A Clustering Approach to Identifying Physical Drivers of Primary Productivity Dynamics in the Salish Sea

Storyboard for paper, as told through paper figures & others

A Clustering Approach to Identifying Physical Drivers of Primary Productivity Dynamics in the Salish Sea

Ocean mixing exerts a control on primary productivity by influencing light limitation and nutrient supply in the euphotic ocean. Here, we apply a static clustering algorithm to four metrics of mixing and to phytoplankton abundance extracted from a biophysical regional ocean model of the Salish Sea (SalishSeaCast) to assess for spatial coocurrence. Running the clustering algorithm on four years' worth of model output, we find a strong interannually persisting difference between mixing and productivity dynamics in the Northern and Central Strait of Georgia. In the Northern Strait, a deeper winter halocline and episodic mixing events that persist throughout summer coincide with higher phytoplankton biomass, while in the Fraser river stratified Central Strait, shallower haloclines and less summer mixing coincide with lower summer phytoplankton productivity. Our approach elucidates a possible physical mechanism for this difference while demonstrating the usefulness of data science techniques for finding structure in large model-derived datasets.

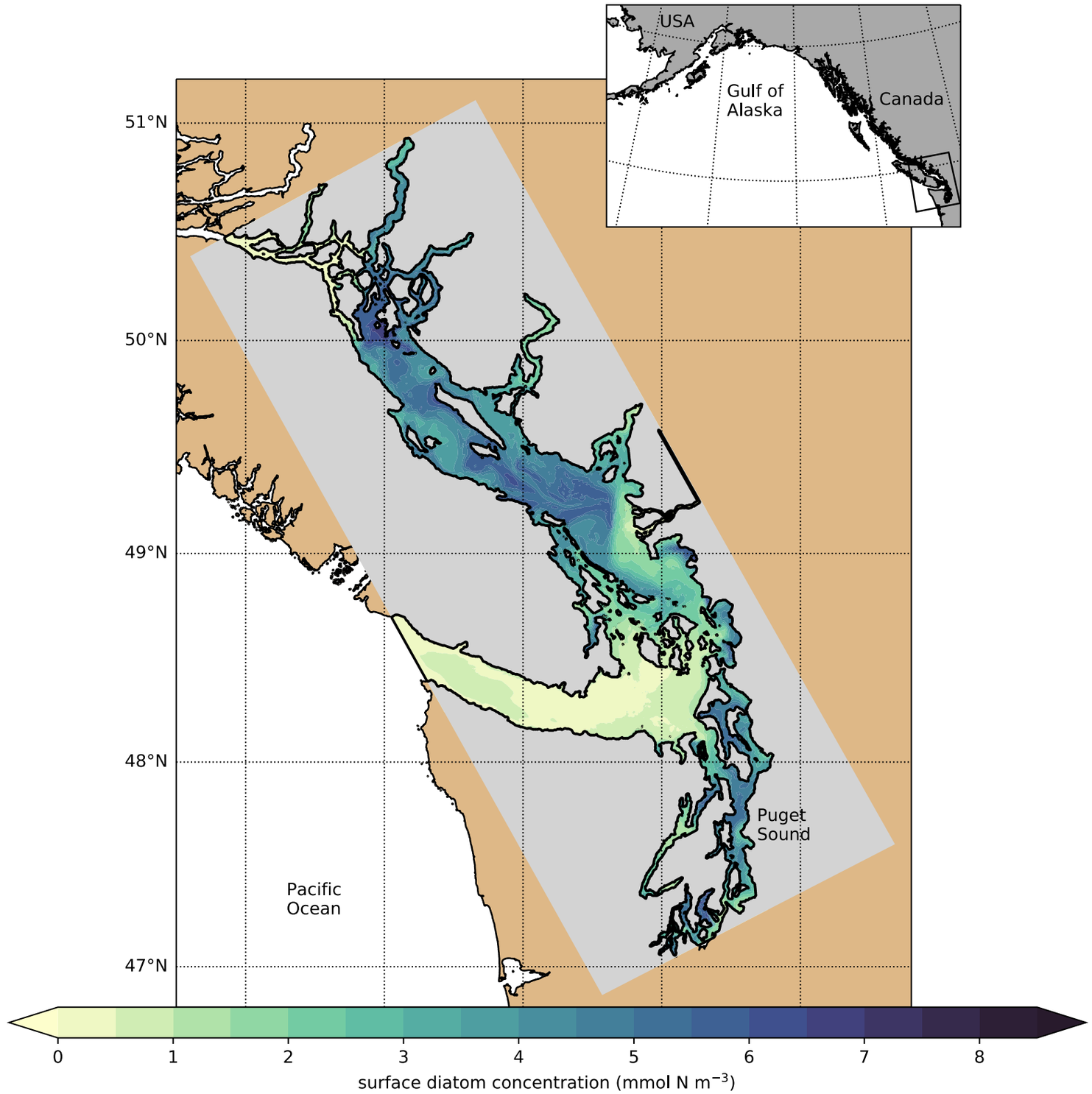
Key Points

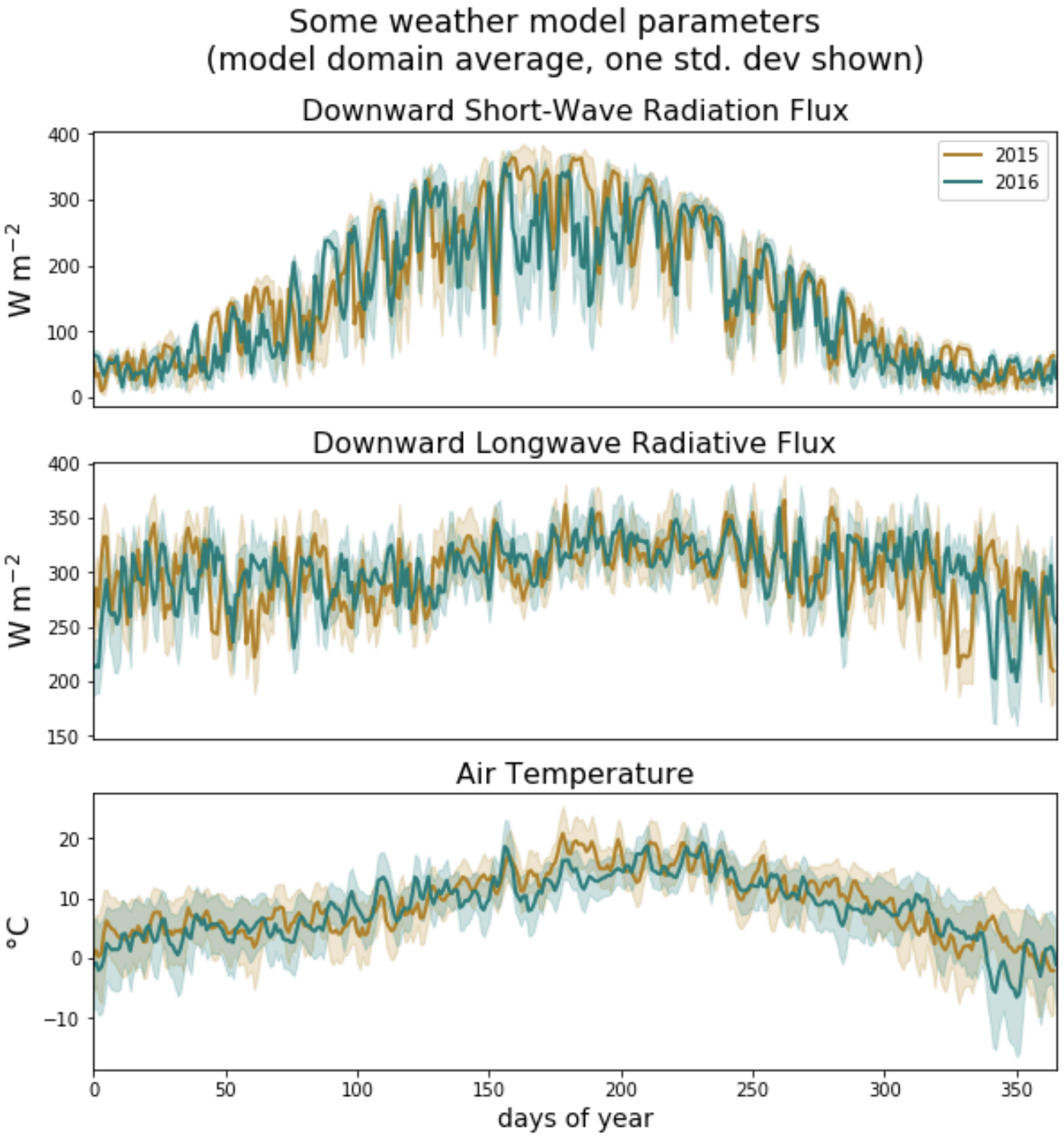
In the Salish Sea, interannually persistent regional differences in freshwater input drive similarly persistent regional differences in summer mixing, expressed as halocline depth and variability.

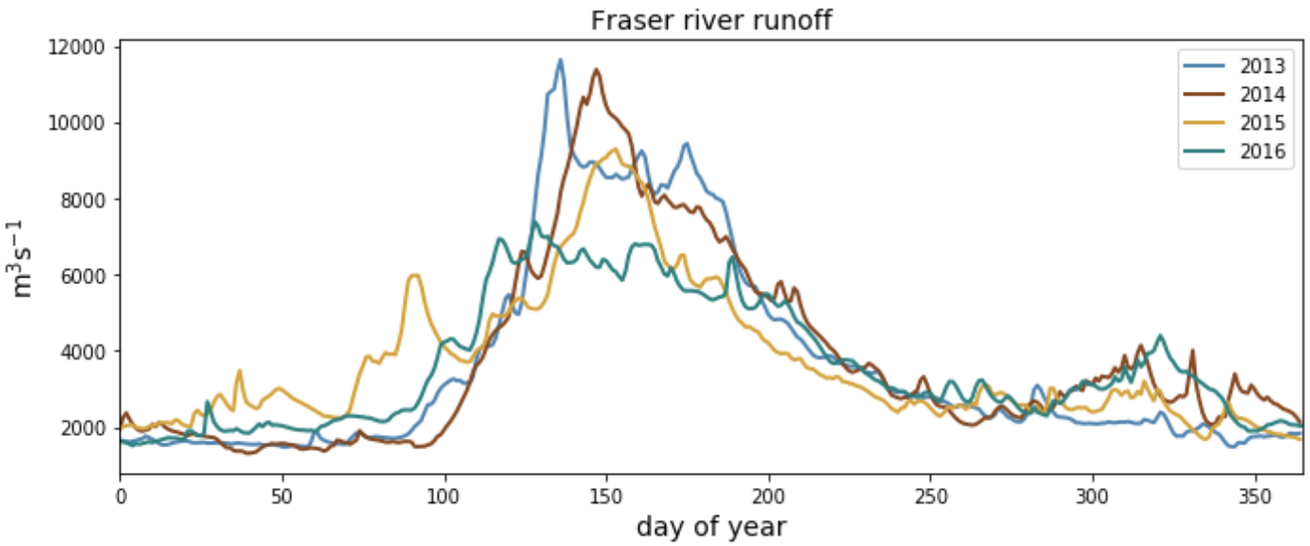
Deeper and more variable haloclines in the northern Strait of Georgia spatially coincide with higher summertime primary productivity in all four analyzed years.

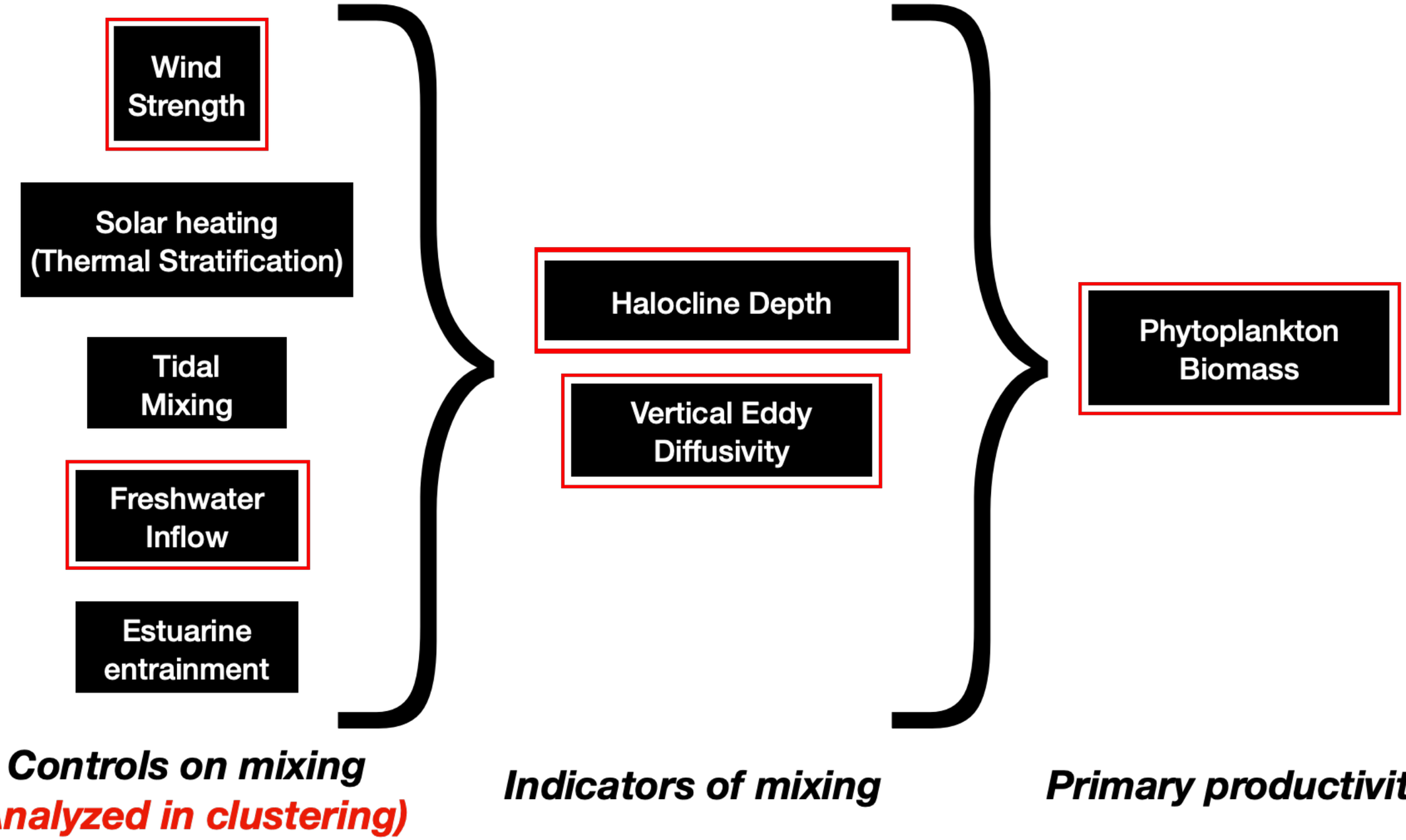
Clustering methods can provide a way to understand underlying patterns in large model-derived datasets.

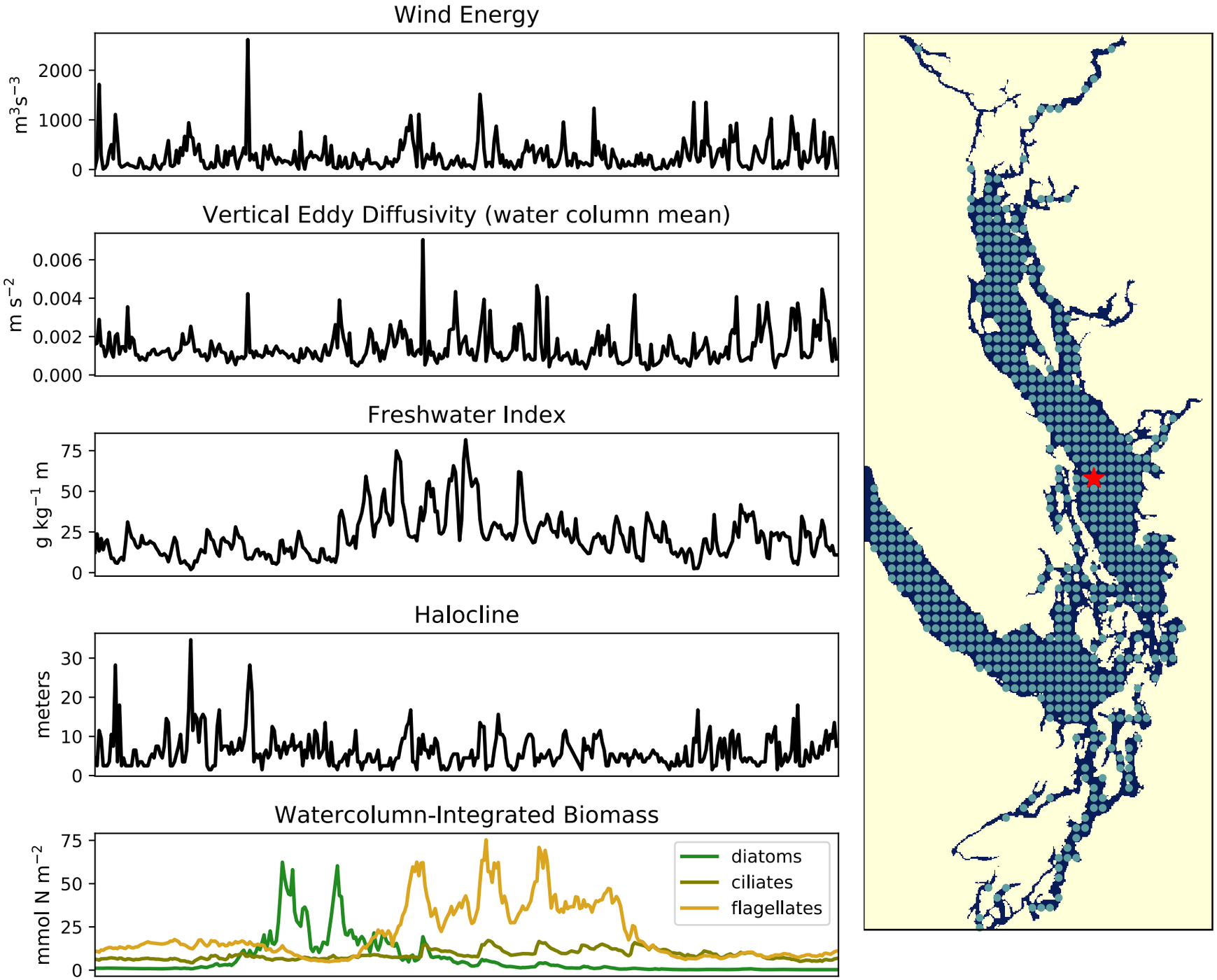
MF_DOMAIN


USA
Gulf of
Alaska
Canada
51°N
50°N
49°N
48°N
47°N
Pacific
Ocean
Puget
Sound
0
1
2
3
4
5
6
7
8
surface diatom concentration (mmol N m^{-3})


Some weather model parameters
(model domain average, one std. dev shown)
Downward Short-Wave Radiation Flux
W m^{-2}
2015
2016
Downward Longwave Radiative Flux
W m^{-2}
Air Temperature
°C
days of year

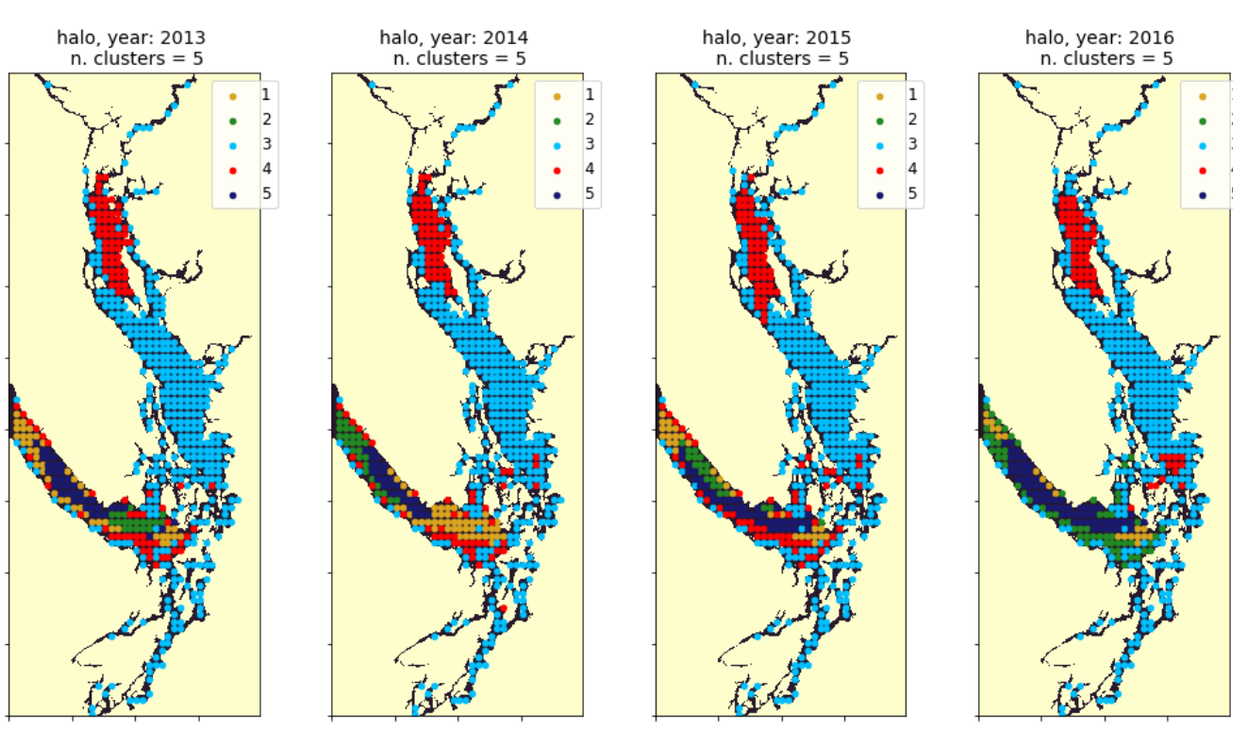

Fraser river runoff
m^{3}s^{-1}
2013
2014
2015
2016
day of year

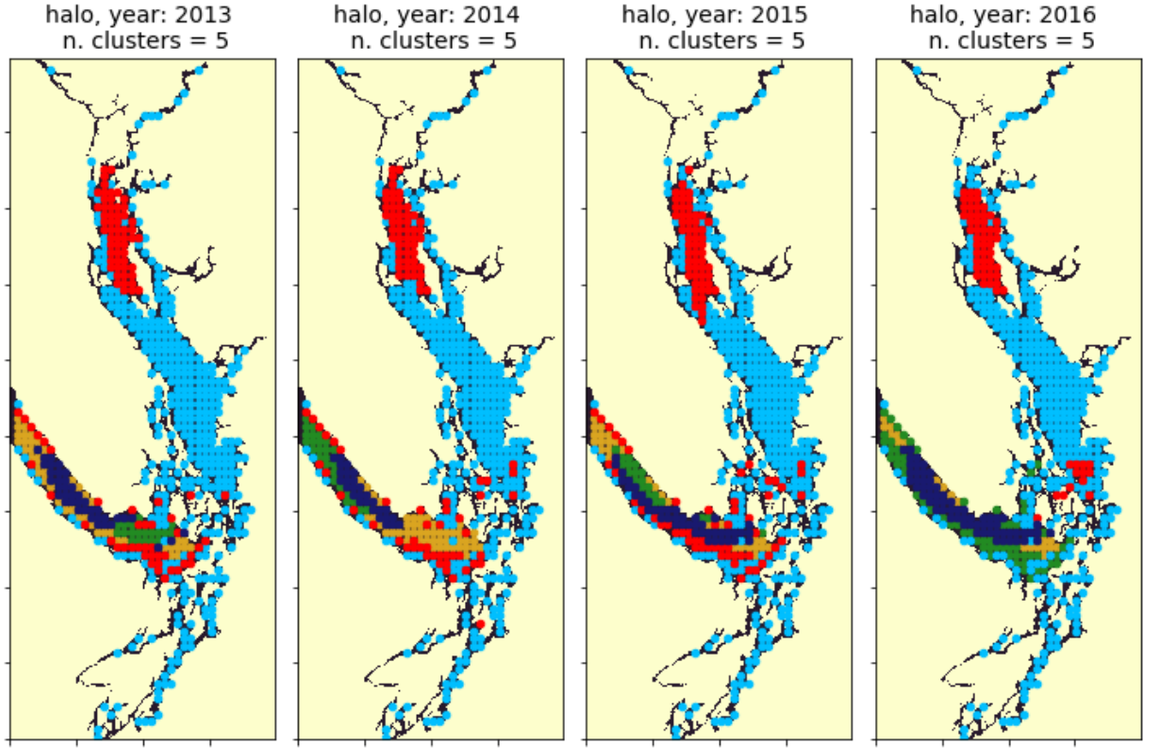

Wind Strength
Solar heating (Thermal Stratification)
Tidal Mixing
Freshwater Inflow
Estuarine entrainment
Halocline Depth
Vertical Eddy Diffusivity
Phytoplankton Biomass
Controls on mixing (Analyzed in clustering)
Indicators of mixing
Primary productivity

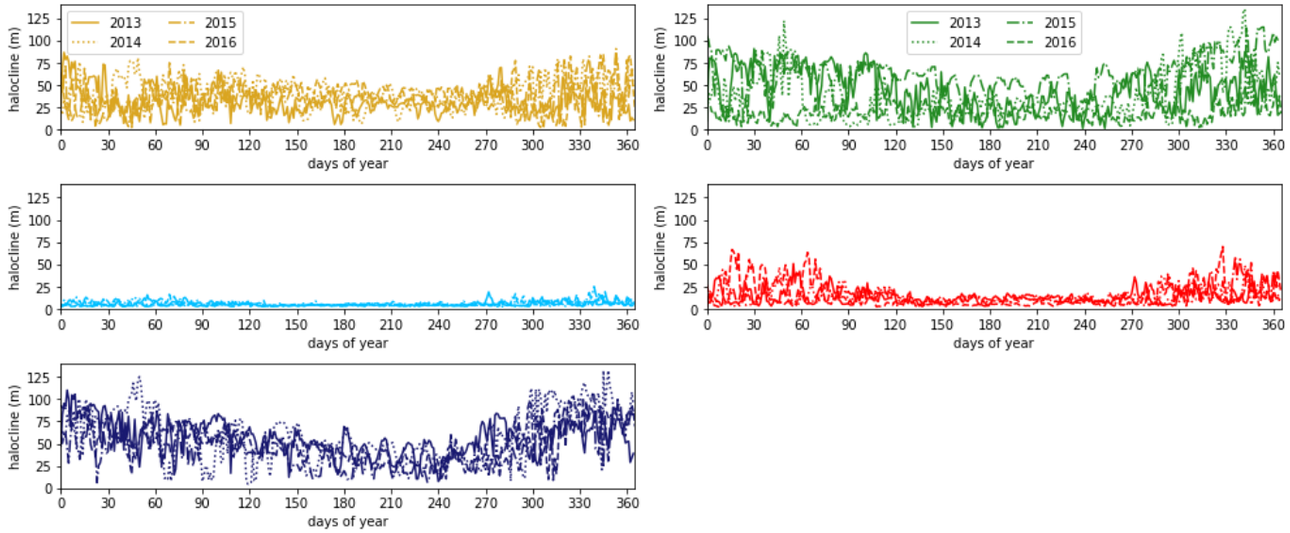

Wind Energy
m^3s^{-3}
2000
1000
0
Vertical Eddy Diffusivity (water column mean)
$m\ s^{-2}$
0.006
0.004
0.002
0.000
Freshwater Index
$g\ kg^{-1}\ m$
75
50
25
0
Halocline
meters
30
20
10
0
Watercolumn-Integrated Biomass
$mmol\ N\ m^{-2}$
75
50
25
0
diatoms
ciliates
flagellates

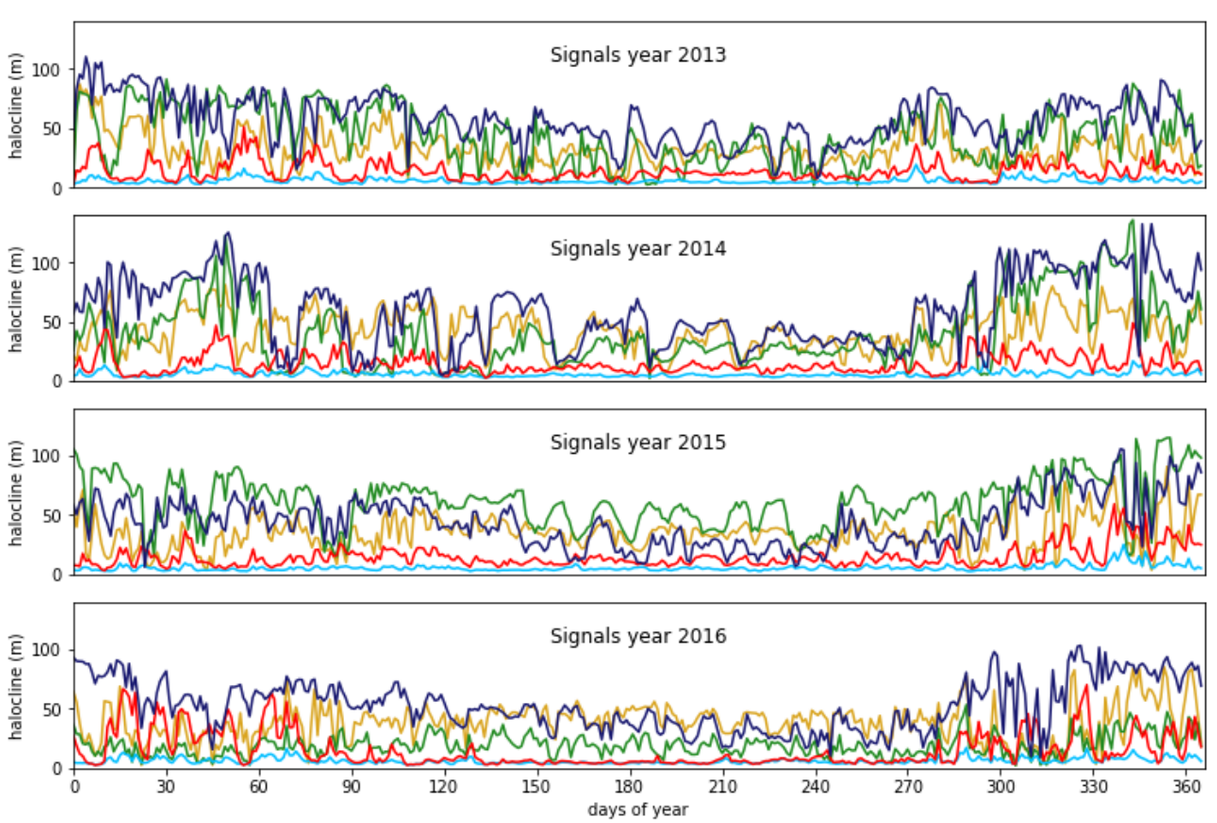
MF_SIGNALS

PHYSICS CLUSTERINGS


halo, year: 2013
n. clusters = 5
halo, year: 2014
n. clusters = 5
halo, year: 2015
n. clusters = 5
halo, year: 2016
n. clusters = 5
1
2
3
4
5

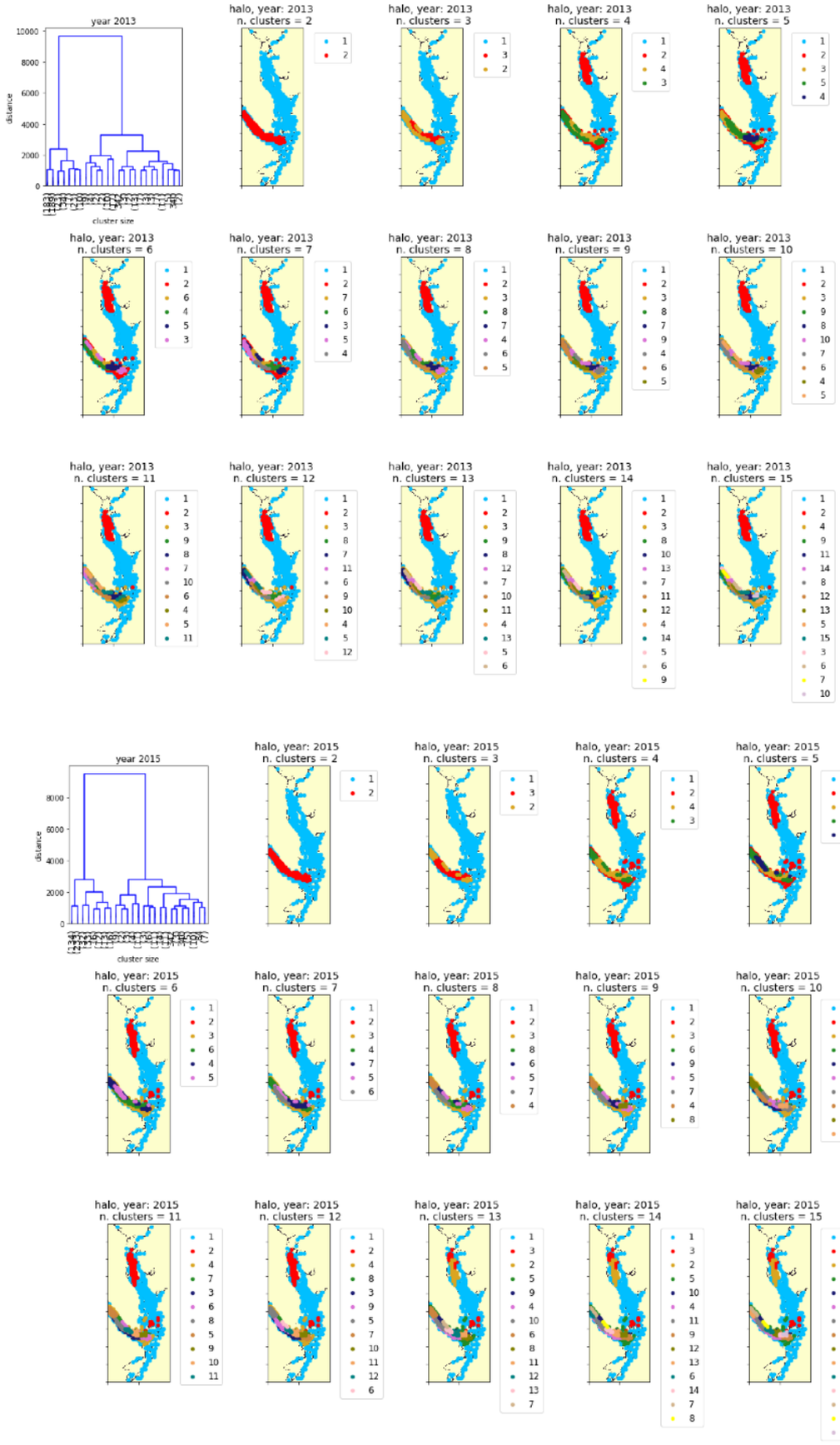

halo, year: 2013
n. clusters = 5
halo, year: 2014
n. clusters = 5
halo, year: 2015
n. clusters = 5
halo, year: 2016
n. clusters = 5

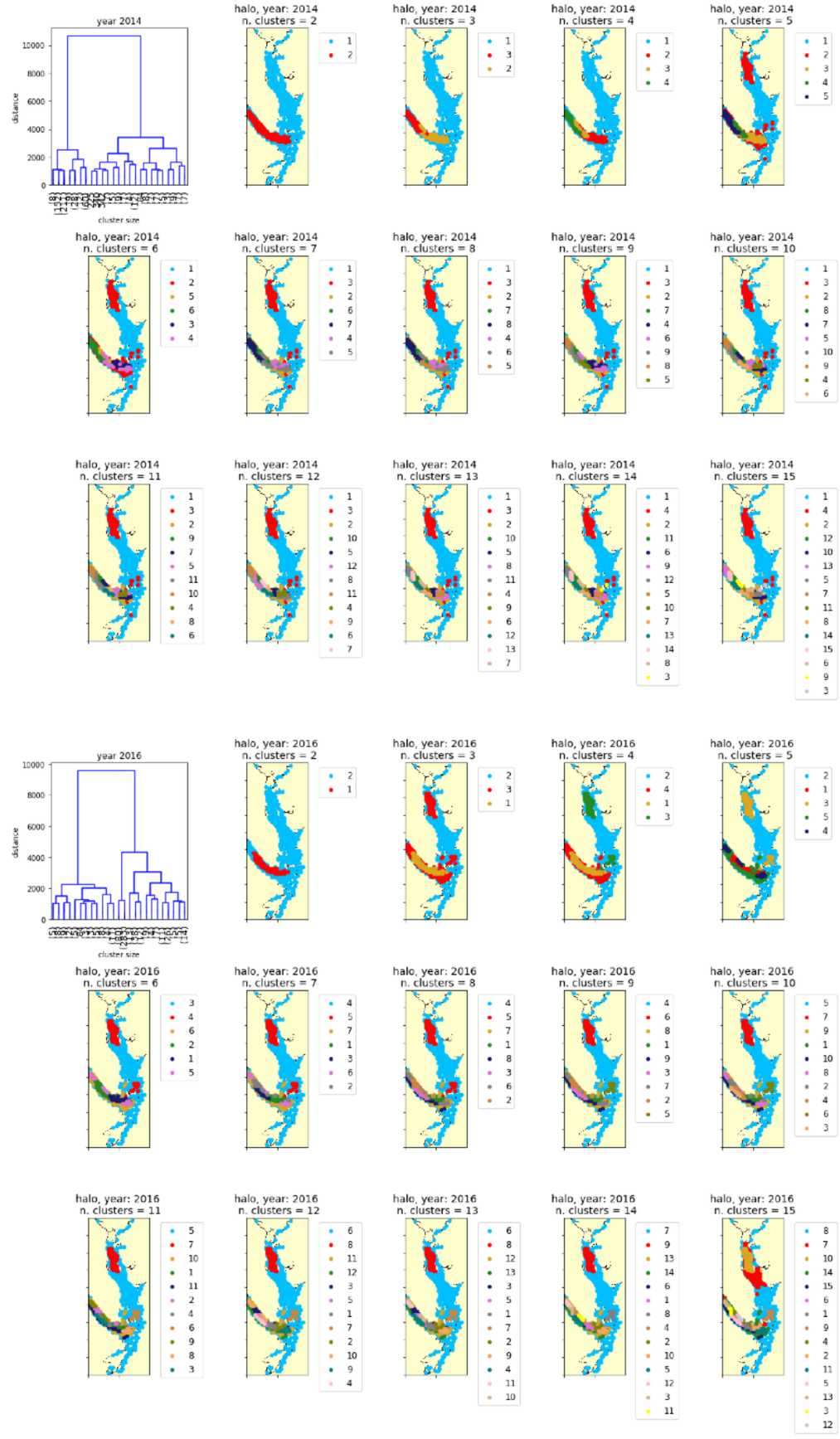

halocline (m)
days of year
2013
2014
2015
2016


Signals year 2013
Signals year 2014
Signals year 2015
Signals year 2016
halocline (m)
days of year

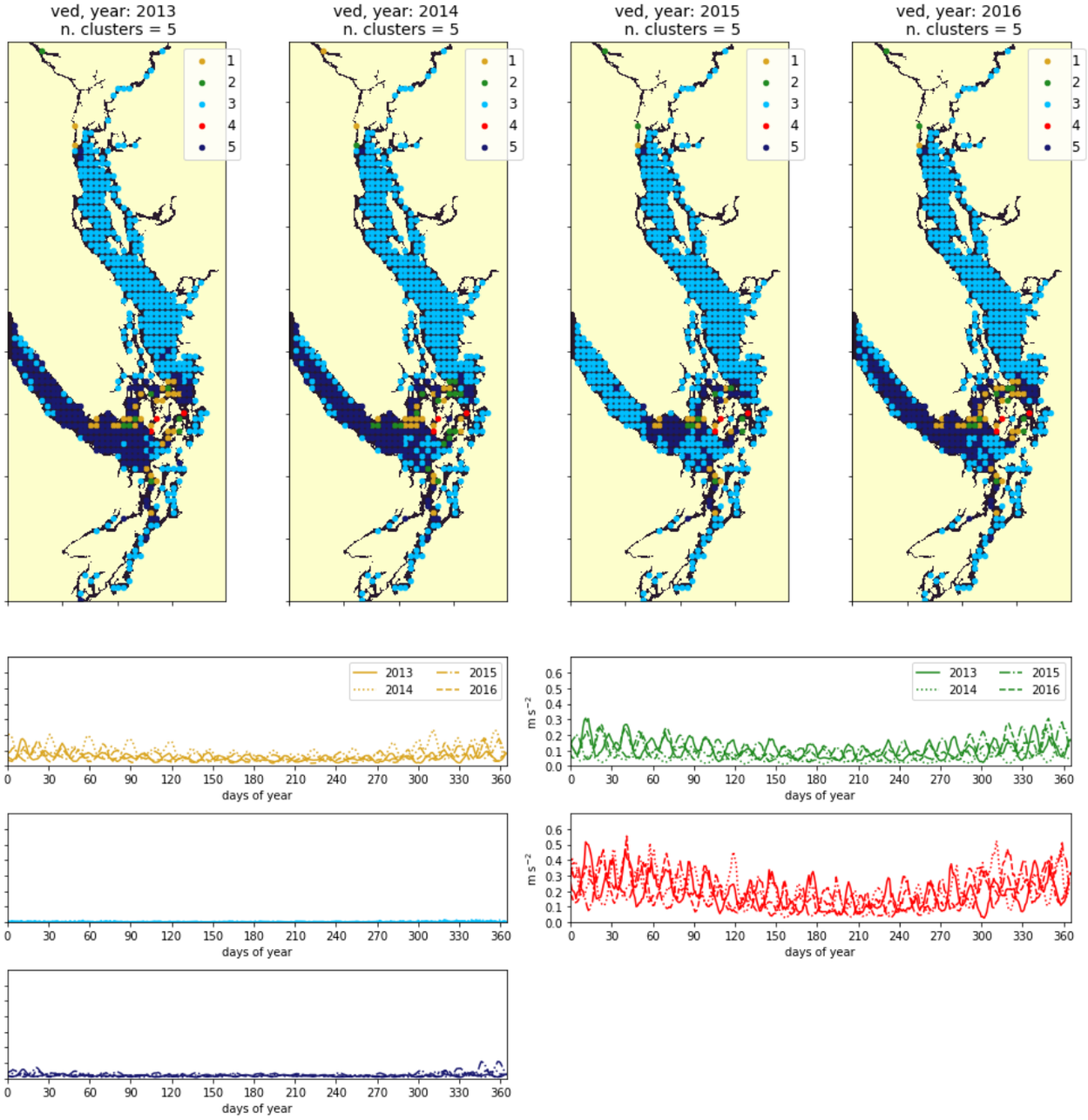
HALO

MF_HALO





HALO CLUSTERS


ved, year: 2013
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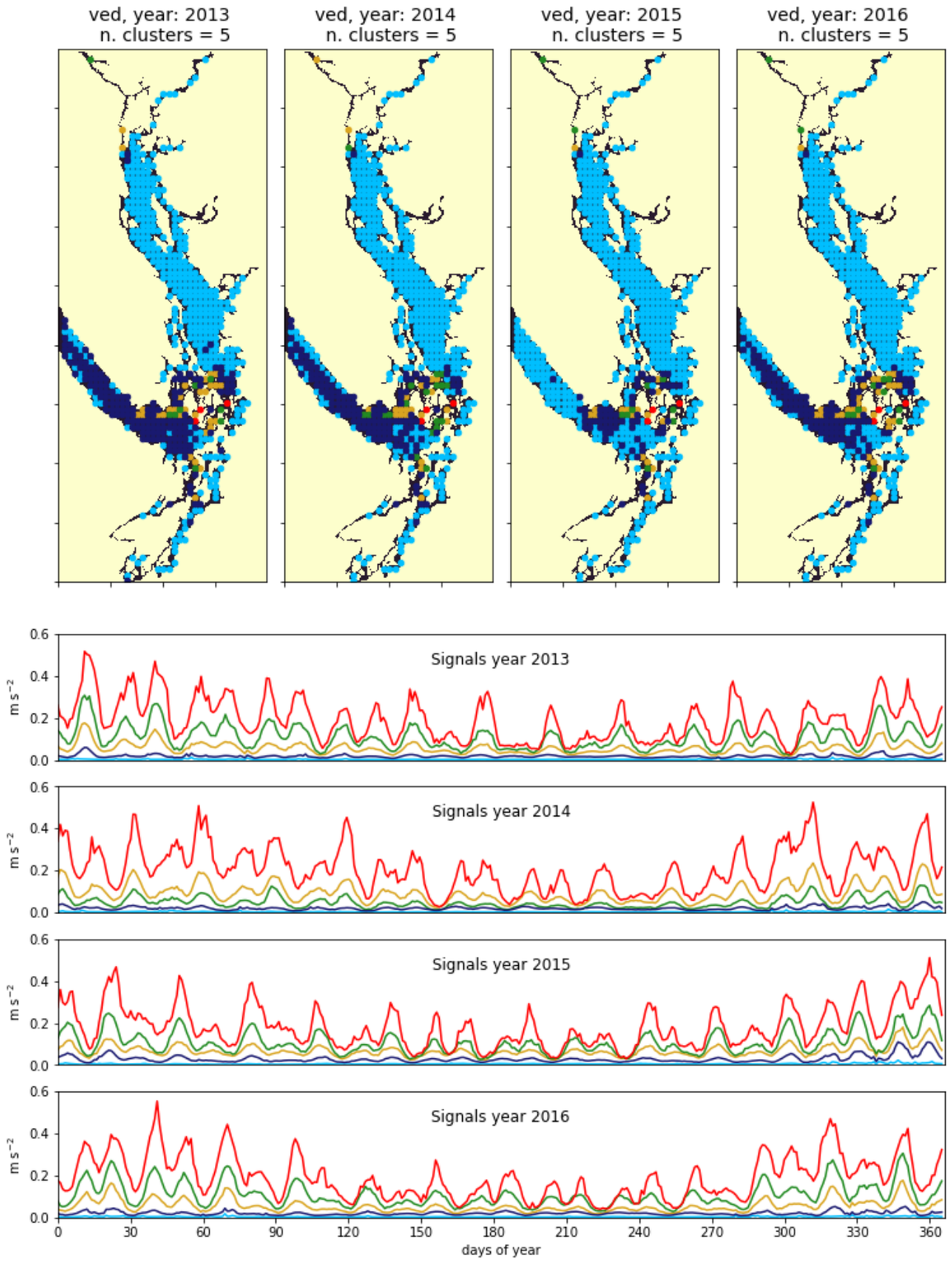
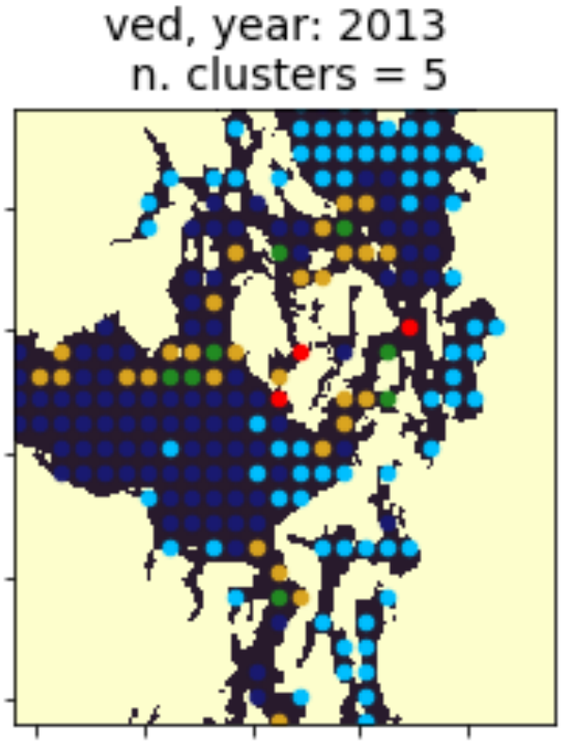
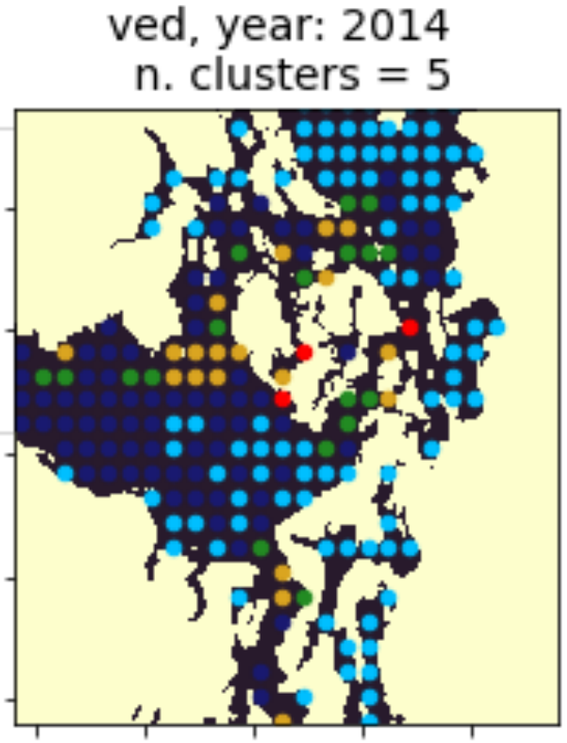
ved, year: 2014
n. clusters = 5
ved, year: 2015
n. clusters = 5
ved, year: 2016
n. clusters = 5
1
2
3
4
5
2013
2014
2015
2016
m s⁻²
days of year


ved, year: 2013
n. clusters = 5
ved, year: 2014
n. clusters = 5
ved, year: 2015
n. clusters = 5
ved, year: 2016
n. clusters = 5
Signals year 2013
Signals year 2014
Signals year 2015
Signals year 2016
m s⁻²
days of year

VED


ved, year: 2013
n. clusters = 5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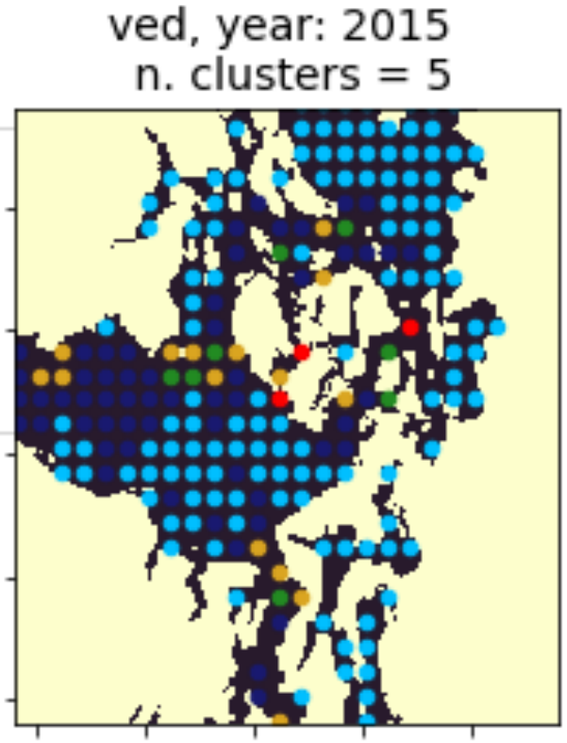
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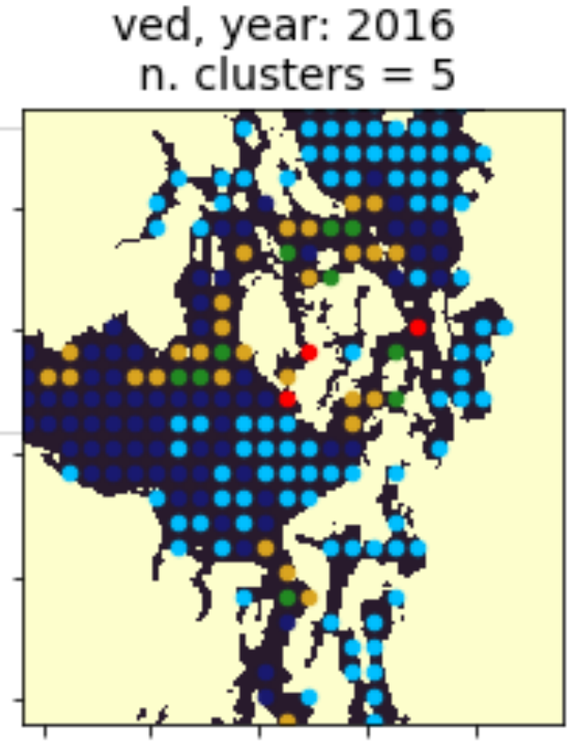
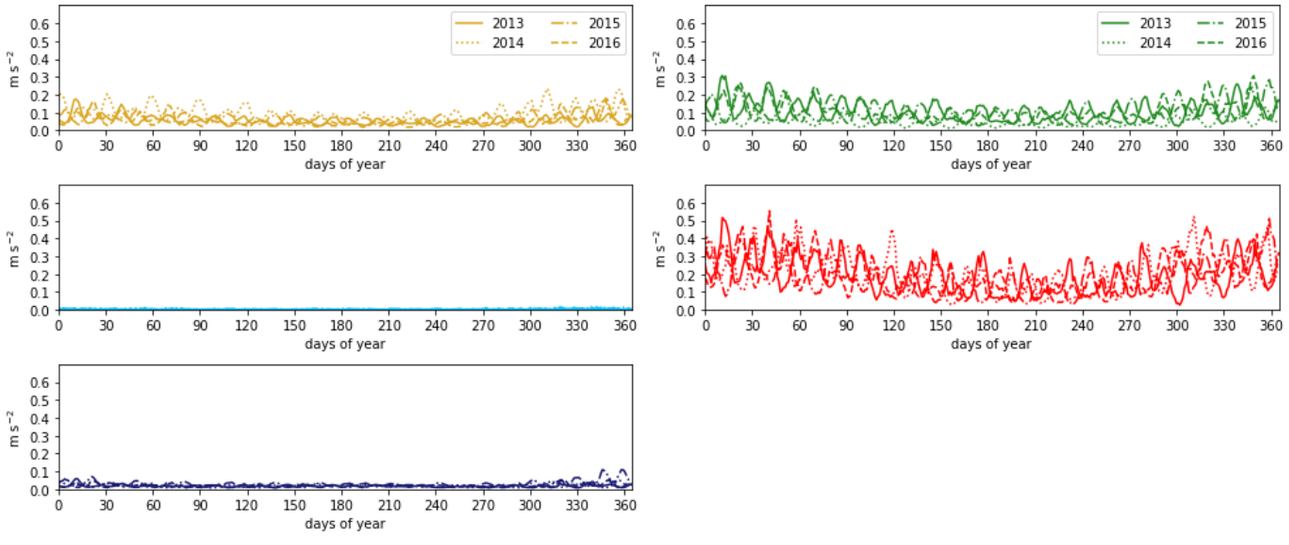
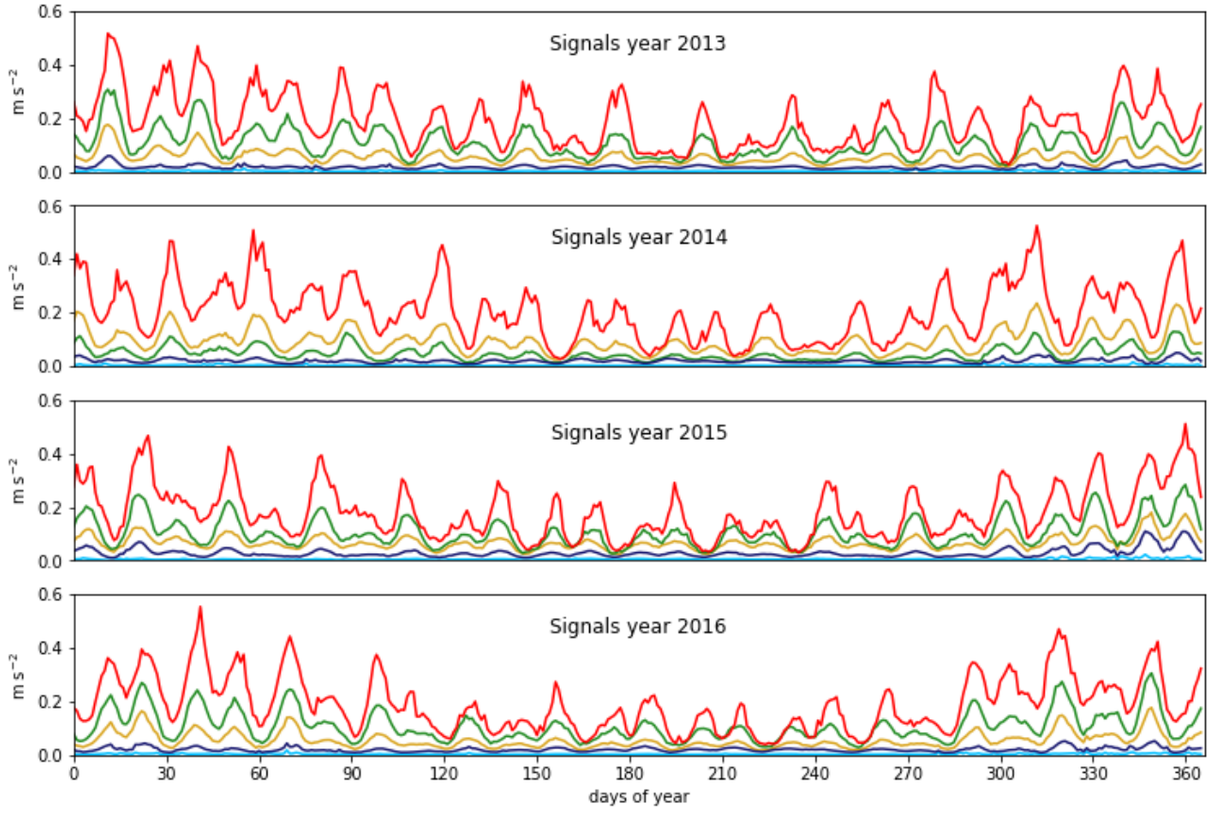
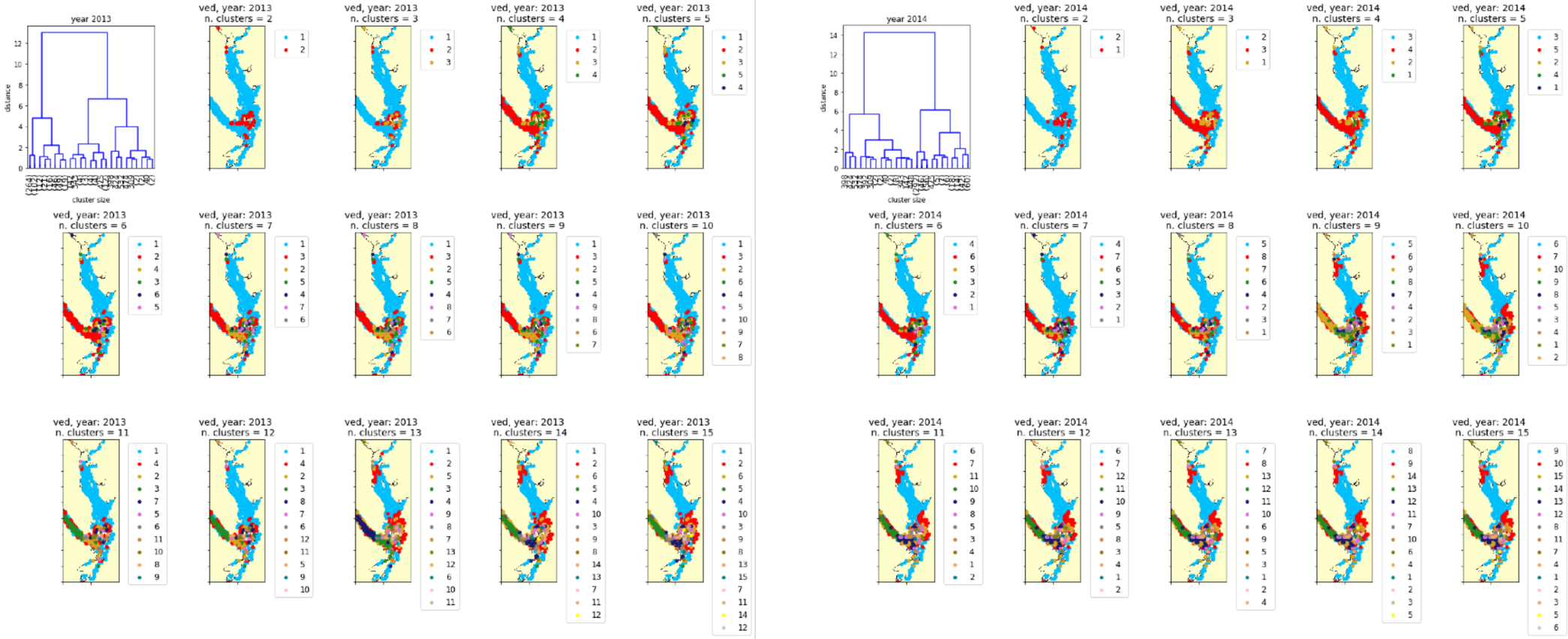
n. clusters = 5


ved, year: 2016
n. clusters = 5

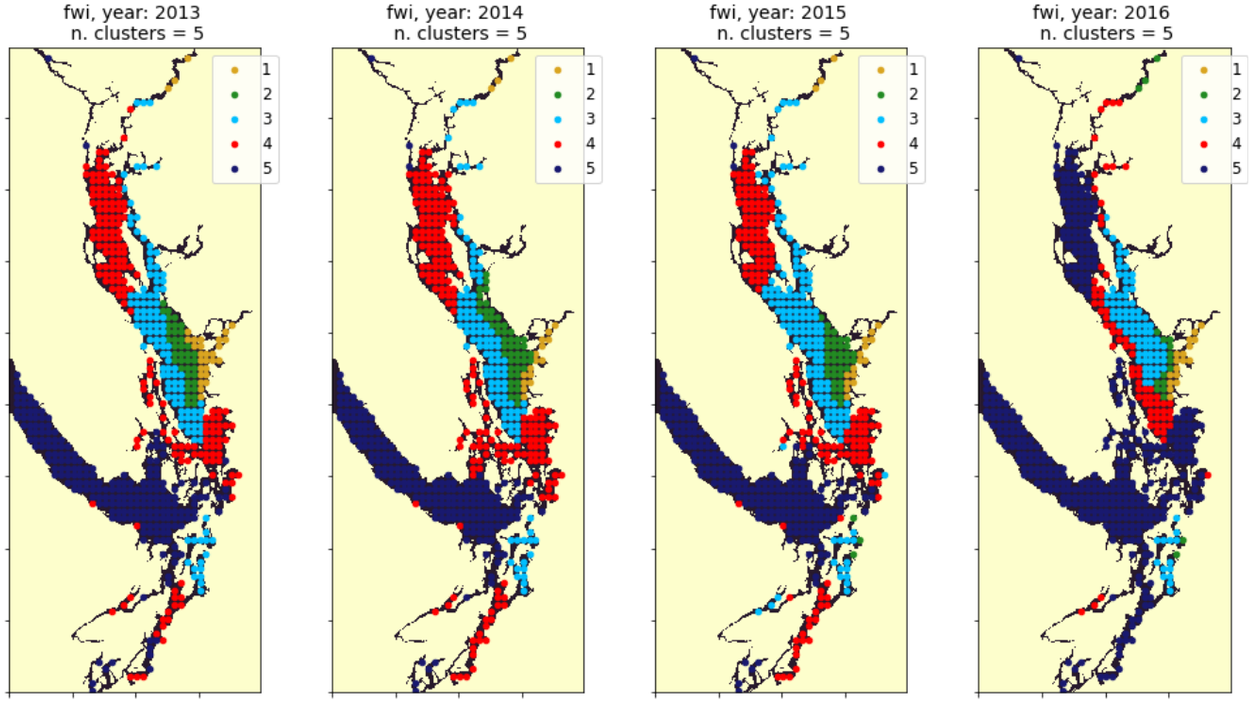

2013
2014
2015
2016
m s⁻²
days of year

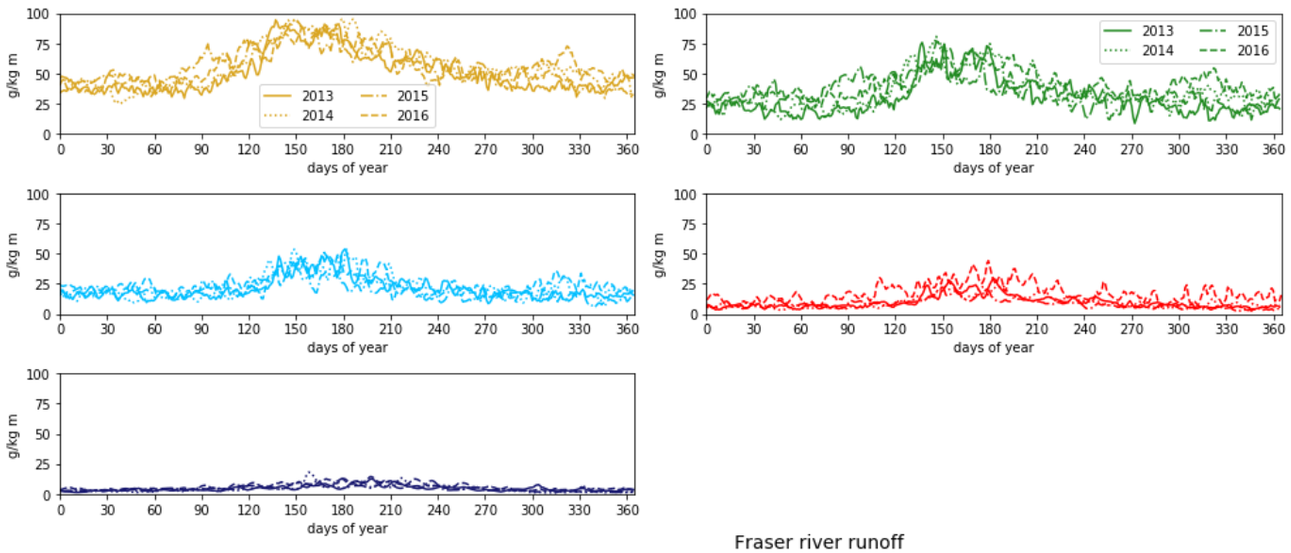

Signals year 2013
Signals year 2014
Signals year 2015
Signals year 2016
m s⁻²
days of year

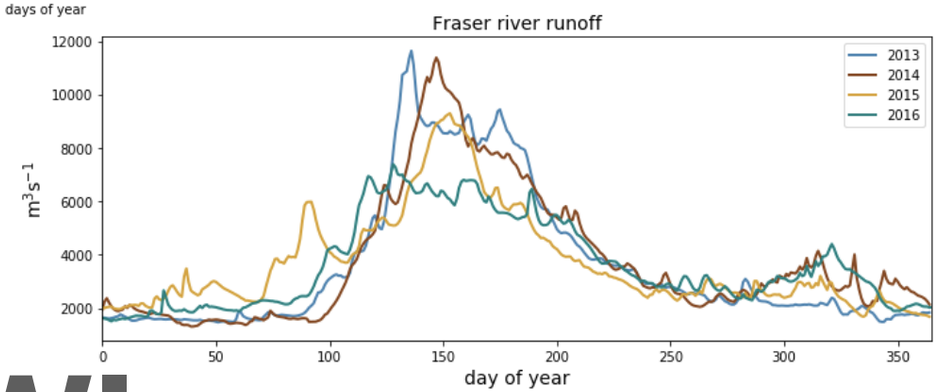
VED



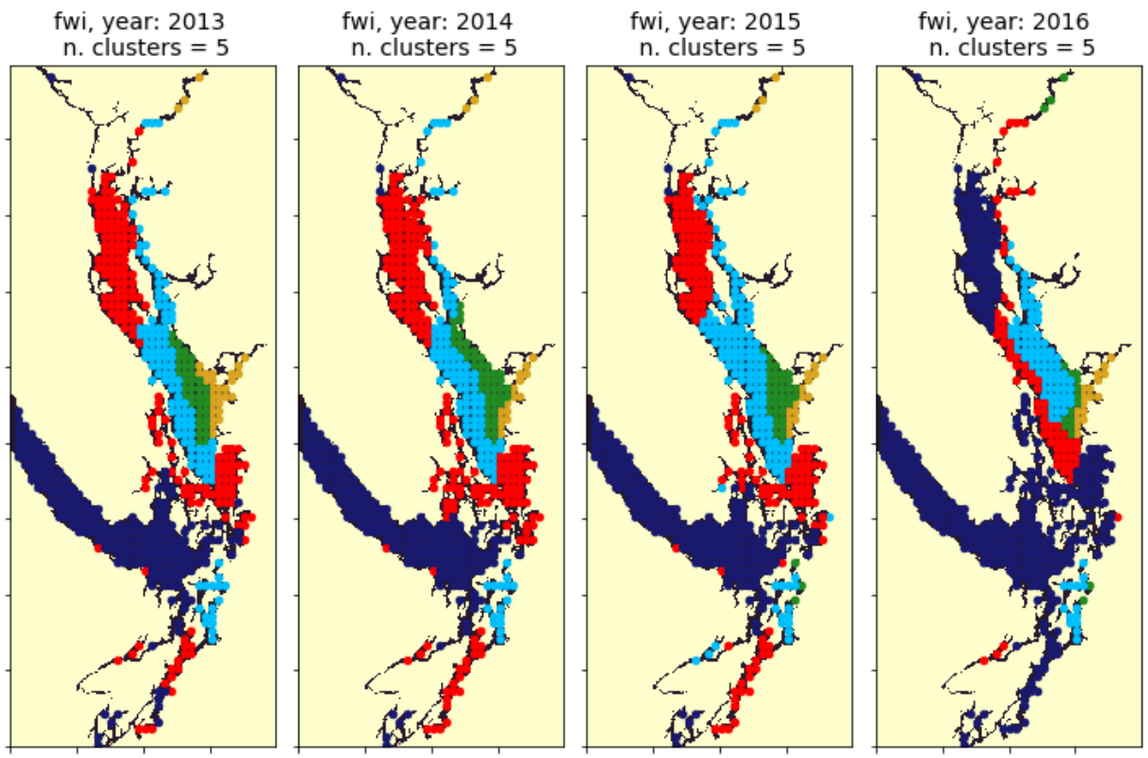
VED CLUSTERS

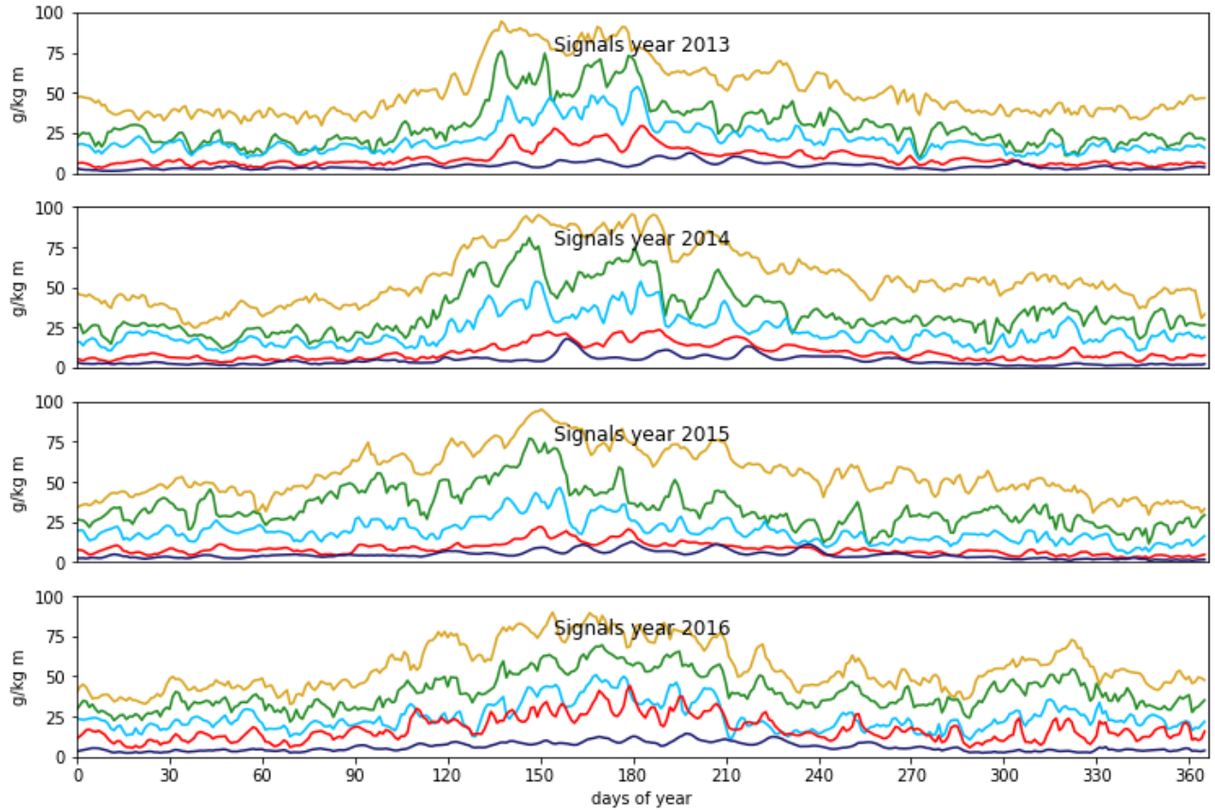

fwi, year: 2013
n. clusters = 5
fwi, year: 2014
n. clusters = 5
fwi, year: 2015
n. clusters = 5
fwi, year: 2016
n. clusters = 5
1
2
3
4
5

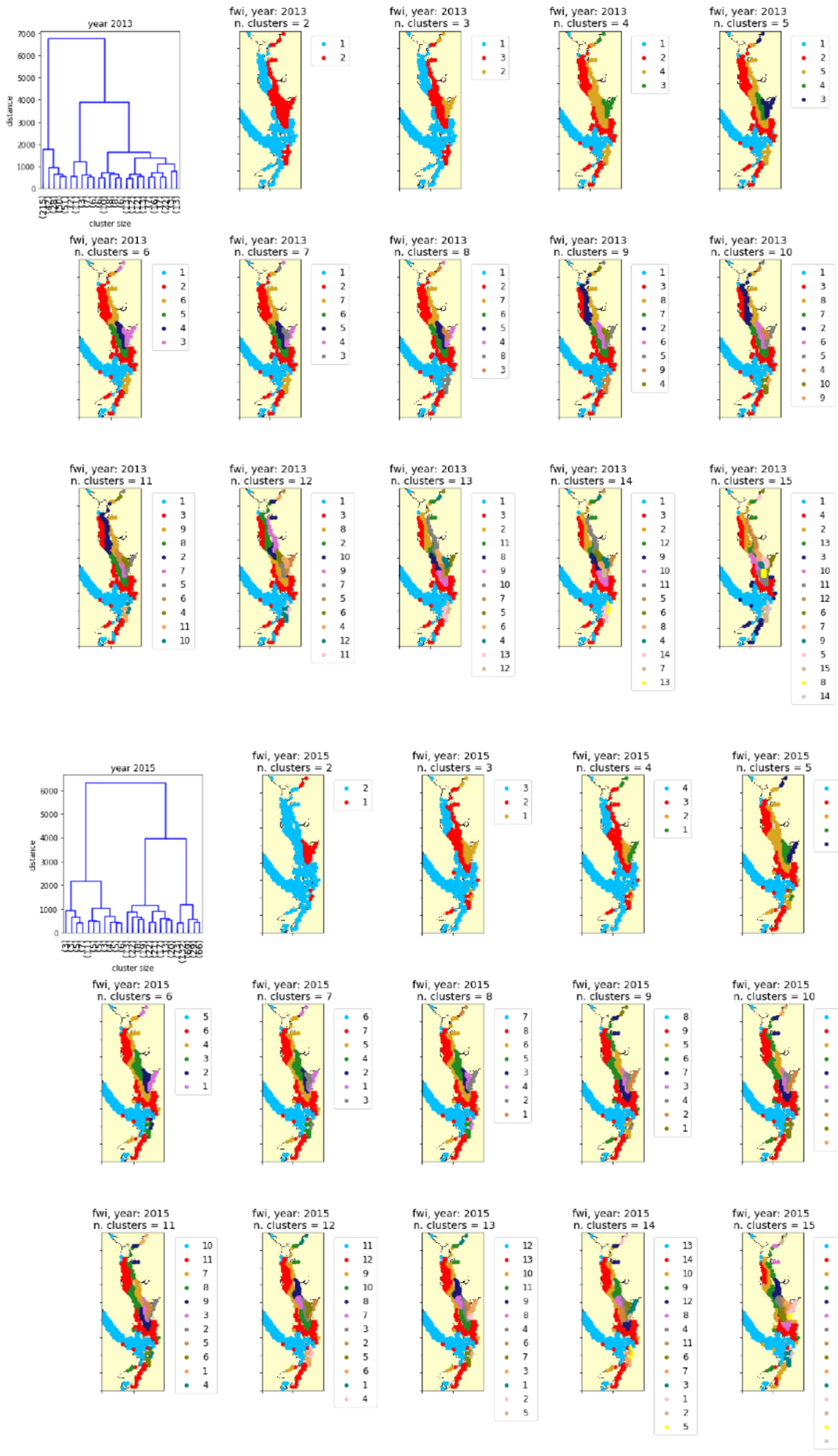

g/kg m
days of year
2013
2014
2015
2016

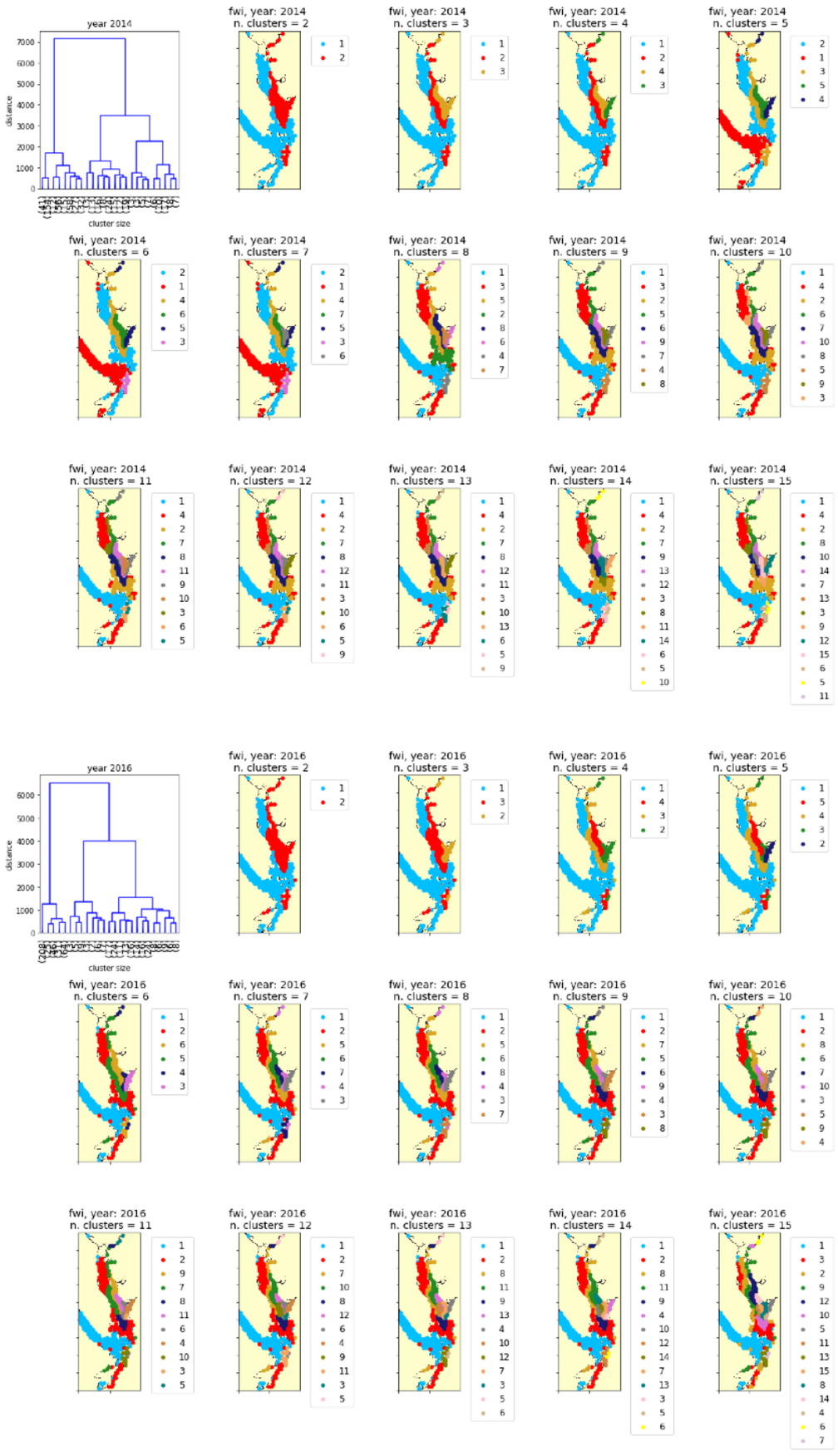

Fraser river runoff
m^3s^{-1}
day of year
2013
2014
2015
2016

FWI

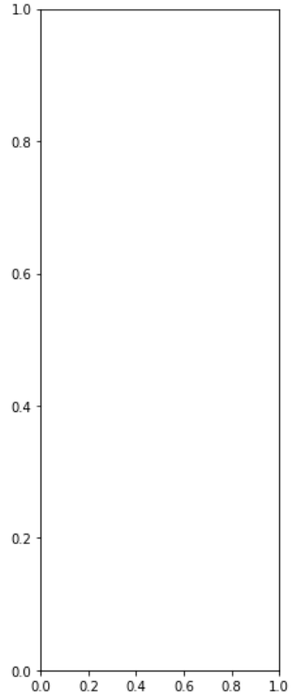

fwi, year: 2013
n. clusters = 5
fwi, year: 2014
n. clusters = 5
fwi, year: 2015
n. clusters = 5
fwi, year: 2016
n. clusters = 5

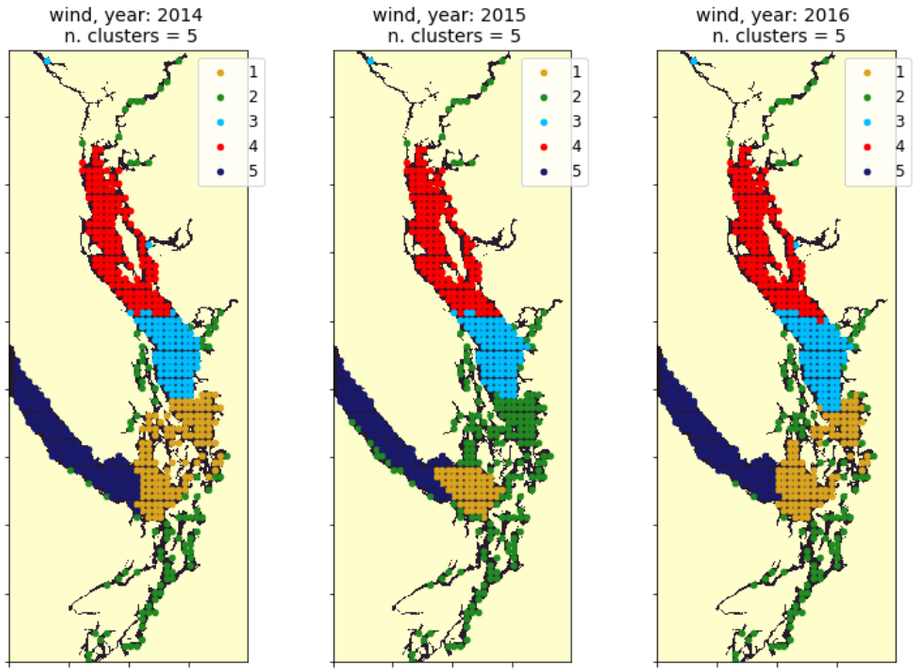

Signals year 2013
Signals year 2014
Signals year 2015
Signals year 2016
g/kg m
days of year





FWI CLUSTERS




wind, year: 2014
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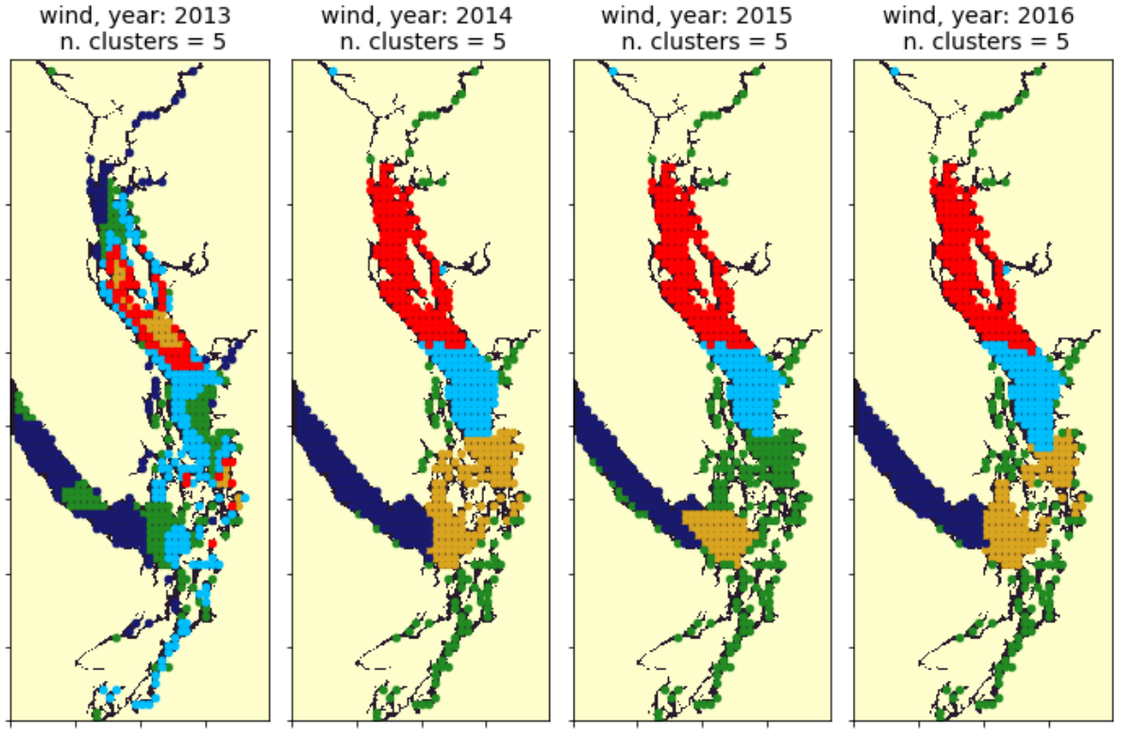
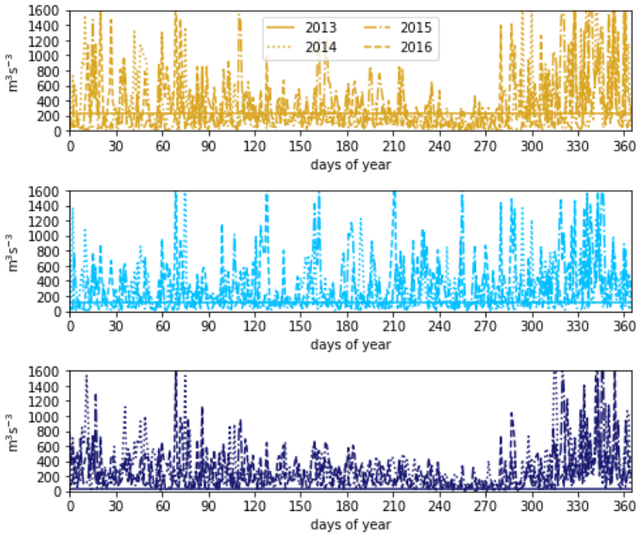
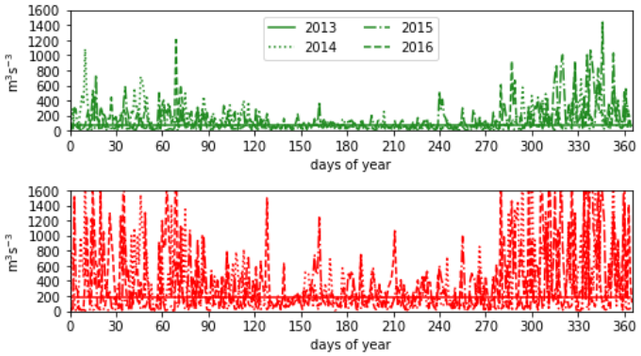
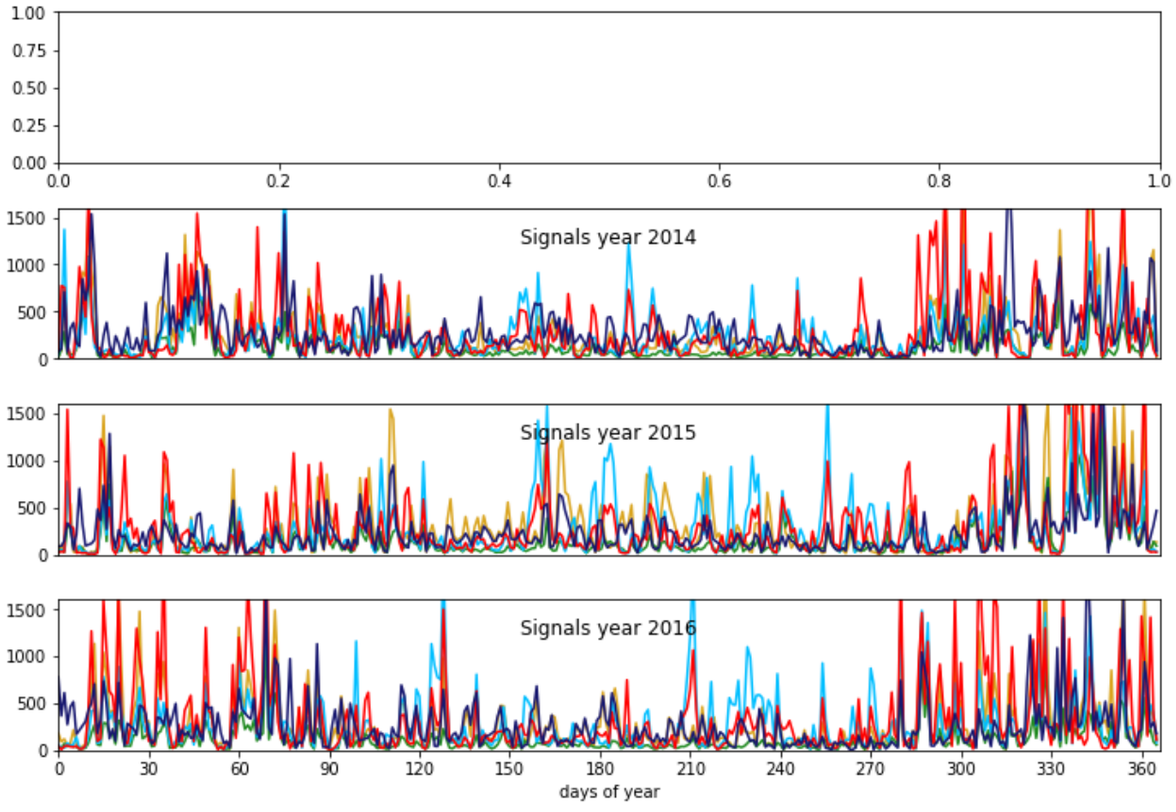
wind, year: 2015
n. clusters = 5
wind, year: 2016
n. clusters = 5
1
2
3
4
5

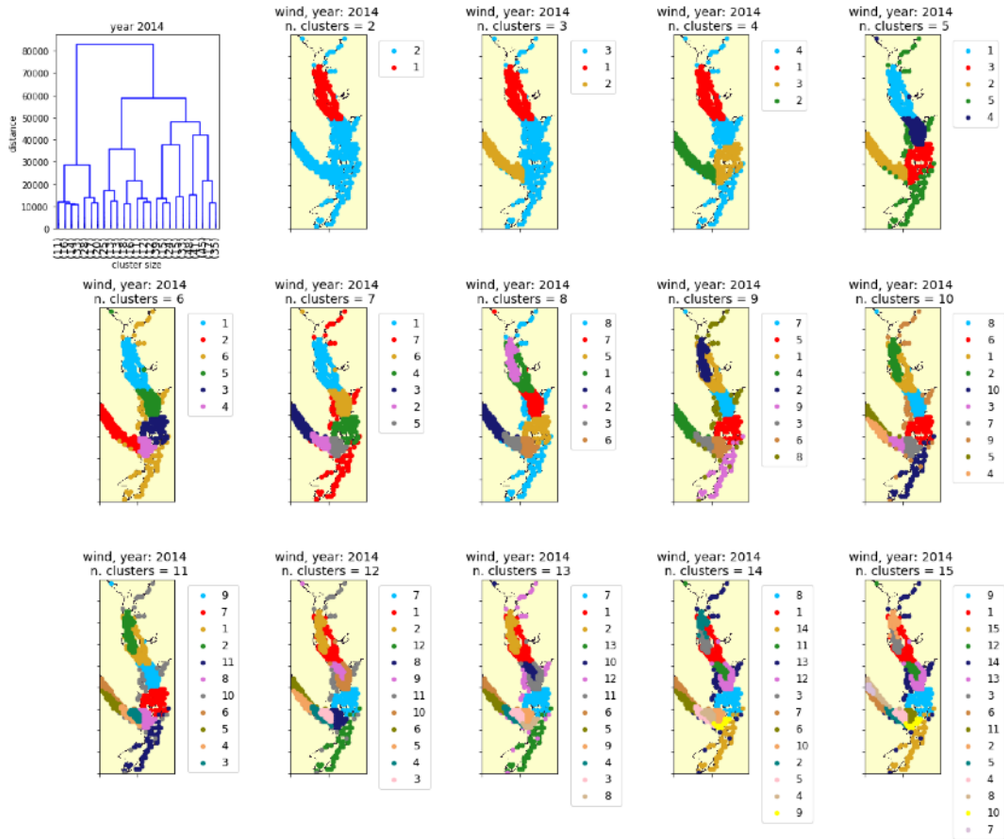

wind, year: 2013
n. clusters = 5
wind, year: 2014
n. clusters = 5
wind, year: 2015
n. clusters = 5
wind, year: 2016
n. clusters = 5

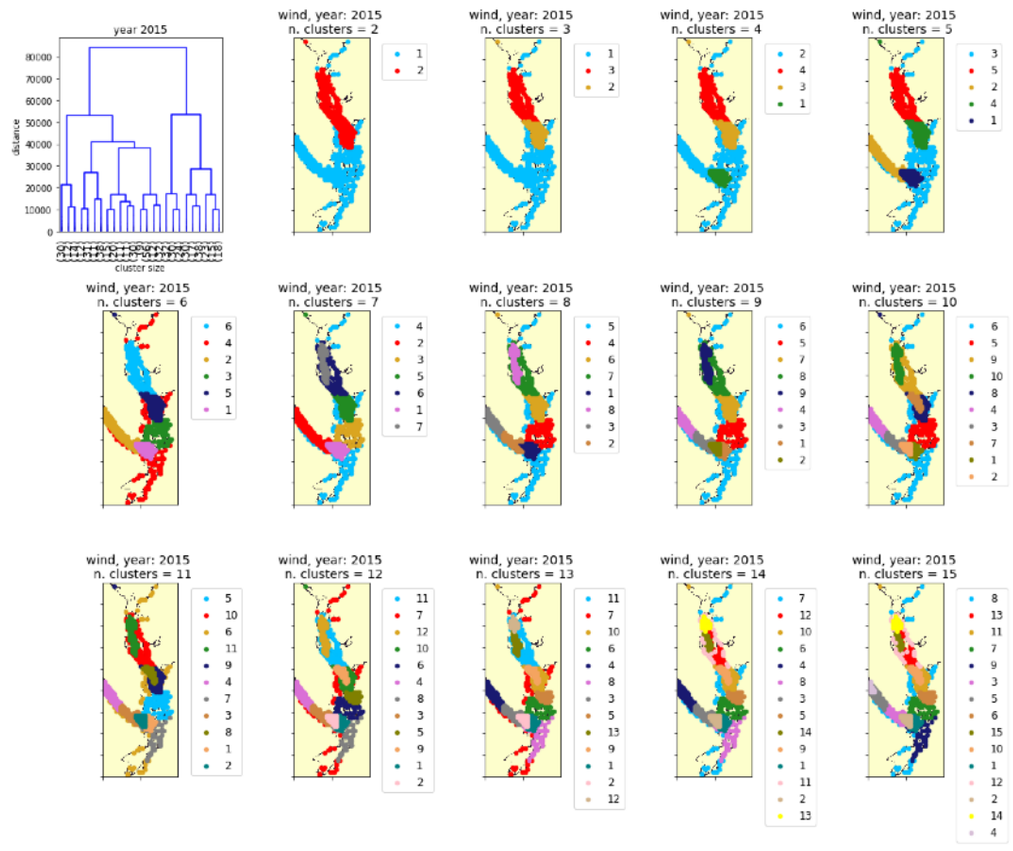

2013
2014
2015
2016
m³s⁻³
days of year

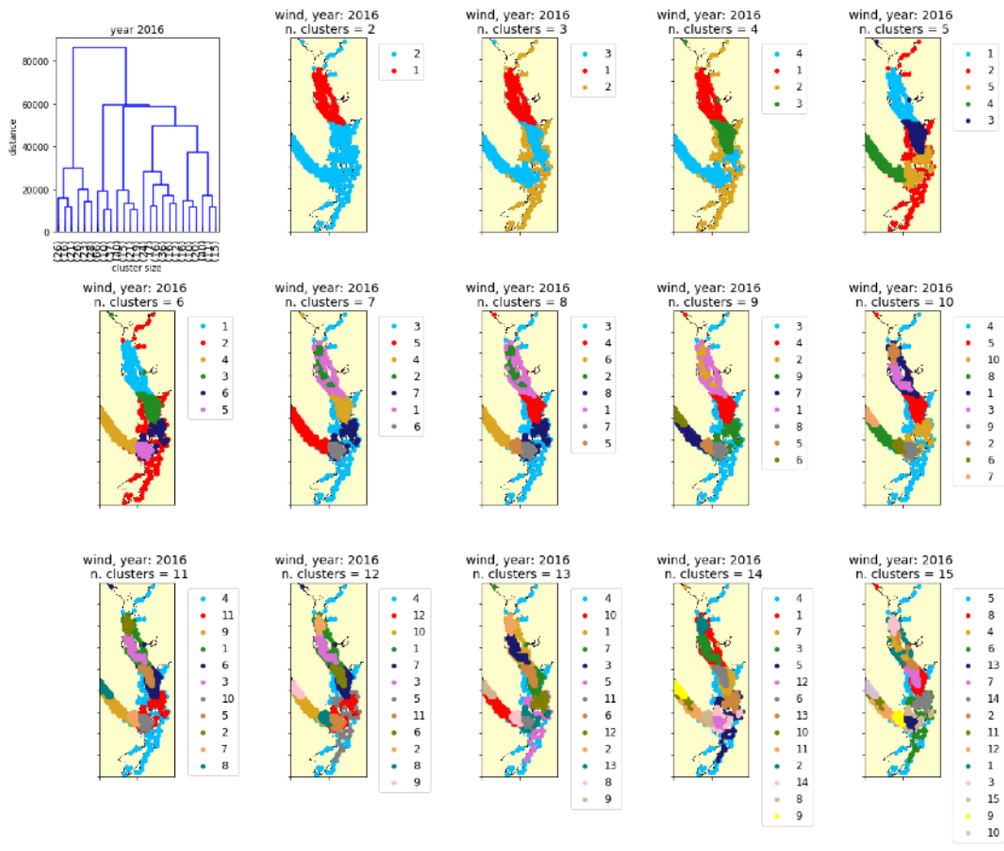

2013
2014
2015
2016
m³s⁻³
days of year


Signals year 2014
Signals year 2015
Signals year 2016
m³s⁻³
days of year

WIND

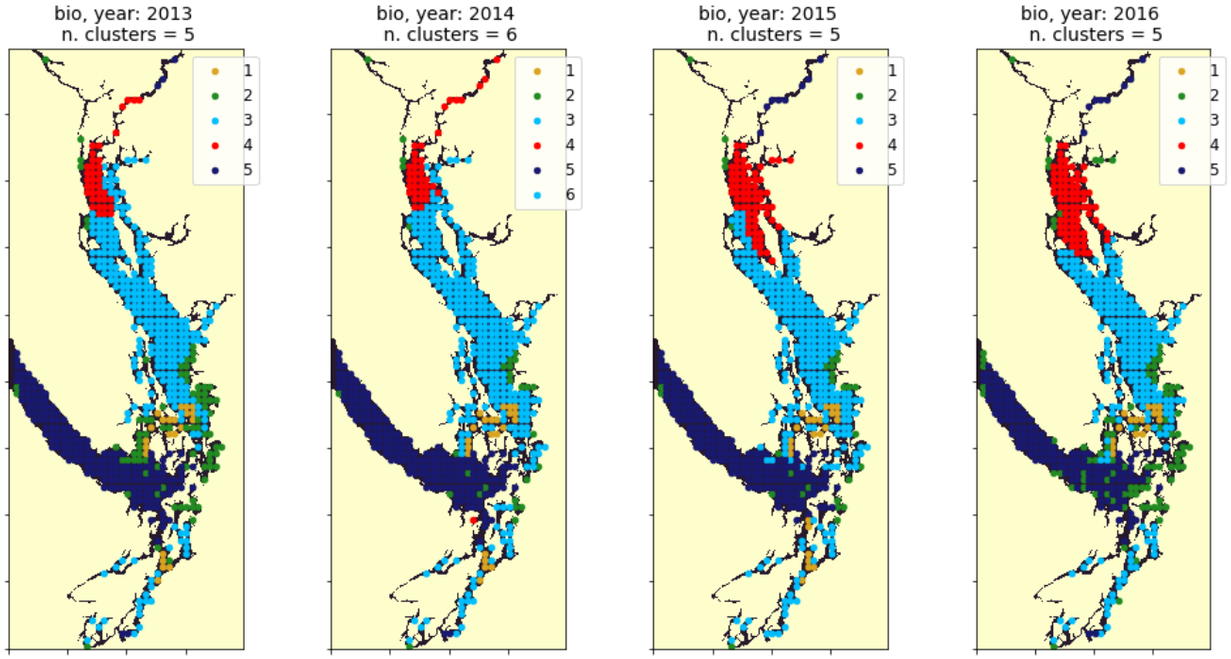


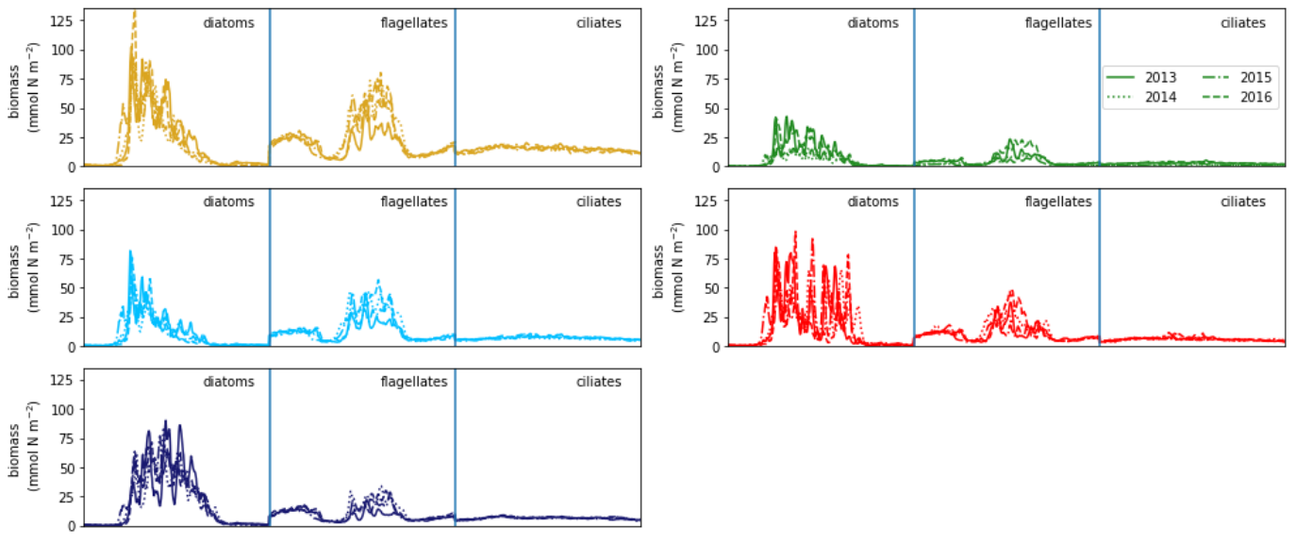


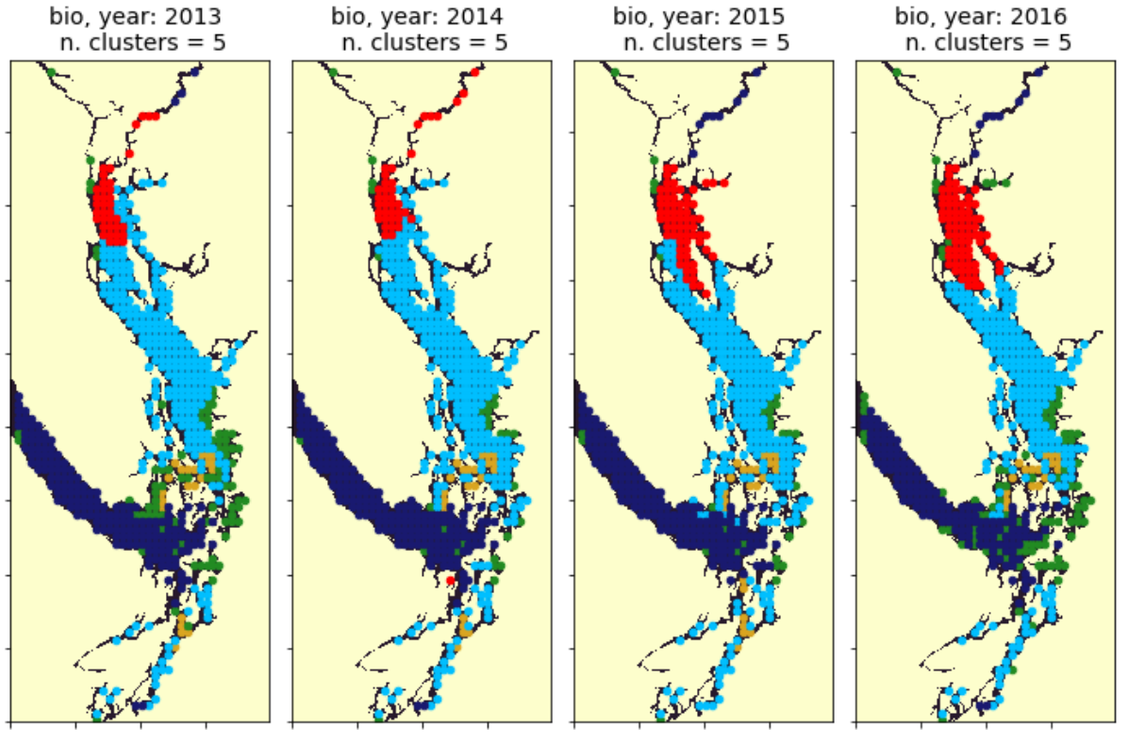


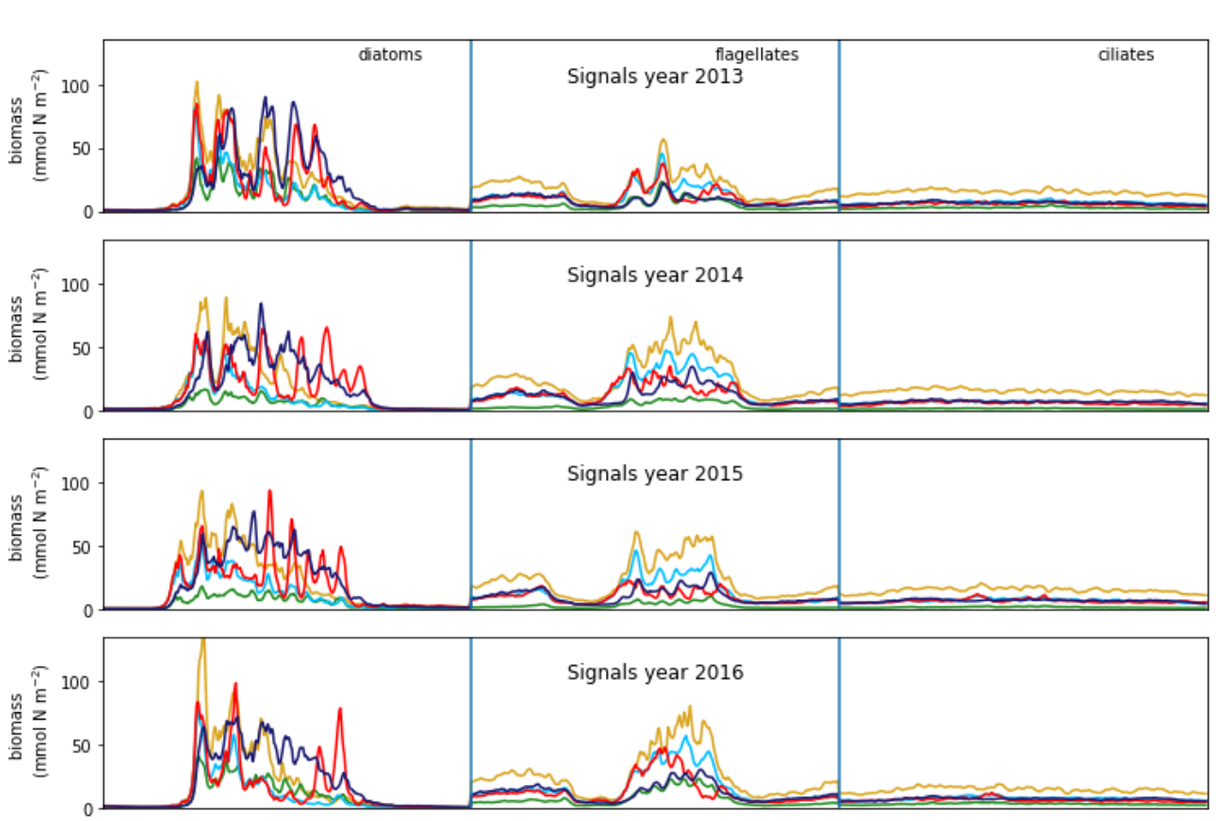
WIND CLUSTERS

BIOLOGY CLUSTERINGS

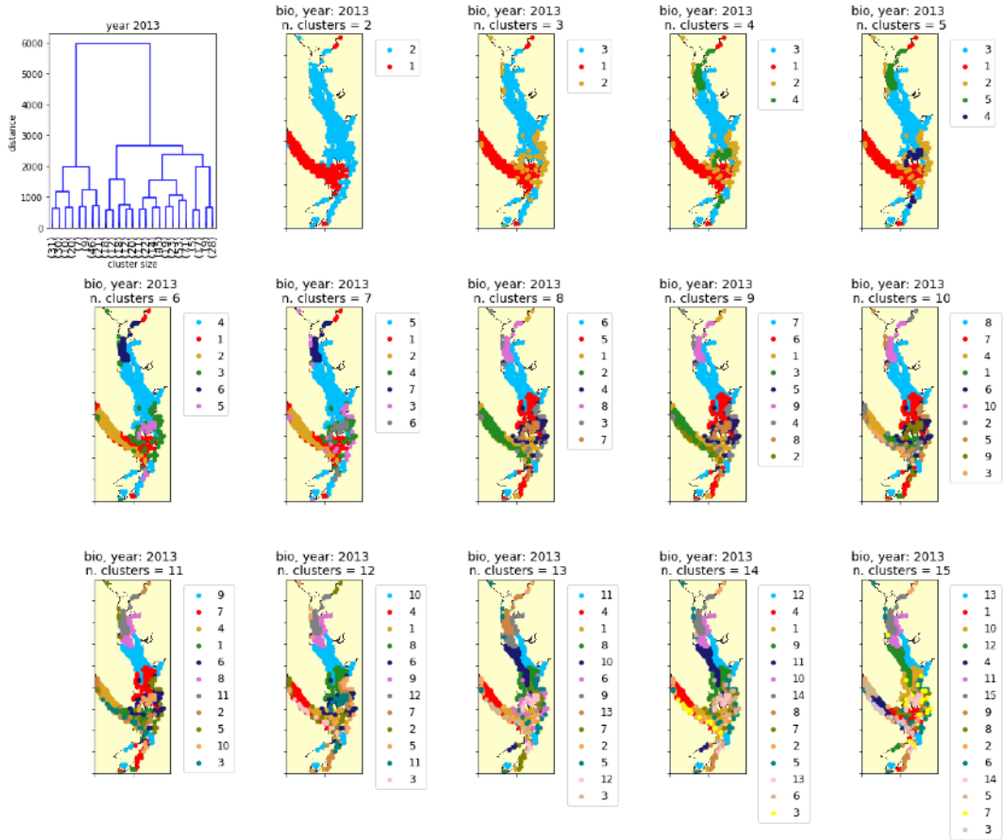




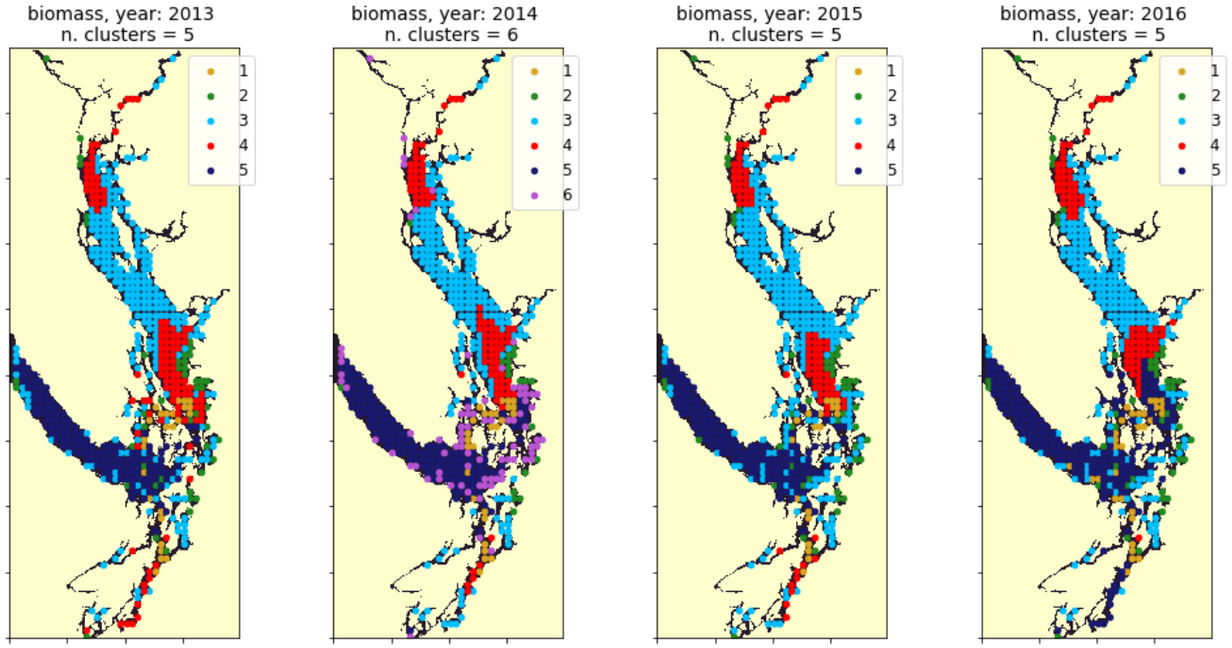




BIO (Fxn groups included)



BIO CLUSTERS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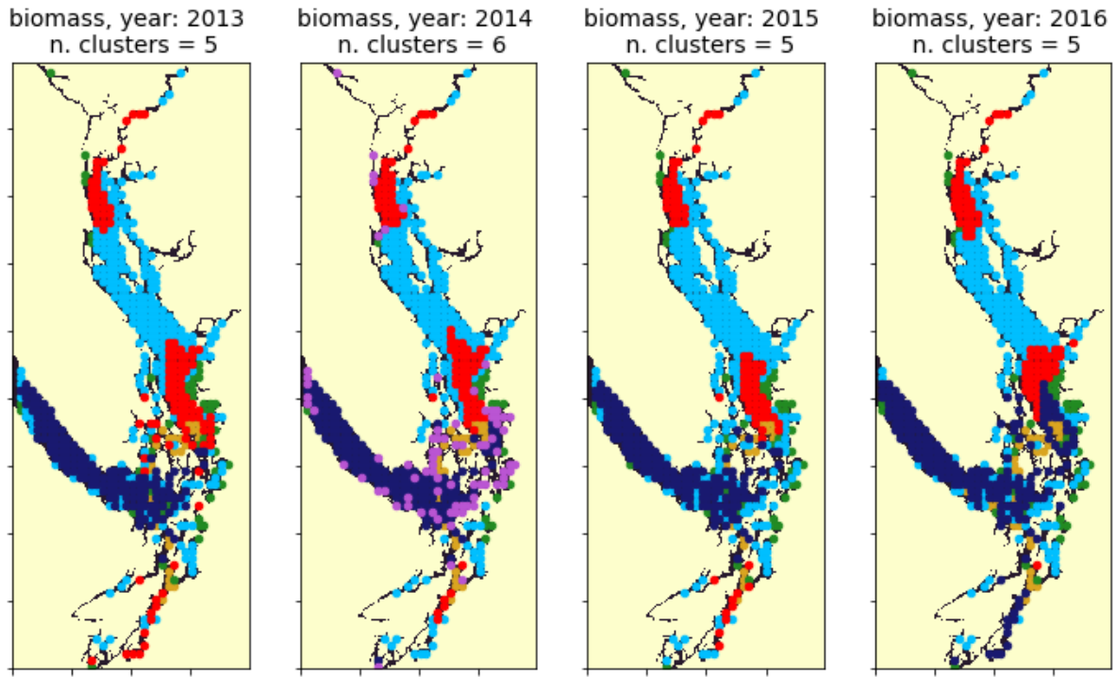
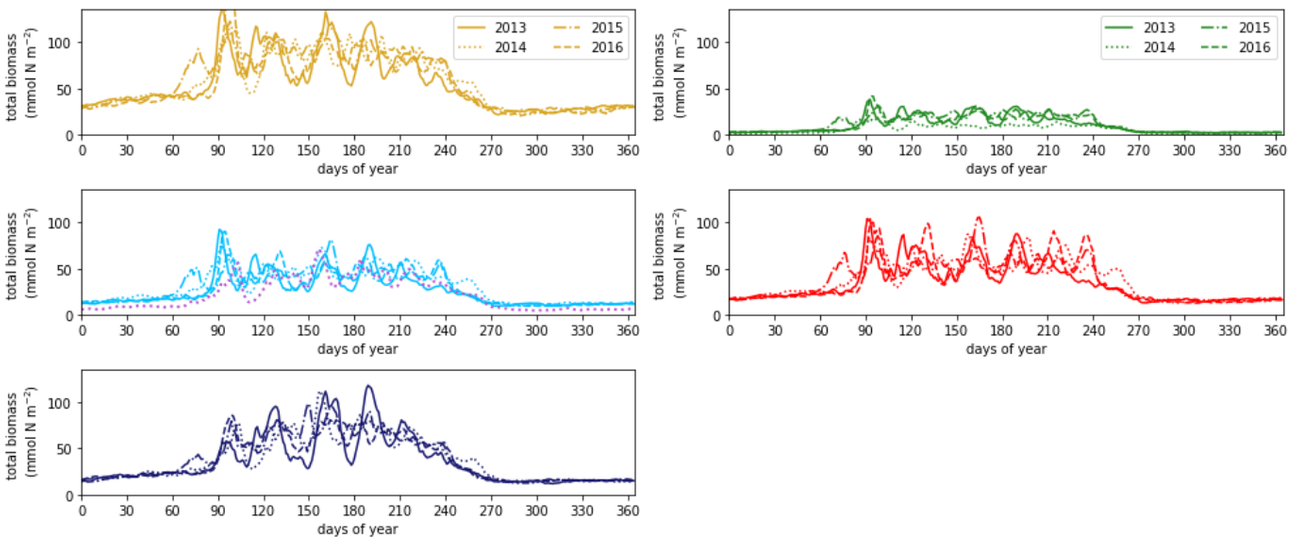
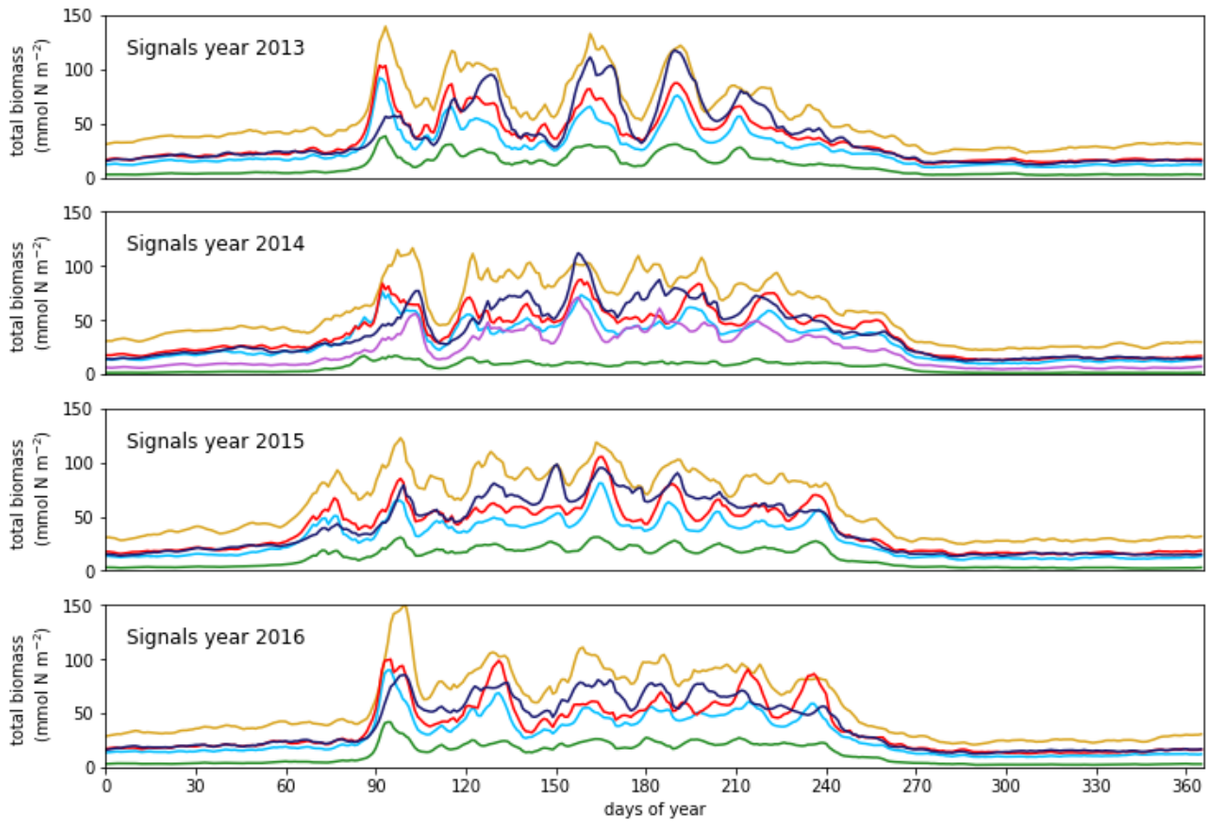
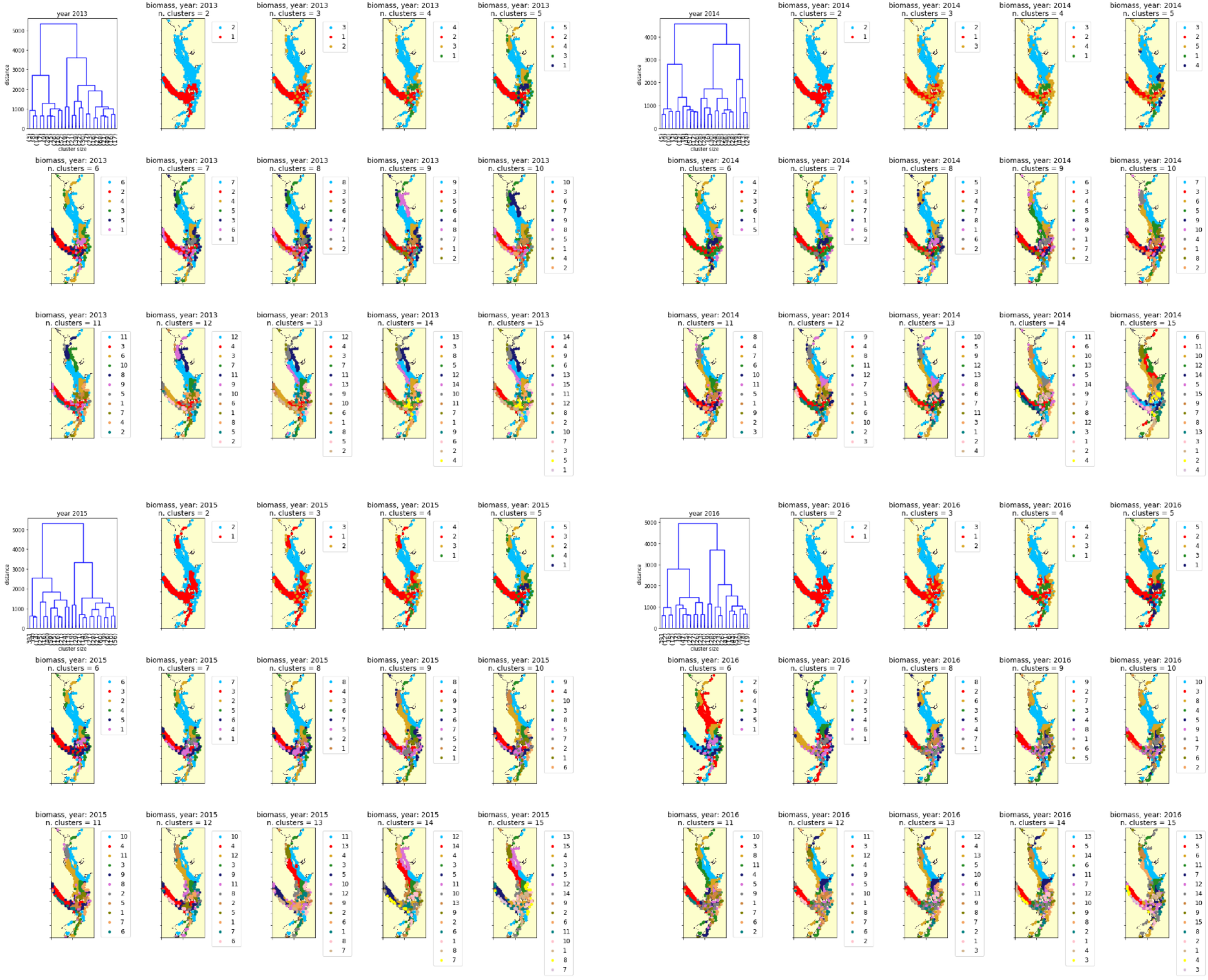
biomass, year: 2014
n. clusters = 6
biomass, year: 2015
n. clusters = 5
biomass, year: 2016
n. clusters = 5


biomass, year: 2013
n. clusters = 5
biomass, year: 2014
n. clusters = 6
biomass, year: 2015
n. clusters = 5
biomass, year: 2016
n. clusters = 5


total biomass (mmol N m⁻²)
days of year
2013
2014
2015
2016


Signals year 2013
Signals year 2014
Signals year 2015
Signals year 2016
total biomass (mmol N m⁻²)
days of year

BIOMASS



BIOMASS CLUSTERS [21]