AmeriGEOSS WEEK
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AUGUST 6-10, 2018
INPE - São José Dos Campos, Brasil
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Brazil's experience using multi-platform satellite data to monitor the Doce River coastal plume after a major environmental disaster with a tailings dam collapse

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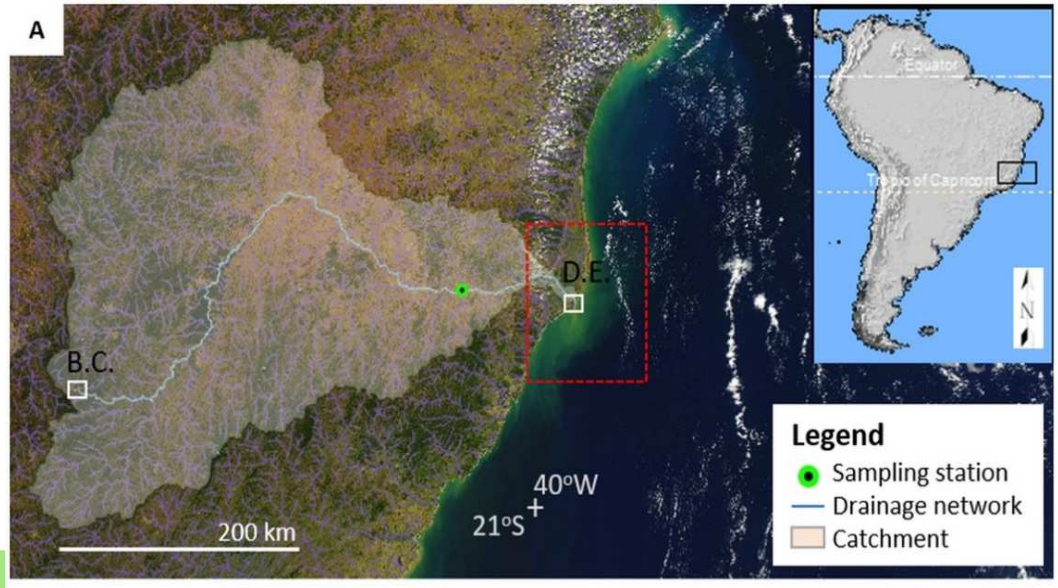
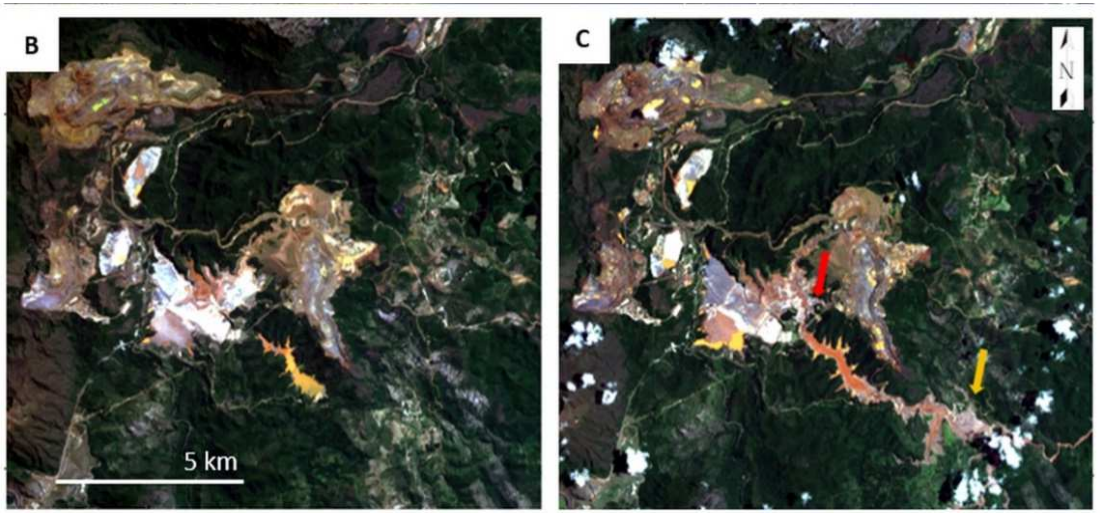
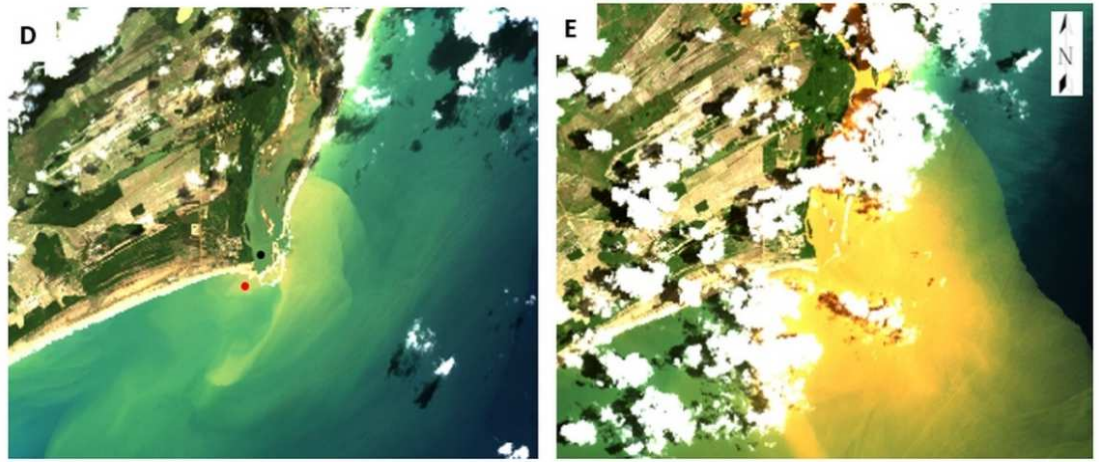
Introduction

- Tailings dam collapse Mariana district (MG) Nov 5, 2015:
- 60 M m^3 of contaminated mud into the Doce River mainstream >600 km








O GLOBO 90

TRAGÉDIA EM BARRAGEM DE MINAS

Avalanche de lama destrói distrito de Mariana

Direct damage:

- 20 deaths
- ~ $1.2 billion of property loss
- loss of water and food supply
- destruction of aquatic habitats killing plants and animals (ANA, 2016).
- loss of regional environmental services estimated in US$521 million per year (Garcia et al., 2017)

Introduction

Challenges

- More than two years after the disaster, despite the efforts to quantify and monitor the impacts of the disaster for inland and coastal ecosystems, many uncertainties remain. Parallel studies have shown different results especially regarding the extension of the areas affected by the contaminated plume over the ocean (Garcia et al., 2017; Marta-Almeida et al., 2016; Bastos et al., 2017).

- Combining diferente approaches: in situ, numerical modelling and satellite observations is key to monitor and analyze the impacts and recovery of the system.

Introduction

Monitoring approaches:

- **National Water Agency and Geological Services (ANA & CPRM) (in situ)**
- Navy (in situ)
- Universities (in situ + modelling)
- Environmental Agency (IBAMA) (in situ + satellite)
- *Fundação Renova* (in situ)

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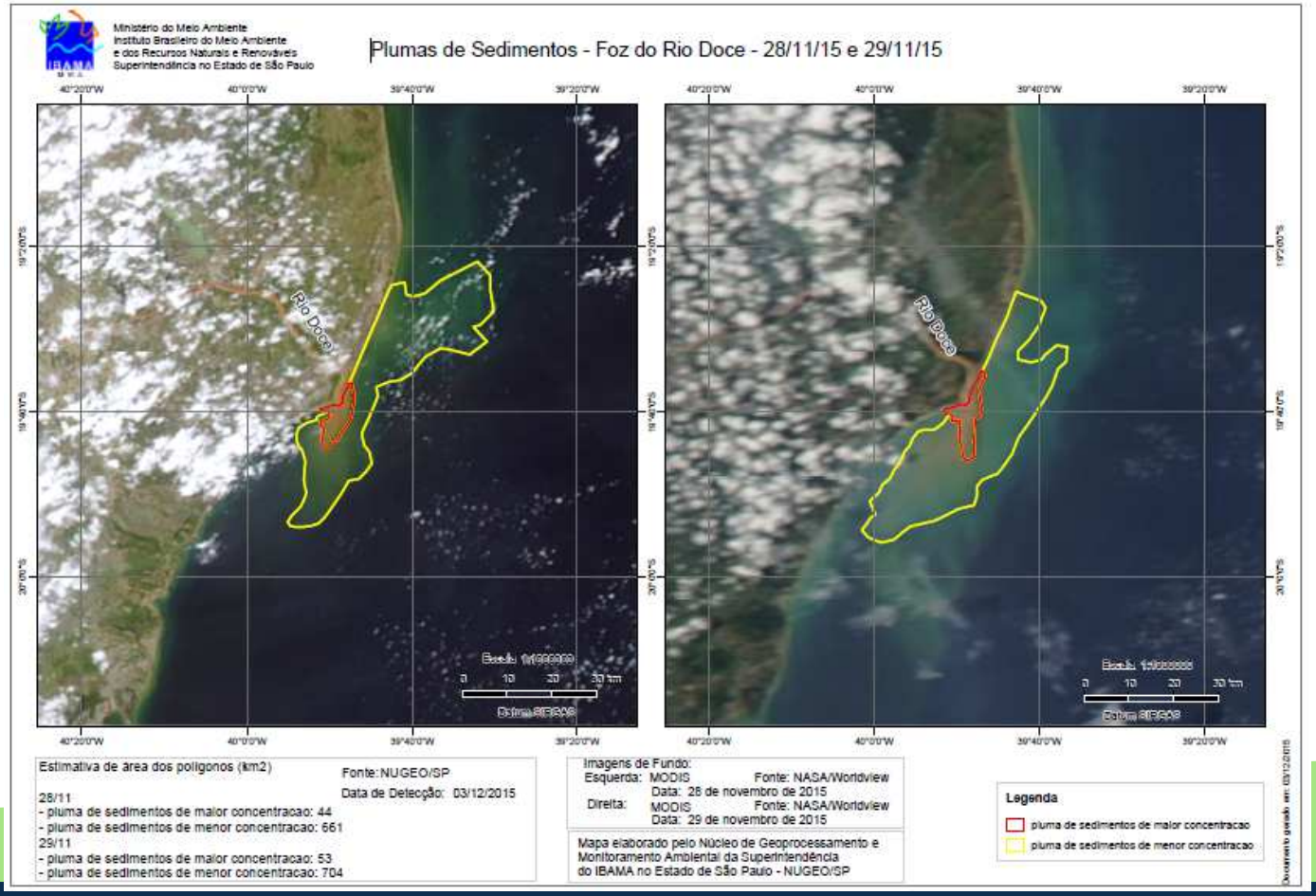
Introduction

Monitoring approaches:

- Environmental Agency (IBAMA) (in situ + satellite)
- *Fundação Renova* (in situ)

Governança pelo Rio Doce:
Maps, reports and alerts to society



Objective

Our goal:

- Provide a quantitative approach to analyze the surface water sediment load (indexed by turbidity) at the Doce River mouth and adjacent ocean, before and after the disaster, using multiplatform satellite data to assess the impacts and recovery of the system;

Materials & Methods

Satellite Surface Water Turbidity

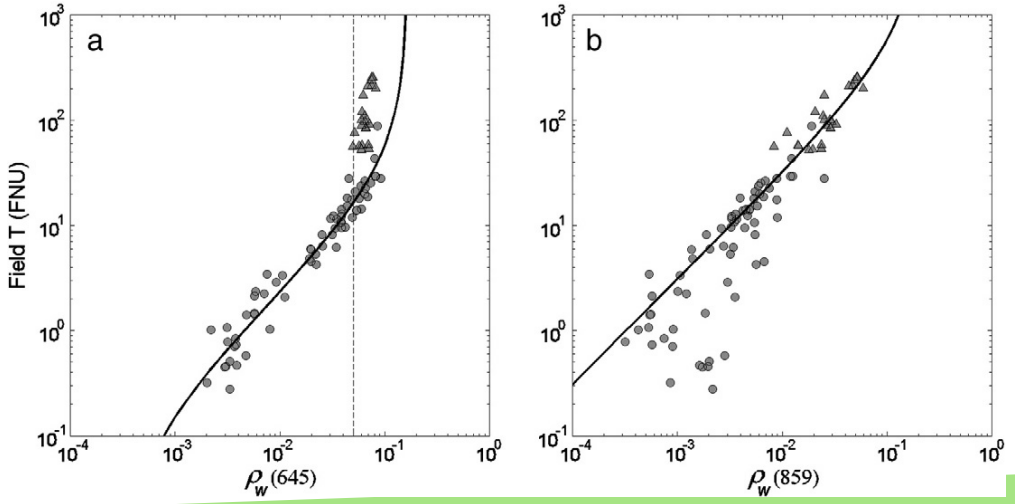
- Atmospheric correction for turbid coastal waters:
  - 6S (Vermote, 1997) for Landsat-5-TM;
  - Acolite (Vanhellemont and Ruddick, 2015) for Landsat-8 OLI
  - MUMM (Ruddick et al., 2000) for MODIS-Aqua
- Dogliotti et al. (2015) Turbidity Algorithm
- Post-disaster adjustment for extreme turbidity (>1000 NTU)
- In situ turbidity (since Nov, 2015) and water discharge (since 1980) near the river mouth (ANA) to compare with satellite retrievals and obtain a pre-disaster turbidity-streamflow relation
- Auxiliary data: sea surface wind fields (ASCAT/METOP-A/B; Precipitation rate)

Results - 1

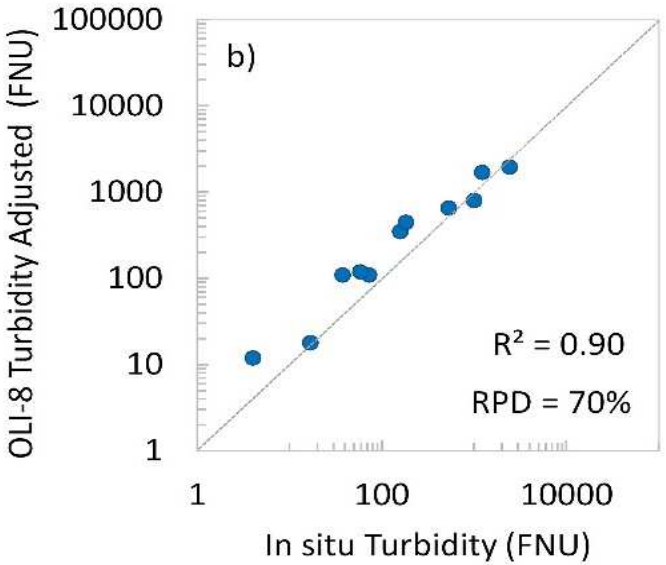
- **Turbidity Algorithm**

Global two-band algorithm
Dogliotti et al. (2015)
(0-1000 NTU)

$$T = \frac{A_T^{\lambda}\rho_w(\lambda)}{\left(1-\rho_w(\lambda)/C^{\lambda}\right)} \quad [\mathrm{FNU}]$$



In situ Match-ups:



Extreme value adjustment (>1000 NTU):

Turbidity (FNU) = 33.732 $^{17.505*\rho(865)}$

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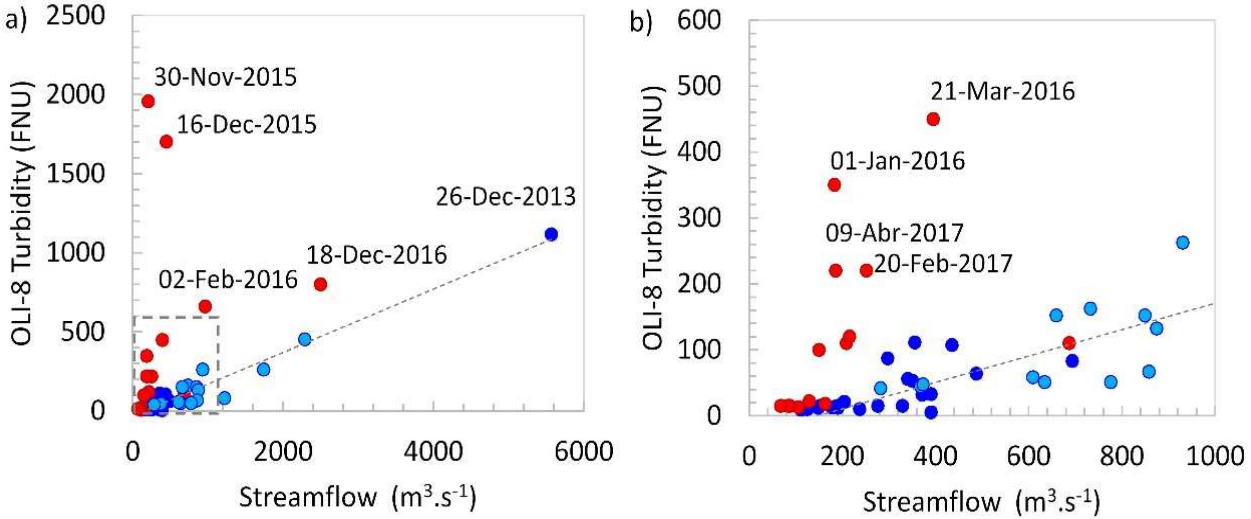
Results 2: Impact on Surface Water Turbidity

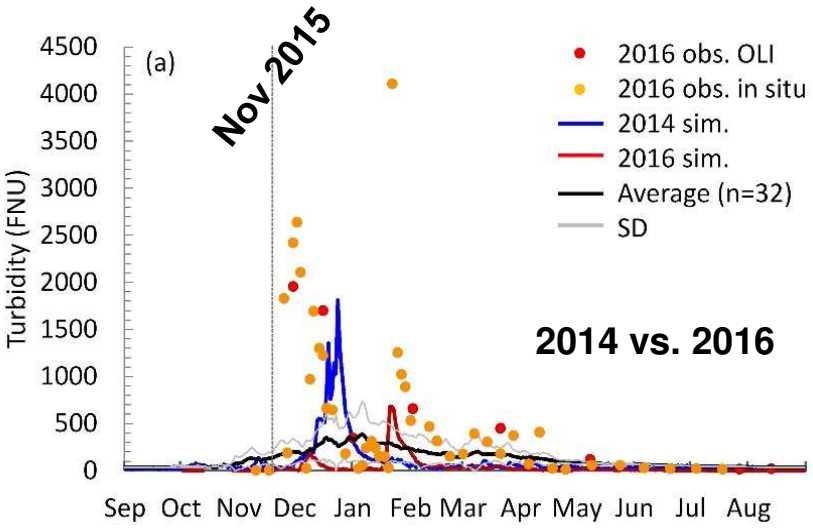
Landsat TM and OLI time series (since 1985)
Relation between Turbidity and Streamflow: before

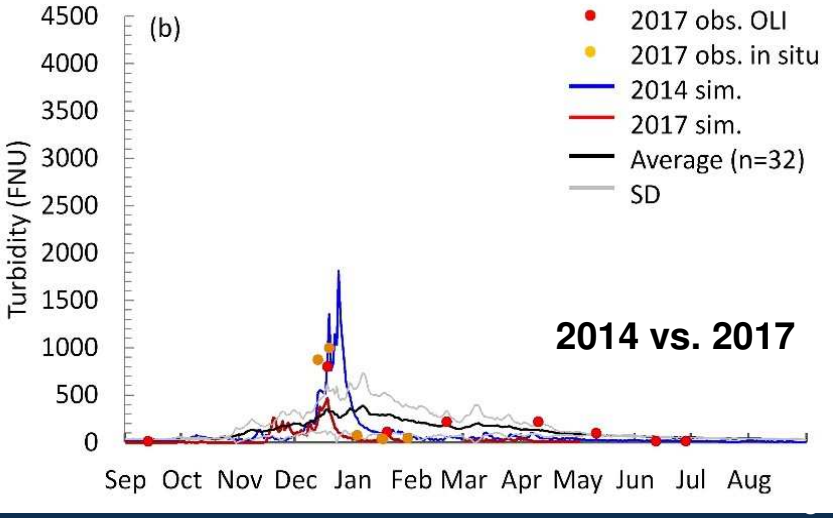


Red dots = post disaster

Turbidity = 0.2001 x streamflow - 29.308

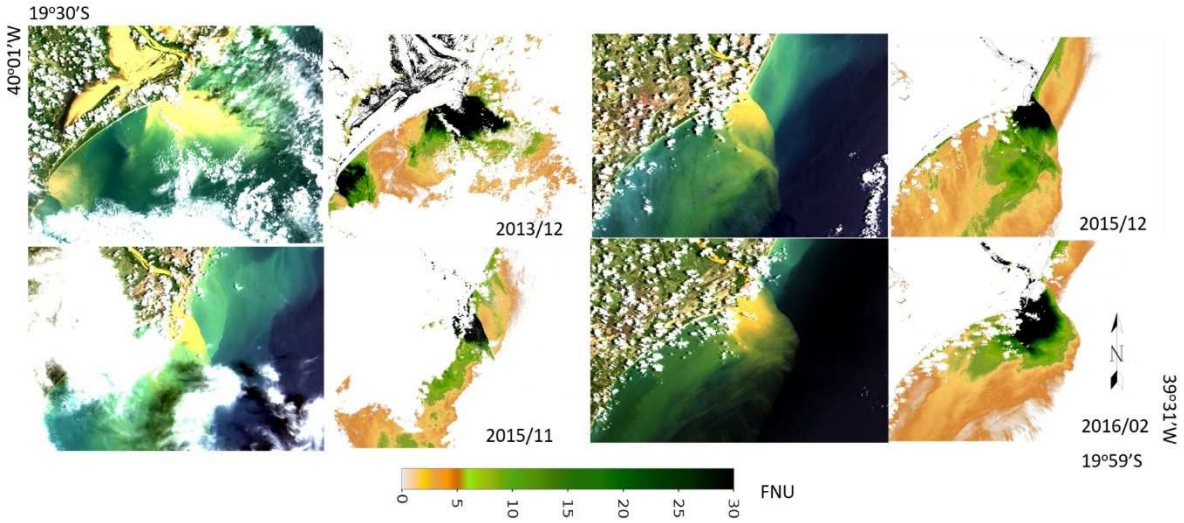
Simulated Turbidity vs. measured

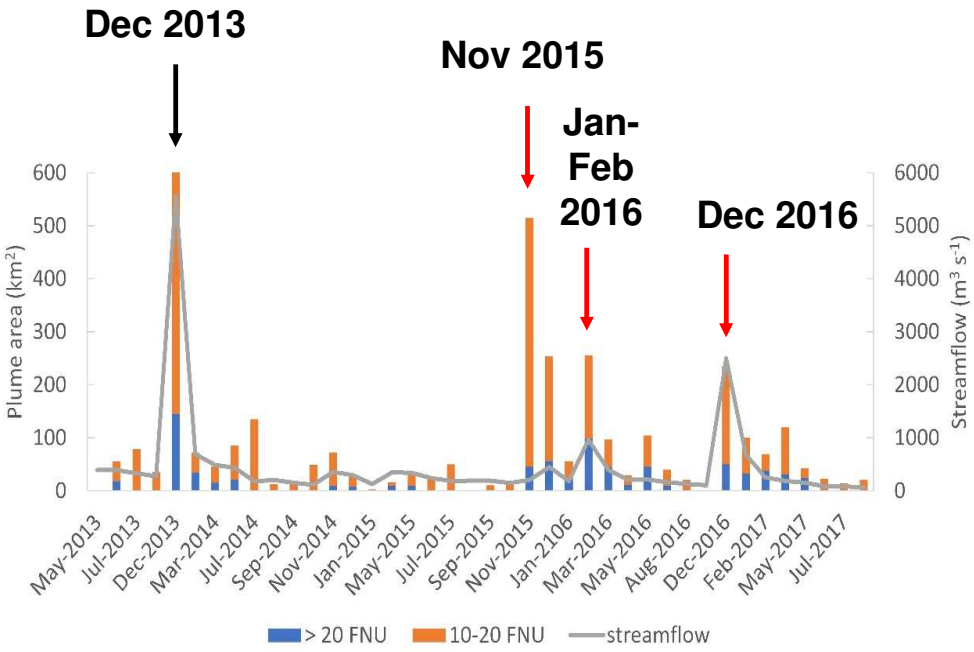




Results - 3

- **Turbidity Plume dispersion: extension; area and direction**

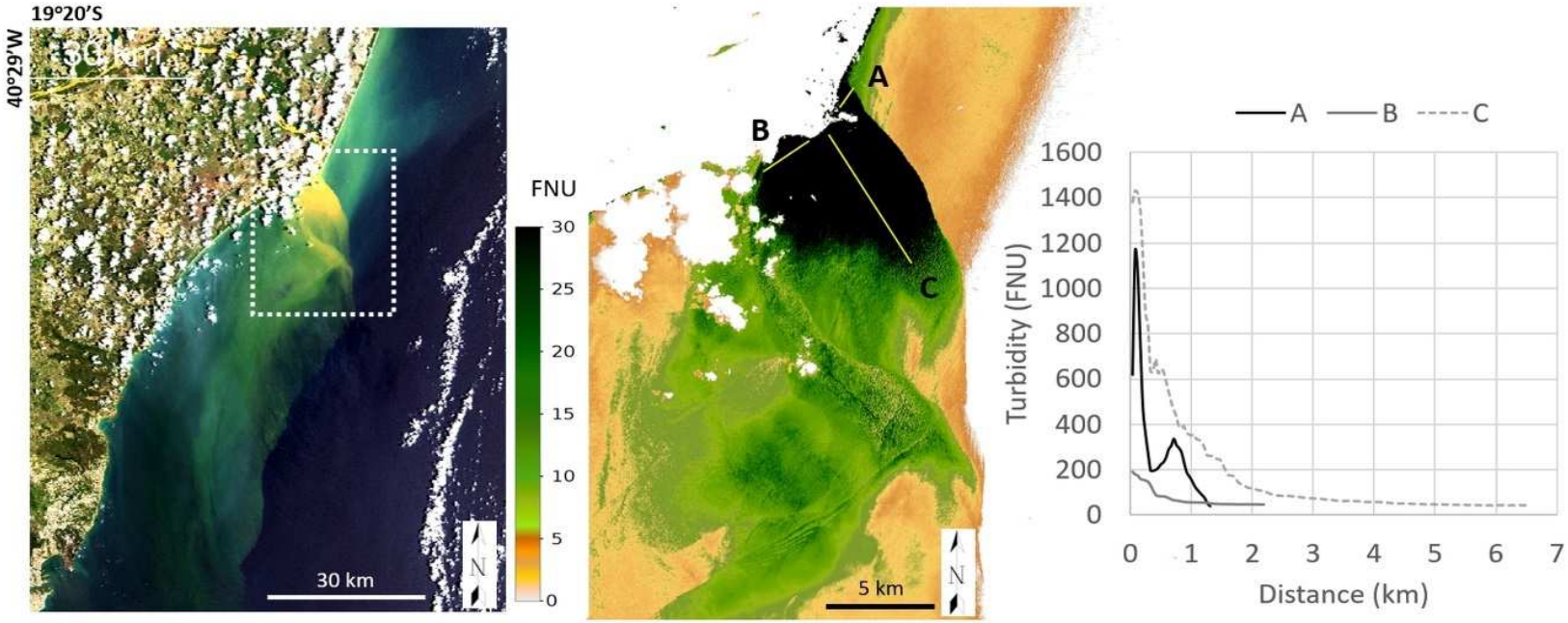




Max. dist. 11 km SE > 20 NTU
Max dist. 39 km S > 10 NTU

Results - 3

- **Turbidity Plume dispersion: just off the river mouth**



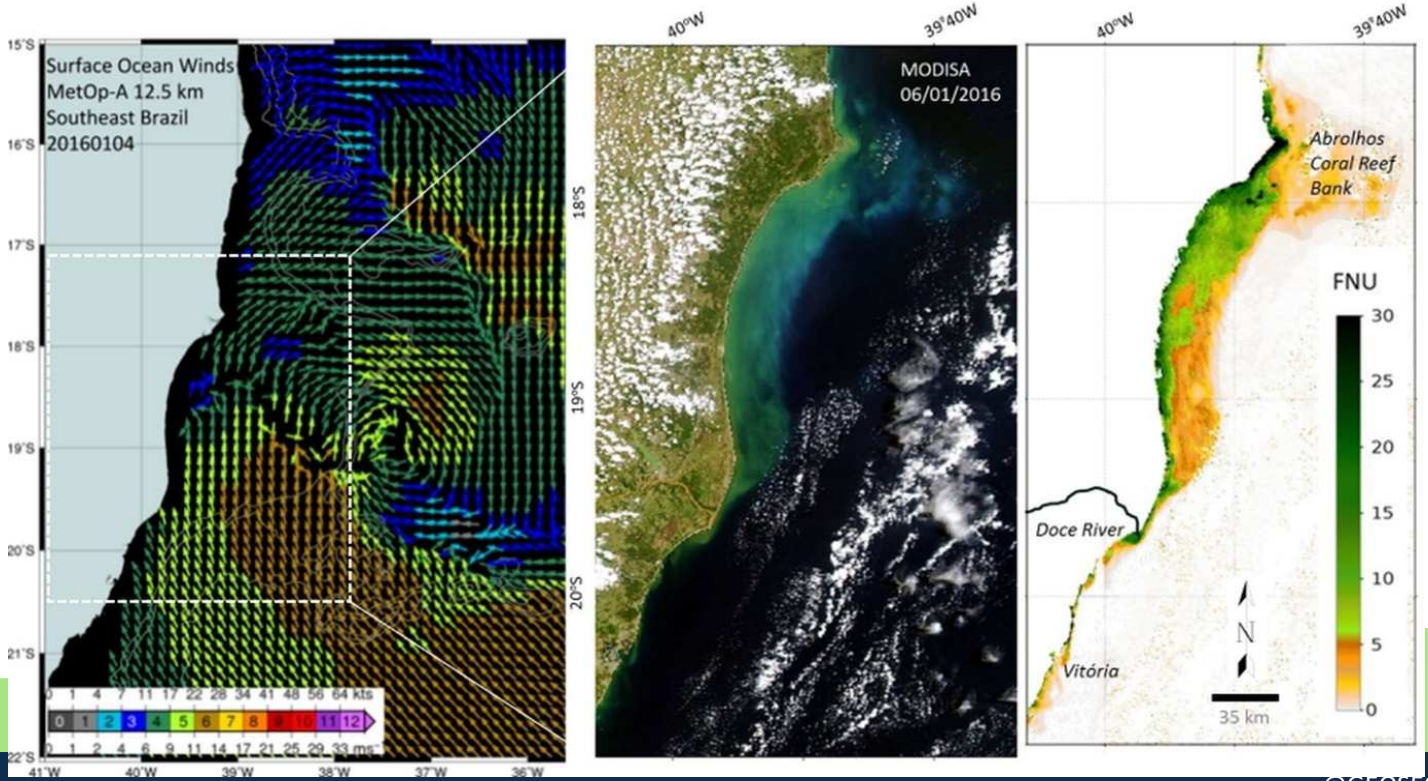
Landsat-8; Dec. 2015

Results - 3

- **Turbidity Plume dispersion: "intensive" met-ocean events**

Jan 2016: Subtropical Front

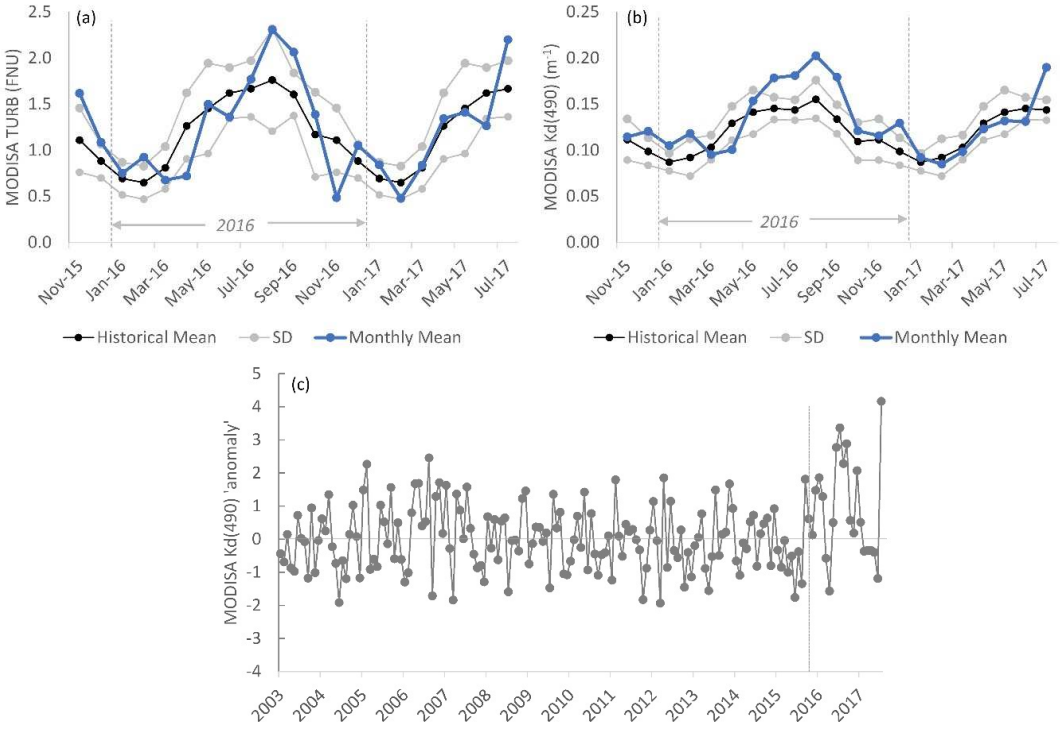
Awareness of the plume possibly reaching the Abrolhos Marine Park (Coral Reef Bank)



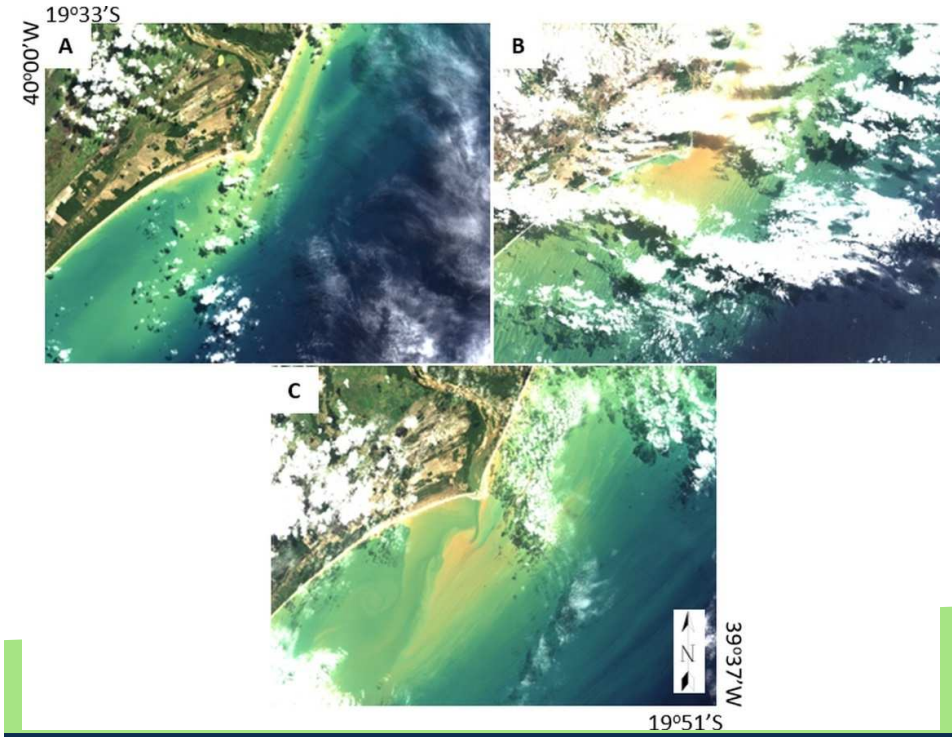
Results - 4

- **Impact on the coastal water turbidity:**

MODIS-Aqua time series (since 2003)



Landsat-8 showing increased turbidity during winter due to resuspension and coastal drift



Conclusions

- Applying proper atmospheric correction quantitative water quality parameters such as surface water turbidity can be accessed by satellite optical imagery and applied to a long time series to determine the impact of the tailings dam disaster at the Doce River mouth
- Turbidity levels were much higher just when the mud wave reached the river mouth (max. 2400 NTU), even under a severe drought condition (2014-2015), and compared to an extreme flood event in Dec 2013;
- In the following winter, turbidity recovered to minimum values (>15 NTU); but increased above expected values after intensive precipitation events in the follow summer
- The maximum turbidity plume extension >20NTU reached 11 km toward the southeast inner-mid shelf; and 39 km S up to 10 NTU
- Just off the river mouth shallow sand bars promote sediment resuspension contributing to increased coastal surface water turbidity
- At a broader scale, the coastal water turbidity was especially increased during the winter season, despite of the low river discharge due to intensive coastal processes e.g., resuspension driven by winds, waves and coastal currents.

Final Remarks

- Satellite data can provide unique spatio-temporal analysis when properly used providing complementary analysis for in situ monitoring, as well as numerical modelling efforts to detect the impacts and the recovery of the system.
- Existing and upcoming satellite constellations, e.g., JPSS and the Sentinels are valuable resources to address critical social-economical-environmental needs
- Initiatives to provide accessible tools to visualize, process and extract valuable information, as well as the integration of different data sources, such as those promoted by AMERGEOSS are an urgent need and should be prioritized by partner collaborators.
- The monitoring and management of such an event would greatly benefit from this, unifying the efforts and providing faster and more robust solutions.

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Thanks!

Obrigada!

Gracias!