon outlines mangrove area

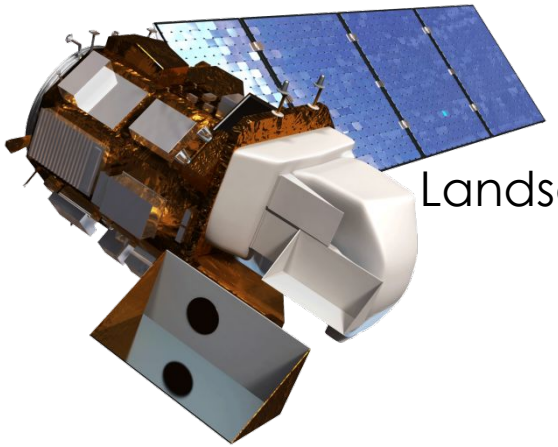
Source: Eastern India Ecological Forecasting

Community Concerns

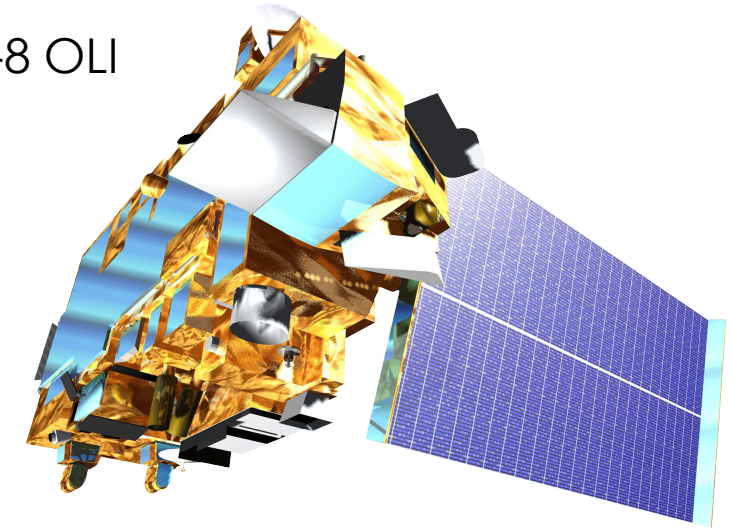
- Residents from **36 villages** receive valuable resources and services from the mangroves.
- Mangroves have been **overexploited** or **converted** to various other forms of land use.
- **Encroachment** upon forests, **unauthorized aquaculture practices**, and **discharge of effluent** place even more pressure on mangrove forests and biodiversity.

Source: Wildlife Institute of India (2003)

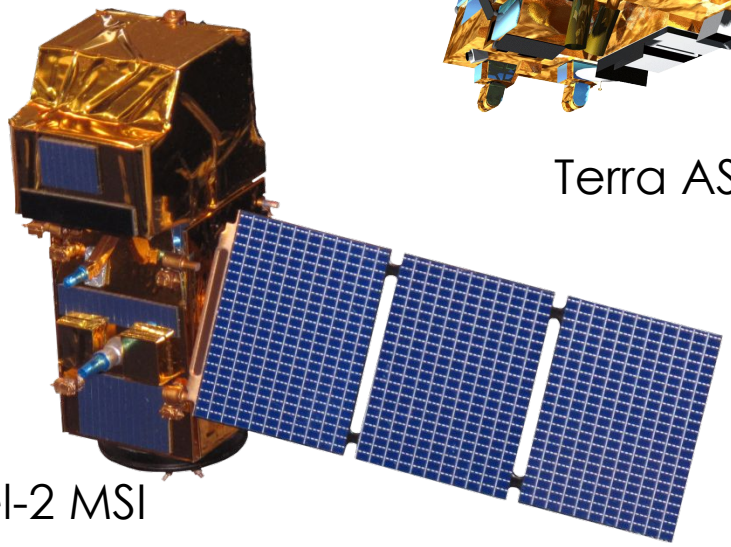
Objectives



Landsat-8 OLI



Terra ASTER and MODIS



Sentinel-2 MSI

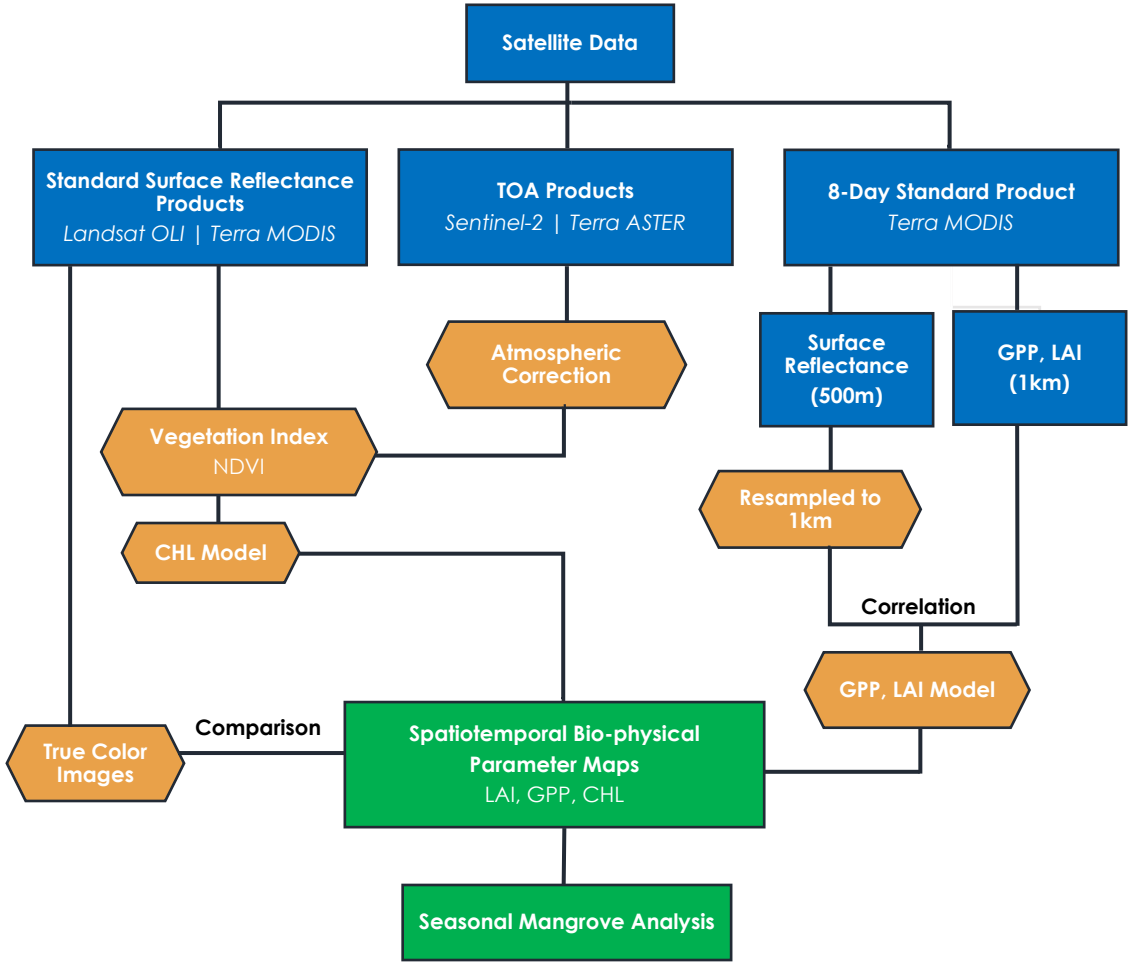
Source: NASA

4 **Develop a multi-sensor mangrove biophysical characteristics prediction tool** for Bhitarkanika Wildlife Sanctuary and Chilika Lagoon using moderate resolution remote sensing reflectance data.

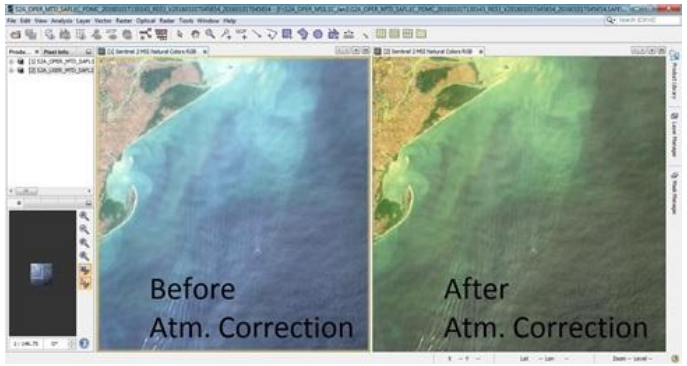
4 Derive a phenology in order to **enhance management and restoration efforts** by the Department of Forest and Environment in Odisha, India.

Methodology

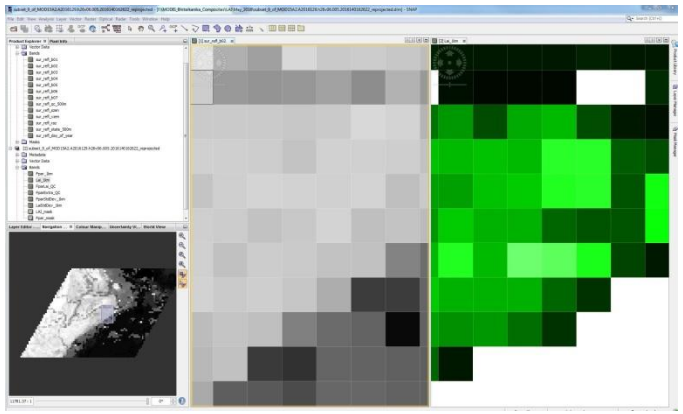
Workflow Diagram



Atmospheric Correction



Re-sampling Pixels at 1km

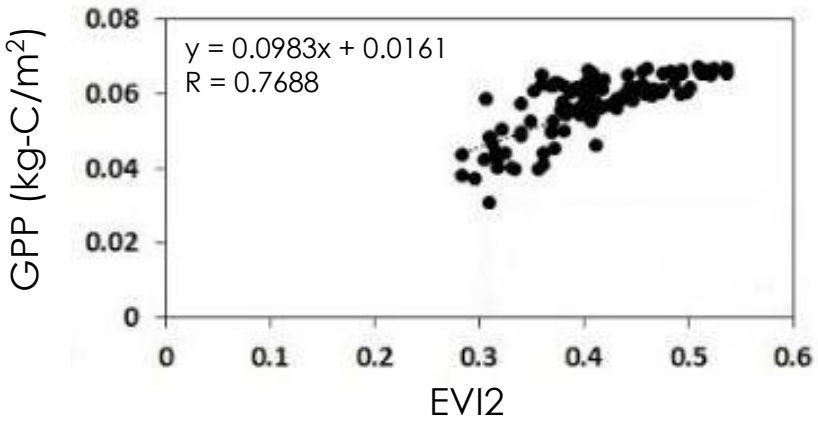


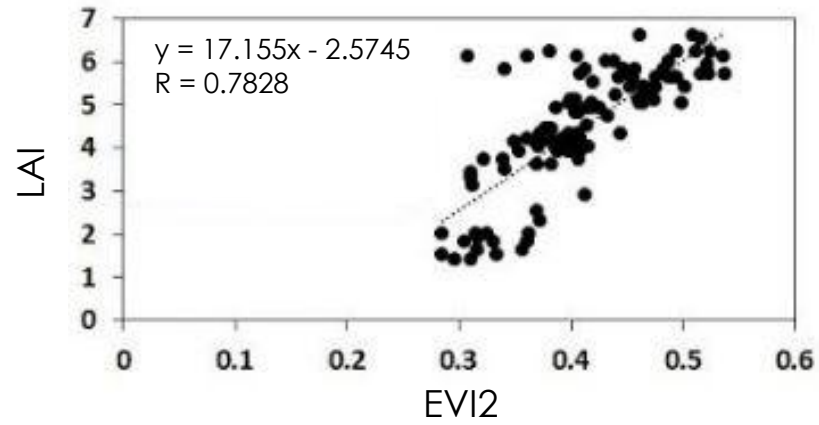
Source: Eastern India Ecological Forecasting

Results

Calibration Results

Bands & Indices	Abbreviation	Formula	LAI Correlation Coefficient (R)	LAI Correlation Equation	GPP Correlation Coefficient (R)	GPP Correlation Equation
Blue	B3	R_{rs}(B3)	0.64	y= -.93.098x + 6.7841	0.64	y = -0.5418x + 0.0699
Red	B1	R_{rs}(B1)	0.69	y= -55.106x + 6.8859	0.71	y = -0.3287x + 0.0709
Green	B4	R_{rs}(B4)	0.53	y= -54.753x + 7.5682	0.59	y = -0.3543x + 0.0765
Near-InfraRed	B2	R_{rs}(B2)	0.49	y= 24.498x – 2.102	0.45	y = 0.1315x + 0.0212
Shortwave Infrared-1	B5	R_{rs}(B5)	0.1	y= -3.9268x + 5.5421	0.095	y = -0.0218x + 0.0624
Shortwave Infrared-2	B6	R_{rs}(B6)	0.54	y= -18.622x + 7.2501	0.56	y = -0.1126x + 0.0733
Normalized Difference Vegetation Index	NDVI	[R_{rs}(NIR)- R_{rs}(B1)]/ [R_{rs}(NIR)+R_{rs}(B1)]	0.69	y= 9.5734x – 2.392	0.73	y = 0.0599x + 0.0135
Enhanced Vegetation Index 1	EVI1	2.5*[(R_{rs}(NIR)- R_{rs}(B1)]]/ (1+R_{rs}(NIR)+6*R_{rs}(B1)-7.5* R_{rs}(B3)]	0.78	y= 17.009x – 2.6598	0.77	y = 0.098x + 0.0153
Enhanced Vegetation Index 2	EVI2	2.5*[(R_{rs}(NIR)- R_{rs}(B1)]]/ (1+R_{rs}(NIR)+2.4*R_{rs}(B1)]	0.78	y= 17.155x - 2.5745	0.77	y = 0.0983x + 0.0161
Normalized Difference Vegetation Index (Green)	NDVI(G)	[R_{rs}(NIR)- R_{rs}(B4)]/ [R_{rs}(NIR)+R_{rs}(B4)]	0.63	y= 12.398x - 3.6427	0.68	y = 0.078x + 0.0054
Simple Ratio	SR	[R_{rs}(NIR)/R_{rs}(B1)]	0.65	y= = 0.3428x + 2.0964	0.67	y = 0.0021x + 0.0421
Normalized Difference Moisture Index	NDMI	[R_{rs}(NIR)- R_{rs}(B6)]/ [R_{rs}(NIR)+R_{rs}(B6)]	0.65	y= 7.4622x + 2.3086	0.69	y = 0.046x + 0.0431



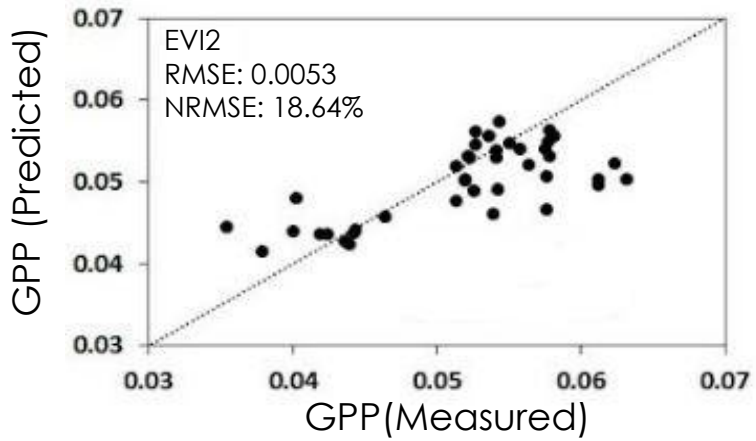


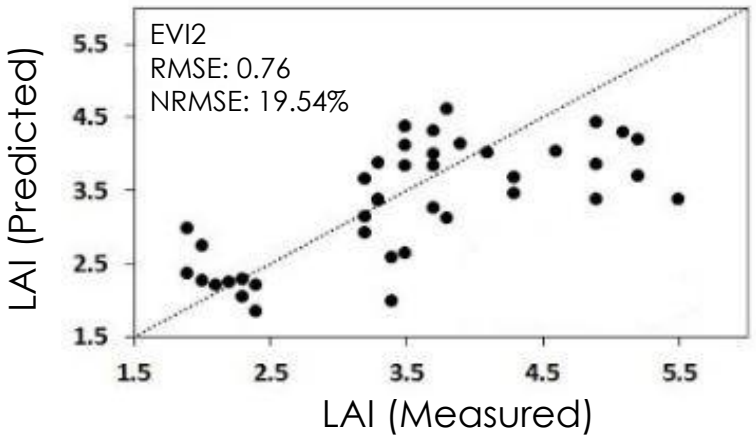
Source: Eastern India Ecological Forecasting

Results

Validation and Error Estimation

Bands & Indices	LAI: Root Mean Square Error (RMSE)	LAI: Percentage Normalized Root Mean Square Error (%NRMSE)	GPP: Root Mean Square Error (RMSE)	GPP: Percentage Normalized Root Mean Square Error (%NRMSE)
Blue	1.15	31.89	0.0066	23.63
Red	1.08	30.19	0.0063	22.76
Green	1.33	37.01	0.0076	27.47
Near-InfraRed	0.82	22.88	0.0059	21.26
Shortwave Infrared-1	1.47	40.91	0.0087	31.28
Shortwave Infrared-2	1.42	39.49	0.0082	29.51
Normalized Difference Vegetation Index	1.29	33.32	0.0073	25.64
Enhanced Vegetation Index 1	0.77	19.86	0.0055	19.26
Enhanced Vegetation Index 2	0.76	19.54	0.0053	18.64
Normalized Difference Vegetation Index (Green)	1.28	32.93	0.0072	25.41
Simple Ratio	1.46	37.46	0.011	37.44
Normalized Difference Moisture Index	1.18	30.32	0.0069	24.19

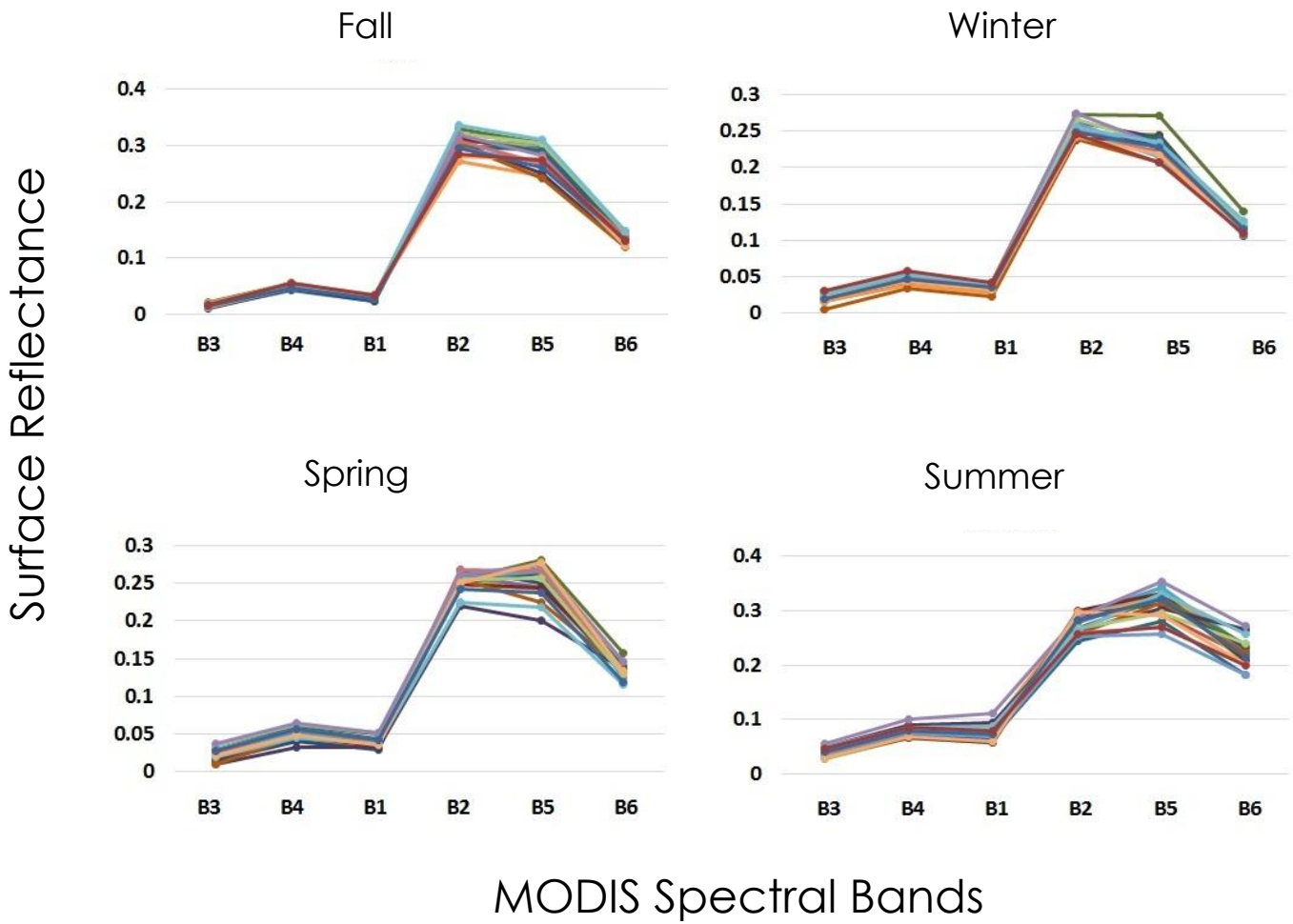




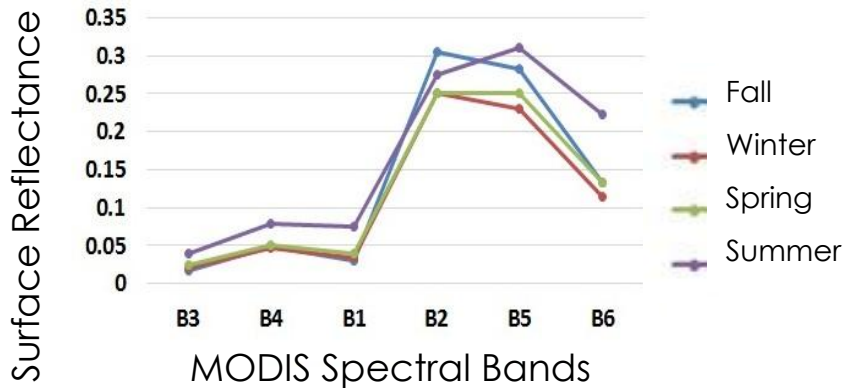
Source: Eastern India Ecological Forecasting

Results

Seasonal Spectral Variability



Mean Spectra



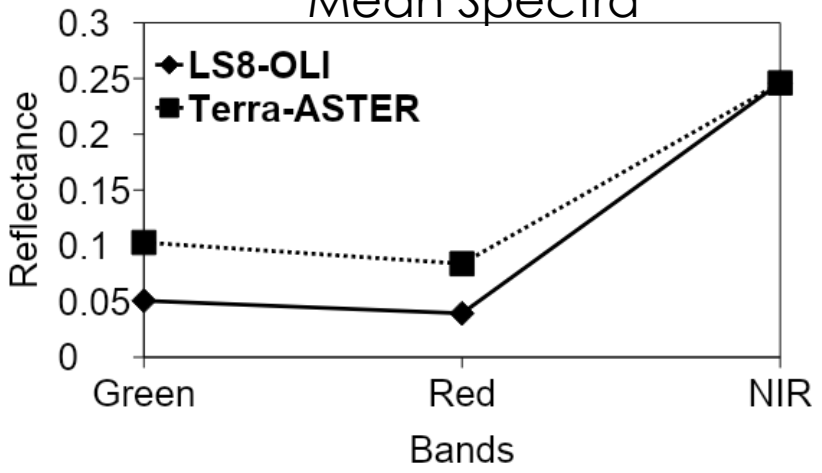
MODIS Bands	Center Wavelength and Bandwidth (nm)
Blue (B3)	469 (459 – 479)
Green (B4)	555 (545 – 565)
Red (B1)	645 (620 – 670)
Near-Infrared (B2)	859 (841 – 876)
Shortwave Infrared-1 (B5)	1240 (1230 – 1250)
Shortwave Infrared-2 (B6)	1635 (1628 – 1652)

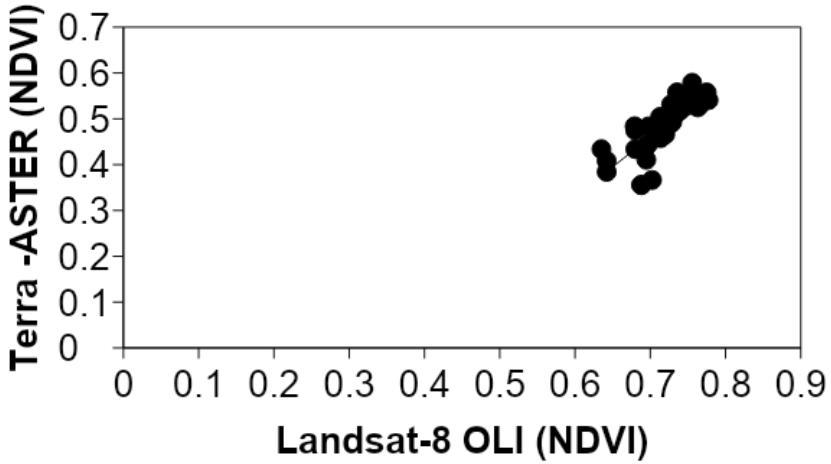
Source: Eastern India Ecological Forecasting

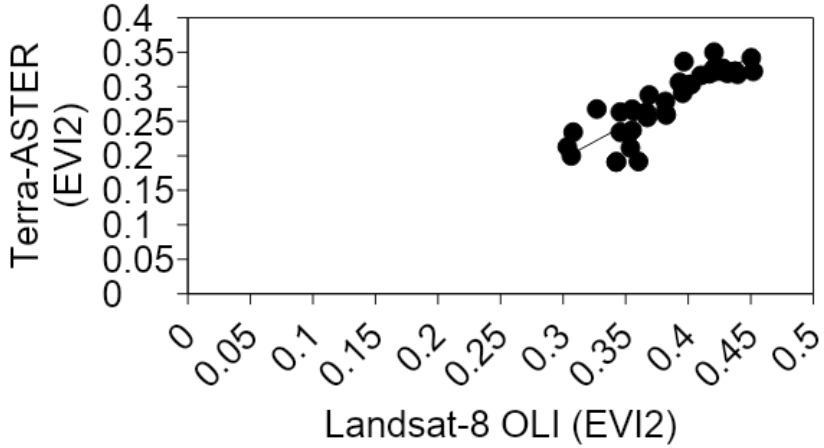
Results

ASTER Cross-Calibration

Mean Spectra

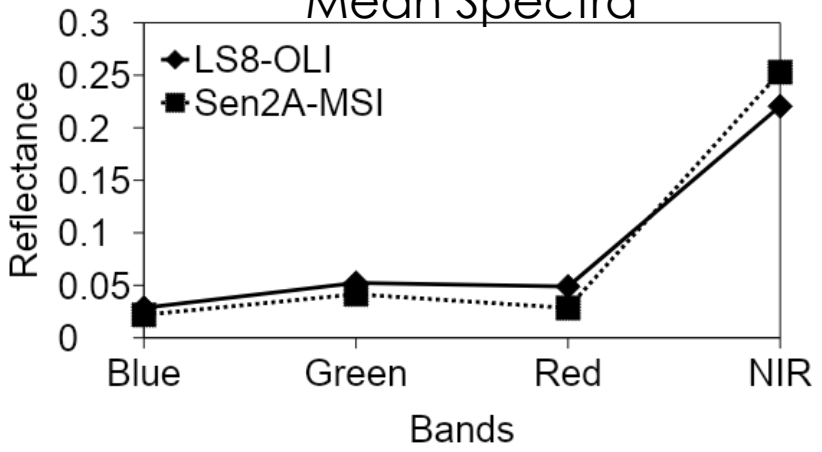


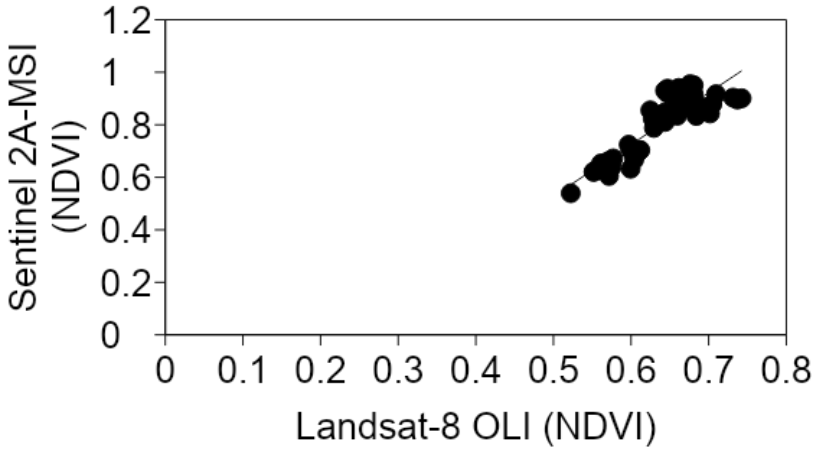


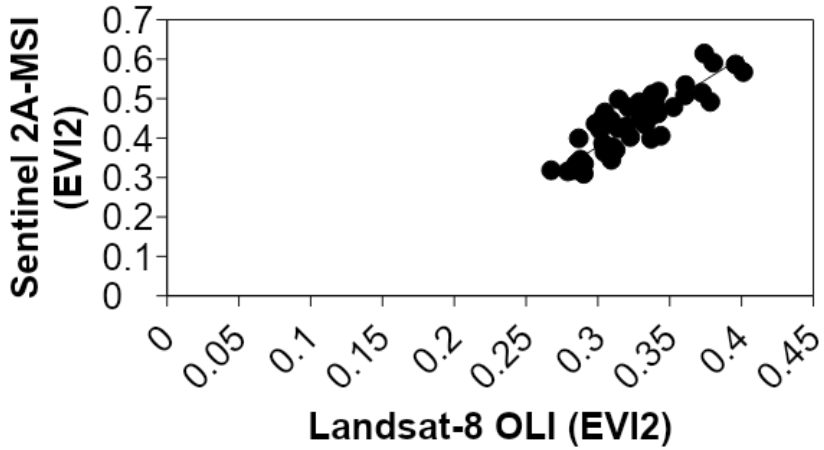


Sentinel-2 Cross-Calibration

Mean Spectra



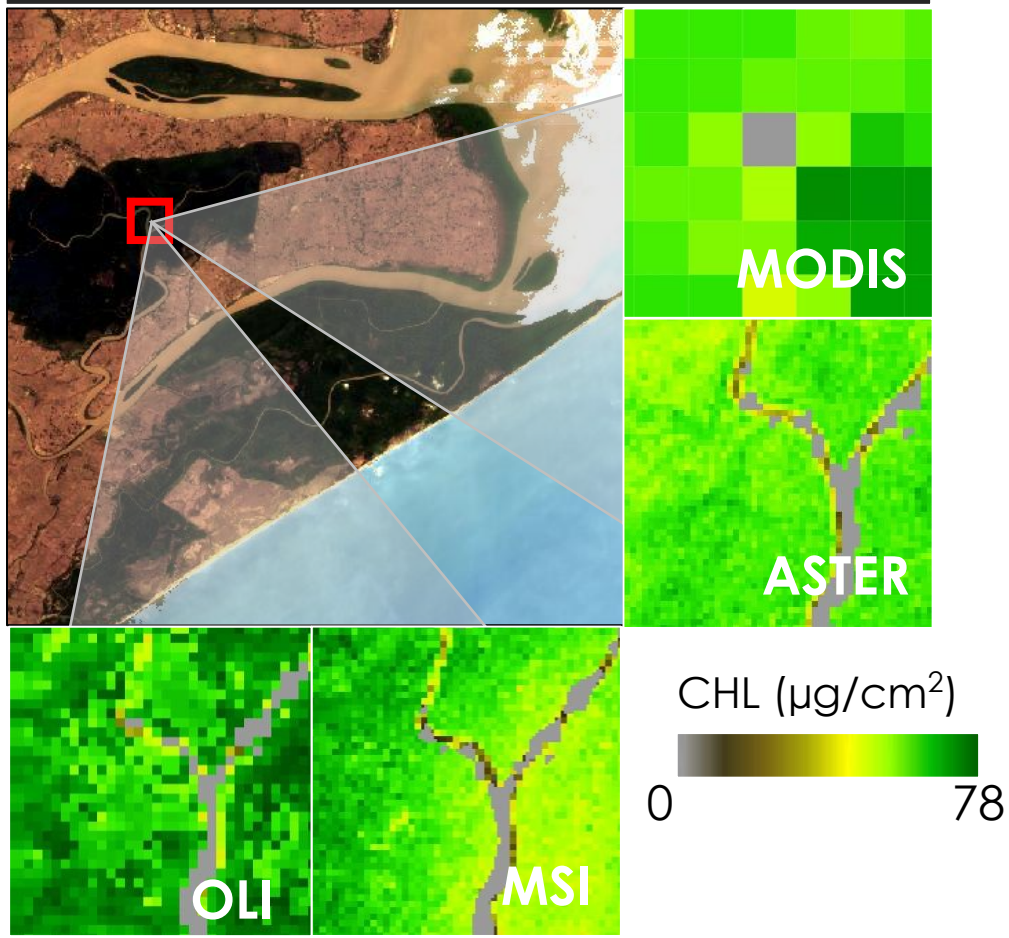




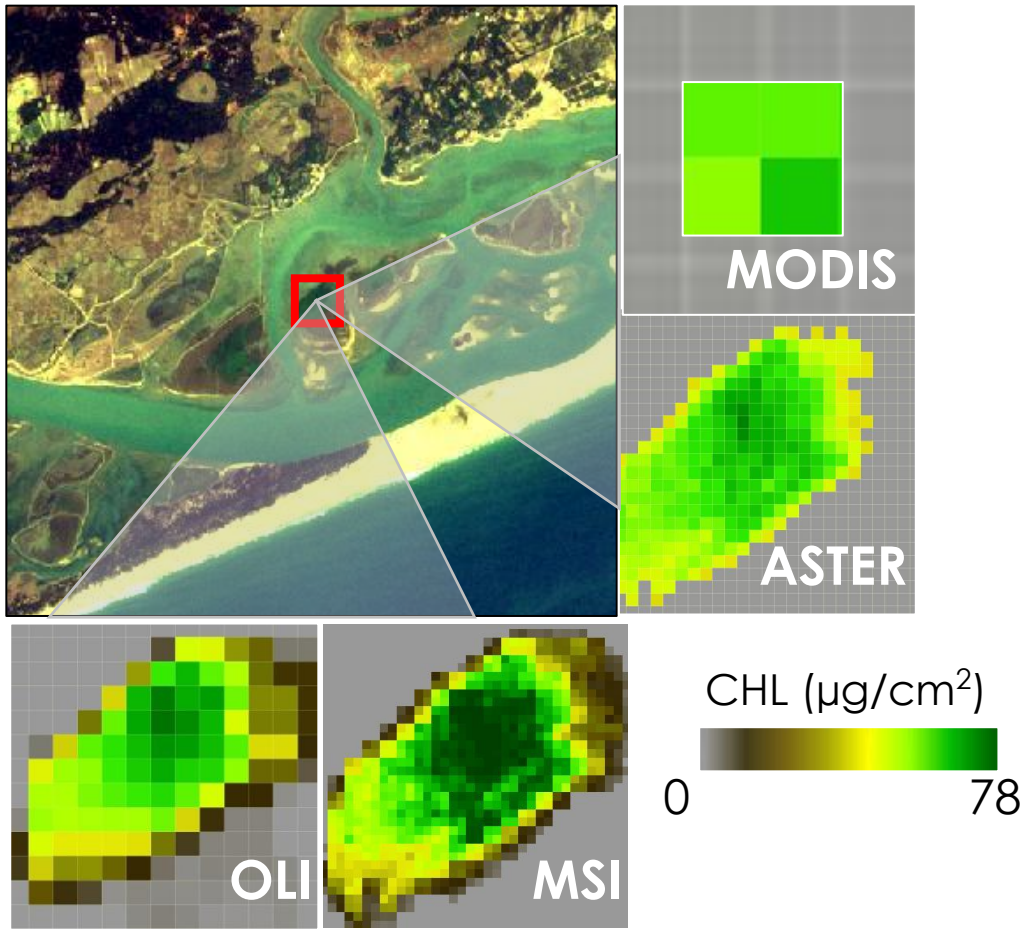
Source: Eastern India Ecological Forecasting

Results

Bhitarkanika



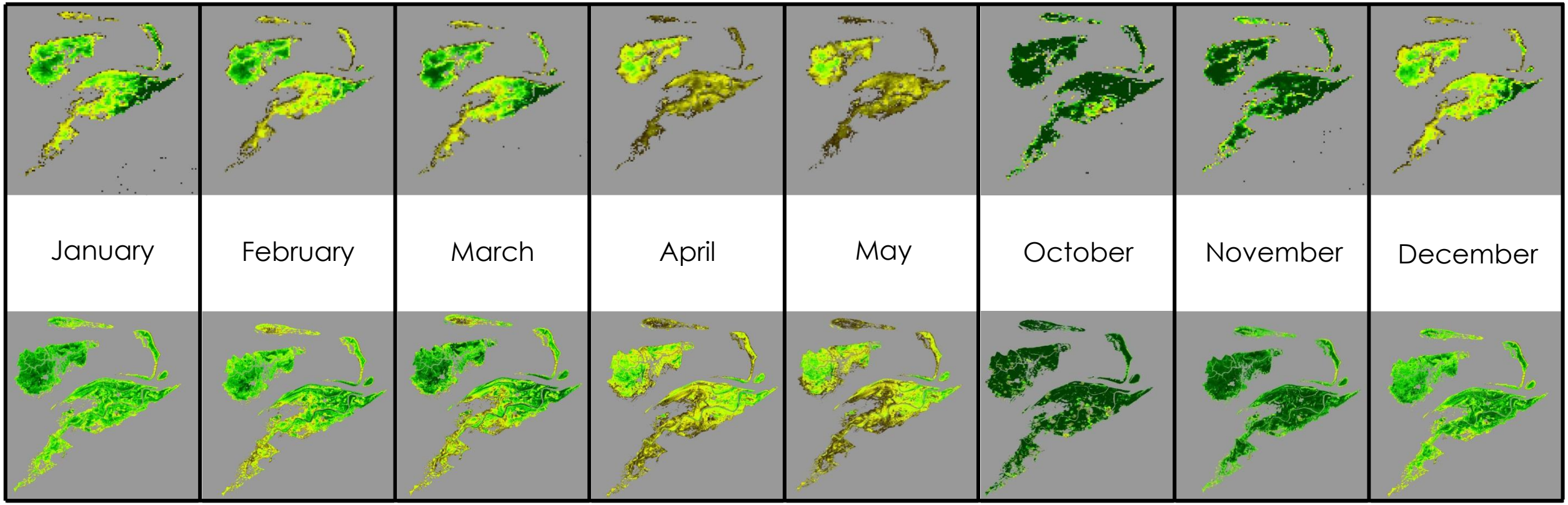
Chilika



Source: Eastern India Ecological Forecasting

Results

CHL: Terra MODIS Composites (2013 – 2016)



CHL: Landsat 8 OLI Composites (2013 – 2016)

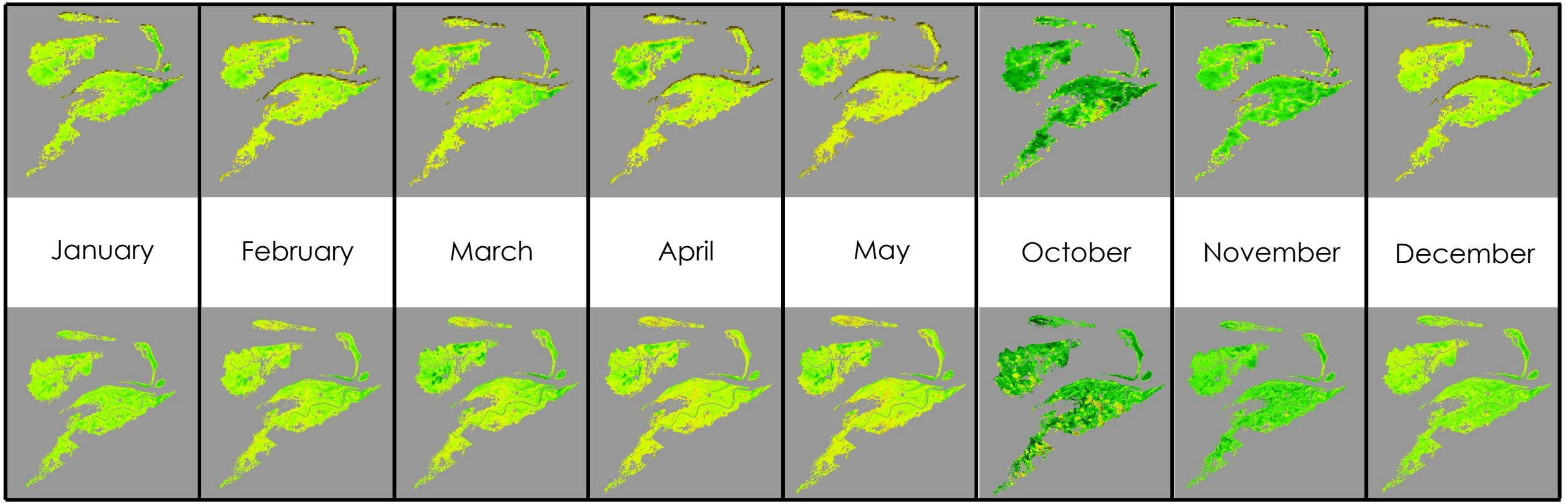
CHL (µg/cm^2)

0 78

Source: Eastern India Ecological Forecasting

Results

GPP: Terra MODIS



GPP: Landsat 8 OLI

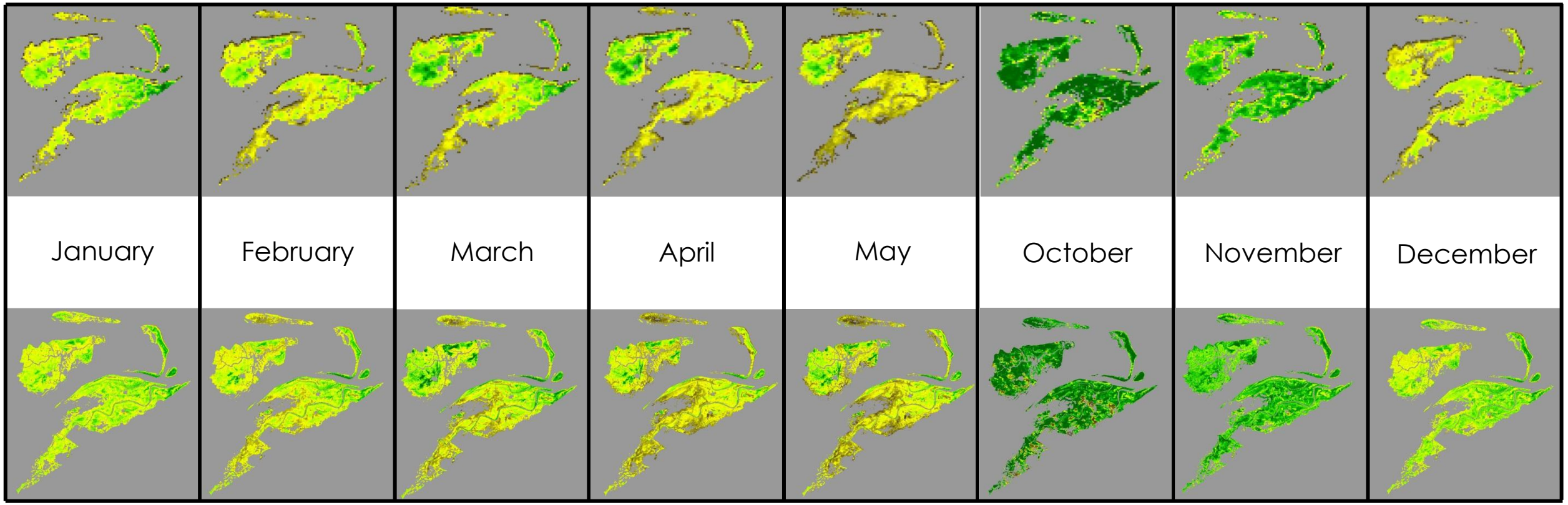
GPP (g-C/m^2)

0 56

Source: Eastern India Ecological Forecasting

Results

LAI: Terra MODIS



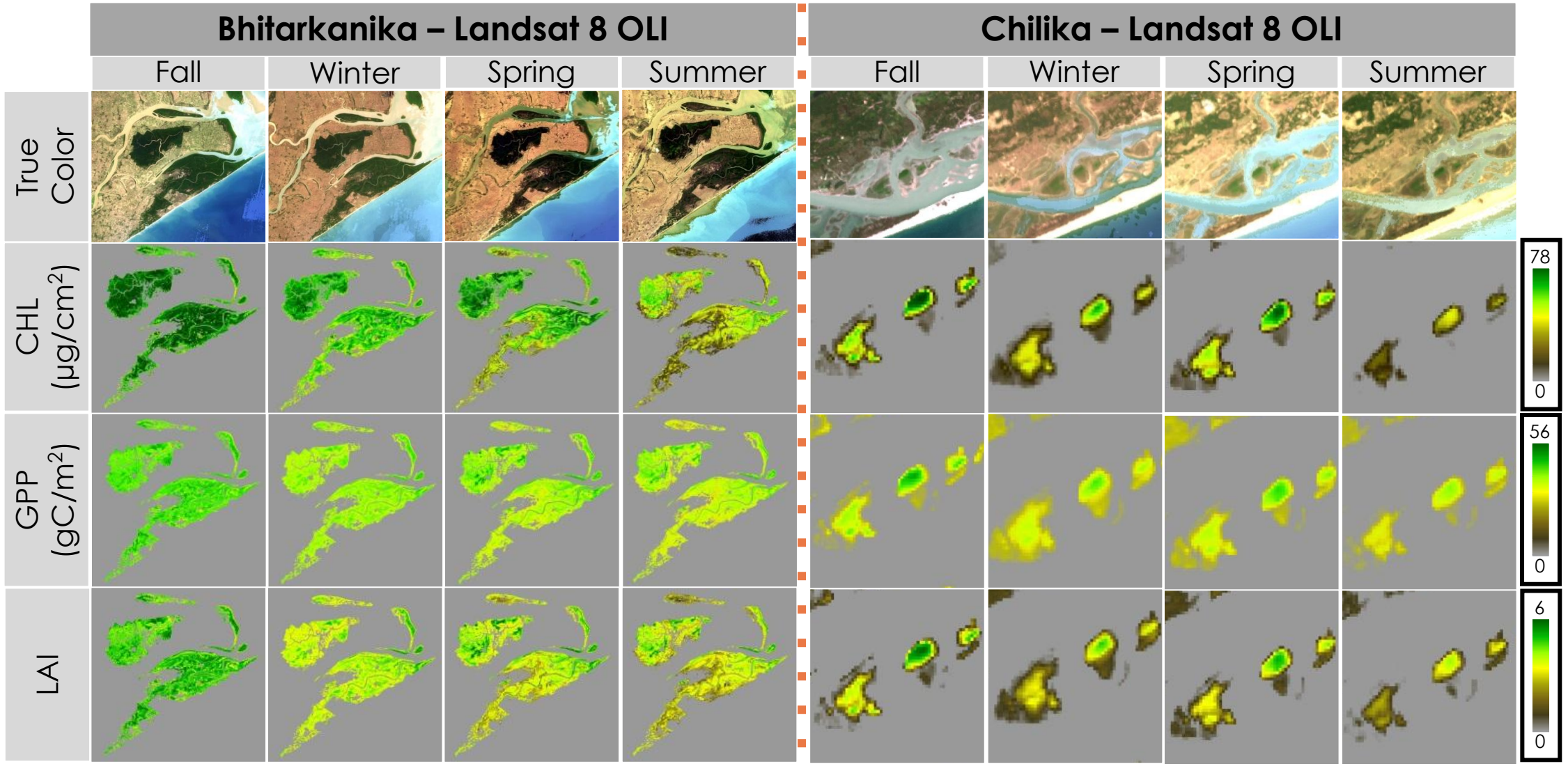
LAI: Landsat 8 OLI

LAI

0 6

Source: Eastern India Ecological Forecasting

Results

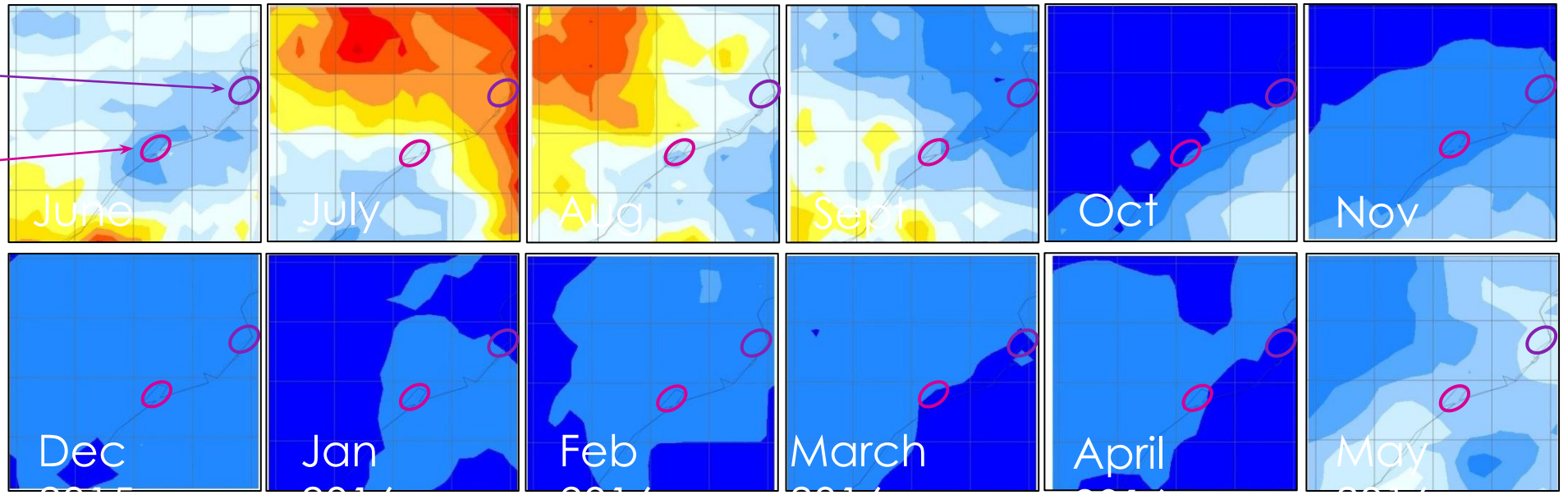


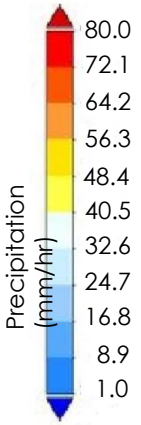
Source: Eastern India Ecological Forecasting

Results

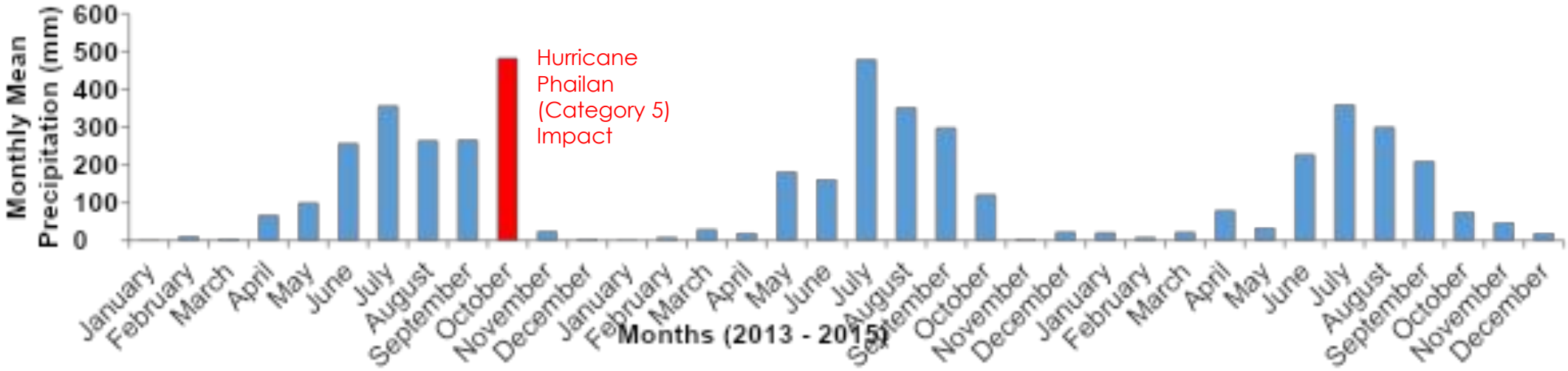
Bhitarkanika

Chilika





Precipitation Results



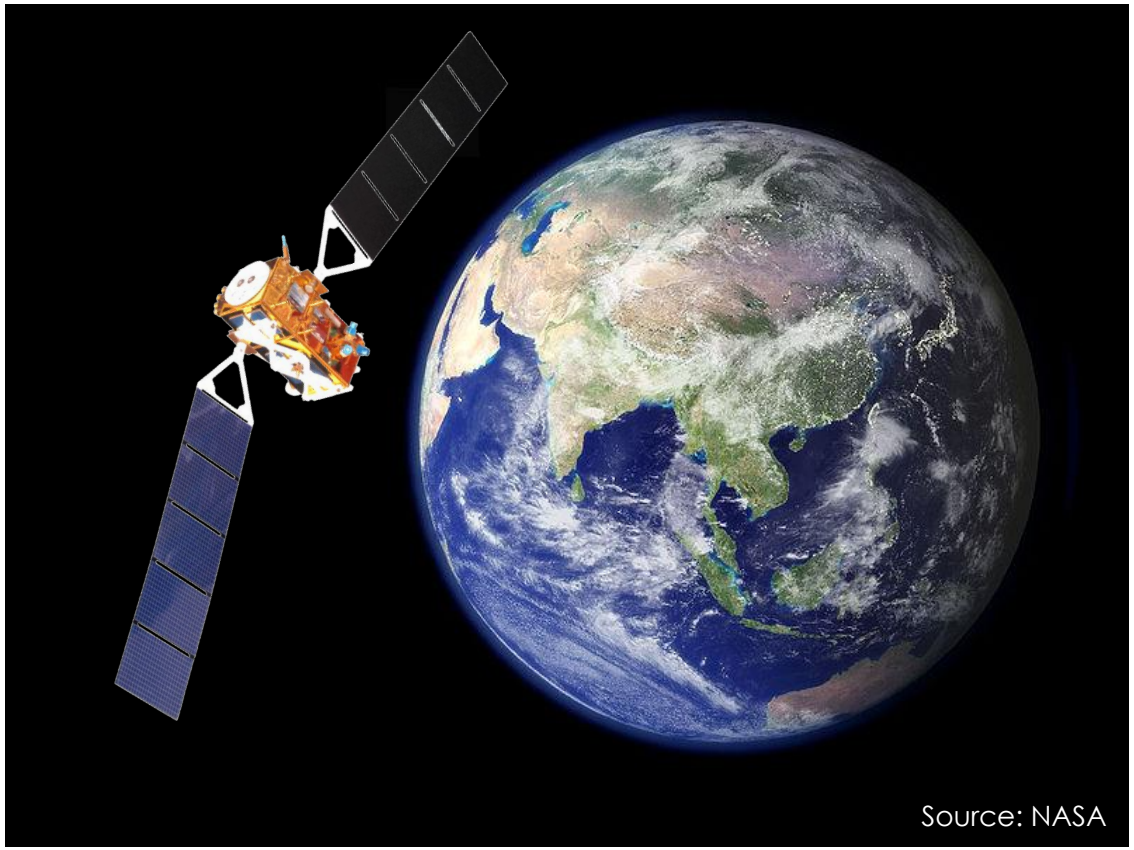
Source: NASA Giovanni

Conclusion

- The methodology developed in this study can be used to **predict mangrove biophysical parameters**.
- All biophysical parameters followed **a similar seasonal pattern**.
- **Cross-calibration** was required for Top of Atmosphere (TOA) Products because they differ in **atmospheric correction technique**.
- The **accuracy** of biophysical models can be further improved by incorporating **field data**.

Future Work

- Incorporate **field data**.
- Improve the **cross-calibration** of satellite sensors.
- Utilize **radar data** to overcome cloudy satellite images.
- Analyze the **factors** affecting mangrove health and seasonality.
- **Classify** different types of mangrove in the study area using **hyperspectral data**.
- Estimate **long-term change** in mangrove **land area coverage**.



Source: NASA

Acknowledgements

Science Advisor

Dr. Deepak Mishra, University of Georgia Department of Geography

Project Partner

Dr. Gurdeep Rastogi, Senior Scientist, Wetland Research and Training Center

Others

Sean Cameron, Assistant Center Lead and Project Coordination Fellow
Dr. Marguerite Madden, UGA Lead Science Advisor

This material is based upon work supported by NASA through contract NNL11AA00B and cooperative agreement NNX14AB60A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration