

PML

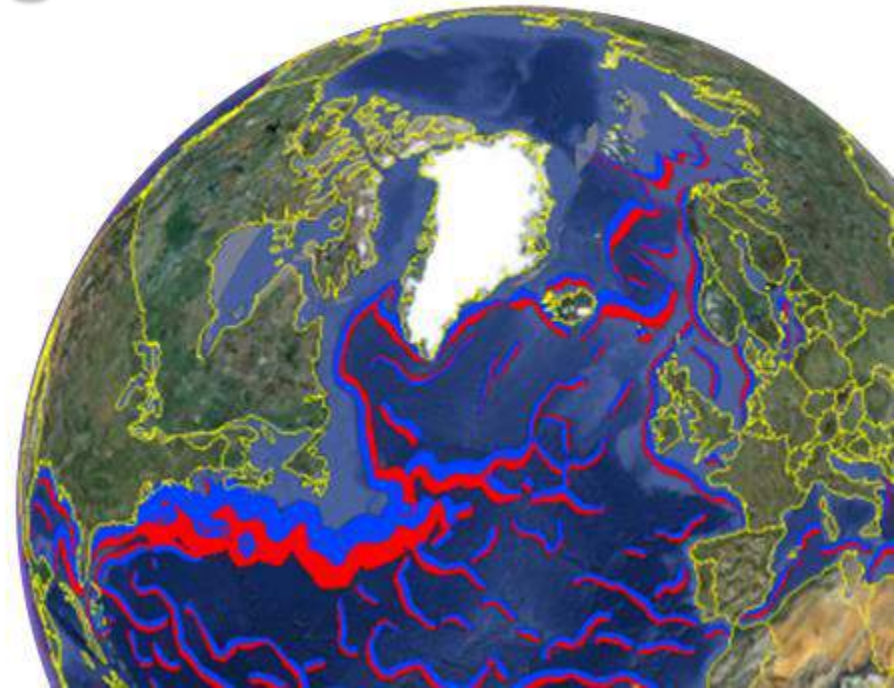
Plymouth Marine
Laboratory

Listen to the ocean

Ocean front metrics for understanding foraging locations of gannets and basking sharks

Peter Miller

Kylie Scales, Simon Ingram,
David Sims & Steve Votier



PLYMOUTH
UNIVERSITY

UNIVERSITY OF
EXETER

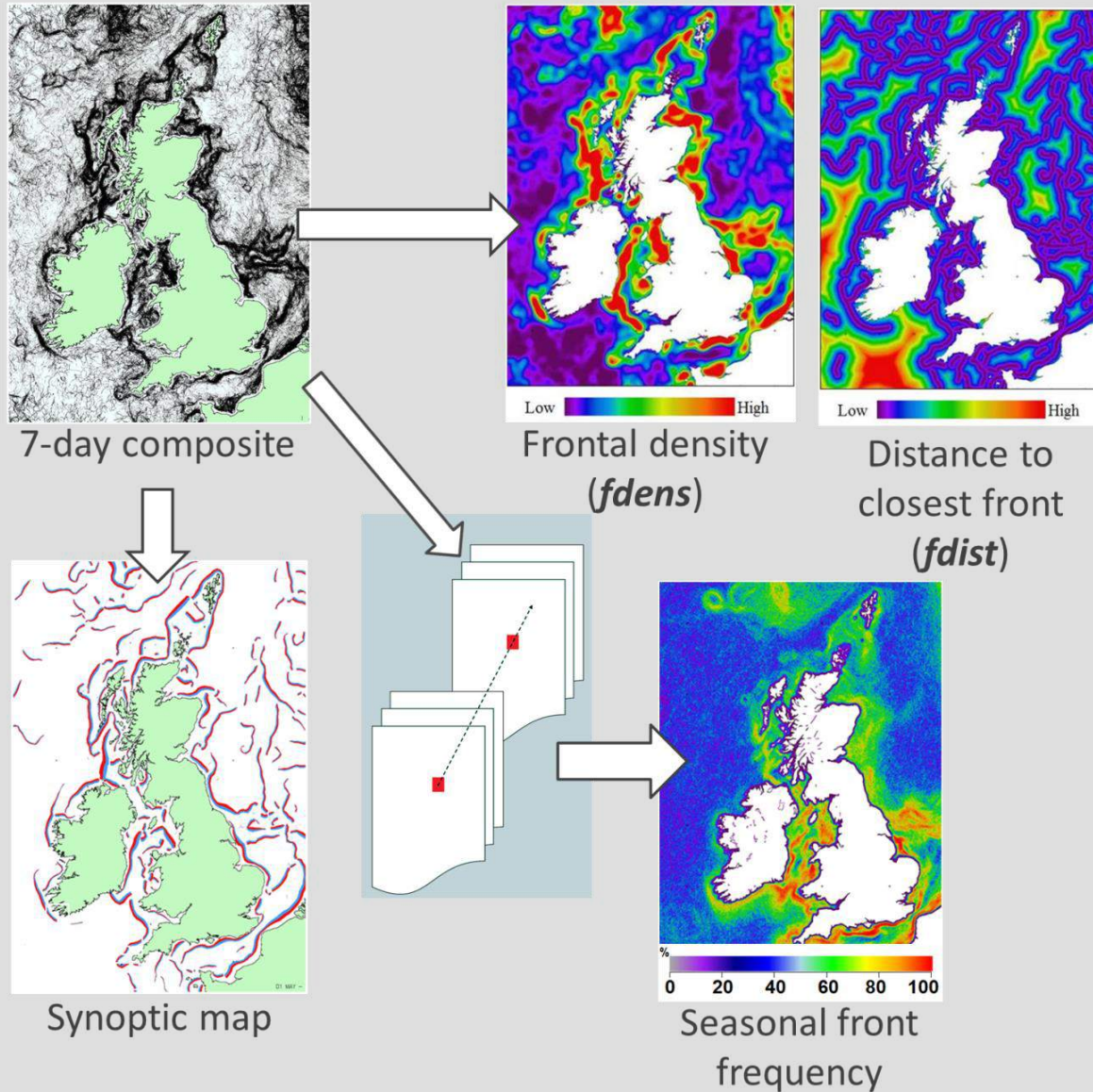


NERC

Oceanic fronts



Composite front mapping



Miller, P.I. (2009)
J. Mar. Sys. **78**,
327-366.

Key Questions - gannets



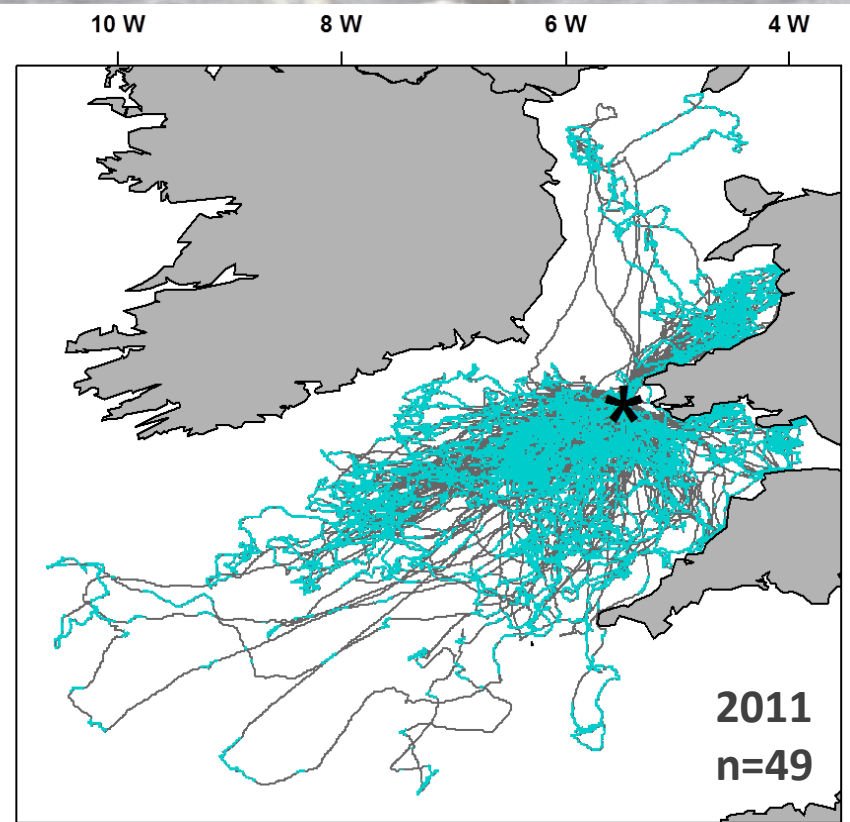
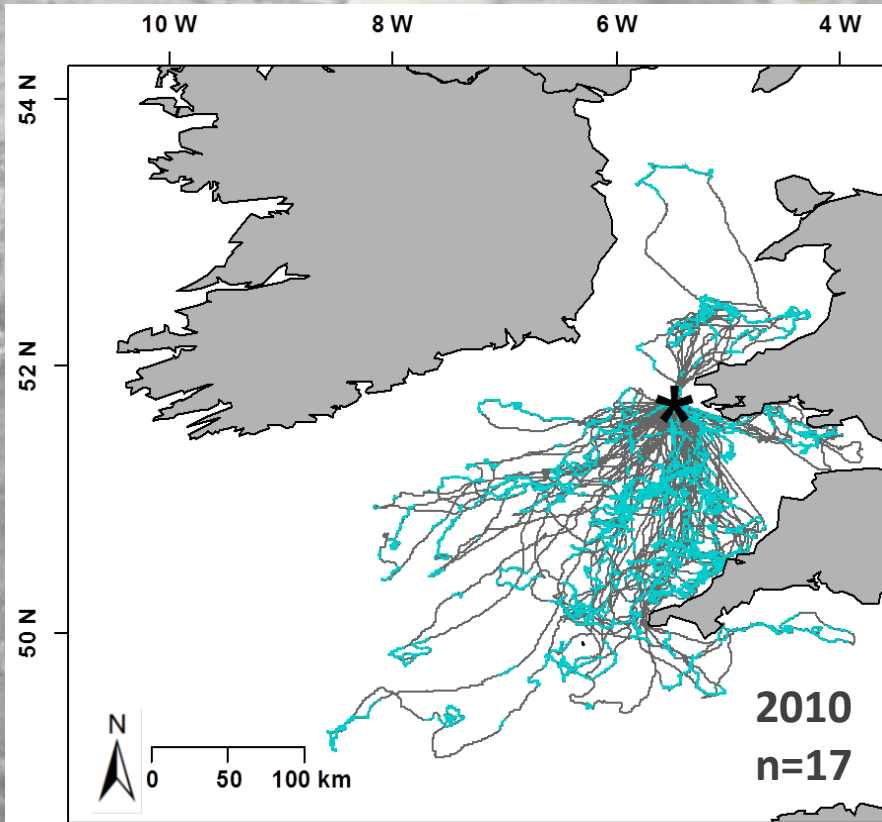
Key Questions - gannets

- **Do gannets respond to contemporaneous thermal or chl-a fronts as foraging cues?**

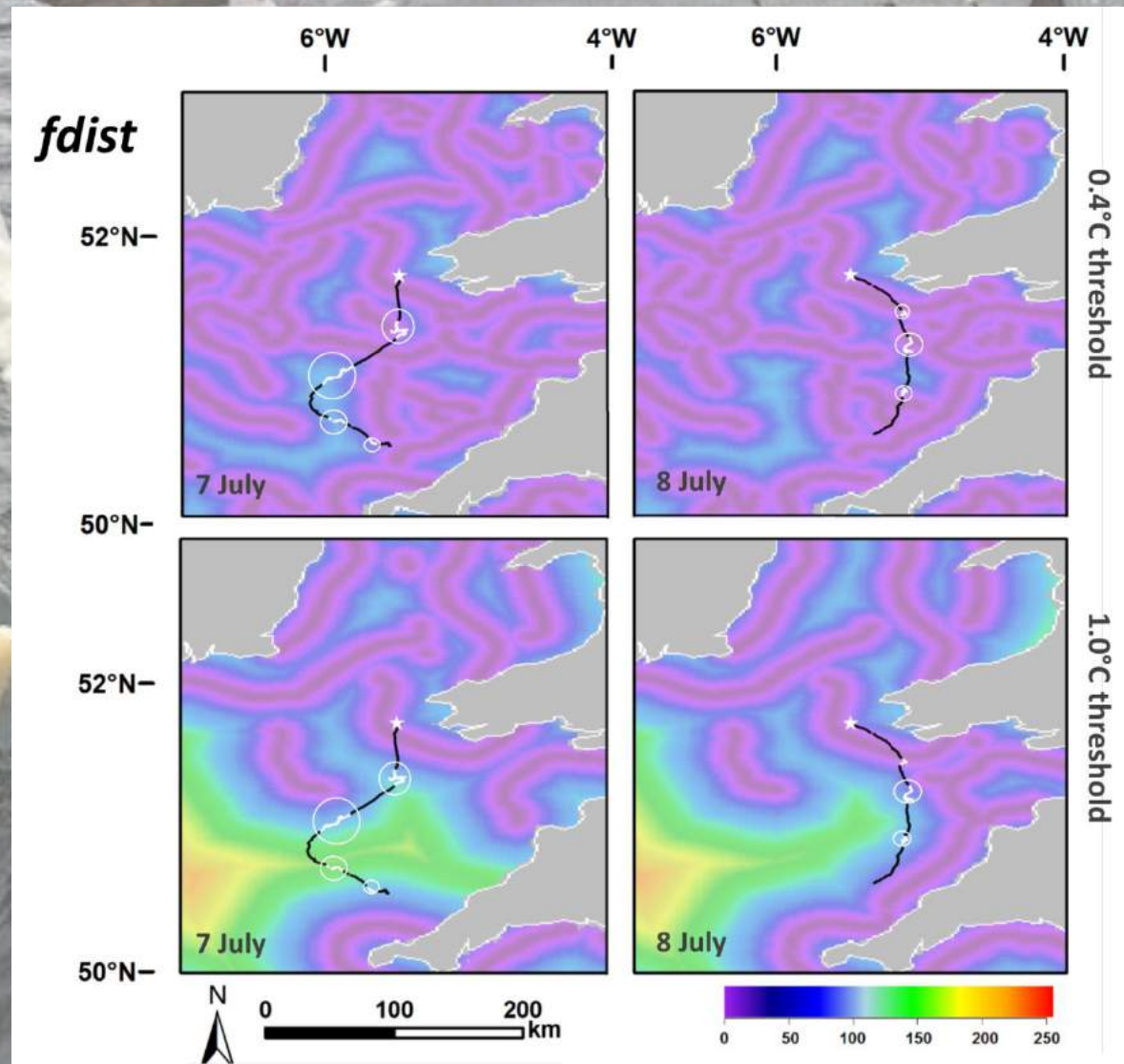
Key Questions - gannets

- **Do gannets respond to contemporaneous thermal or chl-a fronts as foraging cues?**
- **Are broad-scale, seasonally persistent frontal zones preferred foraging habitats?**

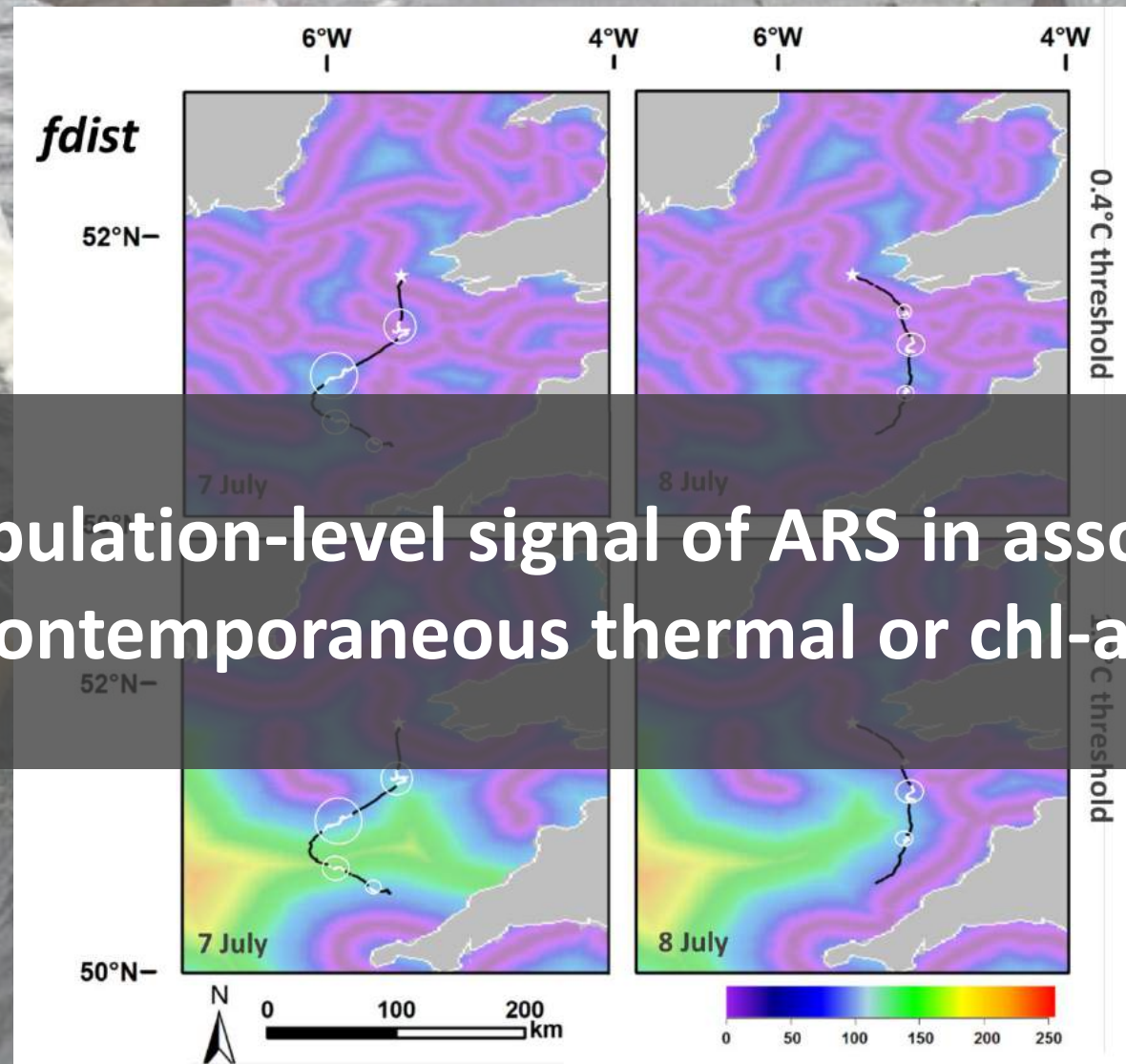
Foraging: Area-Restricted Search



Do gannets respond to contemporaneous fronts?

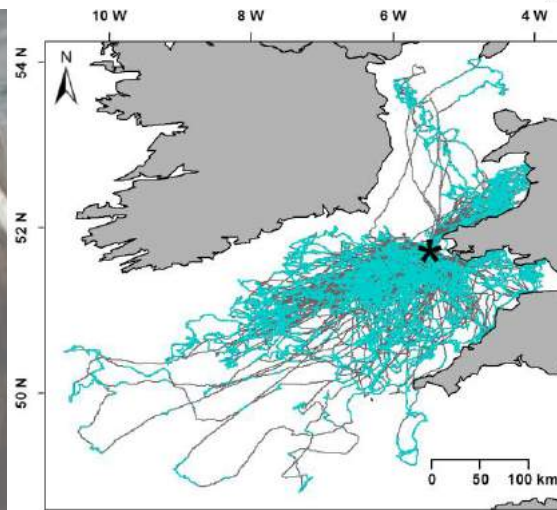
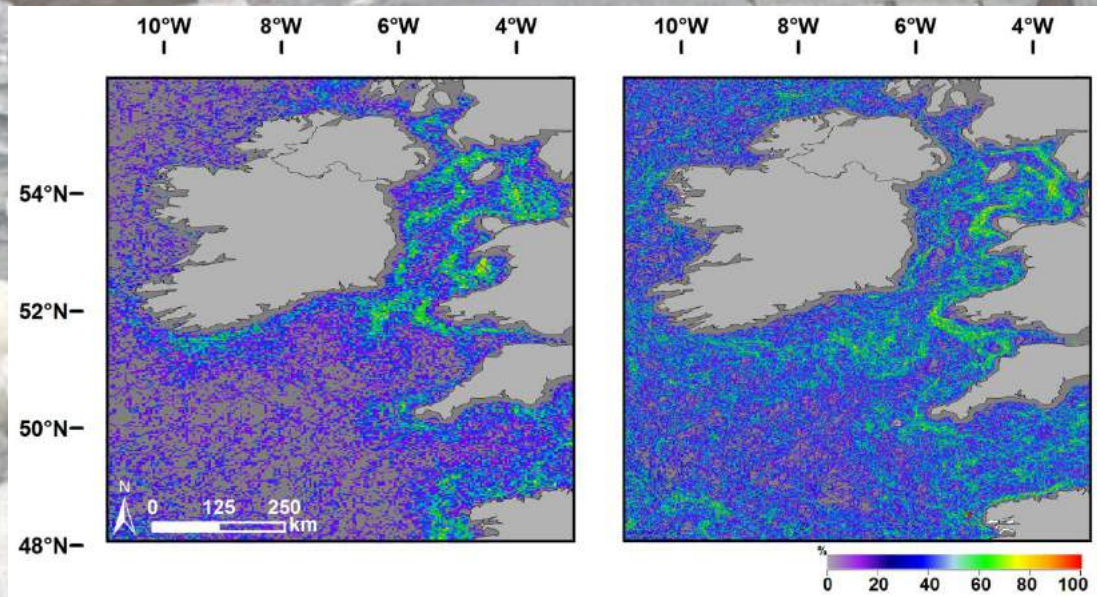


Do gannets respond to contemporaneous fronts?

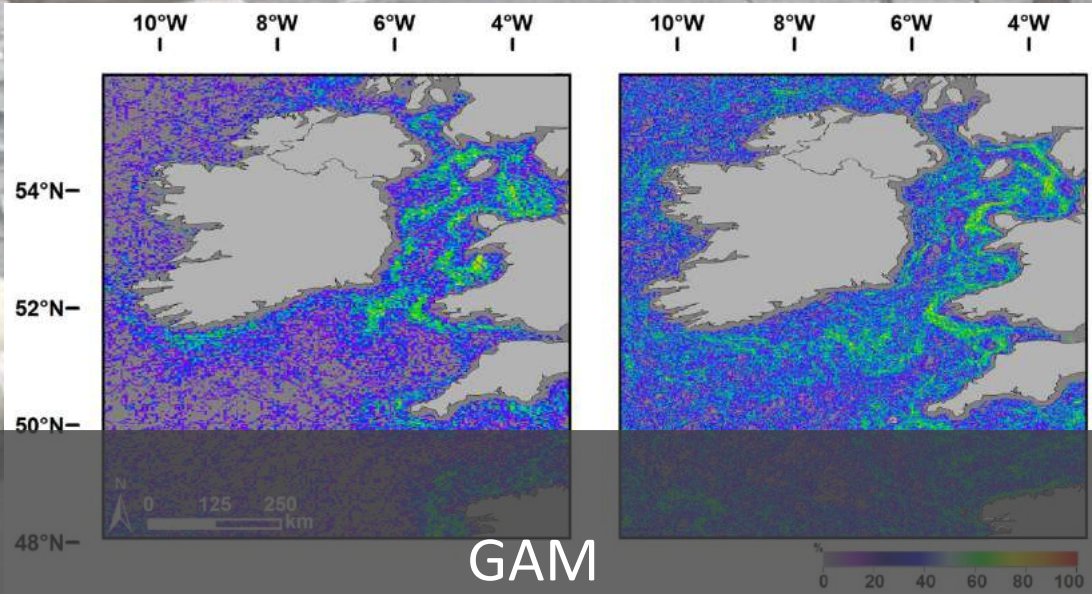


No population-level signal of ARS in association with contemporaneous thermal or chl-a fronts.

Are persistent frontal zones preferred foraging habitats?

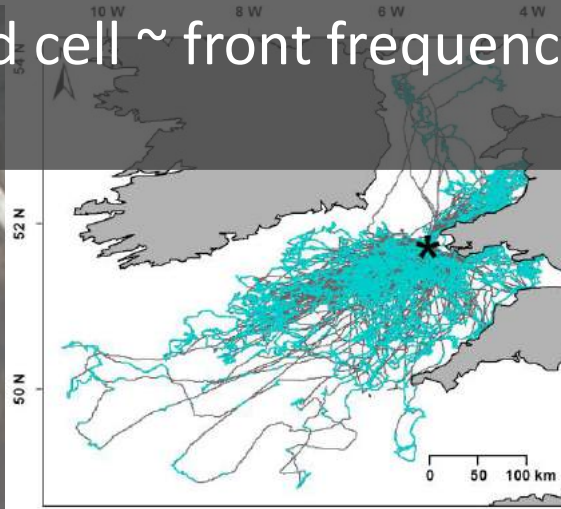


Are persistent frontal zones preferred foraging habitats?

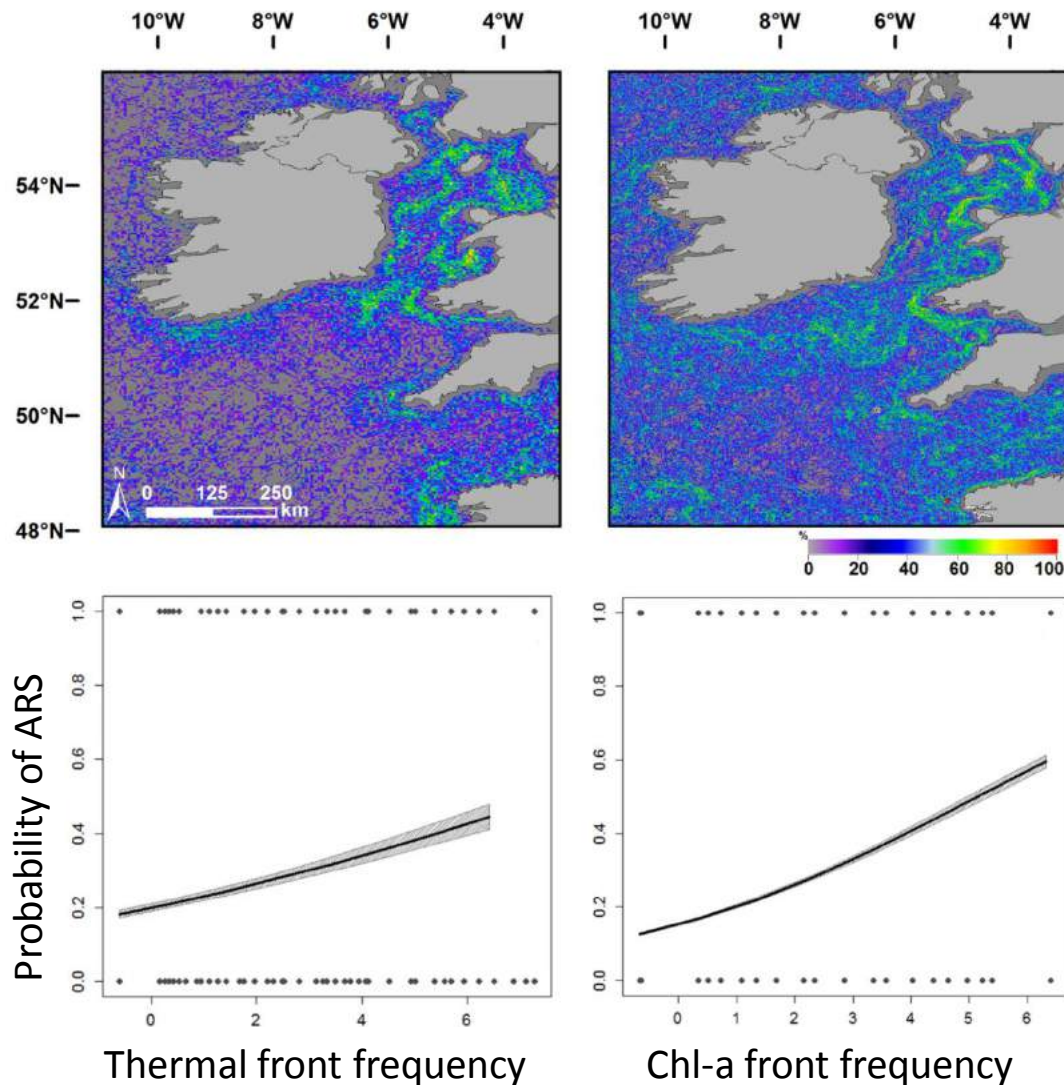


GAM

ARS (0/1) per grid cell \sim front frequency + accessibility

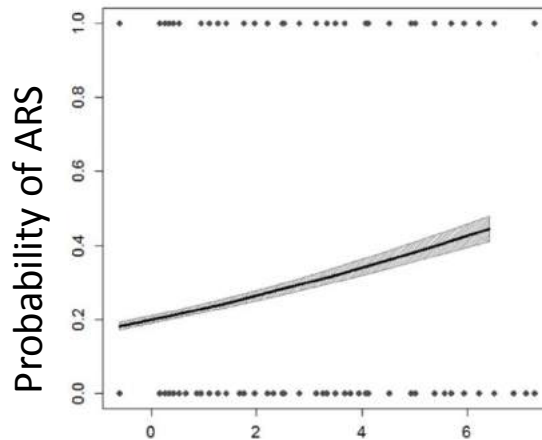
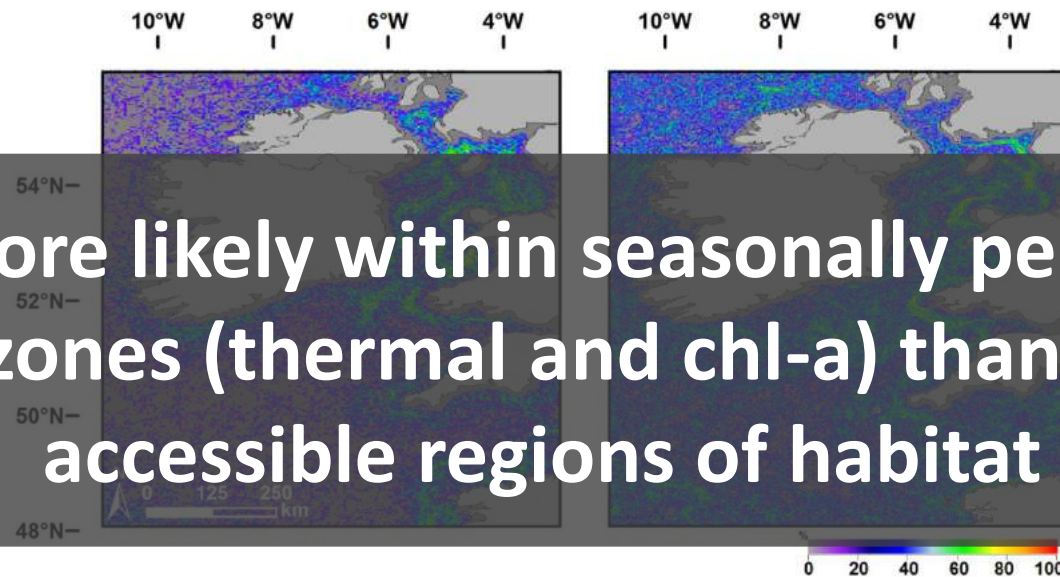


Are persistent frontal zones preferred foraging habitats?

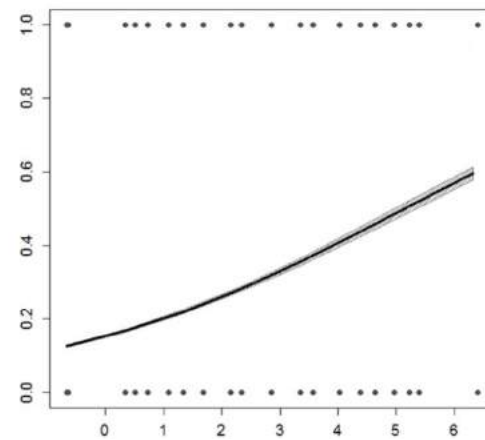


Are persistent frontal zones preferred foraging habitats?

ARS more likely within seasonally persistent frontal zones (thermal and chl-a) than in other accessible regions of habitat



Thermal front frequency



Chl-a front frequency

Summary - gannets

Northern gannets in the Celtic Sea forage preferentially within spatially predictable, persistent frontal zones, but responses to contemporaneous fronts vary

↳ **learning and memory**

JOURNAL
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THE ROYAL
SOCIETY

Interface

Mesoscale fronts as foraging habitats: composite front mapping reveals oceanographic drivers of habitat use for a pelagic seabird

Kylie L. Scales, Peter I. Miller, Clare B. Embling, Simon N. Ingram, Enrico Pirotta and Stephen C. Votier

Basking sharks



Basking sharks & fronts: what we know

Selective foraging behaviour of basking sharks on zooplankton in a small-scale front

David W. Sims & Victoria A. Quayle

*Department of Biological Sciences and Plymouth Environmental Research Centre,
University of Plymouth, Plymouth PL4 8AA, UK*

Sims & Quayle (1998) Nature 393, 460-464
Sims et al. (2000) Proc Roy Soc B 267 (1455), 1897-1904
Sims, DW et al. (2003) MEPS 248, 187-196

Basking sharks & fronts: what we know

Selective foraging behaviour of basking sharks on zooplankton in a small-scale front

David
Departm
Univers

Annual social behaviour of basking sharks associated with coastal front areas

David W. Sims^{1*}, Emily J. Southall², Victoria A. Quayle² and Adrian M. Fox¹

¹*Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen AB24 2TZ, UK*

²*Department of Biological Sciences, University of Plymouth, Drake Circus, Plymouth PL4 8AA, UK*

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¹Department of Oceanography, University of Southampton, Southampton, UK

Seasonal movements and behaviour of basking sharks from archival tagging: no evidence of winter hibernation

David W. Sims^{1,*}, Emily J. Southall¹, Anthony J. Richardson², Philip C. Reid²,
Julian D. Metcalfe³

Basking sharks and satellite fronts



Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres



Short communication

A basking shark (*Cetorhinus maximus*) tracked by satellite together with simultaneous remote sensing II: New analysis reveals orientation to a thermal front

Imants

Functional Ecology



British Ecological Society

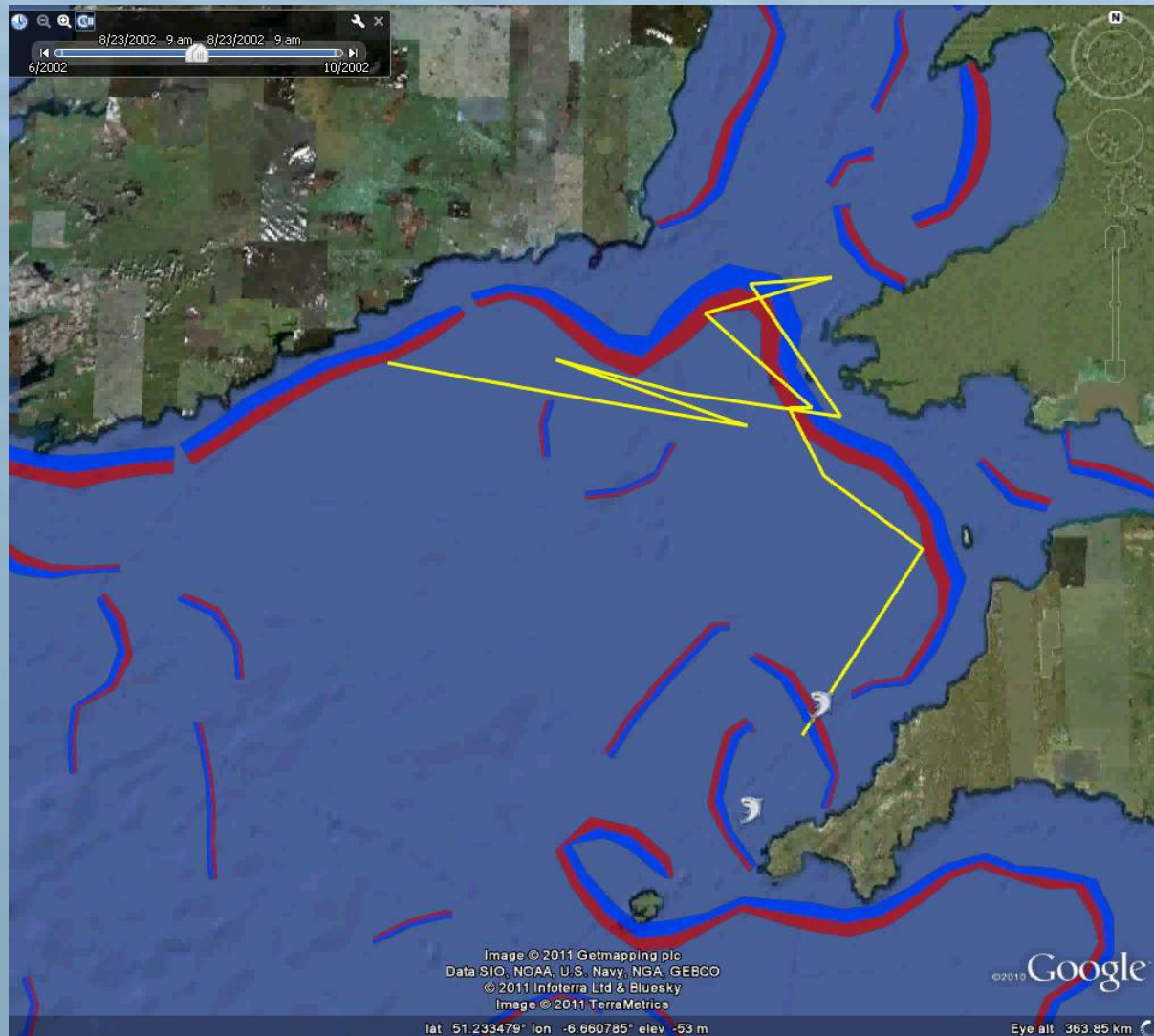
Functional Ecology 2015

doi: 10.1111/1365-2435.12423

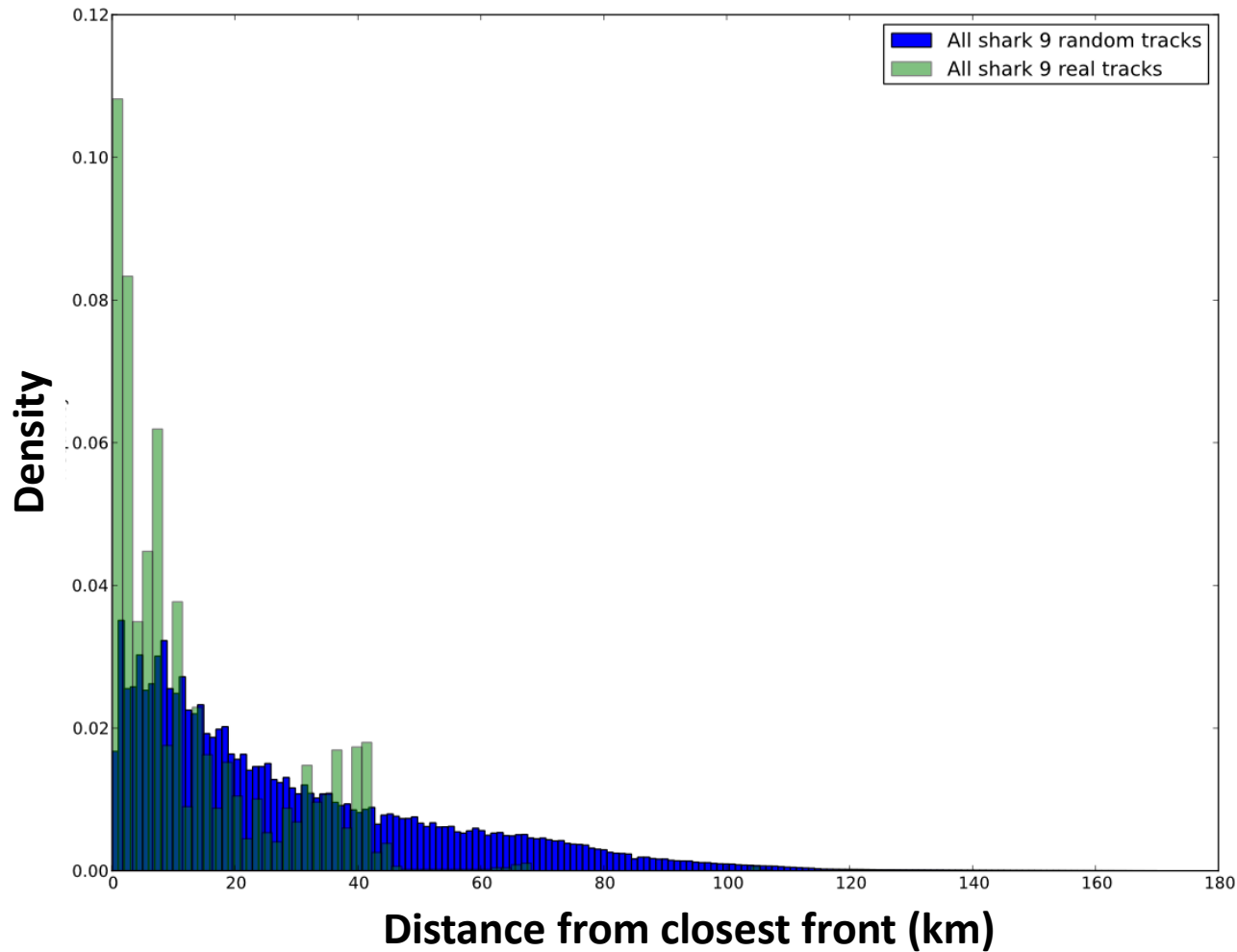
Basking sharks and oceanographic fronts: quantifying associations in the north-east Atlantic

Peter I. Miller^{*,1}, Kylie L. Scales^{*,†,1,2}, Simon N. Ingram³, Emily J. Southall⁴ and David W. Sims^{4,5,6}

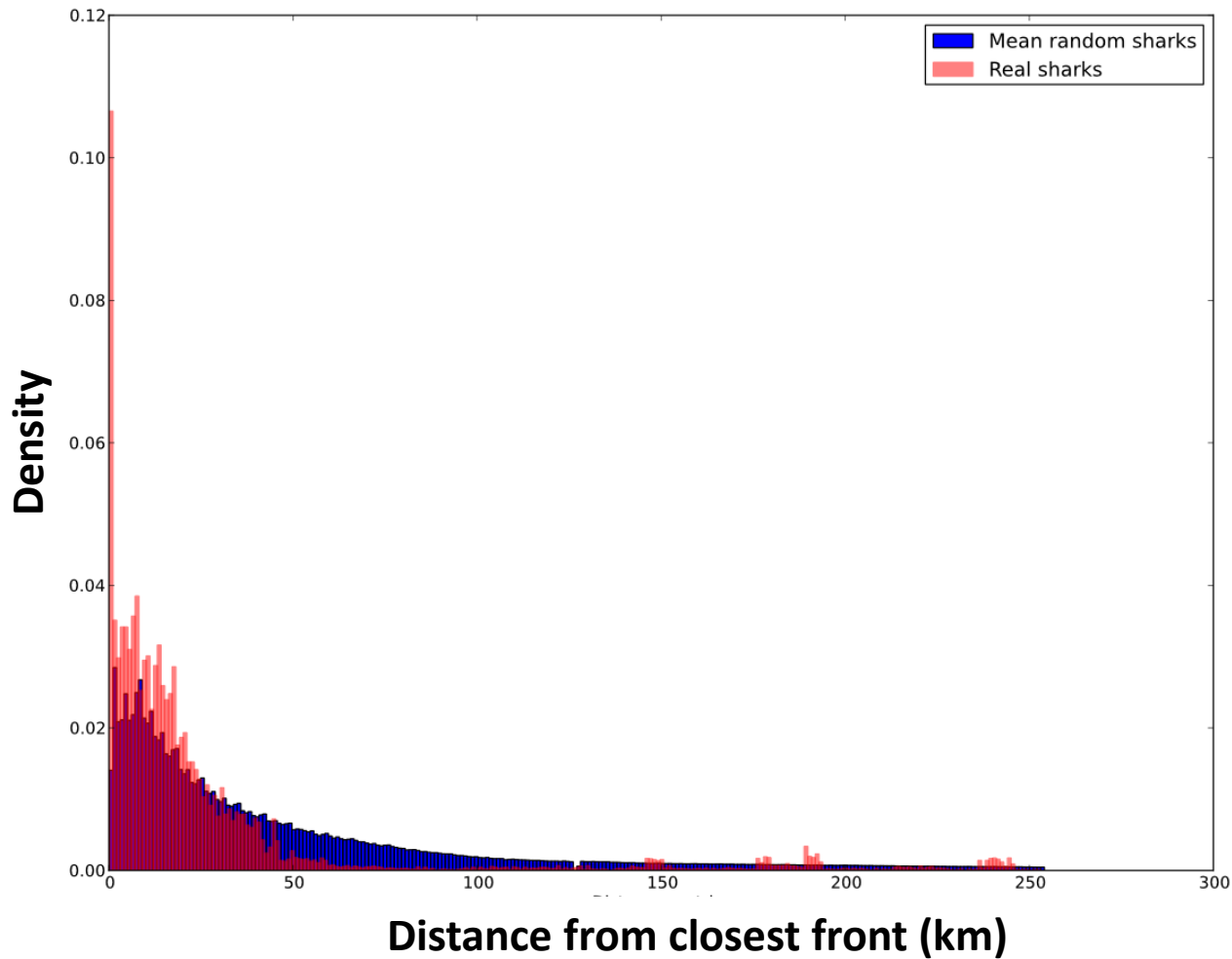
Basking shark tracked with GLS tag vs. fronts



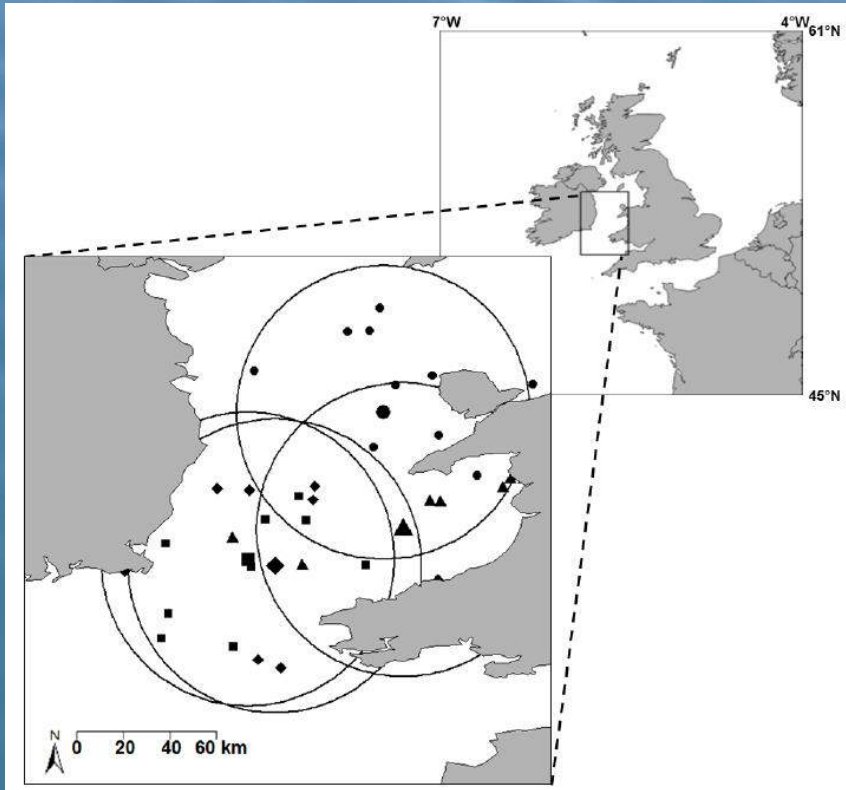
Our favourite shark stays close to the front



Do sharks forage near fronts generally?



Modelling real and random sharks

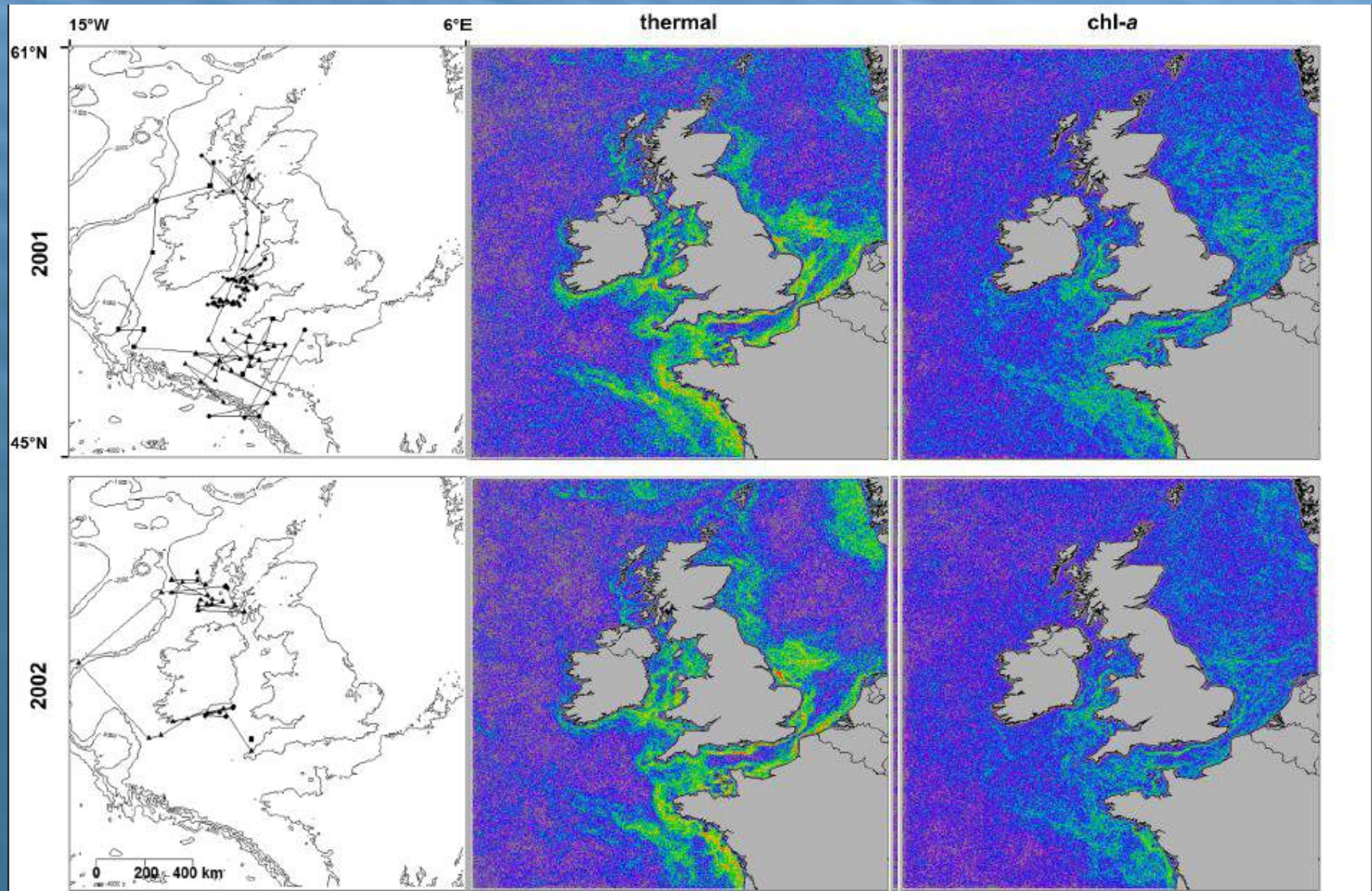


Resampling real shark presence

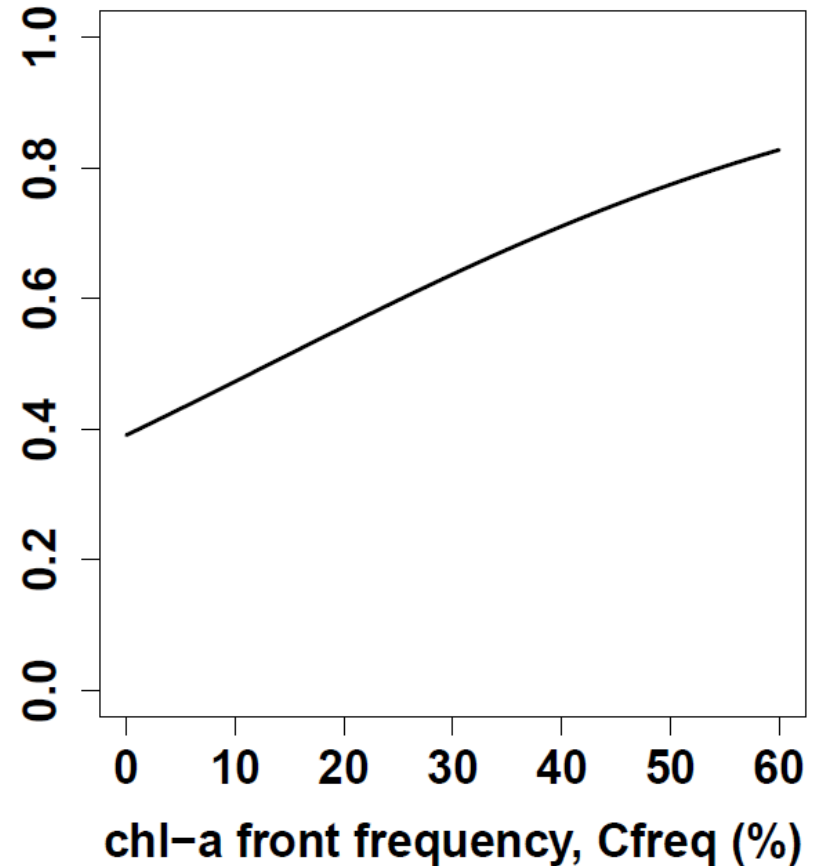
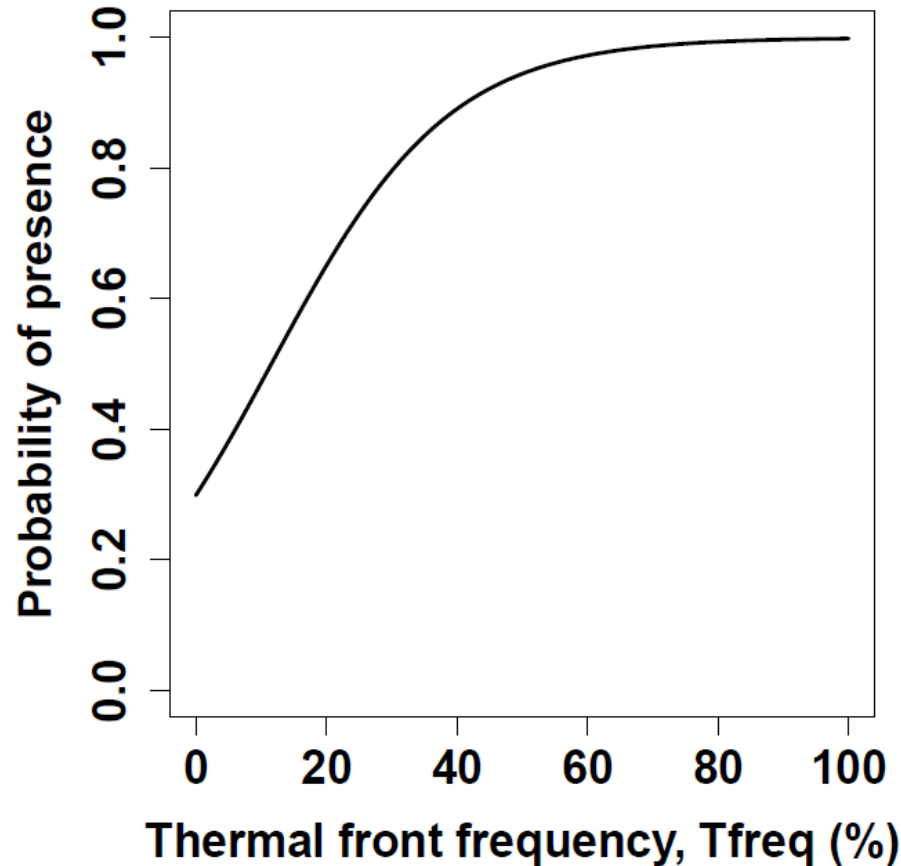


10 random shark tracks

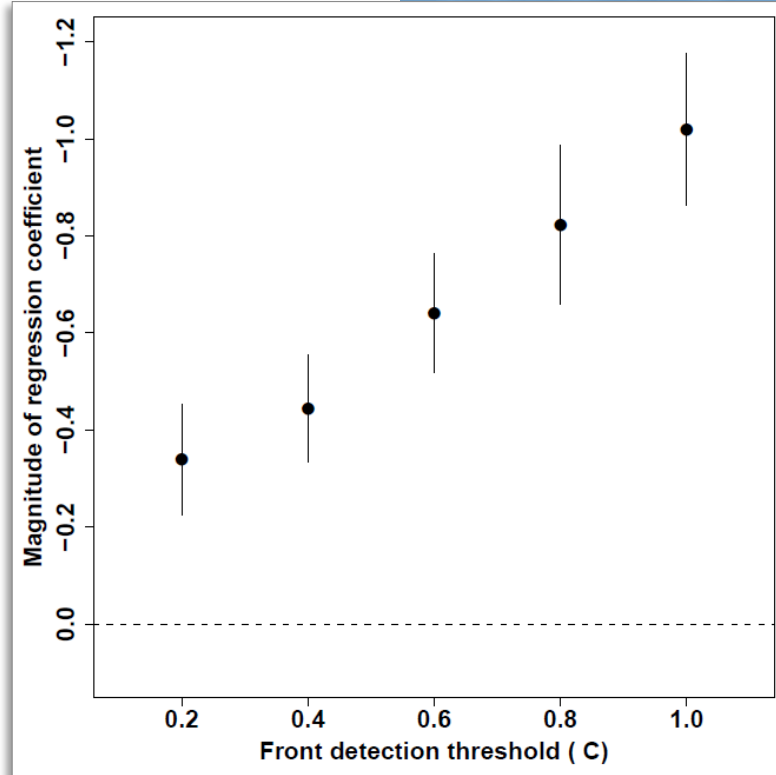
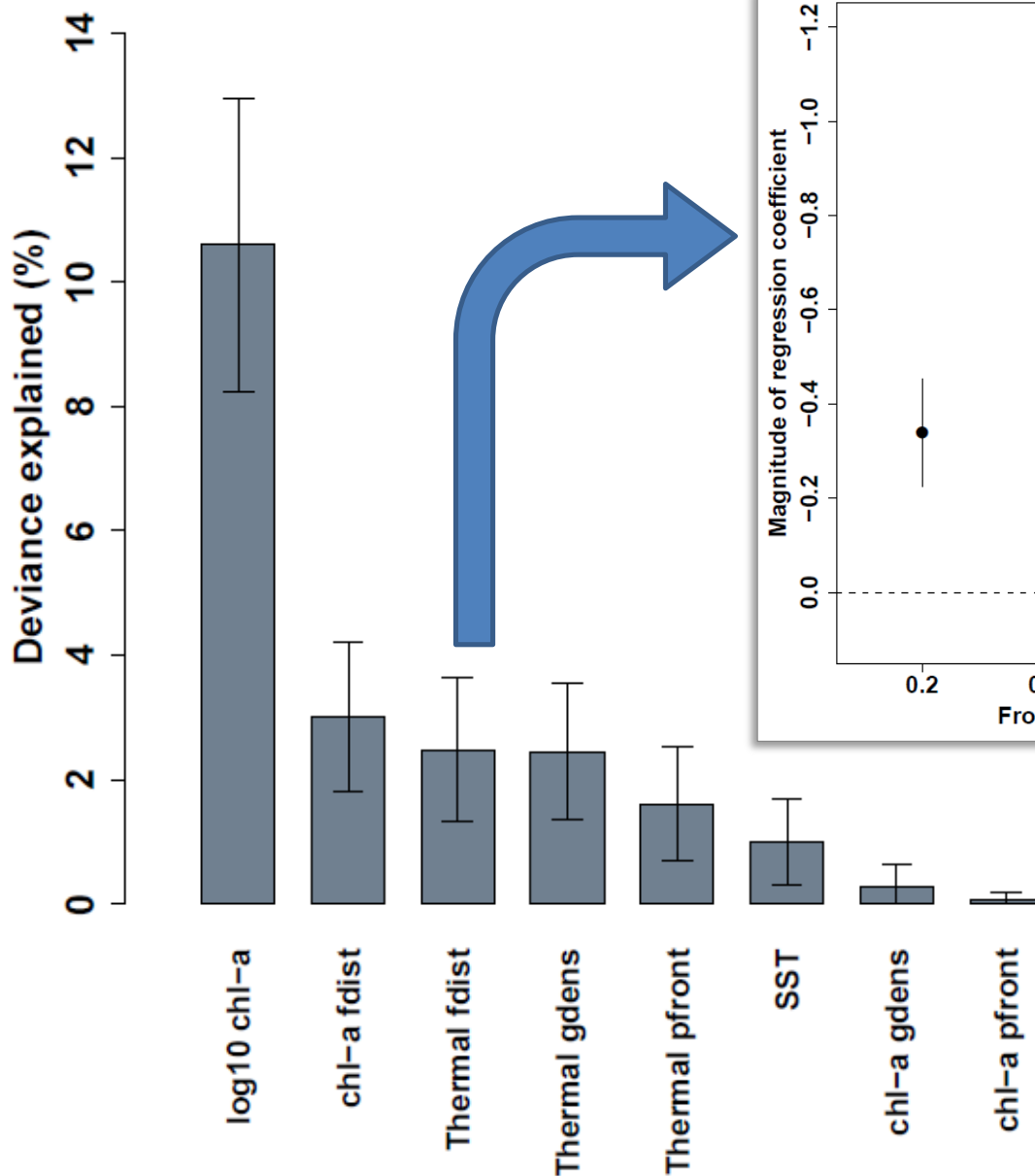
Basking sharks vs. seasonal front frequency



Basking sharks vs. seasonal front frequency



Basking sharks vs. real time factors



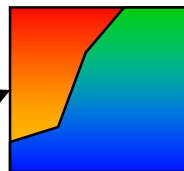
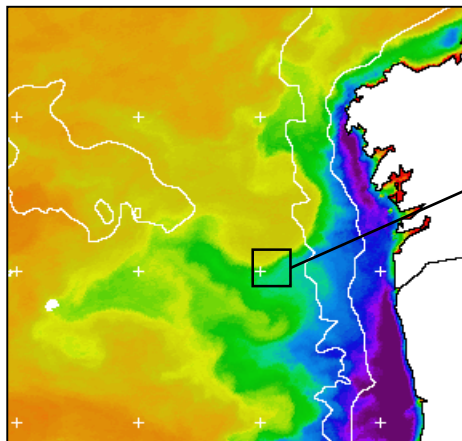
Summary

- Composite front mapping is useful for investigating mesoscale oceanographic drivers of habitat selection by marine predators
- Basking sharks and northern gannets associate with mesoscale thermal fronts in UK waters
- Regional oceanography important – frontal persistence, spatial scale, gradient – influence use by foraging animals

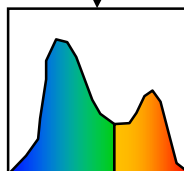
Extra slides



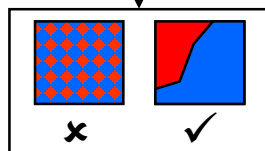
SST map



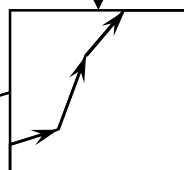
Local window



Histogram bimodality test and threshold

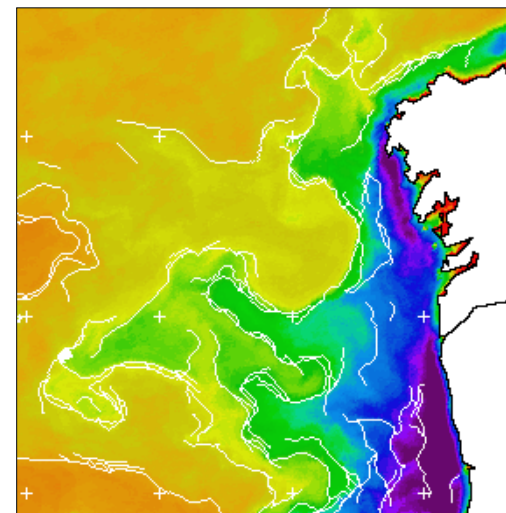
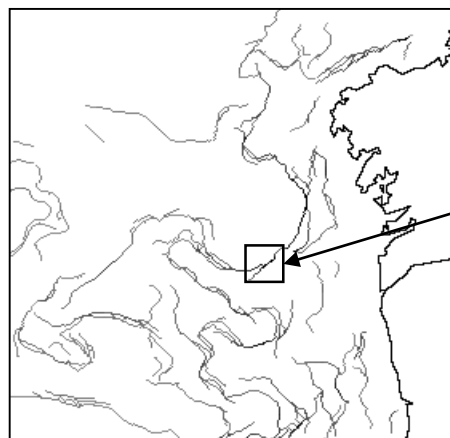


Cohesion test

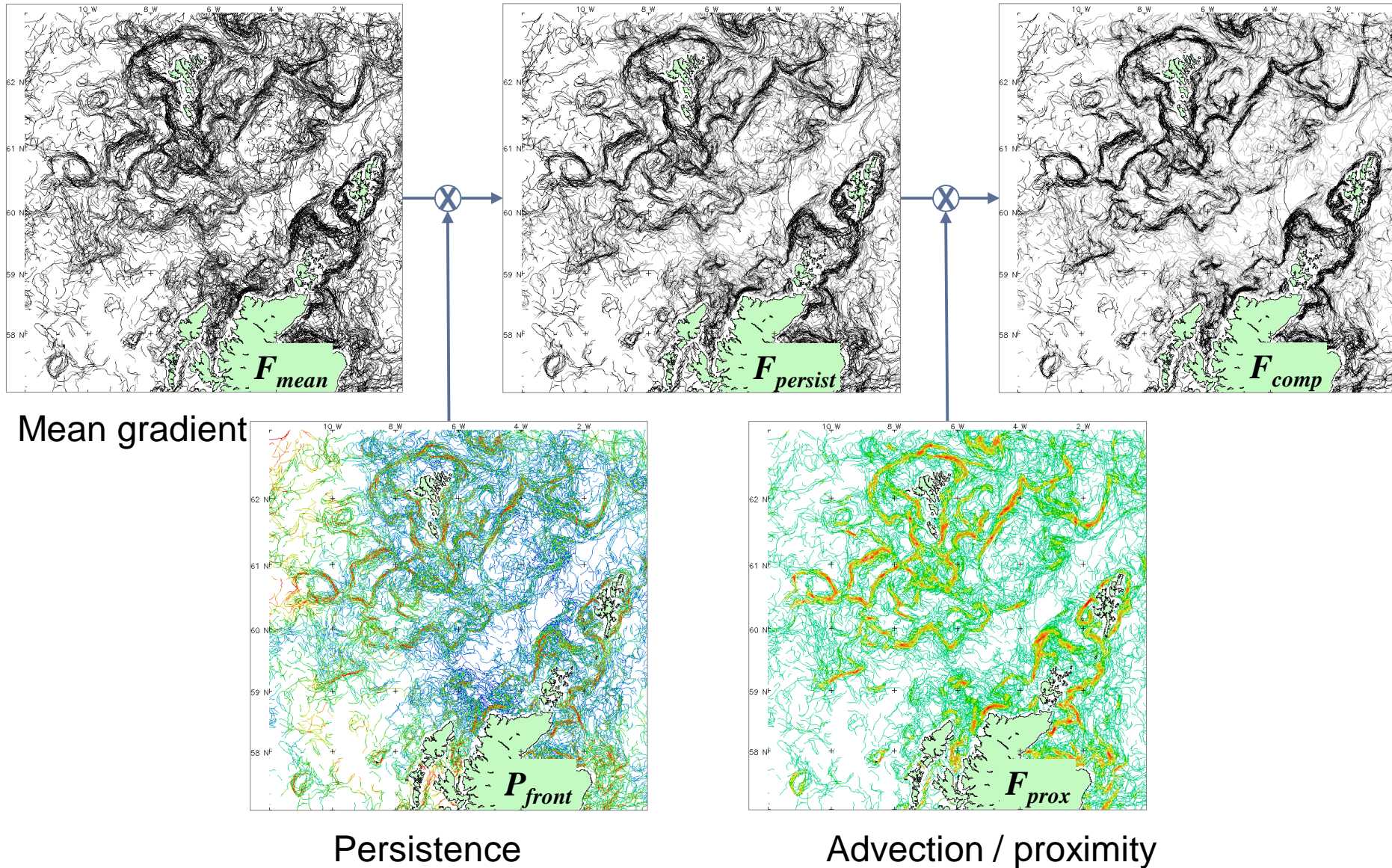


Contour following

Front map



Composite front maps: revealing strong fronts



Marine predators associate with fronts



Polovina, JJ, et al. (2000) Fisheries Oceanography 9:71-82
 Graham, RT, et al. (2012) PLoS ONE 7(5), e363834
 Biuw, M, et al. (2007) PNAS 104:34,13705-13710
 Bost, CA, et al. (2009) Journal of Marine Systems 78:3,363-376

Sims, DW, et al. (2000) Proceedings of the Royal Society B 267:1455,1897-1904
 Sims, DW and Southall, EJ (2002) JMBA 82:927-928
 Teo, SLH and Block, BA (2010) PLoS ONE 5:5,e10756
 Weimerskirch, H (2007) Deep Sea Research II 54:3-4,211-223

Do gannets respond to contemporaneous fronts?

Oikos 000: 001–008, 2013

doi: 10.1111/j.1600-0706.2013.00406.x

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Subject Editor: Ben Chapman. Accepted 8 May 2013

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Samantha C. Patrick, Stuart Bearhop, David Grémillet, Amélie Lescroël, W. James Grecian, Thomas W. Bodey, Keith C. Hamer, Ewan Wakefield, Mélanie Le Nuz and Stephen C. Votier

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A Bird's Eye View of Discard Reforms: Bird-Borne Cameras Reveal Seabird/Fishery Interactions

Stephen C. Votier^{1,2*}, Anthony Bicknell², Samantha L. Cox², Kylie L. Scales³, Samantha C. Patrick^{2,4}

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Bird-Borne Video-Cameras Show That Seabird Movement Patterns Relate to Previously Unrevealed Proximate Environment, Not Prey

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Fine-scale recognition and use of mesoscale fronts by foraging Cape gannets in the Benguela upwelling region

Philippe S. Sabarros^{a,b,*}, David Grémillet^{c,d}, Hervé Demarcq^b, Christina Moseley^d,
Lorien Pichegru^d, Ralf H.E. Mullers^c, Nils C. Stenseth^{a,e}, Eric Machu^{a,f}

Predictability



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Are seabirds foraging for unpredictable resources?

Henri Weimerskirch*

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Henri Weimerskirch*

The Journal of Experimental Biology 213, 2365–2371
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doi:10.1242/jeb.042267

Northern gannets anticipate the spatio-temporal occurrence of their prey

E. Pettex^{1,2,*}, F. Bonadonna¹, M. R. Enstipp³, F. Siorat⁴ and D. Grémillet¹

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Inter-annual changes in prey fields trigger different foraging tactics in a large marine predator

Stefan Garthe,^{a,*} William A. Montevecchi,^b and Gail K. Davoren^c

D. Grémillet¹

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Mar Biol (2007) 151:687–694
DOI 10.1007/s00227-006-0523-x

RESEARCH ARTICLE

Contrasting foraging tactics by northern gannets (*Sula bassana*) breeding in different oceanographic domains with different prey fields

Stefan Garthe · William A. Montevecchi ·
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