Model-data synthesis and high resolution simulation of the Bering Sea

Panteleev G.(1),J.Zhang (2), A.Kurapov (3), S.Durski(3), J.Stroh(1), T.Weingartner(4) ,R.Woodgate(3)

1-IARC, UAF, 2-APL UW, 3-COAS UO, 4-UAF

Synthesis and modeling of the Bering Sea ice/ocean climate

Introduction

The Bering Sea is the source of over 50% of the total US fish catch and the home to immense populations of birds and marine mammals. This extraordinarily productive ecosystem is vulnerable to climate regime shifts that have occurred over the past decades. These regime shifts are closely linked to warming and cooling of the atmosphere and ocean, and the coincident retreat or expansion of the sea ice cover with strong interannual and decadal variability. Here we investigate changes in the Bering ice/ocean system in recent years. One of key tools for this investigation is the Bering Ecosystem STudy ice-ocean Modeling and Assimilation System (BESTMAS) for synthesis and modeling of the Bering ice/ocean system.

Key Features of BESTMAS

- A coupled Parallel Ocean (POP) and sea Ice Model
- Multi-category thickness & enthalpy distribution (TED) sea ice model
- Sea ice dynamics model for efficient, stable, high-resolution simulation
- Nested to a global ice-ocean model
- Incorporating tidal forcing (up to 8 components).
- Capable of assimilating satellite sea ice concentration and SST data

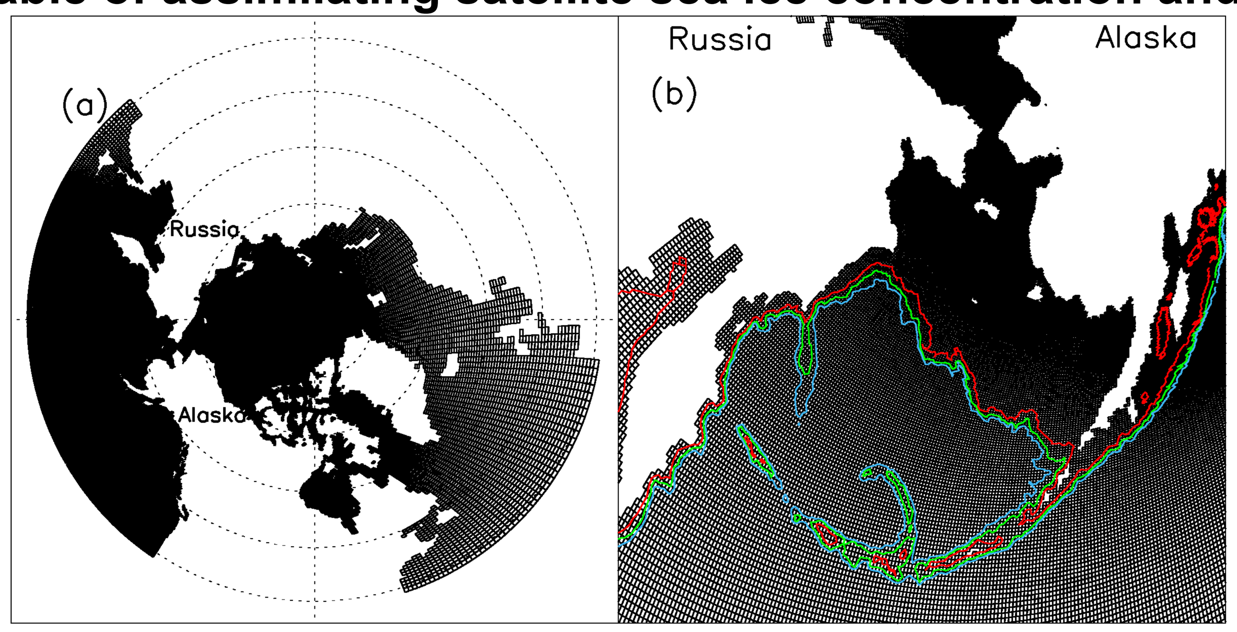


Fig.1. (a) BESTMAS grid configuration. BESTMAS has a large model domain that includes the Arctic and North Pacific with high resolution coverage for the eastern Bering Sea. (b) Zooming of the Bering Sea. The model resolution for this region ranges from 2 km along the Alaskan coast to 12 km along the Aleutian Chain, with an average of about 7 km for the eastern Bering Sea.

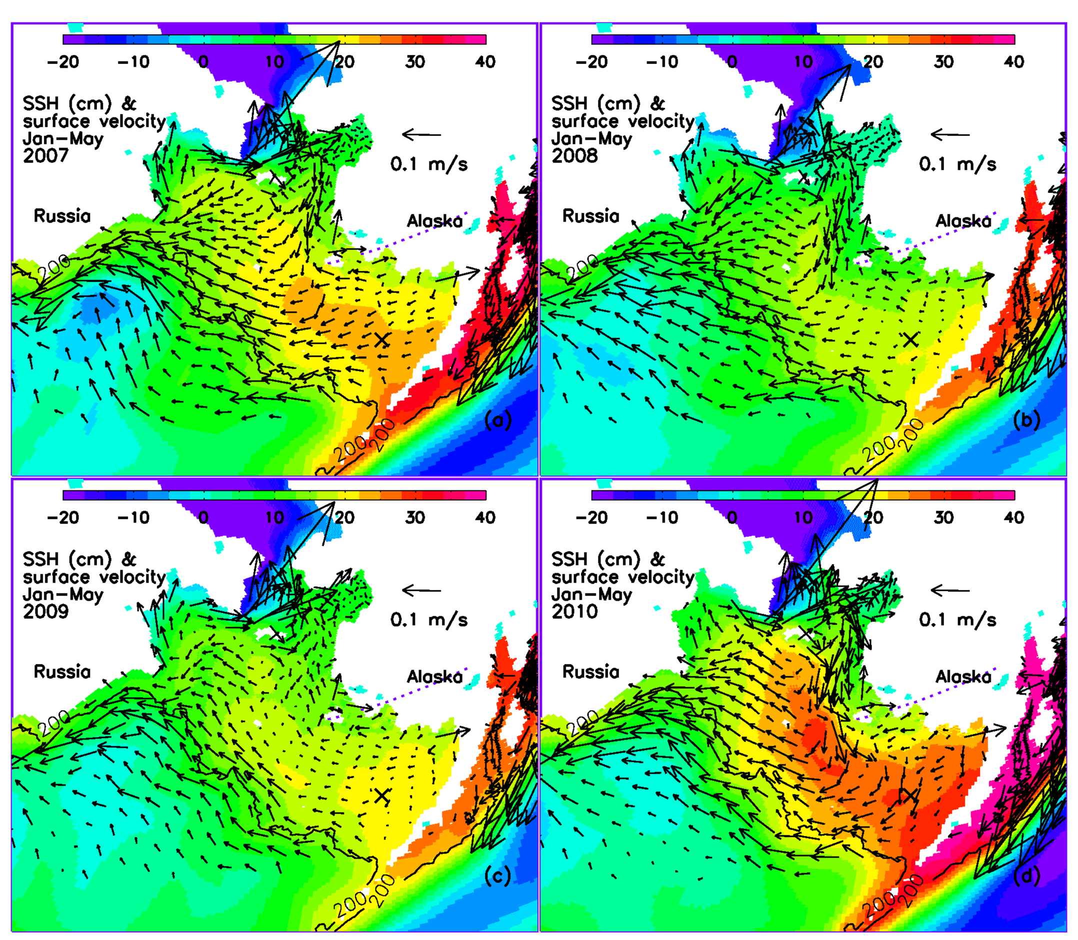


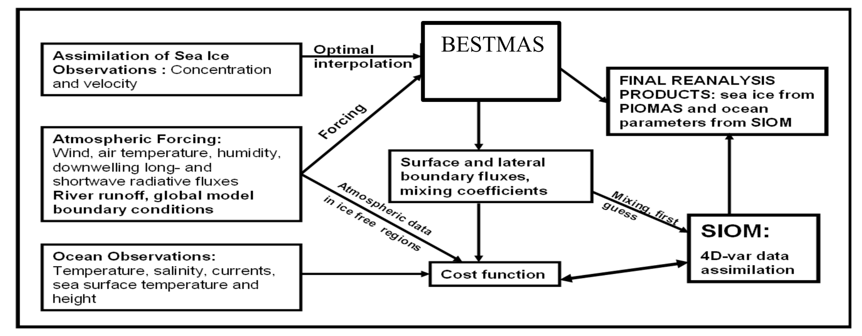
Fig.2. BESTMAS simulated Jan-May mean sea surface height (SSH) and ocean surface velocity (one of 49 vectors plotted) for 2007-2010. This figure shows considerable interannual variability of SSH and ocean surface circulation. The model tends to create an anticyclonic circulation gyre in the eastern Bering Sea in recent years that may enhance upwelling in the coastal areas. There is often a return flow near the Alaska coast, which may bring nutrient rich waters in the

Reconstruction of the Bering Sea circulation during 2007-2010

Introduction: The rich collection of BEST-BSIERP observations and other sources of data provide an excellent opportunity for synthesis through modeling and data assimilation to improve our understanding of changes in physical forcings of the Bering ecosystem in response to climate change. Assimilating data of different origins, which may be sparse in space and time, is difficult using simple algorithms (traditional optimal interpolation, correlation analysis etc.). The 4Dvar approach is effective for performing spatiotemporal interpolation of sparse data via interpolation (covariance) functions with scales based on ocean dynamics (Bennett, 2002).

SIOM- BESTMAS data assimilation system

- SIOM Data Assimilation System – semi-implicit ocean model combined with tangent linear and adjoint models (conventional 4Dvar); control vector includes a complete set of initial, surface, and open boundary conditions
- BESTMAS momentum, heat and salt fluxes are used as background fields for SIOM DAS
- Nested, "weakly constrained" 4Dvar data assimilation algorithm: High Resolution (HR) model for the Northern Bering Sea and Coarse Resolution for the Eastern Bering Sea



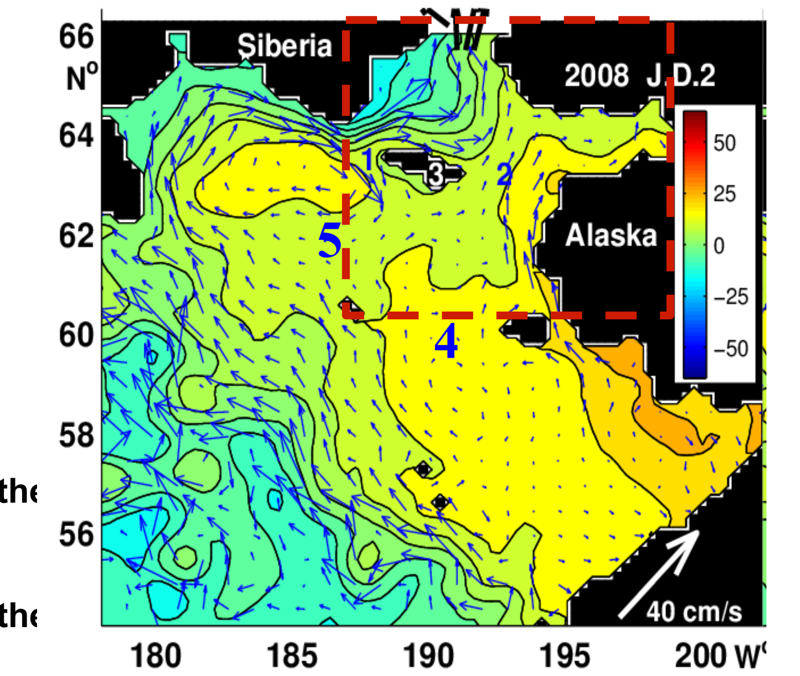


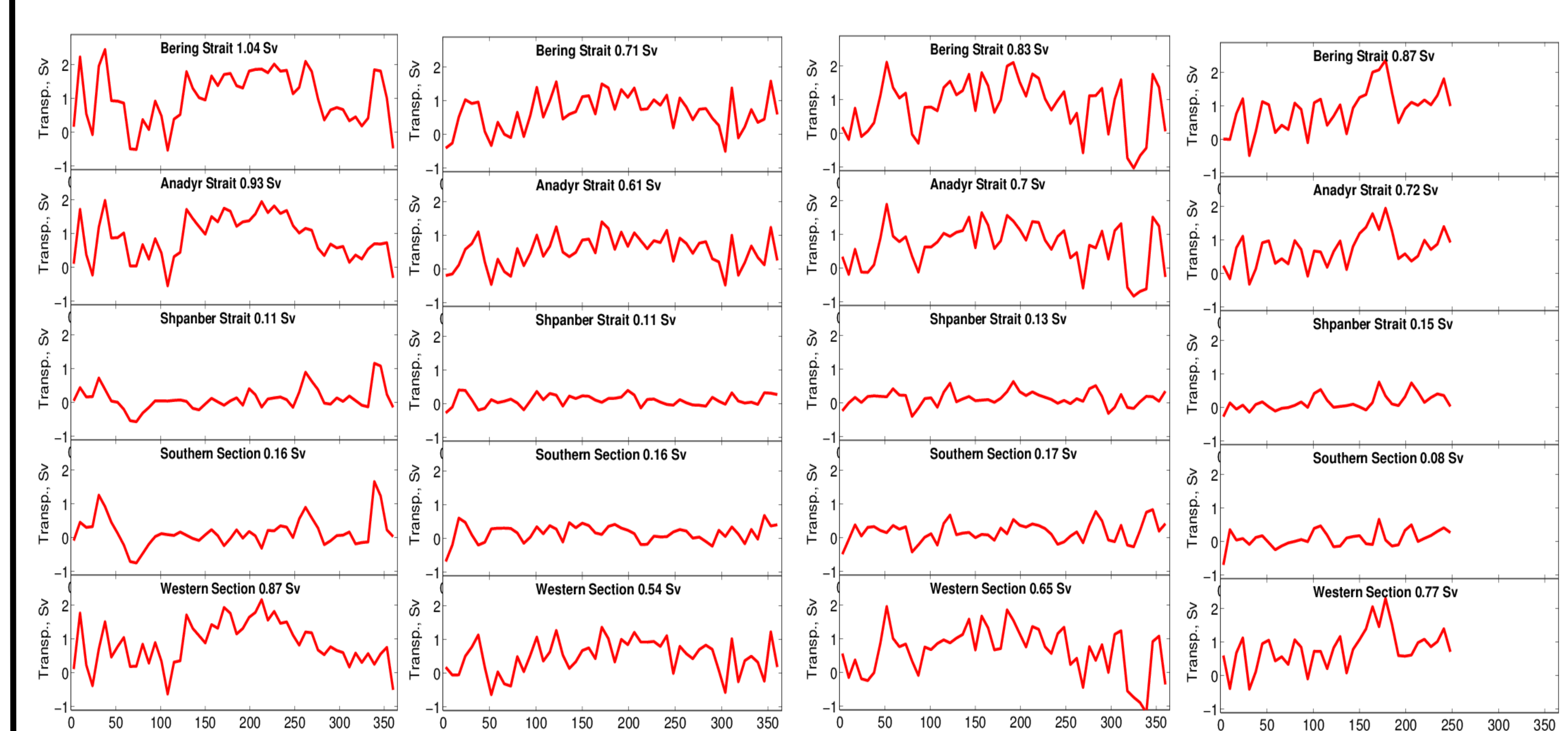
Fig.1. (above) Schematic of the SIOM-BESTMAS data assimilation system

Fig.2. (right) Reconstructed Sea Surface Height and velocity for the Coarse Resolution domain. Domain of the high resolution is shown by a dashed line. Numbers 1,2,4,5 designate the Anadyr and Spanberg straits and western and southern sections utilized for analysis of the volume fluxes (Figure 3). Number 3 – designate St. Lawrence Island.

Data

1. Time series of velocity, T/S data from moorings in the Bering Strait and N55,40,25, C55,C40,C25 and S55,S40,S25
2. T/S data from all hydrological surveys
3. Satellite SSH observation referenced to the high resolution MDOT (Panteleev et al., 2009)
4. Surface drifter observations
5. Realistic (NCEP/NCAR) wind stresses and heat/freshwater surface fluxes
6. OSTIA Sea Surface Temperature
7. Ice concentration

Fig.3. Volume transports through five sections in the Northern Bering Sea during 2007-2010



High resolution modelling of the Eastern Bering Sea

Introduction: A 2 kilometer-resolution model of the Eastern Bering Sea is developed to capture dynamical processes on the scale of the Rossby radius of deformation on tidal to seasonal time scales. The high resolution throughout ensures that the mesoscale dynamics of significant sub-regions of the domain, such as the Aleutian Island Passes, Bering Sea Slope and the Bering Shelf canyons are captured simultaneously without concern for loss of interconnectivity between regions.

Key Features of the high res. model

- Regional Ocean Modeling System (ROMS)
- 2-km horizontal resolution
- Initialization: melding of BESTMAS (for Bering Sea shelf) and global HYCOM.
- Side Boundary Conditions: Global HYCOM plus 5 tidal constituents.
- Atmospheric Forcing (NARR –a221 grid, 3-hr resolution)
- 5-month simulations 6/1/2009 - 11/1/2009

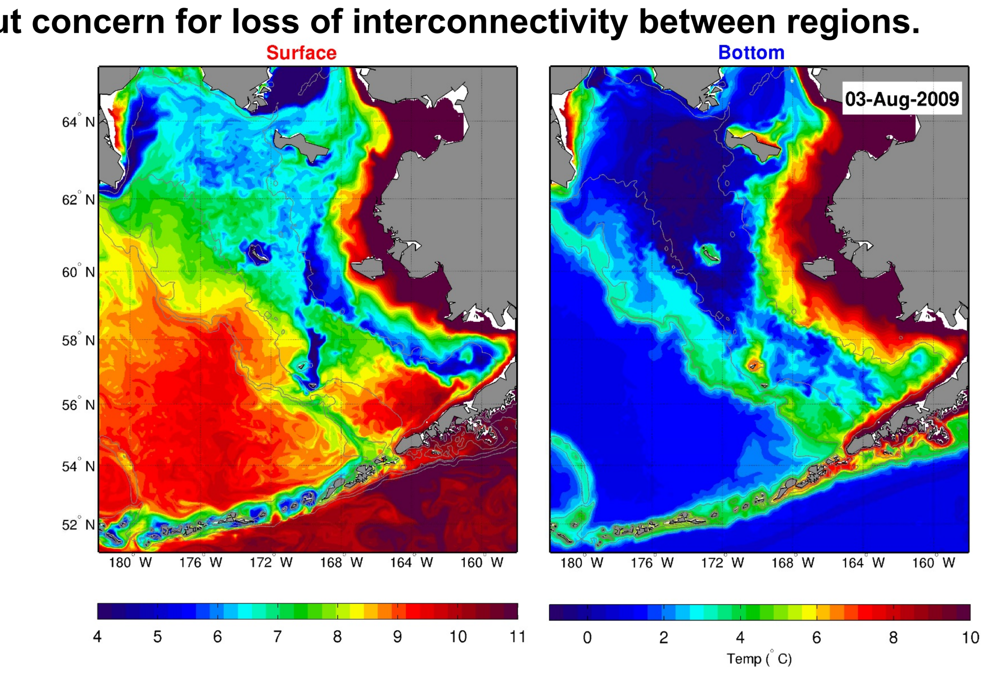
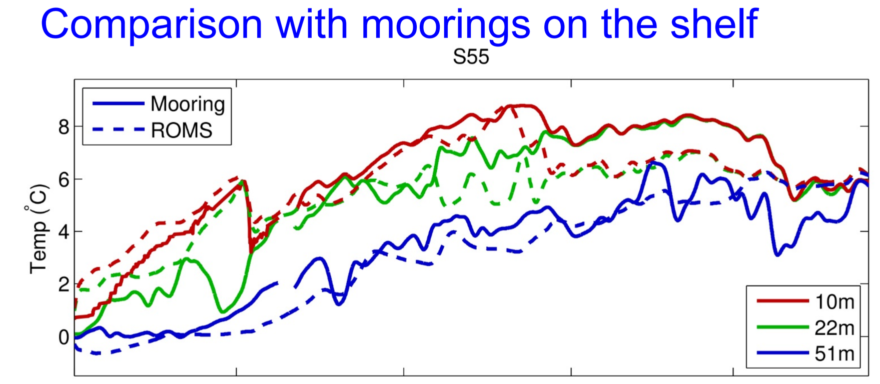
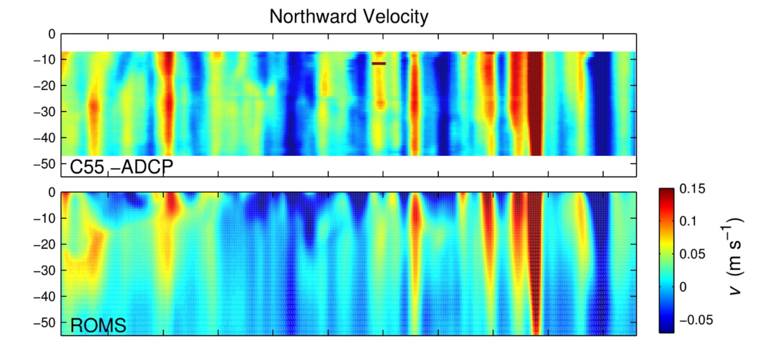


Figure: Simulated model surface and bottom temperature, 8/3/2009

Comparison with moorings on the shelf



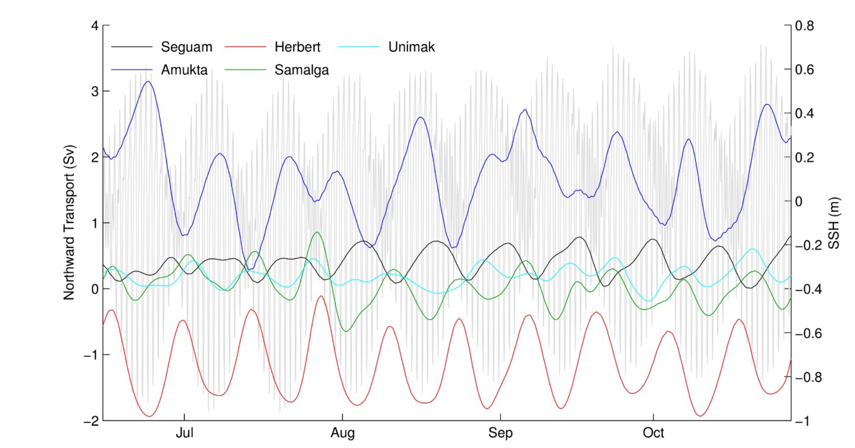
Low-pass filtered temperature time series at three depths, at the S55 BEST-BSIERP mooring location with a comparison to the model.



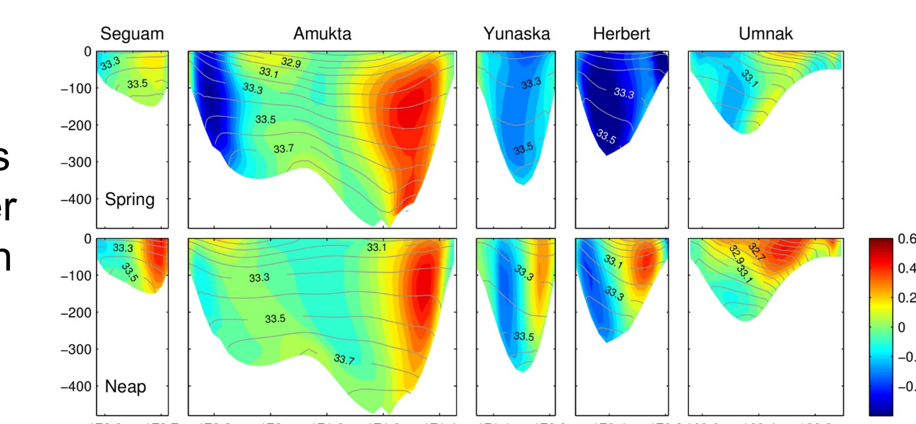
Low-pass filtered northward velocity time series as a function of depth at the C55 BEST-BSIERP mooring location with a comparison to the model.

Transport through Aleutian Island Passes

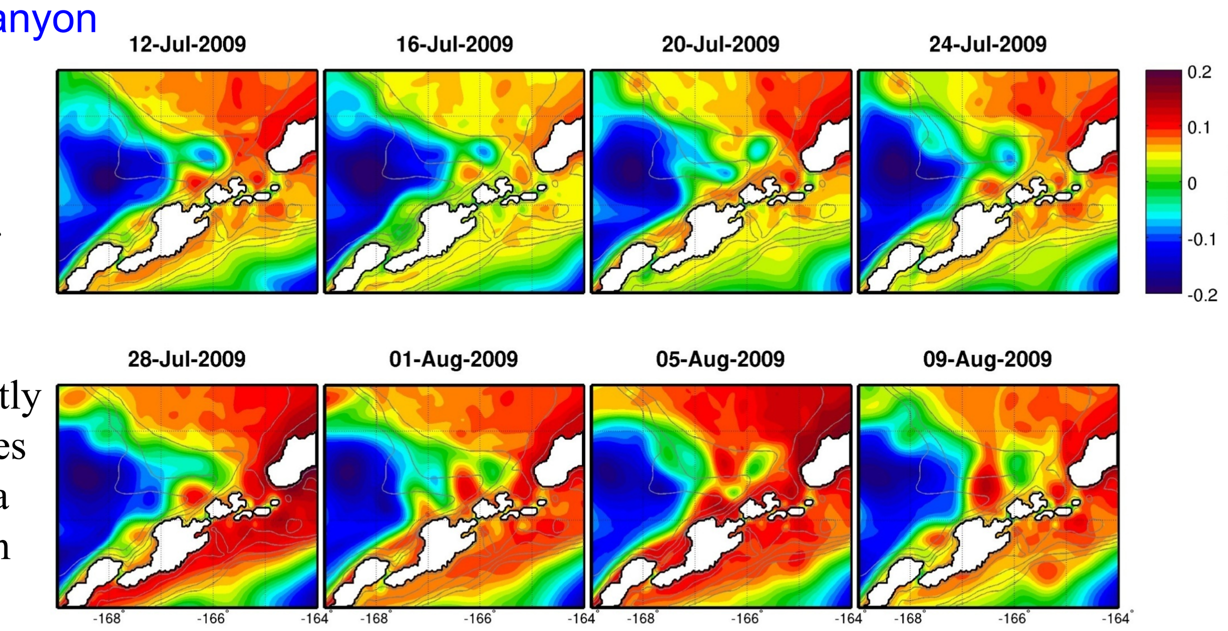
The low-pass filtered transports through the Aleutian Island passes show strong two-week oscillations correlated with the diurnal spring-neap cycle (K1-O1). Amukta Pass and Herbert Pass to the east each exhibit peak transport at spring tide but with strong northward flow through Amukta pass and strong southward flow through Herbert.



The northward velocity and salinity stratification within the passes averaged over peak spring and neap periods shows distinct differences. Stratification is higher in Amukta pass during spring tide as fresh water, transported from the east is inhibited from passing through Samalga, Herbert and Yunaska passes.



Eddy activity in Bering Canyon



The evolution of low-pass filtered model SSH in the vicinity of Bering Canyon shows repeated shedding of mesoscale eddies in the up-canyon direction. The eddies form as fortnightly sea surface elevation changes on the north side of Yunaska Island, cause basin waters in the canyon to become 'pinched off' from the Aleutian North Slope/ Bering Slope current waters. These eddies tend to move up the canyon toward Unimak pass where their water mixes with water from the pass and the shelf. They provide a potential mechanism for the transport of organisms from the basin to the shelf environment.