Study on the Ocean Colour Fluorescence Product

Product Catalogue

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Contents

1 The OC-Fluo algorithm

We investigated and developed a new Ocean Colour Fluorescence Processor for Sentinel-3 OLCI and validated the fluorescence product.

Phytoplankton absorb sun light and use this energy through photosynthesis to produce organic material. Chlorophylls, present in all phytoplankton cells, induce two dominant peaks in absorption spectra, the primary in the blue (440 nm) and the secondary in the red part of the spectrum (675 nm). Phytoplankton also dissipate a fraction around 0.03 of the absorbed solar energy through Fluorescence which generates a radiance peak around the wavelength of 681 nm. The concept of the new fluorescence algorithm is to limit the analysis range to the red part of the spectrum and to approximate the phytoplankton fluorescence peak and the secondary absorption peak with two Gaussian functions, while all other absorption and scattering processes are captured by a slope and an offset.

The measured radiance or reflectance (the equation only expresses radiance for clarity) is described as:

$$L_{TOA}(\lambda) = O + S \cdot \lambda + APD \cdot exp((\lambda - \lambda_A)^2/w_A) + FPH \cdot exp((\lambda - \lambda_F)^2/w_F), \quad (1)$$

which is a function of 4 unknown (state) parameters:

- O = offset, accounting for atmospheric and oceanic scattering processes.
- S = slope gradient, accounting for atmospheric and oceanic scattering processes and absorption.
- APD = amplitude of Gaussian function at λ_A (absorption minimum of chlorophyll).
- FPH = amplitude of Gaussian function at λ_F (chlorophyll fluorescence peak).

(For the components see Figure 1):

The OC-Fluo algorithm delivers different products. The main products delivered from this study are L-FPH, if Level1 data is processed, and ρ_w-FPH, if Level2 data is processed, but the processor delivers also L-APD and ρ_w-APD.

All products should be correlated to the chlorophyll concentration of the observed water body. FPH is additionally influenced by solar insolation, physiological state of the phytoplankton, depth of the phytoplankton layer and phytoplankton species, whereas APD should be influenced mainly by phytoplankton biomass and only second order by other effects.

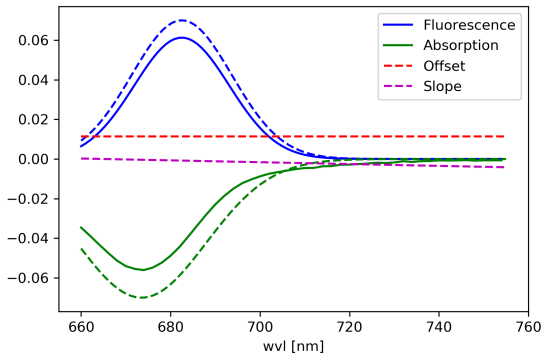

Figure 1: Components of the curve, which is fitted to the radiance spectrum.

Input	Bands	Processing Level	Description	Output	Description	Unit
L_{TOA}	Oa08-Oa12	Level-1B	spectral top-of-atmosphere radiance	L-FPH / L-APD	radiance Fluorescence Peak Height / radiance absorption peak depth	$mWm^{-2}sr^{-1}nm^{-1}$
ρ_w	Oa08-Oa12	Level-2	water-leaving reflectance / Surface directional reflectance, corrected for atmospheric attenuation, the Sun illumination geometry, and the mean Earth-Sun distance.	ρ_w-FPH / ρ_w-APD	water-leaving reflectance Fluorescence Peak Height / water-leaving reflectance absorption peak depth	-

Table 1: In- and output description of the OC-Fluo algorithm.

1.0.1 Radiance Fluorescence Peak Height (L-FPH)

L-FPH is the amplitude of the Gaussian function, which is related to the fluorescence peak (centered at 682.5 nm) that is fitted to Level-1 radiance (L_{TOA}). It is therefore a measure of the fluorescence signal in the TOA radiance spectrum without any normalization. L-FPH is given in units of $mWm^{-2}sr^{-1}nm^{-1}$.

1.0.2 Water-leaving-reflectance Fluorescence Peak Height (ρ_w-FPH)

ρ_w-FPH is the amplitude of the Gaussian function, which is related to the fluorescence peak (centered at 682.5 nm) that is fitted to Level-2 water-leaving reflectance (ρ_w). It is a measure of the fluorescence signal in the water-leaving reflectance which is dimensionless and therefore ρ_w-FPH is dimensionless. Operational OLCI L2 products are defined as the directional water-leaving reflectance. The OLCI L2 products include the corrections to the water reflectance value with the Sun at zenith, the mean Earth-Sun distance, and non-attenuating atmosphere. They do not include the BRDF corrections for viewing geometry, water optical properties, and the sky radiance distribution.

1.0.3 Radiance Absorption Peak Depth (L-APD)

L-APD is the amplitude of the Gaussian function, which is related to the absorption dip (centered at 673.5 nm) that is fitted to Level-1 radiance. It is therefore a measure of the absorption signal in the TOA radiance spectrum without any normalization. L-APD is given in units of $mWm^{-2}sr^{-1}nm^{-1}$.

1.0.4 Water-leaving-reflectance Absorption Peak Depth (ρ_w-APD)

ρ_w-APD is the amplitude of the Gaussian function, which is related to the absorption dip (centered at 673.5 nm) that is fitted to Level-2 water-leaving reflectance (ρ_w). It is therefore a measure of the absorption signal in the remote-sensing reflectance which is normalized by irradiance. ρ_w-APD is dimensionless.

Input	Bands	Processing Level	Description	Output	Description	Unit
L_{TOA}	Oa08-Oa12	Level-1B	spectral top-of-atmosphere radiance	L-FPH / L-APD	radiance Fluorescence Peak Height / radiance absorption peak depth	$mWm^{-2}sr^{-1}nm^{-1}$
ρ_w	Oa08-Oa12	Level-2	water-leaving reflectance / Surface directional reflectance, corrected for atmospheric attenuation, the Sun illumination geometry, and the mean Earth-Sun distance.	ρ_w-FPH / ρ_w-APD	water-leaving reflectance Fluorescence Peak Height / water-leaving reflectance absorption peak depth	-

2 Results at Nishinoshima volcano

2.1 Daily Images, 2020

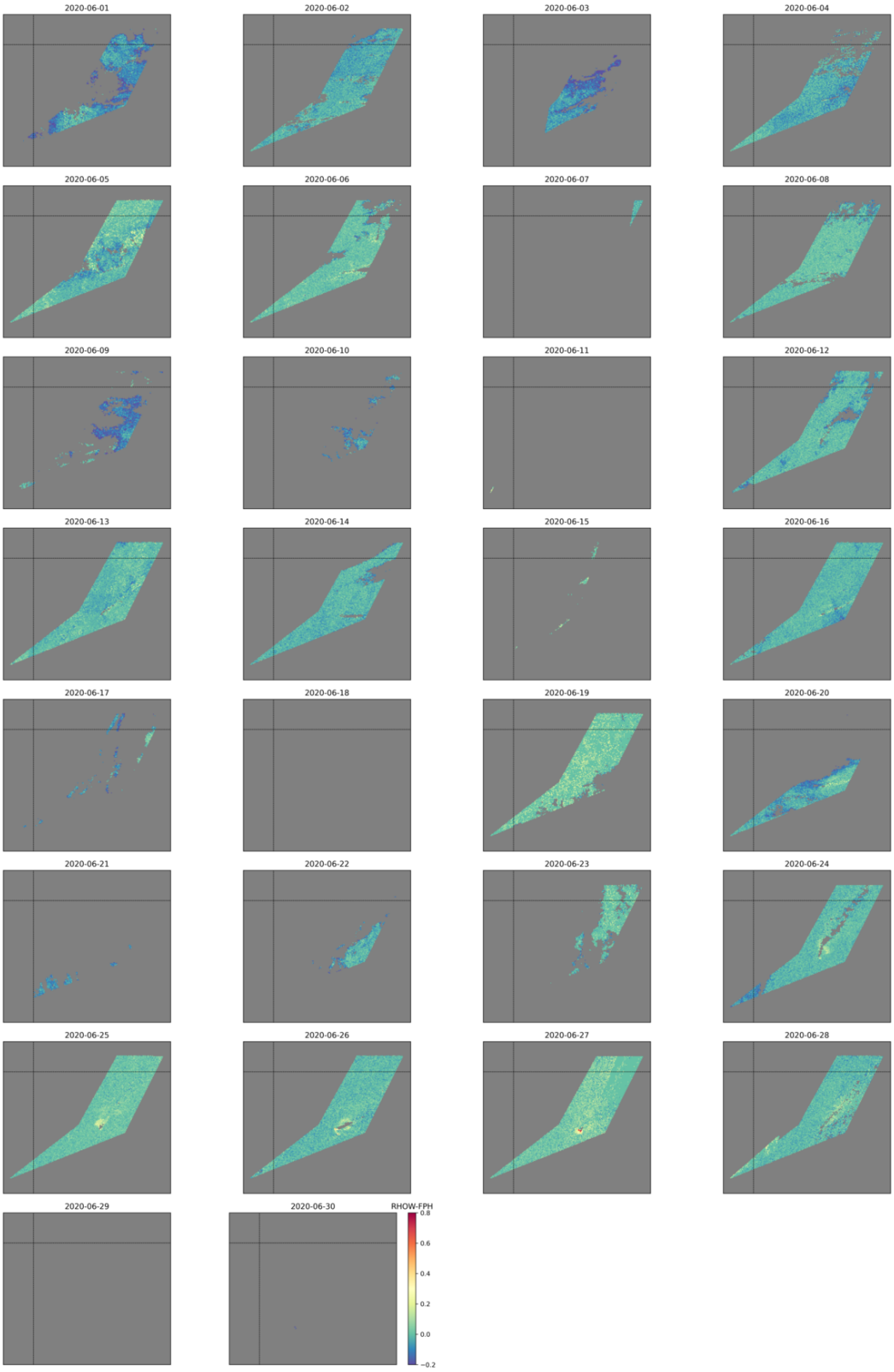

Figure 2: RHOW-FPH at Nishinoshima volcano, June 2020.

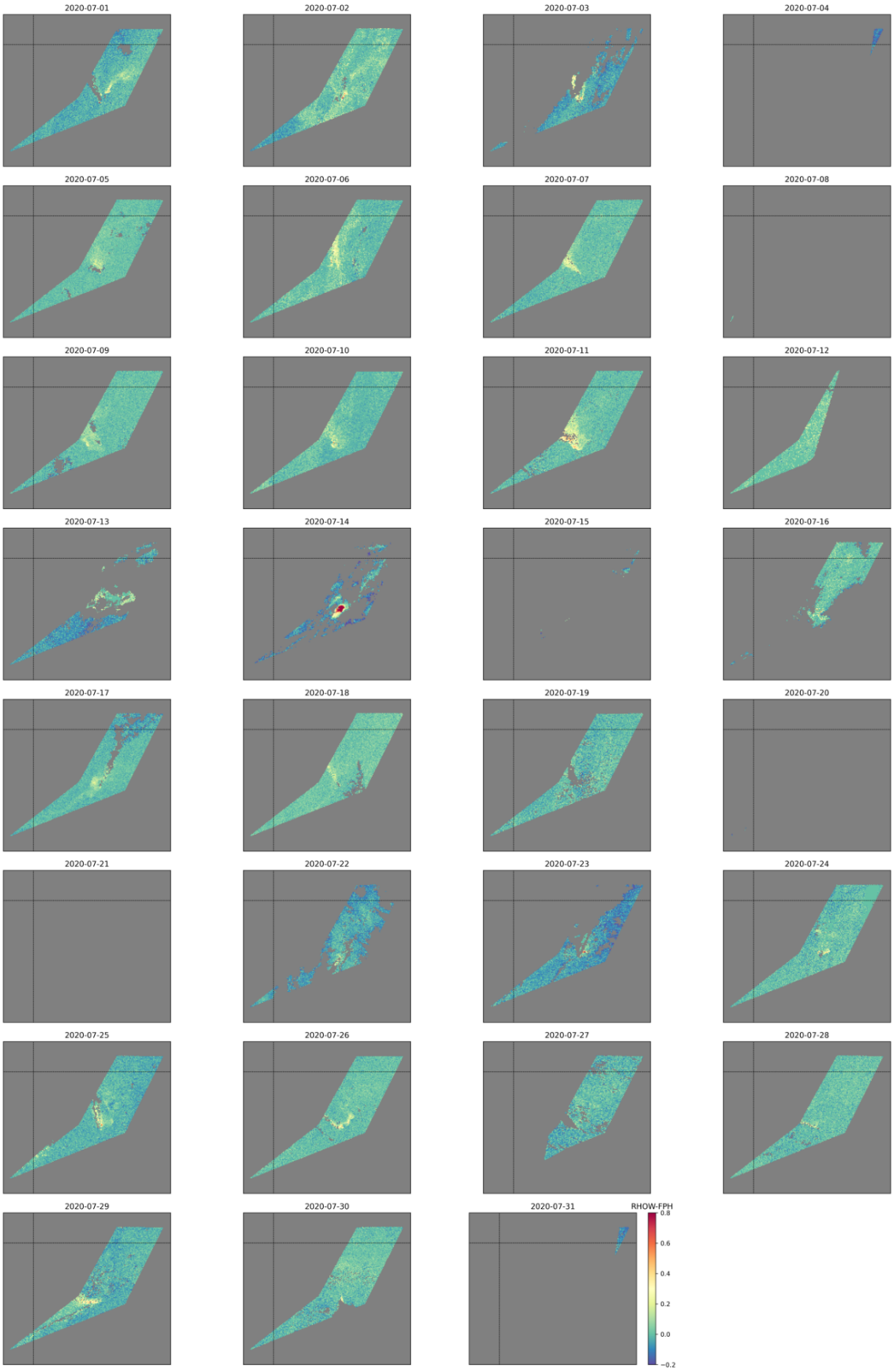

Figure 3: RHOW-FPH at Nishinoshima volcano, July 2020.

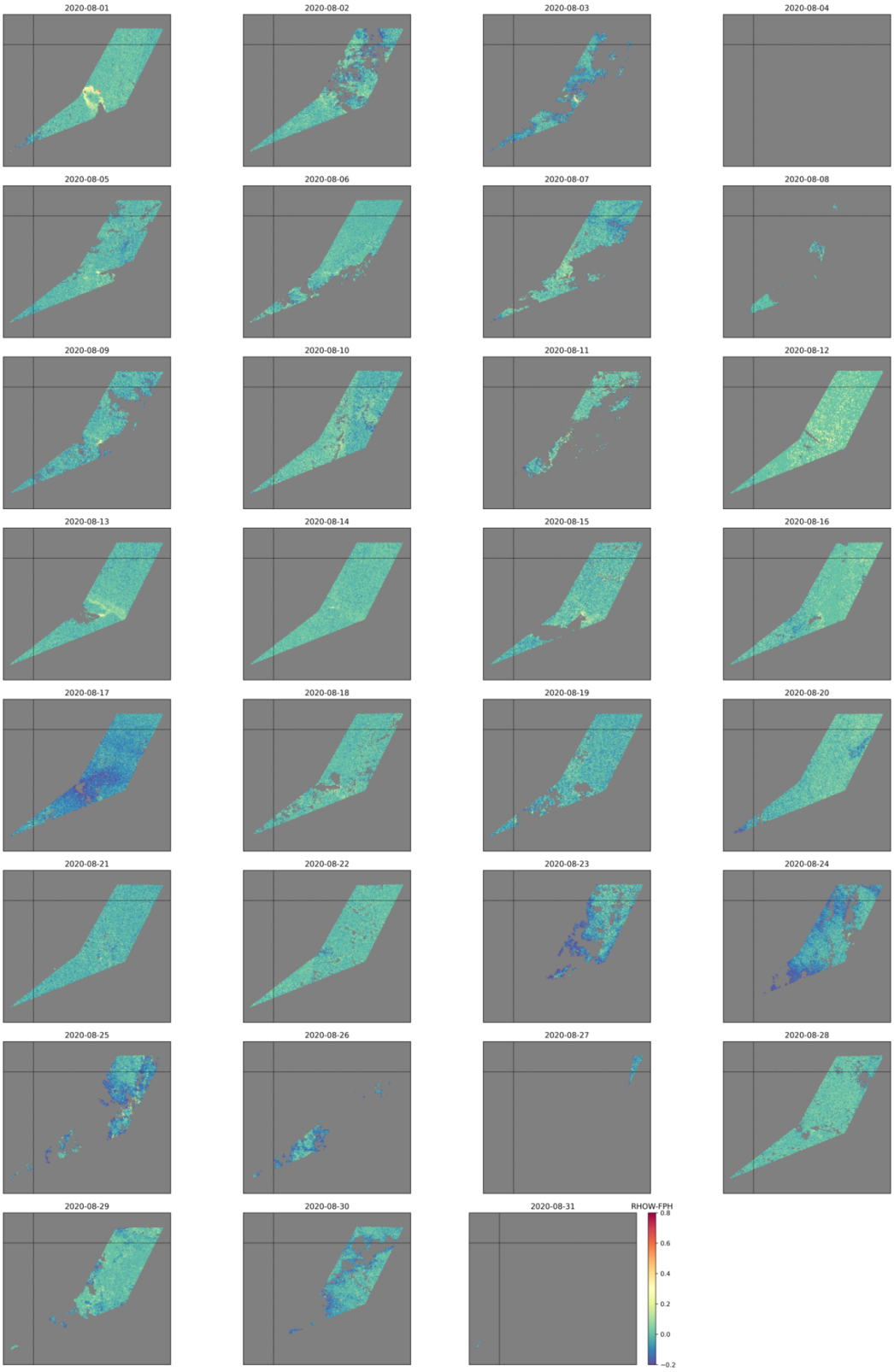

Figure 4: RHOW-FPH at Nishinoshima volcano, August 2020.

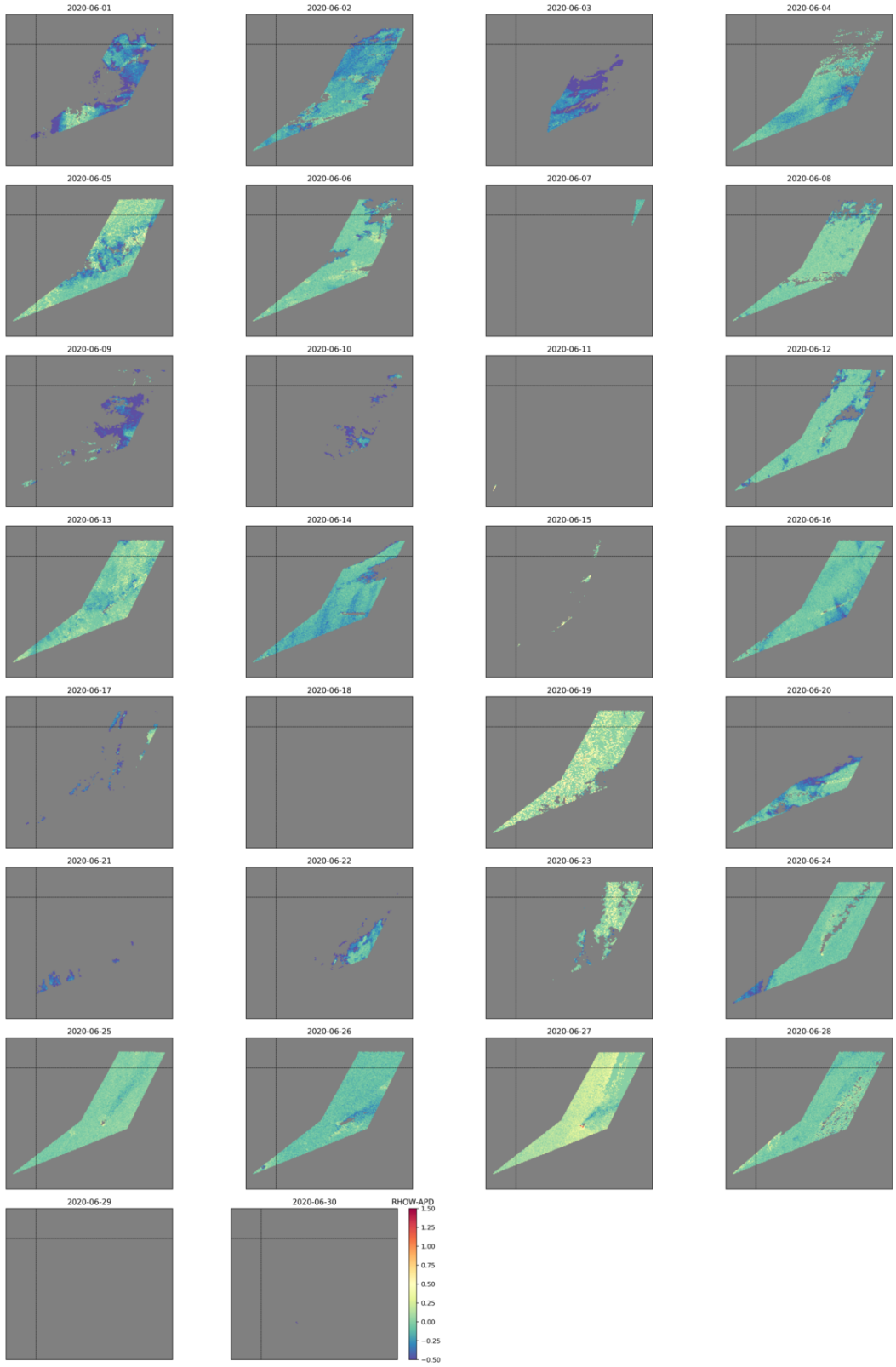

Figure 5: RHOW-APD at Nishinoshima volcano, June 2020

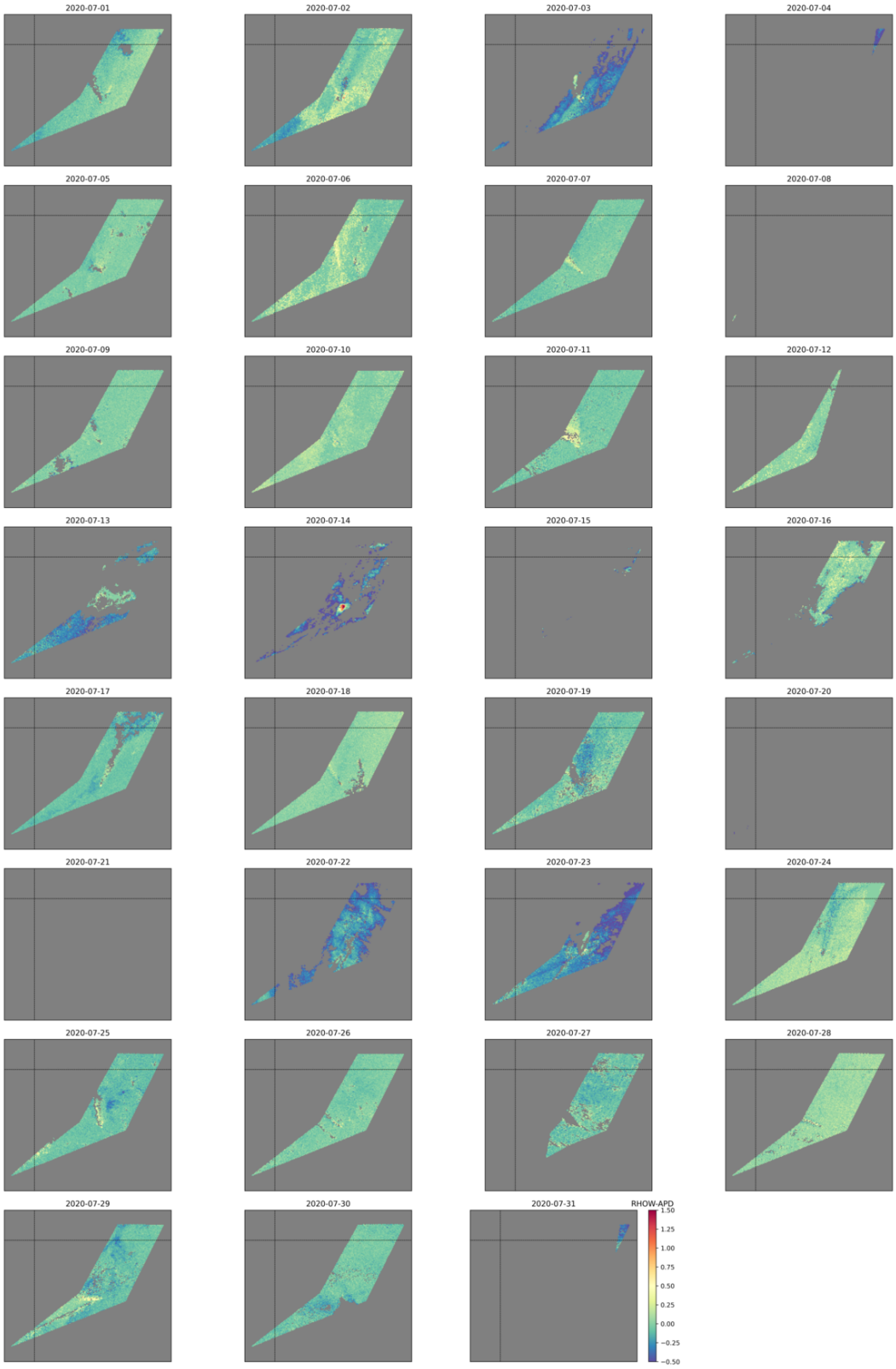

Figure 6: RHOW-APD at Nishinoshima volcano, July 2020

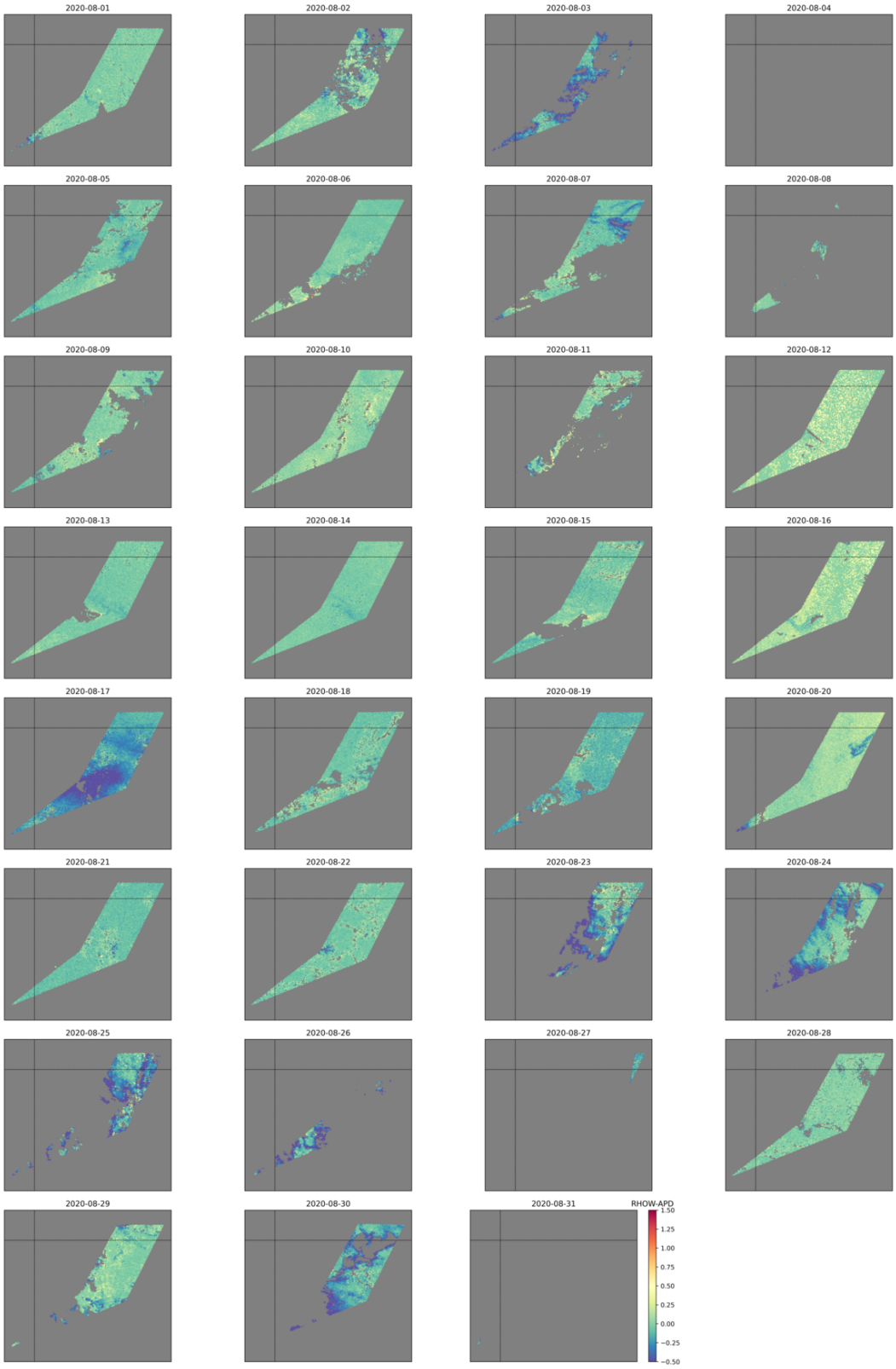

Figure 7: RHOW-APD at Nishinoshima volcano, August 2020

3 Time Series

In order to see the development of the L-FPH and L-APD signal with time, we calculated the mean over 1 degree latitude and longitude around the volcano.

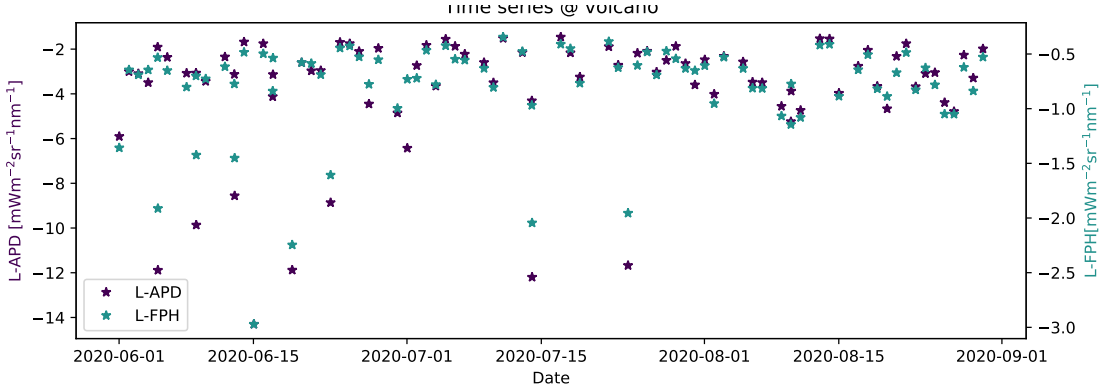

Figure 8: L-FPH and L-APD over three month evaluated at the volcano.

4 Comments from Liam Kelly

Highest values for FPH and APD seem to be around Nishinoshima. The large gaps in the images correlate with the volcanic plume at Nishinoshima, and highest FPH values are seen on the edges of the plume. The more explosive activity began in June 2020, which is also reflected in the images. Activity heightened at Nishinoshima in July, which is also reflected in the provided images in the increase in the area of heightened FPH and APD. The CHL OC4ME product included in downloadable products from Sentinel-3 follow a similar pattern to what is shown by the OC-FLUO processor. By mid-August, the eruption at Nishinoshima entered a phase that was not characterized by eruptions of the same scale as those that occurred from June to mid-August, and this is seen by the subsidence of the heightened FPH and APD values around Nishinoshima in the provided images. Specific images that show evidence of volcanic plumes with surrounding heightened FPH and APD values are June 24, July 11, and July 25, among others, and images such as the one on July 7 and July 18 show a plume-like area of heightened FPH and APD, indicating that places of ash deposition are likely corresponding to higher FPH and APD values.