The use of ocean color in New Caledonia, Vanuatu, Fiji, and Tonga archipelagos: from large *Trichodesmium* oceanic blooms to chlorophyll a in shallow waters: an overview

Cécile Dupouy[1], **Andra Whiteside* (ARTS)[1]**, Awnesh Singh[2], Jérôme Lefèvre[1],

G. Wattelez[3], Rémi Andreoli[4], H. Murakami[5], and R. Frouin[6]

1   2   3   4   5   6
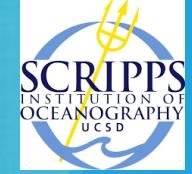
The Western Tropical Pacific Ocean: a blue ocean

Oligotrophic, Deep chla max, NO3-depleted surface waters, Chla < 0.1 ug.m-3...

Vanuatu

Fiji

N. Caledonie

MODIS NASA 4 km Chla
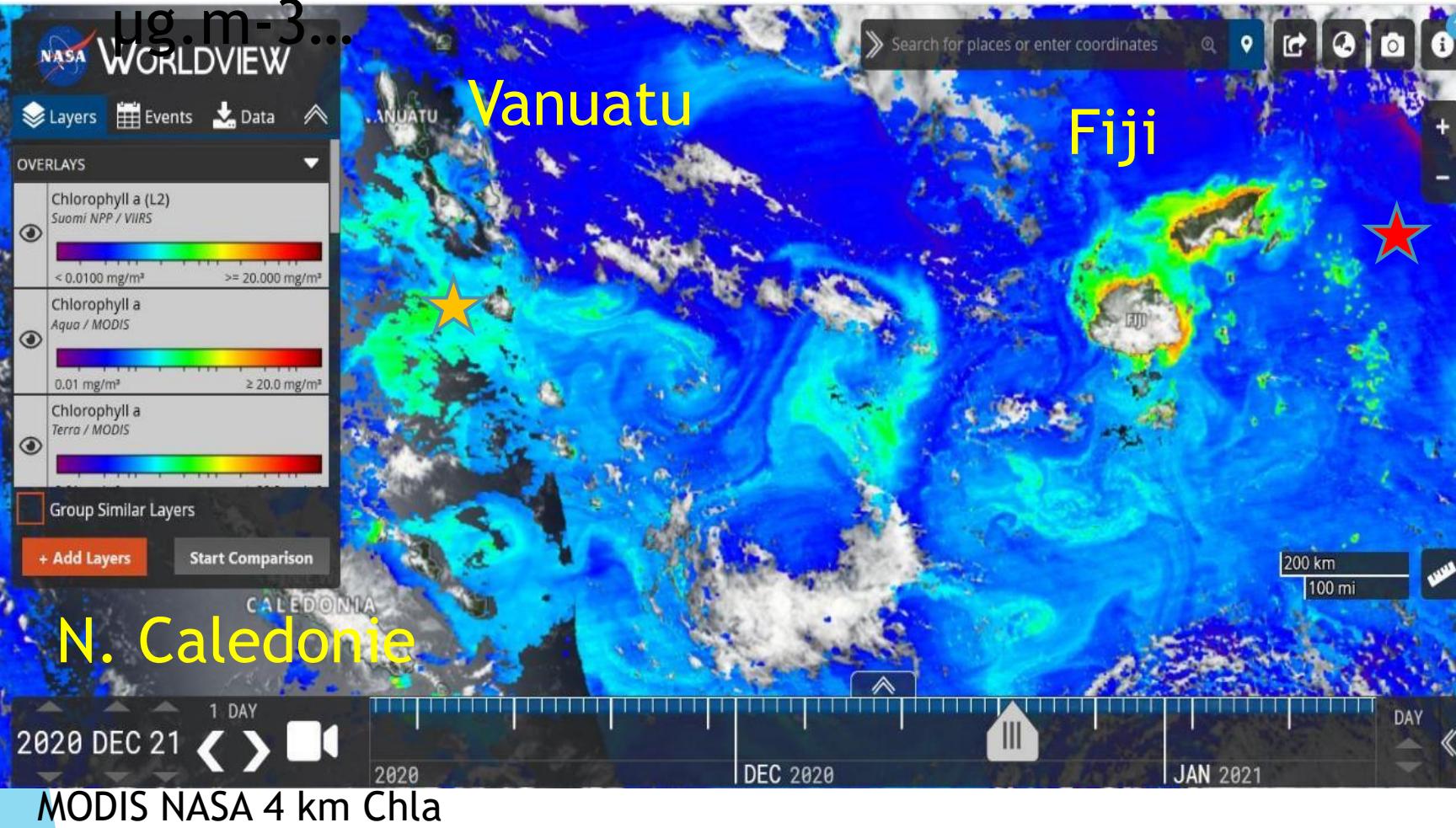
Characterization of Chlorophyll a enrichments in archipelagos at 15°S

➢ Island mass effect ?
➢ Iron< sub-marine active volcanism?
➢ *Trichodesmium* blooms?

Can we discriminate *Trichodesmium* from space ?

Algorithms for *Trichodesmium*

Colonies of marine cyanobacteria *Trichodesmium* interact with associated bacteria to acquire iron from dust
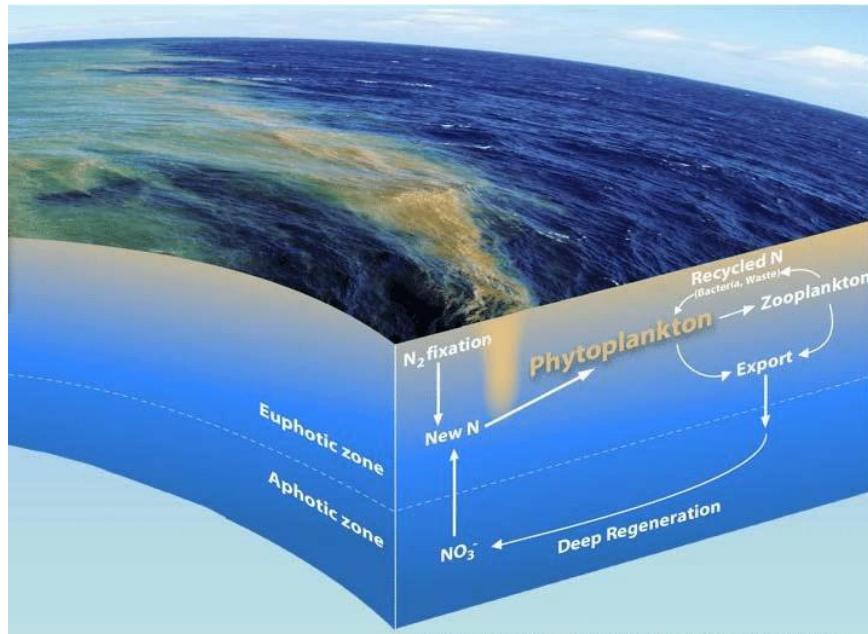
Trichodesmium and other diazotrophs fuel new production through N 2 fixation. Photo shows a surface slick of Trichodesmium in the western South Pacific Ocean. Inputs of new nitrogen stimulate the growth of phytoplankton. New production can be exported out of the euphotic zone, drawing down surface concentrations of carbon. Photo courtesy of Daniel Ohnemus. Illustration by E. Paul Oberlander, WHOI.

# Slick observations around Pacific Islands are essential !

CRUISE REPORT

S-288: SUSTAINABILITY IN POLYNESIAN ISLAND CULTURES AND
ECOSYSTEMS

SCIENTIFIC DATA COLLECTED ABOARD THE
SSV ROBERT C. SEAMANS

American Samoa – Tonga – Fiji – New Zealand
23 September – 7 November, 2019

-19.825105°S
179.498191°E
Open ocean

-18.381634°S
178.636499°E
Near Dakuiloa Island and reef

S288 trichos sample 1 october 2019
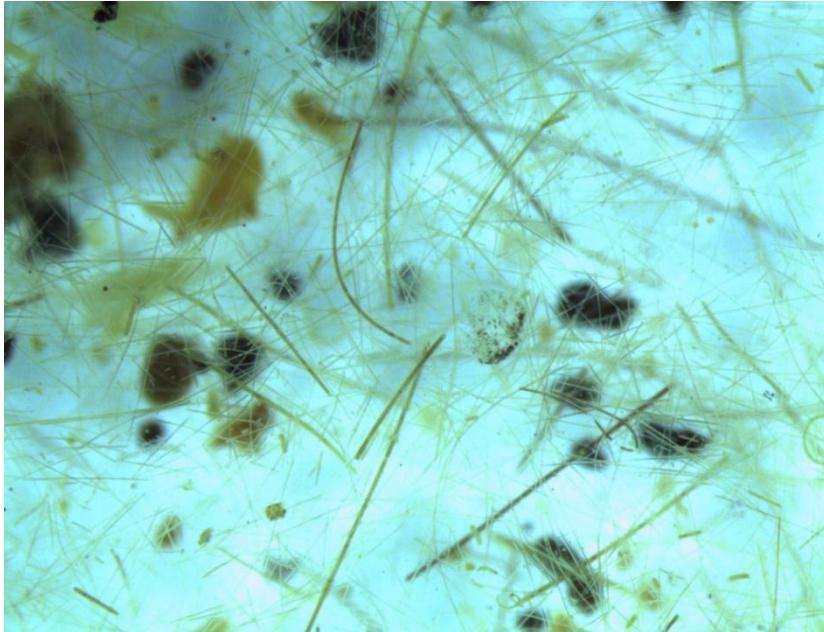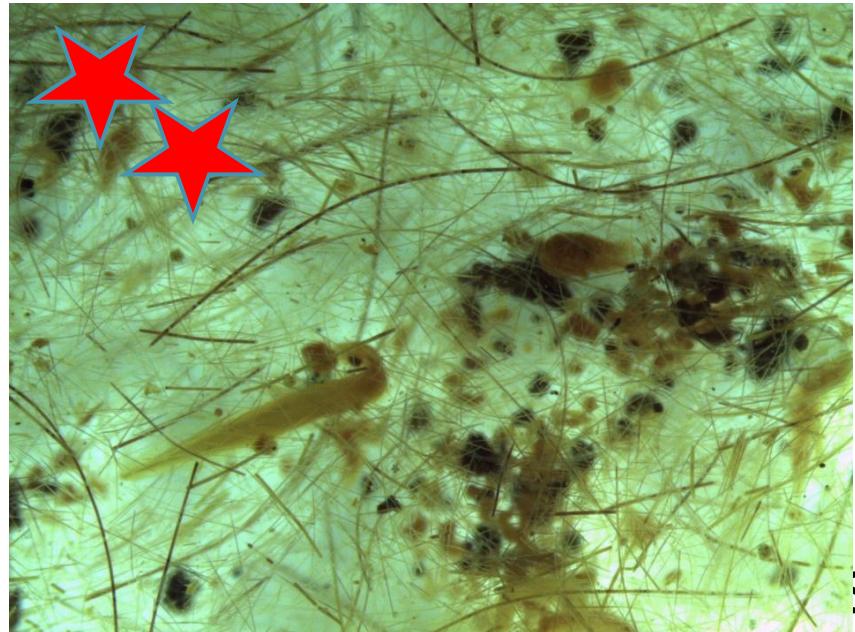
> 200 samples
from slicks
in the whole SWTP

Can we discriminate *Trichodesmium* ?

Trichodesmium blooms are fixing N2 and CO2 at high rates

*Trichodesmium* slick, RV *Alis* 9 November 2020
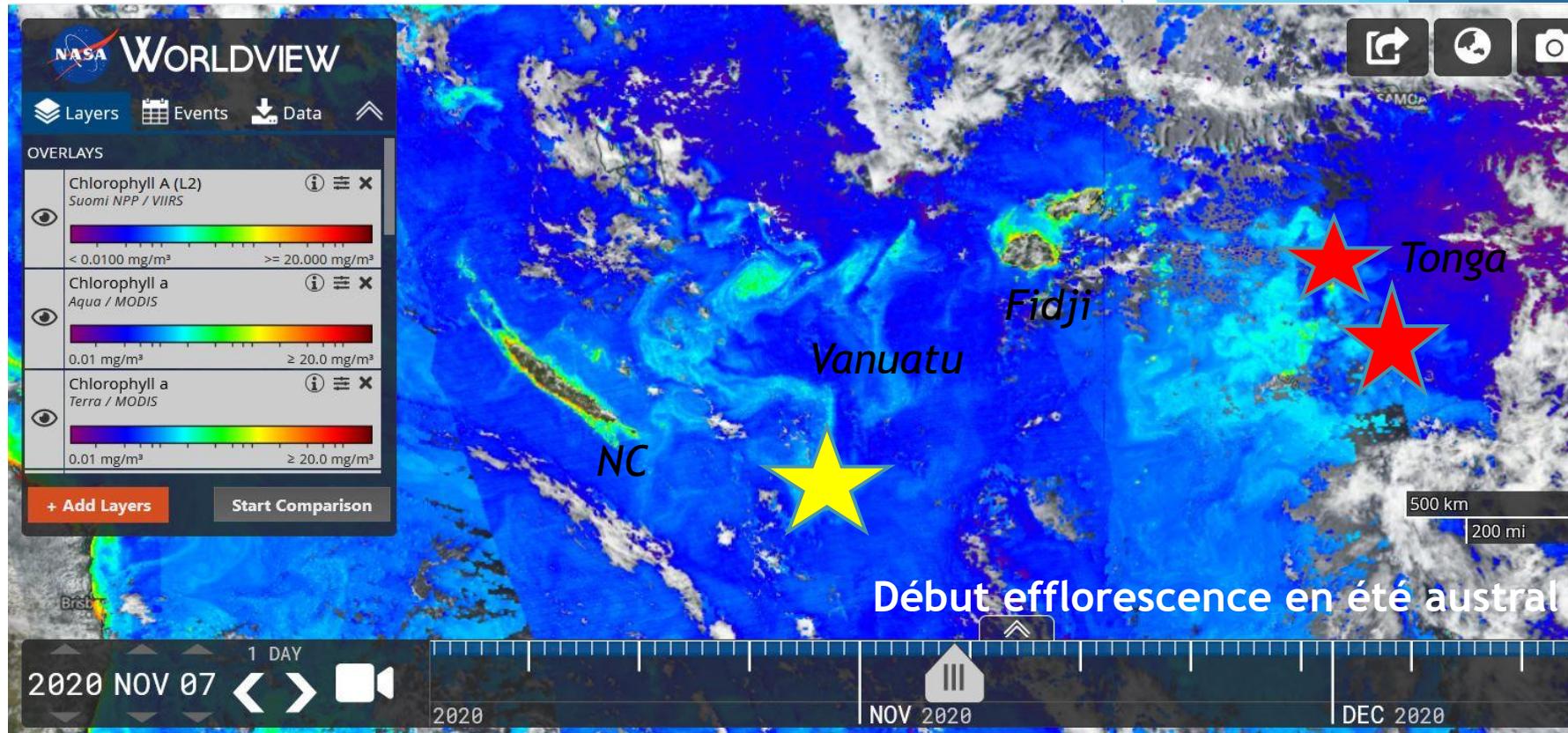
< JF Barader, Alis, return of the cruise Tonga Recup

# *Trichodesmium* blooms may develop during 6 months

MODIS images of Chla December 2014
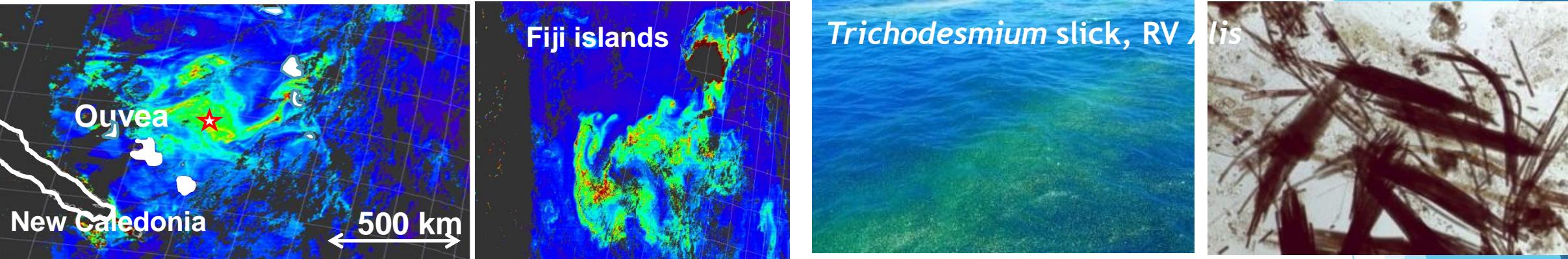
MODIS composite of Chla OUTPACE cruise: March-April 2015
St 1- 2- LDA 3-4-5-6-7 -8-9- 10-11-12- LDB- 13 -LDC-14-15
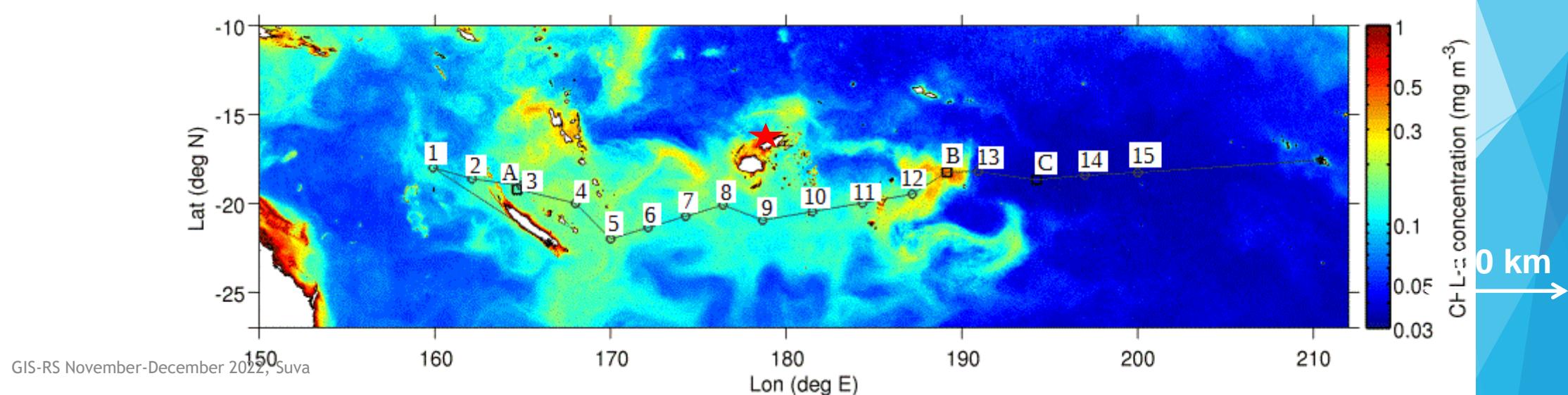
# *Trichodesmium* blooms cross South Pacific archipelagos

New Caledonia   Vanuatu   Fiji   Tonga   Niue

March-April 2015: OUTPACE RV *Atalante cruise Sections 0-70 meters*

Trichodesmium blooms are fixing N2 and CO2 at high rates

Rousset et al., 2018, Biogeosciences
In situ observations of slicks (Dupouy et al., 2011) used for coincidences with MODIS data
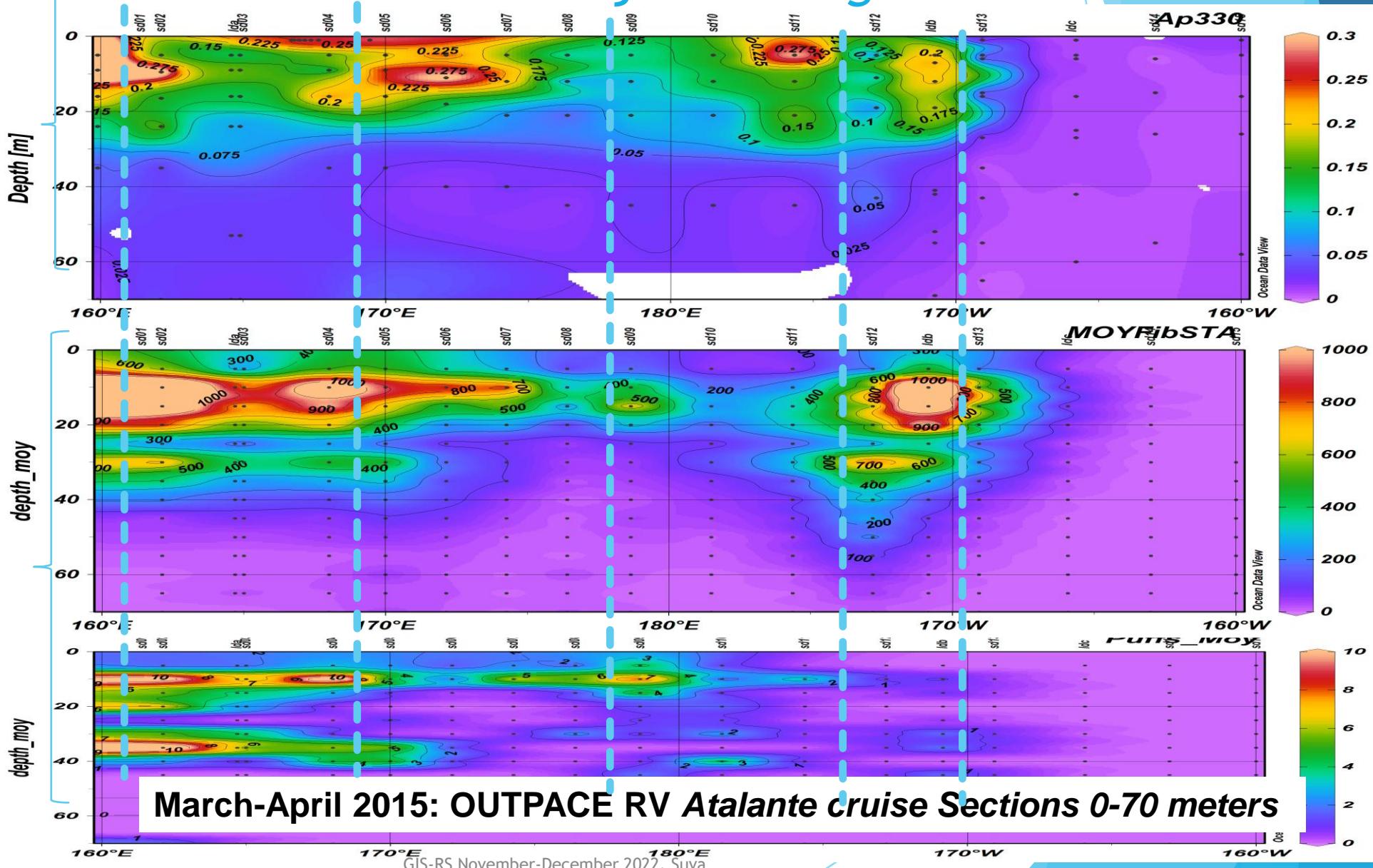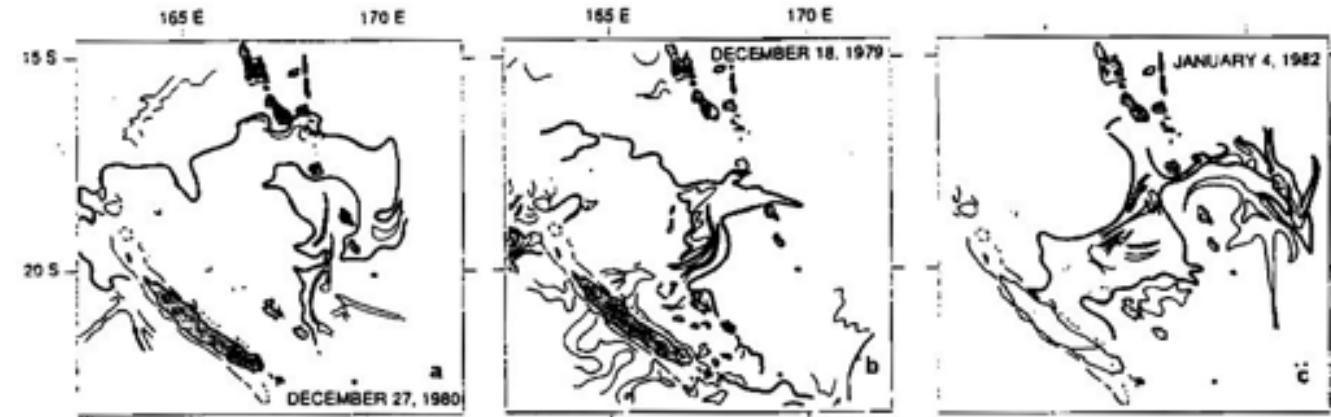
Fig.3. Schematic representation of the pigment rich waters for 1979, 1980 and 1982 summer conditions, showing the extension of Trichodesmium blooms. The CZCS pigment contour follows approximately the 0.2 mg.m⁻³ isopleth. a) December 27, 1980. b) December 18, 1979. c) January 4, 1982.

40 satellite observations with Coastal Zone Color Scanner, 1978-1984

Dupouy et al., 1990

• 329 REMMOA observations in Nov–Dec 2014
• 178 French Navy + Alis observations (1998–2015)

Discriminate *Trichodesmium* from space : estimate Carbon flux

Rousset et al., 2018
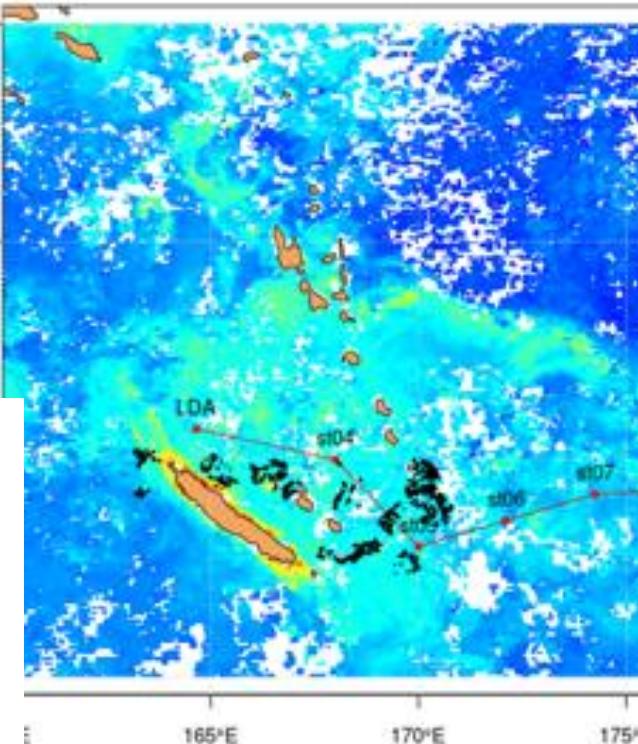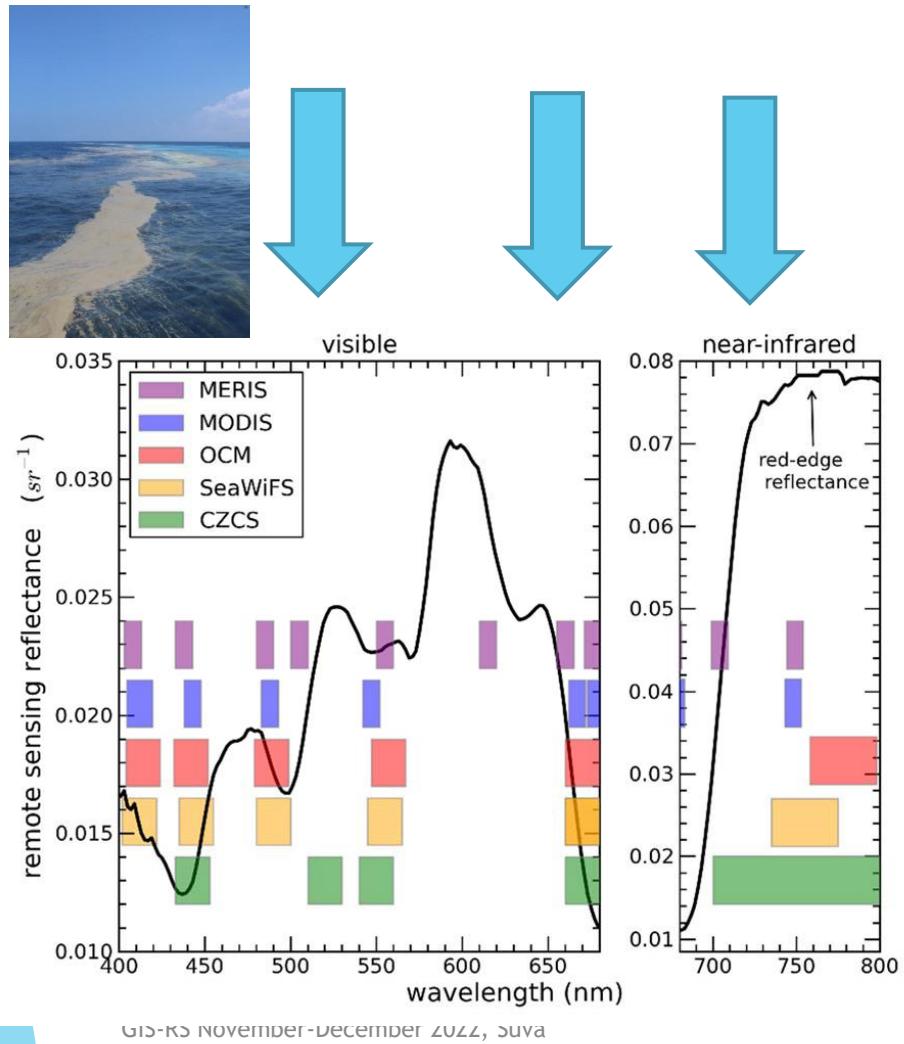
Bell, 2021 (< Rousset et al., 2018)

New algorithm

- $Rrs(678) < 0$

- $Rrc(748) < Rrc(859)$

- $Rrc(645) < Rrc(531)$

Rrs: Rayleigh corrected + aerosol correction

Rrc: Rayleigh corrected, no aerosol correction

The lagoons of the SW Tropical Pacific : blue ?

Oligotrophic, NO3-depleted surface waters, Chla < 0.1-0.4 µg.m-3…

Chl a (mg m-3)

Characterization of Chlorophyll a enrichments in lagoons :

➢ Coastal River impacts on coral reefs ?
➢ Coral sustainability ? (particles, contaminants)

J. M Fernandez photographs

MODIS image of the New Caledonia lagoon after strong rain (250m)

The lagoons of the SW Tropical Pacific : blue ?

Characterization of Turbidity impacts in lagoons :
➢ Coastal River impacts on coral reefs ?
➢ Coral sustainability ? (particles, contaminants)
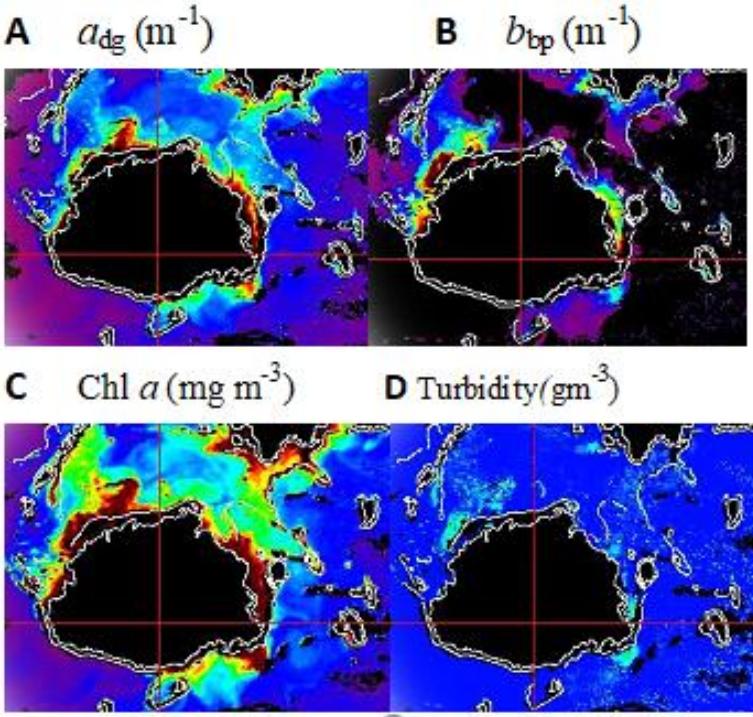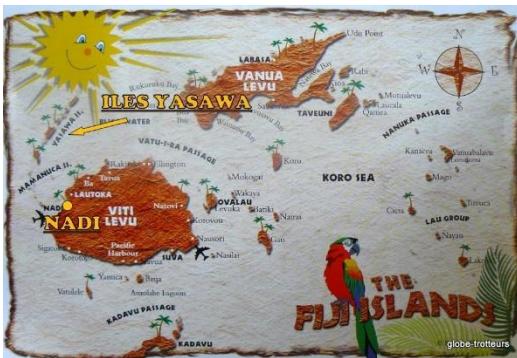
MODIS-DB products
(IRD Noumea, Lefèvre, 2010)
Fiji Island of Viti Levu (250 m)

b. Looking across the Rewa River from the Suva bank.

Can we discriminate Chla, CDOM, turbidity, seabed color mosaic ?

Algorithms for lagoon waters

- **Better Estimation of Chla in lagoons**
- **Better estimation of turbidity in lagoons**
- **First estimation of seabed color**
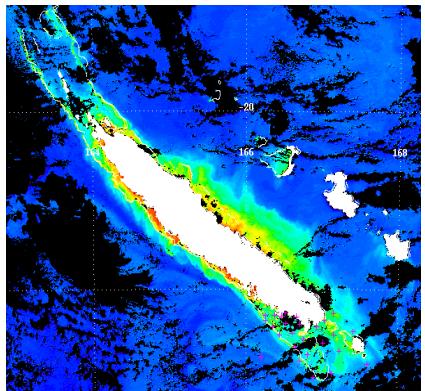
Estimate of Chla

MODIS New Caledonia lagoon – estimation of Chla ?

NC Lagoon Chla regional algorithm – Support Vector Regression SVR model (<Seabass+ NcDatabase Rrs/C

Chla maps (< MODIS)
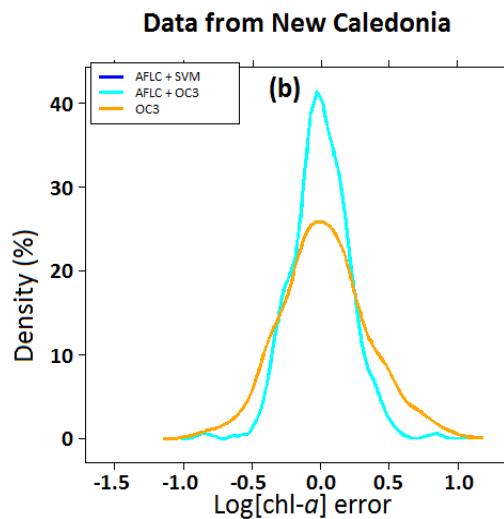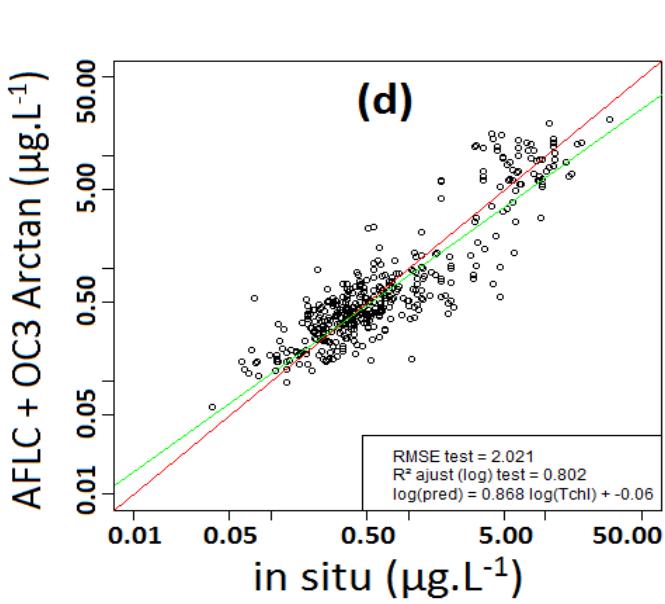
OC3-NASA   Our algo

SVM AFLC
OC3 Chla
error
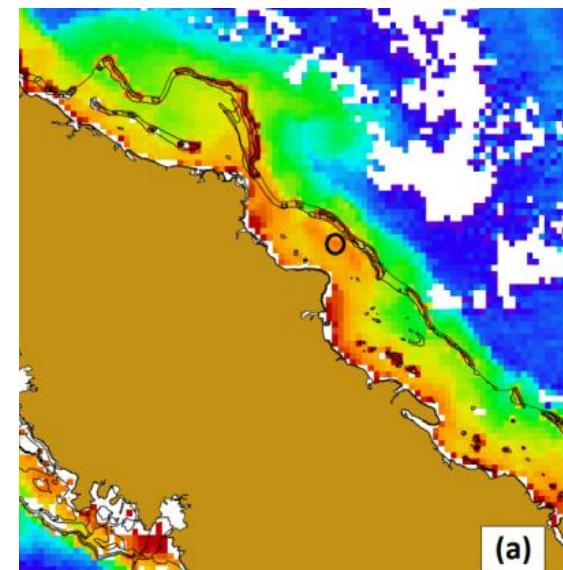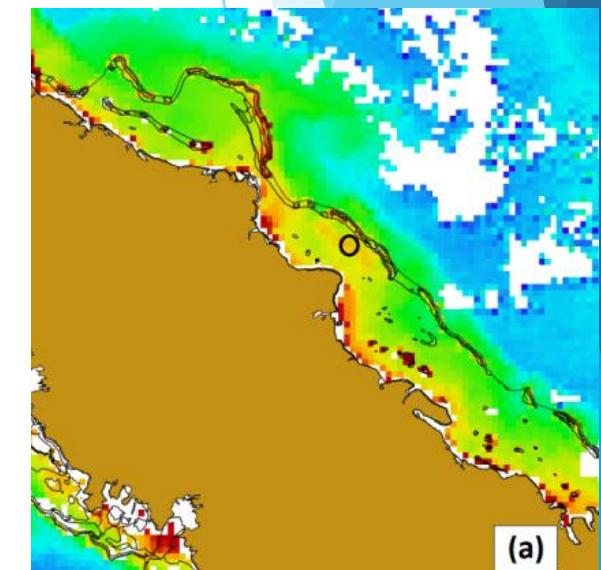
Wattelez et al., 2016, Remote Sensing

Detect seabed colors
Sentinel 2 Koné lagoon – estimation of seabed color ?

Our algo -> 3 or 5 distinct seabed color classes
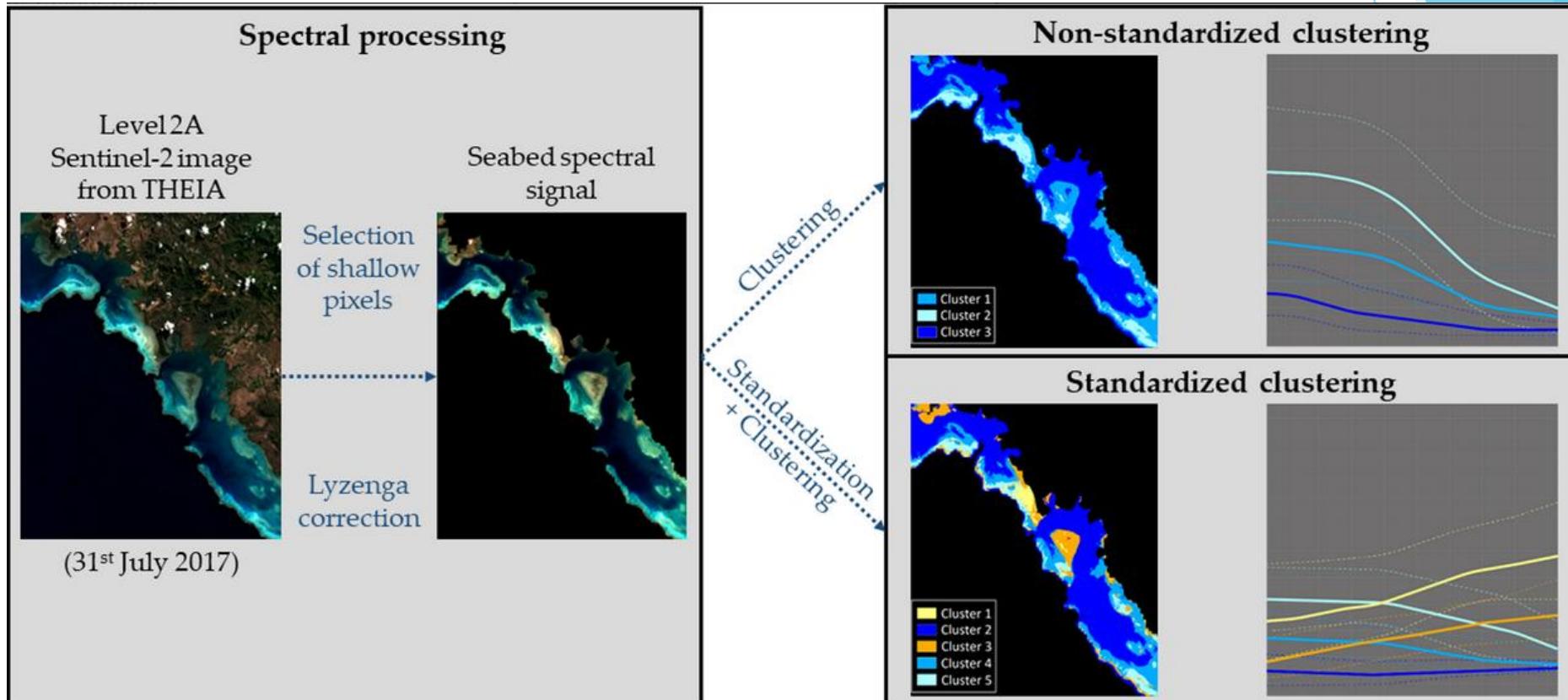
Standardization: by enhancing red channels, better definition: 5 classes instead of 3 !

Wattelez et al., 2022 Remote Sensing
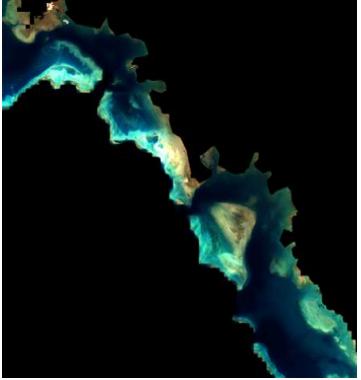
Estimate of turbidity

MODIS Koné lagoon – estimation of turbidity ?

Koné lagoon turbidity algorithm – SVR model (< 80 coincidences of reflectance vs in situTurb, bathymetry

Turbidity maps (< MODIS)

Ouillon et al., 2008, others   Our algo

in situ (NTU)
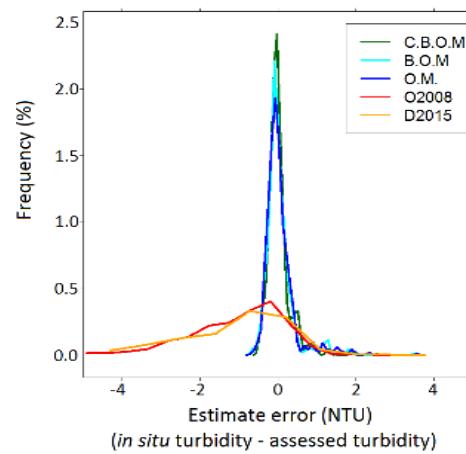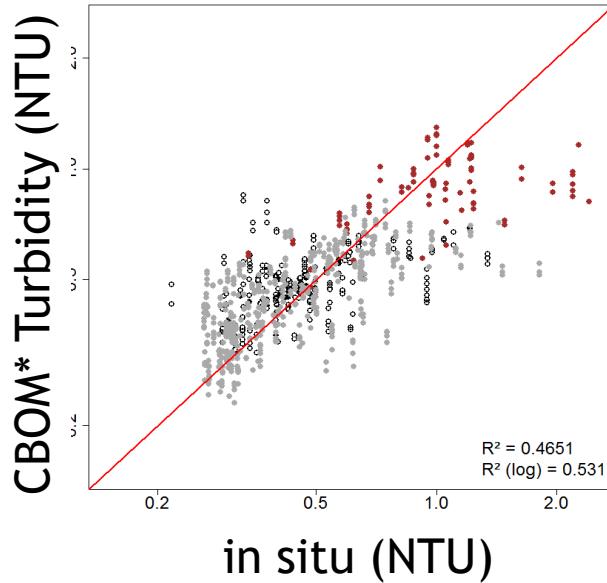
SVM Turbidity error
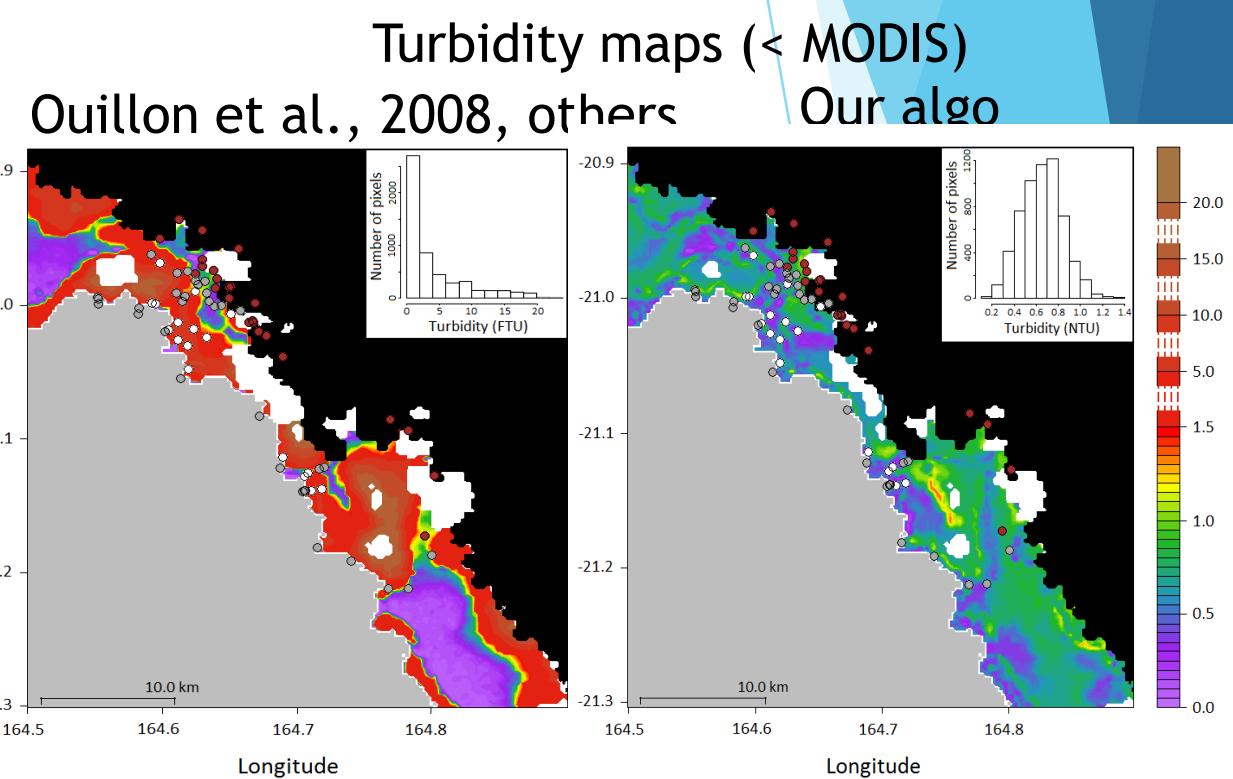
Wattelez et al., 2017 Water

C.B.O.M. Optical Model + Bathymetry + Bottom Color estimate (5 types)

# Impact of the Rewa river on ocean
Sentinel 2 Laucala Bay – estimation of turbidity, Chla, in the plume ?

Suva

Rewa

OCsmart Sentinel 2
calculated products

-> RGB
492, 560, 665

Suva

Rewa
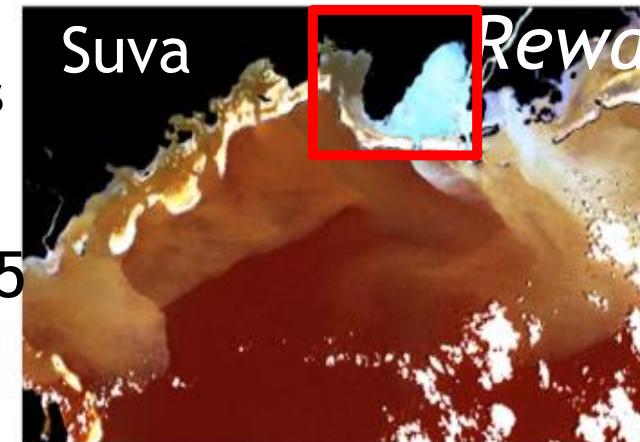
Laucala Bay
Sediments stirred after the Yasa
cyclone - South of Fiji
Singh et al., in prep
Whiteside et al., 2022

-> Chl a

-> B$_{bp}$440

Suva

Rewa

Rewa

-> CDOM ?

chlor_a [mg/m*3]

0.01 0.01 0.02 0.02   0.04   0.07 0.11 0.14 0.17 0.24 0.34   0.67 1.01 1.67 2.34 3.34   6.67 10.0 13.3 16.6 20.0

bbp_443nm [m^-1]
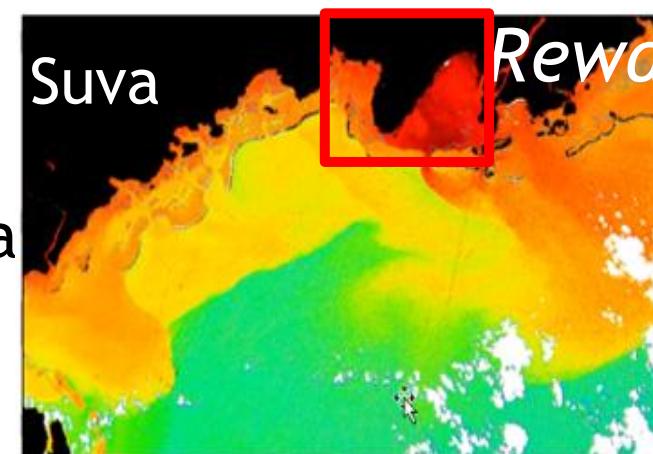
0.0   0.0 0.0 0.0   0.0   0.0 0.00 0.01 0.01 0.02   0.03 0.05 0.08 0.12 0.17   0.33 0.50 0.67 0.88 1.0

Algorithms : validation around volcanic eruptions ? Tonga region

January 2022
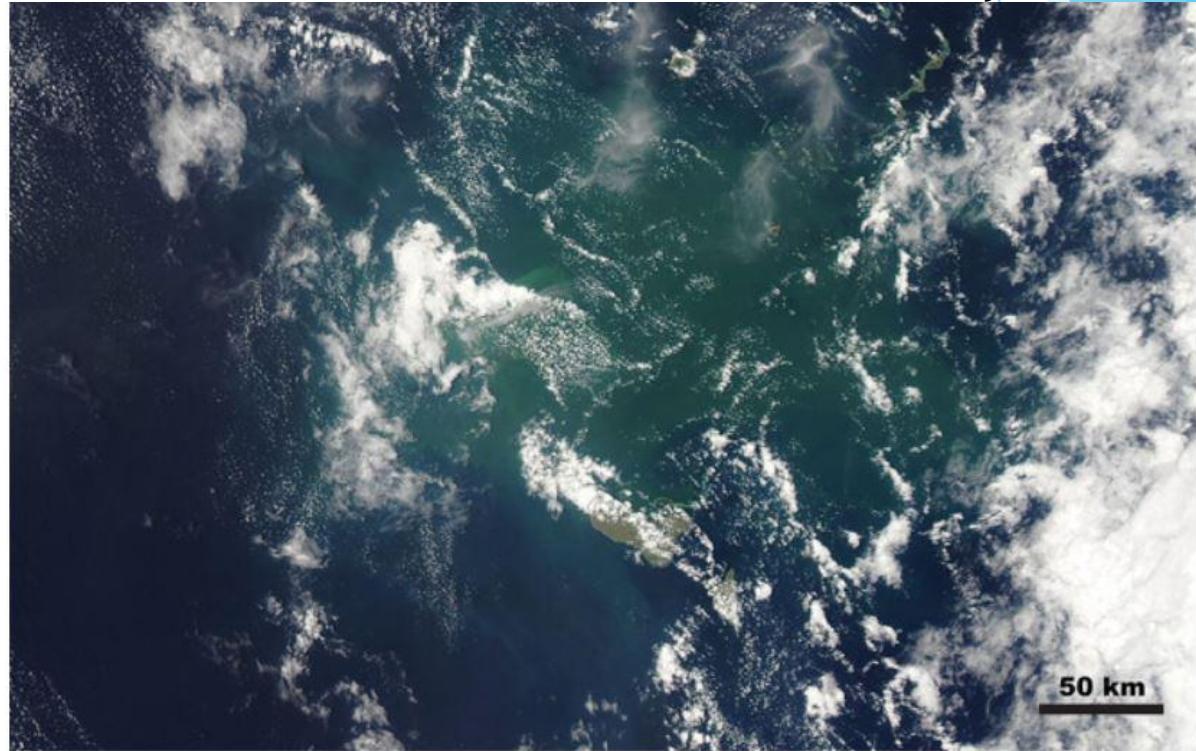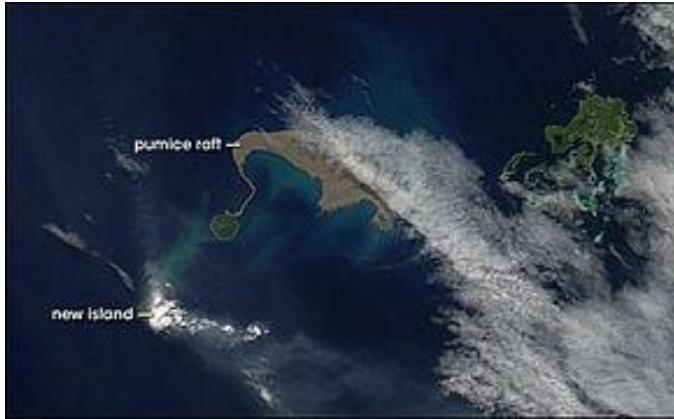
The massive area of discoloured water from the Hunga Tonga-Hunga Ha'apai. Most of the light coloured waters saw significant ash and pumice fall during the January 15, 2022 eruption. Taken January 17, 2022 by Aqua. Credit: NASA

Impact of Tonga eruptions

MODIS Tonga eruptions – estimation of Chl a linked to pumice or ashes ? ?

2019
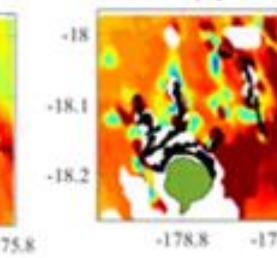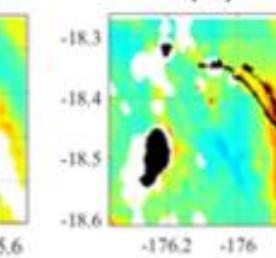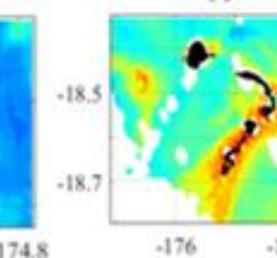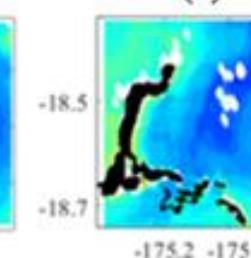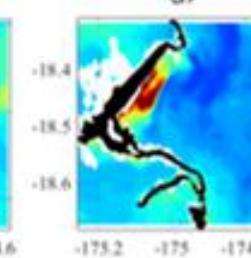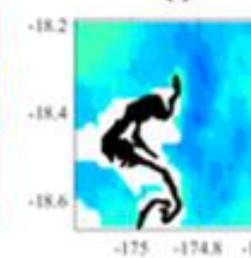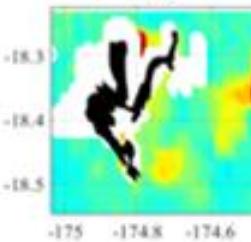
Low chla in discoloured waters: false response of the Chla algorithm (1)

Whiteside et al., 2019, Remote Sensing

2022

GIS-RS November-December 2022, Suva

High chla in ashes-full waters: false response of the Chla algorithm (2)
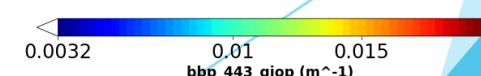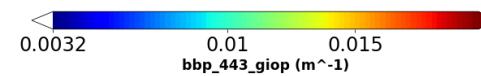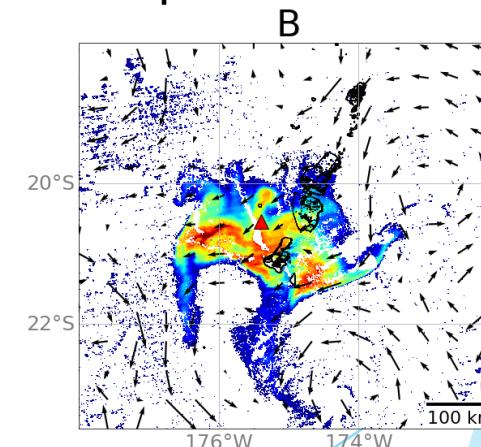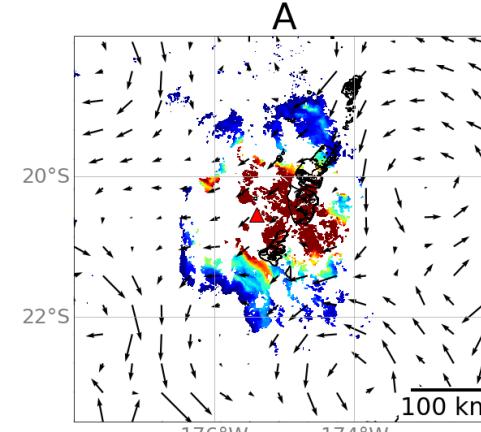
Whiteside, Dupouy, Singh, Bani, Frouin, Frontiers in Marine Science, in review

Biogeosciences EGU Open Access

Remote sensing of *Trichodesmium* spp. mats in the western tropical South Pacific

Guillaume Rousset[1], Florian De Boissieu[2], Christophe E. Menkes[3], Jérôme Lefèvre[4], Robert Frouin[5], Martine Rodier[6], Vincent Ridoux[7,8], Sophie Laran[7], Sophie Bonnet[9], and Cécile Dupouy[9]

remote sensing MDPI

1 Article
2 ## Classification of the seabed color in the Voh-Koné-
3 Pouembout lagoon from Sentinel-2 image

4 Guillaume Wattelez[1], Cécile Dupouy[2,*] and Farid Juillot[3]
5 [1] Affiliation 1; Guillaume.wattelez@unc.nc

remote sensing

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Automatic Detection of Optical Signatures within and around Floating Tonga-Fiji Pumice Rafts Using MODIS, VIIRS, and OLCI Satellite Sensors

by Andra Whiteside[1,2,*], Cécile Dupouy[1,2], Awnesh Singh[2], Robert Frouin[3], Christophe Menkes[4] and Jerome Lefèvre[4]

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water MDPI

1 Article
2 ## Application of the Support Vector Regression method
3 for turbidity assessment with MODIS on a shallow
4 coral reef lagoon (Voh-Koné-Pouembout, New
5 Caledonia)

6 Guillaume Wattelez[1,2,*], Cécile Dupouy[1,2], Jérôme Lefèvre[1,3], Sylvain Ouillon[3], Jean-Michel
7 Fernandez[2,4], Farid Juillot[2,3]

OPEN ACCESS

remote sensing

Article

A statistical algorithm for estimating chlorophyll concentration in the New Caledonian lagoon

Guillaume Wattelez[1,*], Cécile Dupouy[2], Morgan Mangeas[3], Jérôme Lefèvre[4], Touraivane[1] and Robert Frouin[5]

[1] University of New Caledonia, Campus de Nouville BP R4, 98851 Nouméa CEDEX, New Caledonia; E-Mail: guillaume.wattelez@univ-nc.nc; Tel.: +687 290 591.

Journal of Operational Oceanography ›
Volume 15, 2022 - Issue sup1: Copernicus Ocean State Report, issue 6

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Pages 1-220 | Published online: 29 Sep 2022

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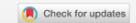
What remains to do (1) ?

▶ Go further to discriminate *Trichodesmium,* the major nitrogen fixing species from other phytoplankton at sub-bloom concentrations

▶ Estimate Carbon sink by *Trichodesmium* in the whole South West tropical Pacific

▶ Estimate the effect of T*richodesmium* blooms on coastal areas around the Islands

Thanks to NASA PACE hyperspectral sensor !!!
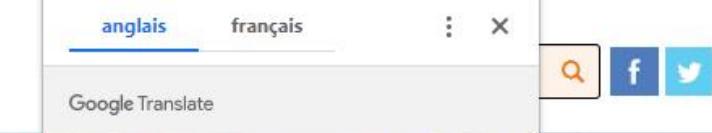
What remains to do (2) ?

▶ Analyse Sentinel 2 for surveys of the lagoon health :

  ▶ To follow health of water surrounding coral reefs

  ▶ To follow the freshwater runoffs at estuaries

  ▶ To follow the health of protected marine areas

  ▶ To estimate direction and surface of pollution plumes

  ▶ To follow the health of fishing grounds

Thanks to NASA, JAXA, ESA

https://eo4society.esa.int/projects/ocean-virtual-laboratory/
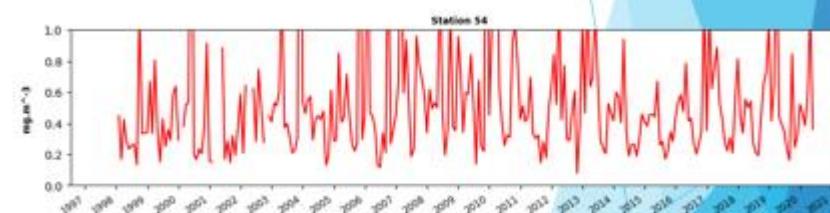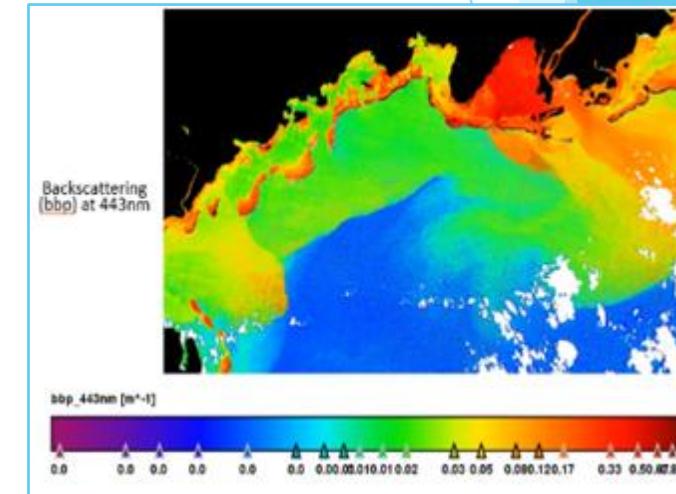
What remains to do (3) ?

► **In situ continuous Bio-optical**

Observations to validate Satellite imagery

► **(Buoys, autonomous radiometers)**

► **Gliders ?**
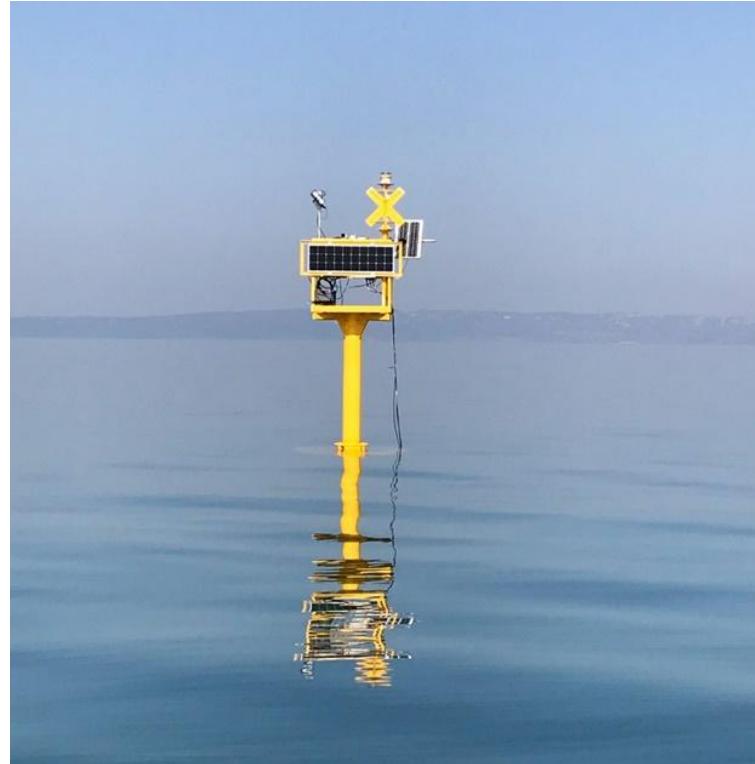
Sokowasa French-Fijian cruise: An example of glider use
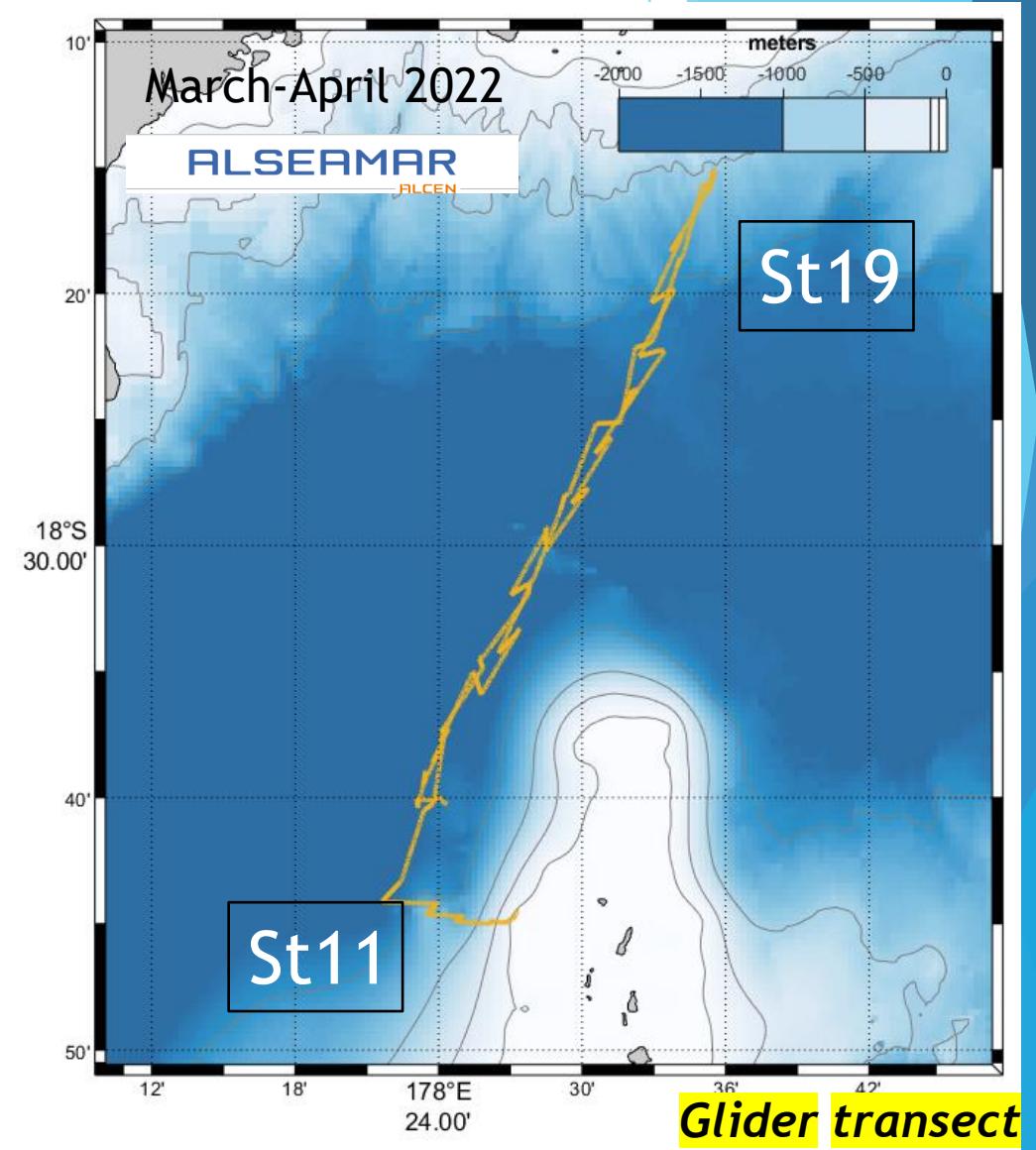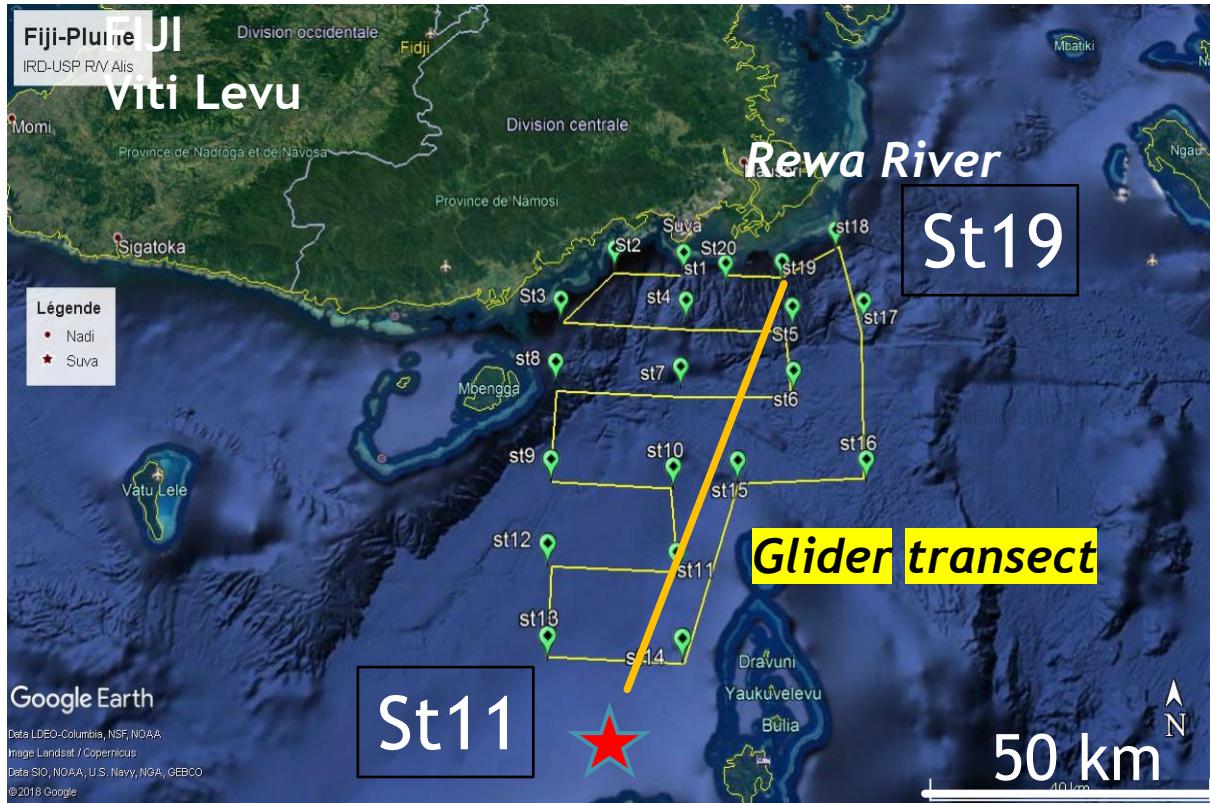
Conclusions

► The SWTP ocean shows many enrichments of phytoplankton and is a larger sink for CO_2 that previously thought

► Effects of river outputs to nearshore environments are strong

► The use of Ocean Color satellite data should be generalized

  ► Process the S2 and MODIS archived data with adapted algorithms

  ► Provide validated data to stakeholders

  ► Use of turbidity and chlorophyll maps to survey lagoon health, at MPA areas and touristic zones

► Disseminate information, train MSC and PHD students to form a Pacific Ocean color Task Team

  ► **Contact: PaCE-SD, USP – COMETE project (Fonds Pacifique)**

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FONDS PACIFIQUE

RERIPA Call 3: Living Labs for Innovative Solutions to Address Climate Change Impacts

RERIPA   OACPS R&I   acp

Grant Opportunity

Calls for Proposals: Living Labs for Innovative Solutions to Address Climate Change Impacts

Deadline: 9 December 2022

The RERIPA Project is launching its third call for proposals **dedicated to support multi-disciplinary regional consortia (Living Labs)** that are able to address the Impact of Climate Change **through innovative and sustainable user-centered solutions founded on research-based evidence** with a focus on three priorities: coastal vulnerability, lagoon and ocean health, and sea level rise.

GIS-RS November-December 2022 Series

https://www.pidf.int/reripa-call-3-living-labs-for-innovative-solutions-to-address-climate-change-impacts/

contact@reripa.com