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Power Availability in the Florida Current and Impact of its Extraction on the Gulf Stream

Alexandra Bozec

Eric Chassignet, Howard P. Hanson

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Power Availability in the Florida Current and Impact of its Extraction on the Gulf Stream

Alexandra Bozec[1], Eric Chassignet[1], Howard P. Hanson[2] (abozec@coaps.fsu.edu)

[1]Center for Ocean-Atmospheric Predictions Studies, Florida State University, Tallahassee, FL, USA
[2]Center for Ocean Energy Technology, Florida Atlantic University, Dania Beach, FL, USA

GOALS OF THE PROJECT

The goals of the project are:
✓ to assess (and eventually predict) the power availability in the Florida Current

✓ to assess the impact of turbines on the Florida Current/Gulf Stream system (**First Results**)

HYCOM GLOBAL CONFIGURATION

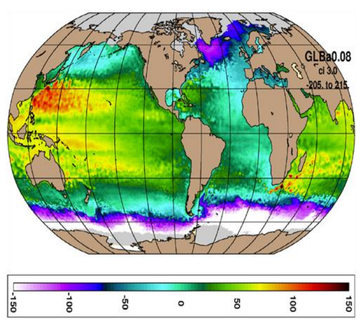
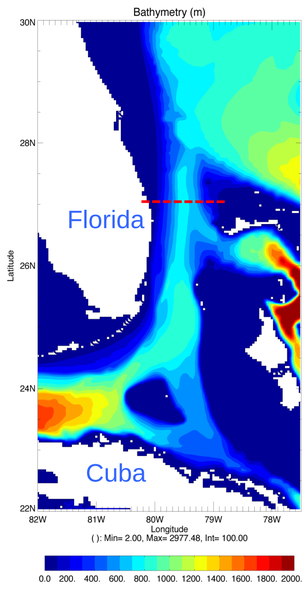


Fig. 1: Sea Surface Height map from the Global HYCOM + NCODA system (cm) (top) and zoom of the bathymetry in the Fort Lauderdale Region (right). Red line: location of the Cable.



✓ From Jun 2007 to Oct 2009 for this particular experiment (Expt 74.2)

✓ 1/12º (~7 km) horizontal resolution at 27ºN

✓ 32 hybrid-layers (combination of geopotential, isopycnal, sigma layers)

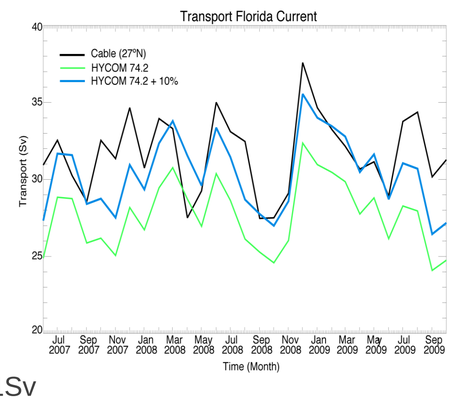
✓ Navy Operational Global Atmospheric Prediction System (NOGAPS) 0.5º resolution

✓ Navy Coupled Ocean Data Assimilation (NCODA) system

http://www.hycom.org/dataserver

HYCOM vs. CABLE TRANSPORT

Fig. 2: Northward Transport at 27ºN from the Cable (black), from HYCOM (green) and from HYCOM increasing the velocity by 10% (blue).



Monthly Transport:

✓Negative bias:
Cable: ~ 32Sv
HYCOM: ~ 28Sv
HYCOM+ 10% vel: ~ 31Sv

✓Similar variability

VELOCITY and POWER DENSITY at 27ºN

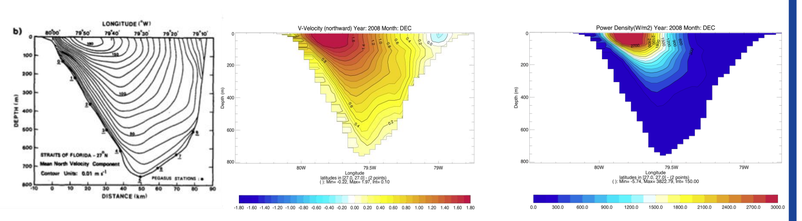


Fig. 3: Northward velocity at 27ºN from mooring Apr1982-Jul1984 (Leaman et al.,1987 on the left), northward velocity from HYCOM for December 2008 (middle) and the derived power density (right).

✓ The model reproduces well the structures of the current at 27ºN.

✓ Maximum power density in the first 500m, 50km from the Florida Coasts : between 1.1kW/m^2 in Sep 2008 to 3.8kW/m^2 in Dec 2008.

TOTAL POWER AVAILABILITY

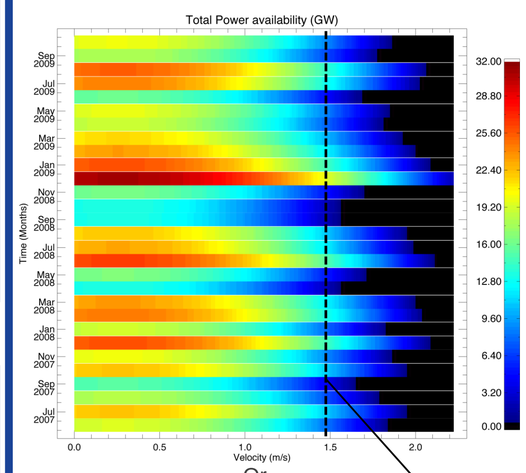


Fig. 4: Evolution of the Total Power Availability sorted by velocity or Rotor minimum speed over the 27ºN section (data from HYCOM + 10%).

✓ Semi-annual variability.

✓ Max/Min in Dec/Sept 2008.

✓ Best efficiency : At best ~ 60% of the energy can be captured.

✓ Strong variability of the available power : From 1GW to 10GW.

N.B.: 1GW=1 nuclear power plant

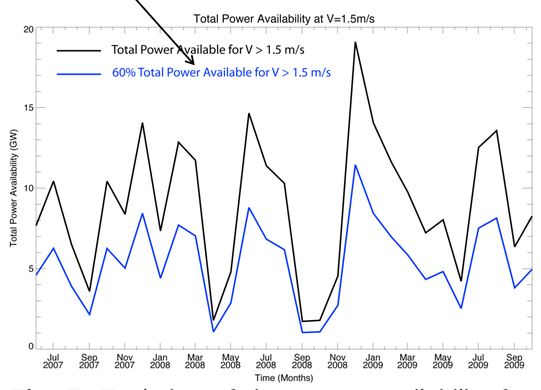


Fig. 5: Evolution of the power availability for velocity (or rotor minimum speed) **greater** than 1.5m/s.

HYCOM ATLANTIC CONFIGURATION FOR TURBINES SIMULATIONS

Atlantic configuration of HYCOM :

✓ 1/12º horizontal resolution

✓ 32 hybrid layers

✓ Initial conditions (T,S) from GDEM3

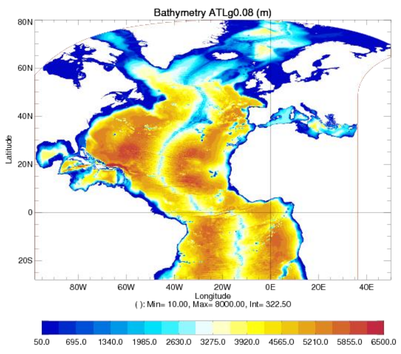
✓ Climatological ERA40 atmospheric forcing

✓ 2 Simulations starting from a **10 year run** :

✓ 1 control simulation

✓ 1 simulation with “4 turbines” at 20m parameterized as a drag :

First Test: C_T = 1 (Only 5 months available for now)



$$-\frac{1}{2} C_T \sqrt{(U^2 + V^2)}$$

TURBINES in the FLORIDA CURRENT (1)

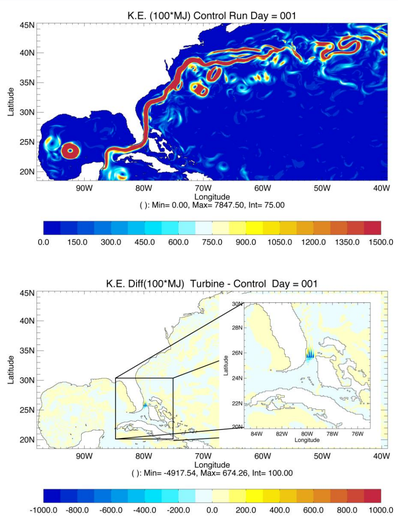
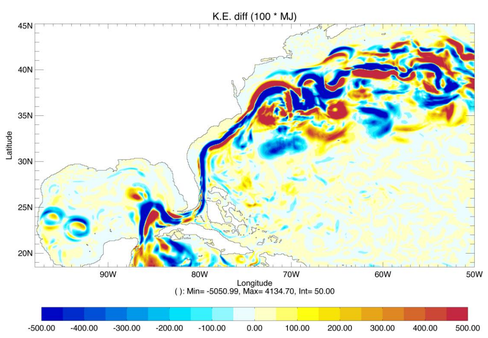


Fig. 6: Kinetic Energy in CONTROL (top) for day 1 at 20m. Difference of kinetic energy between CONTROL and TURBINES for day 1.

✓ 4 “turbines” in the Florida Current at 25.7ºN.

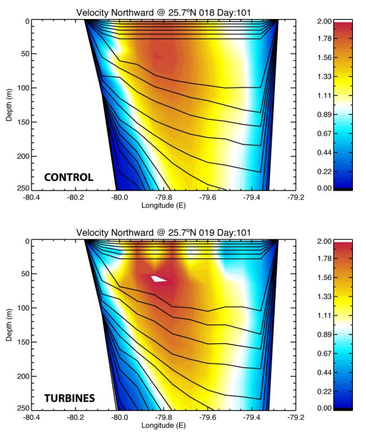
Fig. 7: Difference of Kinetic Energy between the CONTROL and TURBINES simulations (Average over the 5th month).

✓ Impact on the path of the current **upstream and downstream** but not in intensity.



TURBINES in the FLORIDA CURRENT (2)

Fig. 7: Northward velocity section at 25.7ºN for CONTROL (top) and TURBINES (bottom) at day 101. Black contours are layer interfaces of HYCOM.



✓ Disturbance of the flow over the whole section.

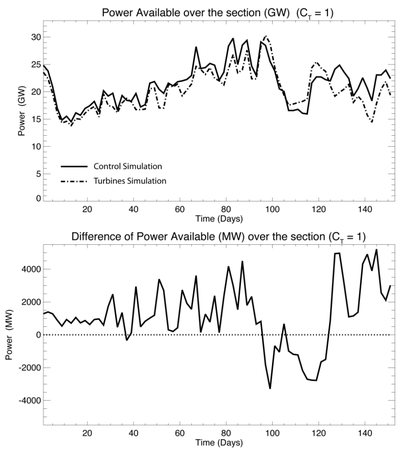
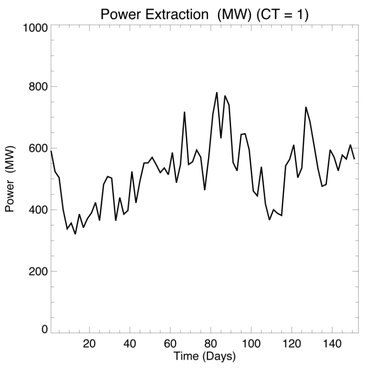


Fig. 8: Evolution of the total power available over the whole section at 25.7ºN for CONTROL and TURBINES (top) and the difference (bottom).

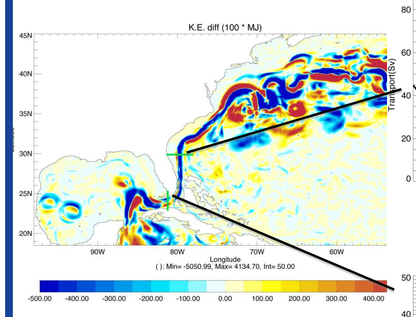
✓ The presence of turbines impacts the power available over the whole section (even increasing it).

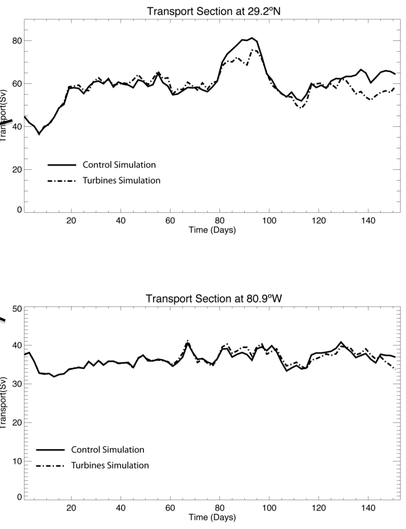


✓ Estimation of the power extracted only by the 4 “turbines” (power extracted over the 4 grid cells): 400MW to 800MW.

N.B.: 1MW=1000 homes

✓ Impact on the Upstream and Downstream Transport





✓ Little impact on the total transport of the flow downstream and upstream (except for few days in the downstream transport).

Fig. 9: Evolution of the transport at 29.2ºN (top) and 80.9ºW (bottom) for CONTROL and TURBINES .

FUTURE WORK

✓Continue the simulation to complete a year.

✓Test different C_T number.

✓Impact of turbines on the energetics of the Florida current/Gulf Stream system.

✓Develop a realistic high-resolution configuration of the Fort Lauderdale region (with assimilation).