Development of a local ocean prediction model of the Fort Lauderdale region for energy extraction purpose

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Florida Energy

✓ Population of Florida is increasing (30 Millions by 2030)
✓ Electricity demand is predicted to increase by at least 30% in the next 10 years

Florida is over ~ 98% reliant on outside energy
- Natural Gas (39%)
- Coal (23%)
- Other fossil fuels (24% petroleum)
- Nuclear power (8%)

Volatile Market

Florida renewable power generation (less than 2%)

=> Ocean Energy

(Mission of the Florida's Southeast National Marine Renewable Energy Center at FAU)

Objectives

The goals are:

- ✓ to assess (and eventually predict) the power availability in the Florida Current in the Fort Lauderdale region.

- ✓ to assess the impact of turbines on the Florida Current/Gulf Stream system

Method

- ✓ to assess the power availability in the Florida Current

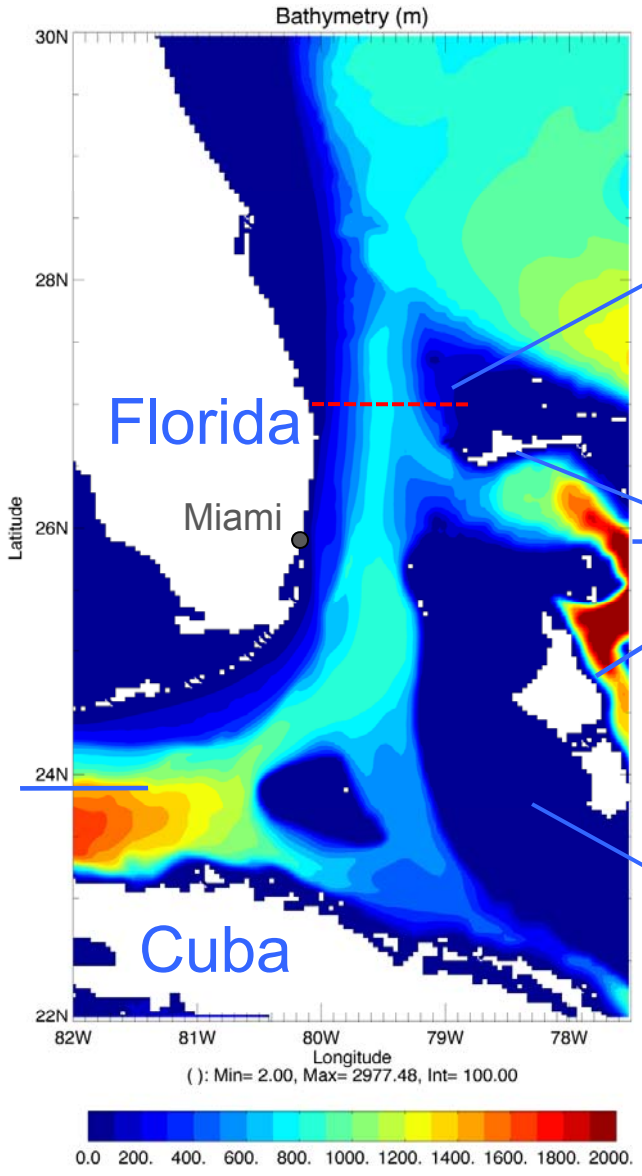
  ⇒ Global 1/12º resolution (~8 km) assimilated simulations of the HYbrid Coordinates Ocean Model (HYCOM)

- ✓ to assess the impact of turbines on the Florida Current/Gulf Stream system

  ⇒ Atlantic Ocean 1/12º resolution HYCOM simulations (no assimilation) : Preliminary results

Assessment of the Power availability in the Florida Current

Bathymetry of the region



Leaman et al. (1987) section
Cable

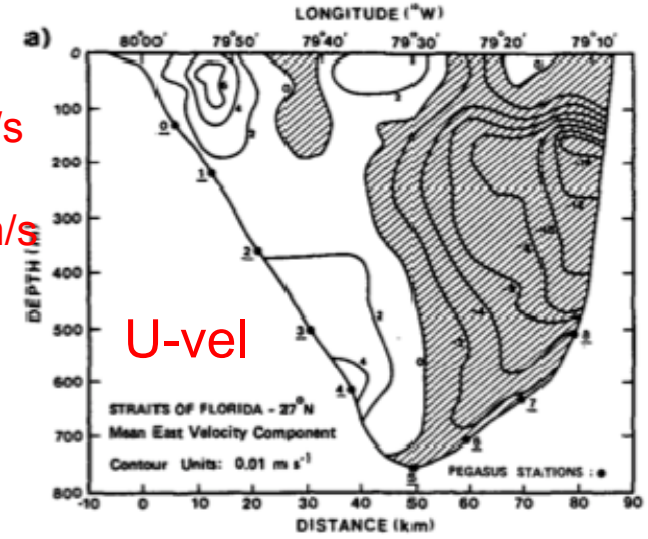
The Bahamas

Strait of Florida

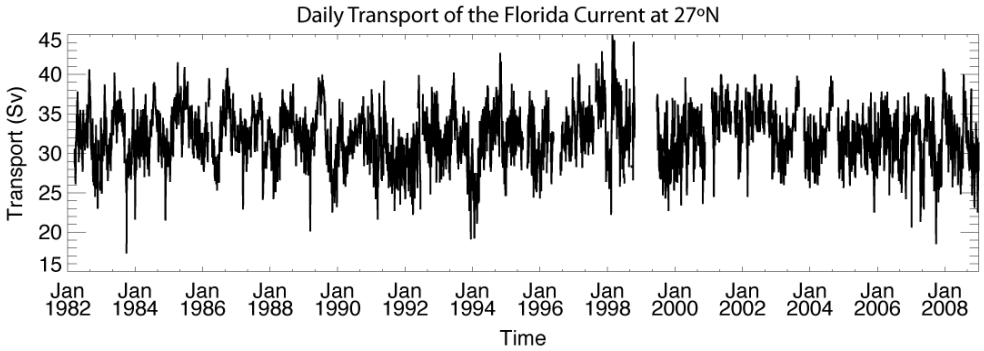
Grant Bahama Bank

Structure and Variability of the Florida Current

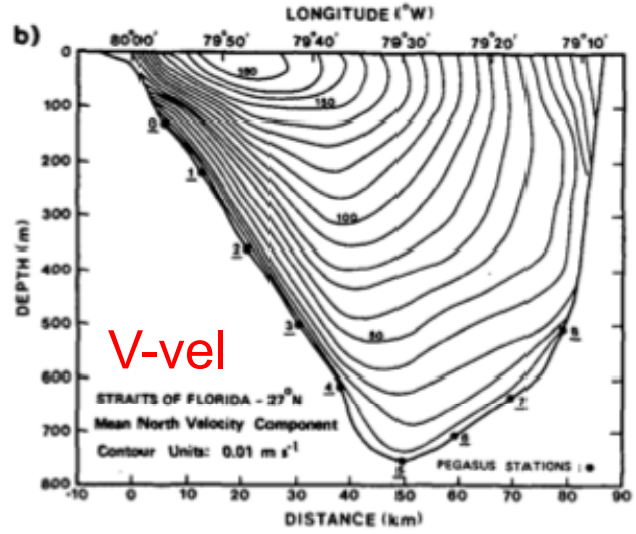
Max
0.06m/s
Min
-0.14m/s



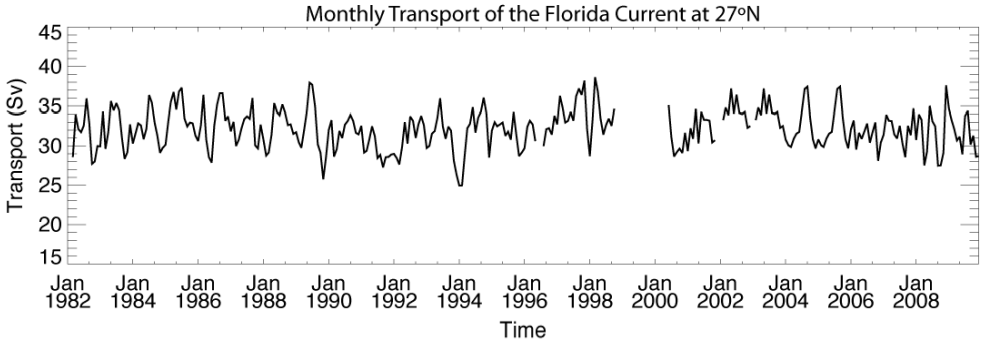
<= Section at 27ºN for the period Apr 1982 to Jul 1984 (Leaman et al. 1987)



Max
1.8m/s



Averaged Transport ~32Sv



http://www.aoml.noaa.gov/phod/floridacurrent/data_access.php

HYCOM Global configuration

- From Jun 2007 to Oct 2009

- ~7-8km resolution

- 32 layers

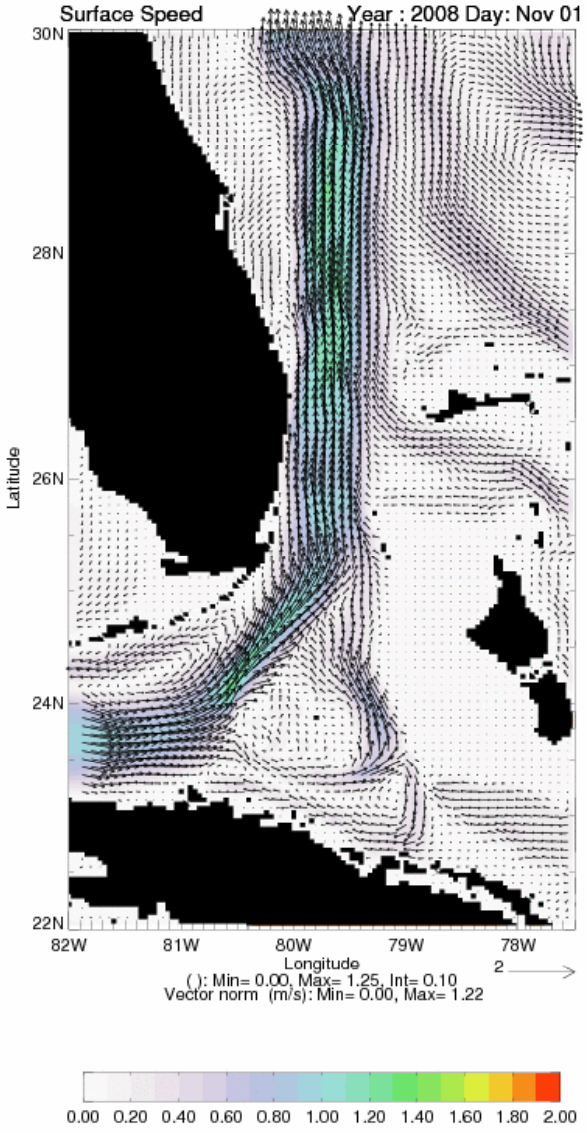
- Navy Operational Global Atmospheric Prediction System (NOGAPS)

- Navy Coupled Ocean Data Assimilation (NCODA) system

- No tides

http://www.hycom.org/dataserver/glb-analysis

Variability of the Florida Current



Daily surface current Nov-Dec 2008

✓Almost laminar flow except for some meanders

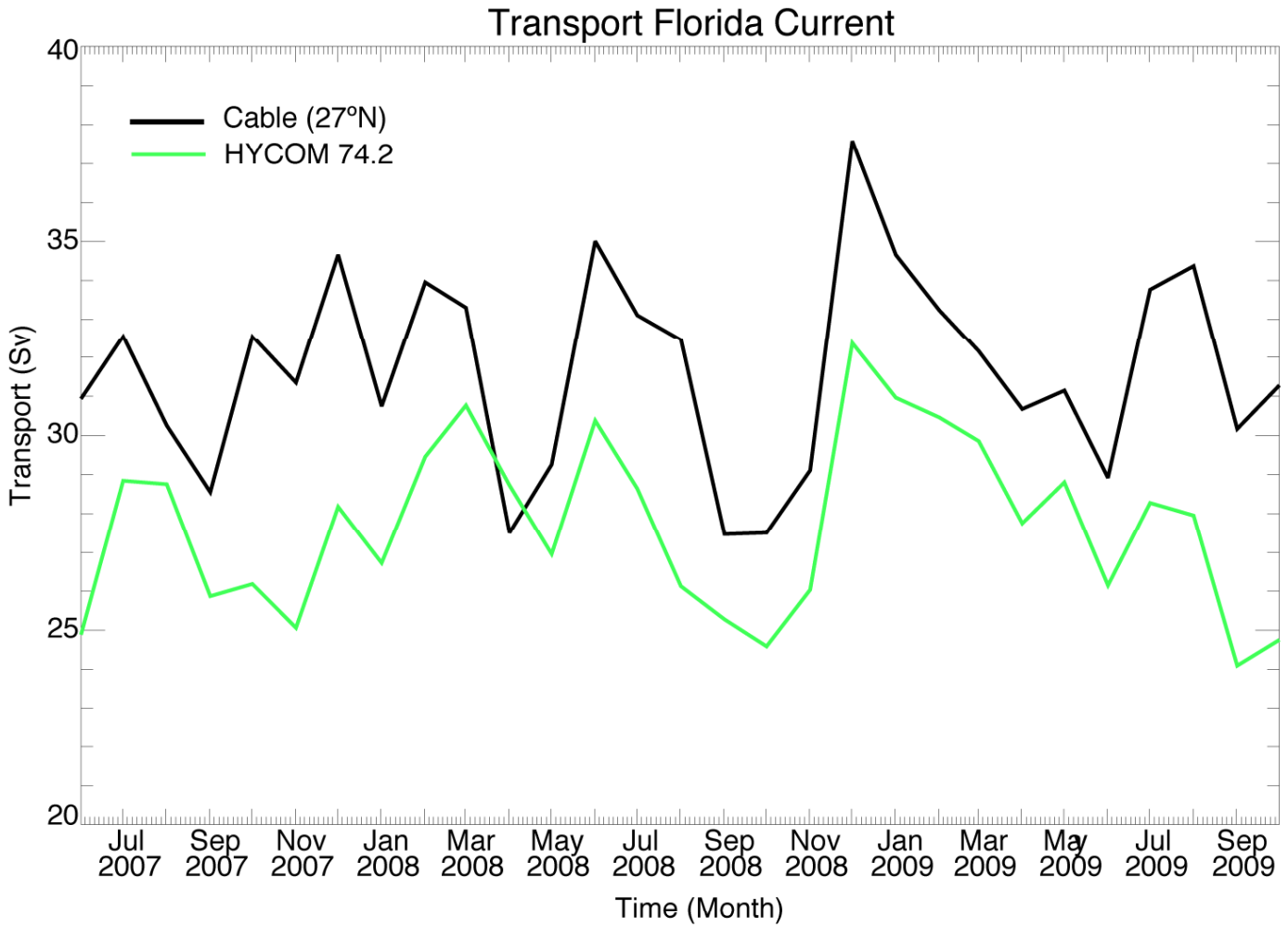
✓Speed up too 2.3 m/s

Comparison with Cable data

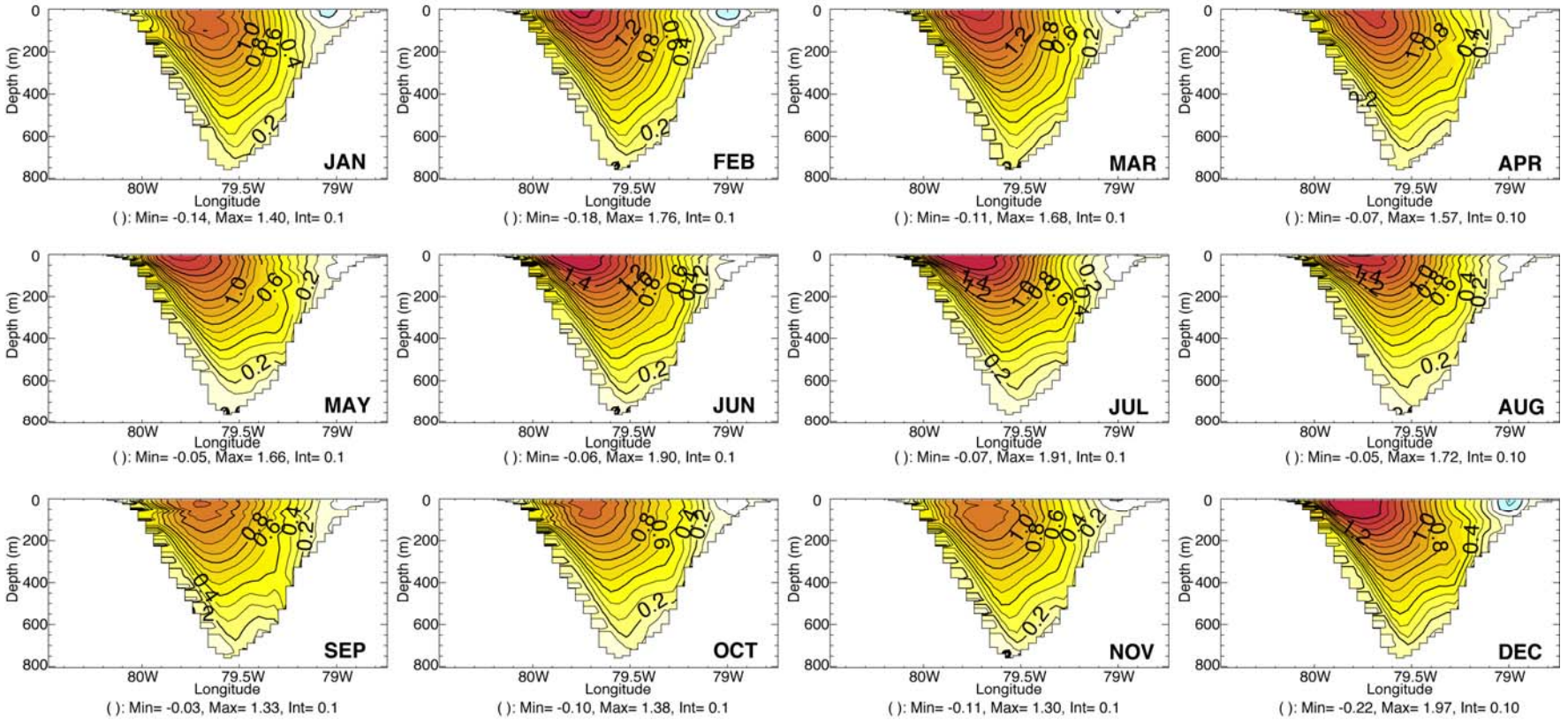
Monthly transport:

✓Negative bias:
Cable: ~ 32Sv
HYCOM: ~ 28Sv

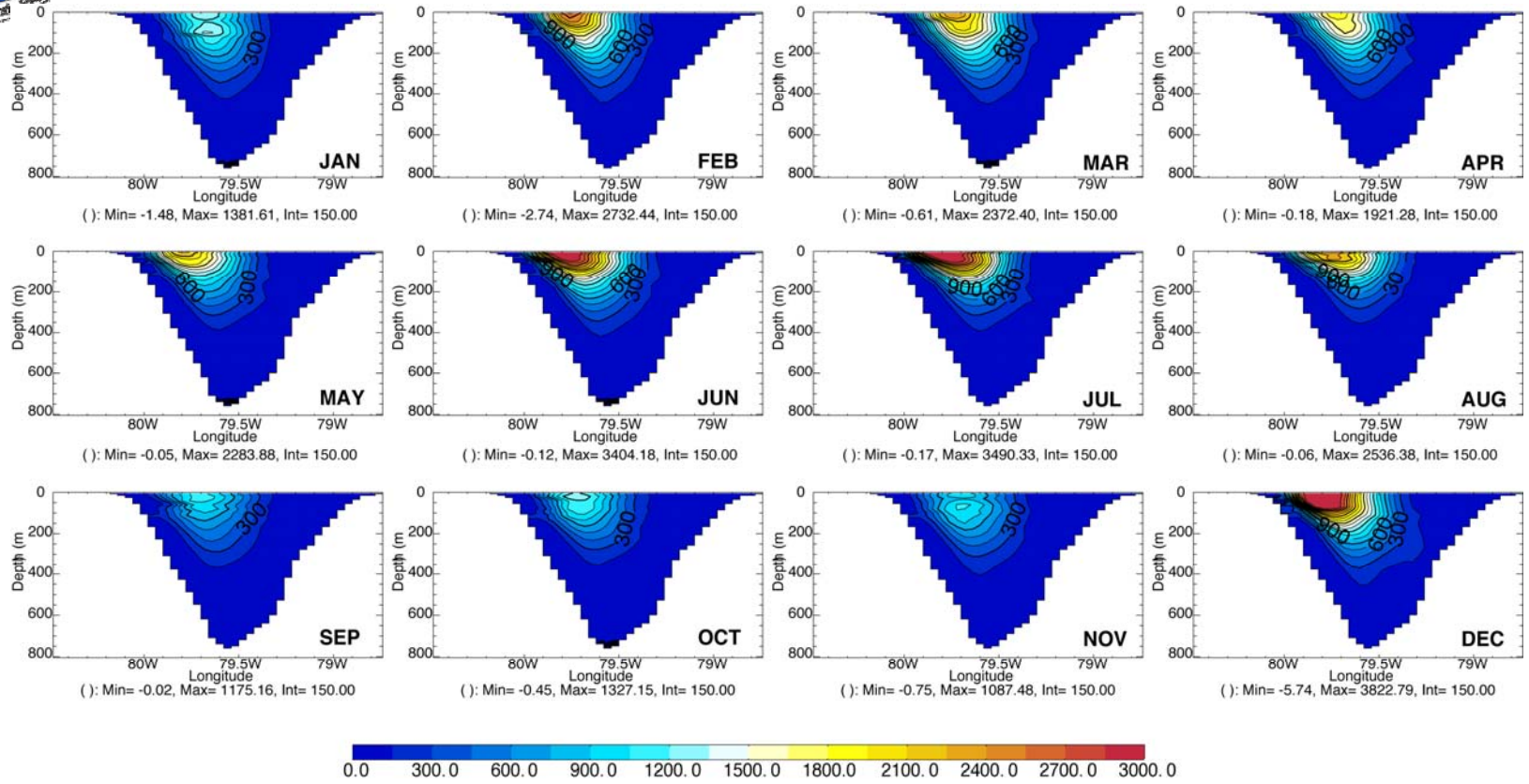
✓Similar variability



Velocity Structure at 27ºN Year 2008



Power Density (W/m^2) Year 2008



Power Density:

$$P = \frac{1}{2}\rho U^3$$

Max power density varies from

~1.0kW/m^2 (at 60m November 2008)

to

~3.8kW/m^2 (at 5m in December 2008)

Total Power Availability (GW)

Total Power Availability:

1GW = 10^9 W ≈ 1 Nuclear Power Plant

$$P = \frac{1}{2}\rho \int_A U^3 dA$$

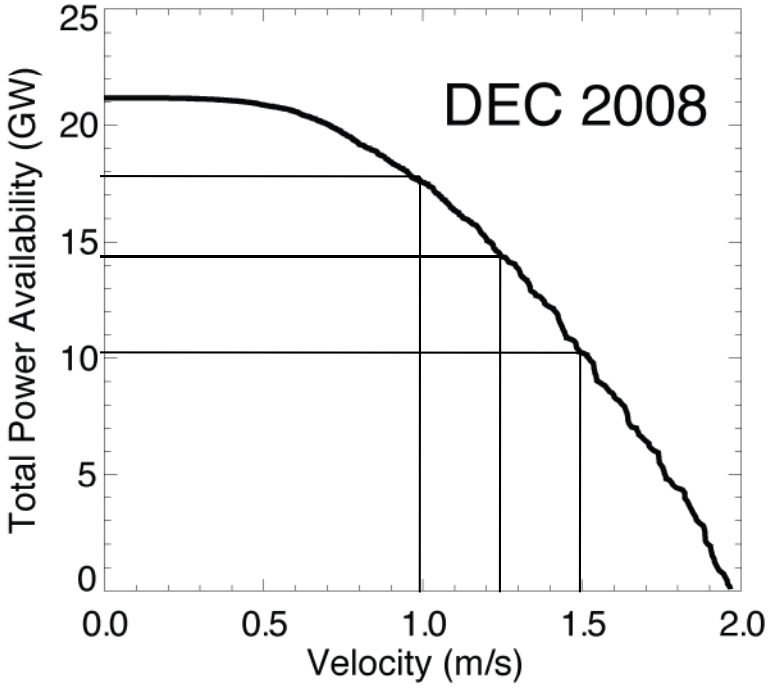
18 GW available

10 GW available

↓ - 40%

10.8 GW available

6 GW available



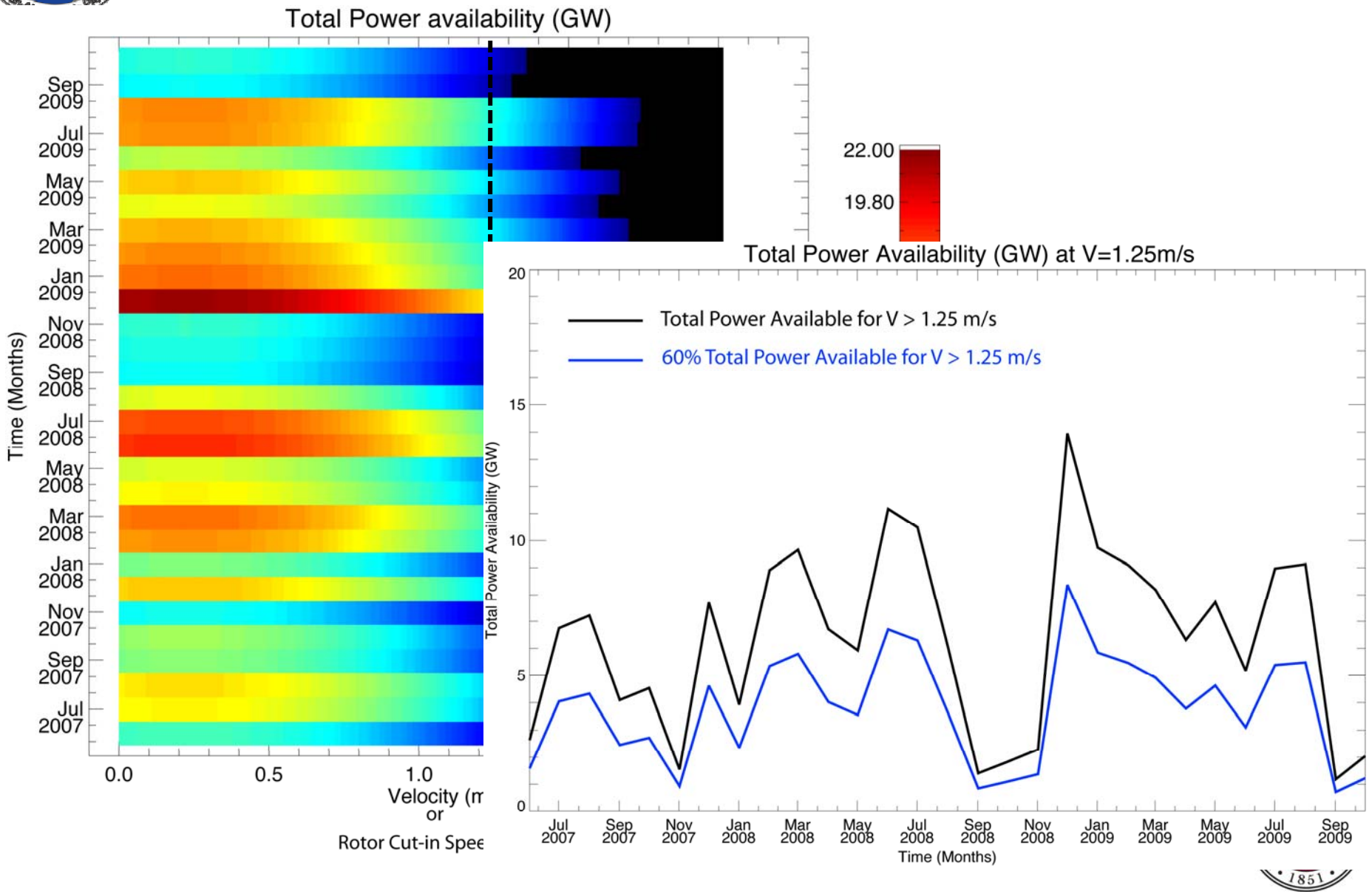
or

Rotor minimum Operating Speed

>1m/s >1.5m/s

Best efficiency : Only ~ 60% of the energy can be captured

Total Power Availability (2)



Assessment of the impact of turbines on the Florida current/Gulf Stream System

Atlantic Ocean Configuration

Atlantic configuration of HYCOM :

⇒ 1/12º horizontal resolution (~7-8km)

⇒ 32 hybrid layers

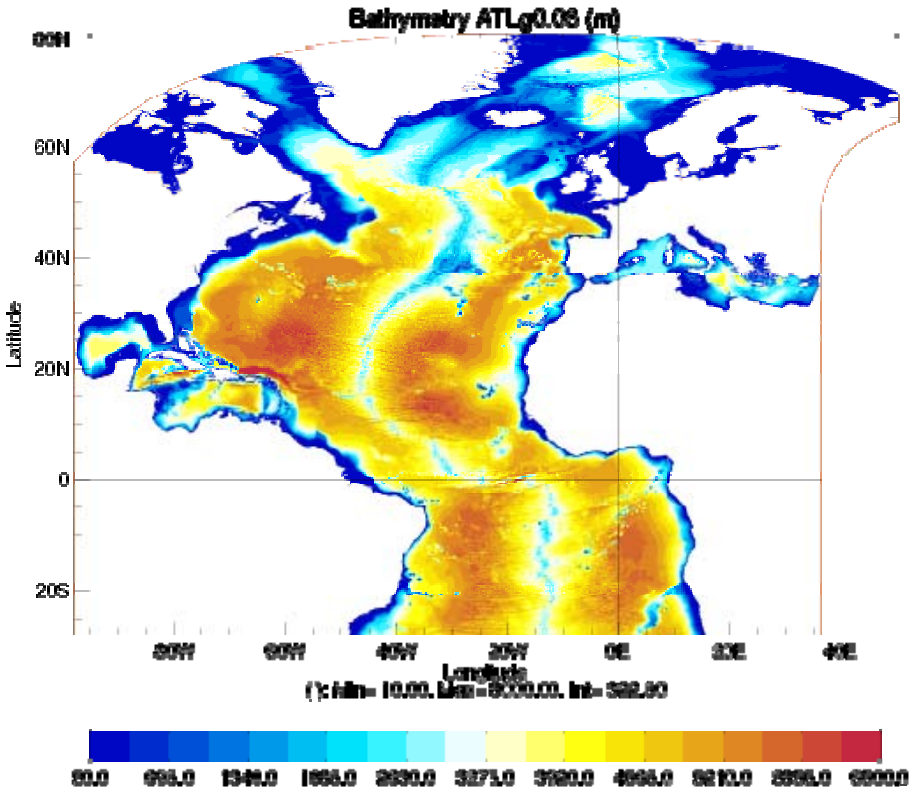
⇒ Climatological initial conditions (T,S) from GDEM3 (Mean state of the ocean for the last ~50 years of Obs)

⇒ Climatological atmospheric forcing from ERA40 (Mean state from 1978-2002)

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

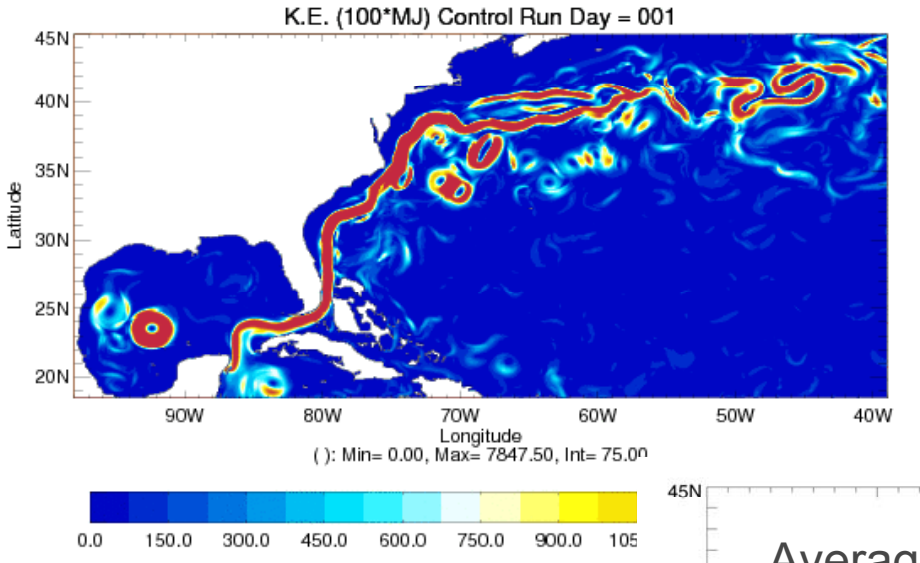
  ⇒ 1 control simulation

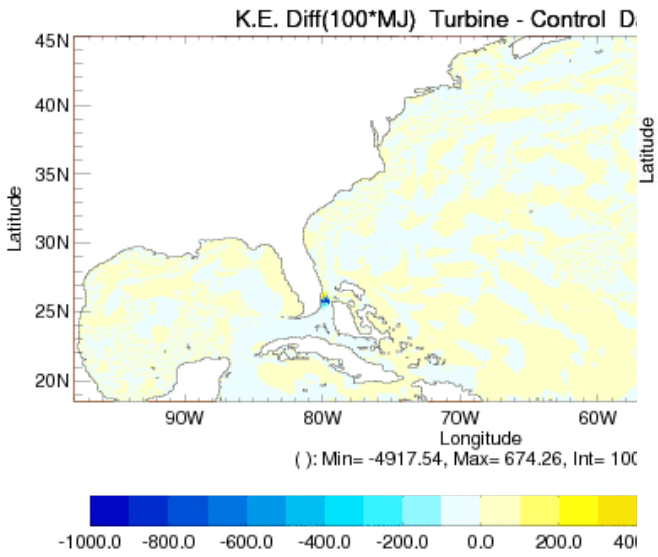
  ⇒ 1 simulation with “4 turbines” at 20m parameterized as a drag :

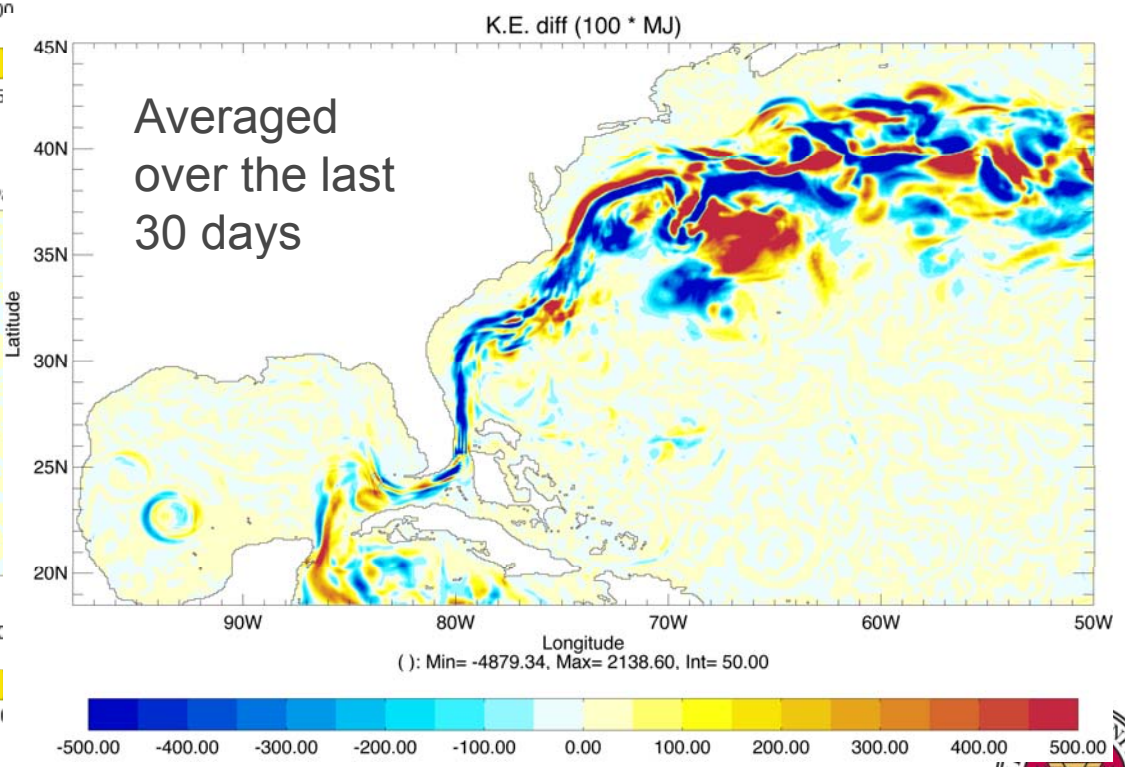


$$-\frac{1}{2} C_T \sqrt{(U^2 + V^2)}$$ With C_T =1

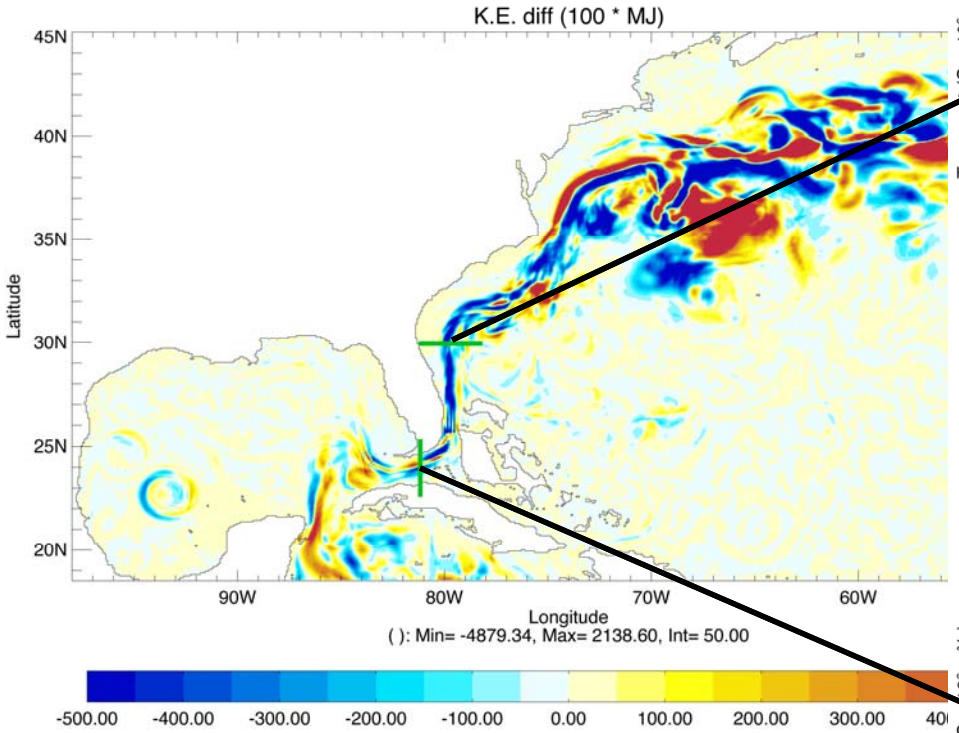
Kinetic Energy at 20m

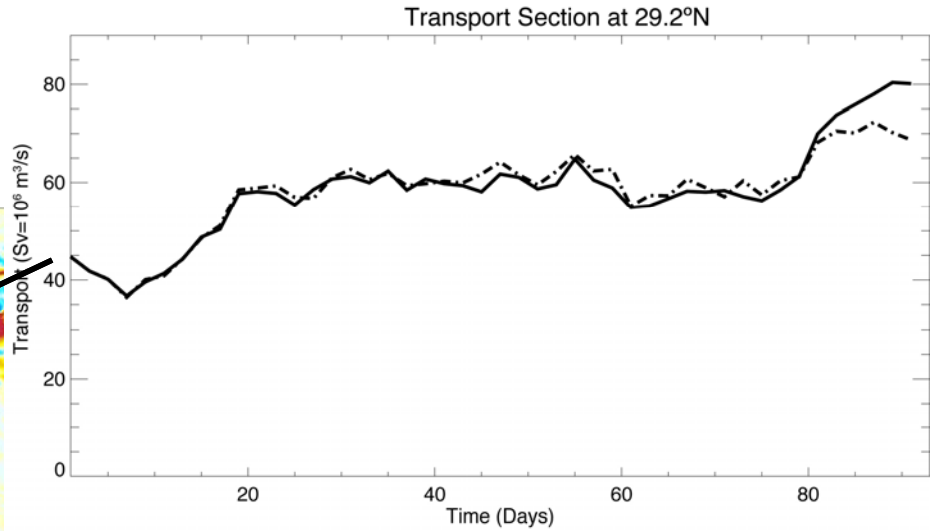


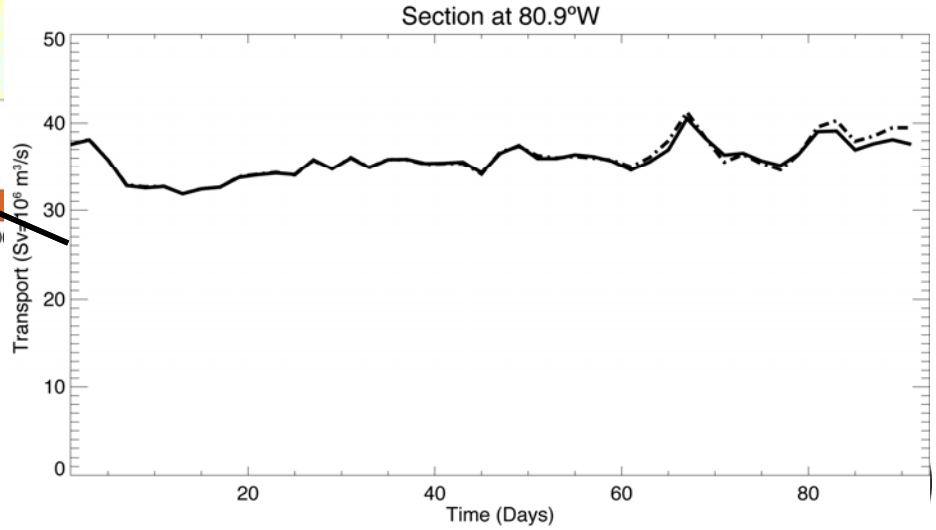




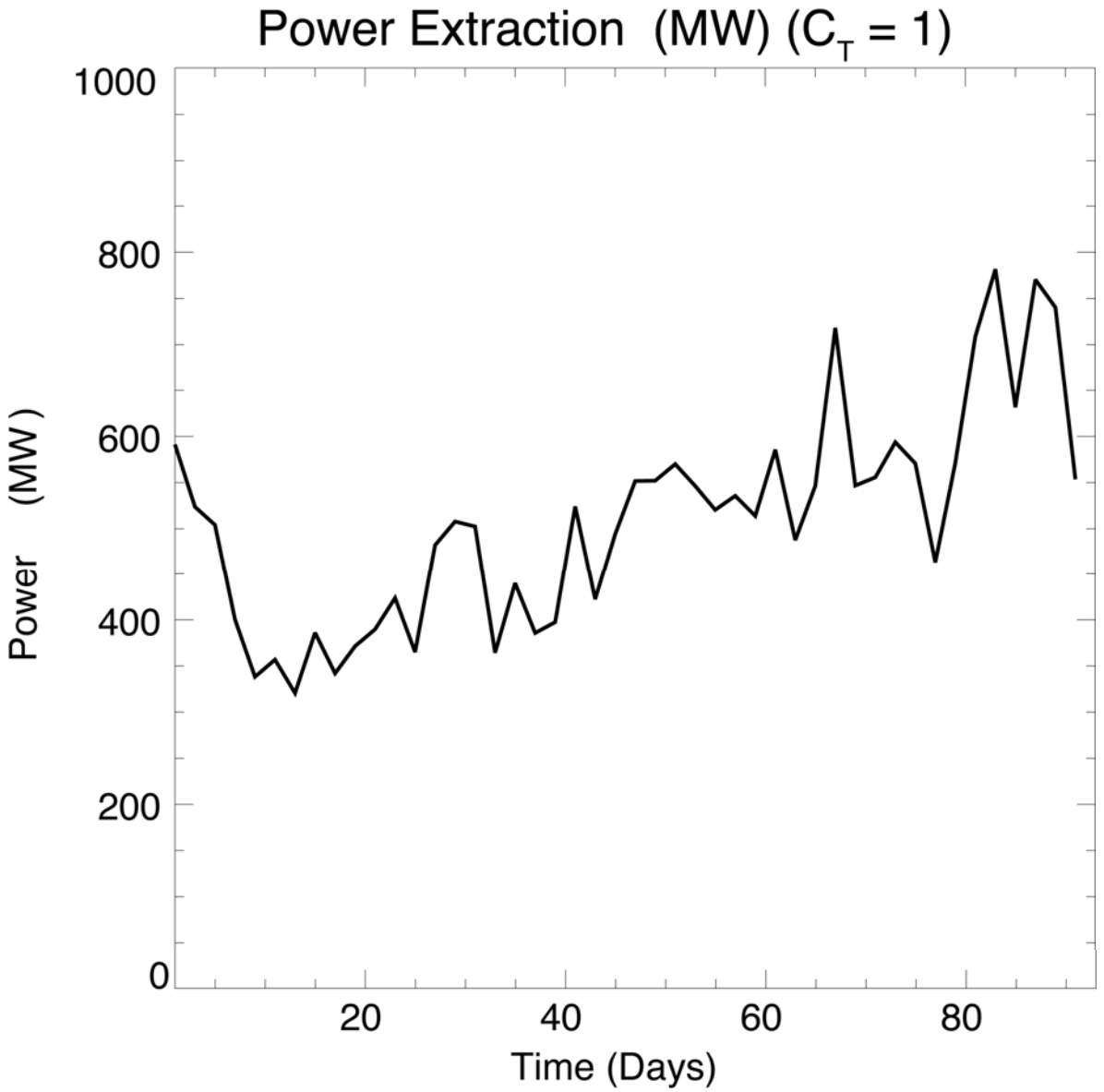
Impact on the Current Transports







Power extraction Estimation



Future Work

- ✓ Test different C_T
- ✓ Impact of turbines on the energetics of the current
- ✓ Determine the wake of the turbines for the optimal placement of the turbine array
- ✓ Develop a realistic high-resolution configuration of the Fort Lauderdale region (with assimilation).