



## Connecting the world around ocean forecasting



### **An overview of the South and Central America operational systems: Strengths and gaps**

Clemente A. S. Tanajura, Federal University of Bahia (UFBA) and REMO, Brazil

Boris Dewitte, Center for Advanced Studies of Arid Zones (CEAZA), Chile



# Presentation Outline

## Operational Systems in South and Central America:

- Argentina
- Brazil
- Chile
- Colombia
- Mexico
- Peru

## Strengths and Gaps



## Members of the South and Central America Regional Team:

Dr. Boris Dewitte (CEAZA, CL) (chair)

Dr. Clemente A. S. Tanajura (UFBA and REMO), BR (co-chair)

Dr. Alberto Piola (UBA), AR

Dr. Camila Artana (IRD e UFSC), AR

Dr. Carlos A. E. Garcia (FURG), BR

Dr. Carlos Kan (SENACYT), PA

Dr. Claudia Simionato (CIMA/CONICET-UBA), AR

Dr. Claudia Urbano (DIMAR), CO

Dr. Diego Moreira (CIMA), AR

Dr. Diego Narvaez (U of Concepcion), CL

Dr. Francisco Garcia (SENACYT), PA

Dr. Ivonne Montes (IGP), PE

Dr. Julio Scheinbaum (CICESE), MX

Commander Luiz Cláudio M. da Fonseca (CHM), BR

Dr. Leonardo Moreno (DIMAR), CO

Dr. Matias Dinápoli (CIMA), AR

Dr. Ronald Buss de Souza (INPE), BR

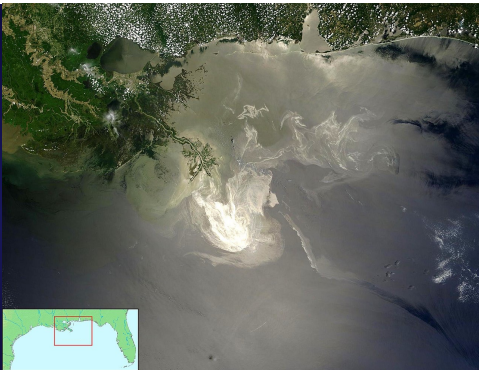
# Motivations and Applications



## Oil and Gas Industry



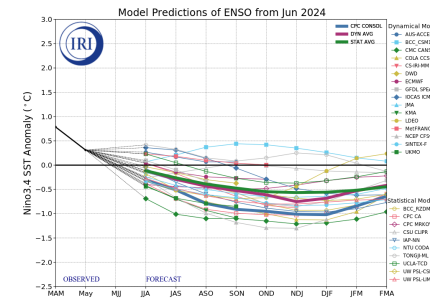
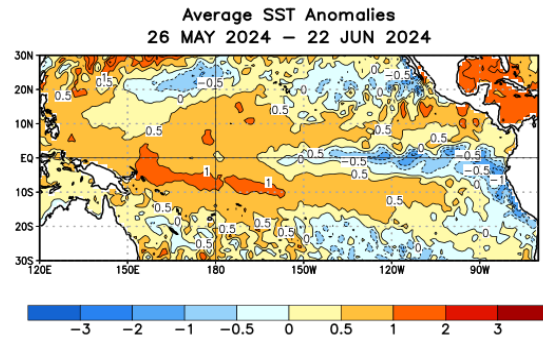
## Mitigation of Oil Spills and Pollution Gulf of Mexico May 2010



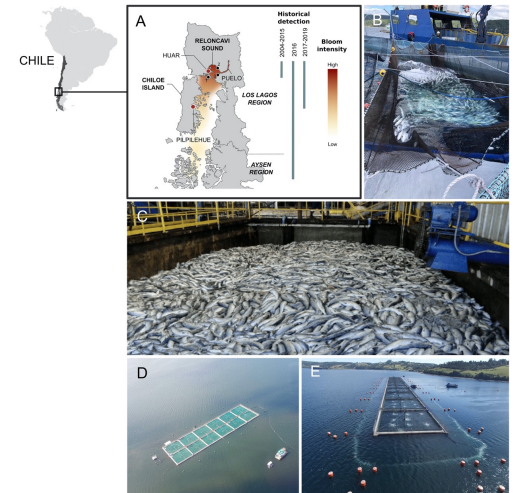
## Search and Rescue Equatorial Atlantic Jun 2009 AF447 228 deaths



## Weather and Climate ENSO Forecast May 24 - Feb 25



## Harmful Algal Bloom Chile Jan-Feb-Mar 2016 US\$ 800 M loss



Mardones et al. 2021, Sc  
Total Environ.

and more  
safety of life at sea  
navigation  
ports  
tourism....



# Argentina



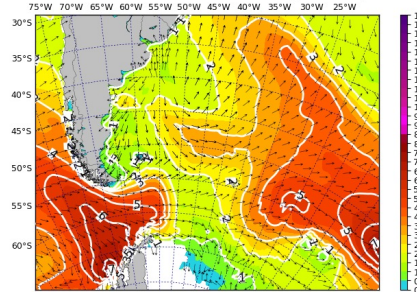
SERVICIO DE  
HIDROGRAFÍA NAVAL



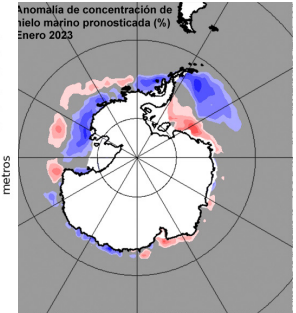
Servicio  
Meteorológico  
Nacional  
Argentina

- Forecasts are responsibility of the **Naval Hydrography Service (SHN) and National Meteorological Service (SNM)**
  - WaveWatch III – waves and surface currents
  - tides and tidal currents for specific regions (e.g. La Plata River)
  - Forecasts of sea ice concentration in Antarctica

Altura significativa de las olas (sombreado y contornos)  
Dirección dominante de las olas (vectores)



Inicializado 2023/01/07 06Z, válido para 2023/01/07 00Z  
Modelo de olas Austral-WAVEWATCH III



- PronoMAR** - “Forecasting the Argentinean Sea” – Multi-institutional
  - 3-yr Project (Jul 2022 – Jun 2025): - Implement an operational forecasting system for sea level, waves and currents for the Southwest Atlantic and high resolution models for specific regions
  - Promote capacity building and research
  - Reach potential users by making all products available by internet
  - Improve the system along time with the current and new collaborations





# Argentina



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Servicio  
Meteorológico  
Nacional  
Argentina



## Forecasting Argentinean Sea (PronoMAR) UN Decade of Ocean Science for Sustainable Development Action 91.2

Aim: a joint work between institutions to form a network of science, technology and innovation organizations to develop, implement, support and give continuity to a state-of-the-art operational ocean forecasting system, in co-production with the National Meteorological Service (SMN).

Funding:

Ministry of Science, Technology and Innovation  
(PIDT Pampa Azul Initiative)  
University of Buenos Aires (UBACyT and PDE)



GlobalCoast

CoastPredict's Global Coastal Ocean Experiment.  
Learn more and complete our survey to get involved.



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# Brazil



Centro de Hidrografia da Marinha  
www.marinha.mil.br/chm



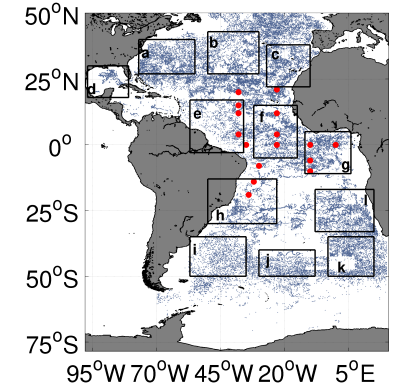
rederemo.org

- Ocean operational system running since 2009 in **Navy Hydrographic Center (CHM)**
- **The Oceanographic Modeling and Observation Network (REMO)** with support from Petrobras was formed in 2007 to construct an operational ocean forecasting system
- GODAE OceanView/OceanPredict member since 2011
- **HYCOM + REMO Ocean Data Assimilation System (RODAS) (HYCOM+RODAS)**
  - HYCOM+RODAS in a nested grid system with 1/12° L32 - 1/24° L32 with tides
  - Assimilation of SST analyses, along track SLA and vertical T/S profiles based on **Ensemble Optimal Interpolation (EnOI)** scheme
  - Daily 6-day forecasts forced by GFS NCEP/NOAA (25 km) in the 1/12° domain and 4-day forecasts forced by COSMO/CHM (7 km) in the 1/24° domain
  - Main users: Petrobras and the Navy

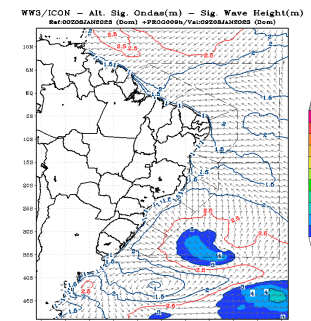
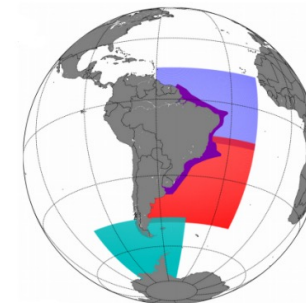
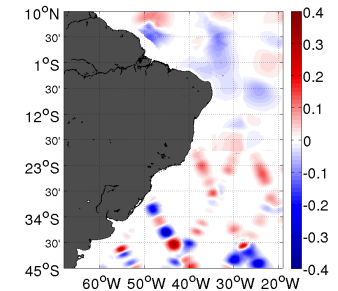
## WaveWatch III

- Two runs per day (00Z and 12Z) forced by GFS/NCEP/NOAA
- Global: 1/3° ; Antarctica: 0.1° ; METAREA V South: 0.1° , North: 0.15°

## SST & T/S Profiles



## Along-track or gridded (SLA)





# Brazil



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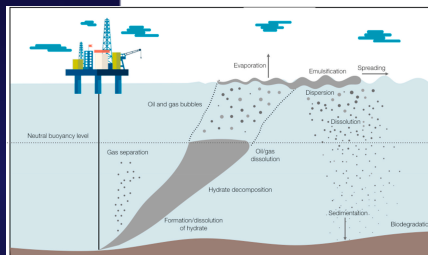


## ADCIRC – SWAM

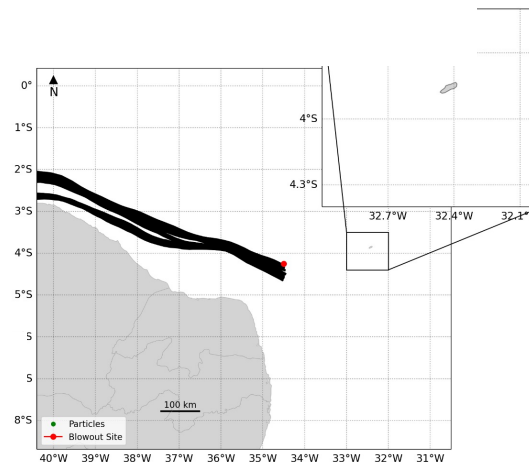
- Guanabara Bay; São Sebastião Cape; Sepetiba Bay currents, winds and waves
- Santos Port and Paranagua Port under development
- Products available for visualization at <https://pam.dhn.mar.mil.br> and **SISCORAR App**

## Coupled Model for Oil Spill Prediction (CMOP) (INPE & CHM)

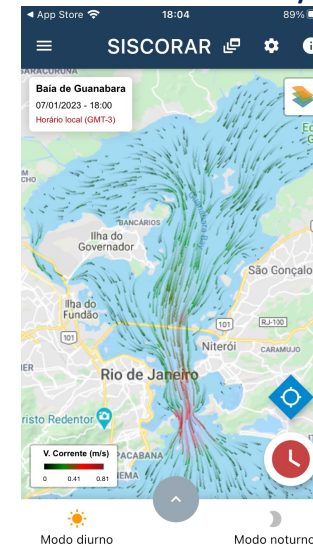
- Physical and chemical behaviour of the oil coupled to 3D Lagrangian particle advection



Barreto et al. 2021, Coastal and Oc. Manag.



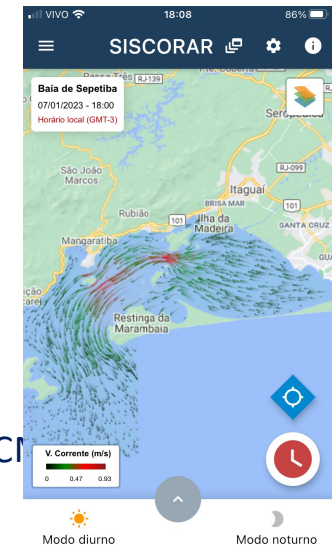
## Guabanbara Bay



Modo diurno

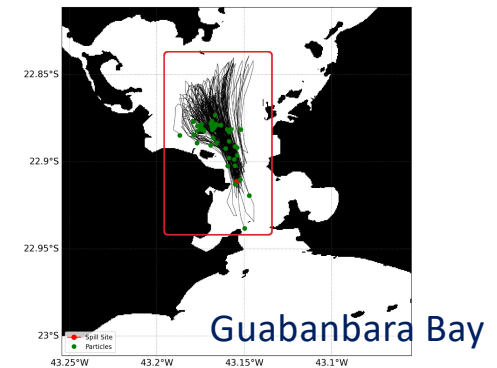
Modo noturno

## Sepetiba Bay



Modo diurno

Modo noturno





# Brazil

## The Brazilian Sea Observatory - Coastal Service

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NATURAL RESOURCES & ENERGY

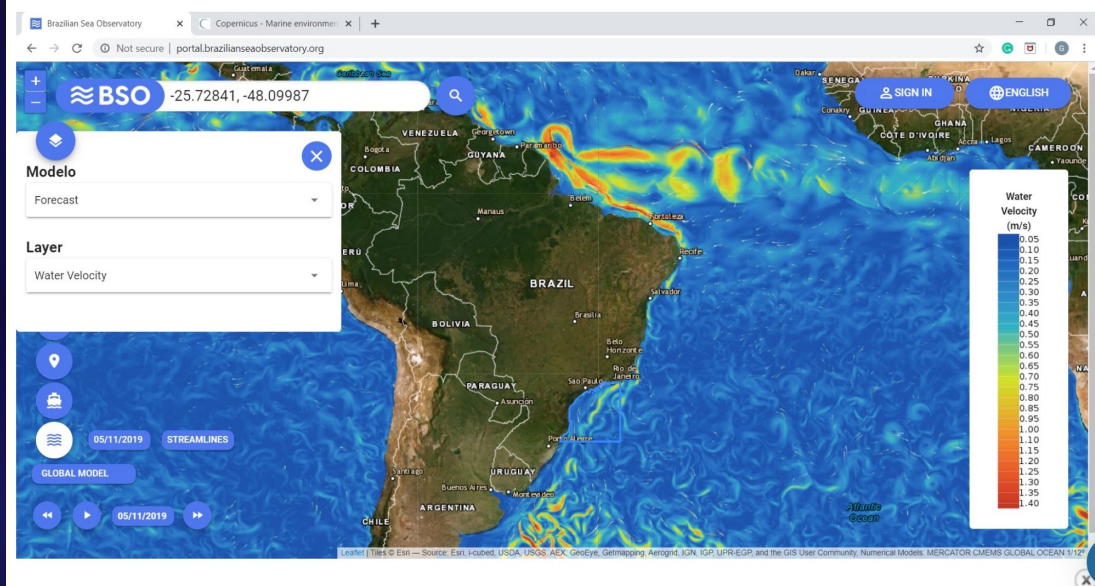


EXTREMES, HAZARDS & SAFETY



COASTAL SERVICES

PDF DOWNLOAD THIS USE CASE



## Collaboration: CMEMS, Federal University of Paraná (UFPR) and IST/University of Lisboa

### MOHID: Focus on

- off South/Southeast Brazil ( $1/24^\circ$ )
- Coastal areas (São Paulo, Santa Catarina and Paraná ( $1/60^\circ$ ))
- Bays and estuaries (120 m)
- 24 h. forecasts forced by 7 km WRF (INPE)



Brazil

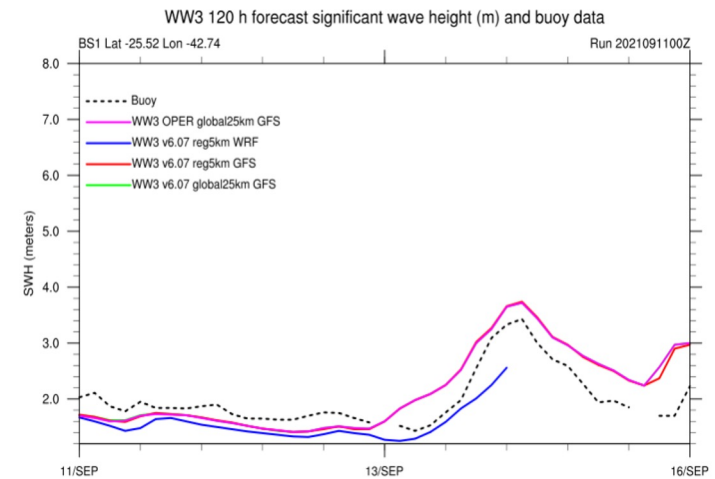
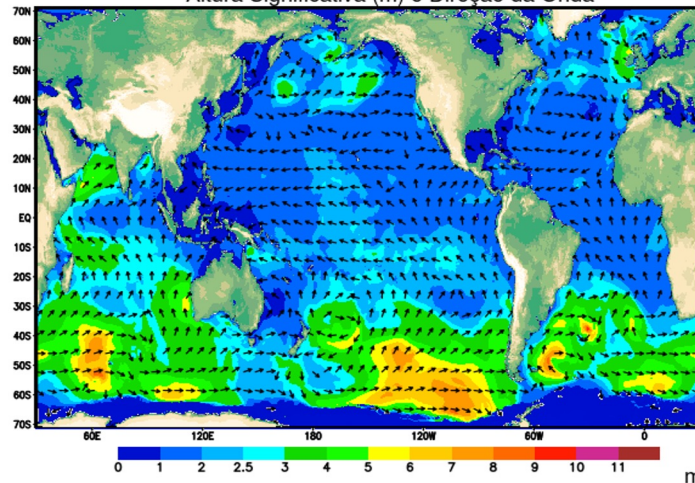


National Space Research Institute (INPE)

## Wave Forecasting at INPE

ANÁLISE: 28/06/2024  
PREVISÃO (00h): 28/06/2024 00Z  
Altura Significativa (m) e Direção da Onda

CPTEC/INPE/MCT  
WWATCH/Global



- WaveWatch III® model, Global-25 km
- Forced by winds and sea ice from Global Forecast System (GFS/NCEP)
- Forecast horizon of 5 days
- ST4 physics (Ardhuin et al. 2010)
- Spectral resolution: 25 frequencies x 24 directions



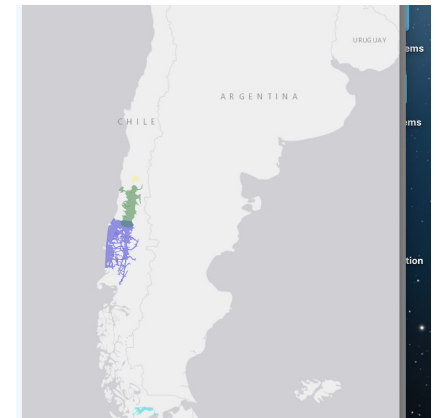
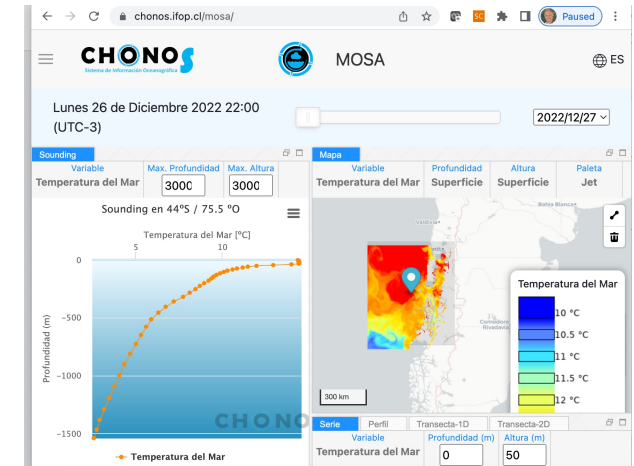
Chile



<http://chonos.ifop.cl/>

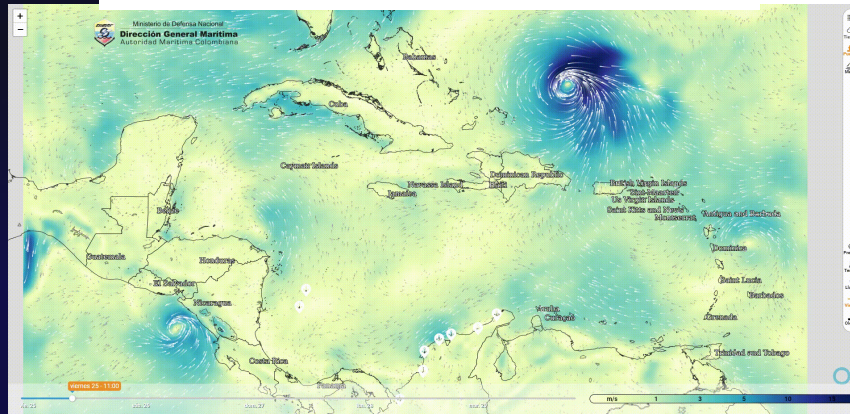
▪ **IFOP (Institute for Fisheries Foment) Oceanographic Information System**

- Knowledge and sustainable environment and fisheries in Northern Patagonia and fjord areas
- **MOSA** (South-Austral Operational Forecast Model) based on **WRF and CROCO** (uncoupled) high resolution operational systems (3-d forecasts) nested in GFS and Mercator forecasts
- Includes discharge of 35 rivers
- **Parti-MOSA** Particle dispersion model. It offers observational information of salmon virus and harmful algal bloom. The model is now being adapted for plastics and oil spills
- Wave and biochemical models are also under development for larvae, algae and parasites



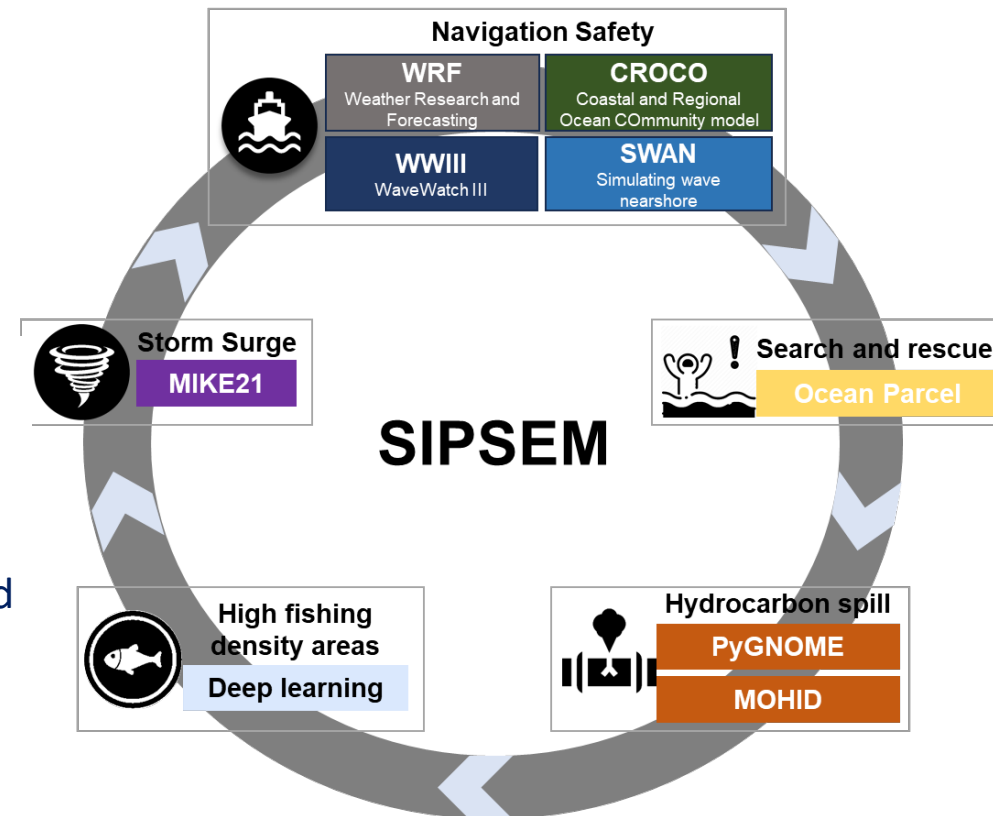


<https://meteorologia.dimar.mil.co/>



- **SIPSEM Project - Integrated Forecasting System for Maritime Safety**
  - Ocean and atm. short-range forecasts for the Colombian Caribbean and Pacific
  - Based on WRF, ROMS, SWAM and WWIII with ensemble and Model Output Statistics (MOS)
  - Oil Spill forecast capability based on PyGNOME and MOHID
  - Downscaling from Regional to Coastal and Coastal to Local (ports)

## SIPSEM's ecosystem of services



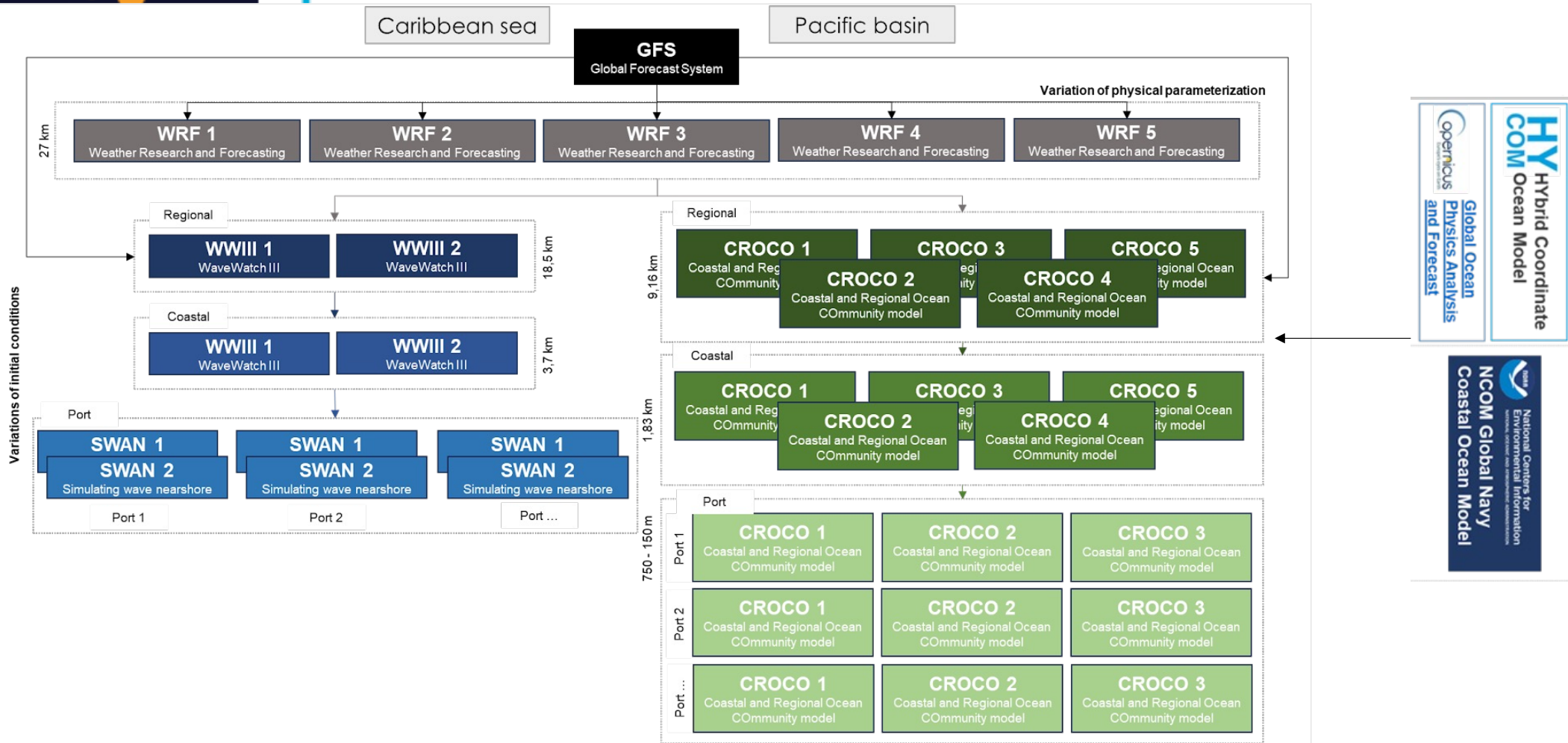


# Colombia SIPSEM Project

# Ensemble forecasts



Ministerio de Defensa Nacional  
**Dirección General Marítima**  
Autoridad Marítima Colombiana



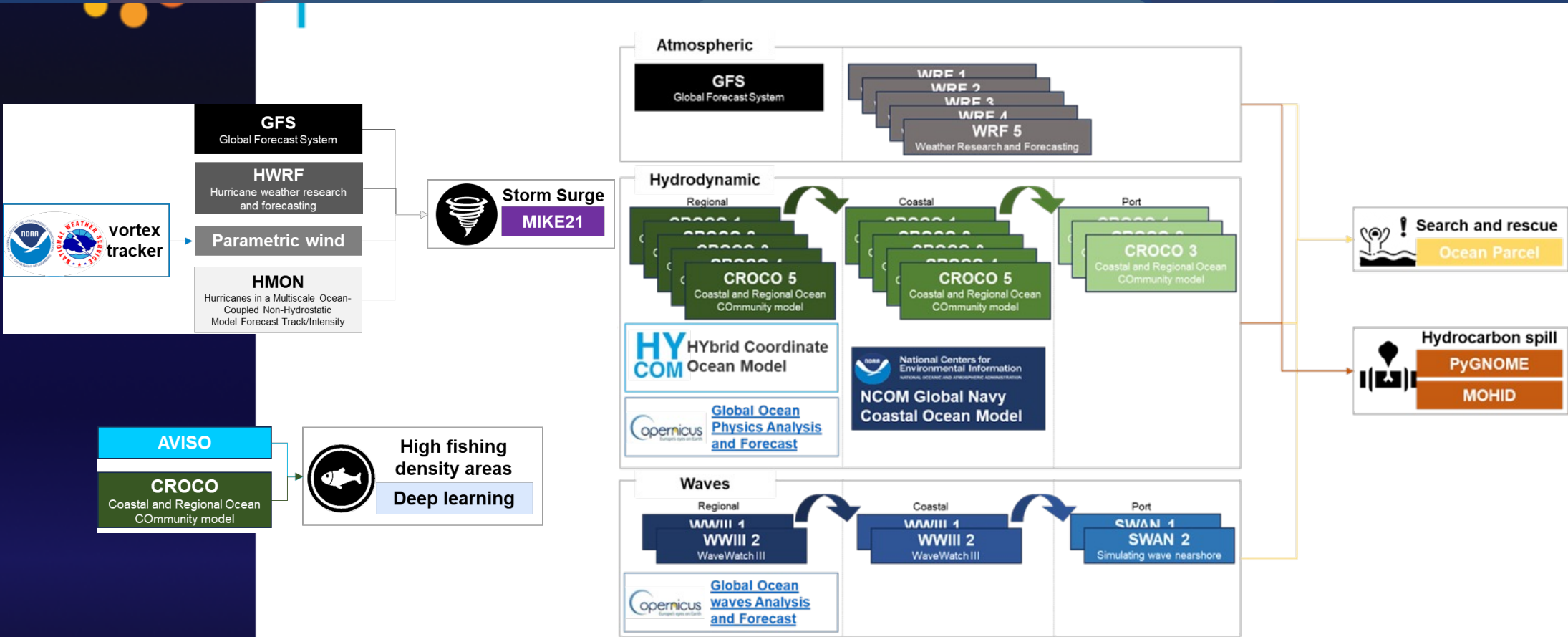


# Colombia SIPSEM Project

## Services



Ministerio de Defensa Nacional  
**Dirección General Marítima**  
Autoridad Marítima Colombiana



*“Consolidamos nuestro país marítimo”*

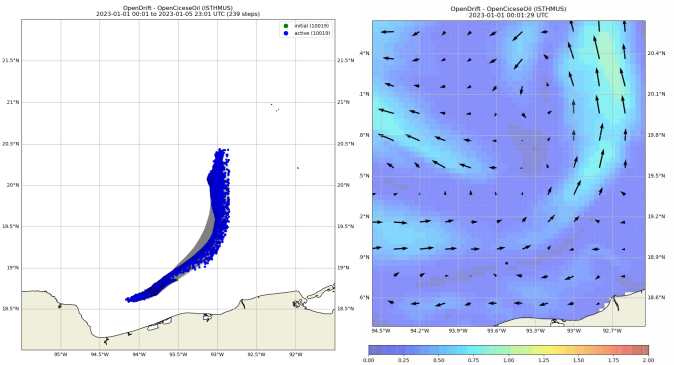


# Mexico

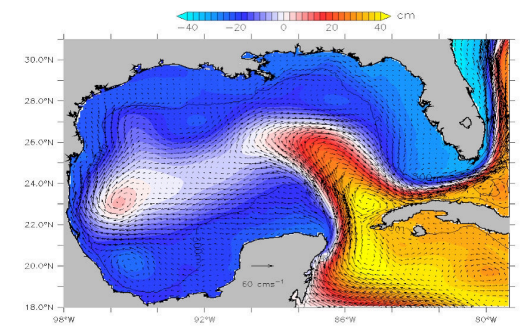


<https://modelacion.cigom.org>

- **Consortio de Investigación del Golfo de Mexico (CIGoM): CICESE, CINVESTAV, CIDESI, UNAM, INECC and others**
  - Oil spill in Gulf of Mexico: daily runs by the model TAMOC+CICOIL for 4 locations in Gulf of Mexico funded by PEMEX
  - Other oil spill models (OIL-SPILL; PETRO-TRANS) also implemented
  - Observations (moored buoys, HF radars, drifters, gliders)
  - ROMS-AGRIF (5 km L40) and NEMO (2.8 km L75) nested in HYCOM and Mercator forecasts are quasi-operational
  - NEMO-PISCES, ROMS-FENNEL, ROMS-BioEBUS employed for long runs
  - Efforts to make these models operational and include ROMS 4D-Var

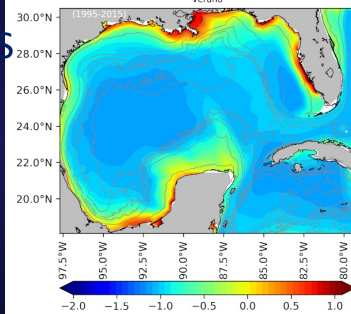


### ROMS-AGRIF



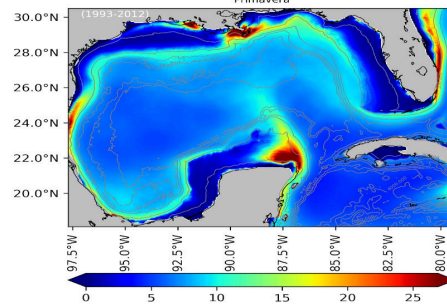
NEMO\_PISCES

### Promedio estacional de Clorofila en superficie Log(mg/m<sup>3</sup>) NEMO-PISCES Verano



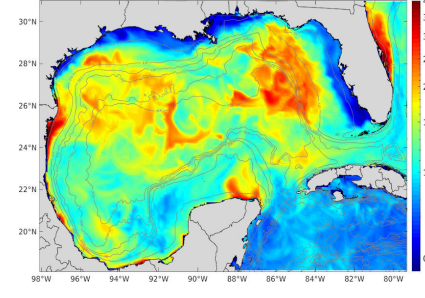
### ROMS-FENNEL

#### Promedio estacional de Clorofila integrada (mg/m<sup>3</sup>) ROMS-FENNEL Primavera



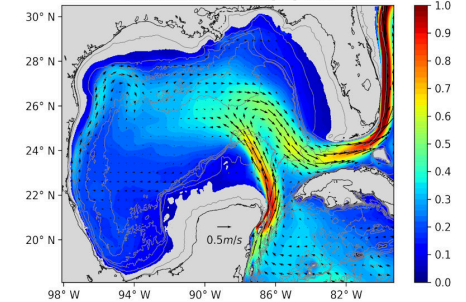
### ROMS-BioEBUS

#### Promedio de clorofila superficial [mg m<sup>-3</sup>]: Primavera ROMS-BioEBUS



### NEMO

#### Promedio de velocidad a 50m [m/s] NEMO



# IGP Regional Earth System Model CROCO-OASIS-WRF (IGP RESM-COW v1) for the Peruvian territory

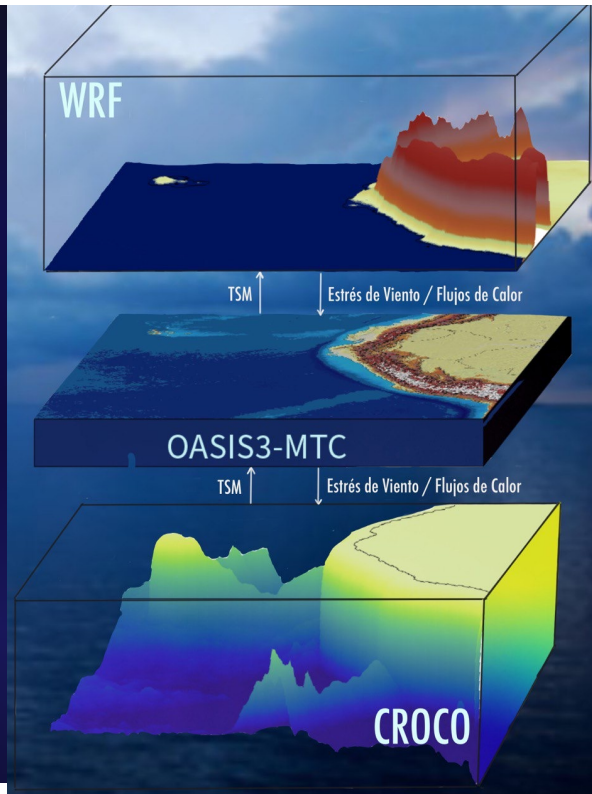


Montes, I., B. Segura, F. Castellón, K. Goubanova, B. Dewitte, K. Mosquera, K. Takahashi

... to establish a forecast tool to the ENSO => contributing to the Multisectorial Commission for the Study of "El Niño" Phenomenon (ENFEN) of Peru

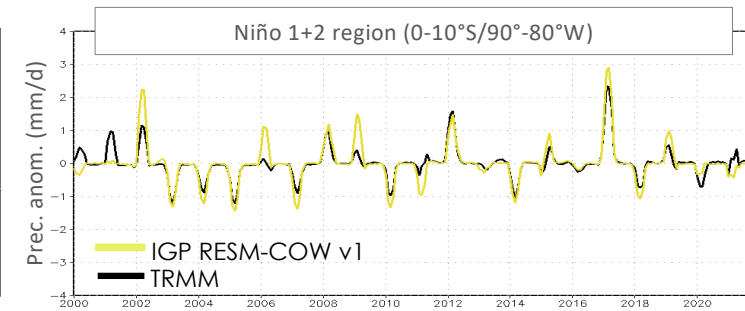
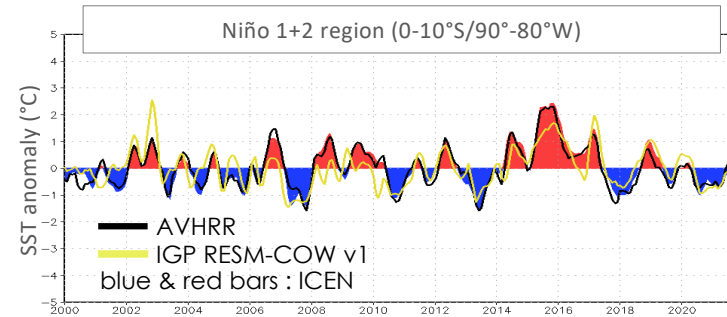
... to investigate the air-sea-land interaction!

Based on CROCO-OASIS-WRF

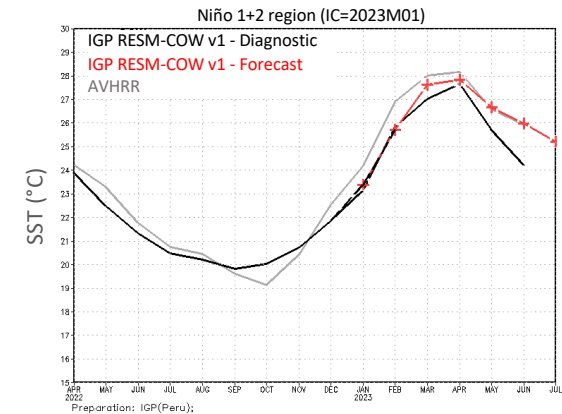
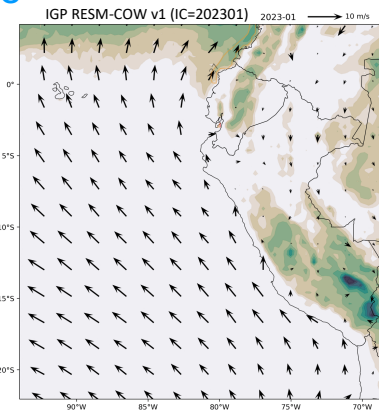


Segura & Montes (2021); Montes et al. (2023)

## Diagnostic mode



## Forecast mode



Preparation: IGP(Peru);

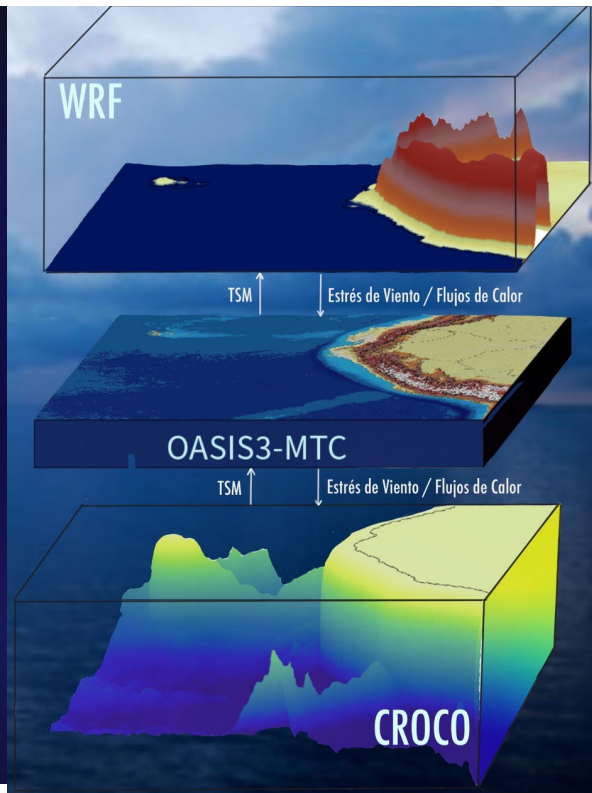
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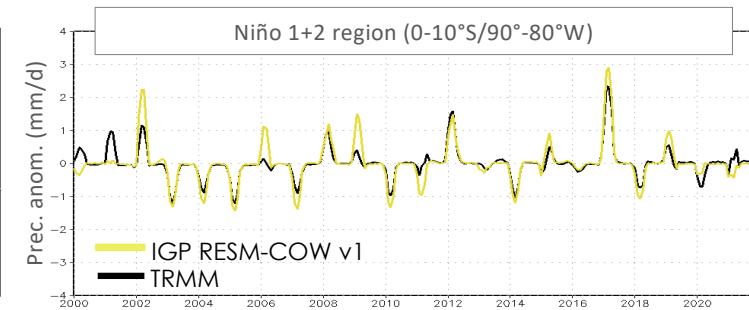
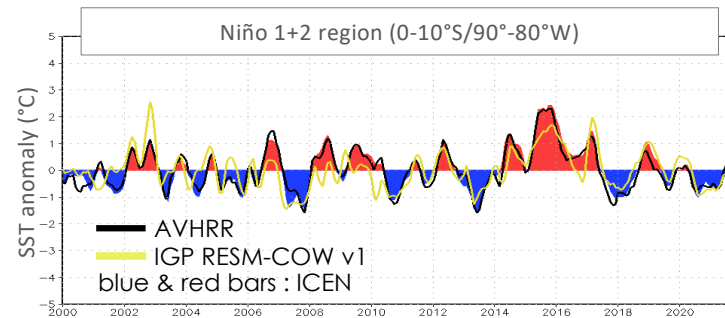
Based on CROCO-OASIS-WRF



Segura & Montes (2021); Montes et al. (2023)

... to investigate the air-sea-land interaction!

## Diagnostic mode



**IMARPE – Operational forecasts of equatorial and coastal Kelvin waves for subseasonal scales with shallow water model**



## Strengths

- Large diversity of models, configurations and applications
- Large diversity of stakeholders
- Motivation to improve the operational forecasts, observational systems and data assimilation
- Expertise in modeling, observations, maintenance of instruments
- Motivation to disseminate data, analyses and forecasts
- Acknowledgment that collaborative networks are needed inside each country, among SA and CA countries and with other countries and advanced centers
- Several ongoing efforts in these directions

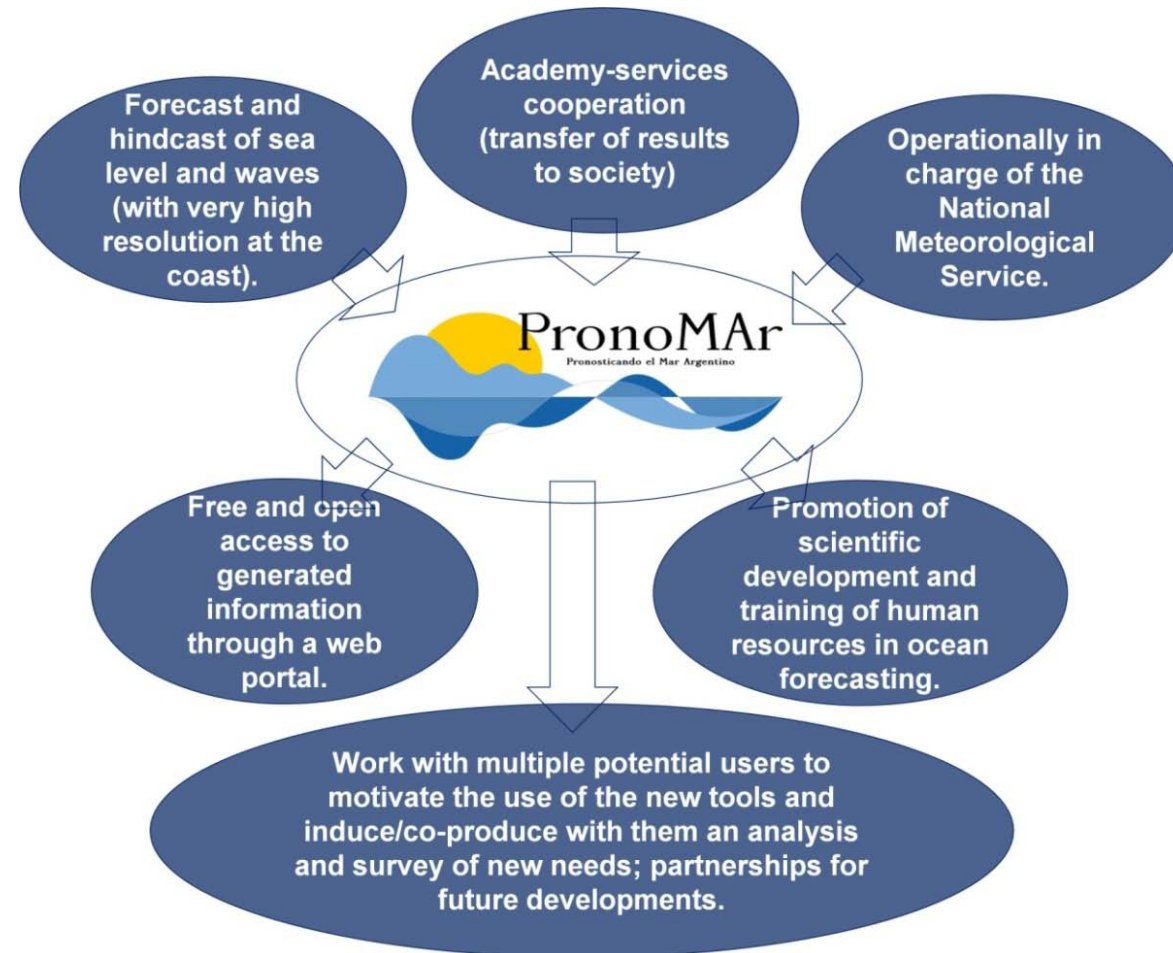
# Argentina



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Argentina



# Brazil



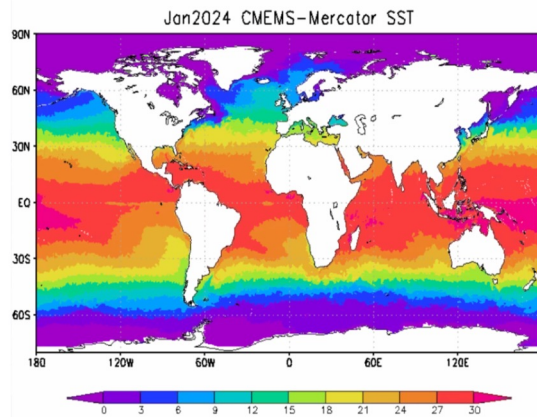
# National Space Research Institute

## SisMOM (Oil Spill Monitoring System) Project Ocean-Atmosphere Modeling Component

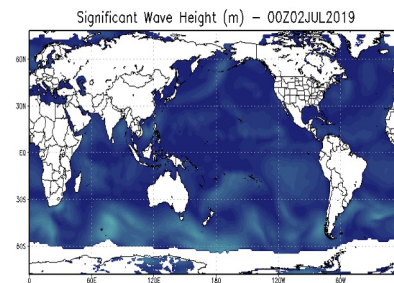
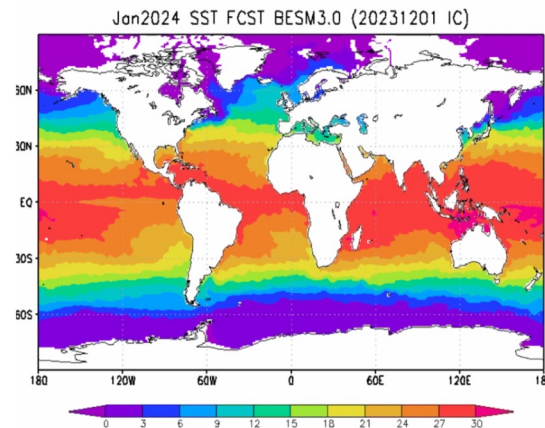
### Seasonal Climate Forecast with BESM

### Case: 2019 Northeast Brazil oil spill

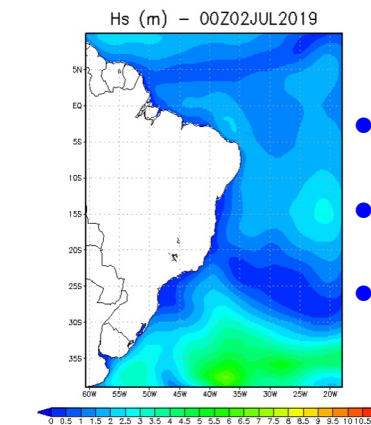
#### MERCATOR ANALYSIS



#### BESM 30 days FCST



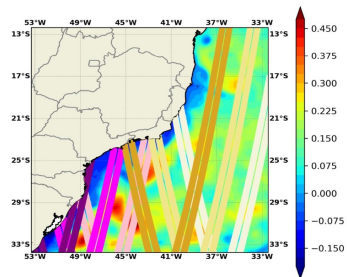
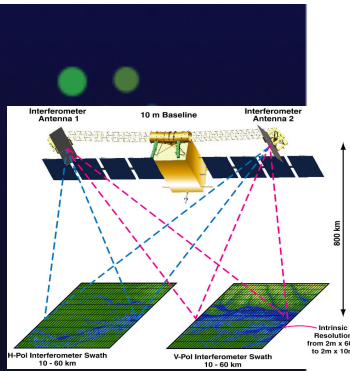
- WaveWatch III® model, Global domain at 25 km
- Forced by winds and sea ice from BESM/INPE global coupled model
- Forecast horizon of 10 days



- WaveWatch III® model, high resolution at 5km for METAREA V
- Forced by winds from regional atmospheric model ETA/INPE
- Forecast horizon of 10 days

- Brazilian Earth System Model (BESM)  
Brazilian Atmospheric Model (BAM-CPTEC/INPE) + MOM6+SIS2-GFDL
- At present, BESM has been tested
  - with resolutions of up to 25 Km, for both atmosphere and oceans, and
  - using as ocean initial conditions data from Global Ocean Physics Analysis and Forecast, CMEMS (Global Monitoring and Forecasting Centre, Mercator), for seasonal forecast.

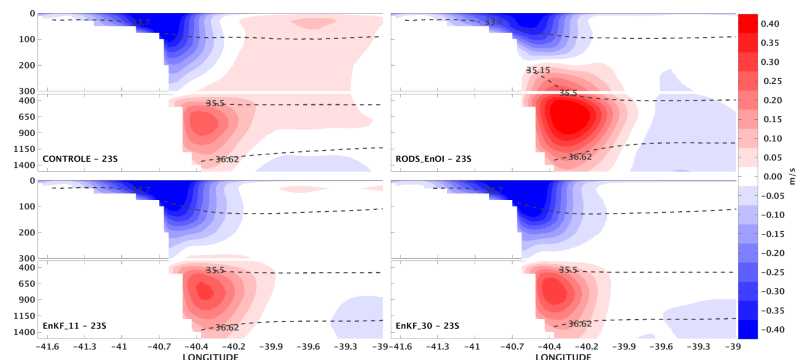
# Brazil Improvements into HYCOM+RODAS



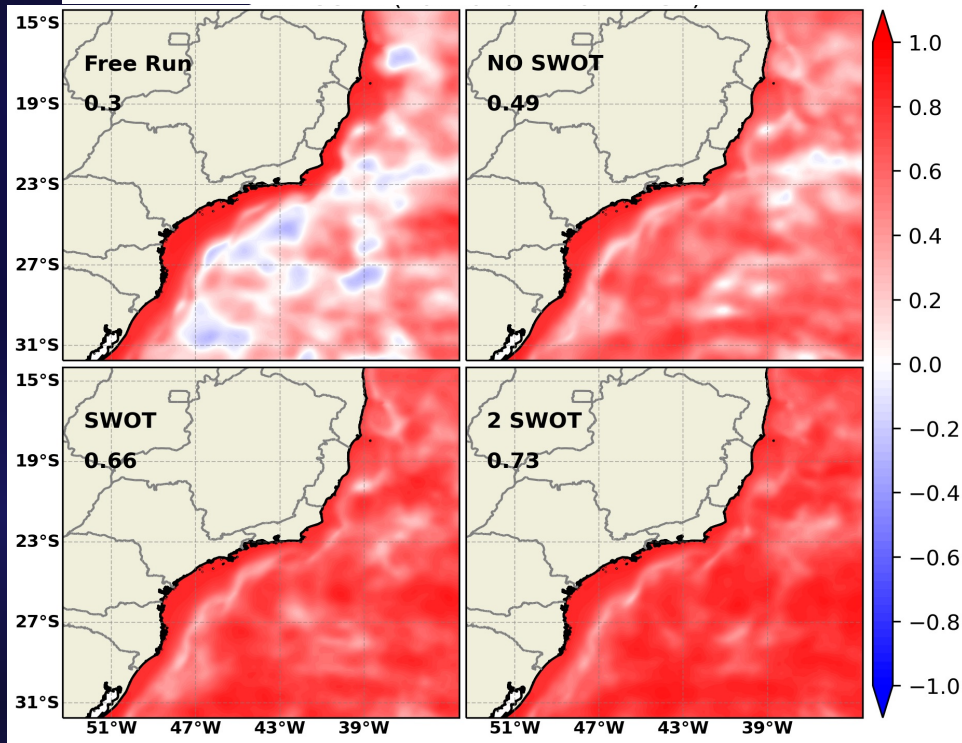
Centro de Hidrografia da Marinha

**EnKF** to capture the “error of the day”  
3-d forecasts 1 June 2017 - 31 Dec 2017

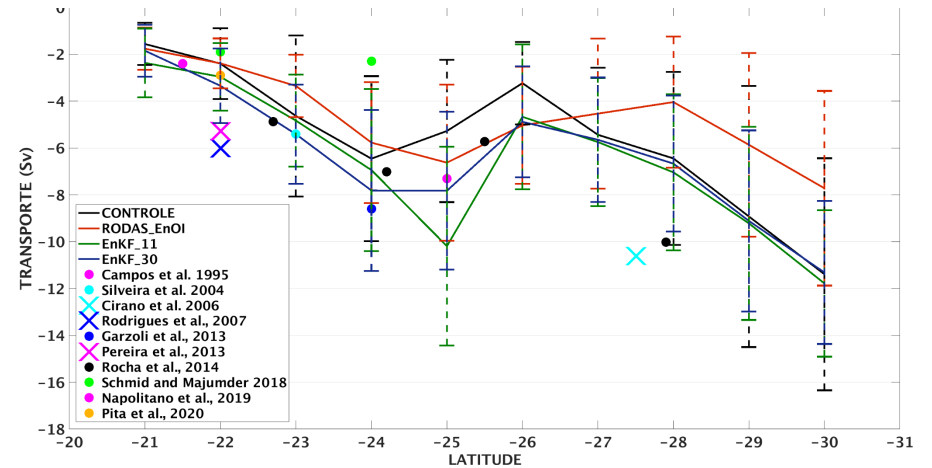
Meridional vel. (m/s) at 23°S



## OSSE 1 SWOT and 2 SWOT



## Brazil Current transport (Sv) along the latitude





**Colombia**  
SIPSEM Project

Future projects



Ministerio de Defensa Nacional  
**Dirección General Marítima**  
Autoridad Marítima Colombiana

- rip currents
- river dynamics
- flood maps due to climate change
- coastal erosion due to climate change
- biogeochemical model
- sediment module

*“Consolidamos nuestro país marítimo”*



## Peru

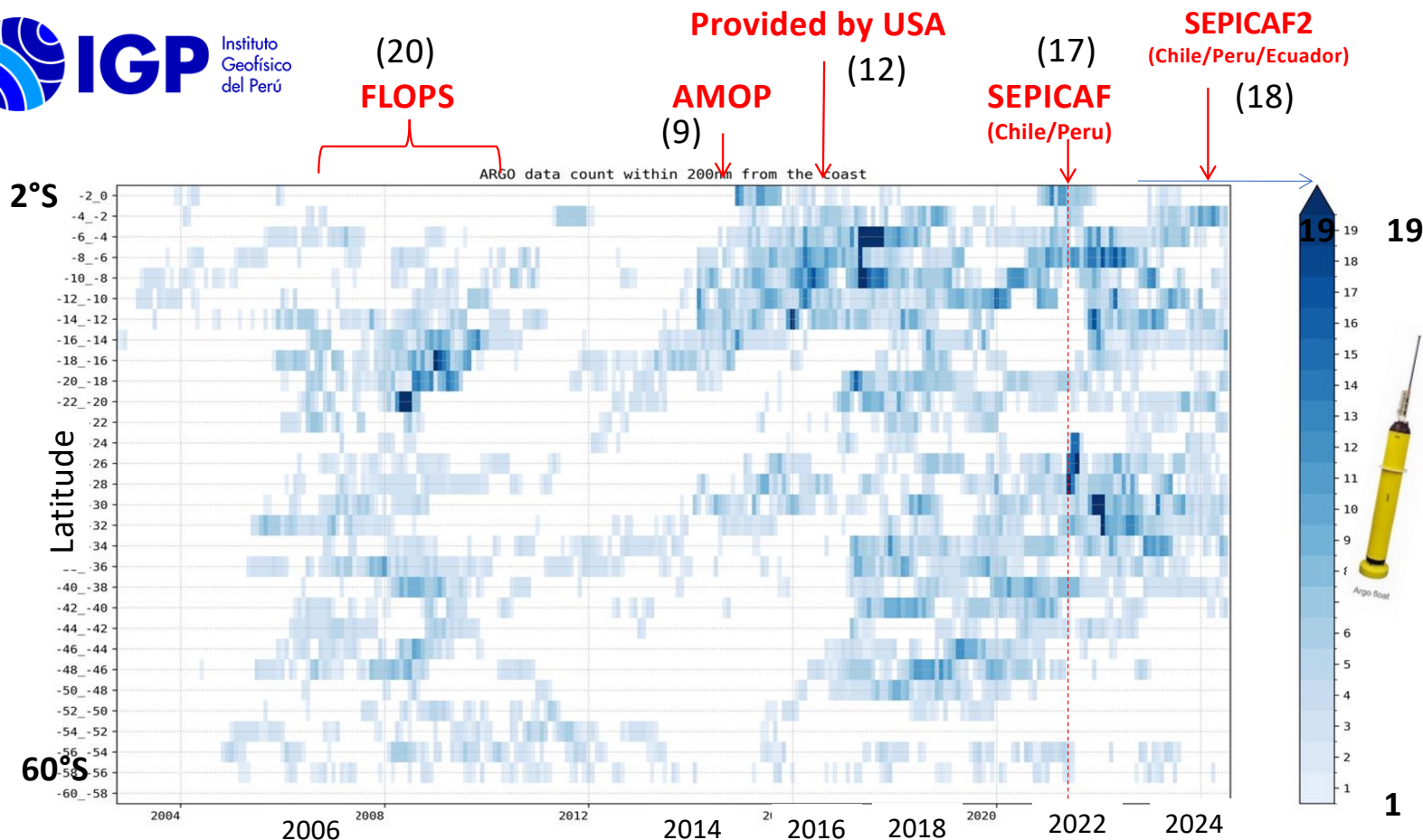


### Perspective to improve (IGP RESM-COW v1)

- \* Perspective (short time)
  - Include biogeochemical model (BioEBUS)
  - Release IGP RESM-COW v2 which (1) fix the technical issues that WRF presents, (2) improve the climate difference methodology to correct the average bias to global models in our region, (3) rerun the diagnostic mode using the same OGCM



# Number of ARGO profiles within 200 mn from the coast (SEPICAF project)



Source: ARGO GDAC  
Processing: IGP

UPDATED: 01JUL2024

Courtesy of K. Mosquera

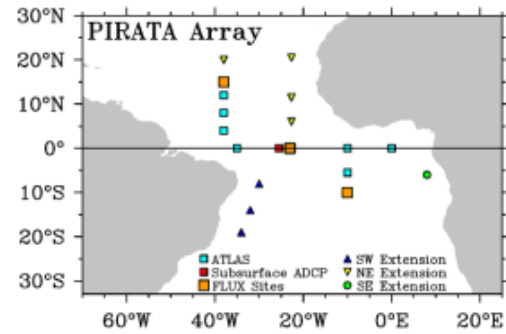


# Brazil

## SiMCosta Buoys & Tide Gauges



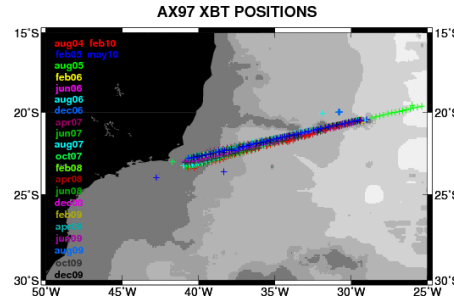
## PIRATA



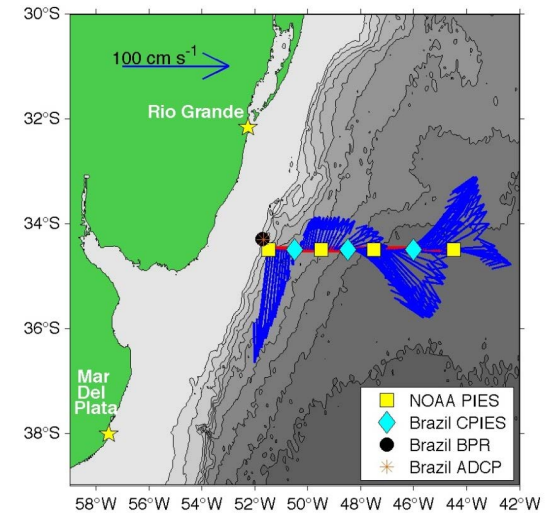
## PNBOIA



## MOVAR (AX97)



## SAMBA - SAMOC

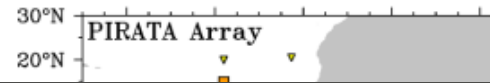
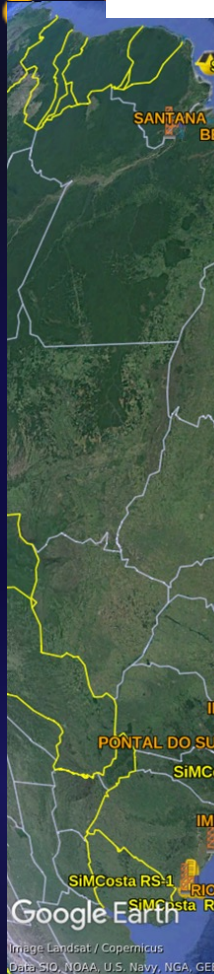



# Brazil INPO & RENOMO

## SiMCosta Buoys & Tide Gauges

### PIRATA

### PNBOIA



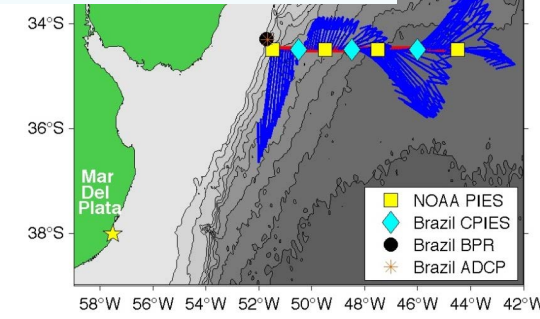
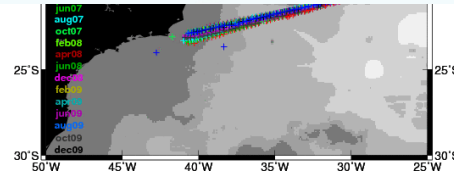


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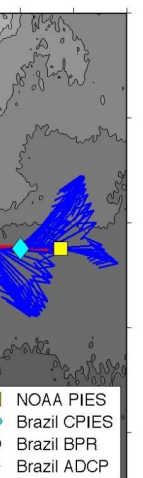
## Bem-vindo(a)!

Essa é a plataforma digital da ReNOMO. Aqui os dados da rede serão distribuídos livremente

- 20 coastal buoys
- **In 2025**
- 9 new buoys



### MOC





## Gaps

- Scarcity of trained human resources and training programs in Operational Oceanography
- Lack of solid infrastructure – computational, vessels, organizational, connection with users, permanent financial support for observational systems
- Lack of data sharing and public repository with QC information
- Lack of high-resolution topographic data (coastal and estuarine scales)
- Lack of high-resolution data assimilation and dense data sets (coastal domain, submesoscale, estuaries)
- Lack of biogeochemical forecasts, data and data assimilation of BGC variables mainly in SA east coast
- Lack of data in the deep ocean (~200 Deep Argo today)
- Coarse vertical resolution of the global reanalyses (coarse bathymetry)



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**Thank you!**