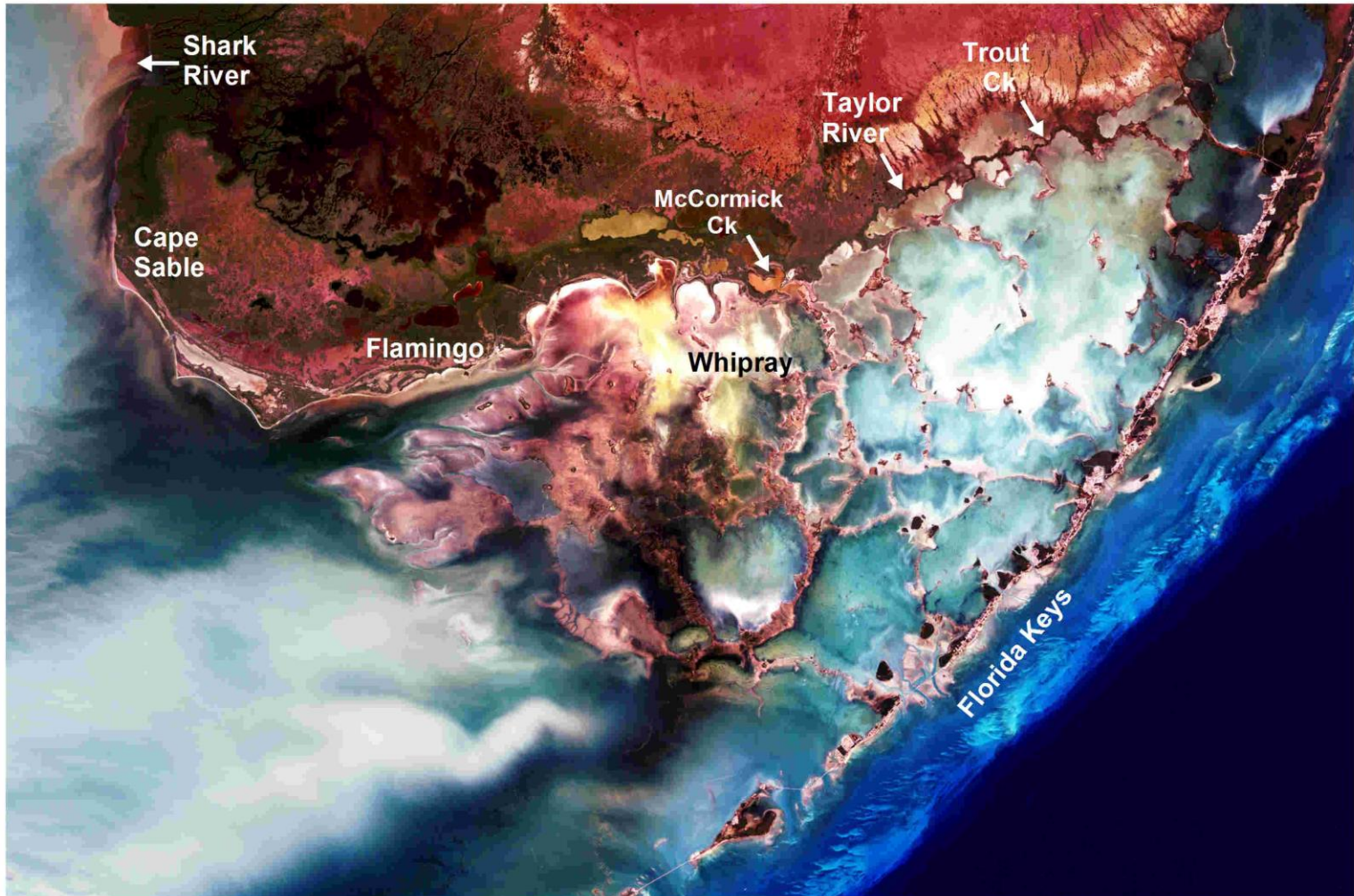# Understanding Florida Bay Hypersalinity and Water Exchange

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Libby Johns, Ryan Smith and Peter Ortner-AOML;
DeWitt Smith-ENP; and Ned Smith-HBOI

Aerial view of Florida Bay (FB) and the southern Everglades showing the banks (tan) and basins (blue and green) configuration, Whipray basin (WB), and river discharge points.

Seasonal cycle of monthly average salinity for the four regions of Fla Bay, from Nuttle *et al.*, 2000.
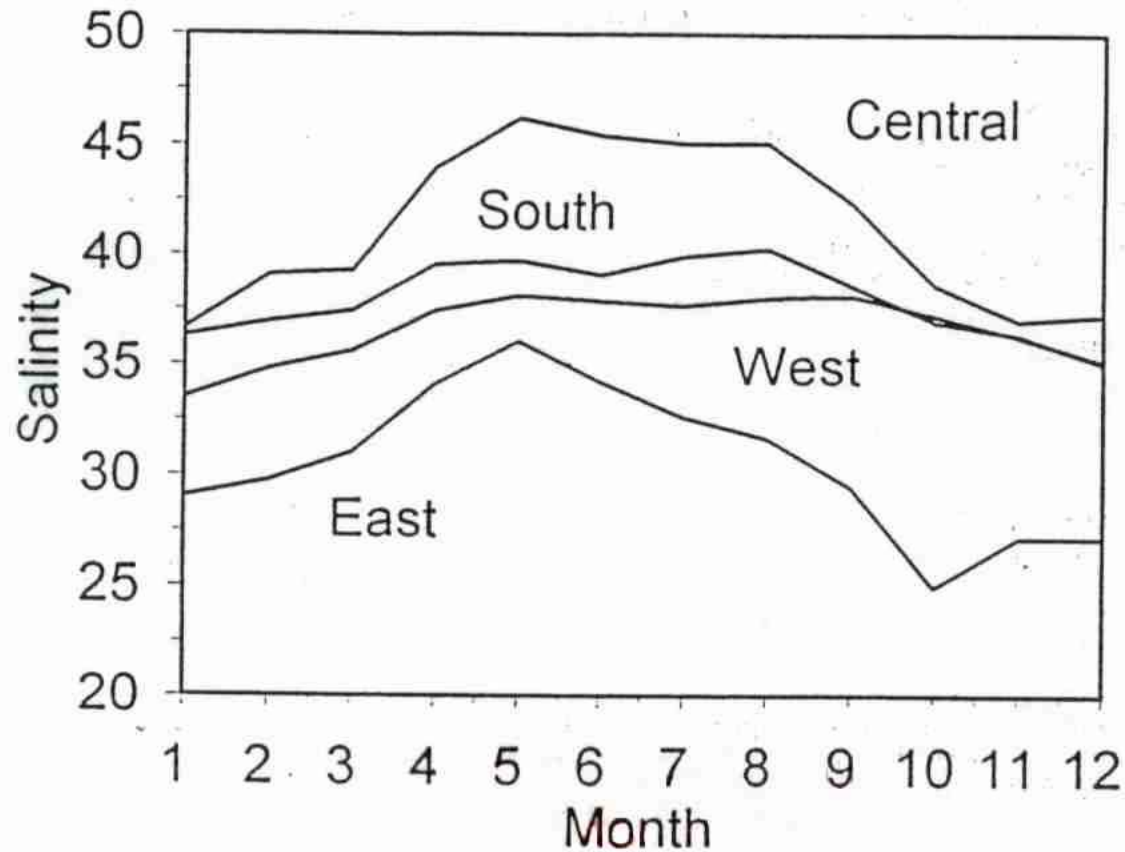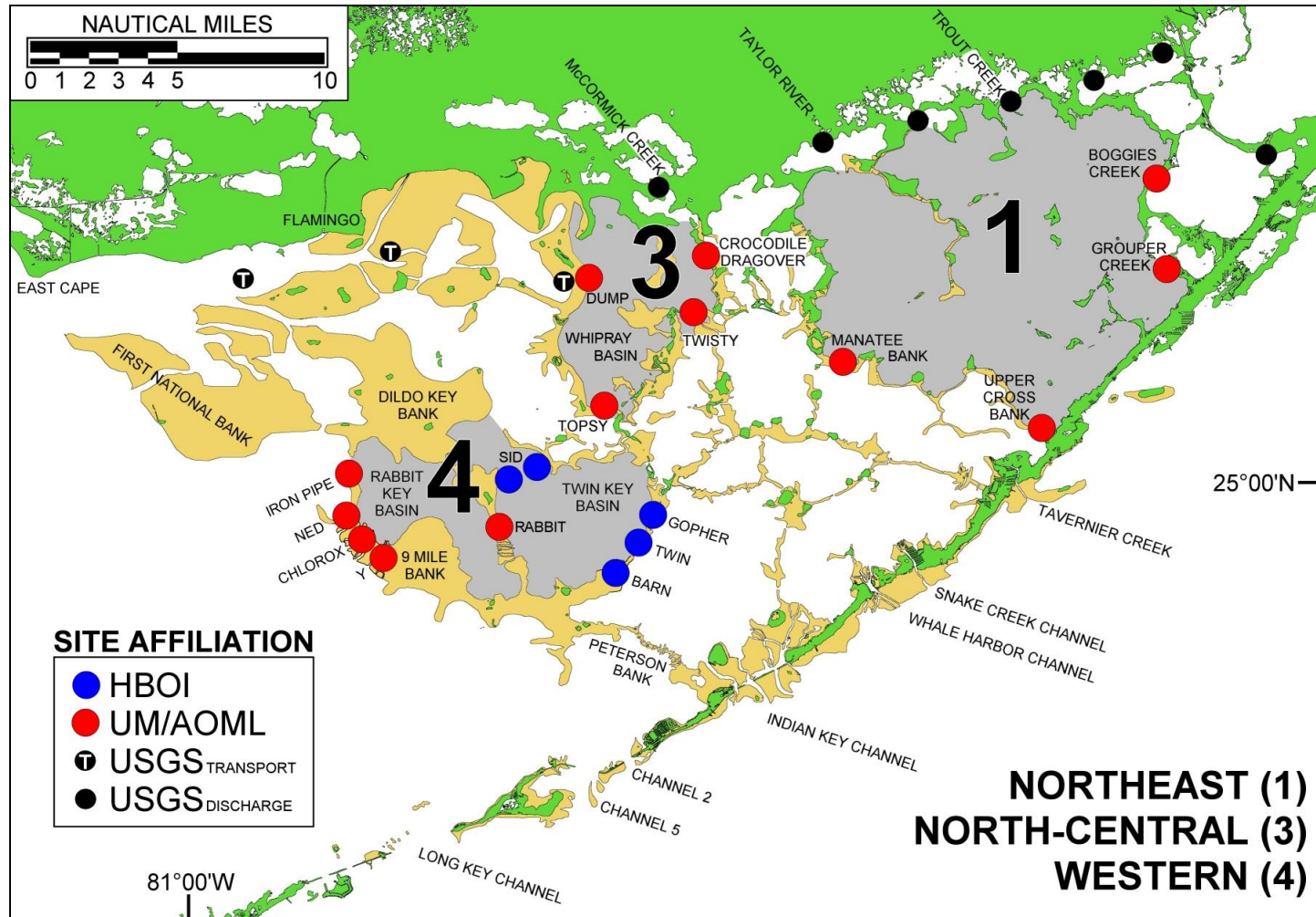
Figure 1. Moored instrumentation sites from recent studies of the inner basin circulation and exchange processes in northeast, north-central, and western basin sub-regions of Florida Bay. Also shown are USGS transport and river discharge measurement stations.

Location of WB measurement stations: crosses indicate current, temperature and salinity stations; diamonds show ENP tide stations; groups of 3 small crosses show drifter release sites; ADCP transport transects are shown with dashed lines and vessel survey track with solid bold line, upon which the arrow heads indicate vessel heading.
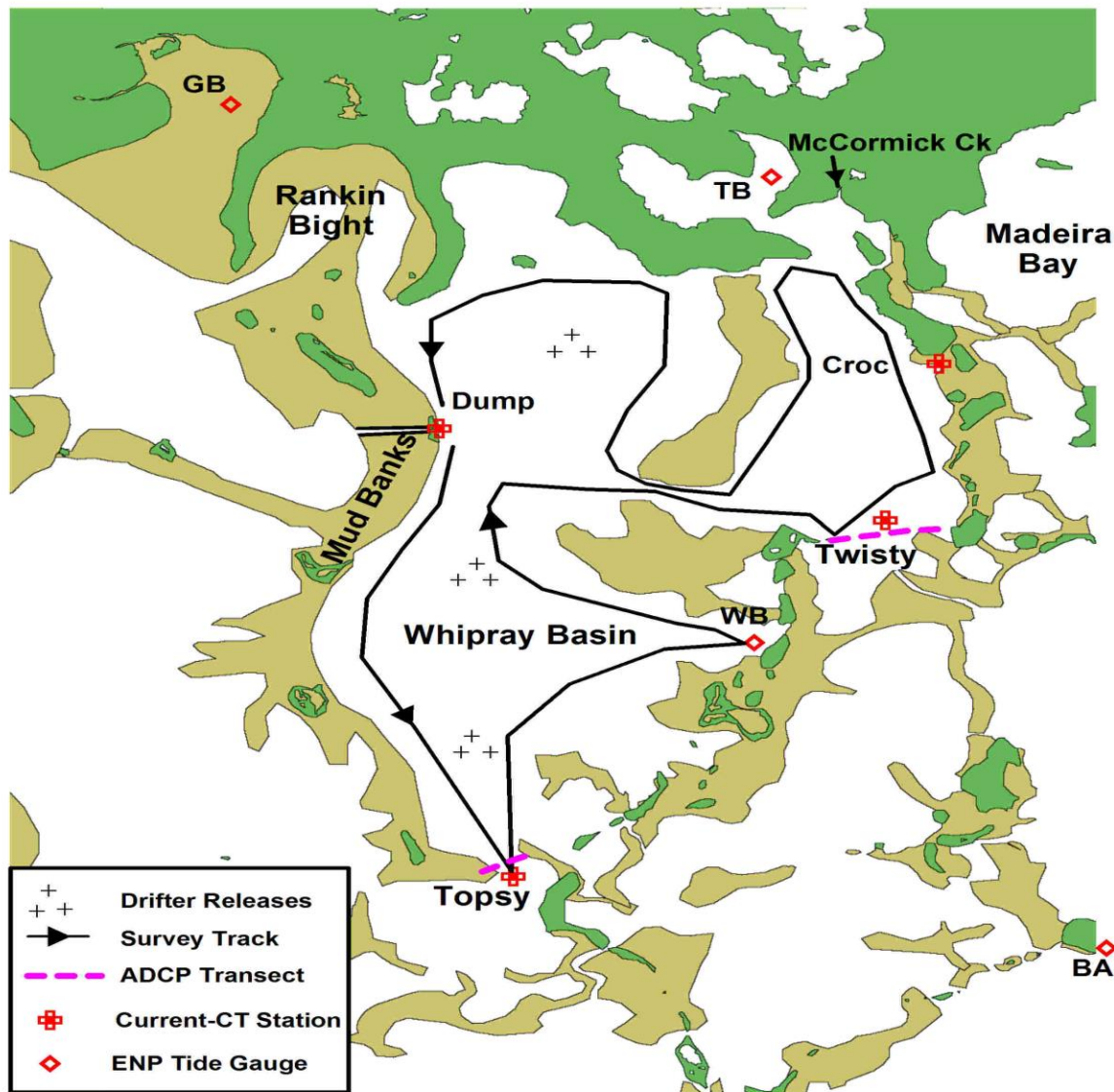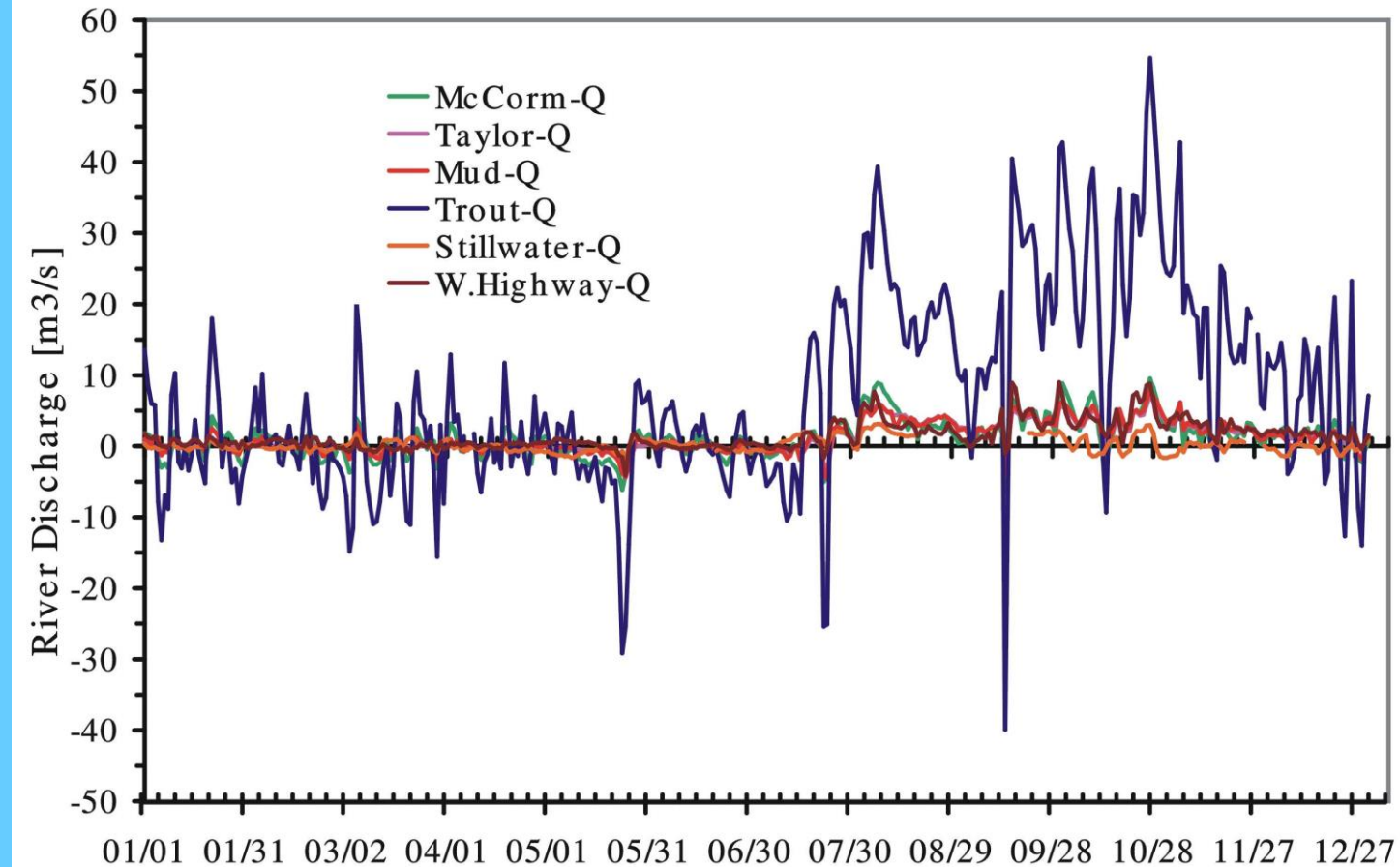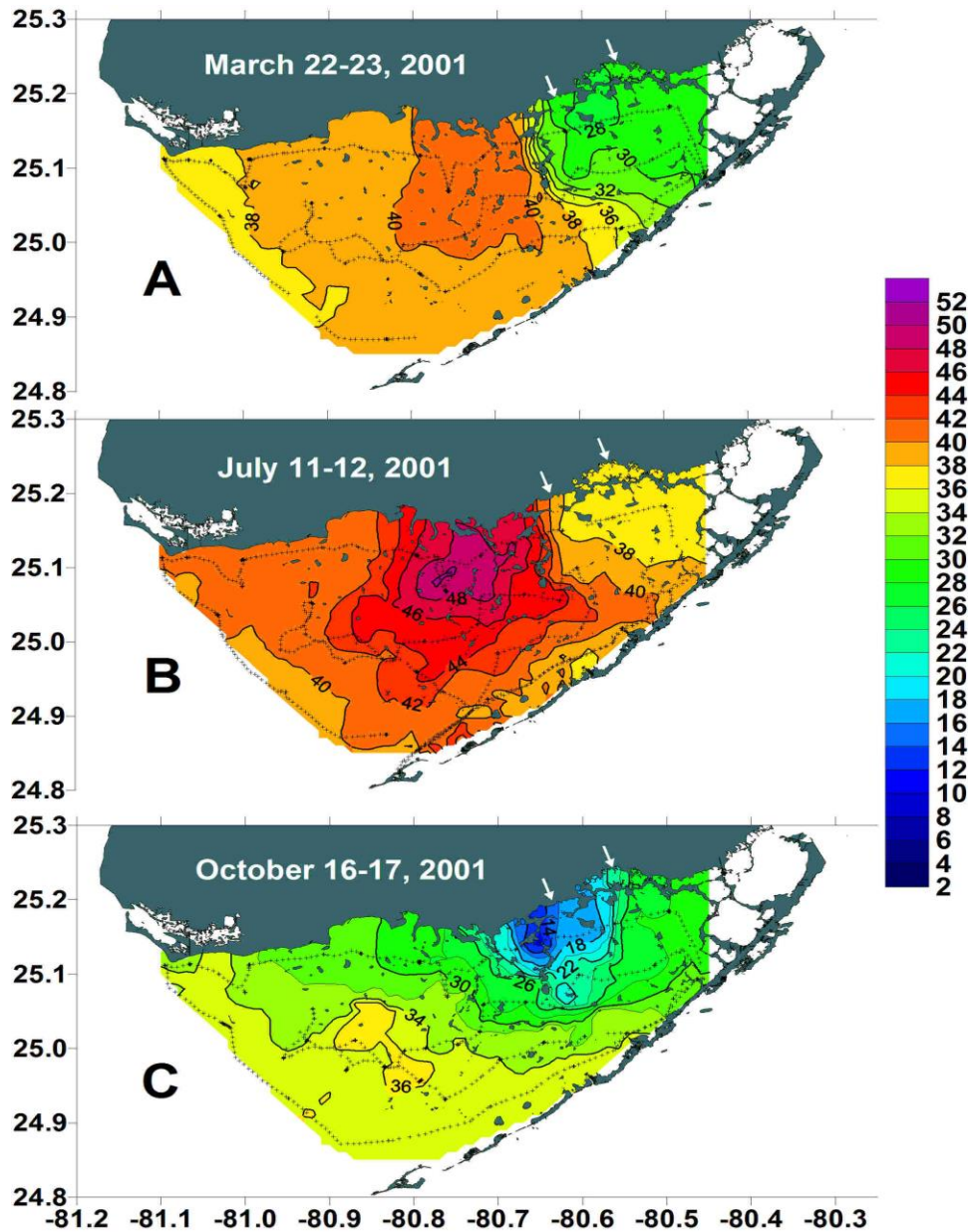
R/V Virginia K

Monthly average fresh water fluxes to Fla Bay from long-term measurements. (from Nuttle *et al.*, 2005).
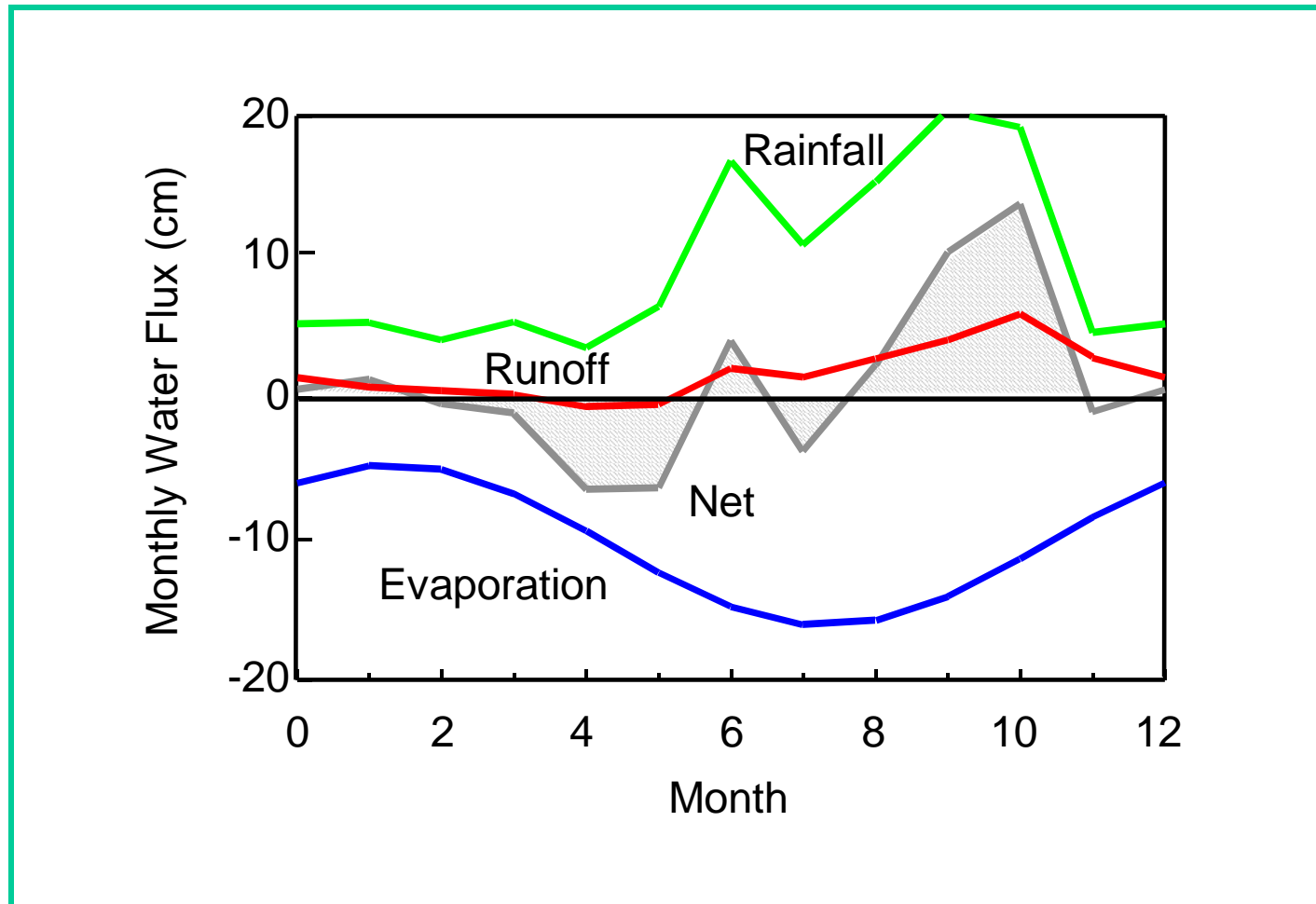
# Daily average fresh water discharge to Florida Bay for 2001. Data provided by U.S Geological Survey, South Florida Ecosystem Program, Information Access Site (USGS, 2005).

Florida Bay surface salinity from 2001 monthly surveys of the *R/V Virginia K* using continuous underway measurement for: A) March 22-23 dry season; B) July 11-12 near the end of the dry season; and C) October 16-17 wet season. Vessel track shown with dotted line.

WB surface salinity from high-resolution surveys of the *R/V Virginia K* using continuous underway measurement for: A) Mar. 28 dry season; B) Jul. 16 near the end of the dry season; C) Sept. 16 wet season; and D) Oct. 28 near the end of wet season 2001. Vessel track shown with dotted line. Surface drifter trajectories shown with red arrows.
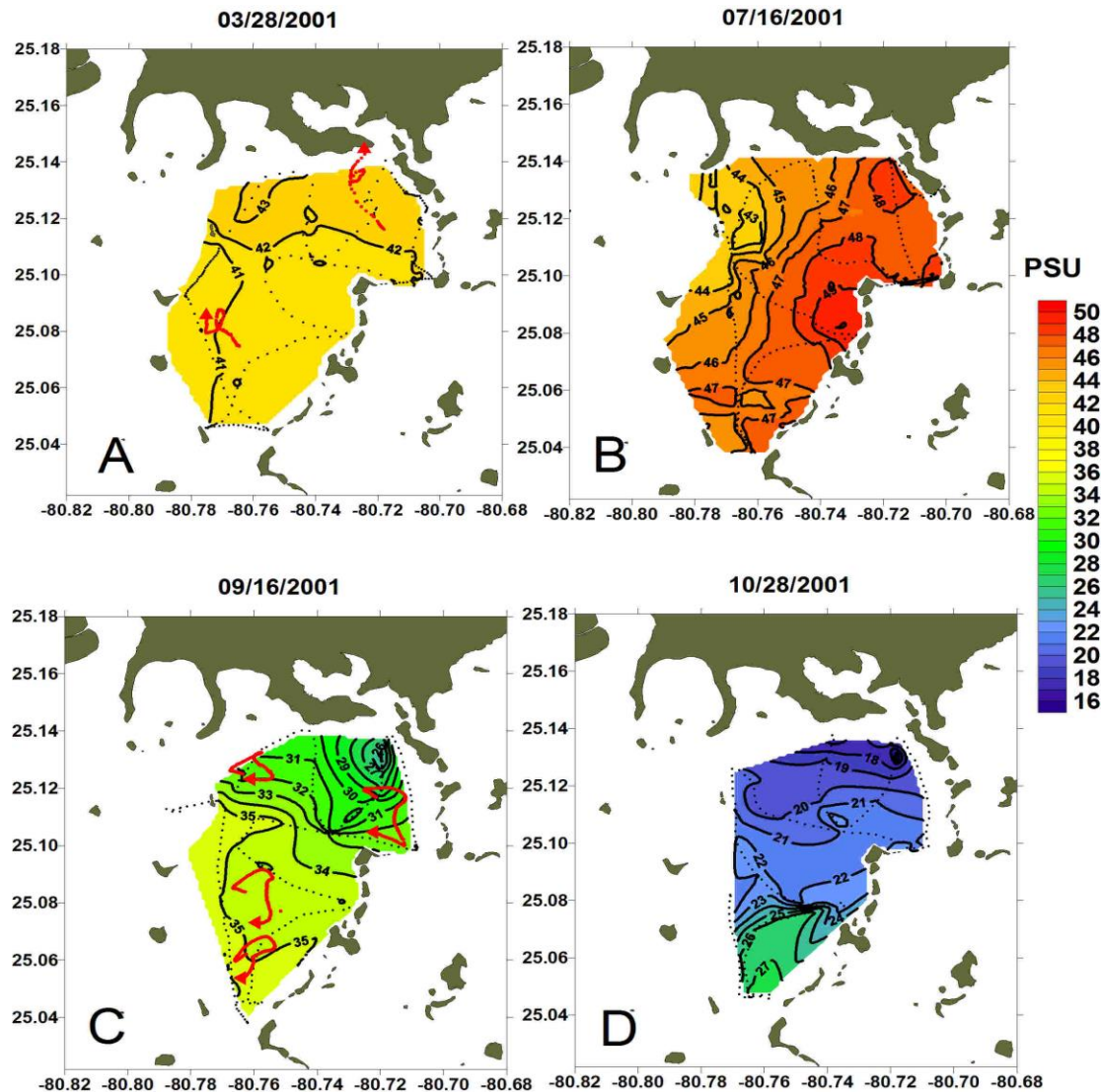
Time series of basin average salinity for WB during dry and wet seasons of 2001 from *R/V Virginia K* spatial surveys.
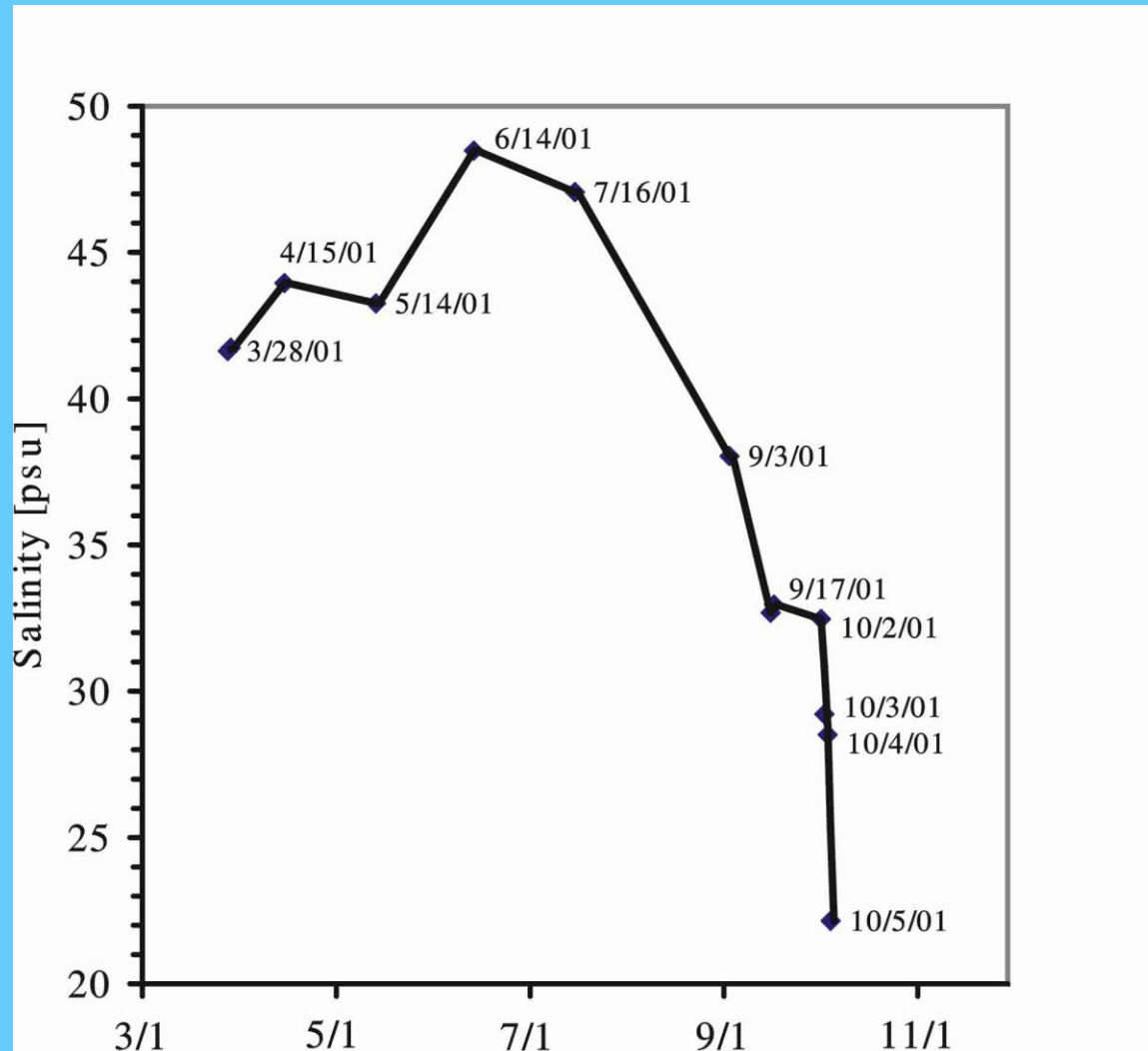
Terms used in the salt balance model for estimating the fractional rate of volume exchange (Q'$_i$)/mo and water renewal time (T) for WB during dry and wet seasons 2001. Q'$_i$ = Q$_i$/Vol; R = r + P - E; R' = R/Vol; Vol = Whipray Basin mean volume.

$$Q'_i = (\partial S_{WB}/\partial t + S_o R')/(S_i - S_o)$$

Season	$\partial S_{WB}/\partial t$ (mo^{-1})	R' (mo^{-1})	S$_i$	S$_o$	Q'$_i$ (mo^{-1})	T (mo.)
Dry	2.6	-0.078	42.7 to 41.7	44.69	0.44 to 0.3	2.3 to 3.4
Wet	-5.8	0.22	28.38	32.65	-0.32	3.1

Linear regression of along-channel currents against volume transport measured with shipboard ADCP transects across the current meter sites at Topsy (top) and Twisty (bottom) transects during the wet season of 2001. Regression relationships used to convert current to transport and the squared correlation coefficient are shown.
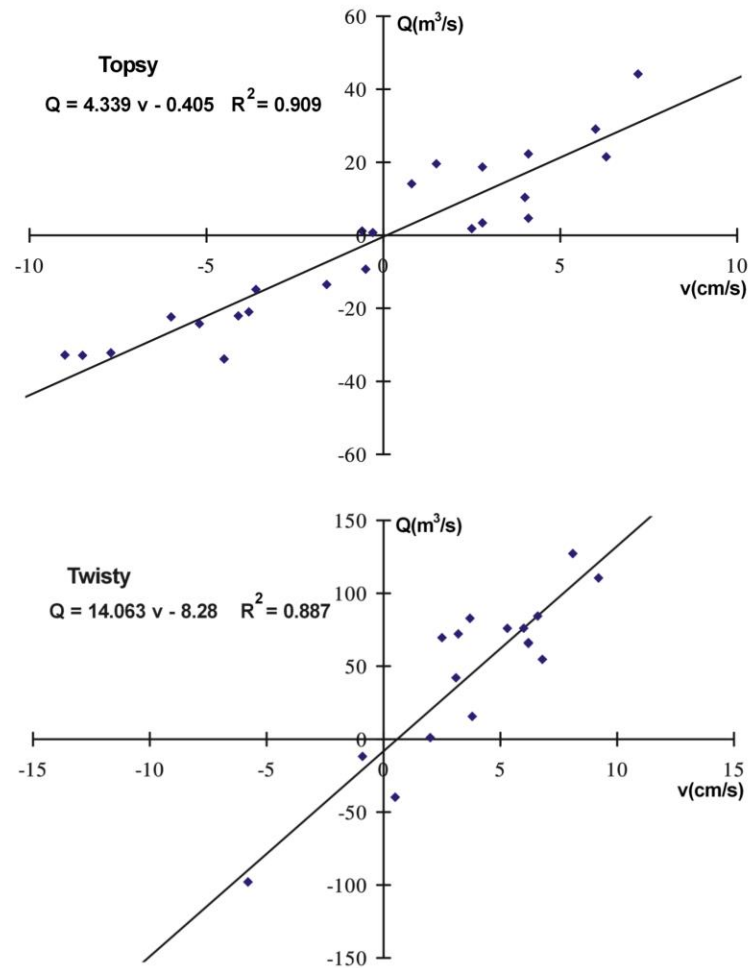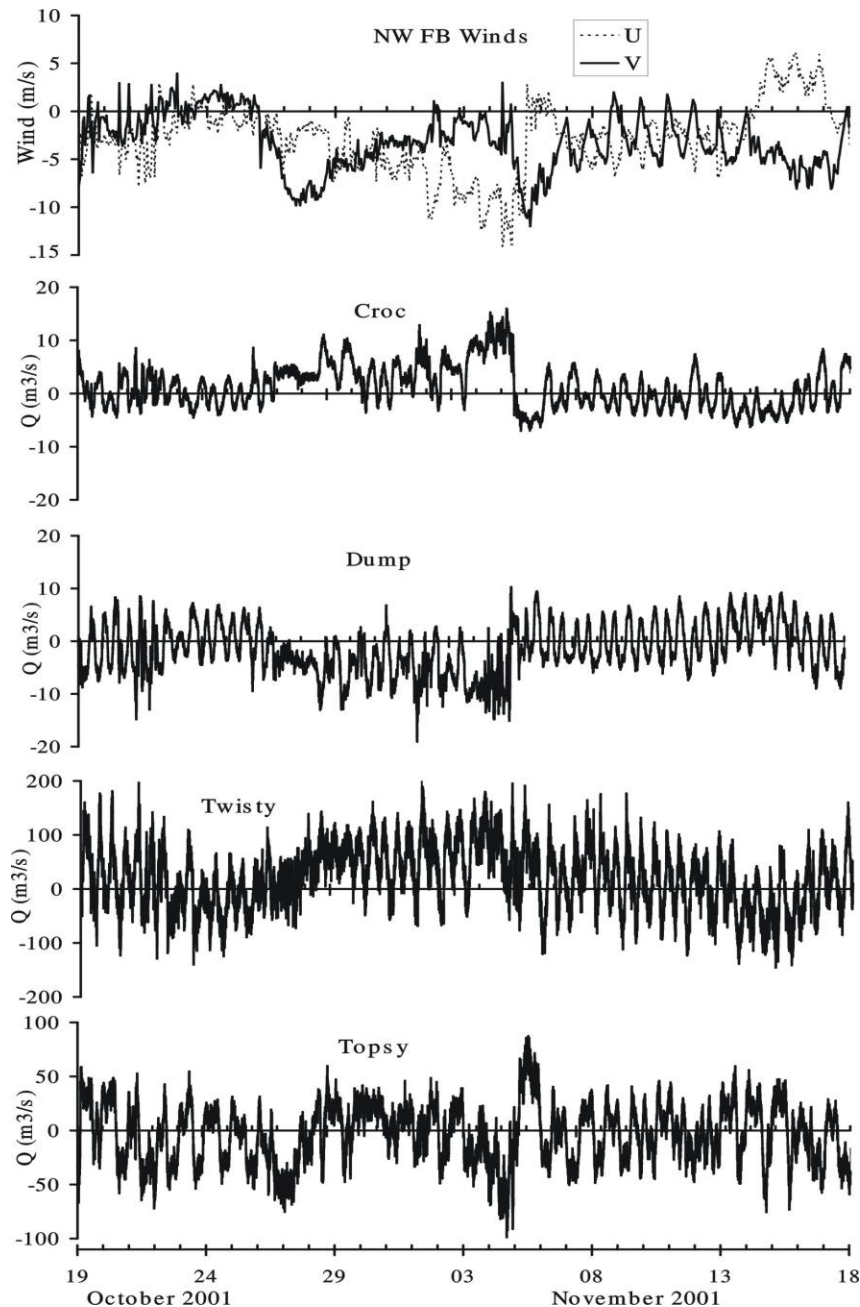
Channel Volume Transports Wet Season

3 hour low-pass filtered volume transports derived for the major flow channels to WB for a one month period from the 2.5 month total record of the wet season 2001. Positive values are inflows and negative are outflows. Also shown are east-west and north-south wind components from the NWFB SeaKeys site.

40 hour low-pass filtered NWFB wind components and volume transports through WB flow channels during wet season 2001. Positive values are inflows and negative are outflows.
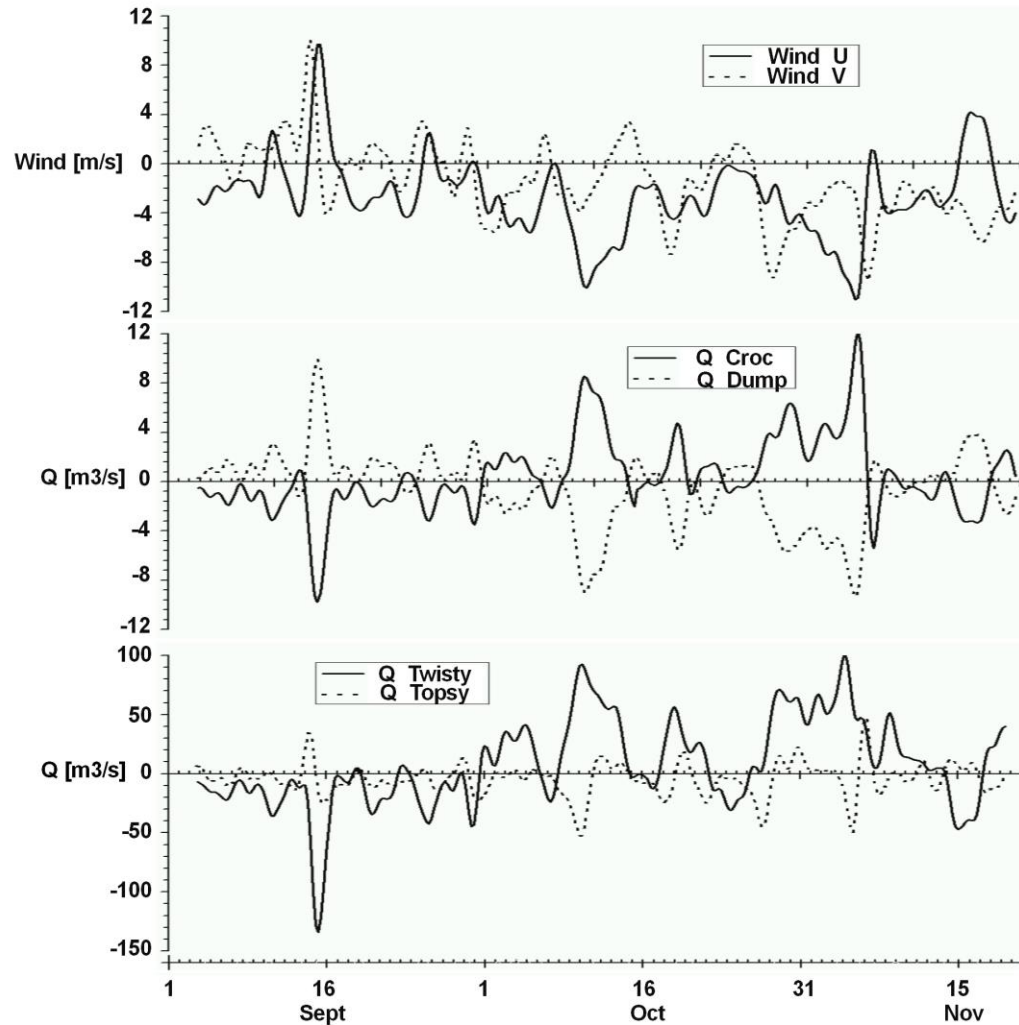
Linear regression between subtidal time series of east-west wind and transports through WB flow channels during the wet season 2001.
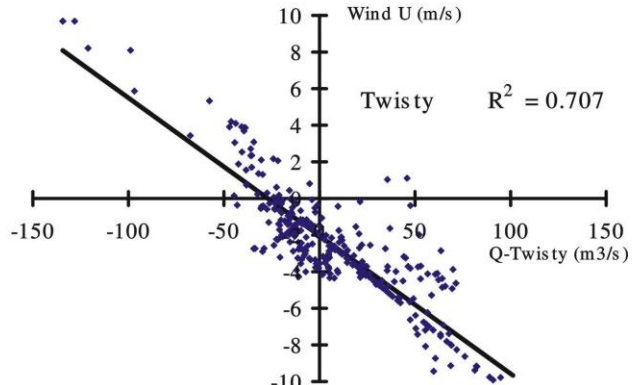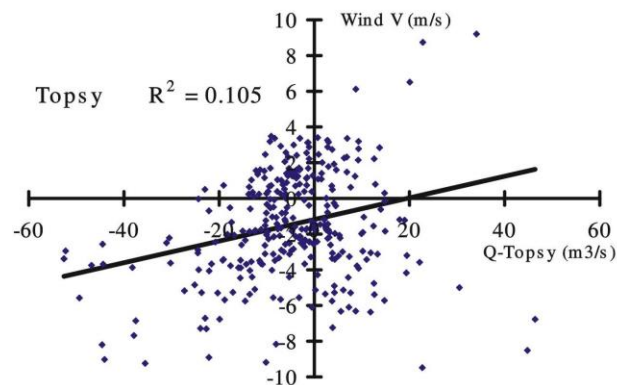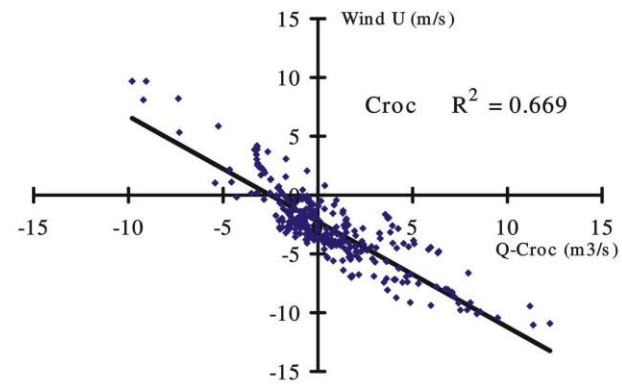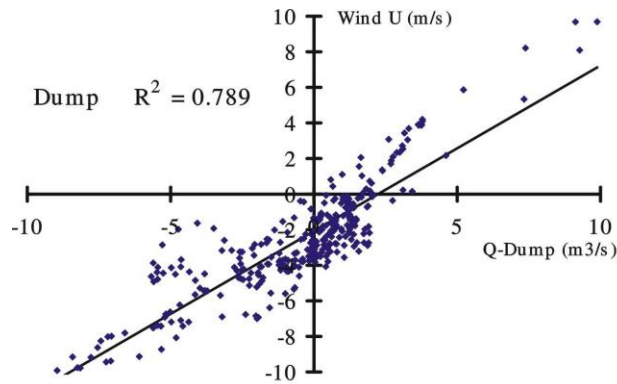
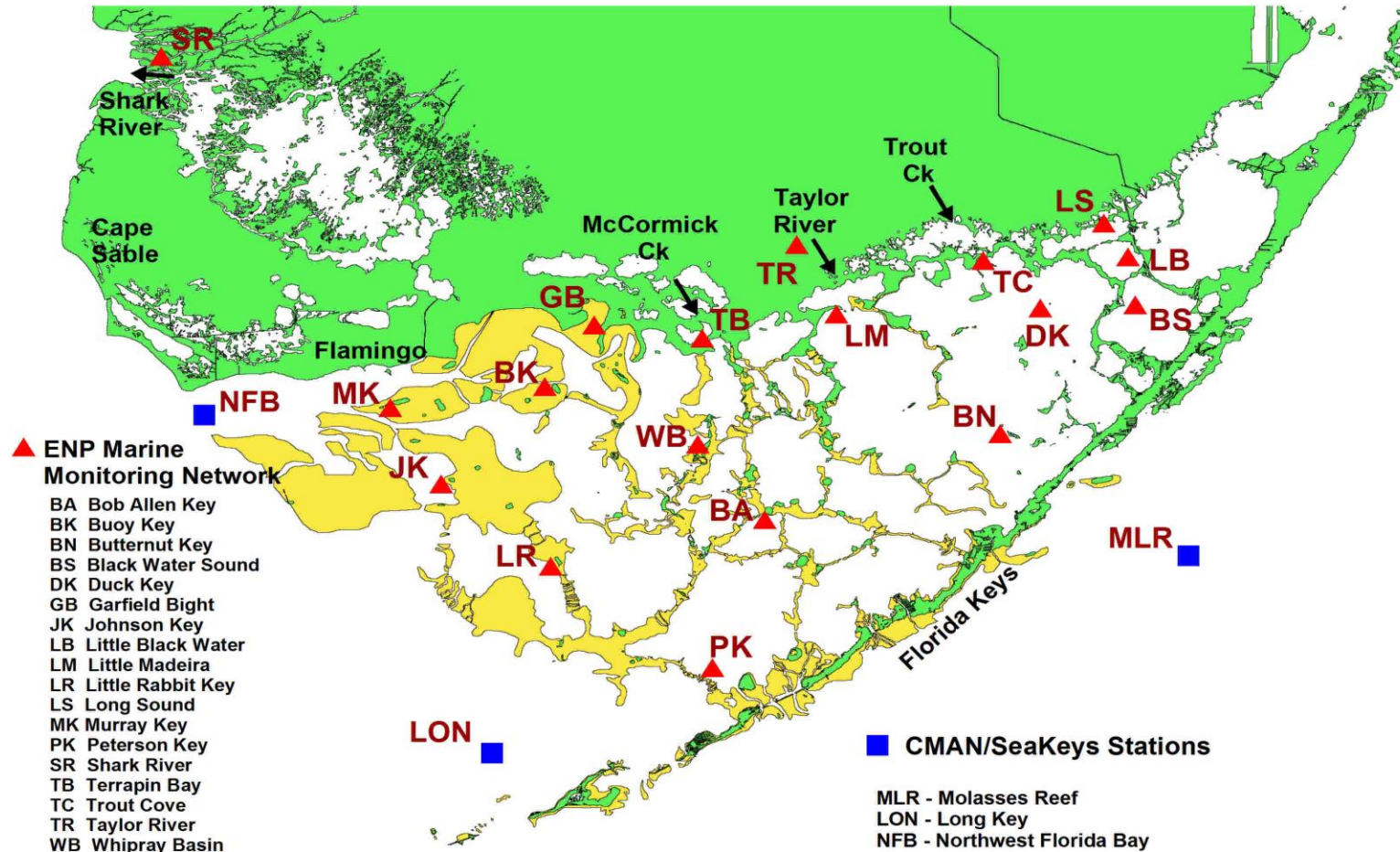Location of ENP marine monitoring stations in Florida Bay (triangles), CMAN/SeaKeys wind stations (squares), and the location of fresh water discharge points (arrows) superimposed on the bays bank/basin configuration (yellow/white) and mangrove islands (green).

▲ ENP Marine Monitoring Network

BA Bob Allen Key
BK Buoy Key
BN Butternut Key
BS Black Water Sound
DK Duck Key
GB Garfield Bight
JK Johnson Key
LB Little Black Water
LM Little Madeira
LR Little Rabbit Key
LS Long Sound
MK Murray Key
PK Peterson Key
SR Shark River
TB Terrapin Bay
TC Trout Cove
TR Taylor River
WB Whipray Basin

■ CMAN/SeaKeys Stations

MLR - Molasses Reef
LON - Long Key
NFB - Northwest Florida Bay

Subtidal sea level time series from selected stations of the ENP monitoring array and winds for the NWFB SeaKeys station, rotated 50O into along-bay axis and cross-bay axis components (along-axis winds + toward 50O and cross-axis winds + toward 140O. Sea level stations were selected to provide coverage of the entire bay.
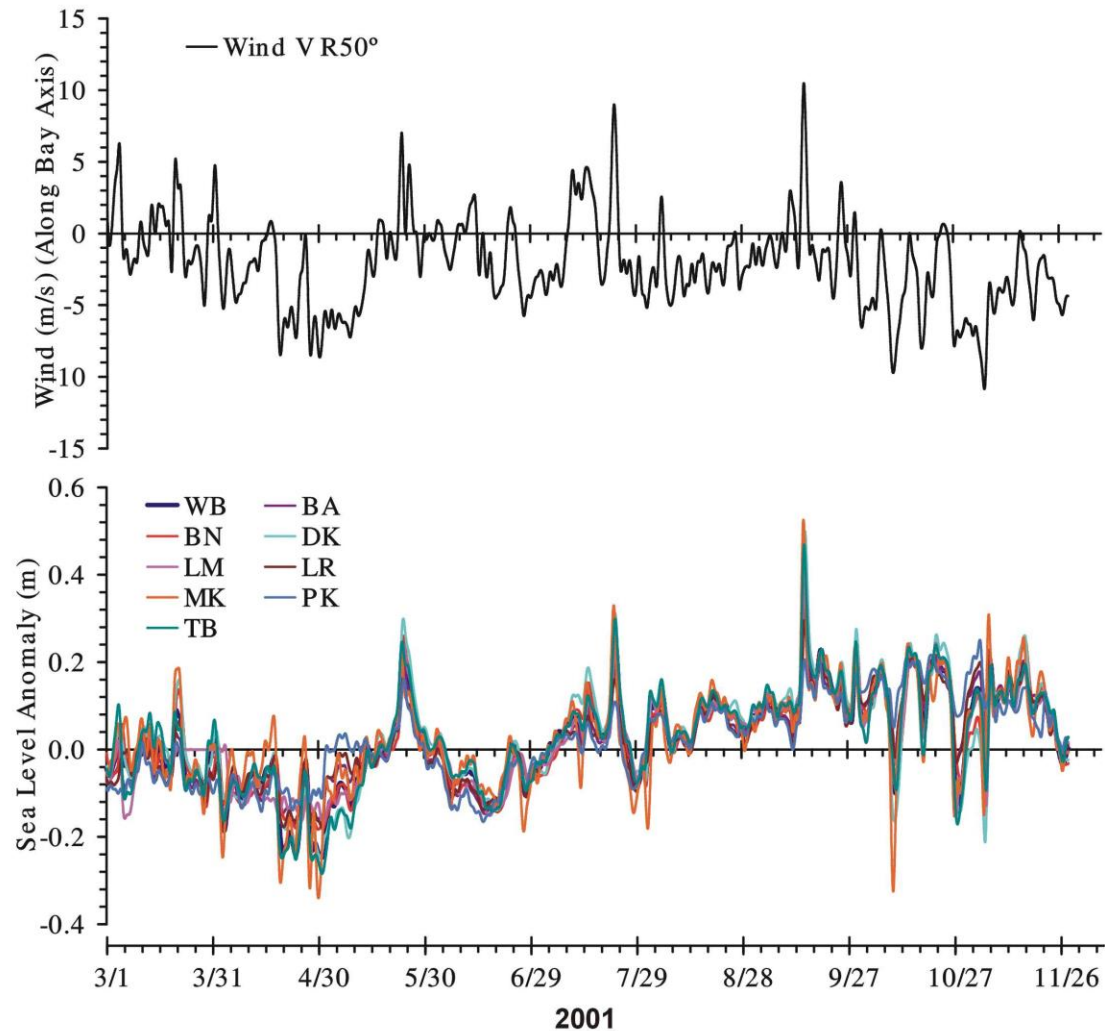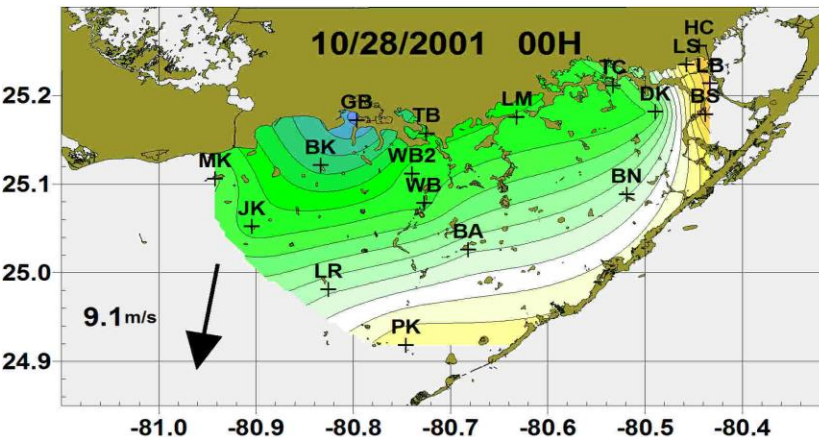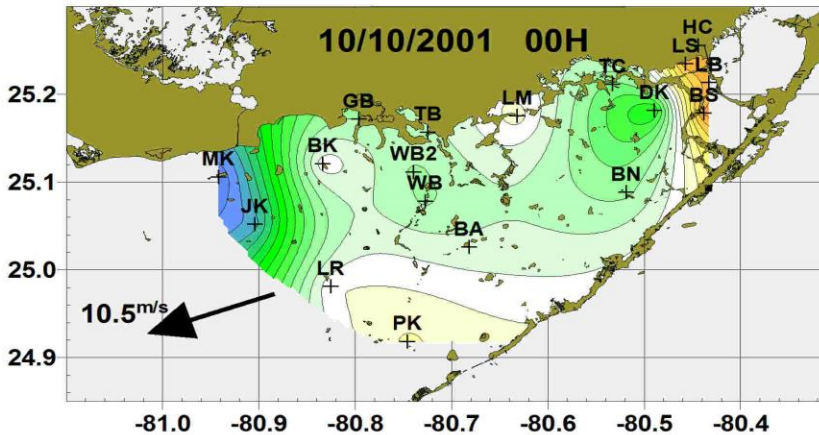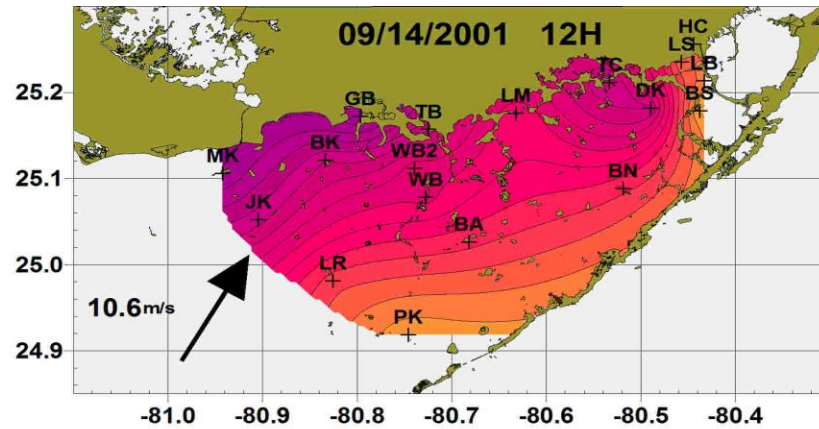
Gridded and Contoured Sea Level Fields

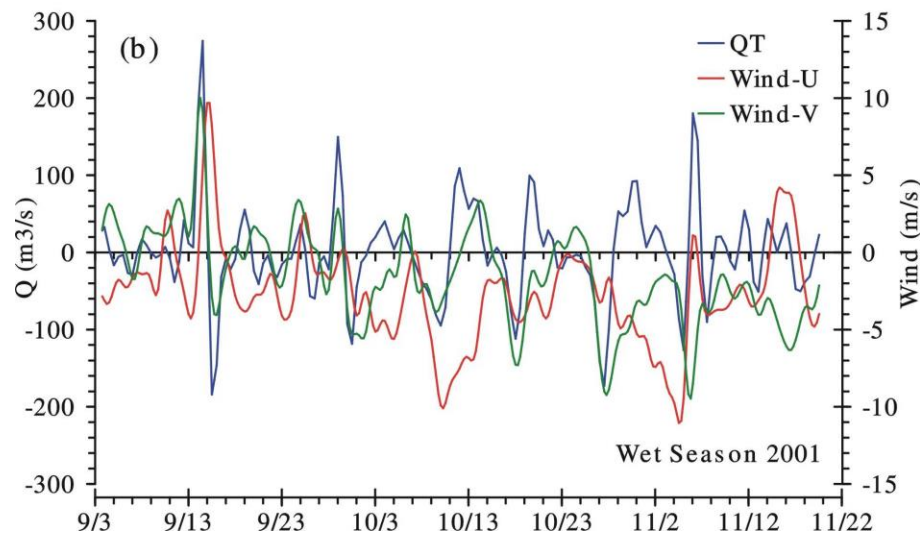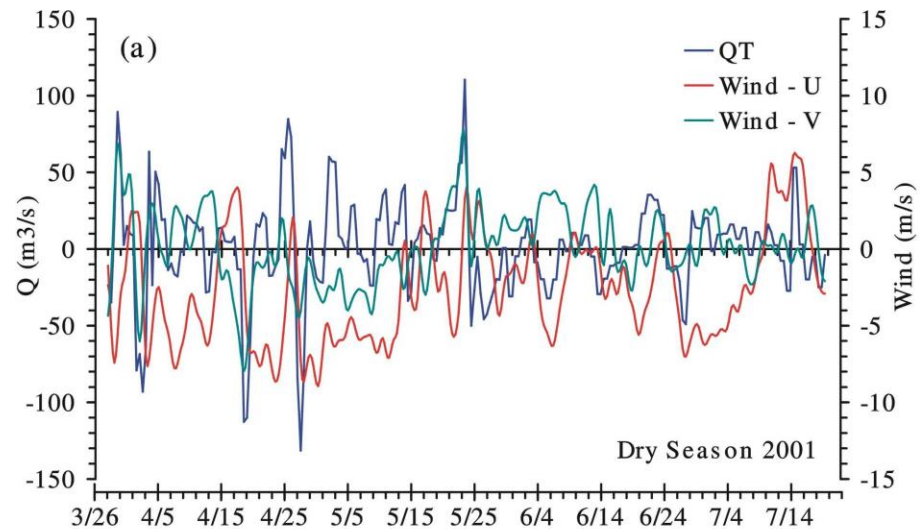Derived from the ENP monitoring array using Golden Software surfer interpolation for fall 2001 wind events. Winds from the NWFB SeaKeys station are shown with black arrows.

Subtidal time series of the total volume transport (Q_T) into (+) and out of (-) WB derived from gridded sea level fields, shown with east-west (U) and north-south (V) winds for dry (a) and wet (b) seasons of 2001.
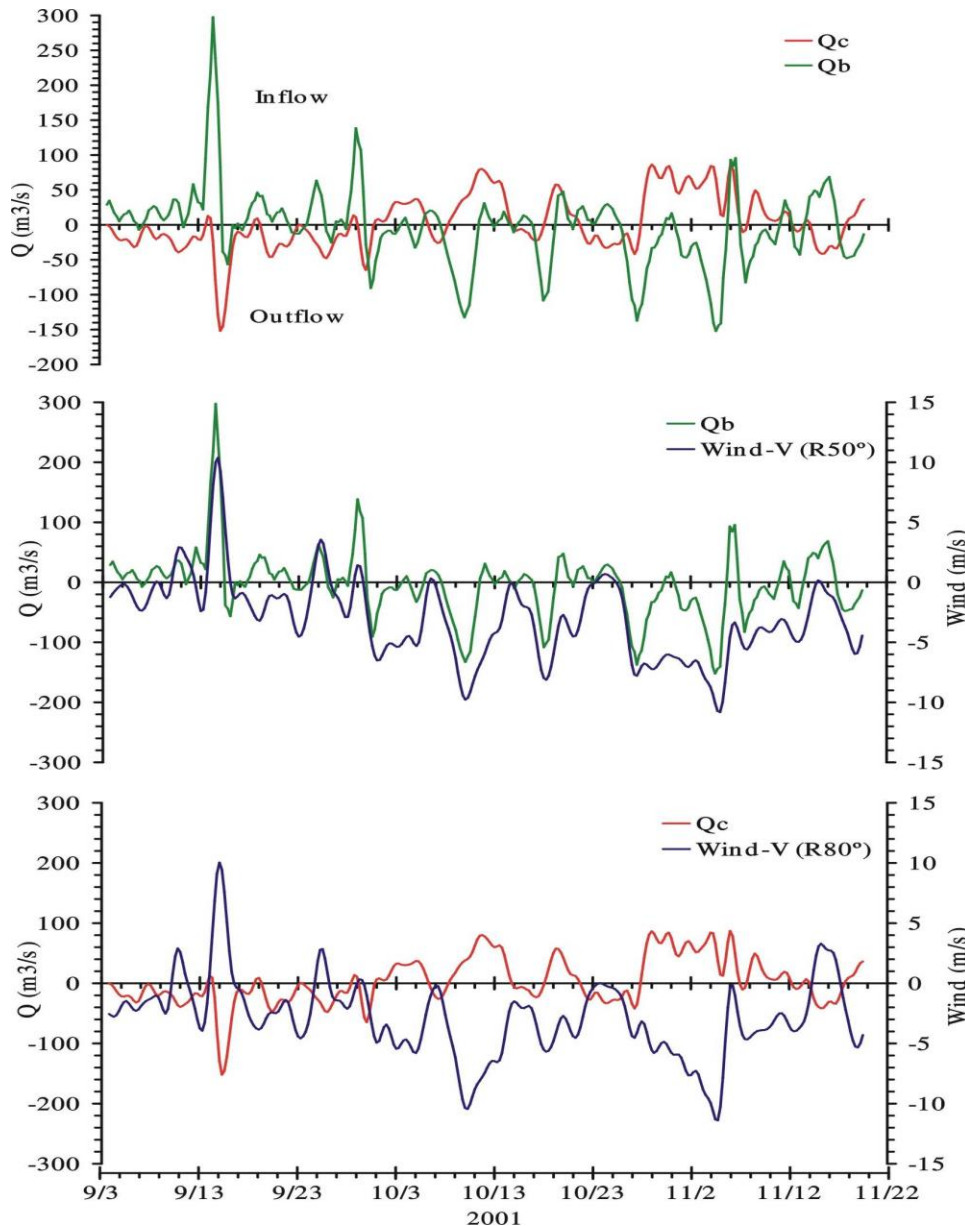
$Q_T = Q_c + Q_b$

Wet season 2001 subtidal time series of the total channel flow (Q_c) and total bank flow (Q_b) (top panel); total bank flow plotted with along-axis winds (middle panel); and total channel flow plotted with winds rotated 80deg (bottom panel).

Seasonal and annual means of total transport (Q_T) from WB sea level monitoring data, total measured channel transport (Q_c) and residual bank transport (Q_b) from $Q_b = Q_T - Q_c$ in m^3/s for 2001.

[Mean volume of Whipray Basin is 56.55 x 10^6 (m^3).]

Transport	Dry Season	Wet Season	Annual Mean
Q_T	0.8	-0.1	0.4
Q_c	-10.48	3.2	-3.6
Q_b	11.2	-3.3	3.9
Basin Renewal Time (months)	2.1	6.8	6.1

# Physical data for Whipray Basin and values for annual water balance model during wet and dry seasons of 2001.
Conversion: 1 m³/s = 2.98 cm/mo.

Mean depth (m)	Surface area (km²)	Mean volume x 10⁶ (m³)
0.65	86.9	56.55

Seasonal and Annual Water Balance Model in m³/s

	Q_w	$+ Q_g$	$+ r$	$+ P$	$+ E$	$=$	Q_T
Dry	0.8	1.65	- 0.5	3.07	- 4.25	=	0.77
Wet	- 0.07	- 4.67	3.5	4.81	- 3.64	=	- 0.07
Annual average	0.36	-1.51	1.5	3.94	- 3.94	=	0.35

Annual Mean Volume Transports (m3/s) in Florida Bay and Keys (blue arrows) and Estimated Mean Flow Pathways (red arrows). River Discharge shown by black arrows. Estimated Bank Flow (pink arrows).
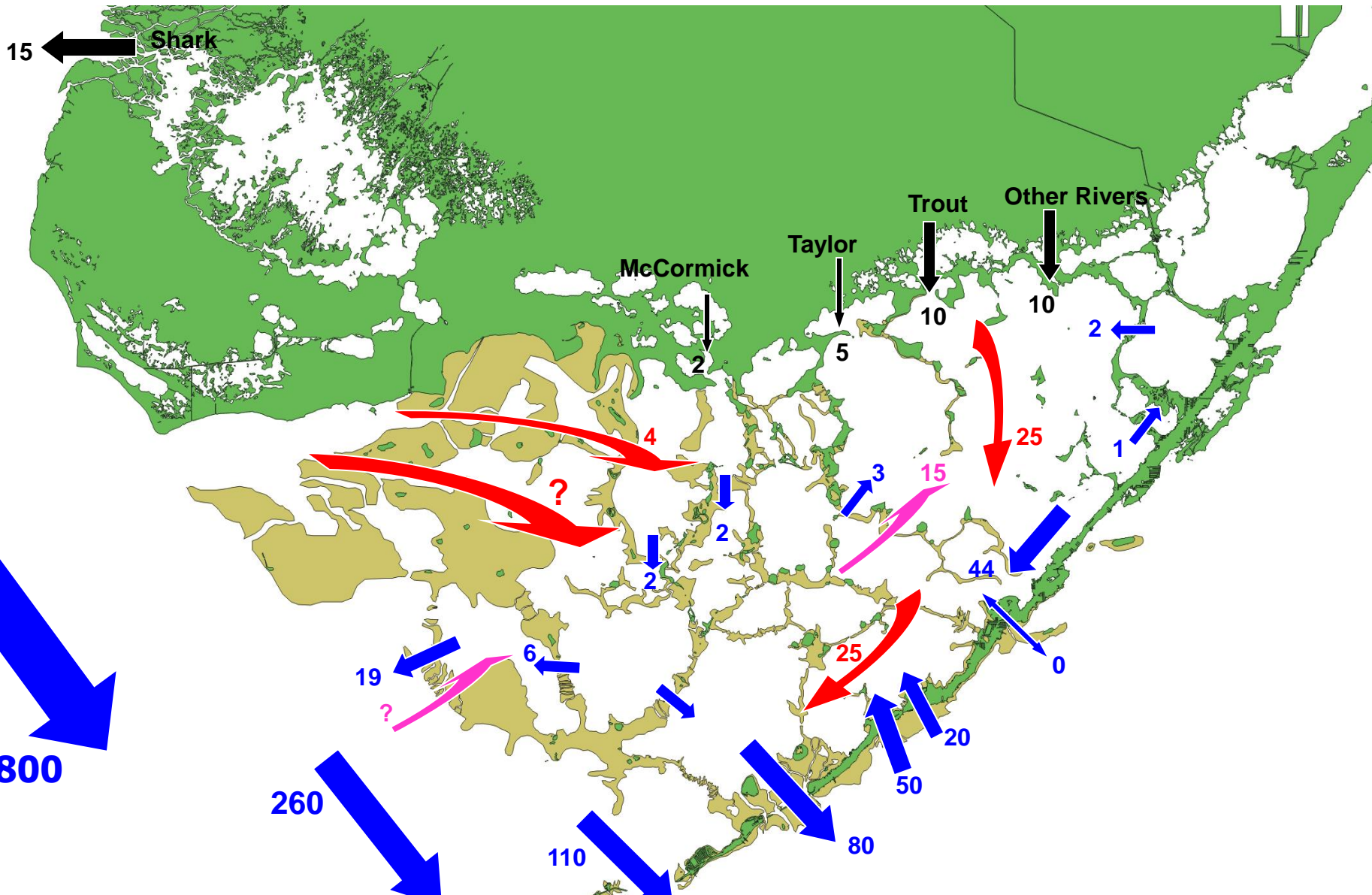
Conclusions

- **Water renewal and residence times in Whipray Basin are controlled by local wind forcing.**

- **Dry Season - eastward winds produce mean through-flow of 11 m3/s and basin renewal times of 2-3 mo.**

- **Wet Season – westward winds cause mean through-flow of 3 m3/s and basin renewal times of 6-7 mo.**

- **Flushing time for complete water renewal ~= 6-12 mo.**

- **Ground water inflow is weak in dry season = 1-2 m3/s and downwells during the wet season at – 4.7 m3/s.**

- **Hypersalinity development in north-central Florida Bay results from reduced fresh water inputs during the dry season coupled with poor exchange with surrounding regions.**

- **Hypersalinity development could be regulated by redirection of a portion of Everglades flow to Whipray Basin via McCormick Creek during the dry season.**