Variability of the Red River plume in the Gulf of Tonkin from a numerical approach

A part of PhD thesis, by Duy Tung Nguyen
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Nguyen-Duy T, Ayoub NK, Marsaleix P, Toublanc F, De Mey-Frémaux P, Piton V, Herrmann M, Duhaut T, Tran MC and Ngo-Duc T (2021) **Variability of the Red River Plume in the Gulf of Tonkin as Revealed by Numerical Modeling and Clustering Analysis**. *Front. Mar. Sci.* 8:772139. doi: 10.3389/fmars.2021.772139

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1. Introduction

Gulf of Tonkin:

- A shallow, semi-enclosed basin, west of South China Sea
- Effect of monsoon:
  - Summer: southwesterly wind
  - Winter: northeasterly wind

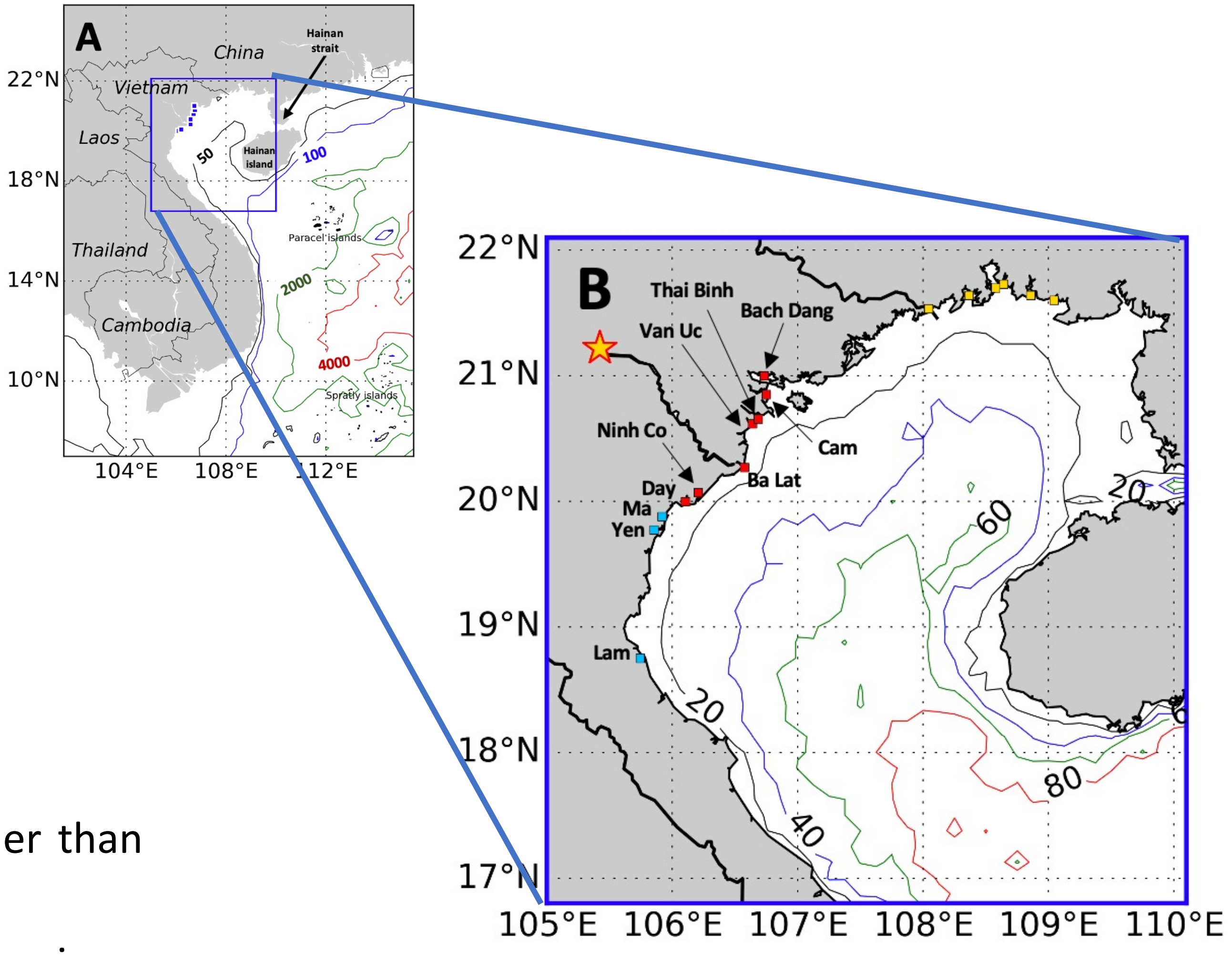
Red River

- Second largest river in Vietnam (~ $3000 m^3/s$)
- Mean sediment load: > 10Mt/year

Red River delta

- Formed from 11 provinces, 22.5 millions people
- Population density: 1060 inhabitants/km^2, 4 times higher than the national average
- High population density exerts a strong pressure on the rivers and their environment

=> it is important to be able to identify and understand the variability of the river plume in the Gulf of Tonkin



1. Introduction

Objectives

Using numerical method to:

- Describe the development of the river plume in the Gulf of Tonkin
- characterize its variability at different scales over the period 2011-2016
- describe the physical processes underneath the plume variations

Approaches

- The river plume is identified using passive tracer
- The plume regimes are classified with the help of K-means clustering analysis

2. Methods and tools

SYMPHONIE coastal model (Marsaleix et al., 2008**)**

- Configuration adapted from Piton et al., 2020
  - **Variable mesh**: **300m at coast**, 5km near the open boundary
  - **20** vertical sigma levels
  - Boundary condition: global Copernicus simulation (**Mercator reanalysis** 1/12 degree)
  - Atmospheric conditions: **ECMWF analysis** (3 hours)
  - Tidal forcing: FES2014 (Lyard et al., 2021)
  - Run from **2010 – 2016**, 1 year spin-up

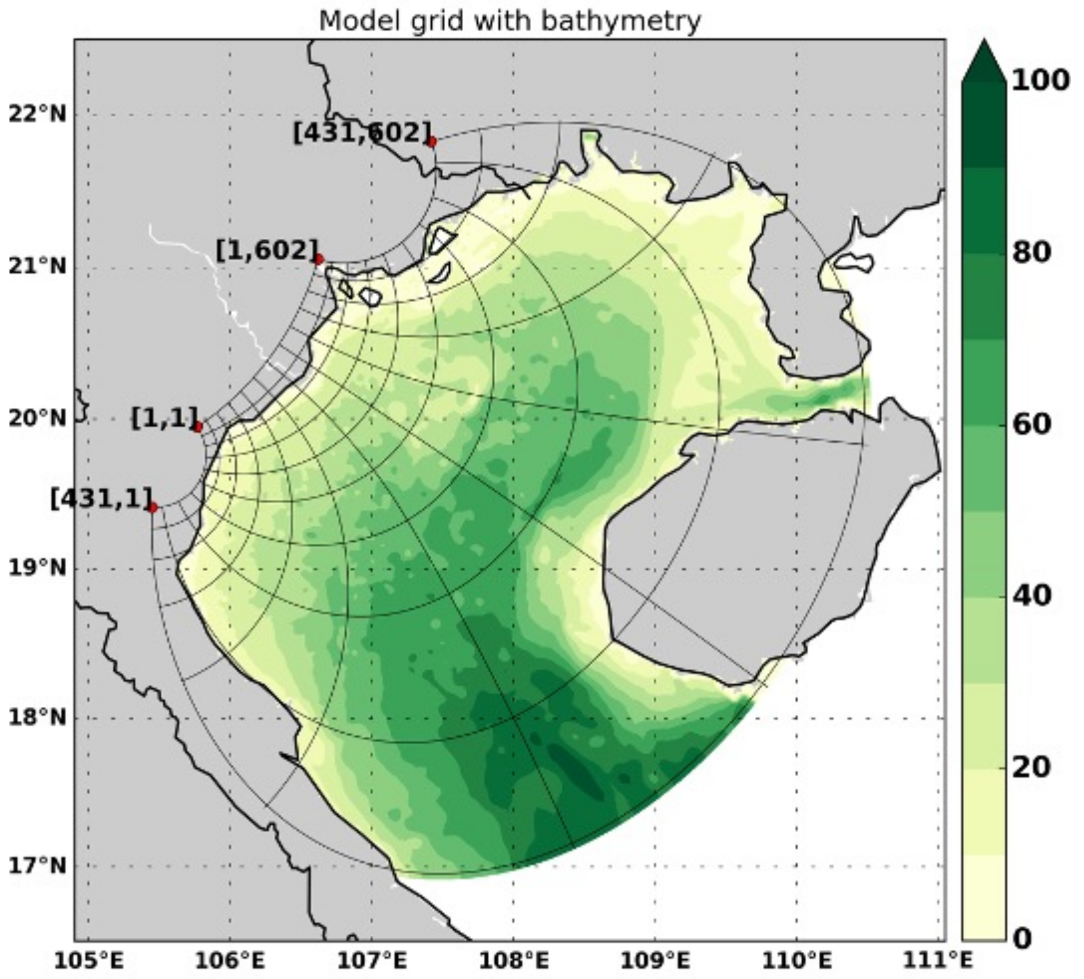


Fig: model grid with bathymetry (ratio: 1/50)

2. Methods and tools

River's settings:

Red Rivers

- Daily discharge data from hydrological stations
- **Each river connects to a channel** to better simulate the effect of tides on the estuarine waters

Other Rivers

- Monthly mean climatological runoff

Passive tracers

- Injected continuously at the river input point, with concentration = 100 unit/m^3
    - 1 for Red River
    - 1 for southern rivers
    - 1 for northern rivers

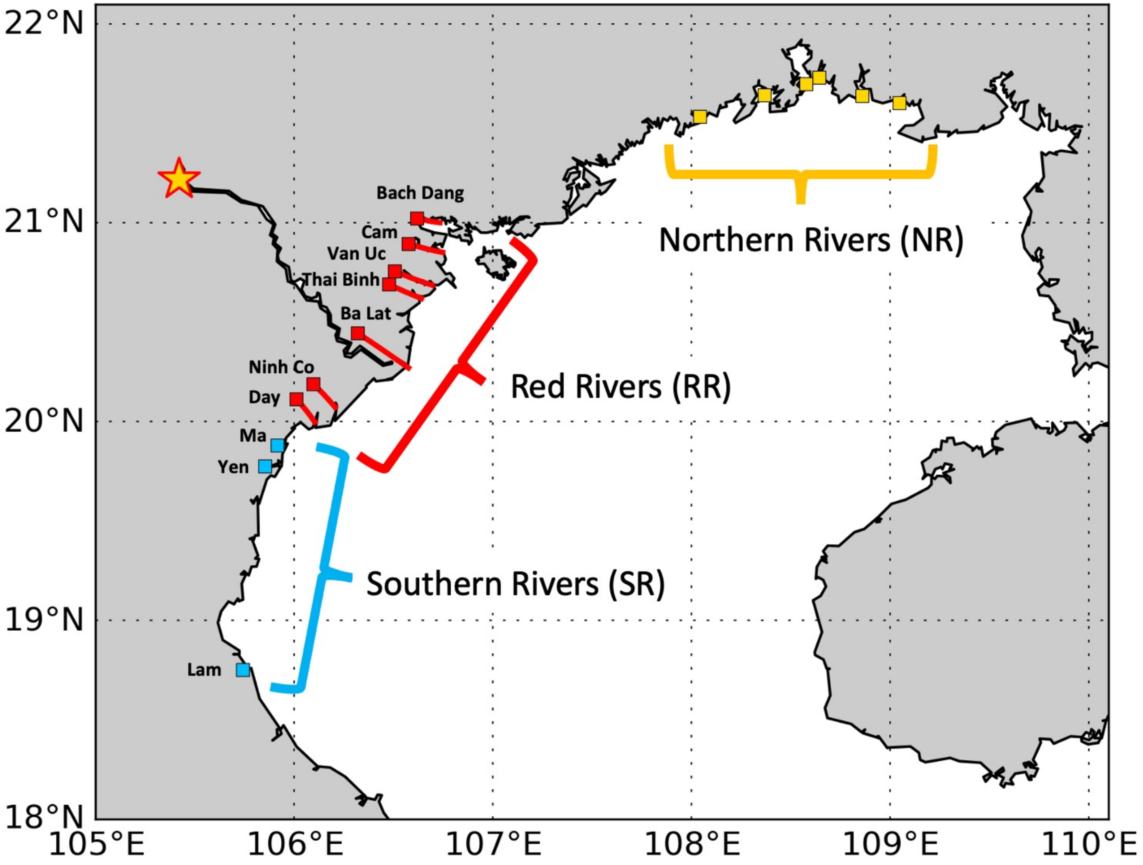


Fig: Locations of the rivers in the gulf

3. Variability of the river plume

3.1. Identify river plume and its surface variability

Using tracer

- Can distinguish the river runoff from different rivers and avoid the dilution impact of precipitation
- ***The plume is defined as the area where the tracer concentration >=7 unit/m³***

The plume has strong variability, both in space and time (not shown)

⇒ Need a method to simplify the analysis

South of 20N, the Red River plume is quickly joined by southern rivers plume along Vietnamese coast

⇒ in the following analyses, we will analyze the plume created by the all the Red rivers and other VN rivers.

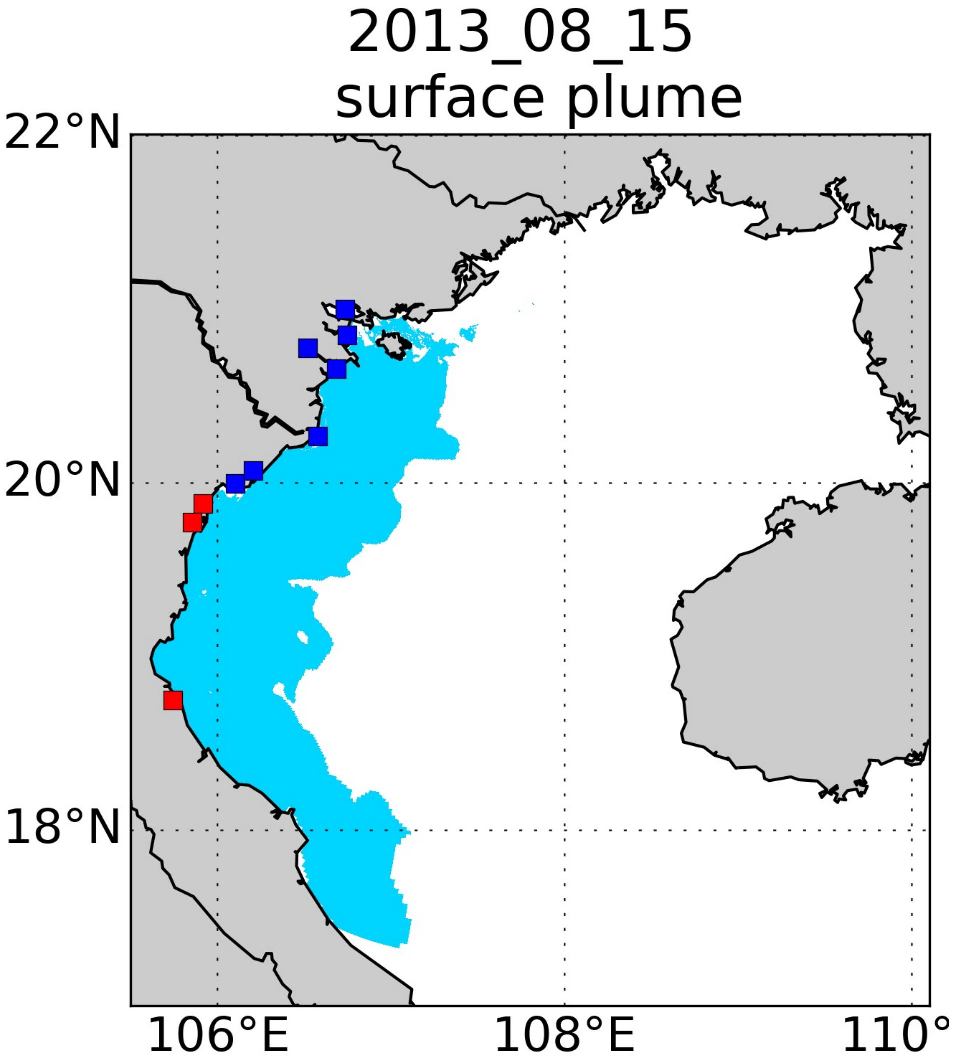


Fig: an example of plume surface area in high discharge period

3. Variability of the river plume

3.2. Identify the general pattern of plume surface area using K-means clustering analysis

- In this study, the surface plume area is classified into 4 general regimes.
- Library: scikit-learn

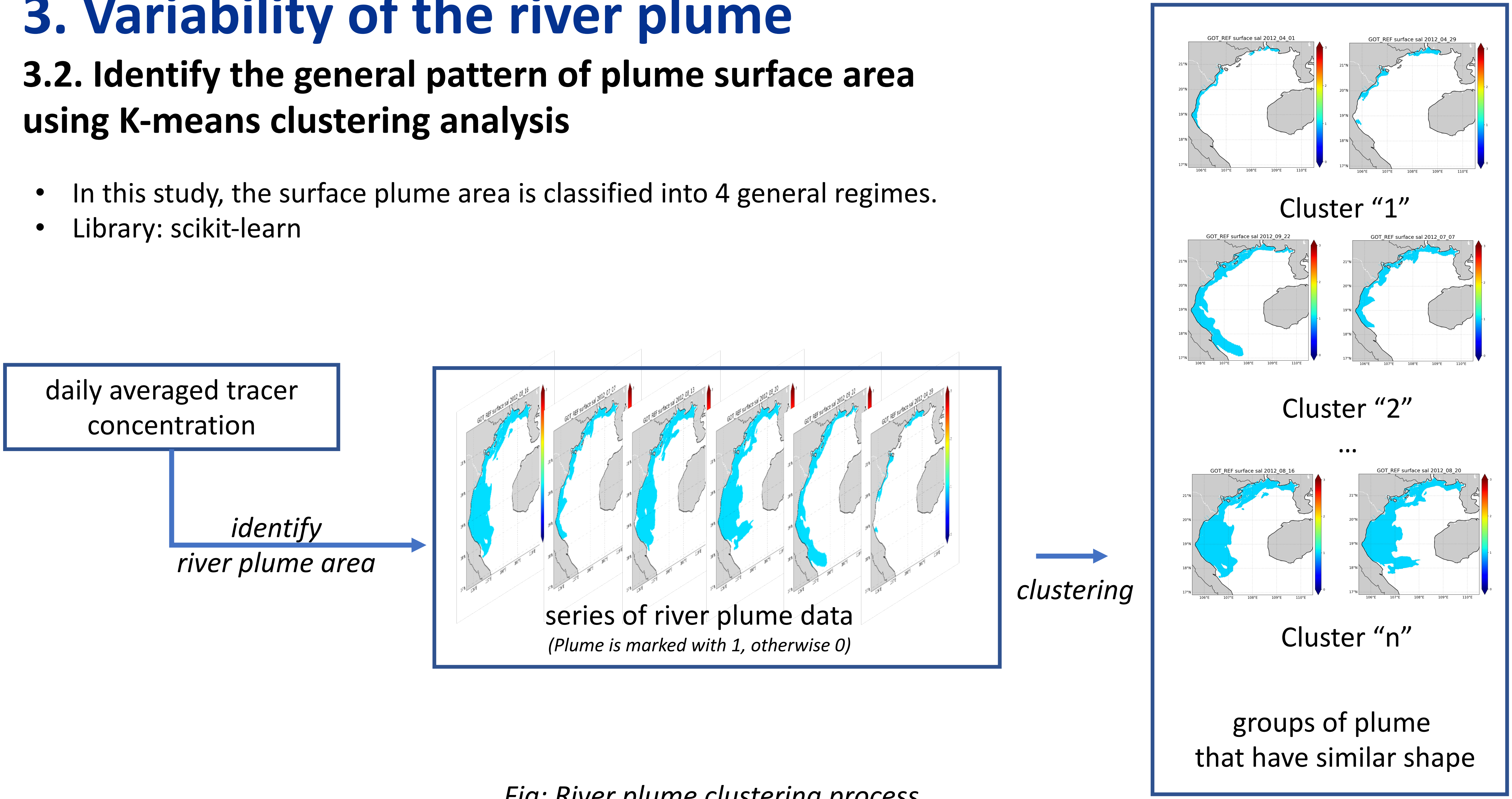
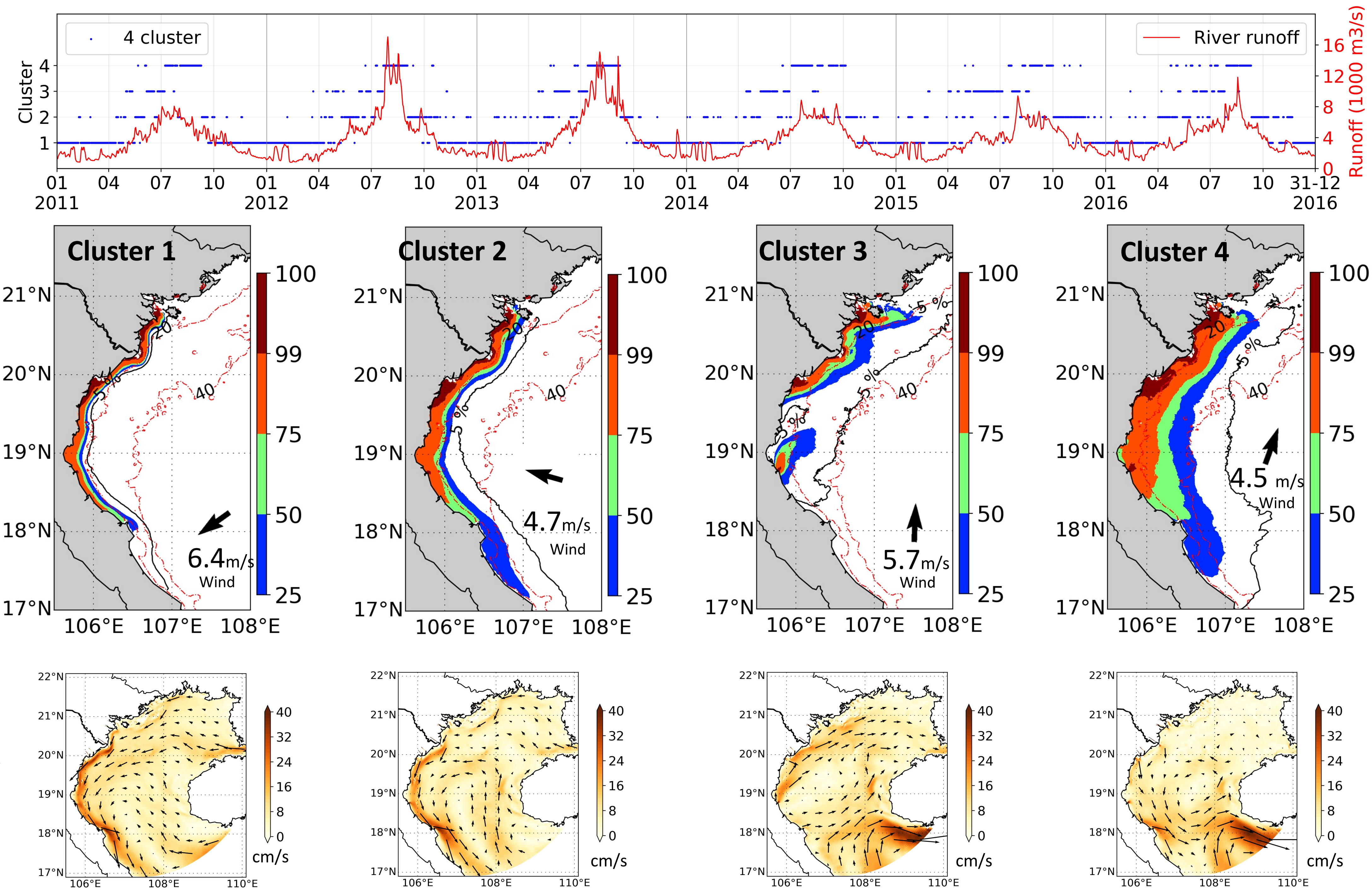


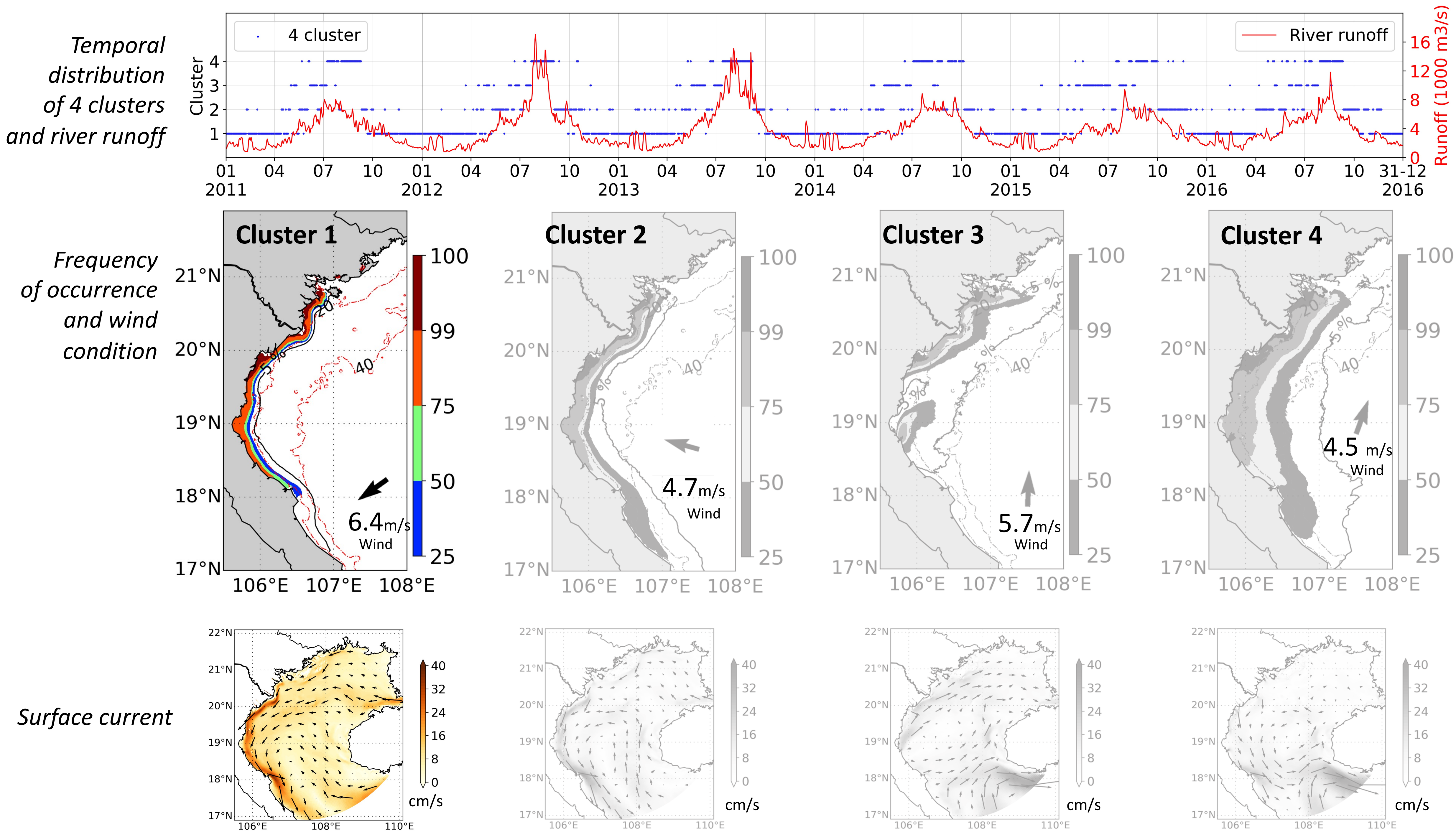
Fig: River plume clustering process

Temporal distribution of 4 clusters and river runoff

Frequency of occurrence and wind condition

Surface current

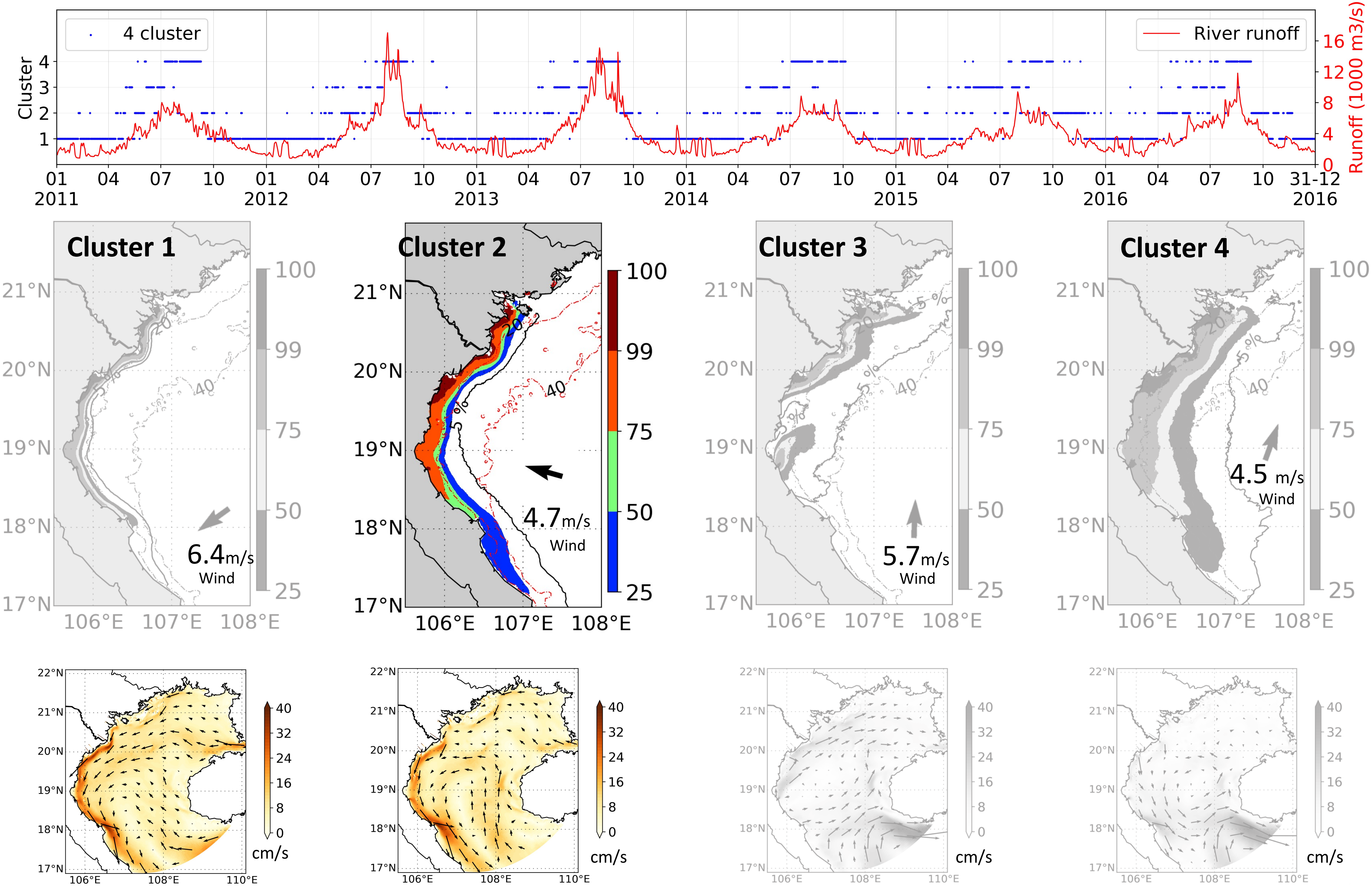


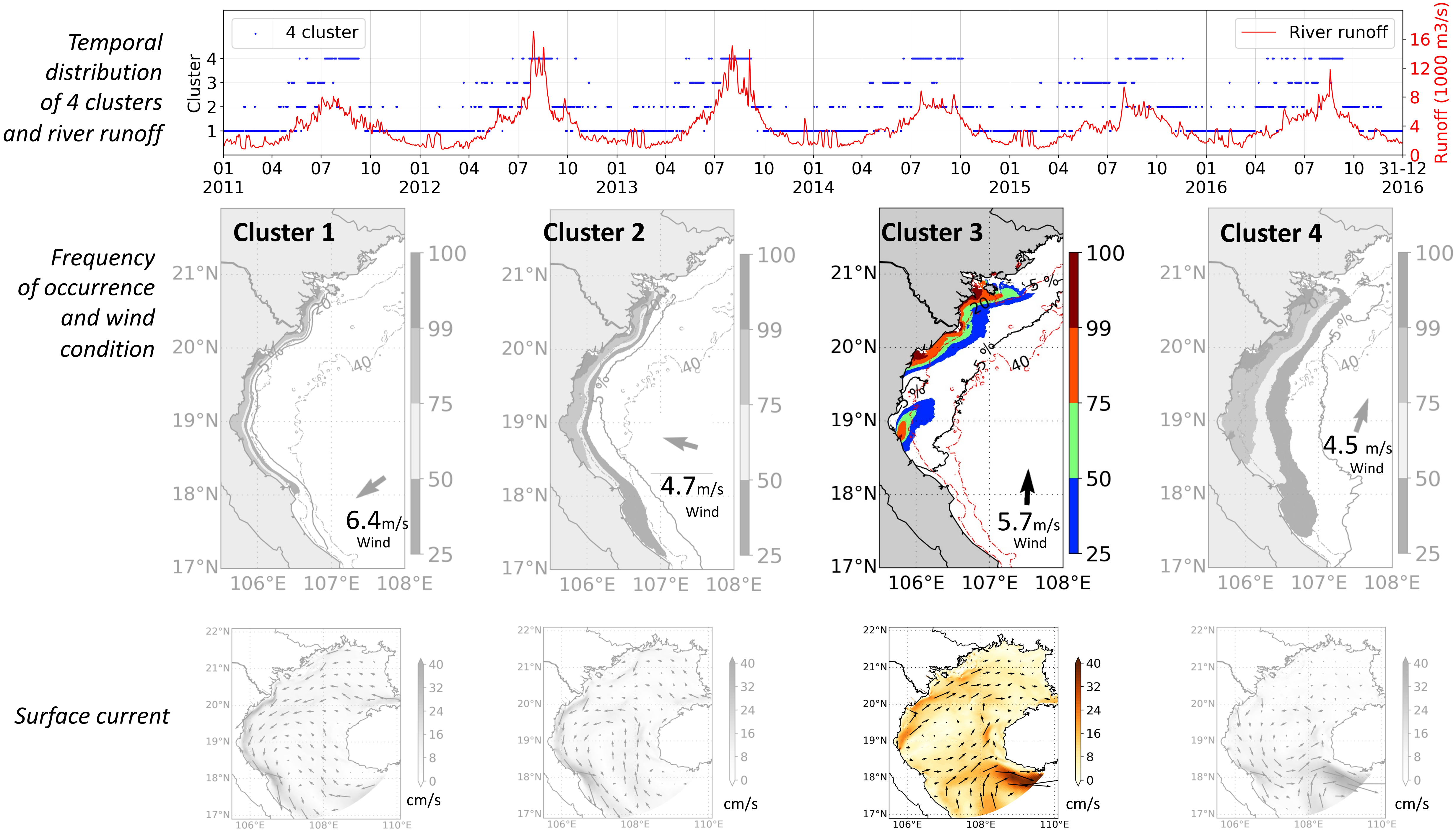

Temporal distribution of 4 clusters and river runoff
4 cluster
River runoff
Cluster
Runoff (1000 m3/s)
01 2011
01 2012
01 2013
01 2014
01 2015
01 2016
31-12 2016
Frequency of occurrence and wind condition
Cluster 1
Cluster 2
Cluster 3
Cluster 4
6.4m/s Wind
4.7m/s Wind
5.7m/s Wind
4.5 m/s Wind
21°N
20°N
19°N
18°N
17°N
106°E
107°E
108°E
Surface current
cm/s

Temporal distribution of 4 clusters and river runoff

Frequency of occurrence and wind condition

Surface current




Temporal distribution of 4 clusters and river runoff
4 cluster
River runoff
Cluster
Runoff (1000 m3/s)
01 2011
04
07
10
01 2012
01 2013
01 2014
01 2015
01 2016
31-12 2016
Frequency of occurrence and wind condition
Cluster 1
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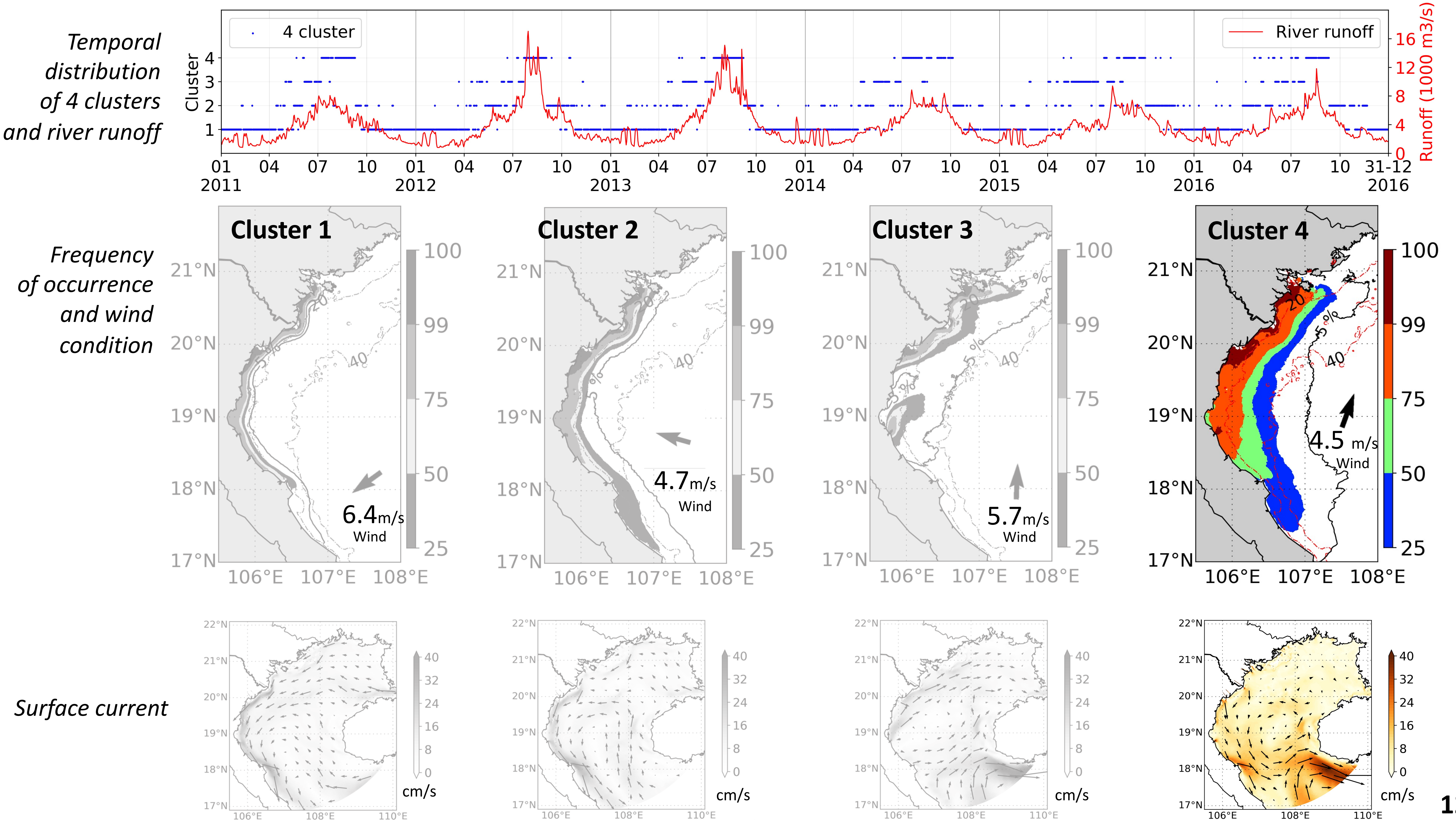
Wind
Cluster 2
4.7m/s
Wind
Cluster 3
5.7m/s
Wind
Cluster 4
4.5 m/s
Wind
5 %
20
40
100
99
75
50
25
21°N
20°N
19°N
18°N
17°N
106°E
107°E
108°E
Surface current
cm/s
22°N
110°E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100
99
75
50
25
Surface current
cm/s

4. Conclusions and perspectives

4.1. Conclusions

- **Passive tracer** is useful to identify the river plume, especially in the basin with several river sources
- We explored the application of **K-means clustering analysis** to detect the main regimes of the river plume.
- The processes and **forcings (wind, current, runoff)** linked with these regimes are analysed.
- We also examine the **impact of tides** on the plume regimes and plume thickness

These results have been published in an article:

Nguyen-Duy T, Ayoub NK, Marsaleix P, Toublanc F, De Mey-Frémaux P, Piton V, Herrmann M, Duhaut T, Tran MC and Ngo-Duc T (2021) **Variability of the Red River Plume in the Gulf of Tonkin as Revealed by Numerical Modeling and Clustering Analysis**. *Front. Mar. Sci.* 8:772139. doi: 10.3389/fmars.2021.772139

4. Conclusions and perspectives

4.1. Perspectives

- In each cluster, the plume is strongly affected by the wind.

⇒ What is the robustness of these results due to wind uncertainty?

⇒ ***We are working on the ensemble simulations with perturbed wind forcing***