

# Filling the Gap of Missing Pixels in the Satellite Images Using the DINEOF Method

Xiaoming Liu and Menghua Wang

NOAA Center for Satellite Applications and Research (STAR)

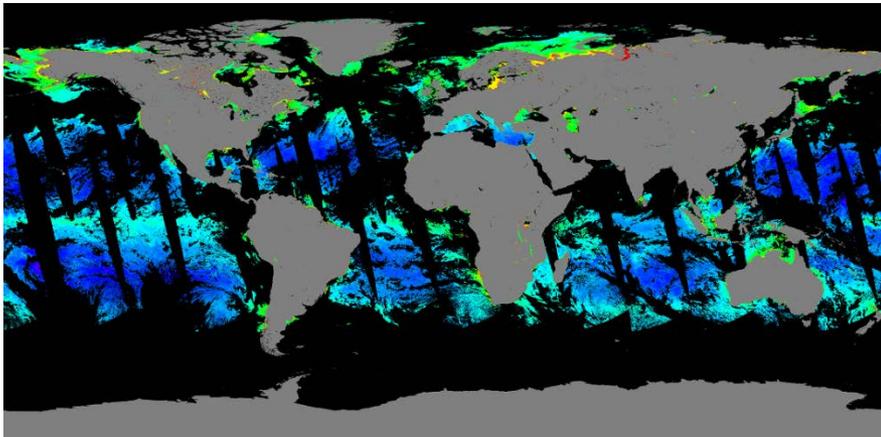
STAR JPSS 2016 Annual Science Team Meeting

August 8-12, 2016

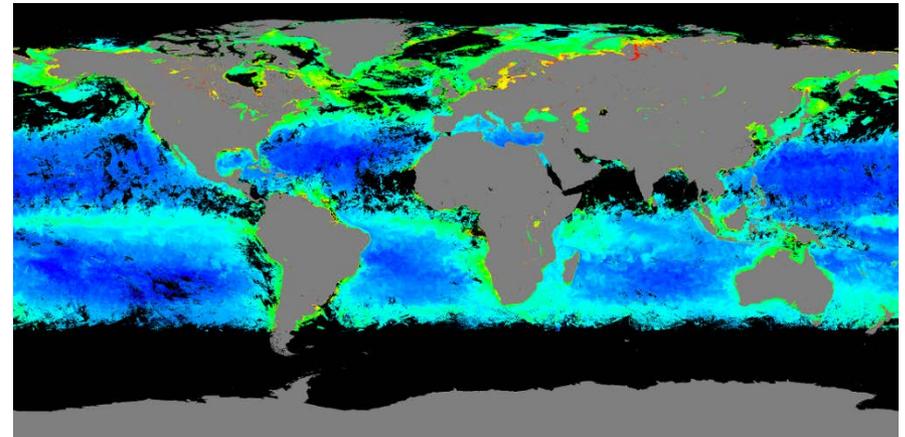


# Why Using DINEOF?

- Satellite ocean color images provide a variety of ocean optical, biological, and biogeochemical property products, and can be used for various applications such as the short- and long-term ocean environment monitoring, disaster and ocean hazard monitoring and prevention, ocean ecosystem and water quality evaluation and analysis.
- However, there are generally many missing pixels in the satellite images due to various reasons, mainly from cloud cover.



VIIRS Chl-a, 7/1, 2016

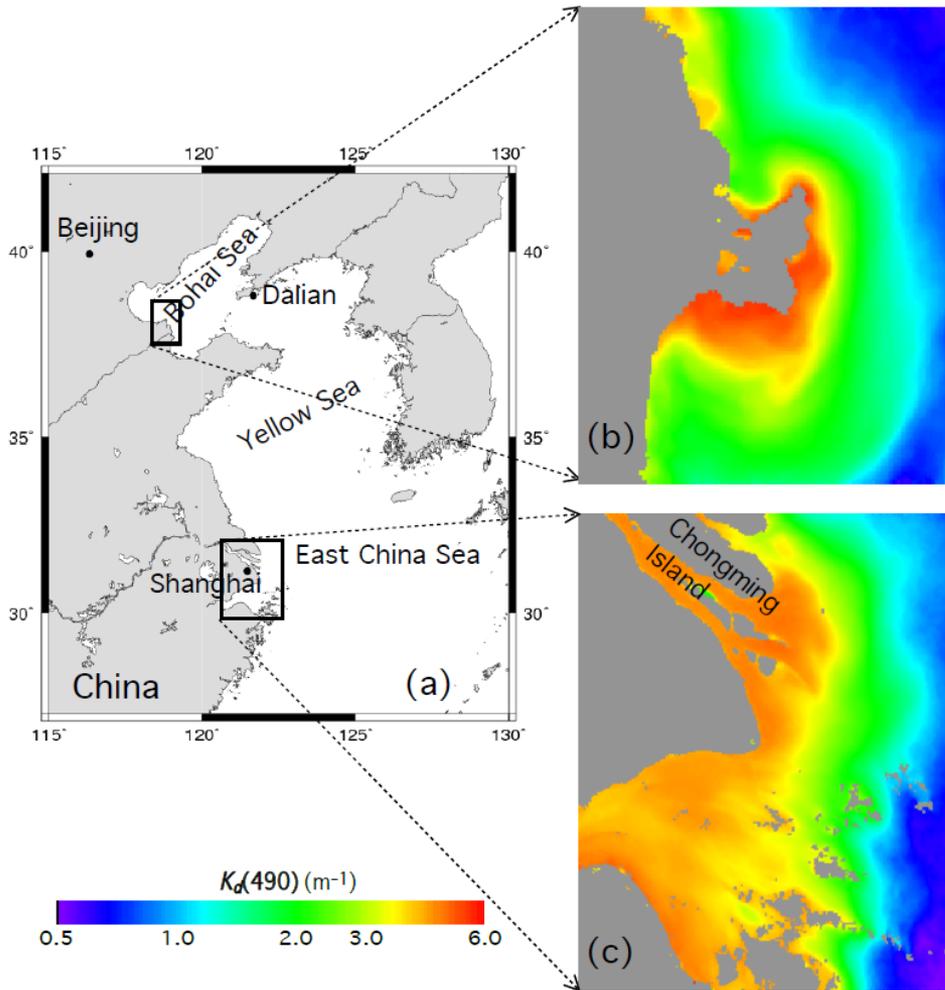


VIIRS Chl-a, 6/25–7/2, 2016

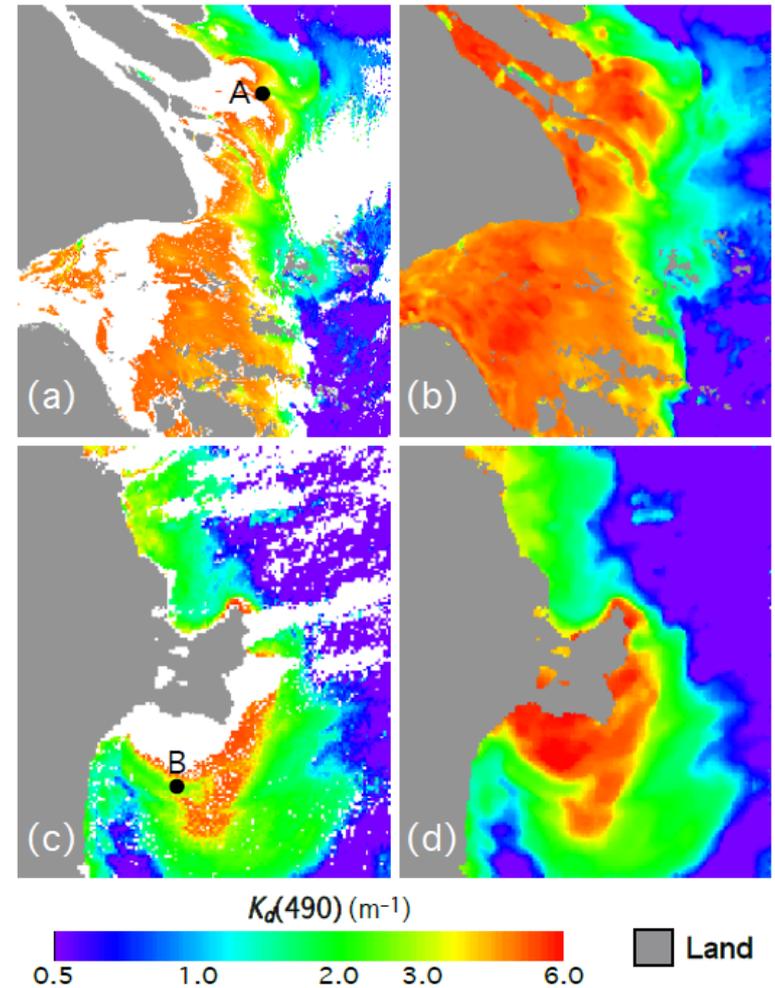
# What is DINEOF?

- The Data Interpolating Empirical Orthogonal Functions (DINEOF) (*Alvera-Azcarate et al., 2005; Beckers and Rixen, 2003*) is an EOF-based technique developed to reconstruct missing data in geophysical datasets. It exploits the spatio-temporal coherency of the data to infer a value at the missing location.
- The Empirical Orthogonal Function (EOF) analysis is a method to determine a set of orthogonal functions that characterizes the co-variability of time series for a set of grid points. It is often used to study possible spatial modes (patterns) of variability and how they change with time.
- The DINEOF method is based on the fact that an EOF analysis aims to extract a small number of significant modes, present in the physical system, from a large data set. These reduced variables should represent a large fraction of the original variability of the data set. The combination of the dominant EOF modes and their amplitudes can therefore help recover missing data values.

# A Case Study on GOCI $K_d(490)$ Images



Areas of study (8/1 – 9/30, 2013)



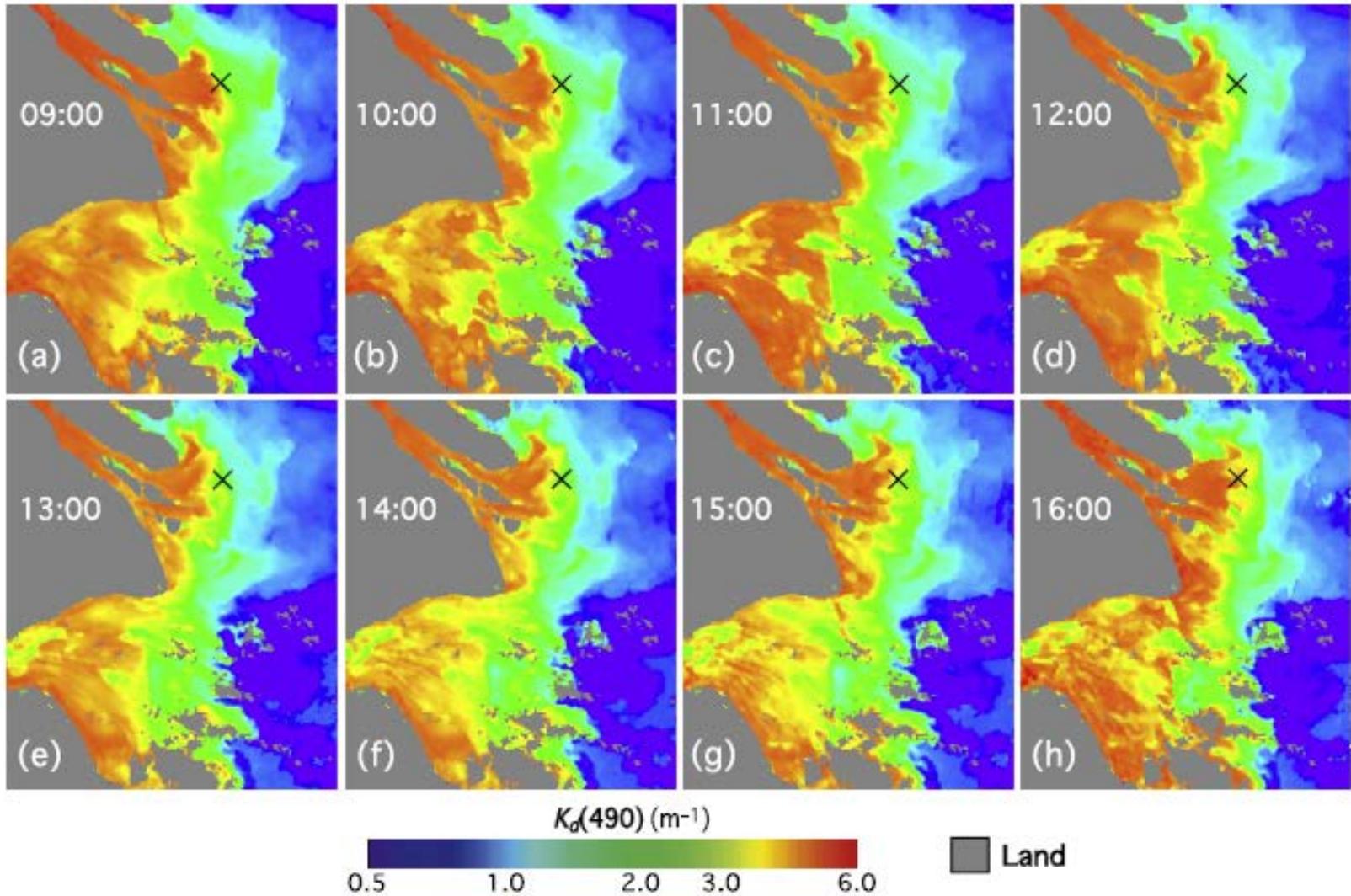
Examples of reconstructed images

Liu, X. and M. Wang, "Analysis of diurnal variations from the Korean Geostationary Ocean Color Imager measurements using the DINEOF method," *Estuar. Coast. Shelf Sci.*, **180**, 230–241, 2016.

<http://dx.doi.org/10.1016/ecss.2016.07.006>

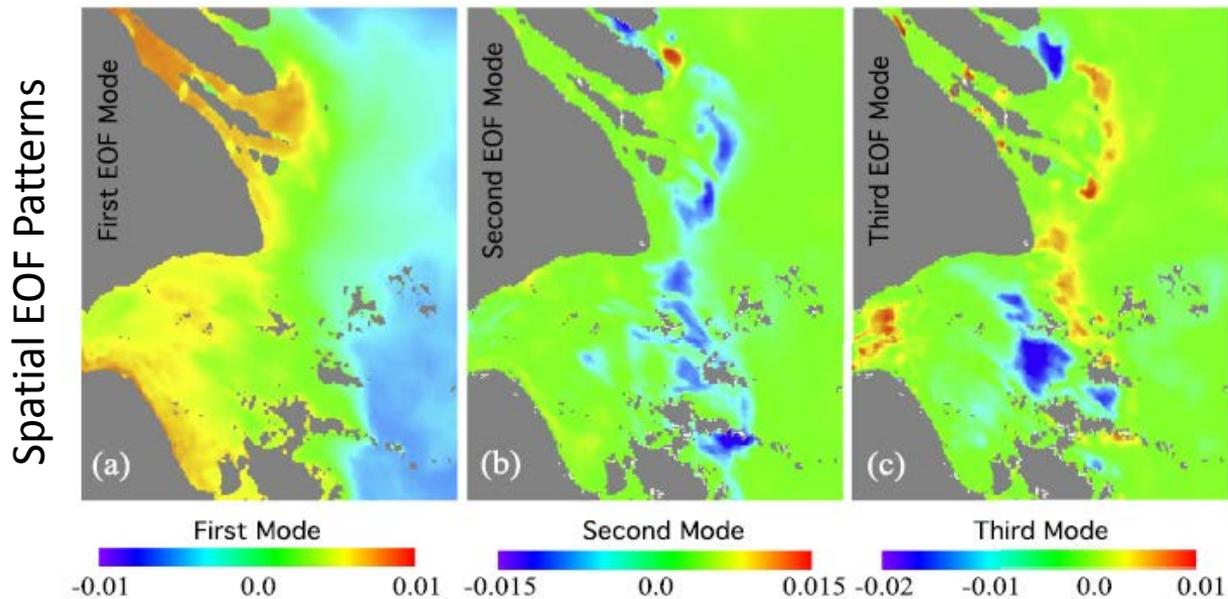
8/10/2013 9:16 AM 8/23/2013 12:16 PM

# Analysis of Tidal Variations

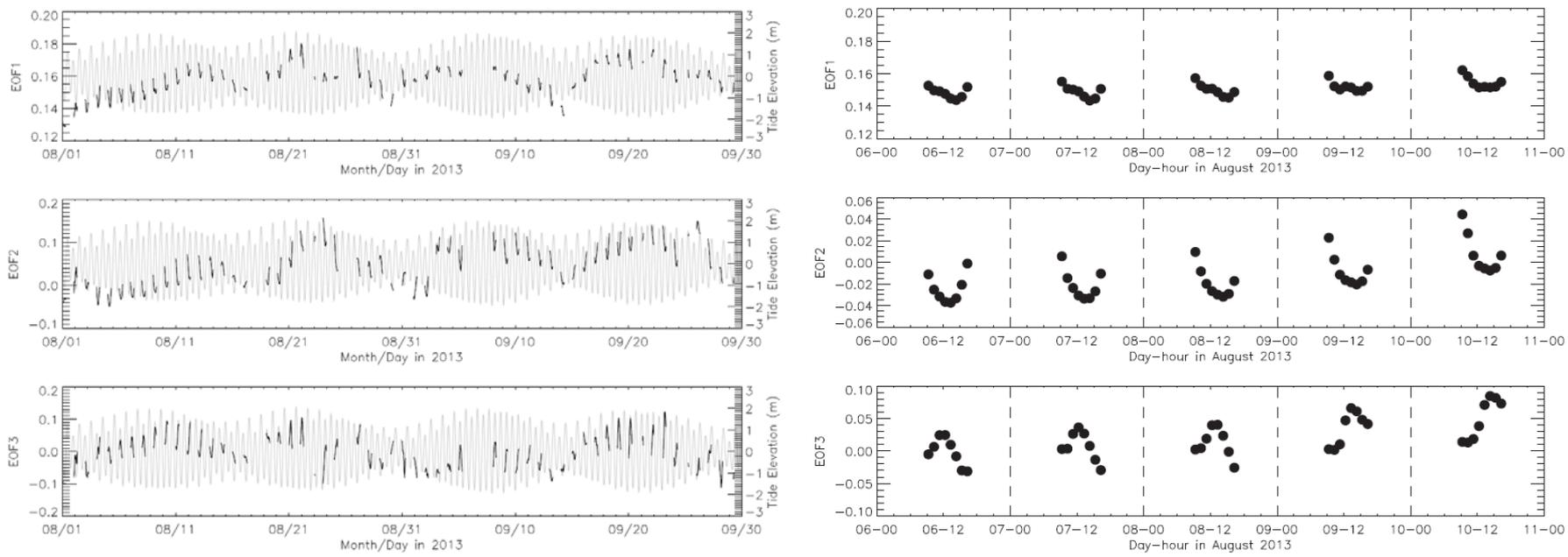


Example of eight filled consecutive  $K_d(490)$  images at about 09:00 to 16:00 local time hourly (a-h) for the Yangtze River mouth region on August 6, 2013.

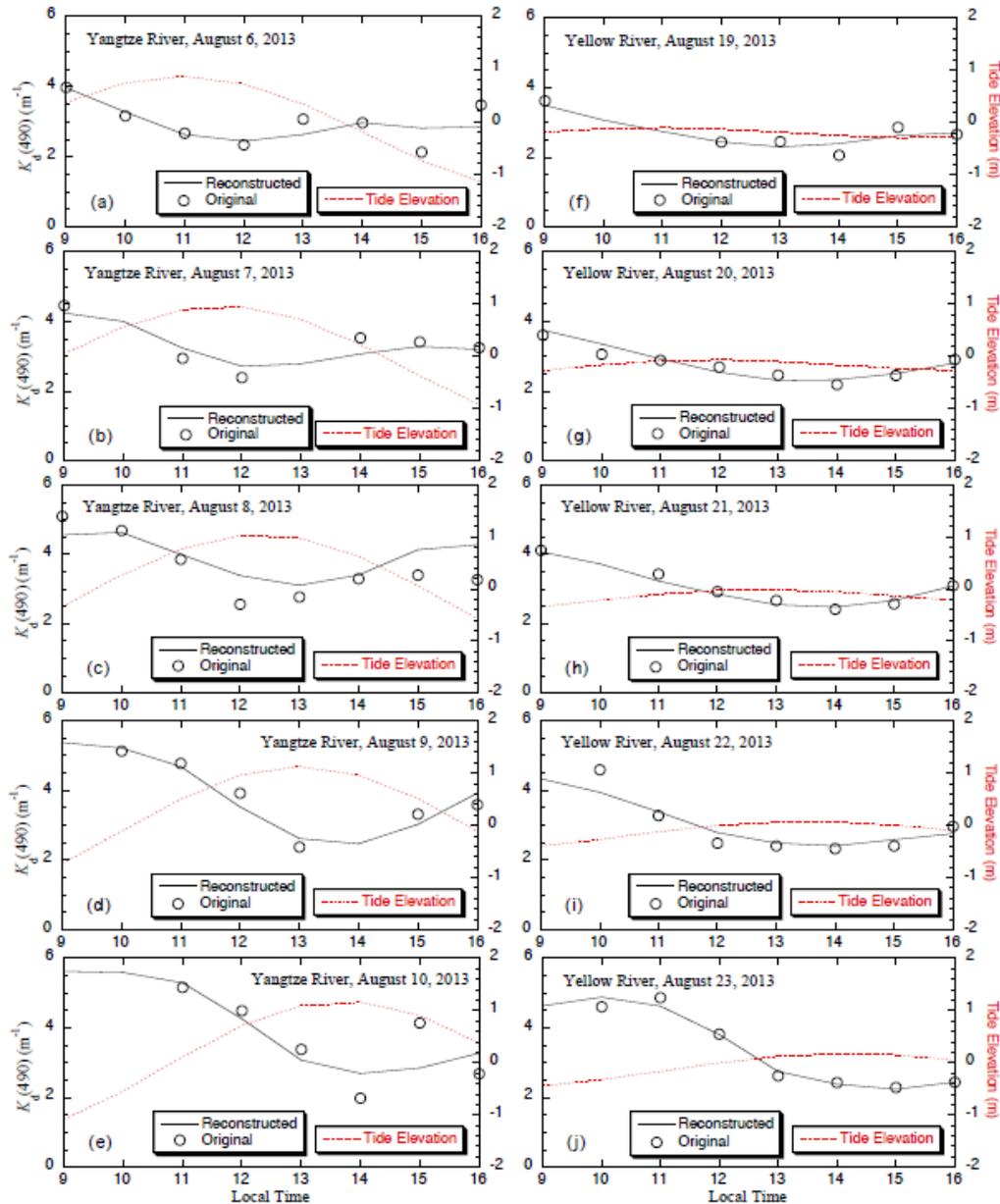
# Analysis of Tidal Variations



## Temporal EOF Functions

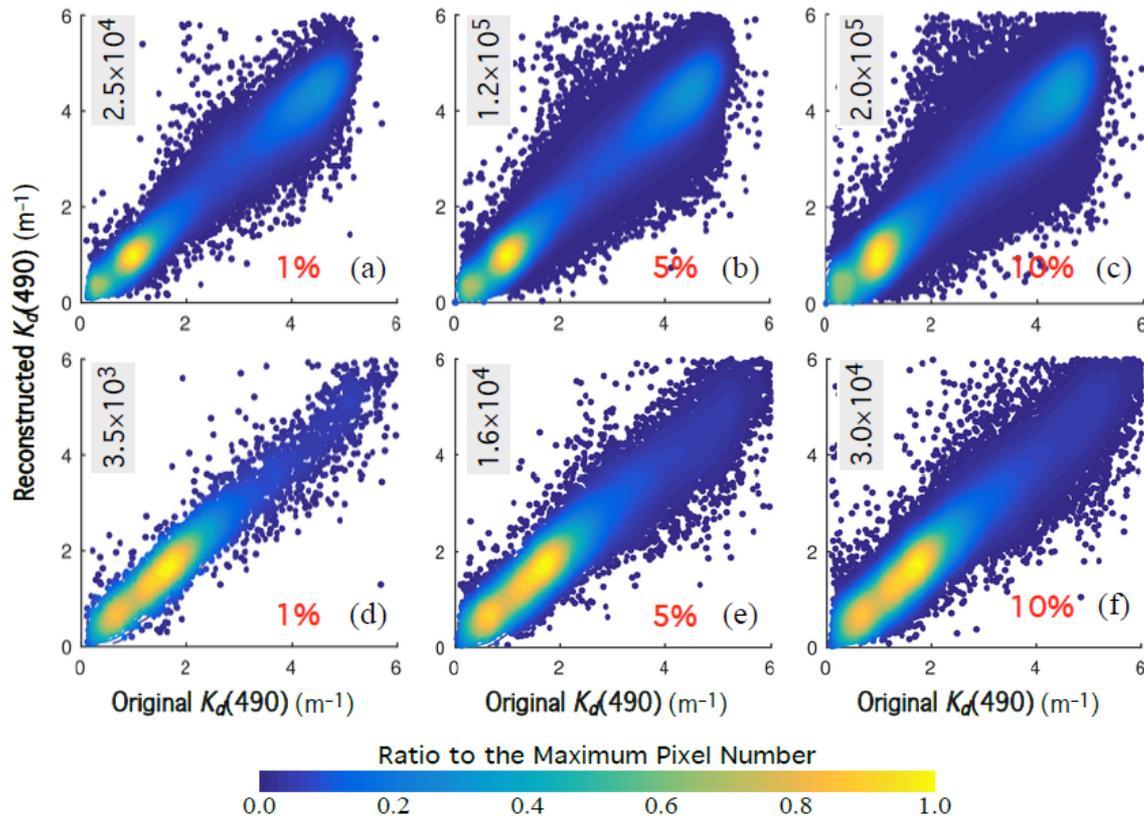


# Validation of DINEOF on GOCI



Time series (diurnal variation) of  $K_d(490)$  for the original and reconstructed pixels, as well as the tide elevation (scale noted in right), for the locations A and B, respectively, for the Yangtze River mouth for August 6-10, 2013 (a-e) and the Yellow River mouth for August 19-23, 2013 (f-j).

# Validation of DINEOF on GOCI



Yangtze River Mouth

|      | 1%    | 5%    | 10%   |
|------|-------|-------|-------|
| Mean | 1.024 | 1.024 | 1.025 |
| STD  | 0.255 | 0.262 | 0.285 |

Yellow River Mouth

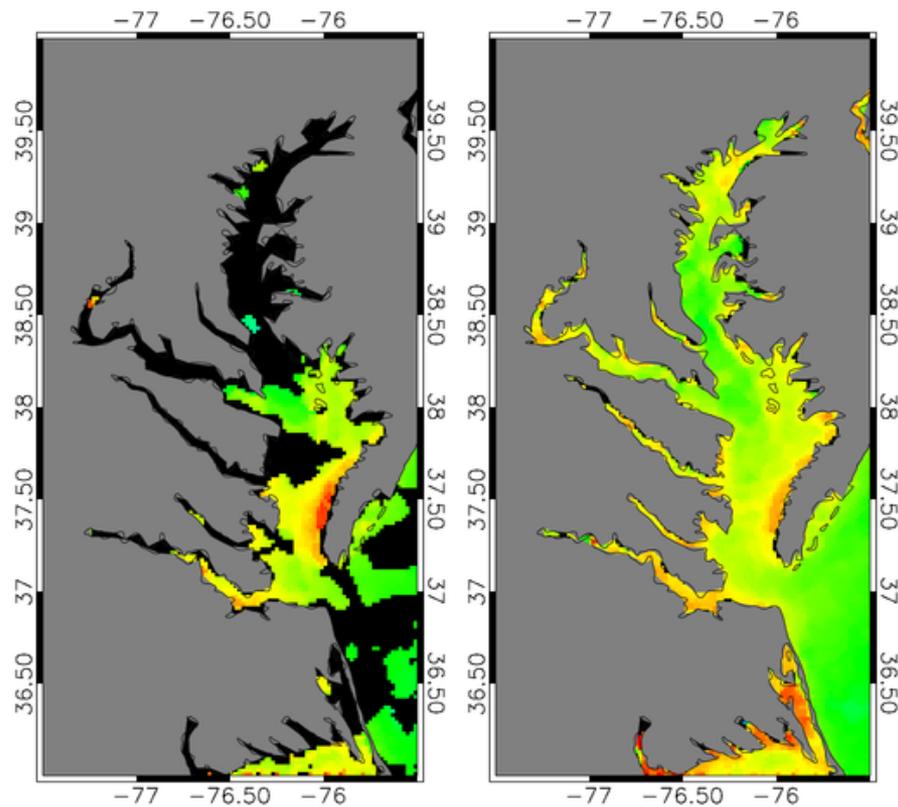
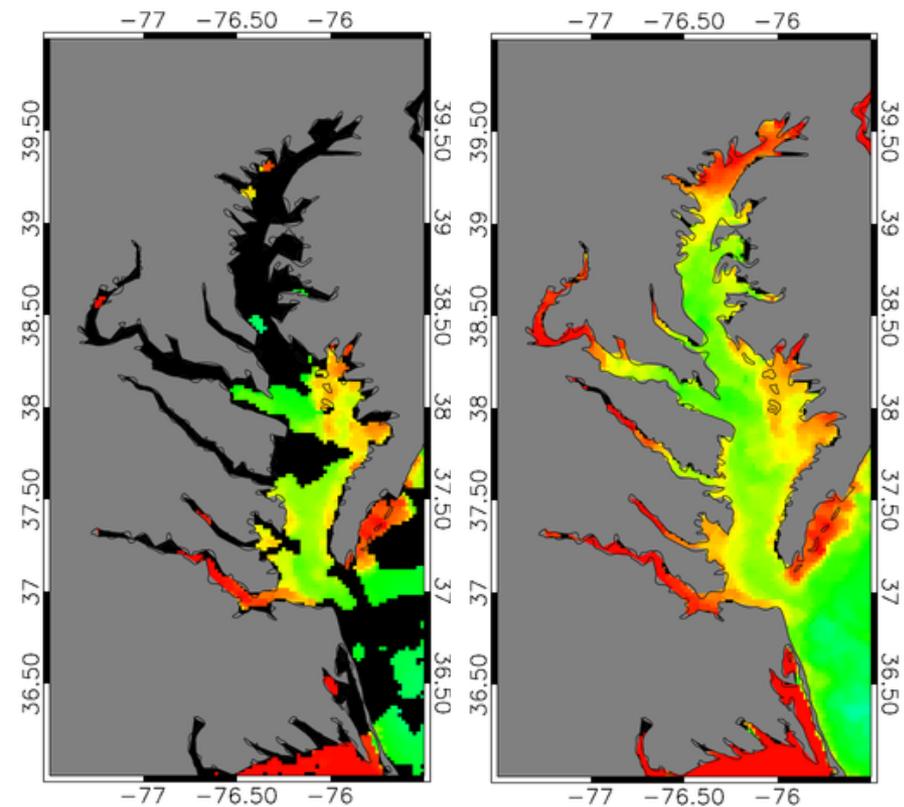
|      | 1%    | 5%    | 10%   |
|------|-------|-------|-------|
| Mean | 1.030 | 1.031 | 1.041 |
| STD  | 0.302 | 0.303 | 0.527 |

Scatter and density plots of the reconstructed versus original  $K_d(490)$  values for the Yangtze River mouth (panels a, b, and c), and the Yellow River mouth (panels d, e, and f). Panels a and d have 1% validation pixels, panels b and e have 5% validation pixels, and panels c and f have 10% validation pixels.

# Application of DINEOF on VIIRS

$K_d(490)$

Chl-a



Original

Reconstructed

Original

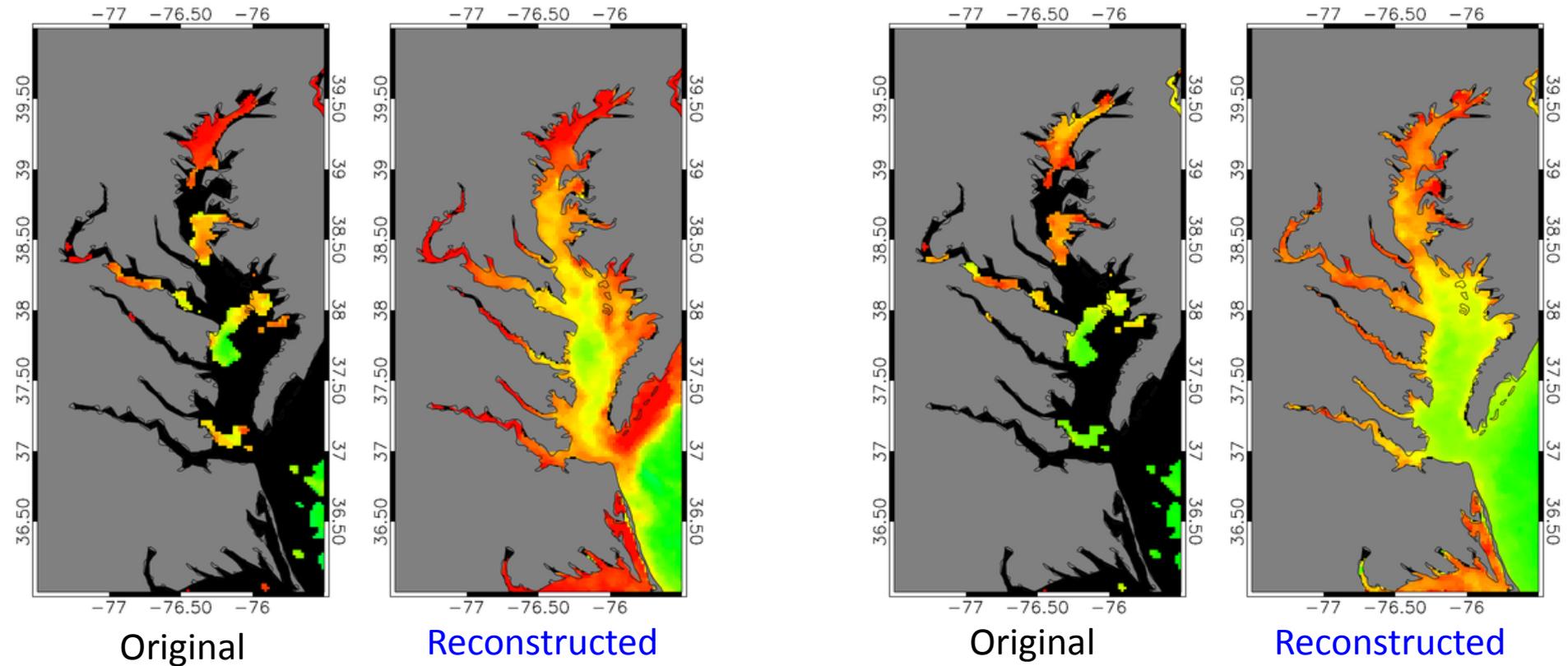
Reconstructed

Chesapeake Bay, April 30 – May 7, 2016

# Application of DINEOF on VIIRS

$K_d(490)$

Chl-a



Chesapeake Bay, Sep. 22–29, 2015

# Summary and Future Work

- DINEOF method has been applied to GOCI and VIIRS ocean color images for filling the gaps of missing pixels. Validation results from GOCI images show the differences between DINEOF reconstructed pixels and the original pixels are small. The missing spatial features in the ocean color images can be reconstructed.
- DINEOF will be used for filling the gaps in VIIRS high resolution (1 km) ocean color images for **selected regions**, such as, the US east and west coasts, Gulf of Mexico, Great Lakes, etc. It will also be used to test and evaluate **non-gap global ocean color images** at 9-km resolution.