



# Gap Filling of Missing Data for Blended SNPP/NOAA-20 VIIRS Ocean Color Products Using the DINEOF Method

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## Algorithm Team Members

Name	Organization	Major Task
Xiaoming Liu	STAR/SOCD	Science and development
Menghua Wang	STAR/SOCD	Lead and Science

# Motivation

- The Visible Infrared Imaging Radiometer Suite (VIIRS) ocean color images, such as chlorophyll-a (Chl-a) concentrations, and the water diffuse attenuation coefficient at the wavelength of 490 nm ( $K_d(490)$ ) (*Wang et al.*, 2013), are very useful for monitoring and understanding coastal biological and ecological processes and phenomena. However, VIIRS-derived daily ocean color image either on the SNPP or NOAA-20 is limited in ocean coverage due to its swath width, high sensor-zenith angle, sun glint, and cloud, etc.
- Merging VIIRS ocean color products derived from the SNPP and NOAA-20 significantly increases the spatial coverage of daily images. Two VIIRS sensors on the SNPP and NOAA-20 satellites have similar sensor characteristics, and global ocean color data are derived routinely using the same Multi-Sensor Level-1 to Level-2 (**MSL12**) ocean color data processing system. Therefore, the merged VIIRS ocean color data are expected to have high quality with consistent statistical property and accuracy globally.
- The [Data Interpolating Empirical Orthogonal Function \(DINEOF\)](#) is a method to reconstruct missing data in geophysical datasets based on [Empirical Orthogonal Function \(EOF\)](#). It utilizes both temporal and spatial coherencies of data to infer a solution at the missing locations (*Alvera-Azcarate et al.*, 2005). In this study, the DINEOF is used to fill up gap pixels in the merged SNPP and NOAA-20 VIIRS global ocean color images.



# Input Needs for the Blended Product Algorithm



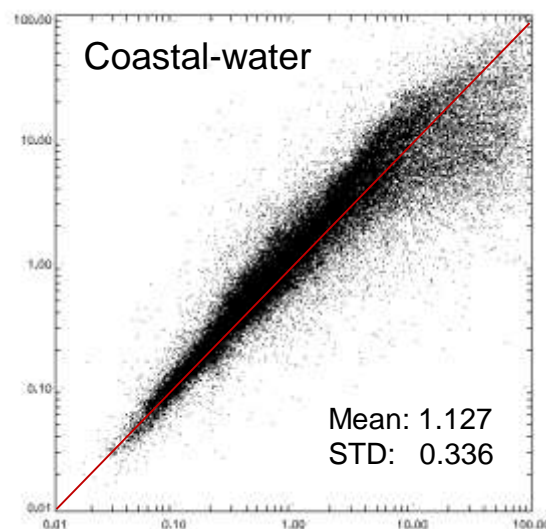
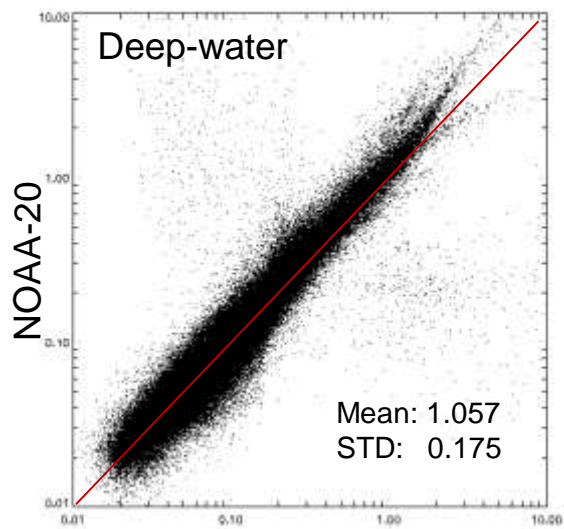
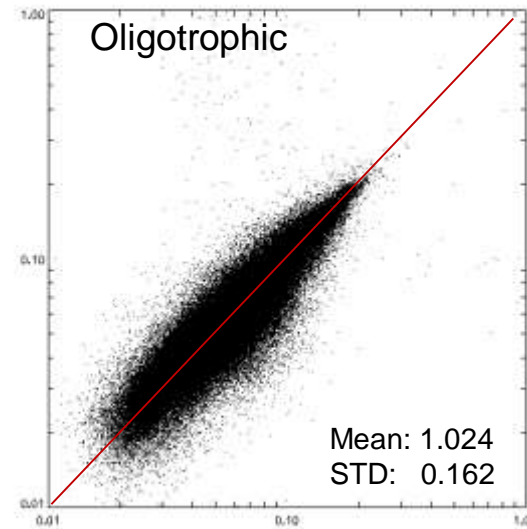
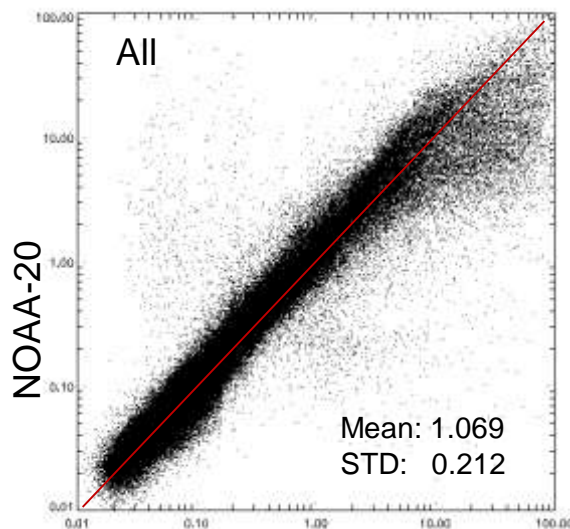
- Blended Product Name: SNPP and NOAA-20 Blended and Gap-filled VIIRS Ocean Color Product

## Required Satellite **Input** Data Products

	<b>Data Product Name (Inputs)</b>	<b>Input Data Type (Satellite/Model Forecasts/<i>In-situ</i>)</b>	<b>Temporal/Spatial Resolution, Format</b>	<b>Source(s)</b>
1	Chl-a, $K_d(490)$ , $K_d(\text{PAR})$	SNPP VIIRS EDR	9-km (Level-3 bin)	OC Team
2	Chl-a, $K_d(490)$ , $K_d(\text{PAR})$	NOAA-20 VIIRS EDR	9-km (Level-3 bin)	OC Team

SNPP and NOAA-20 have similar sensor characteristics, spatial and time resolution, little time difference, and the ocean color data are processed using the same EDR software, i.e., **MSL12**. The statistics of the two data sets are very close.

## 06/21/2018 Chl-a (OCI)



SNPP

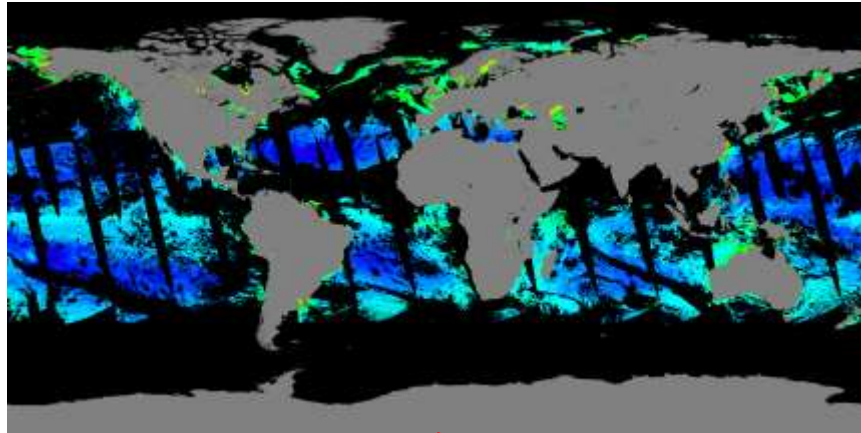
SNPP



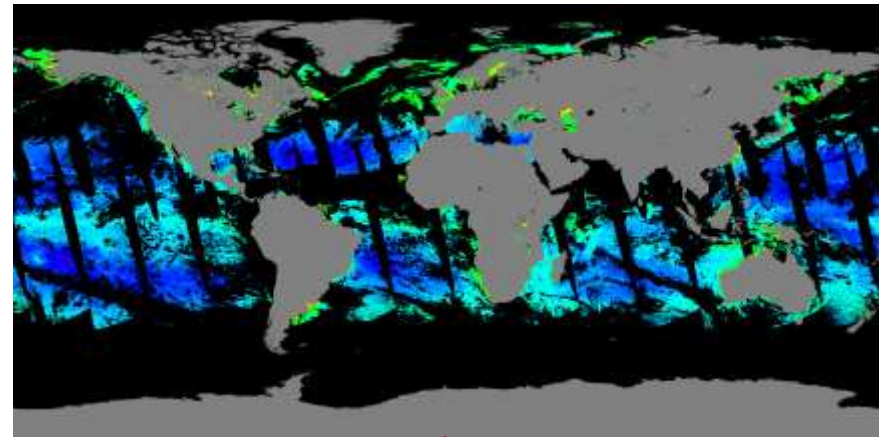
# Merging S-NPP and NOAA-20 Ocean Color Data

Example of Global 9km Chl-a Level-3 images (6/21/2018)

SNPP

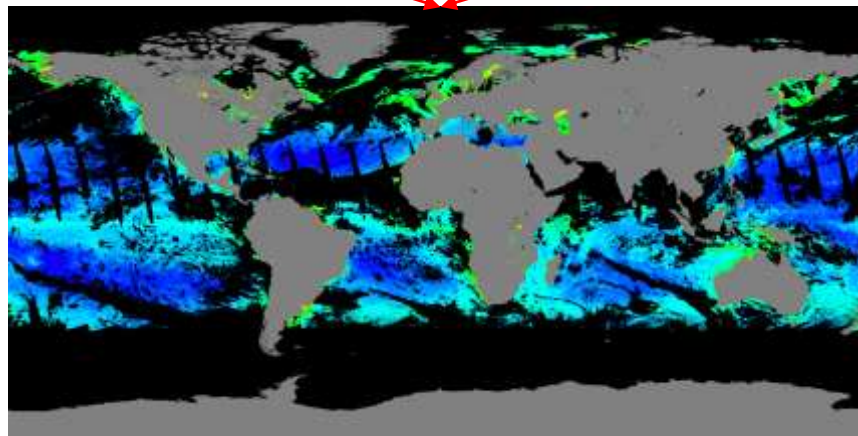


NOAA-20



Merging (L3bin)

Merged



- Input: Global daily SNPP and NOAA-20 merged Level-3 binned data file from June 19 to July 18, 2018.
- To increase DINEOF performance, global data are divided into 16 zonal sections: 80°S-70°S, 70°S-60°S, ... 10°S-Equator, Equator-10°N, 10°-20°N, ... 60°-70°N, 70°-80°N.
- Replace pixels that are missing for the whole month with climatology value.
- Apply DINEOF on each of the 16 zonal sections, fully reconstruct all pixels, including non-missing pixels.
- Output: Fully reconstructed (gap-filled) global daily Level-3 binned data.

**Liu, X.** and **M. Wang**, "Gap filling of missing data for VIIRS global ocean color product using the DINEOF method", *IEEE Trans. Geosci. Remote Sens.*, **56**, 4464-4476 (2018).



- Provide example(s) for each of the output product(s) produced by the Blended Product Algorithm

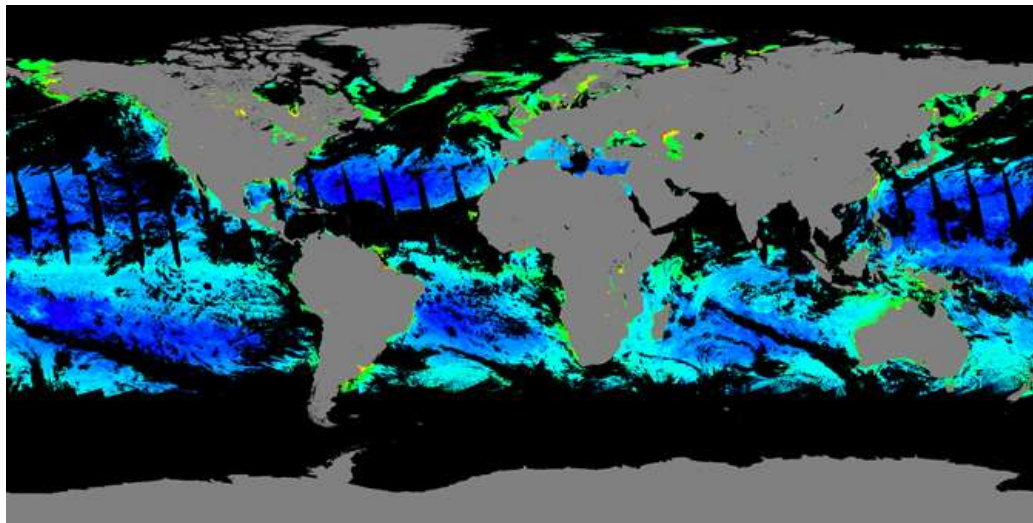
### Output Data Products

	Blended Data Product Name (Outputs)	Output Data Type (Satellite; Model Forecasts; In-situ)	Spatial, Temporal Resolution, Format	Source(s)
1	Chl-a	SNPP/NOAA-20	Level-3 Binned	OC Team
2	$K_d(490)$	SNPP/NOAA-20	Level-3 Binned	OC Team
3	$K_d(\text{PAR})$	SNPP/NOAA-20	Level-3 Binned	OC Team

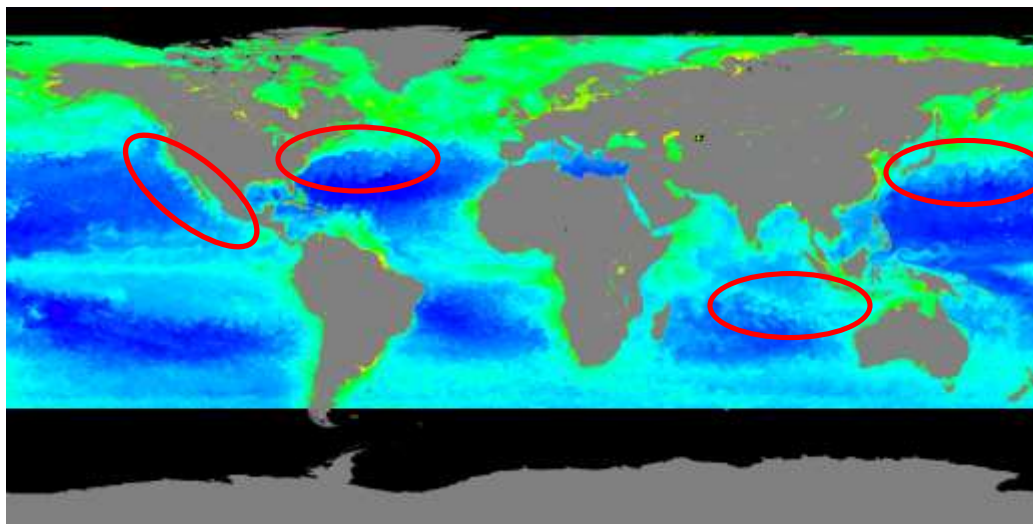
# Example of Gap-filled Products

## Global 9-km Chl-a Level-3 images (6/21/2018)

Merged product

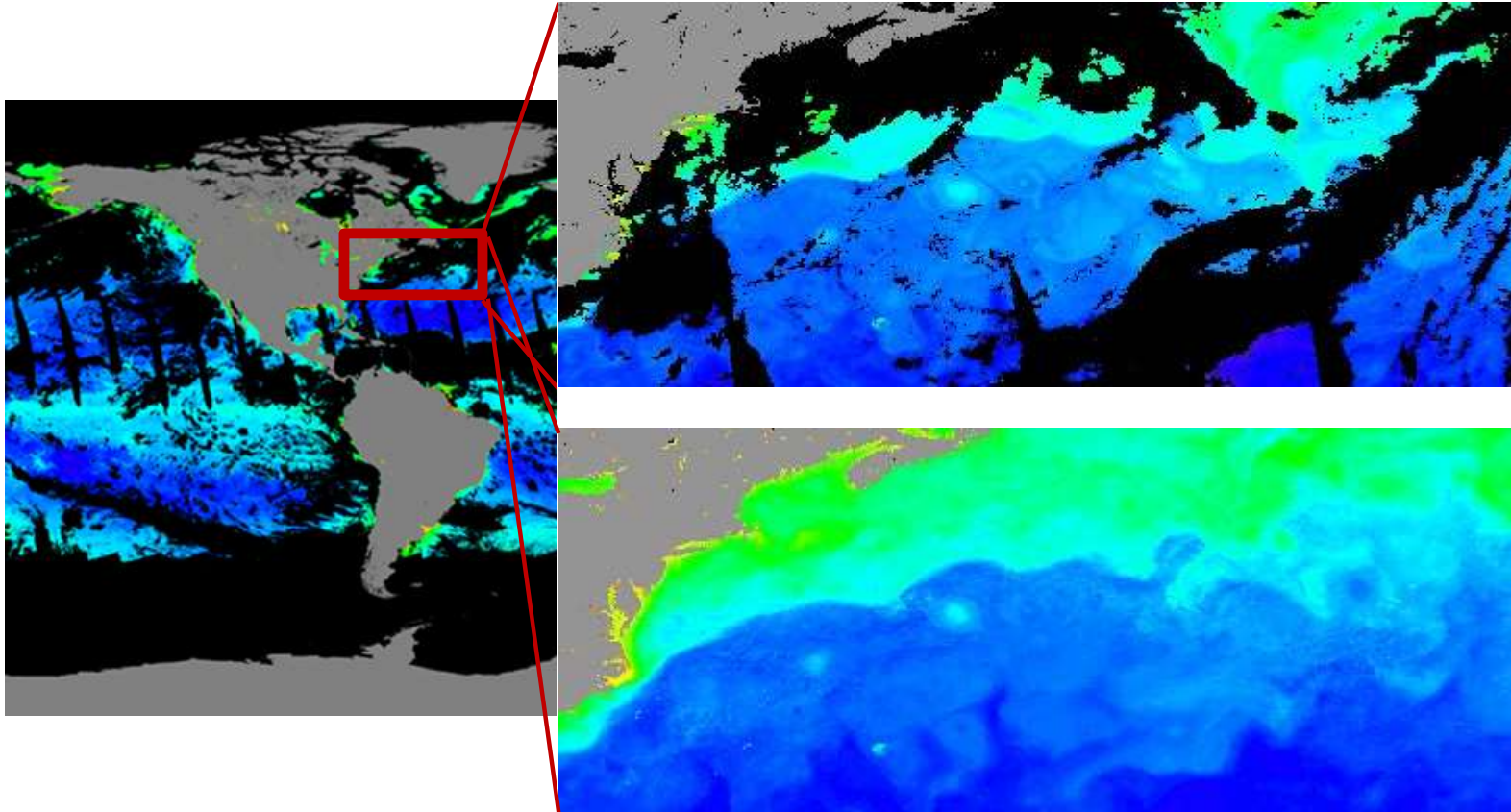


Gap-filled Product



# Example of Gap-filled Products (1)

## Movie of eddies in the north Atlantic



Merged

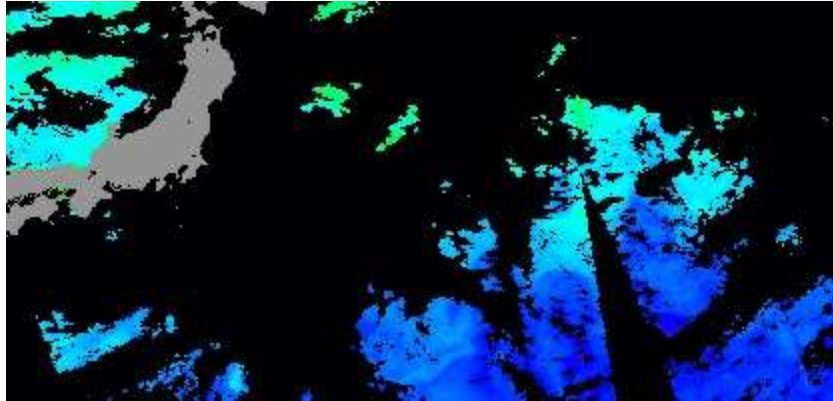
Gap-filled



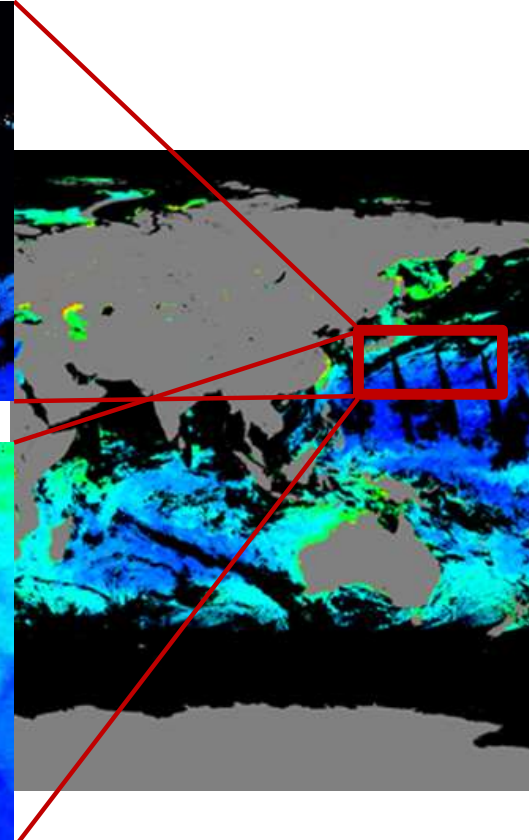
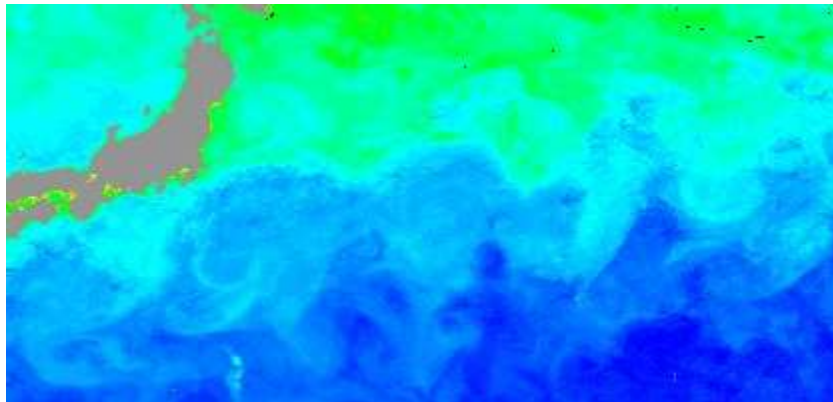
# Example of Gap-filled Products (2)

## Movie of eddies in the north Pacific

Merged

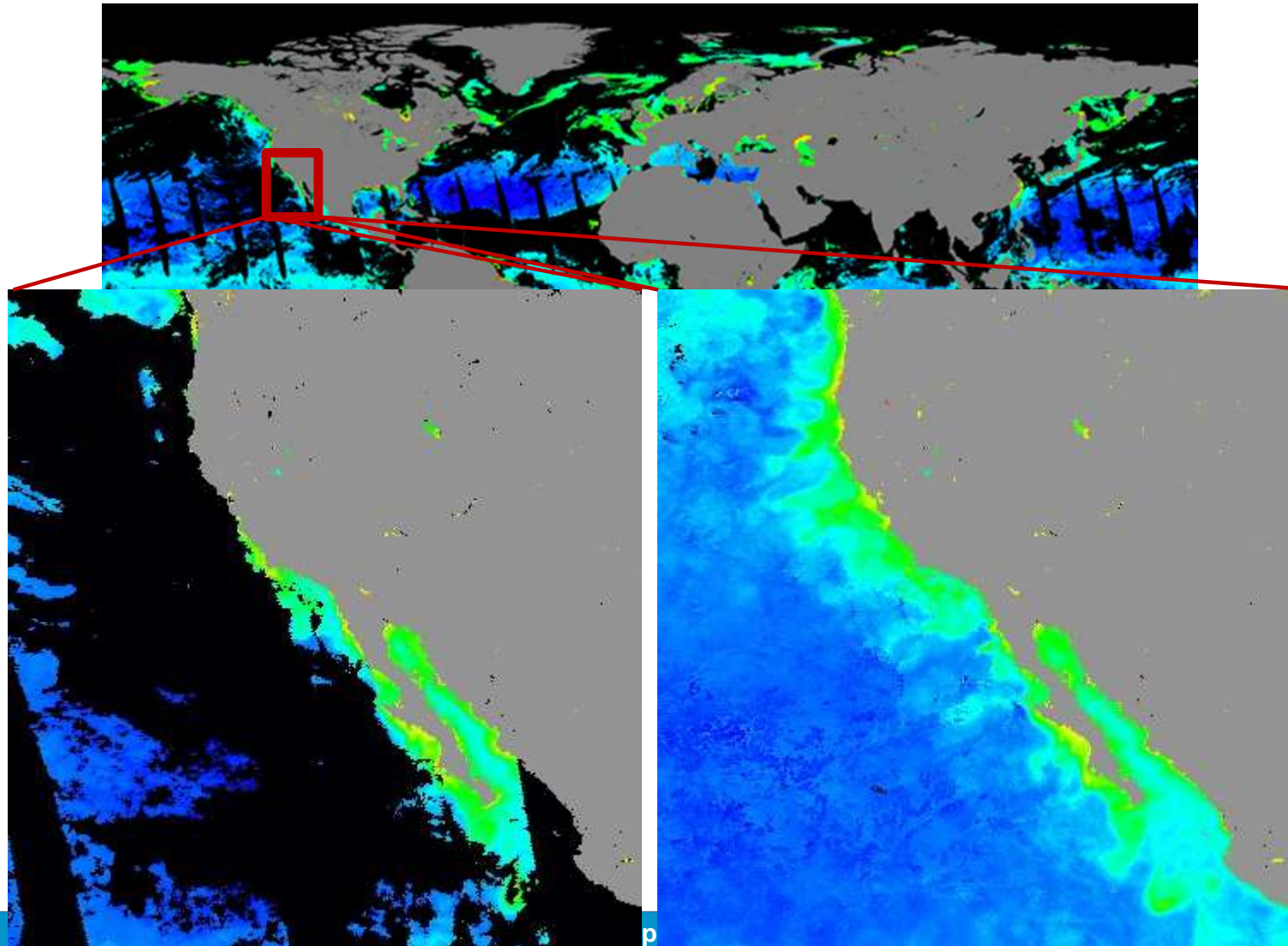


Gap-filled



# Example of Gap-filled Products (3)

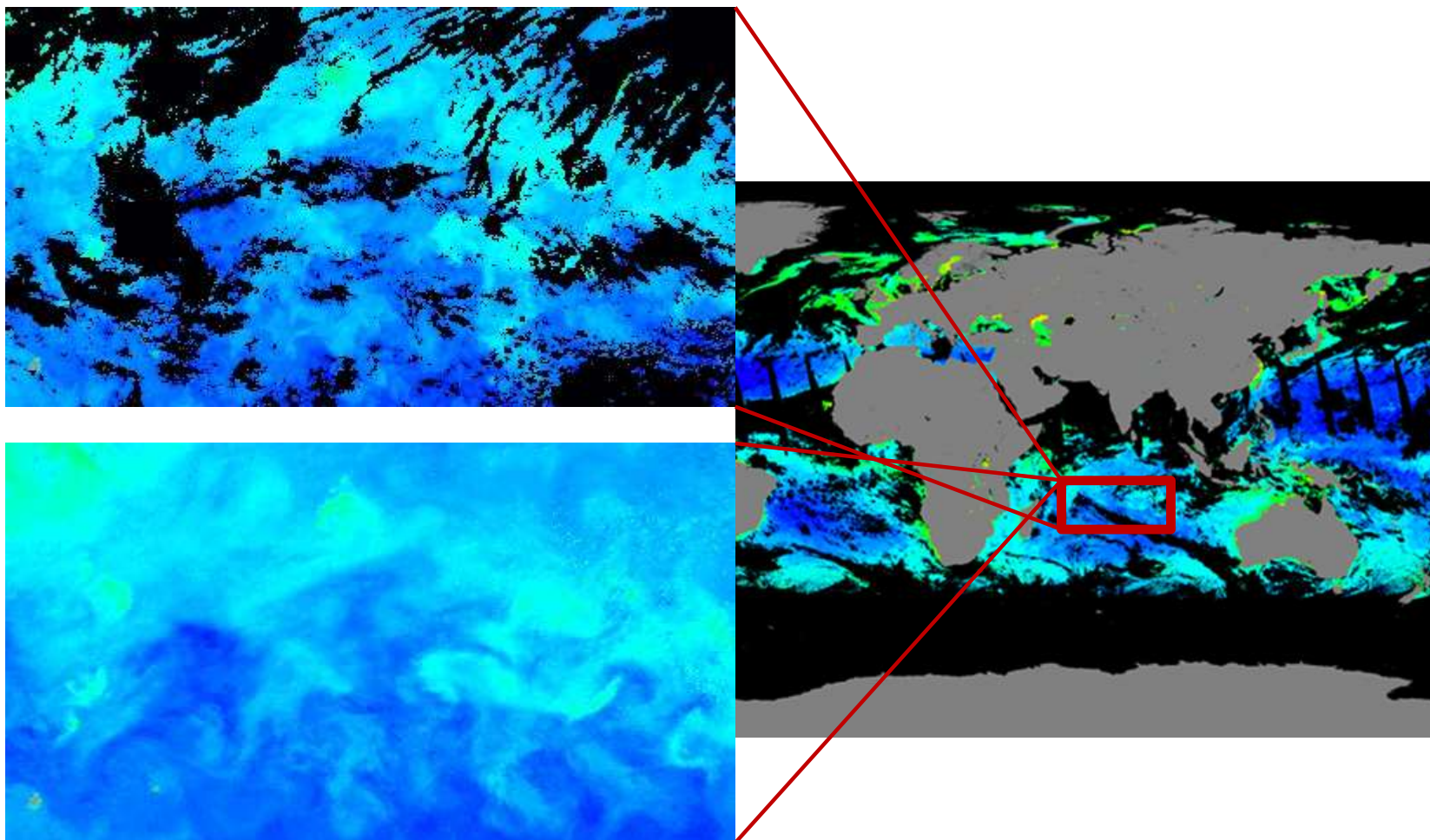
## Movie of eddies (Chl-a) in the California coast





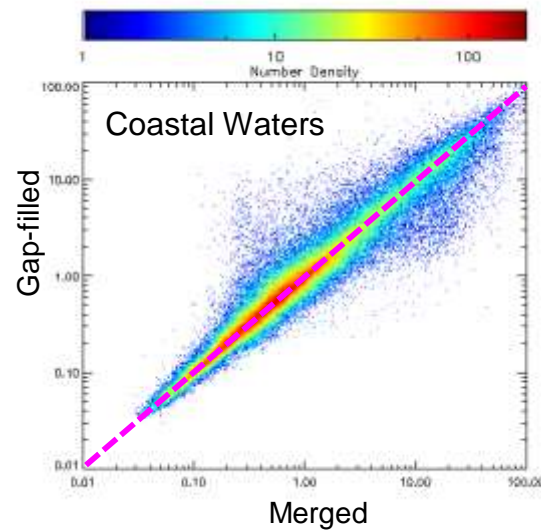
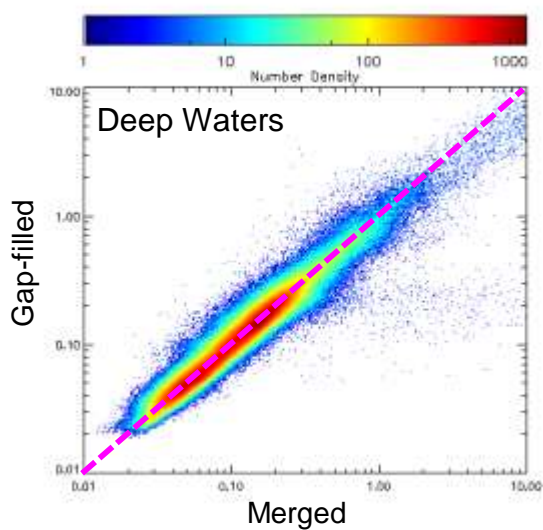
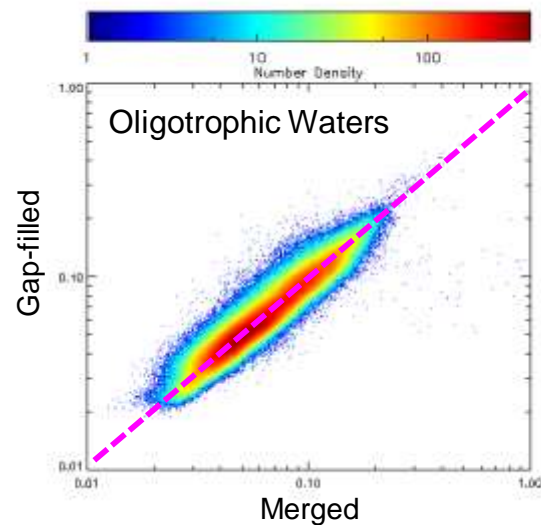
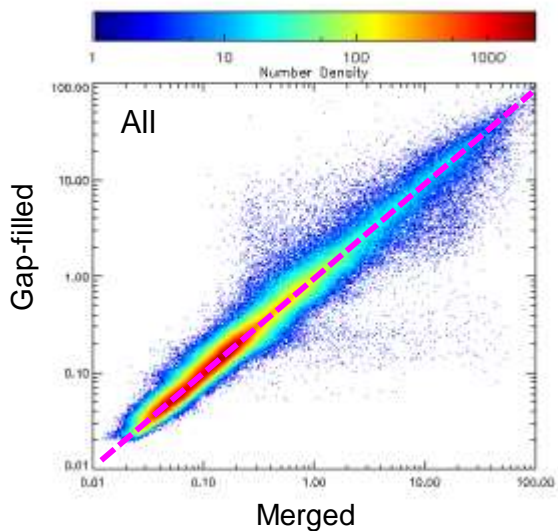
# Example of Gap-filled Products (4)

## Movie of eddies (Chl-a) in the south Indian Ocean

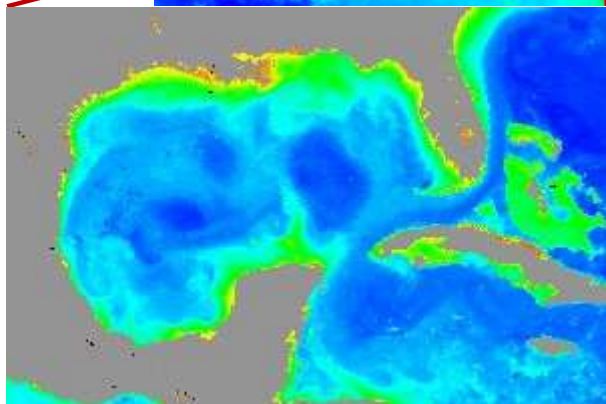
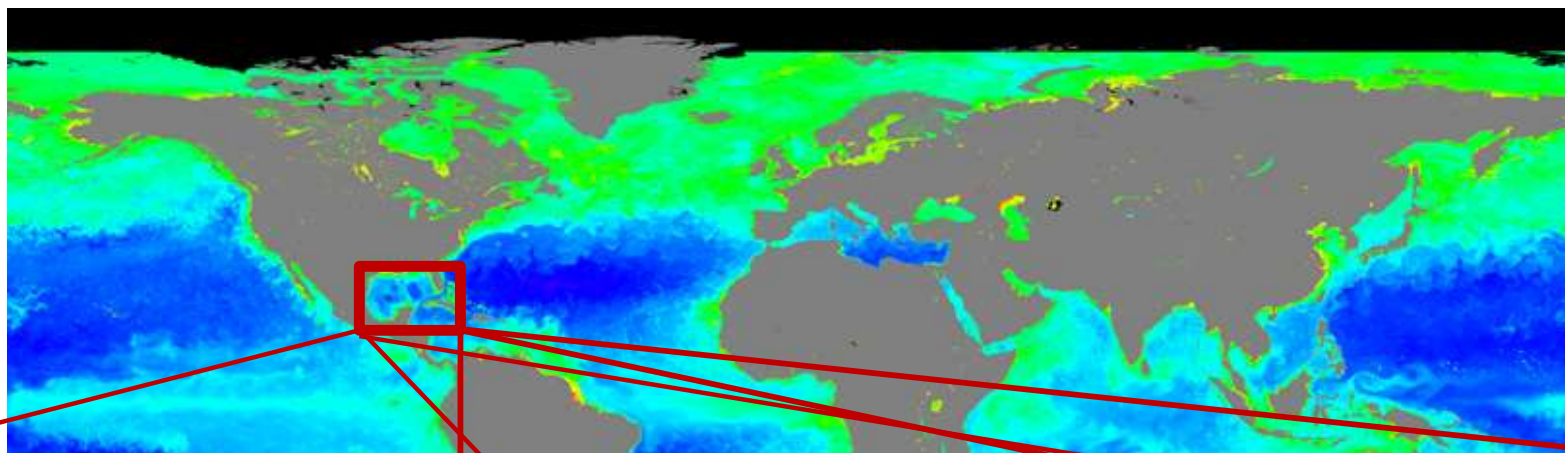




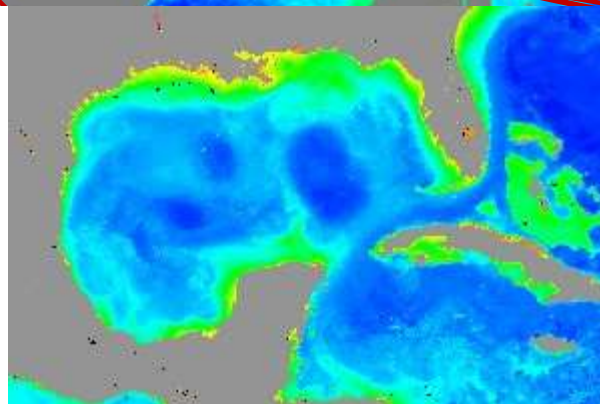
# Gap-filled Results Evaluation



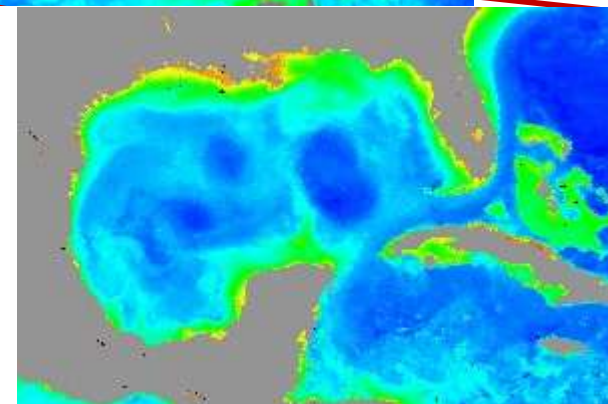
## Movies (6/19–7/18 )



**Merged**



**SNPP**



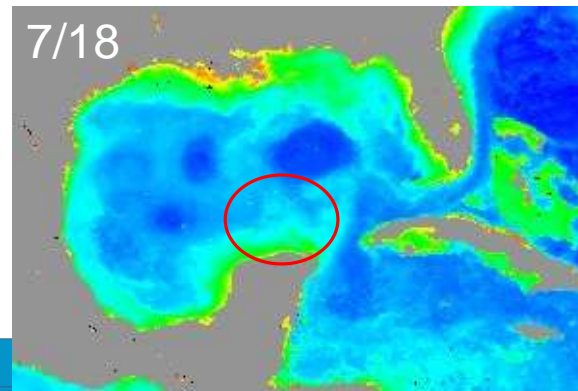
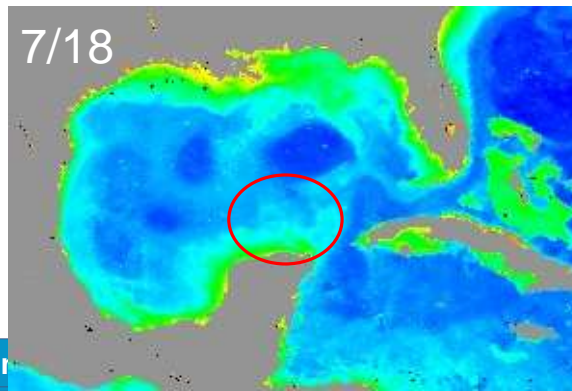
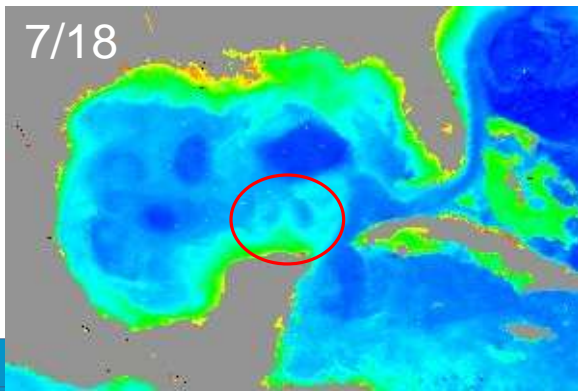
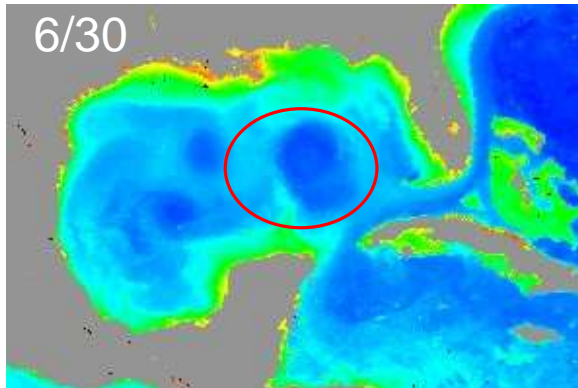
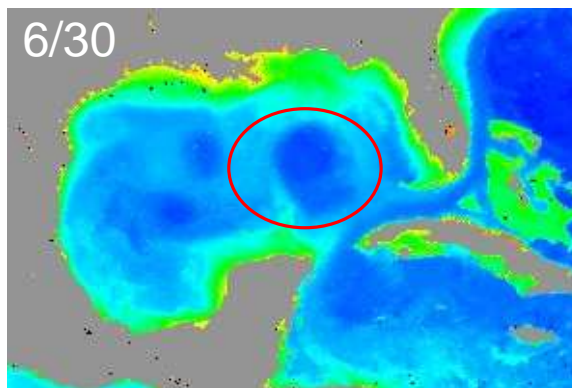
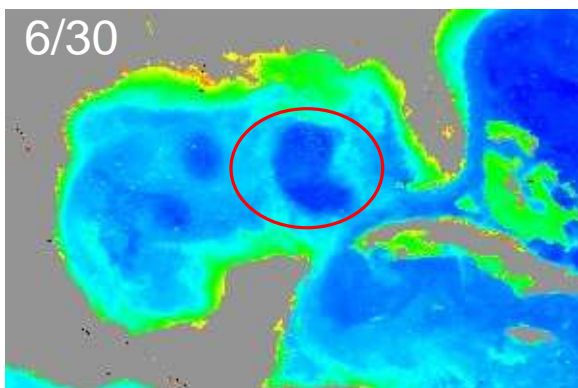
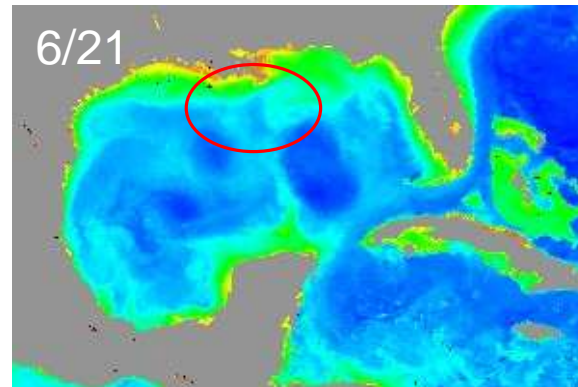
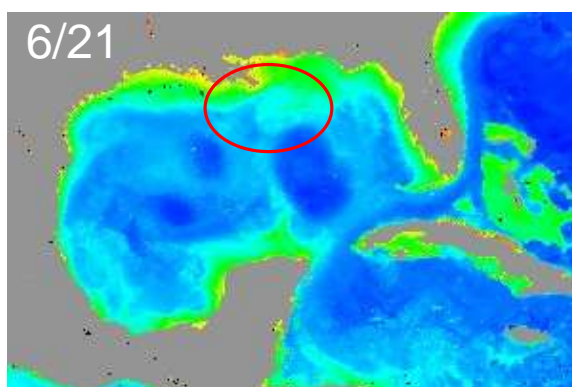
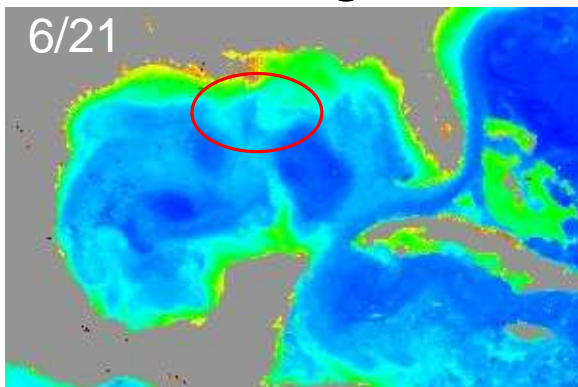
**NOAA-20**



### Merged

### SNPP

### NOAA-20



# Product Evaluation/Validation/Tools

## DINEOF Reconstructed/Original Ratio

Region	SNPP		NOAA-20		Merged	
	Mean	STD	Mean	STD	Mean	STD
<b>All</b>	1.007	0.191	1.007	0.206	1.012	0.200
<b>Deep Water</b>	1.010	0.171	1.009	0.191	1.015	0.182
<b>Coastal &amp; Inland Water</b>	0.995	0.281	0.995	0.273	0.997	0.287
<b>Oligotrophic Water</b>	1.007	0.157	1.009	0.182	1.012	0.164



# Blended Product Development Implementation Status



- Preliminary test on one month (6-19–7/18, 2018) of SNPP and NOAA-20 Level-3 binned data of 9-km spatial resolution
- Implemented as one single process on a Linux machine
- Mixed IDL and Fortran/C code
- No in situ data used in the process



# Future Algorithm Improvements



- Improve the processing software, change IDL code to C/Fortran codes
- Implement higher spatial resolution, and improve the performance using multi-processor.
- Include in situ measurement in the DINEOF data reconstruction



# Summary and Path Forward

- VIIRS SNPP and NOAA-20 have similar sensor characteristics, spatial resolution, and VIIRS ocean color data are routinely processed with the same EDR software, **MSL12**. They can be easily merged with the Level-3 bin tool.
- The VIIRS SNPP and NOAA-20 merged ocean color images still have many missing pixels due to clouds, sun glint, and high sensor zenith angles, etc. The DINEOF method is used to fill the gap in the merged data.
- Further improvement of the processing codes and performance, spatial resolution, and with including in situ data in the data process need to be done for future work.