Environmental cues for herring spawning timing in northern Bristol Bay

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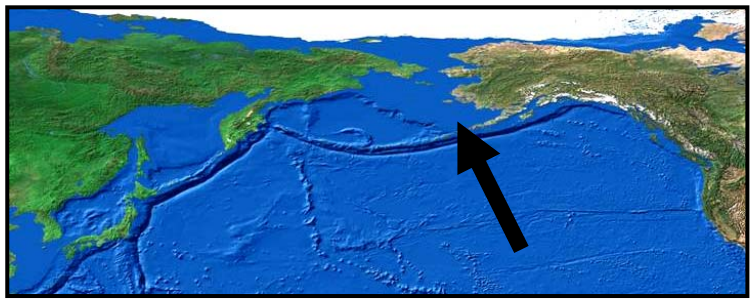
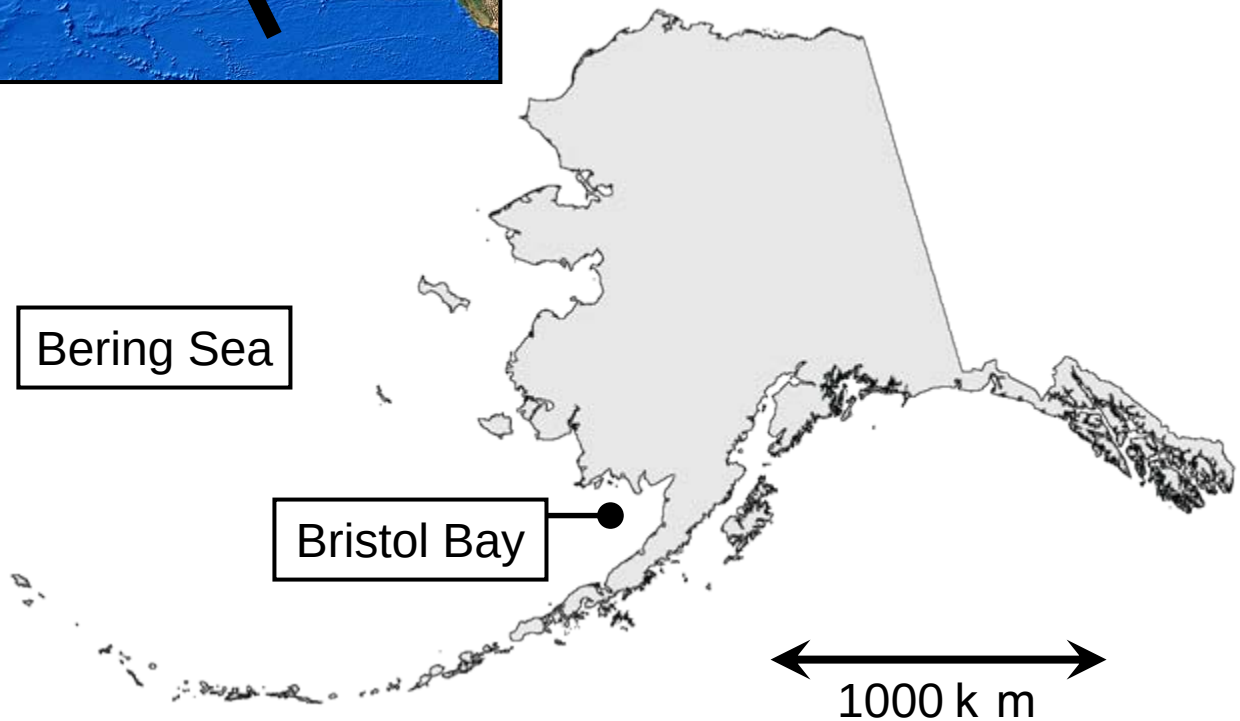
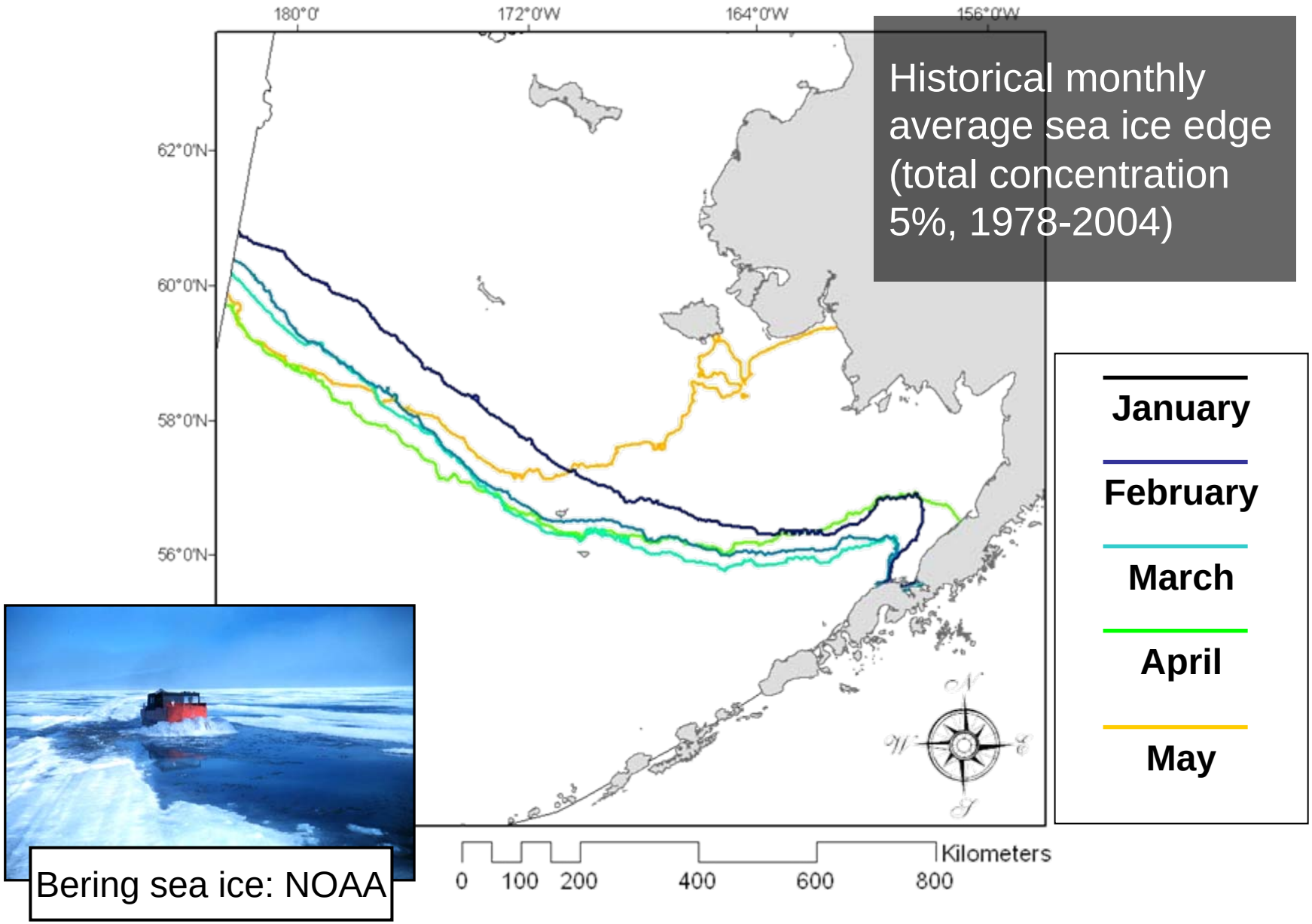
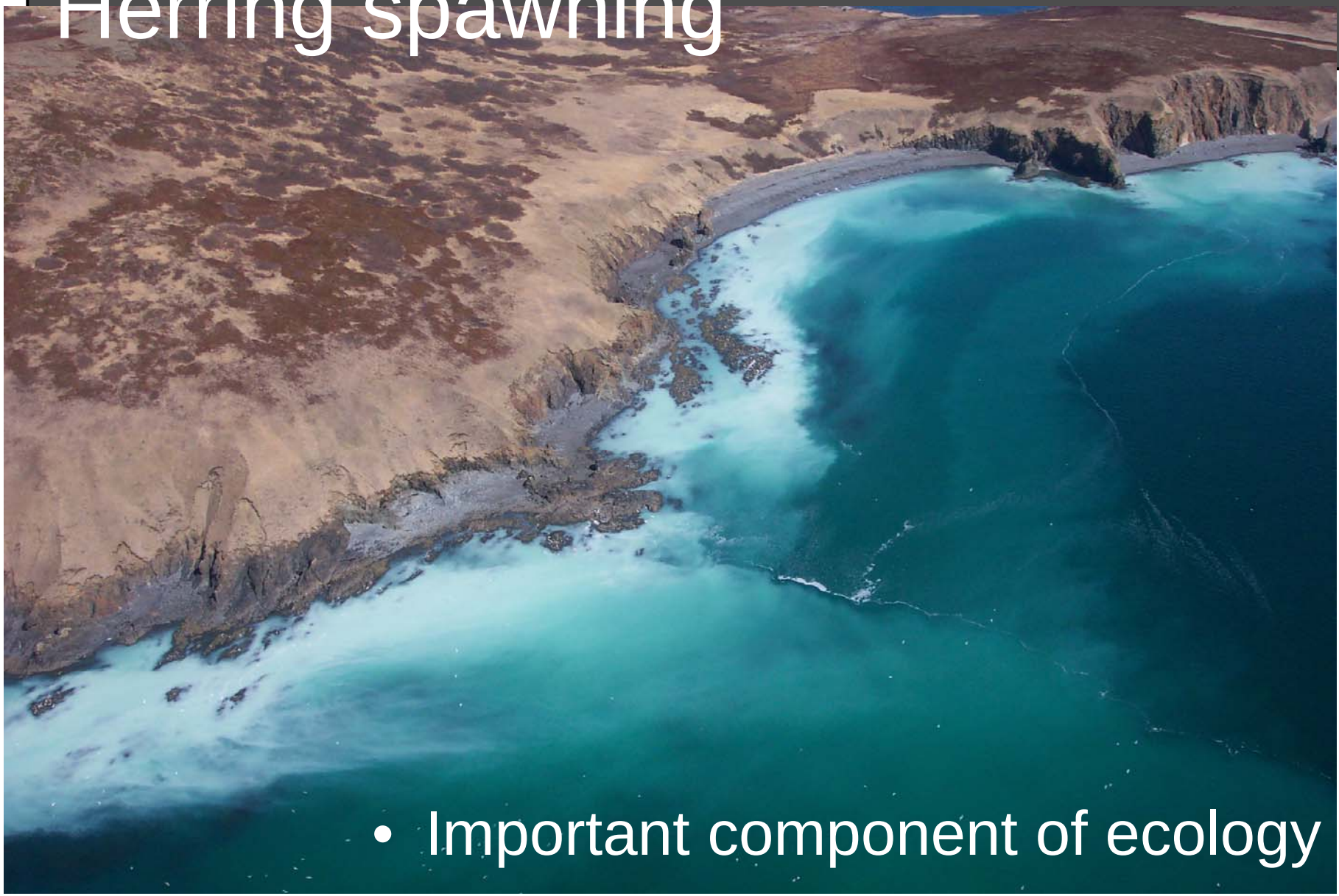
Bristol Bay






Historical monthly average sea ice edge (total concentration 5%, 1978-2004)
180°0'
172°0'W
164°0'W
156°0'W
62°0'N
60°0'N
58°0'N
56°0'N
January
February
March
April
May
0
100
200
400
600
800
Kilometers
Bering sea ice: NOAA

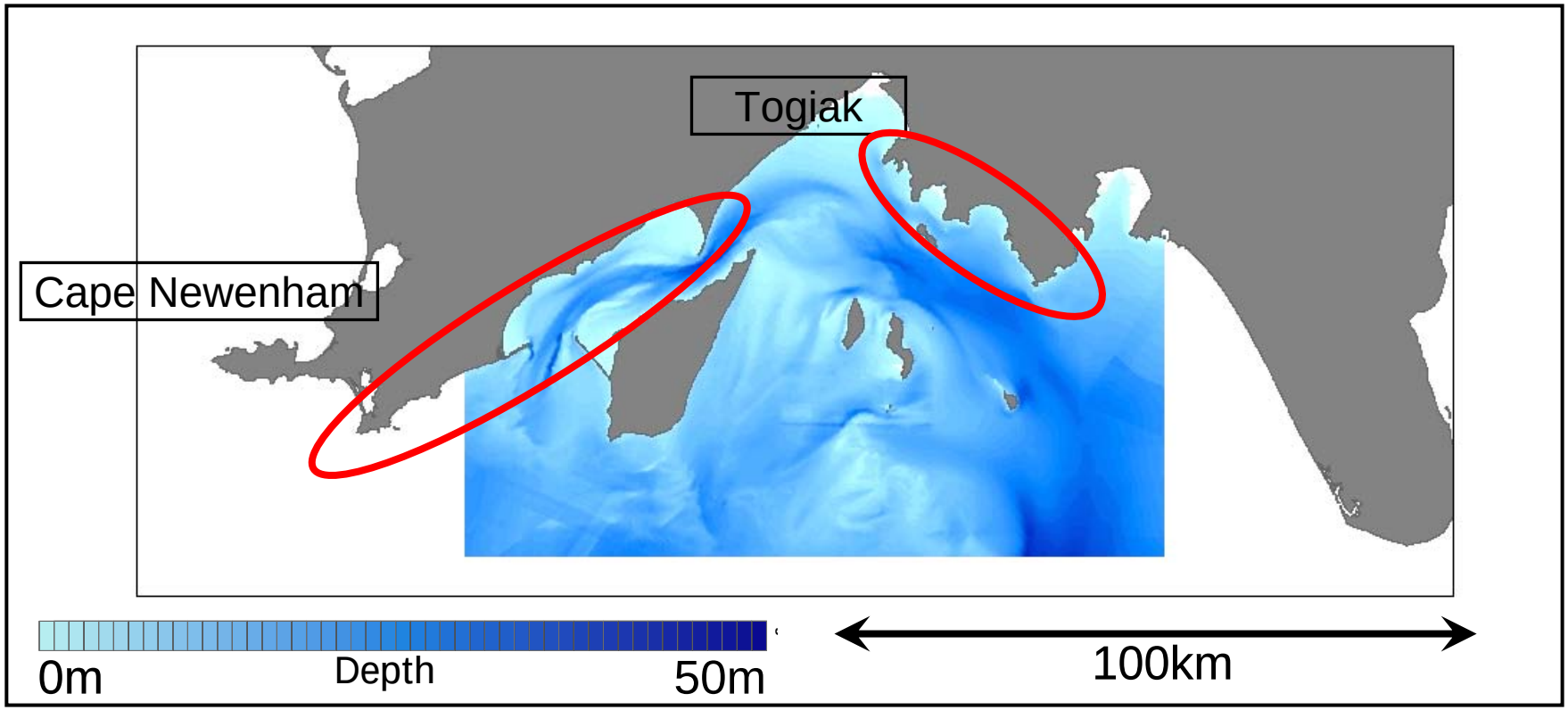
Herring spawning



- Important component of ecology

- Spawning in end of April – beginning of May

Spawning Area

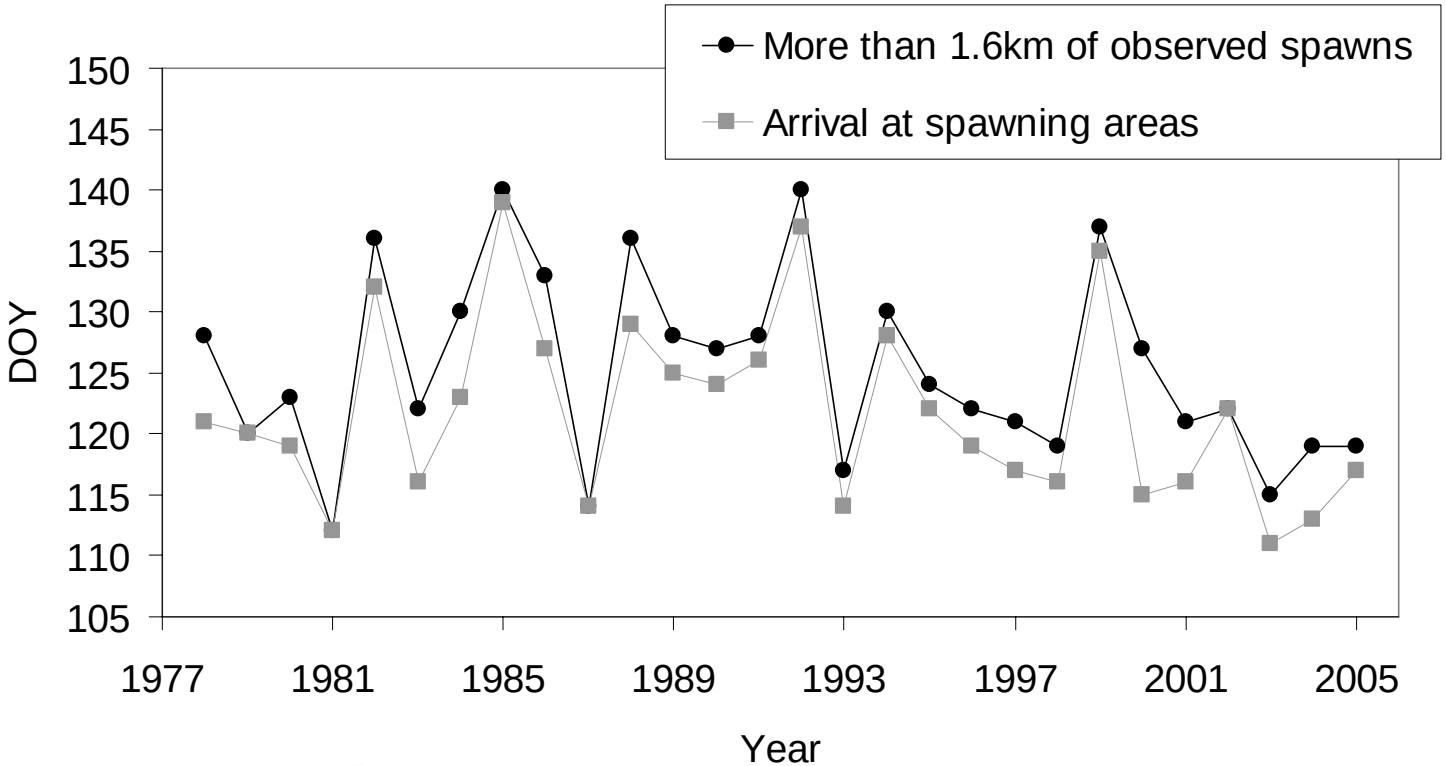


- Main spawning area in EBS

Herring fishing

- Base of the cultures and economy

Variability



- High latitude → later spawning (Hay 1984)
- Interannual variability=30days
  - Prediction models with air temperature (Wespestad and Gundarson 1991) → errors
  - <u>Better and more persisting</u> model with explanation of <u>mechanism</u>

Spatiotemporally explicit analyses

The past models

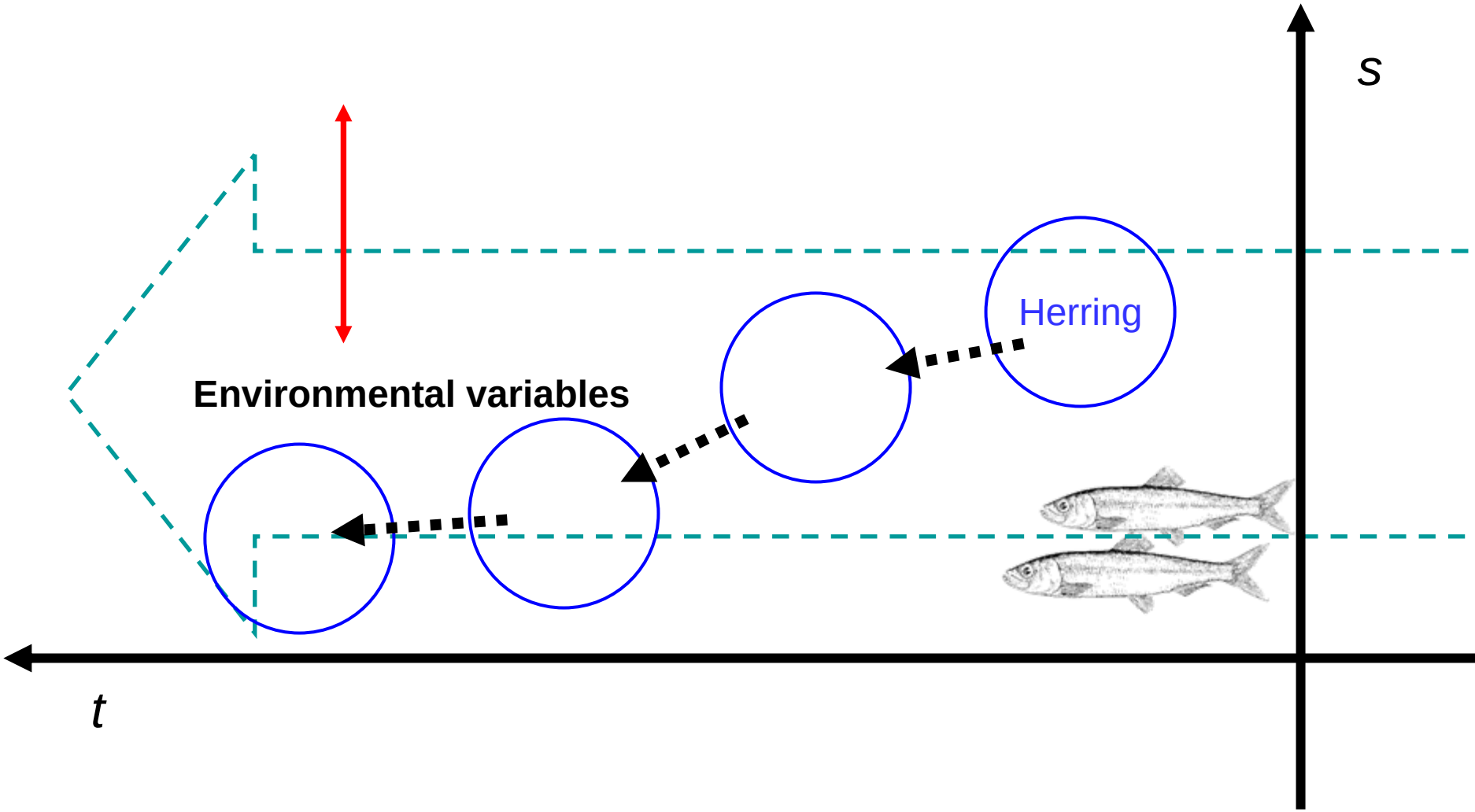
Air temperature ≈ sea temperature change around spawning ground with wind effect

t_{April}

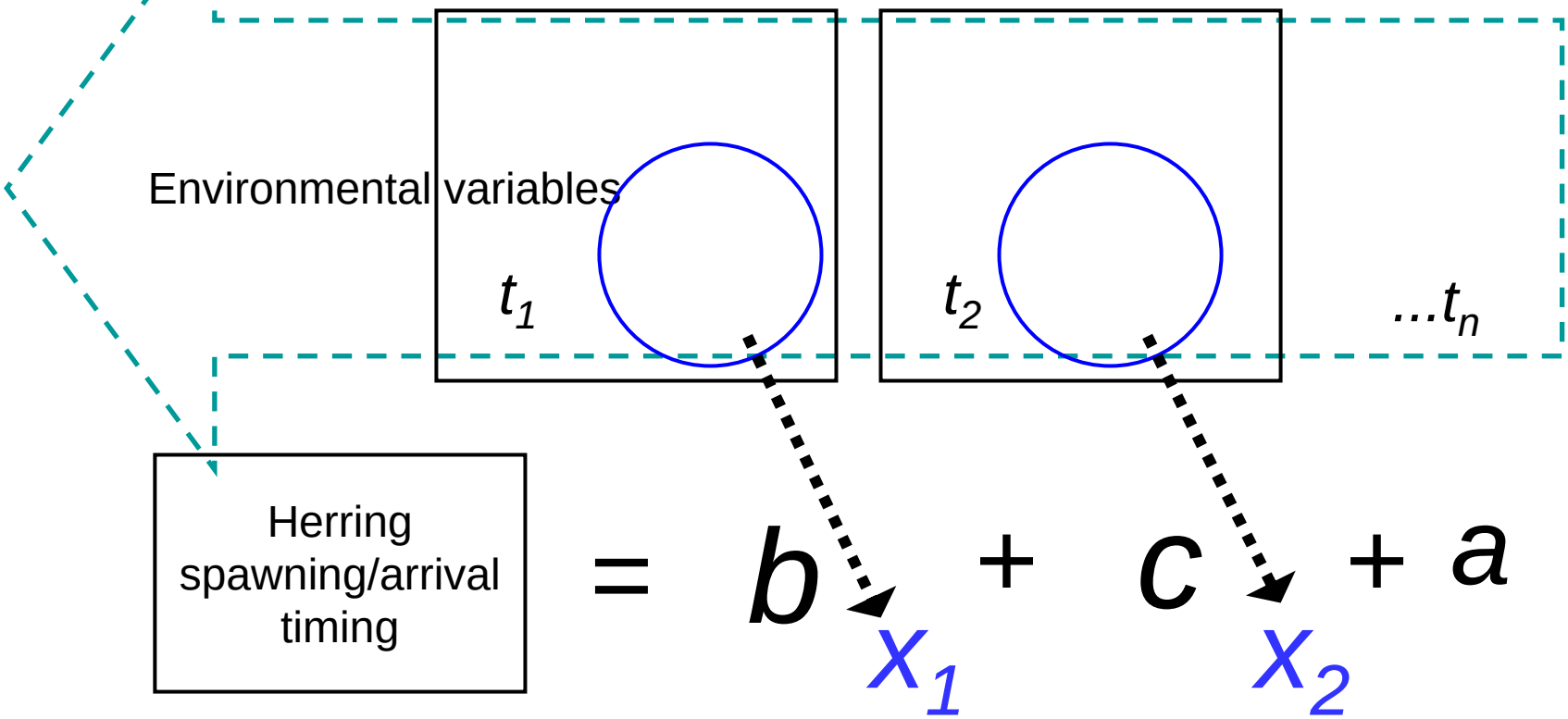
Herring spawning/arrival timing

$$= b \; x_{\text{air temperature at Cape Newenham}} + a$$

Model structures → Past models

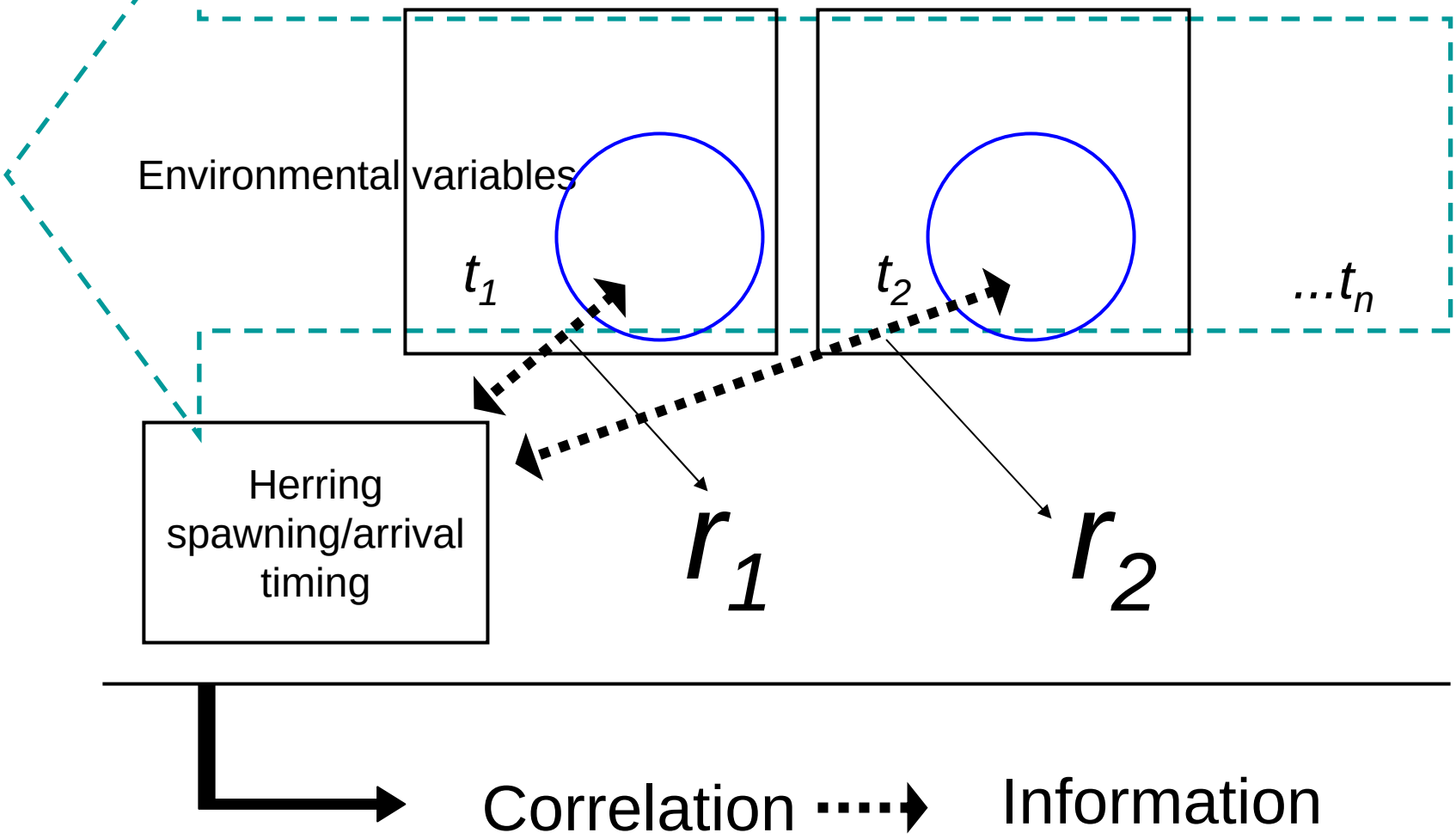

s
Herring
Environmental variables
t

Life-history approach

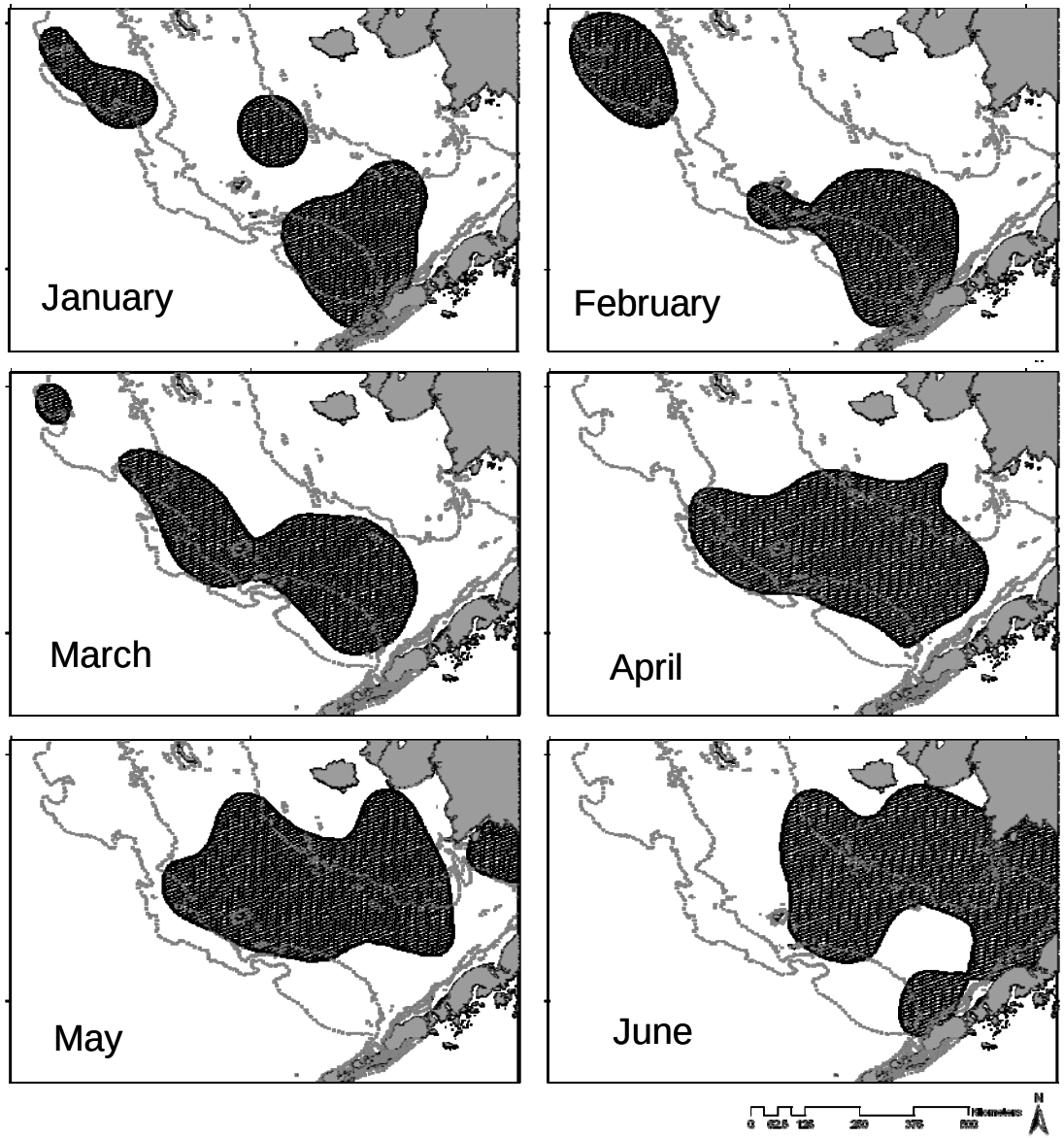


Model structures → New models

Life-history approach



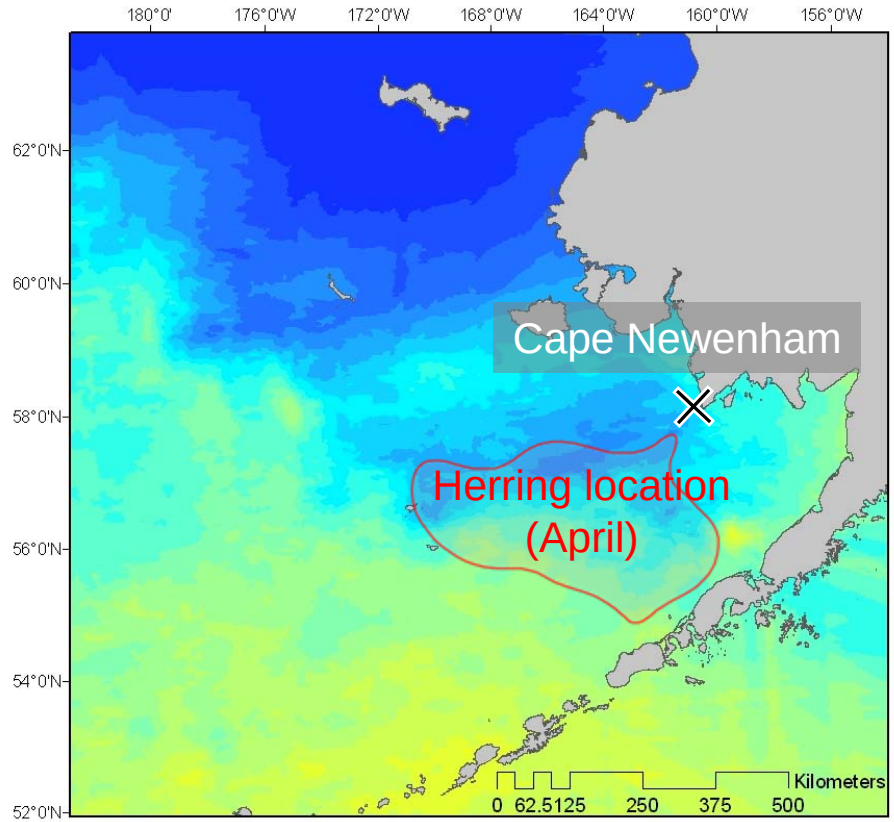
Sampling windows



See poster

Data

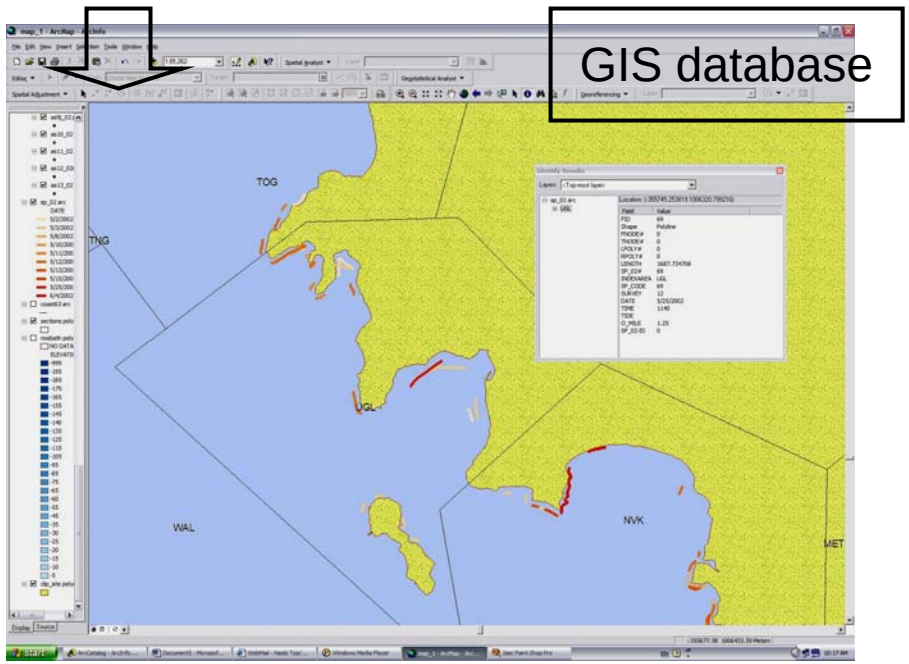
- Environmental variables (January-April)
  - Surface air temperature (SAT), Sea surface temperature (SST)
    - Comprehensive Ocean-Atmosphere Dataset (C O A D S)
    - Validated for the best estimation
  - Sea ice total concentration(Sea ice TC)
    - Joint U.S.-Russian Sea Ice Atlas (~1994)
    - Sea ice archive (National Ice Center)
  - Cape Newenham air temperature (1953-2005)



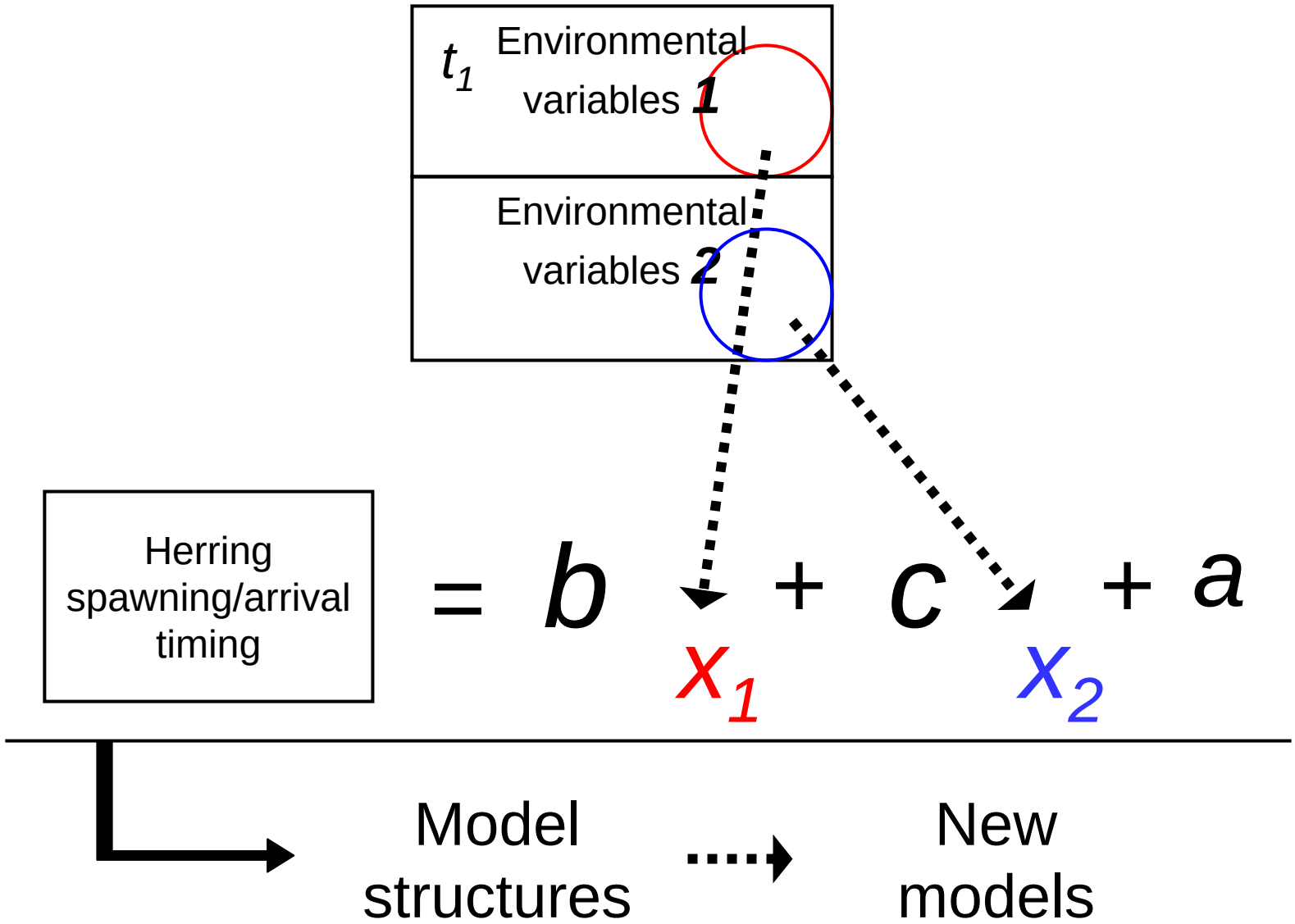
April S S T with April data sources (1976-2005)

Data

- Herring spawning/arrival timing (1978-2004)
  - ADF&G aerial survey records
    - >1.6km(1 mile) spawns (spawning day) ...GIS calculation
    - Arrival at management area (arrival day)

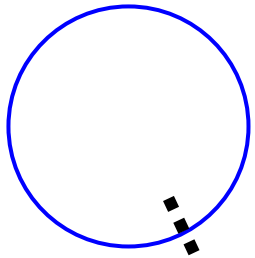


Possible combination



Possible combination

Environmental variables



Air temperature ≈ sea temperature change in spawning ground with wind effect

Herring spawning/arrival timing

$$= b\,x_1 + c\,x_{CN\ air\ temp} + a$$

Model structures → Improved models

Selection of the best combination

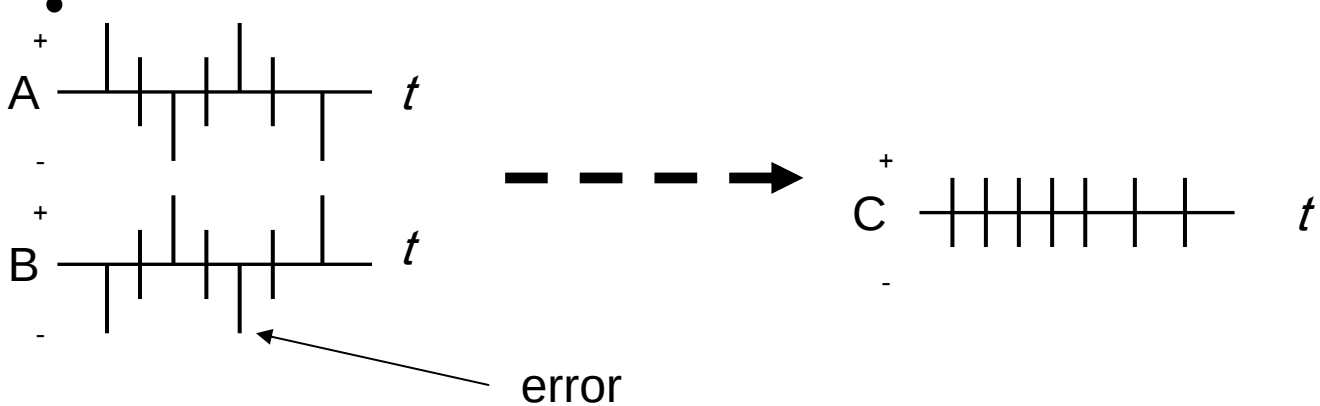
Draft modeling
- Stepwise regression
- Analyses for <u>each variables</u> vs. spawning
- Leave-one-off cross validation

(A) Significance
(B) RMS of error
(C) Error patterns in time series

→ **Candidate models** →

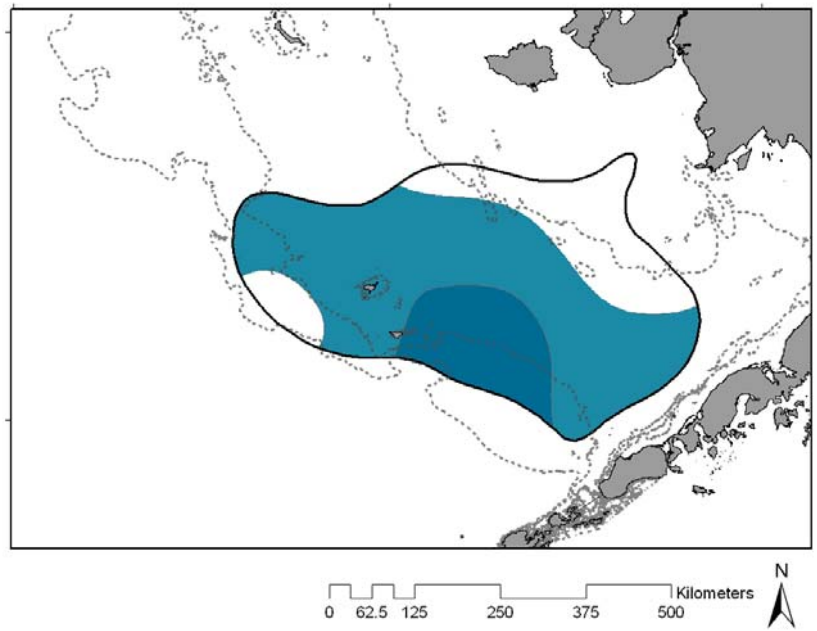
Model selection
(1) AIC
(2) Cross Validation

<u>Best models (structures)</u>

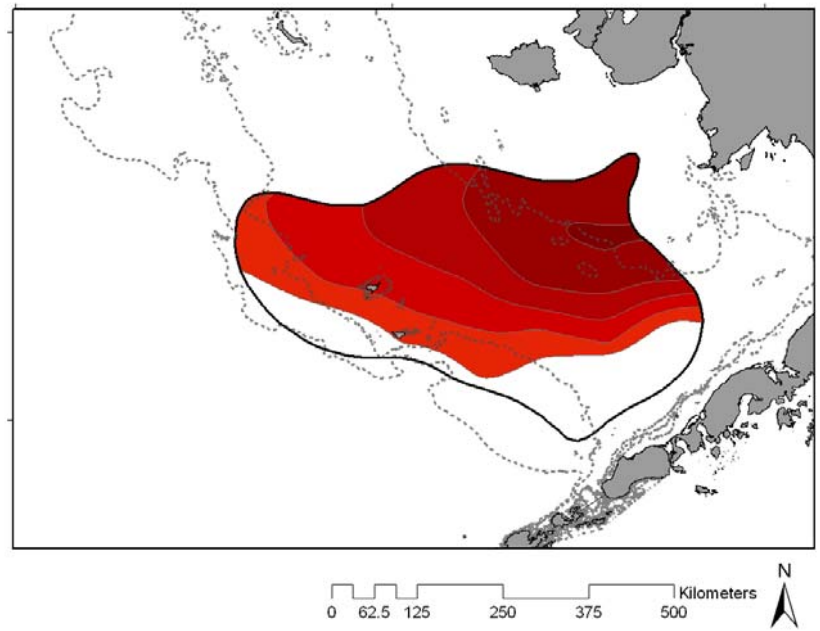


Results (correlation)

Spawning day vs. April SST



Spawning day vs. April sea ice TC



-1 0 1

Correlation (*r*)

…(Only the significant (*P* <0.05) correlation is colored)

Results (draft modeling)

Spawning day prediction

Air-sea-ice variables	r^2	$Month_1$	P_1	$Month_2$	P_2	Intercept
Cape Newenham SAT	0.59	April	<0.01	March	0.02	118
COADS SAT	0.48	April	<0.01	January	0.03	133
COADS SST	0.23	April	0.02			135
sea ice TC	0.69	April	<0.01	March	0.03	118

all…*n* >25, *P*<0.01

Results (draft modeling)

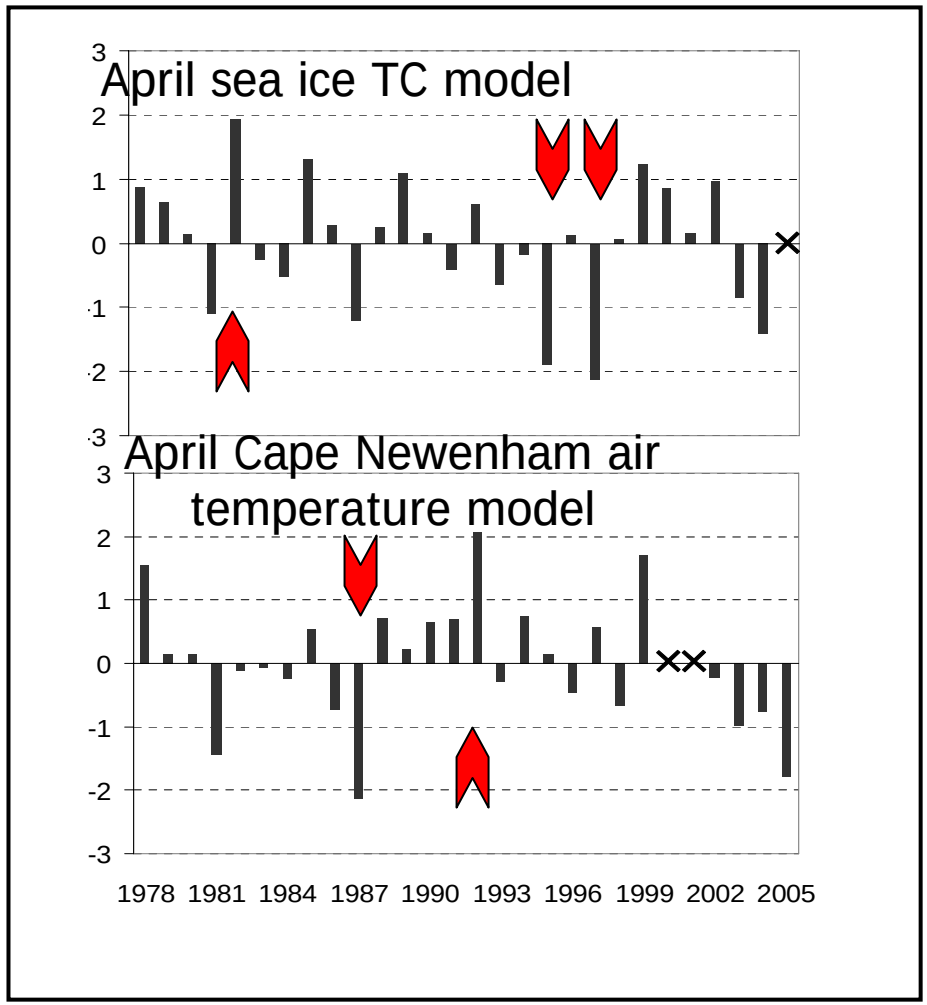
Arrival day prediction

Air-sea-ice variables	r^2	$Month_1$	P_1	$Month_2$	P_2	Intercept
Cape Newenham SAT	0.45	April	<0.01			119
COADS SAT	0.45	April	<0.01	January	0.02	129
COADS SST	0.19	April	0.03			130
sea ice TC	0.60	April	<0.01	March	0.05	114

all…*n* >25, *P*<0.01

Validation (draft models)

- April variable was always significant
- RMS errors are less with:
  - Sea ice total concentration
  - Cape Newenham air temperature



The selected model

a. Spawning date

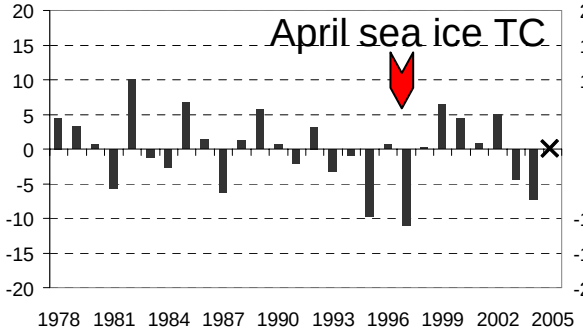
Model	AICc	Δi	r^2	$f(x)$
SP 1	126.5	0.0	0.79	$y = 24.79x_{\text{sea ice TC in April}} - 5.36x_{\text{sea ice TC in March}} - 1.17x_{\text{Cape Newenham SAT in April}} + 118.14$
SP 2	127.5	1.0	0.75	$y = 20.49x_{\text{sea ice TC in April}} - 1.37x_{\text{Cape Newenham SAT in April}} + 117.46$

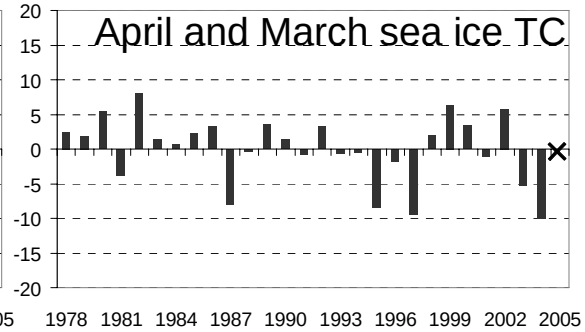
b. Arrival date

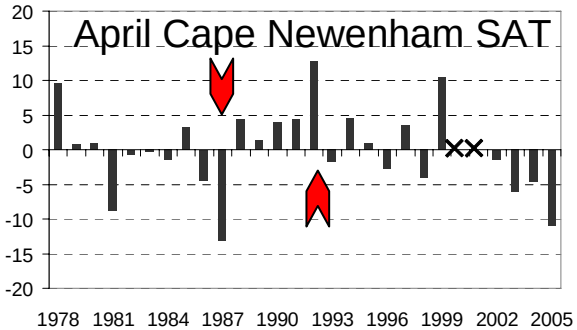
Model	AICc	Δi	r^2	$f(x)$
AR 1	128.0	0.0	0.75	$y = 22.54x_{\text{sea ice TC in April}} - 7.05x_{\text{sea ice TC in March}} - 1.12x_{\text{Cape Newenham SAT in April}} + 116.17$

…*n* =25, *P*<0.01

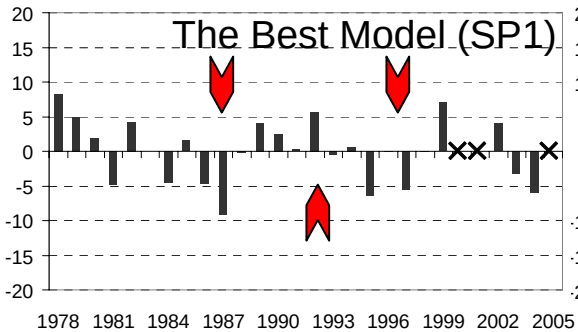
Validation (spawning)

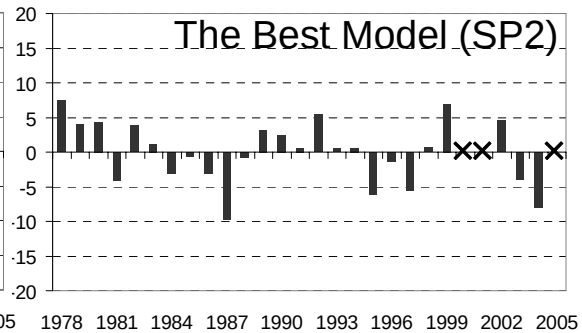




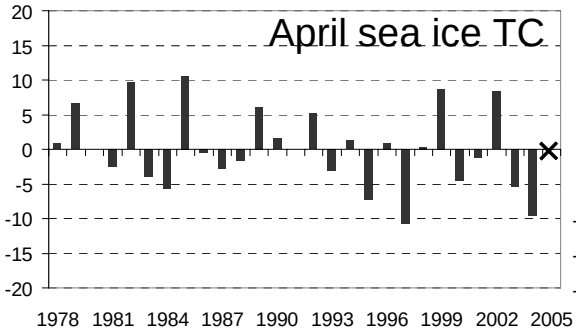


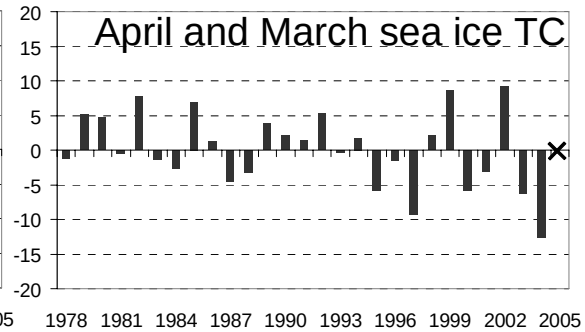
…examples (1987,1992,1997)

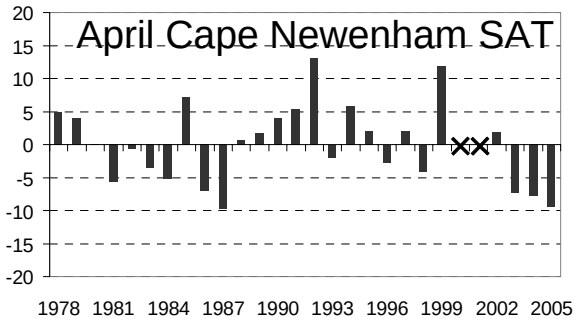


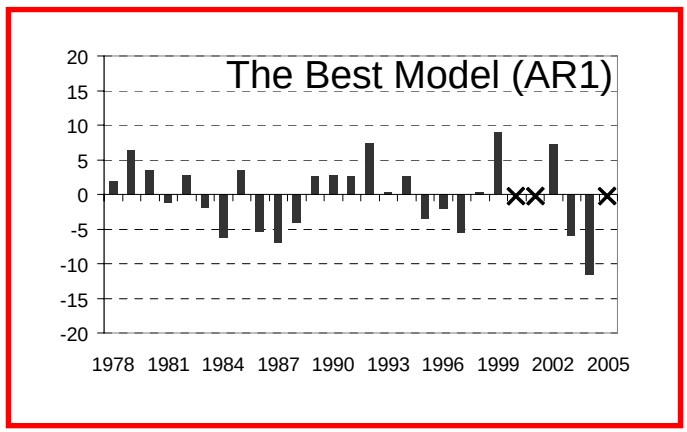


Validation (arrival)

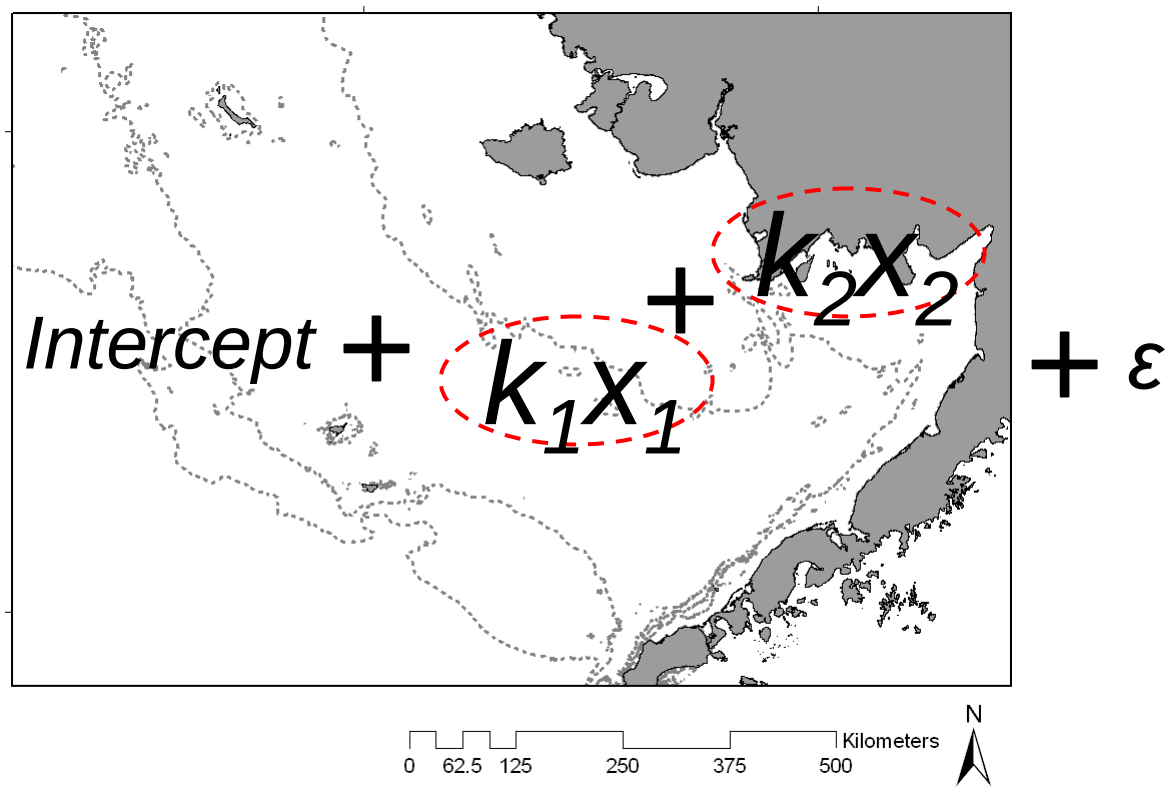








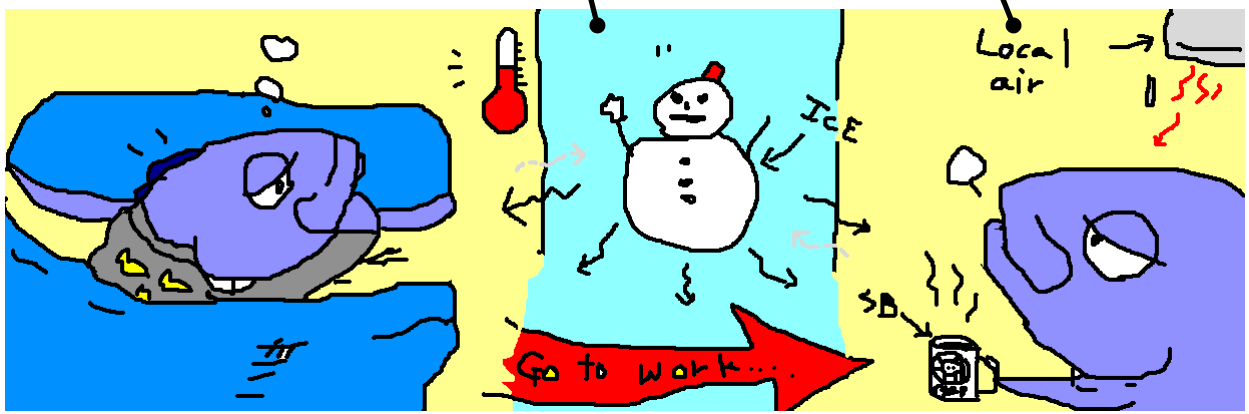
Discussion



- April thermal dynamics at pre-spawning migration passage and coastal pre-spawning habitat

Discussion

$$Intercept + k_1x_1 + k_2x_2 + \varepsilon$$



Then spawn

Wanna' move?

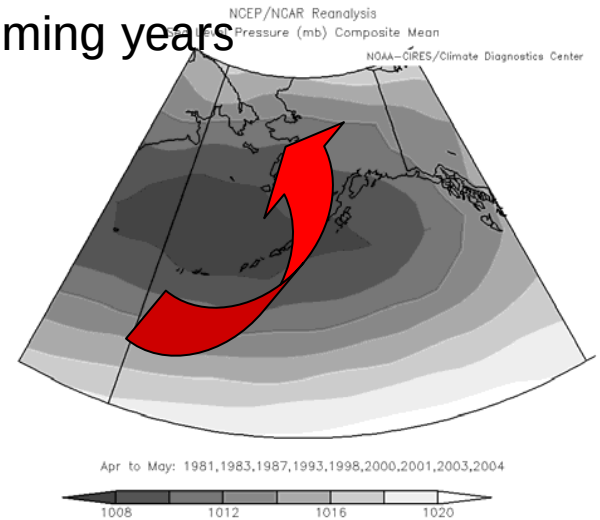
Wanna' work?

- Pre-spawning herring response to environment is spatio-temporally unique depending on years

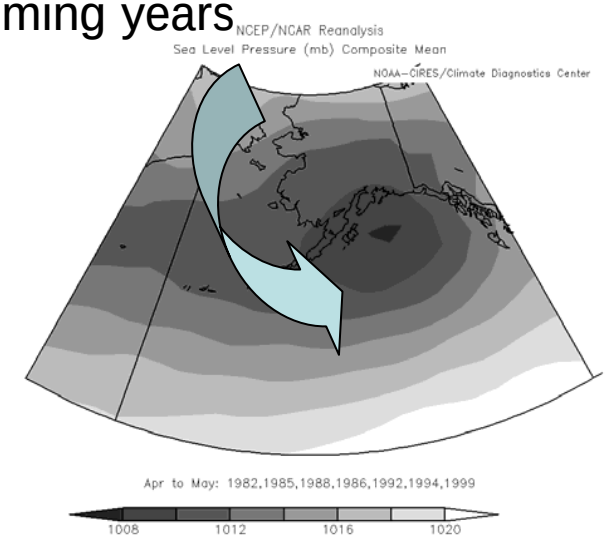
Discussion

- Atmospheric gradients effects to southeastern Bering Sea in April
- Future changes of climate
  - Herring brings the messages of the sea and air

Early timing years

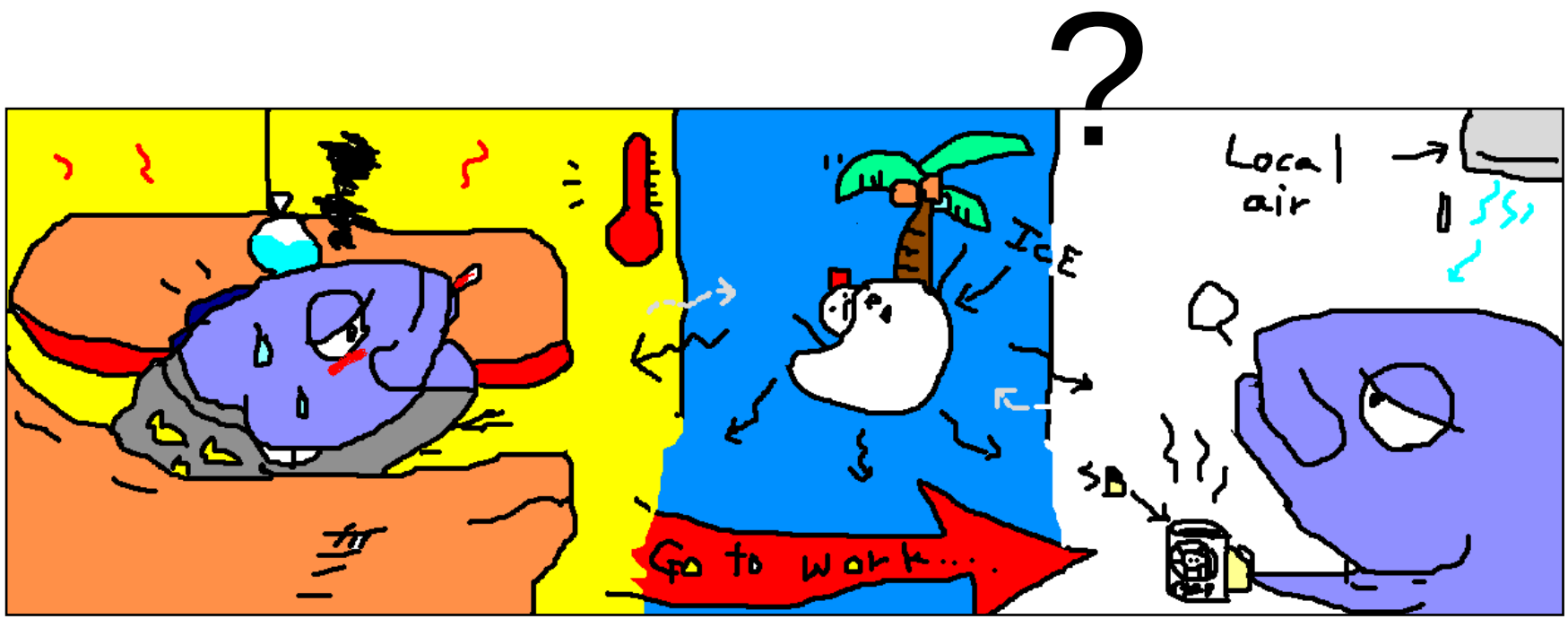


Late timing years



Right: Sea surface level pressure comparisons

For future?

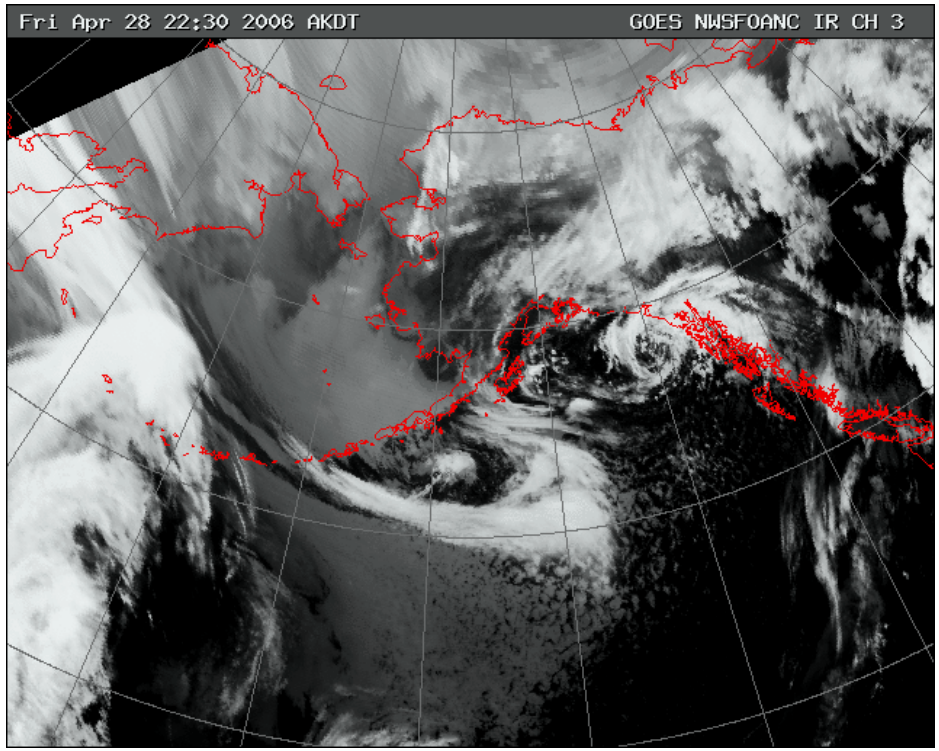


- For example, shifting the spawning location? Or…!?
- What can we share? Imaginations?

For future

(1) Various spatially and temporally specific scenario →<u>simulation</u> (with validations)

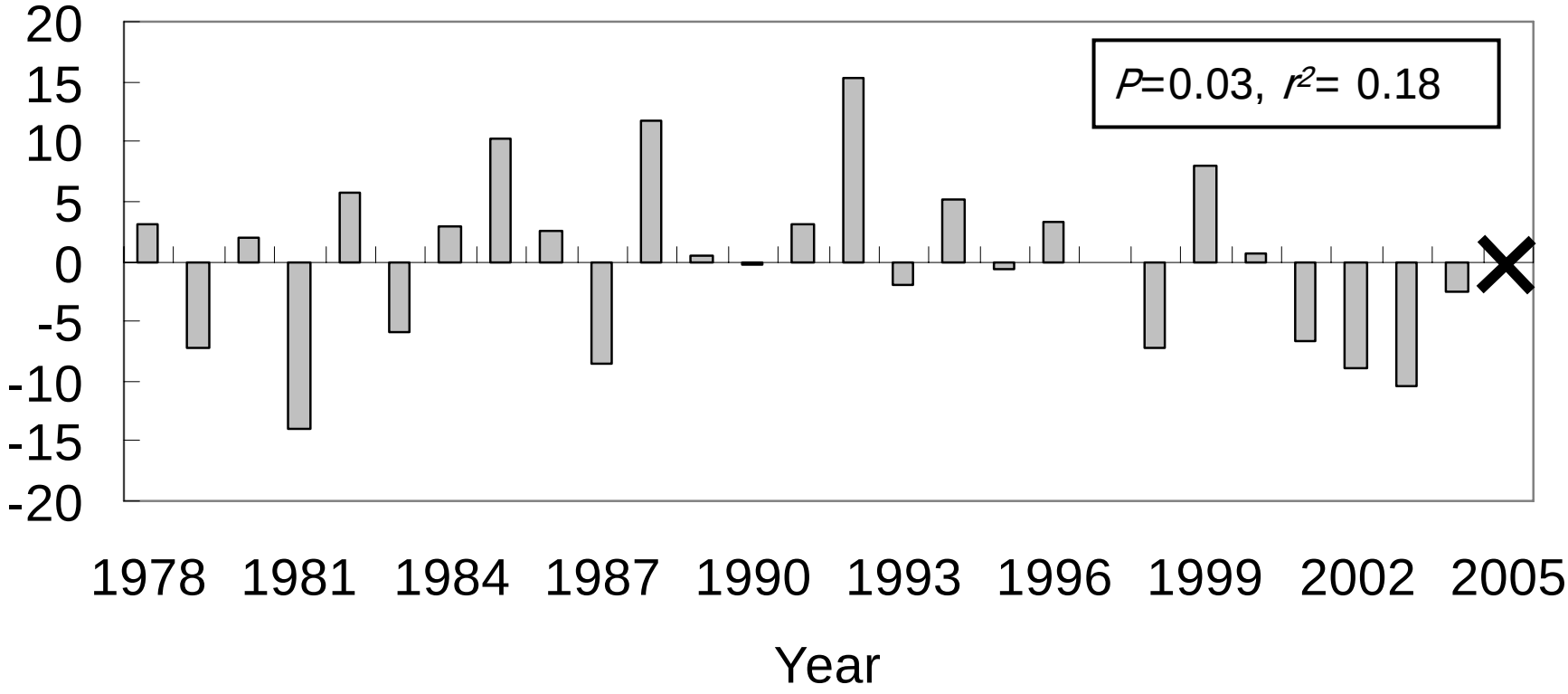
(2) Spatially and temporally explicit designs in field



Extreme changes in finer temporal resolution in 2006 season was brought by strong Siberian high-pressure system in April

Thank you

Example: Residuals from NPI (April) model



Intensity = scientifically informative, but not really useful