Blending Methods: A Brief Overview

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Outline

- What’s blending and why do it?
- Some common methods & products
- Product stability & Improvements
- Addressing public wants and needs
- Summary and Conclusions

What's Blending and Why do it?

- Combining data from multiple sources and instruments for a better measure of a physical property

- Care needed to ensure that the product is suitable for its intended purpose
  - Climate needs differ from weather needs
  - Blending requires compromises to best suit a particular need
  - Compromise means that no product is best for all applications

- Done right, blending reduces uncertainty and yields more useful products

Some Common Blended Products

- Hydrometeorology products
  - Rain, snow, TPW
  - CMORPH, GPCP, etc.
  - Tropical cyclone properties
- SST
  - Different time and space scales, different lengths of analyses
  - OI-like methods good with dense data, EOF-like methods better for sparse data
- Winds, Ozone, Soil moisture, Biomass burning, etc.
- All instruments can have biases that should be addressed

Data and Blending

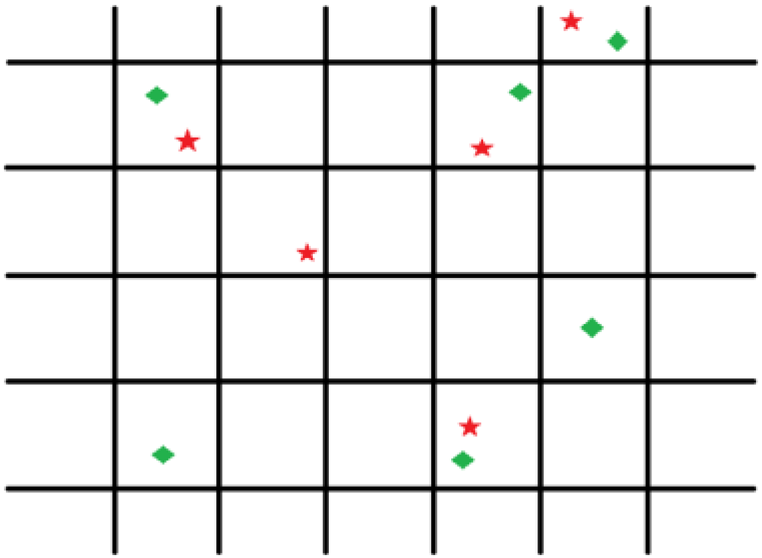
- Combining measurements
  - Consider instruments noise & bias errors, and sampling density
  - Best method depends on measurement properties and product requirements
    - Record length needed, resolution needed, etc.

- Merging & interpolation
  - High resolution real time for weather, may have more bias
  - Minimizing bias may lower resolution and delay analysis
  - A balance of needs should guide analysis development

Analysis Methods

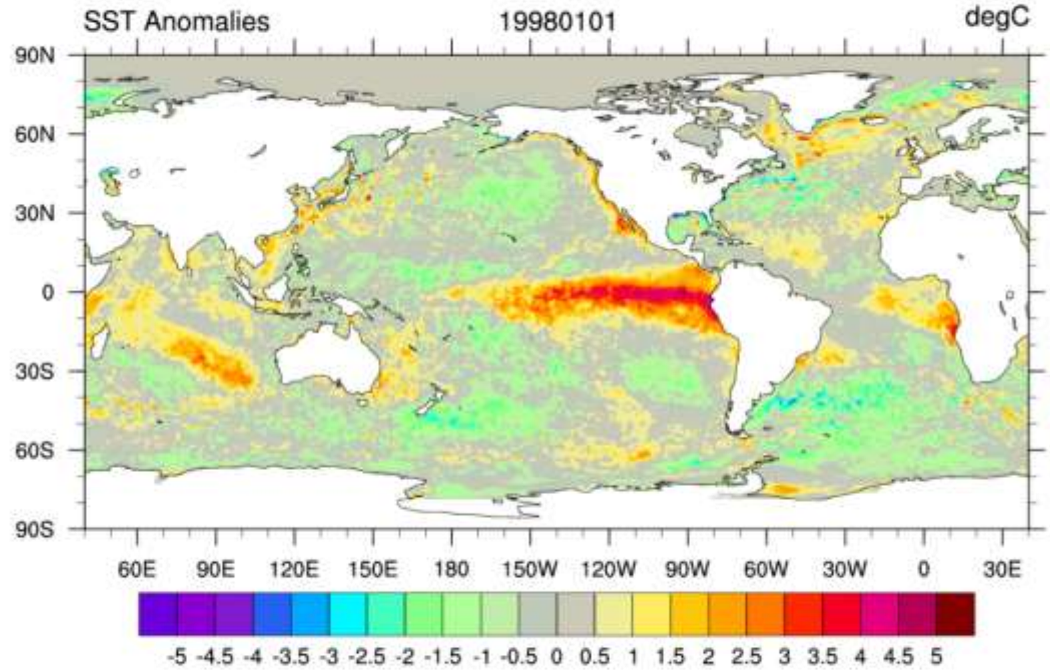
- Merging: combining data within a grid square

- Interpolation: filling gaps between data
  - Linear good when data dense & all have comparable quality
  - Optimum Interpolation (OI) uses statistics for better analysis with sparser data of different quality
  - Variation Methods (nD-Var, for assimilation) simplifies OI statistics, faster when data are dense
  - Morphing Methods, morph between high-quality observations using supplemental data
  - Machine Learning does tuning and adjusting on the fly



Example: OISST

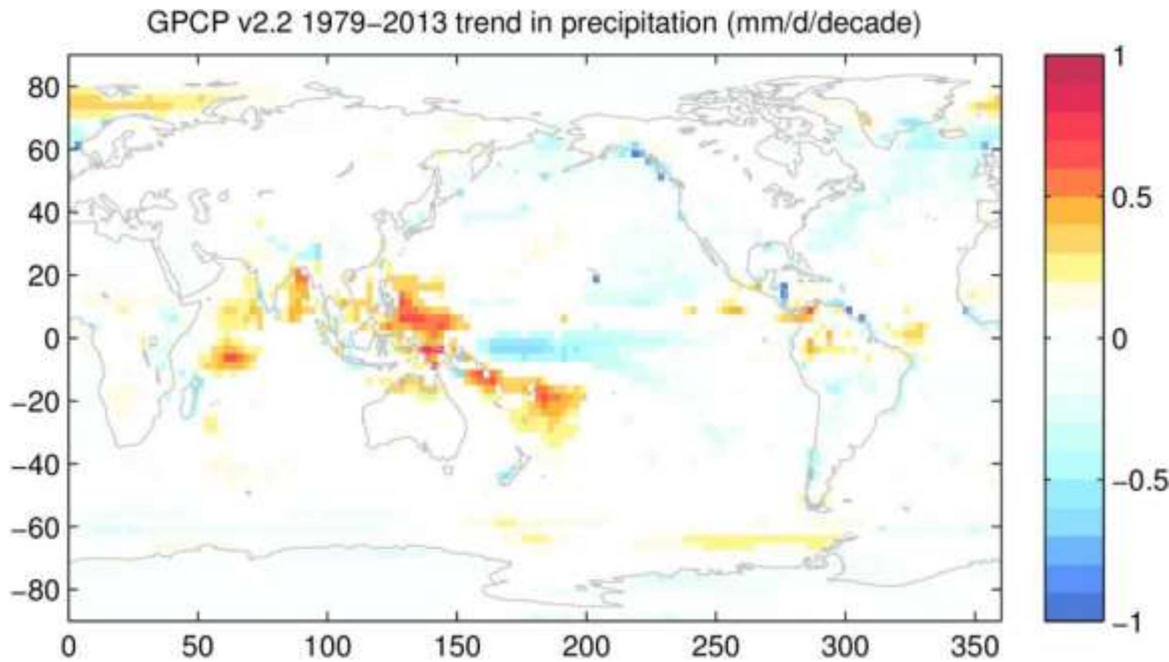
- 0.25-deg daily v2 analysis of sea-surface temperature (SST) using optimal interpolation (OI)
- For data need:
  - Bias estimates
  - Noise/signal variance
  - Spatial scales
- Different inputs:
  - AVHRR (changing to VIIRS)
  - MW for part of period
  - Ships more important early
  - Buoys more important later
- High-latitude ice adjustments



Banzon, Viva, Reynolds, Richard & National Center for Atmospheric Research Staff (Eds). Last modified 21 Apr 2018. "The Climate Data Guide: SST data: NOAA High-resolution (0.25x0.25) Blended Analysis of Daily SST and Ice, OISSTv2." Retrieved from https://climatedataguide.ucar.edu/climate-data/sst-data-noaa-high-resolution-025x025-blended-analysis-daily-sst-and-ice-oisstv2.

Example: GPCP

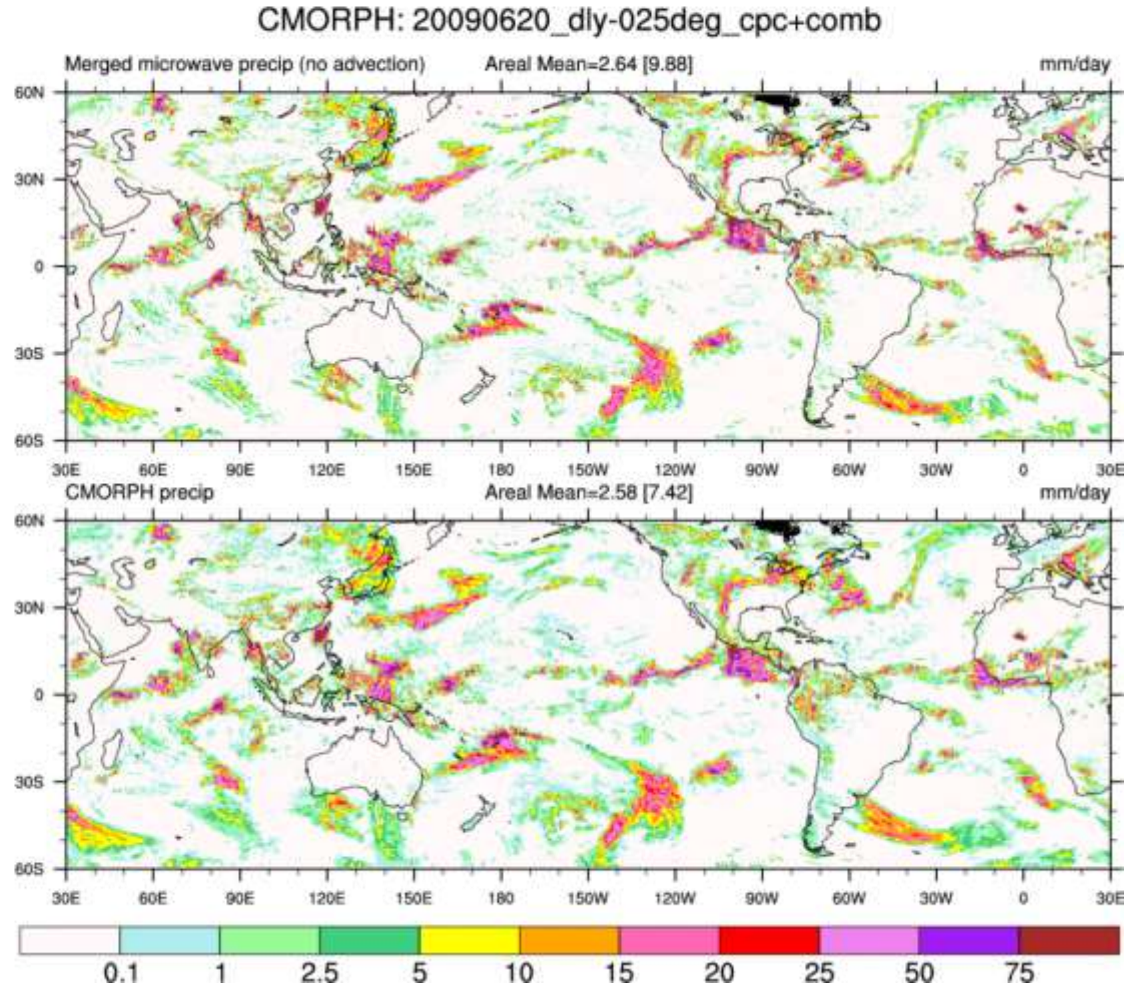
- Global Precipitation Climatology Project (GPCP), monthly 2.5-deg from 1979
- Multiple satellite and *in situ* estimates
  - Relative satellite bias removed
- Coarser but much longer record for climate studies
  - Can be used to show long-term changes, like trends
  - A 1-deg daily available from Oct 1996



Rainfall trend (1979-2013) in GPCP v 2.2. Only trends significantly different from zero at 95% are shown in color. The pattern in the Pacific largely resembles what is expected in response to ENSO, and may be related to decadal variability (Dai 2013). (Fig. from A. Pendergrass)

Example: CMORPH

- Climate Prediction Center MORPHing technique (CMORPH), hourly 0.25-deg since December 2002
  - MW for rain rate, IR for advection
- Most skill from MW estimates
  - Sample without (top) and with (bottom) advection for June 20, 2009. [Climate Data Guide; D.Shea]
- Advection important for hourly estimates
- New CMORPH2: Incorporates more satellite inputs & model inputs for 0.05-deg, 30 min, pole-to-pole analysis



National Center for Atmospheric Research Staff (Eds). Last modified 06 Oct 2017. **"The Climate Data Guide: CMORPH (CPC MORPHing technique): High resolution precipitation (60S-60N)."** Retrieved from https://climatedataguide.ucar.edu/climate-data/cmorph-cpc-morphing-technique-high-resolution-precipitation-60s-60n.

Product Stability & Improvements

- Stability depends on:
  - Stable inputs from satellites or *in situ* sources
  - A continued need for the product
  - Community support for maintenance and upgrades

- Improvements:
  - Products require upgrades to maintain usefulness
  - Some are obsolete but still used (*i.e.*, weekly 1-degree OI SST)
  - Improvements require support (no free lunch)

Public Wants and Needs

- Needs: for physical or economic safety
- Wants: for perceived need or convenience
- Communication of product value
  - Useful to have partners in universities and weather-reporting centers
  - Communicate trade offs: what's it cost, what's its value
- Knowing public needs and wants
  - Listen and consider what the general public says
  - Evaluate events that cause social disruptions
  - Develop products that can minimize future disruptions

Summary and Conclusions

- Blending can refer to a number of different methods for combining and interpolating data
- Different methods are needed to best meet different needs
- Continued support is needed to maintain product value
- Outreach efforts can help gauge what products will be most useful

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

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NOAA/STAR/SOCD

08/30/2018

Outline

- Team Members and Affiliations
- Motivation
- Blended Product Development
  - Inputs needed for the Blended Product Algorithm
  - Technical Approach
  - Product Examples/Outputs
  - Product Evaluation/Validation/Tools
- Implementation status
- Future Algorithm Improvements
- Summary and Path Forward

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

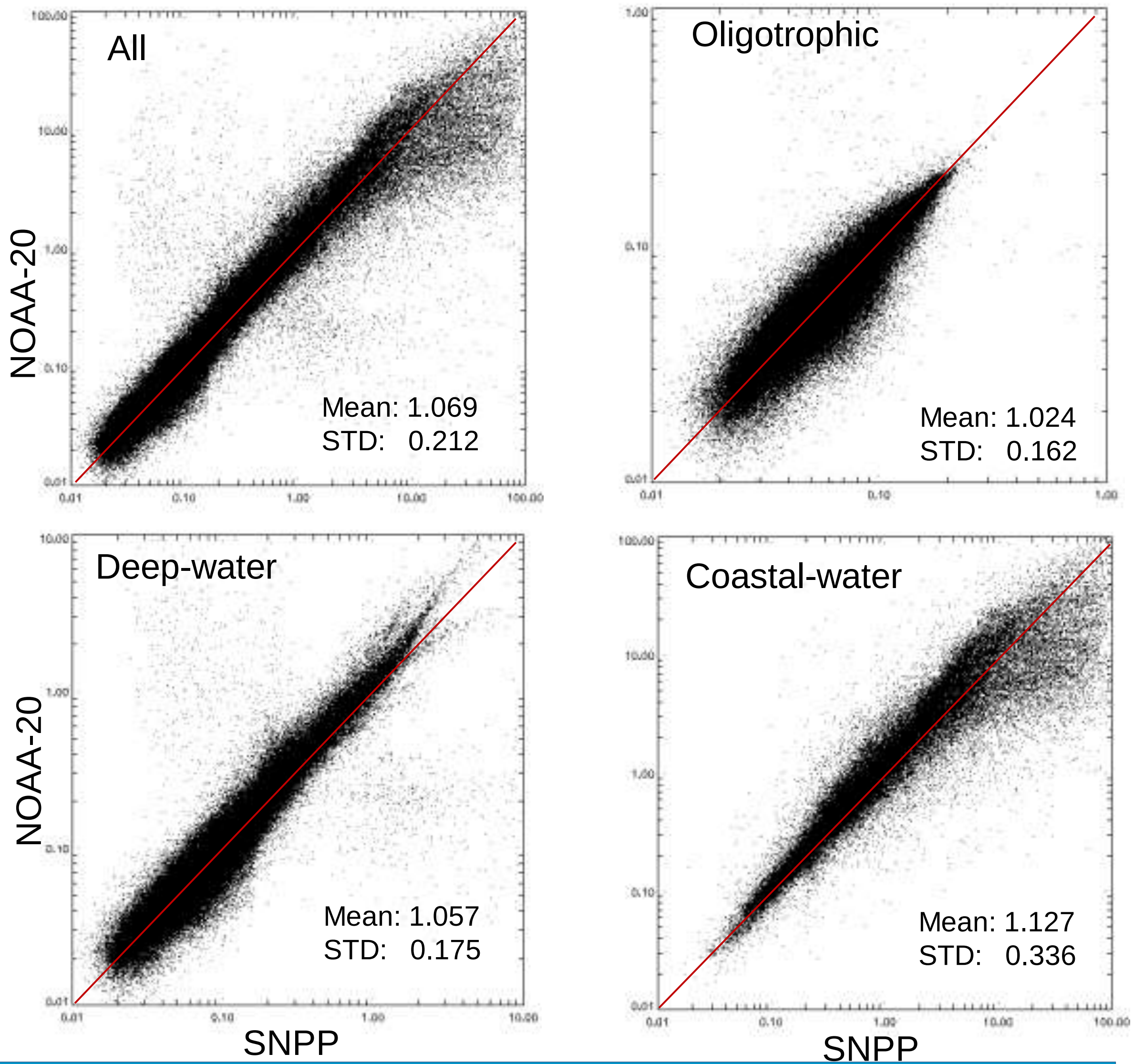
Required Satellite Input Data Products

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

Merging S-NPP and NOAA-20 Ocean Color Data

06/21/2018 Chl-a (OCI)

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.

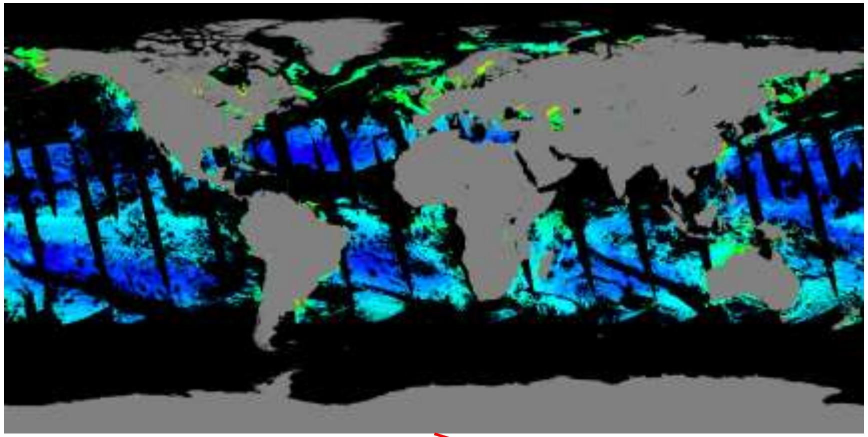


Blended Product Development

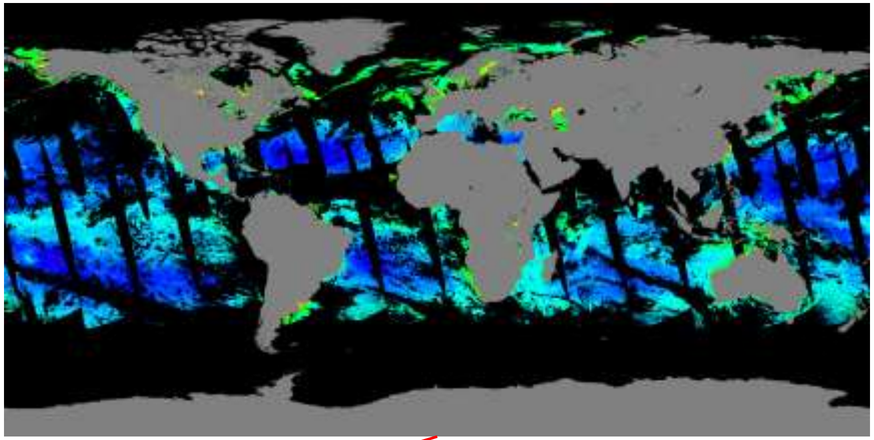
Merging S-NPP and NOAA-20 Ocean Color Data

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

SNPP

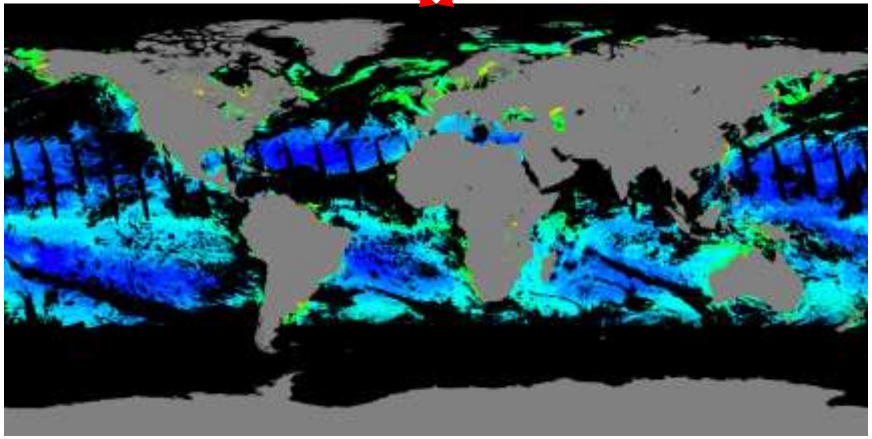


NOAA-20



Merging (L3bin)

Merged



Reconstruct Global Daily Data Using DINEOF

- 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).

Product(s) Examples/Outputs

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

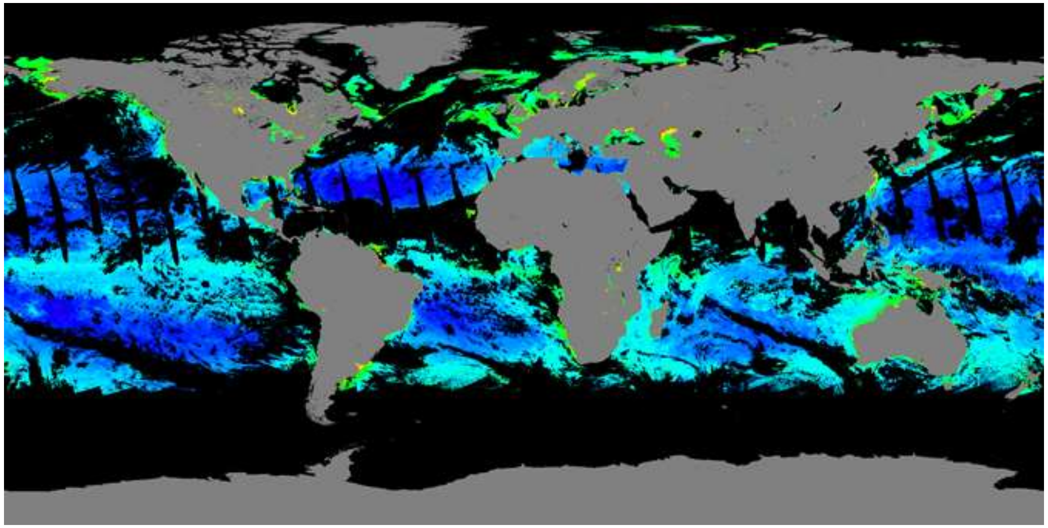
Output Data Products

	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	$K_d(\mathrm{PAR})$	SNPP/NOAA-20	Level-3 Binned	OC Team

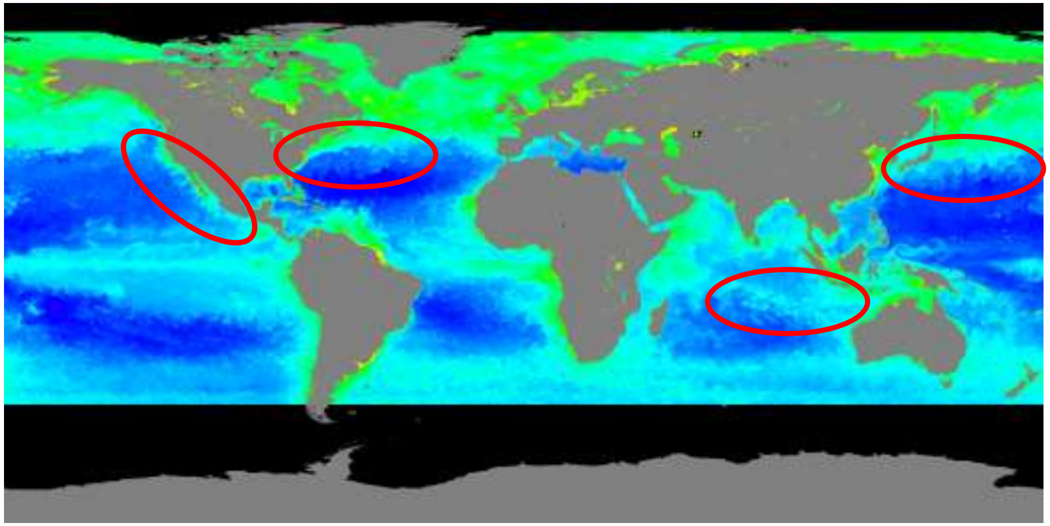
Example of Gap-filled Products

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

Merged product

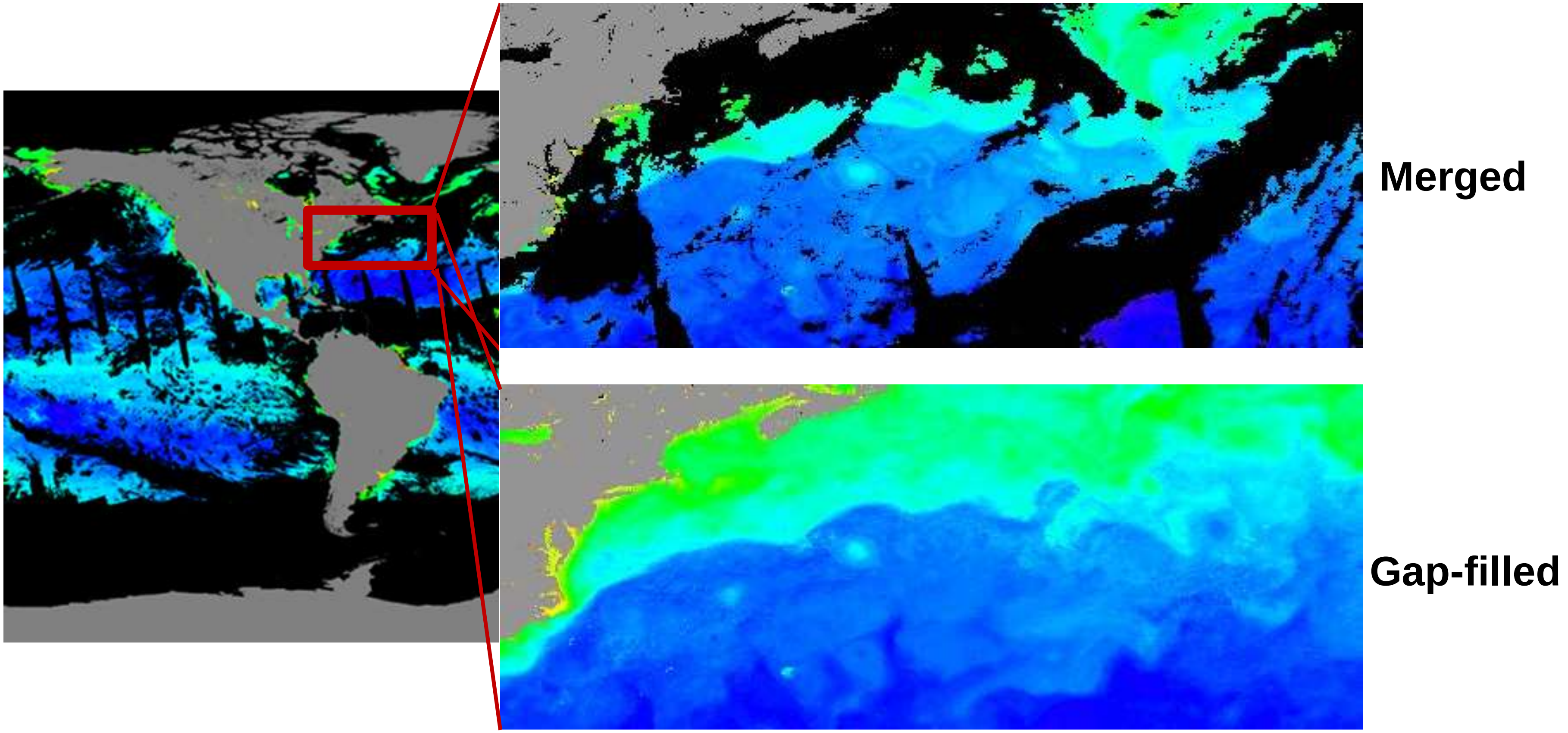


Gap-filled Product



Example of Gap-filled Products (1)

Movie of eddies in the north Atlantic

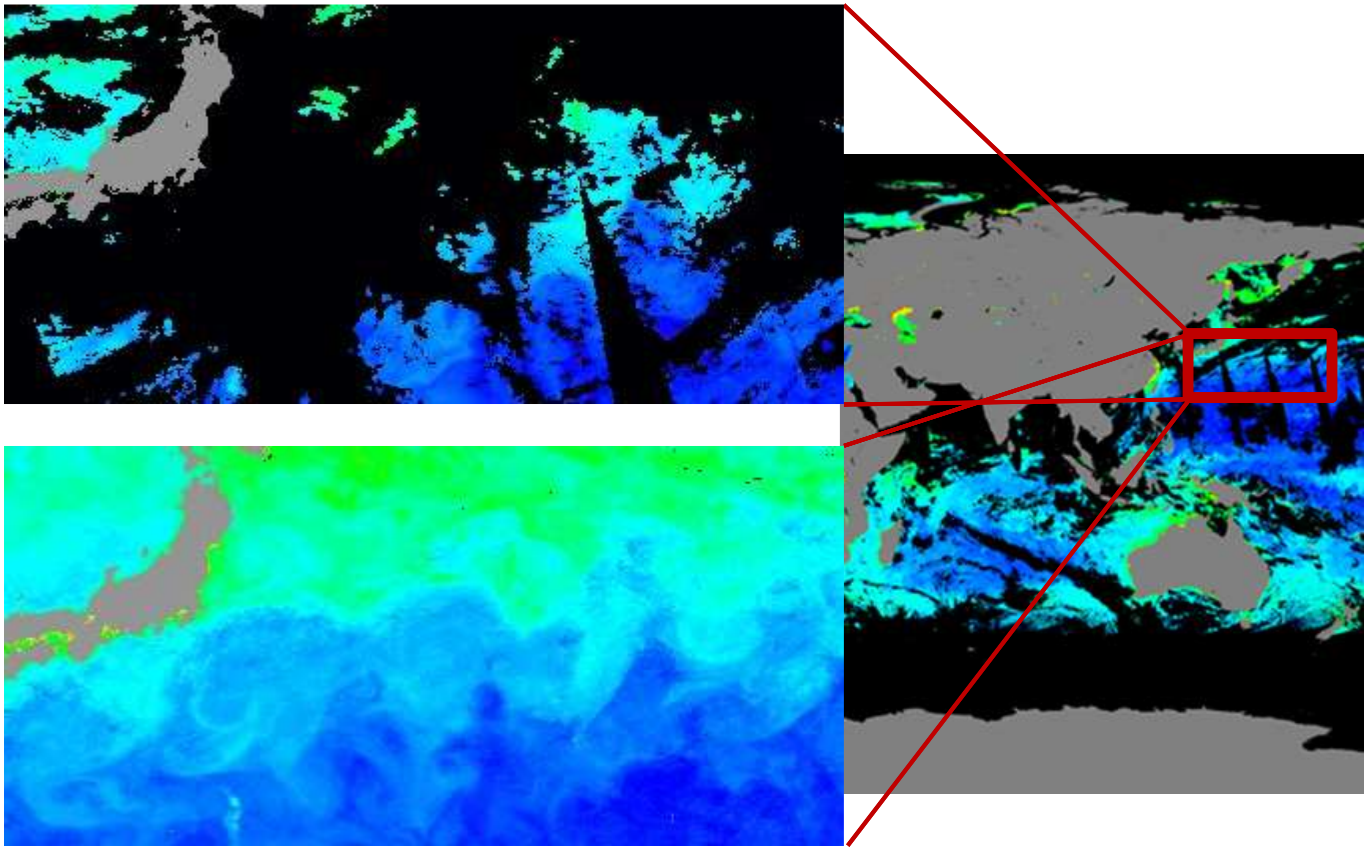


Example of Gap-filled Products (2)

Movie of eddies in the north Pacific

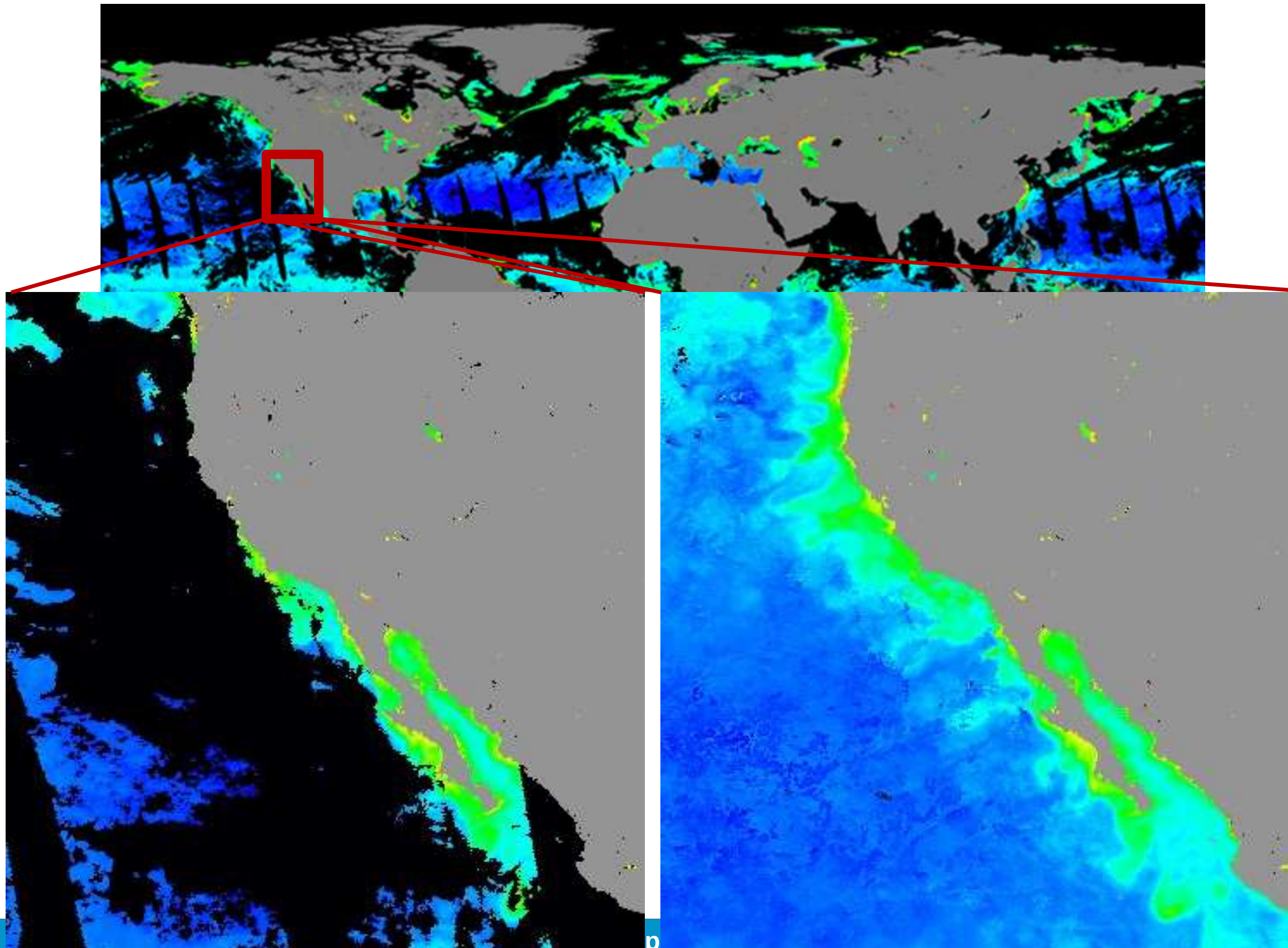
Merged

Gap-filled



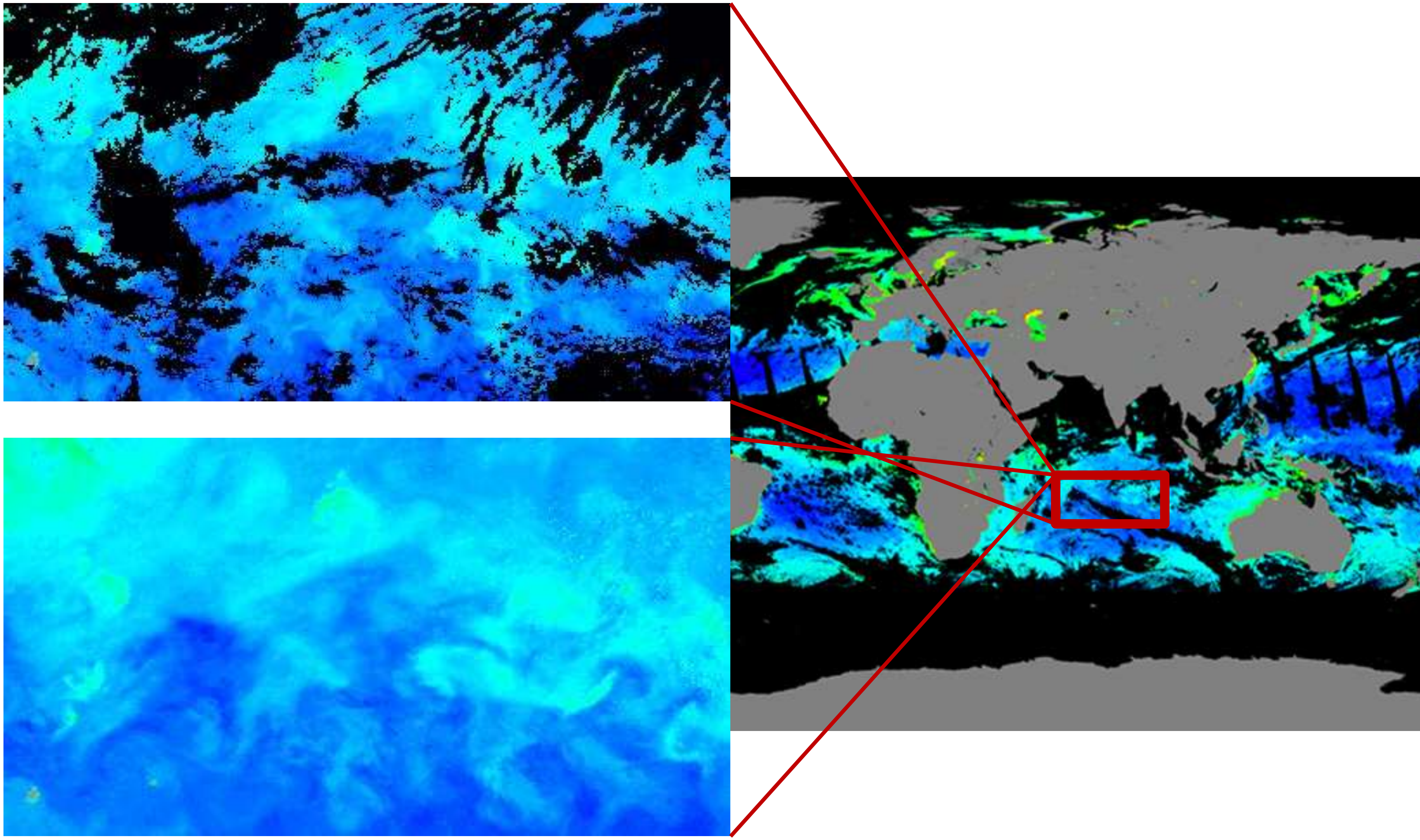
Example of Gap-filled Products (3)

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

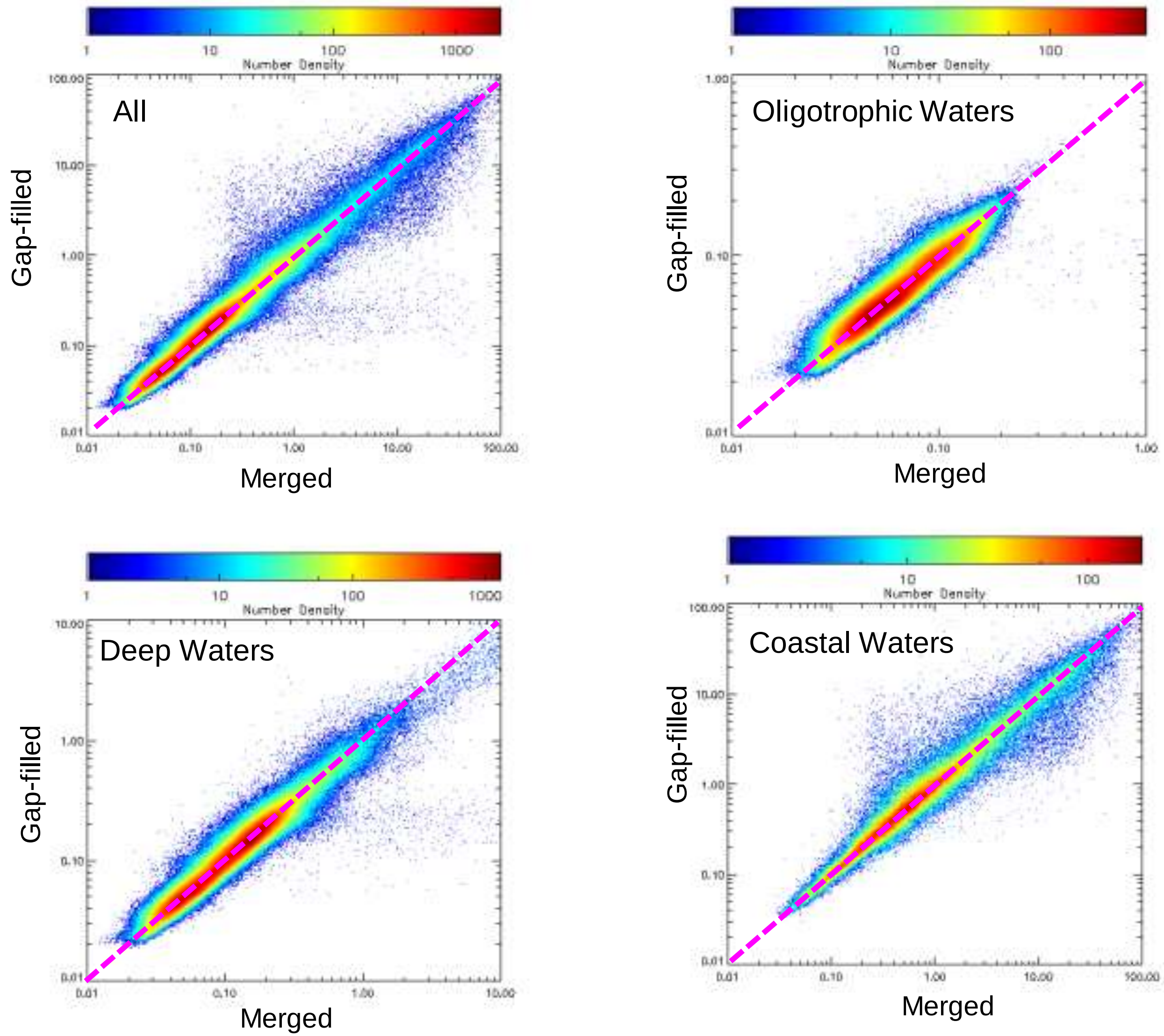


Example of Gap-filled Products (4)

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

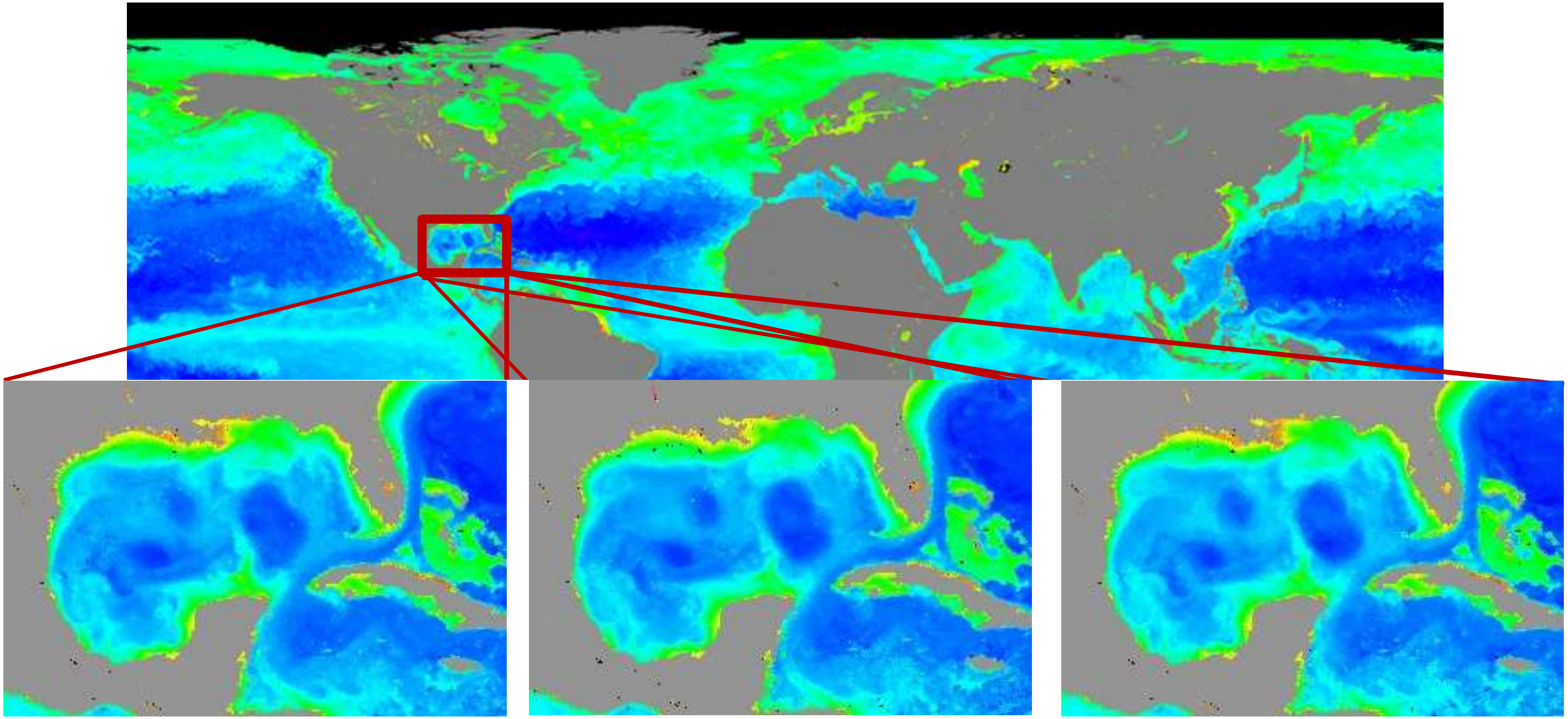


Gap-filled Results Evaluation



VIIRS Chl-a Merged vs. SNPP or NOAA-20

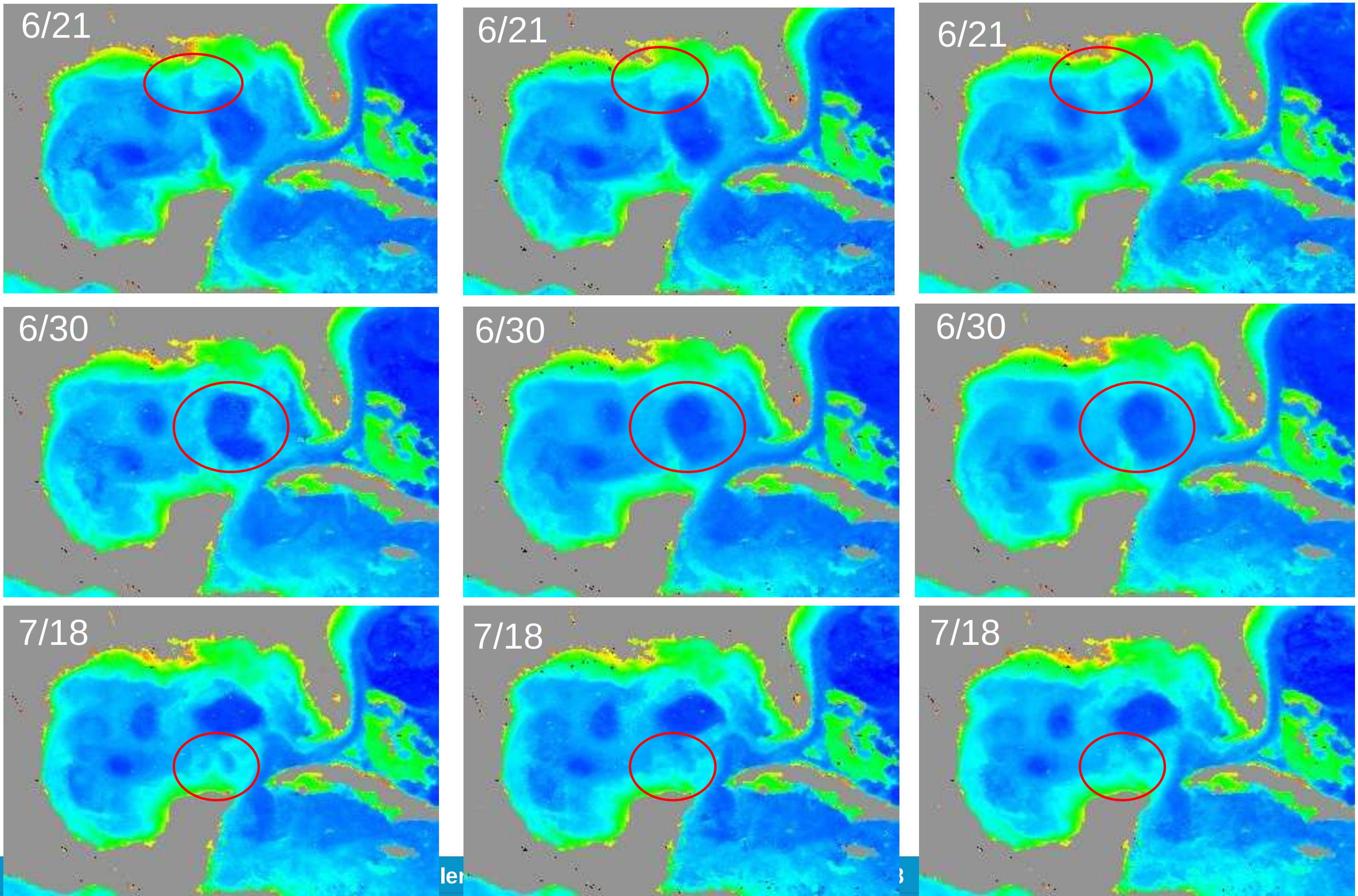
Movies (6/19–7/18)



Merged **SNPP** **NOAA-20**

VIIRS Chl-a Merged vs. SNPP or 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
All	1.007	0.191	1.007	0.206	1.012	0.200
Deep Water	1.010	0.171	1.009	0.191	1.015	0.182
Coastal & Inland Water	0.995	0.281	0.995	0.273	0.997	0.287
Oligotrophic Water	1.007	0.157	1.009	0.182	1.012	0.164

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-processer.
- 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.