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### On the influence of the variability of atmospheric circulation on the Arctic ice dynamics on the basis of numerical modeling

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### **Coupled Ice-Ocean Model**



### 3D World Ocean Circulation Model of ICMMG based on z-level vertical coordinate approach

(Kuzin1982, Golubeva at al.,1992, Golubeva,[2001], Golubeva and Platov,[2007])

- Conservation laws for heat, salt and momentum with Boussinesq, hydrostatic and 'rigid lid' approximations
- Separation of the external and internal mode in momentum equations
- Barotropic momentum equations are expressed in term of stream function
- QUICKEST (Leonard,[1992]) is used in the latest model version for the T-S advection.
- Two versions of mixed layer parameterization:
  - Vertical adjustment based on the Richardson number

- Vertical diffusion coefficient based on the stable solution of turbulent energy equation

### Ice model-CICE 3.0 (elastic-viscous-plastic)

W.D.Hibler ,1979, E.C.Hunke, J.K.Dukowicz,1997, G.A.Maykut 1971 C.M.Bitz, W.H.Lipscomb 1999, J.K.Dukowicz, J.R.Baumgardner 2000, W.H.Lipscomb, E.C.Hunke 2004

### Arctic – North Atlantic model domain



### Grid

The model grid has1x1 degree resolution in the North Atlantic.

The horizontal spacing in the polar grid varies from **50 to 34 km**. Maximum model resolution is in the vicinity of the North Pole.

Vertically, the grid has 33 constant layers, with a higher resolution near the surface.

The minimum shelf depth is 50 m.

### **Open bondaries**

In the Bering Strait, an open boundary is introduced with a prescribed transport of 0.8 Sv.

The river run-off transport is prescribed for most of the

significant Arctic and Atlantic rivers

Southern boundary at 20S: linear distribution between zero transport in the west point and the summarized transport value in the western point.

T,S data are used for all incoming flows and freefollowing condition for outcoming flow.

### **1948-2007 model run** (according to AOMIP)

The characteristics of the lower atmosphere and radiation are prescribed, taken from the **NCEP/NCAR reanalysis** (Kalnay et al., [1996]) and **CIAF**(Large and Yager[2004]).

**As initial condition for temperature and salinity**, the winter season distribution was taken from PHC *(Steele et al., [2000])* data set.

The initial ice distribution was prescribed as ice of 2 m thickness and 0.9 compactnes in the areas of the negative lower atmosphere temperature. Seven years of spin-up run provide a more reasonable sea ice distribution, which is further used as initial sea ice state. The numerical experiments reveal the effect of the ice cover, water circulation, and thermohaline structure of the Arctic Ocean on variations in the state of the atmosphere.

### During the second part of XX we found

- the warming and cooling periods in the Atlantic water layer,
- the freshwater accumulation regimes in the Canadian Basin and freshwater flow through the Fram Strait and Canadian Archipelago straits,
- a reconfiguration of the water circulation of the surface and intermediate layers of the ocean, a shift to the east the Pacific water spreading, lifting up to the surface Atlantic layer
- a significant reduction of the ice area.



www.ldeo.columbia.edu/NAO by Martin Visbeck

### Two main regimes of the Arctic's ice drift and surface circulation

Previous investigation - Gudkovich(1961), Nikiforov and Shpaiker(1980), Proshutinky and Johnson, 1997 and others.

### **Model results**

Anticyclonic regime

**Cyclonic regime** 



1960,1961,1963,1965,1966,1969, 1970-1973,1977-1980,1982-1983, 1985-1986, 1988, 1992,1994, 1996, 1998,2001



1967,1968,1981,1984,1989,1993,1995, 1997,1999,2000,2002,2003



200м. 1960 - 1974



200 м. 1995







*Ice thickness distribution during the model run* 







### Arctic Sea ice extent

(Press release from the National Snow and Ice Data Center , http://nsidc.org/news/ press) .



**Numerical results** 





# Ice extent (september) rrent Ice Extent /26/2006 Total extent = 5.8 million sq km 2006

### 2005

### **National Snow and Ice Data Center**



### Downward longwave radiation



2000 - VIII

Downward Longwave Radiation (W/m<sup>2</sup>) t=2007-08

2007 - VIII



2000 - IX

Downward Longwave Radiation (W/m<sup>2</sup>) t=2007-09



2000 - IX

### Ice drift. Summer 2007



The pattern of surface winds led to an export of ice from the eastern Siberian side of the Arctic northward and westward



## Summer ice thickness in 2005 and 2007 (model run)











## Summer ice thickness in 2005 and 2007 (model run)



## Conclusion

According to the numerical model experiment:

- The thinning of the Arctic sea ice began in end of the1980-s with the period of strong positive NAO
- The dramatic decline of the arctic ice extent in summer 2007 occurred after years of shrinking and thinning, so the Arctic sea ice in the beginning of 2007 was preconditioned for radical changes
- high pressure over the central Arctic Ocean led to fairly clear skies for the most of the summer, promoting melt.
- The unusual strengthened ice advection during summer 2007 causing more ice to move out of the Pacific sector to exit Fram Strait.

## Thank you!