SEFSC-AOML biogeochemical modeling project overview

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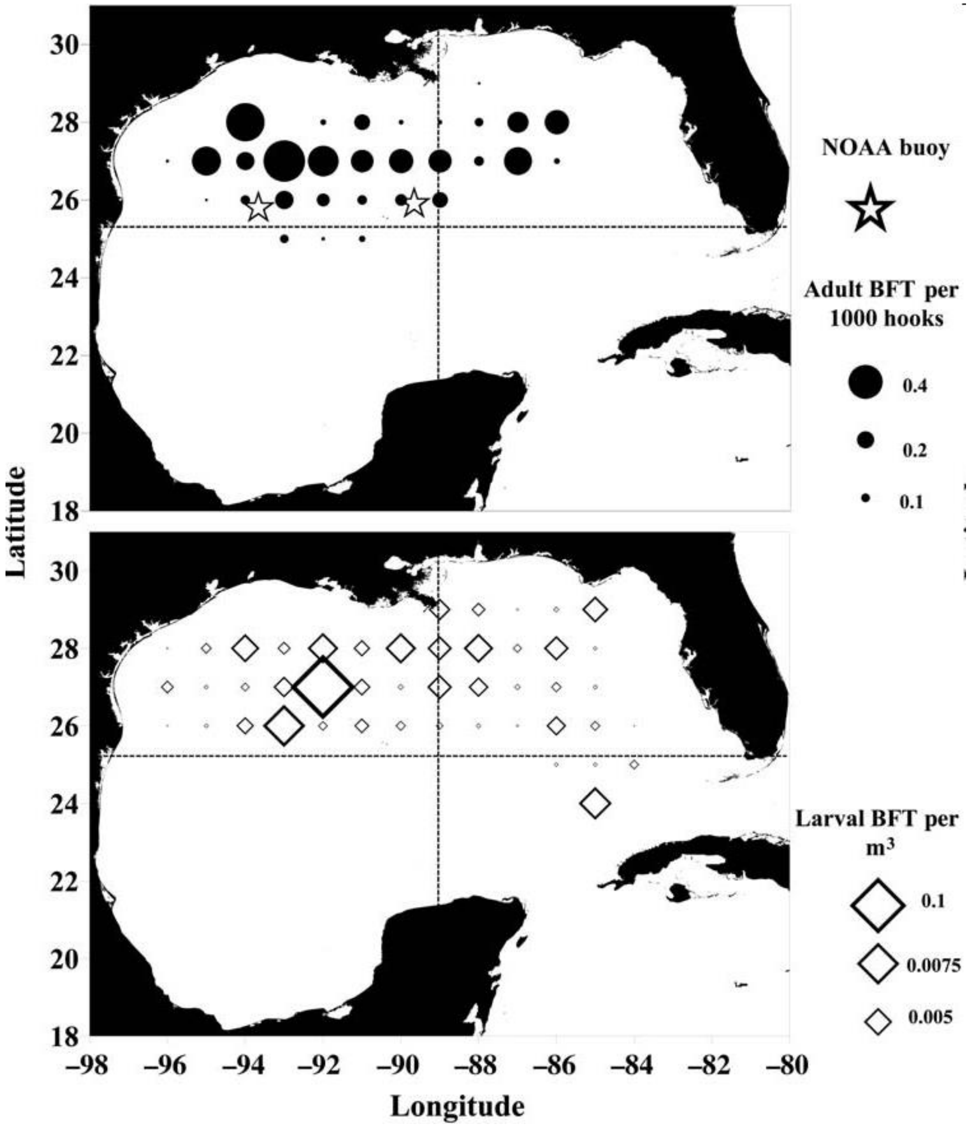
Outline

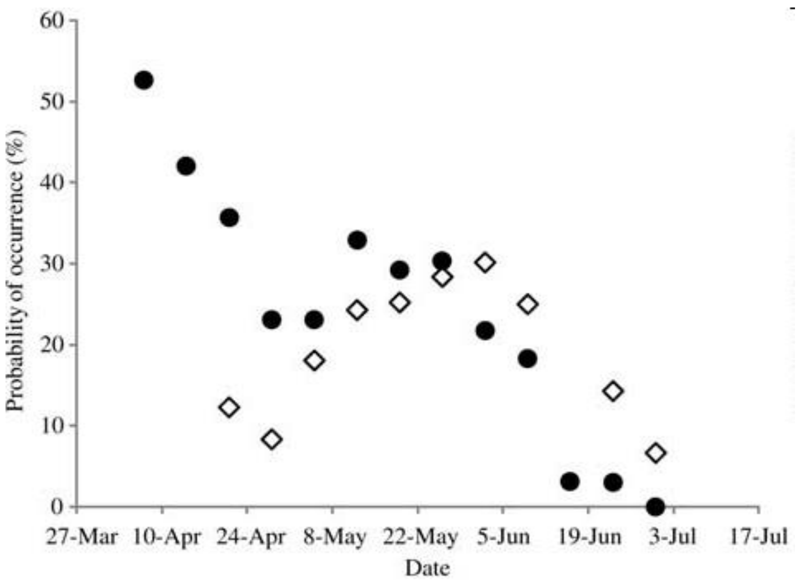
- Introduction to SEFSC-AOML climate & fishery project
- Dynamic downscaling of CMIP5 over the GoM
- Biogeochemical model simulations

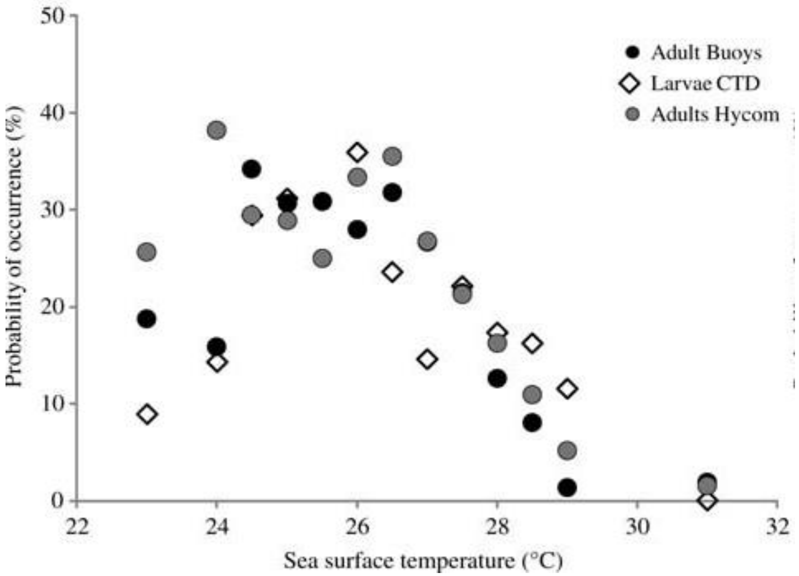
Introduction to climate & fishery project



- NASA - NOAA joint funding
- The Atlantic bluefin tuna (BFT) widely distributed over the North Atlantic
- Its spawning in the western Atlantic predominantly in the northern GoM

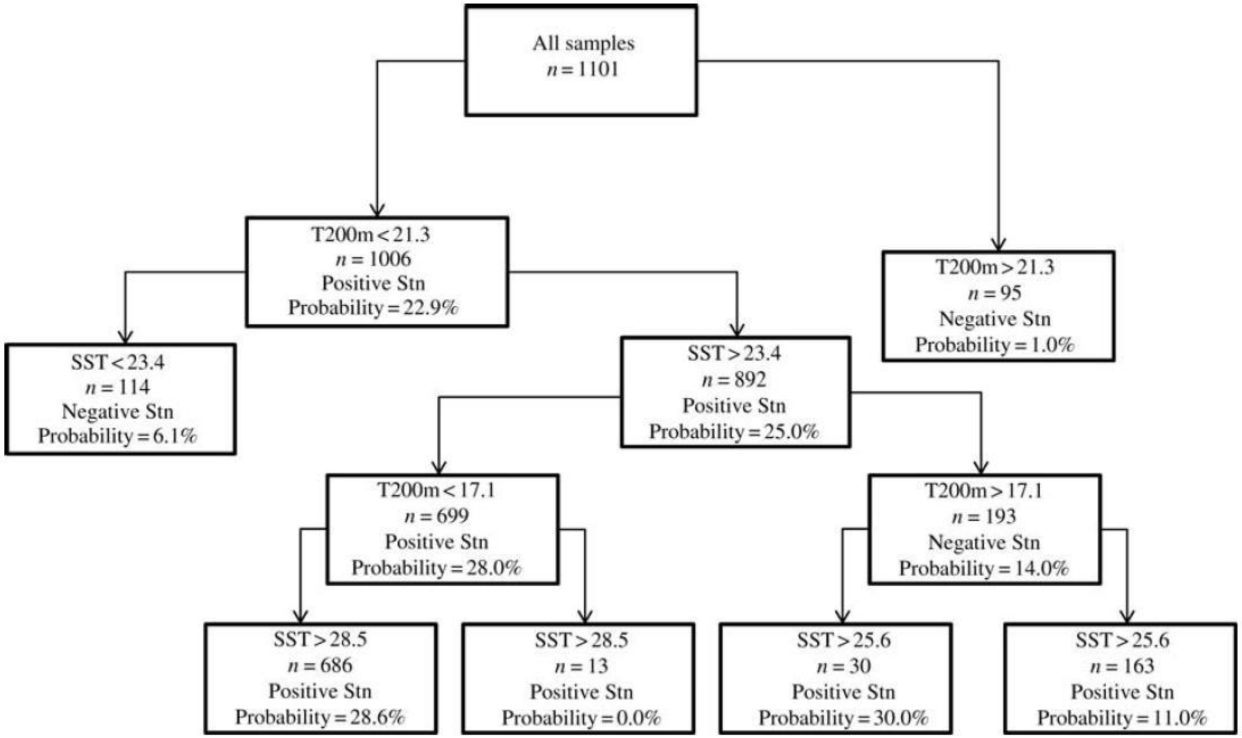
Introduction to climate & fishery project





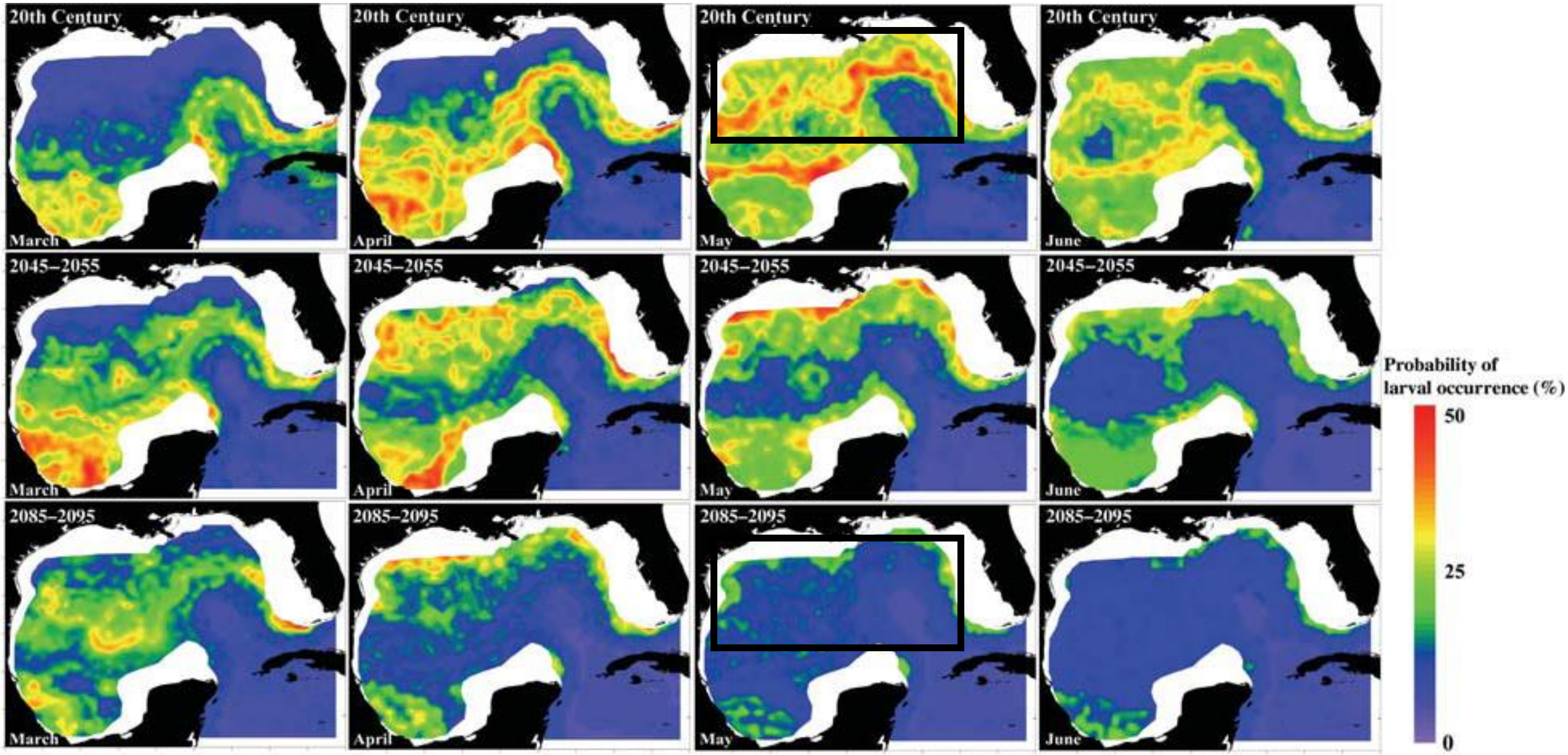
- The optimal SST range for the high probability of BFT larvae occurrence is about 24 ~ 28^{o}C
- The BFT spawning is highly temperature dependent
- The BFT spawning in the GoM mainly in April - June
- What is the impact of future climate change on the BFT spawning?

SEFSC's habitat model for BFT larvae



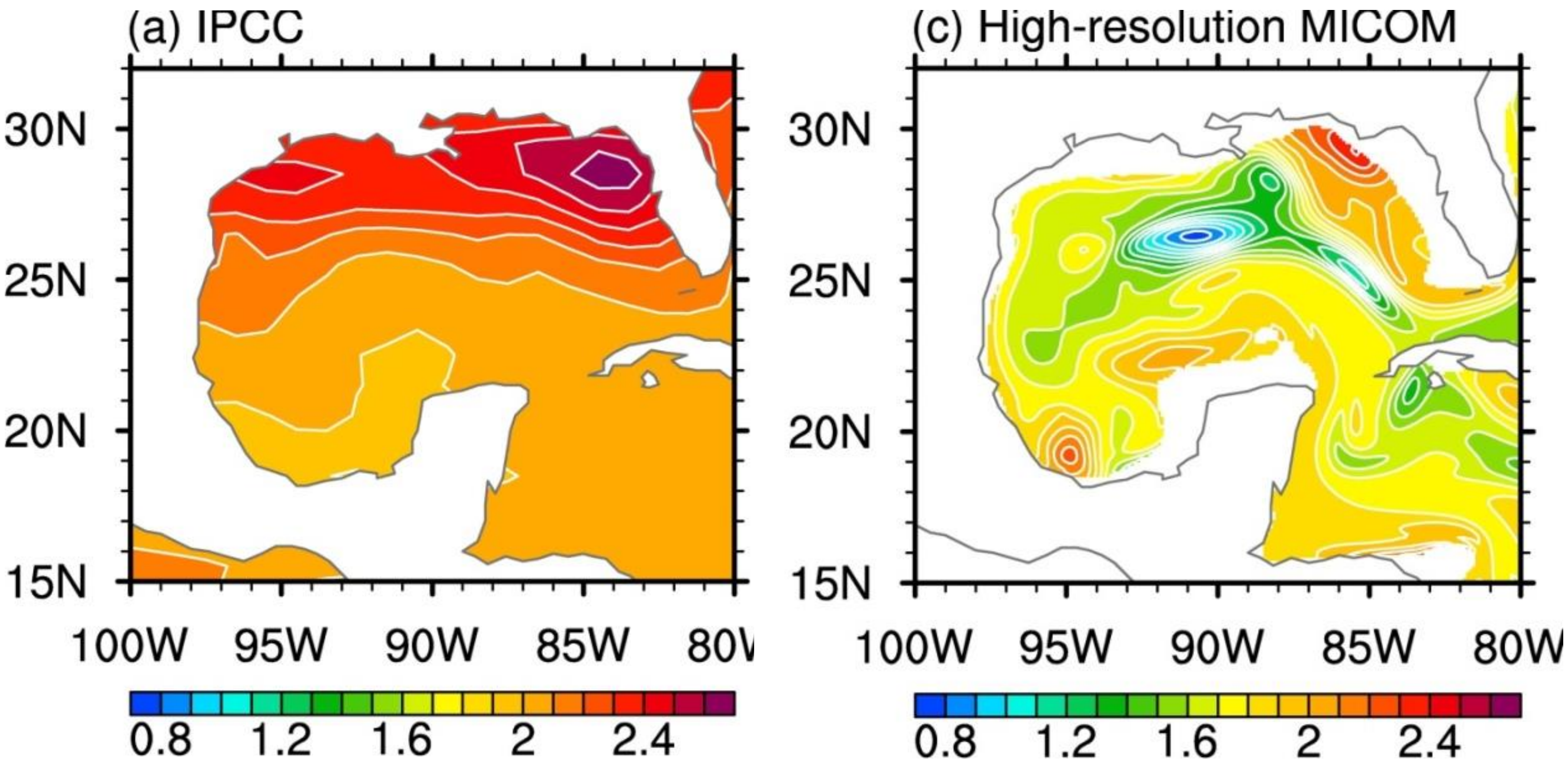
- SEFSC have collected about 30 years (1982 – present) of physical and biological data in the northern GoM
- The relationship between the BFT larvae occurrence and key environmental variables identified
- A habitat model for BFT larvae developed

IPCC-AR4(5) projection of BFT spawning habitat changes



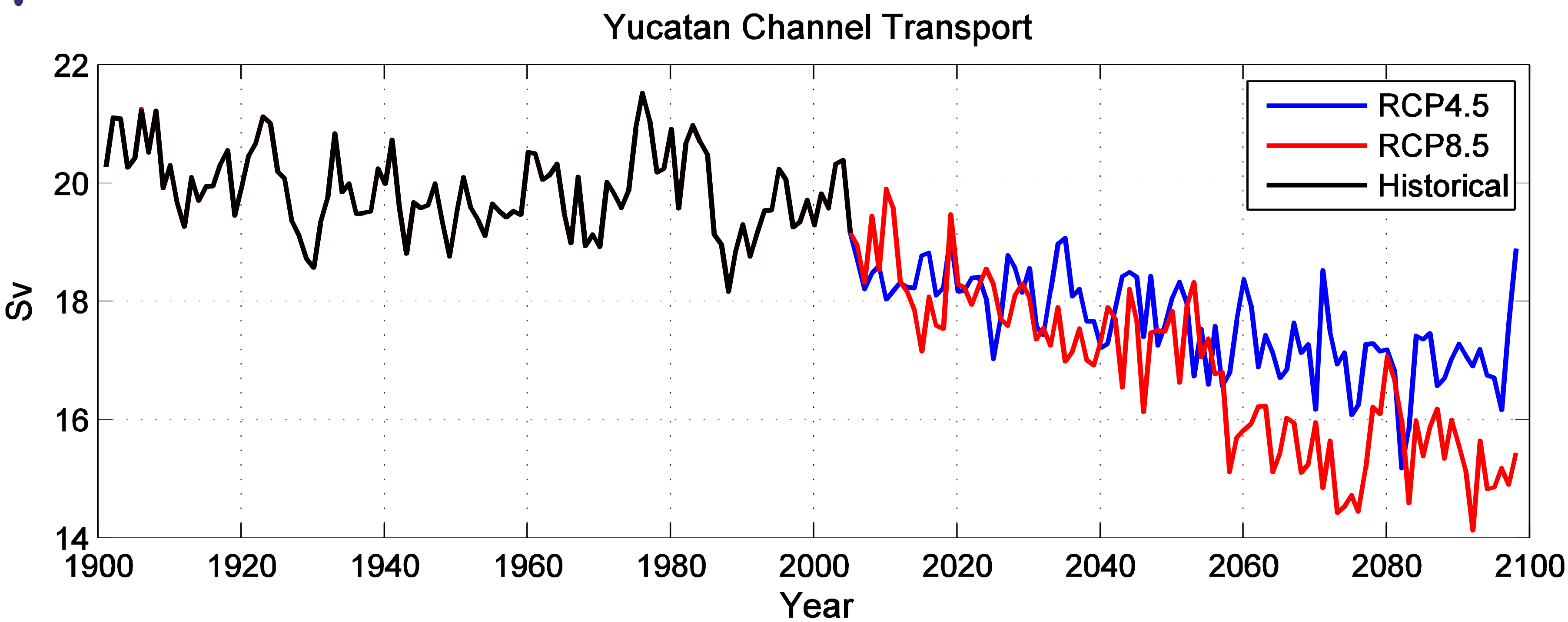
- Due to the projected warming, the area with high larval occurrence in May and June almost disappears toward the end of the 21st century [Muhling et al. 2011].

Dynamic downscaling of IPCC-AR4(5) models



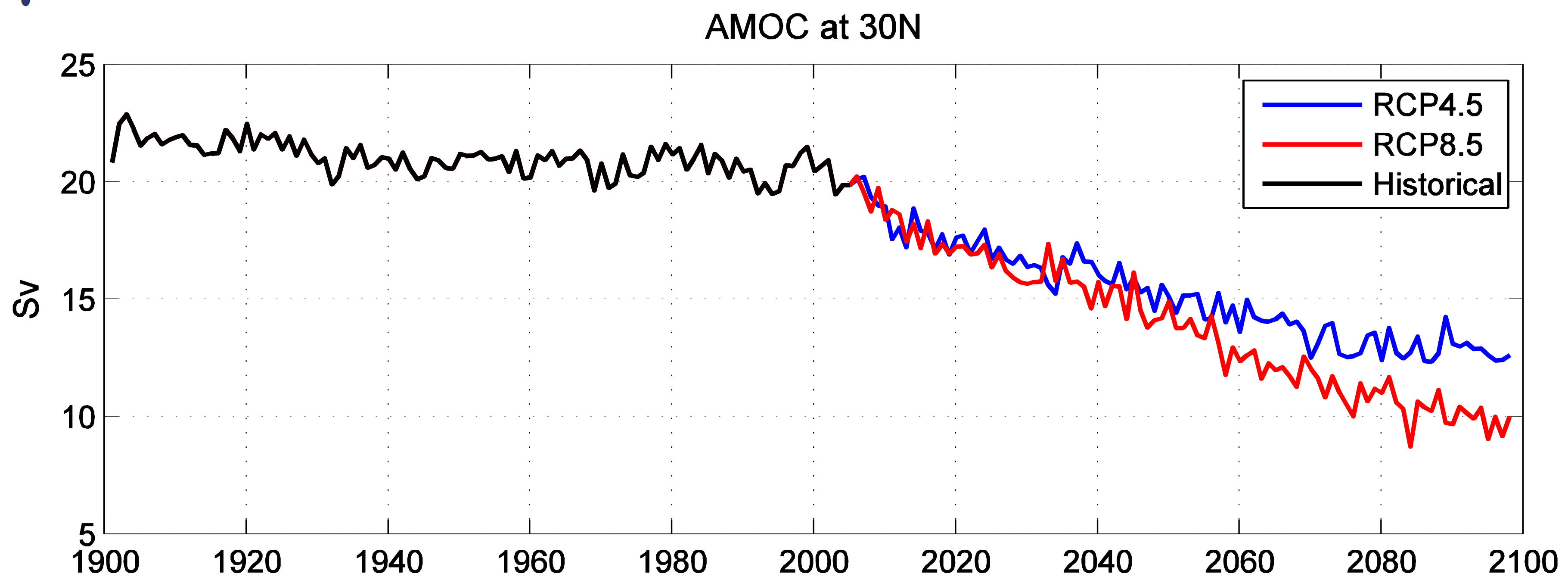
- IPCC: northern GoM warms more than 2^{o}C by the late 21C
- IPCC: too coarse resolution (~100km) to simulate the LC
- Dynamic downscaling: the northern GoM is characterized as the region of minimal warming [Liu et al. 2012].

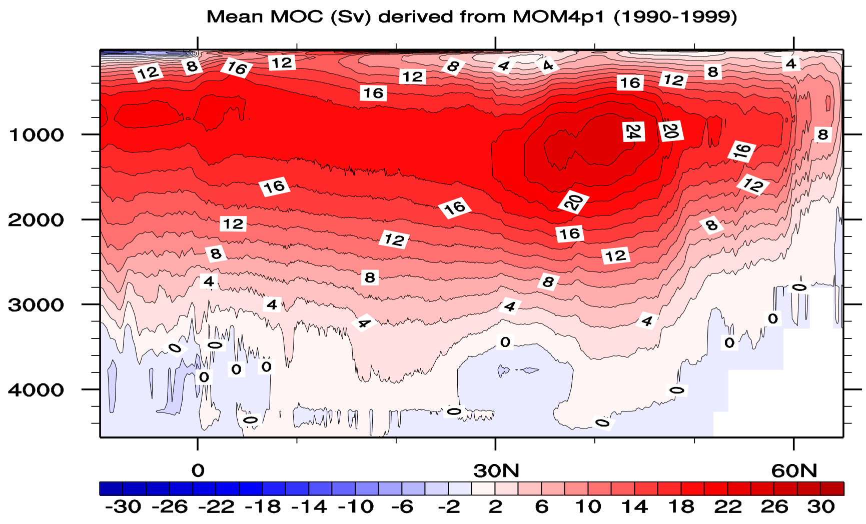
Dynamic downscaling of IPCC-AR4(5) models

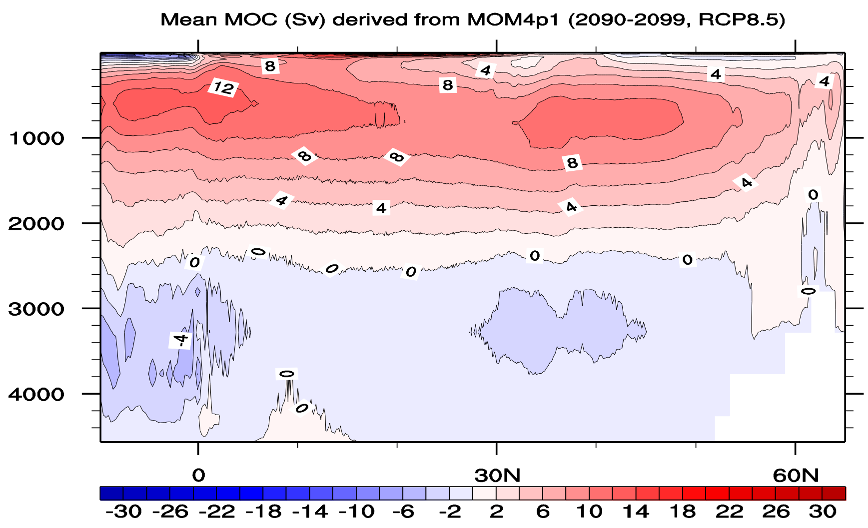


- The LC reduced by ~ 20% during the 21C
- The reduced LC has a large cooling impact in the GoM
- IPCC-AR4(5) models fail to simulate the minimal warming in the northern GoM

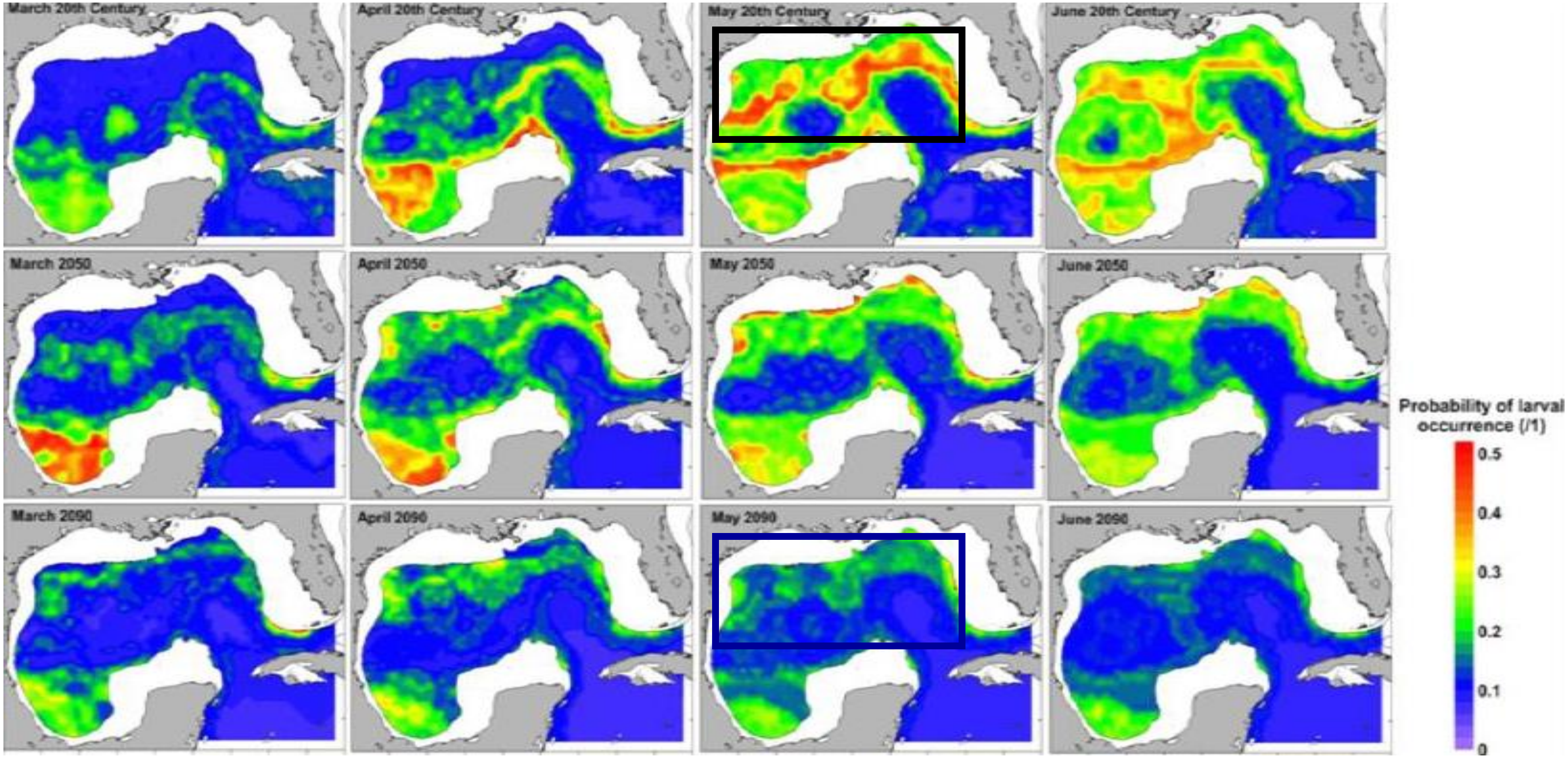
Dynamic downscaling of IPCC-AR4(5) models







Downscaled model projection of BFT spawning habitat changes

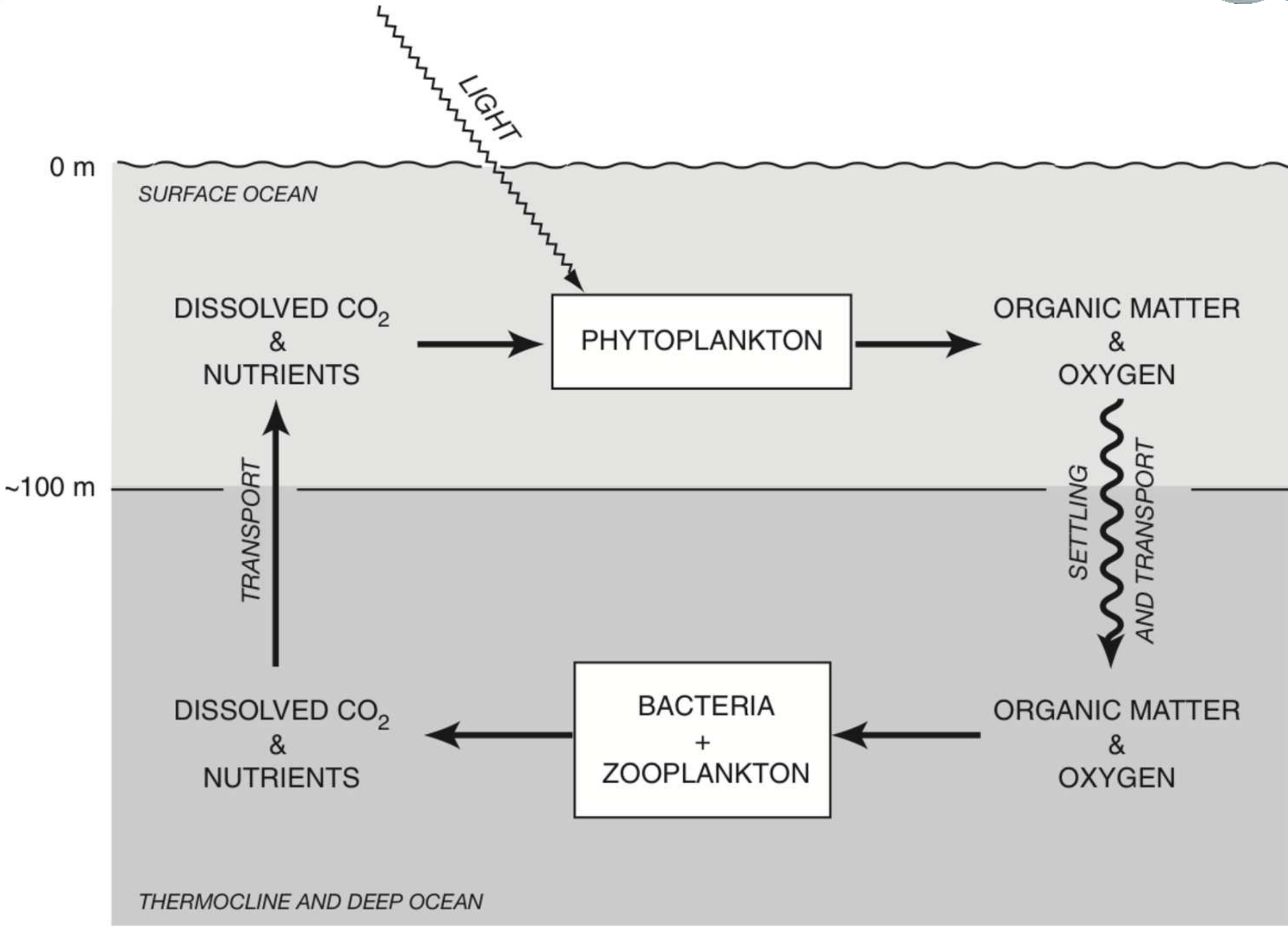


- The area with high larval occurrence in May and June decreases up to 90%, but it still remains during the late 21st century.
- Reduced LC delays the BFT habitat loss in the northern GoM

Modeling biogeochemical processes

- **Biological productivity in euphotic zone (phytoplanktons)**
  - consumes nutrients & inorganic carbon
  - produces organic matter and O_2
- **Export of organic matter out of euphotic zone**
  - sinking particles (soft tissue & $CaCO_3$)
  - circulation of dissolved organic matter
- **Remineralization of organic matter (bacteria and zooplanktons)**
  - respiration: convert organic matter to inorganic carbon and nutrients
- **Ocean circulation**
  - advective transport
  - lateral & vertical mixing
- **Flux at the sea surface**
  - shortwave penetration
  - temperature-dependent air-sea gas exchange

Modeling biogeochemical processes



Sarmiento and Gruber (2006)

Modeling biogeochemical processes

- **Simplest model for biogeochemical modeling: NPZ model**
  - **N:** nutrients (nitrate, ammonium, phosphate, silicate, iron …)
  - **P:** phytoplankton (photosynthesizers)
  - **Z:** zooplankton (grazers)
  - 3 ODEs with 8 parameters (μ, K_N, α, K_P, m_P, m_Z, *and* γ)
  - 8 parameters are determined by incubation experiments in labs

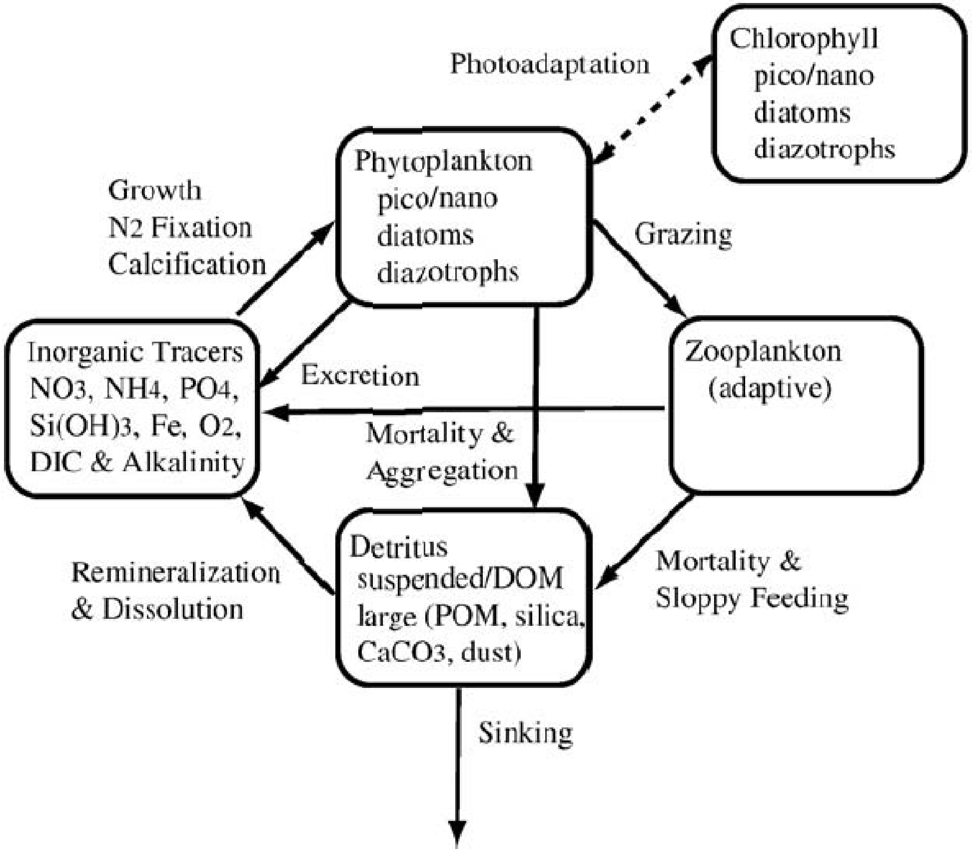
$$\frac{dP}{dt} = \mu\left(\frac{N}{K_N + N}\right)\left(1 - e^{\frac{\alpha E}{\mu}}\right)P - g\left(\frac{P}{K_P + P}\right)Z - m_P P$$

$$\frac{dZ}{dt} = \gamma g\left(\frac{P}{K_P + P}\right)Z - m_P Z$$

$$\frac{dN}{dt} = -\mu\left(\frac{N}{K_N + N}\right)\left(1 - e^{\frac{\alpha E}{\mu}}\right)P + (1-\gamma)g\left(\frac{P}{K_P + P}\right)Z + m_P P + m_Z Z$$

Long and Lindsay (2011)

MOM4 - TOPAZ



Dunne et al. (2010)

- MOM4: Tracers in the Ocean with Allometric Zooplankton (TOPAZ) model
- NPZD model, but very complex (Dunne et al. 2010)
- Includes three phytoplankton groups (i.e., large, small and diazotrophic)
- Diazotrophic phytoplanktons: fix atmospheric N_2 directly
- Includes atmospheric deposition, river inputs, and sediment processes
- 19 prognostic variables (ex: DIC, DO, dissolved iron) coupled to MOM4

Biogeochemical modeling for warming climate

- **Key points to consider:**
  - Increased stratification may lead to a reduced nutrient supply to euphotic zone
  - Gas solubility (ex: O_2 solubility decreases with warming ocean temperature)
  - Reduced PH decreases calcification by some species (e.g., coccolithophores)
  - Changes in ocean circulation affect regional nutrient supply
  - Temperature-dependent biological reactions
- **Steinacher et al. (2010):**
  - Used CMIP3 models with active biogeochemical component
  - Suggested 2~20% decrease in global PP by 2100 with large regional differences
  - Reduced nutrient supply due to increased stratification and reduced circulation
  - Alleviation of temperature limitation in the Southern Ocean

Model Simulations

- Downscaled simulation of CMIP5 historical scenario (1901-2005), RCP4.5 and RCP8.5 scenarios (2006-2100) completed
- Global MOM-TOPAZ model simulation for the 20^{th} century (1948-2009) completed
- Downscaled biogeochemical simulations of CMIP5 historical, RCP4.5 and RCP8.5 scenarios will be completed by end of 2014