# Temporal Evolution and Scaling Properties of Water Masses from Space

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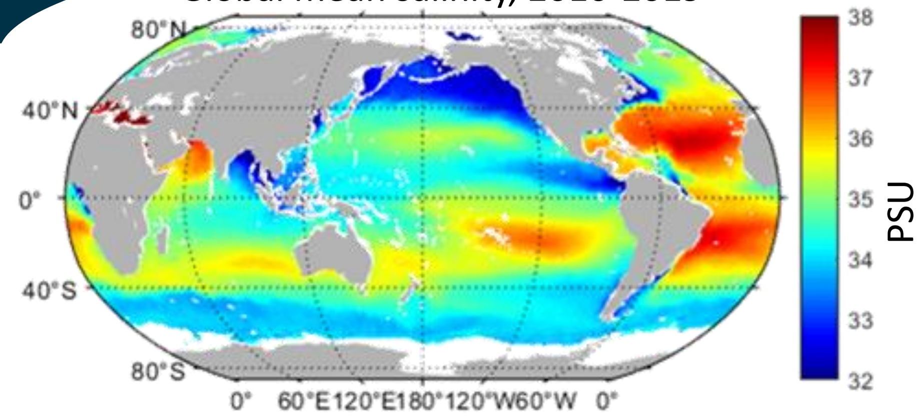
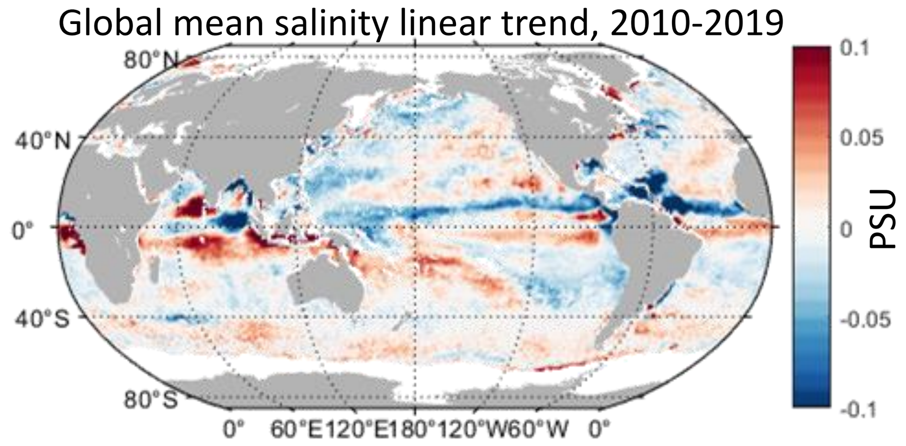
Global mean salinity, 2010-2019




Global mean salinity linear trend, 2010-2019



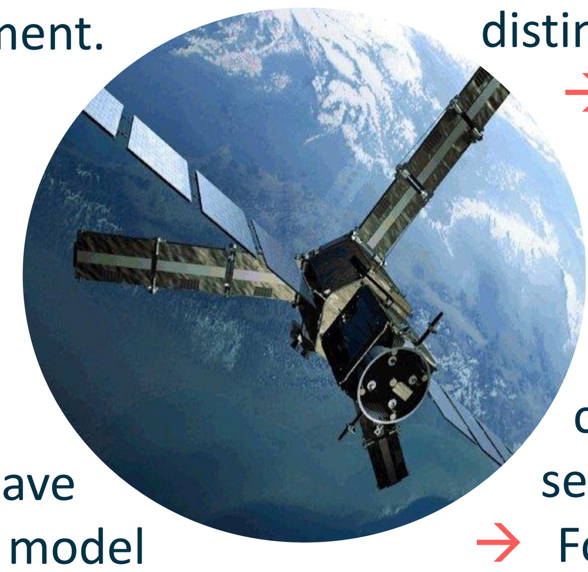

## The role of salinity:

→ ESA'S **SMOS:** first global ocean salinity satellite, launched in 2009. Global coverage every 3 days, 35-50km spatial resolution, MIRAS instrument.

→ Acquired brightness temperatures – emissivity of the surface depends on SSS and SST, converted via empirical models to remove effects of SST and surface roughness.

→ Previously, studies used **direct observational data for SSS** ie ARGO floats, buoys, and ship data. Now, investigations can be carried out using **exclusively satellite data**

→ This study aimed to (i) investigate how chosen water masses have **evolved from 2010 to 2019**, (ii) evaluate the accuracy of the WM model through comparisons against in-situ Argo data and by using **Monte Carlo simulations** to understand which variables induce the greatest uncertainty, (iii) expand functionality by including water mass spiciness within the tool, and by processing data with greater spatial and temporal resolutions.



## What is a water mass?

→ An expansive **body of water** characterised by a defined density range distinct from the surrounding water.

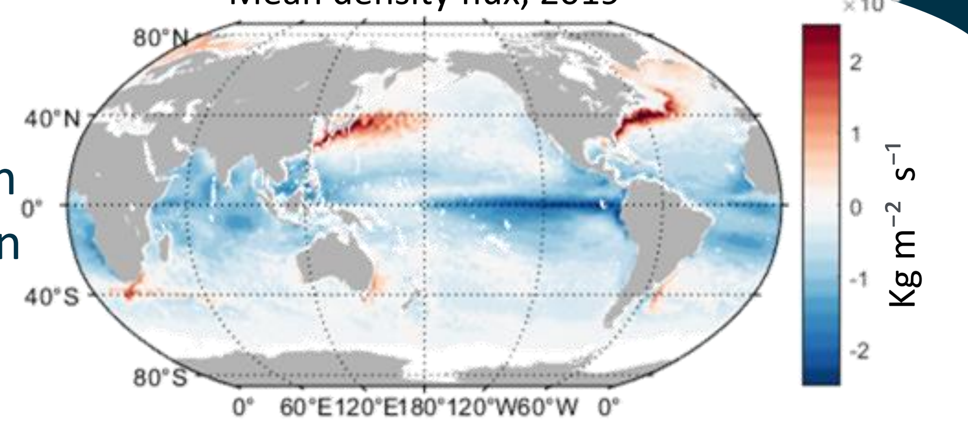
→ Salinity, temperature, evaporation, heat flux and precipitation are all needed to calculate density flux and WM transformation

→ Properties are **conservative** once subducted into the ocean interior after being set at the atmosphere interface

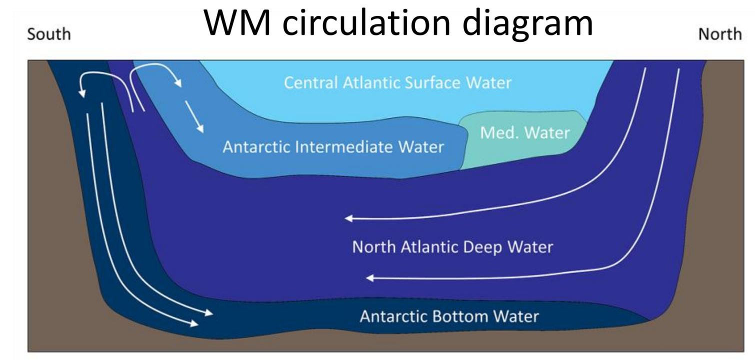
→ Formation is derived from transformation: accumulation via cross **isopycnal volume flux,** occurring commonly through seasonal **convection** associated with winter cooling.

→ Focused on three types of mode water: the **North Atlantic Subtropical Mode Water** (EDW, Eighteen-Degree water), **the North Pacific Subtropical Mode Water** (STMW) and the **Sub-Antarctic Mode Water** (SAMW)

Mean density flux, 2019



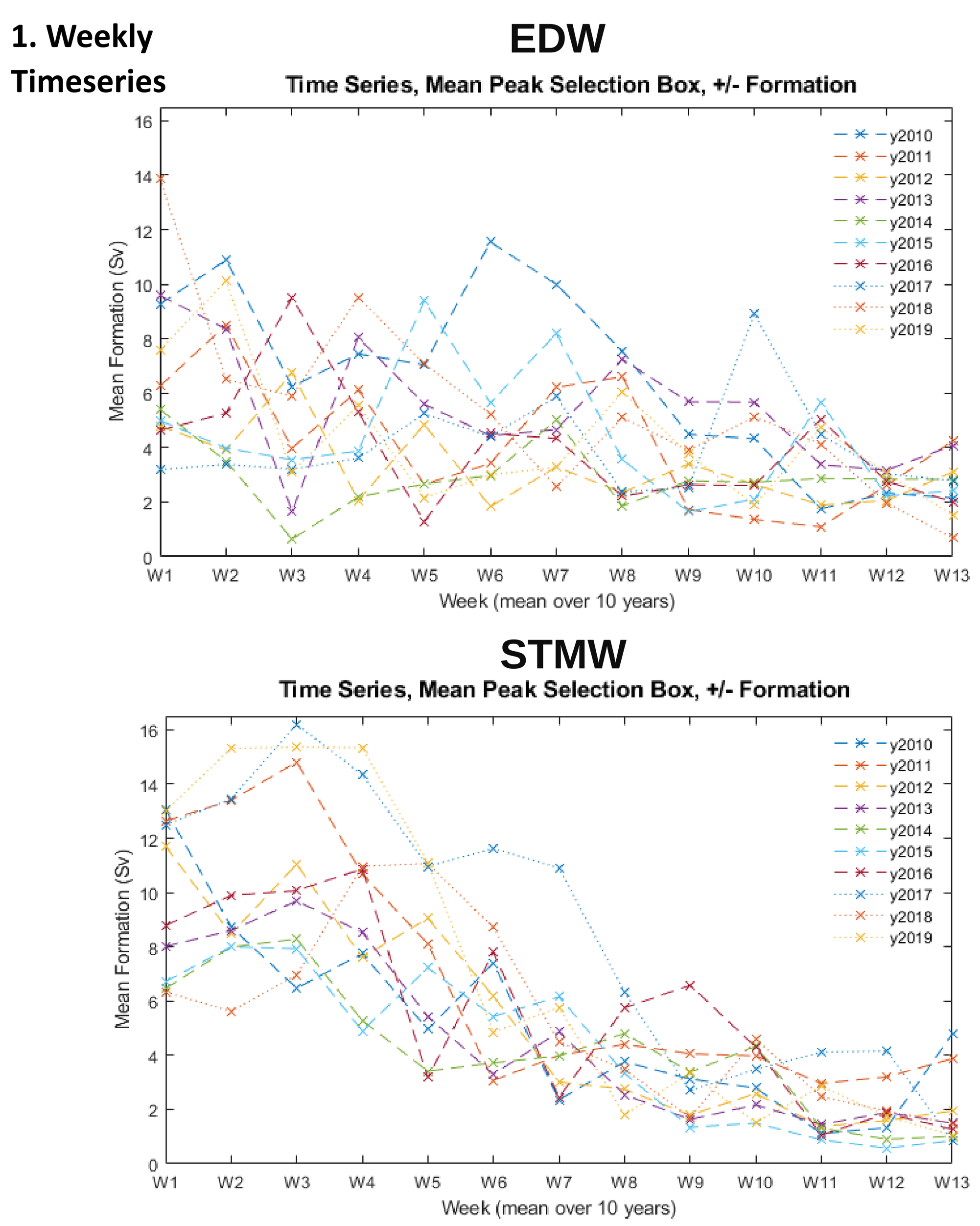

WM circulation diagram



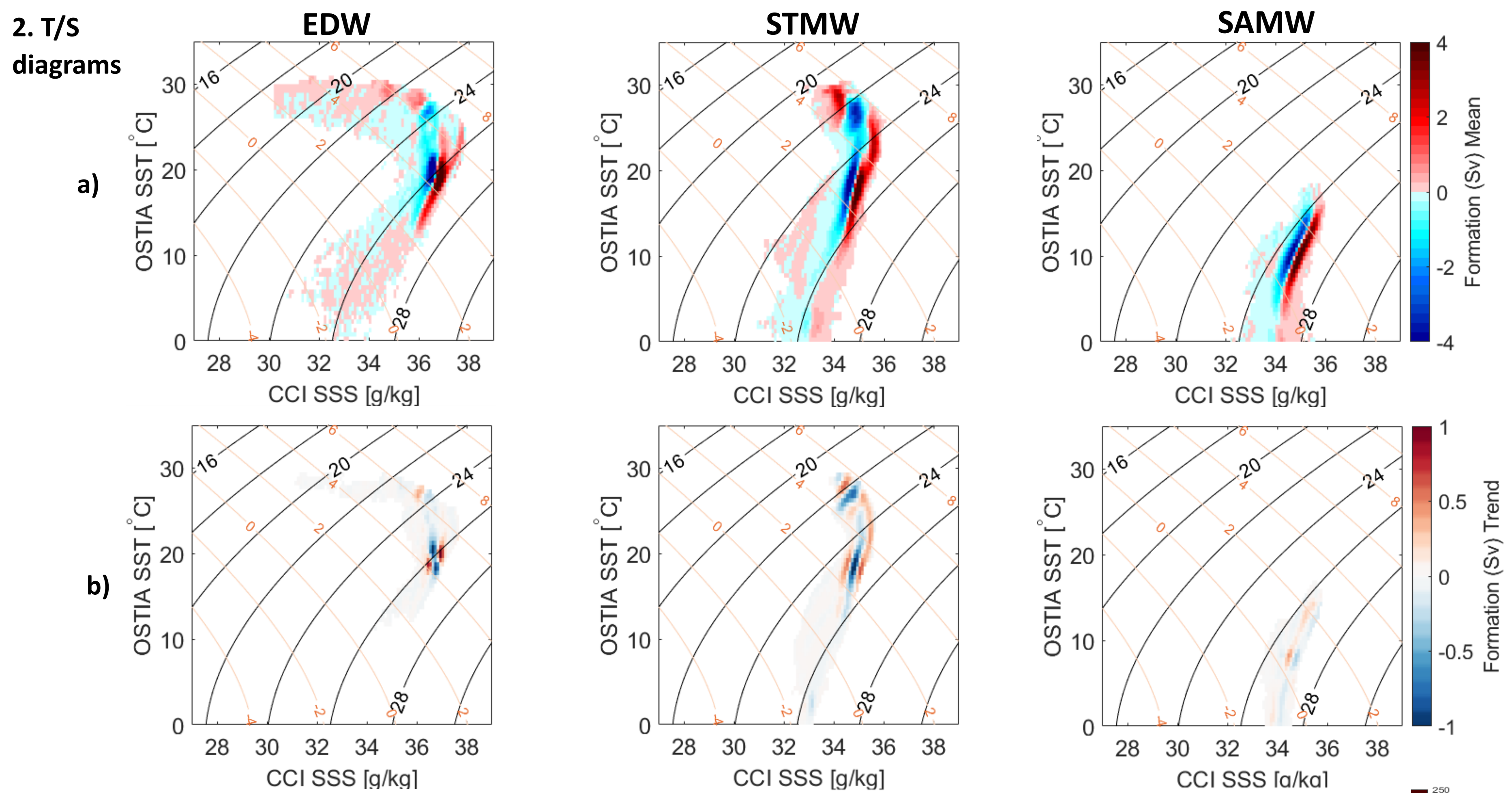

Webb, P. (2019). *Introduction to oceanography*

## Temporal Investigations::

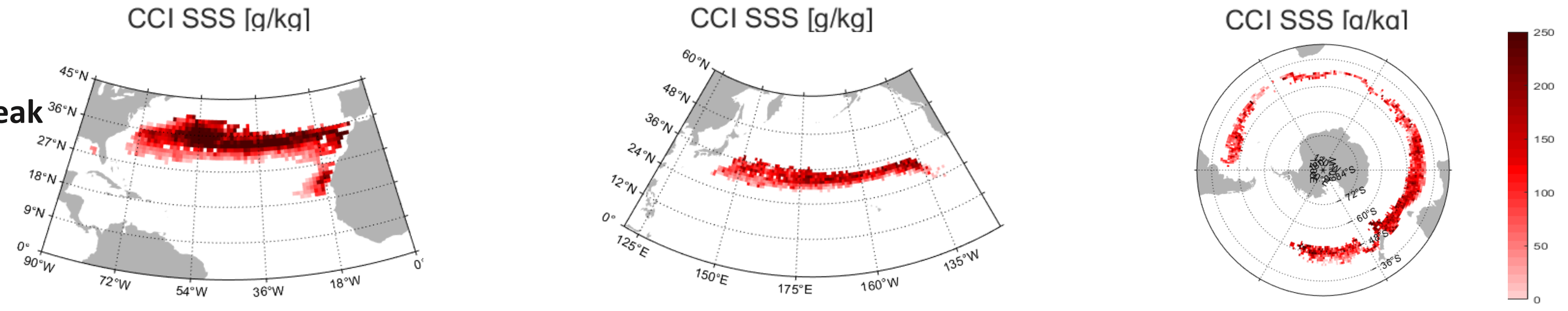
1. Weekly Timeseries




2. T/S diagrams



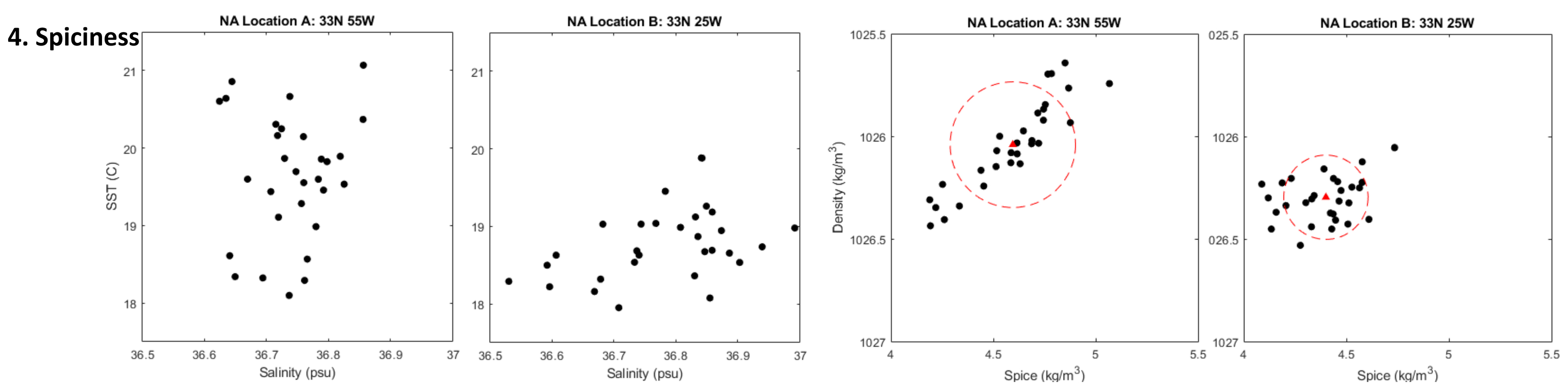

3. Geospatial location of peak formation



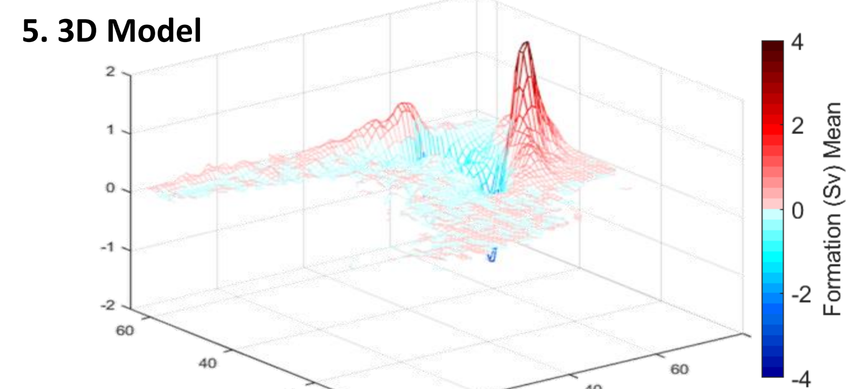

2) T-S diagrams for each of the chosen water masses, in Sverdrup. Black contours indicate density, orange contours indicate spiciness, for a) temporal mean across the period 2010 to 2019, and b) temporal trend across the same time period

## Other Applications and Investigations:

4. Spiciness




5. 3D Model




*Methodology from Huang et al, 2015

4) Two locations within the EDW. SST and SSS taken for each month of the formation season (J,F,M) for each of the 10 years. Look similarly variable in T/S space. Translated to a density-spicity coordinates and calculate the Radius of Signal → clear location A is more variable over time – due to closeness in proximity to the Gulf Stream. 5) 3D modelling to emphasize formation/destruction

## Methodology:

- Main Datasets: **CCI SMOS SSS, OSTIA SST, CERES/OAFLUX** heat flux and evaporation, and **IMERG** precipitation. All datasets were reduced to 1 degree, monthly resolution, over the period 2010 to 2019, and modelled in MATLAB
- Monte Carlo simulation performed with the standard deviation of each dataset, gives the uncertainty of the method
- Tool takes the form of a series of equations, mostly based on **Speer and Tziperman (1992):** Calculate density flux, then discretize and find transformation, then formation, all within MC loop, then automatically find area of peak formation within T/S space and apply extra analysis.

Density Flux:

$$\mathbf{f(x,y,t)} = \frac{-\alpha H}{C_p} + \rho(0,T)\frac{\beta(W\cdot S)}{1-S}$$

Where a represents thermal expansion coefficient, H heat flux, Cp specific heat capacity, p density, B haline contraction coefficient, W freshwater flux, and S salinity

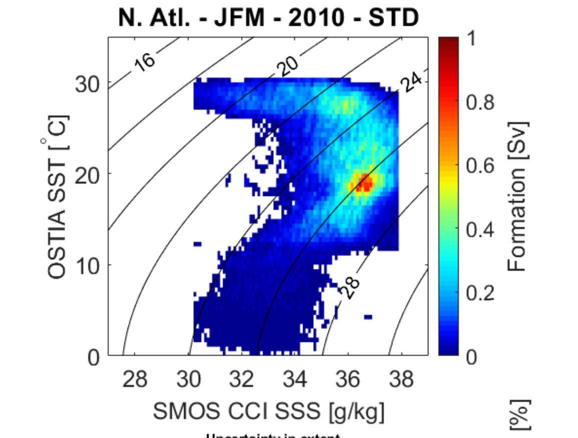
Transformation:

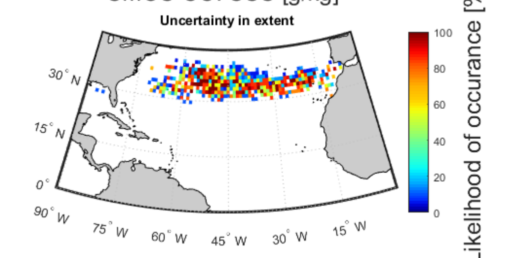
$$\overline{F(\rho)} = \frac{1}{\mathrm{T}\rho}\int dt \iint dA\,\delta(\rho-\rho')f(x,y,t)$$

With F representing transformation ($m^3\,s^{-1}$, with 1 Sv = $10^6 m^3\,s^{-1}$) as a function of density (ρ), averaged over one year (T).

- Base results are in the form of seasonal T/S diagrams (left), where vertical streaks represent different water masses either increasing in formation (red colouring) or decreasing formation (blue colouring). The area of peak formation selected and translated into geographic space.
- From these results, trends, anomalies and other analysis can be performed.
- To investigate effects of different spatial and temporal scales, a 0.5 degree and a weekly dataset were added to the tool eg the time series figure (left) shows the weekly formation rates for the EDW and STMW over their season of peak formation (JFM)

N. Atl. - JFM - 2010 - STD



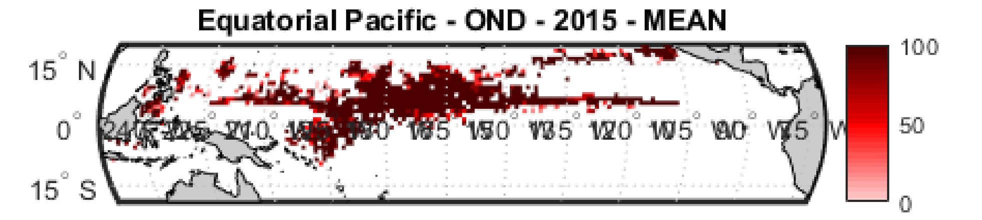




Example of MC results for a chosen year

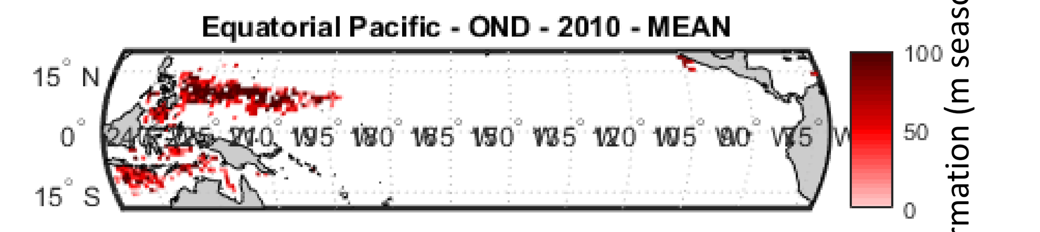
## Example of Potential Future Applications:

Hypothesis: During La Nina, water flows towards the west = more subduction = greater water mass formation in this area. During El Nino, westward flow is weakened or even reversed = formation might be more spread out across the basin and not so concentrated in the west. Preliminary results of the area of peak water mass formation using the tools may demonstrate this.

Equatorial Pacific - OND - 2015 - MEAN



Equatorial Pacific - OND - 2010 - MEAN




ONI Index: 2.6 -1.7