What can we learn about small-scale spatial variability of surface ocean dimethylsulfide (DMS) concentrations from high frequency novel measurements?

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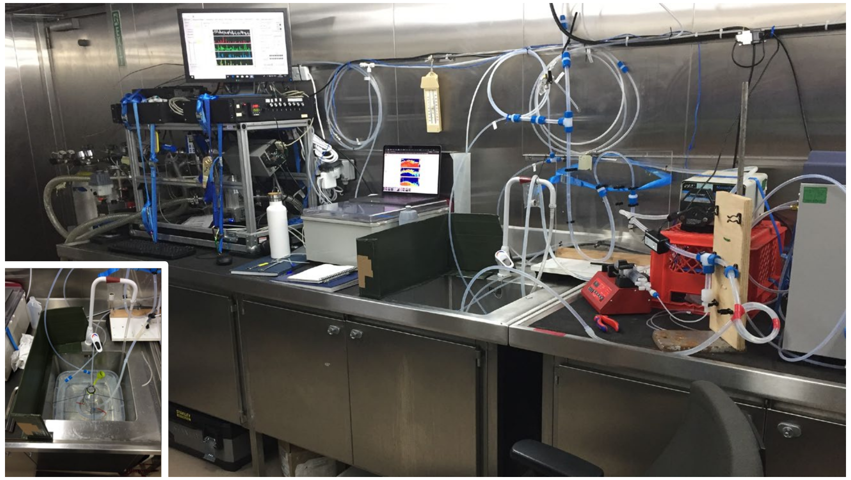
START →

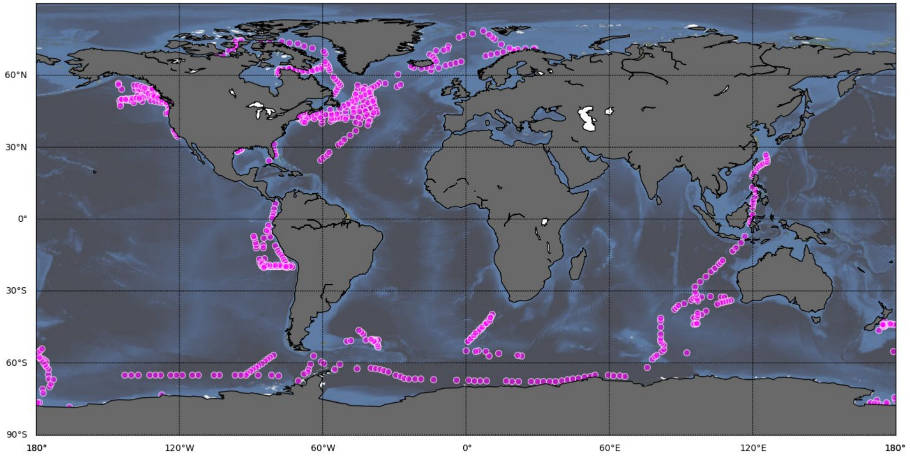
New Opportunities & Existing Limitations

New data – new opportunity

- Dimethylsulfide (**DMS**) is an important **climatically-active** gas emitted from the ocean, but we lack a complete understanding of what controls its oceanic distribution.
- Global coverage of seawater DMS concentration measurements are **relatively sparse**, and little is known about its variability at small spatial scales.
- Recent efforts have enhanced the coverage of **high frequency** observations.
- **Global analysis** of DMS concentration **variability at small scales** is now possible, this may elucidate previously unrecognised drivers of DMS variability.
- Previously **variability lengthscales (VLS)** have been assessed within **specific regions**. See here for more detail.
- Our study brings together **all available high frequency DMS data**, and applies a single **objective method** to explore global patterns in DMS variability lengthscales. We use 35 high resolution data sets from
  - **GSSDD** (Global Surface Seawater DMS Database)
  - **NAAMES** (North Atlantic Aerosol and Marine Ecosystem Study)
  - **SCALE** (Southern oCean SeAsonaL Experiment).
- This analysis allows us to better understand the mechanisms driving variability in DMS concentrations and informs the treatment of sparse observations in **climatological products**. See here for why that's important.



Capturing DMS data on the Southern Ocean SCALE 2019 spring cruise



Map of all available high resolution DMS data. See here for details.

2 – Description

Variability Lengthscale (VLS) Analysis for DMS

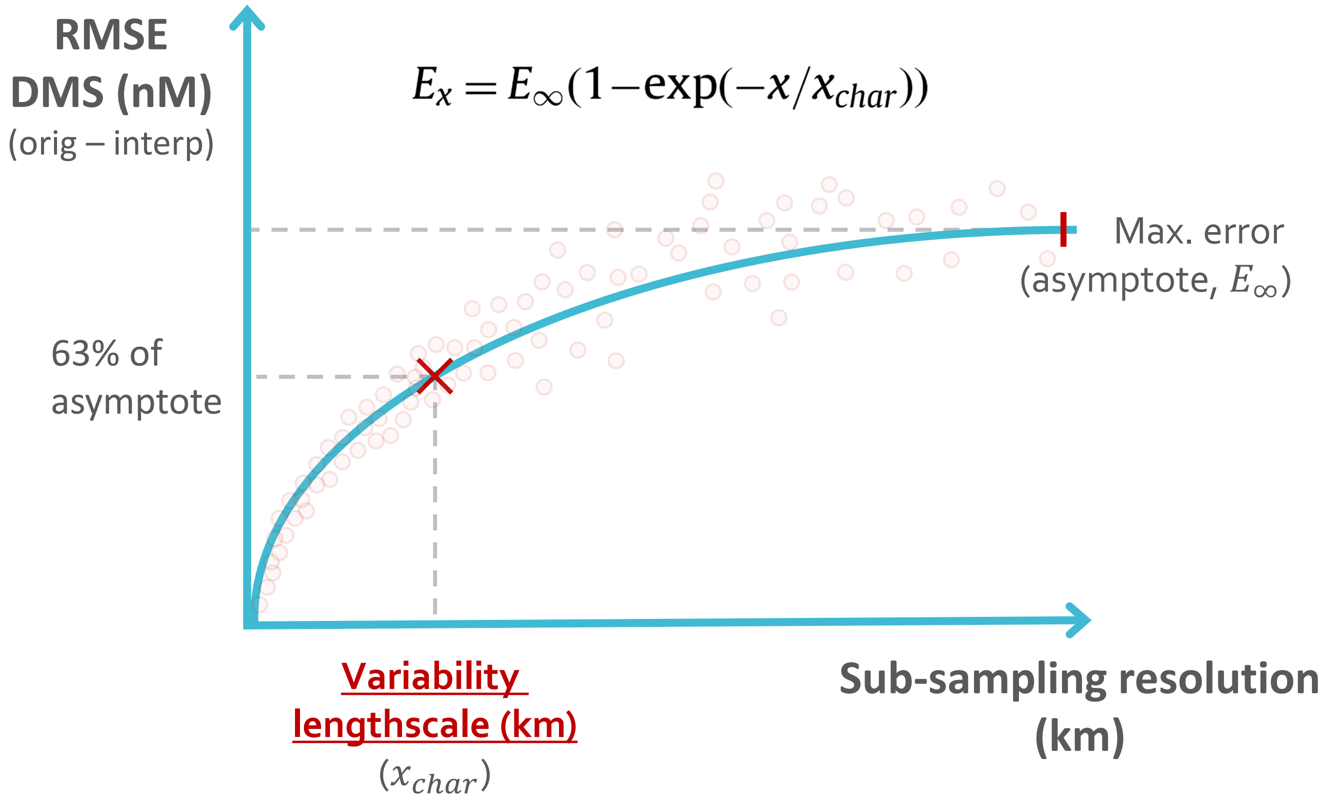
What does variability lengthscale analysis show?

- Variability lengthscale (VLS) analysis indicates the **predictability of DMS spatial distribution**, over increasingly coarse interpolation distances.
- VLS shows the **lowest sampling resolution** necessary to capture most of the spatial variability (*Hales and Takahashi 2004*).

How is it calculated?

- Increasing errors (RMSE) are associated with **sub-sampling and interpolating** high frequency data at increasingly coarse resolutions.
- RMSE increases until a **maximum error plateau**, or asymptote, is reached. This corresponds to the **total variance** of the dataset.
- The characteristic **VLS** distance (x_{char}) is taken as the intersect on the curve at **63% of the asymptote** (E_∞), following *Tortell et al. 2011*.

Characterising the variability lengthscale

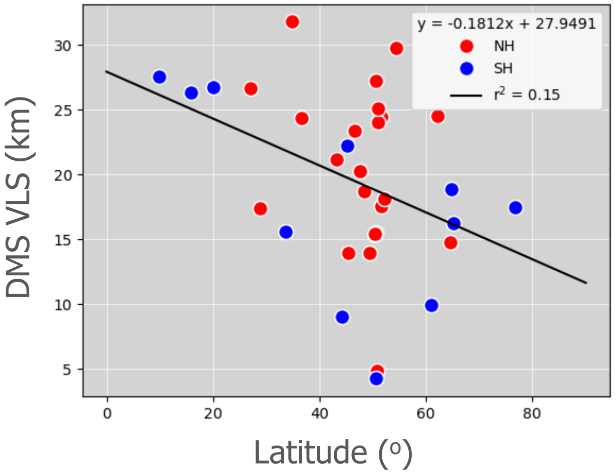


3 – Results

Global patterns in DMS variability – physical drivers

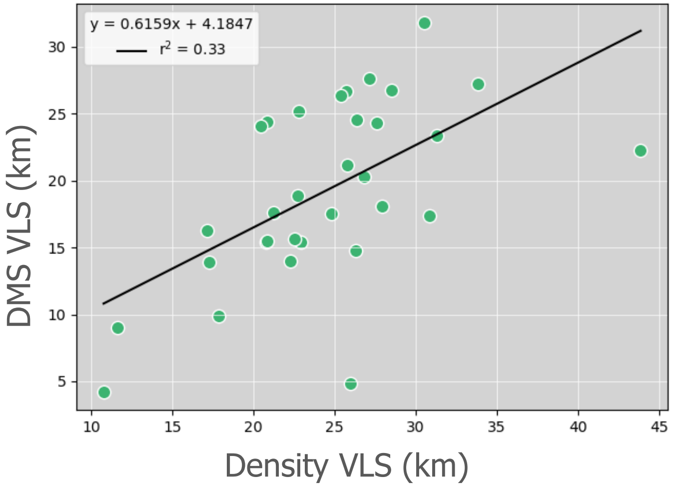
1. **DMS variability lengthscale (VLS) is found to have a global latitudinal dependence.**

- But what could be driving this?
- How important are vertical & horizontal physical mixing processes?



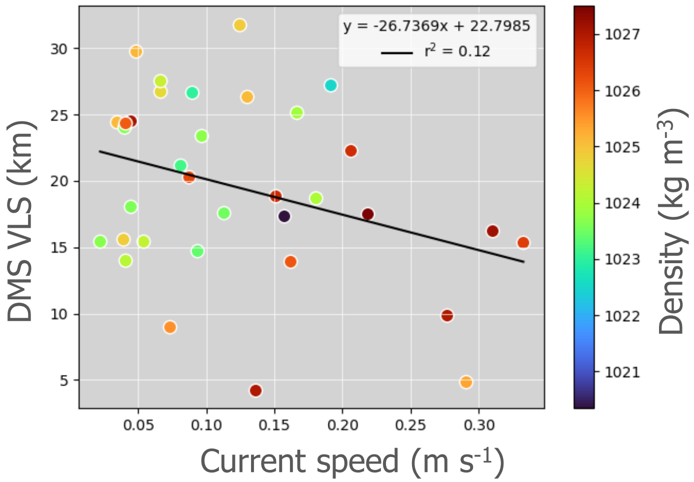
2. Changes in the mixed layer depth (MLD) are hypothesised to impact the vertical dilution of DMS (*Simó and Dachs 2002*). Surface density VLS is used as a proxy for the MLD variability.

- **Surface density VLS has a strong positive relationship with DMS VLS.**



3. Horizontal surface current speeds are an indication of eddy activity at this scale.

- **Lower DMS VLS distances are generally found in areas of higher current speed & higher surface density**



So what does this show?

- Surface DMS generally varies over smaller spatial scales at higher latitudes
- Variability of surface DMS is ubiquitously related to the spatial scale over which surface density varies
- DMS generally varies over larger spatial scales when surface currents are slower

But physical drivers can't explain all the DMS variability, so what about biogeochemical control?

4 – Results

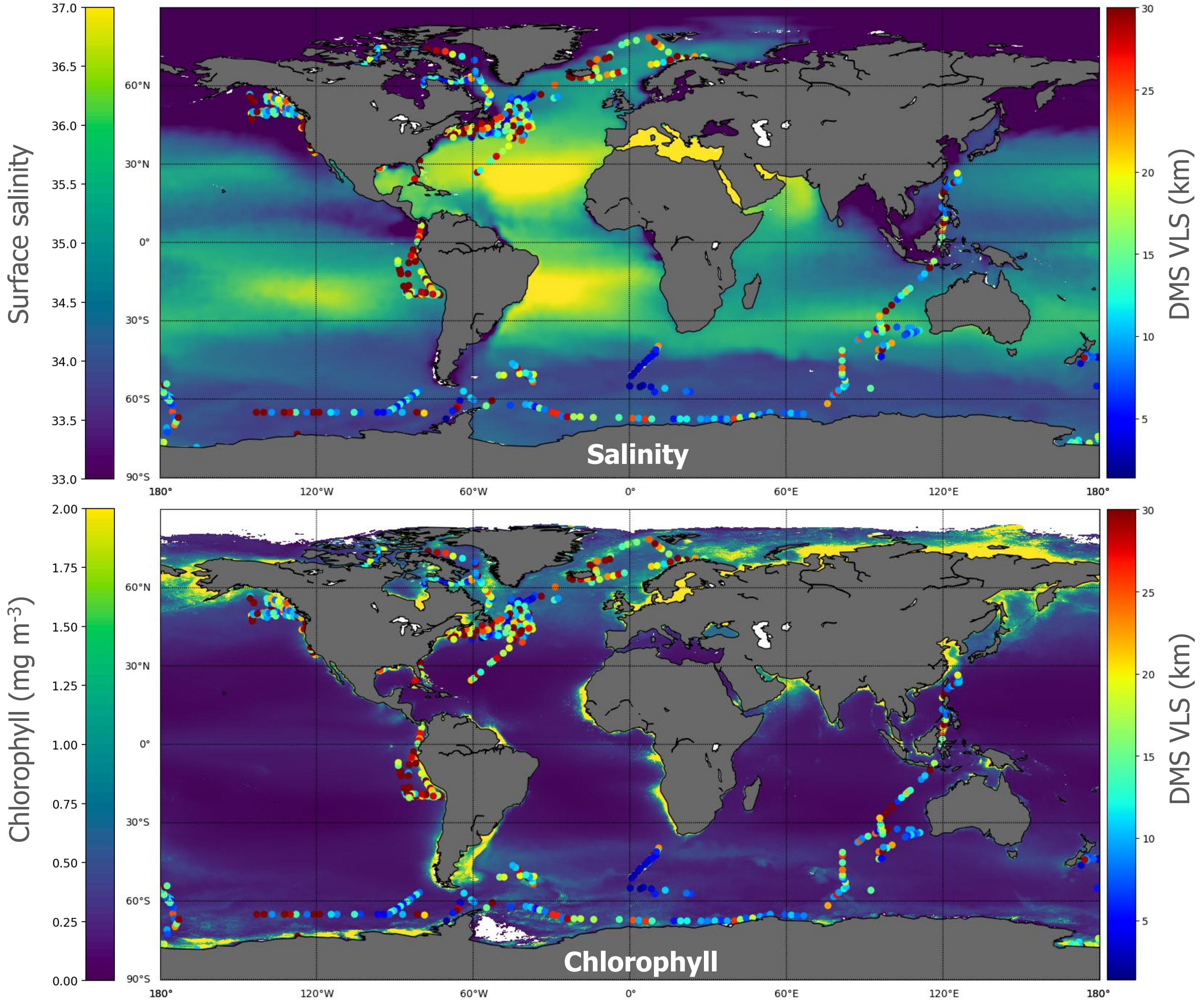
Global patterns in DMS variability – biogeochemical drivers

A first look at surface salinity and chlorophyll maps

- Higher DMS VLS distances generally appear where salinity is elevated, except NE Pacific coastal area – **so is salinity driving DMS VLS?**
- …Not necessarily, but it's a good indicator of regional conditions. Salinity distribution map shows hotspots in the **subtropical gyres**.
- These **oligotrophic** gyres with large DMS VLS distances are characterised by **low chlorophyll**, **high salinity** and **low current speeds**.
- NE Pacific high DMS VLS possibly due to a dominance of coastal chlorophyll in this region – **so does chlorophyll drive DMS VLS?**
- …Not exclusively, but perhaps partly in combination with current speeds. Lower DMS VLS is seen in coastal and high latitude regions with **high productivity** AND **high turbulence**.

Can this be simplified?

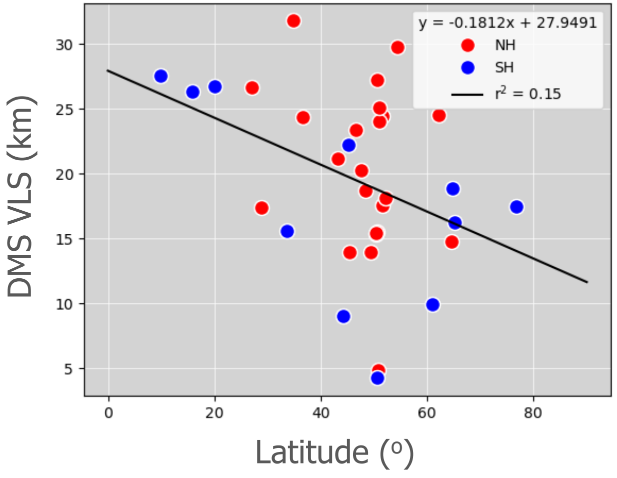
- DMS VLS distances are large when chlorophyll is either very high (e.g. NE Pacific coast) or low (e.g. E equatorial Pacific), i.e. when widely **locally homogenous**
- DMS VLS distances are small in areas of high mixing/currents, creating small pockets of productivity (in eddies), i.e. when relatively **locally heterogenous**



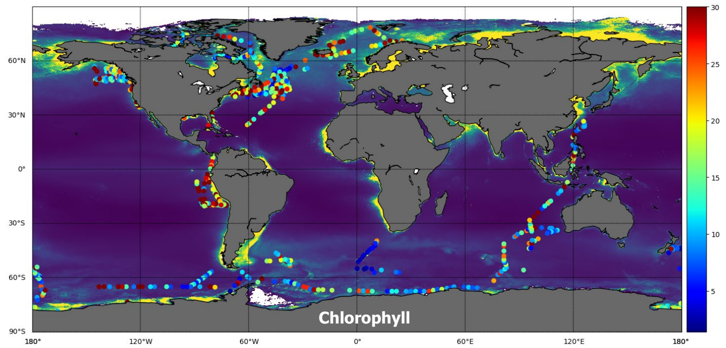
5 – What's next?

Implementation & further investigation

- The latitudinal dependence of DMS VLS found in this study has been implemented in a new DMS climatology (see ***AS4.13 – EGU21-4652, Hulswar et al.***, for details).



- We plan to further interrogate biogeochemical and physical climatological data, including:
  - Co-location of each DMS **transect** to ancillary and climatological comparison data (including MLD).
  - A comprehensive treatment of high resolution **chlorophyll** data from satellites, ideally to enable **VLS analysis** of a biological parameter.
  - Inclusion of **wind and eddy fields** to quantify the importance of horizontal mixing patterns in driving DMS variability.



- **This is a work in progress so we welcome all feedback and suggestions!**

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Supplementary slides below,

i.e. the destinations of hyperlinks in motivation slide.

References at the end.

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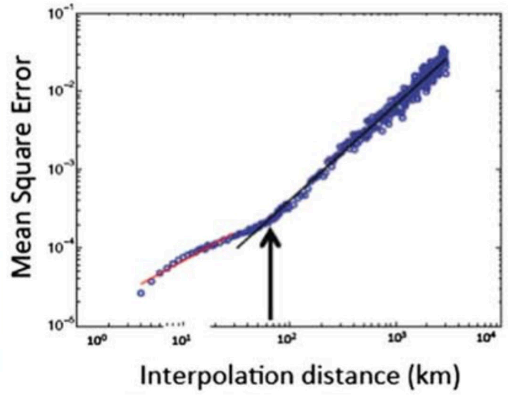
A Closer Look: New Opportunities

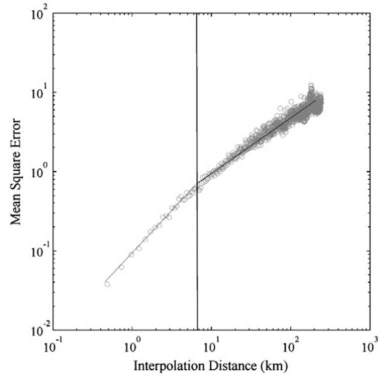
New data – new opportunity

- Analysis of **global** small-scale variability of surface seawater **dimethylsulfide (DMS)** concentrations is now accessible, due to recently enhanced coverage of high frequency observations.
- Previous studies assessing the small-scale spatial variability of DMS, termed the **variability lengthscale (VLS)**, have focussed on local and regional level dynamics, or a confined zonal band of latitudes.
- Quantitative inter-study comparison is limited by the publication of **multiple different methods** to define the characteristic VLS.
- Some qualitative analysis of what drives the spatial variability in DMS has been attempted.
- This study applies an **objective algorithm** to determine the **VLS of DMS globally**, and in all ocean basins at different stages of the seasonal cycle. Datasets include measurements from the GSSDD (Global Surface Seawater DMS Database), NAAMES (North Atlantic Aerosol and Marine Ecosystem Study), and SCALE (Southern oCean SeAsonaL Experiment). GSSDD data **includes measurements used in some previous DMS VLS studies**.

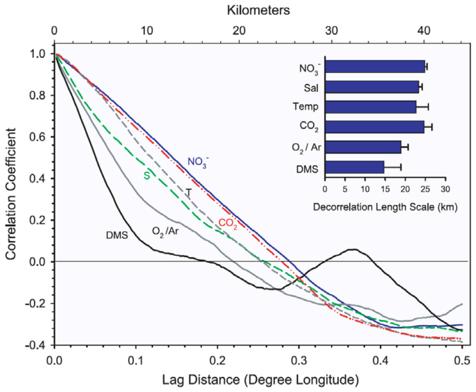
A variety of variability lengthscale methods



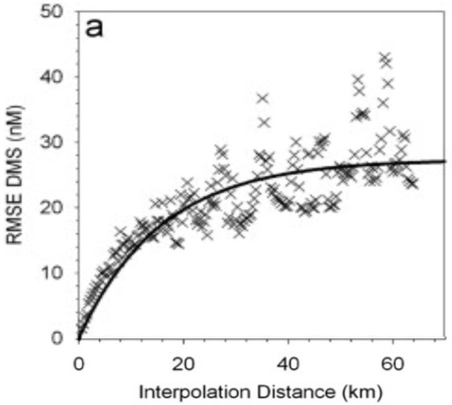
Royer et al. 2015



Asher et al. 2007



Tortell 2005



Tortell et al. 2011

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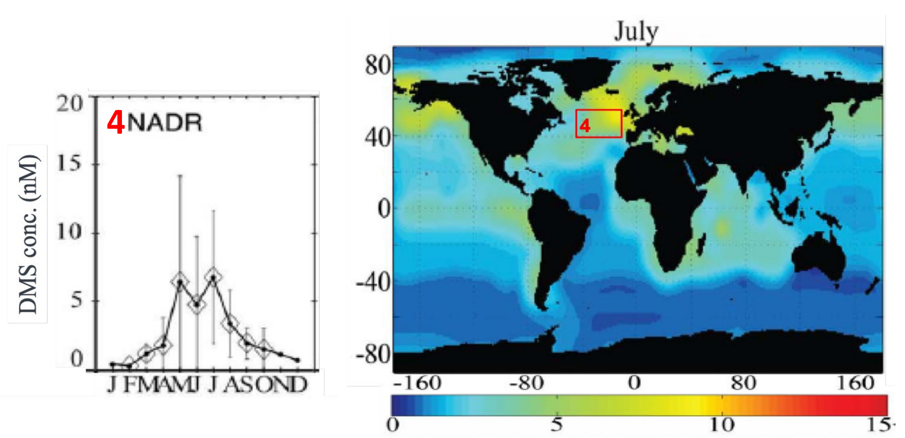
A Closer Look: Existing Limitations

Climatological limitations

- Large **variability** in spatial and temporal seawater DMS concentrations e.g. North Atlantic Drift province (NADR).
- Distance-weighted interpolation **smoothing** applied to DMS climatology uses 555 km radius of influence (*Lana et al. 2011,* hereafter L10).
- **Variability** and **smoothing** combine to create uncertainty.
- L10 used by models to either:
  - validate DMS concentrations
  - directly determine DMS input into the atmosphere
- Climatological uncertainties propagate through into models.
- Uncertainty can be reduced by understanding **global DMS variability lengthscales (VLS)**.



Lana et al. 2011

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35 High frequency observational data sets

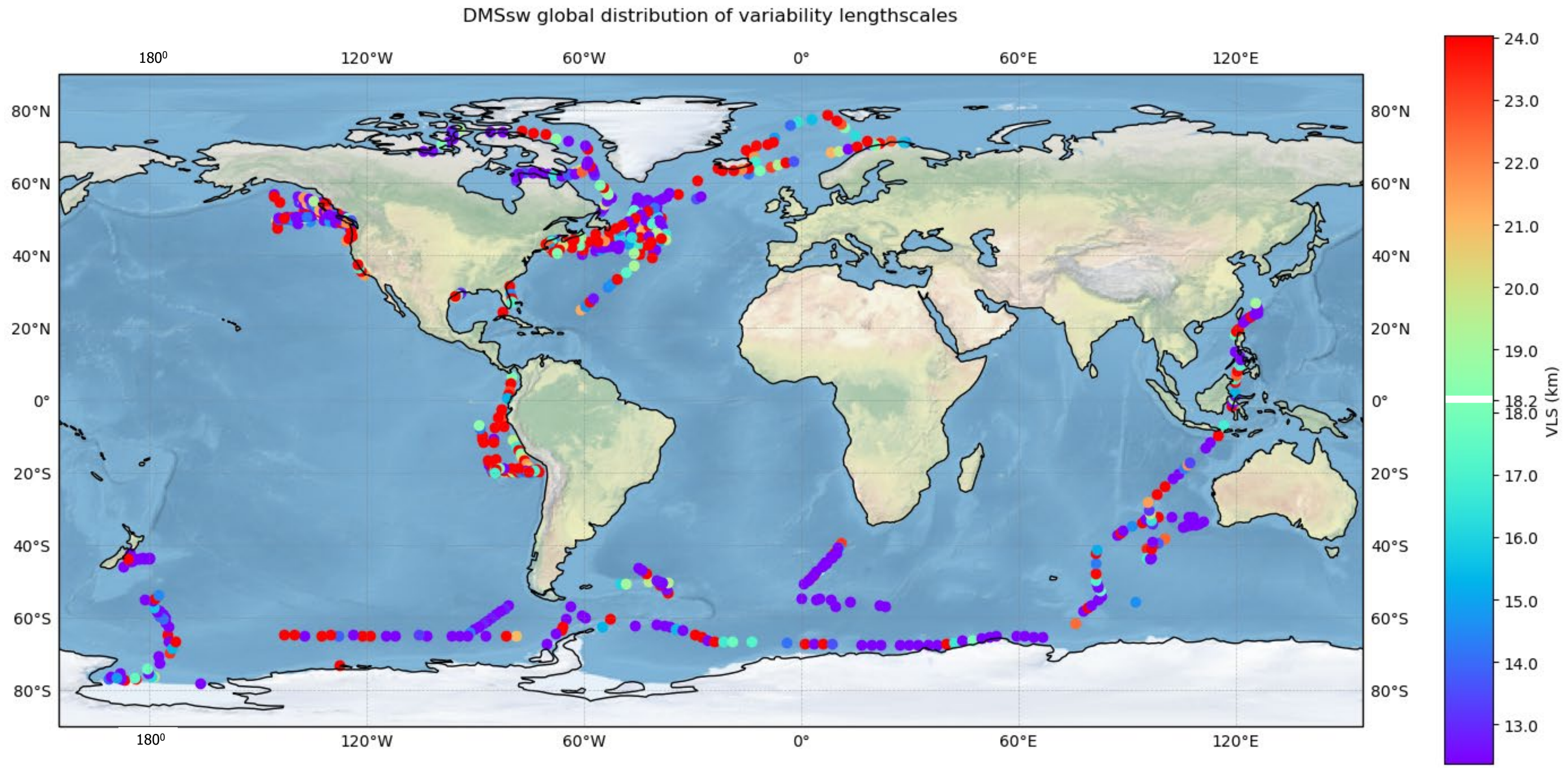
- Data from **35 cruises** are separated into transects of underway (ship speed **>1 ms^{-1}**), continuous measurements, with a maximum sampling frequency of **1 hour**, and a minimum transect length of **100 km**.

- Yields **667 transects** of DMS data, with a global extent.

- Ancillary sea surface temperature (**SST**) & salinity (**SSS**) observations are used to calculate surface density **(SSD)** along each **DMS** transect.

- **Variability lengthscale (VLS) analysis** algorithm is applied to the 667 transects for all 4 parameters: DMS, SST, SSS, SSD.

- **VLS indicates predictability of spatial distribution for each parameter, over increasingly coarse interpolation distances.**



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