Impact of Power Extraction on the Florida Current/Gulf Stream System

Alexandra Bozec[1], Eric Chassignet[1], Howard P. Hanson[2]

1 Center for Ocean-Atmospheric Prediction Studies, Tallahassee, FL
2 Center for Ocean Energy Technology, Florida Atlantic University, Dania Beach, FL, USA

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)

Volatile Market

- Nuclear power (8%)

Florida renewable power generation (less than 2%)

=> Ocean Energy

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

Objectives of the Project

- ✓ to assess 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

Tools

✓ to assess the power availability in the Florida Current

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

(Hanson et al., 2011, EOS Trans. AGU, 92(4), 29-30.)

✓ to assess the impact of turbines on the Florida Current/Gulf Stream system (Transport, Heat Transport, Energy and Power)

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

Atlantic Ocean Configuration

Atlantic configuration of HYCOM (ATLg0.08):

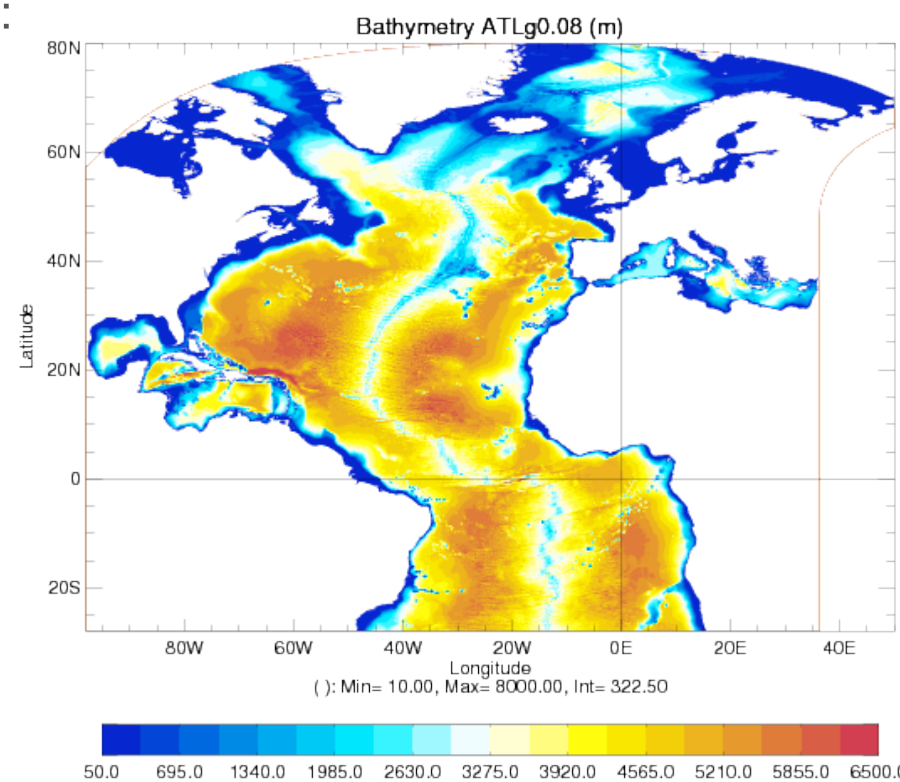
⇒ 1/12º horizontal resolution (~7-8km)

⇒ 32 hybrid layers

⇒ Climatological initial conditions (T,S) from GDEM3

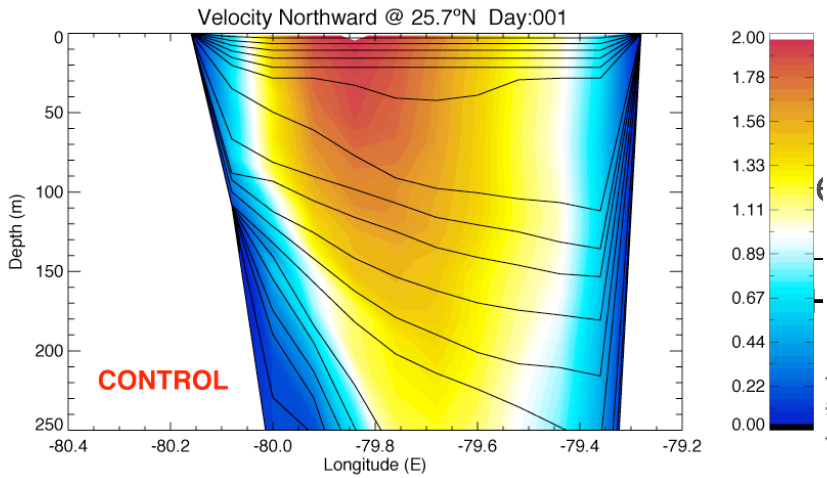
⇒ Climatological atmospheric forcing from ERA40

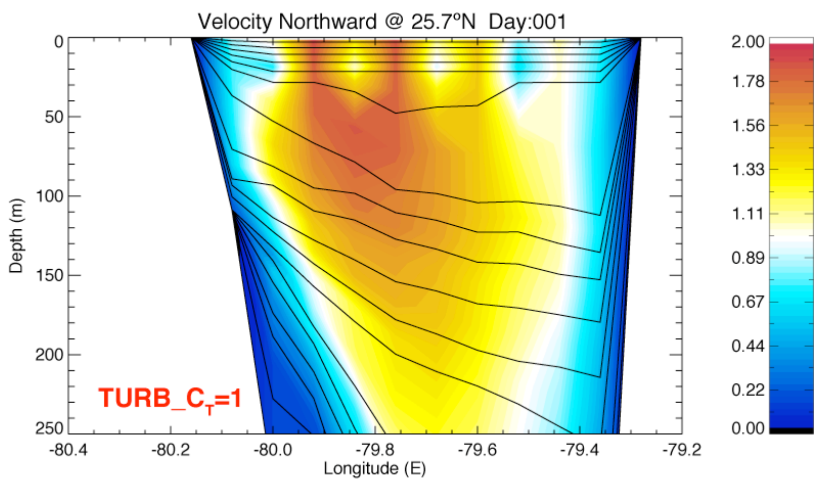
⇒ Start from a 10 year spin-up

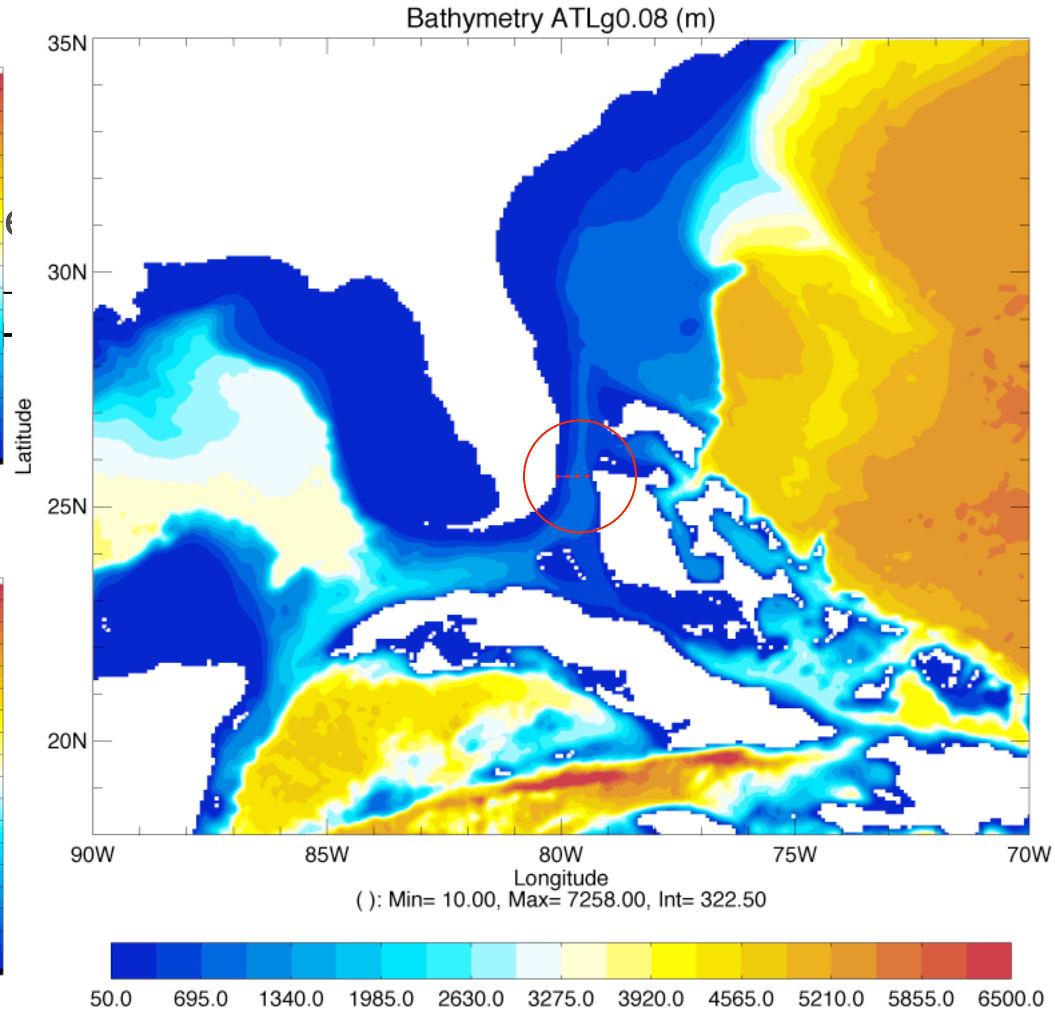


(Courtesy of X. Xu)

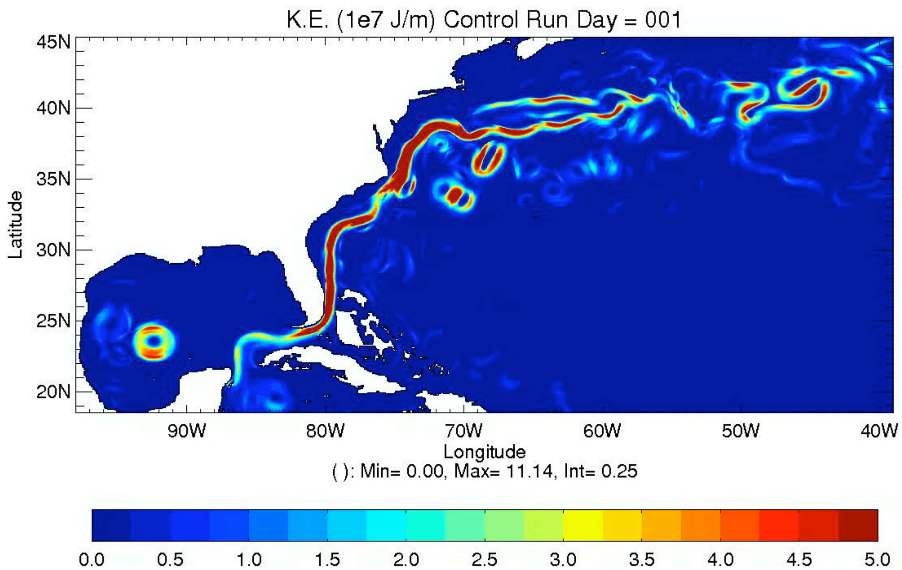
Experimental Set-up

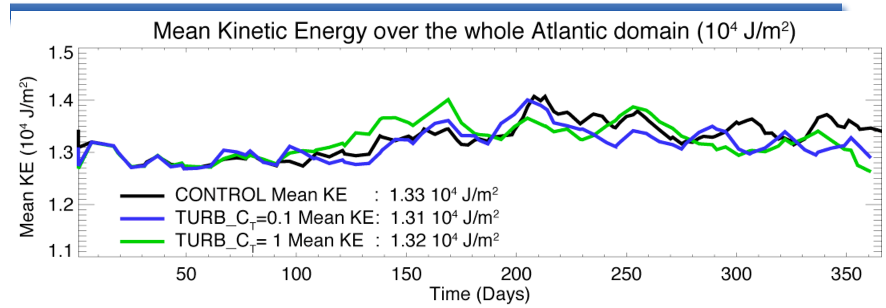


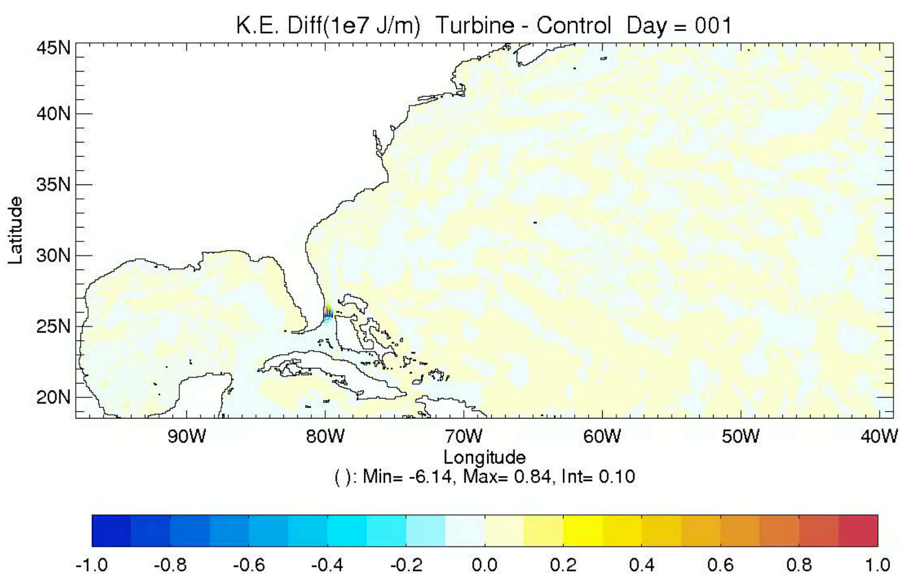




Kinetic Energy







✓ The mean KE over the whole basin does not change with the addition of turbines

✓ Perturbations induced by the turbines are not only present downstream, but also upstream

Mean Kinetic Energy

Kinetic Energy (KE):

$$\frac{1}{2}\overline{\rho}\left(\langle u^2\rangle + \langle v^2\rangle\right)$$

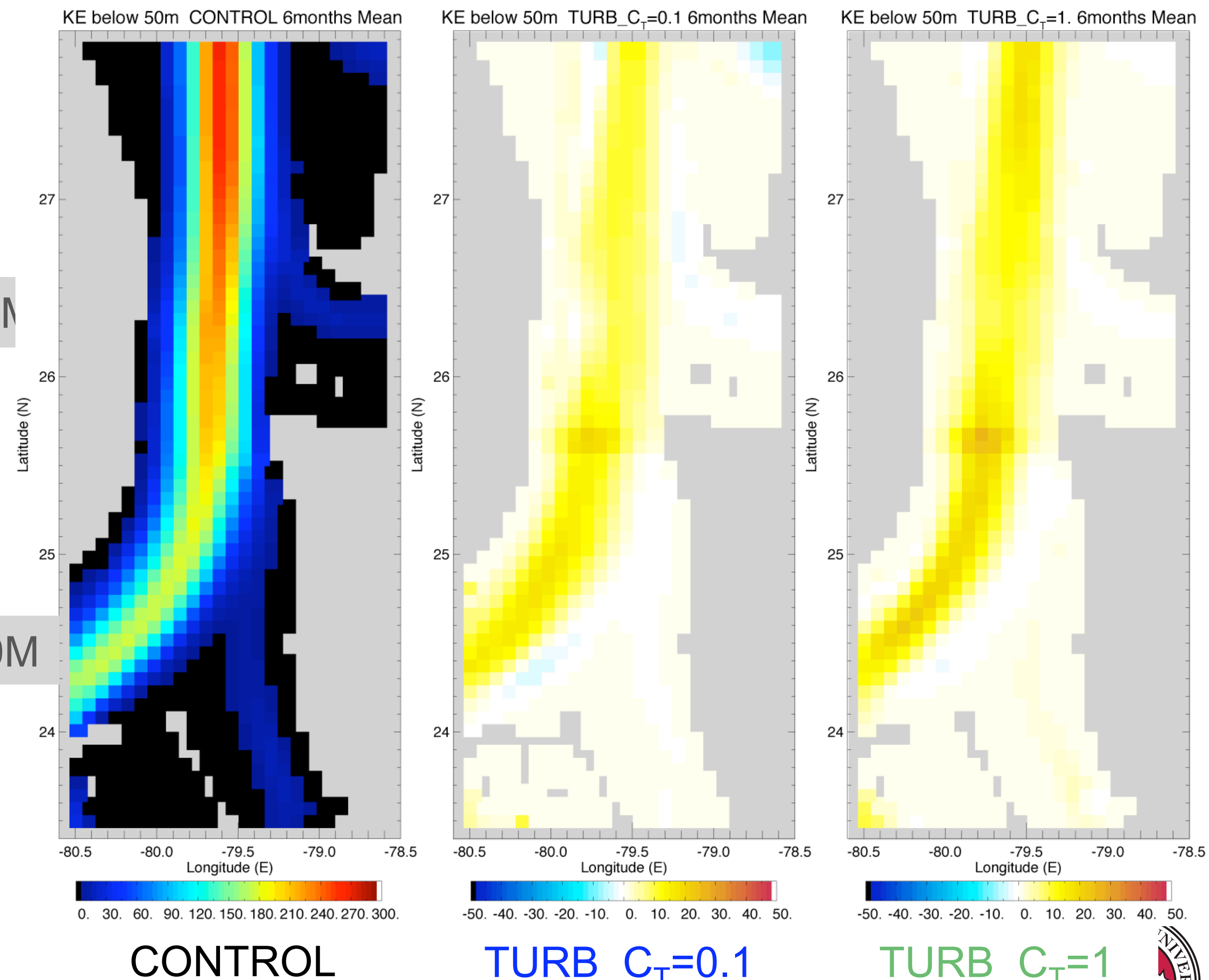
(Mean over the last 6months)

ABOVE 50M

✓ The turbines **decrease** of the mean KE downstream **above** 50m

BELOW 50M

✓ The turbines **increase** of the mean KE downstream and upstream **below** 50m



Eddy Kinetic Energy

Eddy Kinetic Energy (EKE):

$$\frac{1}{2}\overline{\rho}\left(\left\langle u'^2\right\rangle + \left\langle v'^2\right\rangle\right)$$

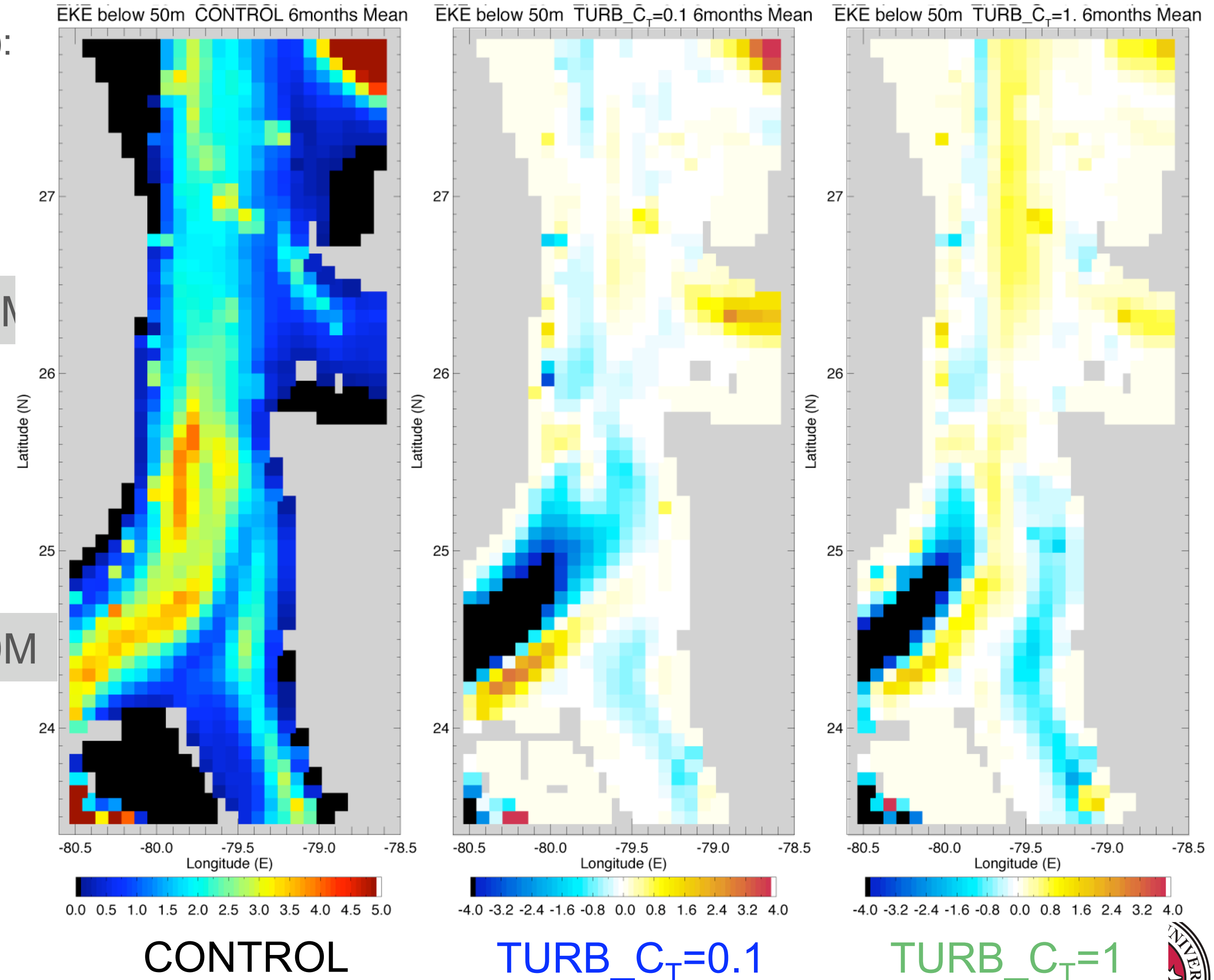
(Mean over the last 6months)

ABOVE 50M

BELOW 50M

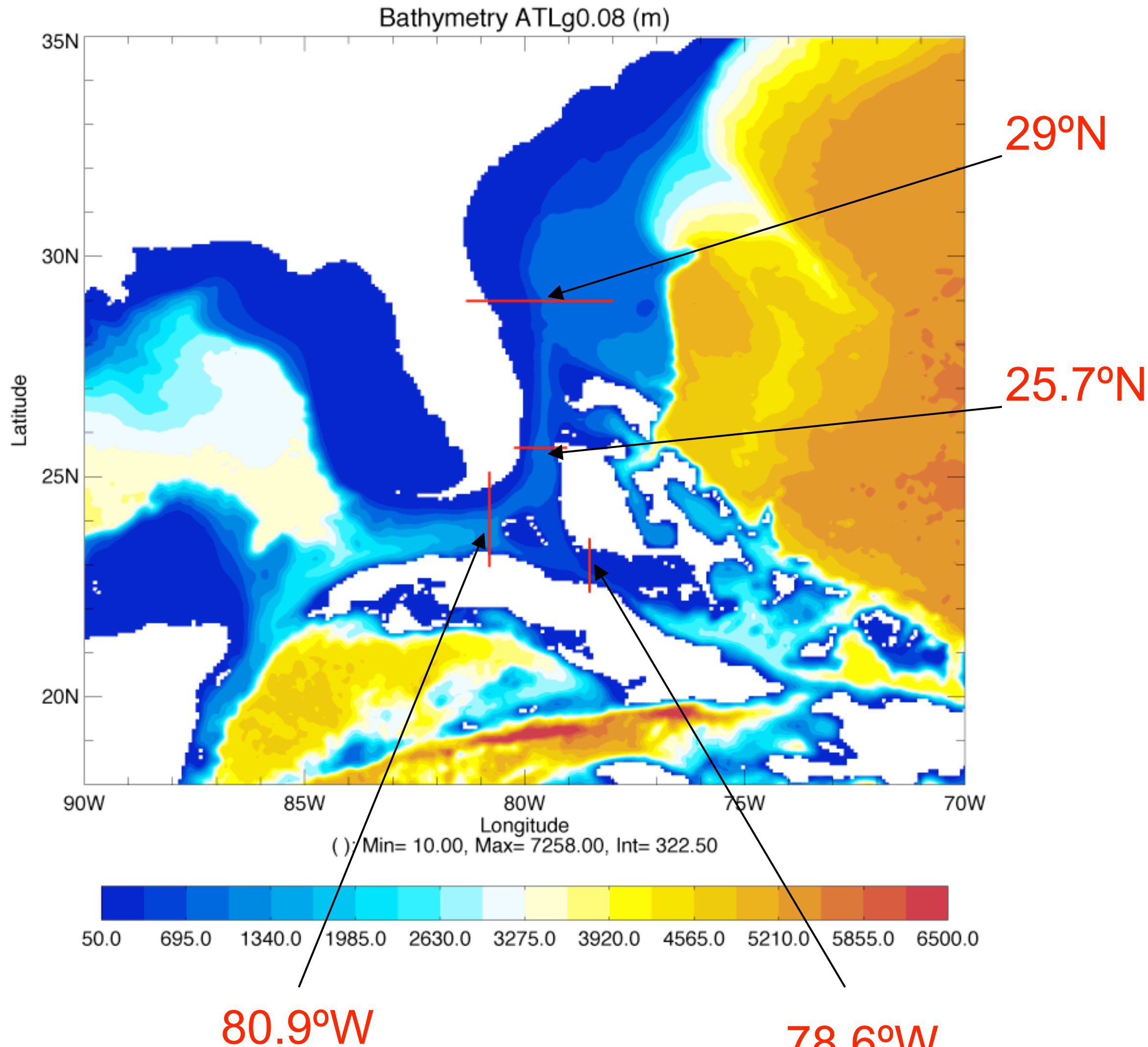
✓ The turbines **increase locally** the EKE **above** 50m

✓ The turbines **modify** the current pathway upstream **above** and **below** 50m

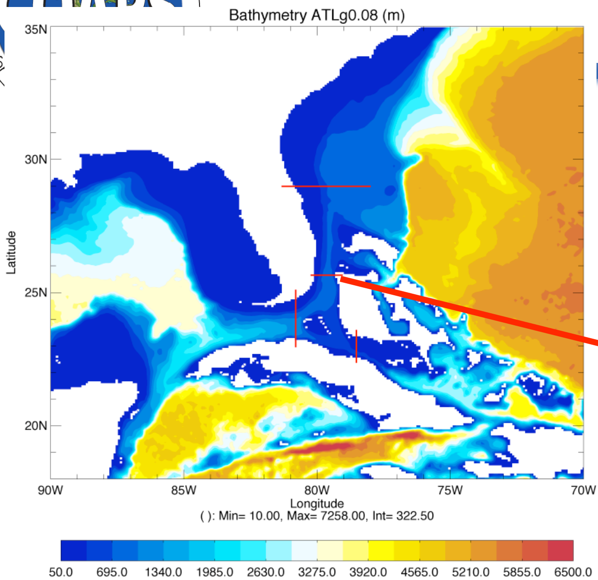


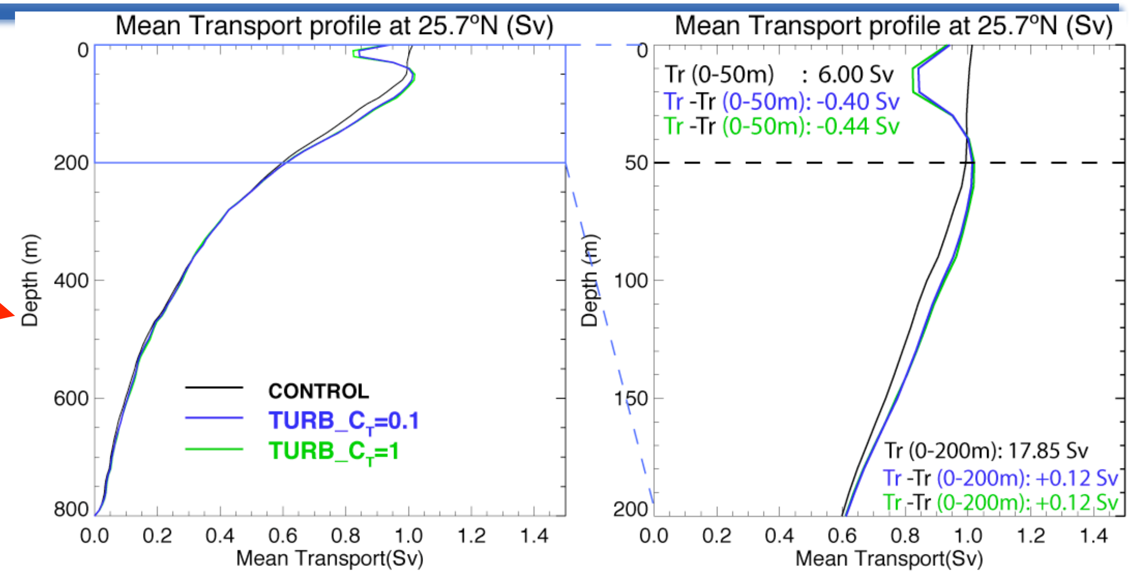
(Mean over 6months)

Impact on Transports

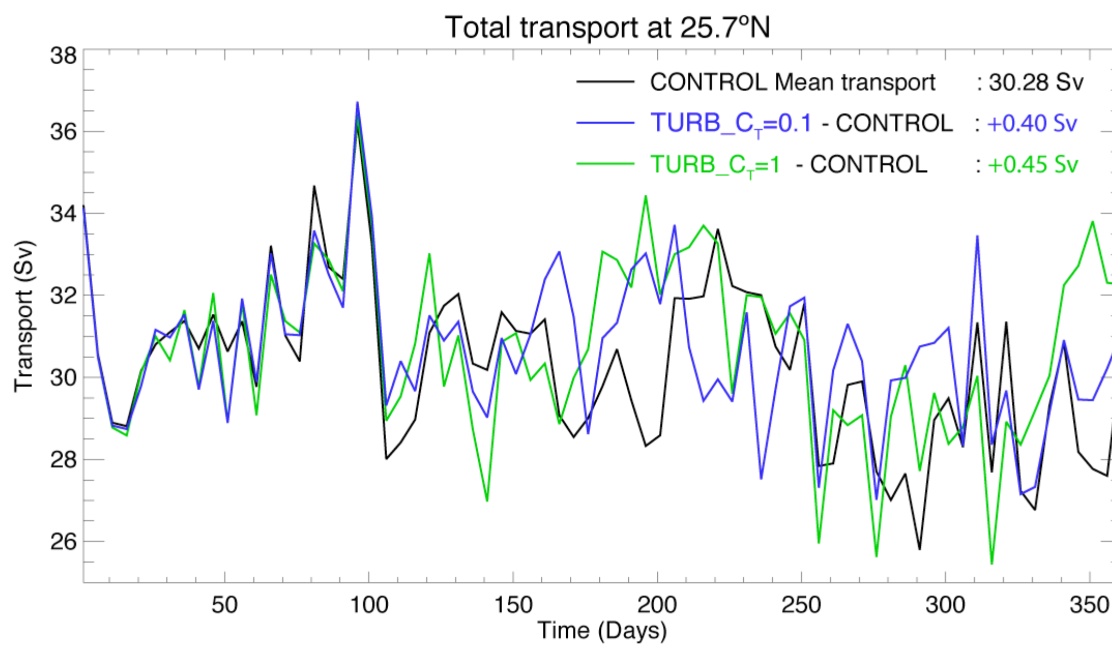


Transport at 25.7ºN

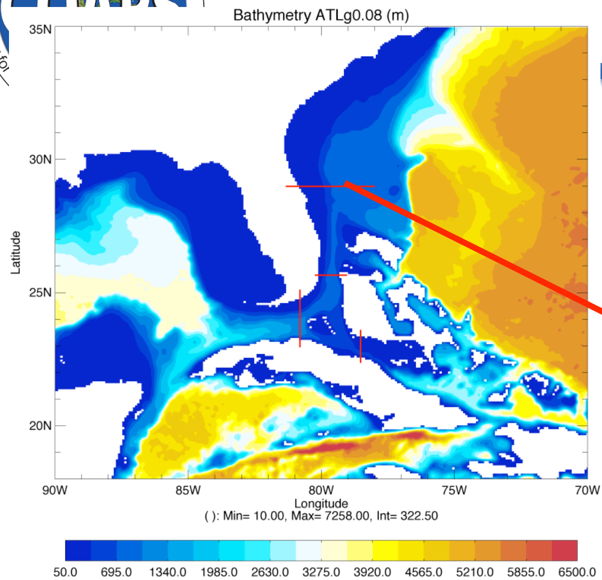


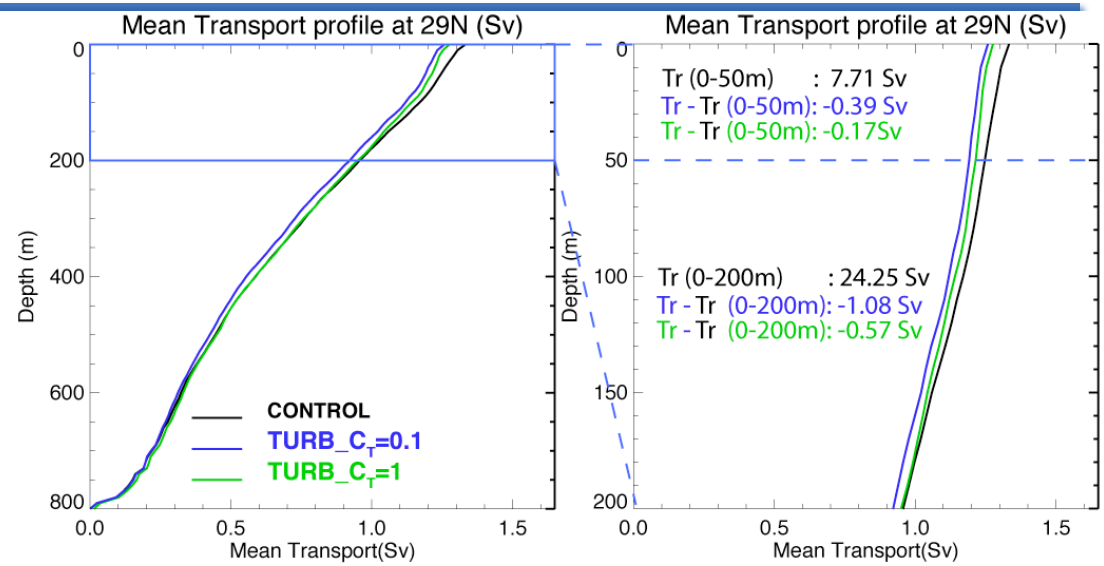


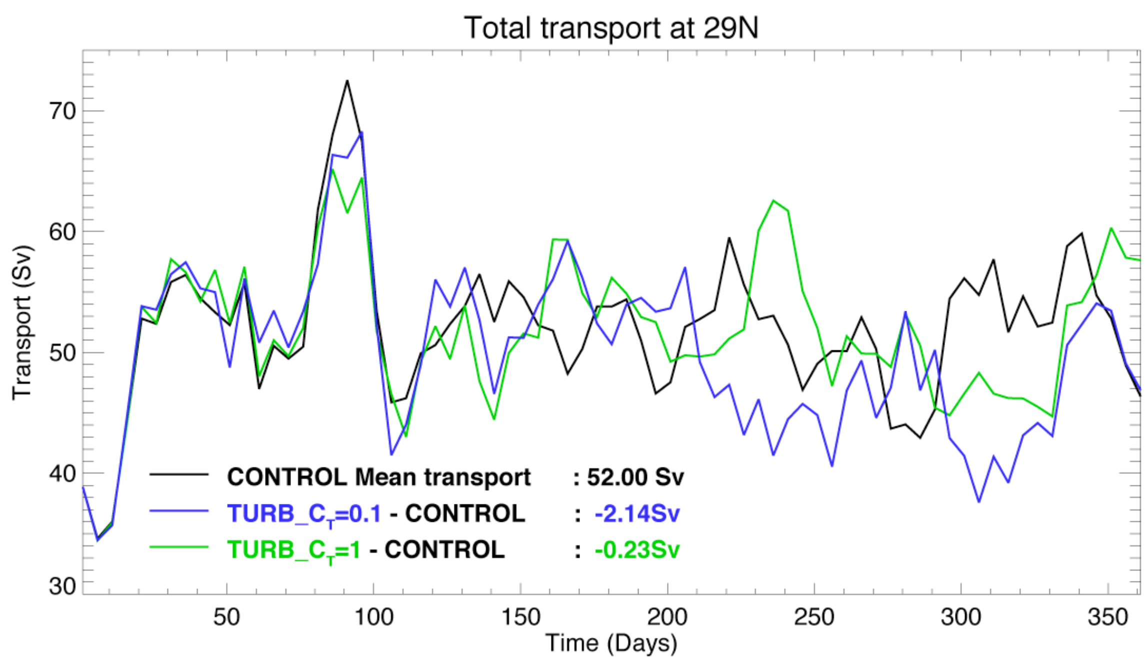
- ✓ The total mean transport is slightly **greater** when turbines are present
- ✓ The turbines **decrease** the transport over the first 50m of the water column
- ✓ The transport is **greater** between **50m** and the **bottom**



Transport at 29ºN



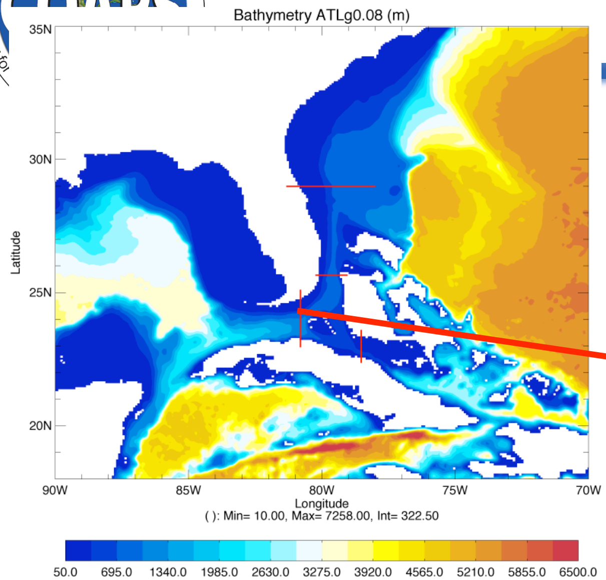


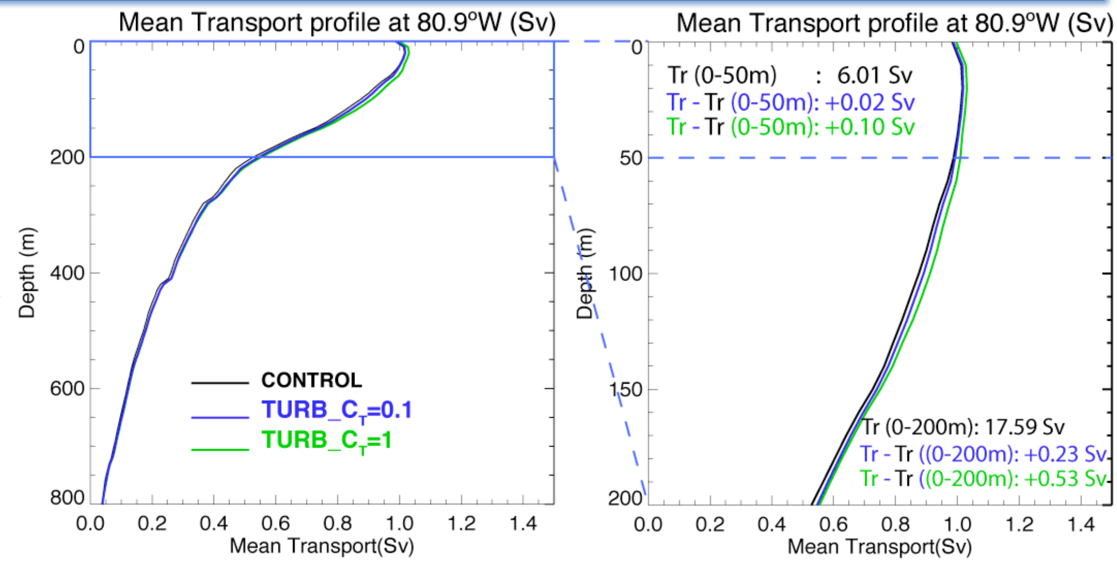


✓ The mean transport is slightly **weaker** when turbines are present above and below 50m

✓ TURB_C$_T$=0.1 has a **weaker** transport than TURB_C$_T$=1.

Transport at 80.9ºW

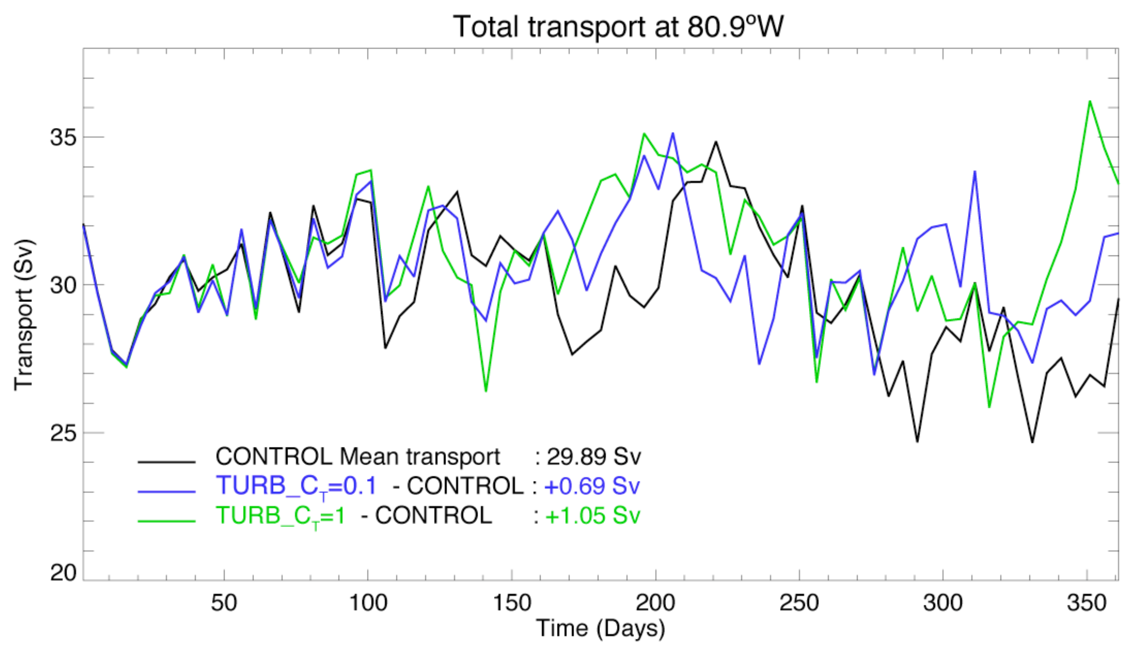




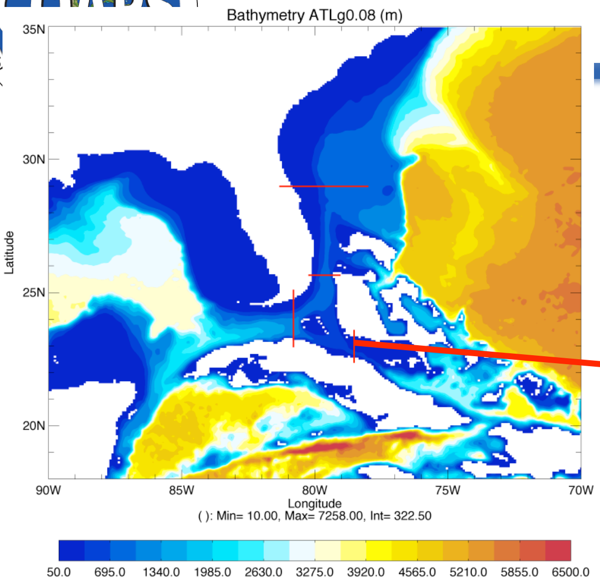
✓ The total mean transport is slightly **greater** when turbines are present

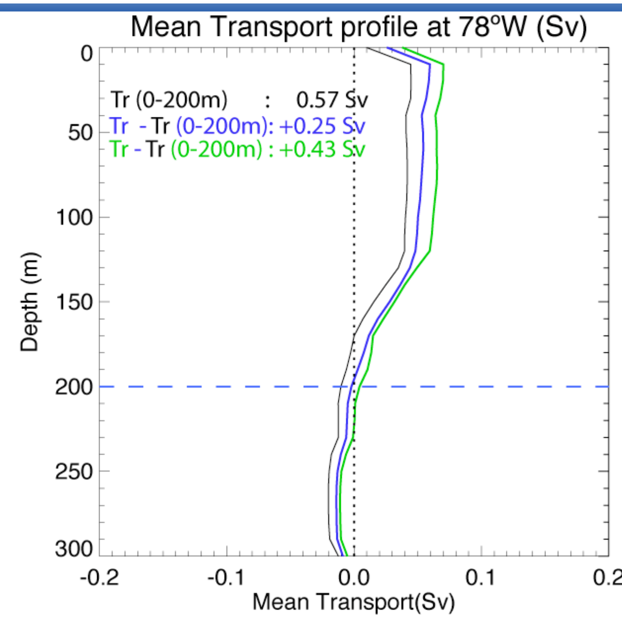
✓ The transport is **greater** between **50m** and the **bottom**

✓ TURB_C$_T$=1 has a **greater** transport than TURB_C$_T$=0.1

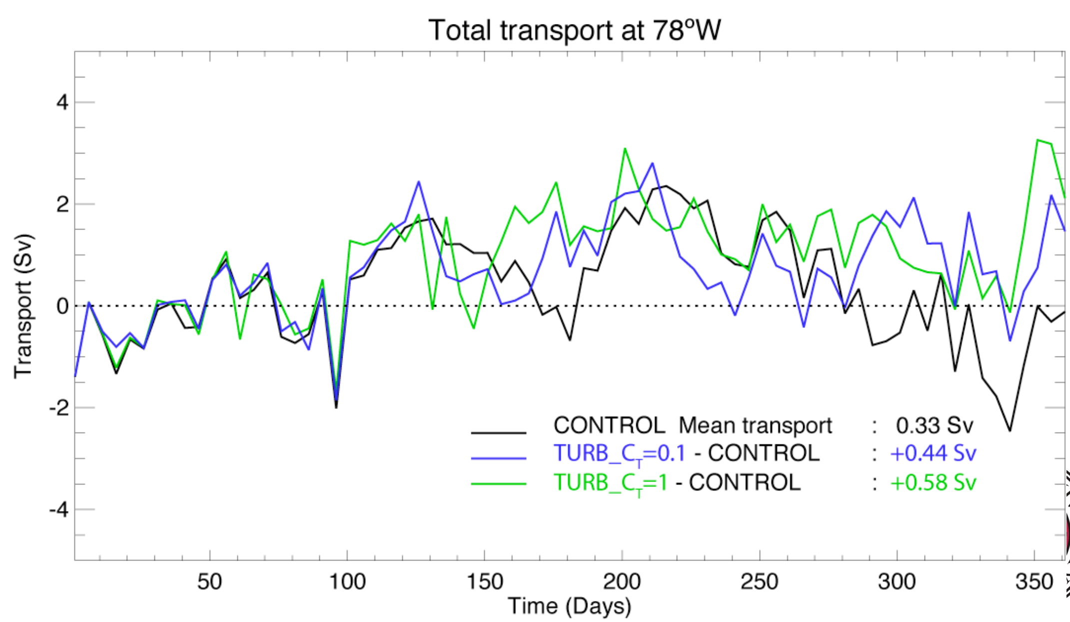


Transport at 78.6ºW

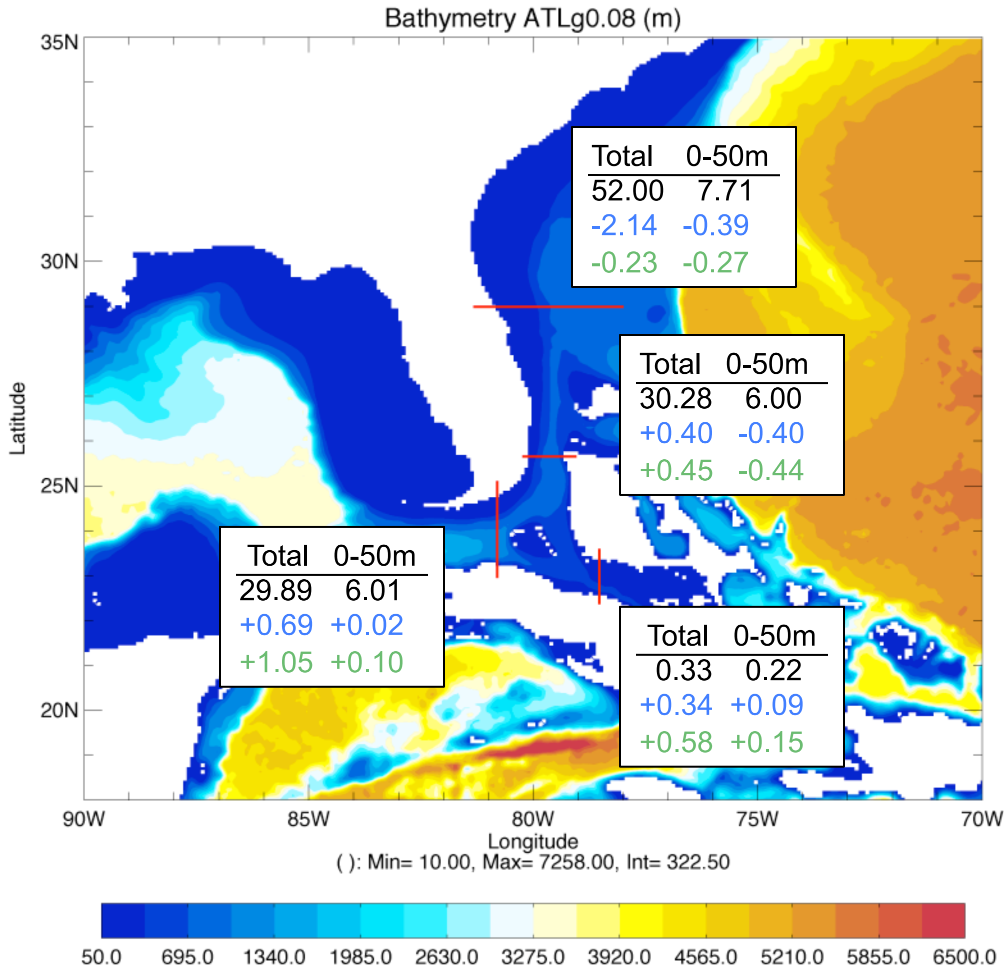




- ✓ The total mean transport is **greater** when turbines are present
- ✓ The transport seems to move from a two-layer system (east-west alternative current) to one layer system (eastern current)



Summary Transports (Sv)



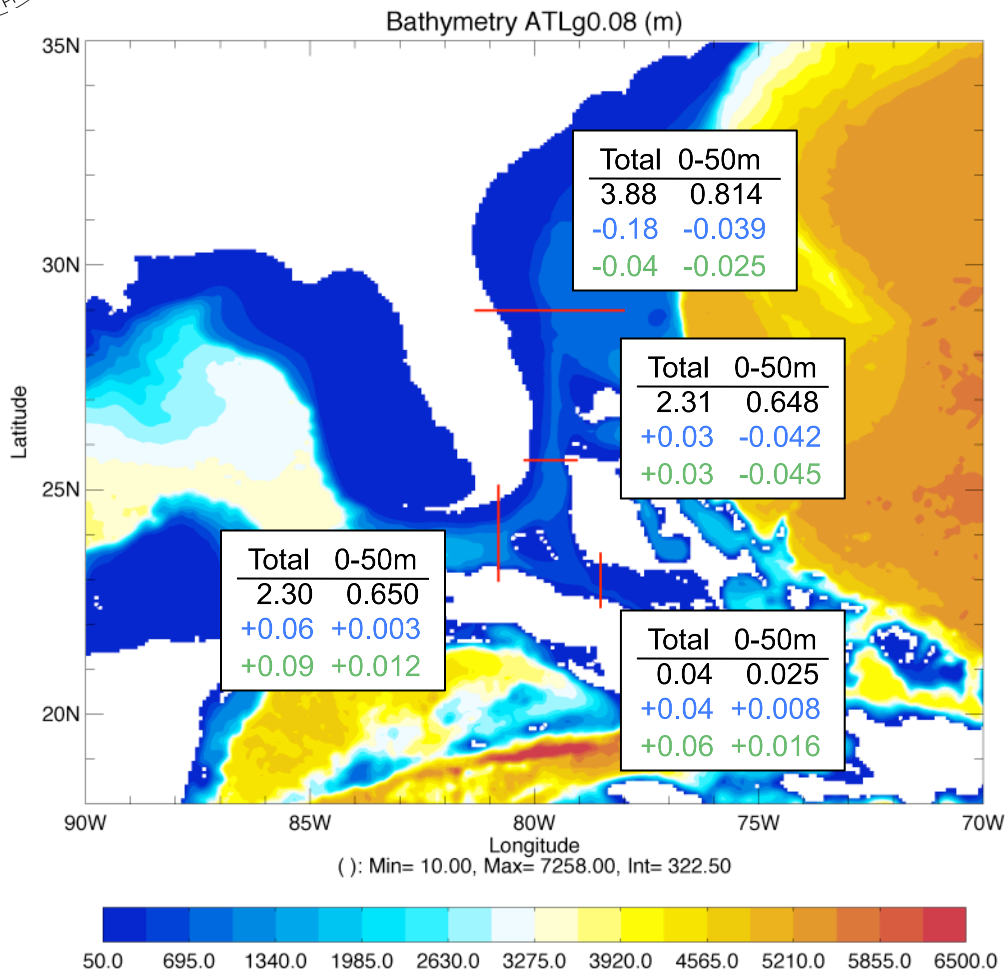
CONTROL
$TURB\_C_T$=0.1 - CONTROL
$TURB\_C_T$=1. - CONTROL

✓ With turbines, the transport in the upper 0-50m decreases downstream

✓ With turbines, the transport below 50m increases upstream

✓ With turbines, the transport at 78.6ºW moves from a two-layer system (east-west alternative current) to one layer system (eastern current)

Heat Transport (PW)



CONTROL

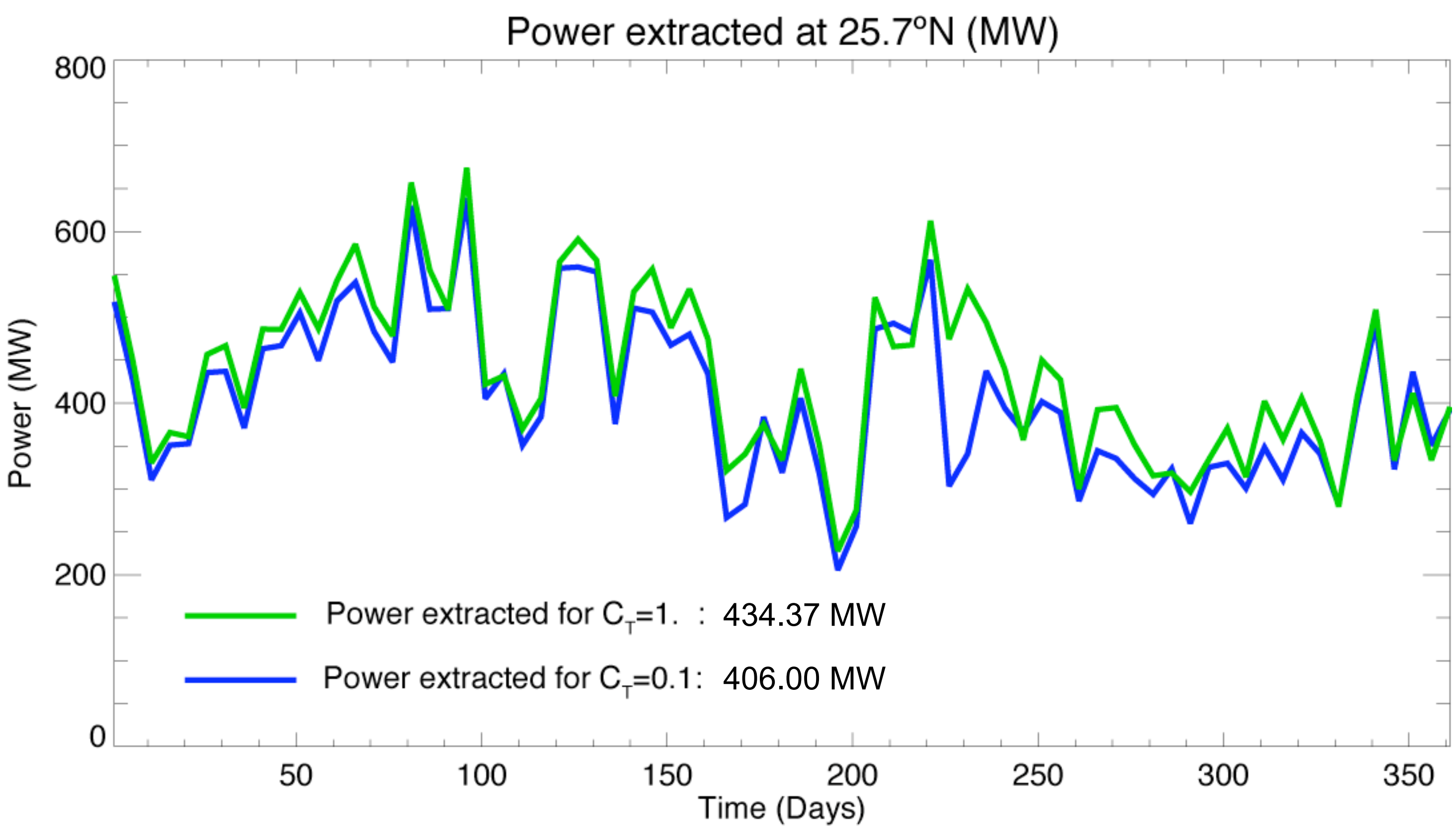
$TURB\_C_T$=0.1 - CONTROL

$TURB\_C_T$=1. - CONTROL

✓ Direct correspondence with the transport

Power Extraction Estimate

Power Estimate : $$P_E = \frac{1}{2}\rho \int_{\substack{4\,Turbine \\ \textbf{Grid Cells}}} V^3{}_{TURB\_C_T}\, dA - \frac{1}{2}\rho \int_{\substack{4\,Turbine \\ \textbf{Grid Cells}}} V^3{}_{CONTROL}\, dA$$



Conclusions & Future Work

Parameterization of turbines as a drag leads to

- A decrease in the upper 50 m downstream transport/mean KE and an increase in the downstream transport/mean KE below 50 m
- A local increase of the EKE in the upper 50m
- A partial eastward diversion of the upstream transport south of the Bahamas
- A modification of the Loop Current eddy shedding process

=> Need more and longer experiments with different C_T to further quantify these features