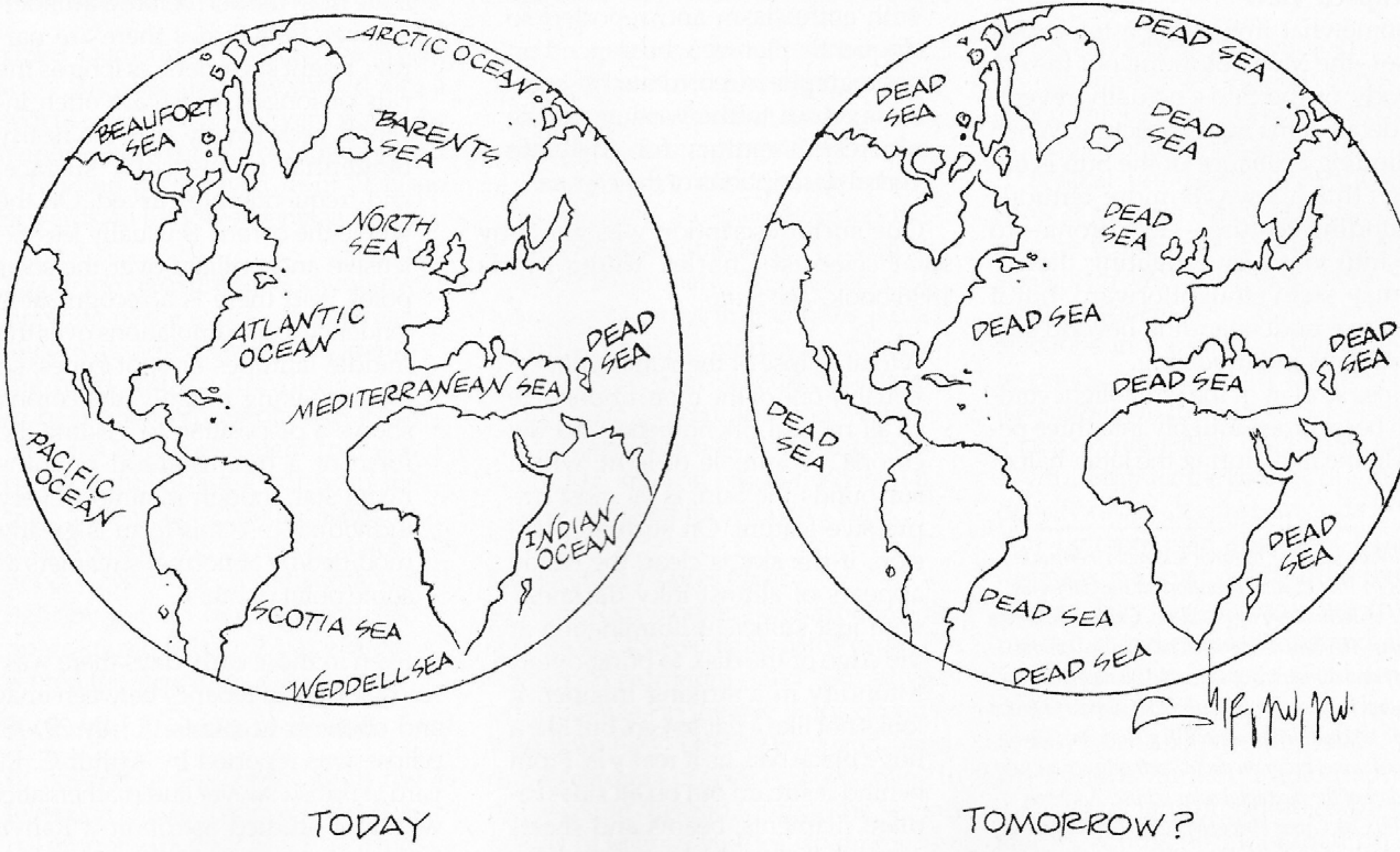

ARCTIC OCEAN
BEAUFORT SEA
BARENTS SEA
NORTH SEA
ATLANTIC OCEAN
DEAD SEA
MEDITERRANEAN SEA
PACIFIC OCEAN
INDIAN OCEAN
SCOTIA SEA
WEDDELL SEA
TODAY
DEAD SEA
DEAD SEA
DEAD SEA
DEAD SEA
DEAD SEA
DEAD SEA
DEAD SEA
DEAD SEA
DEAD SEA
DEAD SEA
DEAD SEA
TOMORROW?

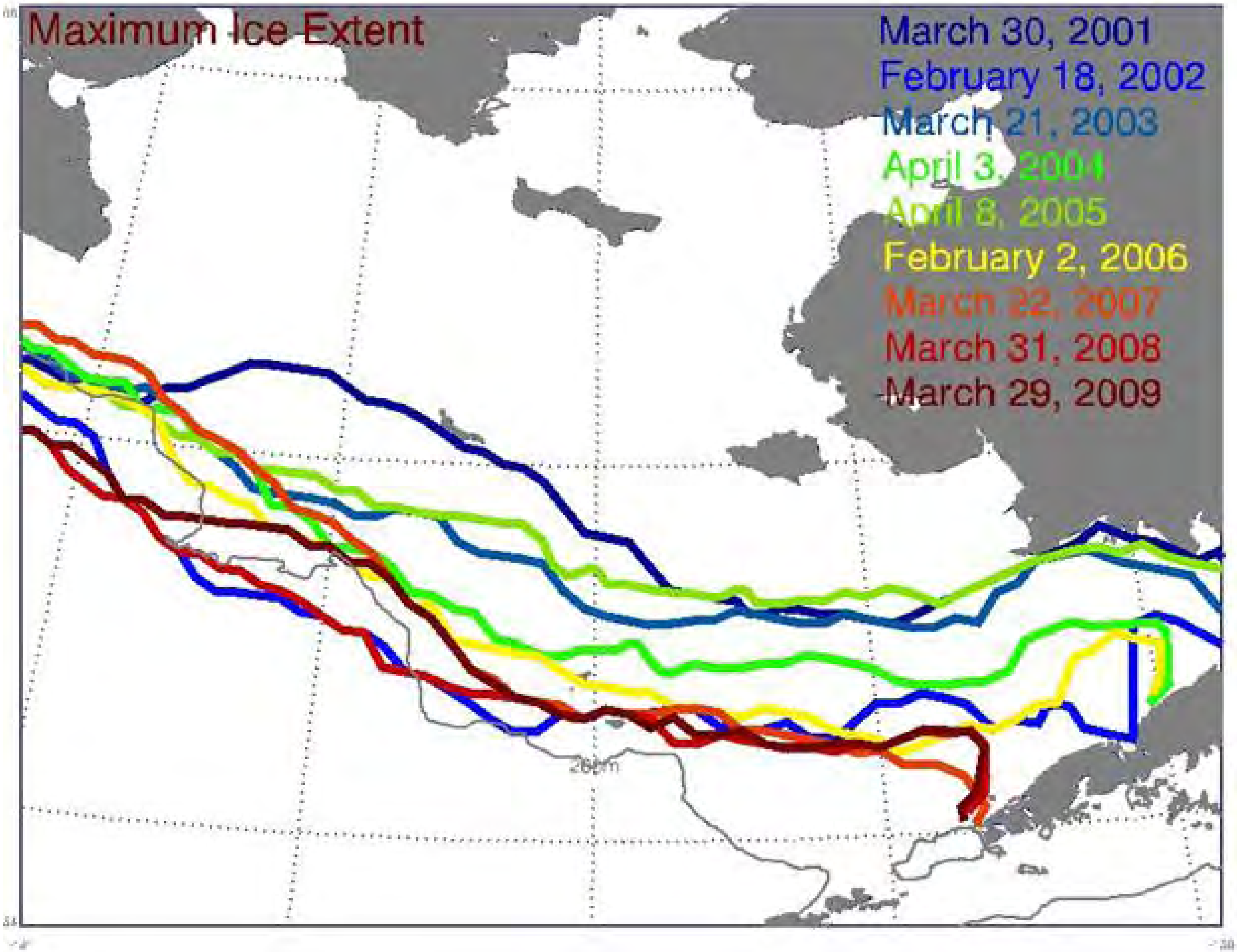
Impacts of Climate Change on the Habitat of Bering Sea Arrowtooth Flounder

Nicholas A. Bond[1]

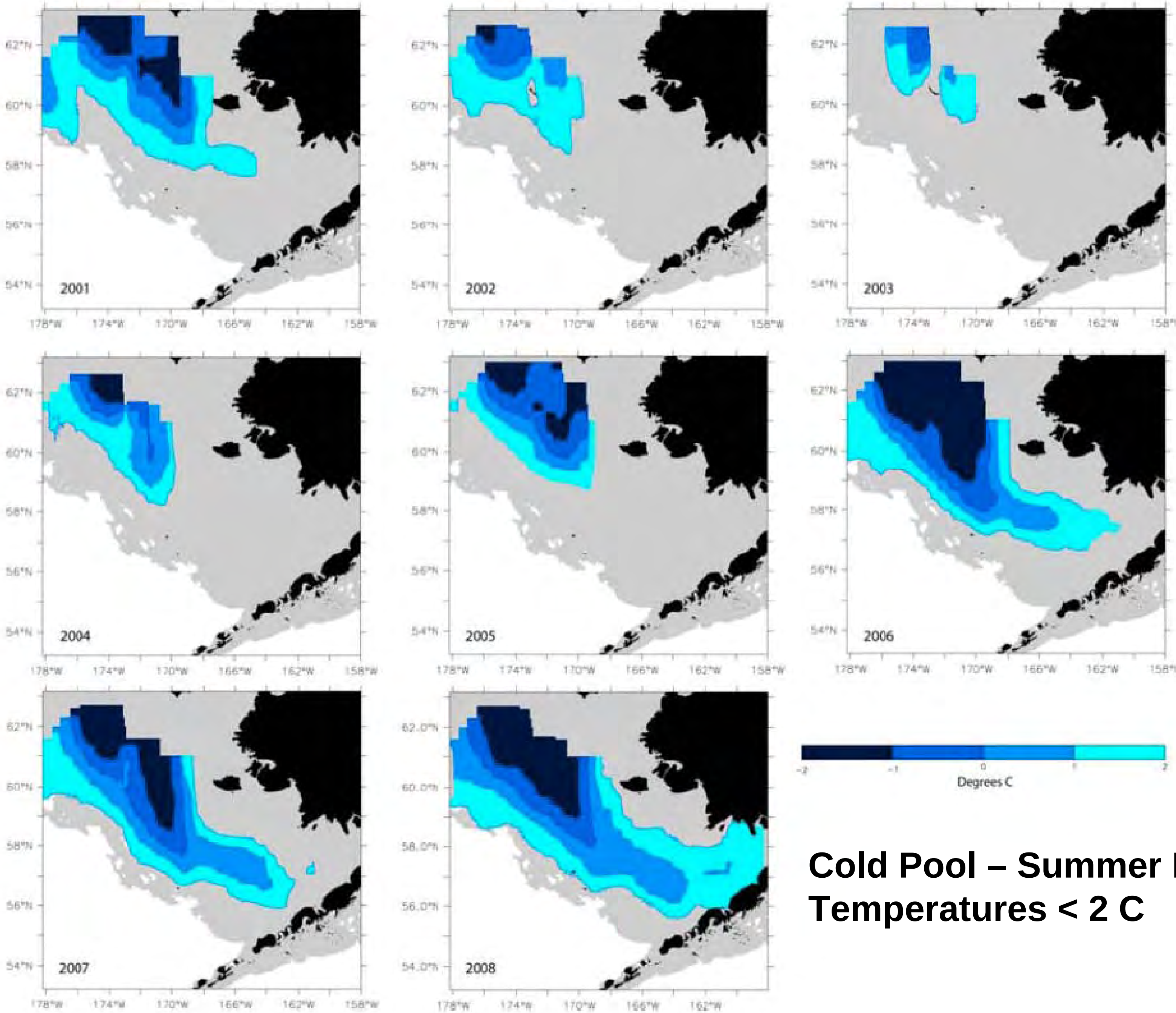
Paul Spencer[2] and Anne Hollowed[2]

[1] University of Washington/JISAO

[2] NOAA/AFSC



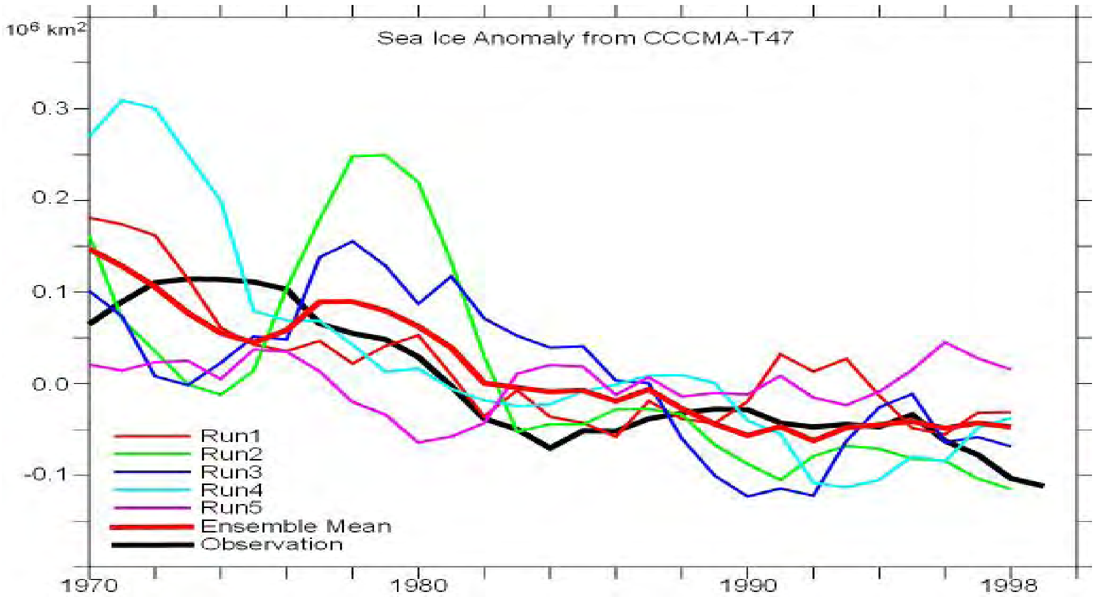
Maximum Ice Extent
March 30, 2001
February 18, 2002
March 21, 2003
April 3, 2004
April 8, 2005
February 2, 2006
March 22, 2007
March 31, 2008
March 29, 2009

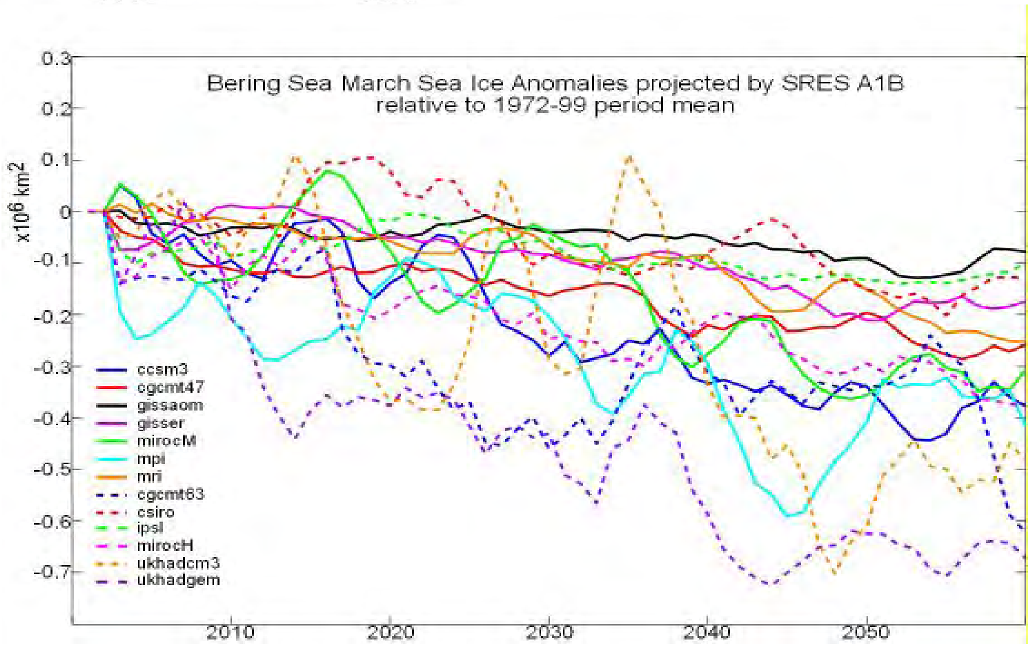


Cold Pool – Summer Bottom Temperatures < 2 C

Bering Sea Ice Projection Under A1B scenario

Wang and Overland

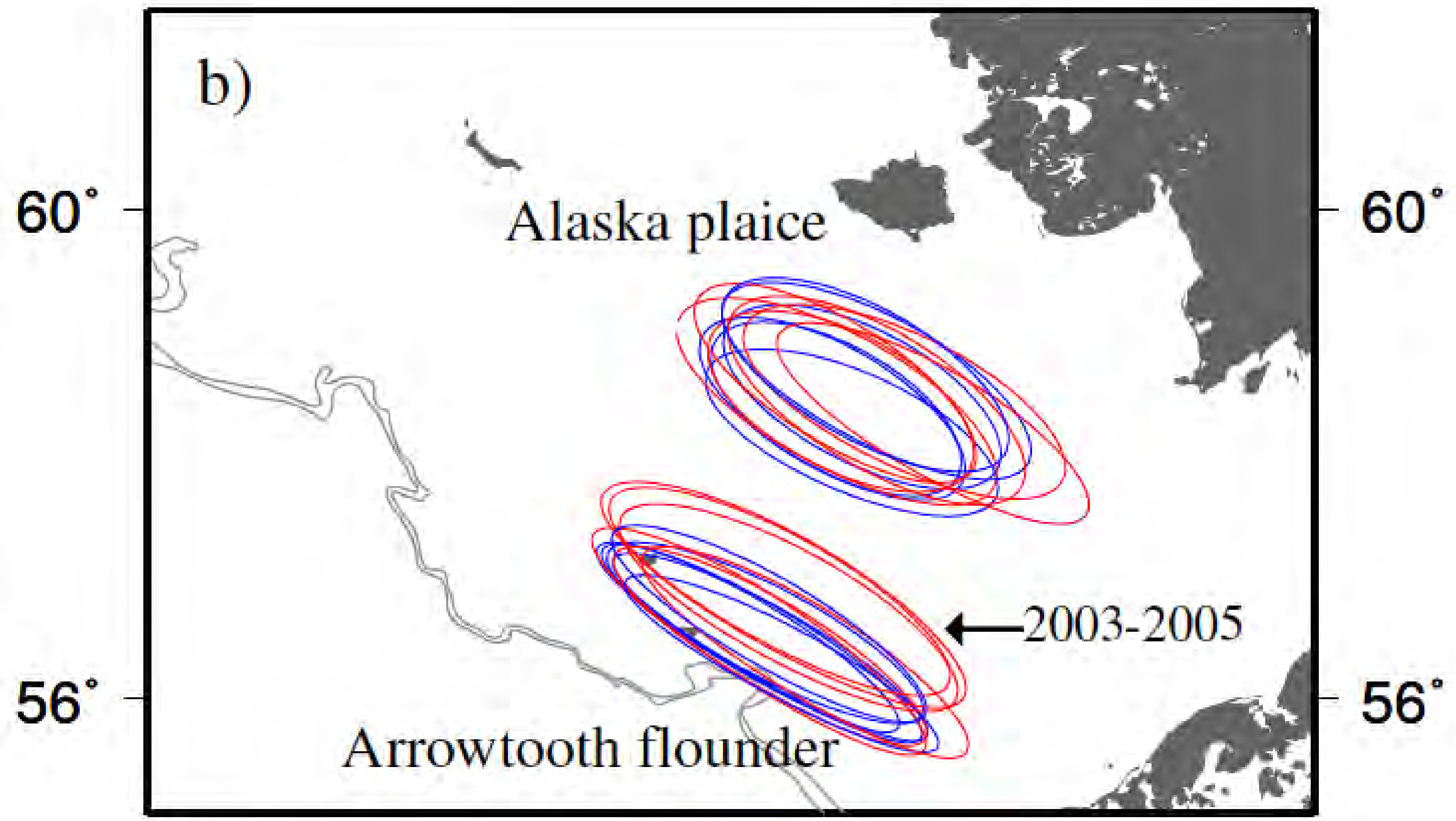


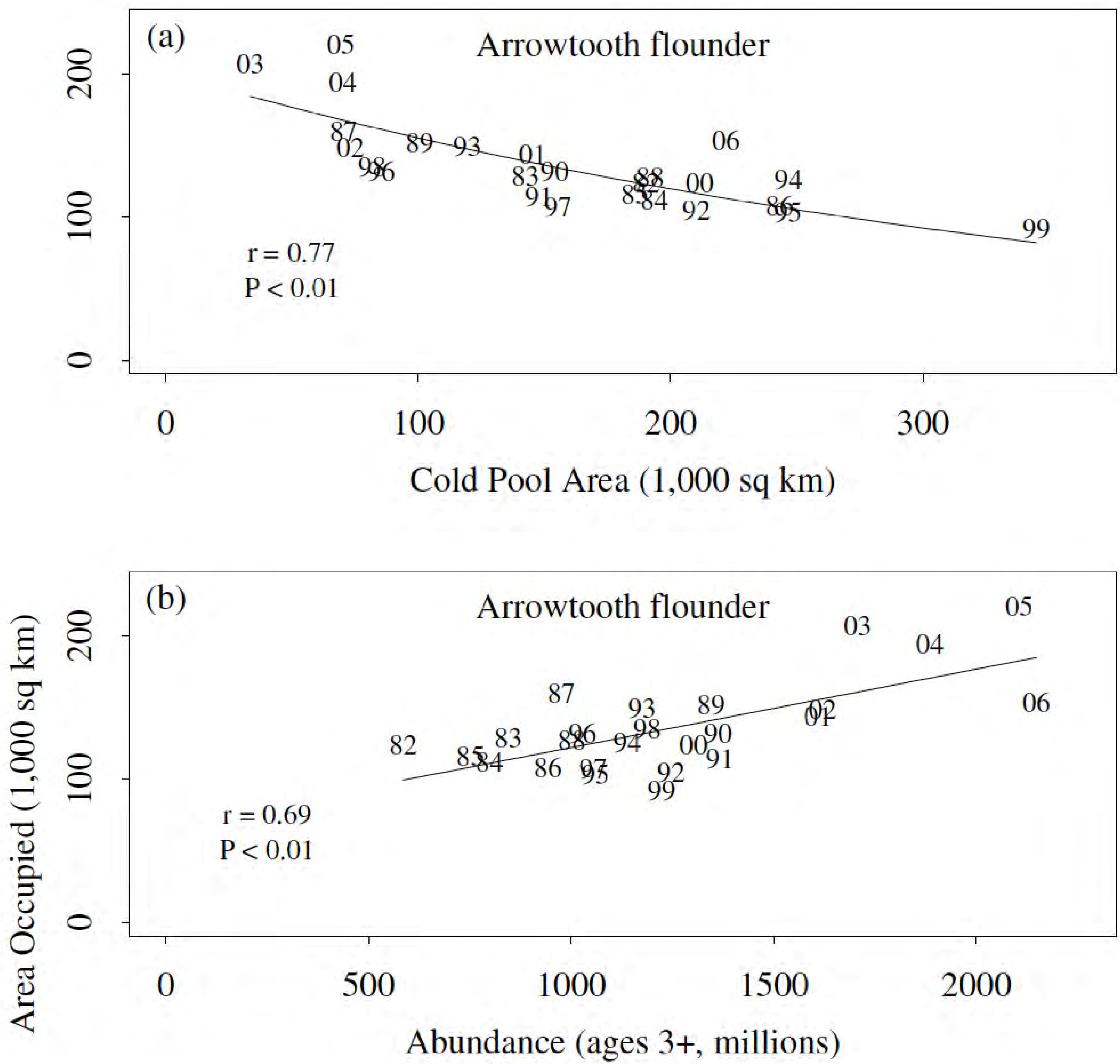


Introduction

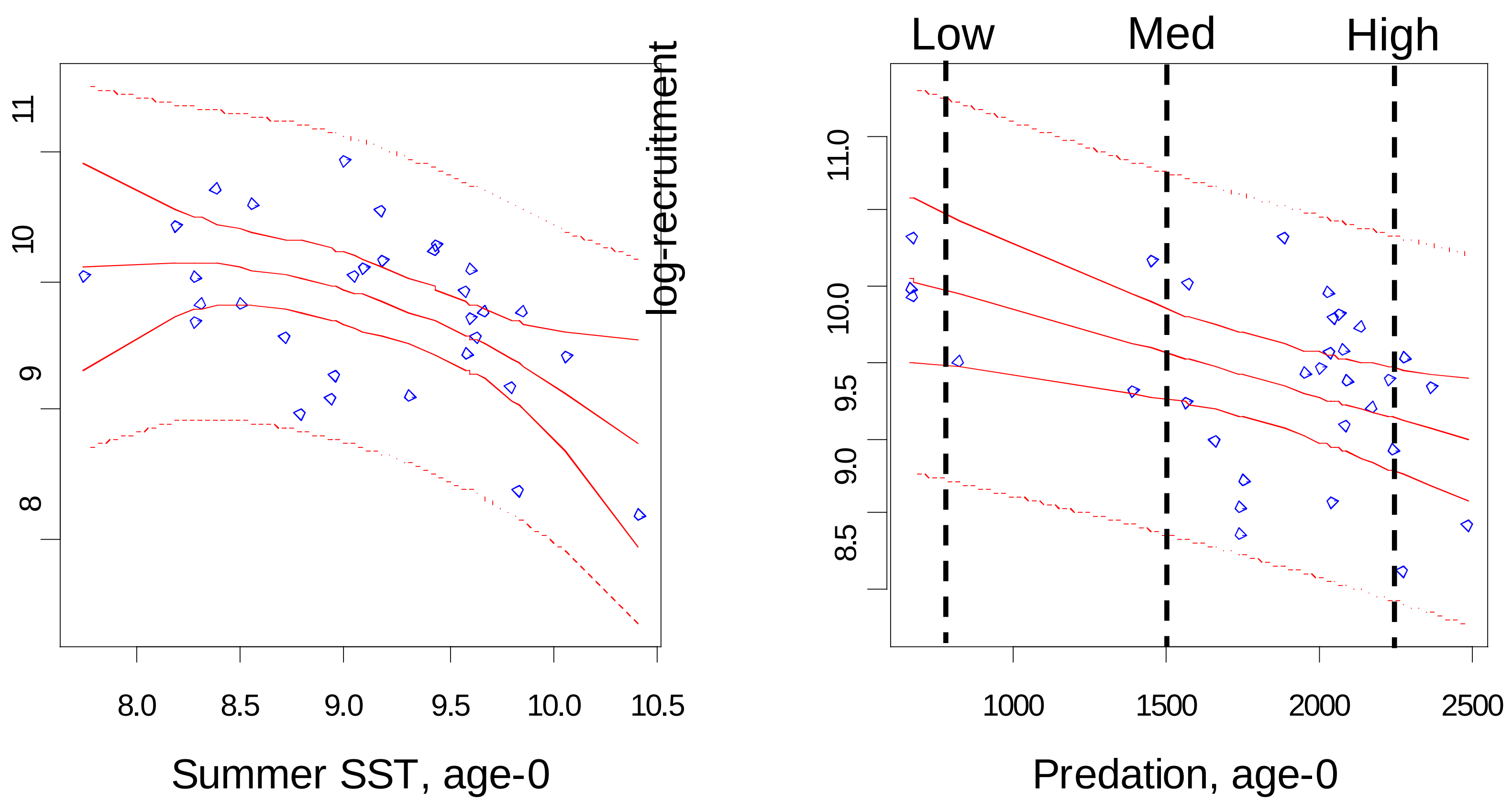
- The population of arrowtooth flounder (*Atheresthes sp.)* in the Bering Sea has grown markedly over the past 20 years.
- Since this species is a major predator on the commercially-valuable stock of walleye pollock (*Theragra chalcogramma*), it is important to determine how its population is liable to evolve in association with climate change.
- The present study employs historical data on the observed abundance of arrowtooth flounder versus summer cold pool extent, and the output from IPCC climate models to project the future abundance and distribution of this key species.

Spencer (2008)




(a)
Arrowtooth flounder
r = 0.77
P < 0.01
Cold Pool Area (1,000 sq km)
(b)
Arrowtooth flounder
r = 0.69
P < 0.01
Area Occupied (1,000 sq km)
Abundance (ages 3+, millions)

Estimated effects of summer SST & predation on log-recruitment of walleye pollock (Mueter et al. 2010)



Empirical Downscaling

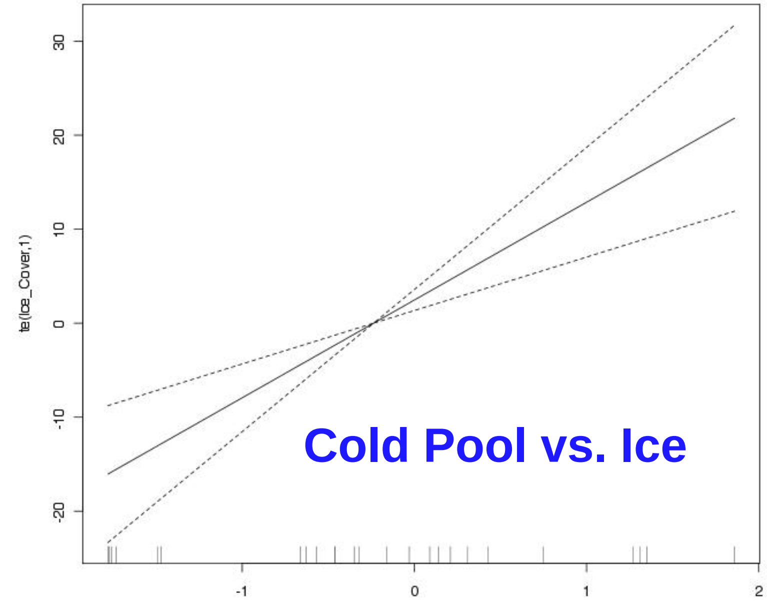
- Compile time series of specific predictands; and for each a set of plausible predictors
- Employ multivariate statistical techniques (e.g., generalized additive models) to establish functional relationships based on historical data
- Use IPCC model forecasts of climate-scale predictors, and relationships based on past data, to project local environmental parameters
- Present application takes advantage of quasi-linear dependence of arrowtooth flounder abundance on summer cold pool extent and in turn, the dependence of cold pool extent on the previous winter's sea ice cover.

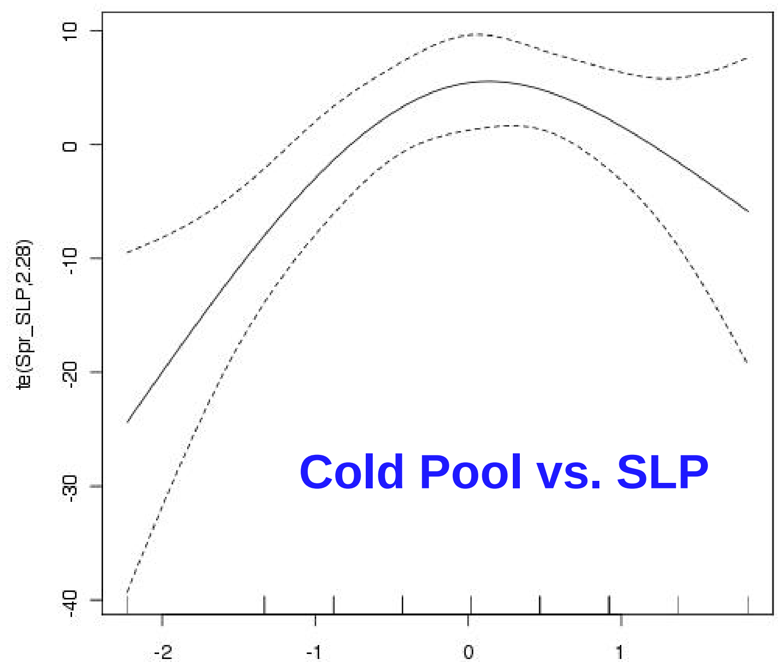
Summer Cold Pool Extent

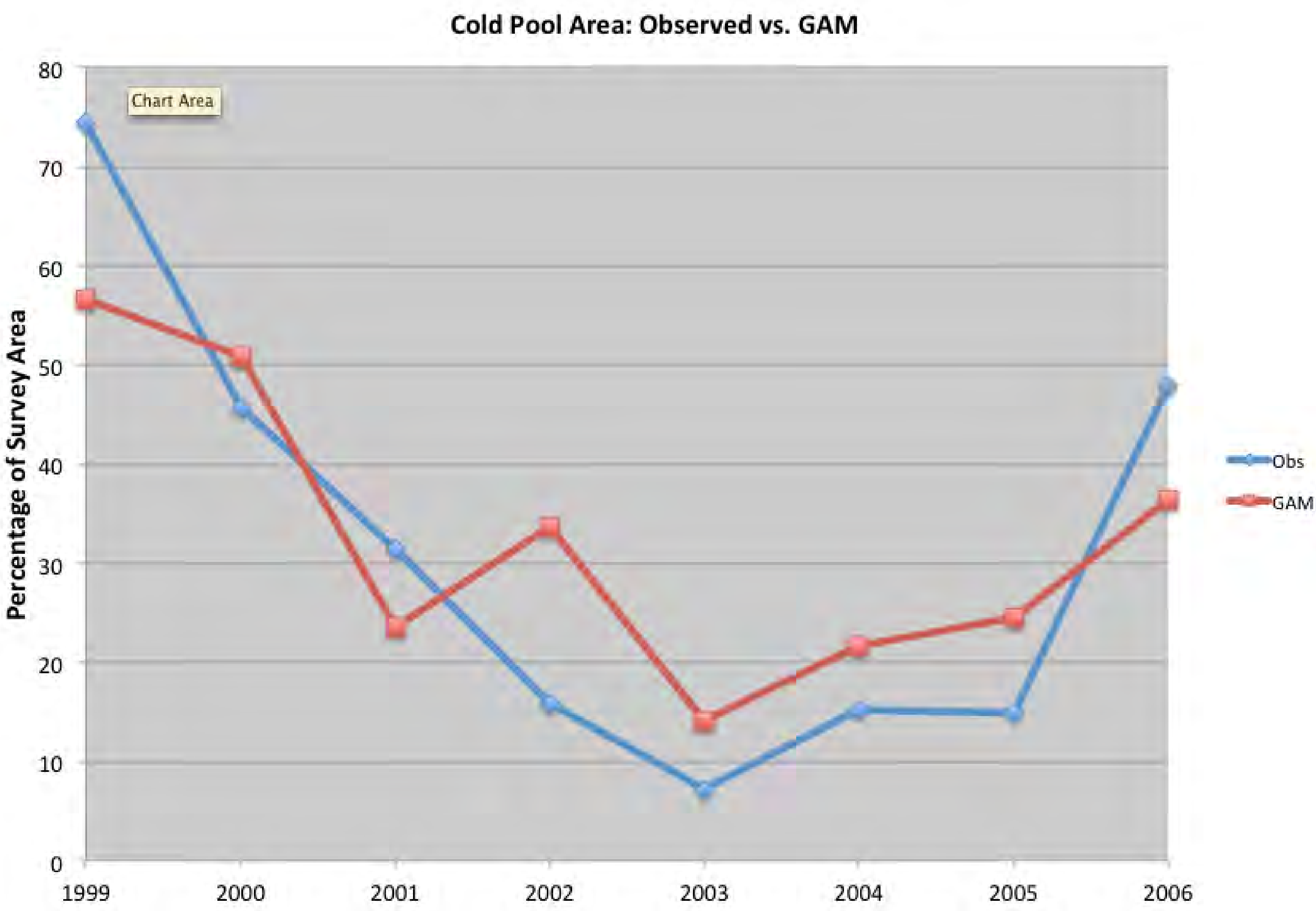
Parametric Term	p-value
SLP (Winter)	0.0235
SLP (Spring)	0.0052
Ice Cover	0.0002
Ice Retreat	0.0756
Wind Mixing (JJ)	0.6294

Total variance explained ~ 76%

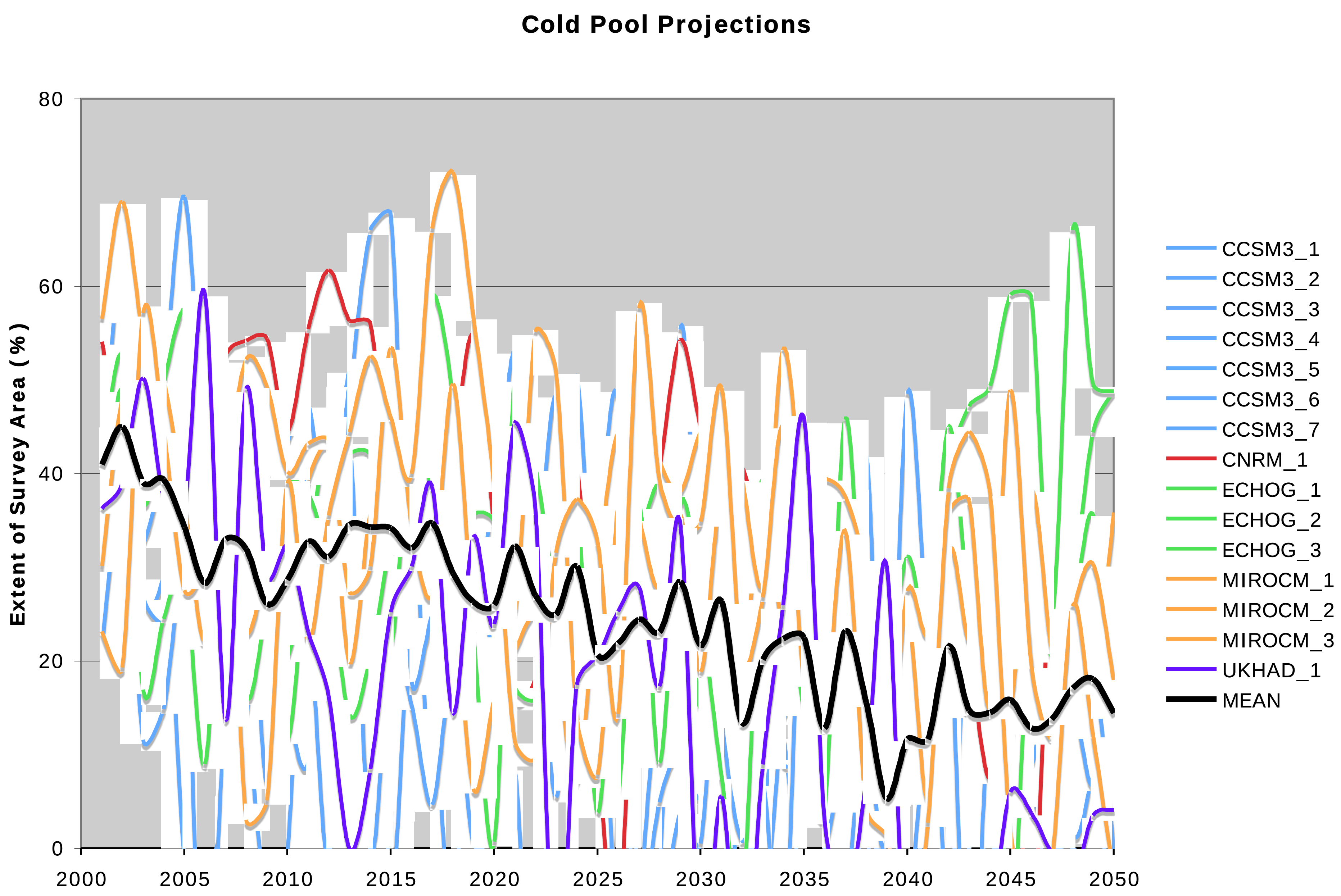
(Using just Spring SLP & Ice Cover, total variance explained ~ 69%)







Cold Pool Area: Observed vs. GAM
Chart Area
Percentage of Survey Area
80
70
60
50
40
30
20
10
0
1999
2000
2001
2002
2003
2004
2005
2006
Obs
GAM



Cold Pool Projections
Extent of Survey Area (%)
80
60
40
20
0
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
CCSM3_1
CCSM3_2
CCSM3_3
CCSM3_4
CCSM3_5
CCSM3_6
CCSM3_7
CNRM_1
ECHOG_1
ECHOG_2
ECHOG_3
MIROCM_1
MIROCM_2
MIROCM_3
UKHAD_1
MEAN

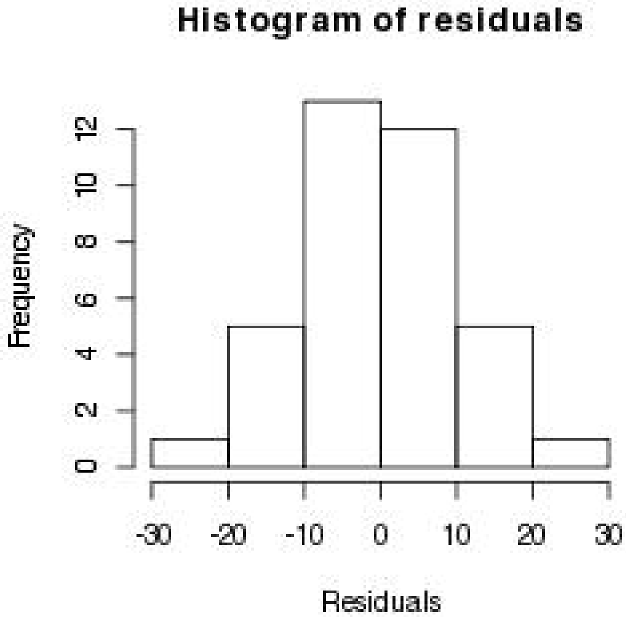
Variables considered relating to the timing of ice retreat

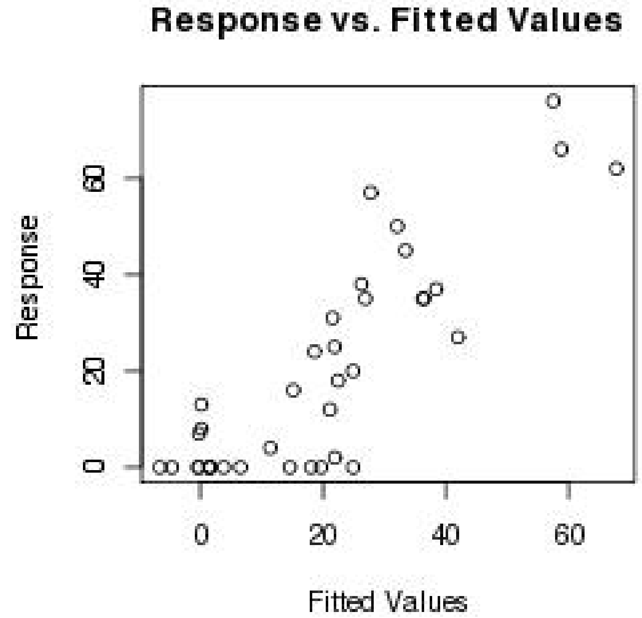
- Previous October Heat Content at M2
- Winter (Nov-Mar) 850 hPa Wind
- Winter (Nov-Mar) 850 hPa Air Temperature
- Winter (JFM) St. Paul SST
- Mar-Apr V currents at M2 (SODA)
- Mar-Apr NW Component of Surface Stress
- Mar-Apr Clouds
- April 850 hPa Air Temperature

Evaluation of Variables

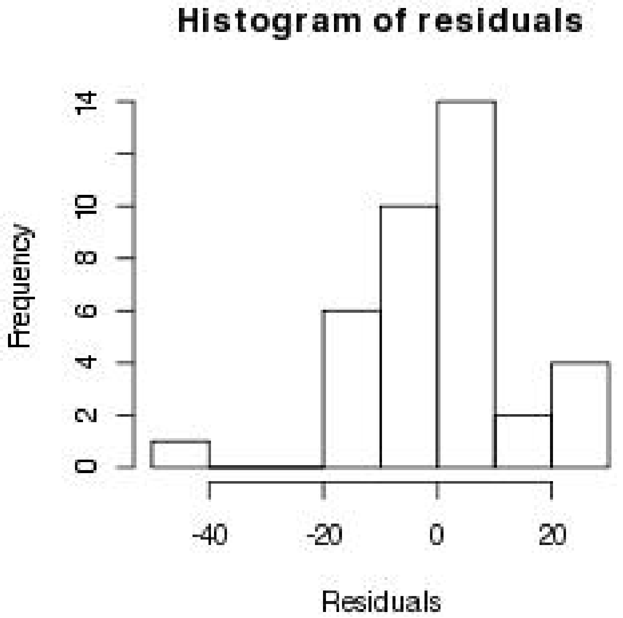
- Best predictors: Spring V Current and Spring NW Wind (explained about 40% of variance)
- Worst predictors: Spring Air Temperatures and Spring Cloud Cover
- Better 2-variable combinations explained 63-78% of variance
- Some 3-variable combinations produced odd functional relationships

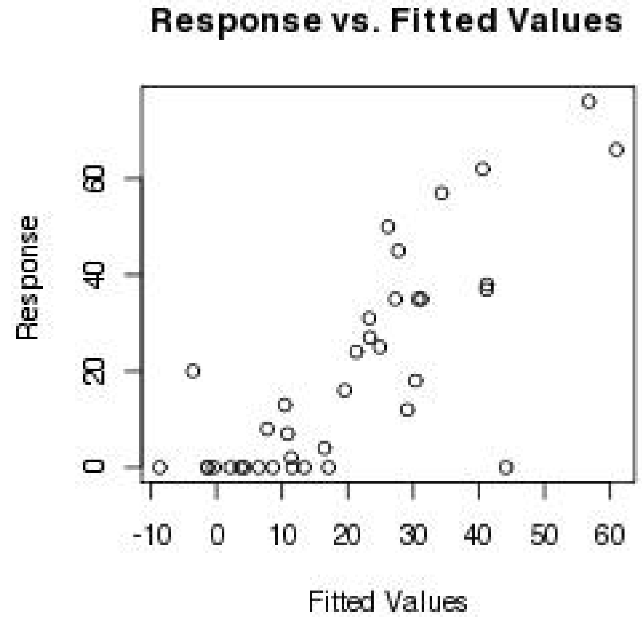
GAM Performance using Winter T_A and Spring Winds

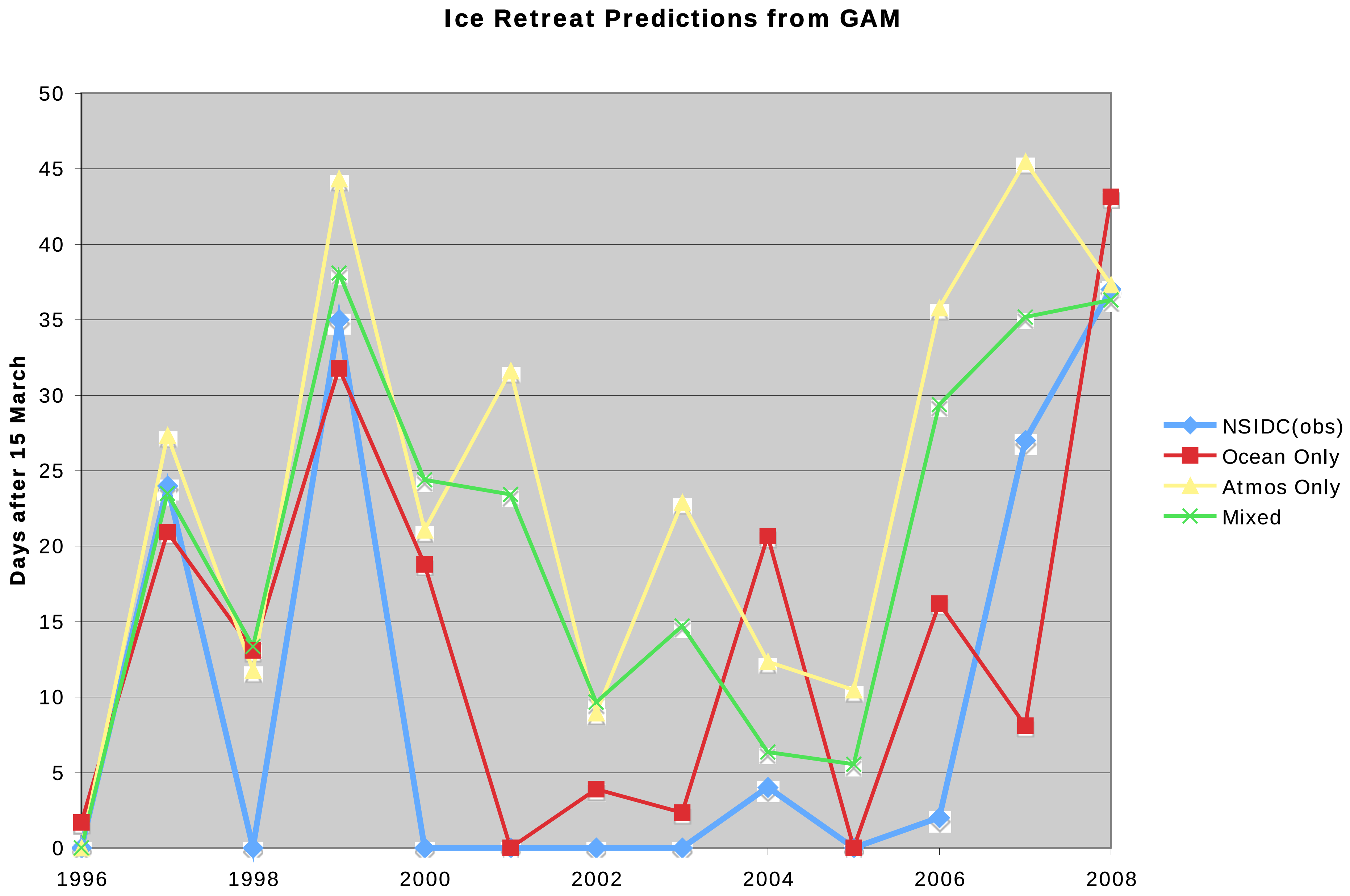




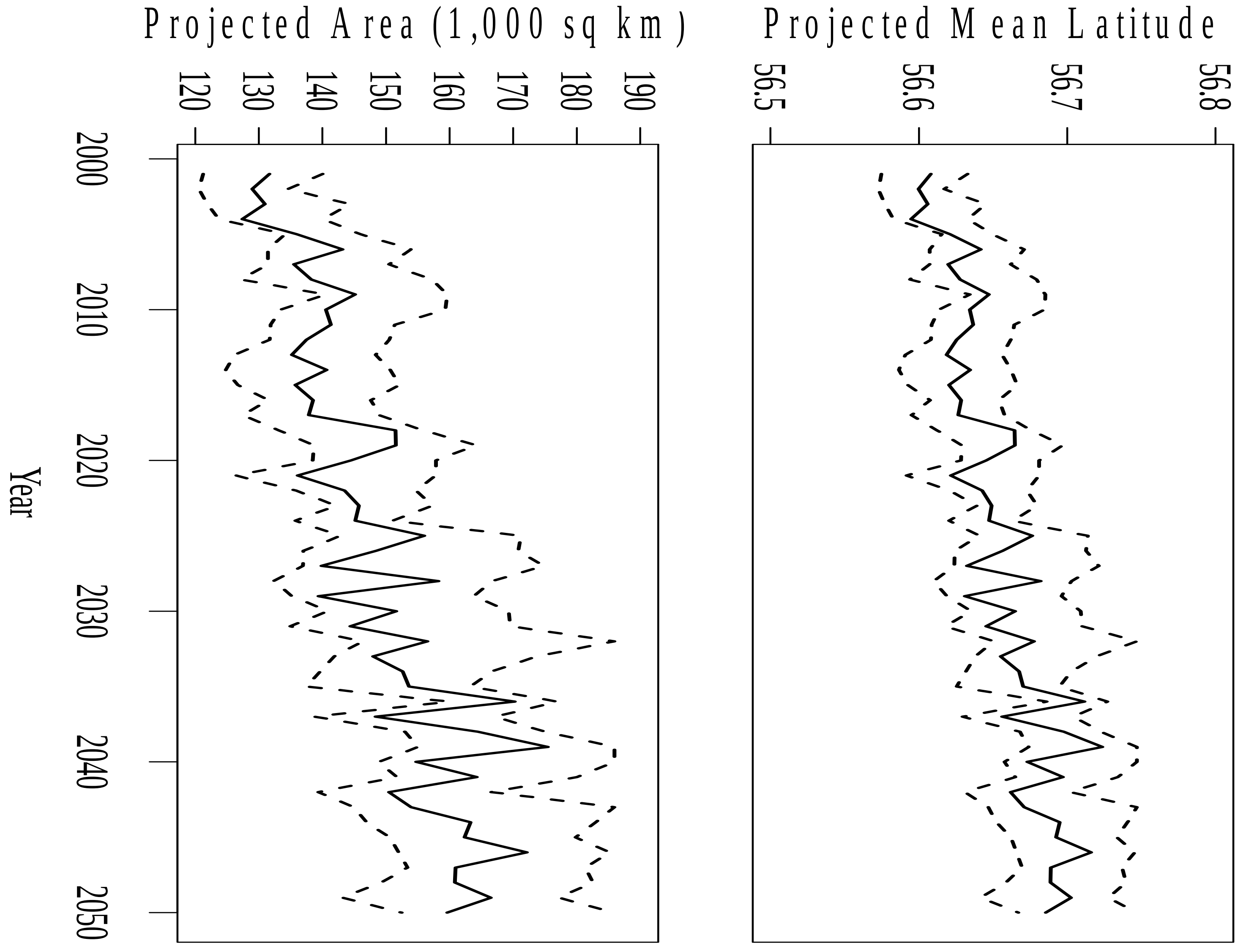
GAM Performance using St. Paul SST and Spring Currents






Ice Retreat Predictions from GAM
Days after 15 March
0
5
10
15
20
25
30
35
40
45
50
1996
1998
2000
2002
2004
2006
2008
NSIDC(obs)
Ocean Only
Atmos Only
Mixed

From Spencer et al. poster in Session 3



Final Remarks

- Empirical downscaling is being employed for local environmental parameters that cannot be reliably simulated by IPCC-class climate models directly.
- Caveat: This method is predicated on the functional relationships based on historical time series remaining valid into the future.
- A large number of climate scenarios can be handled with empirical downscaling; these results can complement those from the vertically-integrated numerical modeling effort.
- This method indicates a decline of ~50% in the extent of the cold pool on the Bering Sea shelf by 2050 and hence considerably more suitable habitat for arrowtooth flounder.