Soil, water and course woody debris CO_2 fluxes and aqueous CO_2 in a tidal mangrove forest in the Florida Everglades

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Respiration fluxes in mangrove forests

- Mangrove forests cover 1% of the continental surface but represent large C stocks (eg. Micronesian forest 400-1400 Mg C $ha^{-1;}$ Kauffman et al. 2011) due to large BG C stocks
- Respiration fluxes, exported to the atmosphere or as dissolved aqueous CO_2, comprise an key component of coastal C cycling
- The soil compartment is comprised of CO_2 fluxes from soil, roots and root structure (i.e. pneumatophores), course woody debris (CWD) to the atmosphere, and when inundated, to surface water (SW).
- Variability a function of numerous physical and biological factors including temperature, root production, benthic microalgae, invertebrates, duration and frequency of inundation, salinity, alkalinity and nutrient availability.

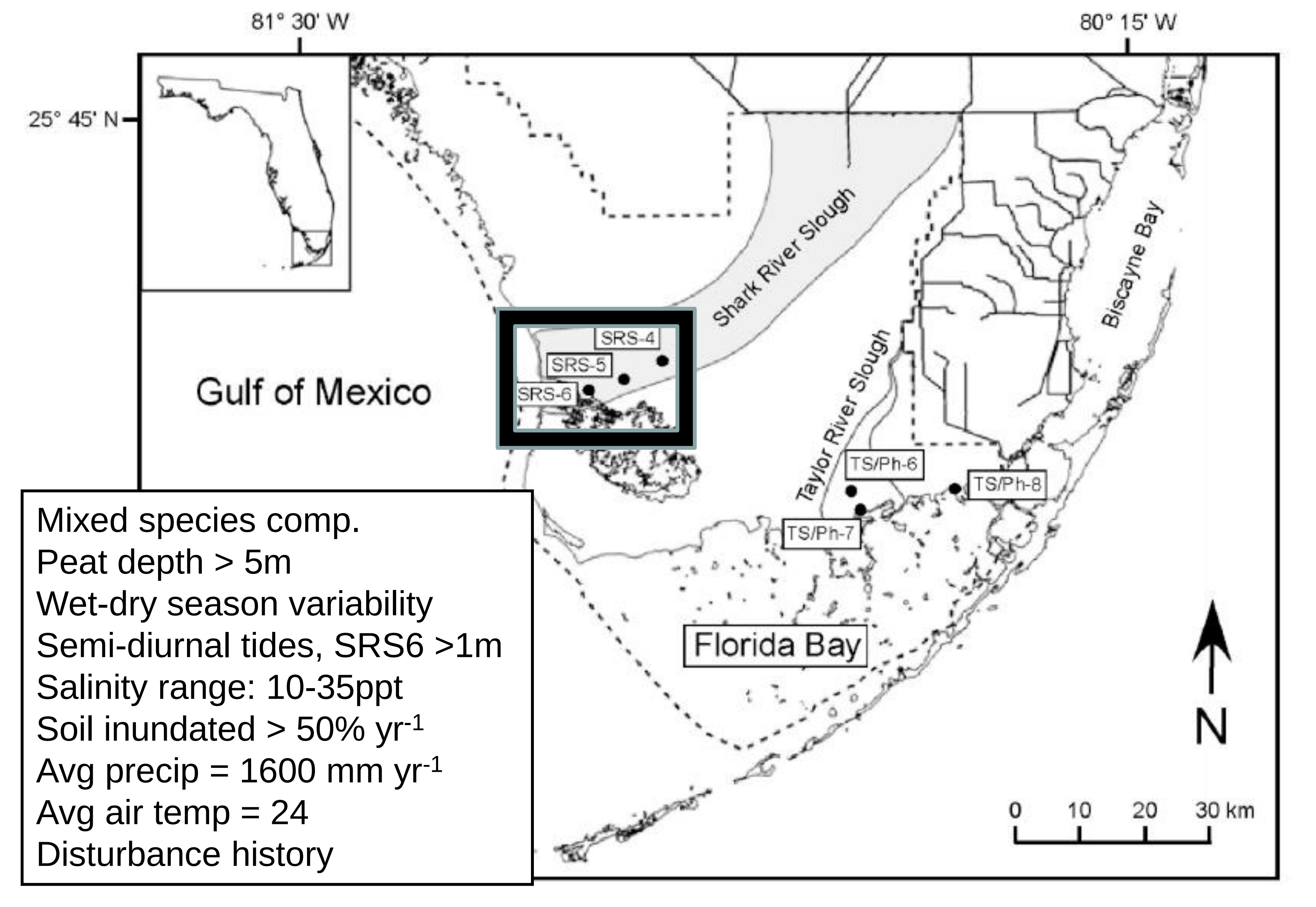
Toward partitioning ecosystem respiration fluxes

- Eddy flux measurements provide important information about forest-atmosphere exchange, but cannot partition parameters that contribute to soil respiration.

- Accounting for variability in CO_2 flux rates as a function of inter- and intra-site variability will help to elucidate important factors controlling soil respiration fluxes and mangrove forest C cycling.

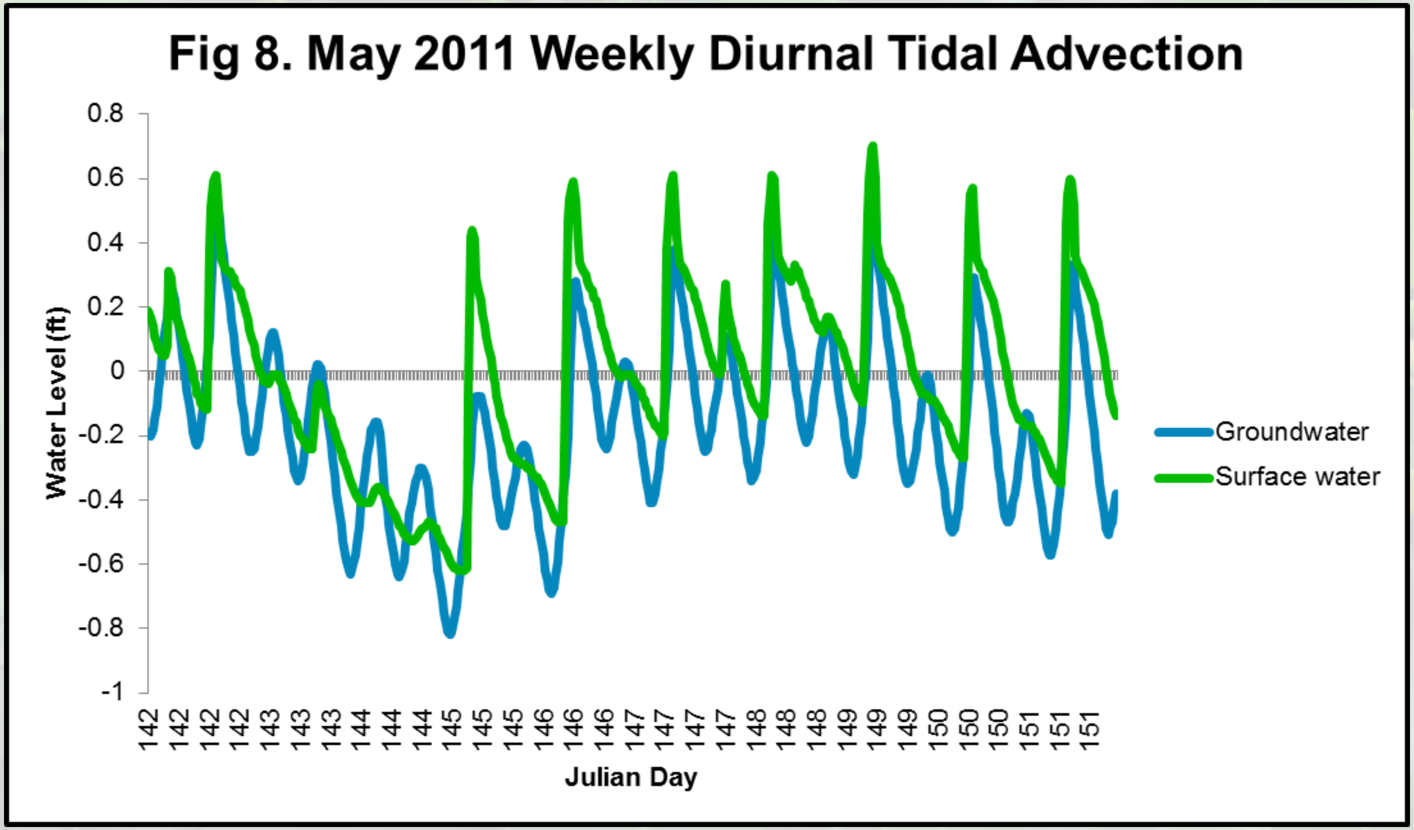
- Ecosystem disturbances can alter the importance of specific fluxes – i.e. contribution of CO_2 fluxes associated with course woody debris (downed wood) after hurricane disturbance or changes in sea level

Shark River Slough FCE LTER study sites



Mixed species comp.
Peat depth > 5m
Wet-dry season variability
Semi-diurnal tides, SRS6 >1m
Salinity range: 10-35ppt
Soil inundated > 50% yr^{-1}
Avg precip = 1600 mm yr^{-1}
Avg air temp = 24
Disturbance history

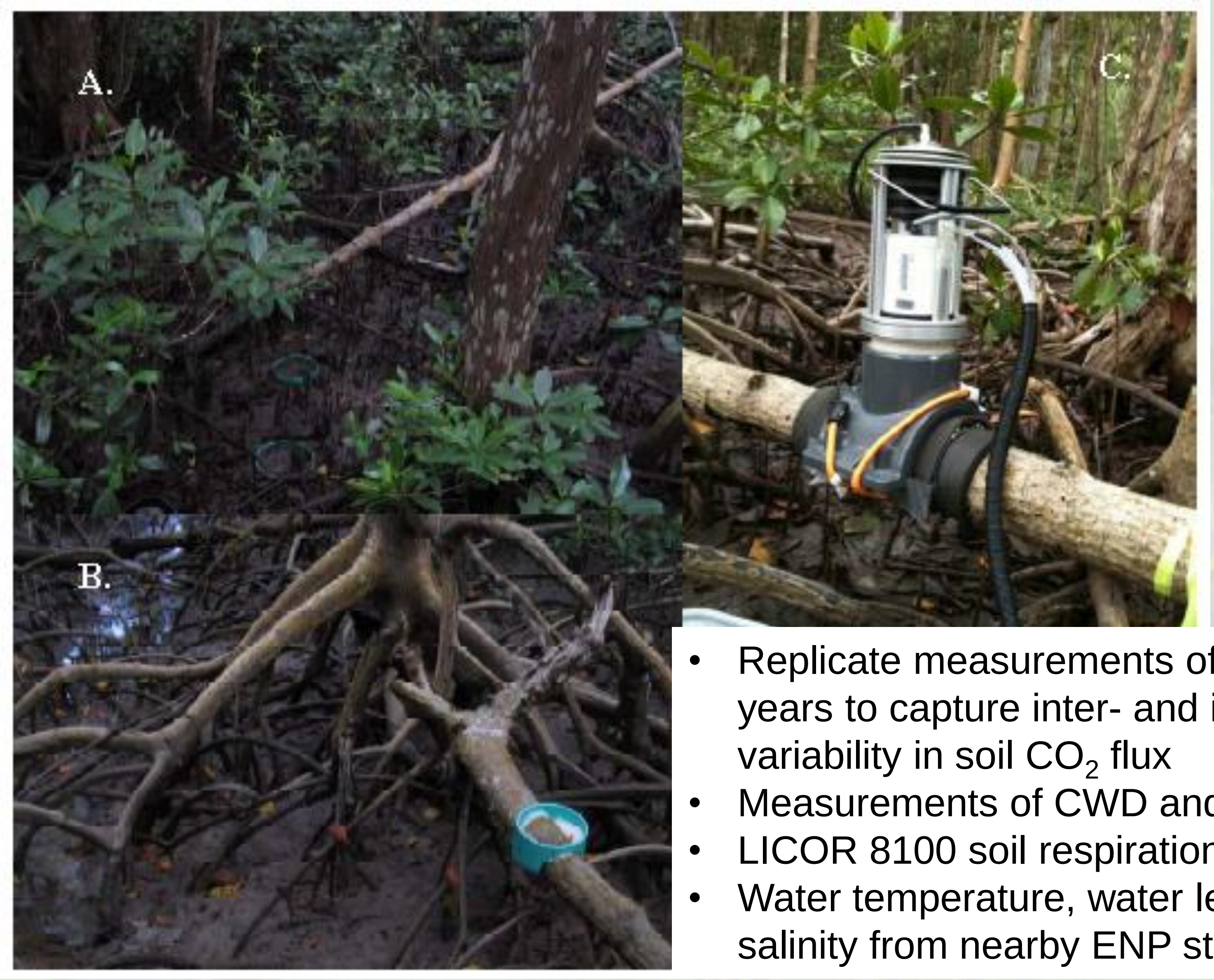
Characteristics of and variation in tidal inundation



Groundwater and surface water differ in salinity as well as temperature (in May 2011 >10ppt and 2.5°C)

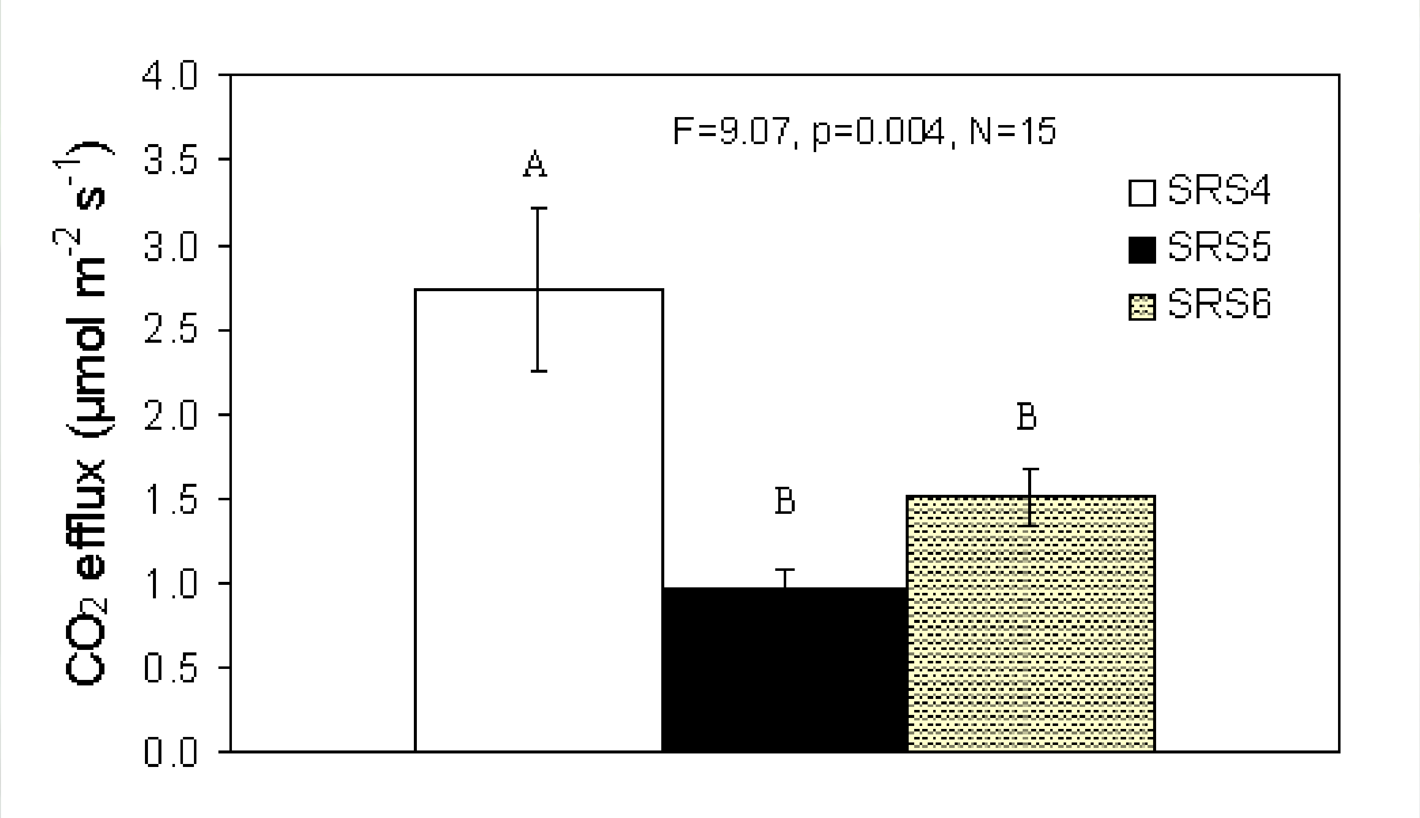
Primary Study Site – SRS 6

Soil, course woody debris and surface water CO_2 fluxes



- Replicate measurements of soil over 2-3 years to capture inter- and intra-site variability in soil CO_2 flux
- Measurements of CWD and SW
- LICOR 8100 soil respiration system
- Water temperature, water level and salinity from nearby ENP station

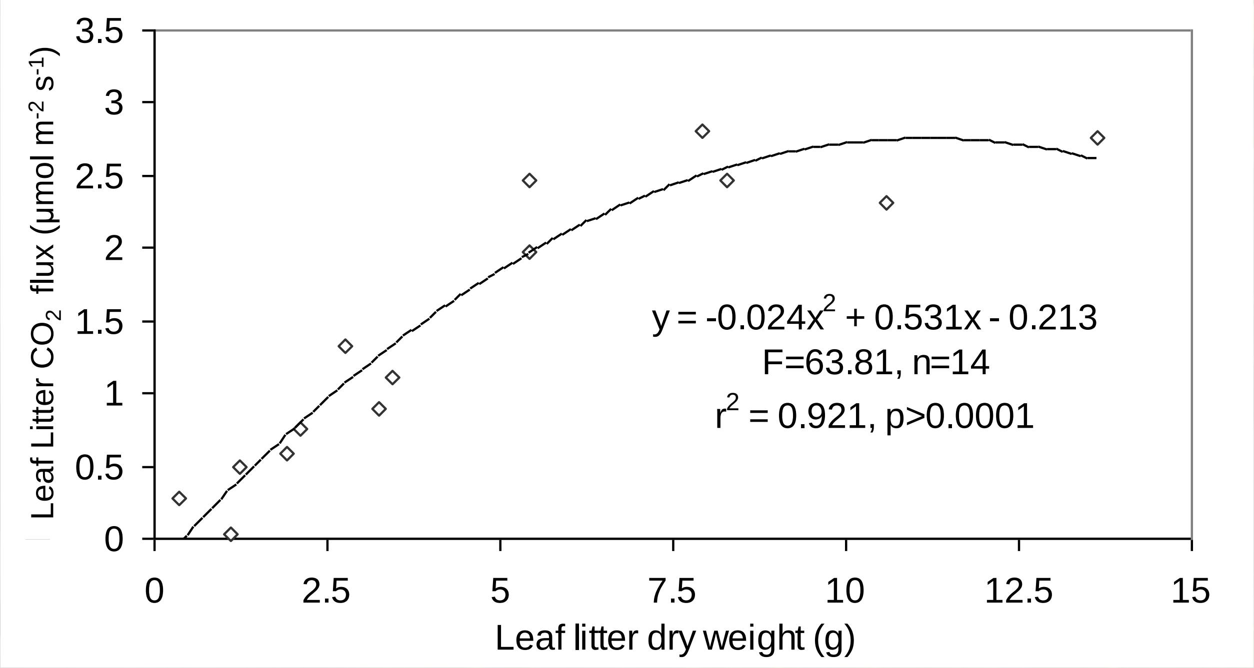
Inter-site variability in soil CO_2 fluxes



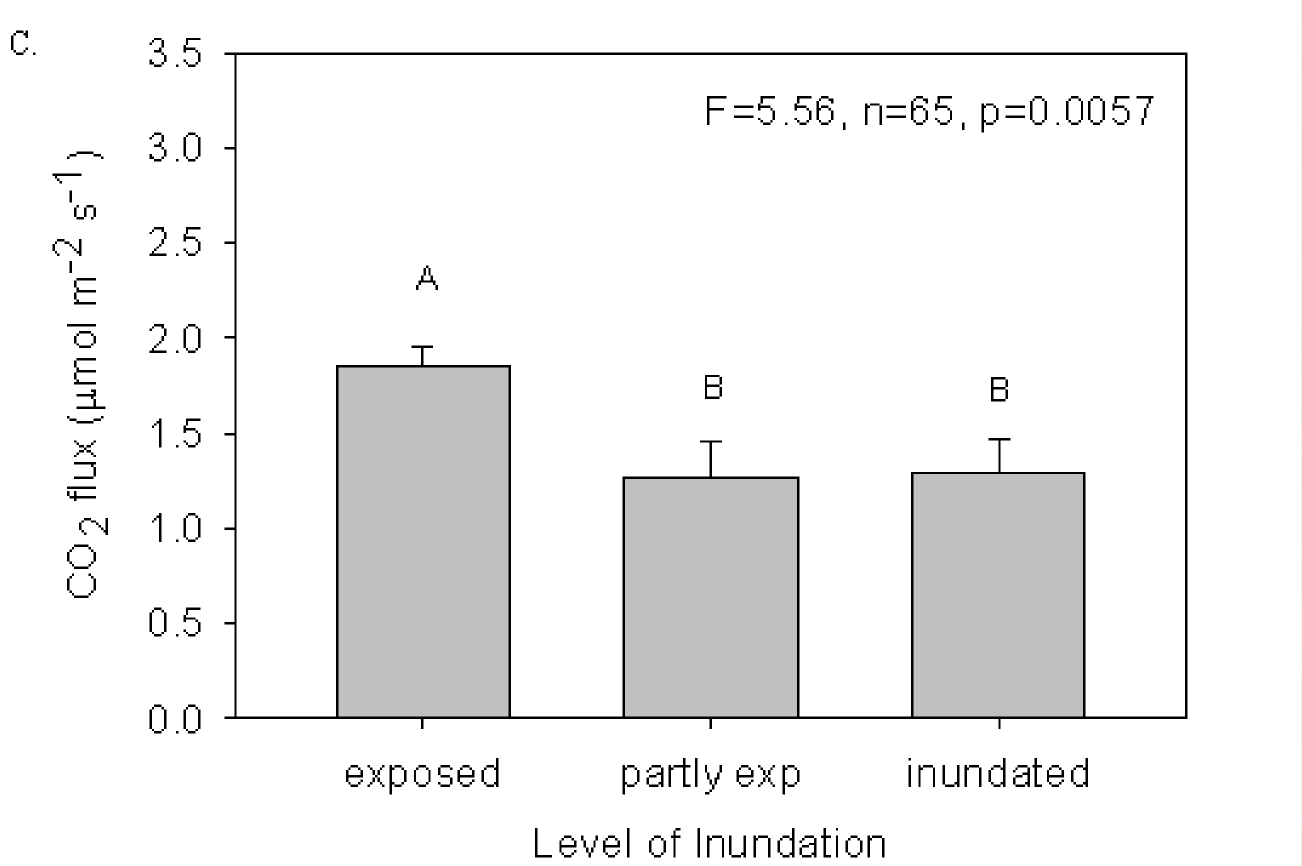
- High inter-site variability
- SRS 5: dominated by red mangrove with little presence of pneumatophores, moderate salinity, lowest frequency of inundation (but longest duration tidal events) and highest soil C:N and soil organic matter content.
- SRS 4: lowest flooding duration and salinity, lowest TP content by volume and the highest tree density (<2.5cm DBH; Castaneda 2010).

Intra-site variability in sub-canopy CO_2 fluxes – leaf litter

- Leaf litter was collected from the soil surface characterized by range of degradation
- N=14



Intra-site variability in sub-canopy CO_2 fluxes – extent of inundation



- Tidal inundation reduces CO_2 flux

Intra-site variability in sub-canopy CO_2 fluxes – surface water, soil, prop roots, CWD and soil with presence of pneumatophores

Soil with pnuematophores and course woody debris among the highest average CO_2 fluxes

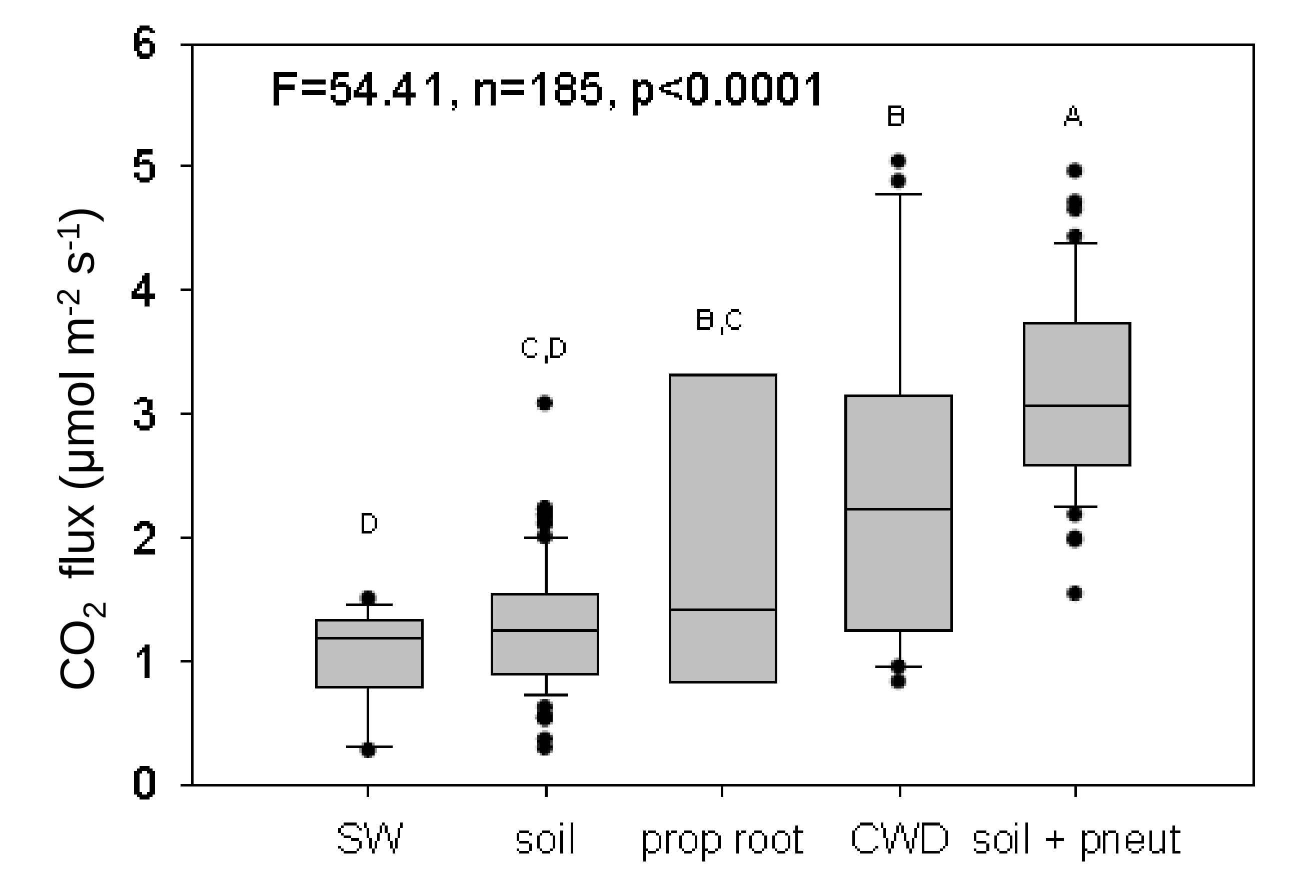
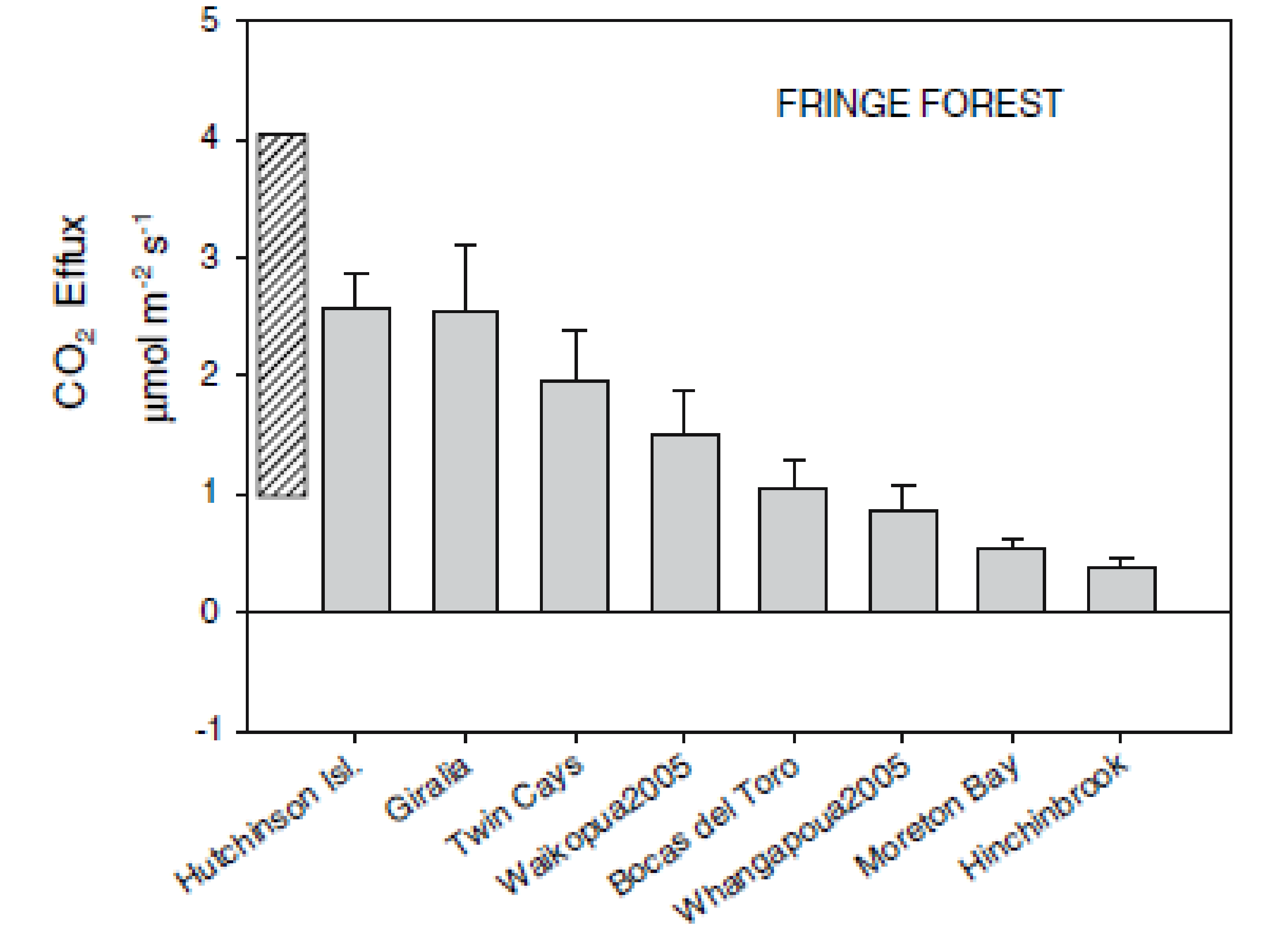


Figure 6. Below-canopy components of CO_2 flux partitioned by surface water (SW; n=16, 1.02±0.10 µmol m^{-2} s^{-1}), soil (n=86, 1.27±0.05 µmol m^{-2} s^{-1}), prop roots (n=8,1.94±0.45 µmol m^{-2} s^{-1}), course woody debris (CWD; n=29, 2.34±0.23 µmol m^{-2} s^{-1}), and soil with pneumatophores present (soil + pneut; n=47, 3.17±0.11 µmol m^{-2} s^{-1}).

Mangrove Fringe Forest Soil Respiration Efflux

Range of variability within the Shark River 6 site approximates the variability in soil respiration among fringe mangrove forests owing to variability among components within the soil compartment

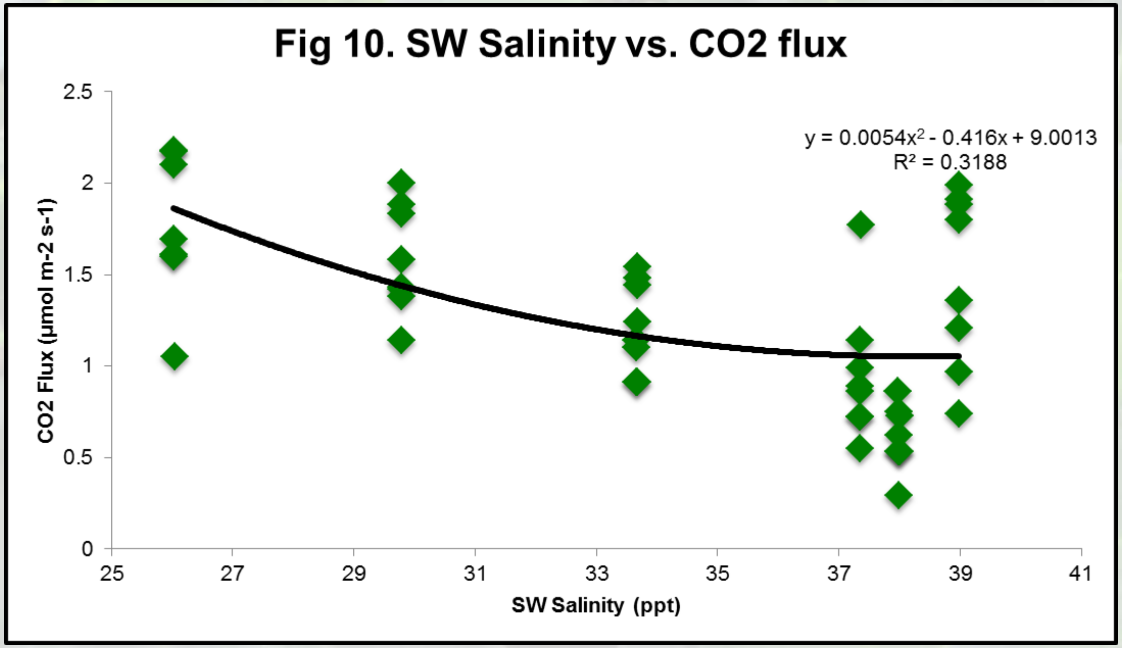


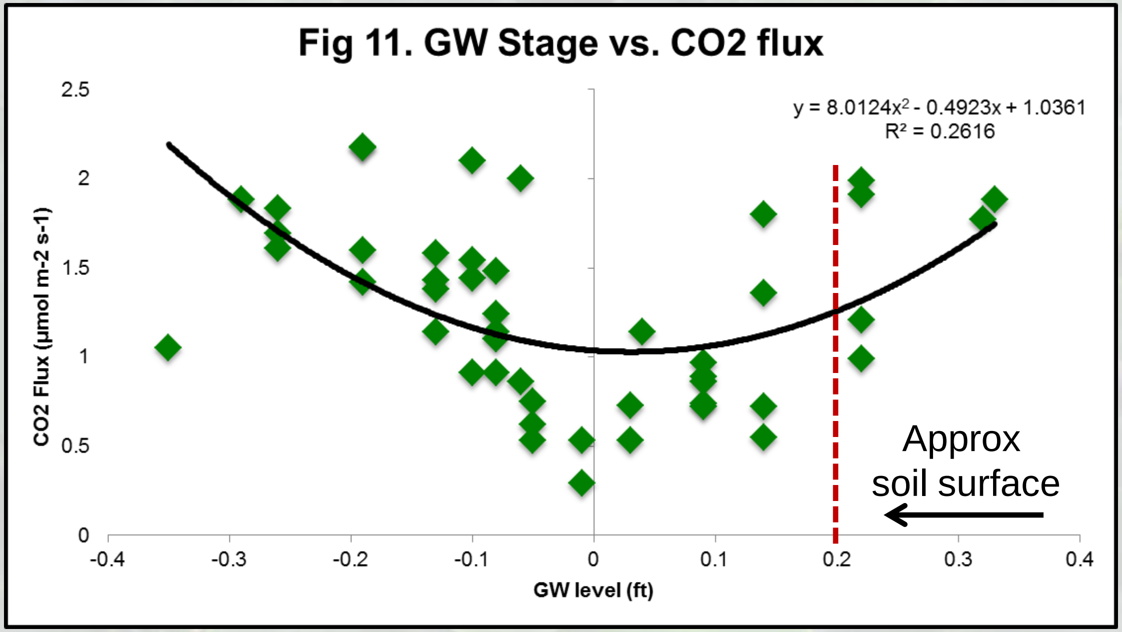
Lovelock, CE. 2008. Soil respiration and belowground carbon allocation in mangrove forests. Ecosystems 11: 342-353.

Intra-site variability in sub-canopy CO_2 fluxes – groundwater level and salinity

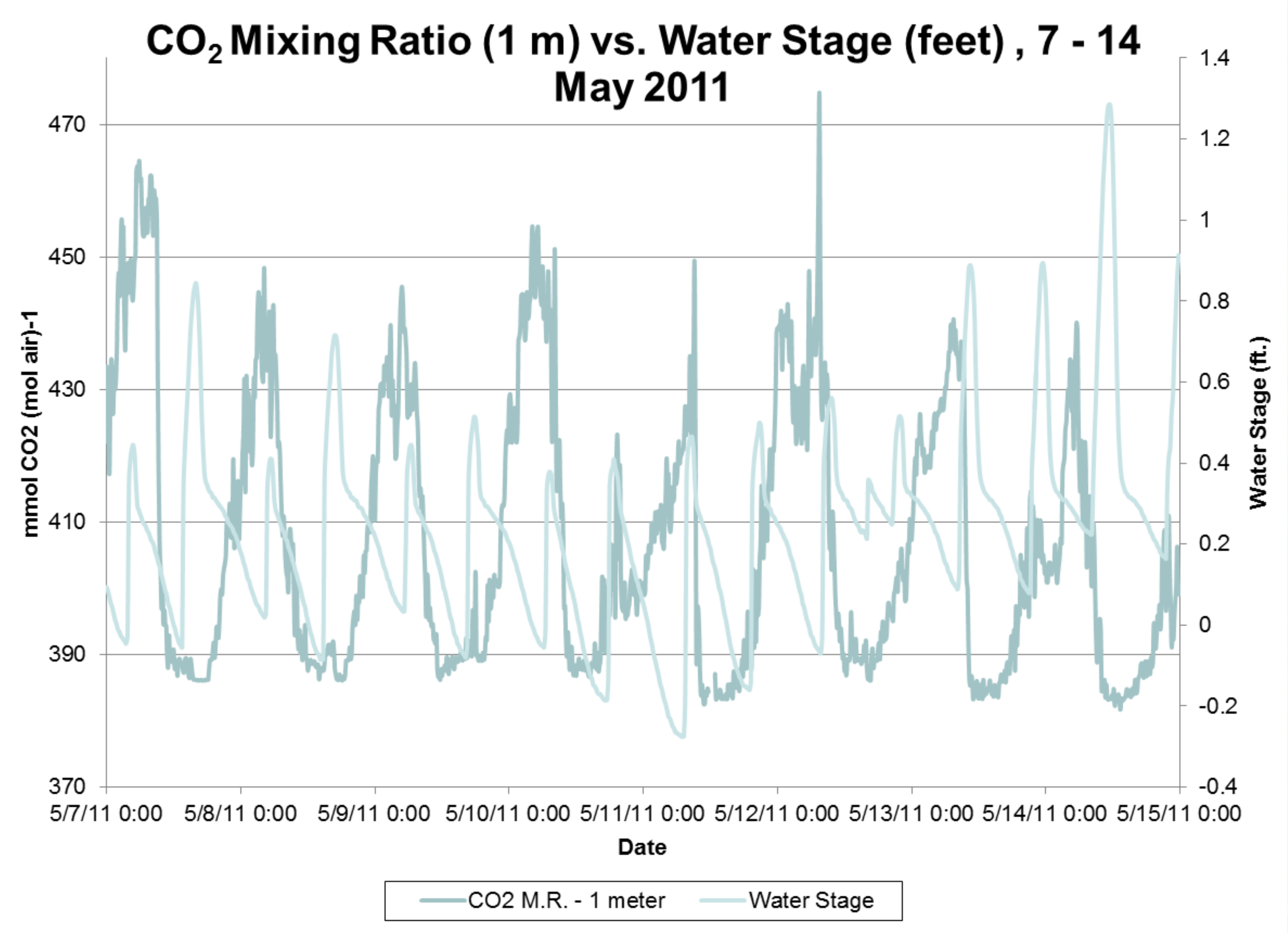
Stepwise regression modeling of all parameters determined that SW salinity and GW stage were the significant (p<.001) independent drivers of CO_2 flux rates.

Together they account for approximately 50% of the total variation in soil CO_2 fluxes at SRS6





Comparison with forest CO_2 flux

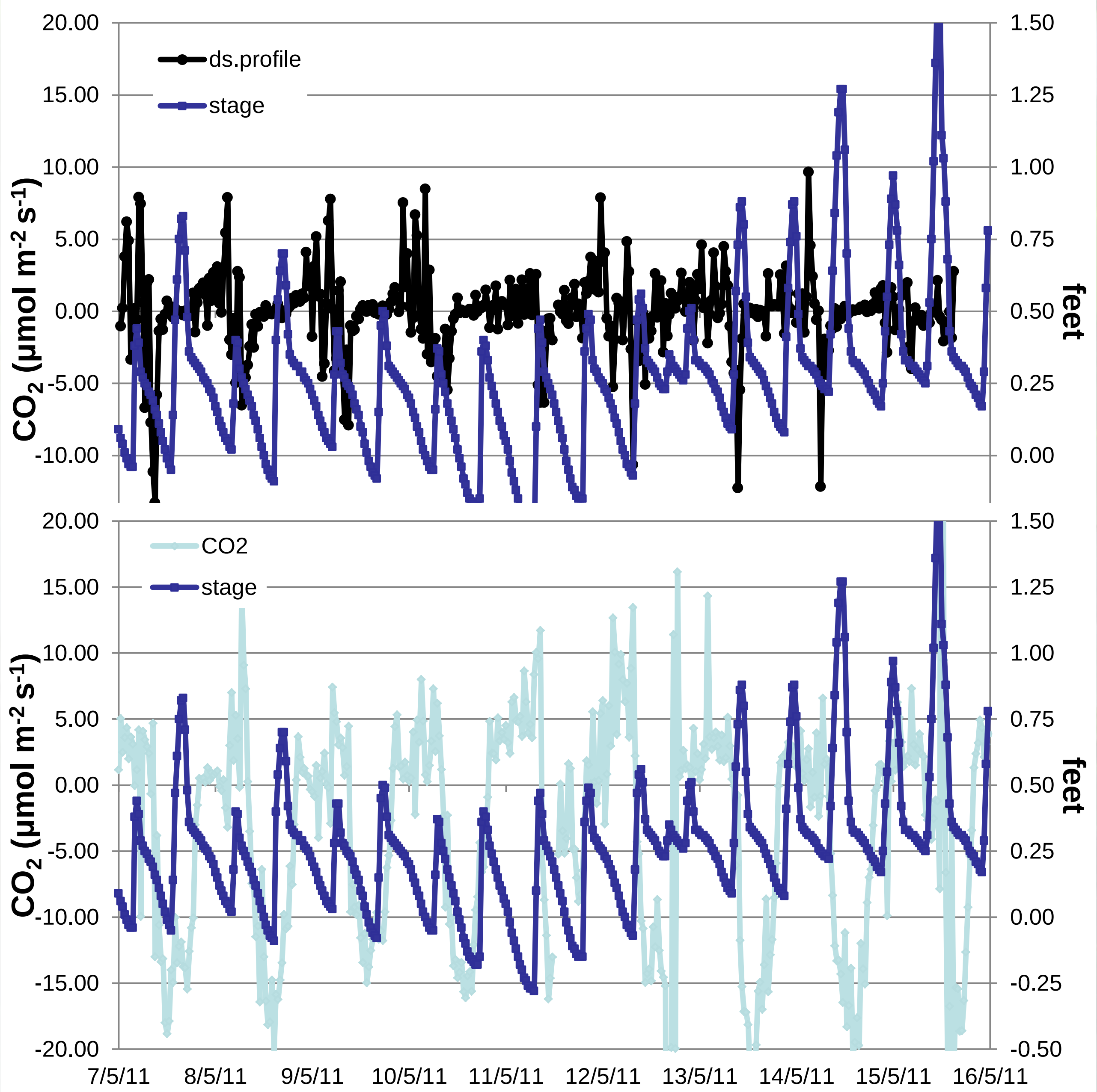


Sub-canopy atmospheric CO_2 concentration decreases with inundation of soil surface by tides

Comparison with forest CO_2 flux

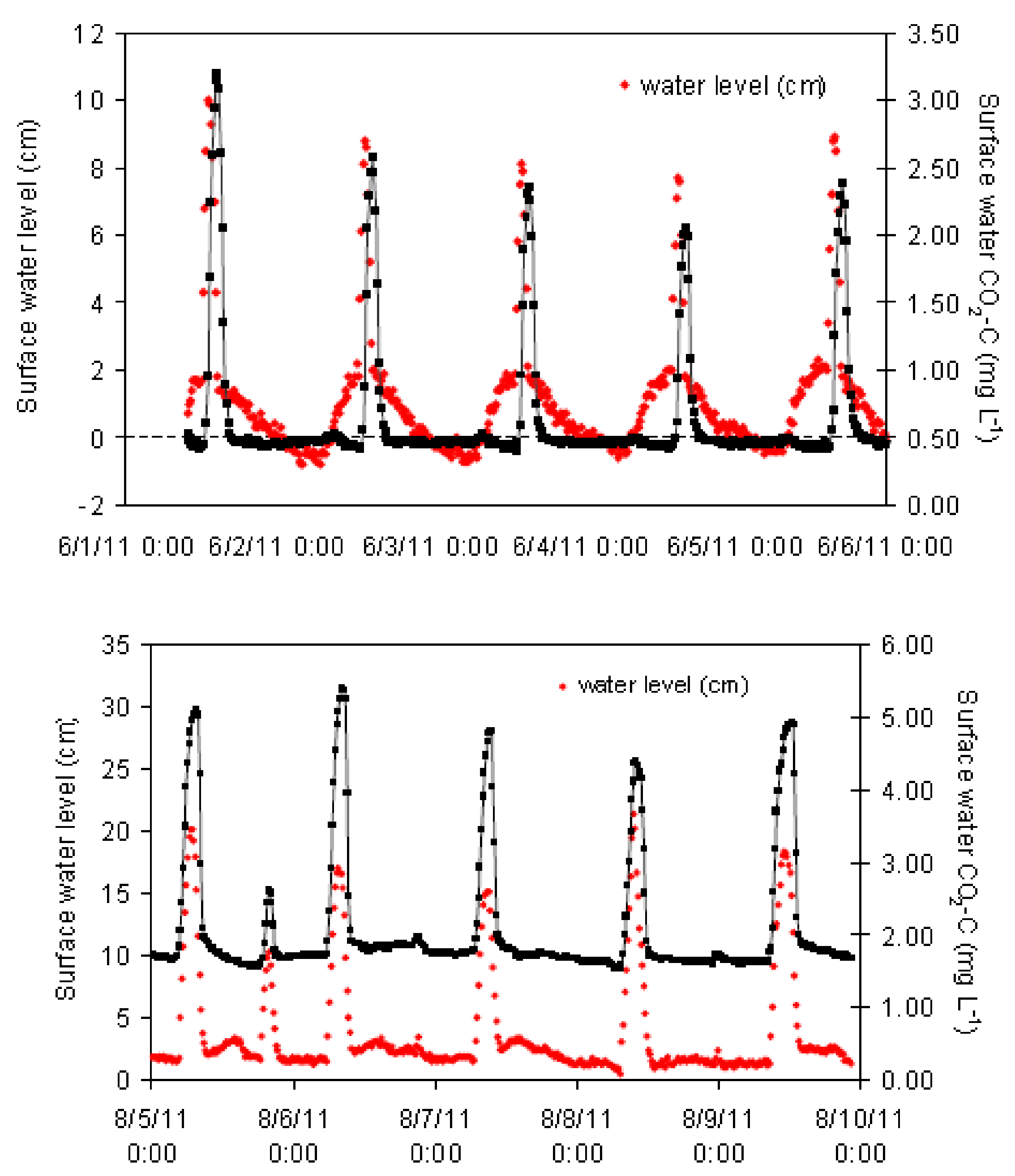
- Decline in CO_2 concentration with tidal inundation corresponds to decline in CO_2 flux over the vertical forest profile and as CO_2 flux to the atmosphere

- Inundation enhances the forest CO_2 sink

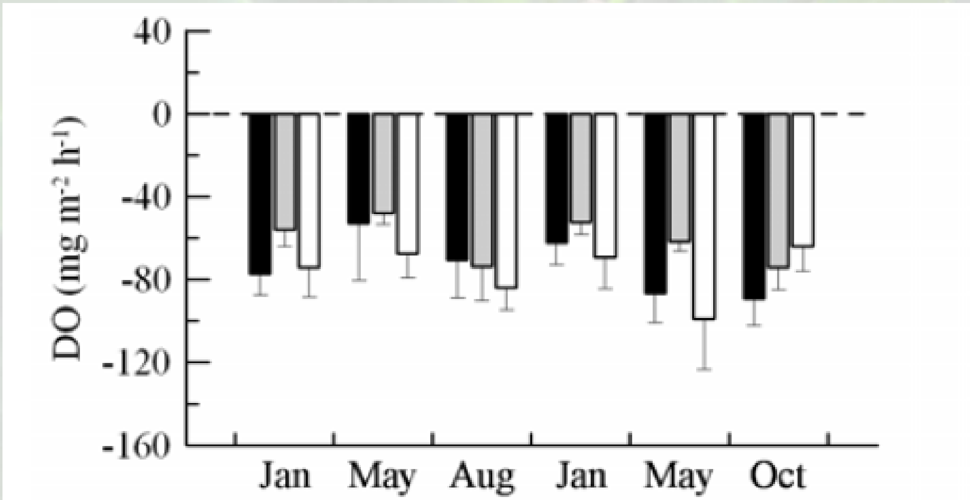


Variability in surface water CO_2 with tidal inundation

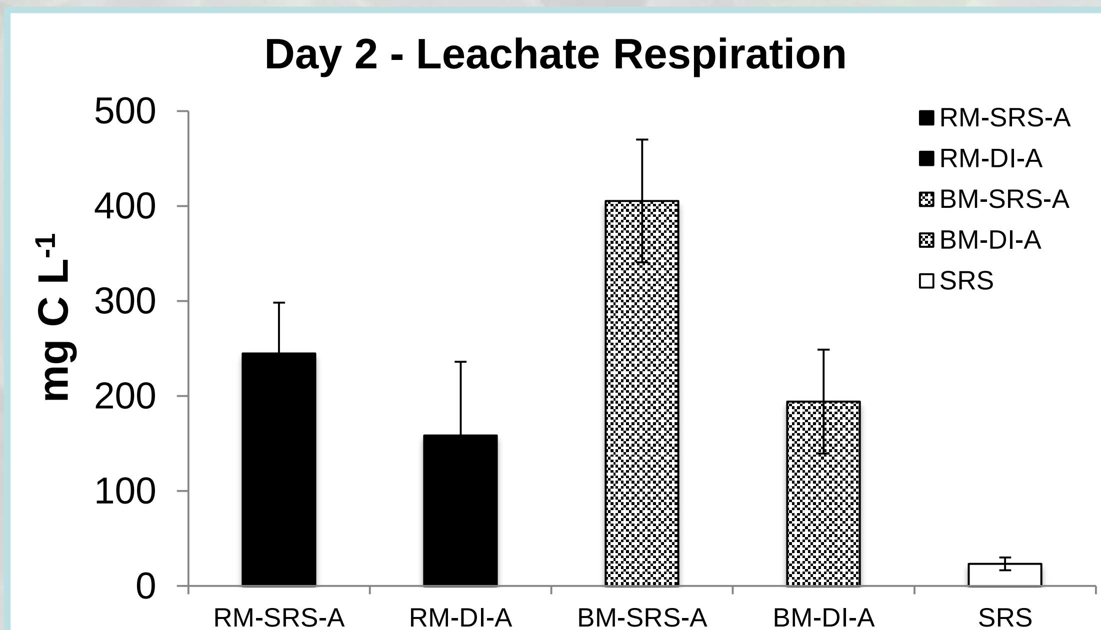
- NDIR sensors deployed at the soil-water interface and following Johnson et al 2009 and Weiss 1974.
- Within the range of values reported for northern peatlands (2-8 mg C L^{-1})
- Porewater pCO_2 is 5-10 higher than SW.
- pH of soil water 7.3-7.4 and surface water 7.5-7.8, dominant carbonate species HCO_3
- Porewater flushing with tidal inundation and advective flux is suggested to be an important mechanism for C export from mangrove forests (Romigh et al 2006)



Laboratory experiments support CO_2 production at soil-water interface



Liu and Davis in prep



Saenz and Troxler in prep

Key Findings

- Significant variability in soil CO_2 fluxes within and among sites
- Pneumatophores contributed the largest average flux
- Tidal inundation and salinity contributed to significant variation in soil CO_2 flux and lower flux to the atmosphere
- Factors that reduce soil oxidation or increase salinity could favor dominance by species with significant pneumatophore density and contribute to increased CO_2 flux
- Tidal inundation reduces soil CO_2 flux but increases CO_2 concentrations in surface water. Fluxes at soil-water interface may constitute a significant component of export.
- Increased CO_2 concentrations at soil-water interface with tidal inundation was supported by laboratory studies showing contributions of leaf leachate and soil to CO_2 production, possibly mediated through increased porewater flushing and advective flux

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