# Reconstruction of Missing Data in the VIIRS Global Ocean Color Images Using the DINEOF Method

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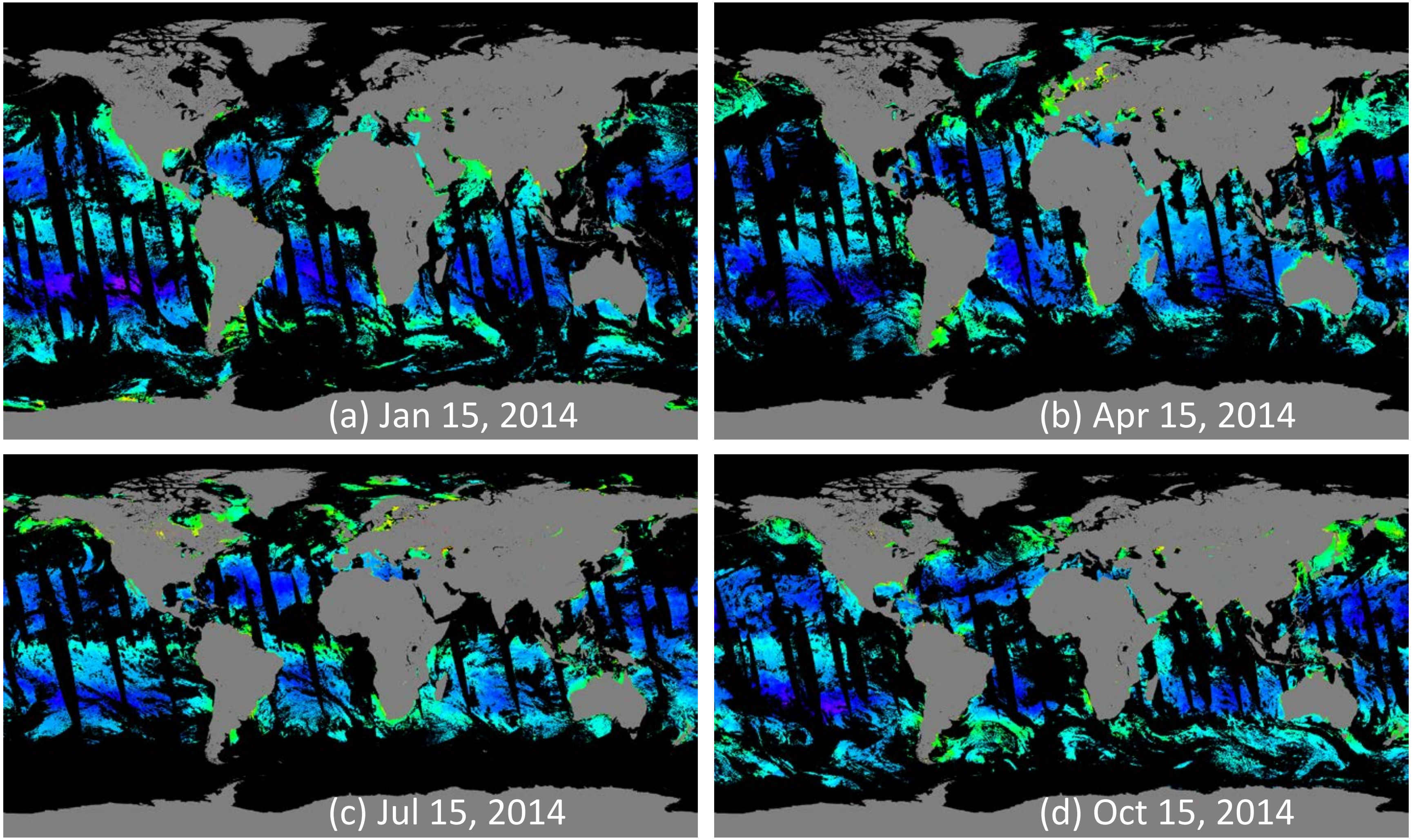
# Introduction

- Visible Infrared Imaging Radiometer Suite (VIIRS) ocean color images, such as normalized water-leaving radiances $nL_w(\lambda)$, 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, there are lots of missing pixels in the ocean color images due to clouds and various other reasons.
- 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 VIIRS global daily, 8-day, and monthly composite ocean color images.

# VIIRS Original Daily Chl-a Images

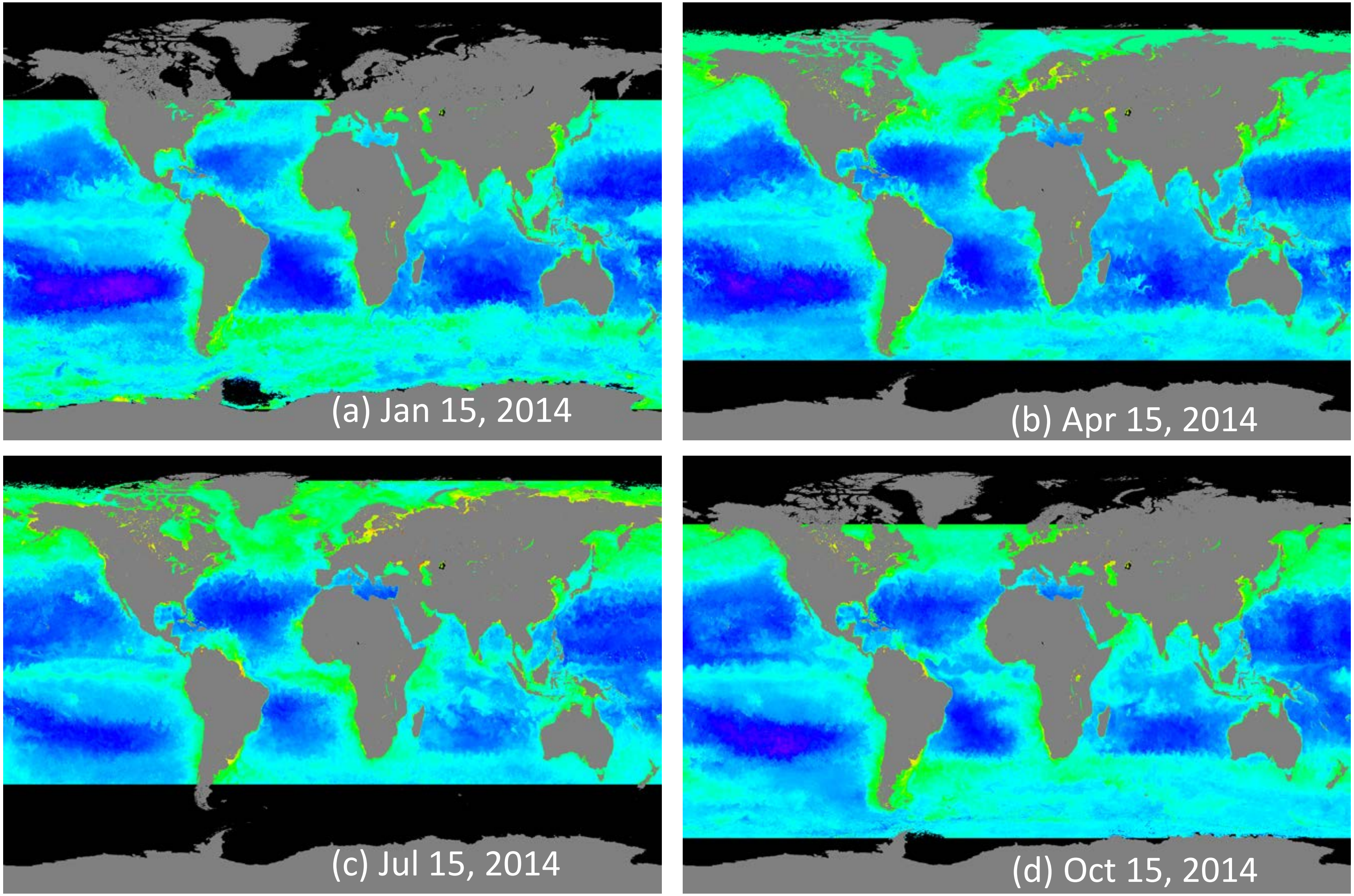



Original VIIRS daily Chl-a for (a) Jan. 15, (b) Apr. 15, (c) Jul. 15 and (d) Oct. 15, 2014, generated from VIIRS global daily Level-3 binned file.

# Reconstruct Global Daily Data Using DINEOF

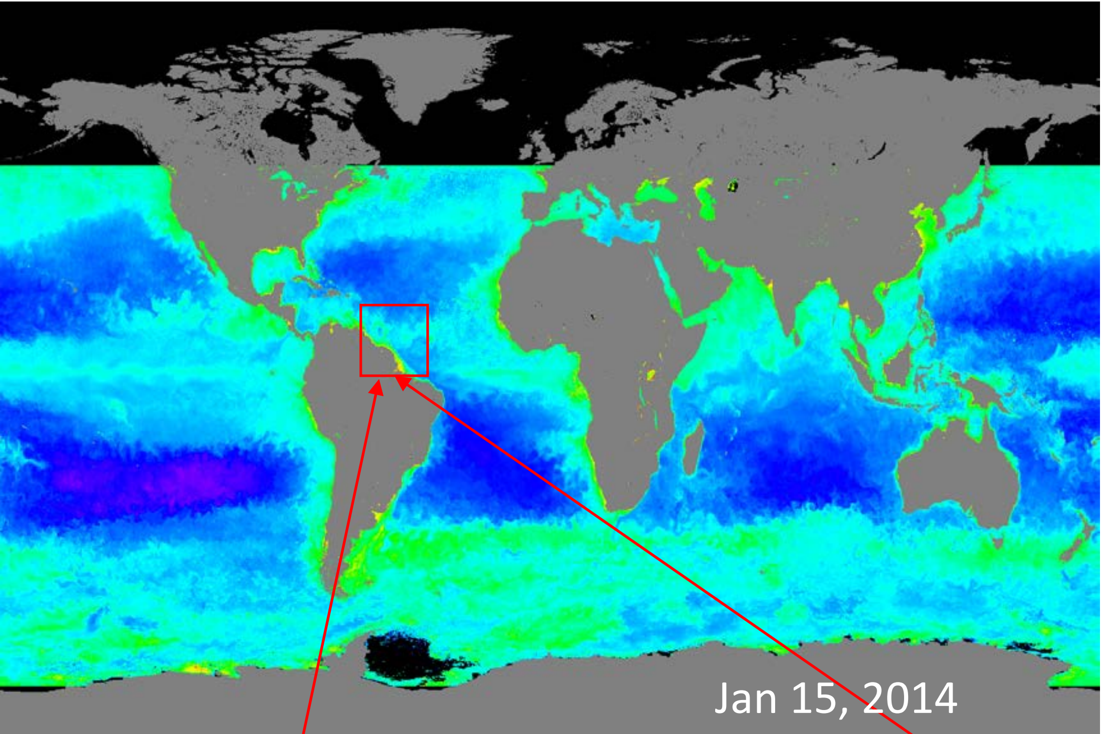
- Input: Global daily Level-3 binned data file in Jan, Apr, Jul and Oct 2014.
- To increase DINEOF performance, global data are divided into 16 zonal sections: 80°S-70°S, 70°S-60°S, … 10°S-Equator, Equator-10°N, 10°-20°N, … 60°-70°N, 70°-80°N.
- Replace pixels that are missing for the whole month with climatology value.
- Apply DINEOF on each of the 16 zonal sections, fully reconstruct all pixels, including non-missing pixels.
- Output: Fully reconstructed global daily Level-3 binned data.

# Fully Reconstructed Daily Chl-a Images



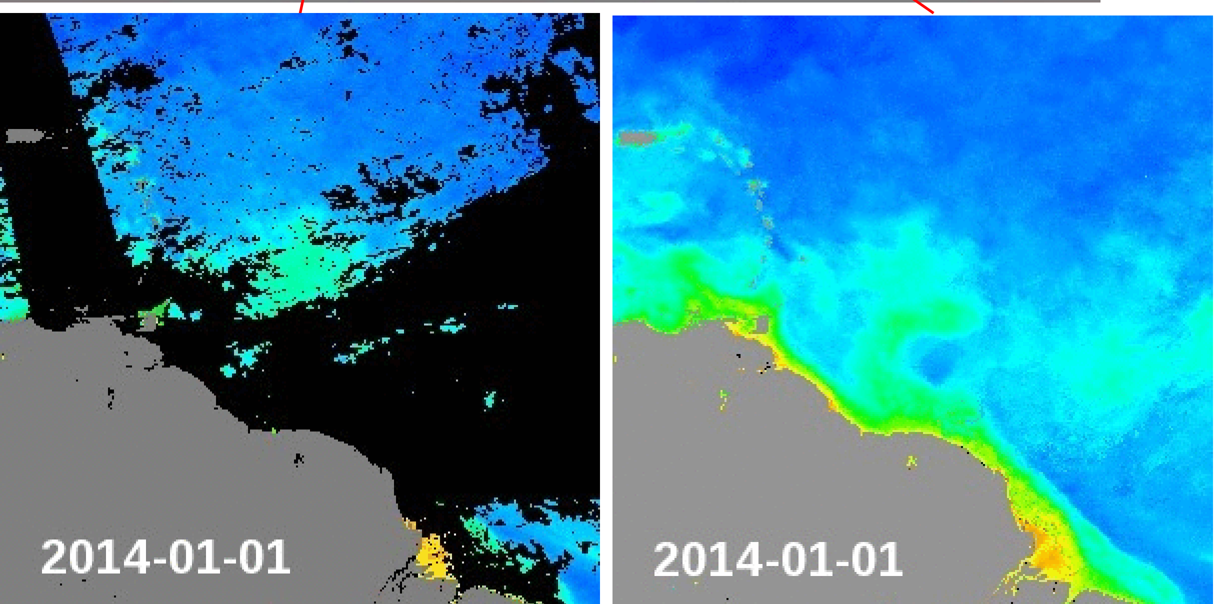

Fully reconstructed daily Chl-a for (a) Jan. 15, (b) Apr. 15, (c) Jul. 15, and (d) Oct. 15, 2014.

# Examples of Reconstructed Chl-a Images (1)




**Eddies near Amazon River**

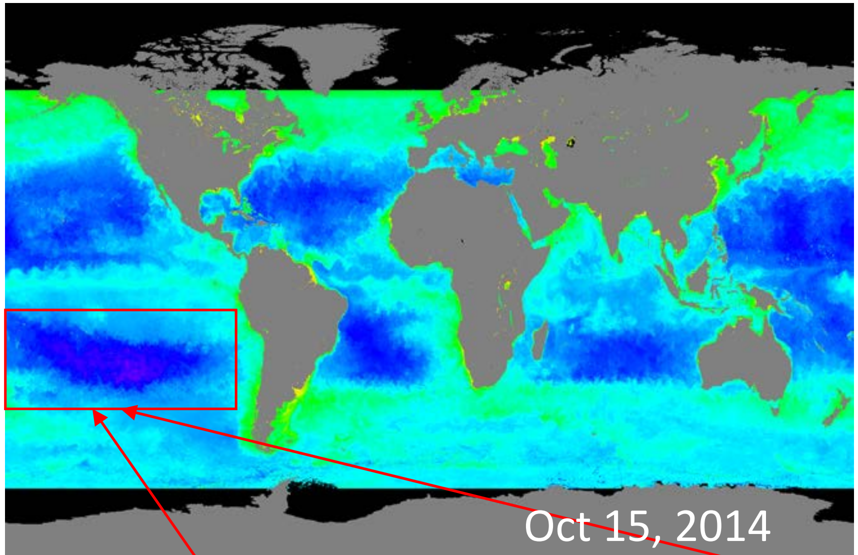
January 1-31, 2014



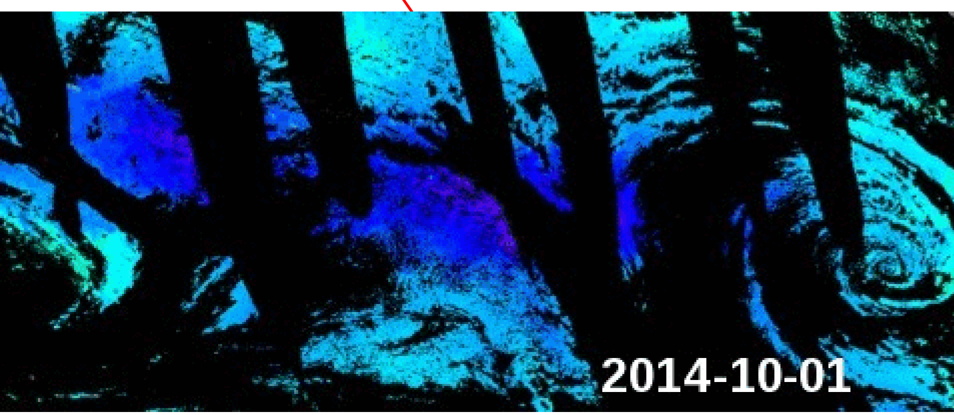

**Original** **Reconstructed**

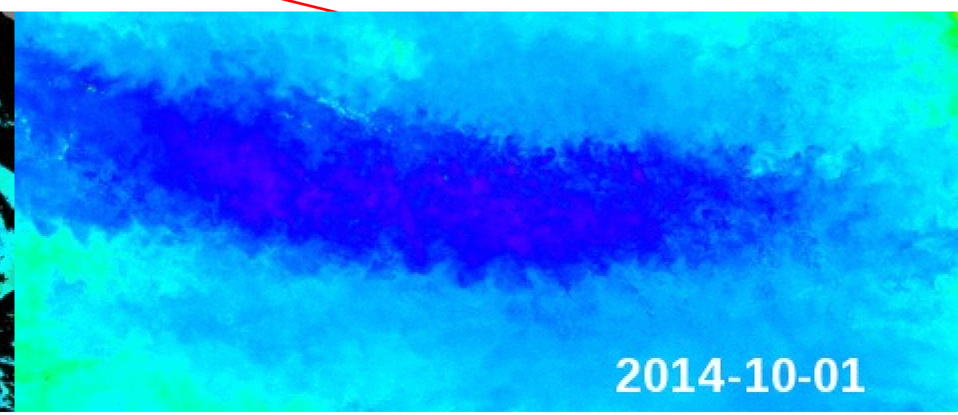
We can now see **eddy movement** in the reconstructed Chl-a images

# Examples of Reconstructed Chl-a Images (2)




**South Pacific Gyre**
Oct. 1-31, 2014



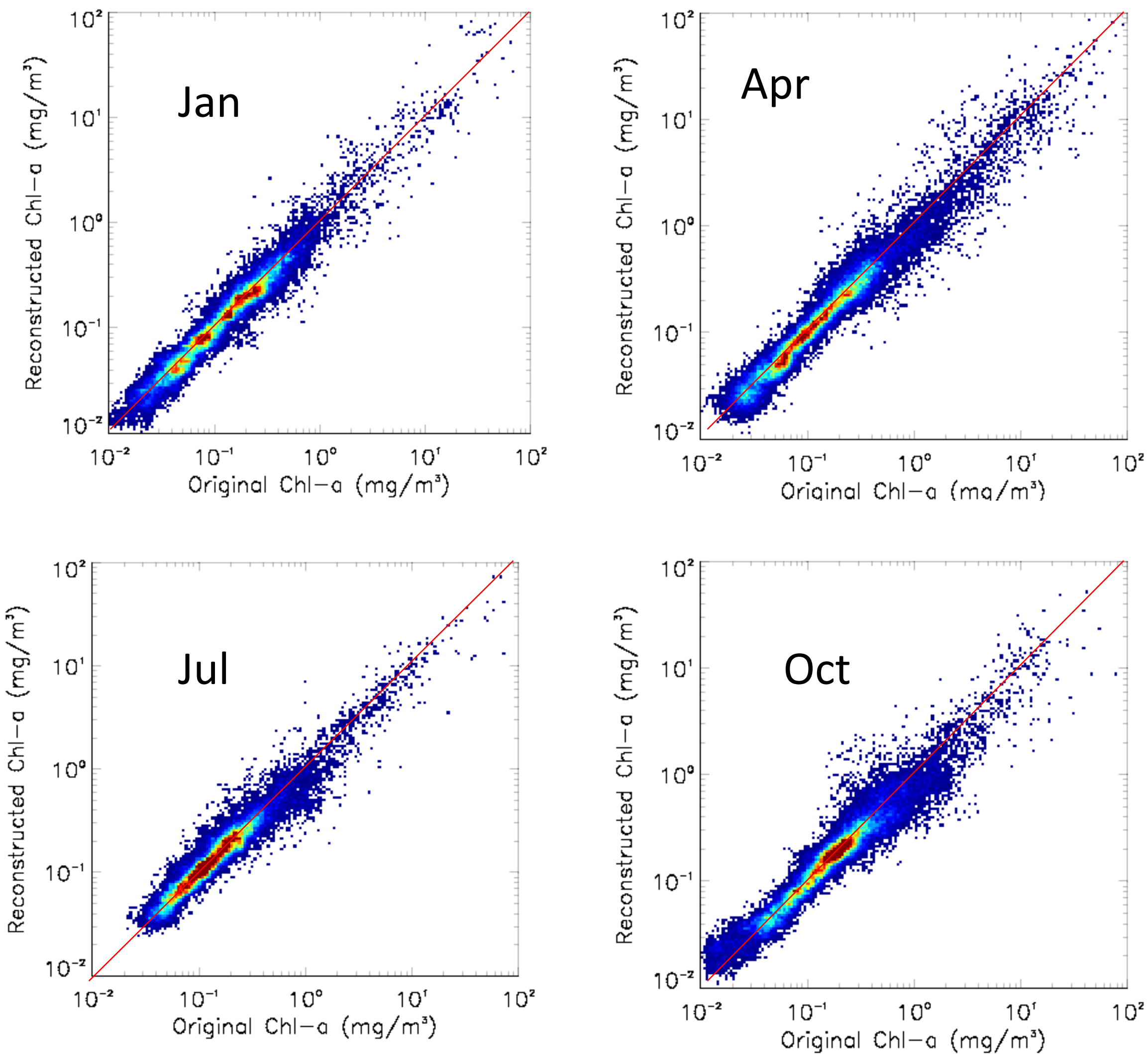




**Original**

**Reconstructed**

We can now see Gyre coverage variation in the reconstructed Chl-a images

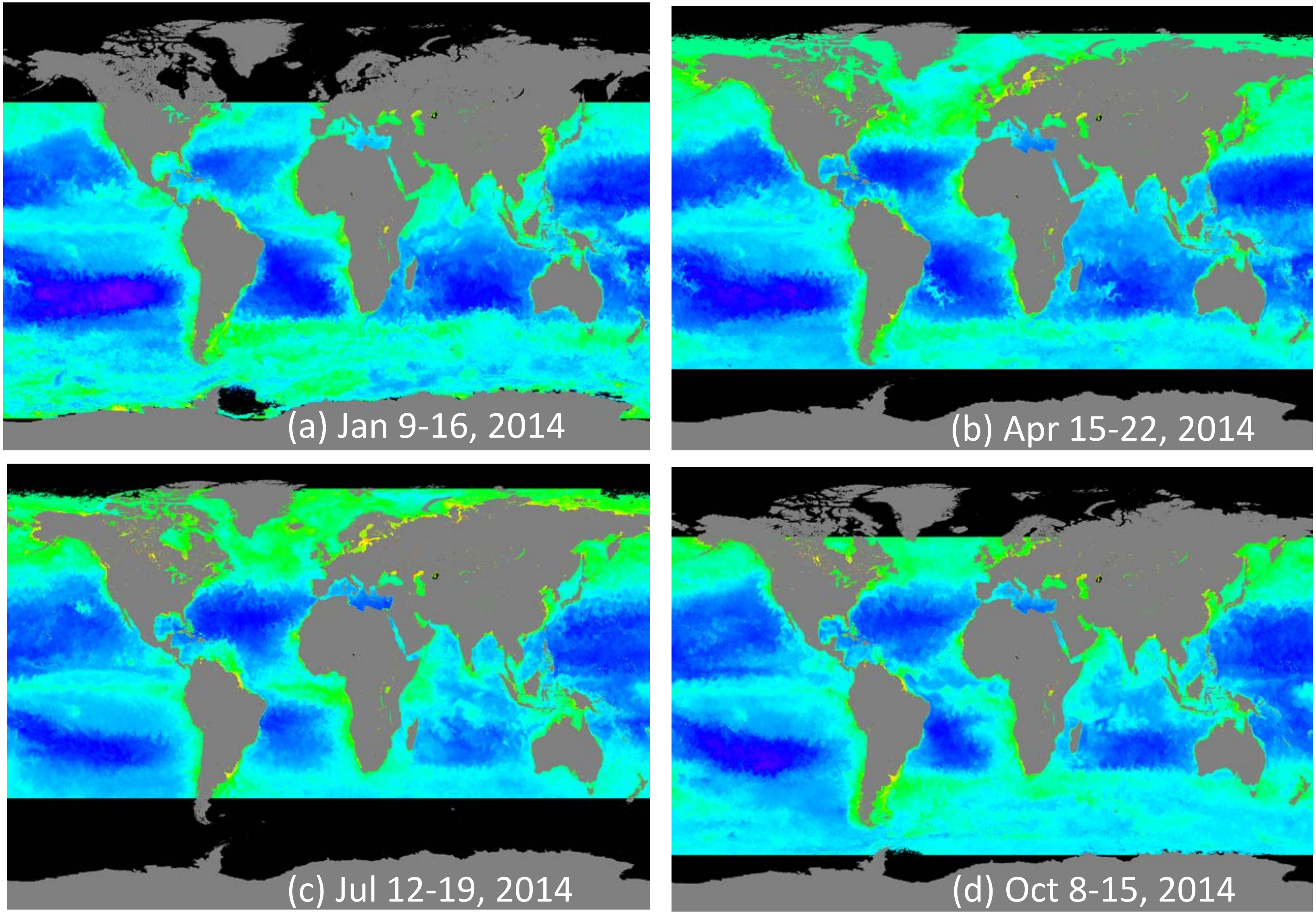
# Validation with 5% valid pixels




Reconstructed/original ratio

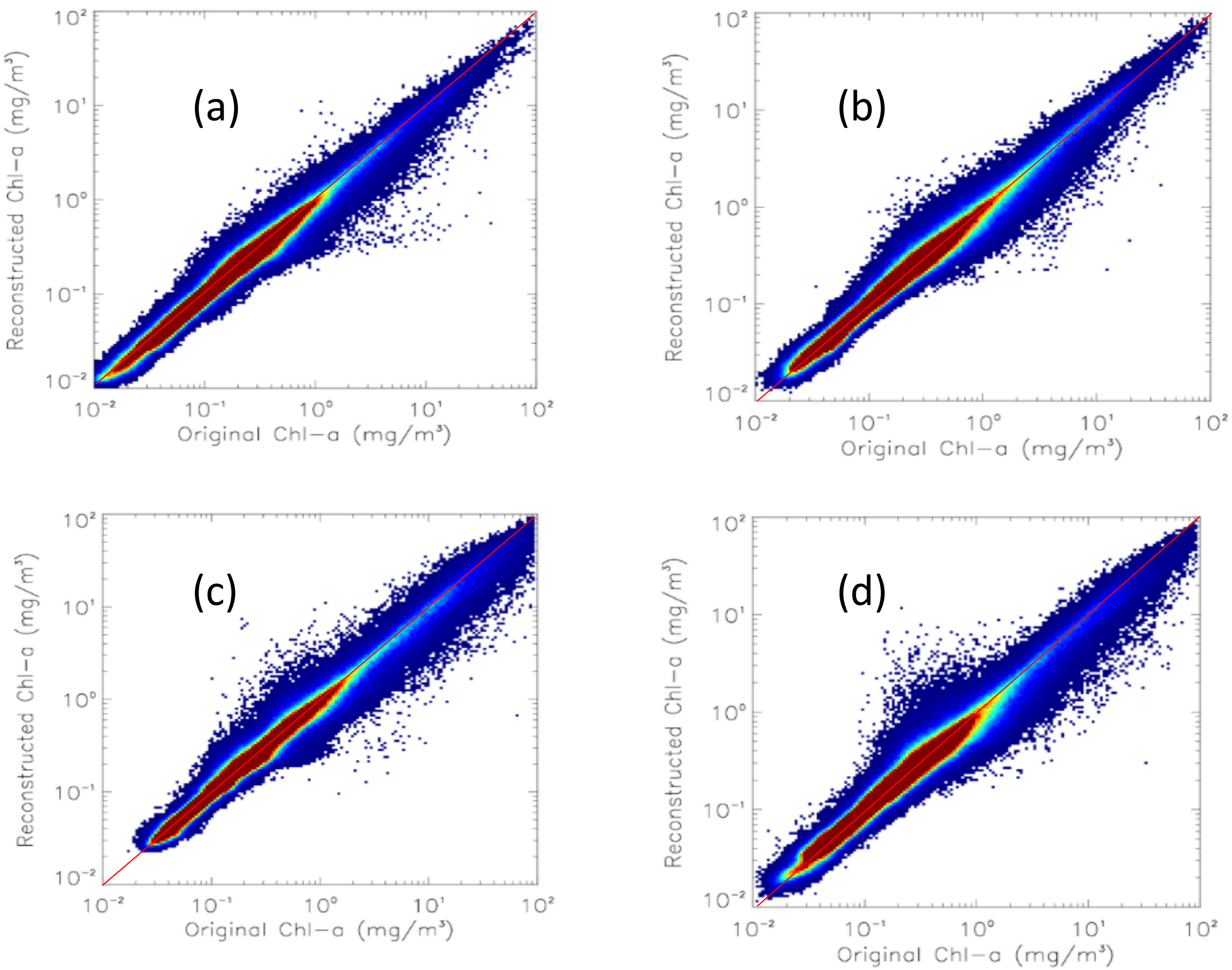
| Month | Mean | Median | STD |
|---|---|---|---|
| Jan | 1.022 | 0.996 | 0.261 |
| Apr | 1.033 | 0.996 | 0.319 |
| Jul | 1.015 | 0.986 | 0.246 |
| Oct | 1.021 | 0.985 | 0.354 |

# Reconstruct Global 8-Day Data Using DINEOF



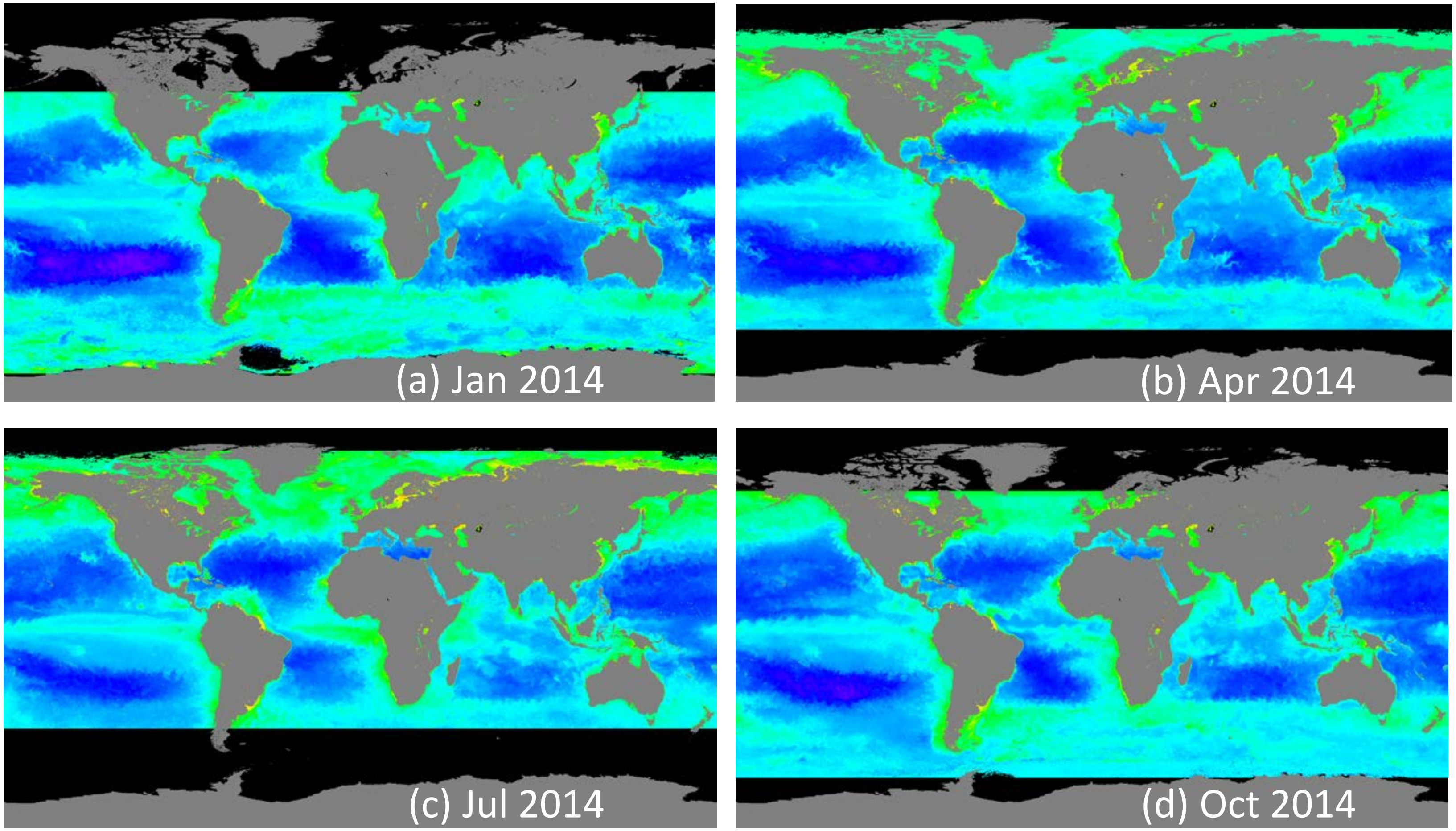

Reconstructed 8-day Chl-a for (a) Jan. 15, (b) Apr. 15, (c) Jul. 15, and (d) Oct. 15, 2014.

# Validations and Evaluations



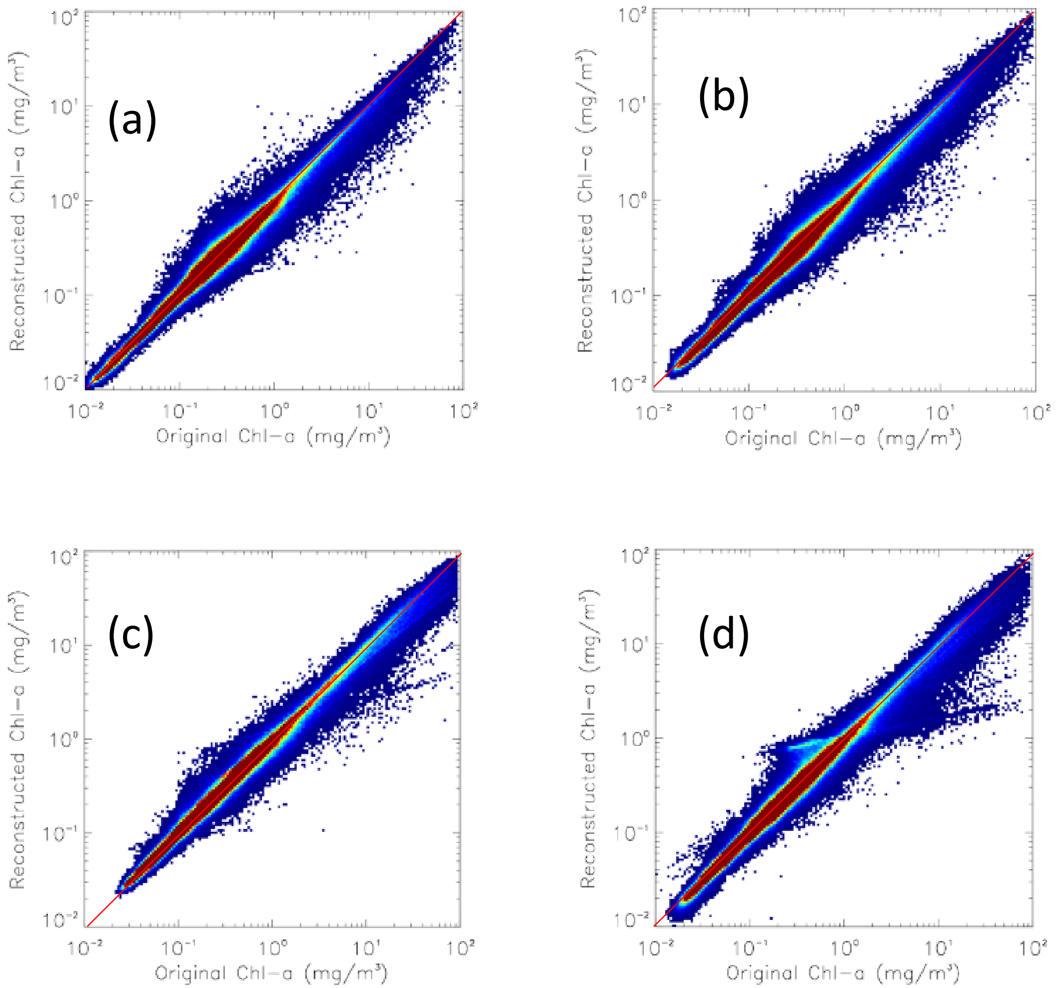

Scatter plot of reconstructed vs. original 8-day Chl-a for (a) Jan. 9-16, (b) Apr. 15-22, (c) Jul. 12-19, and (d) Oct. 8-15, 2014

# Reconstruct Global Monthly Data Using DINEOF



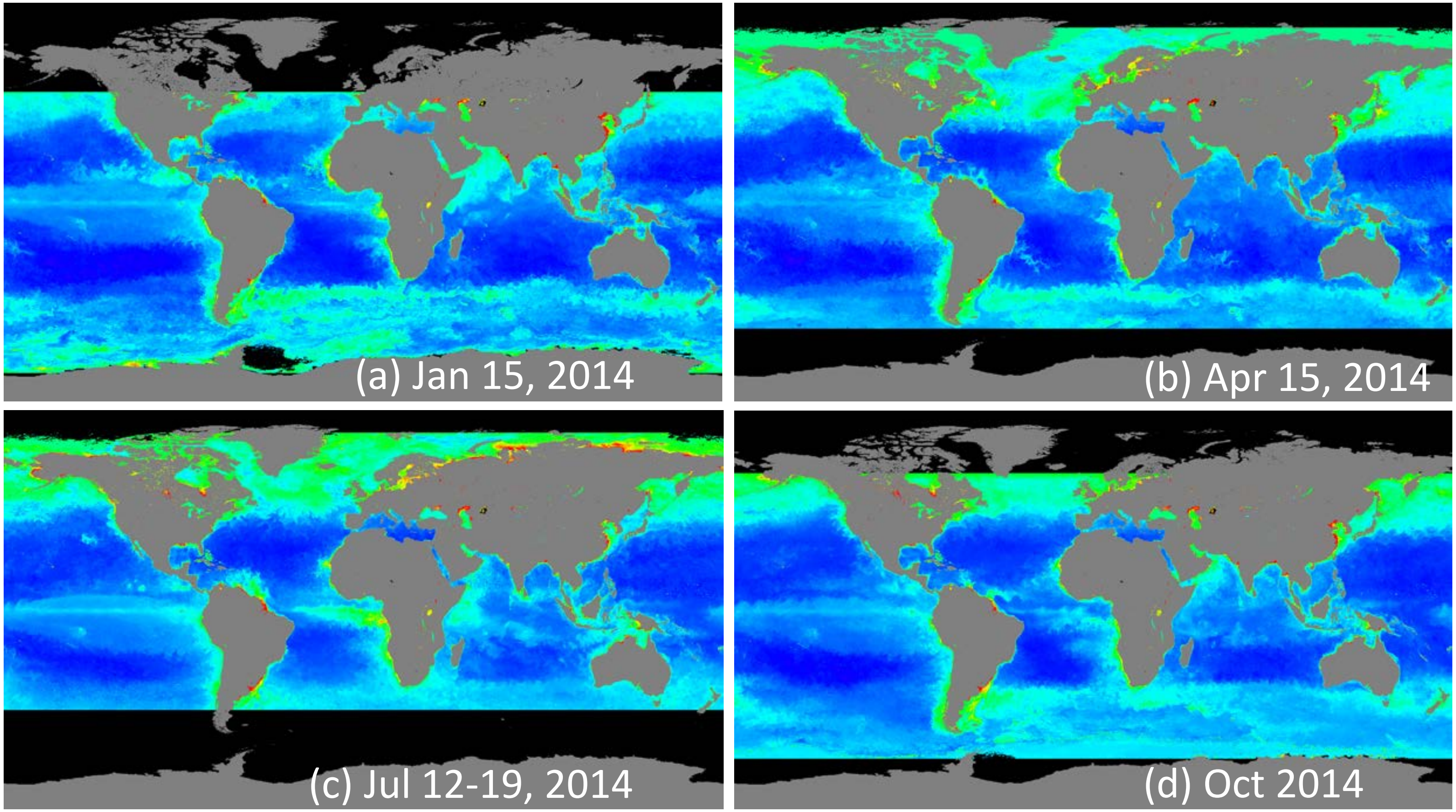

Reconstructed monthly Chl-a for (a) Jan., (b) Apr., (c) Jul., and (d) Oct. 2014.

# Validations and Evaluations



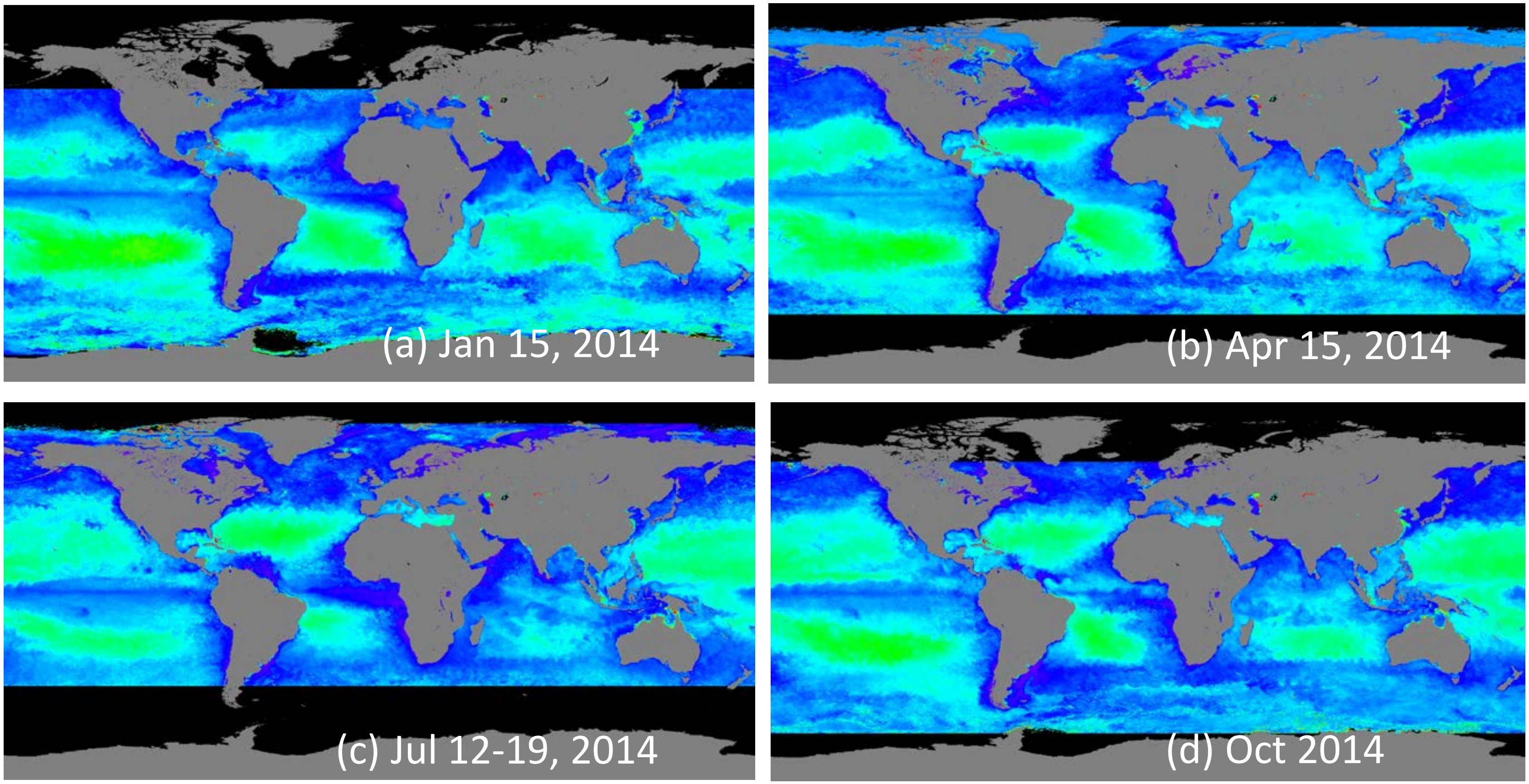

Monthly scatter plot for (a) Jan., (b) Apr., (c) Jul., and (d) Oct. 2014

# Reconstruct Global $K_d$(490) Data Using DINEOF



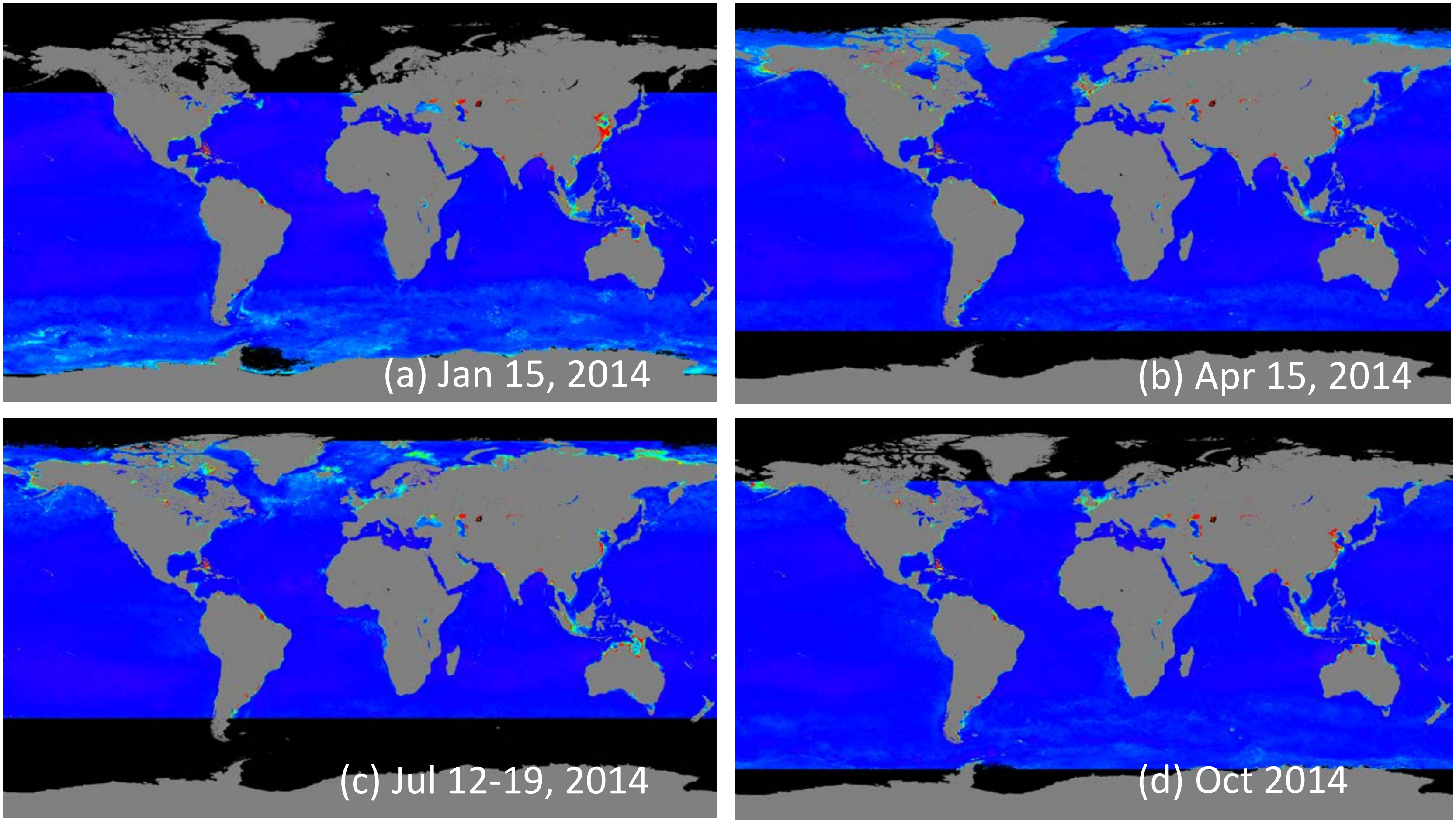

Reconstructed daily, 8-day, monthly $K_d$(490) for (a) Jan. 15, (b) Apr. 15, (c) Jul. 12-19 8-day, and (d) Oct monthly in 2014.

# Reconstruct Global $nL_w(443)$ Data Using DINEOF




Reconstructed daily, 8-day, monthly $nL_w(443)$ for (a) Jan. 15, (b) Apr. 15, (c) Jul. 12-19 8-day, and (d) Oct. monthly in 2014.

# Reconstruct Global $nL_w$(551) Data Using DINEOF




Reconstructed daily, 8-day, monthly $nL_w$(551) for (a) Jan. 15, (b) Apr. 15, (c) Jul. 12-19 8-day, and (d) Oct. monthly in 2014.

**Table 1.** Recon/original Chl-a mean and STD for 8-day and monthly

| Date | Mean | STD |
|---|---|---|
| V20140092014016_test_L3.nc | 0.984342 | 0.152496 |
| V20141052014112_test_L3.nc | 0.983340 | 0.153924 |
| V20141932014200_test_L3.nc | 0.981758 | 0.157412 |
| V20142812014288_test_L3.nc | 0.981371 | 0.171772 |
| V201401_test_L3.nc | 0.988757 | 0.125213 |
| V201404_test_L3.nc | 0.990541 | 0.124521 |
| V201407_test_L3.nc | 0.981305 | 0.115728 |
| V201410_test_L3.nc | 0.979550 | 0.137193 |

**Table 2.** Recon/original $K_d(490)$ mean and STD for 8-day and monthly

| Date | Mean | STD |
|---|---|---|
| V20140092014016_test_L3.nc | 0.991244 | 0.108033 |
| V20141052014112_test_L3.nc | 0.989462 | 0.110404 |
| V20141932014200_test_L3.nc | 0.990725 | 0.121529 |
| V20142812014288_test_L3.nc | 1.02204 | 0.125919 |
| V201401_test_L3.nc | 0.995703 | 0.104477 |
| V201404_test_L3.nc | 0.998743 | 0.0988738 |
| V201407_test_L3.nc | 0.995841 | 0.107785 |
| V201410_test_L3.nc | 1.00713 | 0.110283 |

# Summary and Conclusions

- DINEOF is used to fill gap pixels in VIIRS global Level-3 data for Chl-a, $K_d(490)$ and $nL_w(\lambda)$.
- In the reconstructed daily Level-3 images, variations of both large-scale and small-scale dynamic features are captured.
- The reconstructed pixels are validated with 5% of good pixels that are artificially treated as mixing pixels.
- 8-day and monthly data are also reconstructed by binning the non-gap daily global Level-3 data, and results are quite reasonable.