Poster # 171

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Delayed island effects can trigger nitrogen fixer blooms

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Summary

- The **"classical" island effect** is defined as a chlorophyll concentration (Chl) increase in the vicinity of islands (e.g., Doty and Oguri, 1956).
- Here we demonstrate that a second type of island effect exists, where the phytoplankton response is delayed in time (several weeks) and space (hundreds of km): a **"delayed" island effect**.
- This happens when fast-growing phytoplankton exhaust nitrate in the "classical" island effect, and leftover iron and phosphate are used by slow-growing nitrogen fixers transported away by oceanic currents.
- The classical and delayed island effects are studied using a simple model representing plankton in water masses fertilized nearby islands and advected by oceanic currents, and compared with satellite Chl.
- The model successfully represents Chl variations over time and space, demonstrating that **islands can trigger remote Chl enrichments** and that island effects may have been largely underestimated.

Context

The OUTPACE (Oligotrophy to UlTra-oligotrophy PACific Experiment) cruise sampled the Southwest Pacific from Feb 18th - Apr 3rd, 2015 (**Fig. 1**). A spectacular Trichodesmium bloom was observed near station LDB (**Fig. 2**) and hypothesized to be fertilized by an island effect (de Verneil et al., 2018).

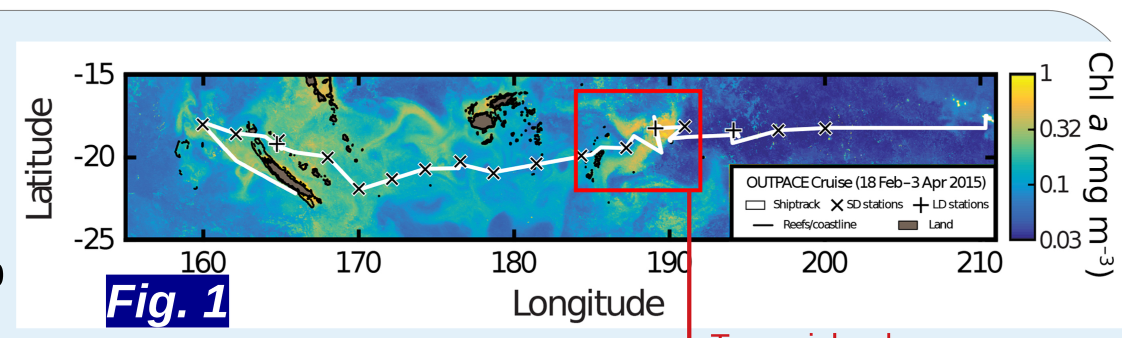


Fig. 1 *OUTPACE ship track overlaid on quasi-Lagrangian weighted satellite Chl. Reproduced from de Verneil et al. (2018).*

research questions

- **Was the bloom triggered by an island effect?**
- **Can the observed Chl be reproduced using only island-driven nutrient inputs and oceanic advection?**

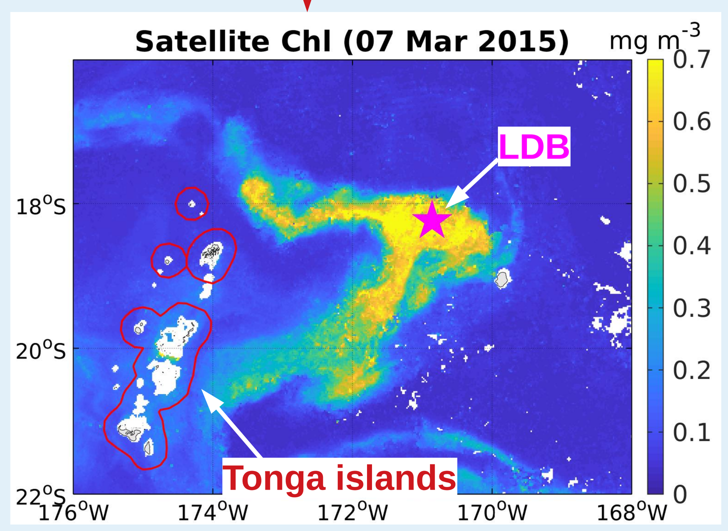


Fig. 2 *Trichodesmium bloom at its peak, and LDB station sampled from Mar 14-20. Red contours highlight regions within 20km of Tonga islands.*

Assumptions: phosphate in excess and non-limiting; island-driven nutrient supply include both nitrate and iron; a Chl increase near the islands signals a nutrient supply proportional to Chl.

Data: CLS daily surface Chl (resolution 0.02°) and altimetry-derived currents (1/8°) for Dec 2014 – May 2015, optimized for OUTPACE (see Rousselet et al., 2018).

A simple plankton model

2 plankton types:

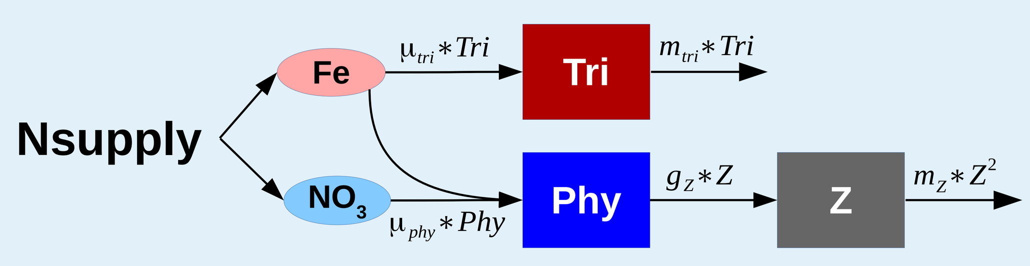
- **diazotrophs (Tri)**, slow growth, Fe-limited, loss by mortality
- **non-diazotrophs (Phy)**, fast growth, N-limited, loss by predation

All parameters constant*, plankton biomass computed over time.
Only variables are island-driven nitrate and iron supply at t=0.

$$\mu_{tri}=\frac{Fe}{k_{Fe}+Fe}*\mu_{tri}^{max}$$

$$\mu_{phy}=\frac{NO_3}{k_{NO_3}+NO_3}*\mu_{phy}^{max}$$

$$g_Z=\frac{Phy}{k_G+Phy}*g_Z^{max}$$



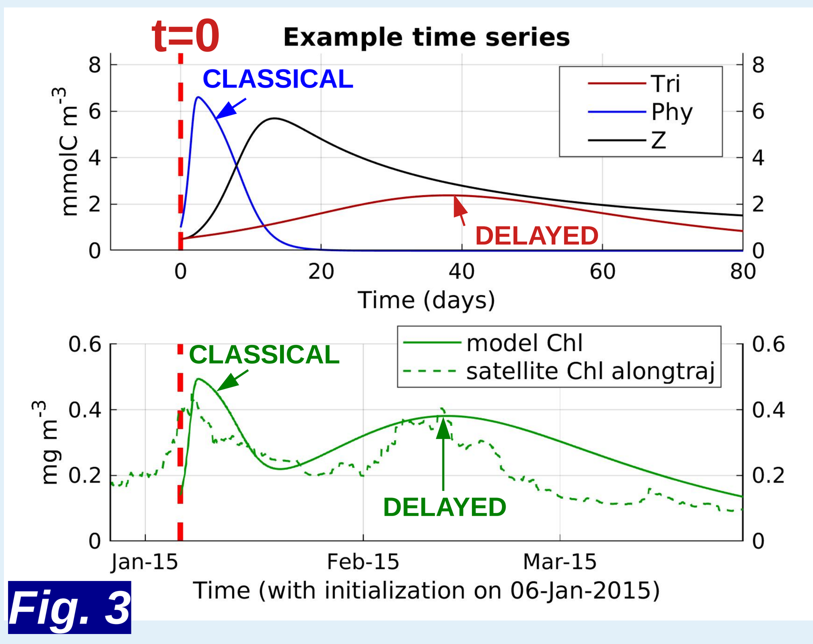


Fig. 3 *Model initialized with [NO3 ini] = 0.9 µmol L-1 and [Fe ini] = 0.8 nmol L-1. The modeled Chl is compared with satellite Chl averaged along trajectories initialized on Jan 6th, 2015 (Fig. 4).*

*parameters from literature (for Tri: Ye et al., 2012; Dutheil et al., 2018); initial Tri/Phy concentrations resulting in Chl(0) = 0.14 mg m-3 (pre-bloom conditions).

Growth/advection method

The plankton model is coupled to altimetry-derived current trajectories, following water masses over time and space after nutrient supply (Messié and Chavez, 2017). Daily runs (example in **Fig. 4**):

algorithm

1) detect island effects as Chl increase nearby islands (red contour)
2) initialize the model with N and Fe inputs proportional to Chl at init location (red crosses)
3) map the model outputs on Ariane 90-days current trajectories (Blanke and Reynaud, 1997).

The resulting trajectories for Dec 2 to Feb 3 daily runs are combined into daily maps (**Fig. 5**, middle column).

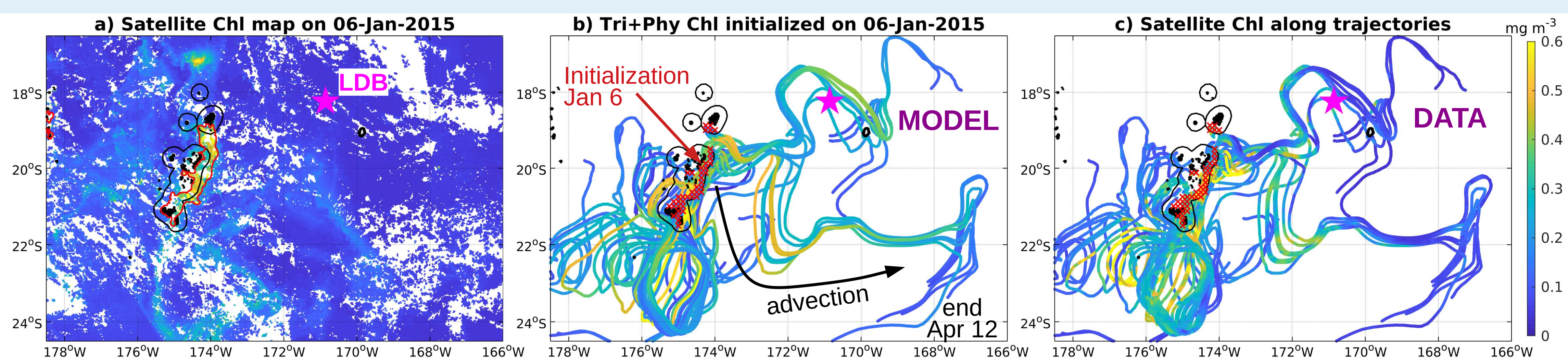


Fig. 4 *Example of the growth/advection method, initialized on January 6th, 2015. The island effect is detected from satellite Chl as 0.3 mg m-3 contours enclosing the islands (red, a) and the model initialized at all pixels where an island effect is detected and within 20 km of the islands (red crosses, b) as a function of Chl. The modeled Chl is mapped along current trajectories for Jan 6 to Apr 12 (b) and compared with satellite Chl at the same time and location (c).*

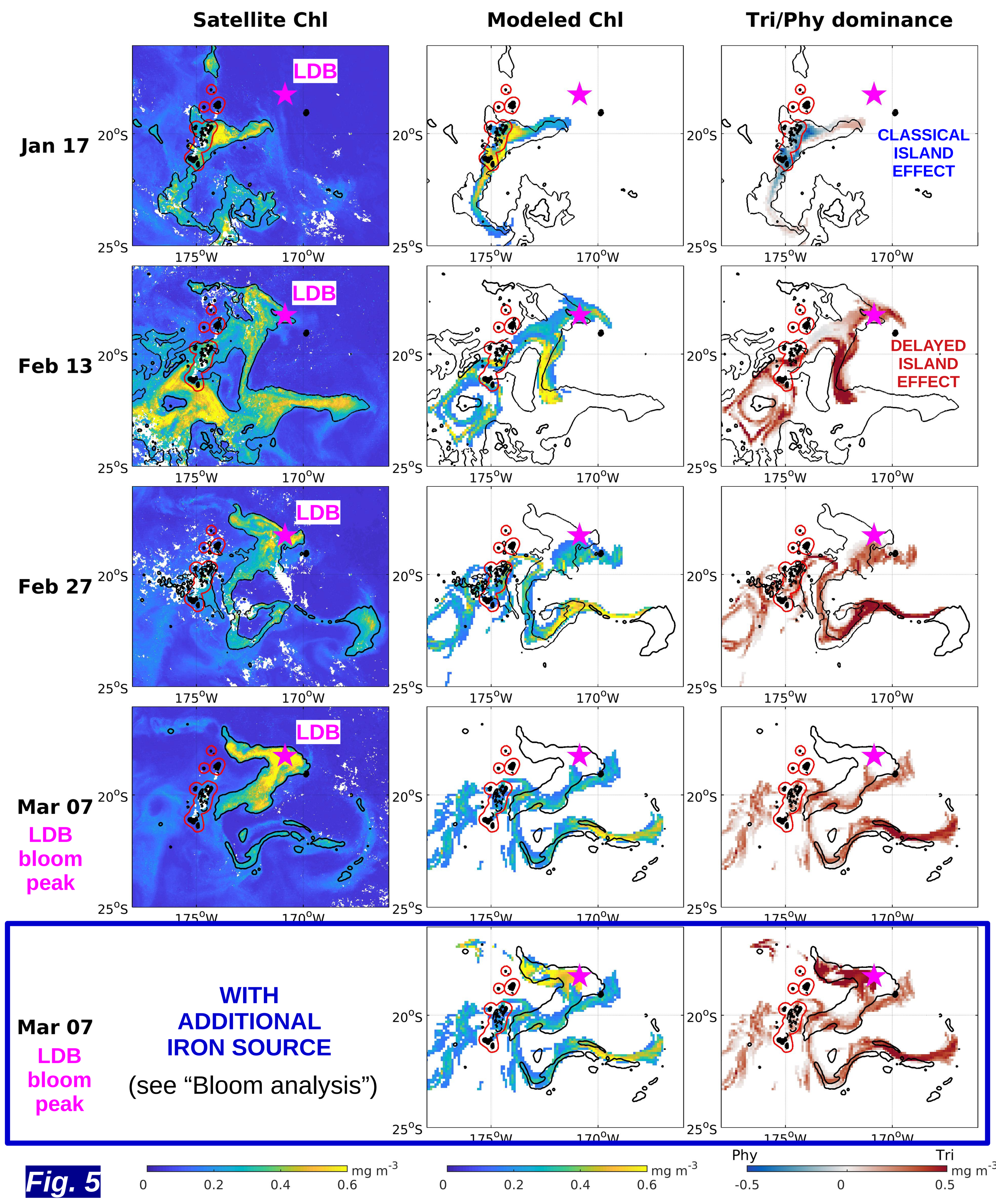


Fig. 5 *Results from the model (middle) as compared to observations (left). The Tri/Phy dominance is calculated as Tri-Phy and highlights that* ***both plankton types are needed to represent all phases of the bloom****, with Phy dominating early and near the islands, and Tri dominating later and away from the islands. Black contours are the satellite 0.2 mg m-3 Chl contour. The model does not represent the LDB bloom peak (March 7th), but does with an additional iron source [Fe ini] = 0.8 nmol L-1 near Vava'u from Feb 1-15 (blue box).*

Bloom analysis

- **The growth/advection model is able to represent the Chl patterns (Fig. 5),** except for LDB bloom peak.

bloom phases

- Jan 1-20: "classical" island effect near islands, Phy-dominated
- Jan 20 - Feb 15: "delayed" island effect, Tri-dominated
- Feb 15 - Mar 1: bloom decrease
- Mar 1-20: LDB bloom, not represented by the model: **WHY?**

- Backward analysis from the bloom peak (**Fig. 6**):
  - water masses originated near Vava'u island around Feb 1-15
  - low Chl at that time (no "classical" island effect) ⇨ no model
  - no nitrate supply but maybe iron (delayed island effect), since subsurface iron concentrations can be very high in the region (Guieu et al., 2018) and could be upwelled near islands.

⇨ An additional iron source near Vava'u can explain the LDB bloom (Fig. 5 blue box).

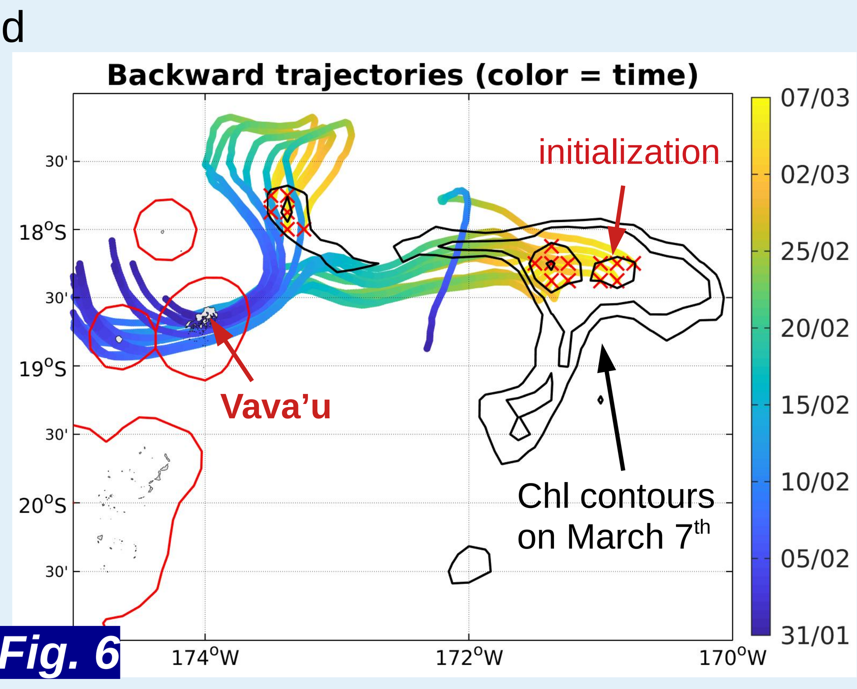


Fig. 6 *Backward trajectories initialized at the bloom peak (March 7th), for highest concentrations (Chl > 0.7 mg m-3) and west concentrations (> 0.55 mg m-3) missed by the model. Red = island 20 km contour.*

Conclusions

⇨ **Island effects were the primary driver of Chl variability** in the region during Dec 2014 – March 2015 and the **primary nutrient input process**.

⇨ **Delayed island effects** can trigger strong Trichodesmium blooms away from the islands because of their slow growth.

⇨ Island-driven Chl enrichments can be disconnected from the islands leading to an **underestimation of island effects.**

Acknowledgements

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