

The CSIRO Atlas of Regional Seas (CARS) v2 *A new marine climatology for Australia*

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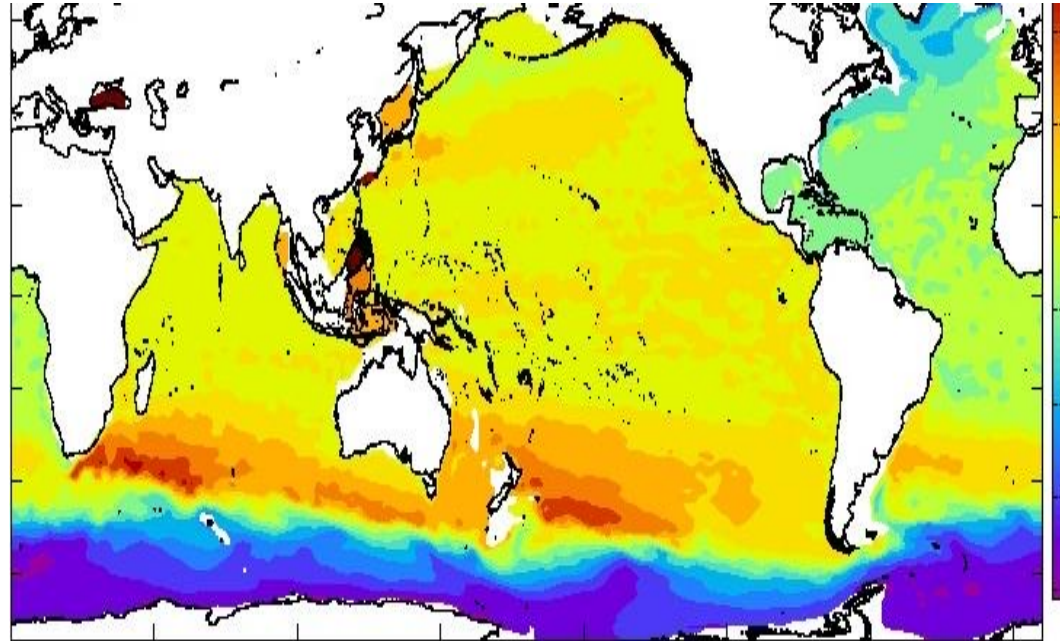
¹CSIRO Environment

²Institute of Marine and Antarctic Studies, University of Tasmania

Forum for Operational Oceanography, 2023

The Original CARS - Product and Philosophy

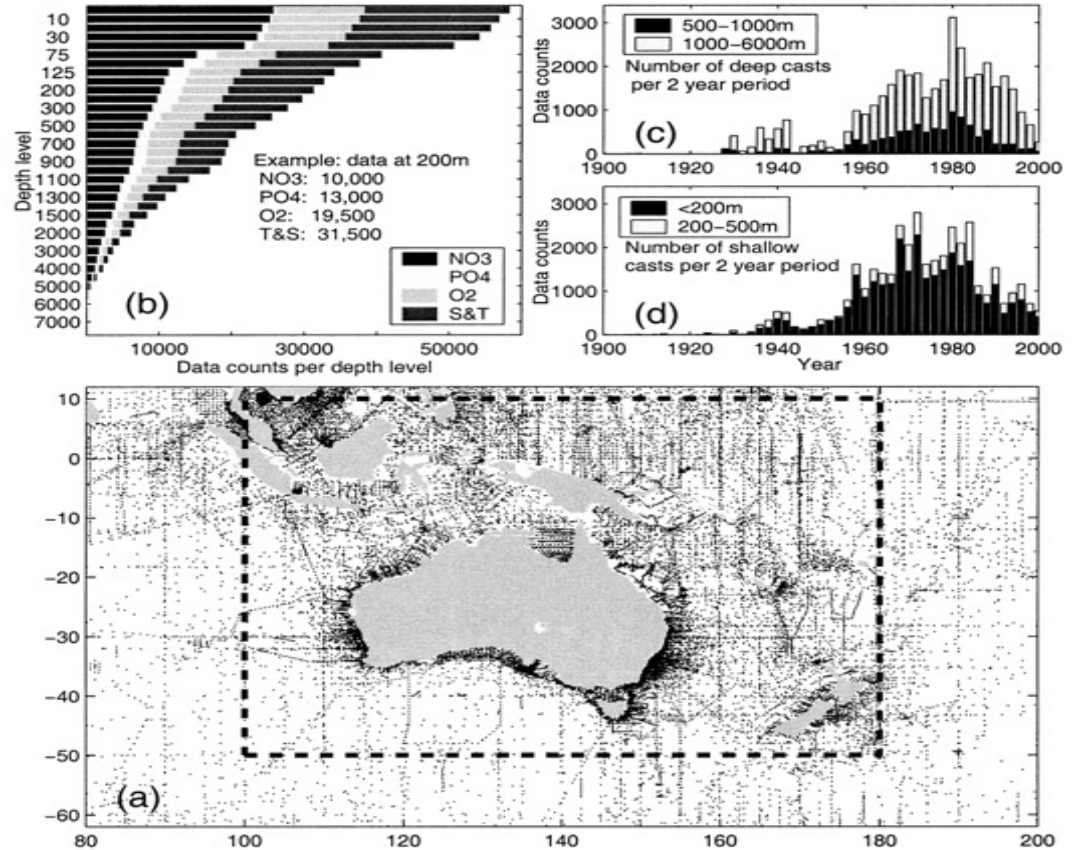
- An "atlas" of seasonal ocean properties
- Gridded ($1/2^\circ \times 1/2^\circ$ and $1/8^\circ \times 1/8^\circ$) horizontal grid spacing
 - Local least-squares fitting
 - Attempts to improve *resolution* in areas of high data density
- Derived from an "in-house" cultivated database of oceanographic observations
- **Extremely successful** – *Ridgeway et al. (2002)* cited 584 times (Google Scholar)



Source: CARS 2009, dynamic height

The Original CARS – where are they now?

- Last comprehensive update - 2009
- Loss of key personnel
- Code base no longer maintainable
- Lots of new observations and platforms since (ARGO, gliders, animal borne sensors, mooring programs, etc...)
- Now – strong demand within the community for updated **an Australian Ocean Atlas**



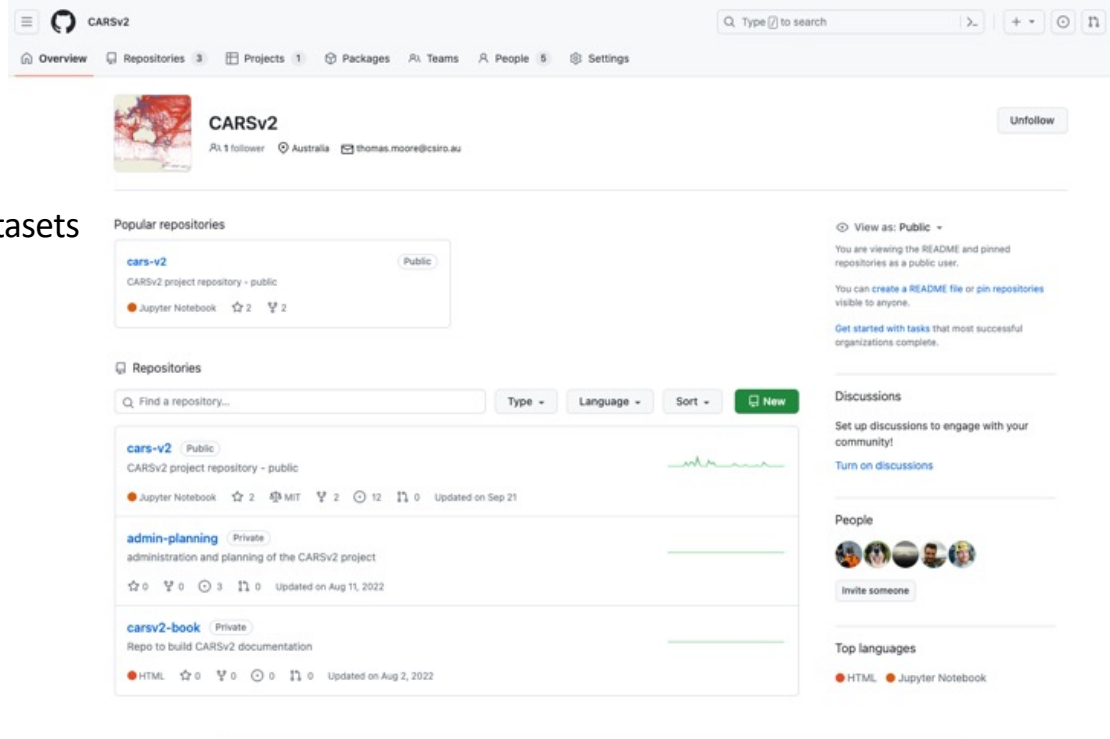
Source: Ridgeway et al (2002) - data distribution of the original CARS product

CARSv2 – what's the difference?

- Will use data from the latest versions of the datasets used in CARS2009, plus new datasets
- New QC & duplicate checking tools
- Updated code base in open source languages
- Published code toolbox and examples
- Shared 'clean' database in a common format
- Mapping done using Julia algorithms

Final CARS product:

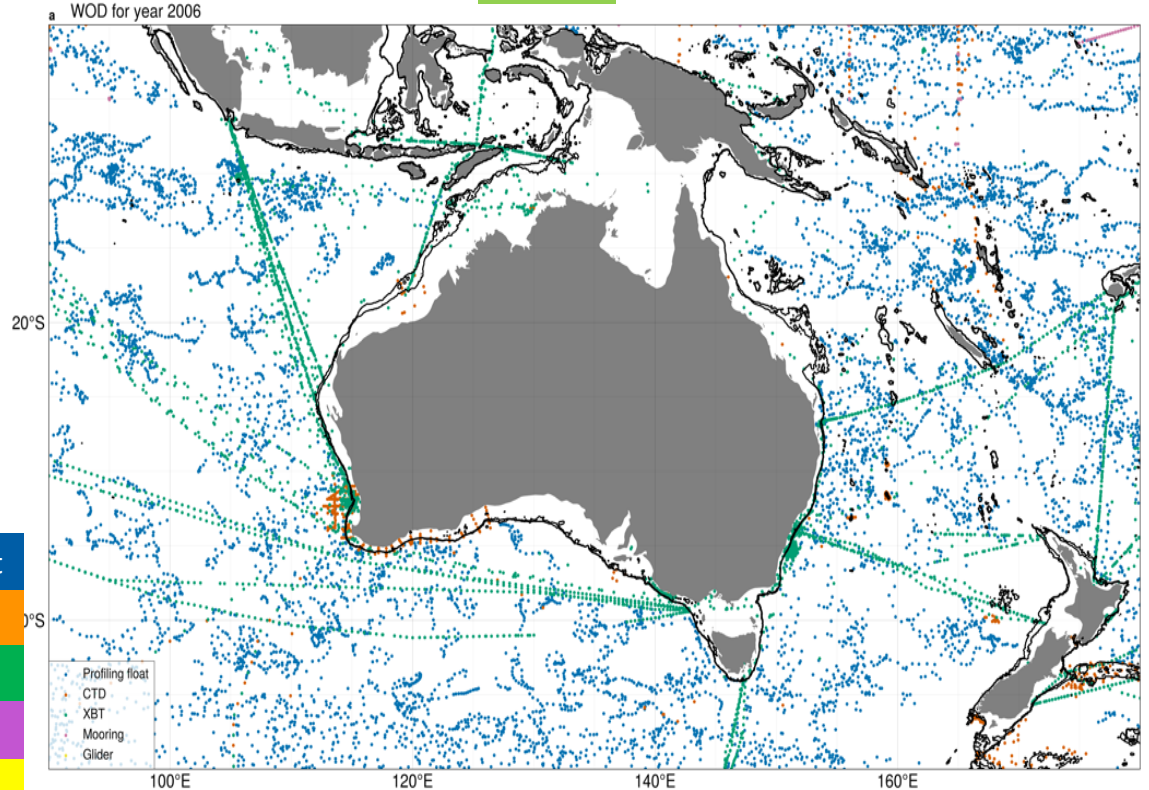
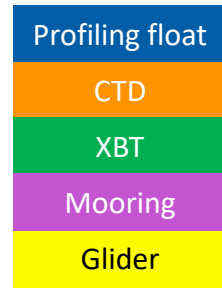
- Higher resolution horizontal grid
- Extra depth in the standard depth levels
- Updated netCDF format
- Other formats TBA



The screenshot shows the GitHub profile for 'CARSv2'. The profile header includes the repository name 'CARSv2', a location 'Australia', and an email 'thomas.moore@csiro.au'. Below this, there are sections for 'Popular repositories' and 'Repositories'. The 'Popular repositories' section lists 'cars-v2' as a public repository, which is a CARSv2 project repository. The 'Repositories' section lists three repositories: 'cars-v2' (public), 'admin-planning' (private), and 'carsv2-book' (private). The 'admin-planning' repository is described as 'administration and planning of the CARSv2 project'. The 'carsv2-book' repository is described as 'Repo to build CARSv2 documentation'. On the right side of the page, there are sections for 'View as: Public', 'Discussions', 'People', and 'Top languages'.

CARS v2 – Product and Philosophy

- An **Australian product** for **Australian conditions**
- Limited observations over shelf and shallow seas

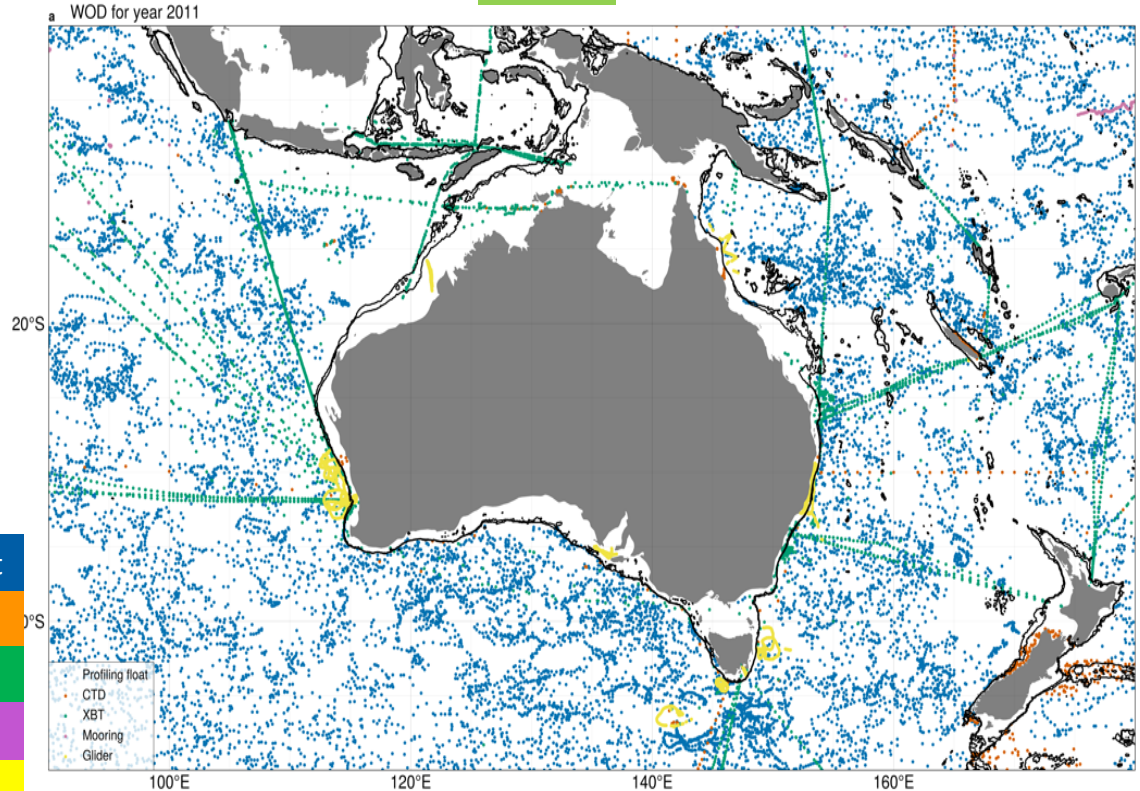
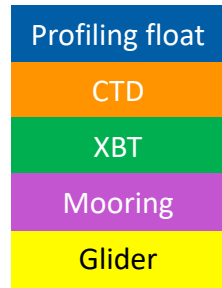


Source: Data from WOD2018

2006

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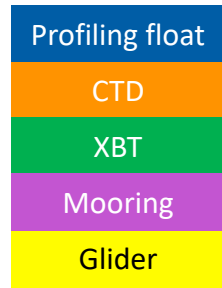


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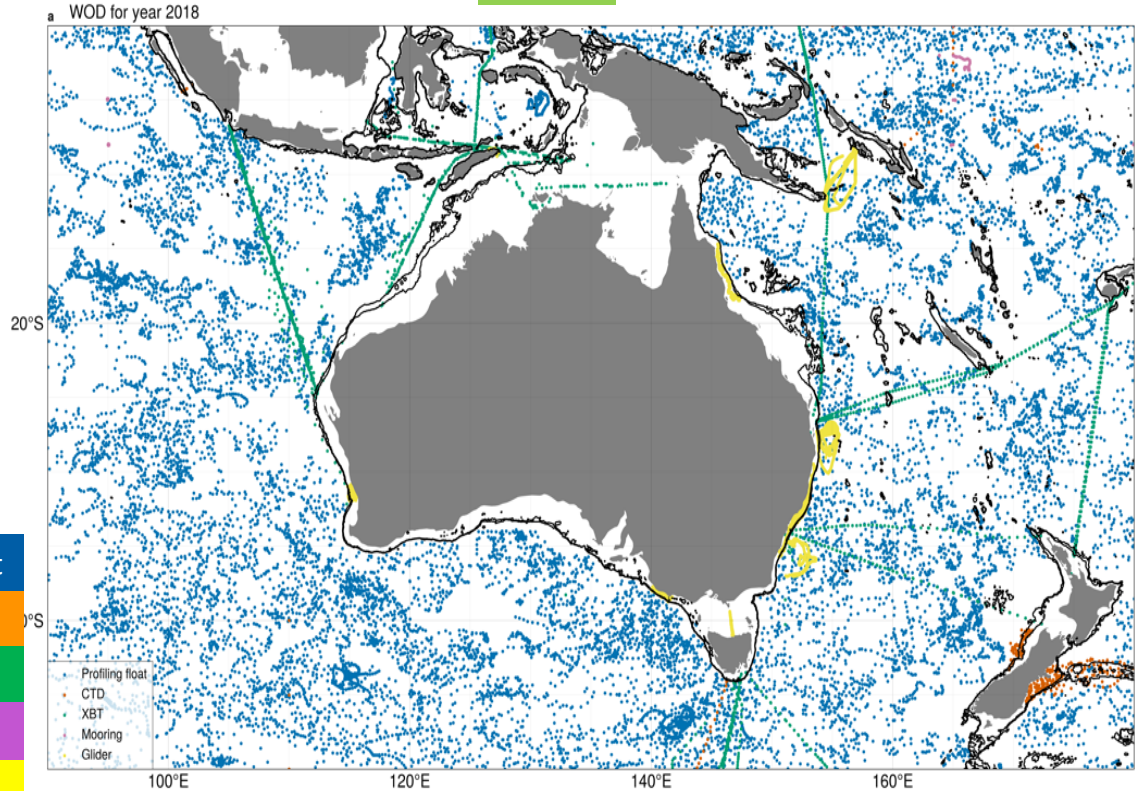
2011

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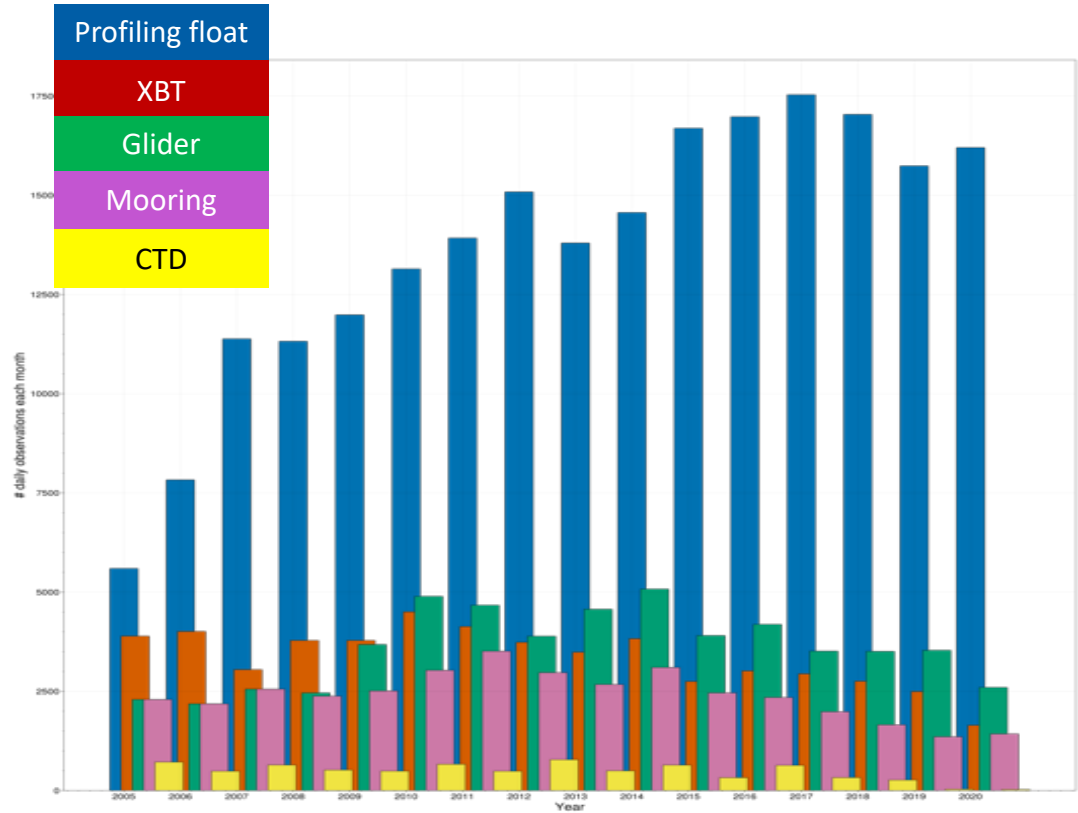
2018



Source: Data from WOD2018

CARS v2 – Product and Philosophy

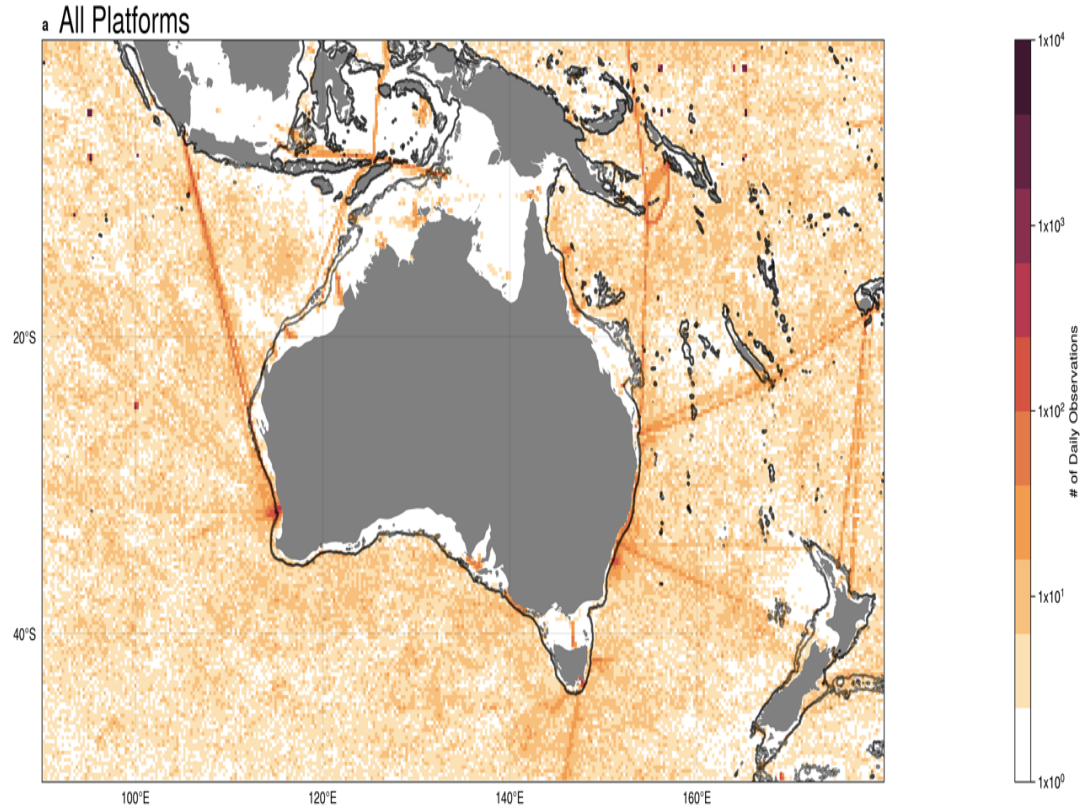
- An **increase** in data since 2006, particularly profiling float data
- Not all data types included in this example!



Data since 2006 (WOD2018)

CARS v2 – Product and Philosophy

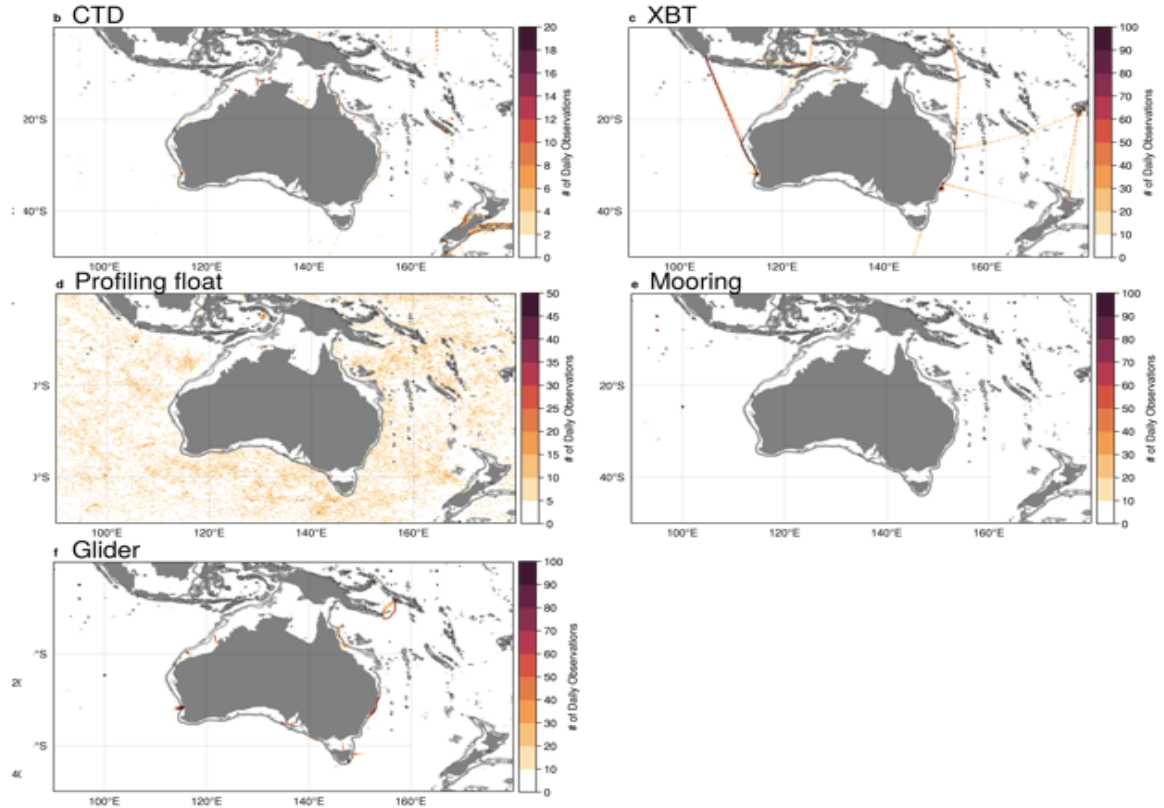
- Density of data (2006-present) around Australia shows paucity of data located in the coastal regions



Data since 2006 (WOD2018)

CARS v2 – Product and Philosophy

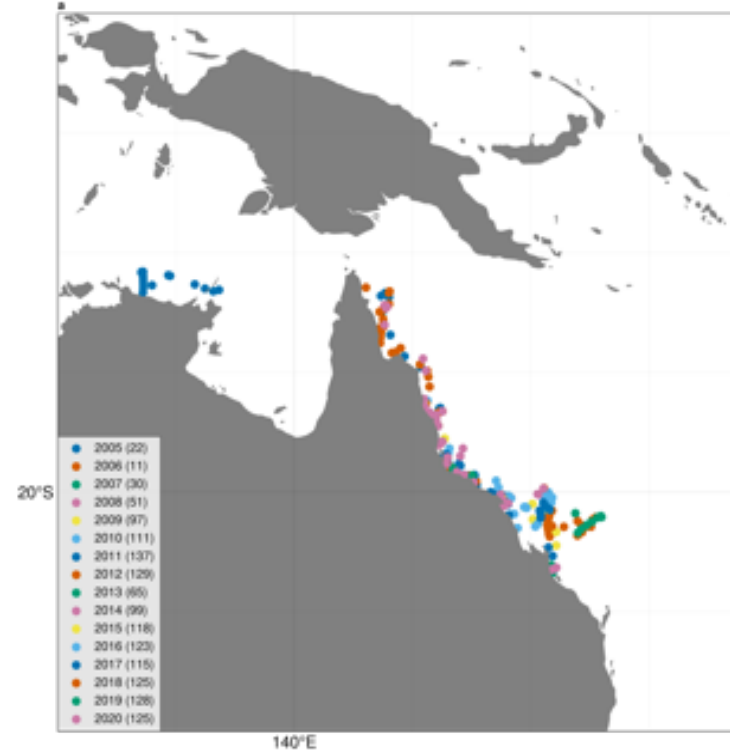
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Data since 2006 (WOD2018)

Data Rescue

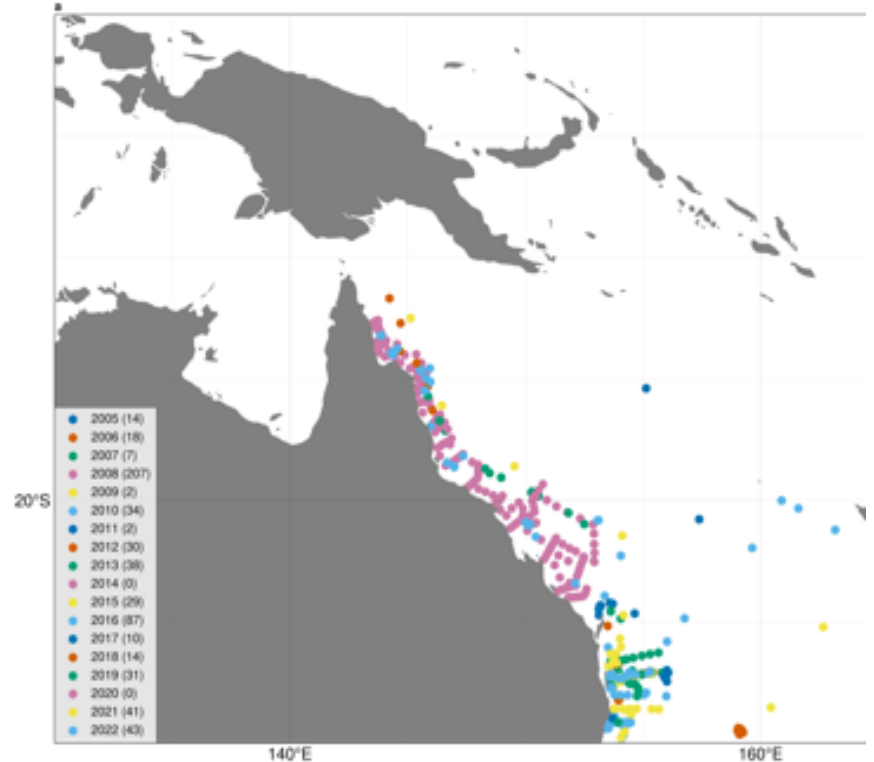
- With limited data in shelf/slope regions in WOD we need **supplementary data**
- Much of this data is **not available on public servers (eg, WOD or AODN) OR is not easily accessible**
- Data is **not all QC'd**
- Some partners who collect data:
 - AIMS
 - MNF (ie. *Investigator, Southern Surveyor*)
 - Defence/Navy
 - State government agencies
- Value of Australian data not FAIR (conservatively) several million dollars



Australian Institute of Marine Science CTD profiles (2005-2020)

Data Rescue

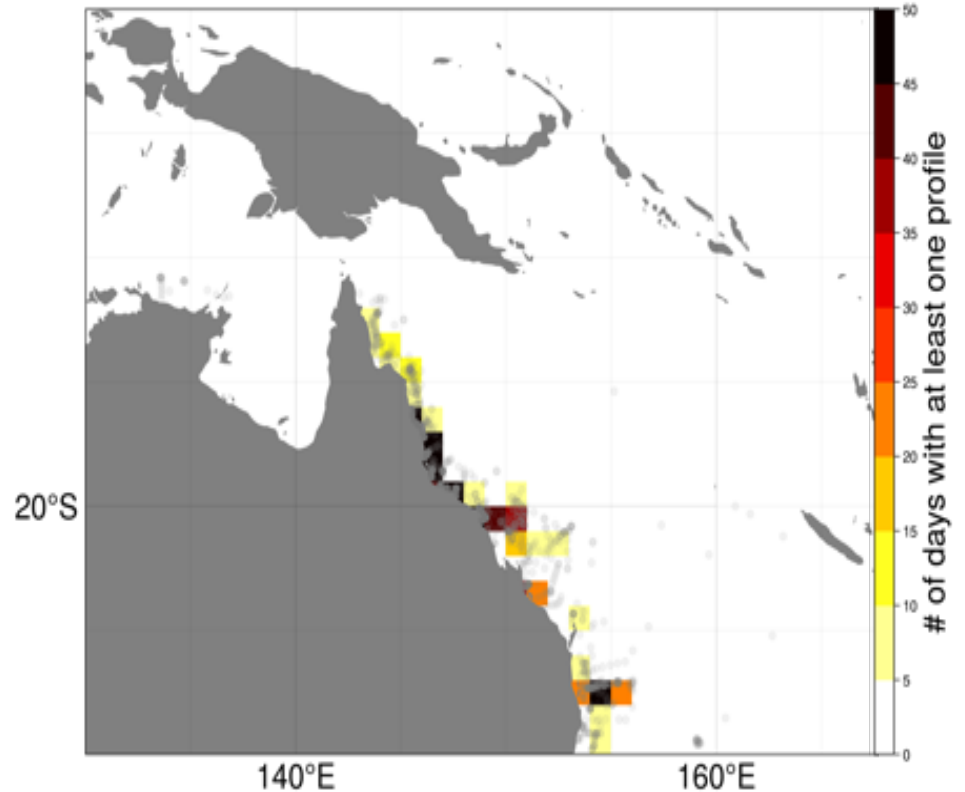
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MNF (RVs Investigator and Southern Surveyor) CTD profiles (2005-2022)

Data Rescue

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Heat map showing days with at least 1 profile from AIMS and MNF (2005-2022)

Data Quality

- Some of the data sourced is QC'd
- For data that isn't, we need to use automated QC tools developed by IQuOD
- Requires us to adapt the tools for file formats or transform the data recovered into a standard format for QC and data ingestion

www.iquod.org



IQuOD aims to maximize the quality, consistency and completeness of the long-term global subsurface ocean temperature database. IQuOD is a product served alongside the World Ocean Database (WOD).

IQuOD includes:

- Intelligent metadata for XBTs.
- Uncertainties assigned to each individual temperature observation.
- Some uncertainties assigned to depth and salinity.

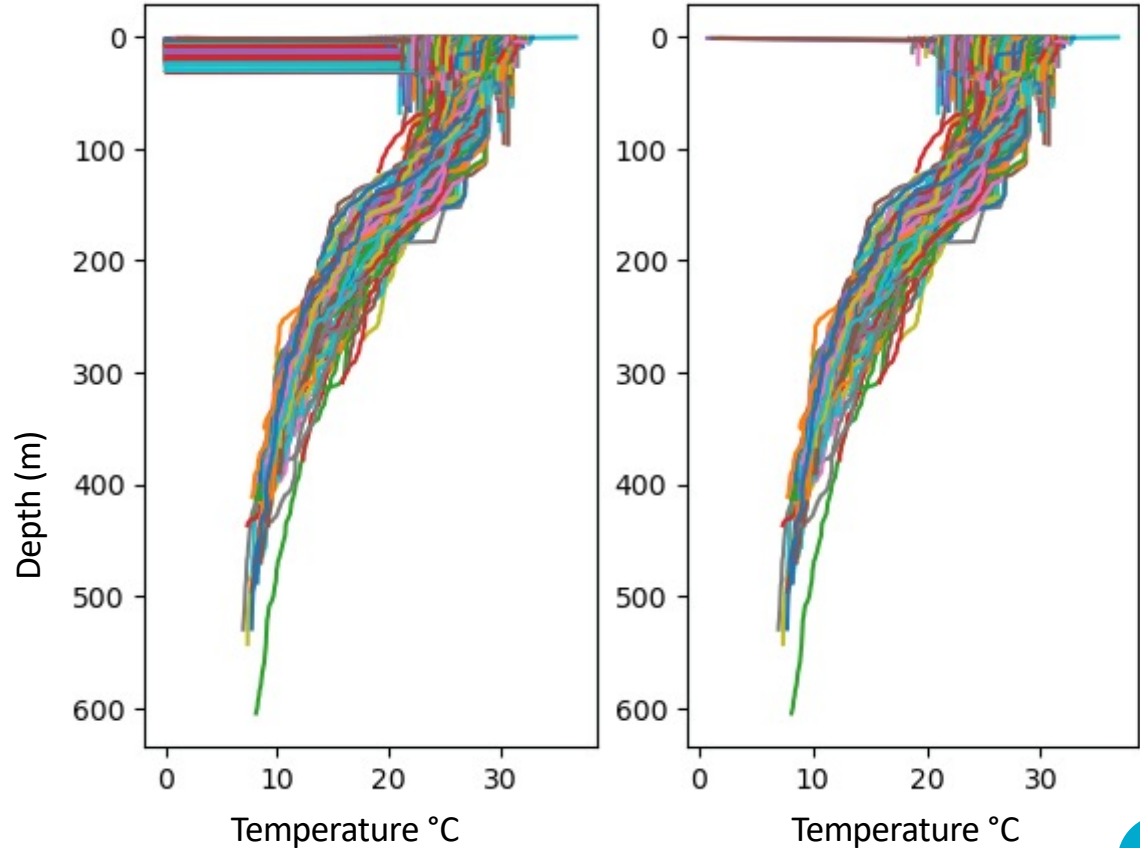
IQuOD will soon include:

- Automated QC flags from the IQuOD community benchmarking tests.
- Duplicate checking tools.
- Machine learning tools implemented alongside expert/visual QC.

Data without Flags

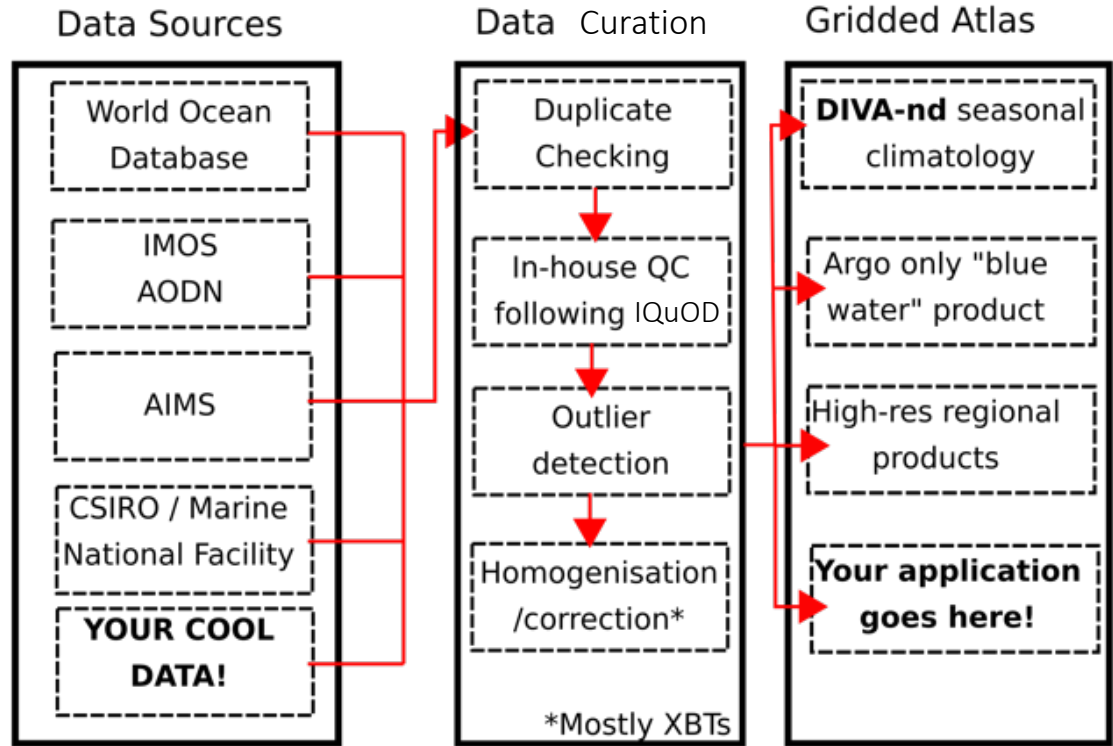
Simple example of CTD data with no QC flags included

- Remove the Temperature data with values of zero gives us the plot on the right



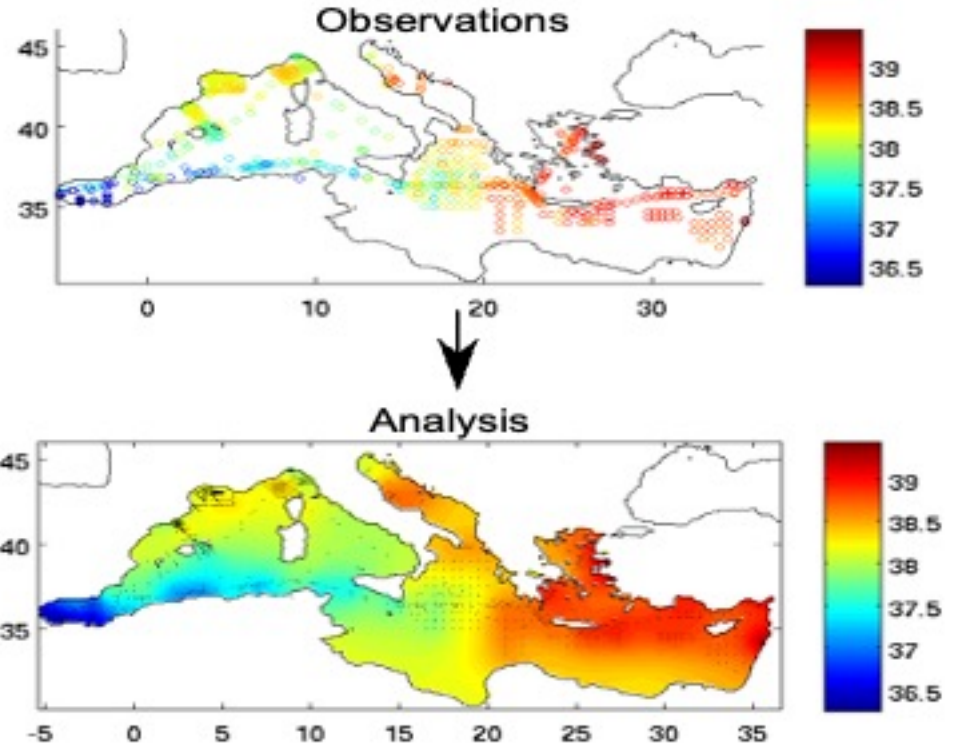
CARS v2 – Product and Philosophy

- An **Australian product for Australian conditions**;
- Limited observations over shelf and shallow seas;
- Supplement data from the international database WOD/IQuOD with "bespoke" observations from stakeholders (AIMS, MNF, Defence, French Navy)



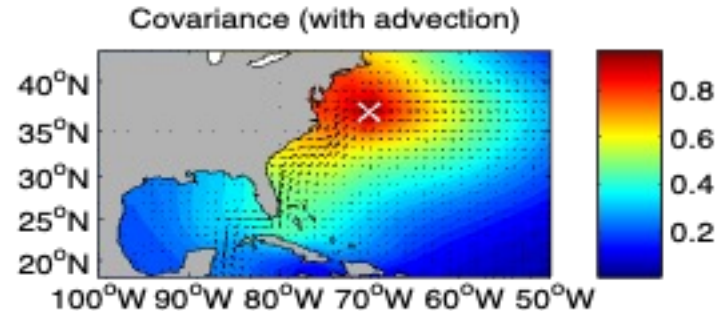
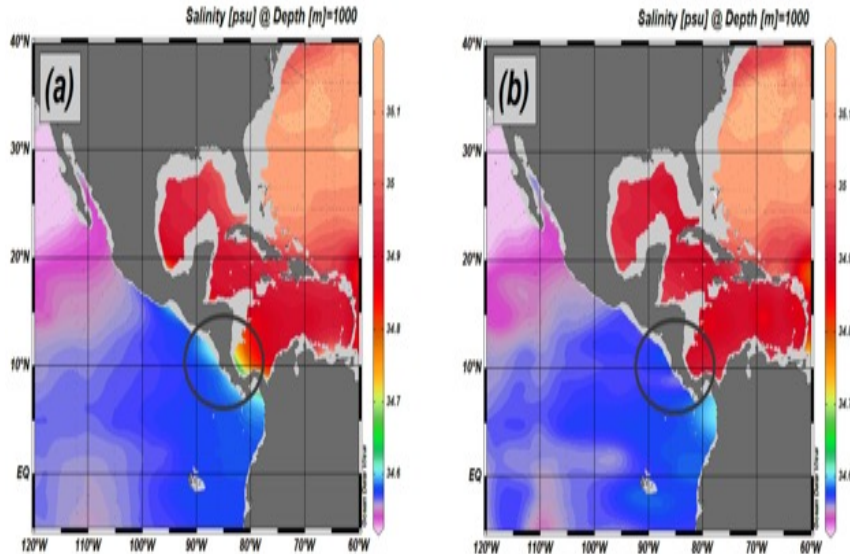
Gridded Product

- Use Data Interpolating Variational Analysis – n dimensions (**DIVAnd**) software to perform gridding
- Developed by the *GeoHydrodynamics and Environment Research Center*, Universite de Liege, Belgium
- Software is open source and actively developed
- Written in Julia – modern, open source scientific language



Constraints

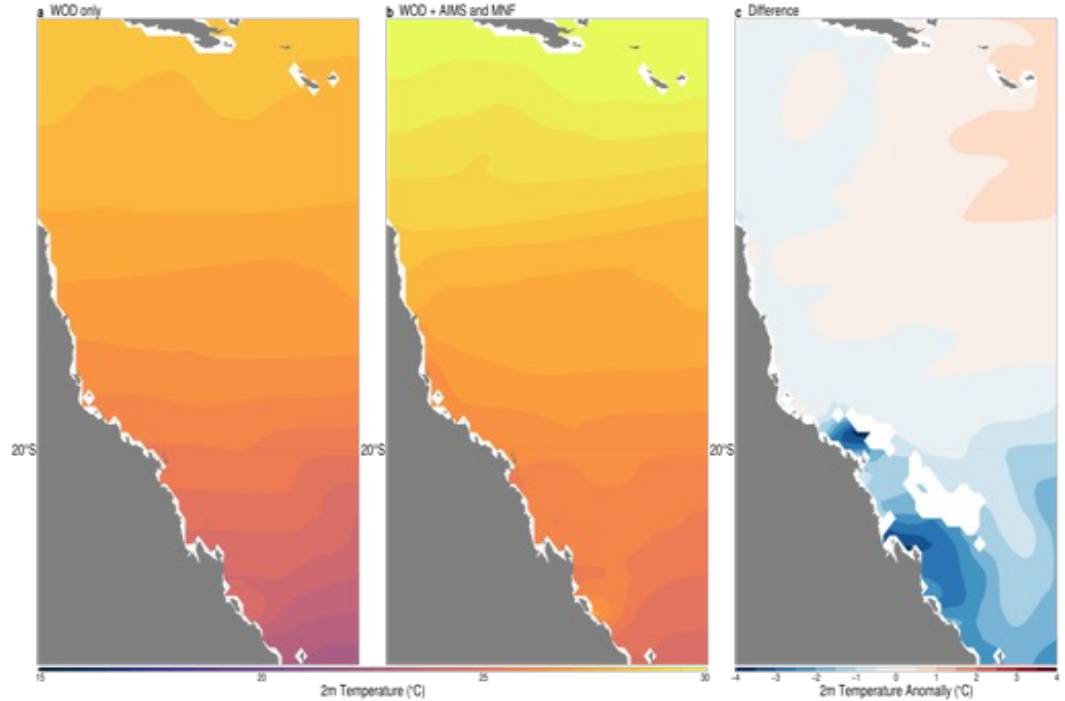
- Incorporation of constraints can aid in including:
 - Coastlines and bathymetry
 - Ocean currents
- Minimal changes in open ocean conditions, BIG differences in coastal regions.



CARS v2 – GBR case study

- DIVAnd run on 0.2x0.2 (~20km) grid;
- Data from 2005 to 2022 used
- 2m to 6000m depth;
- Analysis on slices - CSIRO standard levels (high res in near surface);
- Vertical interpolation handled by Barker and McDougall (2022) fancy interpolation scheme
- BRAN 2020 used to provide ocean current constraints
- Subsample of data types (CTD mostly)

Not representative of the final CARSv2 product.



Note: Background conditions only – no time dependent behavior included

Summary

- The CARS product is highly valued by many communities and an update will be well received
 - Publish code – open for community development
 - Higher resolution spatially
 - Using existing community code for data manipulation and QC steps
 - Using open-sourced software and new mapping tools
- A climatology is only as good as the data upon which is it built
 - Sourcing of not-so-FAIR datasets helps to improve the quality of the product
- Looking for more coastal datasets – please contact us if you have data to share