Mapping and Investigating Barotropic Pressure Gradients in River Plumes Using SWOT

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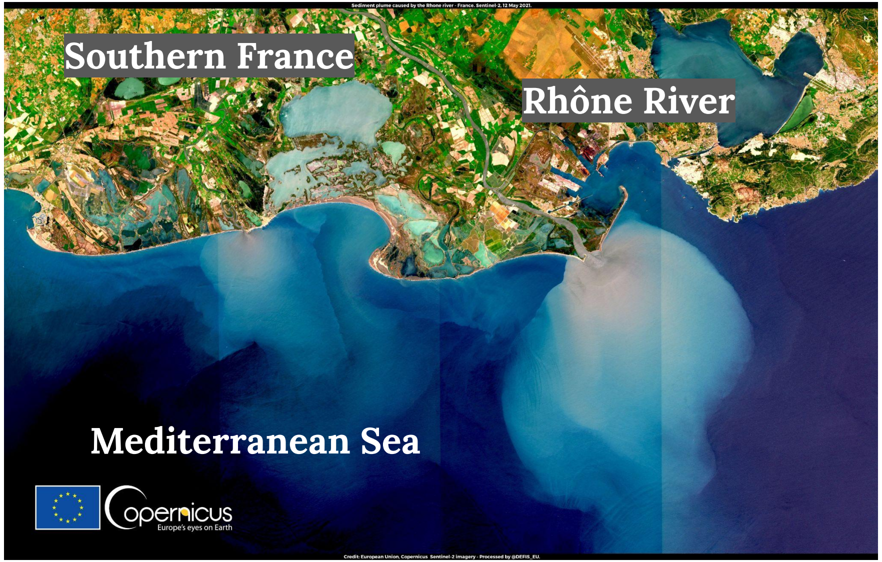
River Plumes

- Buoyant body of fresher water
- Differences not only in density but in overall content and momentum
- Transport of riverborn materials, nutrients and pollutants

Port of Rio Grande in southern Brazil on October 5, 2023 (Landsat 9)

River Plumes



Copernicus Sentinel-2 satellites on 12 May 2021, shows the sediment plume discharged into the Mediterranean Sea by the mouth of the Rhône river in southern France.

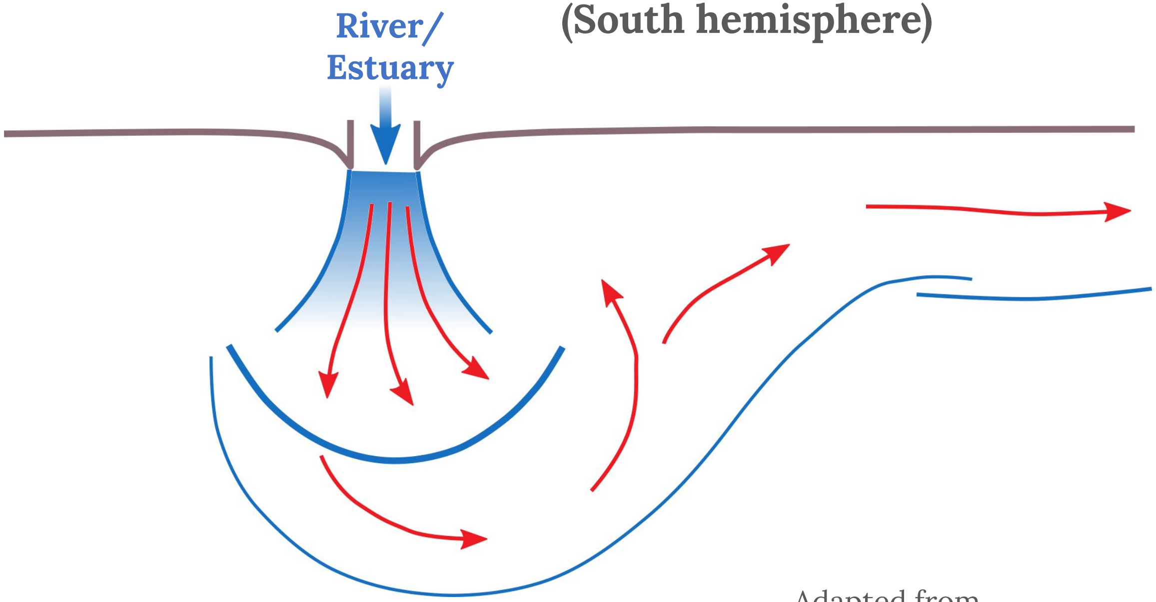
- **Influenced by:**
  - Freshwater discharge (Most variability)
  - Coastline and bathymetry
  - Local currents
  - Wind
  - Earth's rotation (Depending on time and spatial scales)
  - Tidal amplitude (Tidal reset)

Connecticut River Plume, on September 2, 2011, after Hurricane Irene (Landsat 5). Source: NASA Earth Observatory.

River Plume Dynamics

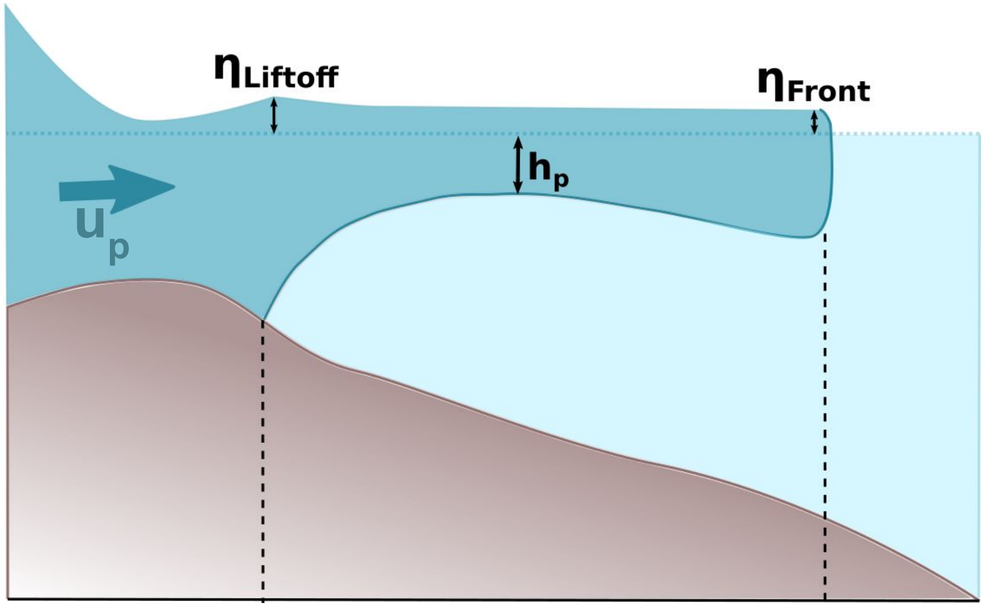
- Little/no bathymetry constrain
- No strong local currents
- Propagate and expand radially oceanward
- Forming a **Tidally Pulsed Prototypical Plume**
- **We expect two characteristic water surface elevation expressions**

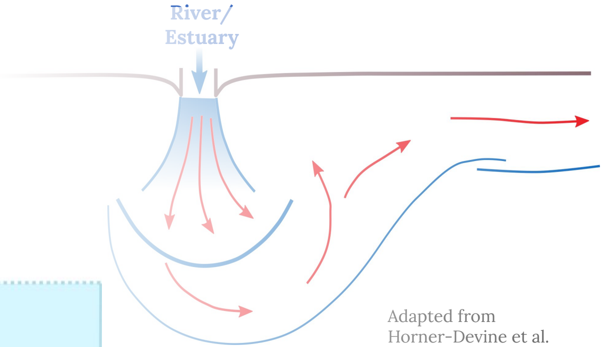
Tidally Pulsed Prototypical Plume



Adapted from
Horner-Devine et al. (2015)

Surface Expression of River Plumes





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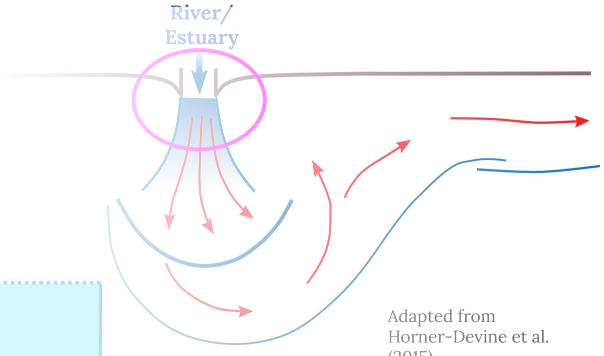
Surface Expression of River Plumes

- **Liftoff** (buoyant freshwater from the river detaches from the bottom)



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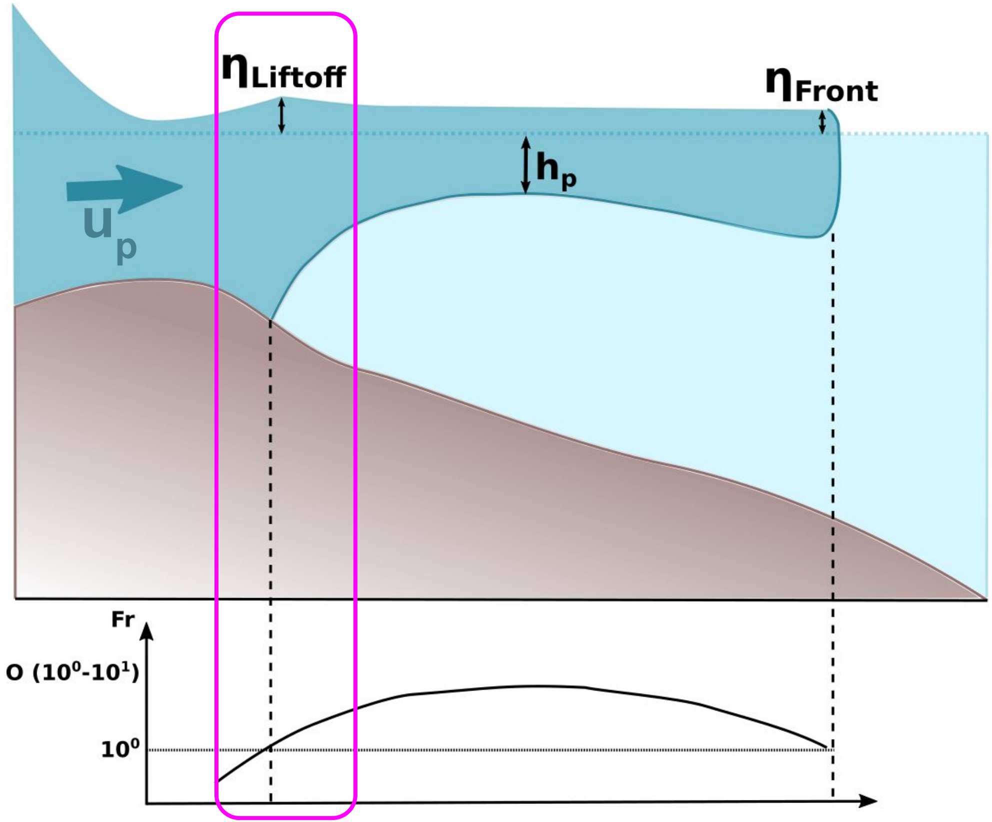
- Two-layer Hydraulics (Armi & Farmer, 1986)

- Upper layer Froude number

$$Fr = \frac{\overline{u_p}}{\sqrt{g' h_p}} \approx 1$$



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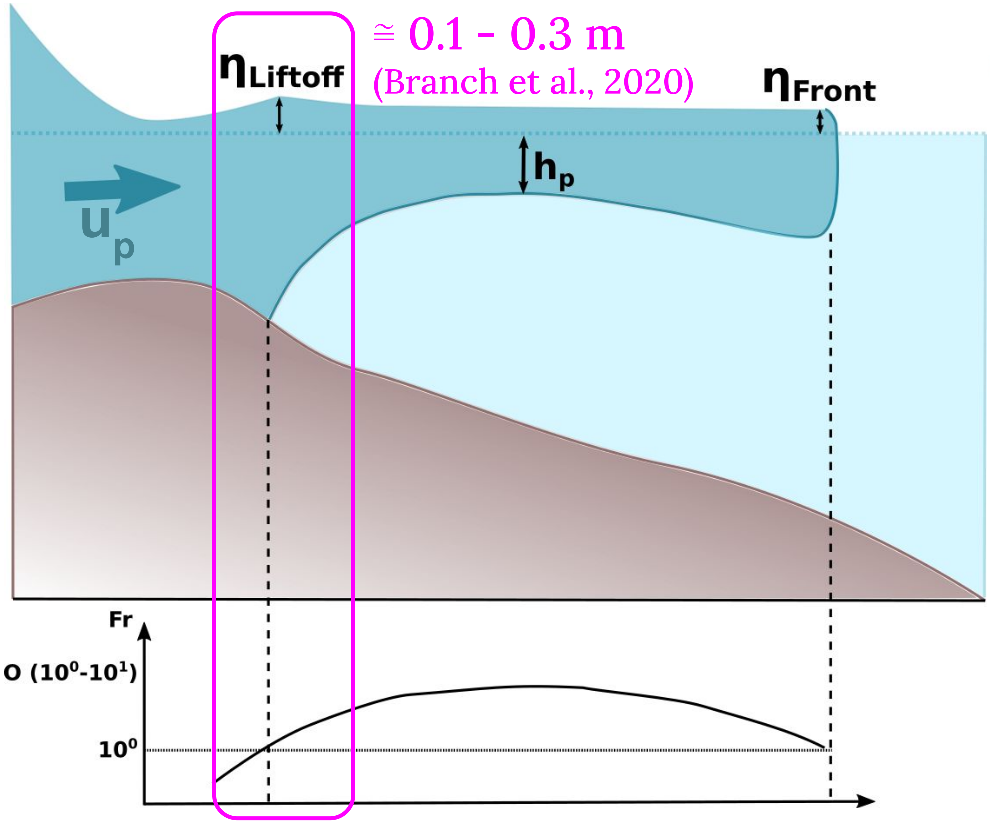

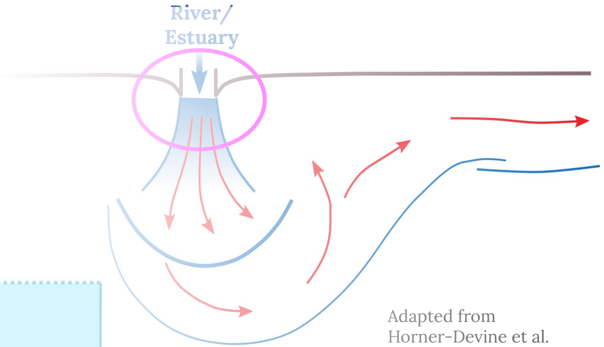

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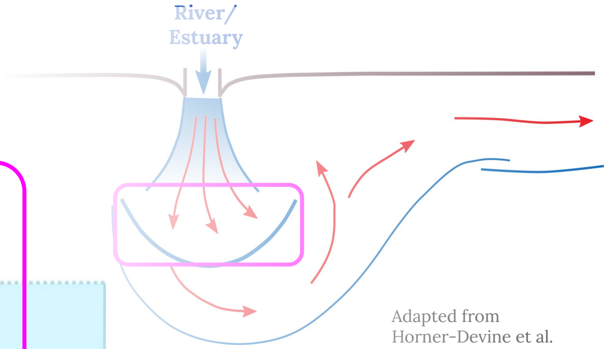
Surface Expression of River Plumes

- Cross-front Barotropic Pressure Gradient



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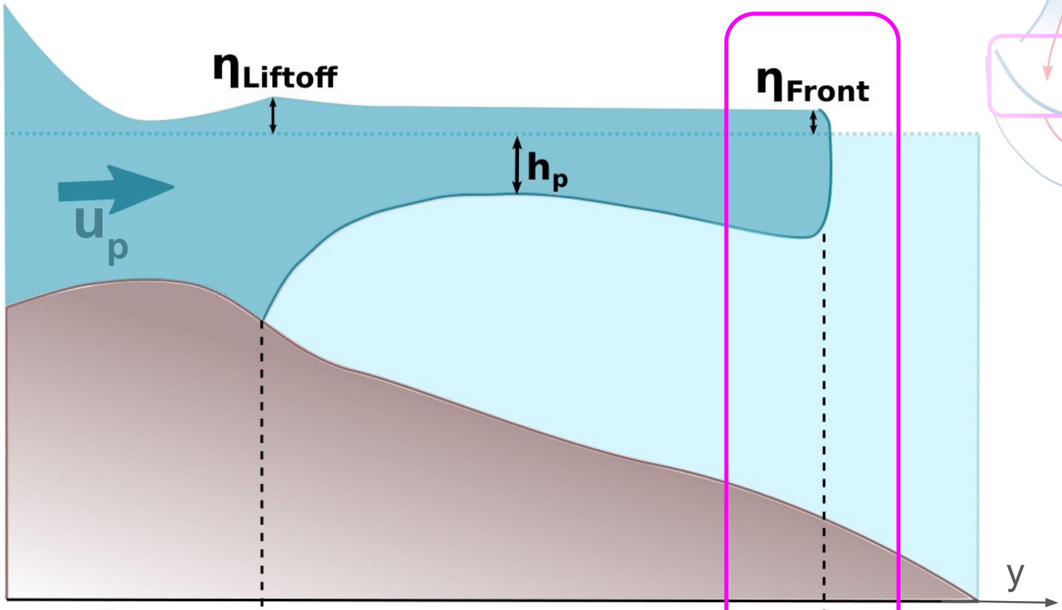

- Mom.Bal. for shallow water equations (Plume depth integrated)

$$\underbrace{\frac{D\bar{u}}{dt}}_{\text{Total Derivative}} = \underbrace{f\bar{v}}_{\text{Coriolis}} - \underbrace{g\frac{h_p}{\Delta x}\left(\frac{\rho_{ocean} - \rho_{plume}}{\rho_{ocean}}\right)}_{\text{Baroclinic Pressure Gradient}} - \underbrace{g\frac{\Delta \eta}{\Delta x}}_{\text{Barotropic Pressure Gradient}} - \underbrace{\frac{(\tau_{w_x} - \tau_{b_x})}{\rho_{plume} h_p}}_{\text{Shear Stress}}$$

Surface Expression of River Plumes

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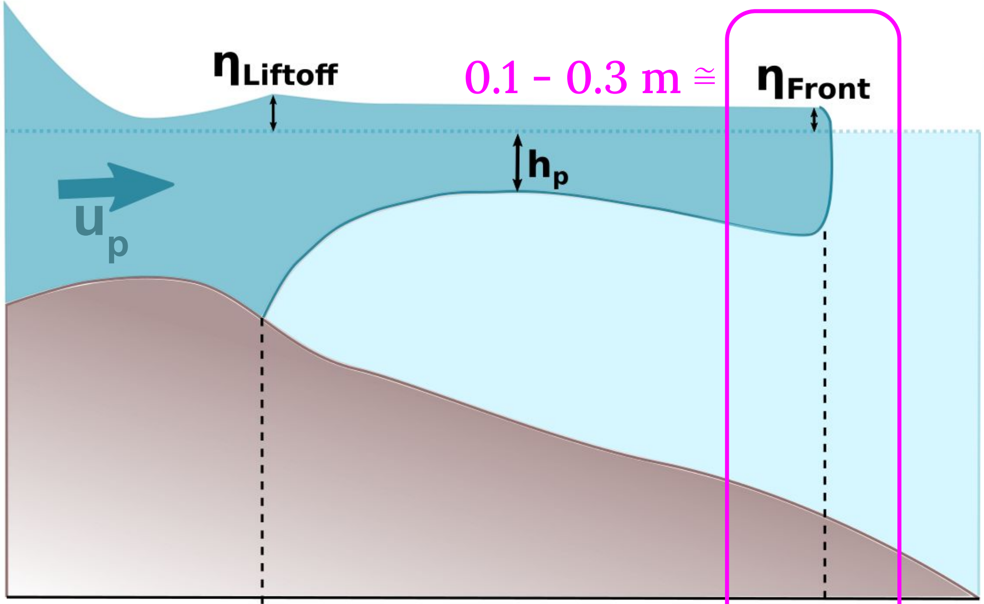

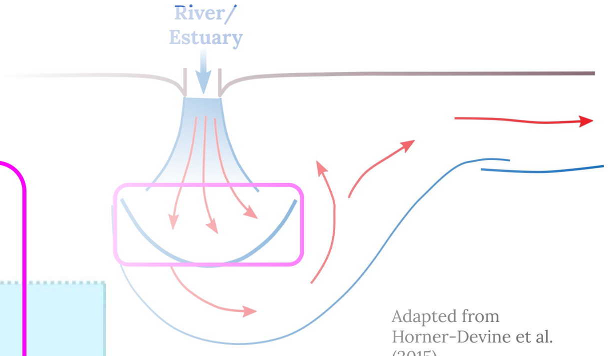

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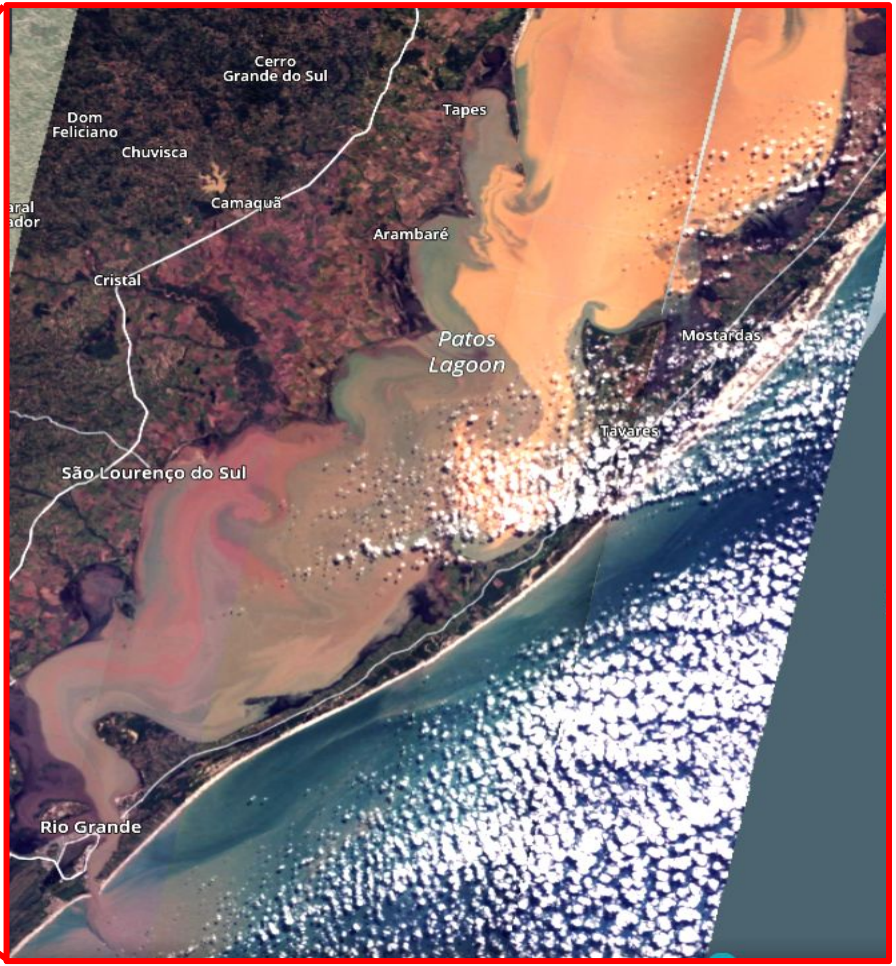
Surface Expression of River Plumes with SWOT

- **Extremely difficult to measure with traditional *in situ* instruments**
  - cm scale differences over distances of km scale
  - Constantly evolving and propagating
- The missing link of the momentum balance of plumes
  - Frontal momentum leads to high turbulence zones, and active mixing

SWOT Product choice:

- Despite the pixel cloud having better resolution it has less snapshots that extend to the coastal zone, covering the plume region
- LR L3 Unedited (Cross-coast swath)
- We opted for no correction of the ocean tides (ssha + internal_tides + ocean_tides)

Rio Grande River Plume



- World's biggest coastal lagoon
  (10,360 km² ~ Ile de France or Massachusetts)

Rio Grande River Plume

- At the time discharge was probably ~13,000 m^3s^{-1} (Columbia ~ 7,500 m^3s^{-1})

- Small tidal amplitude of 0.3m (ebbing at the time)

- Usually strongly dominated by wind, but a that time winds were southeast ~3 ms^{-1}

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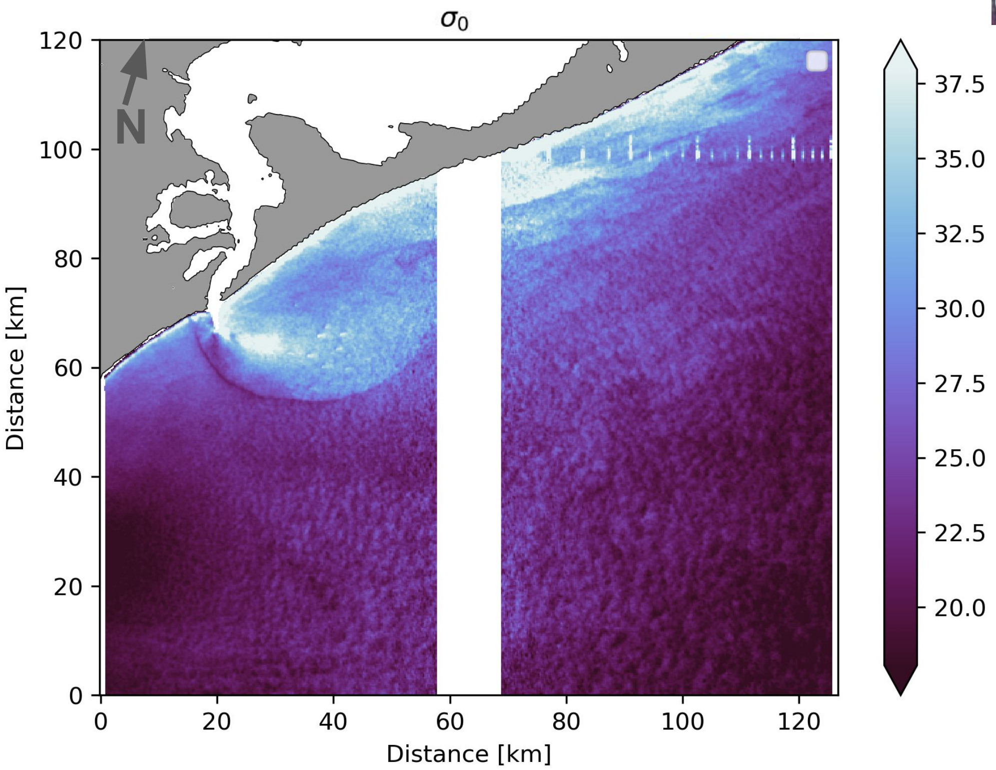

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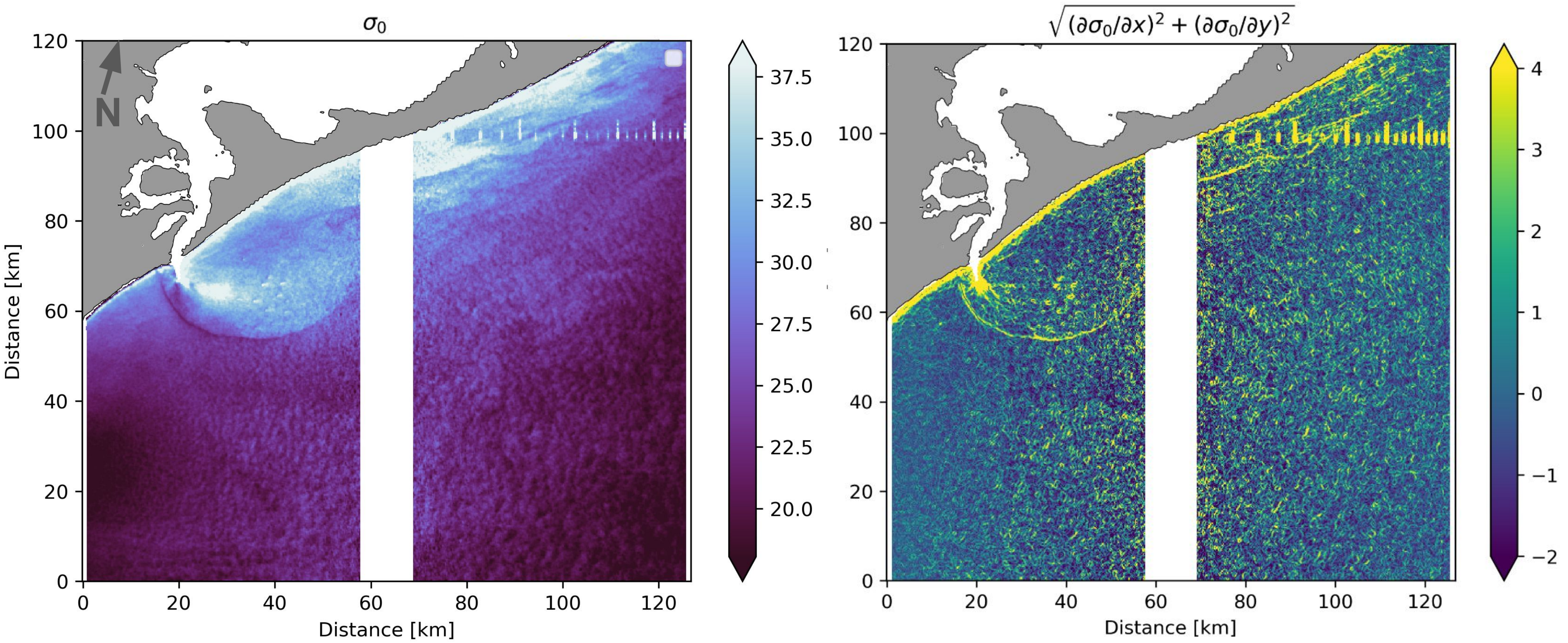

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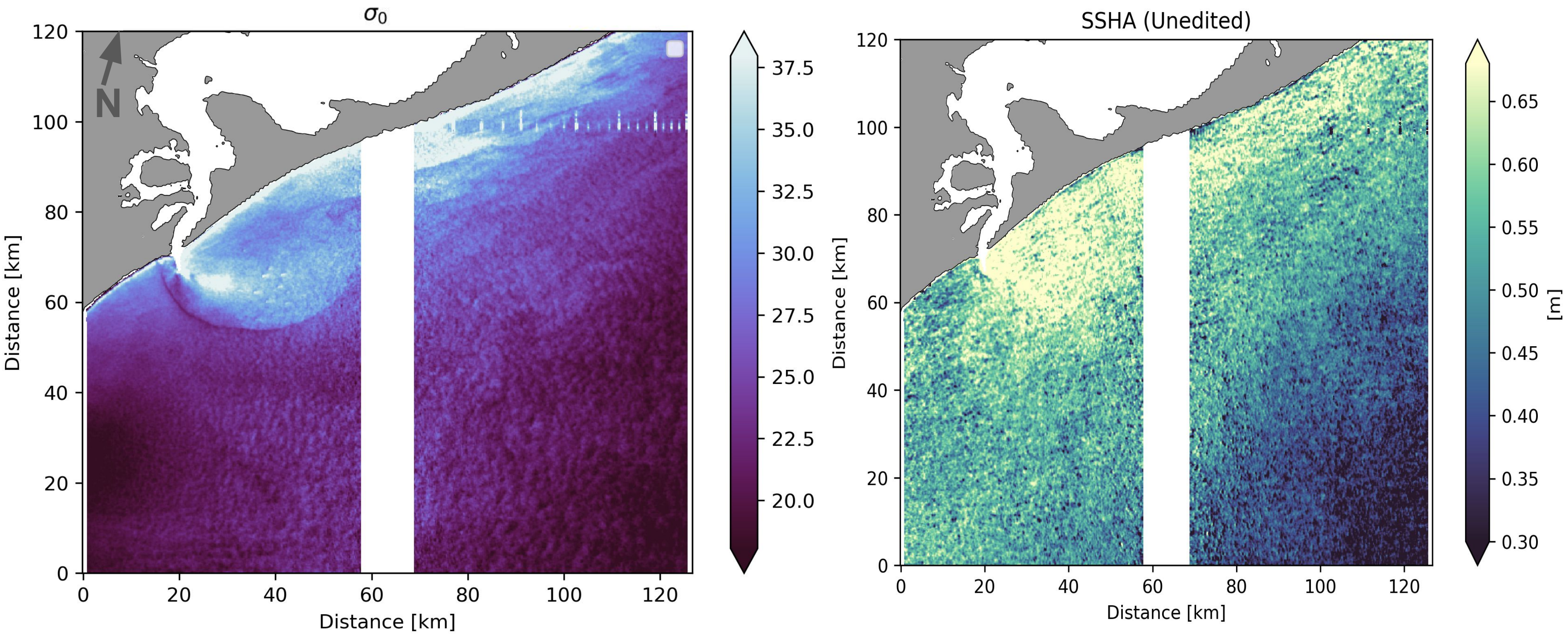

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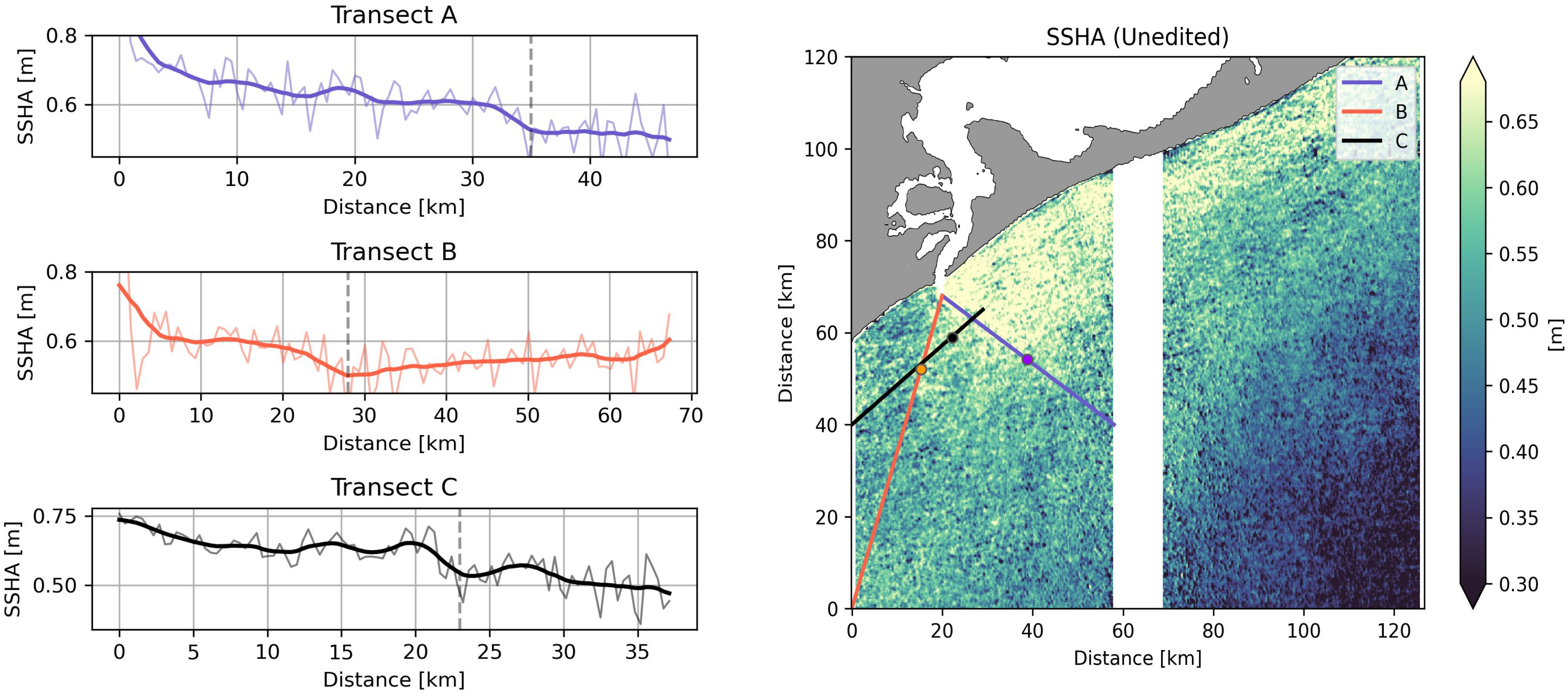

Ongoing analysis

Super cool things so far!

- We CAN observe 2D ssha patterns of river plumes for the first time
  - Even if can't see the front or the liftoff, we see the gradient from plume to ambient
- We can detect the front with sigma0

Challenges:

- The noise is close to our targeted signals
  - We need to improve our filtering

Next steps:

- Map visible plumes and their conditions
- Explain the importance of such gradients on individual plumes dynamics

Thank you so much,

merci beaucoup,

muito obrigada,

SWOT mission team for making this research possible!

You are truly amazing =)