Characterizing the Physical Oceanography of Coastal Waters Off Rhode Island

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RI OSAMP Stakeholder Meeting

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What is Physical Oceanography?

Understanding the **processes** that shape characteristics of ***Water Properties*** (particularly temperature, salinity, density) and ***Currents***

- *Geographic* variations
- *Vertical* variations (surface to seafloor)
- *Temporal* variations:
  - Seasonal, Weather-band, Tidal; Inter-annual

Role of P.O. in the SAMP process

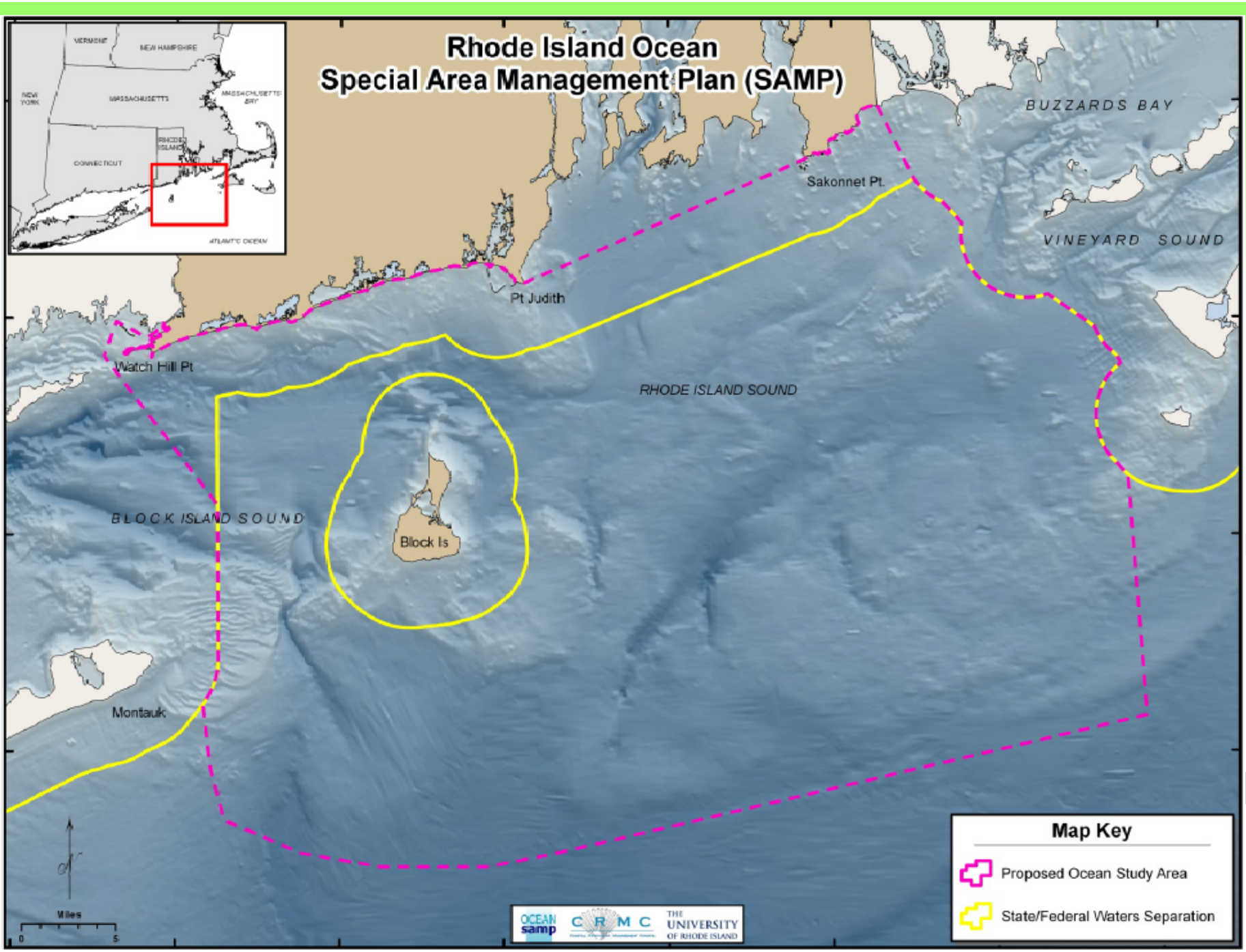
- Water properties define habitat
  - *Example:* Phytoplankton blooms are triggered by temperature and density stratification
- Currents determine flushing rates
  - Transport and dispersal of waterborne materials (sediment, larvae, pollutants)
- SAMP aims to assess potential alterations due to human activities & climate change
- First step: ***baseline characterization*** of SAMP region P.O. characteristics

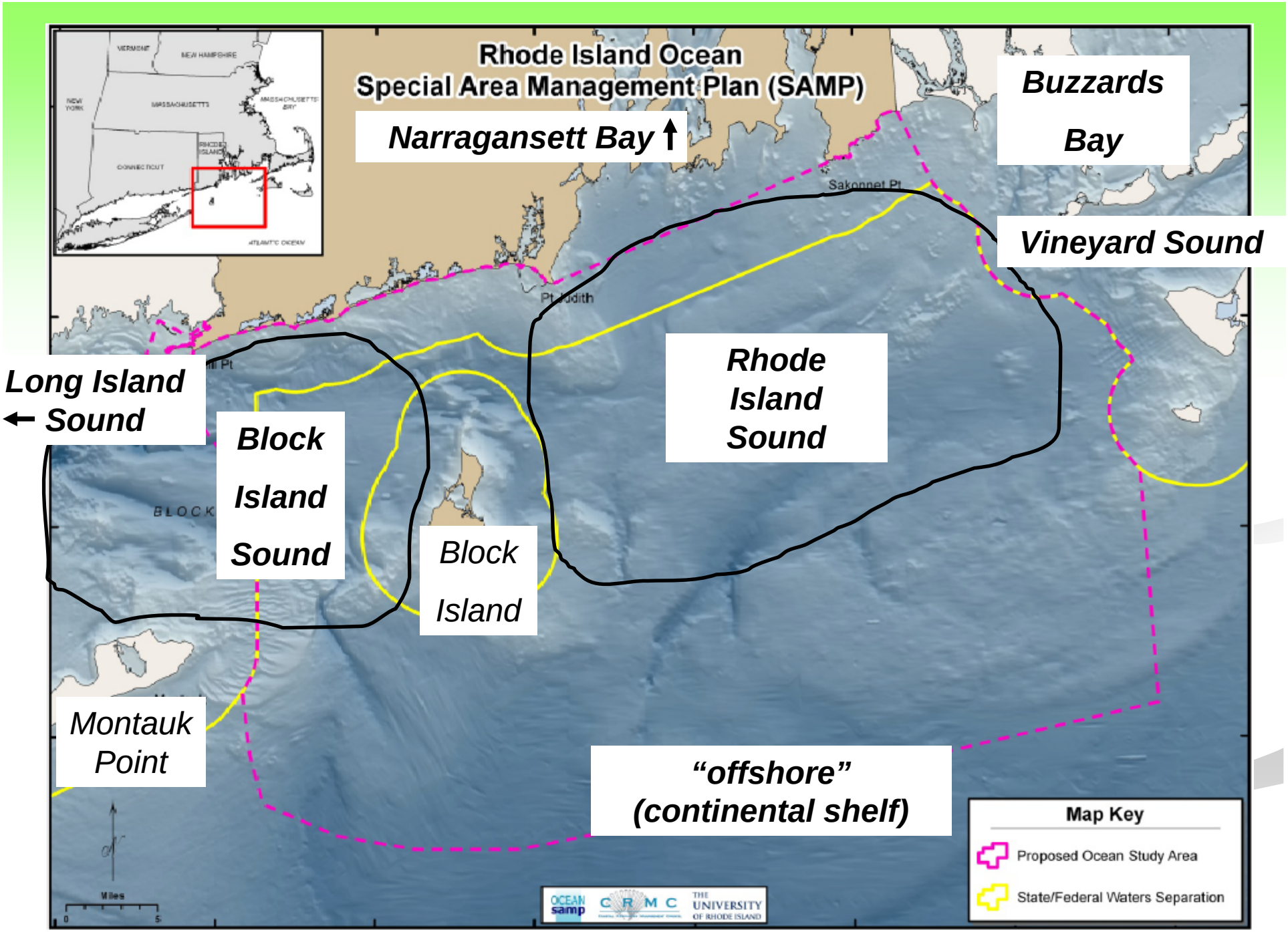
Today's Presentation

- Water properties – Seasonal cycle
  - Hydrographic casts (historical archive 1980-2007)
  - Satellite sea-surface temperature (SST)
- Currents
  - Annual-mean transports: Observations, hypotheses
  - Seasonal-mean surface currents, and weather-band variations (CODAR near Block Island Sound)
  - Tidal ellipses (CODAR near Block Island Sound)
- New P.O. observations for SAMP
  - Brief description of ongoing activities

Water properties

- **Temperature** [degrees Celcius]
  - Processes: Sea surface heat/cooling; arrival/ mixing of warm/cool waters from nearby areas
- **Salinity** [Practical Salinity Scale, PSS]
  - Processes: River/estuary inputs; arrival/mixing of salty/fresh waters from nearby areas; precipitation
- Density: **Sigma-t** [kg m^{-3}]
  - Processes: Both temperature and salinity
- Density ***stratification***
  - Vertical layering: competes with turbulent vertical mixing, which homogenizes water properties

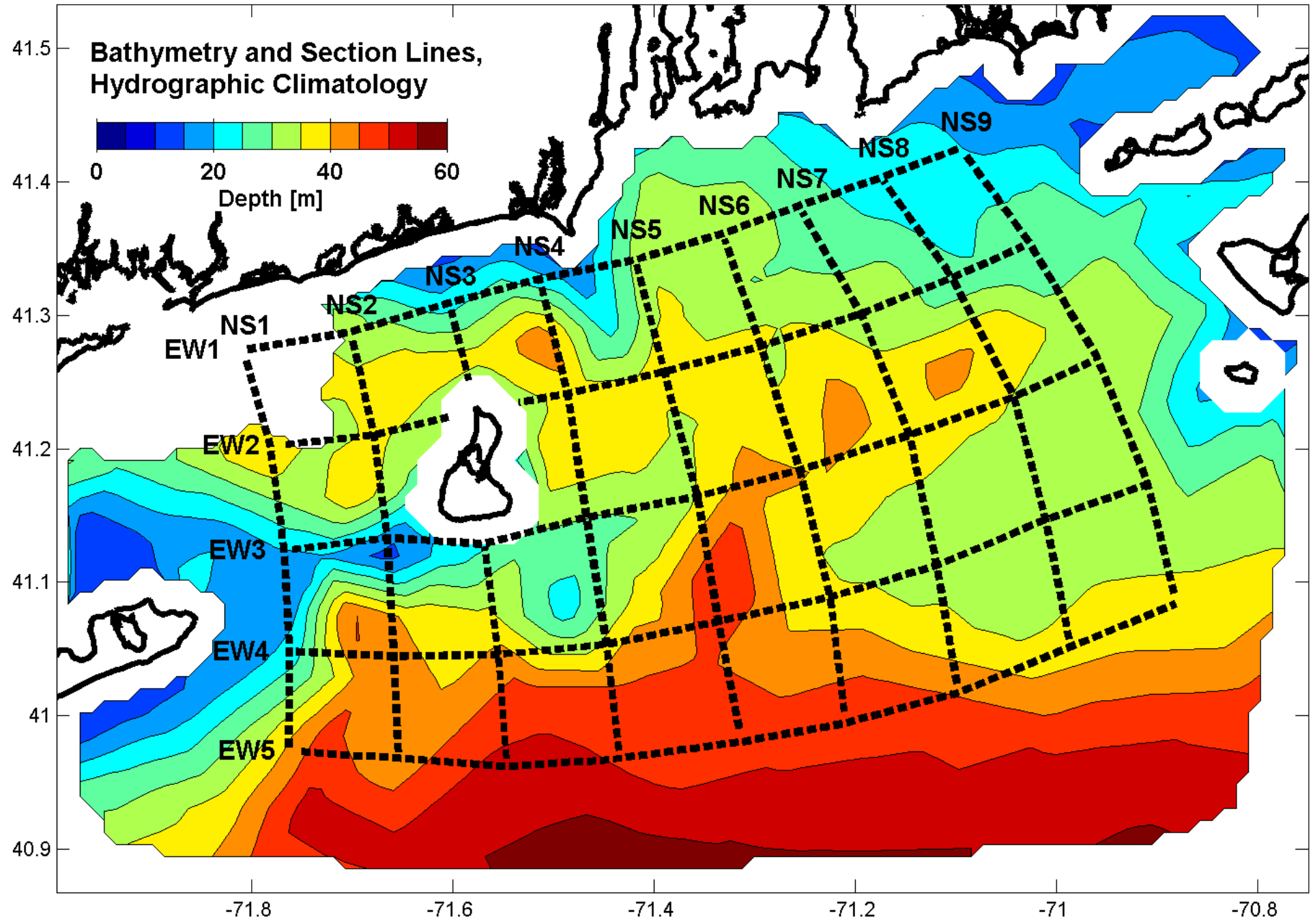

Rhode Island Ocean
Special Area Management Plan (SAMP)
VERMONT
NEW HAMPSHIRE
NEW YORK
MASSACHUSETTS
CONNECTICUT
ATLANTIC OCEAN
BUZZARDS BAY
Sakonnet Pt.
VINEYARD SOUND
Pt Judith
Watch Hill Pt
RHODE ISLAND SOUND
BLOCK ISLAND SOUND
Block Is
Montauk
N
Miles
0
5
OCEAN samp
C R M C
THE UNIVERSITY OF RHODE ISLAND
Map Key
Proposed Ocean Study Area
State/Federal Waters Separation


Rhode Island Ocean
Special Area Management Plan (SAMP)
Narragansett Bay
Buzzards Bay
Vineyard Sound
Sakonnet Pt
Pt Judith
Long Island Sound
Block Island Sound
Rhode Island Sound
Block Island
Montauk Point
"offshore" (continental shelf)
Map Key
Proposed Ocean Study Area
State/Federal Waters Separation
Miles
0
5
OCEAN samp
C R M C
THE UNIVERSITY OF RHODE ISLAND

Hydrographic Climatology

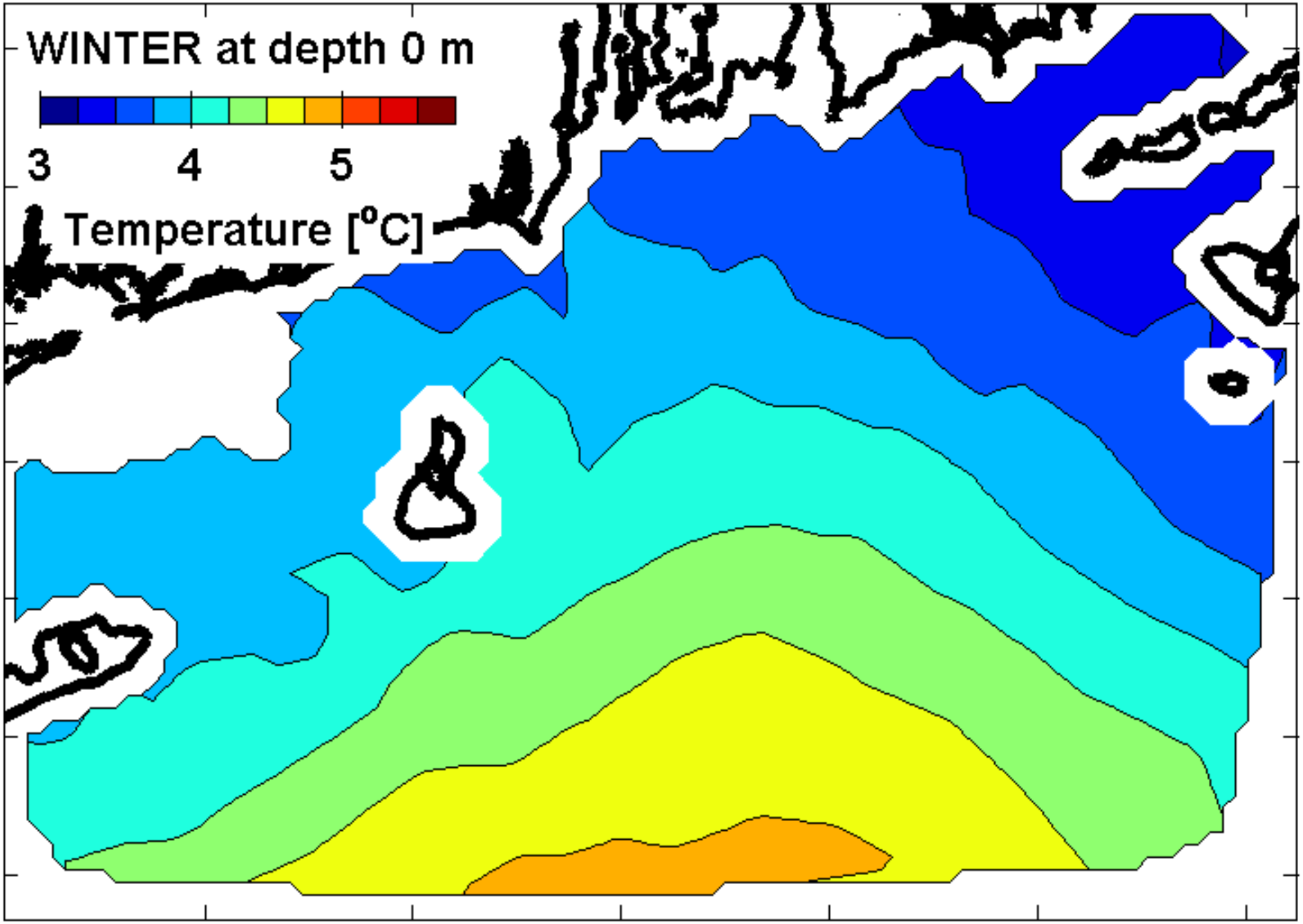
- Archived historical CTD (Conductivity-Temperature-Depth) casts 1980-2007
  - Sources: HydroBase; NOAA/NMFS MARMAP; Fisheries & Ocean Canada
- Grouped in four seasonal periods
  - Winter (Jan-Mar), Spring (Apr-Jun), Summer (Jul-Sep), Fall (Oct-Dec)
  - ~150-300 casts per group, all 27 years collectively
- Heavily smoothed/interpolated
- Obtained via The Nature Conservancy

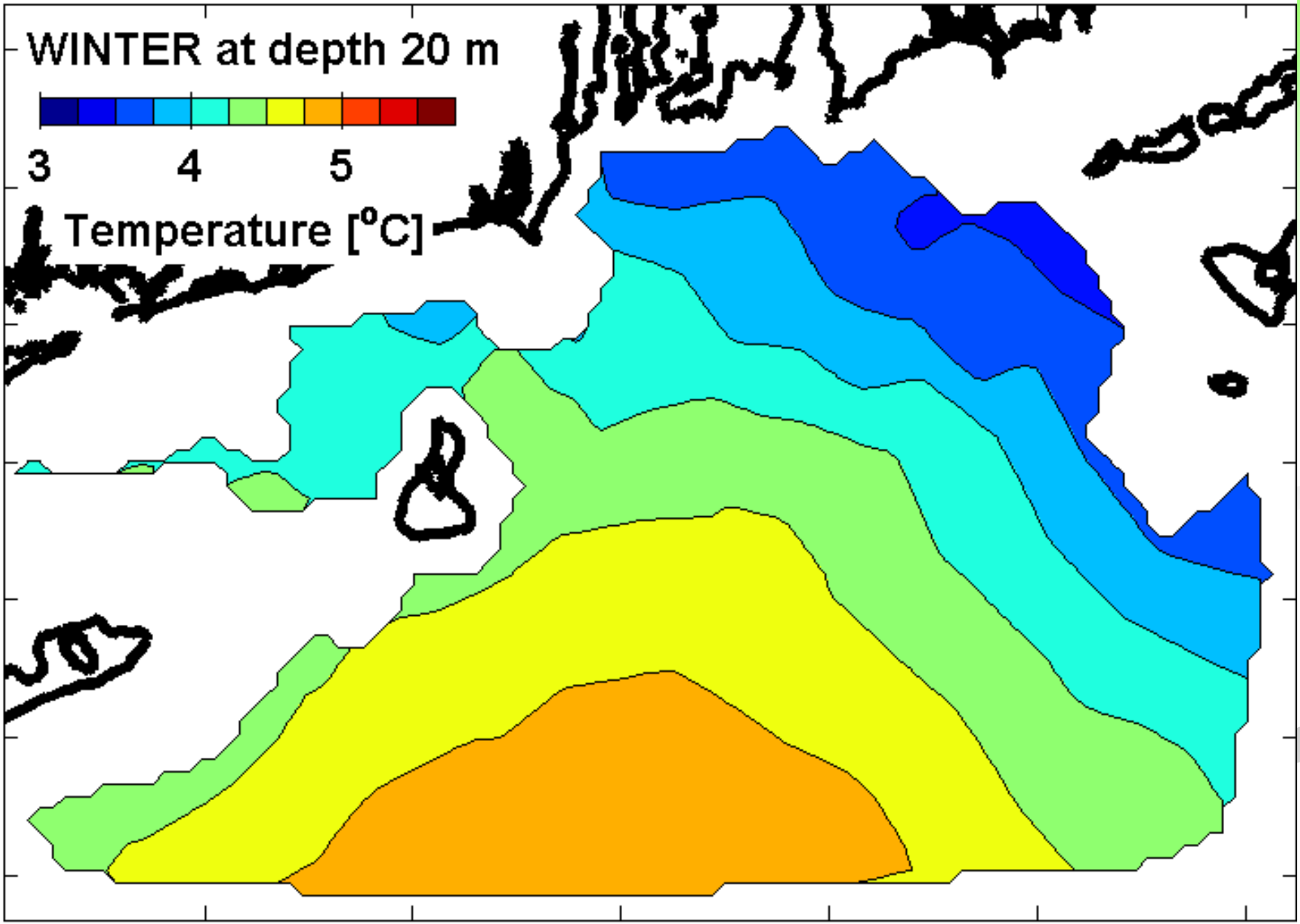
thanks to Grant Law (OHSU) & Kevin Ruddock (TNC)

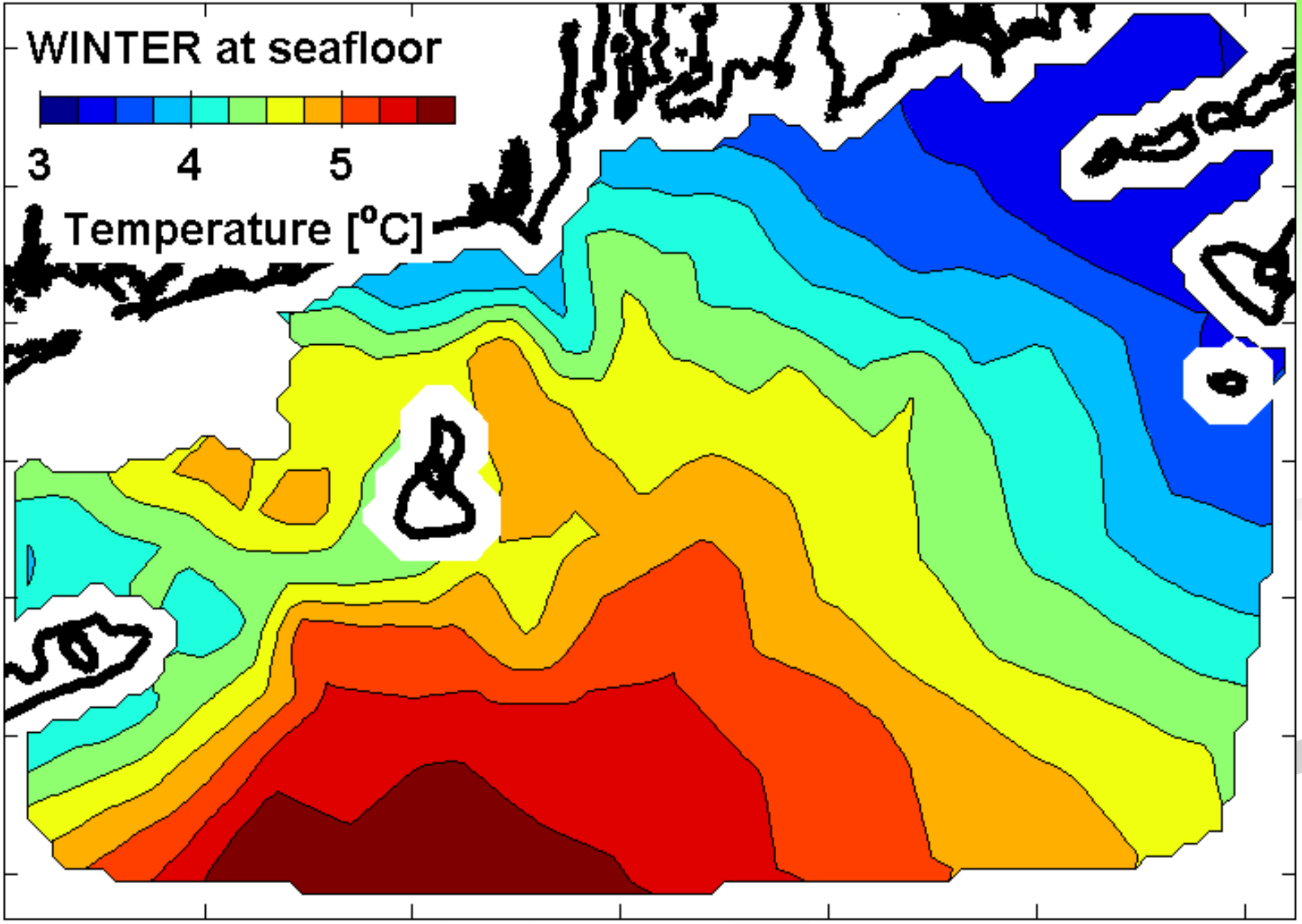

Bathymetry and Section Lines,
Hydrographic Climatology
0
20
40
60
Depth [m]
NS1
NS2
NS3
NS4
NS5
NS6
NS7
NS8
NS9
EW1
EW2
EW3
EW4
EW5
41.5
41.4
41.3
41.2
41.1
41
40.9
-71.8
-71.6
-71.4
-71.2
-71
-70.8

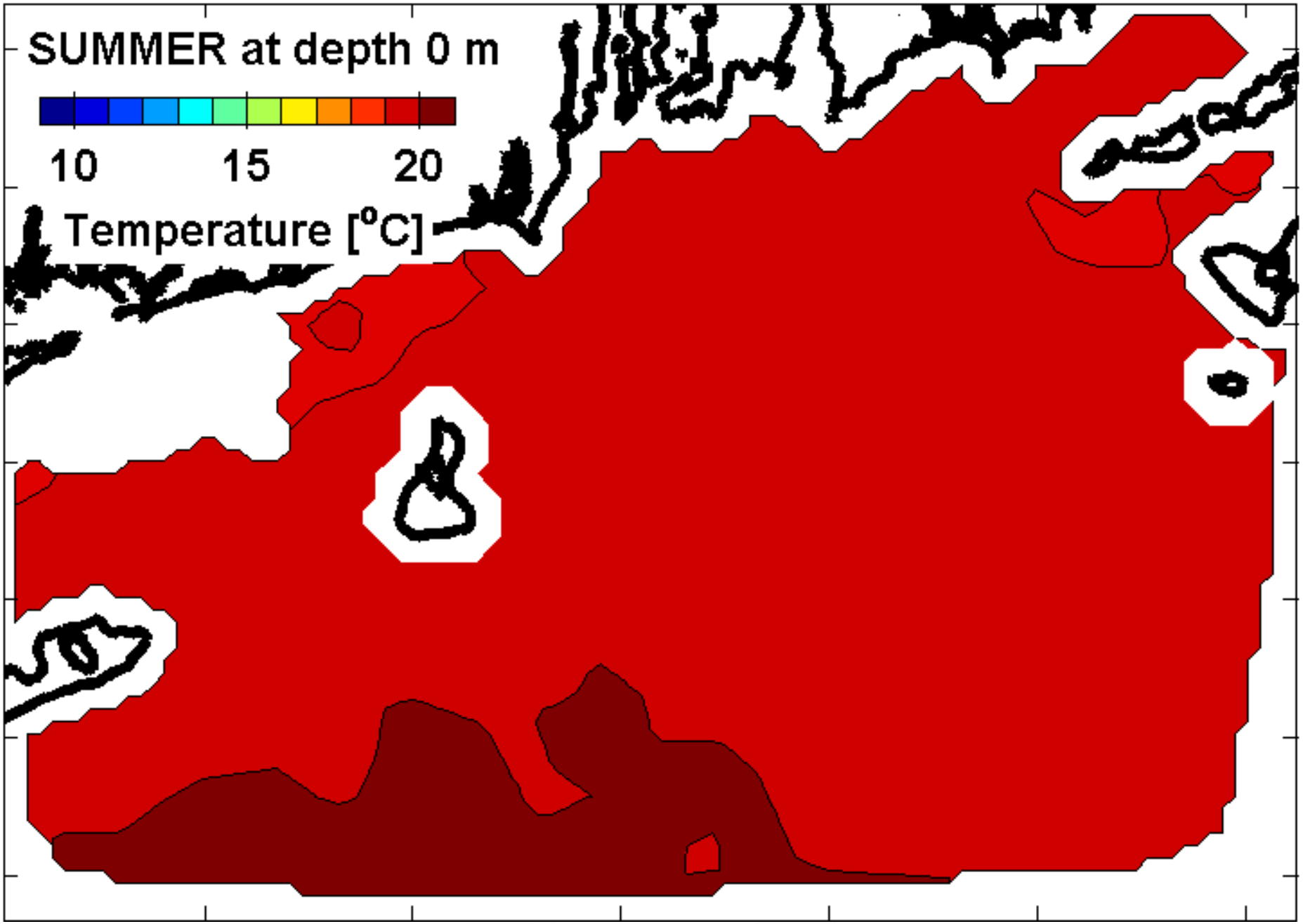
Temperature

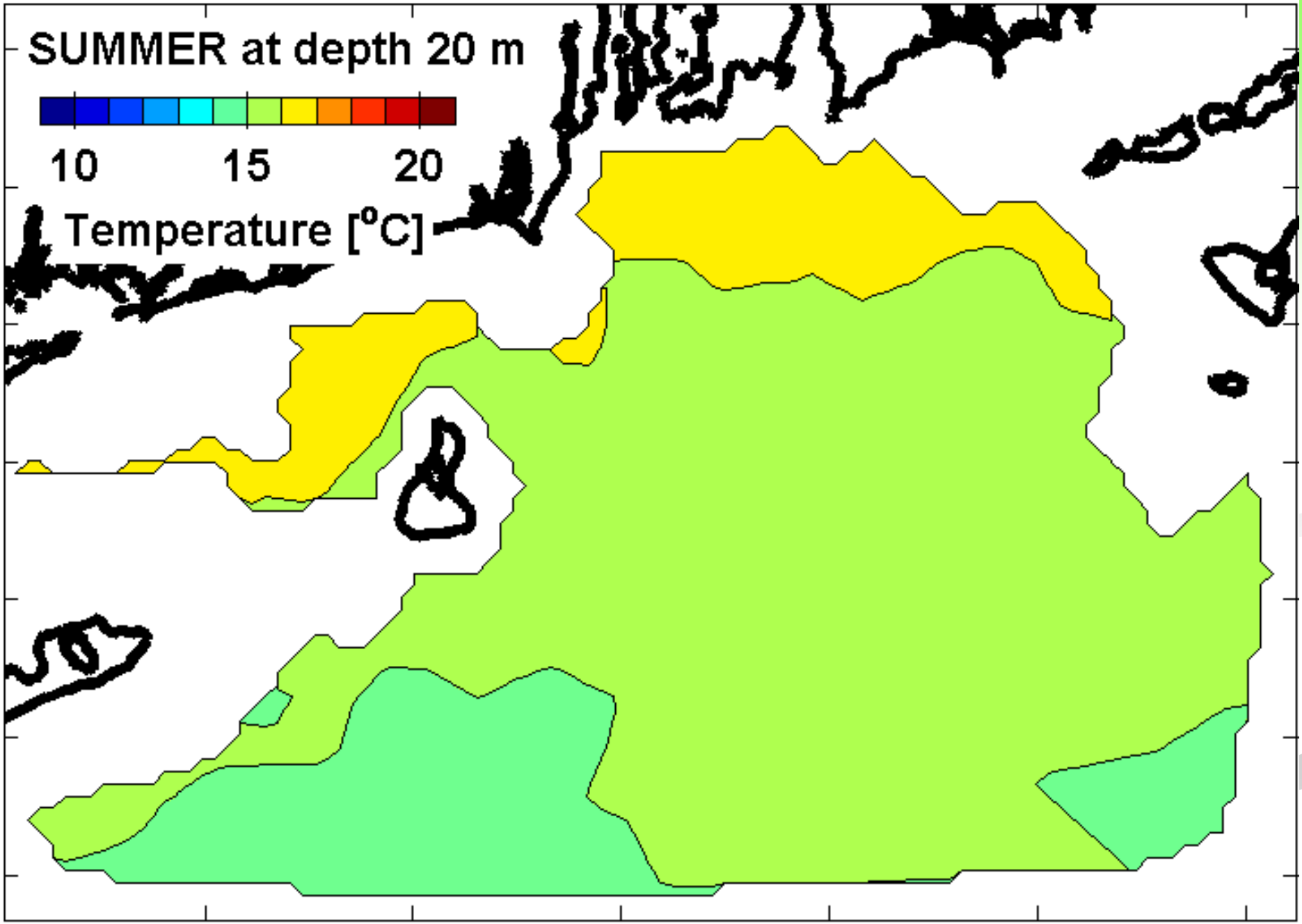
- Pronounced seasonality: Winter ~3-6 ^{o}C, Summer ~10-21 ^{o}C
- Winter
  - Colder inshore, eastward, near-surface
  - Surface/bottom difference ~0-2 ^{o}C, colder over warmer (destabilizing influence on density)
- Summer:
  - Colder at greater depths and farther offshore
  - Surface/bottom difference ~10 ^{o}C, warmer over colder
- Fall and Spring: intermediate to Winter/Summer
- Satellite sea SST generally similar to hydrographic climatology; provides greater detail

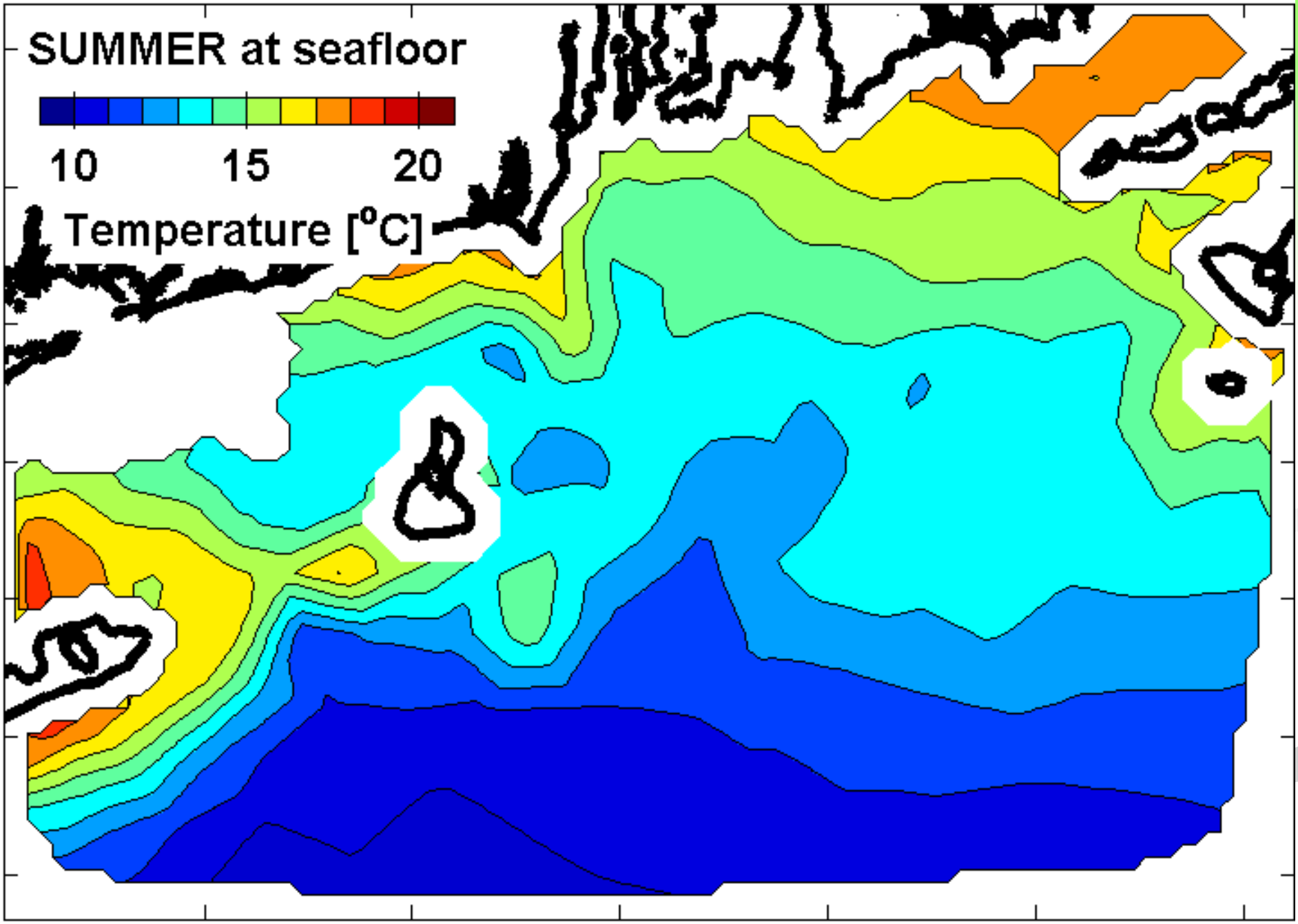

WINTER at depth 0 m
3
4
5
Temperature [°C]


WINTER at depth 20 m
3
4
5
Temperature [°C]


WINTER at seafloor
3
4
5
Temperature [°C]

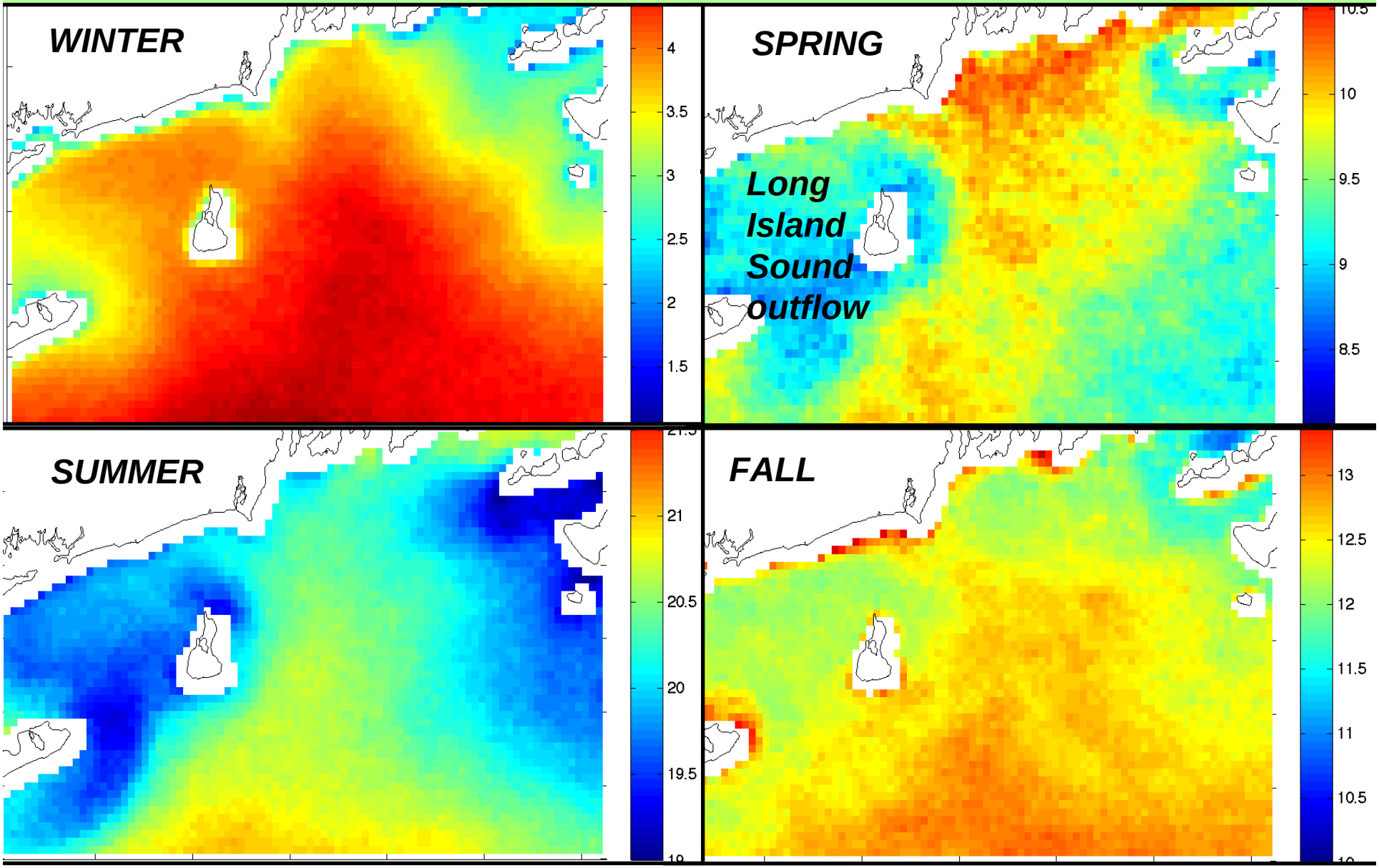

SUMMER at depth 0 m
10
15
20
Temperature [°C]


SUMMER at depth 20 m
10
15
20
Temperature [°C]


SUMMER at seafloor
10
15
20
Temperature [°C]

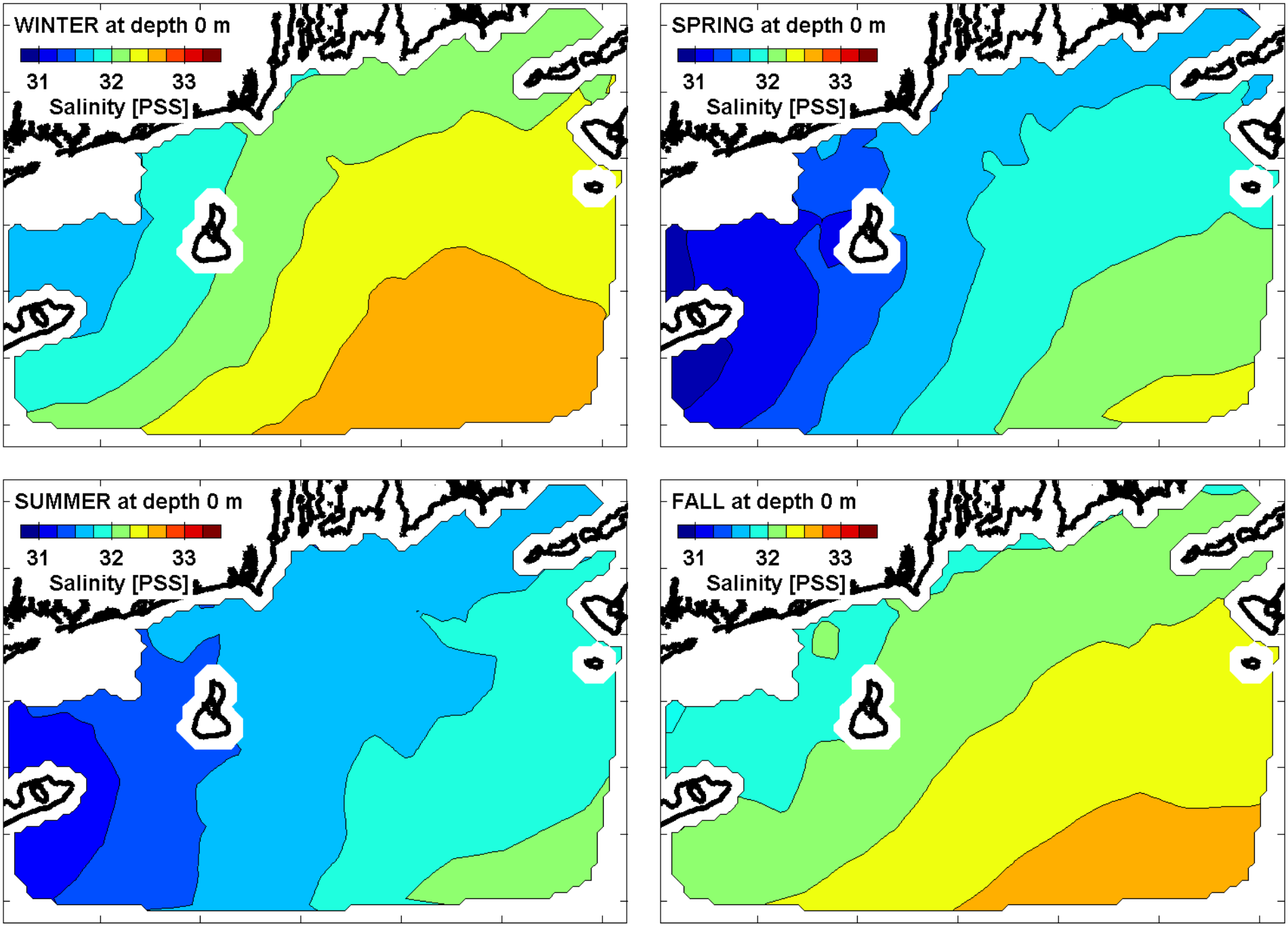
Satellite Sea-Surface Temperature

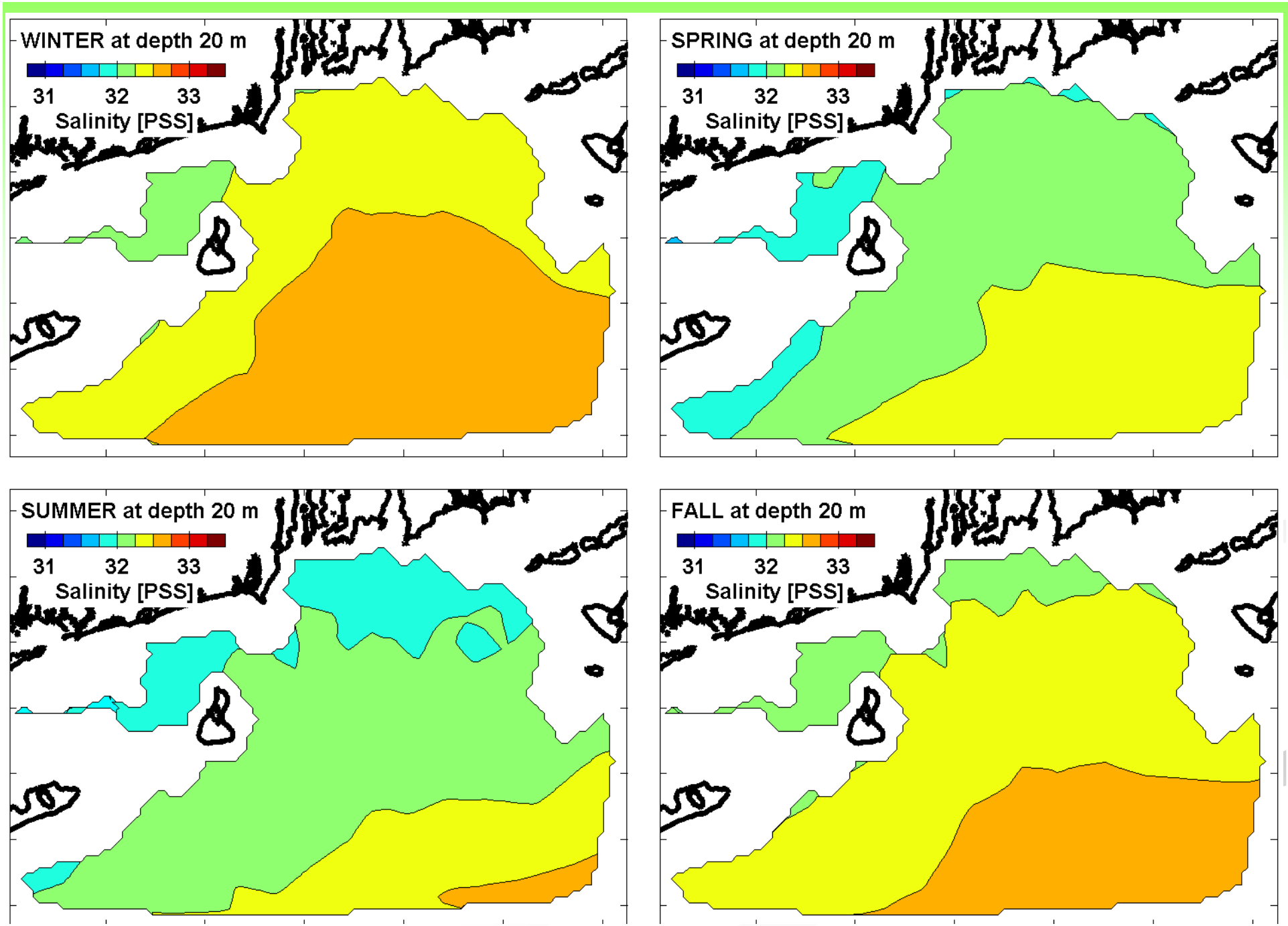
(AVHRR averaged 2004-2008)

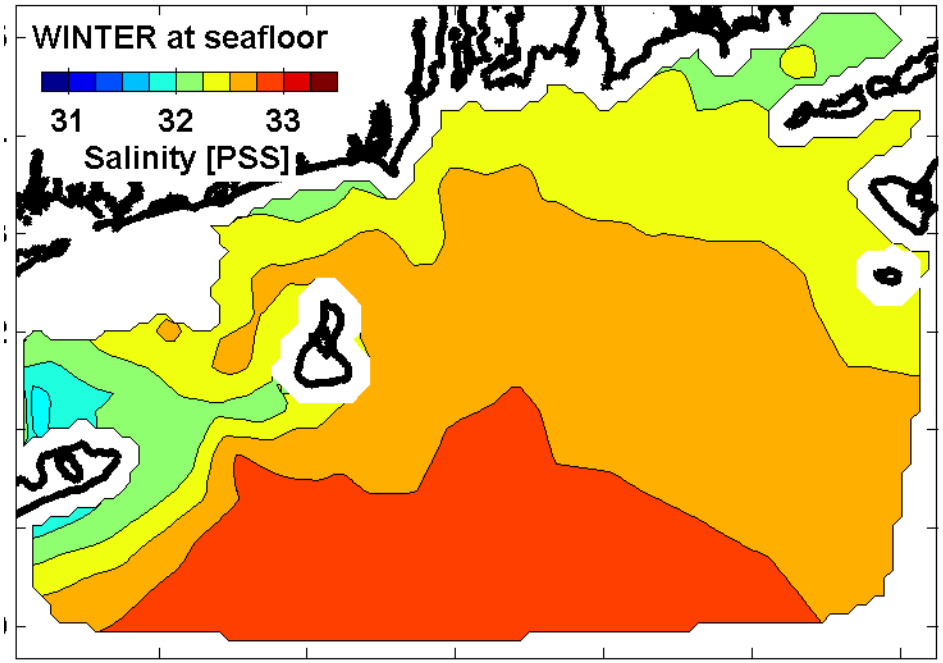


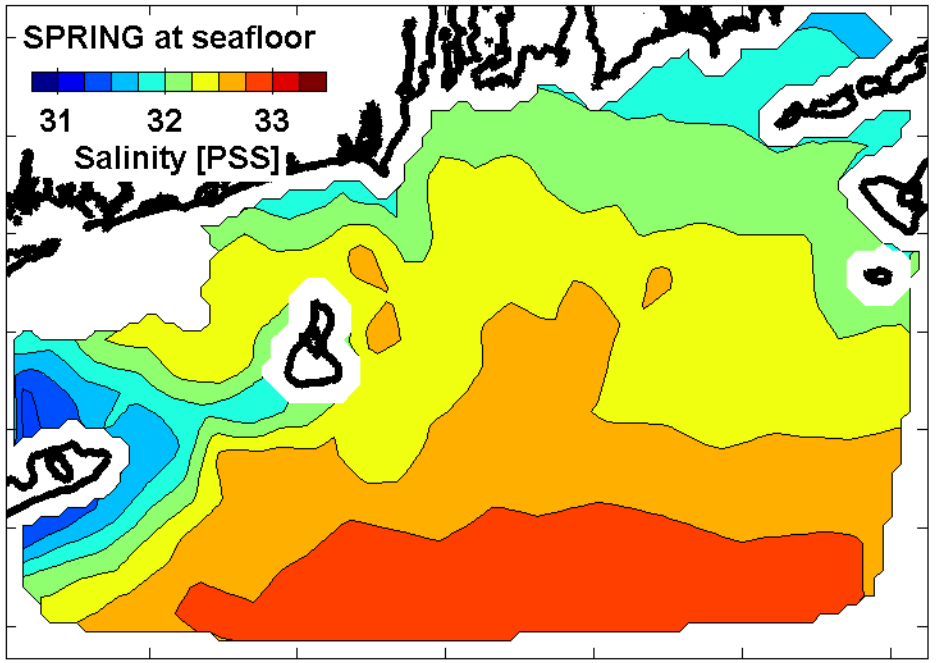
Salinity

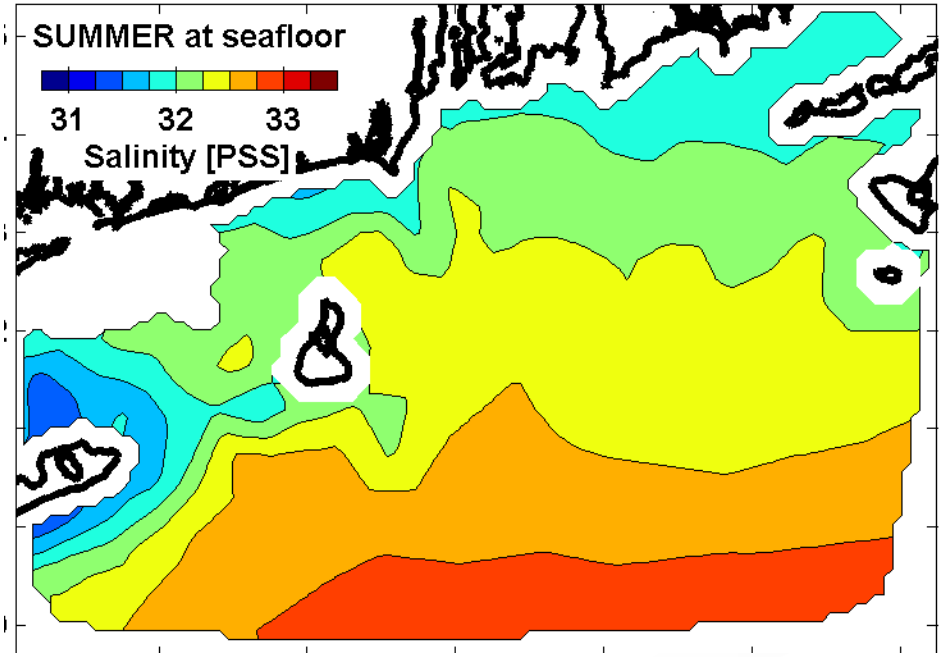
- Range: about 29.75 to 33.50 PSS
- Seasonal cycle modest (weaker than temp.); comparable to geographic variations
- Generally decreases (fresher)
  - … in Block Island Sound (BIS) (Long Island Sound outflow)
  - … near surface
  - … during Spring and Summer
- Generally increases (saltier)
  - … offshore and in Rhode Island Sound (RIS)
  - … at depth below surface
  - … during Fall and Winter
- Surface-bottom difference (stabilizes density): ~0.5 PSS Winter/Fall; ~2-3 PSS Spring/Summer

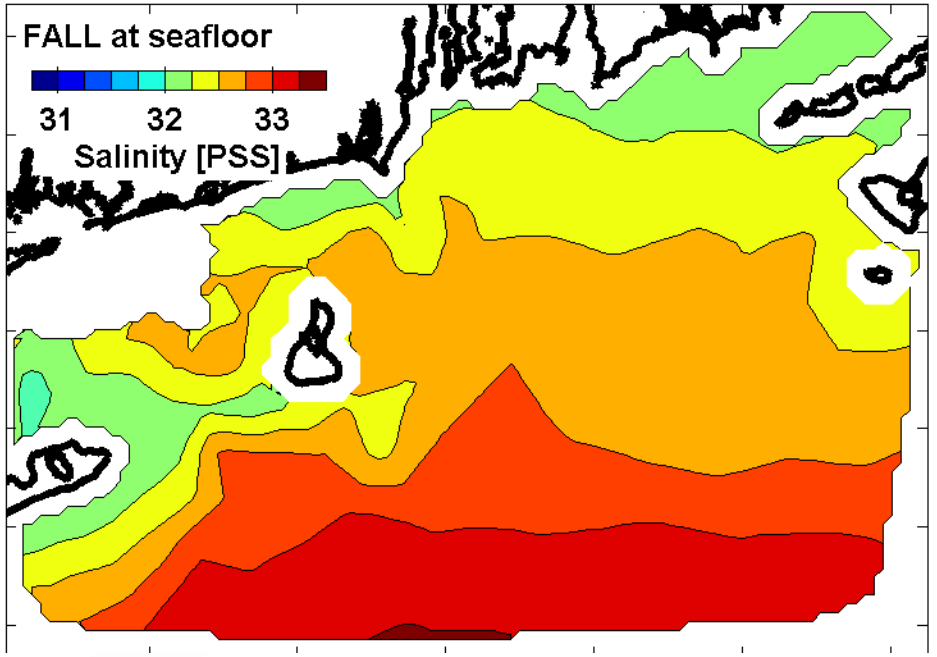

WINTER at depth 0 m
31
32
33
Salinity [PSS]
SPRING at depth 0 m
31
32
33
Salinity [PSS]
SUMMER at depth 0 m
31
32
33
Salinity [PSS]
FALL at depth 0 m
31
32
33
Salinity [PSS]


WINTER at depth 20 m
31
32
33
Salinity [PSS]
SPRING at depth 20 m
31
32
33
Salinity [PSS]
SUMMER at depth 20 m
31
32
33
Salinity [PSS]
FALL at depth 20 m
31
32
33
Salinity [PSS]


WINTER at seafloor
31
32
33
Salinity [PSS]

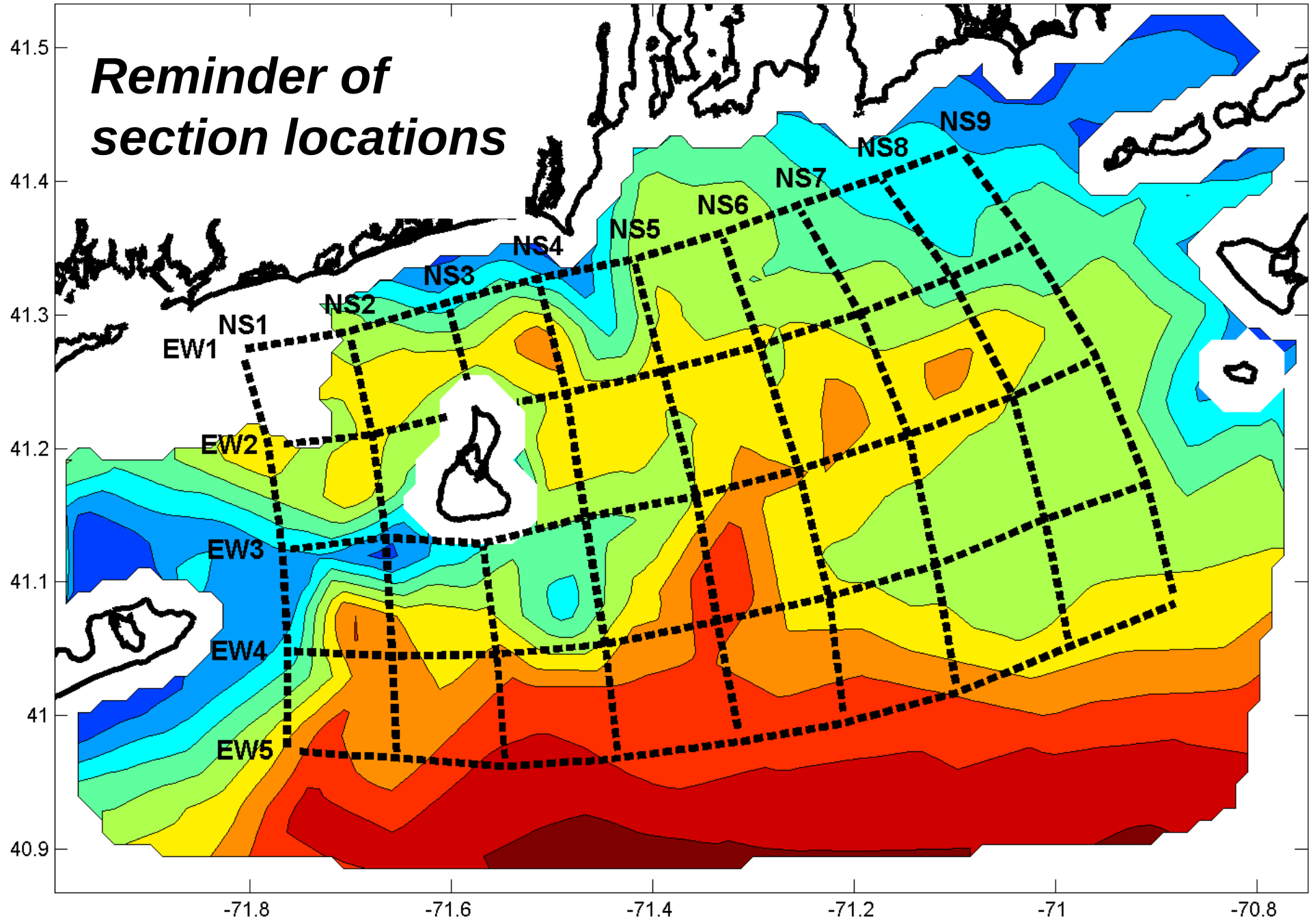

SPRING at seafloor
31
32
33
Salinity [PSS]

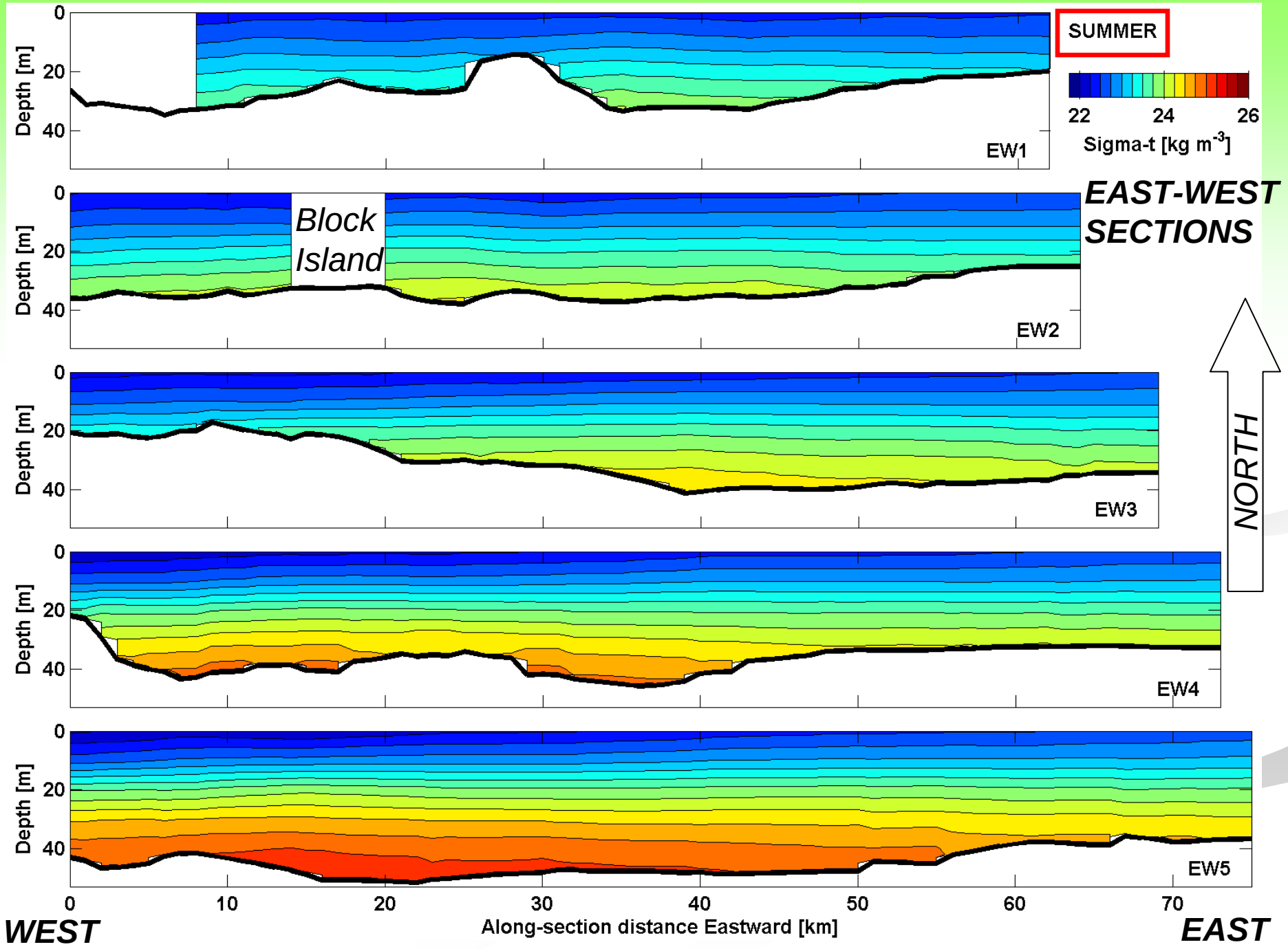

SUMMER at seafloor
31
32
33
Salinity [PSS]

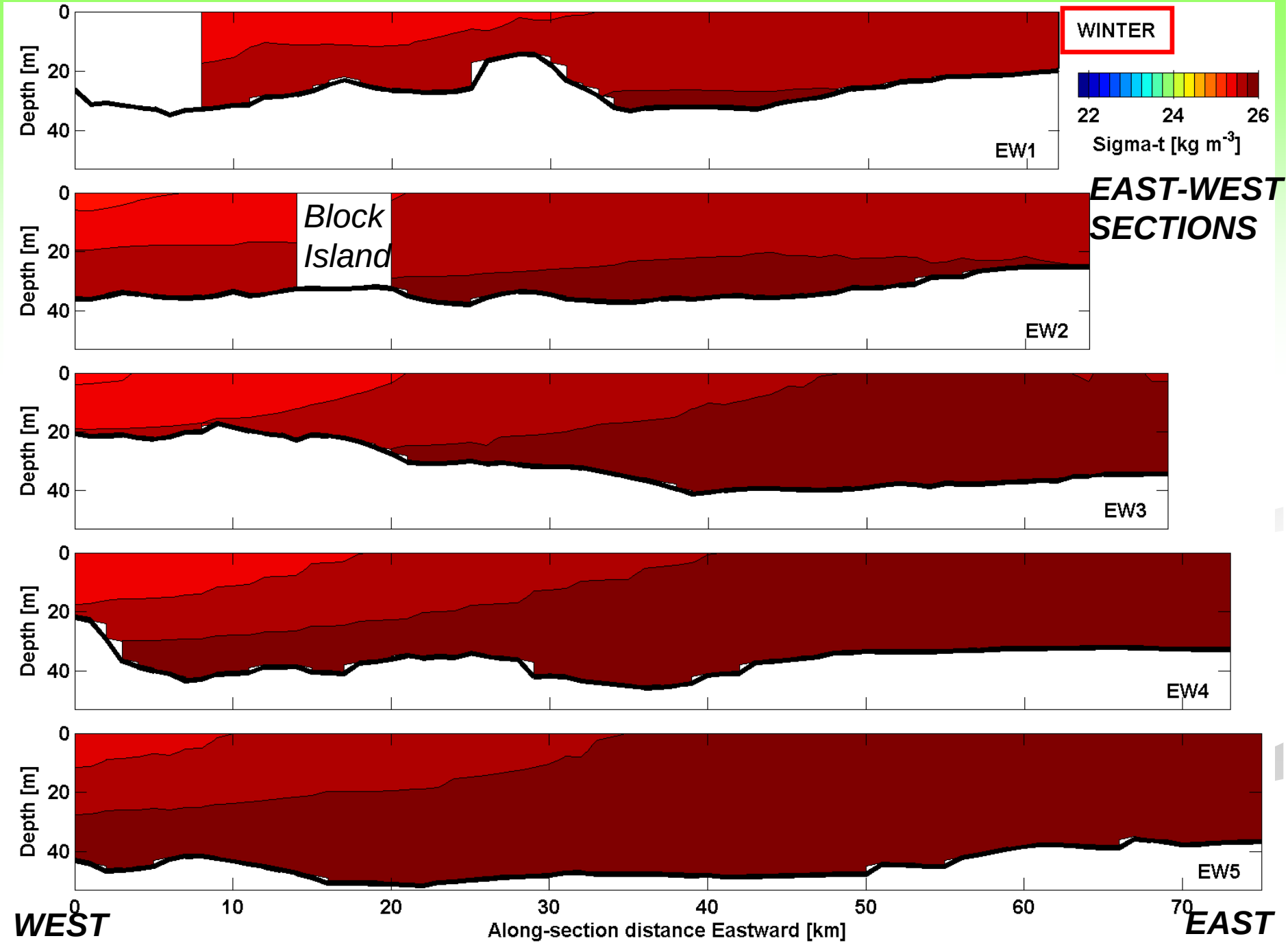

FALL at seafloor
31
32
33
Salinity [PSS]

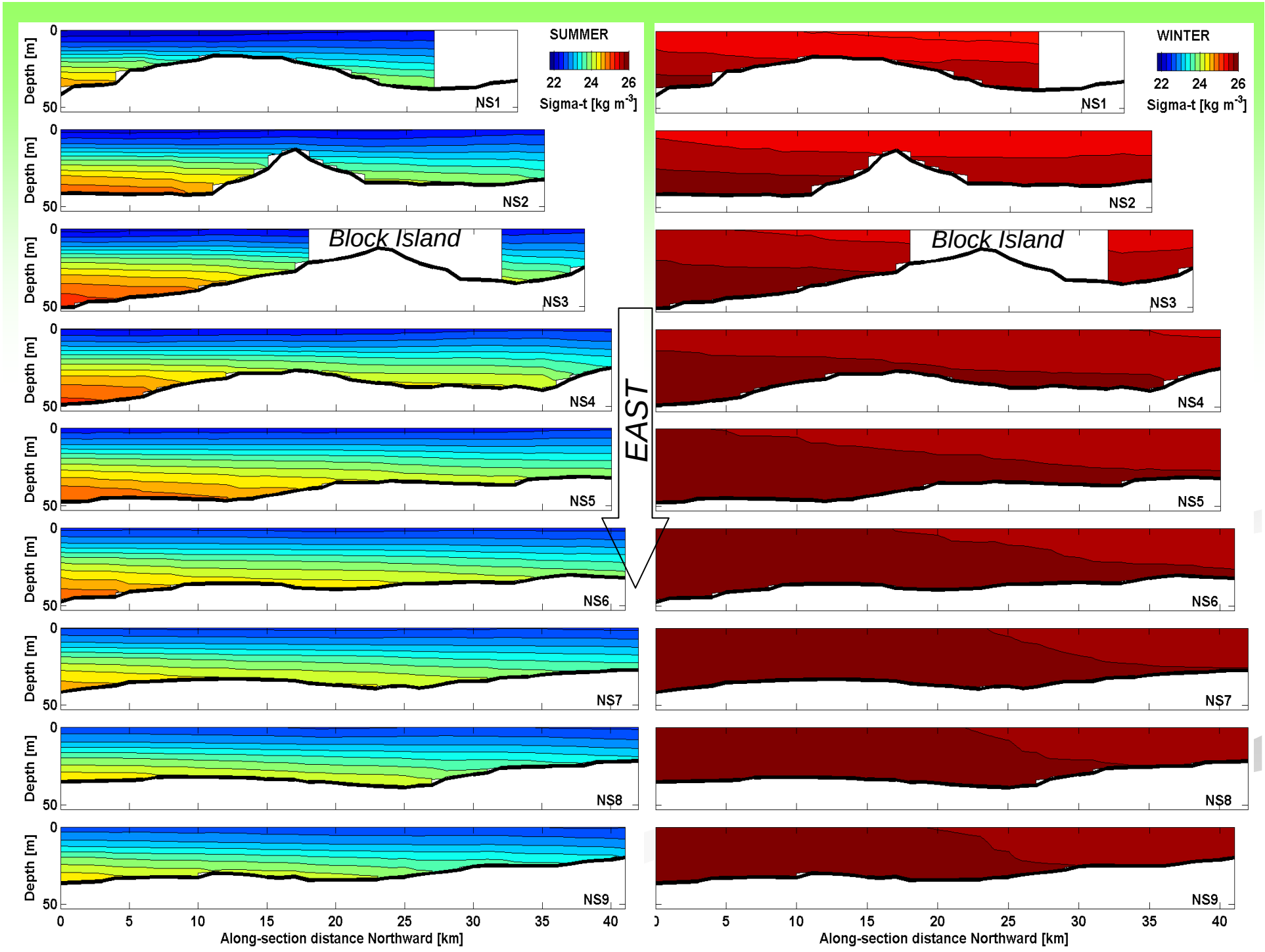
Density (Sigma-t) & Stratification

- Range: about 21.75 to 26.00 kg m^{-3}
- Modest seasonal cycle
- Least dense: in BIS and inshore, near surface, during Spring/Summer
- Most dense: in RIS and offshore, near bottom, during Fall/Winter
- Controlled mainly by salinity, except in summer when temperature and salinity variations contribute about equally
- Surface-bottom difference distinctly seasonal:
  - Spring/Summer: Strat. strong (~2-3 kg m^{-3})
  - Winter/Fall: Strat. weak/absent (0-0.5 kg m^{-3})


Reminder of section locations
NS1
NS2
NS3
NS4
NS5
NS6
NS7
NS8
NS9
EW1
EW2
EW3
EW4
EW5
41.5
41.4
41.3
41.2
41.1
41
40.9
-71.8
-71.6
-71.4
-71.2
-71
-70.8


SUMMER
22
24
26
Sigma-t [kg m-3]
EAST-WEST SECTIONS
Block Island
EW1
EW2
EW3
EW4
EW5
Depth [m]
0
20
40
NORTH
0
10
20
30
40
50
60
70
Along-section distance Eastward [km]
WEST
EAST


WINTER
22
24
26
Sigma-t [kg m-3]
EAST-WEST SECTIONS
Block Island
EW1
EW2
EW3
EW4
EW5
Depth [m]
0
20
40
0
10
20
30
40
50
60
70
WEST
EAST
Along-section distance Eastward [km]


SUMMER
22 24 26
Sigma-t [kg m-3]
WINTER
22 24 26
Sigma-t [kg m-3]
Block Island
Block Island
EAST
Depth [m]
0
50
NS1
NS2
NS3
NS4
NS5
NS6
NS7
NS8
NS9
0 5 10 15 20 25 30 35 40
Along-section distance Northward [km]

Sensitivity of stratification to offshore structures

- Currents moving past pilings of offshore structures generate wakes with enhanced turbulence
- The potential effect on seasonal cycle of stratification deserves careful consideration

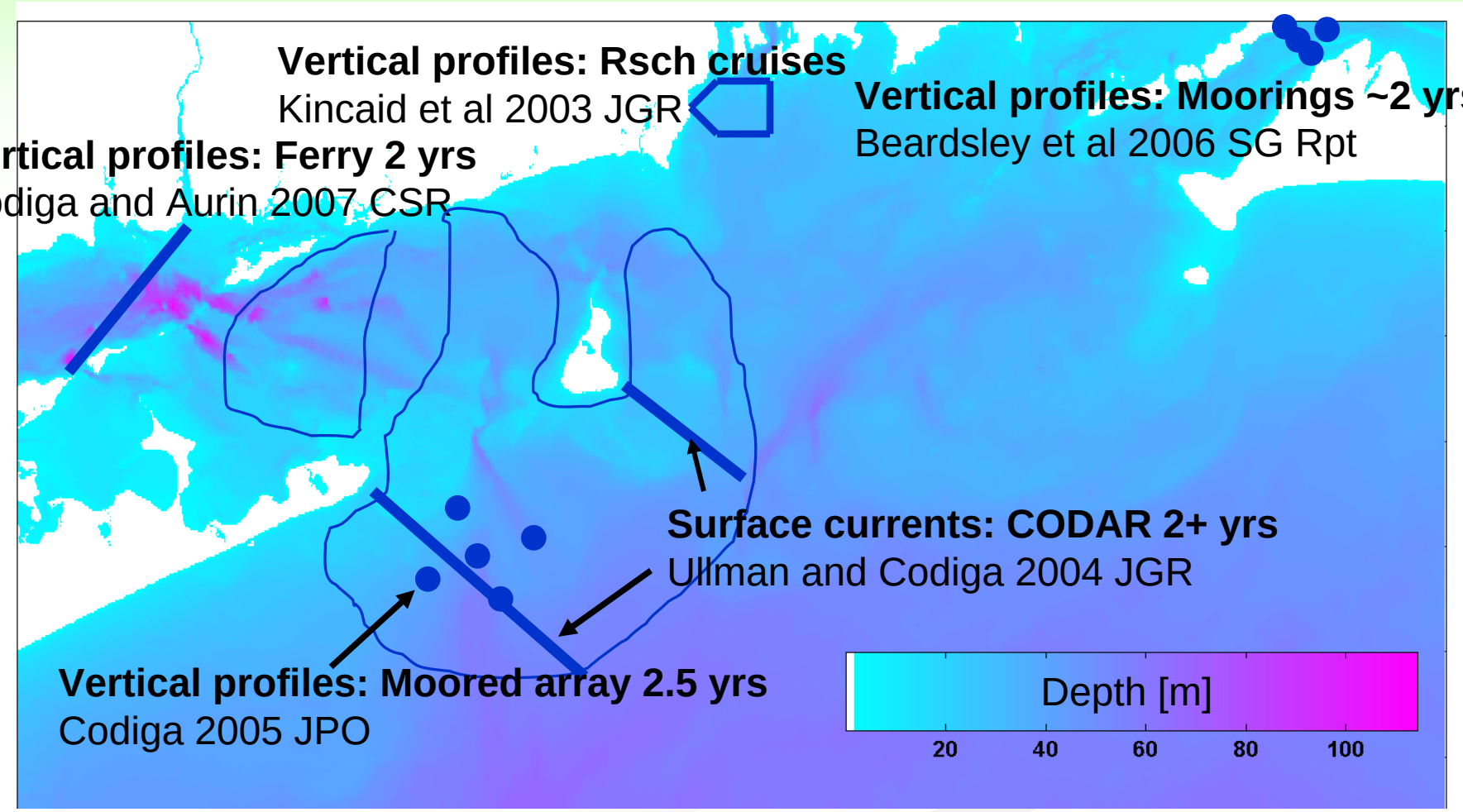
Effect of enhanced turbulence in structure wakes?

- Strat. change = +(surface heating) +(estuarine strain) +(precipitation) –(wind mixing) –(bedstress mixing) **–(wake mixing)**
- Preliminary rough calculation:
  - Assume: 2m piling diam.; 4 pilings/ structure; 0.6-1km structure spacing; 25 cm/s rotary current; 30m depth; mixing efficiency 0.2
  - Result: wake mixing ≅ bedstress mixing
- Tentative conclusion: wake mixing unlikely to cause major change in stratification

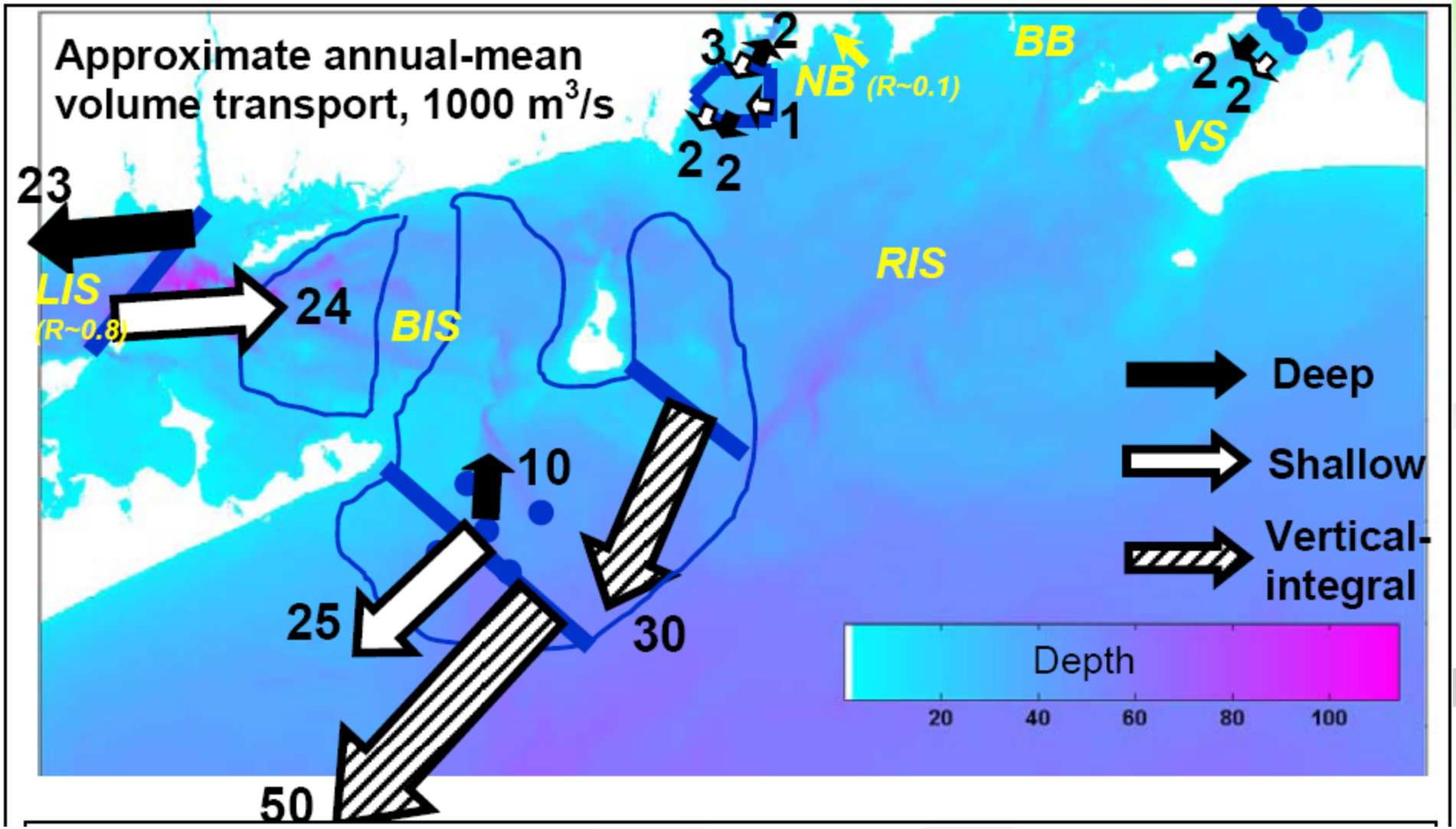
Currents

- Observations:
  - Moored current meters: vertical profiles
    - Long durations (~months), sparse spatial coverage
  - Ship-based surveys: vertical profiles
    - Better spatial coverage, short durations (~days)
  - Shore-based high-frequency radar
    - Good spatial coverage in some areas
    - Multi-year duration
    - Limited to surface currents

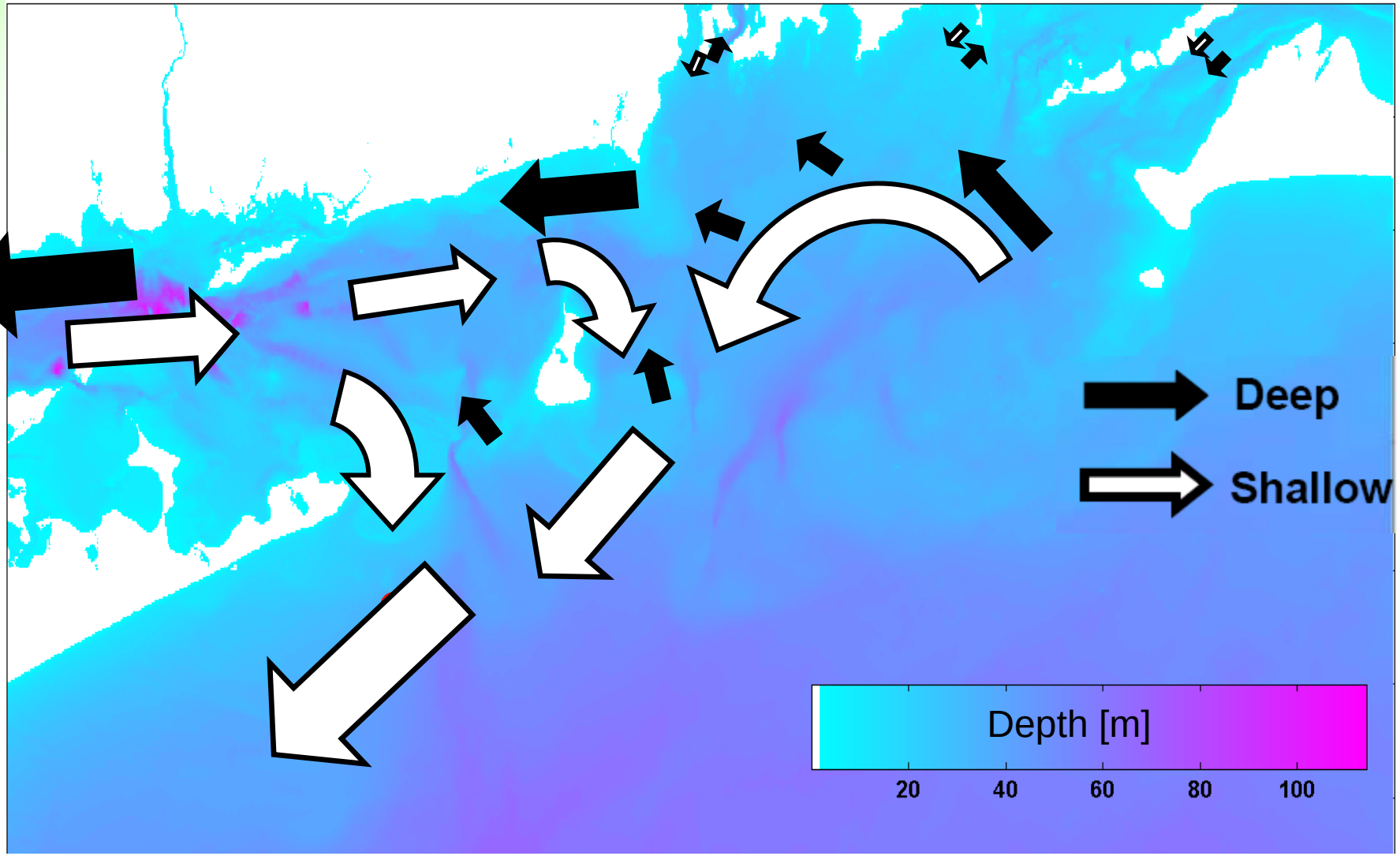
*Observations to estimate **annual-mean, non-tidal*** volume transport



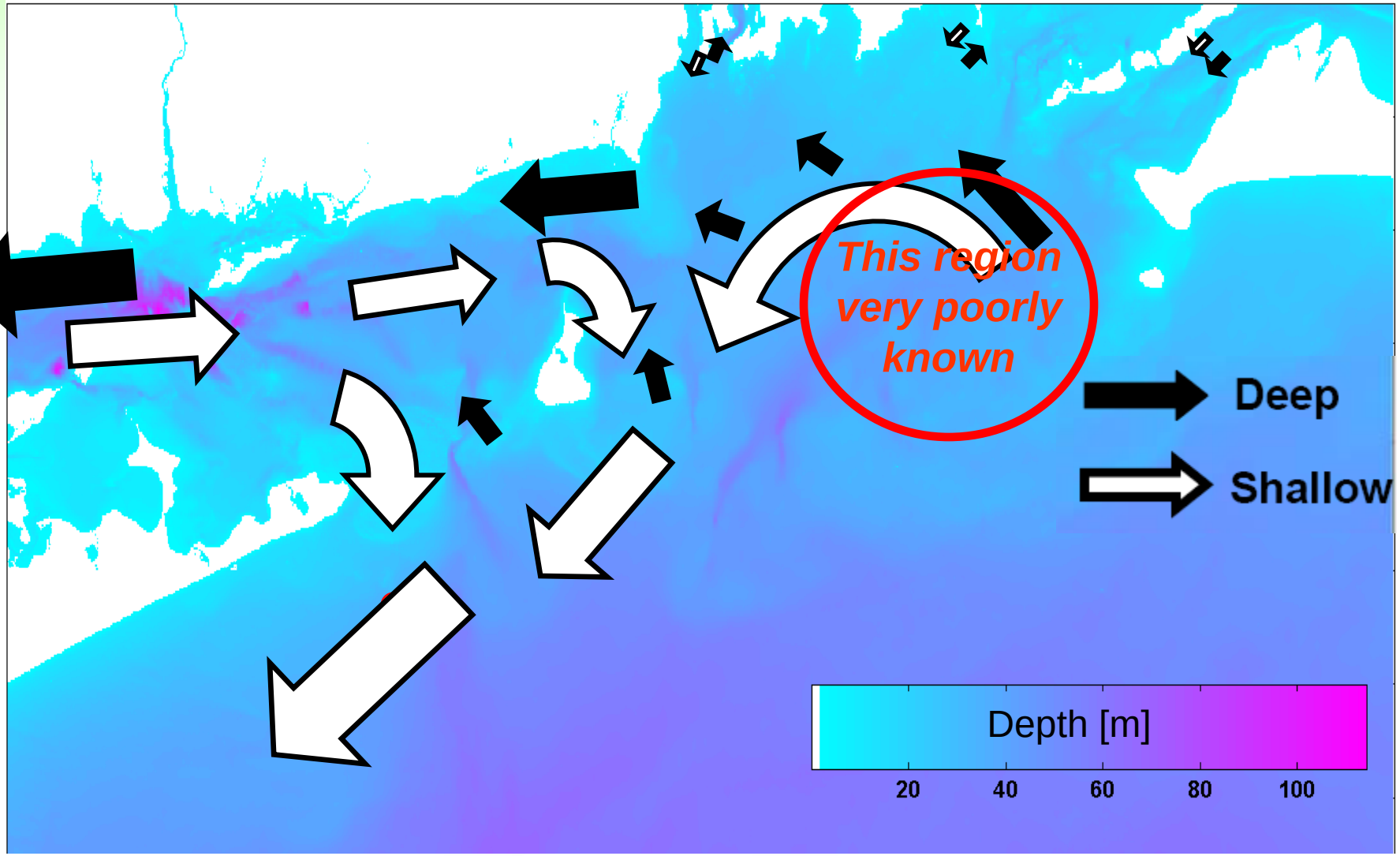
Summary: Observed Transports



Schematic/Hypothesized Annual-mean Transport Pathways



Schematic Annual-mean Transport Pathways

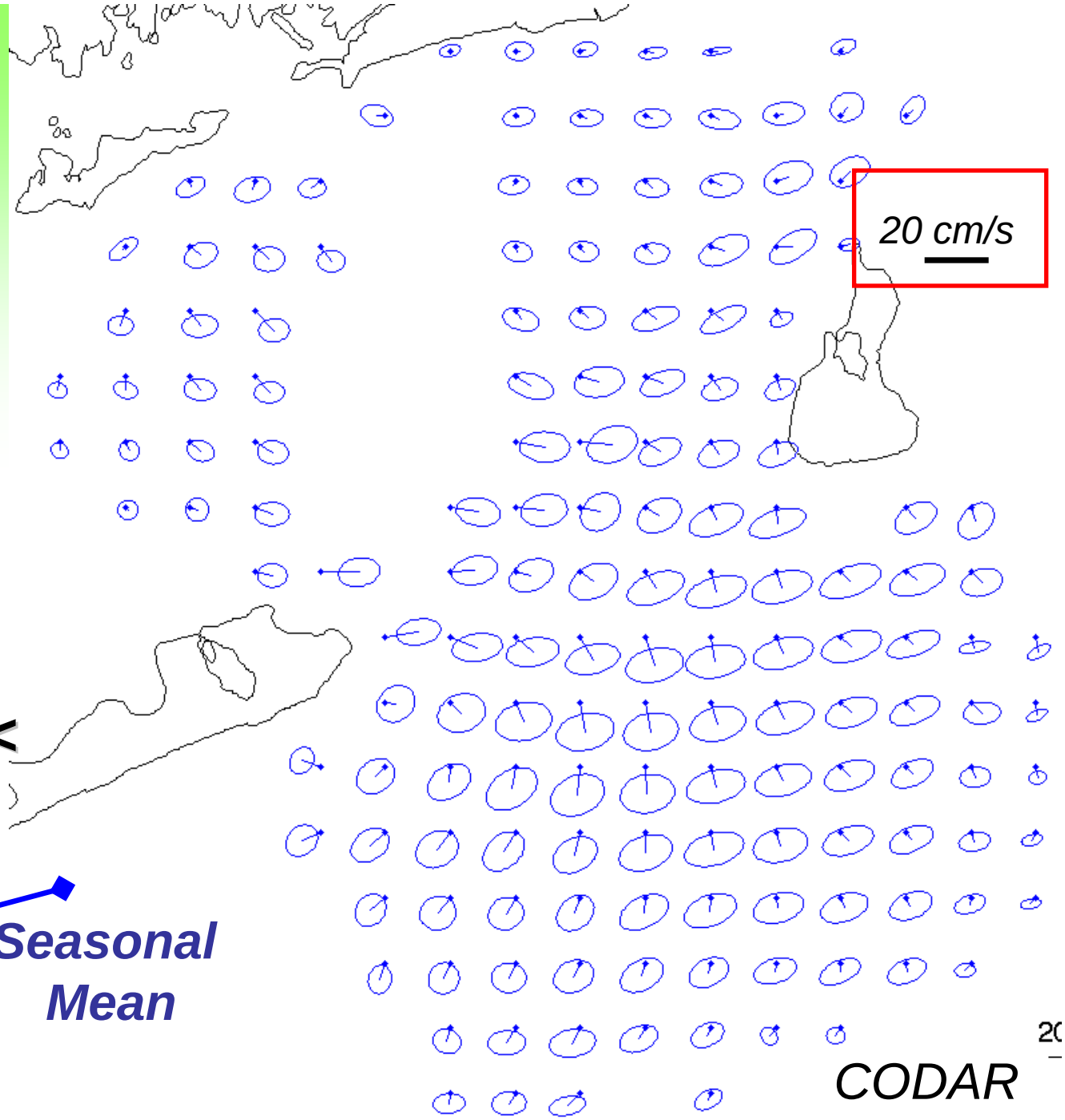


Seasonal-Mean & Weather-Band Variability (non-tidal)

WINTER

Mean offshore
(Long Island Sound outflow)

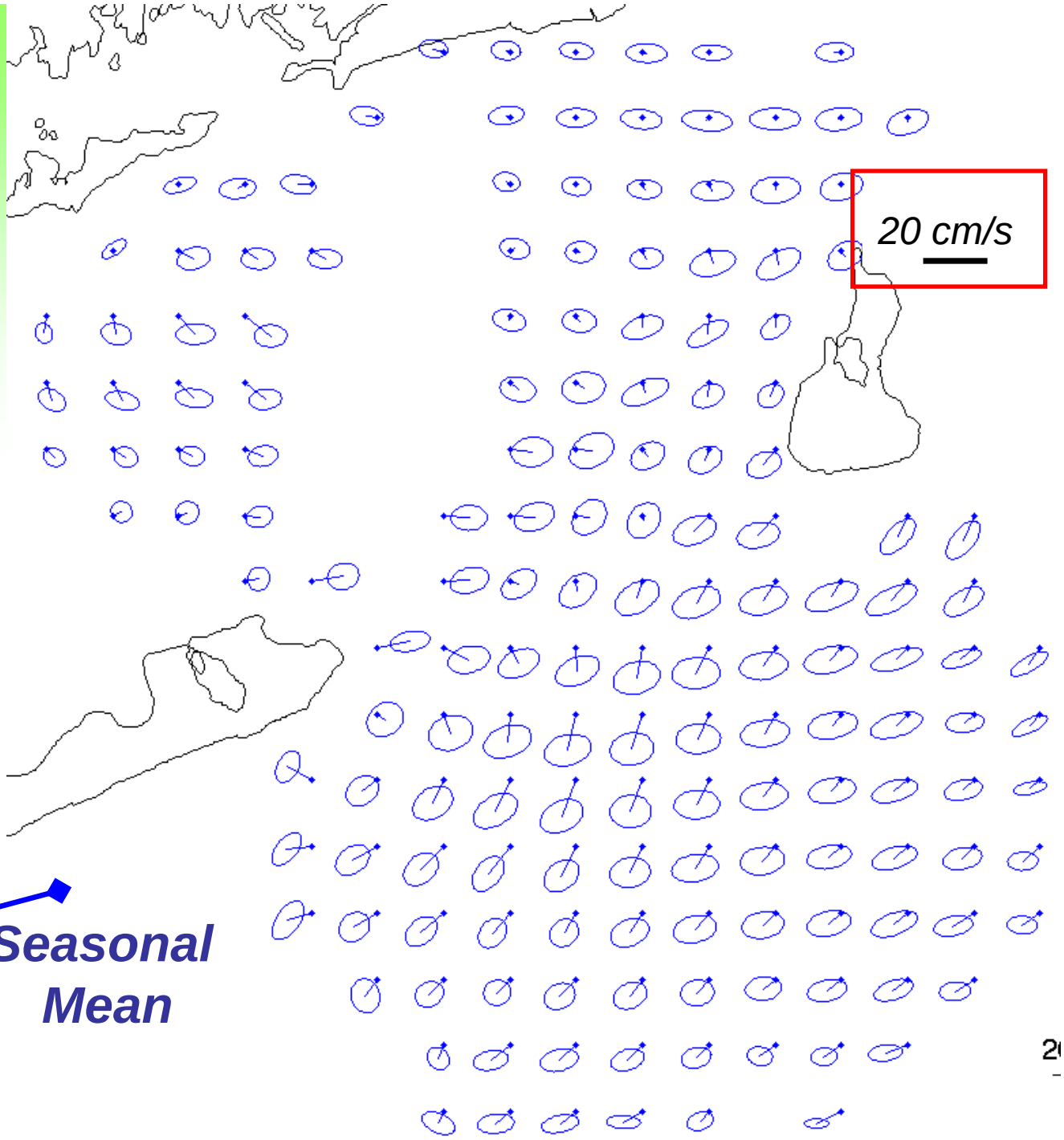
Weather-band ~< mean



SPRING

Stronger mean

Weather-band reduced

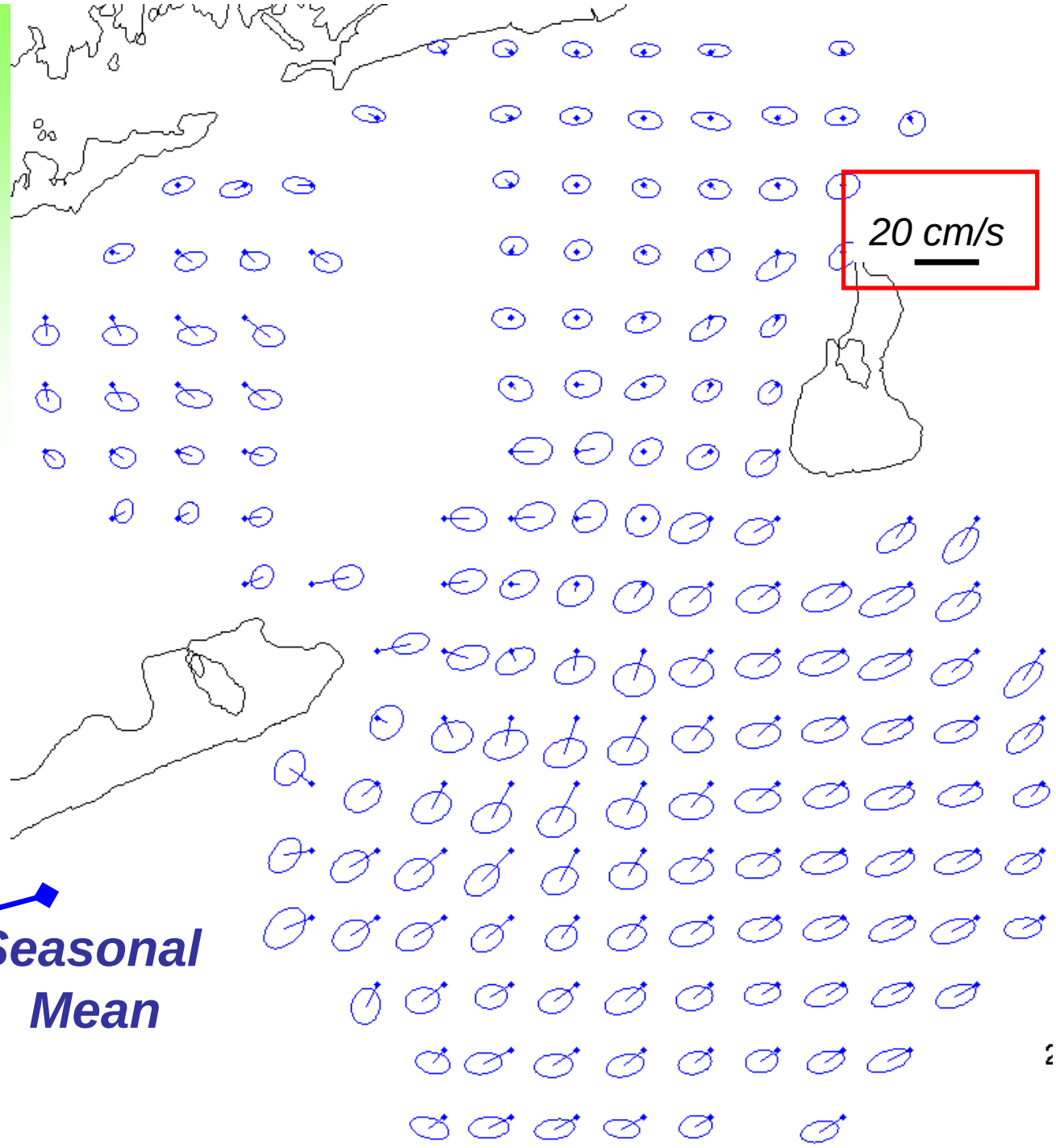


Seasonal Mean

Weather-band Variability

SUMMER

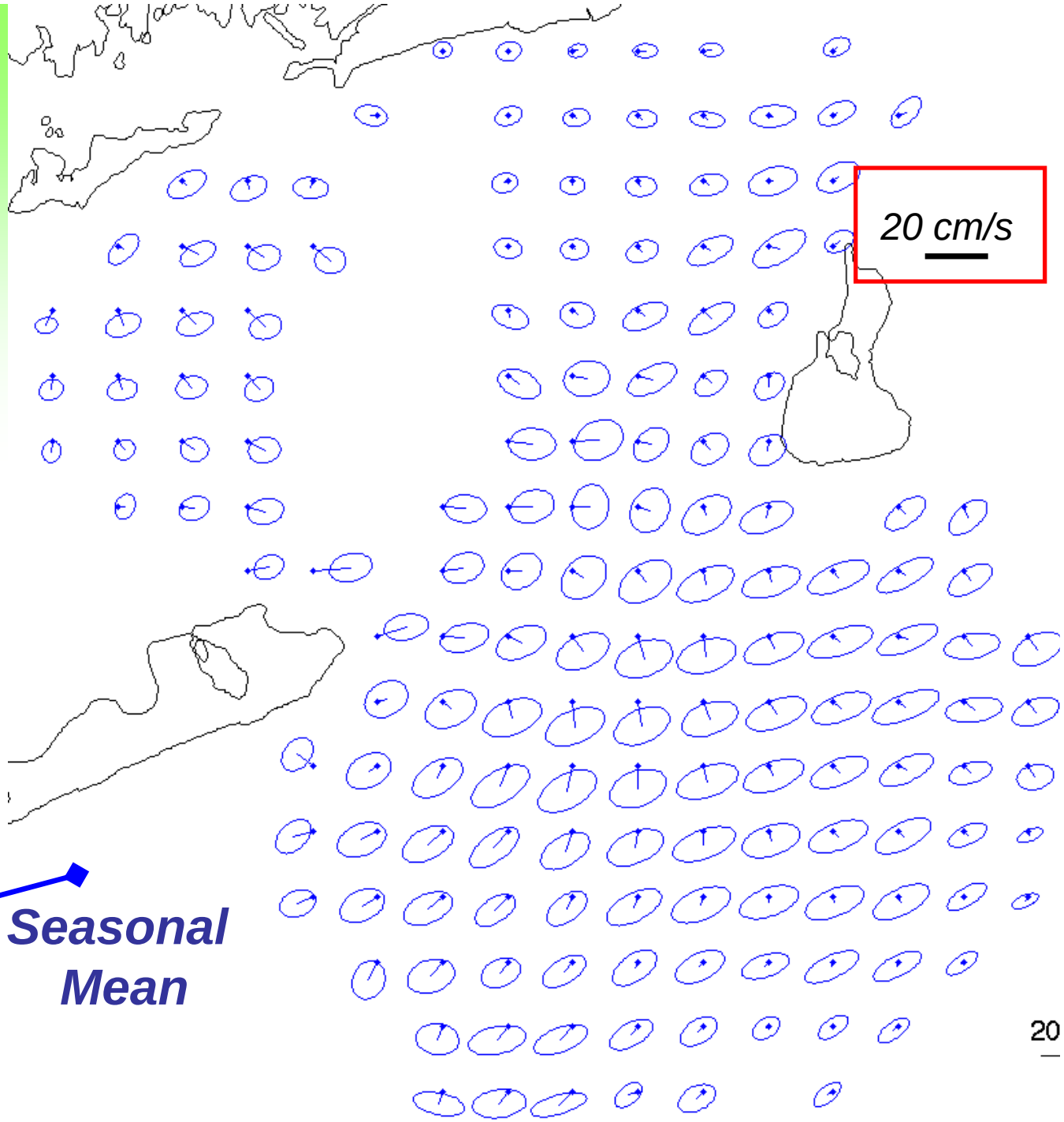
Alongshore summer "jet"

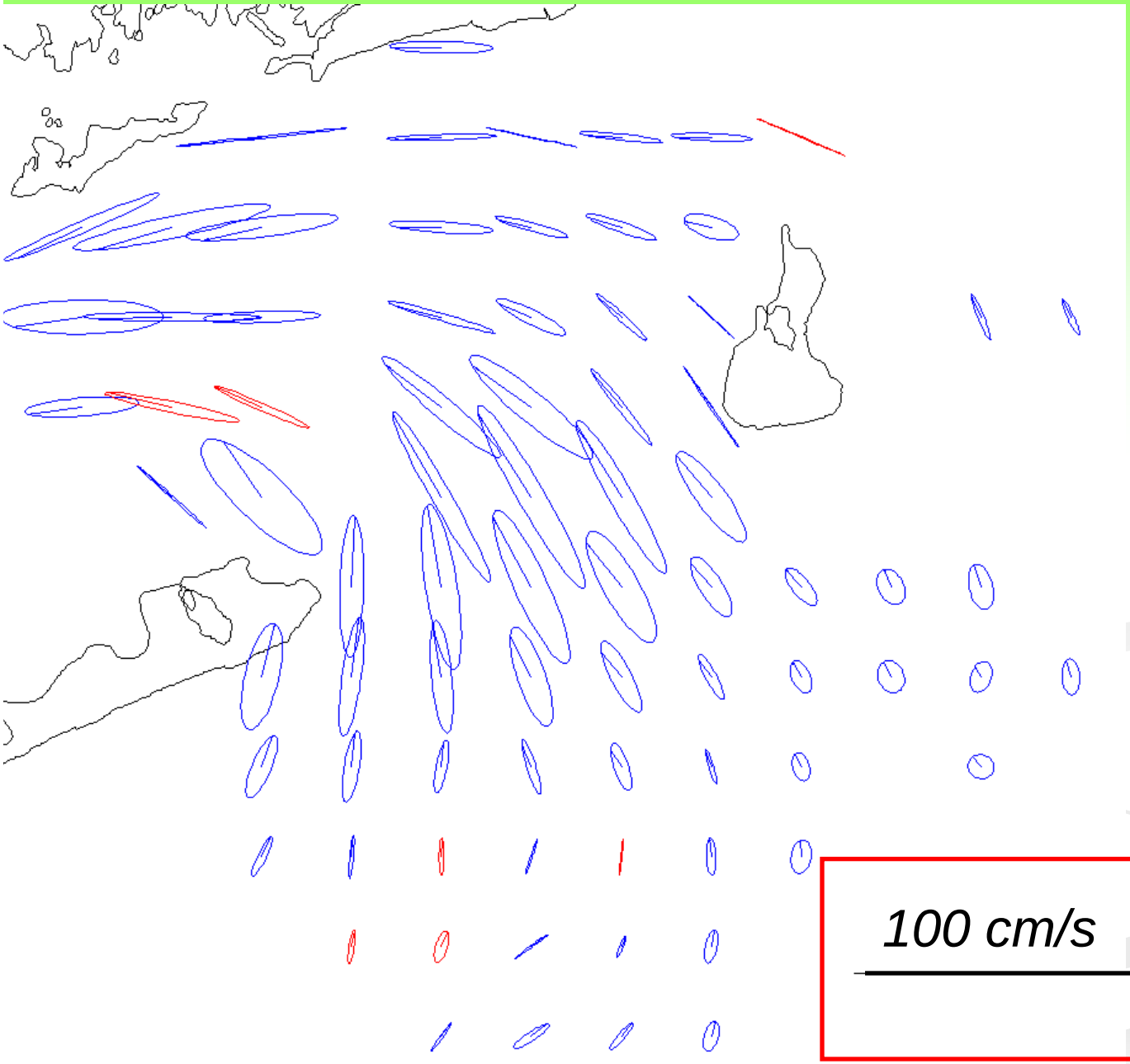


FALL

Mean reduced

Weather-band enhanced





TIDAL CURRENTS

M_2 (12.42-hour) Constituent

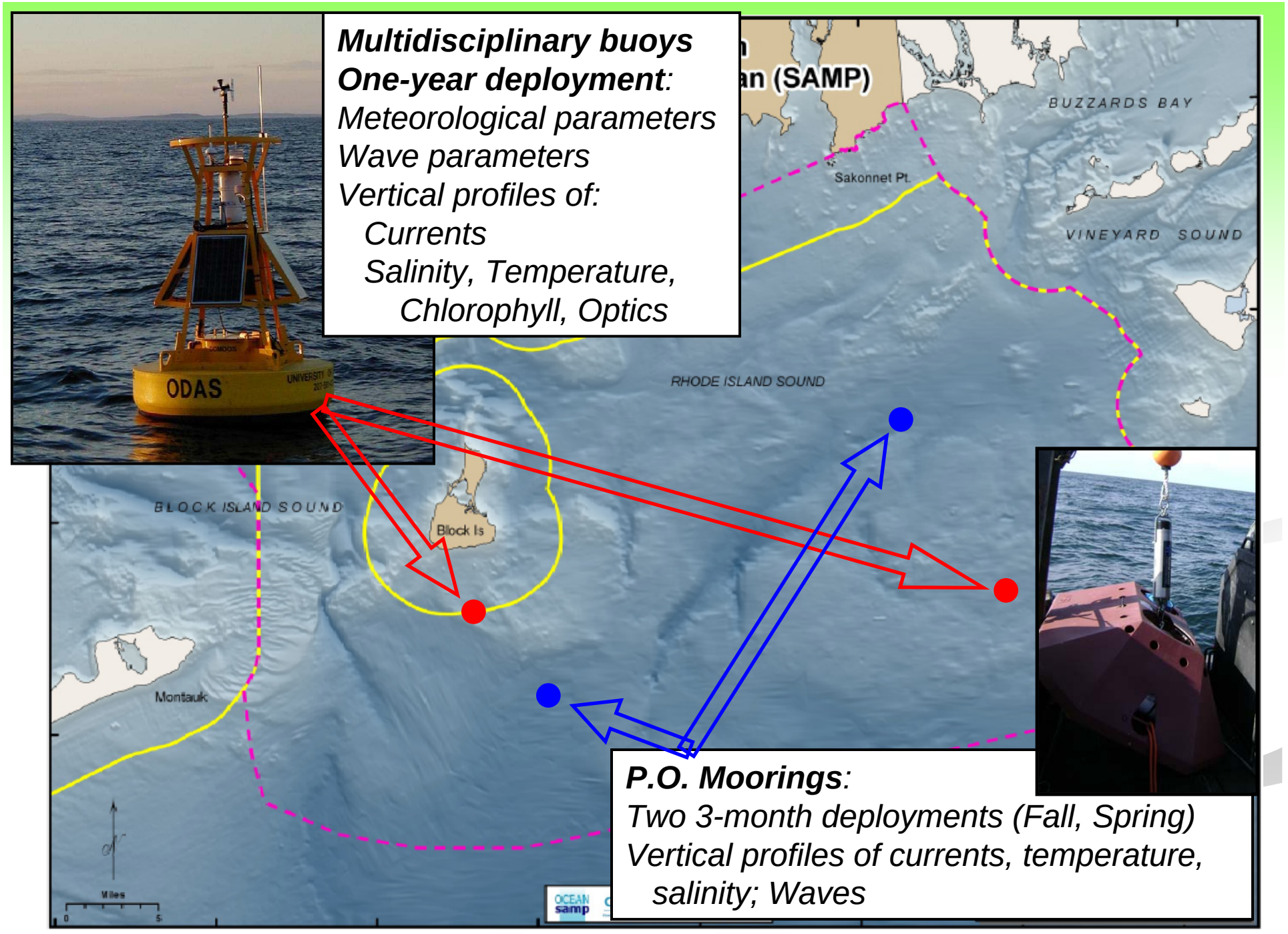
Current ellipses at surface

Blue: Clockwise in time
Red: Counter-clockwise

CODAR

New Measurements for SAMP

- Will provide major advance in baseline understanding of PO characteristics, particularly in Eastern Rhode Island Sound
- One year-long deployment, two fully instrumented buoys (NERACOOS)
- Two 3-mon. mooring deployments (Fall, Spring): Time series vertical profiles of currents, water properties; Surface waves
- 2-3 day CTD survey once/season `09-`10
  - On EW and NS transects shown previously


ODAS
Multidisciplinary buoys
***One-year deployment**:*
Meteorological parameters
Wave parameters
Vertical profiles of:
Currents
Salinity, Temperature, Chlorophyll, Optics
an (SAMP)
BUZZARDS BAY
Sakonnet Pt.
VINEYARD SOUND
RHODE ISLAND SOUND
BLOCK ISLAND SOUND
Block Is
Montauk
Miles
0
5
OCEAN
samp
***P.O. Moorings**:*
Two 3-month deployments (Fall, Spring)
Vertical profiles of currents, temperature, salinity; Waves

Summary of Baseline Characteristics

- Water properties
  - Fresher, cooler in West (Long Island Sound influence)
  - Salinity main control on density; temperature comparably important during summer
  - Density stratification seasonal: weak/absent in Winter and up to ~3 kg m^{-3} in Summer
- Currents
  - Long-term mean circulation
    - Arrives to SAMP region from Southeast, exits to Southwest
    - In West, deep flow toward Long Island Sound (opposite shallow)
  - Weather-band currents larger than or comparable to seasonal mean flow
  - Tidal flow amplified (exceeds mean and weather-band) in West (Long Island Sound resonance)