Variations in offshore advection of Amazon-Orinoco plume waters diagnosed with satellite salinity and altimeter data

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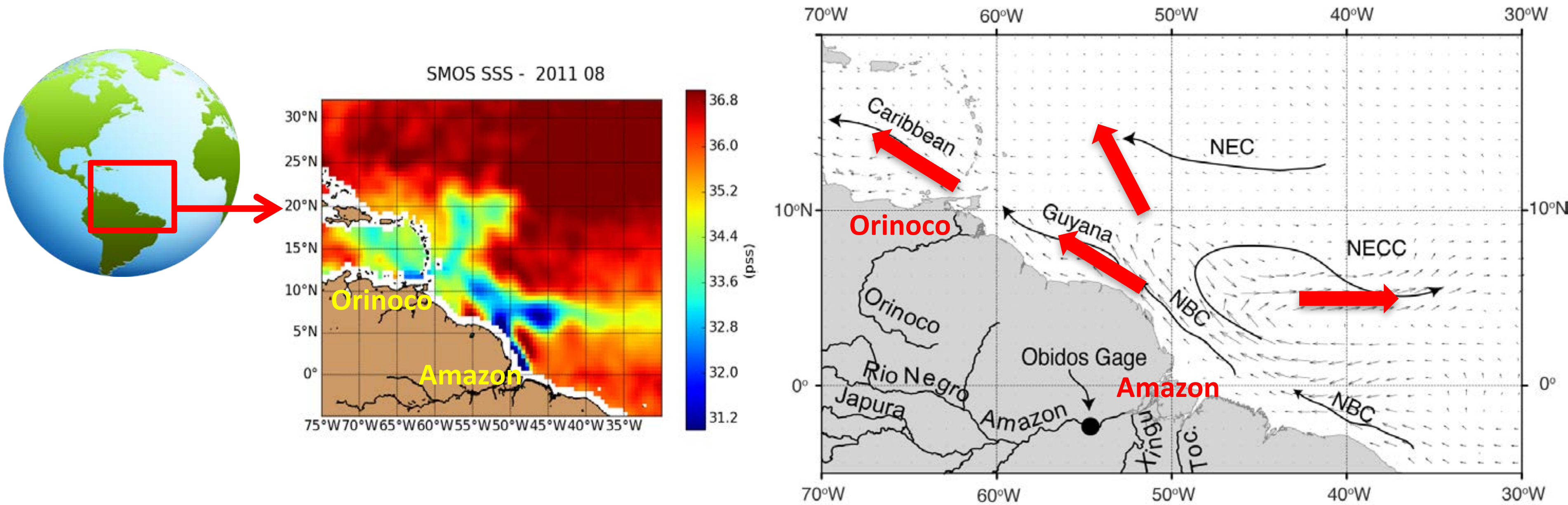
Motivations & Context



- River discharge often dominates regional SSS variations in summer
  - Amazon is world's largest discharge (0.2 Sv); flow increase starts in April
  - Orinoco discharge is the 4th largest (0.04 Sv)
- Horizontal advection of plume-dominated layers extend >1500 km from shore
- Transport includes freshwater, heat, biochemical material

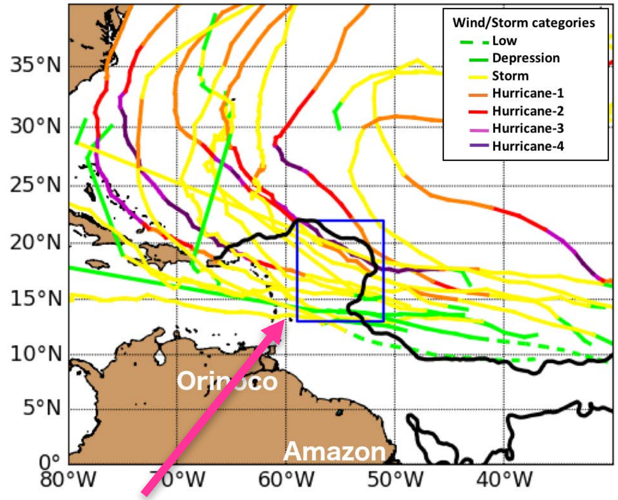
Motivations & Context

Summer river advection : potentially important factors in air-sea coupling

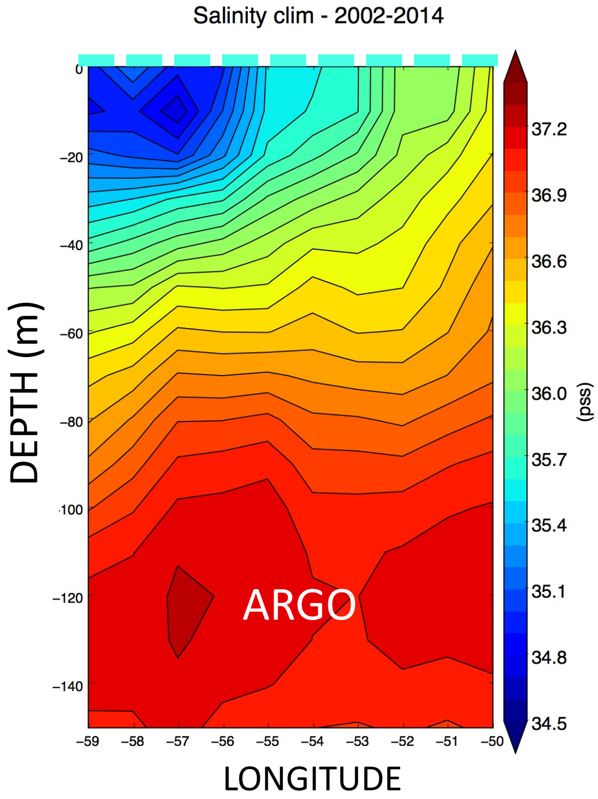
- SSS (density) and SST fronts, buoyancy of surface layer, vertical stratification
- Contribution to density-controlled pycnocline (can exceeds 40 m)
    - prevents exchange between the warm mixed layer and the cold ocean interior
    - can affects temperature in the tropics

➡ **Coincides with Tropical cyclone intensification**
June-November – maximum plume extension

Hurricane tracks 15 July-15 September 2010-2014



Northern Plume Region (NPR)

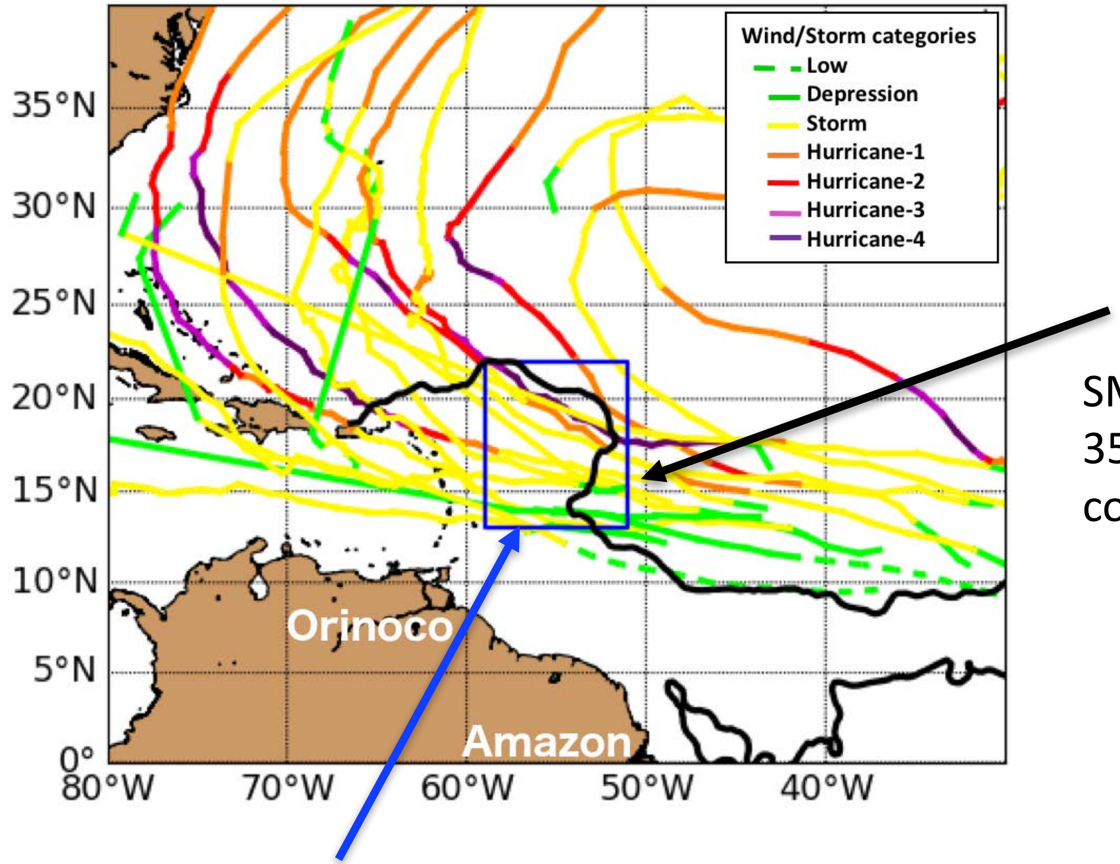


Motivations & Context

Amazon's NNE extension coincides with middle of Tropical cyclone season

15 July – 15 Sept is minimum SSS and max. plume extension

Hurricane tracks 15 July-15 September 2010-2014



SMOS SSS 35.5 psu contour

Chosen study box -> Northern Plume Region (NPR)

Motivations & Context

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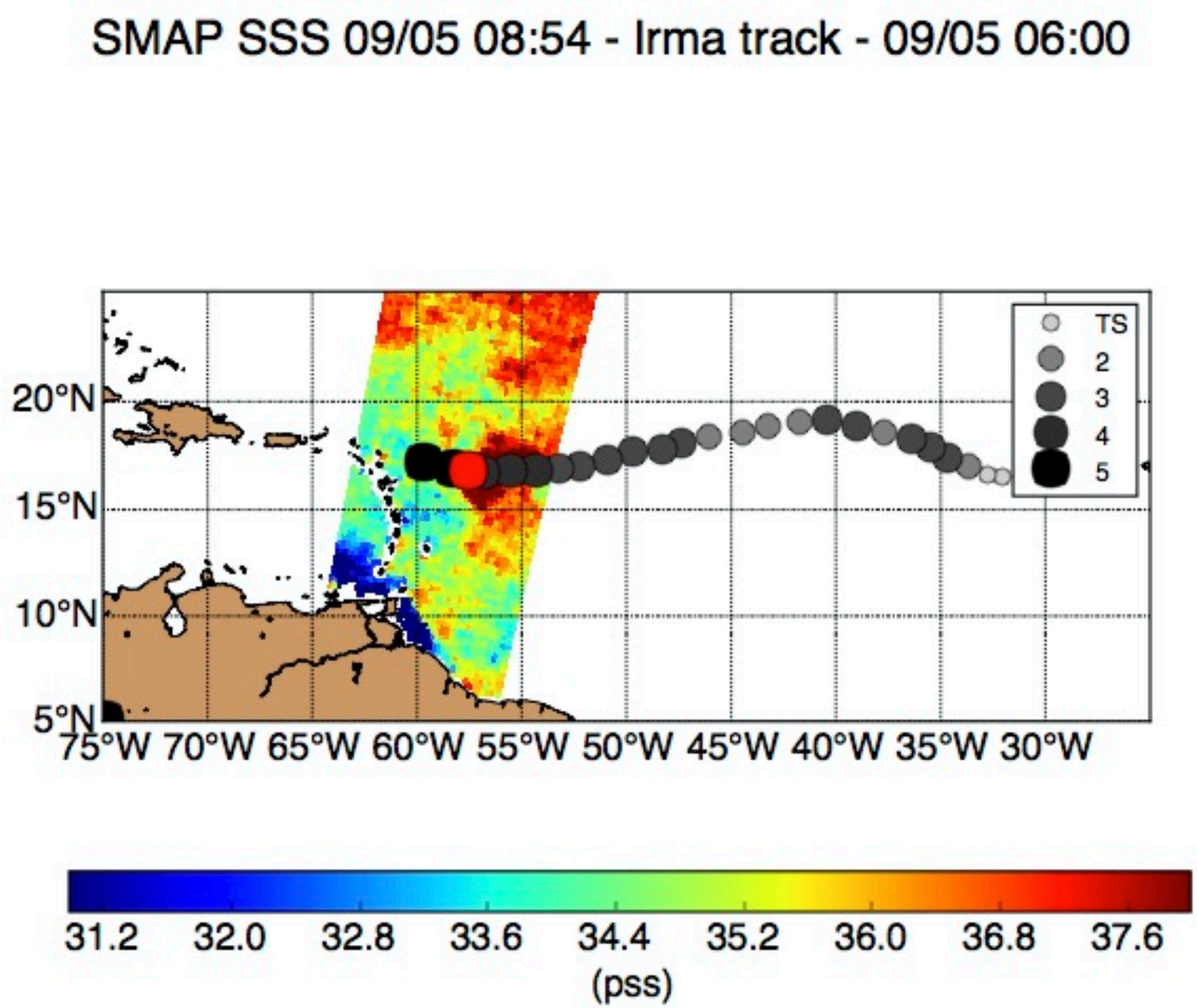


Recent motivating studies

SST variation linked to advected runoff and potential impact on TC formation (preconditions):

Ffield, 2007 (NBC rings and surface heat transport)

Vizy and Cook, 2010 (atmosphere change due to SST-altered ocean; increased TCs)

Pathways of runoff advection:

Coles et al, 2013 (modeled using ROMS, drifter data)

Potential upper ocean-atmosphere interactions with tropical storms:

Reul et al., 2014 (TC interaction with upper ocean, salty wakes)

Grodsky et al., 2012

Hernandez et al., 2016 (model work showing salinity impact is weak on OHC->TC)

Newinger and Toumi, 2015 (twin model experiments showing SST and SSS uncoupled)

Objective

Use satellite observations to improve our view of surface ocean variability and its controls on upper ocean variability and its coupling to atmospheric dynamics (convection, rainfall, interaction with TCs)

SSS, SST, currents, vector winds

Can we now monitor the spatial and temporal dispersal of the Amazon and Orinoco river plumes to evaluate their impact on BL thickness and temperature variations?

Questions

Ocean state

Q1: Do SSS and SST in this plume-impacted region (NPR) vary substantially summer to summer?

Q2: Do SSS and SST covary this far offshore – particularly zonally with warmer SST shoreward (per Vizy and Cook 2010)?

Diagnosis

Q3: Can we use satellite SSS and ocean current (OSCAR) observations to trace near-surface advection of discharge for weeks-months in this dynamic region?

Q4: Which physical controls dominate interannual SSS (& SST) variability:

- changes in river runoff?
- changes in NBC ring/plume interactions?
- changes in local winds?

Data : **observations**

ESA SMOS SSS : 10-day, 0.25° (LOCEAN, CECOS)

OSTIA SST: daily, 0.054° (PO.DAAC)

OSCAR currents : 5-day, 0.33° (PO.DAAC)

ASCAT wind vector: near surface (10m), daily, 0.25° (CERSAT)

MODIS AQUA acdm at 443nm : 8-day running mean, 9km (Ocean Color)

ARGO IPRC/APDRC MLD: monthly 1°x1° (IPRC/APDRC)

River discharge: monthly at Obidos and Bolivar (ORE HYBAM)

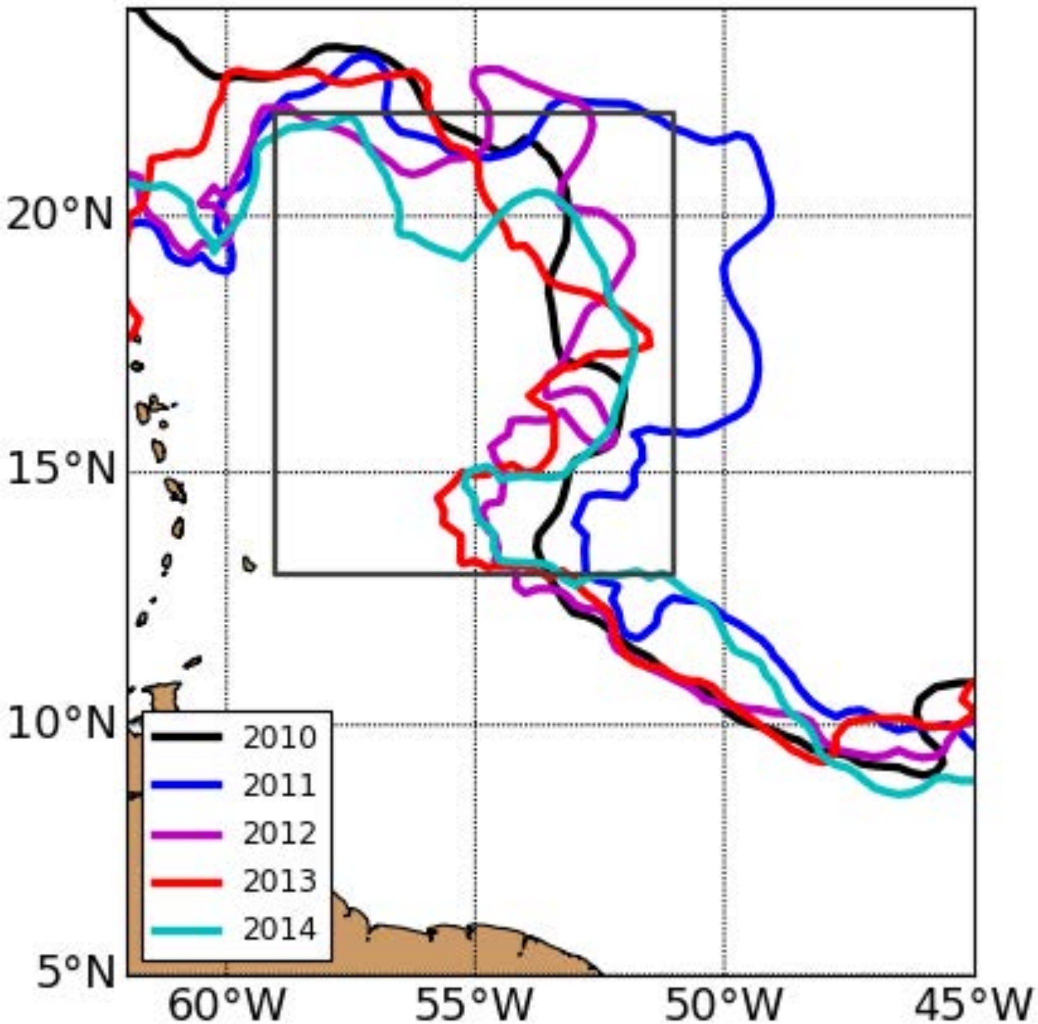
Hurricane storm track record: UNYSIS WEATHER

Tracer Methods

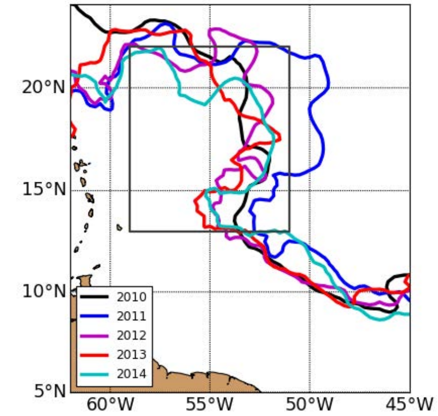
- Forward or backward Lagrangian advection based on AVISO & OSCAR surface currents, locally interpolated, time step = 0.2 days
- Co-register physical OBSERVATIONS with tracers each day

Monthly average in region of interest

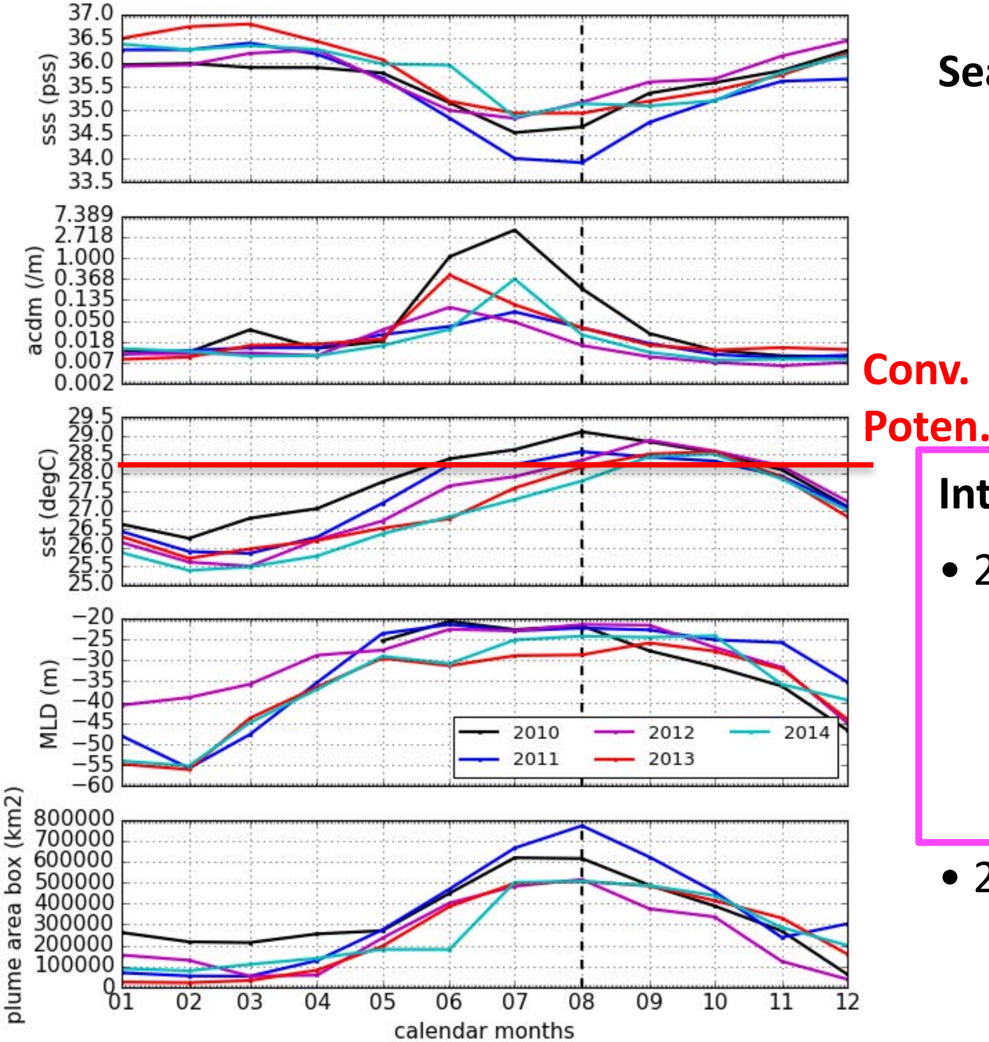
SMOS SSS 35.5 psu front – AUGUST 2010-2014



Monthly avg in region of interest



August = Month of peak advection + coincidence with TC season

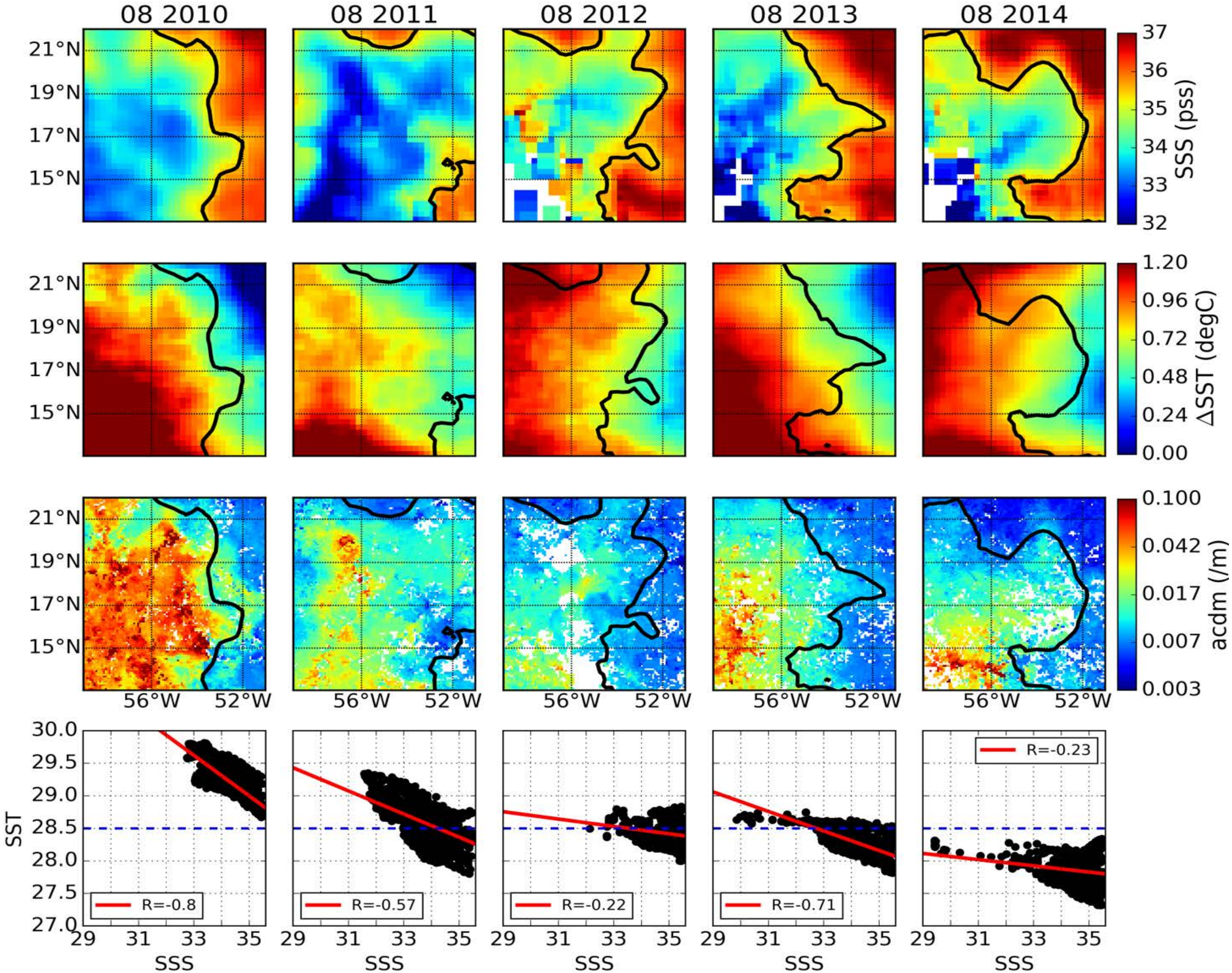


Seasonal variations:

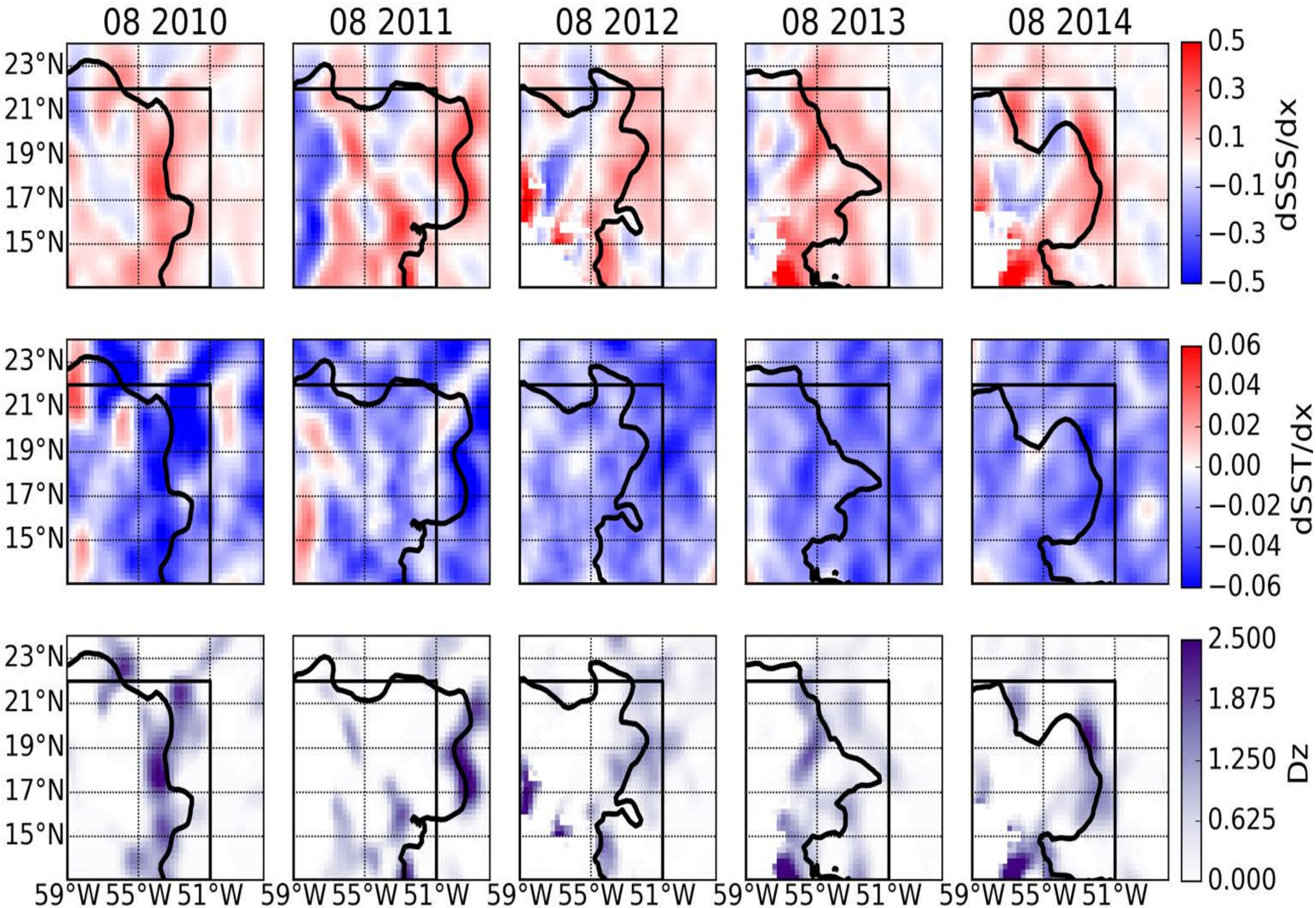
- freshening from April-May
- increase in plume coverage
- increase in acdm
- shoaling of MLD
- warming from winter to summer

Interannual variations:

- 2010-2011, in contrast to 2013-2014:
  - fresher SSS
  - higher SST
  - shallower MLD
  - increased plume coverage
- 2010:
  - consistently warmer from January
  - higher acdm



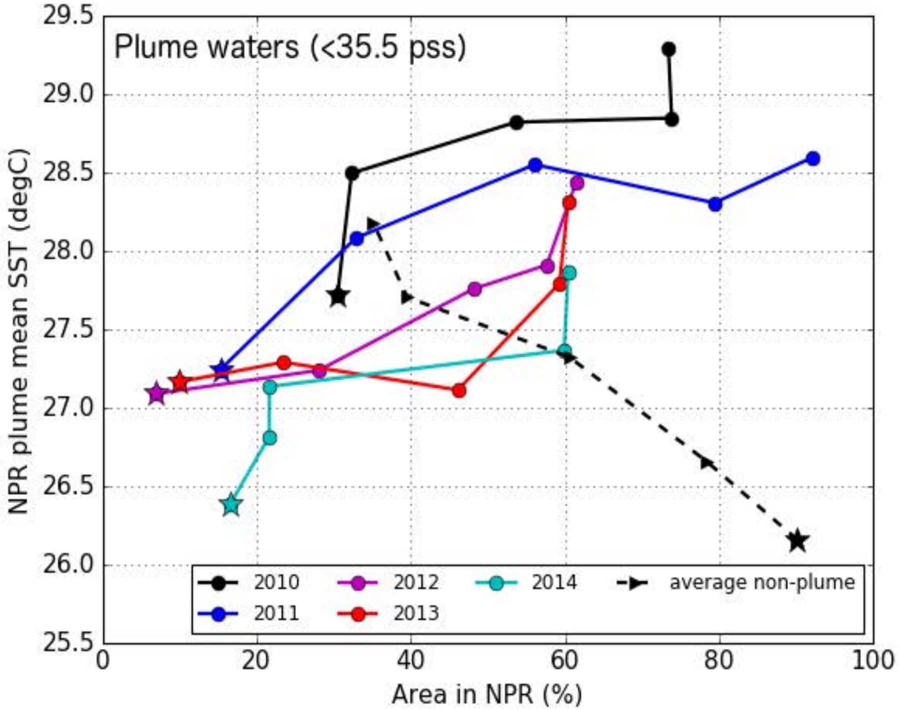
08 2010
08 2011
08 2012
08 2013
08 2014
21°N
19°N
17°N
15°N
37
36
35
34
33
32
SSS (pss)
1.20
0.96
0.72
0.48
0.24
0.00
ΔSST (degC)
0.100
0.042
0.017
0.007
0.003
acdm (/m)
56°W
52°W
30.0
29.5
29.0
28.5
28.0
27.5
27.0
SST
29
31
33
35
SSS
R=-0.8
R=-0.57
R=-0.22
R=-0.71
R=-0.23

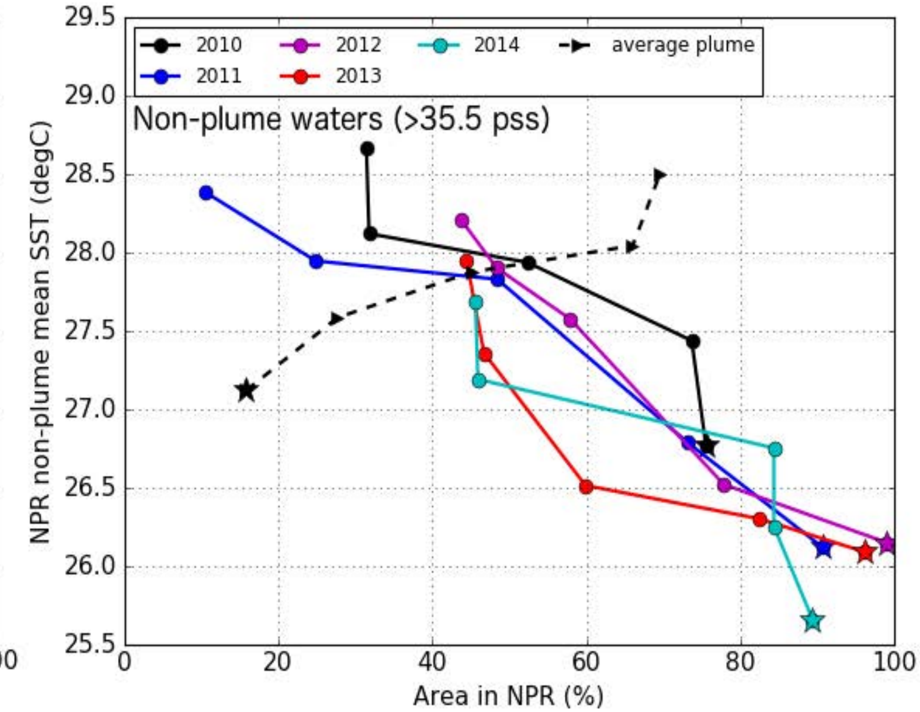


Strongest covariance of zonal SST and SSS gradients near plume edge in each year

SST change within (left) versus out (right) of the plume-impacted NPR from April-August

shown vs. areal coverage across NPR





Questions

Ocean state

Q1: Do SSS and SST in this plume-impacted region (NPR) vary substantially summer to summer?

YES

- 2010-2011 much more freshwater and increased SST
- 2010 much warmer everywhere

Q2: Do SSS and SST covary this far offshore– particularly zonally with warmer SST shoreward?

YES

- weak but persistent SST:SSS anticorrelation
- strongest covariance near eastern plume edge in NPR
- strongest in 2010-2011

Advection and controls

Advection BACKWARD from the NPR

Particles launched everyday in the NPR and advected backward to the Orinoco and Amazon mouths

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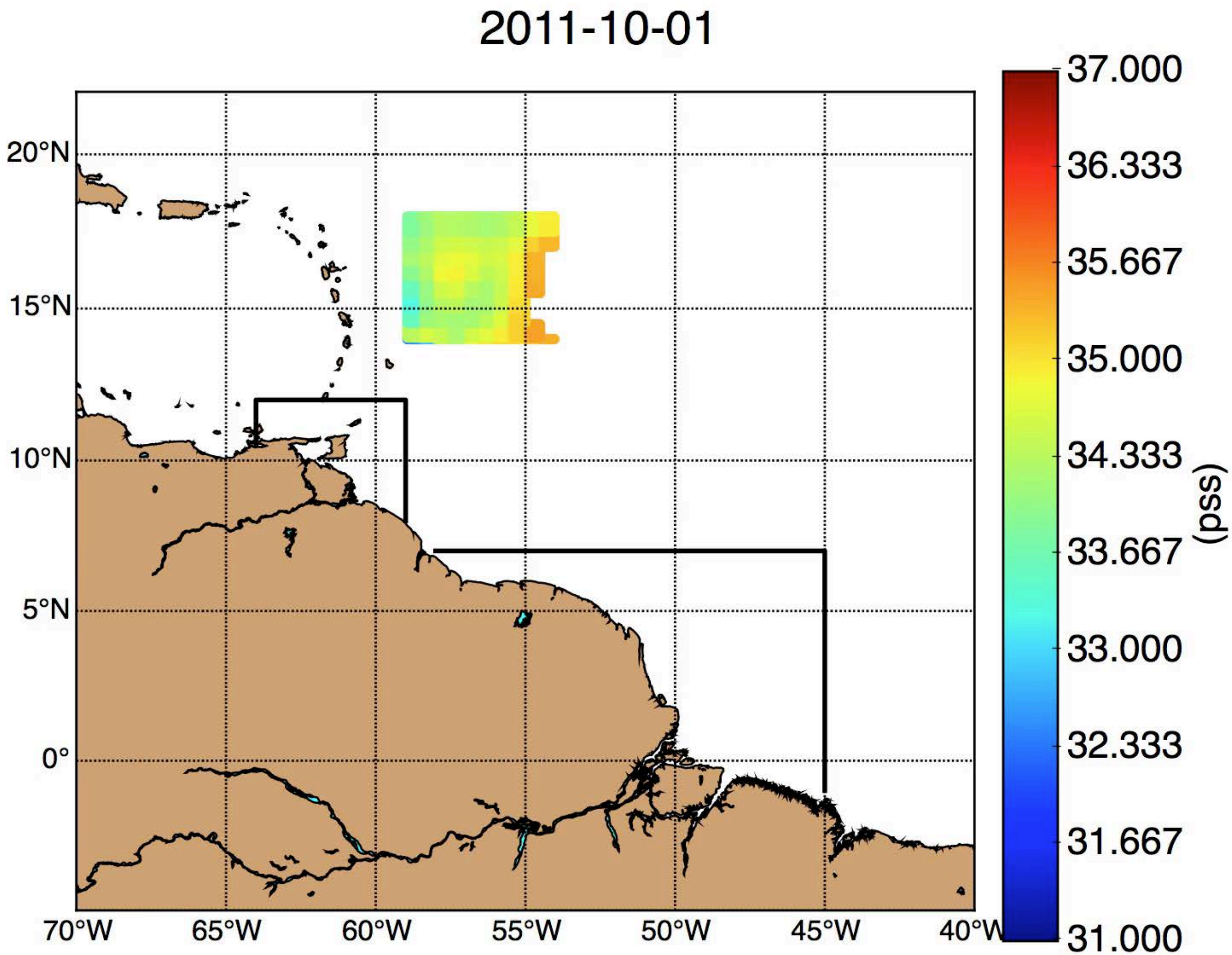
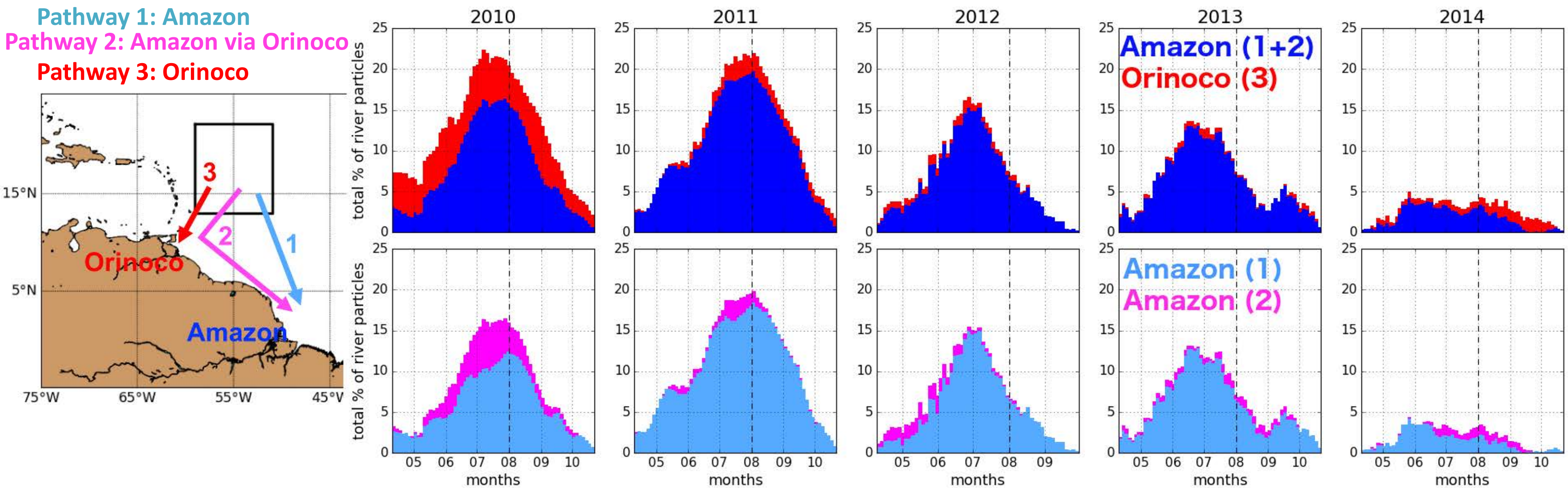
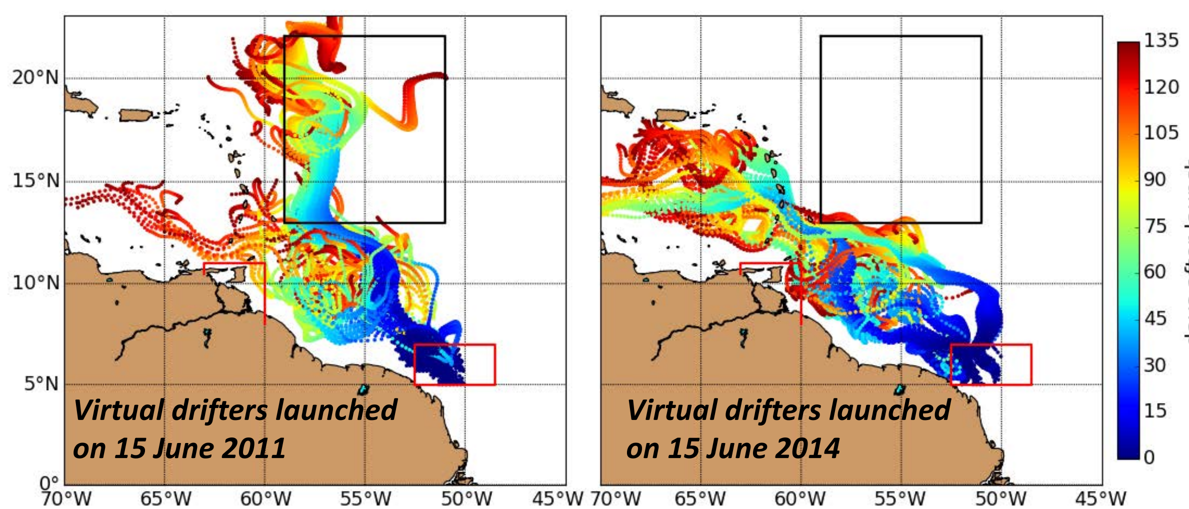


Advection BACKWARD from the TC region



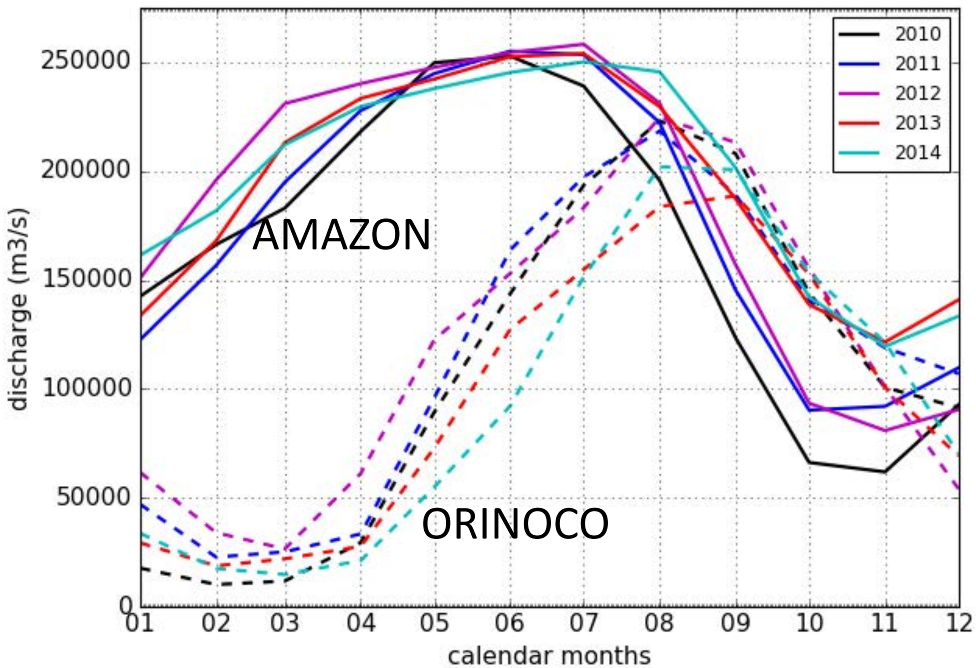
FORWARD



Backward Lagrangian advection from the NPR along 3 pathways:

- Dominance of Amazon versus Orinoco advection
- Amazon path 1 (direct) dominates over path 2
- 2014 has 6-8 times less particles traced back vs. 2010-2011

EVALUATION OF CONTROLS AND OBSERVED INTERANNUAL VARIABILITY
Freshwater input

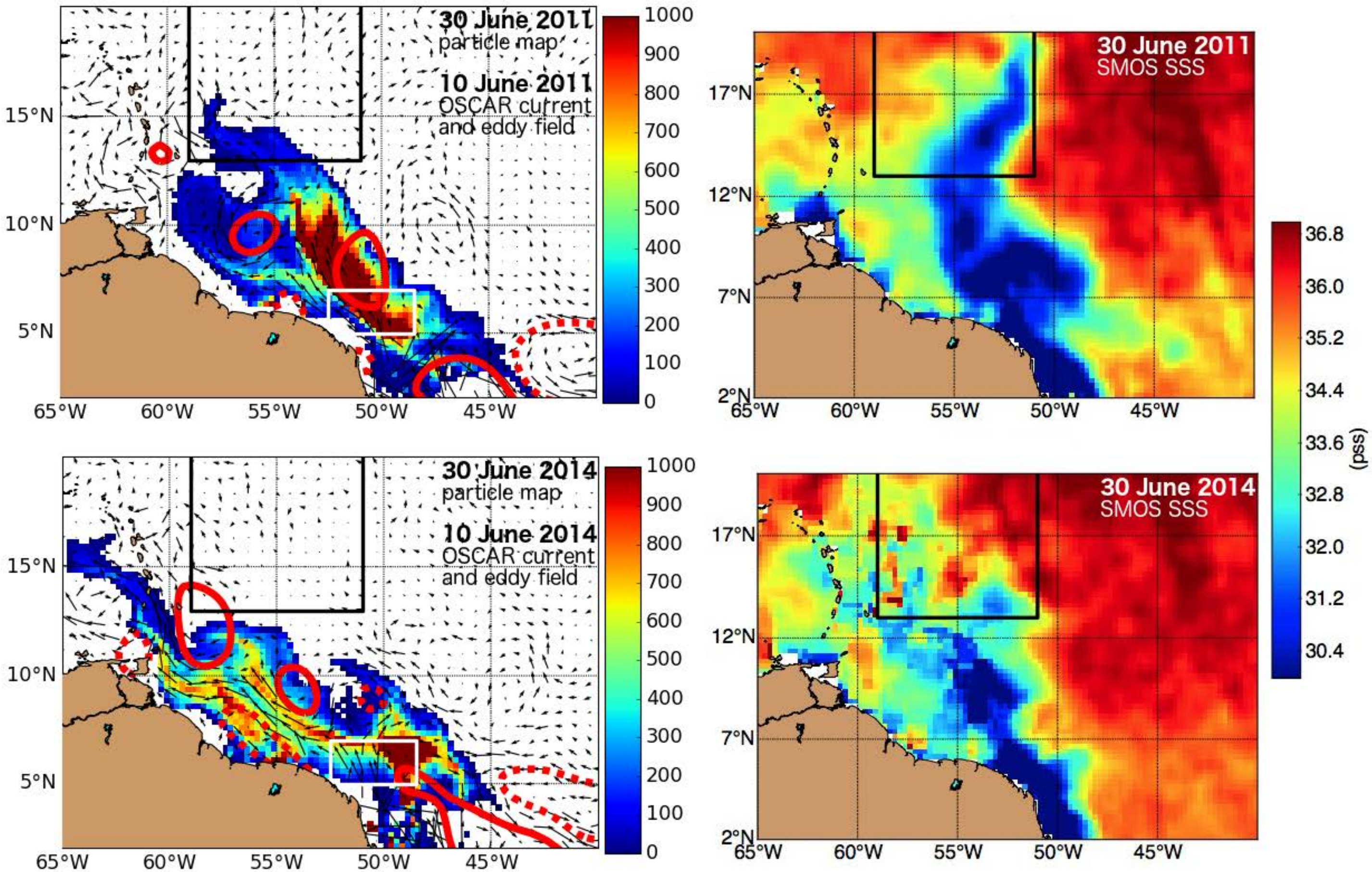


Amazon discharge remarkably consistent over 2010-2014

⬇

Runoff variations do not explain the interannual variability in the freshwater dispersal

EVALUATION OF CONTROLS AND OBSERVED INTERANNUAL VARIABILITY
Eddy-driven transport



Lagrangian tracer mapping of the net particle accumulation: Particles launched (white box) between the 20th of May and the 5th of June, advection stopped on the 30th of June

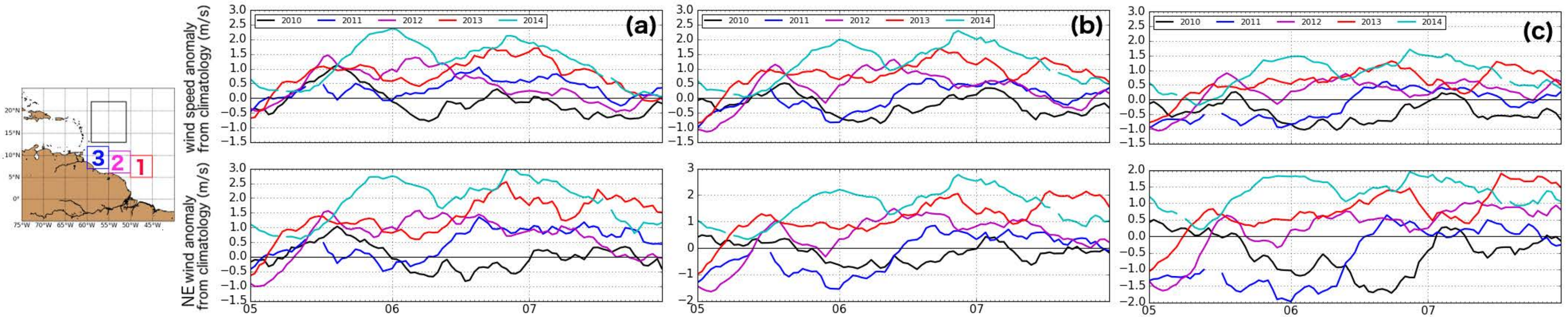
Eddy interaction with Amazon runoff:

- **May-June 2011** - cyclonic eddy exports freshwater off the shelf and to the NE

- **May-June 2014** - twin eddies funnel the flow along the coast transport stays closer to the coast in 2014 vs 2011

EVALUATION OF CONTROLS AND OBSERVED INTERANNUAL VARIABILITY

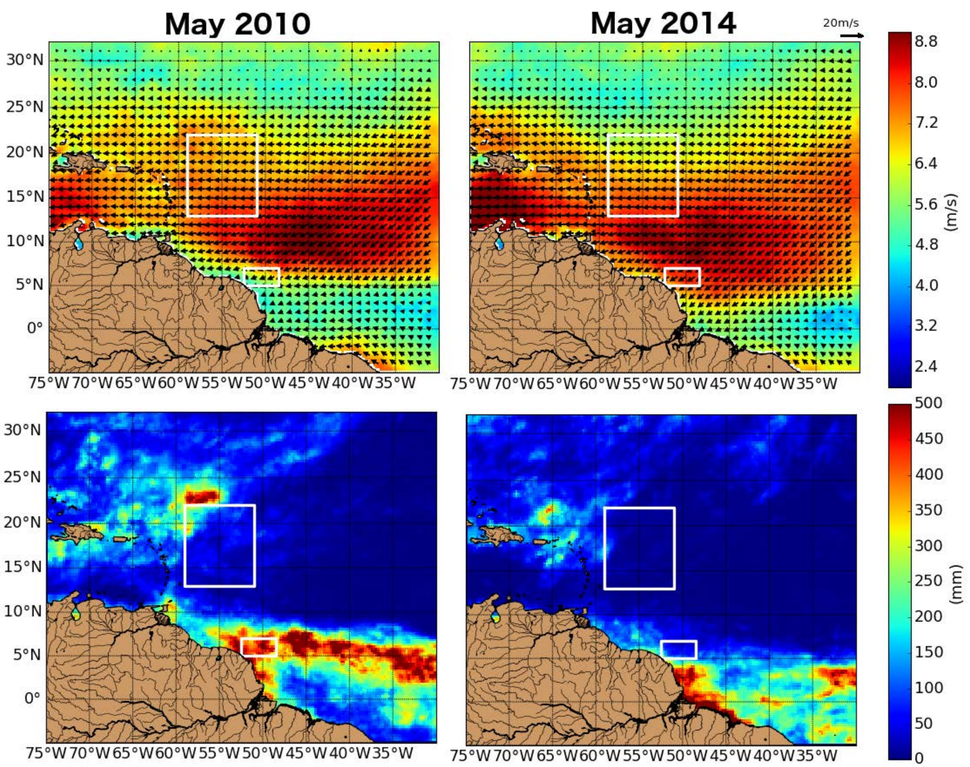
Cross-shore winds



2014: NE winds much stronger than in 2010-2011

- winds allow off-shelf NW advection of water in 2010-2011
- winds contain the plume closer to the coast in 2014

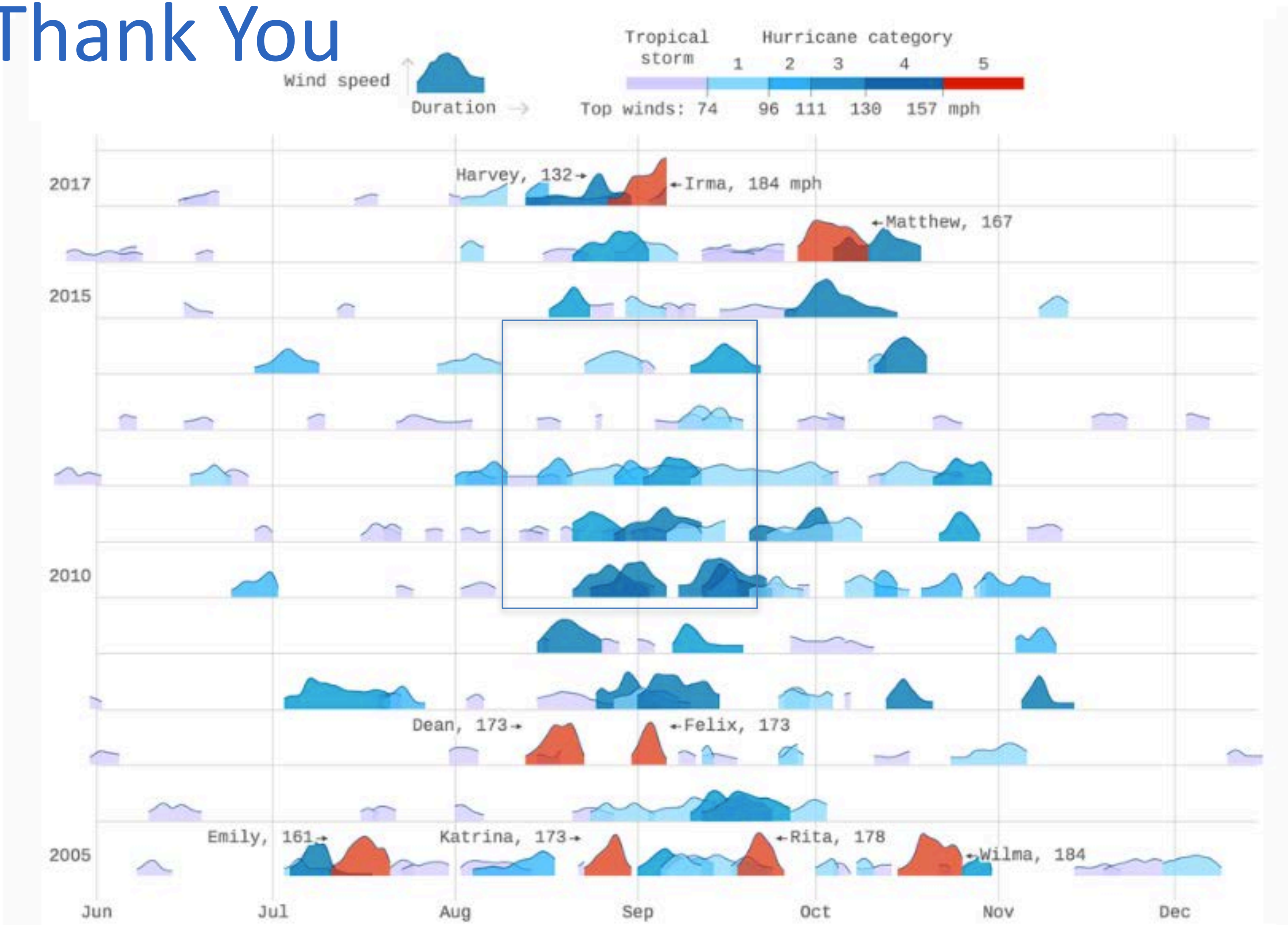
ITCZ location (further south in 2014)



Conclusions and Perspectives

- Areal coverage, SSS, & SST of the distal river plume in the northwestern tropical Atlantic show significant variability east of leeward islands from 2010-2014
- Control by variation in runoff is unlikely (but 2010 Orinoco influence might warrant further study)
- Likely advection control is combination of May-June eddy-plume interactions as well as strength of cross-shore winds
- Persistent zonal SST gradients are linked to freshwater-controlled surface salinity
- Interannual changes in NPR SST, plume-advection, winds, and SSS may be tied to larger-scale dynamics across the tropical Atlantic (AMM, ITCZ)

Thank You



Note: The Atlantic storm season spans June 1 to Nov. 30. Storms do occur outside of that window, but not all of them are shown here. Data: NOAA; Chart: Chris Canipe / Axios

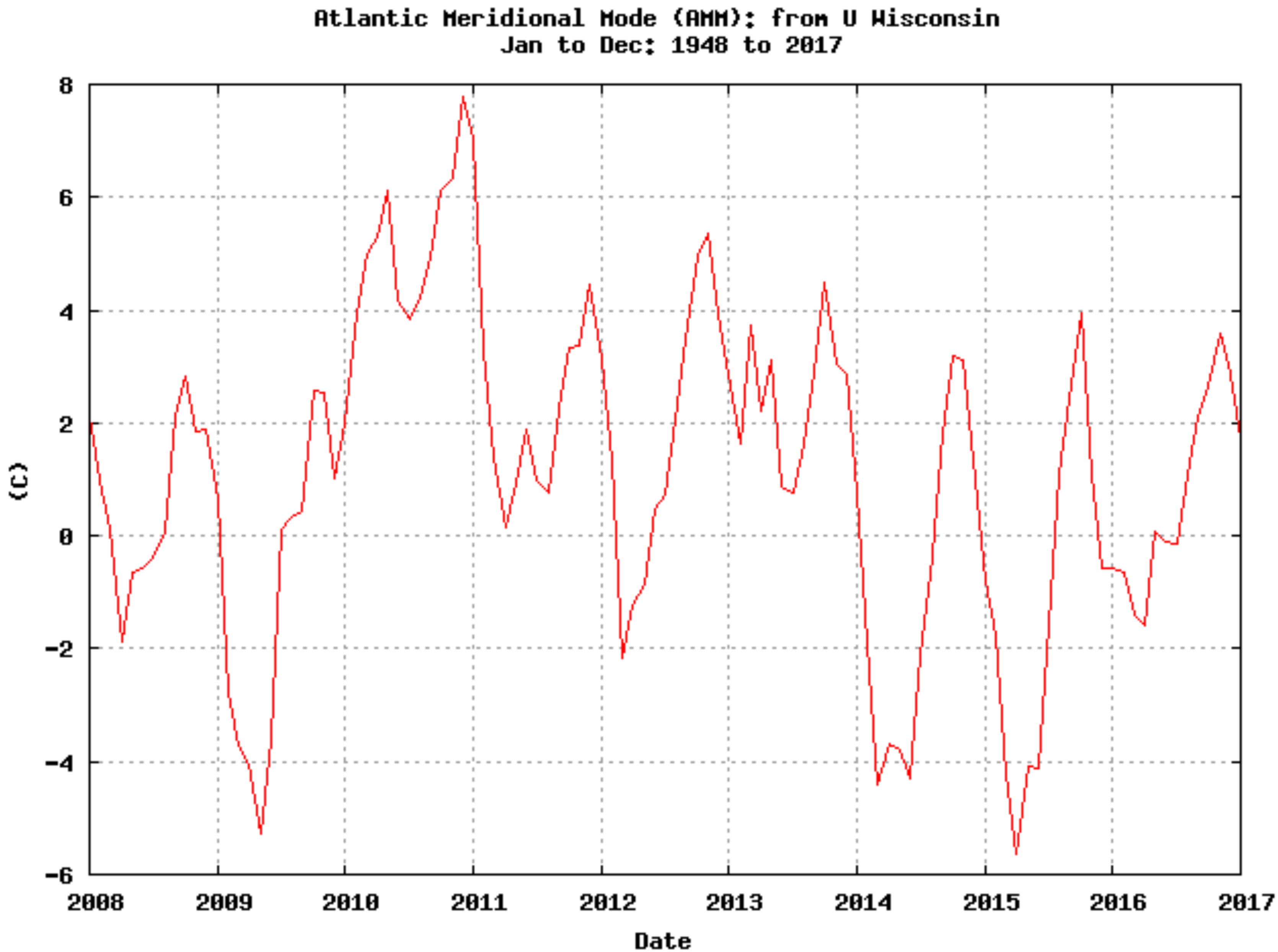
Thank You

AVISO vs OSCAR currents : an ongoing work

- AVISO: geostrophic component only
  - Daily, 0.25 deg (SSH +/- 15d but recalculate everyday)
  - Instrumental error on SSH (2-3 cm)
  - Error compared to real velocity because the Ekman component is missing

- OSCAR: geostrophic + Ekman component
  - 5-day, 0.3 deg (degradation of AVISO SSH to calculate currents -> comparable to what is gained with the addition of the Ekman component ?)
  - Same instrumental error
  - Incertitude on the Ekman component computation (high frequency wind (3 to 6h) and MLD needed)
  - Introduction of tracers information (SST) -> no independance with tracers *(personal communication PODAAC)*

➡ OSCAR should evolve to daily, 0.25 deg -> comparison then possible

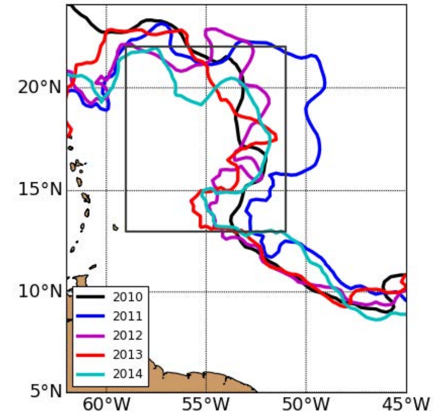

Atlantic Meridional Mode (AMM): from U Wisconsin
Jan to Dec: 1948 to 2017
8
6
4
2
0
-2
-4
-6
(C)
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Date

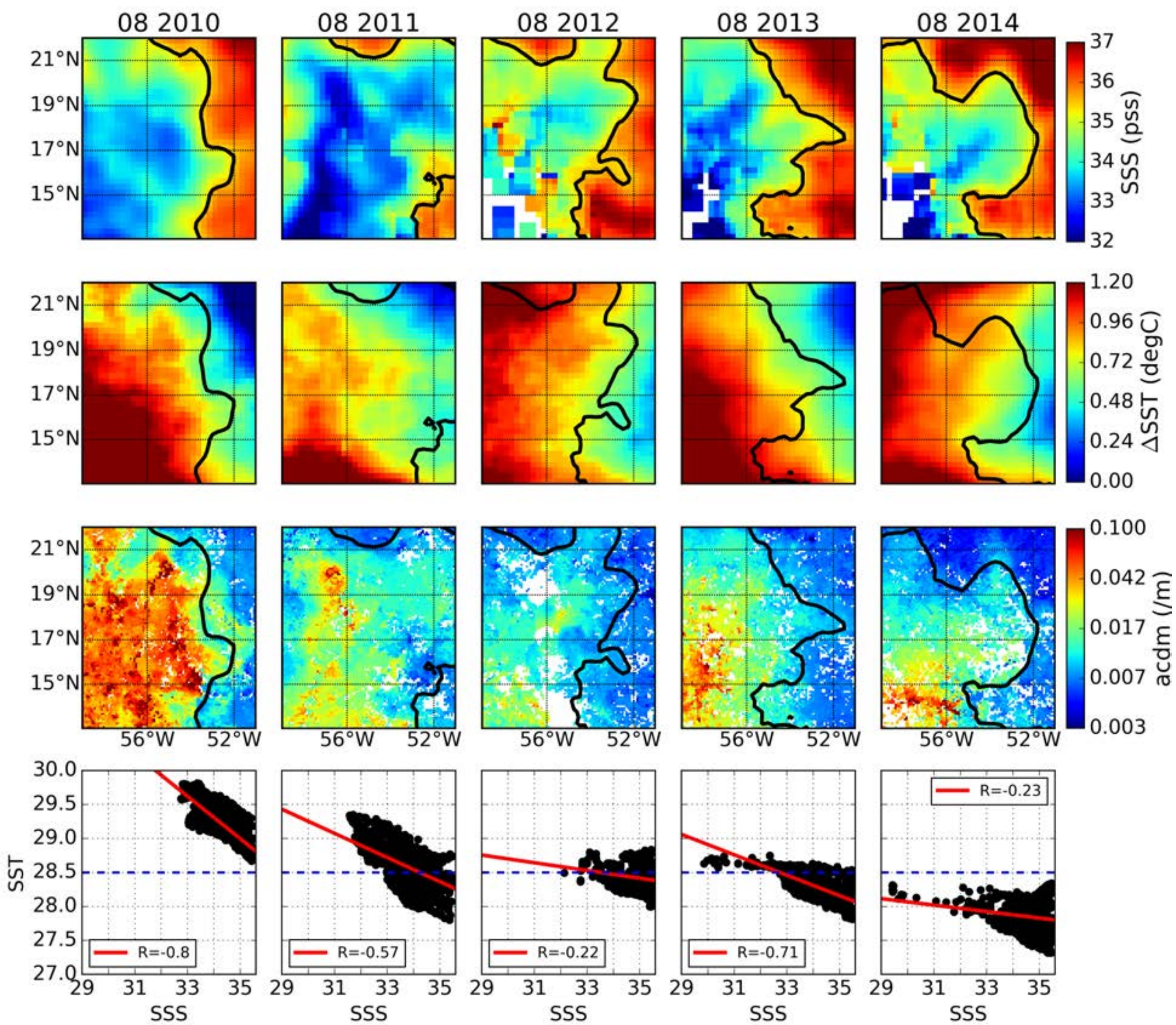
TRACERS USING NO DIFFUSION

- Diffusion would be a brownian mouvement, it only adds noise, no physics behind it

- If working with concentrations, it would be necessary

Our NPR region of interest

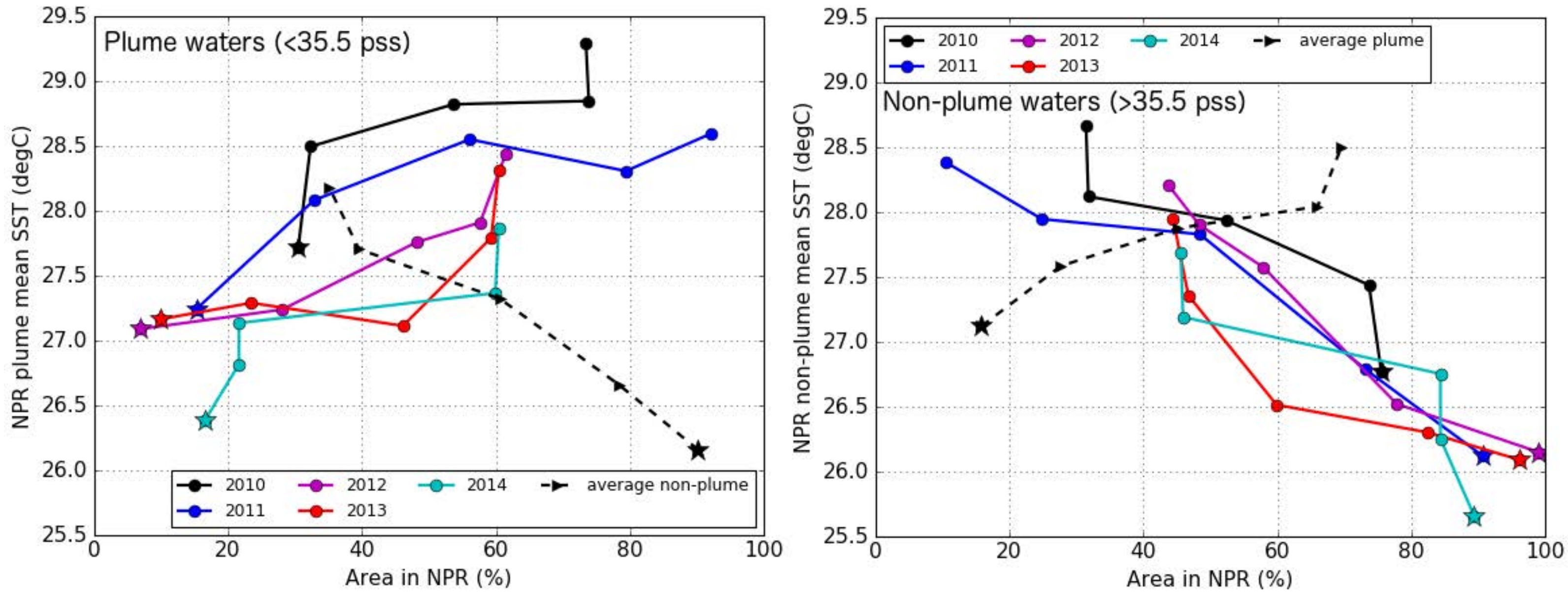




Interannual variations:

- SW area usually fresher and warmer
- correlation fresh SSS/warm SST/high acdm
- SST-SSS inverse correlation -> relationship between plume waters and SST
- 2010: SST 1°C warmer than in 2014

Our NPR region of interest



- May 2010-2011: in- plume SSTs >28.5°C
- July-August plume coverage: ~80% (20% greater than for 2012-2014)
- Spring-to-summer SST increase with time in both cases

Observed interannual changes tied to larger-scale dynamics across the tropical Atlantic Ocean

Significant interannual variation:

- ITCZ location (further south in 2014)

Coastal wind direction near the shelf
Can alter net heat flux and wind fields (impact on spring-summer plume water characteristics/advection)

- Dramatically differing SST of order 1°C across the whole basin (Atlantic Meridional Mode (AMM) – 2010 vs 2014)