A “How To” guide to the digital atlas for physical and biogeochemical conditions in the Chesapeake Bay

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Motivation for an atlas

Typical questions from graduate students:

1. Which month of the year has the highest wind waves?
2. Is the direction of the dominant winds changing across seasons?
3. Where/when is water chemistry appropriate for calcification ($\Omega > 1$)?

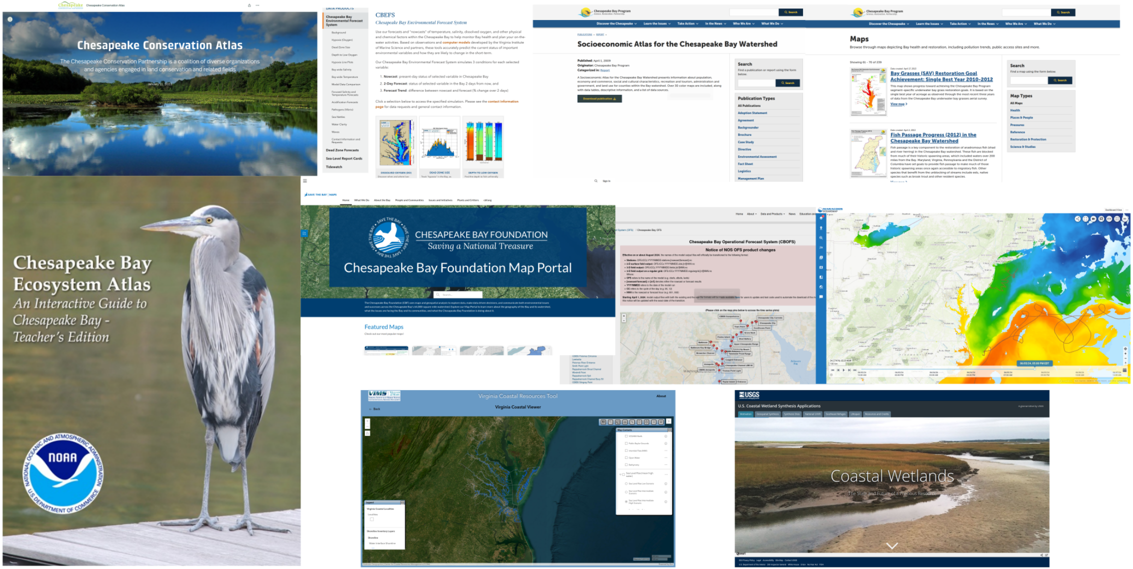
Answers me/Marjy would give back. . .

- “The answers are scattered across these 3 papers; let me find the PDFs and send that to you.”
- “The answer is on chesapeakebay.net, you just need to download the raw data and analyze them.”
- “I can generate a few figures from my model inputs/outputs; I’ll get you that *next week*.”

None of these answers are great from the point of view of the student.

Aren’t there comprehensive resources that answer all these basic questions about the Bay?

Several resources already exist, but their focus is on other topics



Attempting to fill the gap

What I had in hand:

- 4 decades of info about atmosphere, waves, tides, terrestrial fluxes (inputs)
- 4 decades of modeled hydrodynamics, carbonate chemistry and N,C cycling in the Bay (outputs); ~ 2.5 TB (!)

Summarizing this information:

- Surface and bottom only (3-D vars)
- 12 values in time: "January" is average of Jan. 1985–2023, etc.
- Grid 0.00684° long. × 0.00540° lat.

Enough to answer lots of questions, only 114 MB in size.

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An atlas for physical and biogeochemical conditions in the Chesapeake Bay

DATE	2024-03-19
TEMPORAL EXTENT	1985 - 2023
AUTHORS	St-Laurent Pierre [1], Friedrichs Marjorie A. m. [1]
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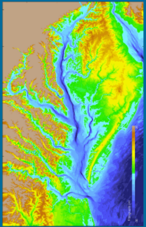
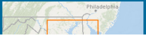
Estuarine environments are characterized by strong spatial gradients and high temporal variability that are difficult to fully capture with discrete field measurements. This is particularly the case in the Chesapeake Bay, the largest estuary in the continental United States. This archive provides a climatological atlas of physical and biogeochemical conditions for the Chesapeake Bay based on numerical model results of 1985-2023. The atlas includes surface and bottom conditions on a fine longitude/latitude grid with a monthly frequency. The environmental variables are stored in a NetCDF file with abundant metadata that can be used in software such as QGIS, Python, R, Matlab or GNU Octave. A 50+ page documentation in PDF format provides additional information on the environmental variables, the numerical model used to generate the climatology, and an evaluation of the model skill over the period of the atlas. The documentation also includes ready-made visualizations for each environmental variable.

DISCIPLINES	Chemical oceanography
KEYWORDS	Estuaries, Biogeochemistry, Chesapeake Bay, Water quality, Eutrophication, Hypoxia, Modeling, Hydrodynamics, Marine Science, Acidification, Carbon cycle
LOCATION	39.609N, 36.5526S, -75.02796E, -77.40144W
LICENCE	(cc) BY

DOWNLOAD DATA



Topography of the Chesapeake Bay



nordet.net/macan2024 for links to atlas + materials presented today.

What the atlas provides:

Topography, Tidal range
Wind velocity, direction
Significant wave height
Sea surface height
Horizontal currents
Bottom stress
Potential temperature
Practical salinity
Vertical diffusivity
ISS, TSS, K_d
Dissolved O_2
DIN, DON, DOC
PON, POC
TA, DIC, Ca^{2+}
pH, pCO_2, Ω_{Ca}, Ω_{Ar}

(27 variables total)

What the atlas does not provide:

The atlas is based on *model* results, not *measurements*. (Tons of measurements go into the inputs and calibration of the model, but there are no 'measurements' in the atlas.)

Although the atlas is based on a simulation of 1985–2023, it only includes the *average* of this 39 year period for each month of the year.

(In future versions we will include information about year-to-year variability, *e.g.*, timeseries of Bay-averaged surface salinity.)

Two ways in which the info is provided

Documentation

Archive of georeferenced rasterized layers

(. . . browse through the documentation. . .)

Examples of how to exploit the NetCDF archive

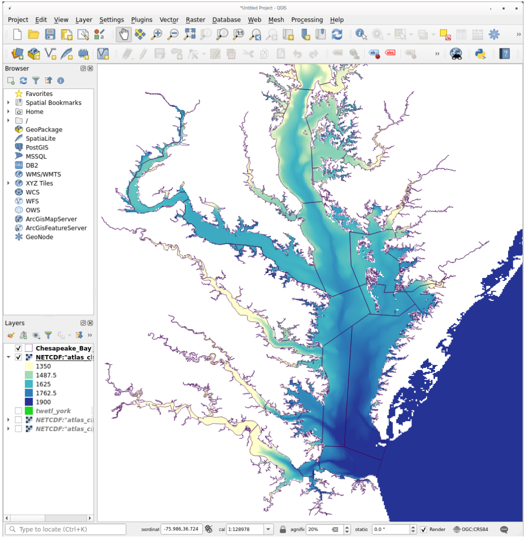
1. QGIS
   Quick visualizations
   Overlays

2. (Python)
   Net calcification of Eastern Oyster

3. Seasonality of the carbonate system
   Habitat suitability index of sandbar shark

4. (Matlab / Octave)
   Along-tributary transects

QGIS

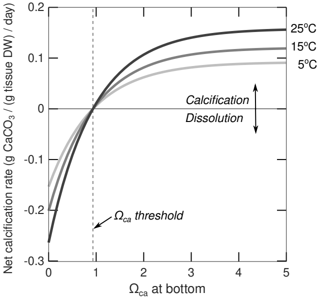


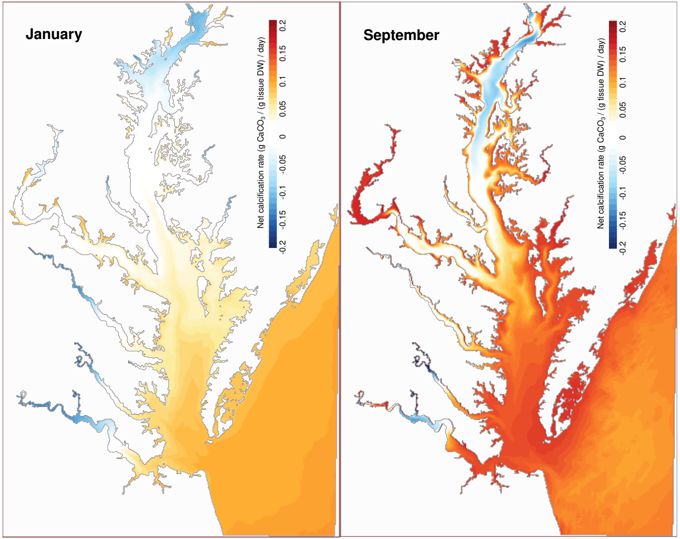
1. Bottom TA in August
2. Overlay TMDL segments.

Net calcification of Eastern oyster

Shells of *Crassostrea virginica*:

(Rivest & Brush, pers.comm.)



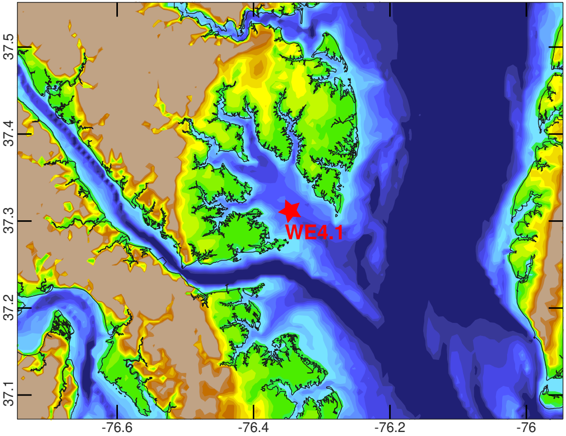


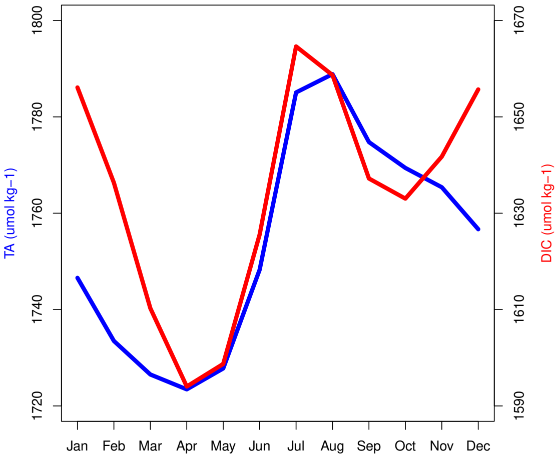
January: Low buffer capacity of tributaries contributes to dissolution conditions.

September: Higher temperatures amplify rates, while primary production enhances Ω_{ca} in shallow water.
In the Potomac, TA and Ca^{2+} are highest in September leading to ~high calcification rates.

Script: `calcification_oysters.py`

Seasonality of the carbonate system



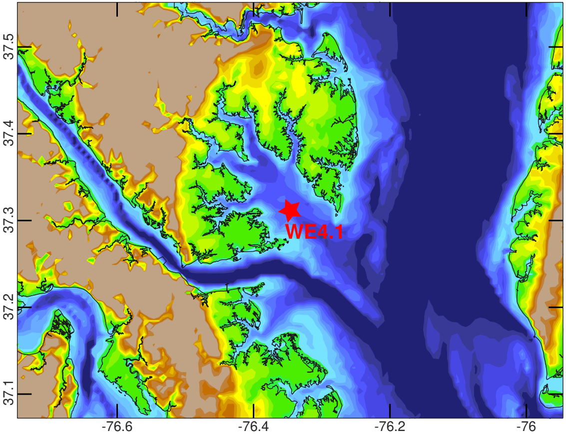


The seasonal cycle of TA,DIC is extracted at WE4.1 and the full carbonate system is computed with `seacarb`.

(Same can be done in Python with `PyCO2SYS`.)

Script: `carbonate_chemistry.R`

Seasonality of the carbonate system



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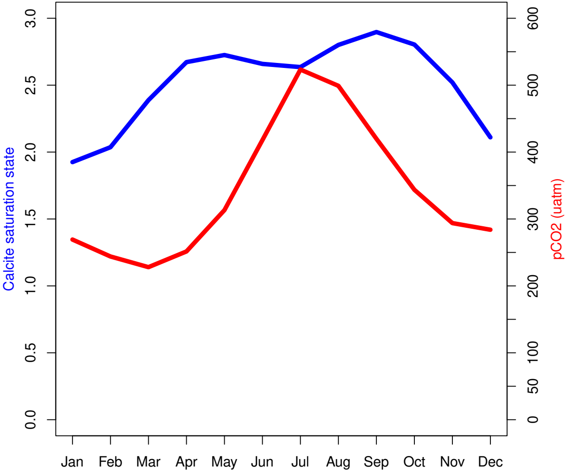

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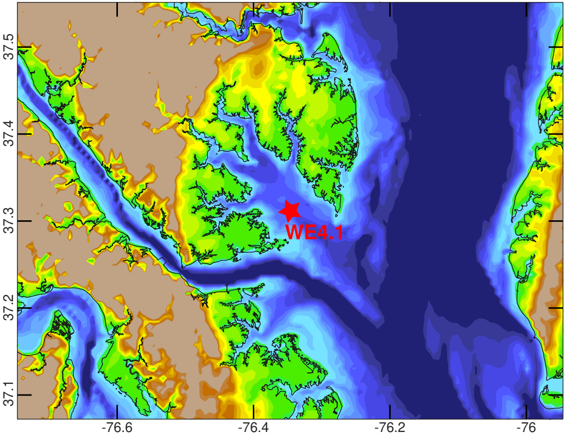

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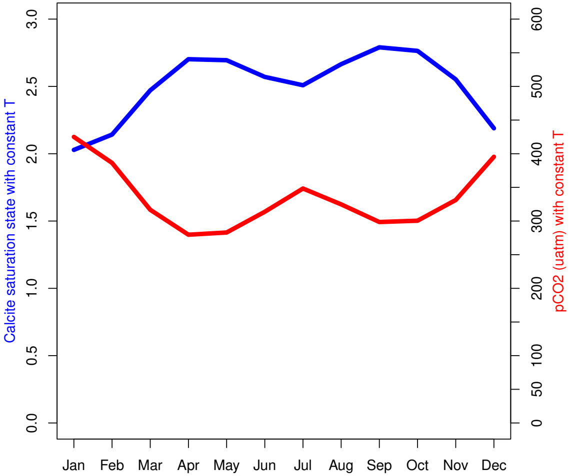


Script: `carbonate_chemistry.R`

Habitat suitability index

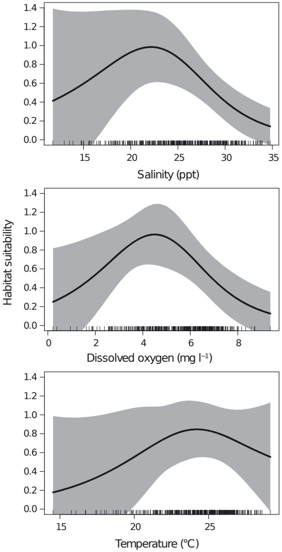
Sandbar shark (*Carcharhinus plumbeus*) uses the Bay as a nursery during the summer.

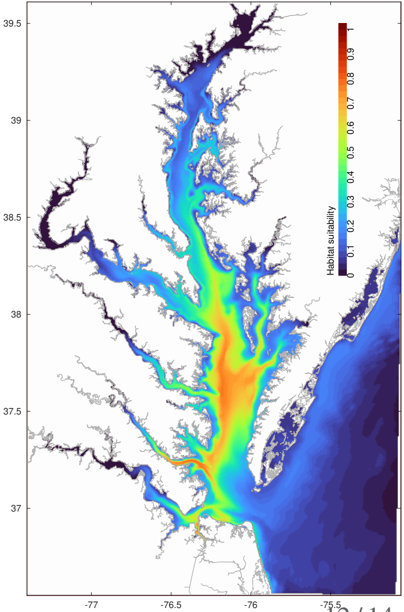
Crear *et al.* 2020 described their habitat preference as a function of salinity, temperature and dissolved O_2.

These preferences can be translated into geographical locations using the atlas.

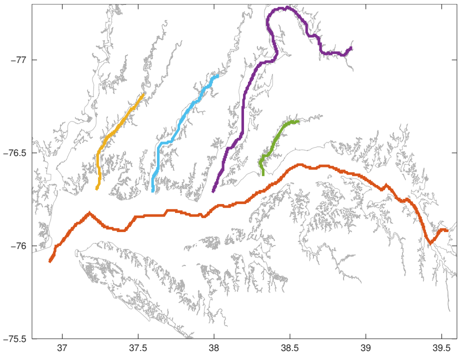
(month of August pictured on the right).

Script: `suitability_sandbar_shark.R`

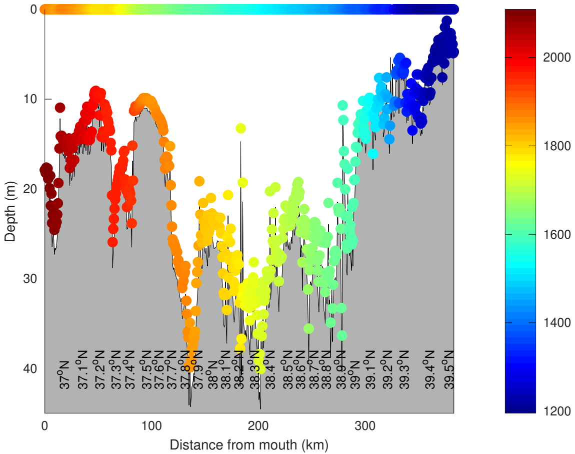




Transects along the tributaries of the Bay

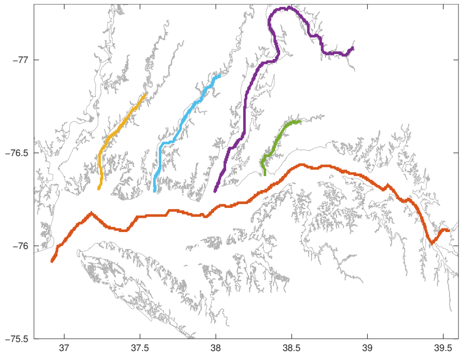


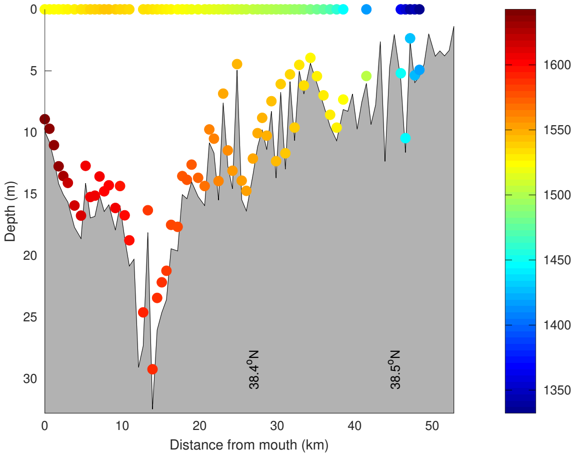
Script: `plot_regional_transects_bay.m`



TA (μmol kg^{-1}, in August) along the Bay's main stem.

Transects along the tributaries of the Bay

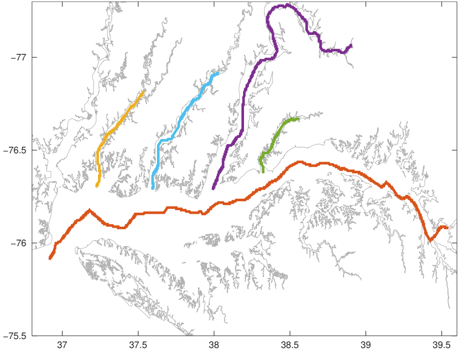




TA (μmol kg^{-1}, in August) along the Patuxent River.

Script: `plot_regional_transects_bay.m`

Transects along the tributaries of the Bay



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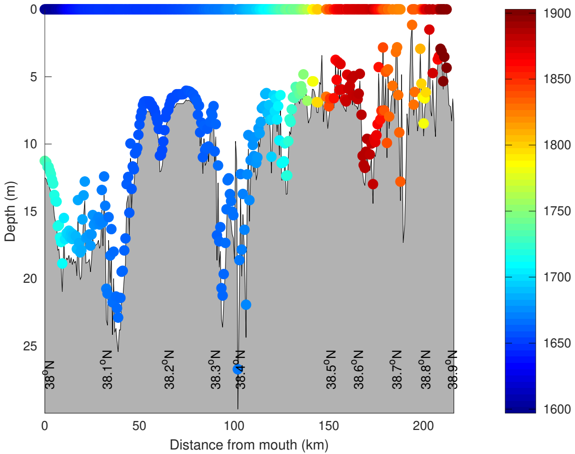
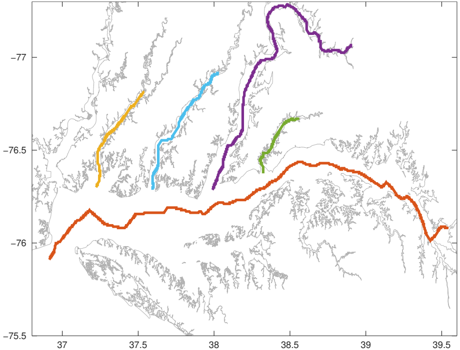


TA (μmol kg^{-1}, in August) along the Potomac River.

Transects along the tributaries of the Bay



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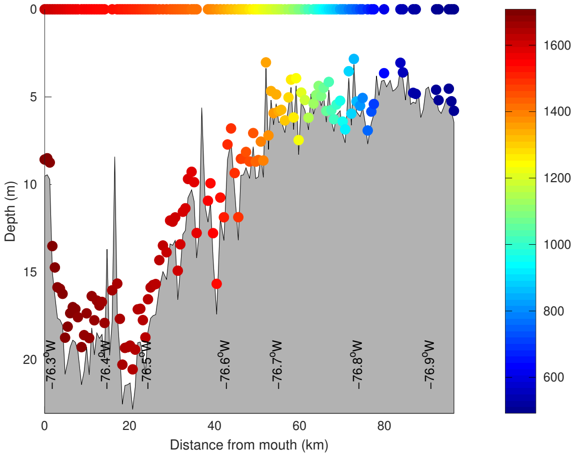
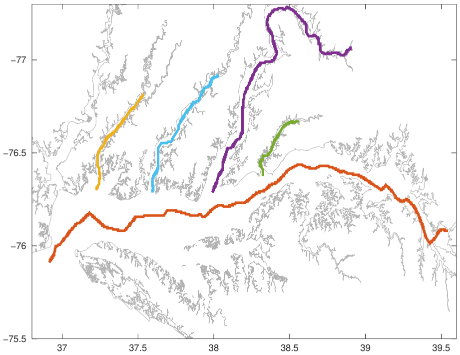
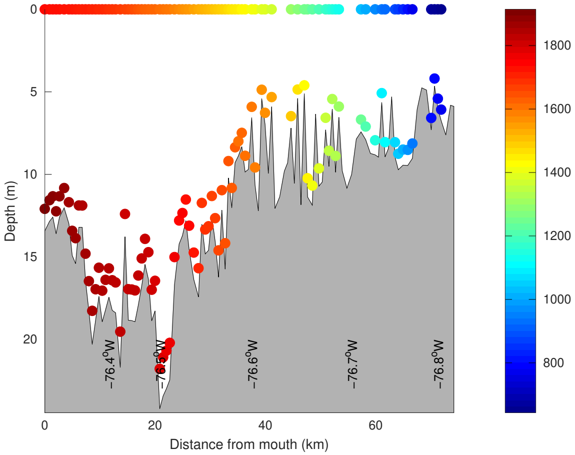


TA (μmol kg^{-1}, in August) along the Rappahannock River.

Transects along the tributaries of the Bay



Script: `plot_regional_transects_bay.m`



TA (μmol kg^{-1}, in August) along the York River.

Questions?

nordet.net/macan2024
has links to atlas + material presented today.

If you prefer, you can email your questions at:
`pst-laurent@vims.edu`

Email me when you have suggestions of additions for future versions of the atlas.

Thank you Kirstin+Janet for hosting!

Thanks to Alexandra+Erica for suggesting the webinar.