Multiple realizations of future biophysical states in the Bering Sea

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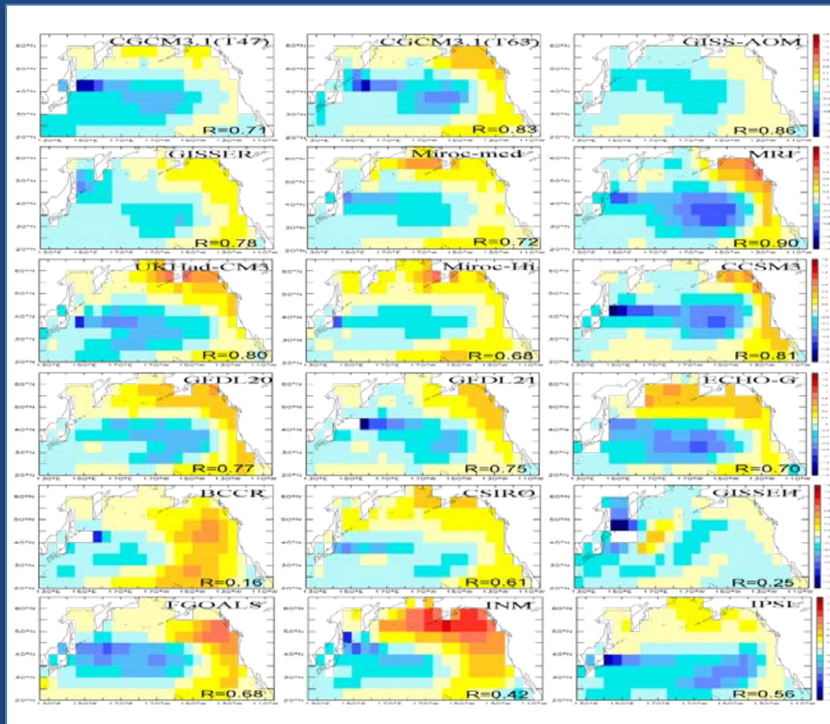
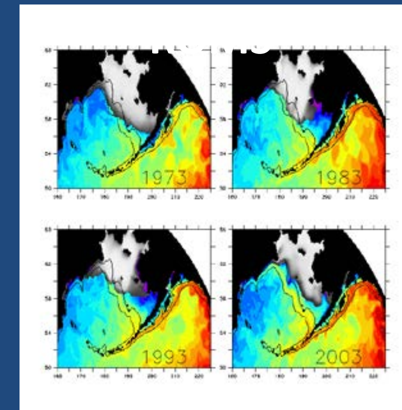
Our method thus far

- Apply a subset of AR4-IPCC models as ***physical*** forcing to a regional model
- NPZ dynamics embedded in the regional model use climatological IC/BC

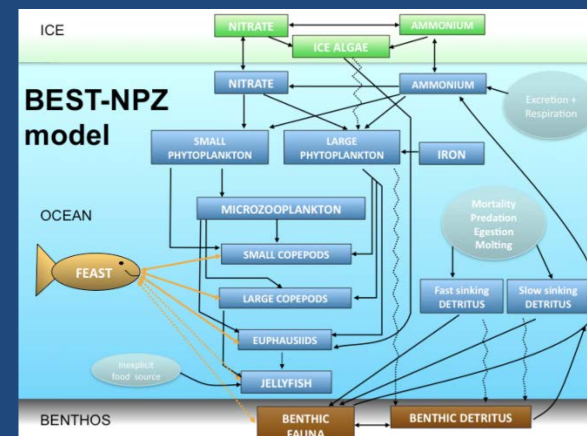
Climate models provide BCs/ICs to *regional coupled models*



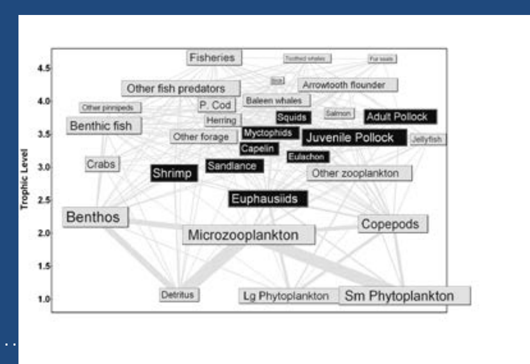
ensemble of runs



NPZ



FOOD WEB (FEAST)



ensemble of projected futures

GOAL:
mutidecadal
projections of physics and biology in the Bering Sea

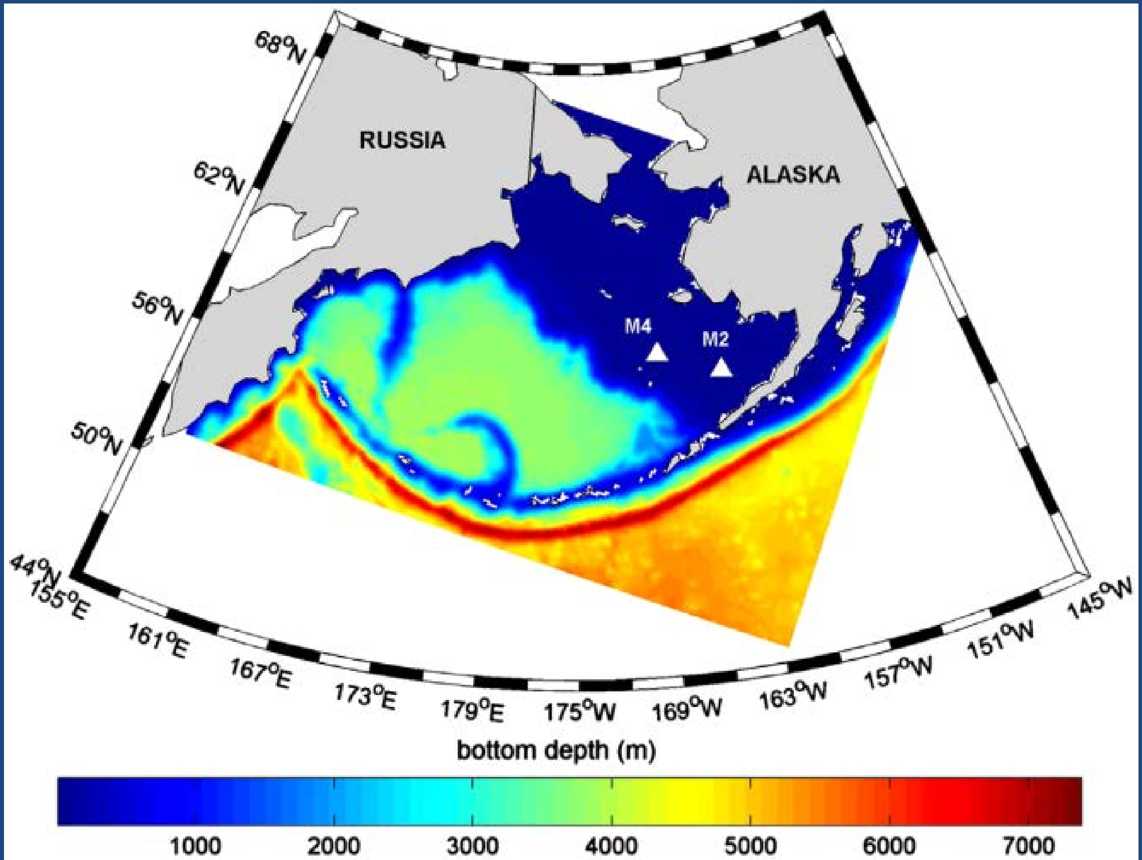
Four model runs used here

- Hindcast
  - CORE (1970-2004)
- IPCC forecast
  - MIROC (2003-2040)
  - CCCMA (2003-2040)
  - ECHO-G (2004-2040)

Model Forcing Variables

- Wind Velocities
- Air Temperature
- Air Specific Humidity
- Sea Level Pressure
- Rainfall
- Runoff
- Downwelling Shortwave
- Downwelling Longwave

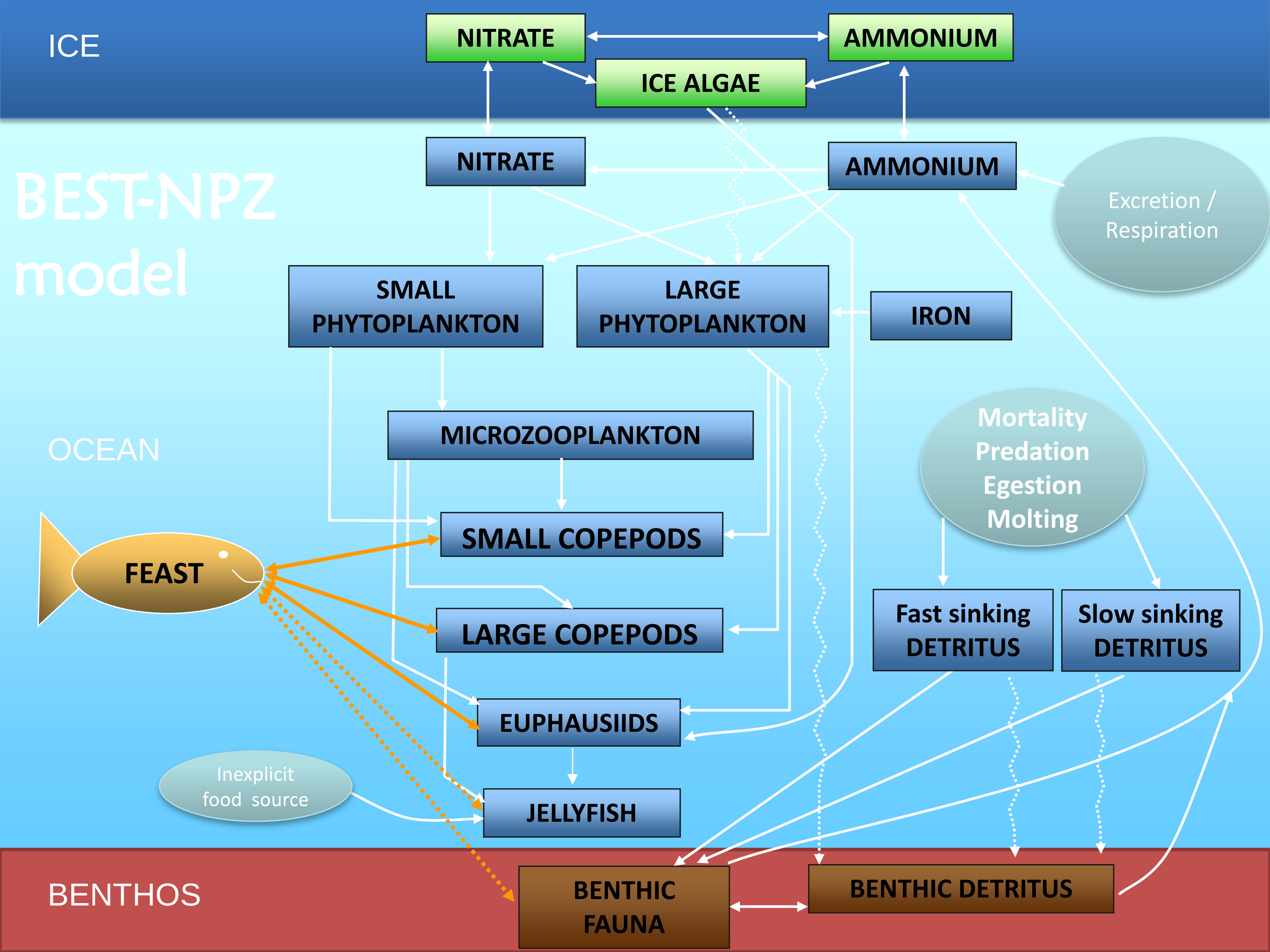
Bering10K model



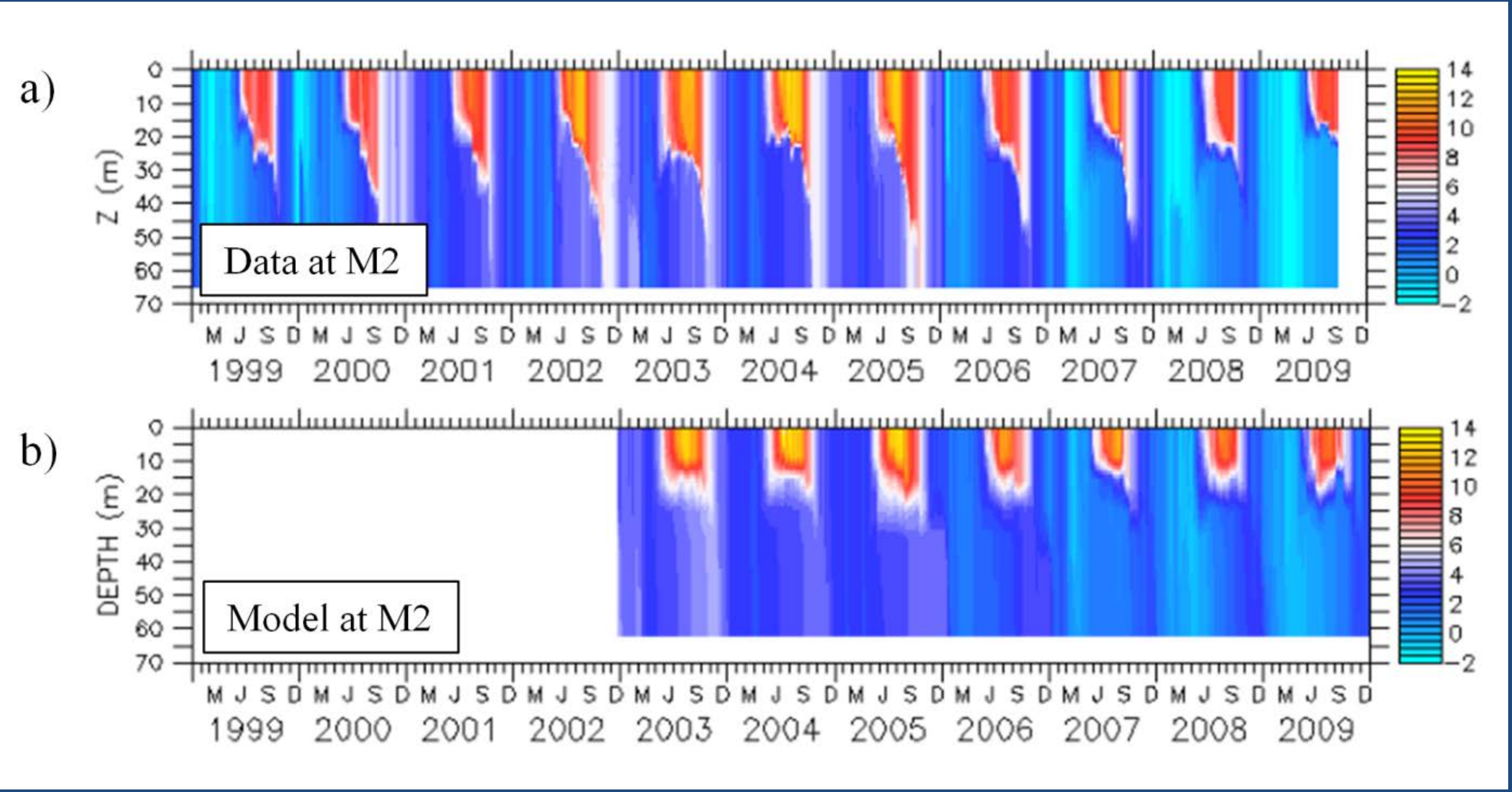
- Descendent of NEP5 (Danielson et al. 2012)
- 10 layers, 10-km grid Includes ice and tides
- CCSM bulk flux
- Details in Hermann et al. (DSR2, 2013)

What is unique about the Bering Sea?

- Physical
  - Seasonal ice with advection to the south
  - Tidal mixing sets up distinct biophysical regimes
- Biological
  - Ice plankton may be a major food source to higher trophic levels
  - Benthic food chain is a major player

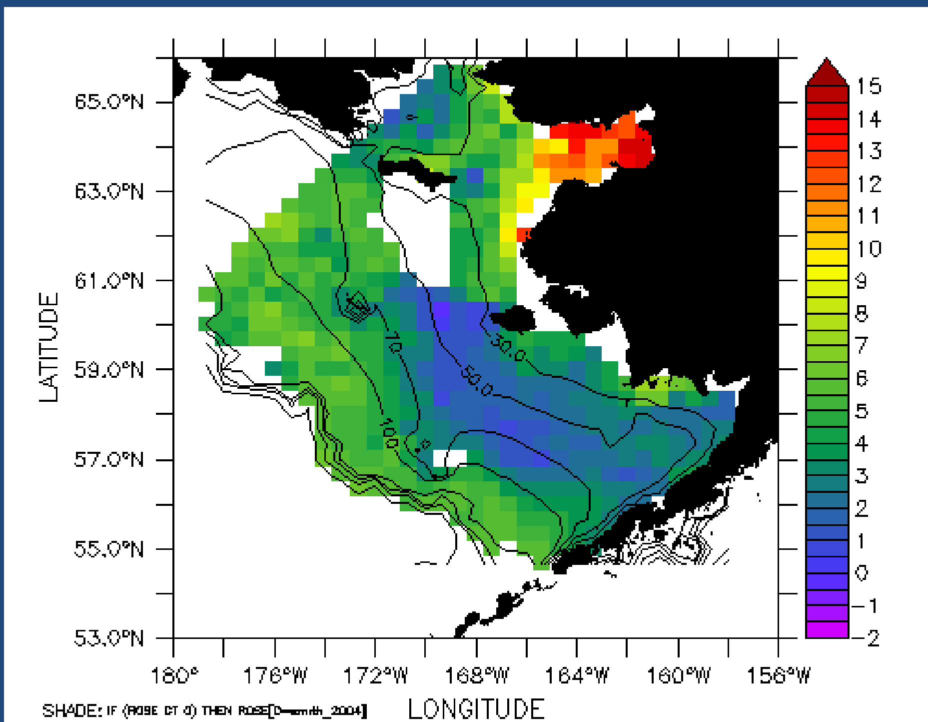

ICE
NITRATE
AMMONIUM
ICE ALGAE
NITRATE
AMMONIUM
BEST-NPZ model
Excretion / Respiration
SMALL PHYTOPLANKTON
LARGE PHYTOPLANKTON
IRON
MICROZOOPLANKTON
OCEAN
Mortality Predation Egestion Molting
SMALL COPEPODS
FEAST
LARGE COPEPODS
Fast sinking DETRITUS
Slow sinking DETRITUS
EUPHAUSIIDS
Inexplicit food source
JELLYFISH
BENTHOS
BENTHIC FAUNA
BENTHIC DETRITUS

Modeled vs observed temperatures at M2

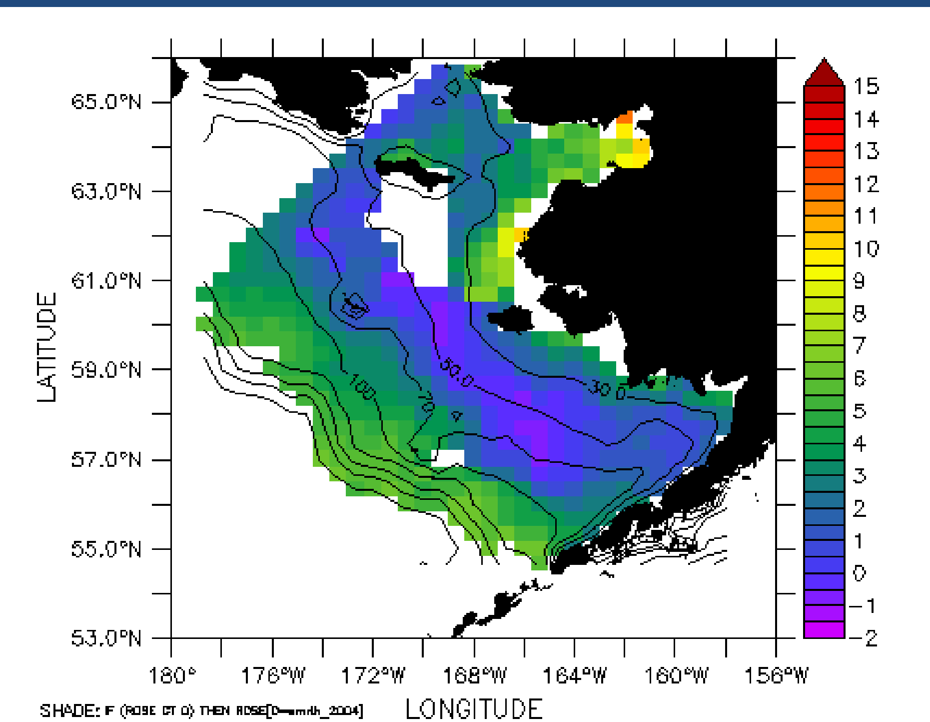


depth-average temperature 2010 (0-40m)

DATA

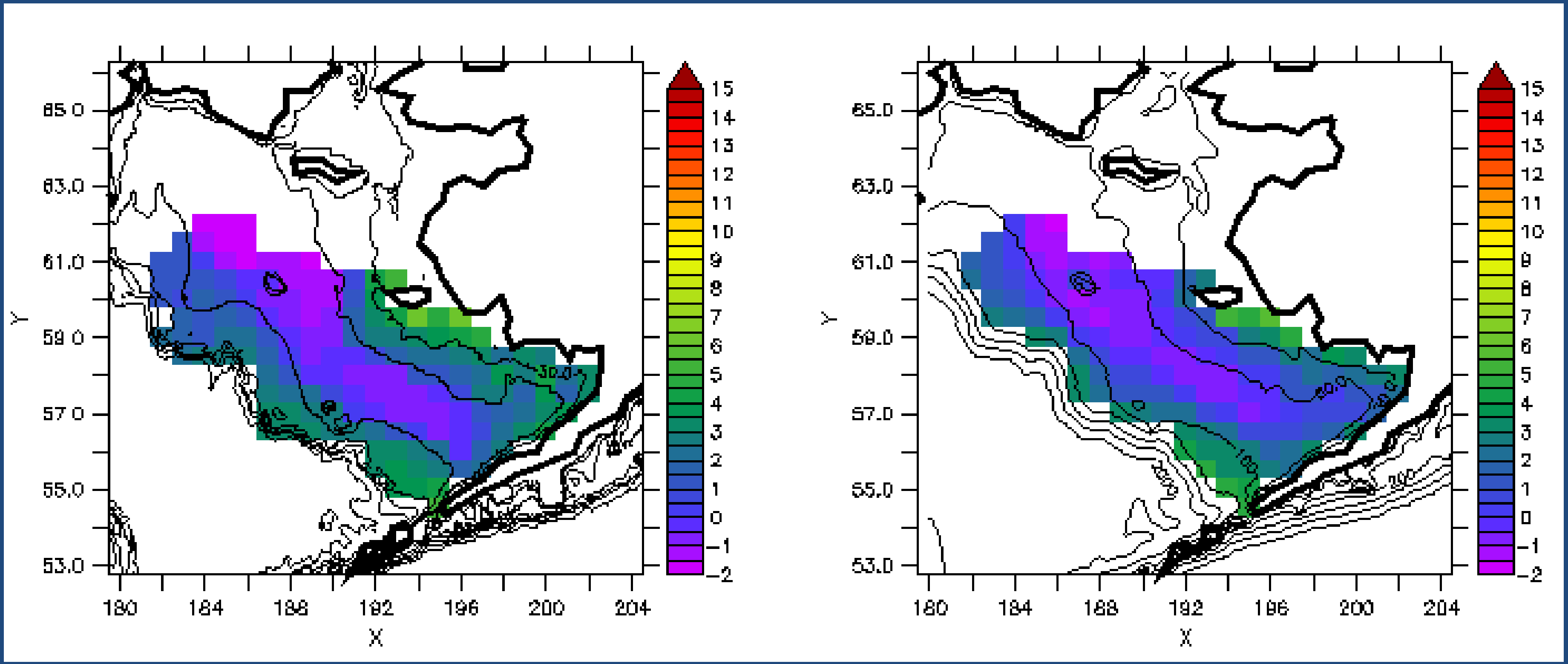


MODEL



Bottom temperature 2009

DATA MODEL



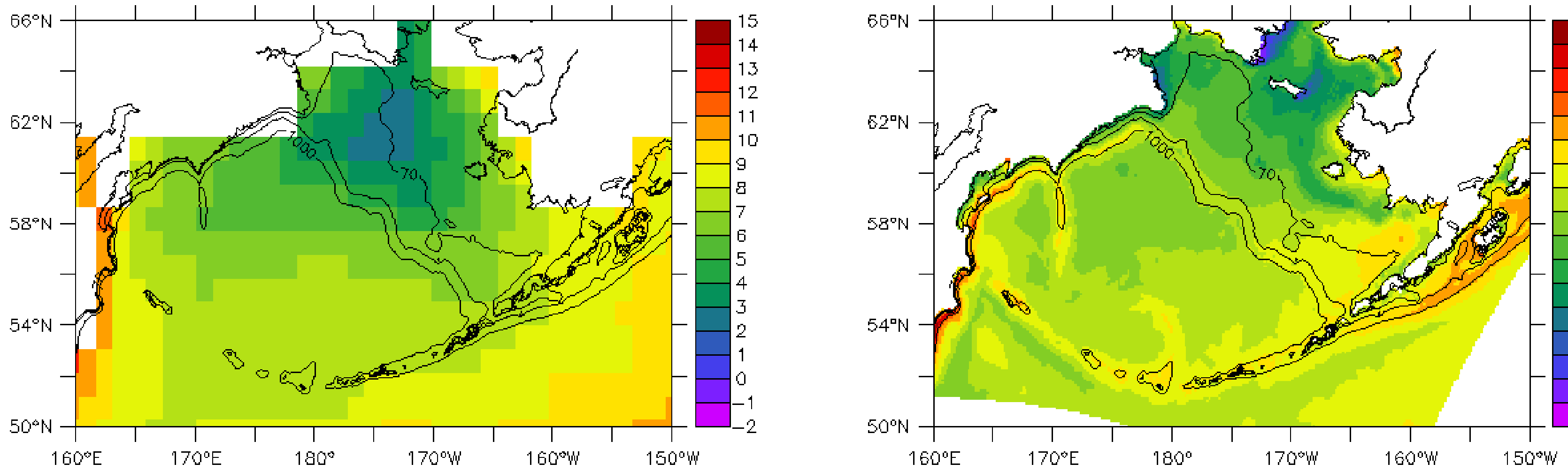
Resolution of AR4-IPCC model output (single A1B scenario realizations)

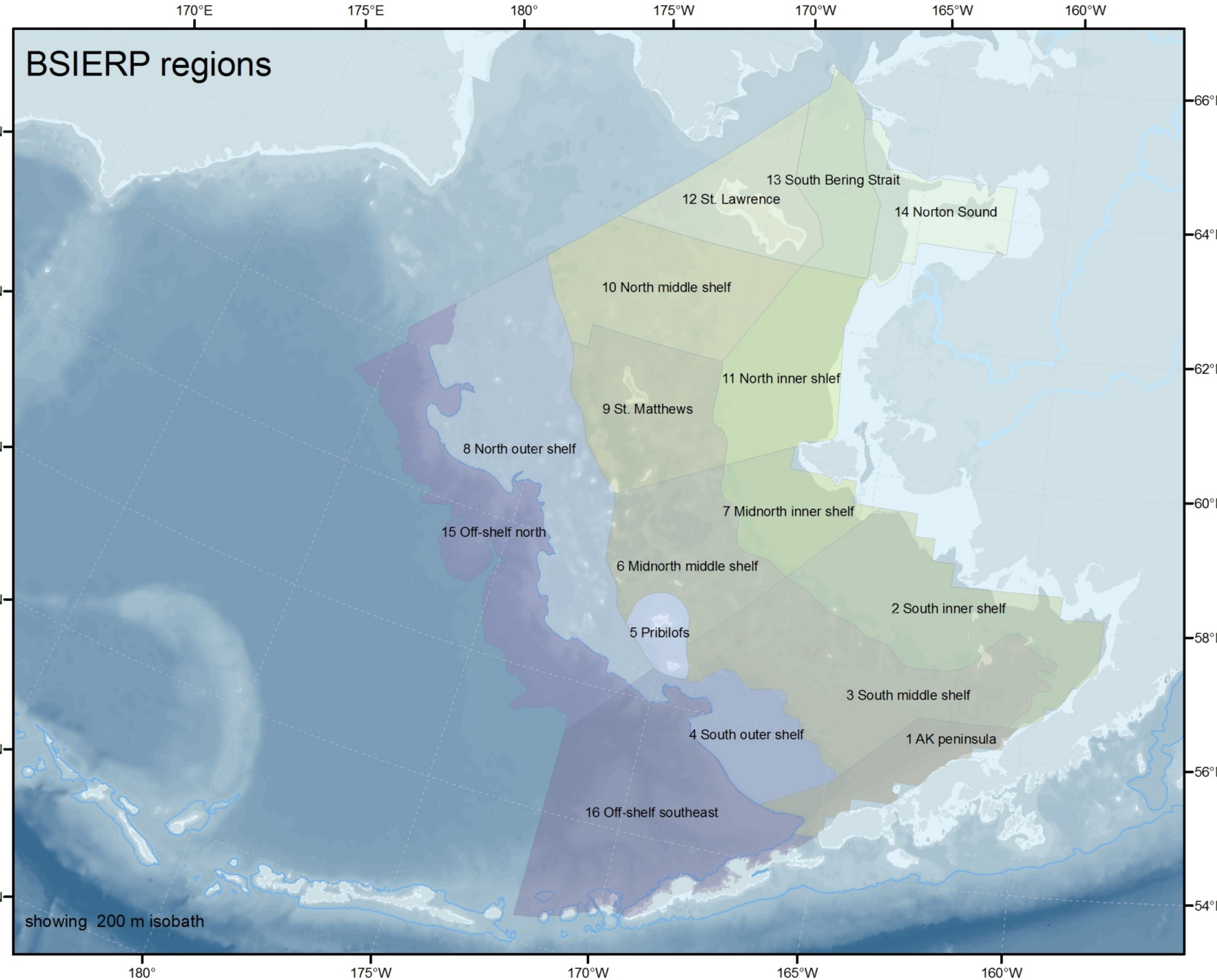
MODEL	CGCM3.1	MIROC	ECHOG
OCEAN	1.85-degree lat 1.85-degree lon monthly	~1.0-degree lat ~0.5-degree lon monthly	~2.8 lat* ~2.8 lon monthly *finer near equator
ATMOSPHERE	3.75-degree lat 3.75-degree lon daily	~2.5-degree lat ~1-degree lon daily	~3.7-degree lat ~3.75-degree lon daily

Bering10K resolves more detail!

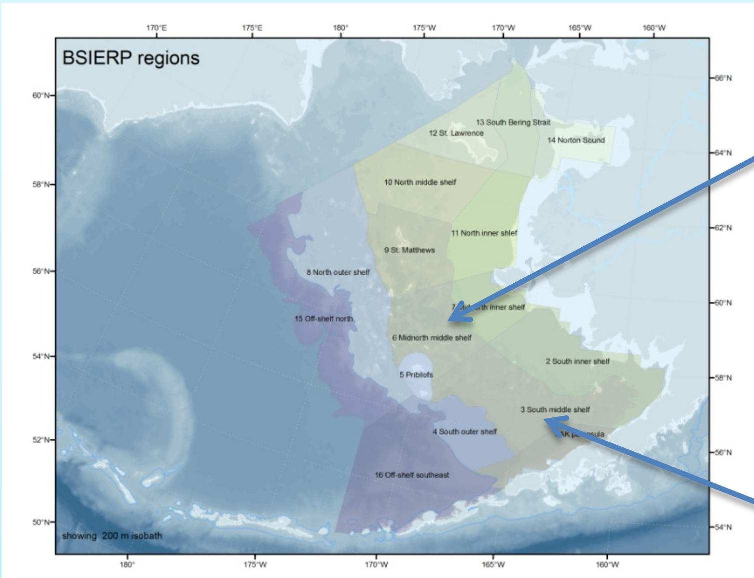
MIROC

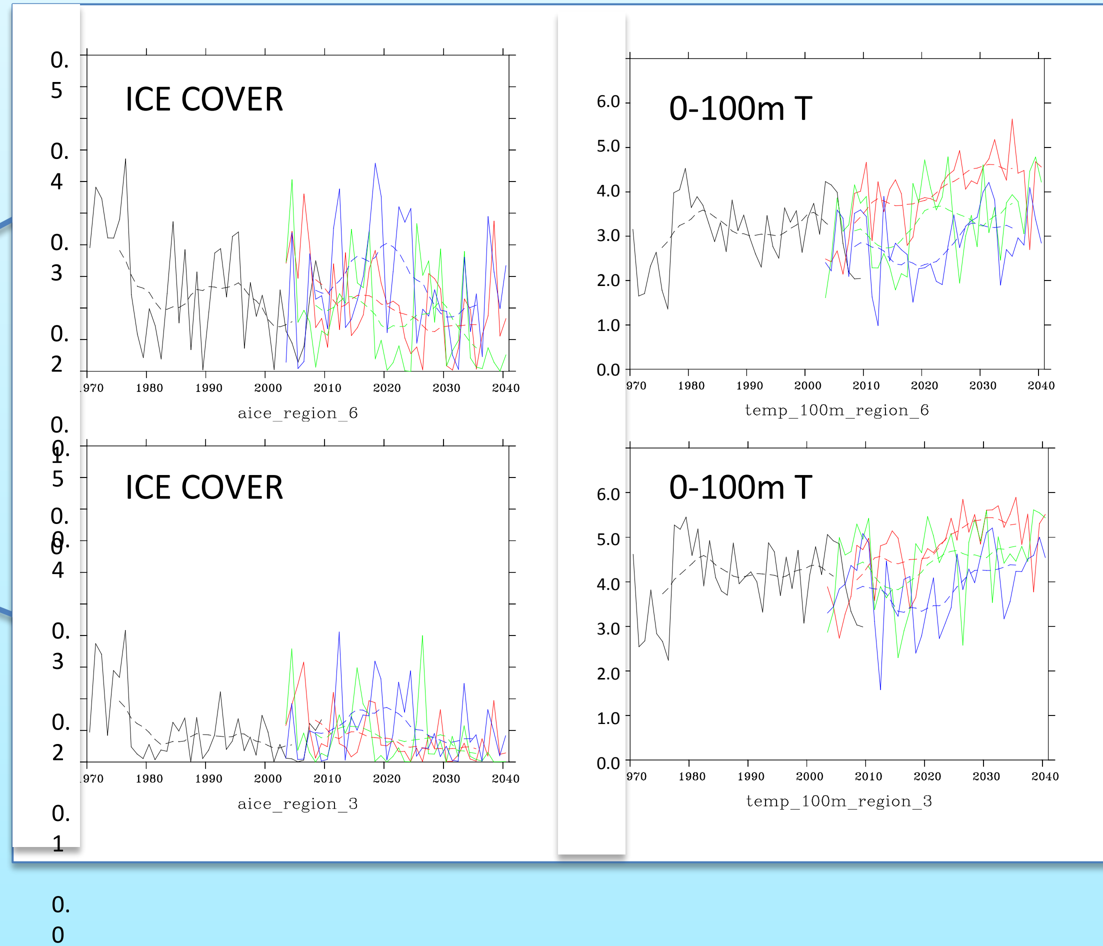
Bering10K




BSIERP regions
170°E
175°E
180°
175°W
170°W
165°W
160°W
60°N
58°N
56°N
54°N
52°N
50°N
66°N
64°N
62°N
60°N
58°N
56°N
54°N
13 South Bering Strait
12 St. Lawrence
14 Norton Sound
10 North middle shelf
11 North inner shlef
9 St. Matthews
8 North outer shelf
7 Midnorth inner shelf
15 Off-shelf north
6 Midnorth middle shelf
2 South inner shelf
5 Pribilofs
3 South middle shelf
4 South outer shelf
1 AK peninsula
16 Off-shelf southeast
showing 200 m isobath
180°
175°W
170°W
165°W
160°W

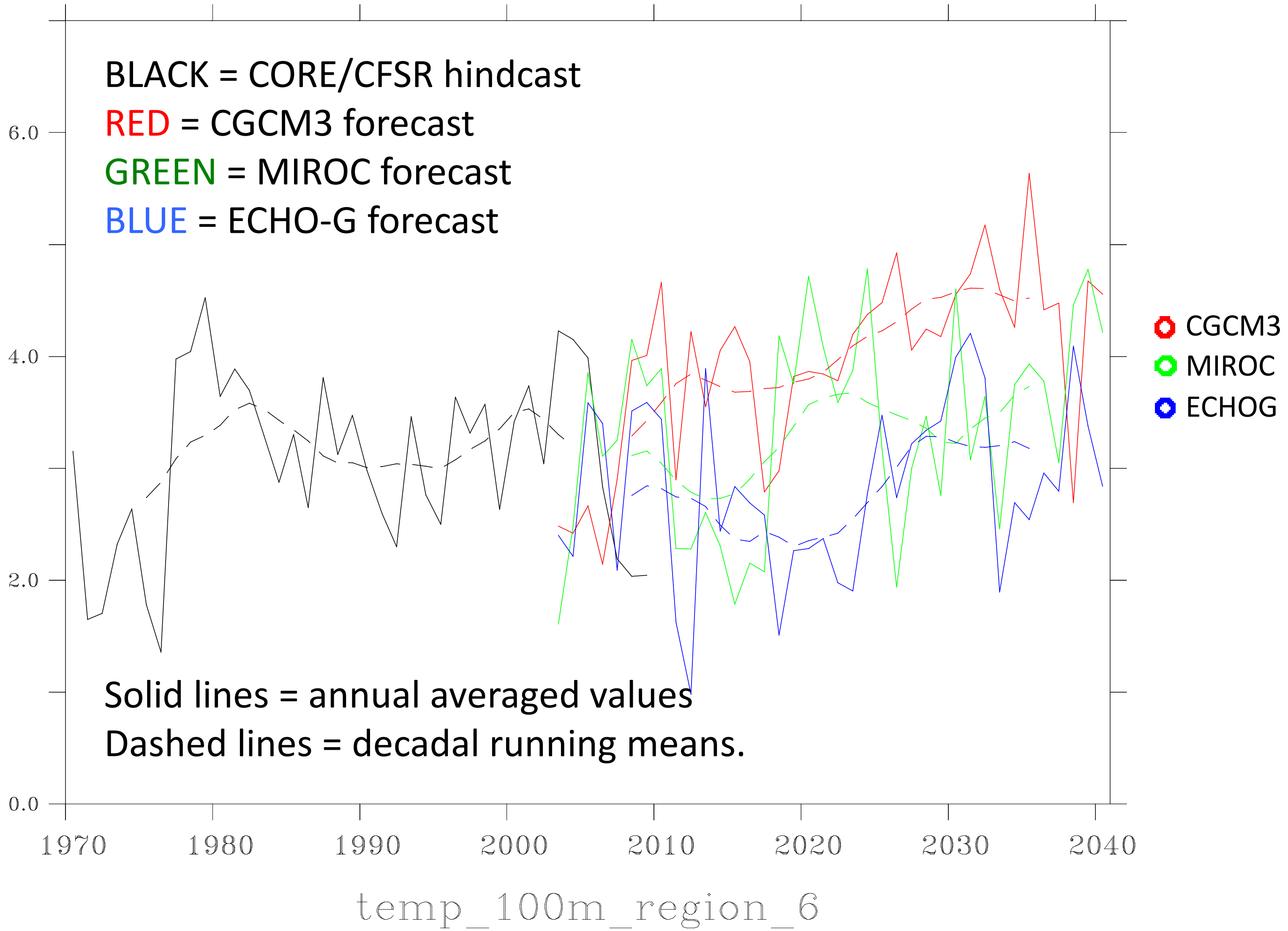
Projected EBS ice cover and vertical average temperature





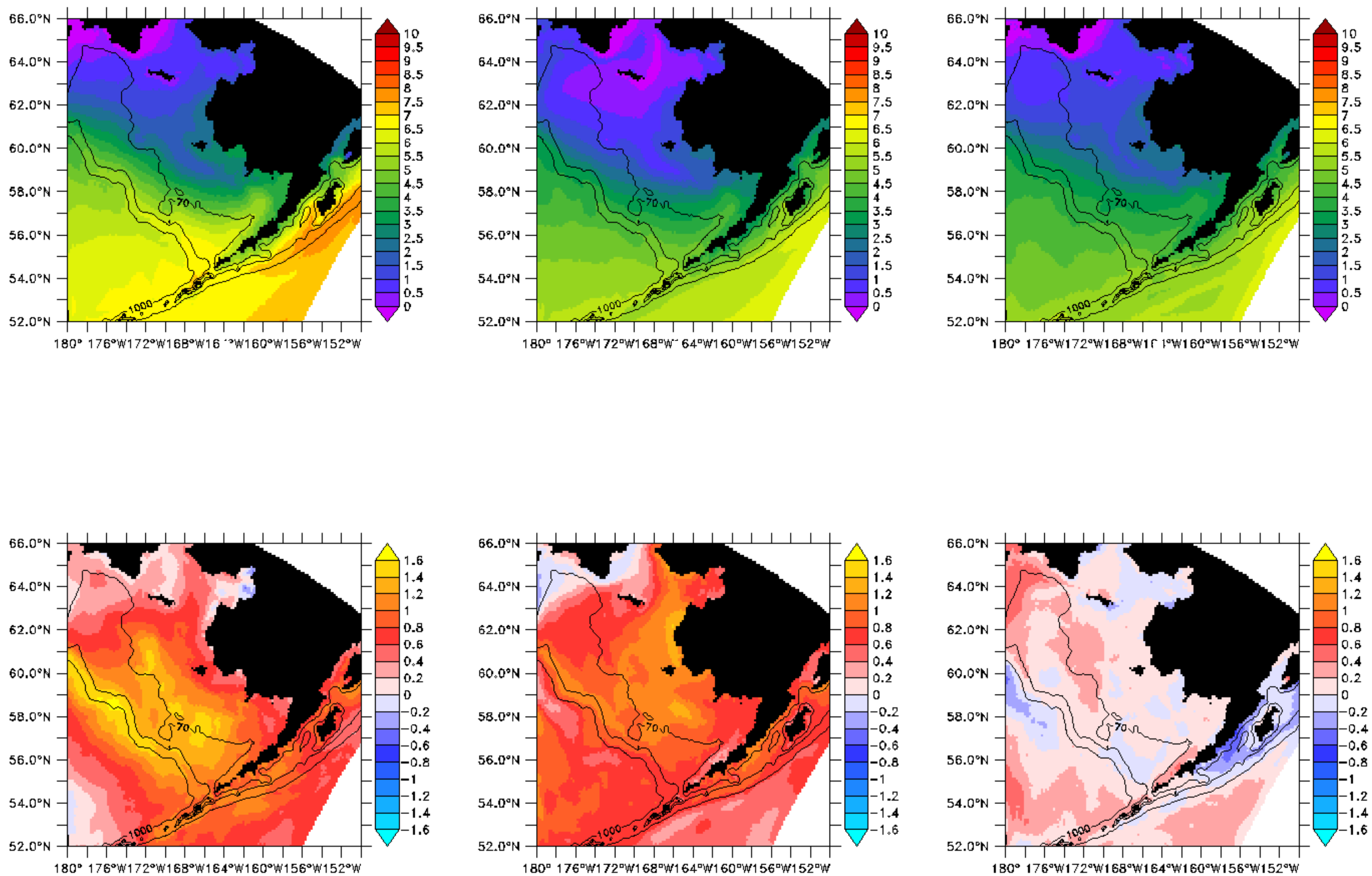
Standard BEST/BSIERP bioregions of the Bering Sea (Ortiz, 2012)

Middle shelf 0-100m temperature



SST (deg C)

	CGCM3	MIROC	ECHOG
"Present" (2003-2012)			
"Future" (2031-2040) *w.r.t.* present			



Ice coverage (fraction)

CGCM3 MIROC ECHOG

"Present" (2003-2012)

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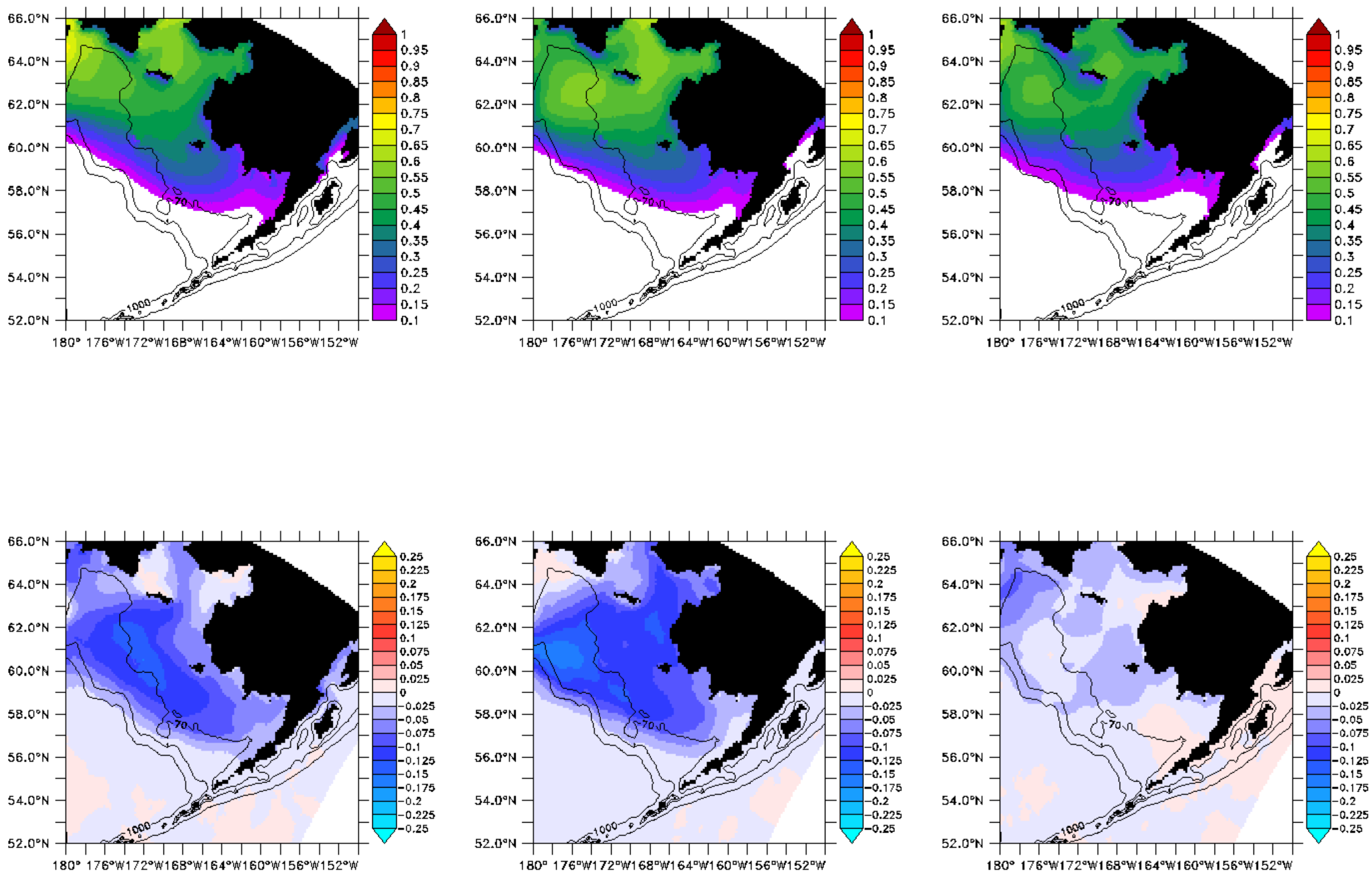
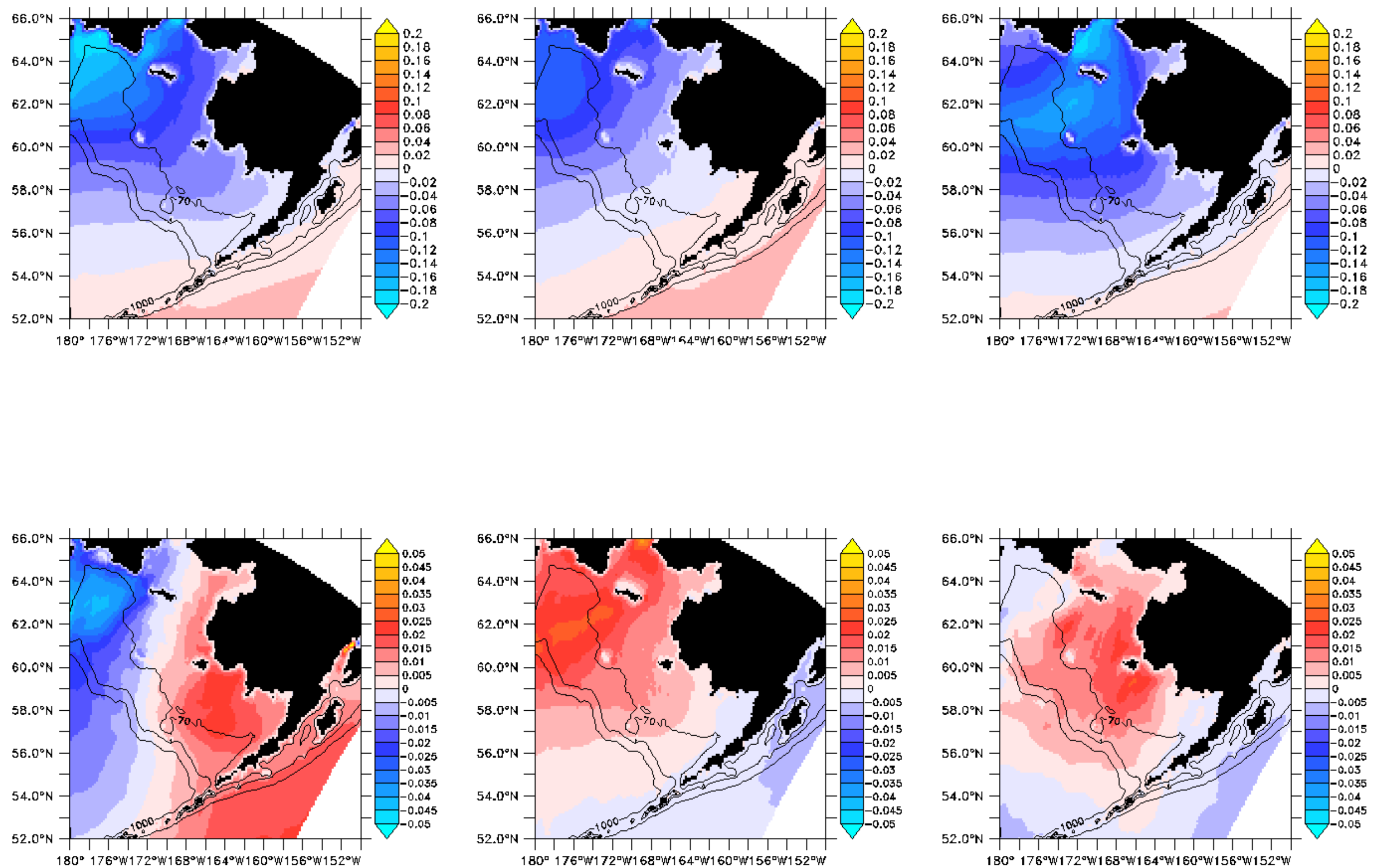


Northward wind stress (N m^{-2})

CGCM3 | MIROC | ECHOG

"Present" (2003-2012)

"Future" (2031-2040) *w.r.t.* present



Large Crustacean Zooplankton (mgC m^{-3})

CGCM3 | MIROC | ECHOG

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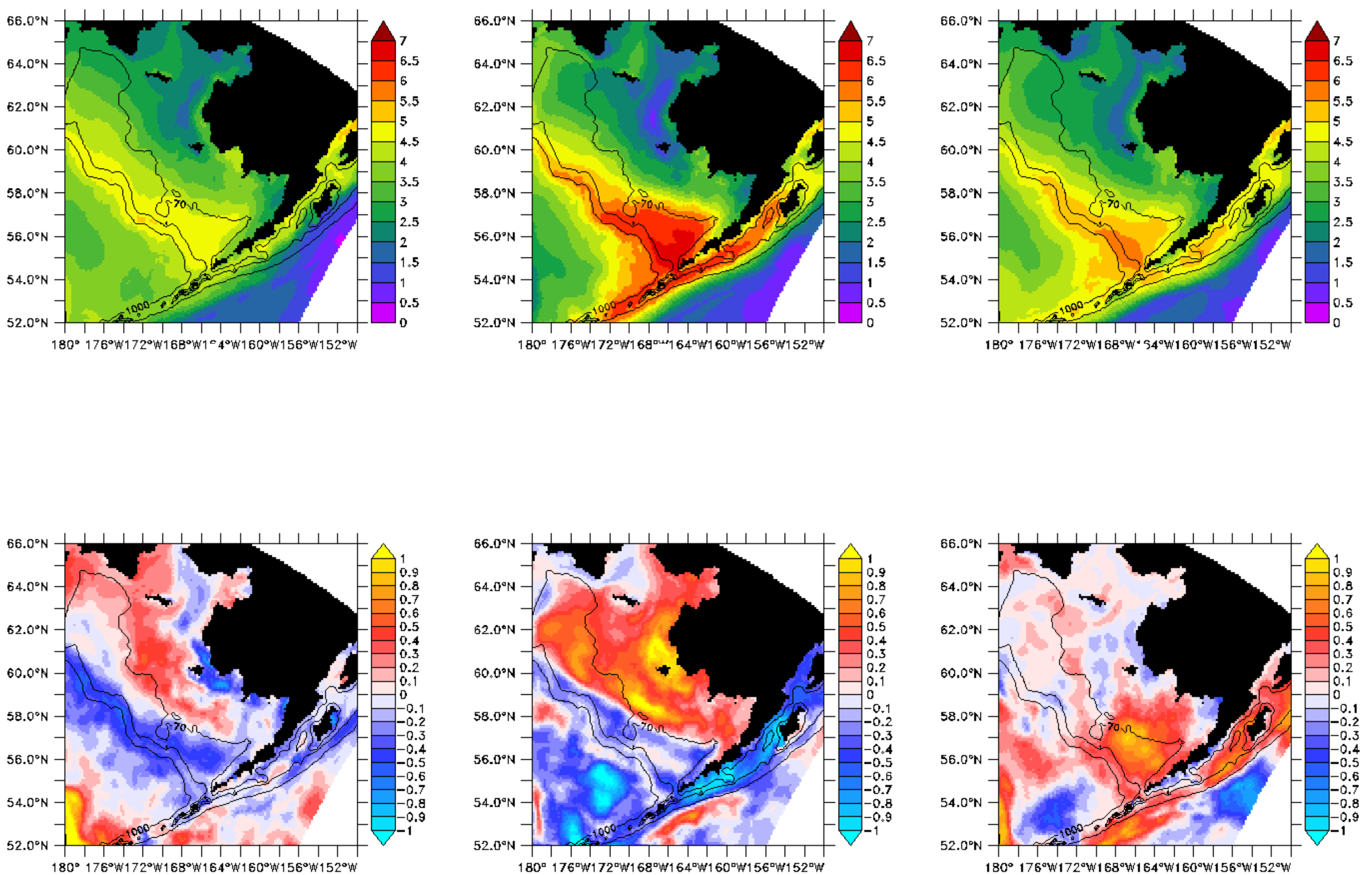
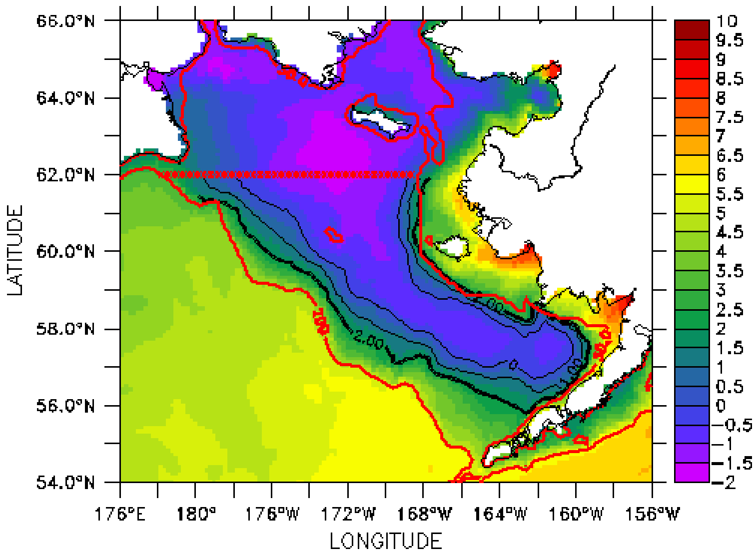
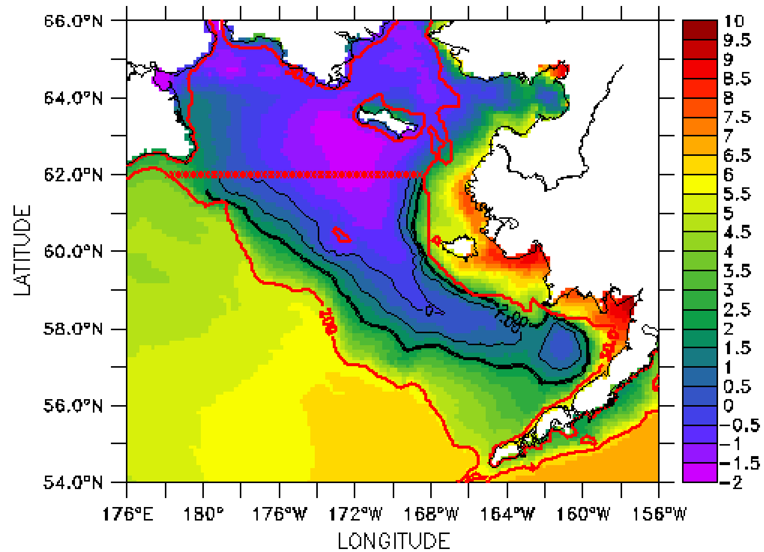


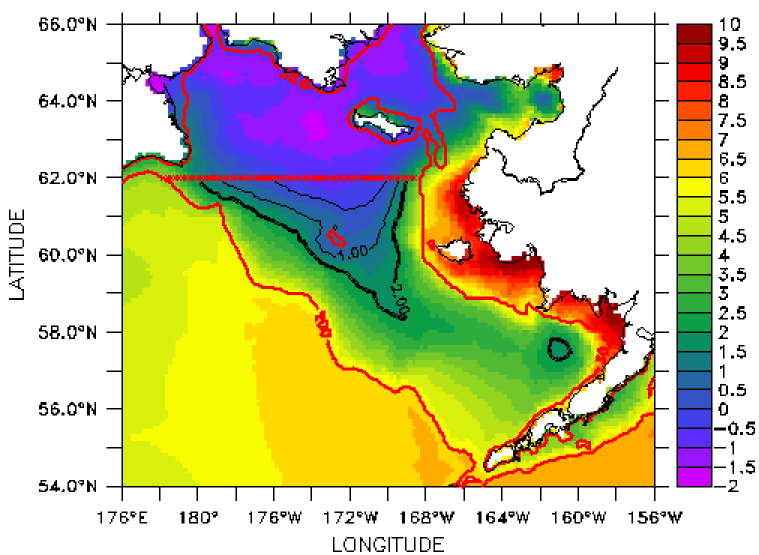
Projected EBS July bottom temperatures



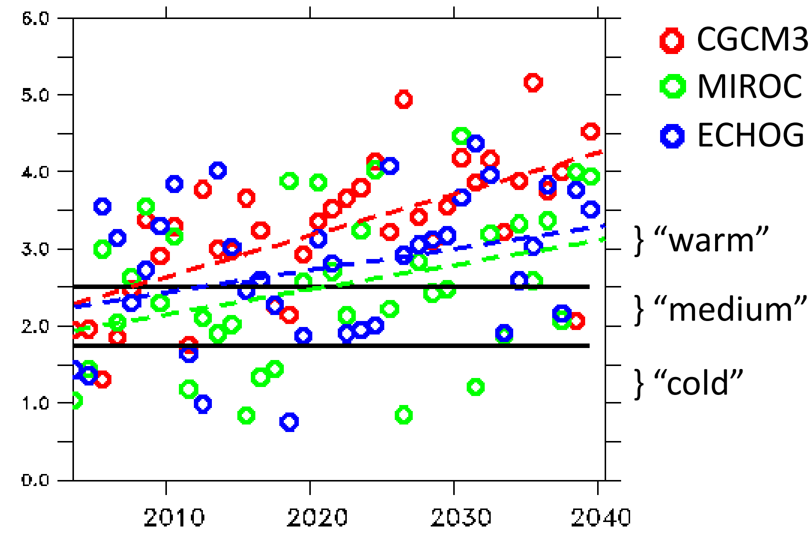
ensemble ave cold year



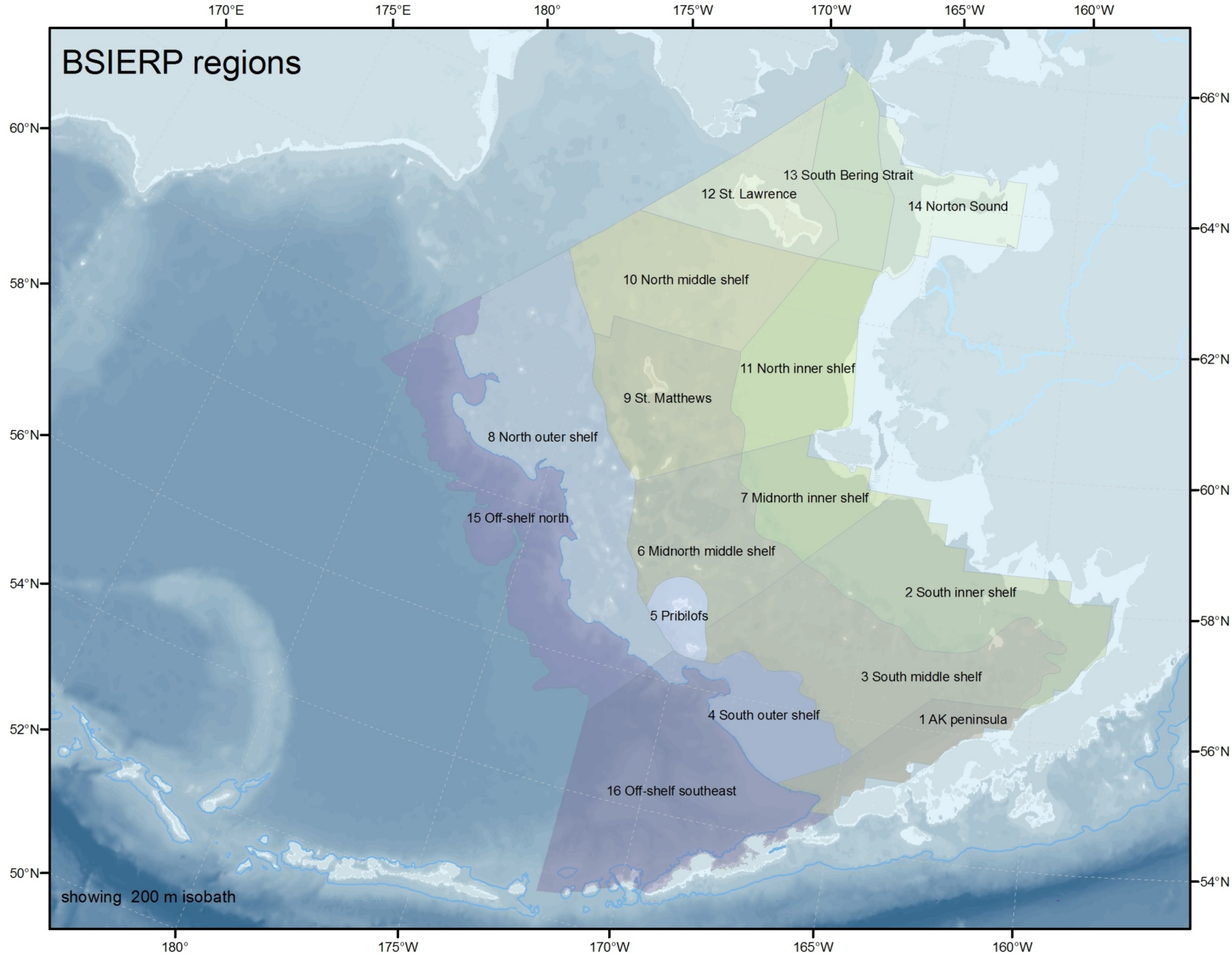
ensemble ave medium year



ensemble ave warm year



mean EBS bottom temperature



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Coherence analysis

- large-scale forcing vs. regional response
- physical vs. biological variables
- separately analyze 4 model runs
  - IPCC forecast
    - MIROC (2003-2040)
    - CCCMA (2003-2040)
    - ECHO-G (2004-2040)
  - Hindcast
    - CORE (1970-2004)

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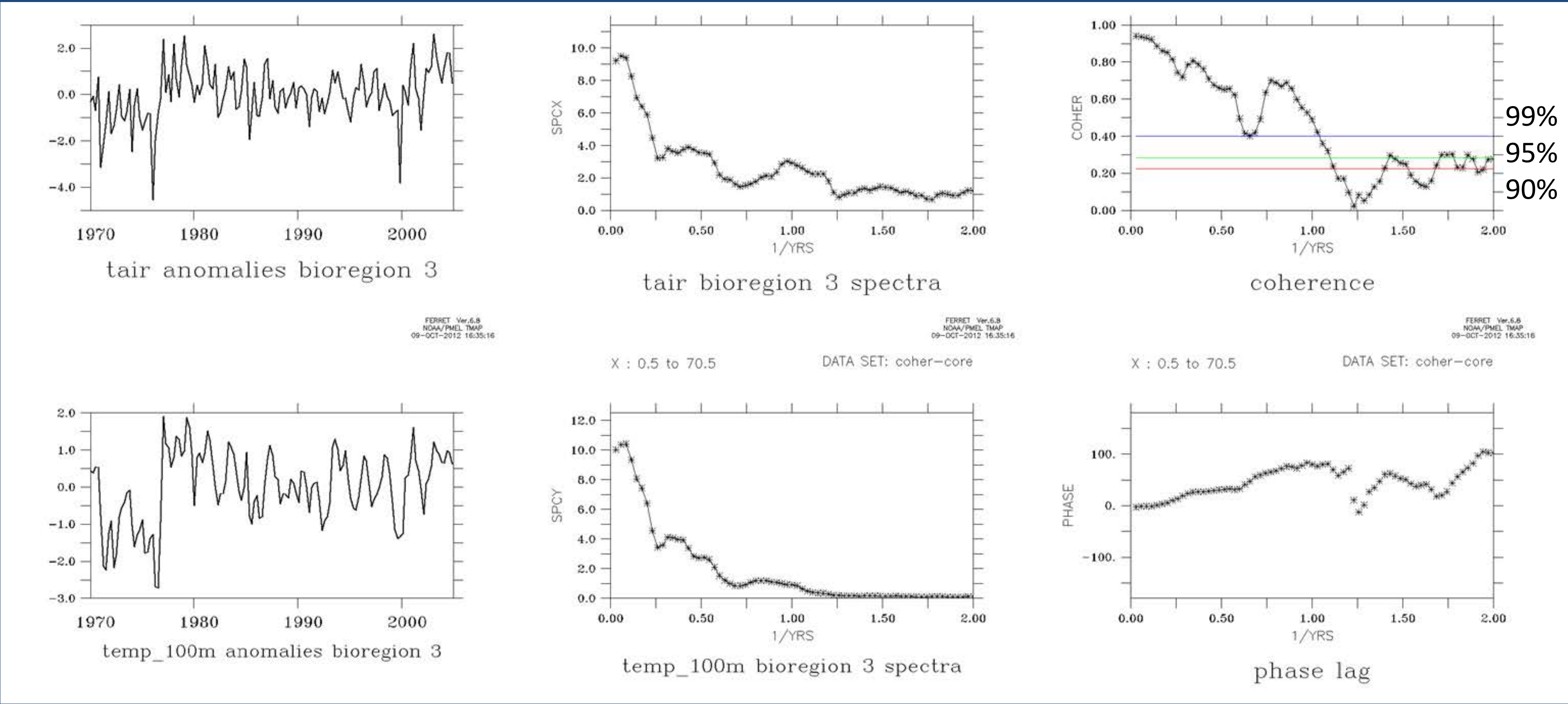
CORE forcing: Mid-shelf T_{ocn} is coherent with T_{air} on annual to decadal scales

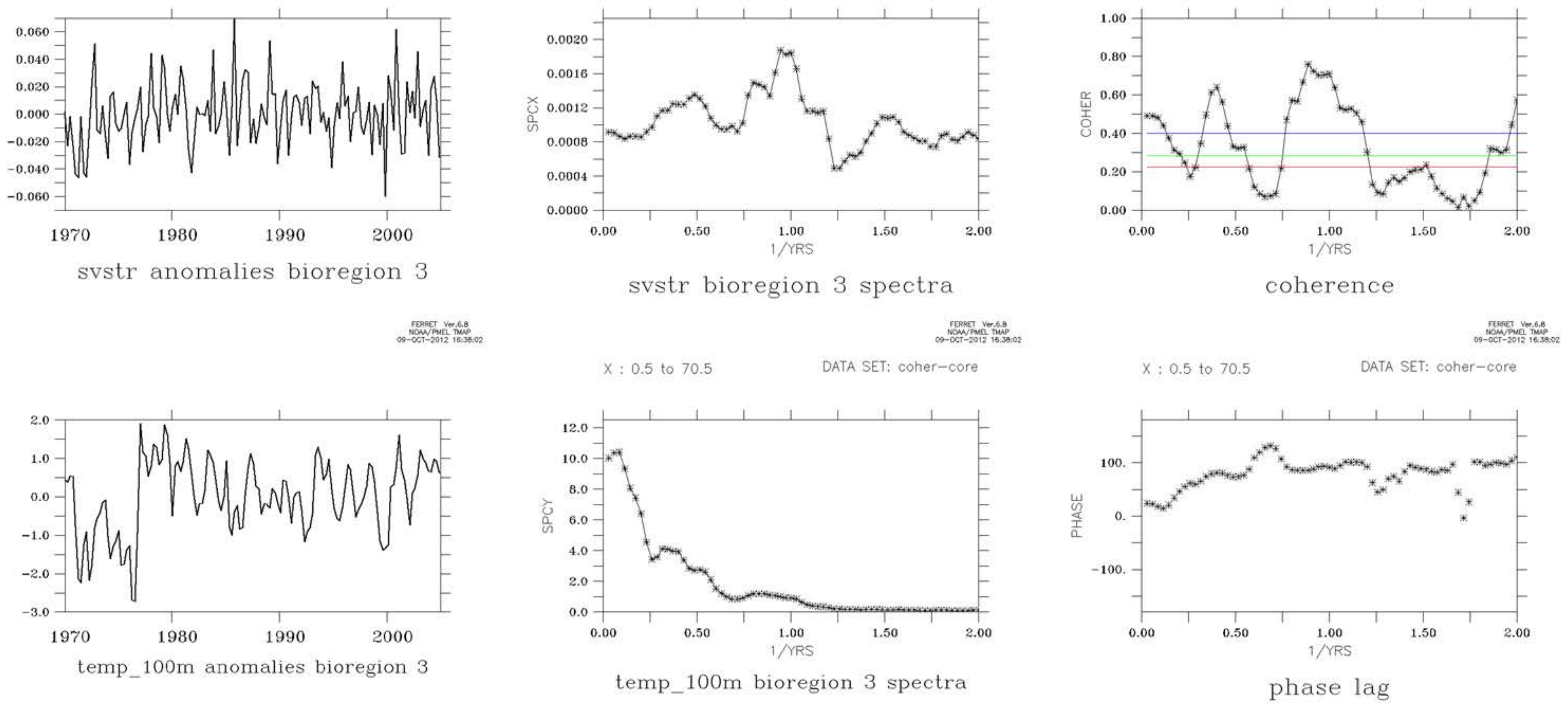
TIME SERIES SPECTRA COHERENCE



- red, green, blue lines indicate 90%,95%,99% confidence levels for significantly different than zero coherence
- positive phase means top variable leads bottom variable

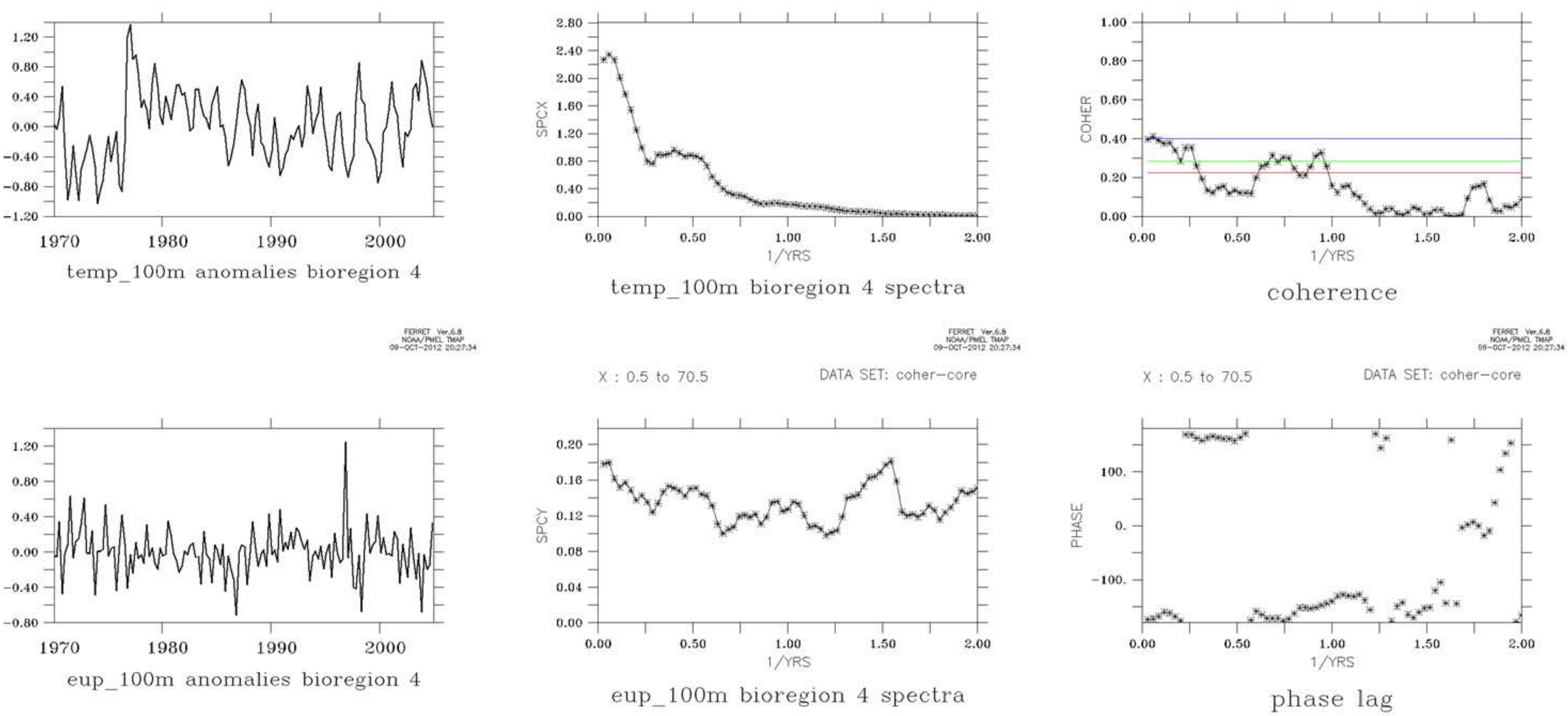
CORE forcing: Mid-shelf Tocn is coherent with alongshelf windstress on annual to interdecadal timescales

TIME SERIES | SPECTRA | COHERENCE



CORE forcing: Outer-shelf euphausiids are *negatively* coherent with Tocn at annual and decadal scales

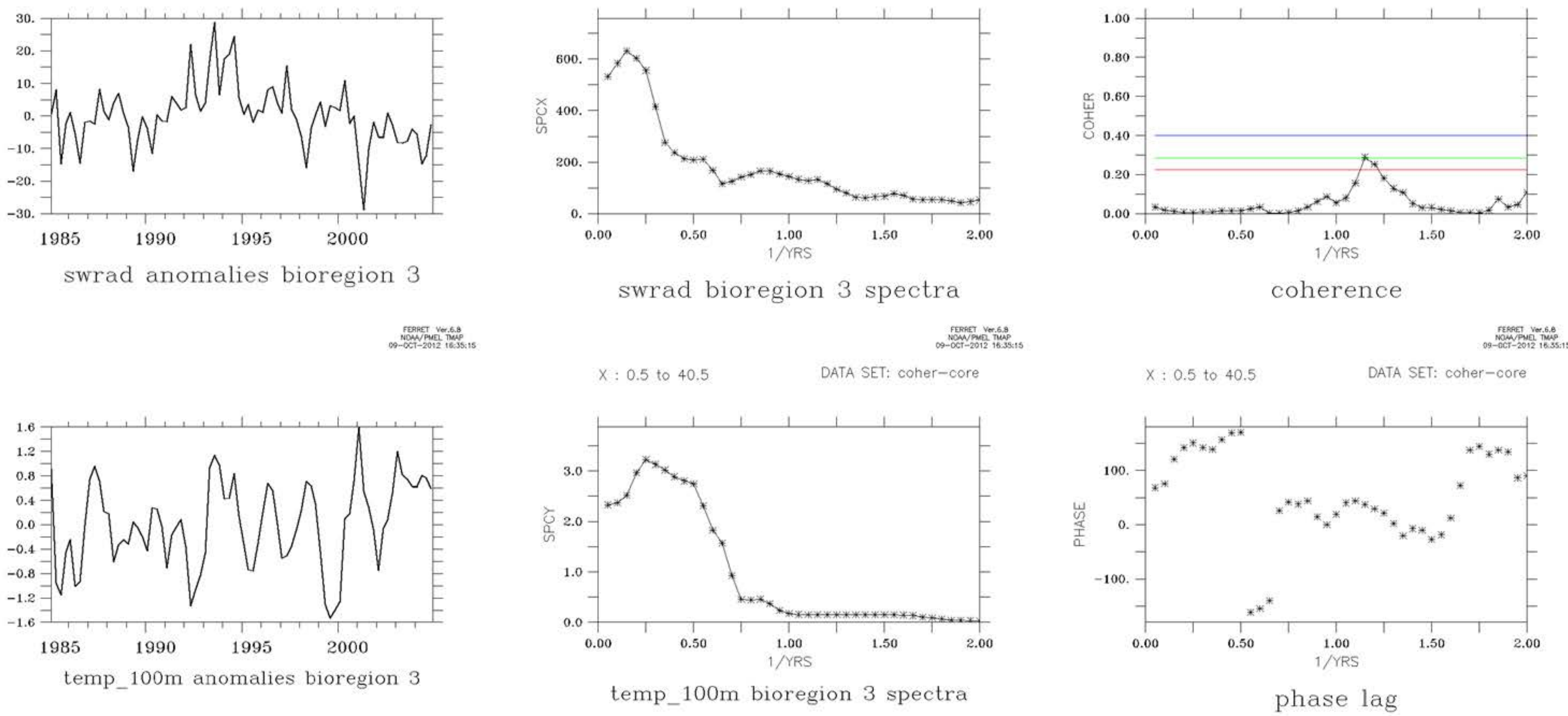
TIME SERIES | SPECTRA | COHERENCE



Note how euphausiids have whiter spectrum than physical ocean variables

CORE forcing: Mid-shelf Tocn is NOT coherent with swrad

TIME SERIES | SPECTRA | COHERENCE



Summer Cloudiness (from Bond 2012)

Year	Cloud Fraction	
	Western Bering	Eastern Bering
2003	0.81	0.86
2004	0.85	0.86
2005	0.80	0.88
2006	0.73	0.86
2007	0.87	0.88
2008	0.76	0.85

Conclusions

- Bering Sea has unique features which benefit from both spatial and trophic downscaling:
  - Ice advection and ice plankton
  - Tidal mixing
- Forecasts suggest ***continued interannual variability*** on top of a warming trend
  - reduced ice in south, not much change in north
  - increased northward winds
- Coherence analysis suggest the following relationships:
  - T_ocean coherent with T_air
  - T_ocean coherent with alongshelf wind-stress
  - T_ocean coherent with euphausiid bionass.
    - out-of-phase on longer time scales
    - in-phase on short time scales
  - T_ocean *NOT* coherent with shortwave input