

Thermally-Driven Vertical Mixing in the Everglades

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Vertical mixing in most natural freshwater bodies is driven predominantly by boundary shear stresses such as wind stress on the free surface of a lake or bed friction on the channel bottom and banks of a rapidly flowing river. However, in the slowly flowing wetlands of the Everglades, thermally-driven convection is the dominant mixing mechanism. This diel mixing has potential implications for mercury methylation, evapotranspiration, oxidation, nutrient and contaminant transport and cycling, and other processes of concern in the Everglades wetlands.

Flow-velocity measurements and temperature profiles collected within an area of medium-dense spike rush on the edge of a large area of dense sawgrass in lower Shark River Slough within Everglades National Park reveal the behavior, timing and extent of thermal mixing. Flow velocities were sampled using an acoustic Doppler velocity meter capable of resolving very low velocities to an accuracy of 1 mm/s over a range of a few cm/s. Two 600-sample measurement bursts are depicted in Figure 1. Each burst was collected at 10 Hz and, therefore, represents a one-minute sample. There are two plots for each burst. The first shows the three components of flow velocity: east-west, north-south and up-down. The second shows a signal quality statistic, correlation, which can be considered an indicator of small-scale turbulence in the acoustic pathway. Lower correlations indicate higher turbulent mixing.

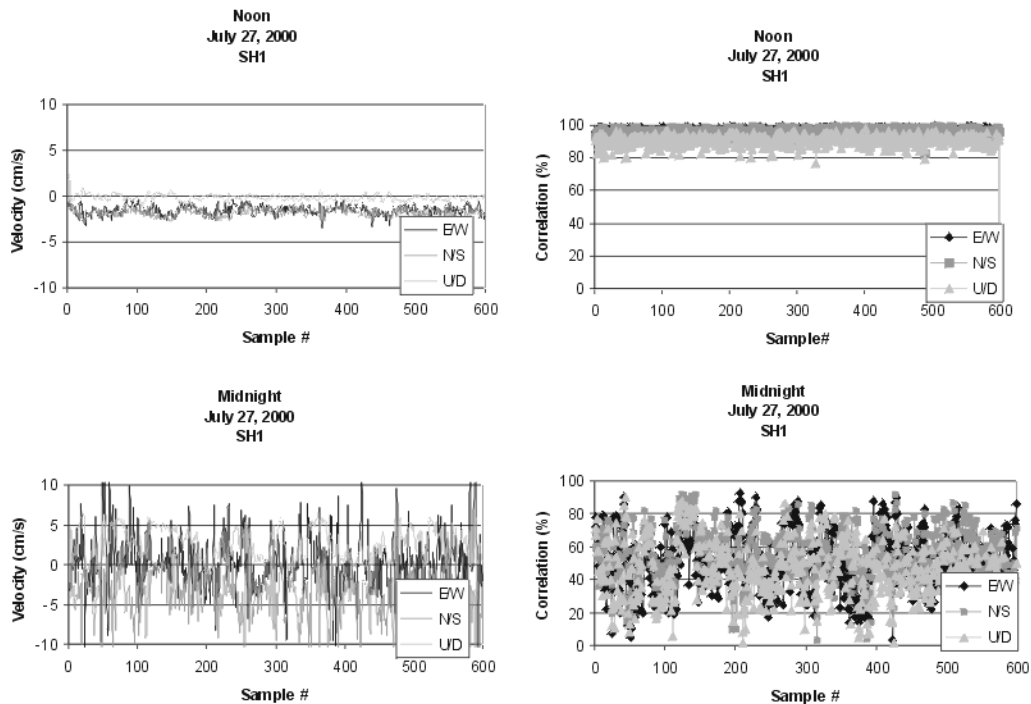


Figure 1. Typical flow velocity and signal correlation at SH1.

Velocity data in the first pair of plots, collected during the daytime, fluctuate minimally about their median values and have very high correlations. In strong contrast, velocity data in the second pair of plots, collected at midnight, fluctuate wildly and have substantially more variable

and lower correlations. This phenomenon is typical and constitutes a pattern observed nearly every day.

Highly variable flow velocities in the hours after sunset can be linked to thermal convection by considering temperature data obtained from a set of thermistors, having an accuracy of 0.1 deg C, cabled vertically 10 cm apart in a string deployed near the velocity meter. Thermistor data show the heavily vegetated water column to be isothermal at the beginning of each day (fig. 2). Initial heating of the water surface at sunrise is followed by progressive heating of the water column with depth throughout the day, resulting in increasing stratification throughout the late morning and early afternoon. Maximum stratification occurs at mid-afternoon and averages approximately 3 °C through 60 cm of the water column (5 °C/m). Typically, the water column reaches its maximum temperature around mid-afternoon. The water column cools through the remaining daylight hours, but remains stratified until approximately sunset when the air temperature begins to fall sharply and eventually drops below the water temperature at the surface.

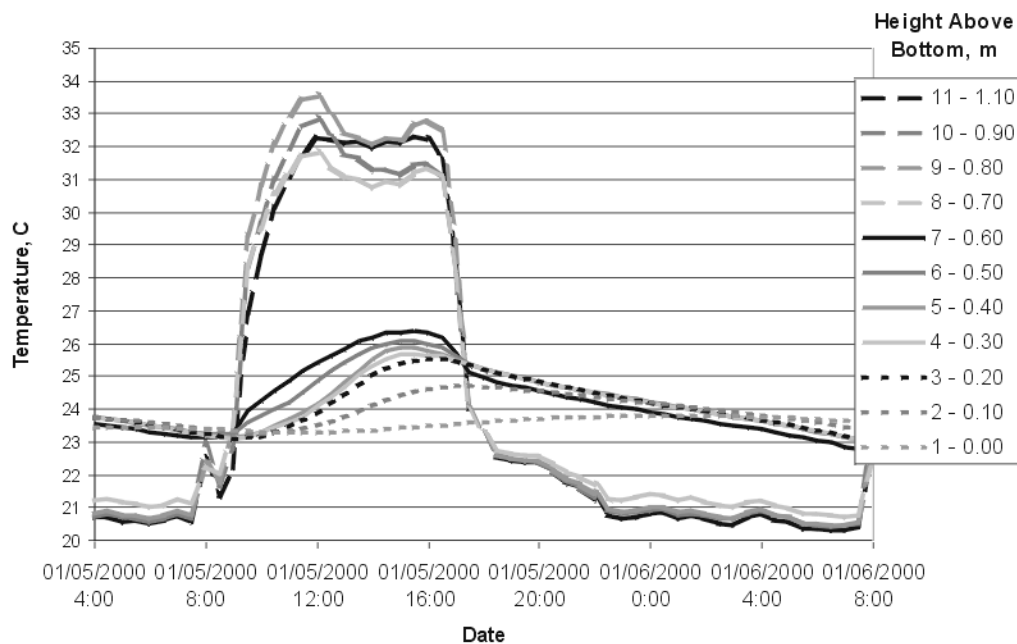


Figure 2. Typical temperature at SH1 (curve 1=plant litter, 2-7=water, 8-11=air).

Diel coincidence of the thermal destratification and pronounced velocity fluctuations indicates the onset of mixing in the water column driven by thermal convection. The mixing process begins abruptly within approximately the upper 40 cm of the water column. Temperatures within this layer coincide through the remainder of the night. This mixed layer continues to cool and deepen throughout the night, not warming until just after sunrise the next day. A thin layer at the water surface remains slightly cooler than the mixed layer through the night, providing a constant source of negatively buoyant water that drives the mixing process. The mixing process continues until the air temperature rises above the temperature of the water at the surface.

The thermally-driven mixing process also affects the temperature structure within the upper portion of the plant-litter layer at the bottom of the water column. The slow exchange of mass and heat across the water-column/litter-layer boundary causes temperatures in the plant-litter layer to lag temperatures in the water column. Decreased heat exchange causes the peak

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temperature in the litter layer to occur after midnight and the minimum temperature to occur around noon. There is a brief time just before sunrise when the temperature in the litter layer is greater than in the water column. The daily range of temperatures in the litter layer (approximately 0.5 °C) is much smaller than the range of temperatures at any particular point in the water column (approximately 3-5 °C).

Individual daily temperature profiles in the Everglades wetlands are observed to vary only slightly with meteorological conditions and indicate that daytime destratification rarely occurs. Thermally-driven mixing appears to dominate at SH1 during more than 90% of the days. Only in the case of persistently strong winds, heavy rainfall or dramatic drops in air temperature is the water column in the Everglades wetlands thermally well-mixed during the daytime. The presence of vegetation appears to be the primary factor increasing the consistency with which thermally-driven convection dominates the vertical mixing process in the Everglades. The ubiquitous nature of this mixing implies a likely role in a number of important processes in the ecologically stressed Everglades wetlands.

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