case study of the Gulf of St. Lawrence Atlantic halibut

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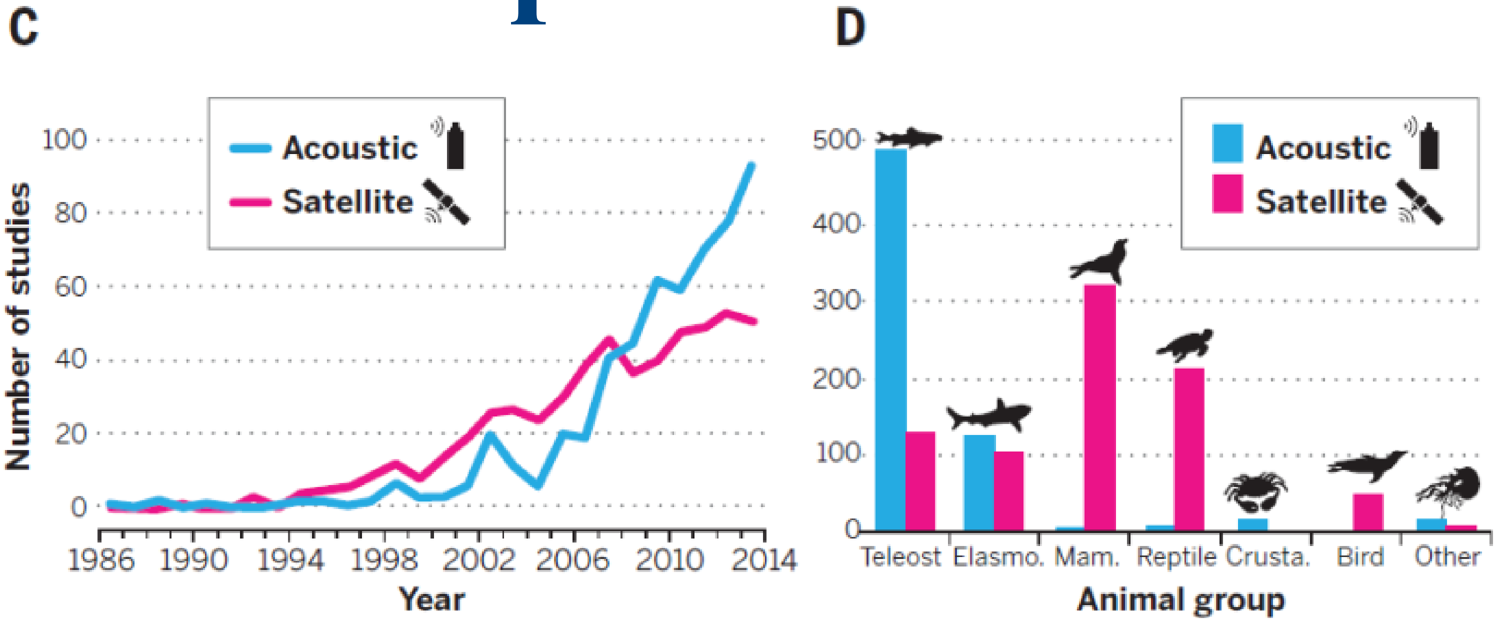
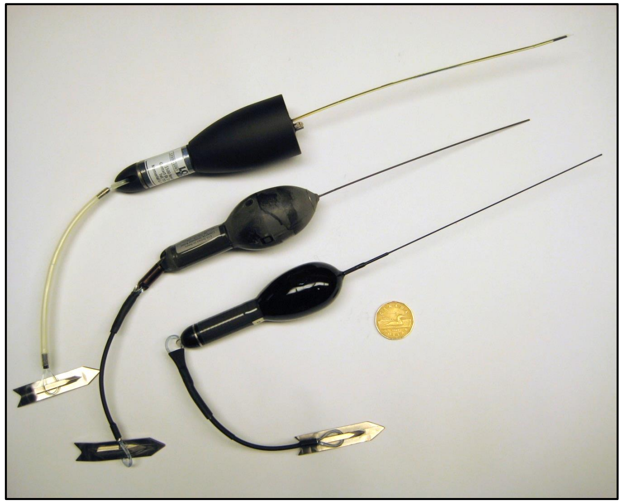
Marine species biotelemetry



Aquatic animal telemetry: A panoramic window into the underwater world

Hussey et al. 2015 Science, 348



<u>Acoustic tags</u>

- Provide direct position when individuals are in proximity of receivers
- Usually smaller spatial scale (10-100kms)
- Do not log / archive environmental data

<u>Archival tags for fish: pop-up satellite tags (PSAT) and data-storage tags (DST)</u>

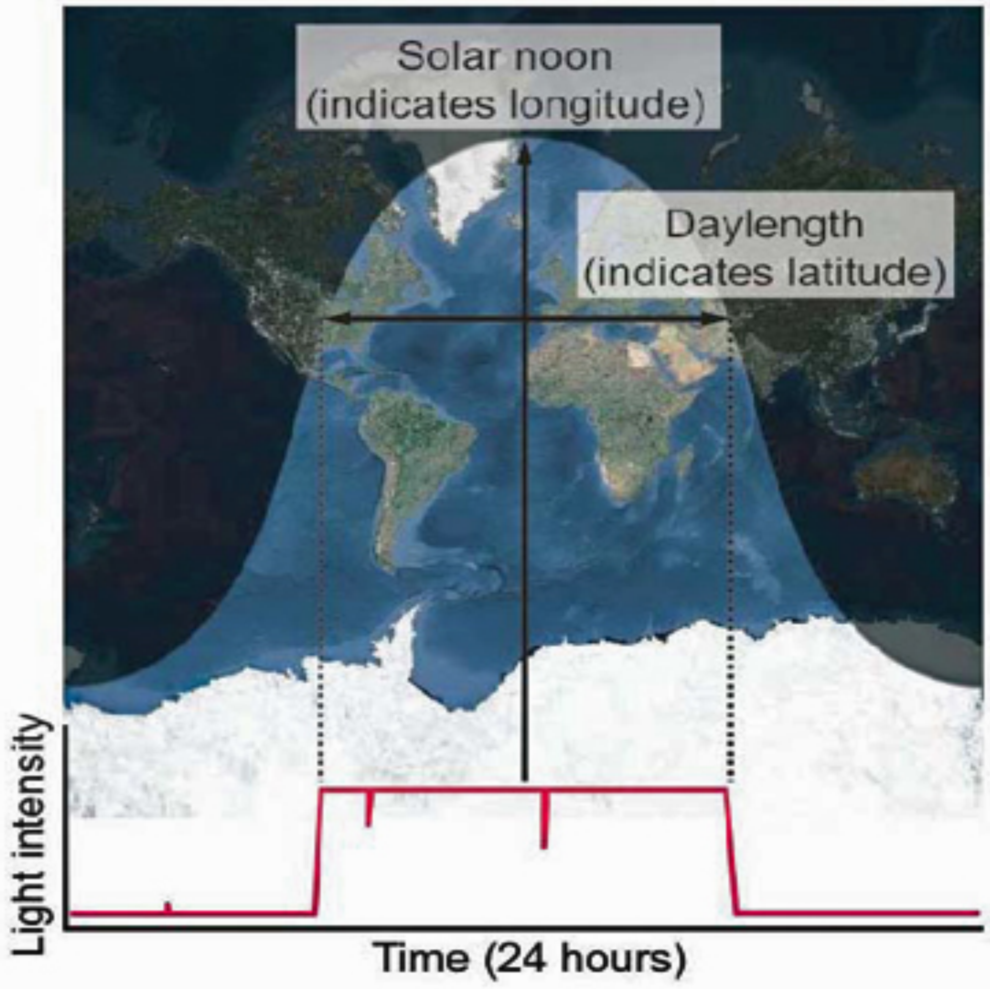
- Provide only tagging and recapture / pop-up locations

Geolocation problem for flatfish when using satellite / archival tags

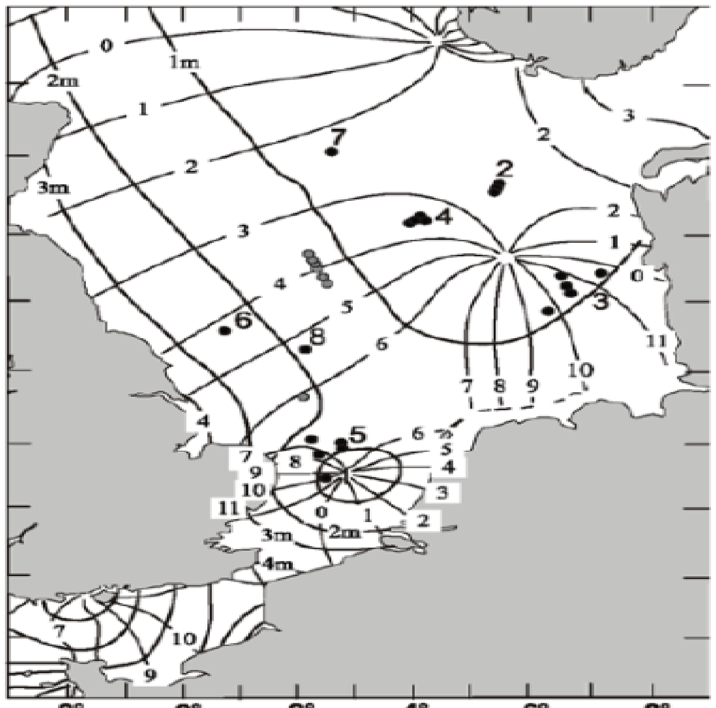
- For pelagic fish equipped with PSATs, positions are inferred from light intensity
- Geolocation problem for flatfish:

- Often distributed too deep to obtain reliable light intensity

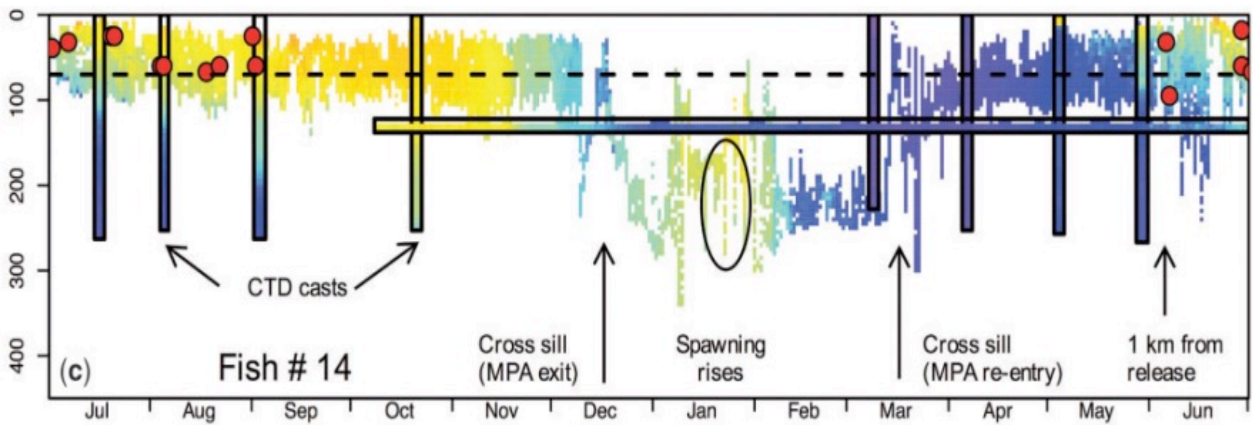
→Positions need to be inferred from recorded depth and temperature data (sometimes salinity)



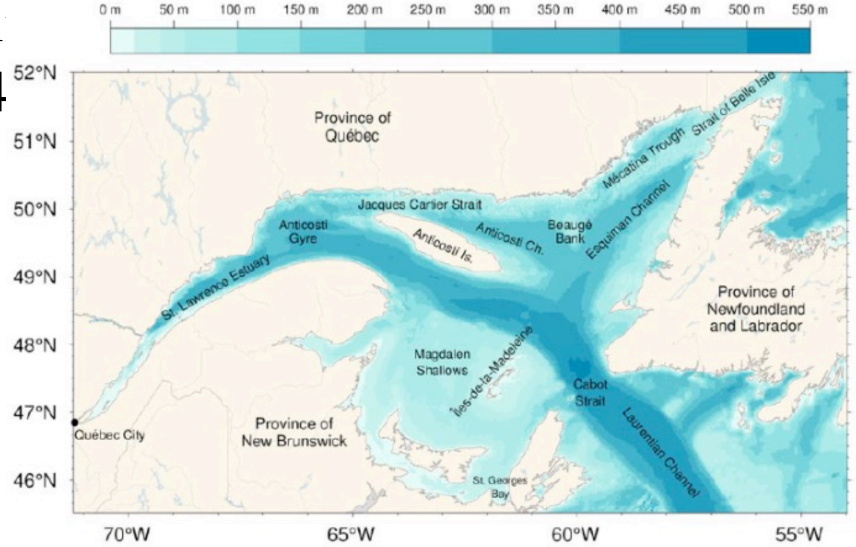
Region specific solutions to flatfish geolocation



North Sea - Tidal location method - plaice
Hunter et al. 2003. Mar. Biol. 142: 601-609



Glacier National Park, Alaska – Comparison with CTD casts.
Pacific hal
2120-2134



Gulf of St. Lawrence – Bathymetry and bottom temperature. Atlantic halibut - Le Bris et al. 201

Compare environmental data (depth, temperature, salinity) recorded by tags with regional oceanographic characteristics to infer individual position

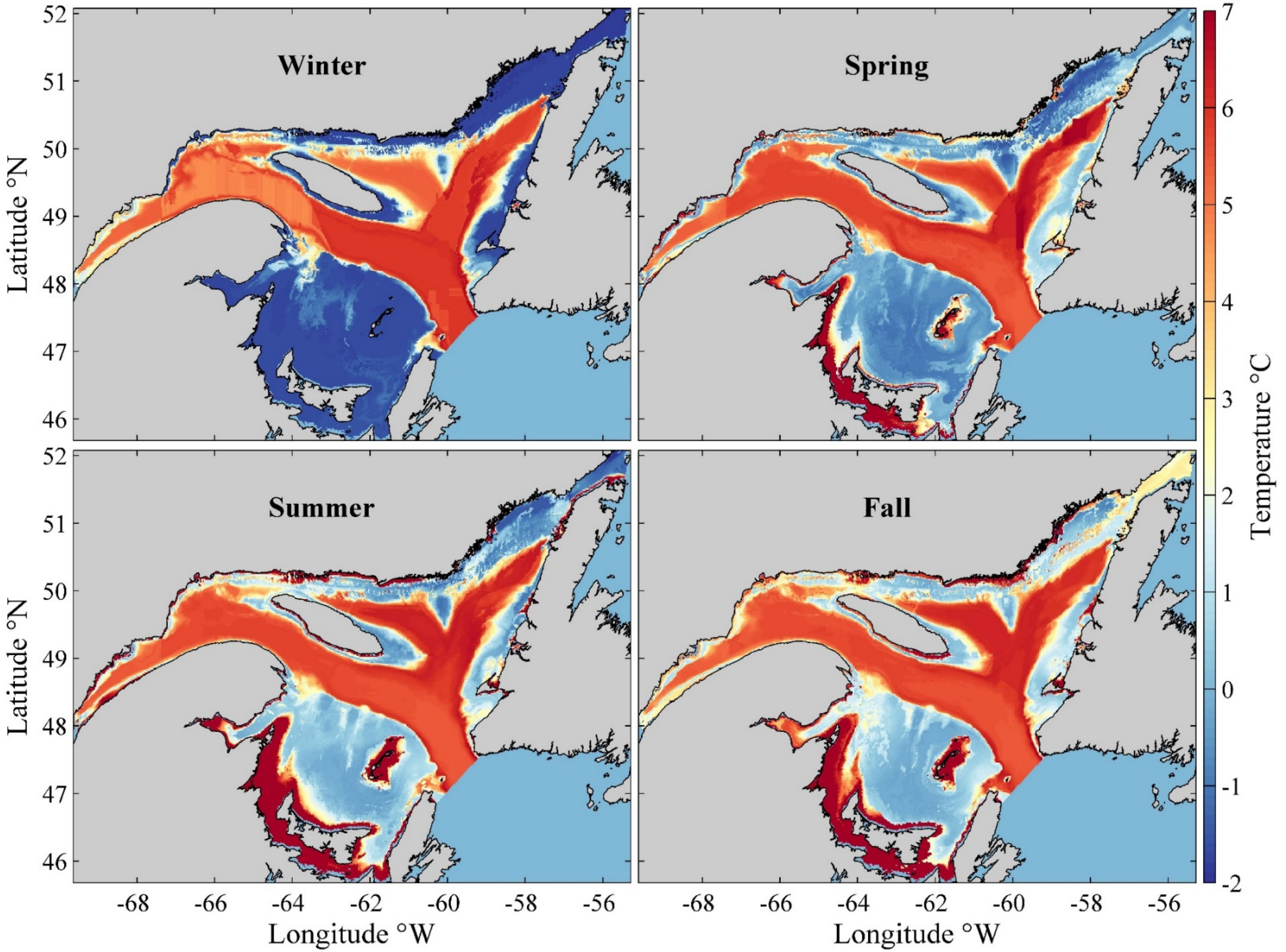
Gulf of St. Lawrence oceanographic characteristics

Very low tidal amplitude <1m

Strong gradients in bathymetry and bottom temperatures

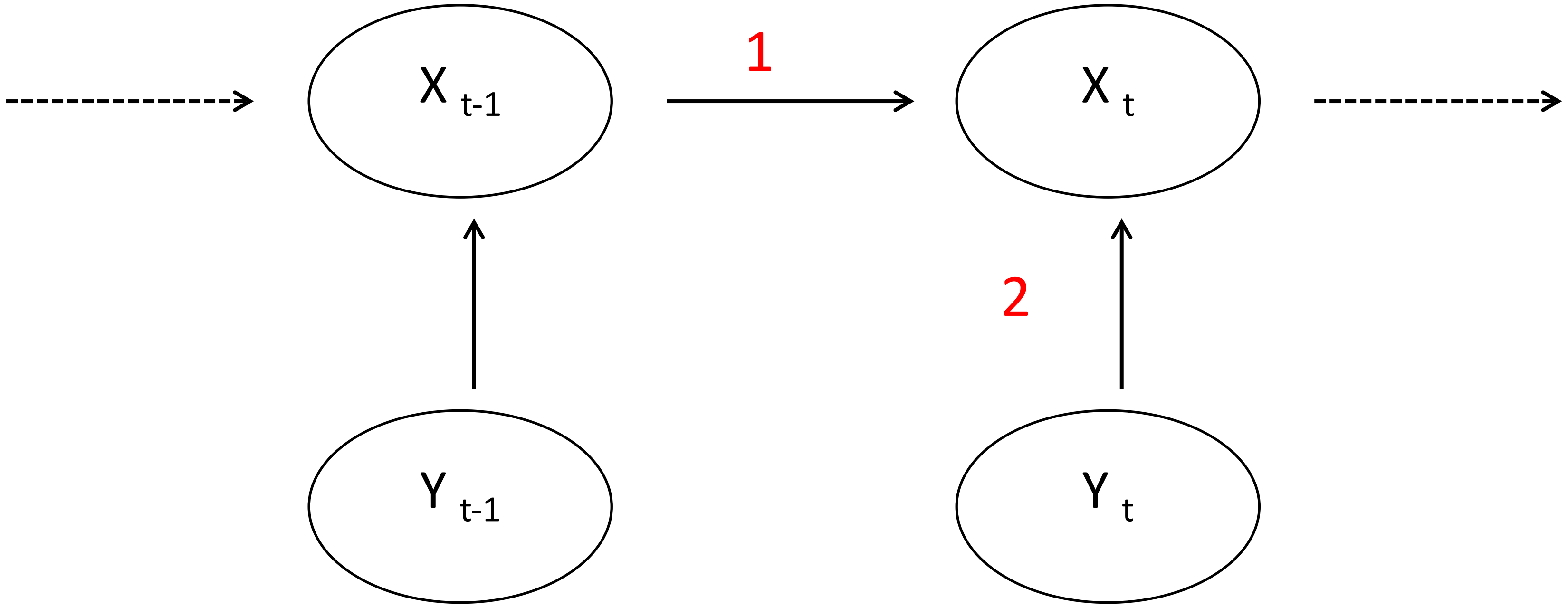
Assumptions: halibut is distributed at least once a day at the bottom.

Daily maximum depth recorded by tag corresponds to bottom and the associated temperature corresponds to bottom



Hidden Markov model (Pedersen et al. 2008. CJFAS 65:2367-2377)

- Separation of the movement process from the observation process
- Discrete time and state

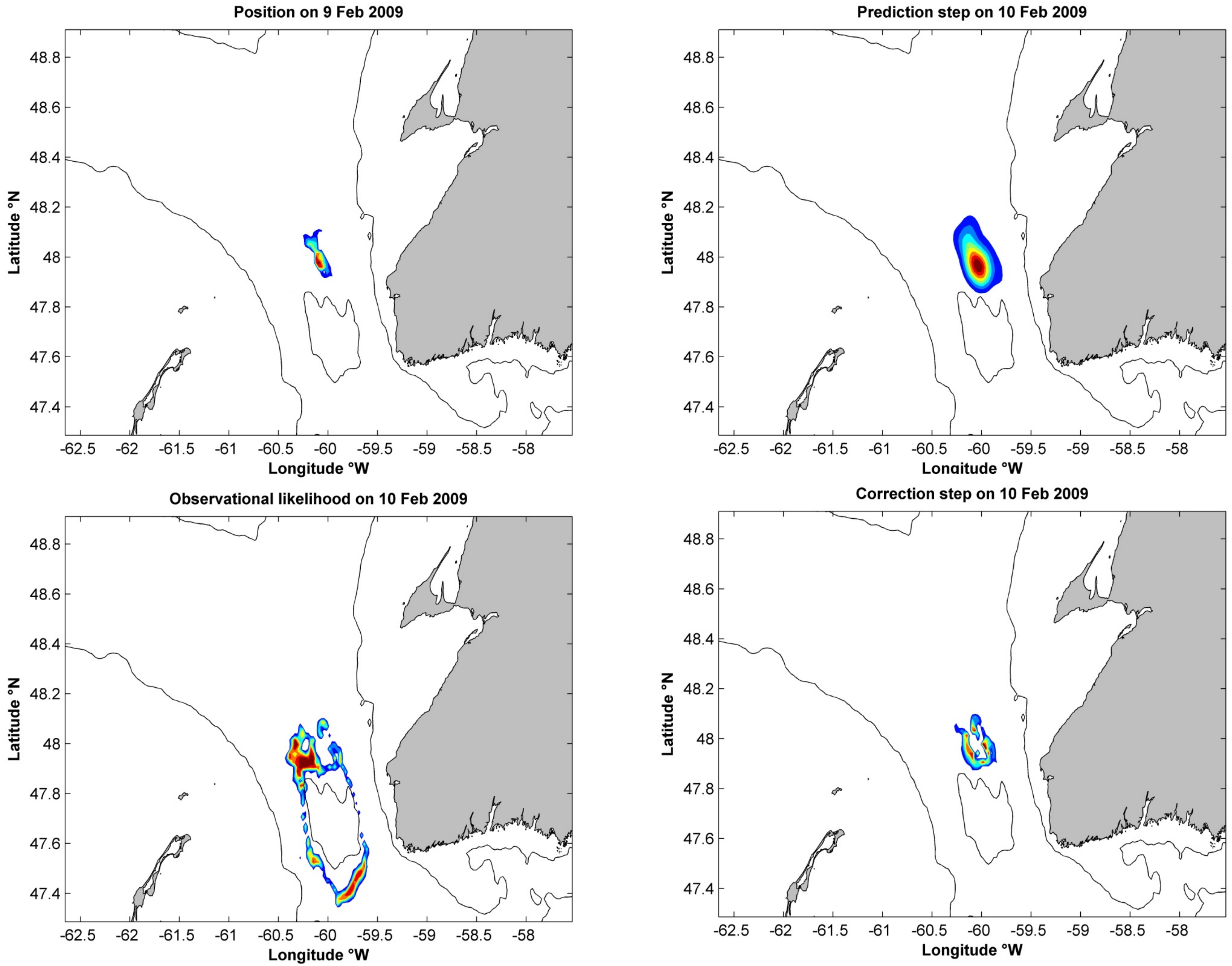


X_t: unknown fish position at time t (hidden state)

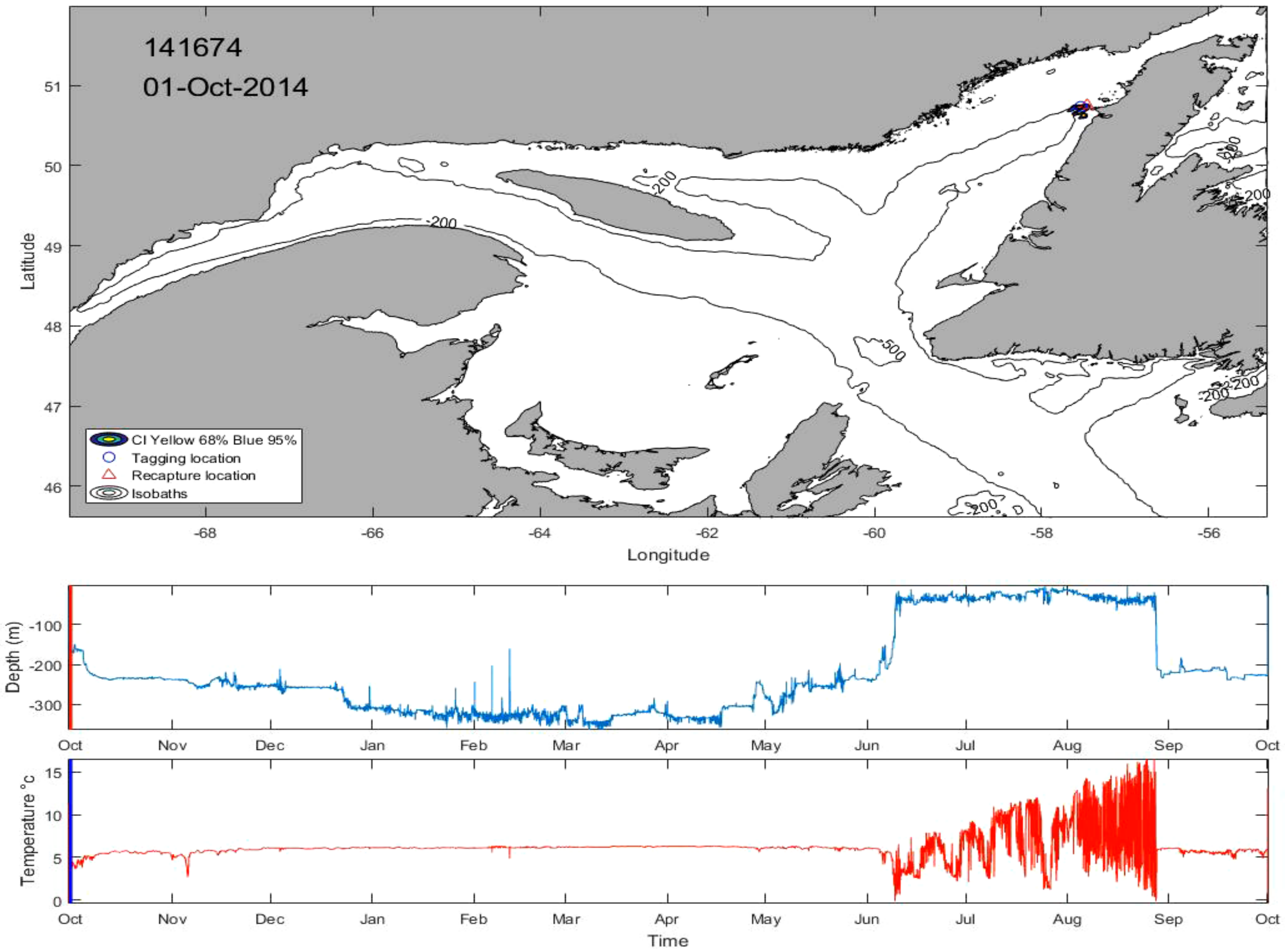
Y_t: observation at time t (depth and temperature data)

1: movement function: diffusion equation $\frac{\partial \emptyset(\boldsymbol{x},t)}{\partial t} = D\left(\frac{\partial^2 \emptyset(\boldsymbol{x},t)}{\partial x^2} + \frac{\partial^2 \emptyset(\boldsymbol{x},t)}{\partial y^2}\right)$

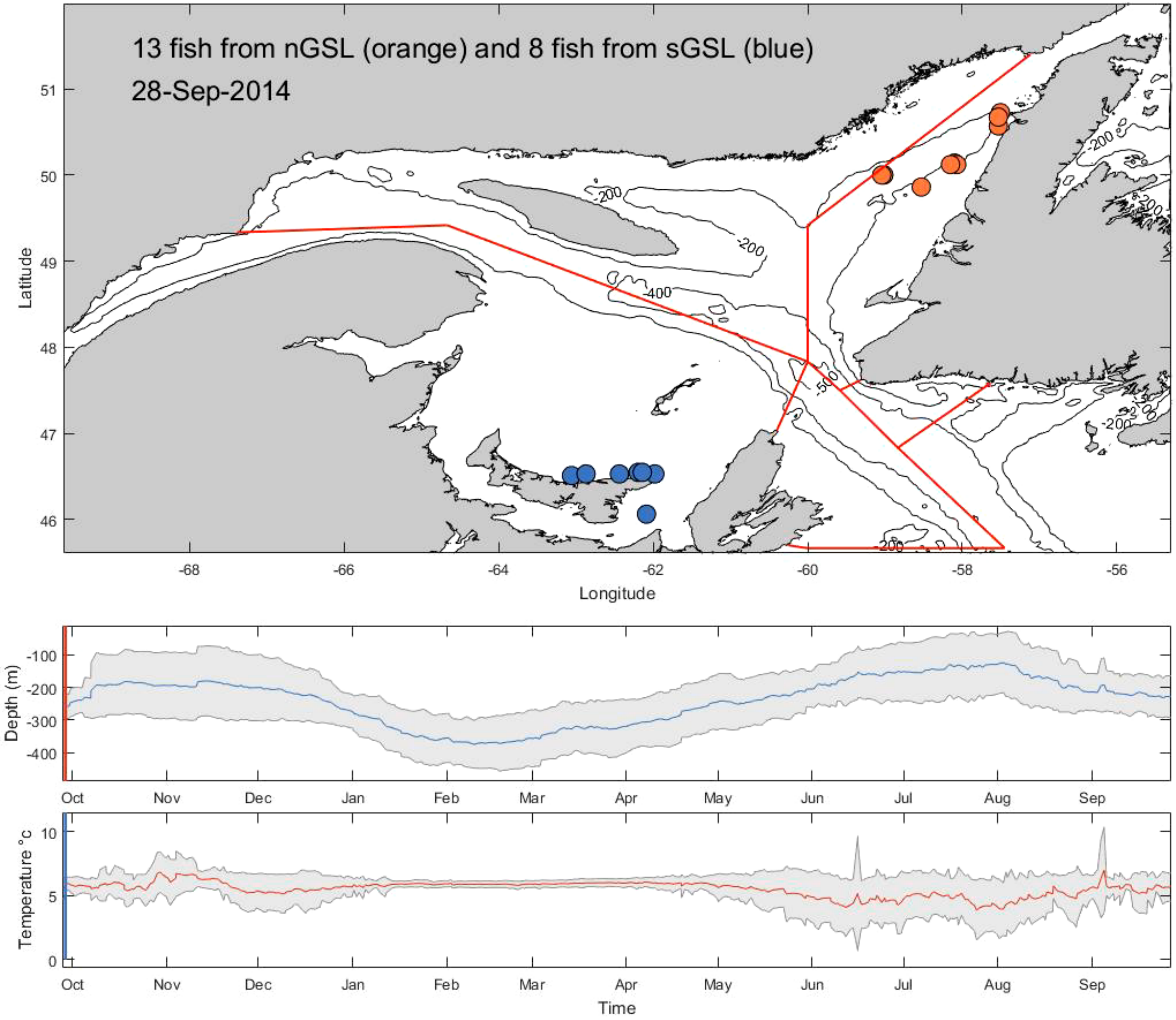
2: observation function: $L(z, tp|\boldsymbol{x}) = \int_{z-\Delta z}^{z+\Delta z} N(z;\ \mu_z(\boldsymbol{x}), \sigma_z(\boldsymbol{x}))\ .\int_{tp-\Delta tp}^{tp+\Delta tp} N\big(tp;\ \mu_{tp}(\boldsymbol{x}), \sigma_{tp}(\boldsymbol{x})\big)$



Position on 9 Feb 2009
Prediction step on 10 Feb 2009
Observational likelihood on 10 Feb 2009
Correction step on 10 Feb 2009
Latitude °N
Longitude °W
48.8
48.6
48.4
48.2
48
47.8
47.6
47.4
-62.5
-62
-61.5
-61
-60.5
-60
-59.5
-59
-58.5
-58

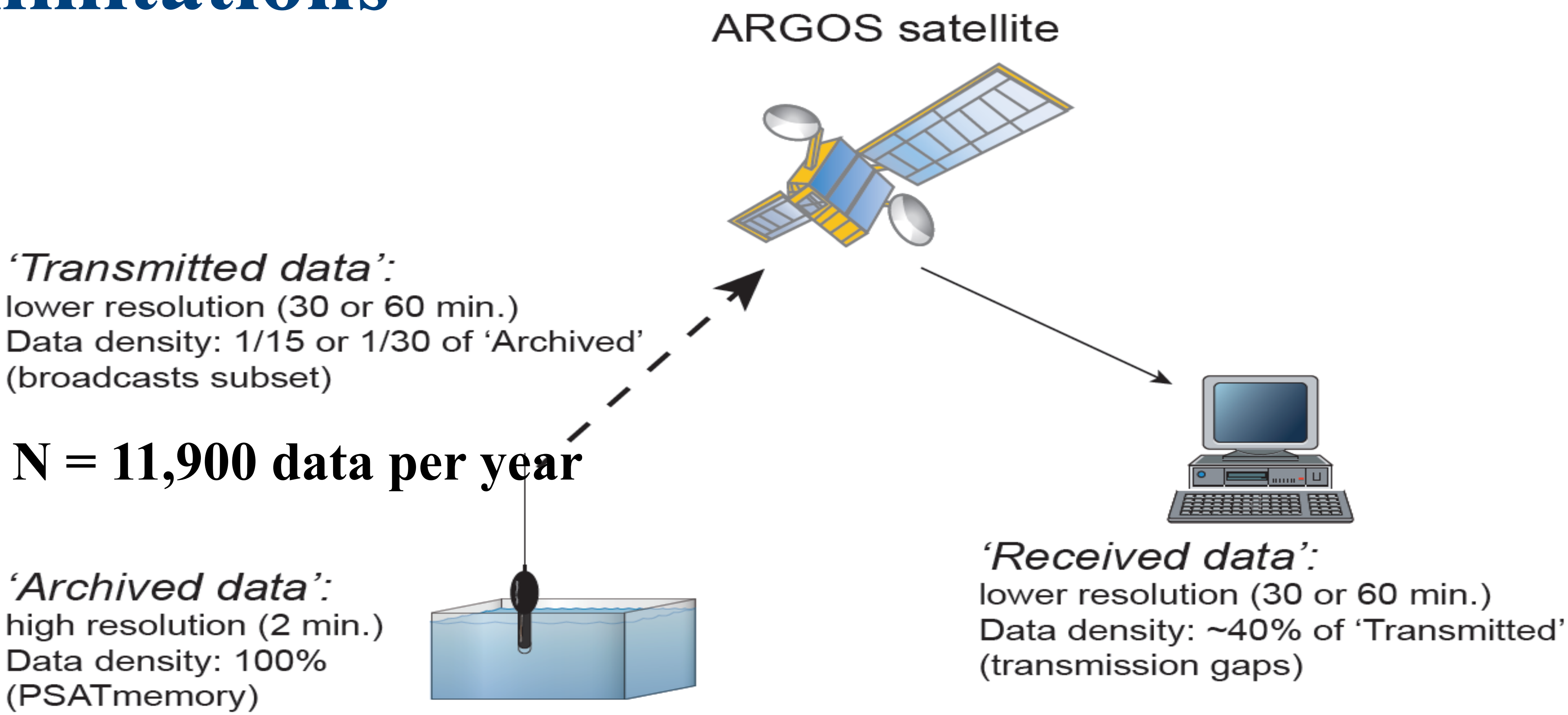


141674
01-Oct-2014
CI Yellow 68% Blue 95%
Tagging location
Recapture location
Isobaths
Latitude
Longitude
Depth (m)
Temperature °c
Time



13 fish from nGSL (orange) and 8 fish from sGSL (blue)
28-Sep-2014
Latitude
Longitude
-200
-400
-500
Depth (m)
Temperature °c
Time
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep

Pop-up satellite archival tag (PSAT) data limitations



N = 11,900 data per year

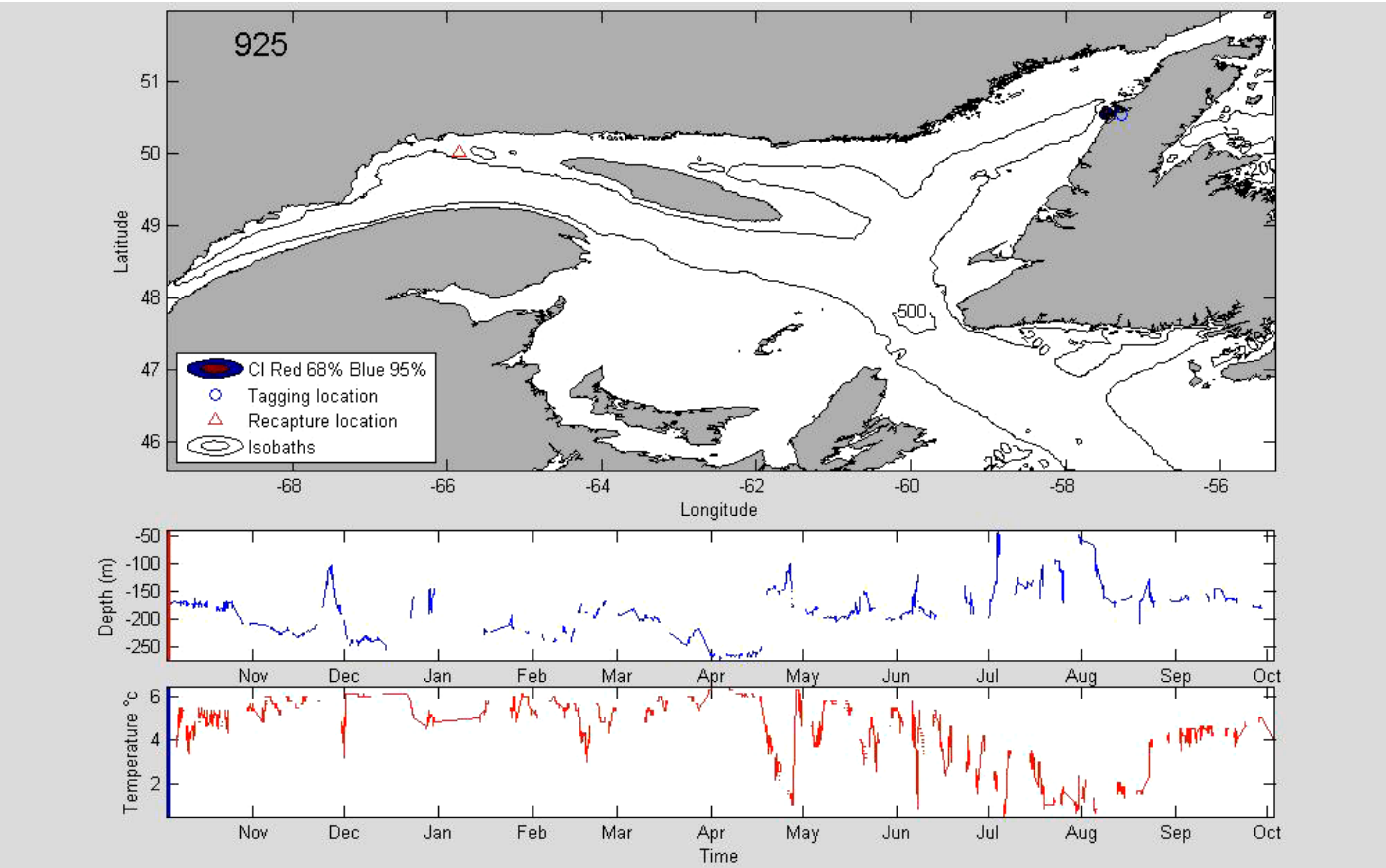
N = 263,000 data per year

N = 4,760 data per year

Tag physical recovery using a "Goniometer"

- '*angle-meter*' detects Argos signals
- Fisher et al. 2017. Animal biotelemetry, 5:21

CLS AMERICA



925
CI Red 68% Blue 95%
Tagging location
Recapture location
Isobaths
Latitude
Longitude
500
200
Depth (m)
Temperature °c
Time
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct

Geolocation model validation

3 Methods

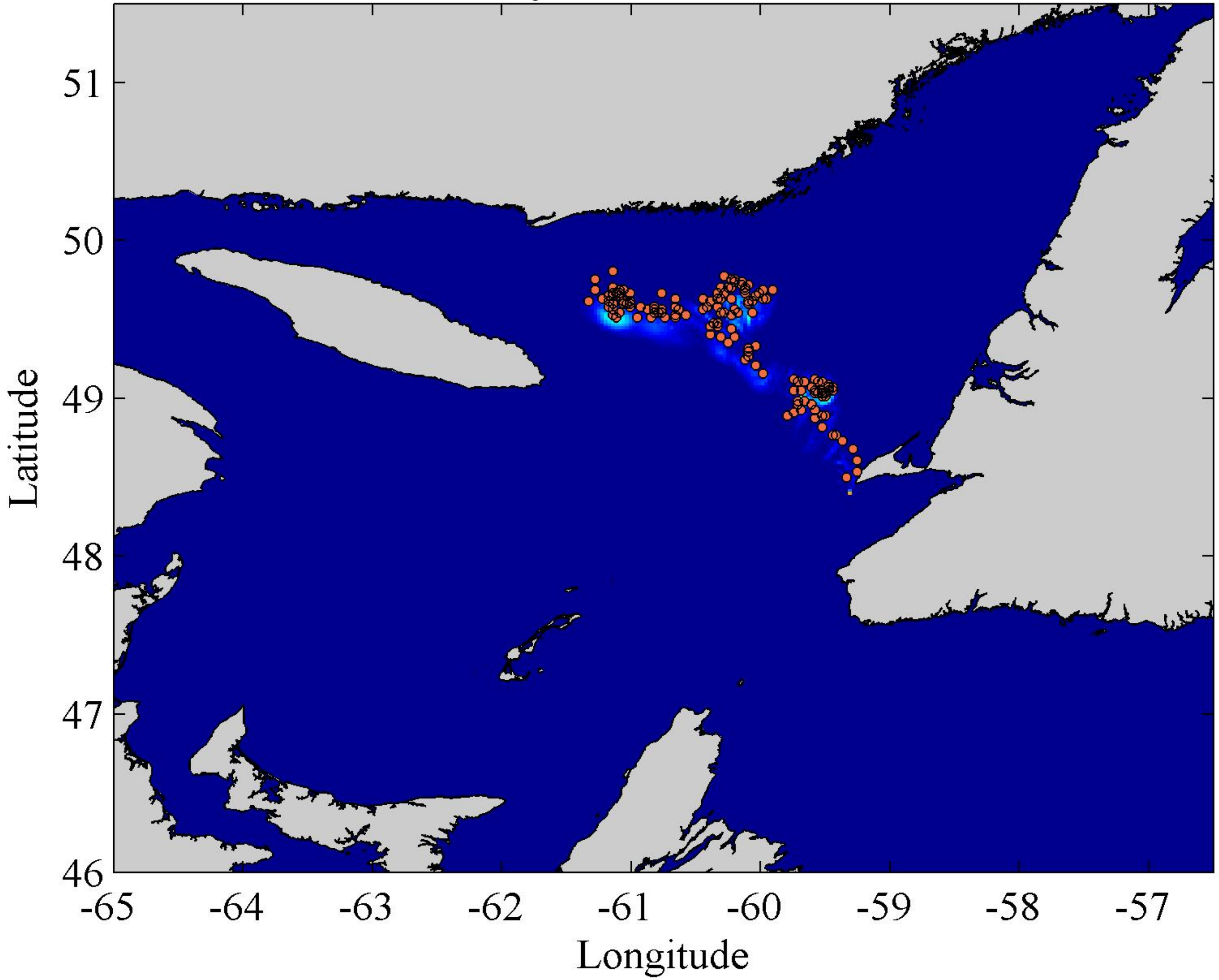
- Simulation – reconstruction of random simulated track

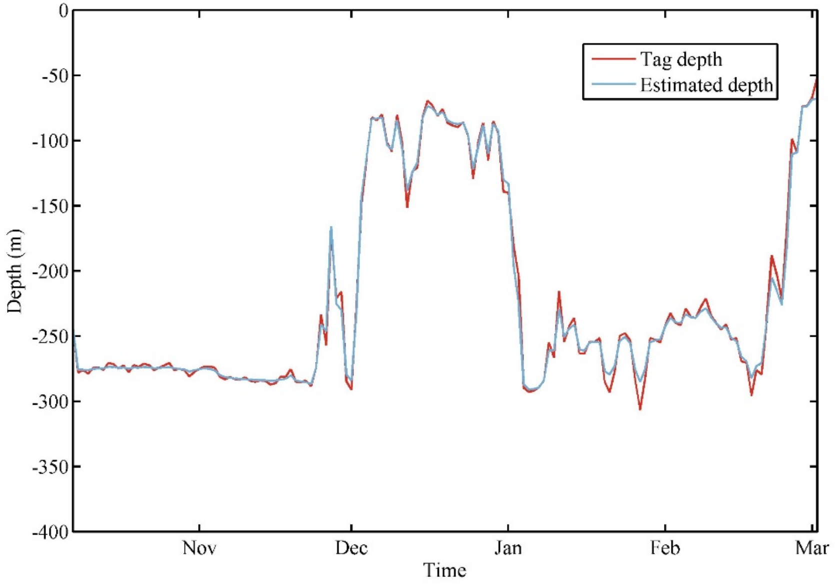
- Observation – stationary tags (known position and stationary behavior of model)

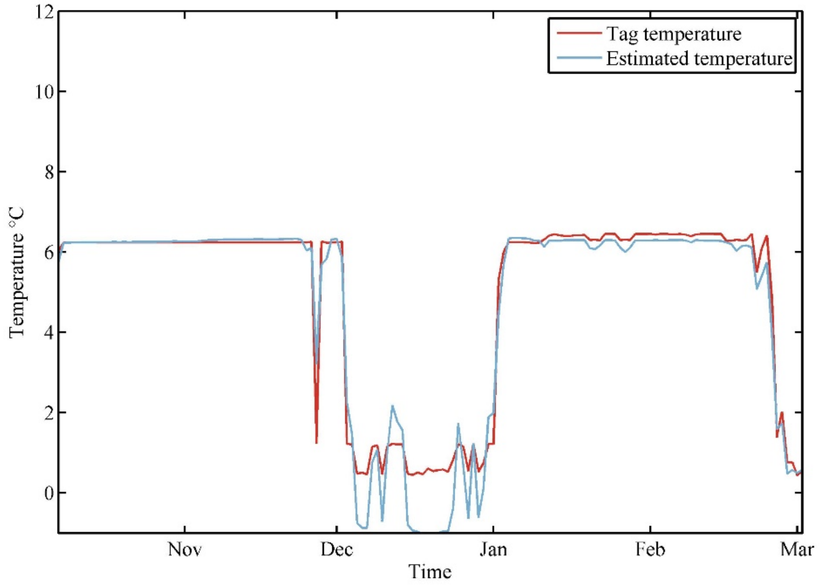
- Observation – double tags (e.g. acoustic and archival)
  - Use for instance in Gulf of Maine - Liu et al. 2017 CJFAS 74: 1862-1877

Geolocation model validation - simulations

Simulated 150 days track







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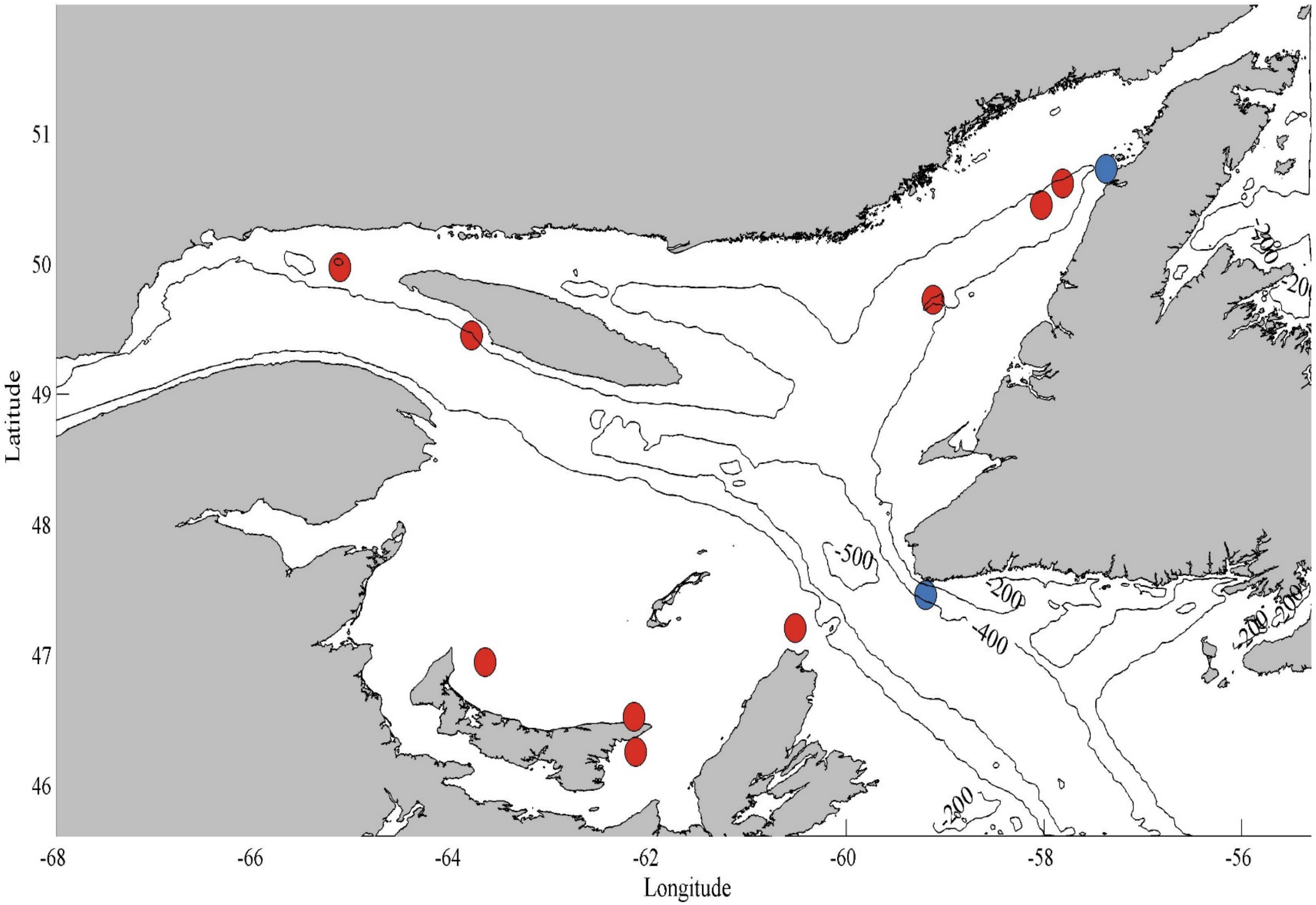
Geolocation model validation – observations

- Moored tags (2 at different locations and depths – blue dots)
- mrPAT (10 double tagged large halibut throughout the Gulf – red dots)



Conclusion

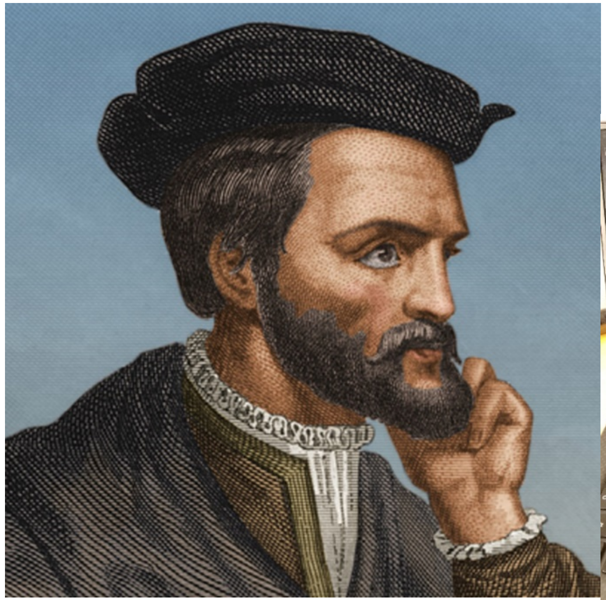
- Geolocation of flatfish is region specific
- Need for in depth geolocation model validation
- When possible, the physical recovery of PSAT greatly improves geolocation estimates

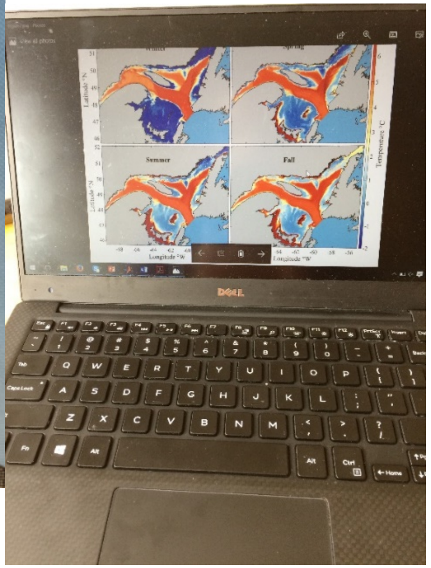
Advertisement

- Fully funded 2-year postdoctoral position

available to work on halibut movement modeling

- www.arnaultlebris.com/PostDoc_MovementModeling.pdf





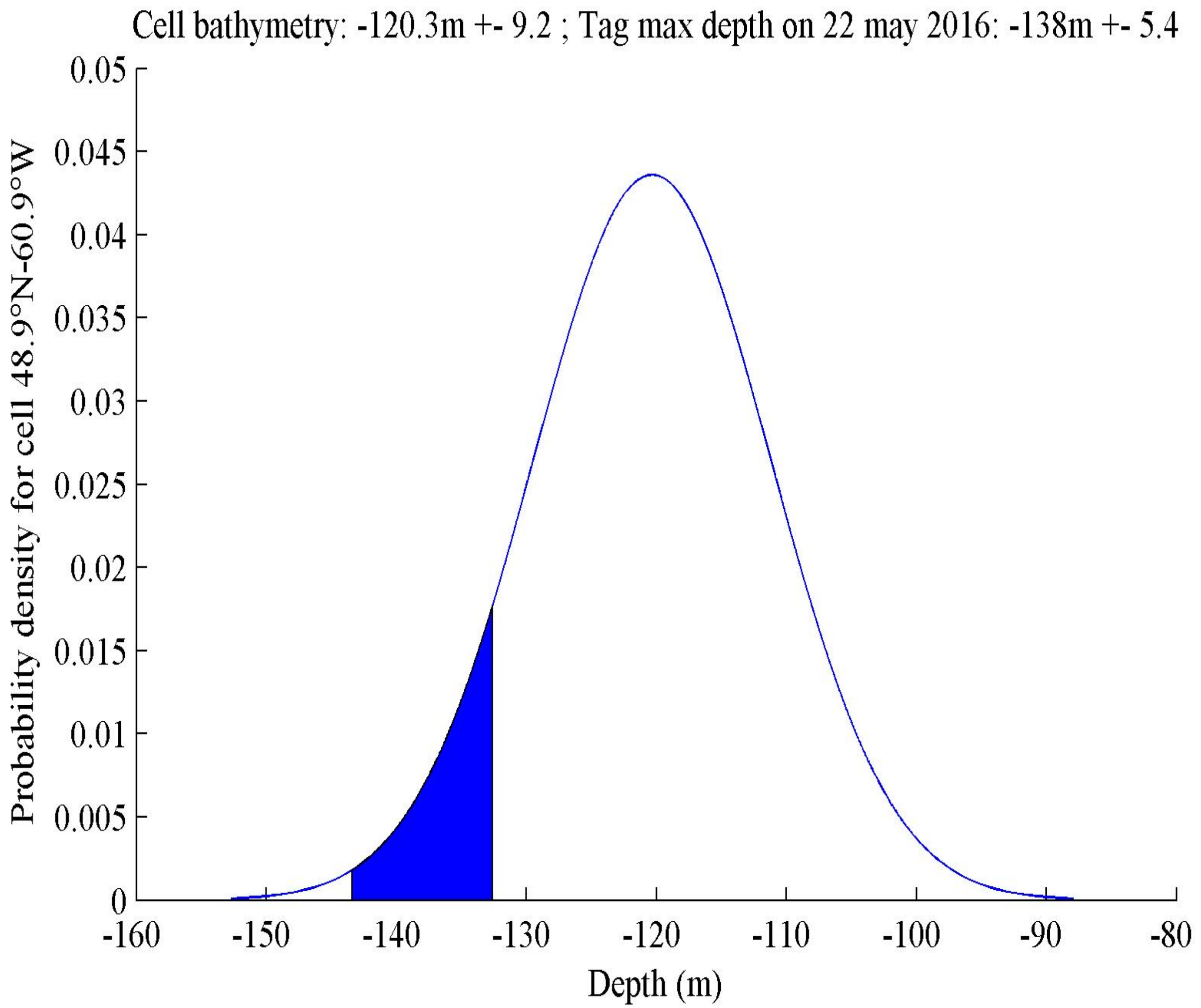
arnault.lebris@mi.mun.ca

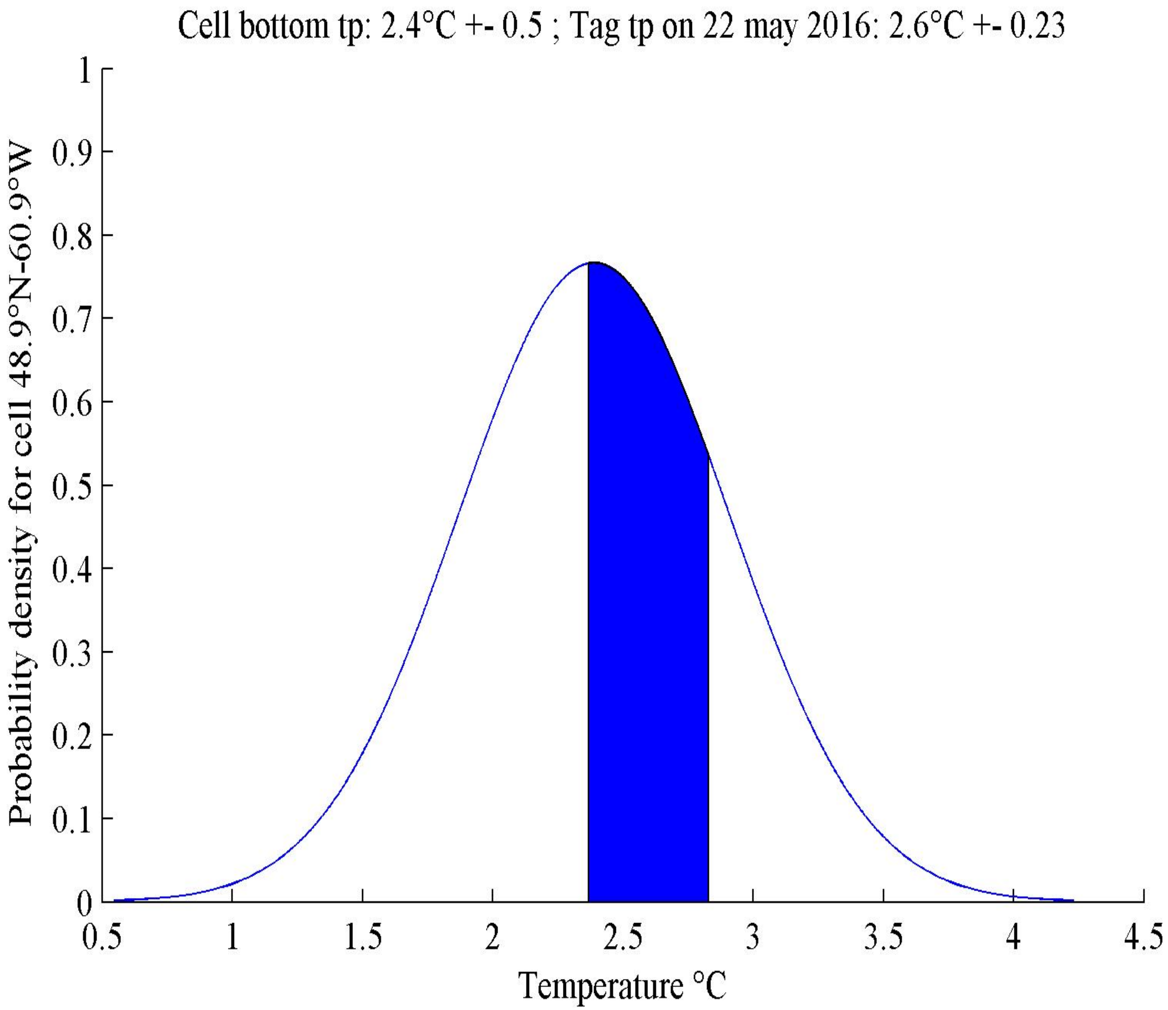
Entract


JACQUES CARTIER'S
VOYAGES TO CANADA
1534 - 42
Statute Miles
0
100
200
1st Voyage
2nd "
3rd "
QUEBEC
NEWFOUNDLAND
NEW
BRUNSWICK
GULF OF
ST LAWRENCE
Anticosti Island
PRINCE EDWARD
ISLAND
Cape Breton
Island
Cabot Strait
Northumberland Strait
Cartier 1535
Cartier 1541
Cartier 1534
Belle Isle
Kirpon Har.
Bell I.
White Bay
Notre Dame
Bay
Fogo I.
Hamilton Sd
Funk I.
(I. of Birds)
C. Freels
Bonavista
Bay
C. Bonavista
Catalina Har.
Trinity Bay
Conception Bay
St Johns
Placentia
Bay
Placentia
C. St Mary
C. Race
Fortune Bay
St Miquelon
Lt. Miquelon
St Pierre I.
C. St George
St George Bay
Bay of Is.
East Cape
(C. St Louis)
Charleton Pt.
S.W. Point
West Pt.
Magdalen Is.
Brion I.
Bird Rks.
C. Anguille
C. Ray
C. North
St Paul I.
Sydney
E. Point
Charlottetown
North Cape
(C. des Sauvages)
Miramichi B.
Chatham
Shippegan I.
Pt. Miscou
Bay
Port Daniel
Perce
Gaspe
Bathurst
Fredericton
Woodstock
St John
MONTREAL
(HOCHELAGA)
Sherbrooke
St Hyacinthe
Sorel
L. St Peter
Berthier
Three Rivers
Hochelay
Cap Rouge
QUEBEC
(STADACONA)
I. of Orleans
(I. of Bacchus)
Levis
L'Islet
I. aux Coudres
Kamouraska
Baie St Paul
Murray Bay
I. aux Lievres
Riviere du Loup
Tadoussac
Chicoutimi
L. St John
Saguenay R.
St Maurice R.
Batiscan R.
Chaudiere R.
Father Pt.
Rimouski
Ste Anne
des Monts
Pt. des Monts
Bersimis R.
Outarde River
Manicouagan River
Moisie R.
Natashkwan River
Romaine R.
Mt. St Genevieve
H.B.Co.
Prepared by James White F.R.G.S. expressly for "The Mariner of St Malo"
Bartholomew, Edin.

Observation function

- $L(z, tp|\boldsymbol{x}) = \int_{z-\Delta z}^{z+\Delta z} N(z;\ \mu_z(\boldsymbol{x}), \sigma_z\ (\boldsymbol{x}))\ .\int_{tp-\Delta tp}^{tp+\Delta tp} N\big(tp;\ \mu_{tp}(\boldsymbol{x}), \sigma_{tp}\ (\boldsymbol{x})\big)$





Model sensitivity – structural errors?

Observational likelihood

- $L(z, tp|\boldsymbol{x}) = \int_{z-\Delta z}^{z+\Delta z} N(z;\ \mu_z(\boldsymbol{x}), \sigma_z\ (\boldsymbol{x}))\ .\int_{tp-\Delta tp}^{tp+\Delta tp} N\big(tp;\ \mu_{tp}(\boldsymbol{x}), \sigma_{tp}\ (\boldsymbol{x})\big)$

- Other data input possible? Light? Tide?

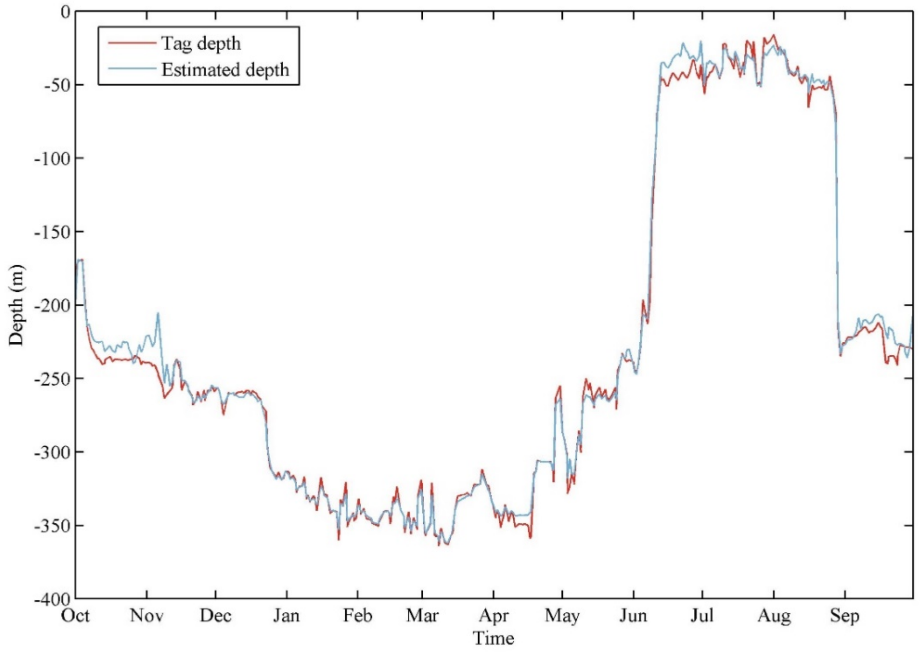
- Use daily variability in depth and temperature?

- Statistical assumptions: normal distributions? Other types of distribution?

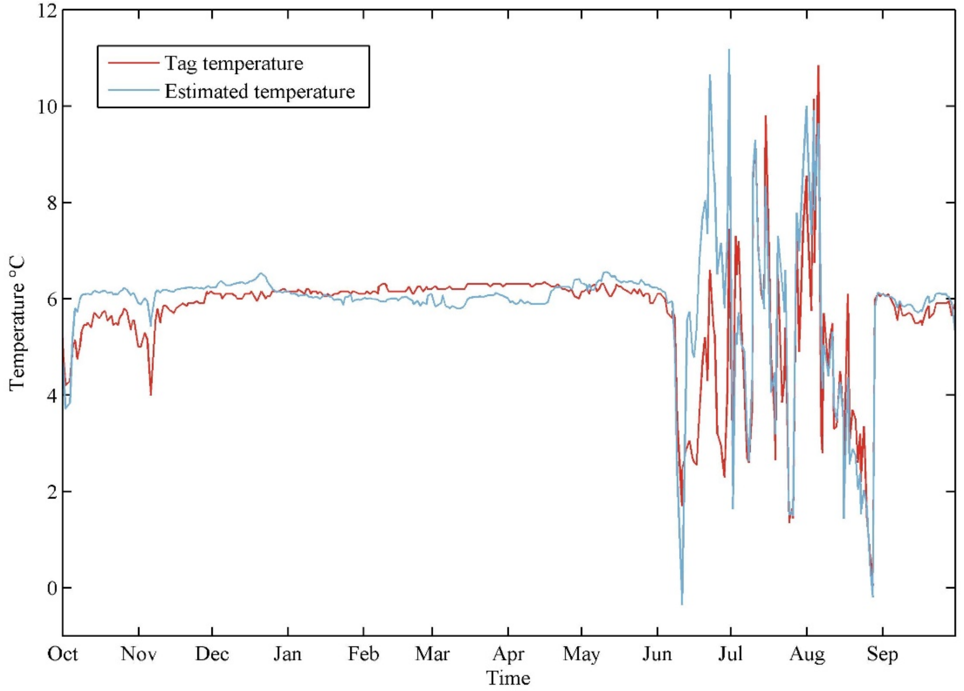
Model sensitivity – observation errors?

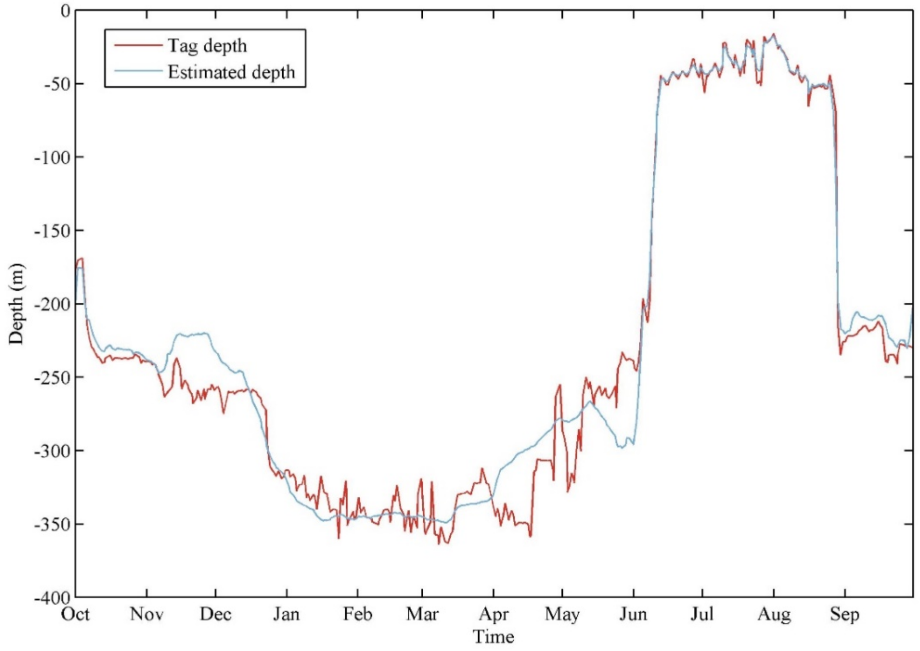
Oceanographic data

- Interpolated observations? Or prediction from circulation model?

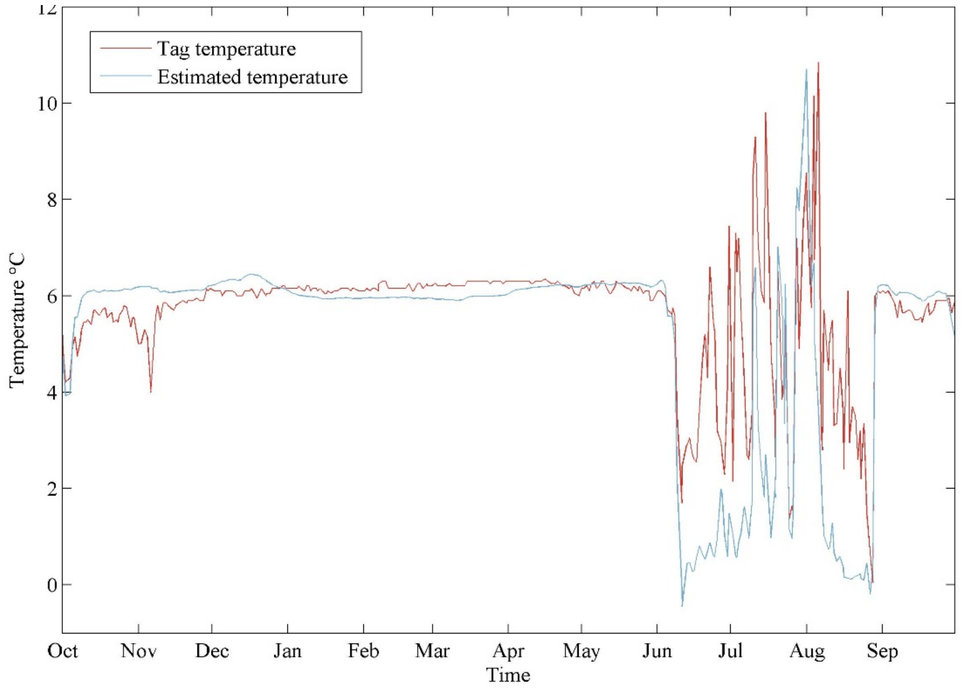

Tag depth
Estimated depth
Depth (m)
0
-50
-100
-150
-200
-250
-300
-350
-400
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Time

Product


Tag temperature
Estimated temperature
Temperature °C
12
10
8
6
4
2
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Time


Tag depth
Estimated depth
Depth (m)
0
-50
-100
-150
-200
-250
-300
-350
-400
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Time

Sum


Tag temperature
Estimated temperature
Temperature °C
12
10
8
6
4
2
0
Oct
Nov
Dec
Jan
Feb
Mar
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May
Jun
Jul
Aug
Sep
Time