New Zealand's national ocean forecast system - present and future

MetOcean Research and Development team (MRD)

What do automated systems need to accomplish?

Ability to re-use functionality as much as possible

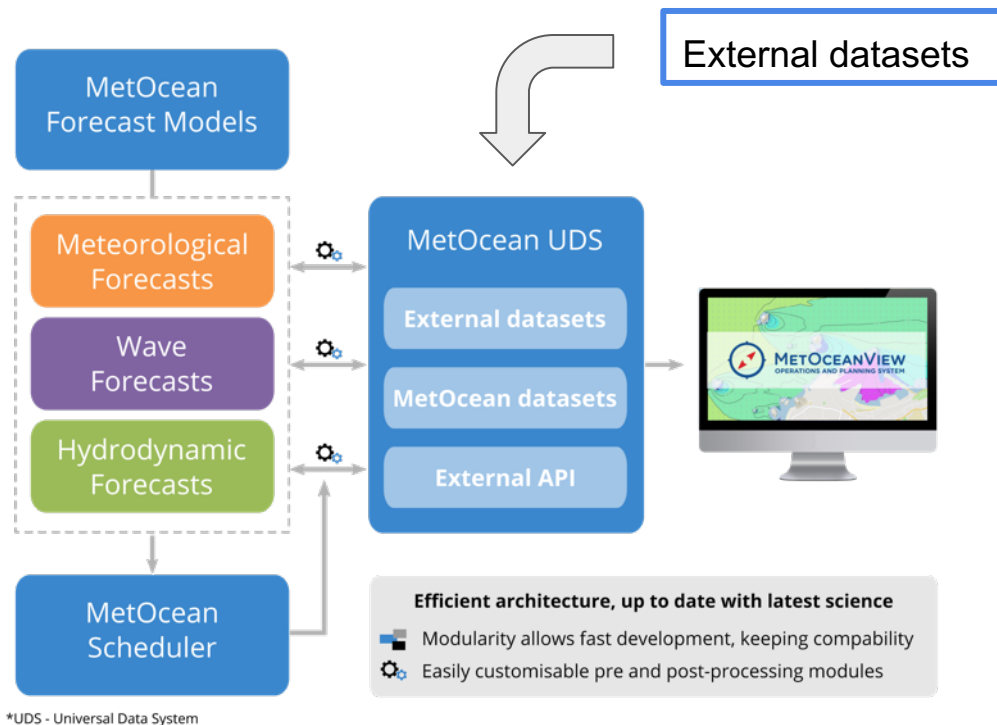**Gracefulness** - use minimal resources, no negative impacts to other systems

Resiliency - capable of overcoming common/expected failures

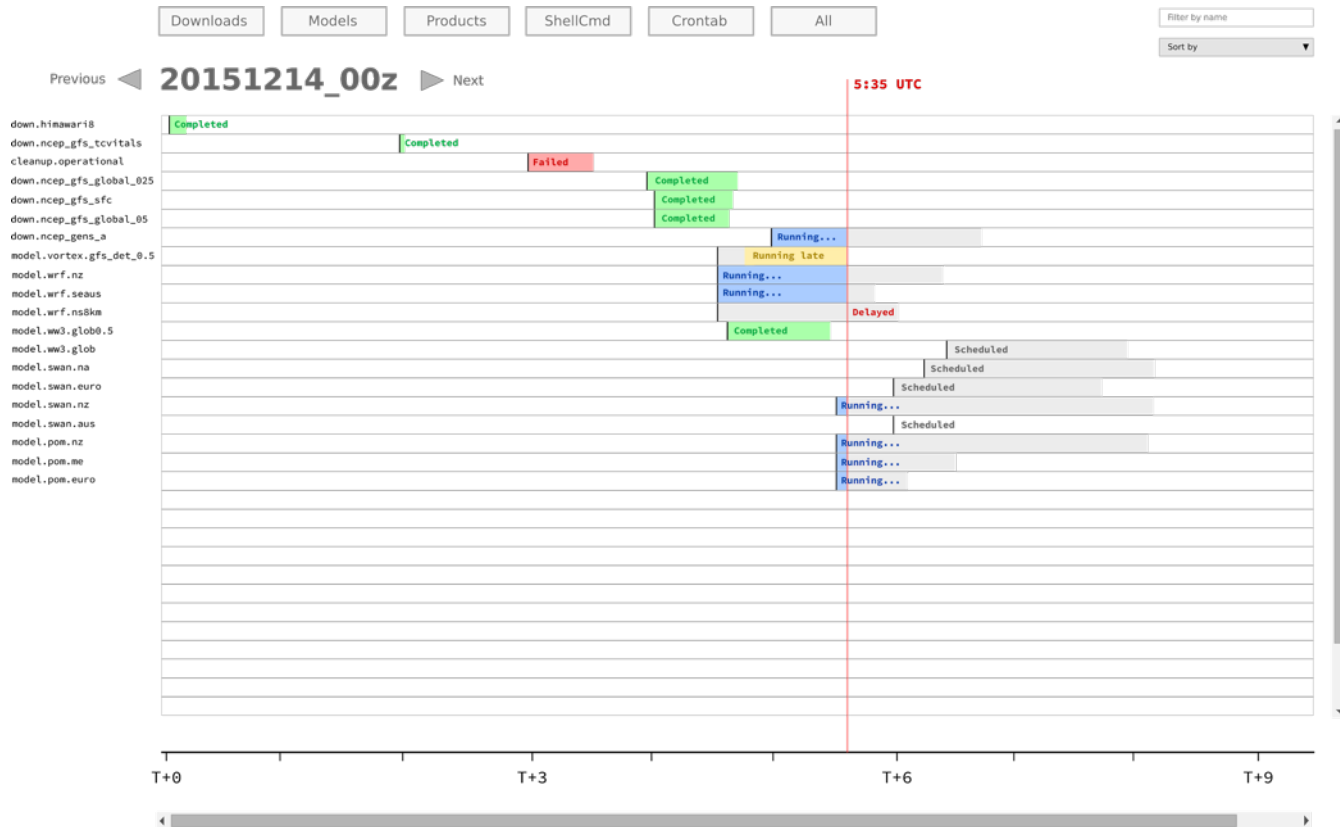**Self-monitoring** - produces meaningful logs and alerts

Disaster recoverability
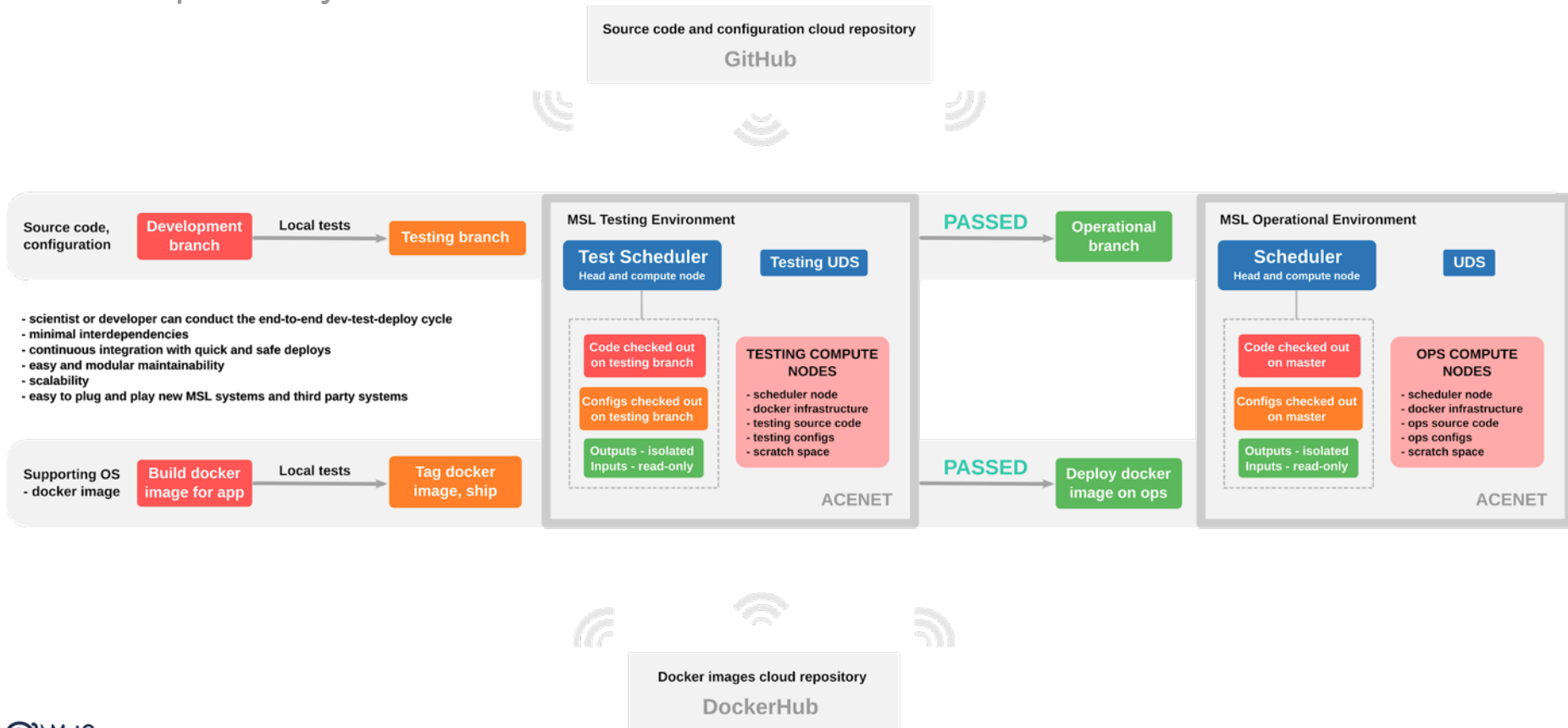
How does our system work?
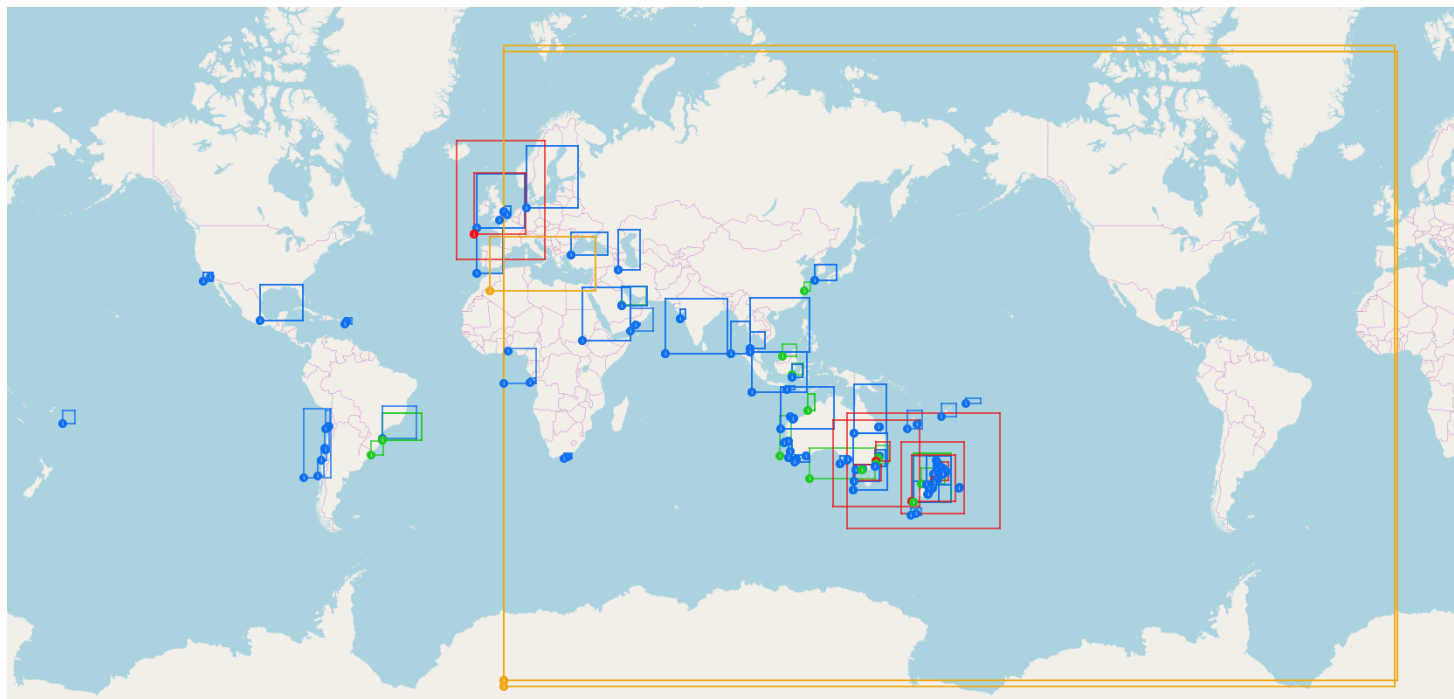
General architecture concept

External datasets

MetOcean Forecast Models

Meteorological Forecasts

Wave Forecasts

Hydrodynamic Forecasts

MetOcean Scheduler

*UDS - Universal Data System

MetOcean UDS

External datasets

MetOcean datasets

External API

MetOceanView
OPERATIONS AND PLANNING SYSTEM

Efficient architecture, up to date with latest science

Modularity allows fast development, keeping compability

Easily customisable pre and post-processing modules

Operational Scheduler

How do we develop, maintain and monitor it?
Development cycle

Source code and configuration cloud repository
GitHub

MSL Testing Environment

Test Scheduler
Head and compute node

Testing UDS

Source code, configuration

Development branch — Local tests → **Testing branch**

- scientist or developer can conduct the end-to-end dev-test-deploy cycle
- minimal interdependencies
- continuous integration with quick and safe deploys
- easy and modular maintainability
- scalability
- easy to plug and play new MSL systems and third party systems

Code checked out on testing branch

Configs checked out on testing branch

Outputs - isolated
Inputs - read-only

TESTING COMPUTE NODES
- scheduler node
- docker infrastructure
- testing source code
- testing configs
- scratch space

PASSED → **Operational branch**

MSL Operational Environment

Scheduler
Head and compute node

UDS

Code checked out on master

Configs checked out on master

Outputs - isolated
Inputs - read-only

OPS COMPUTE NODES
- scheduler node
- docker infrastructure
- ops source code
- ops configs
- scratch space

Supporting OS
- docker image

Build docker image for app — Local tests → **Tag docker image, ship**

ACENET

PASSED → **Deploy docker image on ops**

ACENET

Docker images cloud repository
DockerHub

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Operational models

Simulating WAves Nearshore (SWAN) wave model
Regional Ocean Modeling System (ROMS) current model
Weather Research and Forecasting (WRF) atmospheric model
Wave Watch III wave model
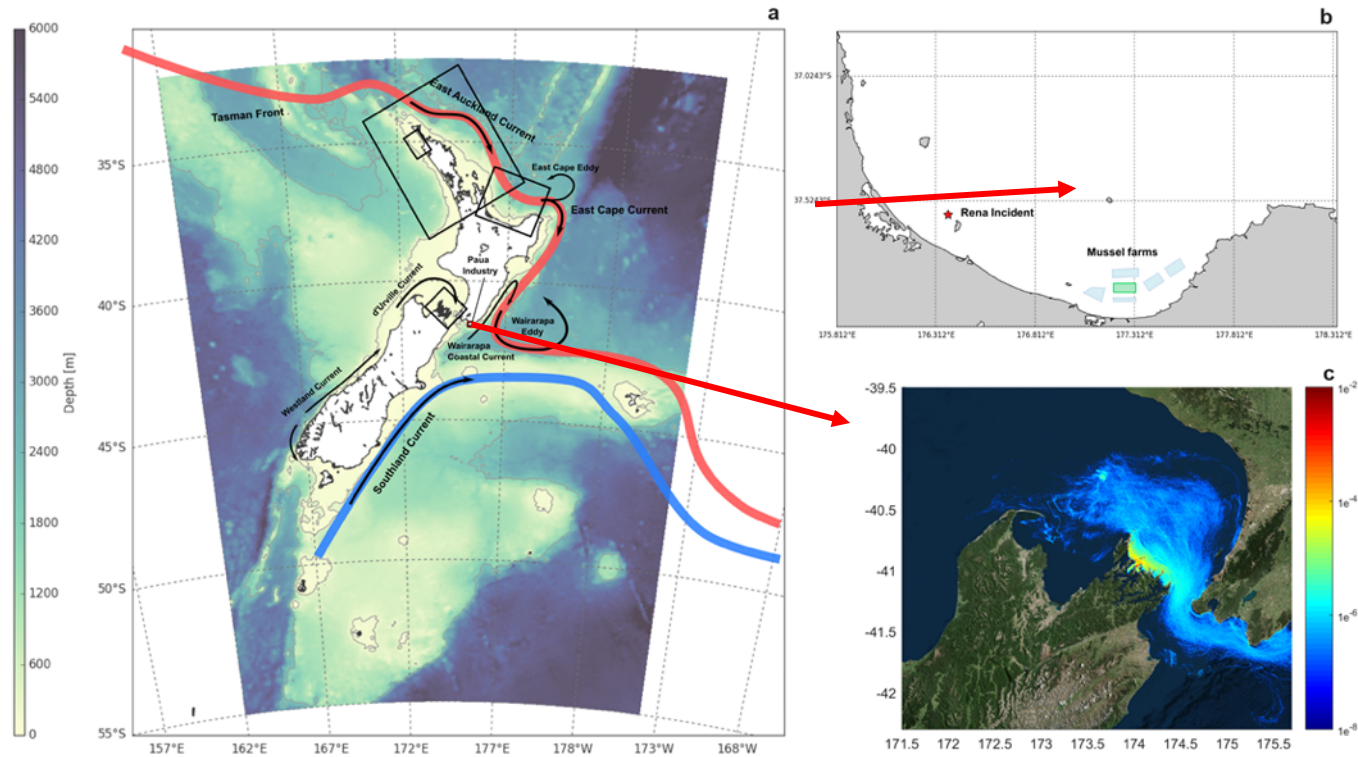
New Zealand - Different spatial scales

Figure 1. Diagram showing the NZ maritime region (left) and the proposed high resolution model domains. Arrows overlaid are adapted from Chiswell et al. (2015) showing the direction of major ocean currents and circulation features. b) Map of the Bay of Plenty, showing WTMB existing and proposed mussel farms c) Schematic showing an example of larval trajectory modelling.

Integrated New Zealand forecast system

- **Atmosphere: 4 WRF domains - migrating to MetService**
- **Waves: 25 SWAN domains**
- **Circulation: 6 ROMS + 3 SCHISM domains**

The horizontal resolution needed to resolve the first baroclinic deformation radius with two grid points

(Hallberg 2013)

1° 1/2° 1/3° 1/4° 1/5° 1/6° 1/8° 1/12° 1/16° 1/25° 1/50°
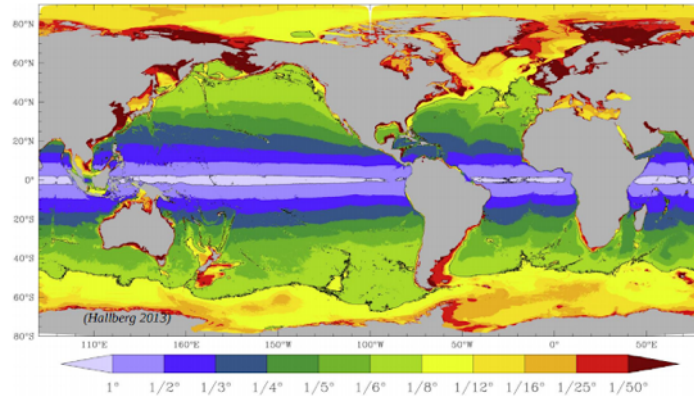
OGCMs at 1/10° resolution (at the equator) do not resolve mesoscale variability poleward of 50 degrees and in most of the shelf regions
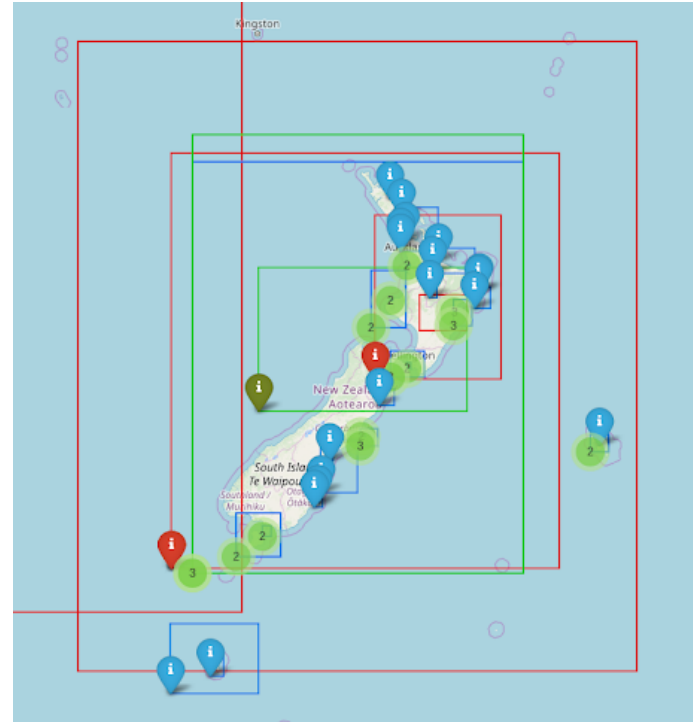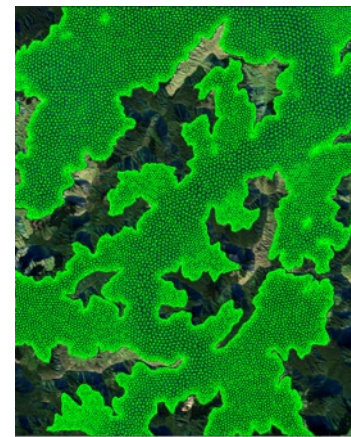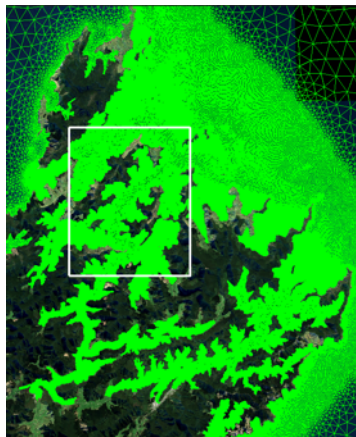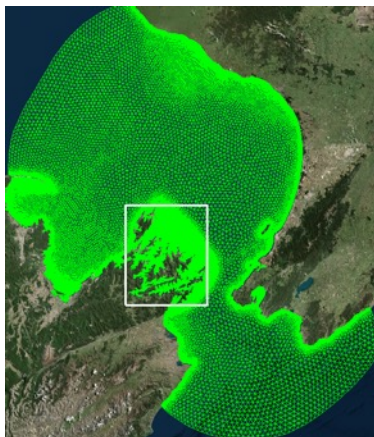
Unstructured High resolution grids

- Grid resolution from ~10 m nearshore to ~1.5 km offshore.
- Defines estuaries, intertidal areas, rivers and streams.
- Boundary conditions from 3km regional ROMS
- Atmospherics from 4km WRF model
- Freshwater discharge sources
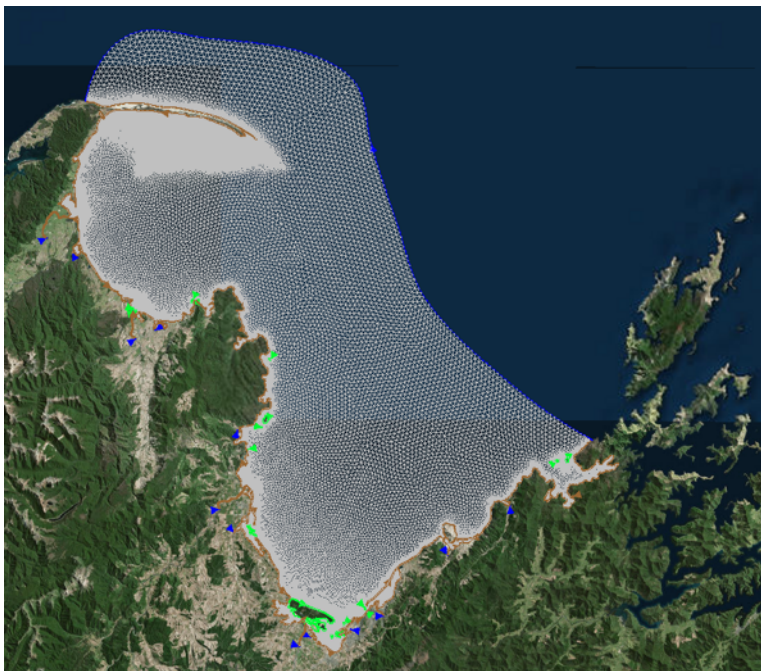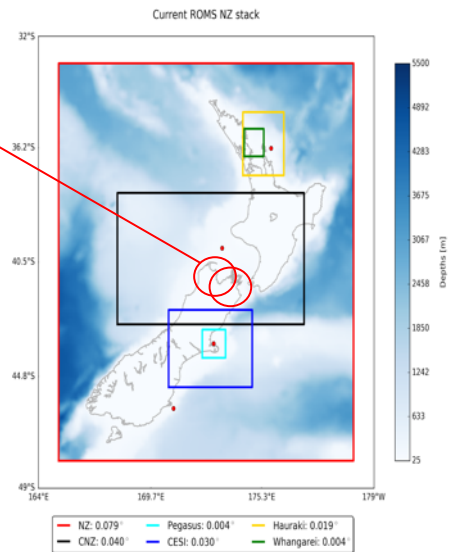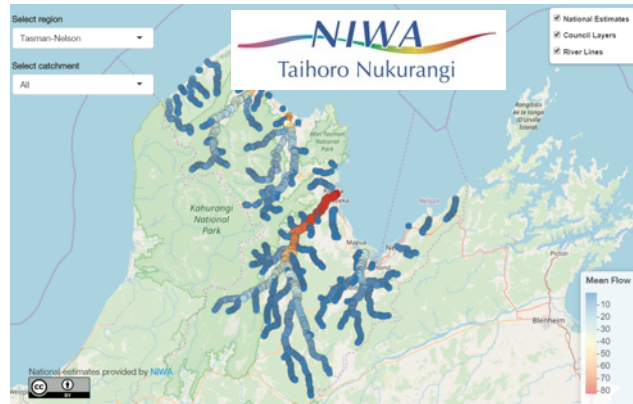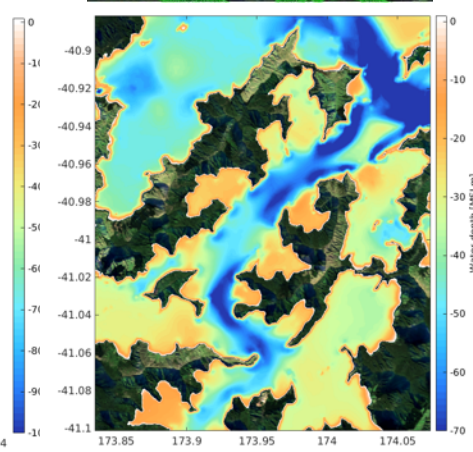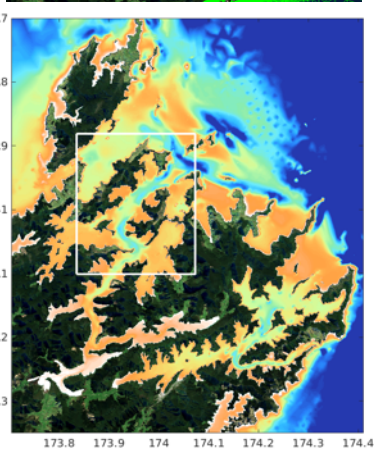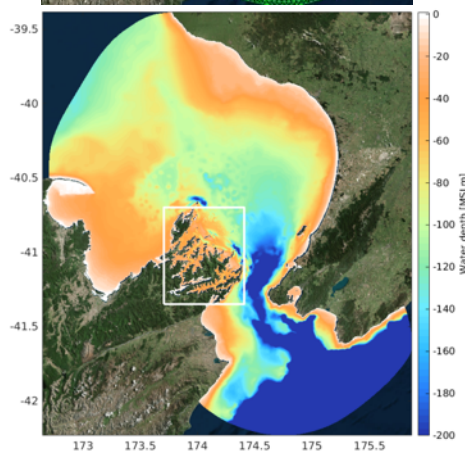
https://shiny.niwa.co.nz/nzrivermaps/
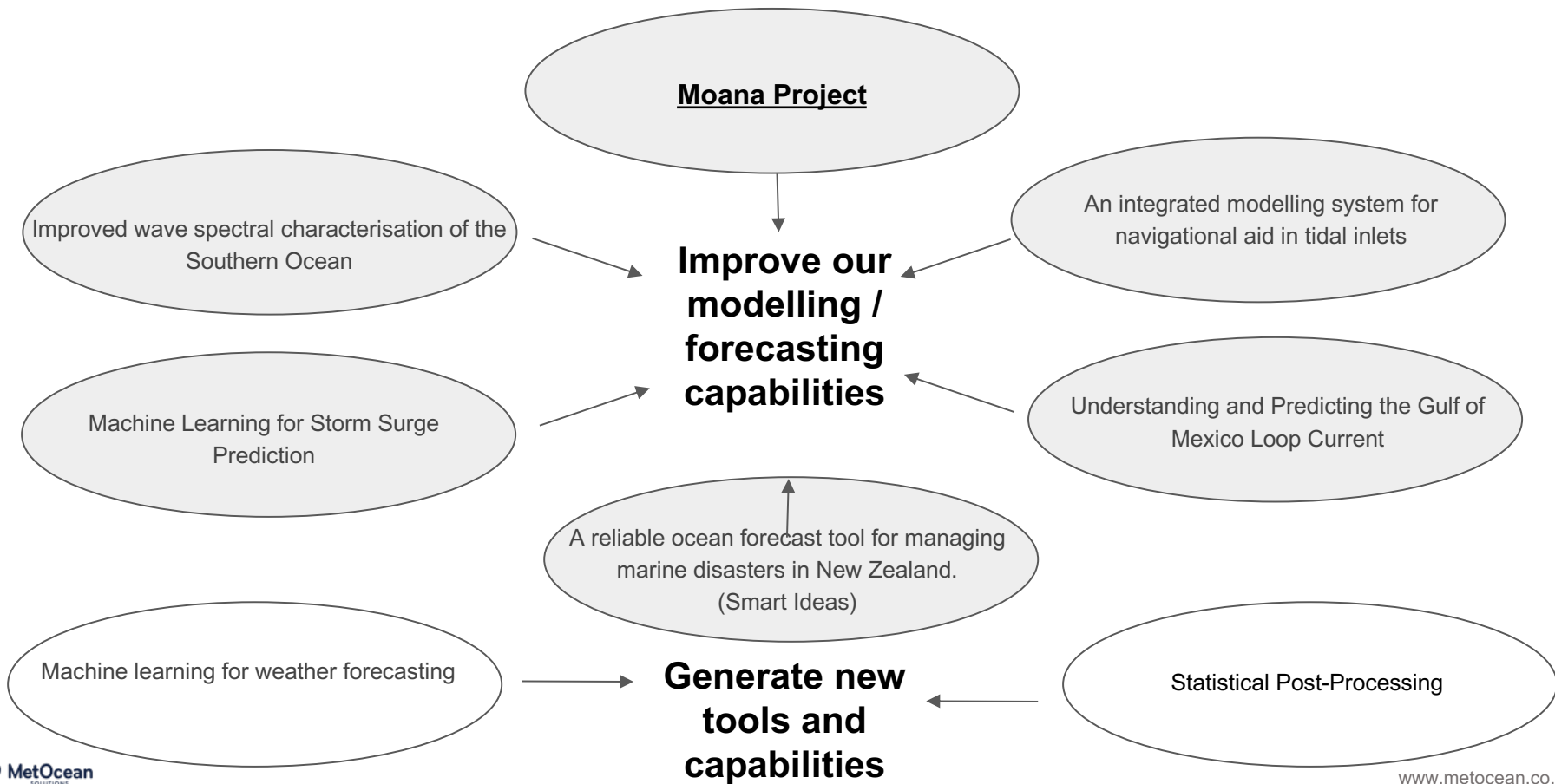

Current ROMS NZ stack

NZ: 0.079° — Pegasus: 0.004° — Hauraki: 0.019°
CNZ: 0.040° — CESI: 0.030° — Whangarei: 0.004°

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Unstructured High resolution grids

RESEARCH PROJECTS – moving us towards the future.

Moana Project

Improved wave spectral characterisation of the Southern Ocean

An integrated modelling system for navigational aid in tidal inlets

Improve our modelling / forecasting capabilities

Machine Learning for Storm Surge Prediction

Understanding and Predicting the Gulf of Mexico Loop Current

A reliable ocean forecast tool for managing marine disasters in New Zealand. (Smart Ideas)

Machine learning for weather forecasting

Generate new tools and capabilities
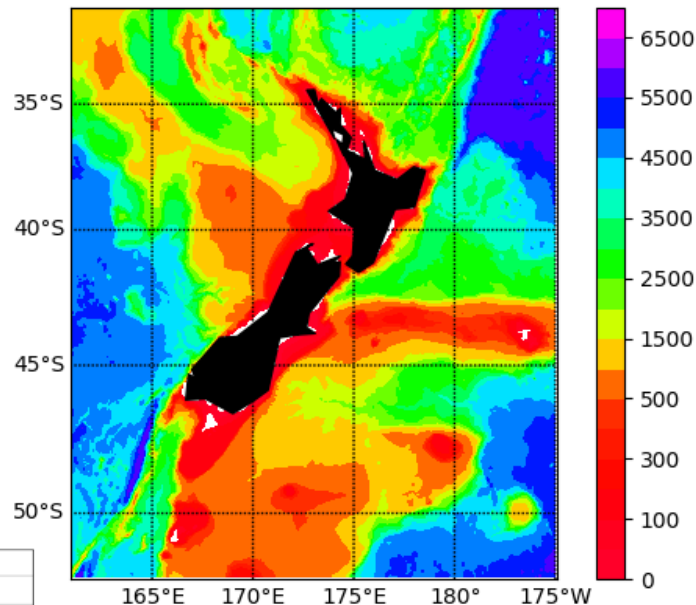
Statistical Post-Processing
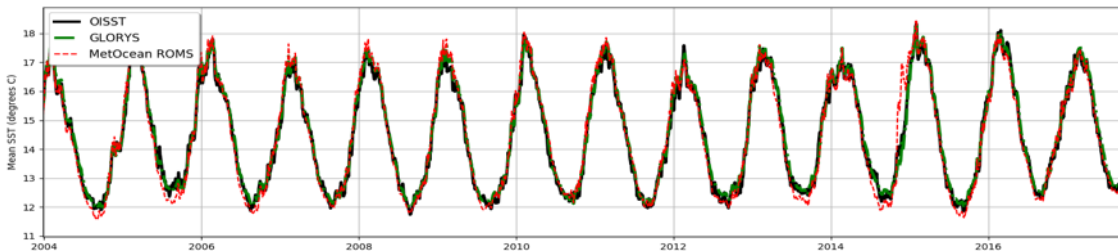
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Moana – Understanding ocean circulation, connectivity and marine heat waves to support an enduring seafood sector
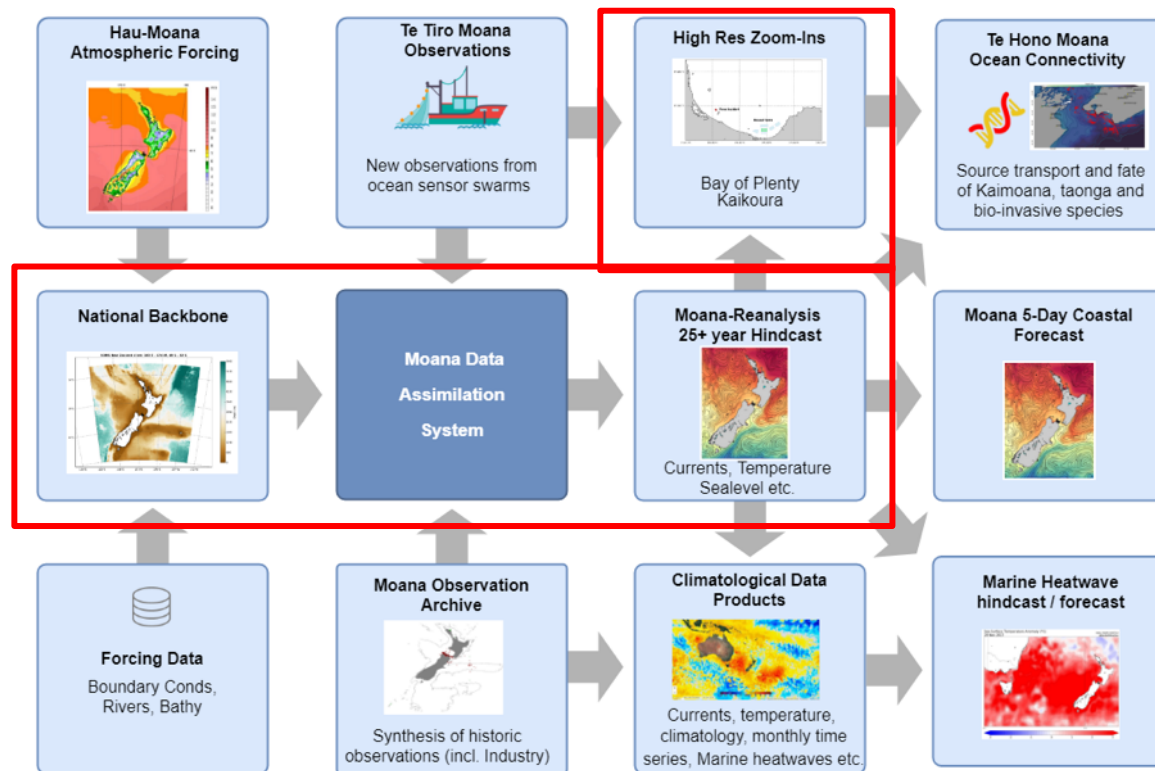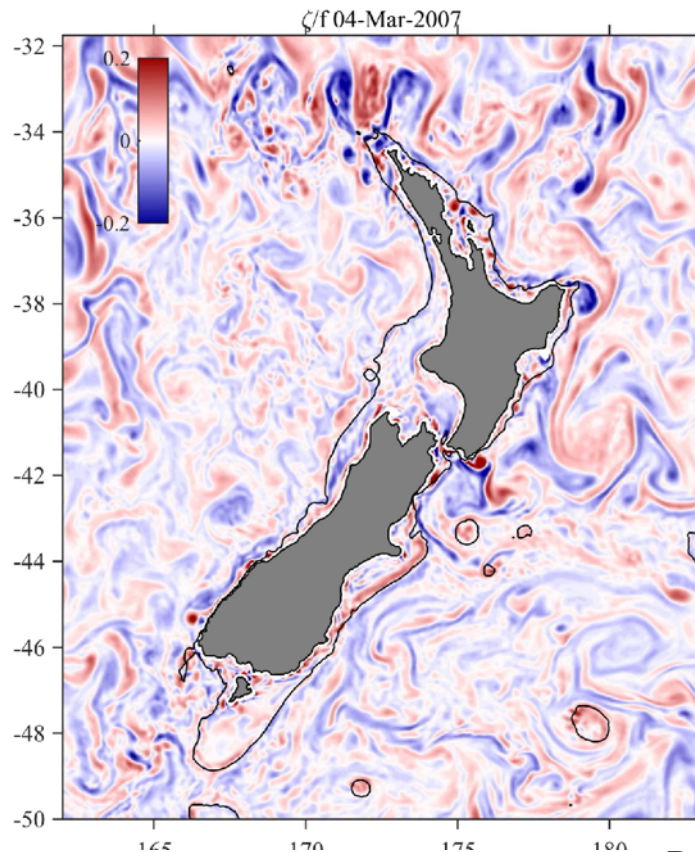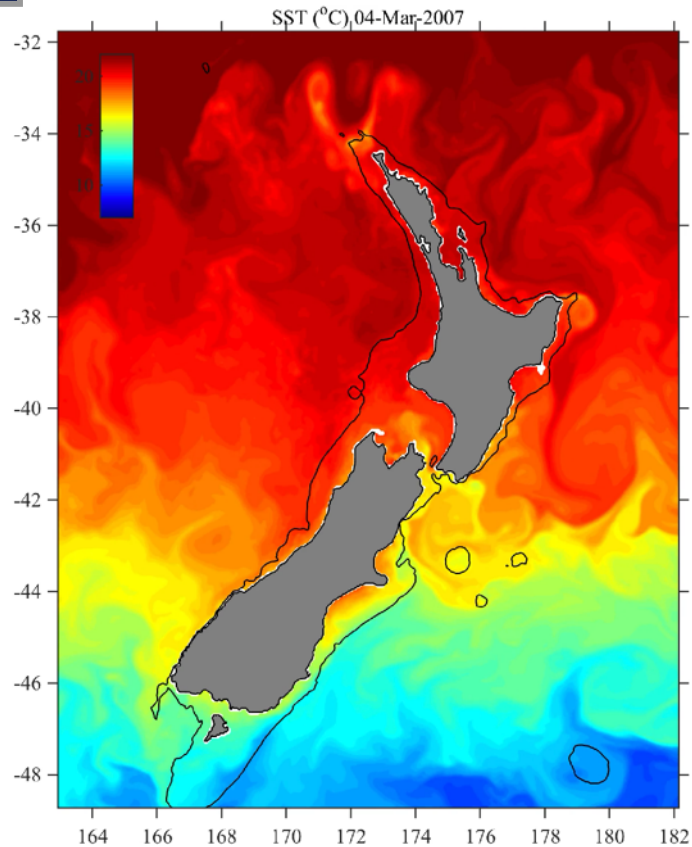
New Zealand National Ocean Hindcast / Forecast System.

➤ ~5km horizontal resolution and 40 vertical sigma layers
➤ Hourly CFSR/ERA5/ECMWF atmospheric forcings
➤ GLORYS (12v1) (Mercator operational) oceanic boundary conditions
➤ Includes spectral tidal forcing from TPXO
➤ 42 climatological rivers (fluxes only)

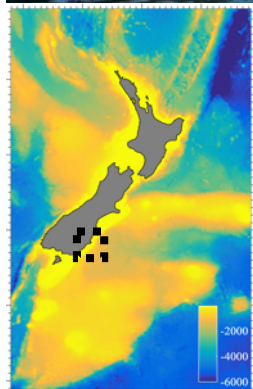 - using NIWA basin catchment model (nests).

➤ Includes IB effect
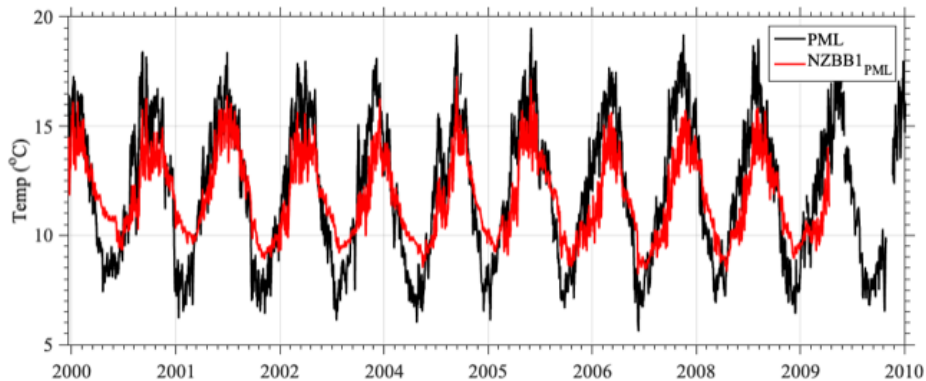
Moana hindcast now available

SST (°C) 04-Mar-2007

ζ/f 04-Mar-2007

25 years
5 km res,
Daily output

Forecast coming soon

Dr J. Souza & Dr A. Suanda
info@moanaproject.org
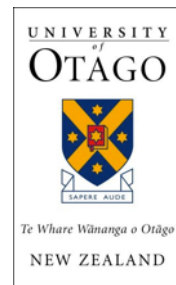
MetOcean SOLUTIONS   MOANA PROJECT

A model without data is just an opinion

Portobello Marine Lab daily sea surface temperature (1953 - present)

Otago Daily Times

Dr A. Suanda

Moana Reanalysis - next steps
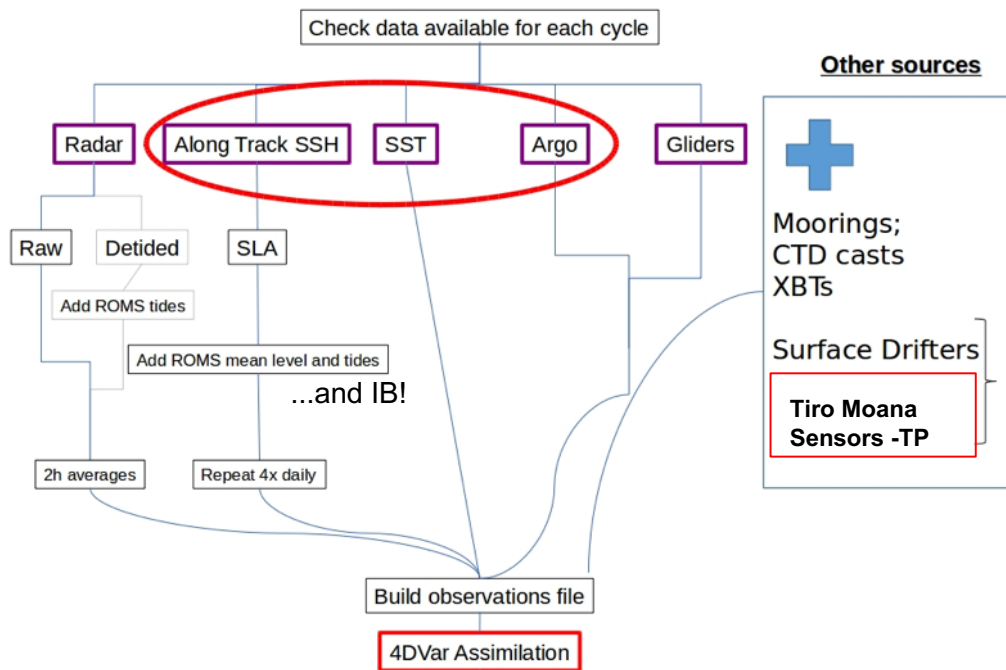
Planned to be completed by mid 2020 !

Renalaysis v1:

- Include data that is available in near-real-time
- Prototype for the forecast system
- Uses the same grid as the hindcast
- Hourly CFSR/ERA5 atmospheric forcing
- GLORYS12 boundary conditions
- Includes spectral tidal forcing from OTIS
- 42 climatological rivers from NIWA (fluxes only) - NIWA basin catchment model (nests)?
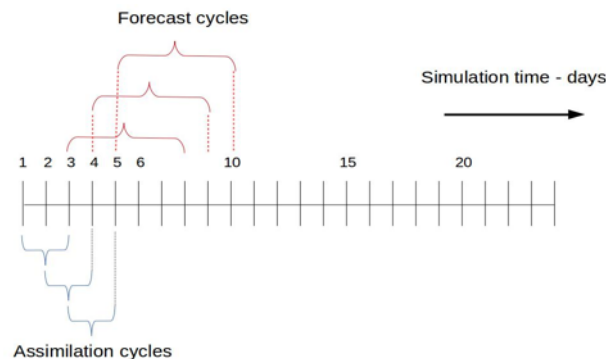
Moana Reanalysis - Observations

CORA 5.2:

It contains data from a diverse set of observational platforms, from mechanical bathythermographs (MBT) prior to 1965; expendable bathythermographs (XBT); conductivity, temperature and pressure sensors (CTD), etc. It includes all ARGO float profiles from the late 1990s forward, which constitutes the majority of the data available for the New Zealand region.

Provided in NRT and DT!

From 1994-2016 (in the model domain):

32892 T profiles ~3.6 p/ day
4314 S profiles ~0.4 p/ day

Along Track SLA:

Altimeter satellite along-track sea surface heights anomalies (SLA) computed with respect to a twenty-year 2012 mean. All the missions are homogenized with respect to a reference mission. The multi-mission cross-calibration process removes any residual orbit error, or long wavelength error (LWE), as well as large scale biases and discrepancies between various data flows; all altimeter fields are interpolated at crossover locations and dates. Downloaded from Copernicus FTP server.

Missions:

Jason-3, Sentinel-3A, HY-2A, Saral/AltiKa, Cryosat-2, Jason-2, Jason-1, T/P, ENVISAT, GFO, ERS1/2.

SST:

AVHRSST (TMI, AMSR-E, AMSR-2, WindSat, GMI) - 1998 to present

Infrared (MODIS-Terra, MODIS-Aqua, VIIRS-NPP) - 2002 to present

Historic Data

Work with partners to

    Identify, catalogue, prioritise and liberate existing oceanographic data

Follow FAIR Data Principles

    Findable, Accessible, Interoperable and Reproducible

QA/QC and Format to International standards

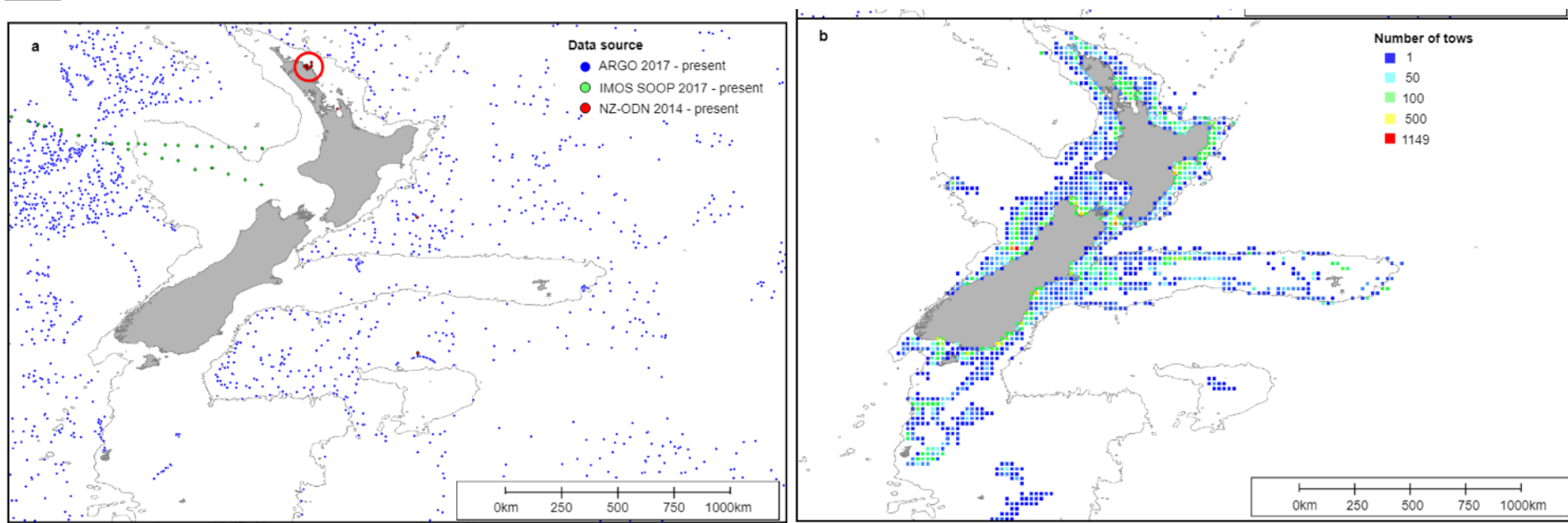   Climate and Forecast (CF) compliant Metadata Conventions v1.6

FAIR Data Principles https://www.go-fair.org/fair-principles/

Eaton, B., Gregory, J., Drach, B., Taylor, K, Hnakin, S., Caron, J., Signell, R., Bentley, P. Rappa, G., Höck H., Pamment A. and Juckes M. 2009. NetCDF Climate and Forecast (CF) Metadata Conventions v1.
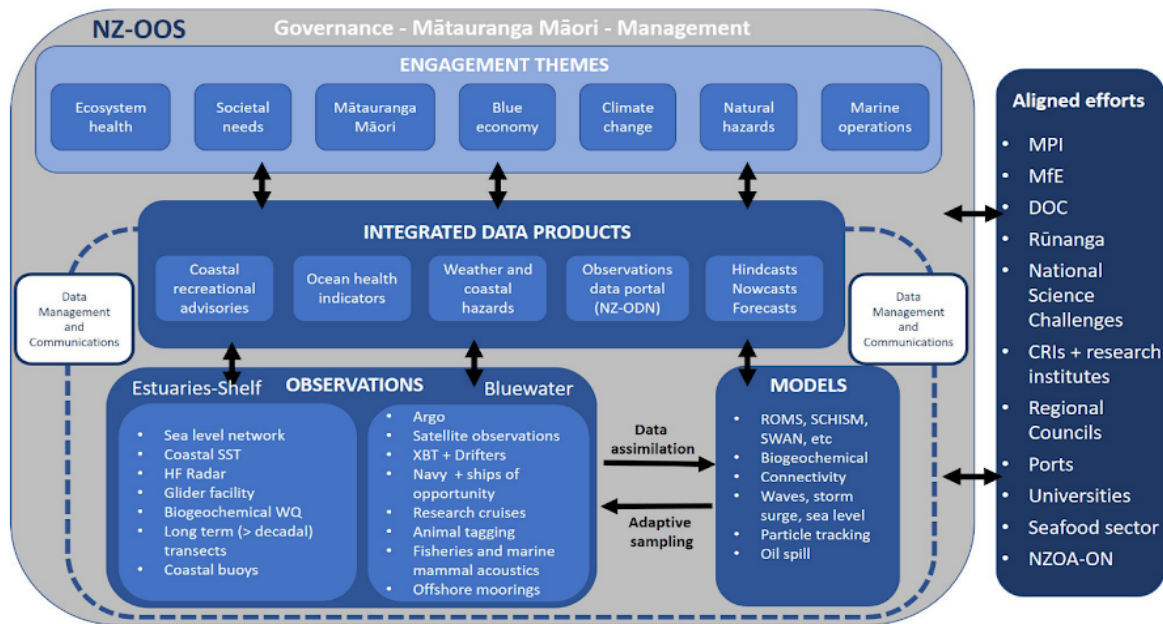
Generate New Data: A step change in ocean data

Seafood Sector Coverage of the Continental Shelf – Crowd Sourcing ocean data
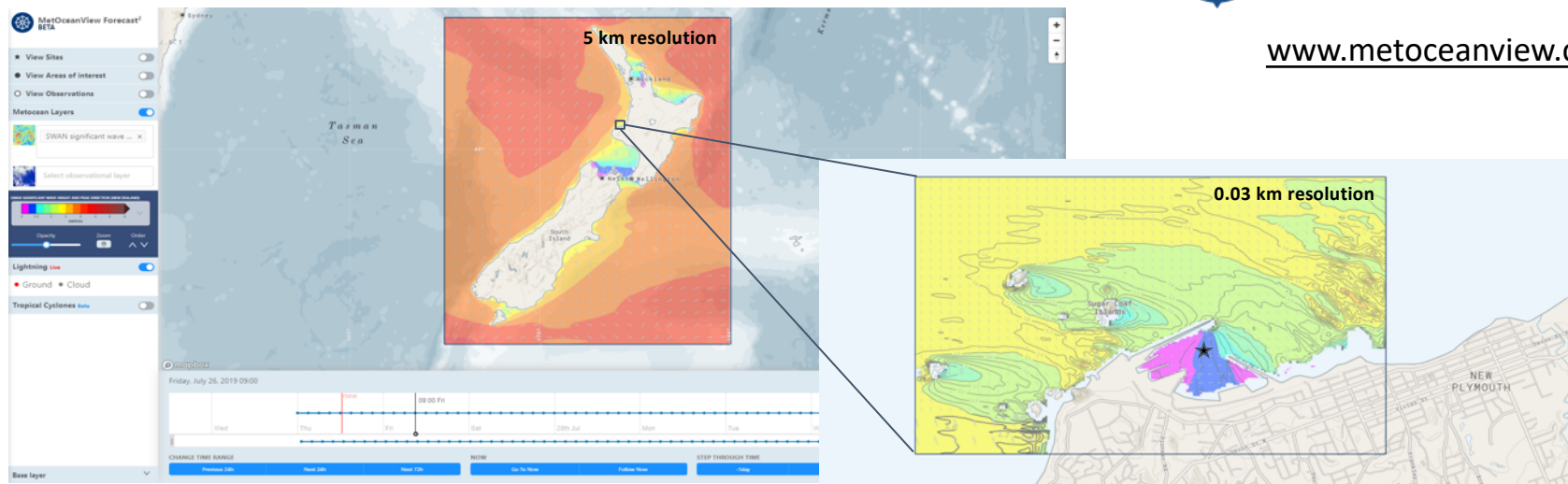
MOANA PROJECT

Towards an Integrated Ocean Observing System

| Framework for the NZ-OOS building on existing efforts in NZ. The proposed structure illustrated has been adapted from that used for the Southeast Coastal Ocean Observing Regional Association.

O'Callaghan et al. (2019) Developing an Integrated Ocean Observing System for New Zealand. Front. Mar. Sci. 6:143. doi: 10.3389/fmars.2019.00143

Accessing Ocean Forecasts

www.metoceanview.com

5 km resolution

0.03 km resolution

7-day Metocean forecast

Workability & Hazard criteria
Waves/ temperature etc.

Real-time instruments display

MetOceanTrack

An interactive application to assist with the investigation of the spread of an organism or contaminant around the coastline of NZ.

Biological parameters
Mortality rate, life-stage duration, vertical migration characteristics...

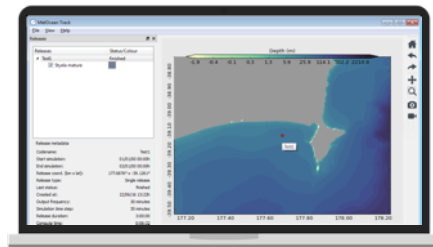## Particle Tracking Model
Lagrangian
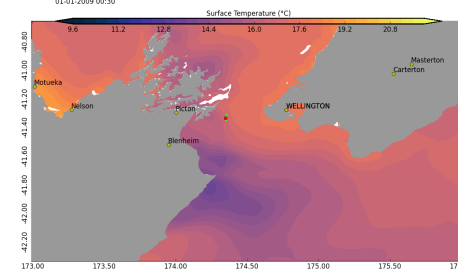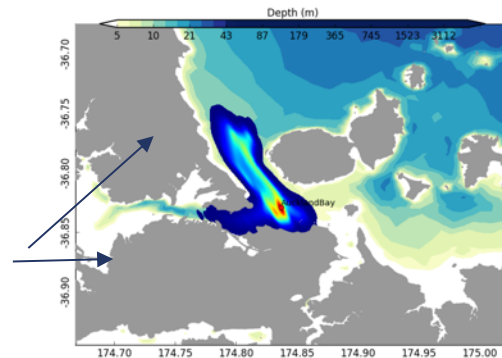
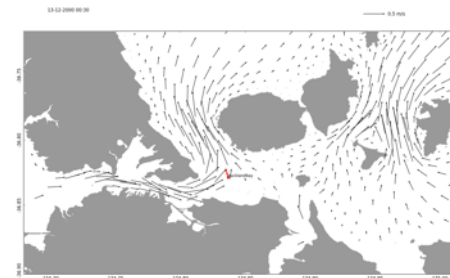$$\frac{du_p}{dt} = \tilde{u}(x,y,z,t) + u_t$$

$$\frac{dv_p}{dt} = \tilde{v}(x,y,z,t) + v_t$$

$$\frac{dw_p}{dt} = -w_s + w_g + w_t$$

Physical Variables
Hydrodynamics, Salinity, Temperature, Bathymetry, Coastline

MOANA PROJECT

Ministry for Primary Industries
Manatū Ahu Matua

RESEARCH PROJECTS - the engine to move forward.

Main research hot-topics:

➤ Data-assimilation (4DVar and EnKF)

> **Moana** - National Reanalysis + operational *4DVar*
> **SMART** - High res. Data assimilation (gliders)
> **GoM** - Deep observations impact

Operational DA forecast system

➤ Wave-current interaction
➤ (towards a Earth System Model)

> **Southern Ocean** - Impact of currents on swell propagation
> **Tidal Inlets (Port Phillip Bay)** - Impact of waves on the near-shore circulation - operational *coupled model* (SCHISM)

Operational unstructured grid coupled models

➤ Machine Learning /
➤ Statistical Post-processing

> **Moana** – Seasonal forecast – Marine Heat Waves
> **SMART – Storm Surge** – Tool for storm surge forecast
> **SPP** - Developing a tool to improve ocean forecasts

Explore new tools for ocean forecast

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Summary

What we have:
- A dev-ops philosophy, with scientists leading/participating the whole development, deploy and operation processes.
- A modular system that provides easy transitions of new modules/tasks to operations;

Where we are going:
- Towards a national ocean forecast system that includes new observations (Tiro Moana) and data assimilation models.
- Inclusion of wave-current coupling and unstructured grid models – towards Earth System Modelling.
- Machine Learning and Statistical post-processing to improve forecasts and explore seasonal predictability.

Looking outward:
- Play a central role in the NZ OOS design.
- Working in synergy with all main organizations in NZ to provide an centralized, open data service.
- Looking forward to improve international collaboration and engagement.

Thank you!