

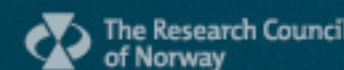
ARCEx

# Ocean bottom seismometers for passive acoustic monitoring of baleen whales

Léa Bouffaut, Richard Dréo , Abdel Boudraa, Martin Landrø, Guilhem Barruol

December 15th, 2020

[lea.bouffaut@ntnu.no](mailto:lea.bouffaut@ntnu.no)

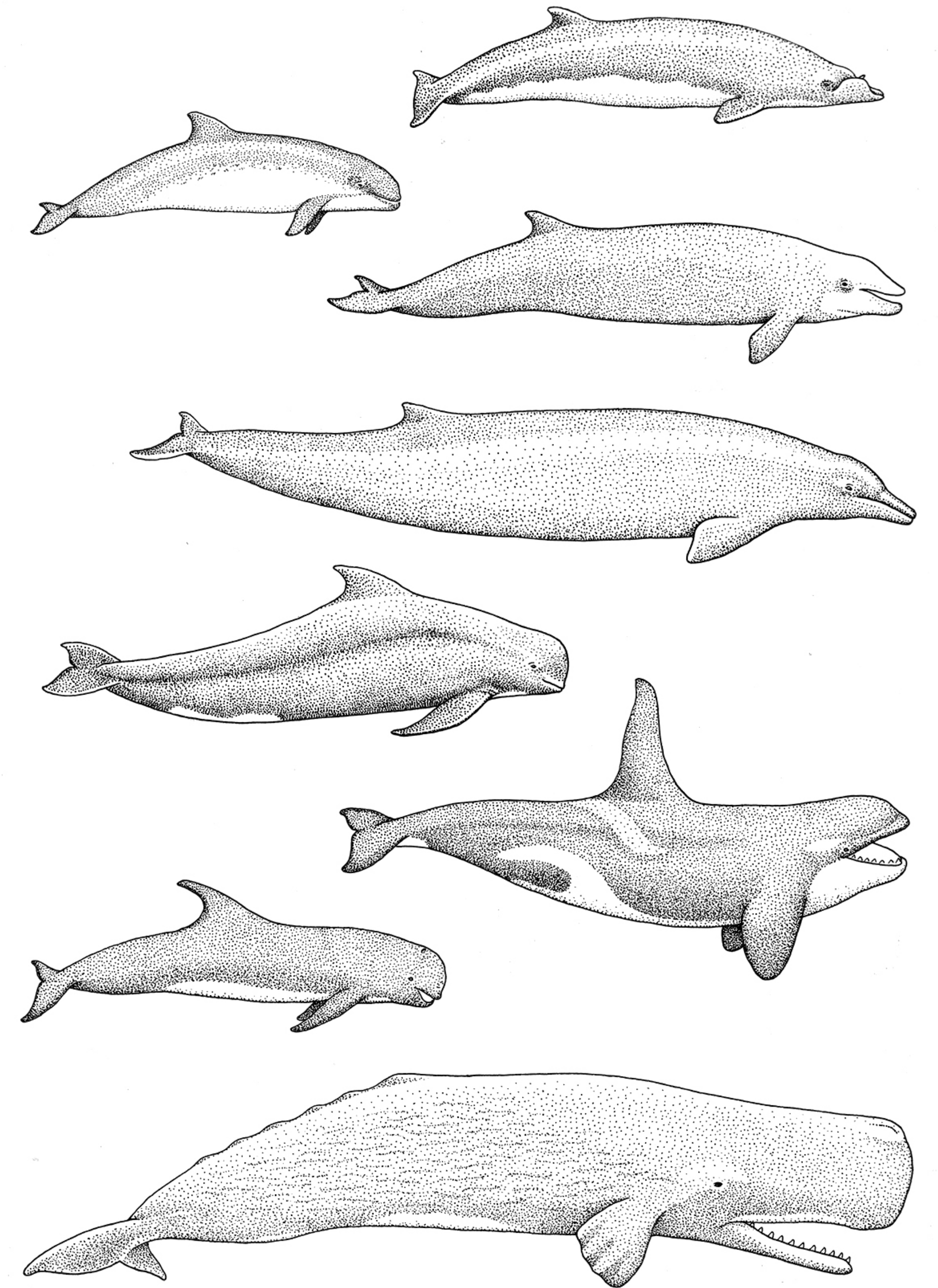




**How can OBSs  
contribute to  
understanding baleen  
whales ?**



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contribute to  
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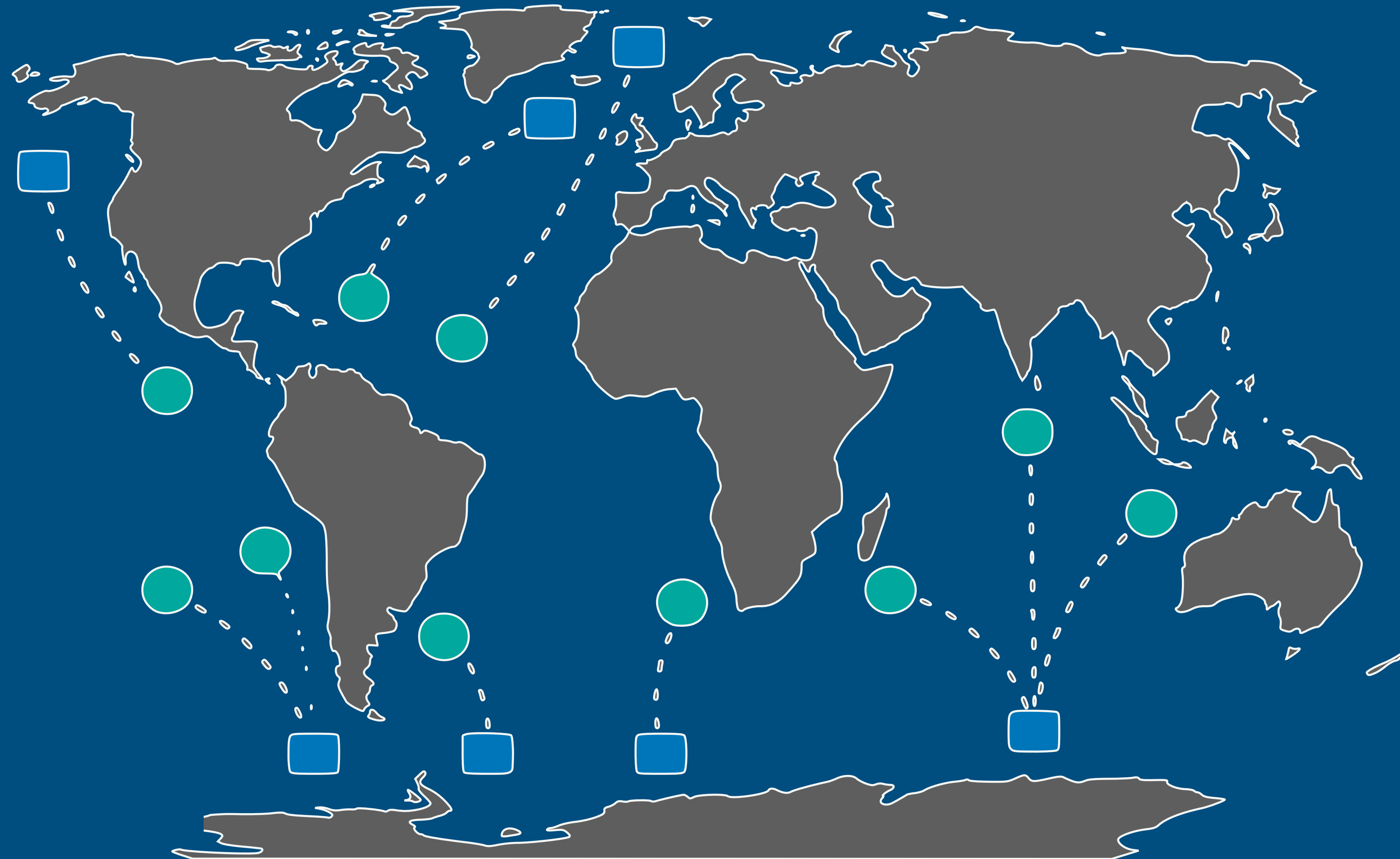




# Blue whales

Feeding grounds

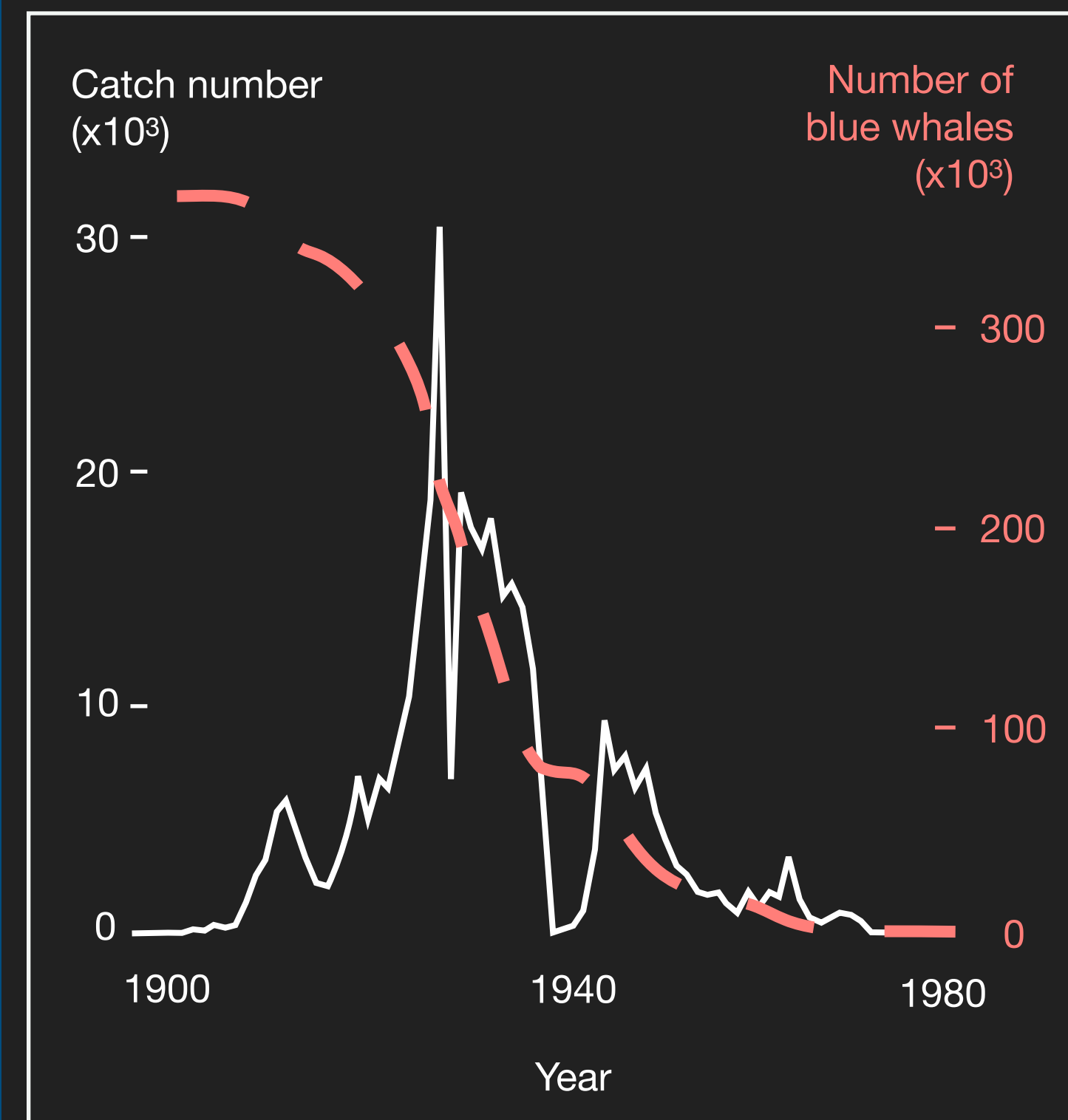
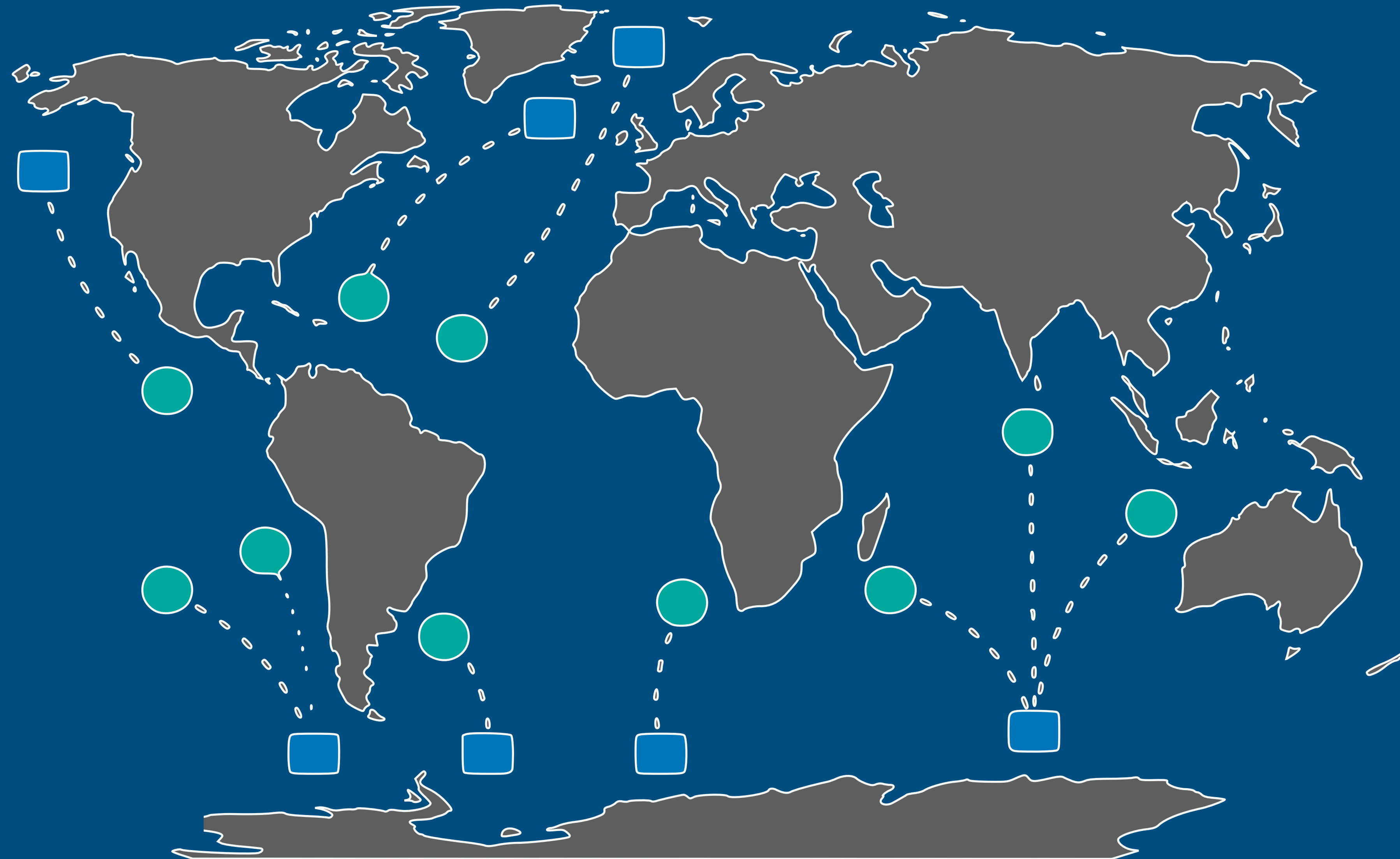
Breeding grounds





# Blue whales

- Feeding grounds
- Breeding grounds

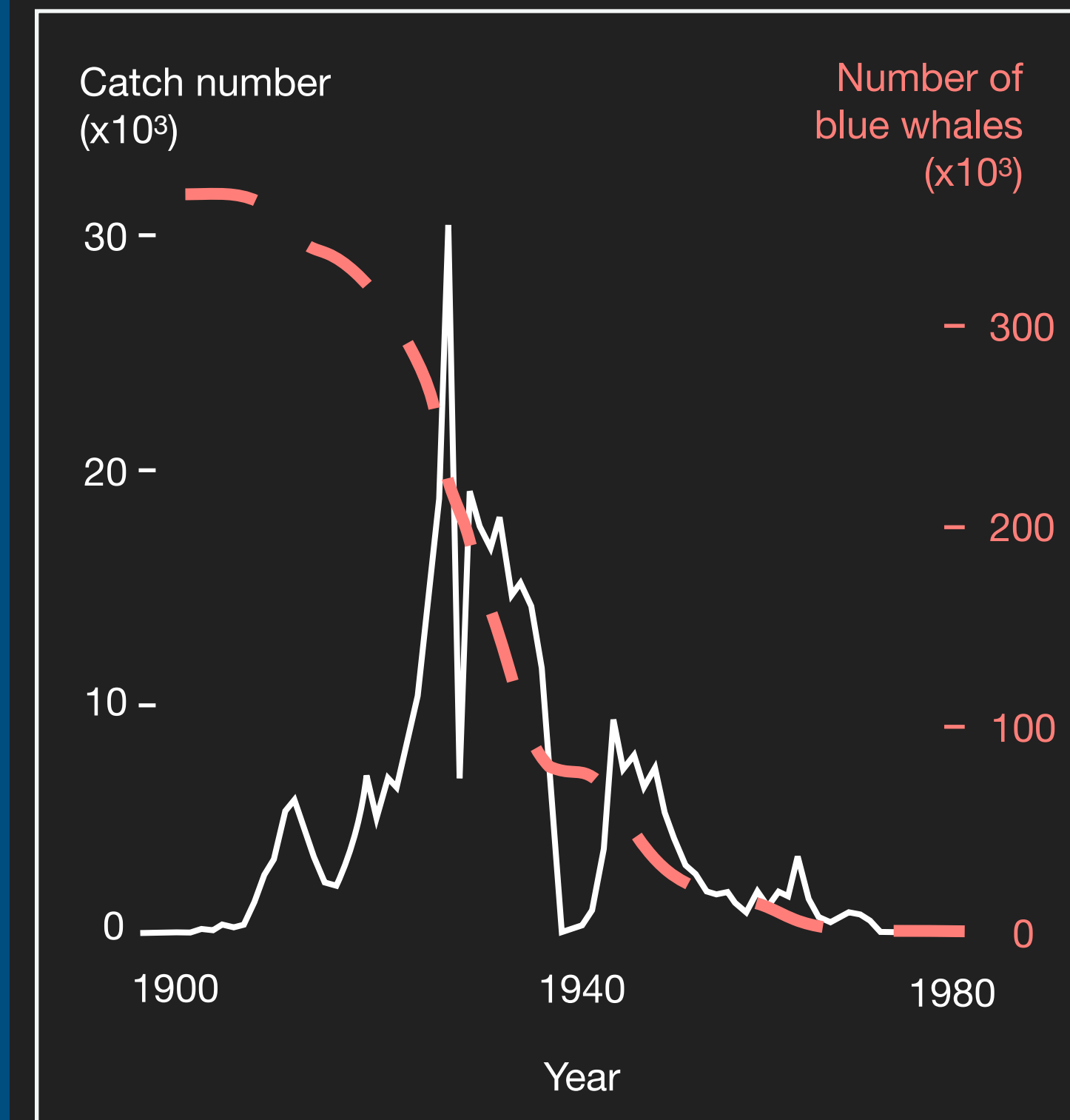
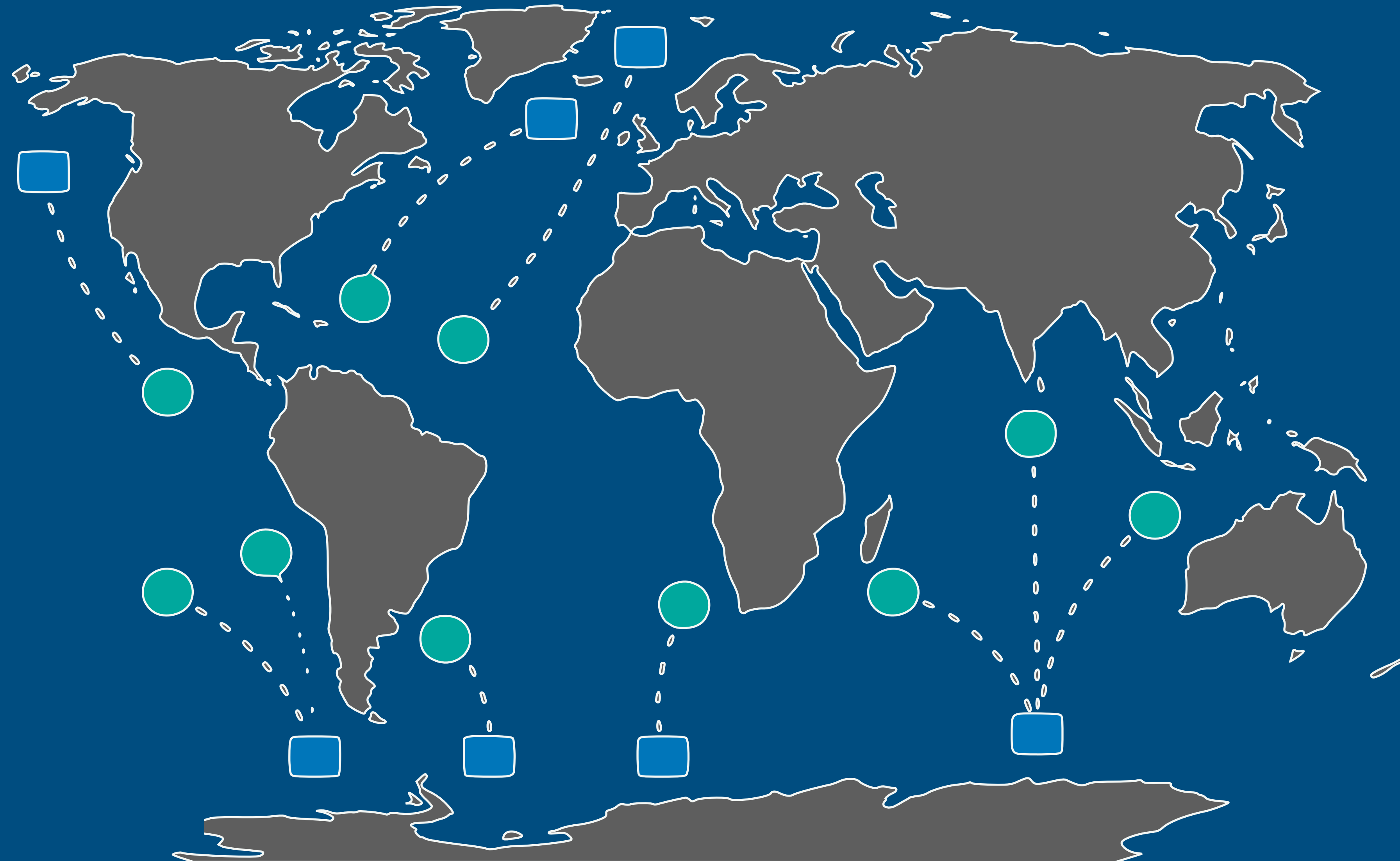


Adapted from Leroy (2017),  
based on IWC data



# Blue whales

- Feeding grounds
- Breeding grounds



Adapted from Leroy (2017),  
based on IWC data

**A small number of  
individuals scattered  
across wide areas:**

**Visual monitoring is  
limited**



# Passive acoustic monitoring of baleen whales

Blue whale produce  
loud, low-frequency  
sounds!



# Passive acoustic monitoring of baleen whales

**Blue whale produce loud, low-frequency sounds!**

Passive acoustic monitoring

- Autonomous
- Continuous
- Long-term
- Large scale

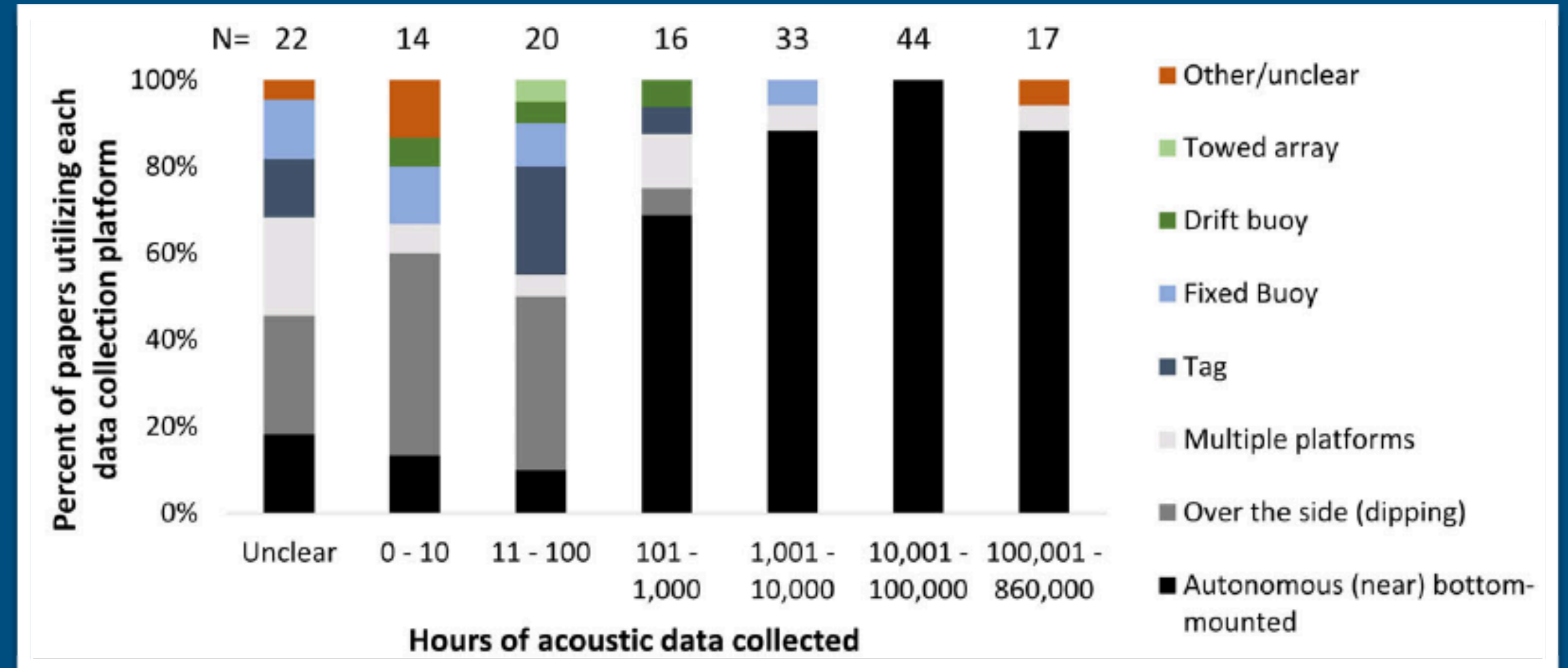


# Passive acoustic monitoring of baleen whales

Blue whale produce loud, low-frequency sounds!

Passive acoustic monitoring

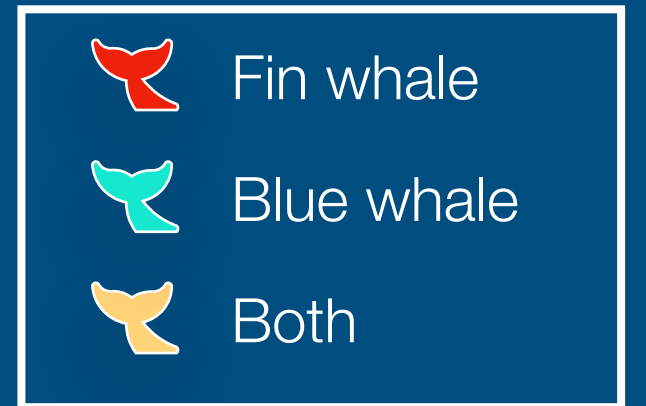
- Autonomous
- Continuous
- Long-term
- Large scale



Kowarski & Moors-Murphy (2020)



# OBSs and whales in the literature



Weirathmueller  
(2011, 2014, 2017)  
Wilcock (2012)  
Soule (2013)



Rebull  
(2006)



Harris (2013)  
Pereira (2020)



Dunn & Hernandez  
(2009)

Franck & Ferris  
(2011)




Gavrilov & McCaulay  
(2018)





Brodie & Dunn  
(2014)

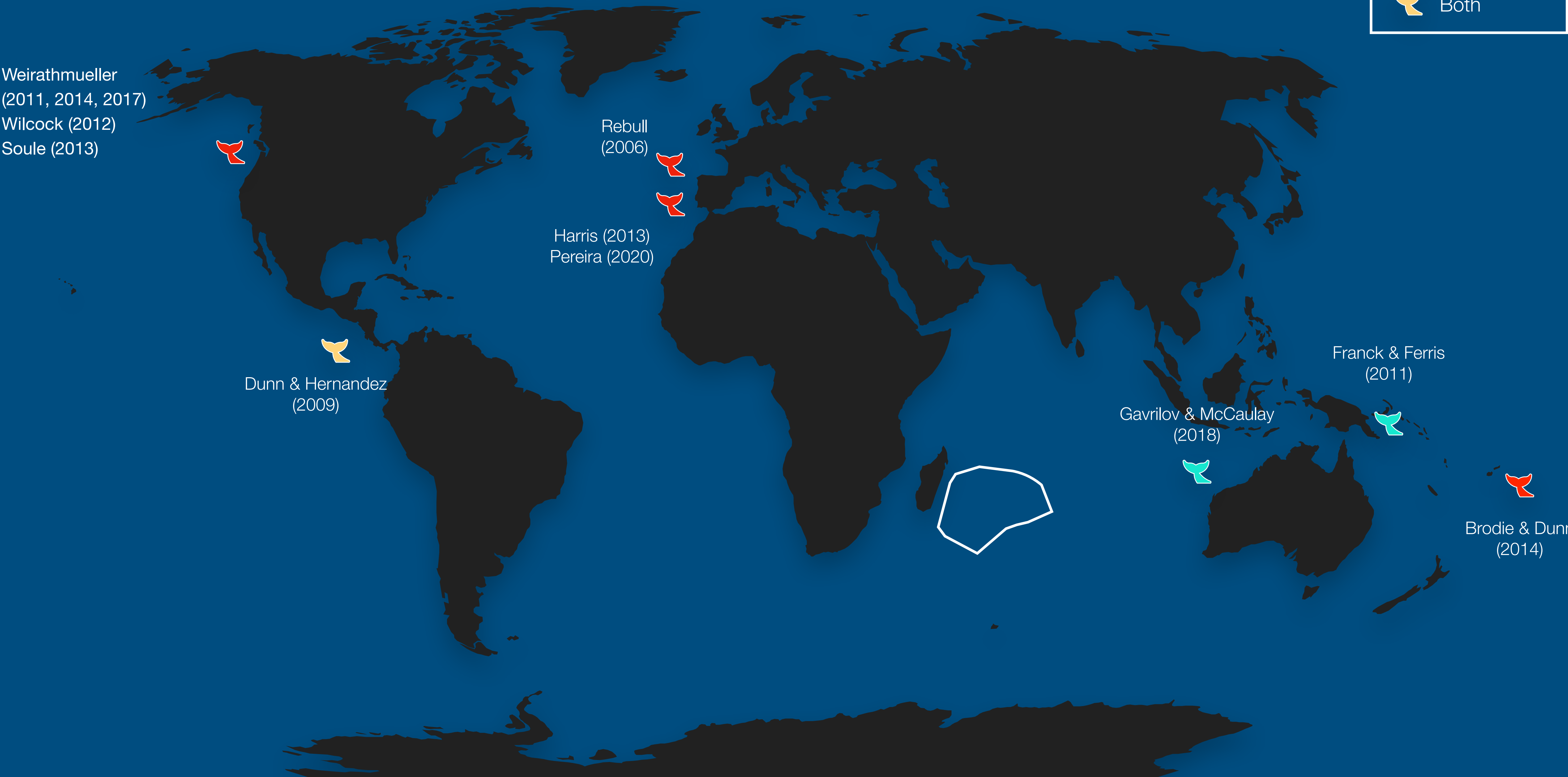


# OBSs and whales in the literature

 Fin whale

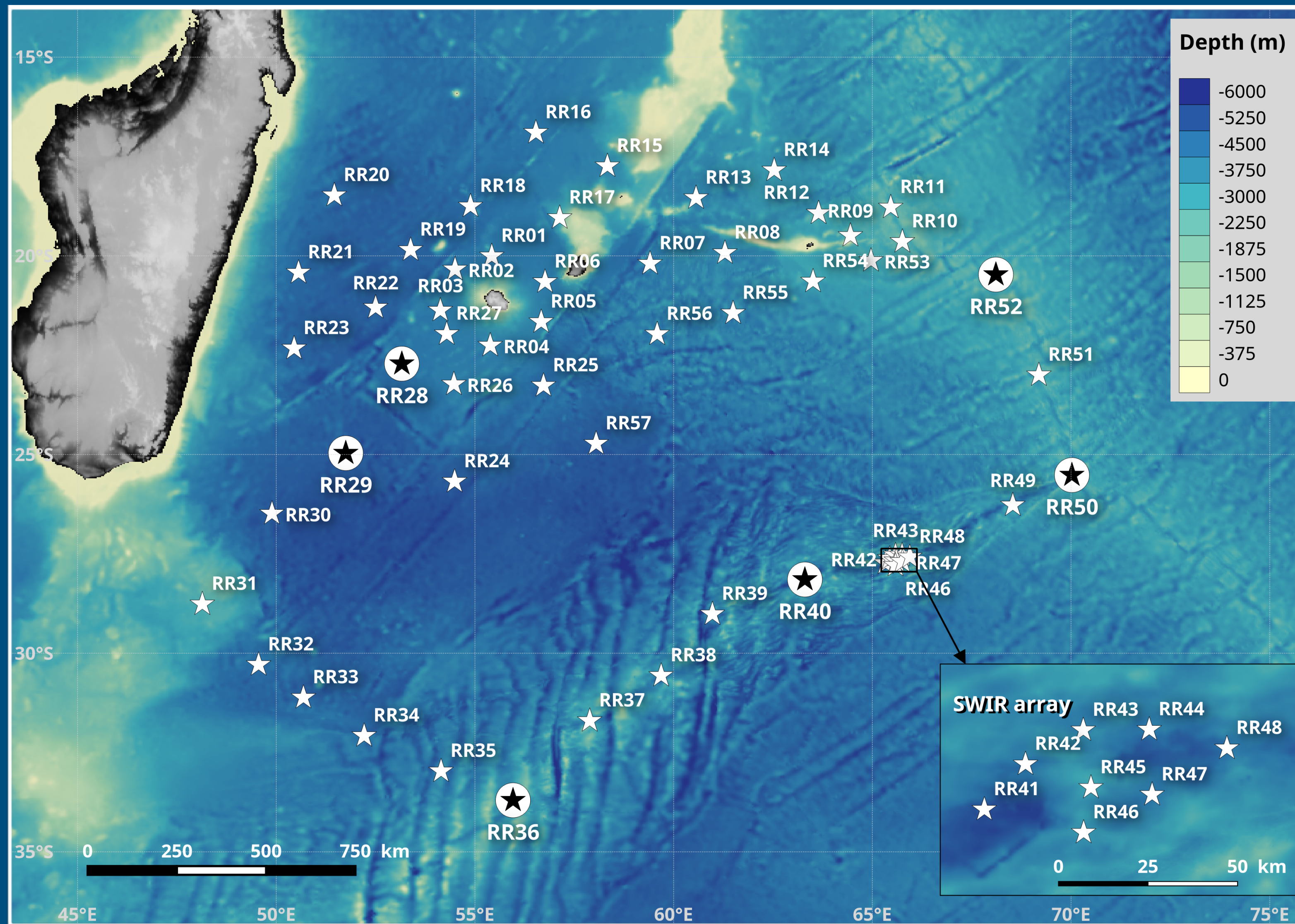
 Blue whale

 Both





# The RHUM-RUM experiment



RHUM-RUM data is open source!

- ▶ RESIF data center, under the code name YV

<https://doi.org/10.15778/RESIF.YV2011>

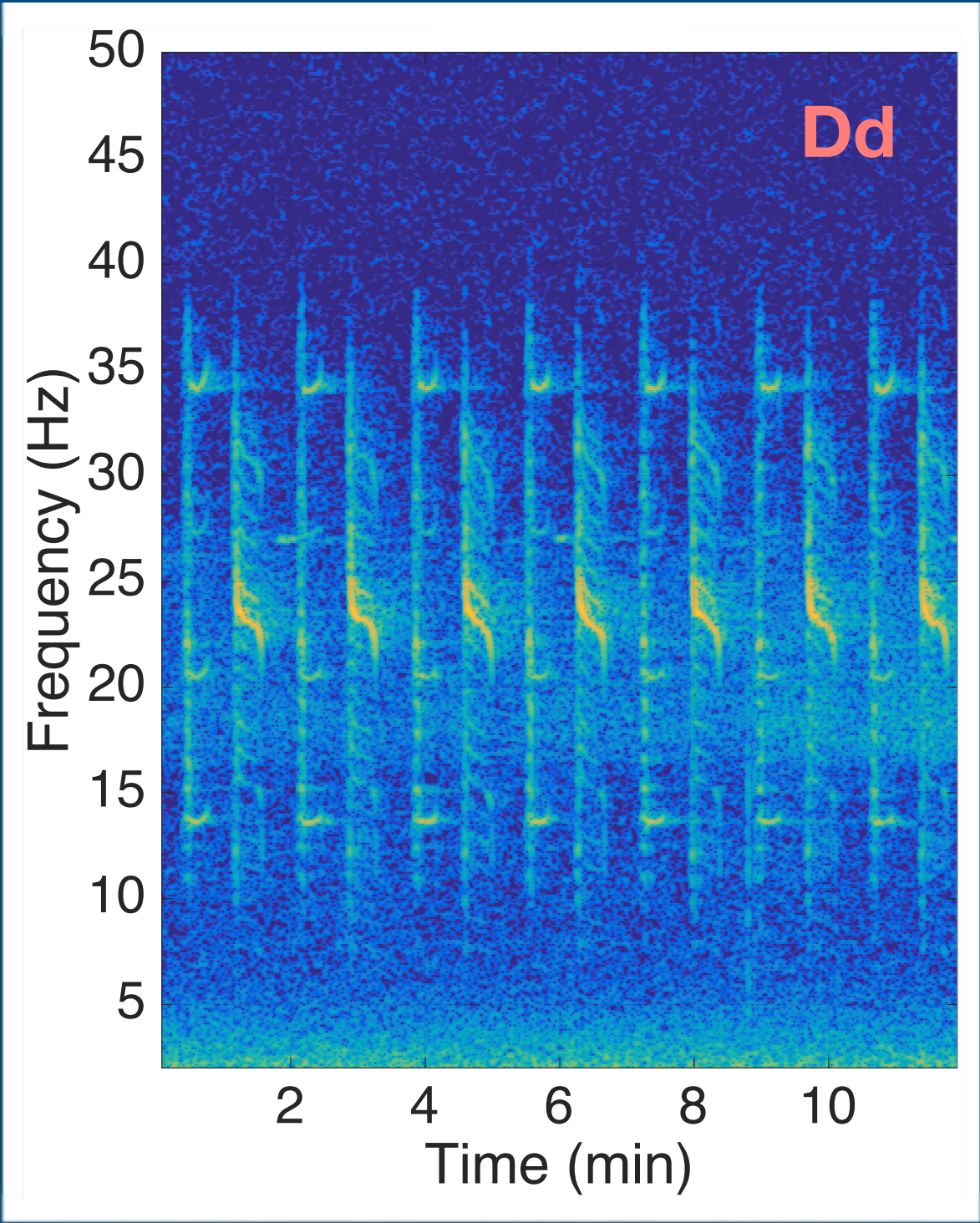
- ▶ Find more information on RHUM-RUM on Researchgate

<https://www.researchgate.net/project/RHUM-RUM>

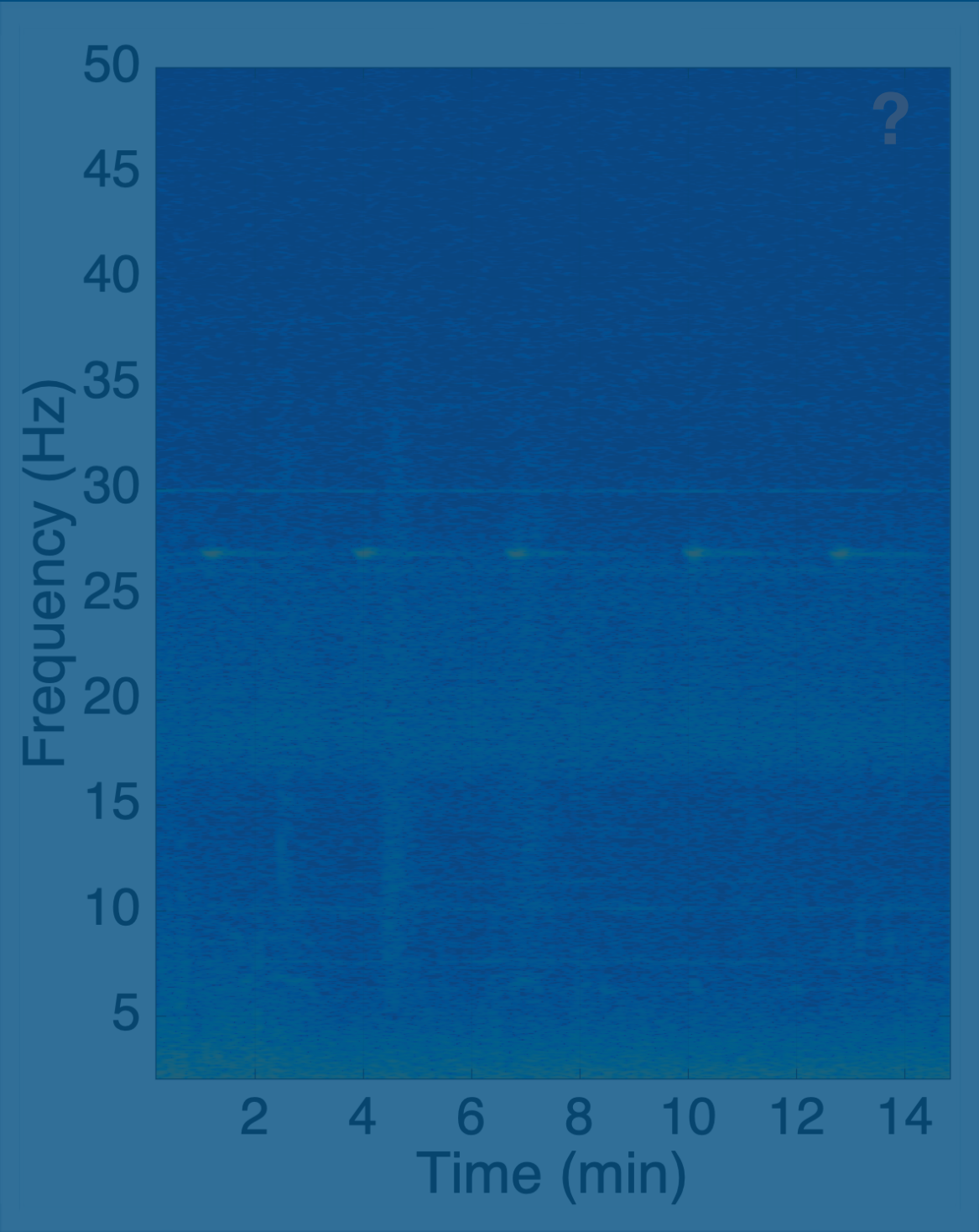


# Recorded baleen whale sounds

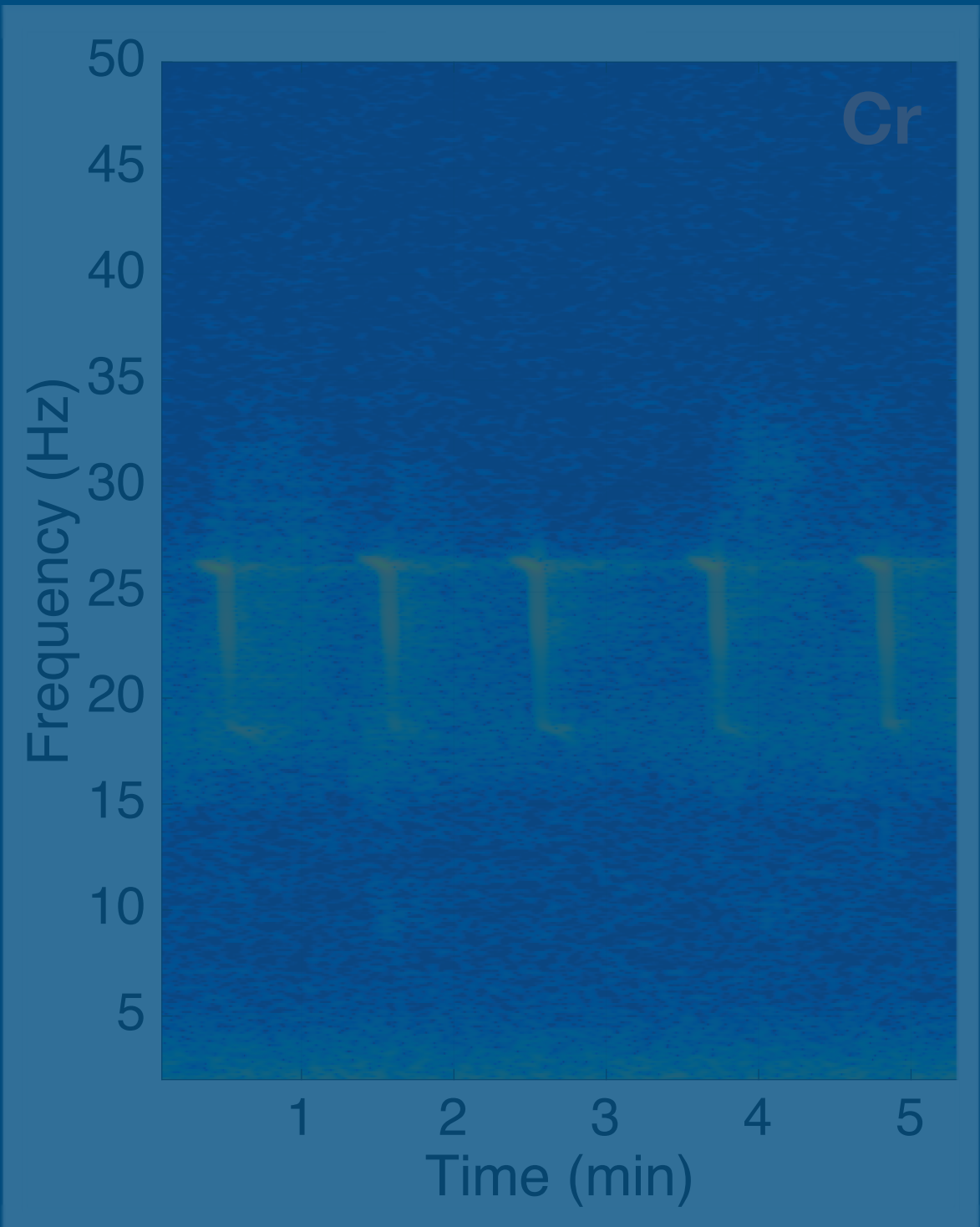
Very local Not so local



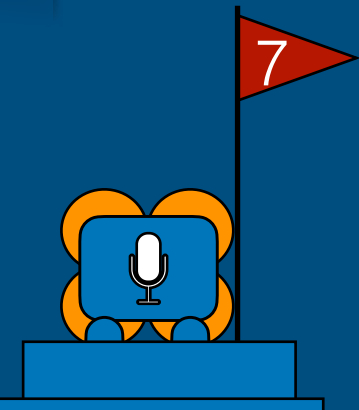
Madagascar Pygmy blue whale  
*Balaenoptera musculus brevicauda*



P-call or spot call  
*unknown*



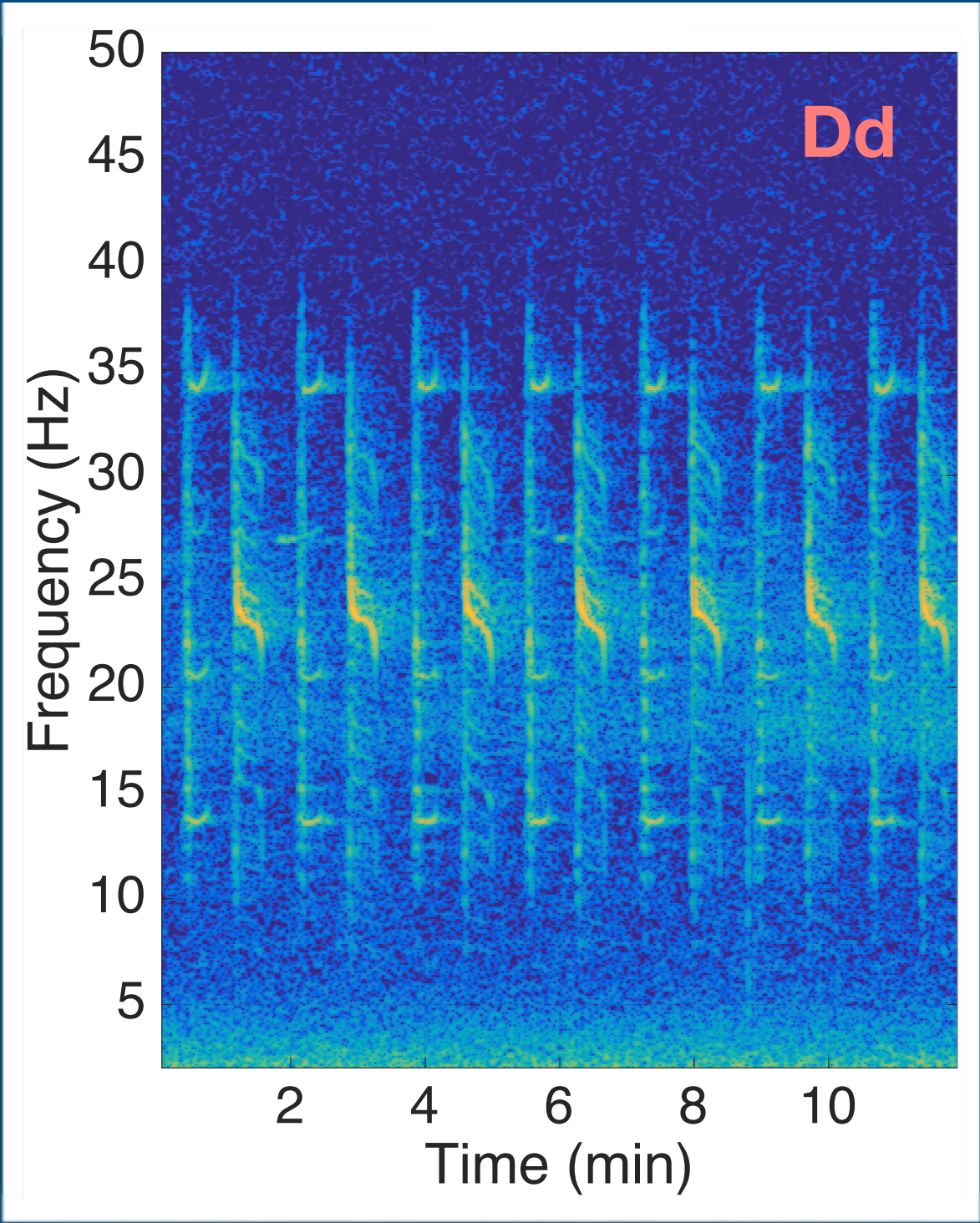
Antarctic blue whale  
*Balaenoptera m. intermedia*



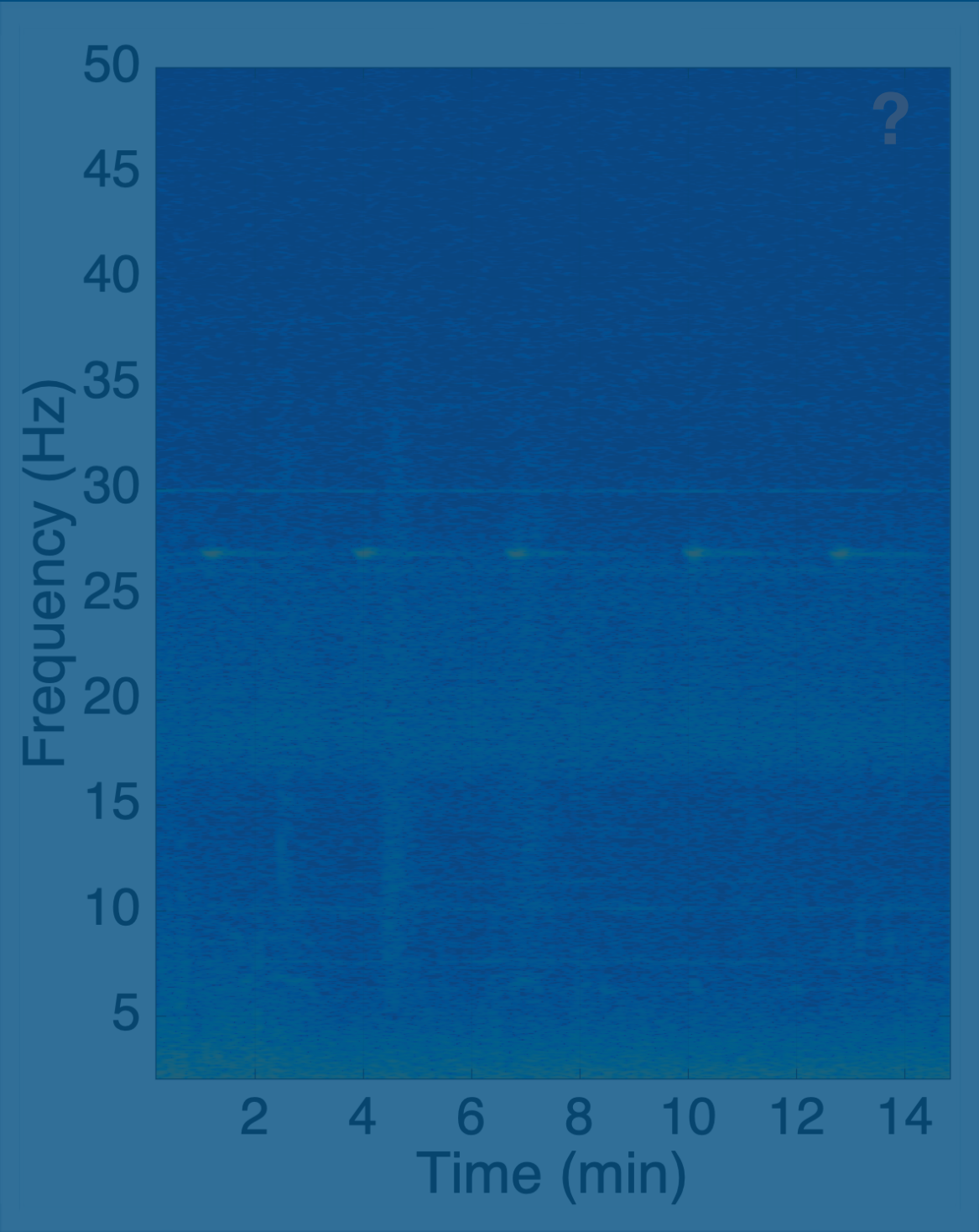


# Recorded baleen whale sounds

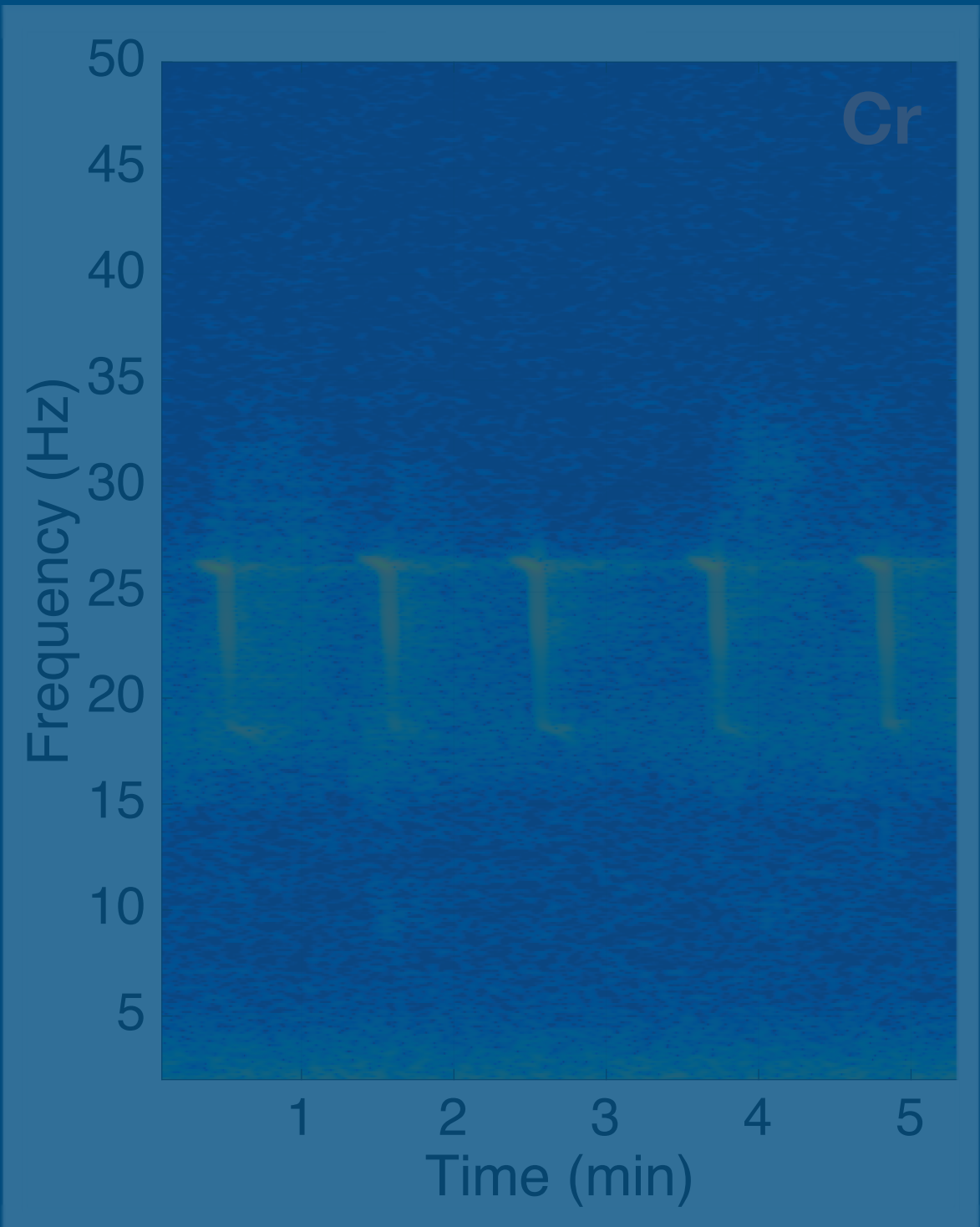
Very local Not so local



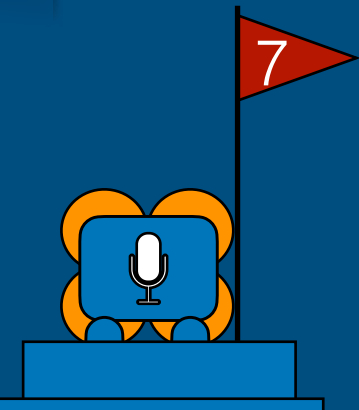
Madagascar Pygmy blue whale  
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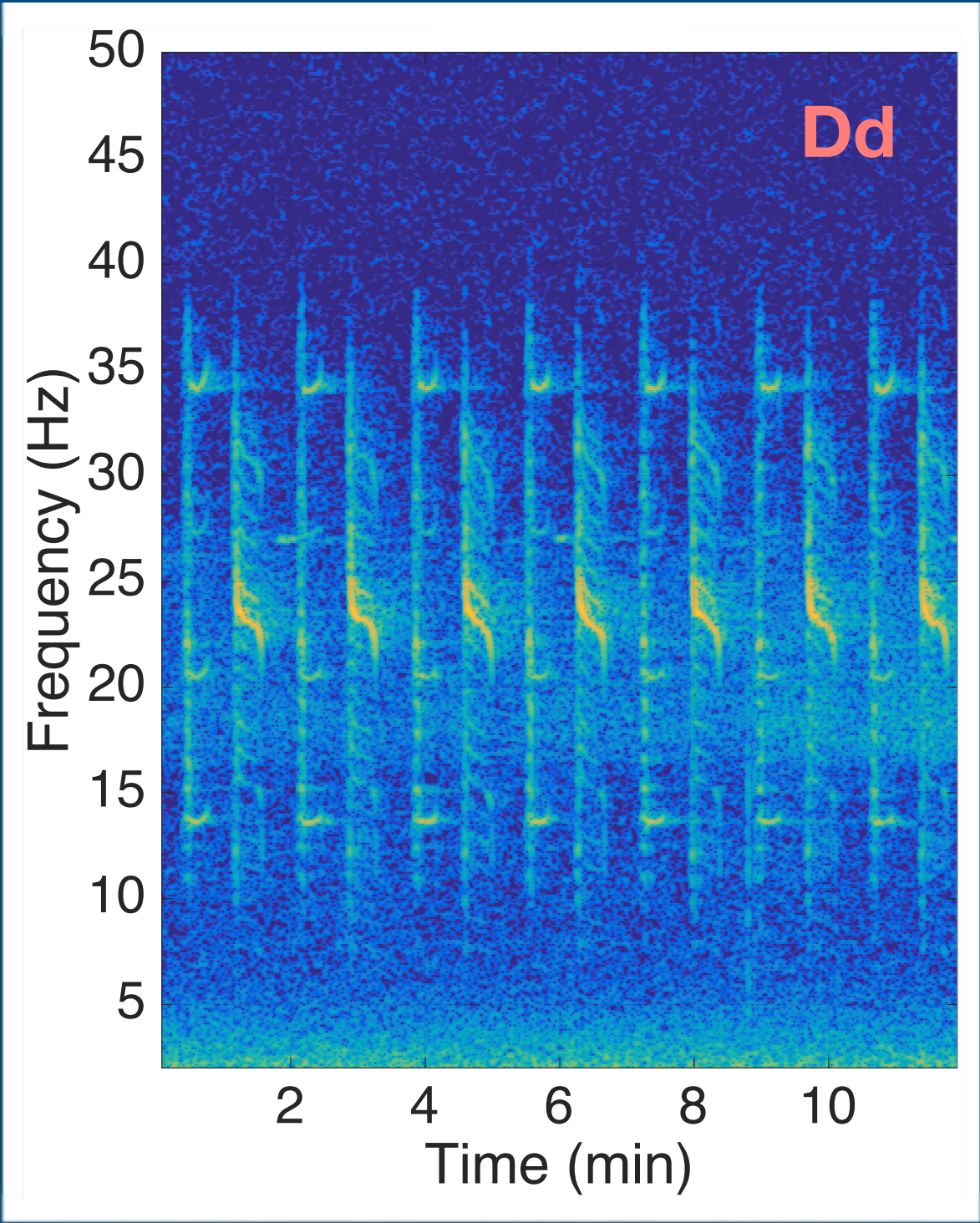
Antarctic blue whale  
*Balaenoptera m. intermedia*



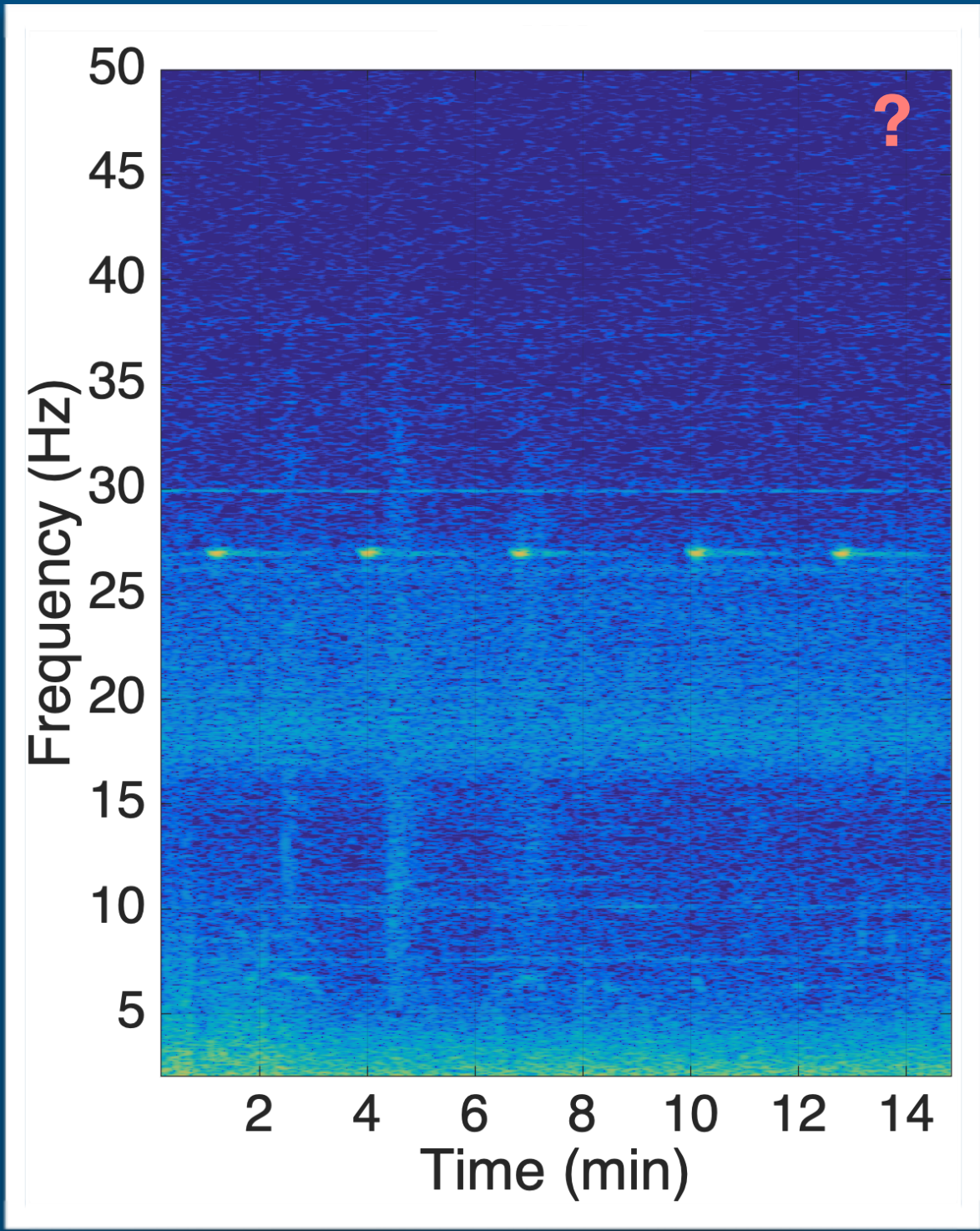


# Recorded baleen whale sounds

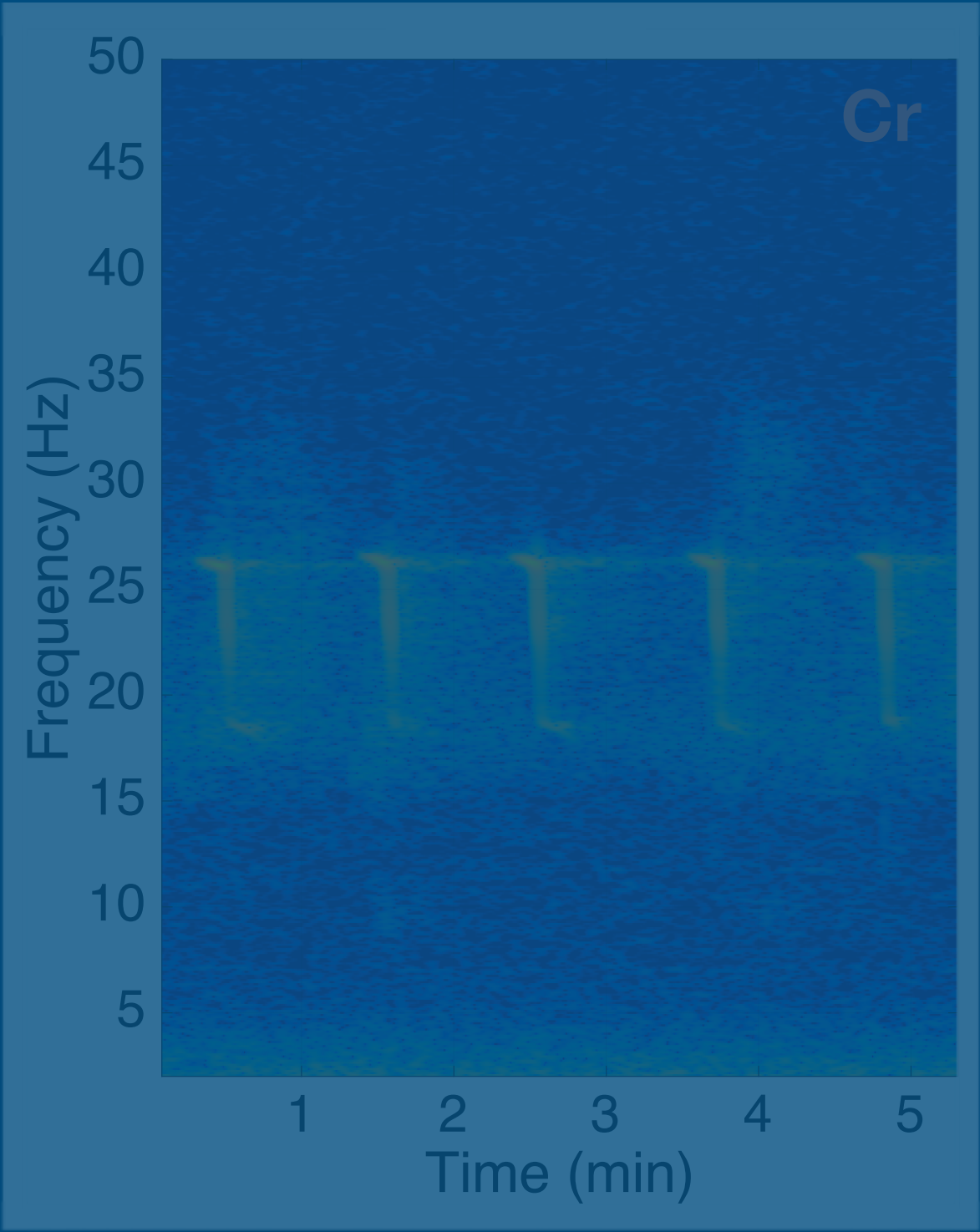
Very local Not so local



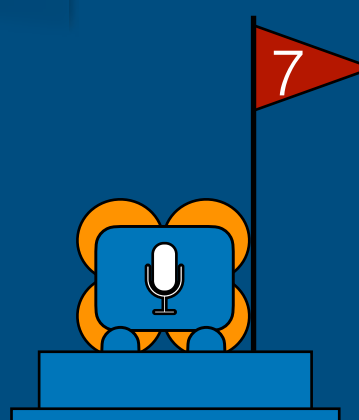
Madagascar Pygmy blue whale  
*Balaenoptera musculus brevicauda*



P-call or spot call  
*unknown*



Antarctic blue whale  
*Balaenoptera m. intermedia*

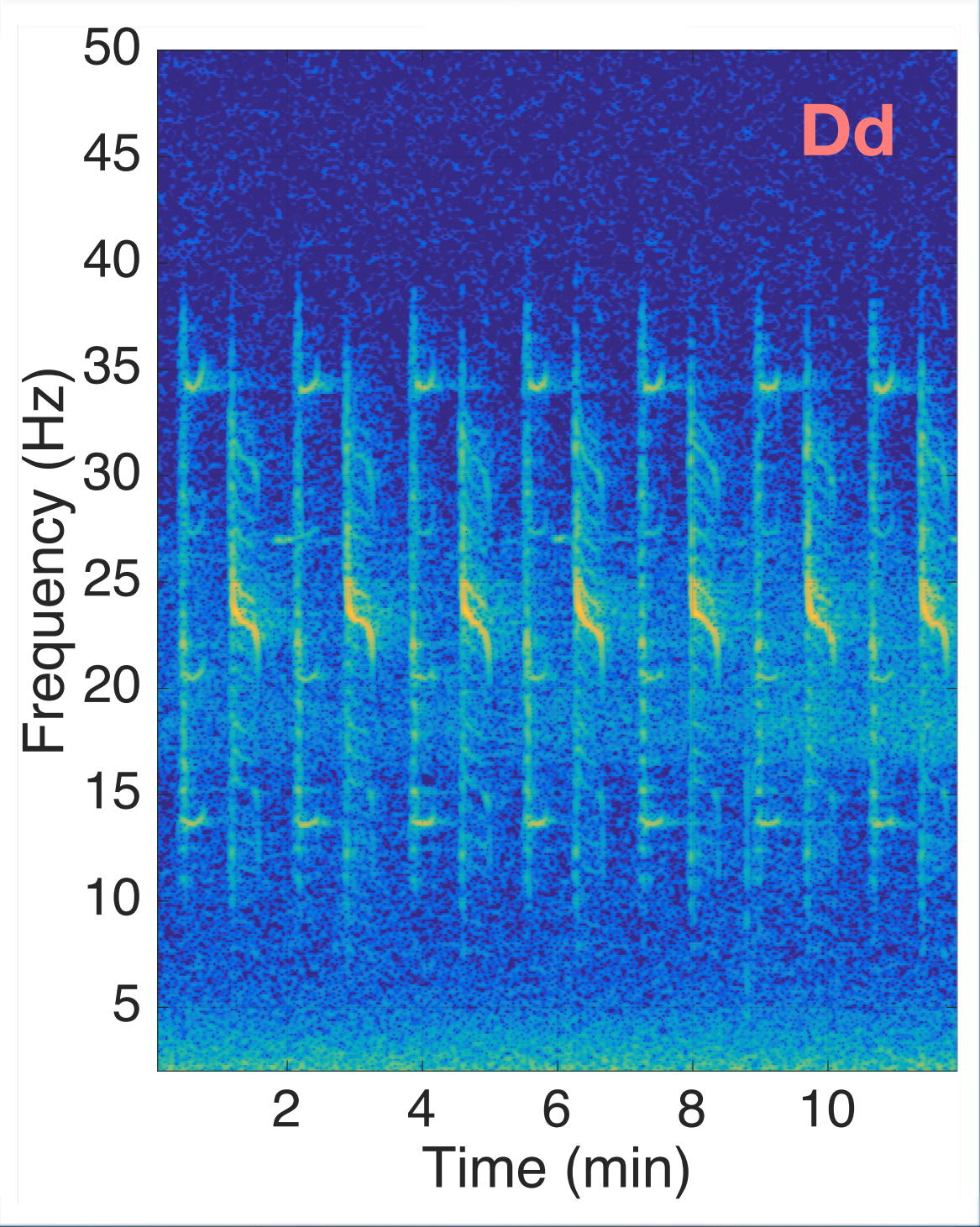




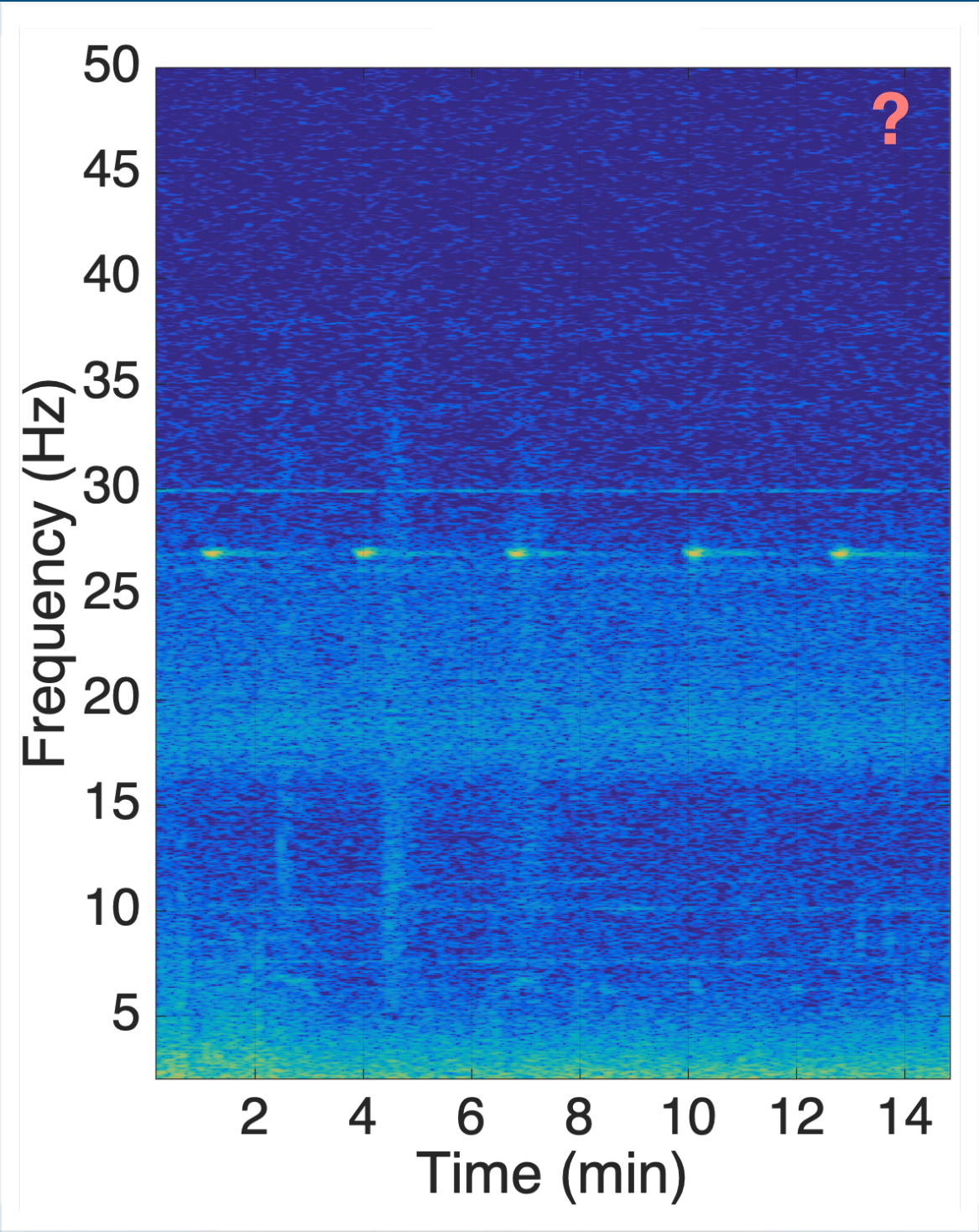
# Recorded baleen whale sounds

Very local

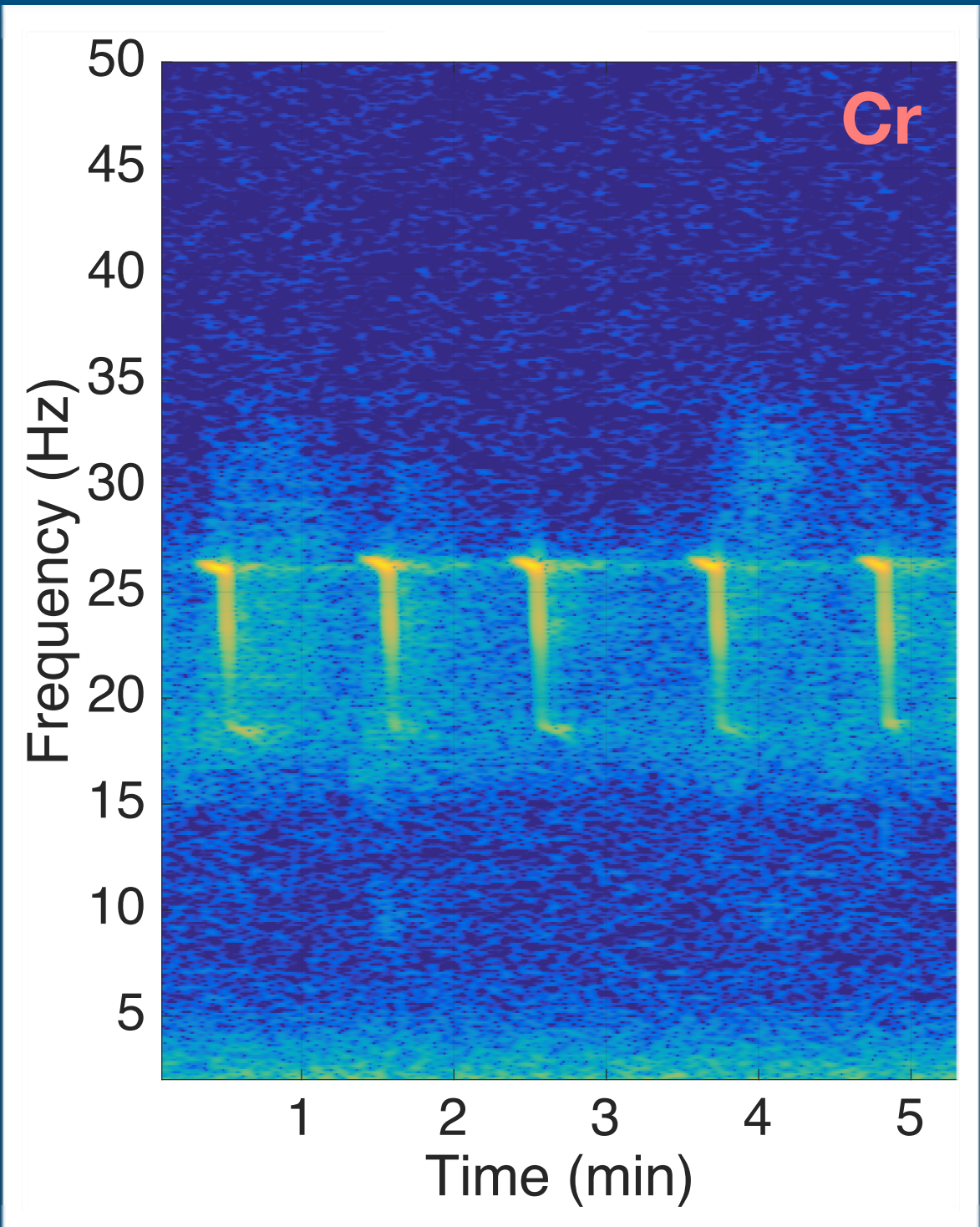
Not so local



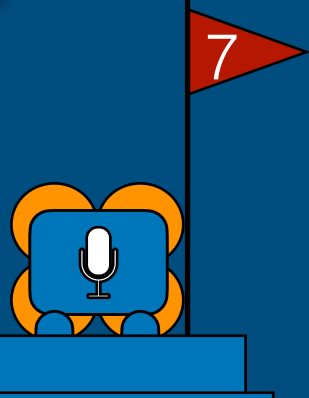
Madagascar Pygmy blue whale  
*Balaenoptera musculus brevicauda*



P-call or spot call  
*unknown*



Antarctic blue whale  
*Balaenoptera m. intermedia*

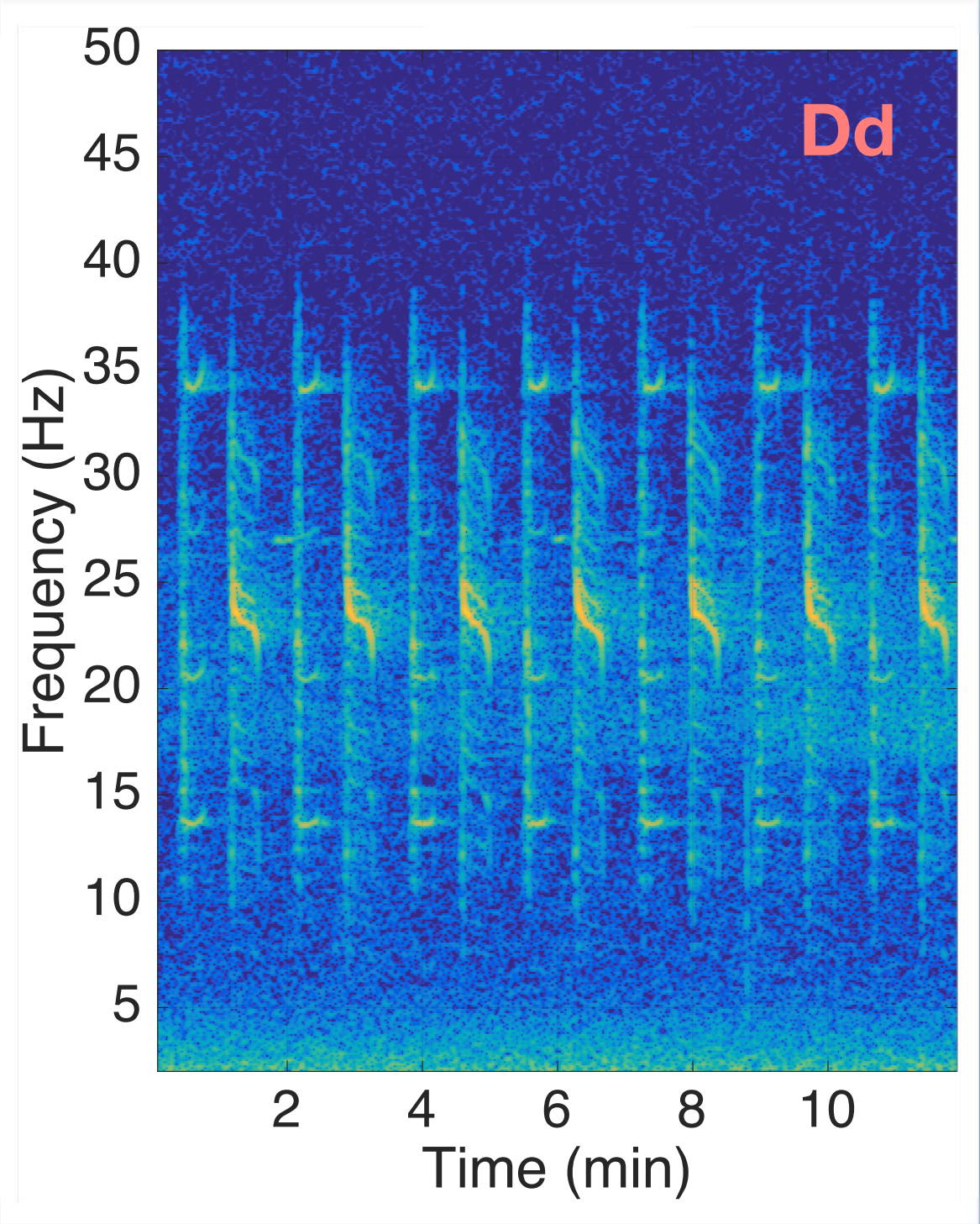




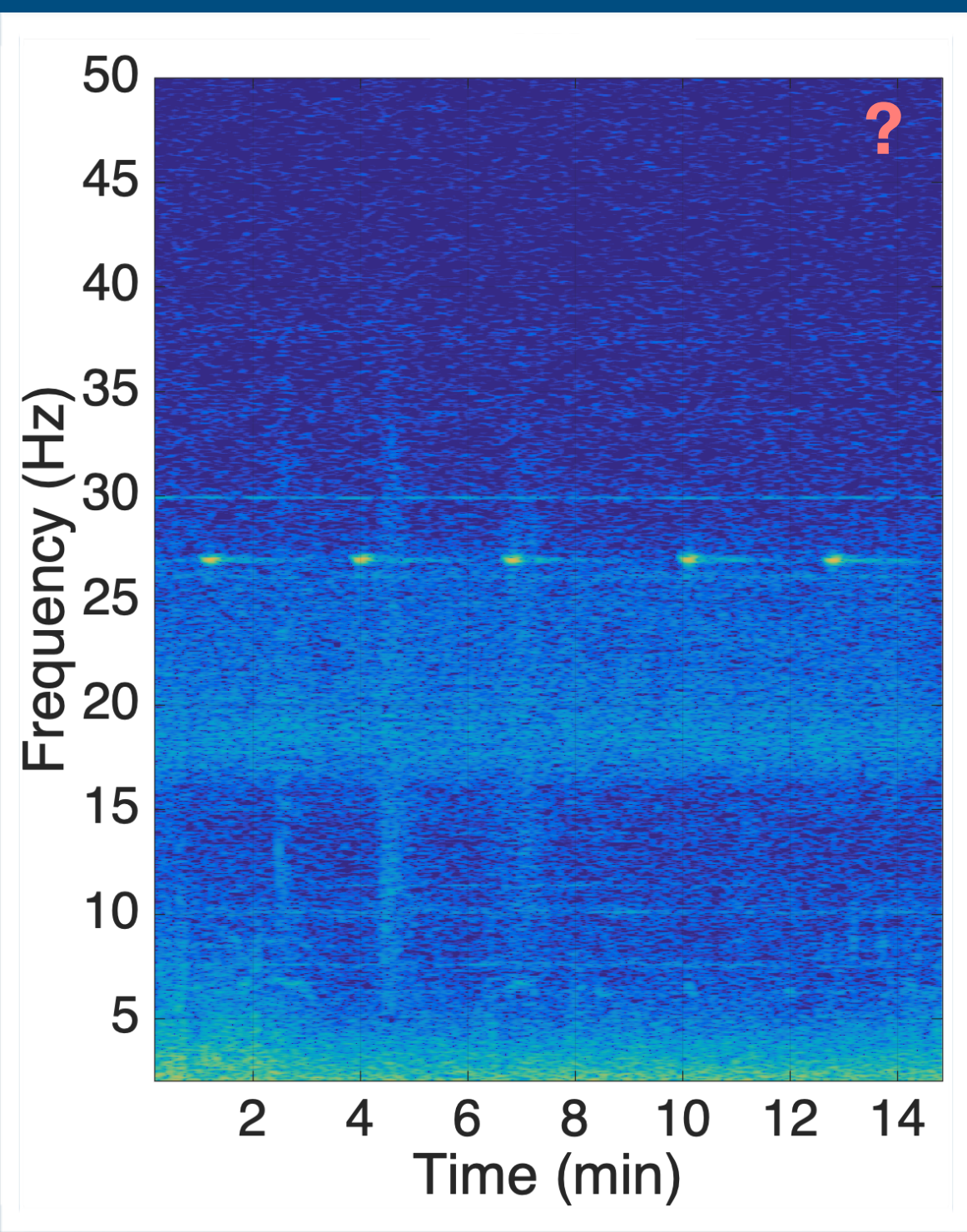
# Recorded baleen whale sounds

Very local

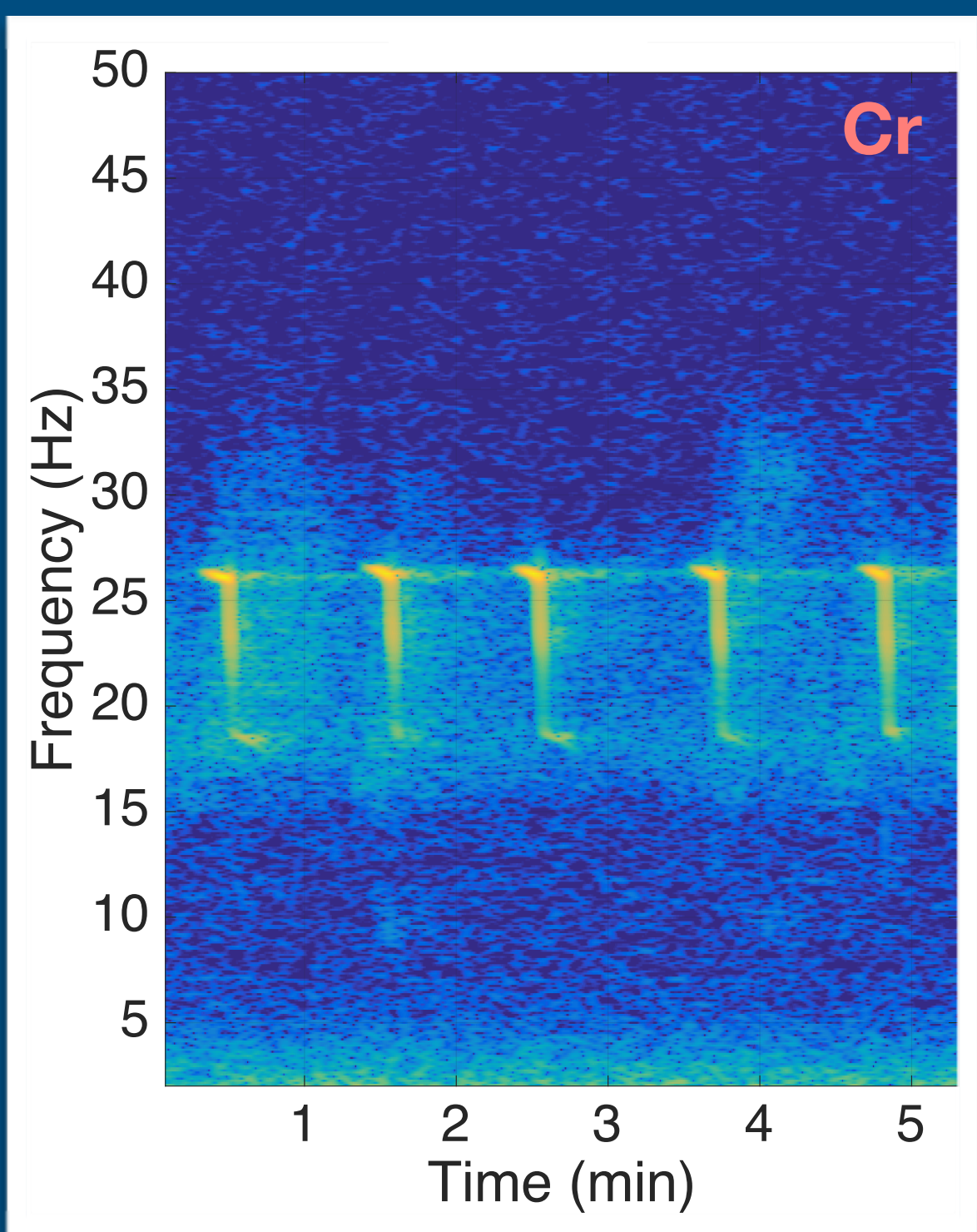
Not so local



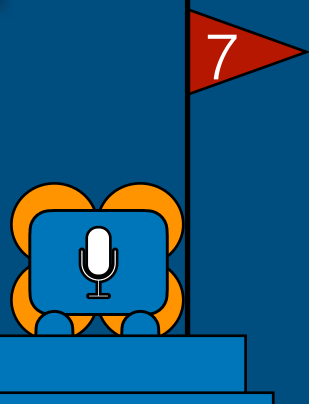
Madagascar Pygmy blue whale  
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P-call or spot call  
*unknown*

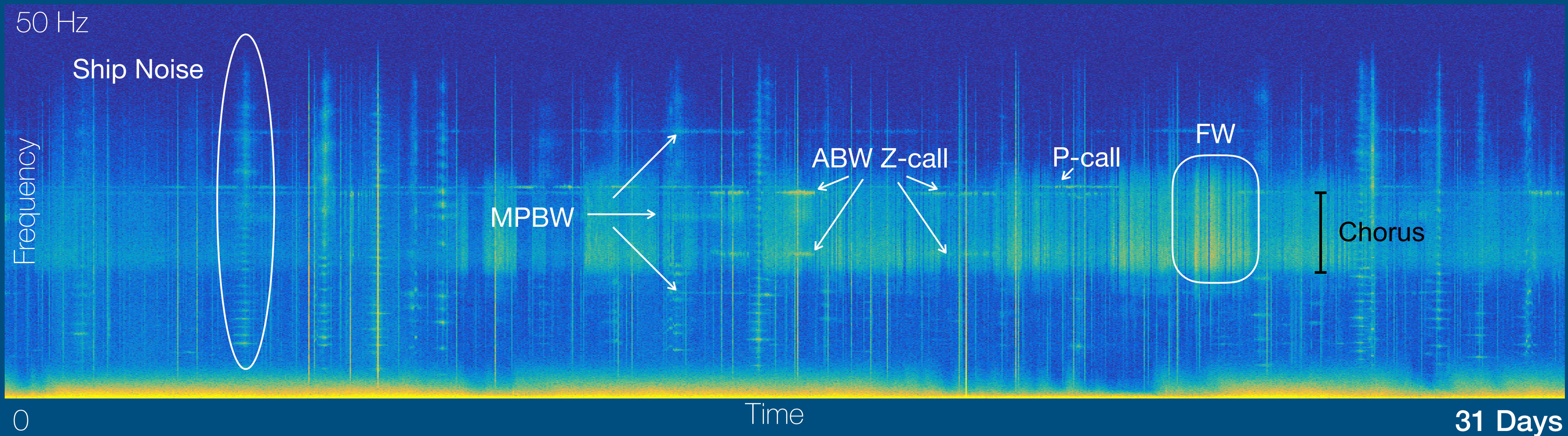


Antarctic blue whale  
*Balaenoptera m. intermedia*



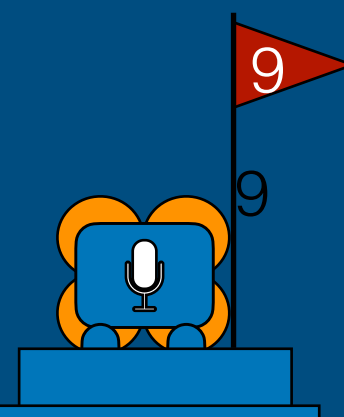


# From large temporal and spatial scales...



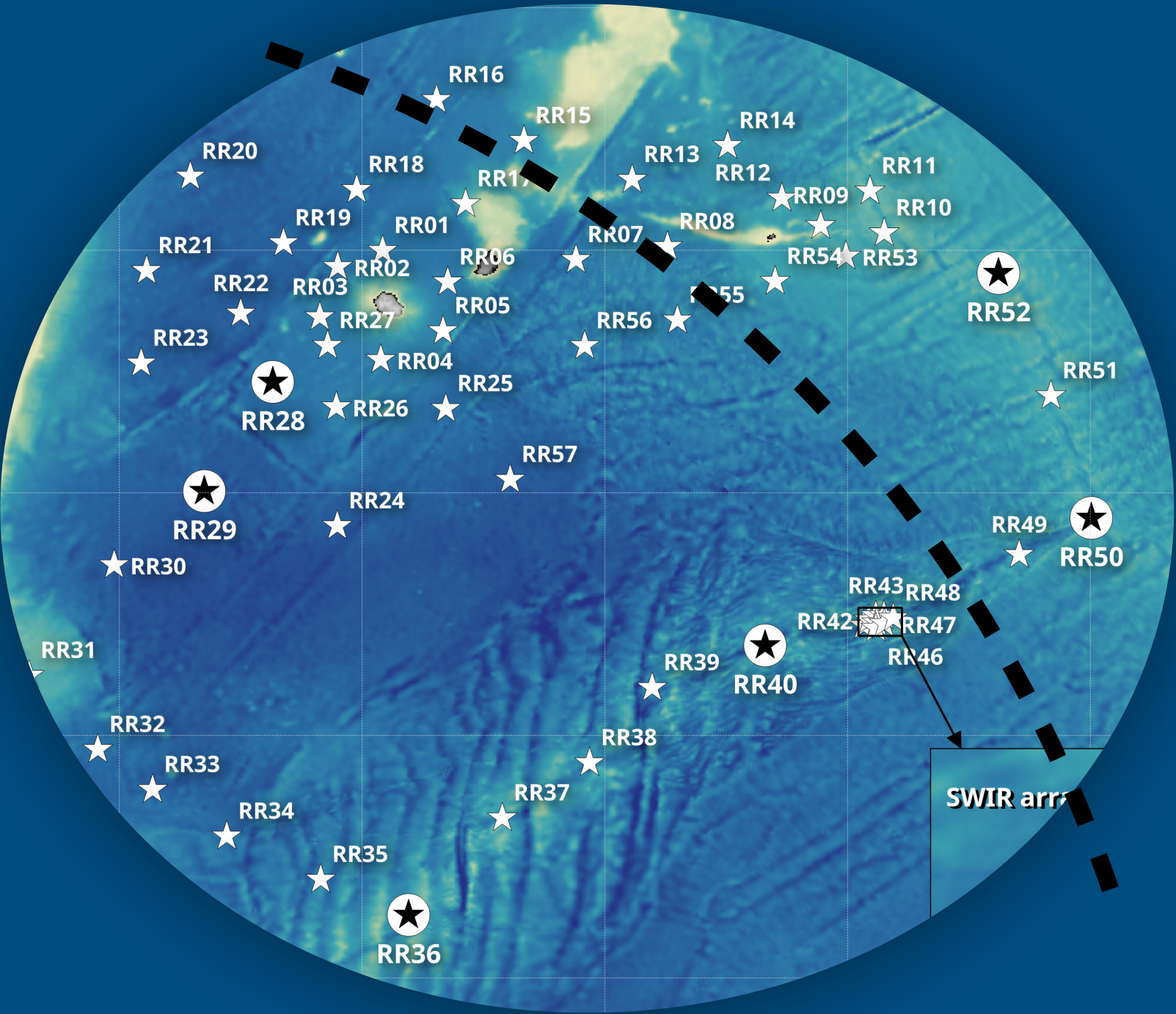


# From large temporal and spatial scales...

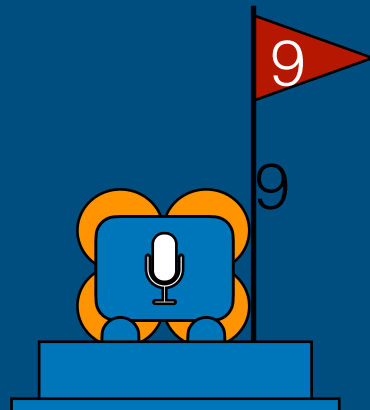


# From large temporal and spatial scales...

Madagascar pygmy  
blue whale



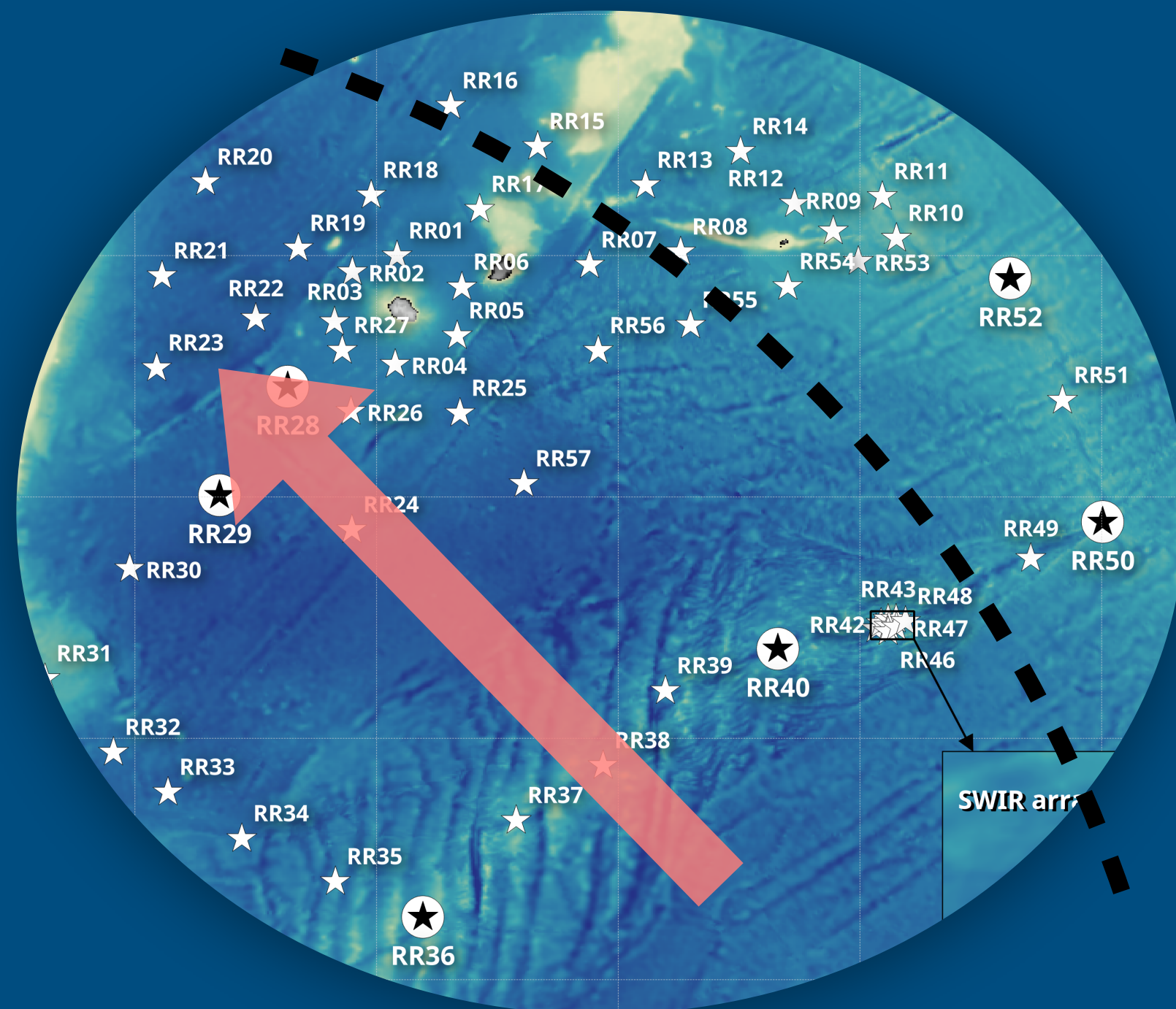
March -> June



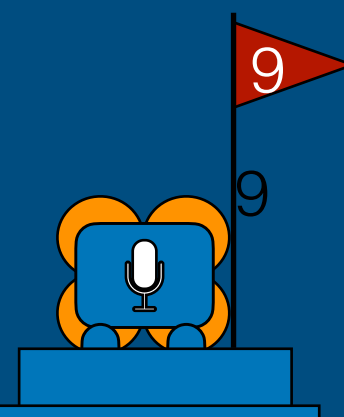


# From large temporal and spatial scales...

## Madagascar pygmy blue whale



March -> June



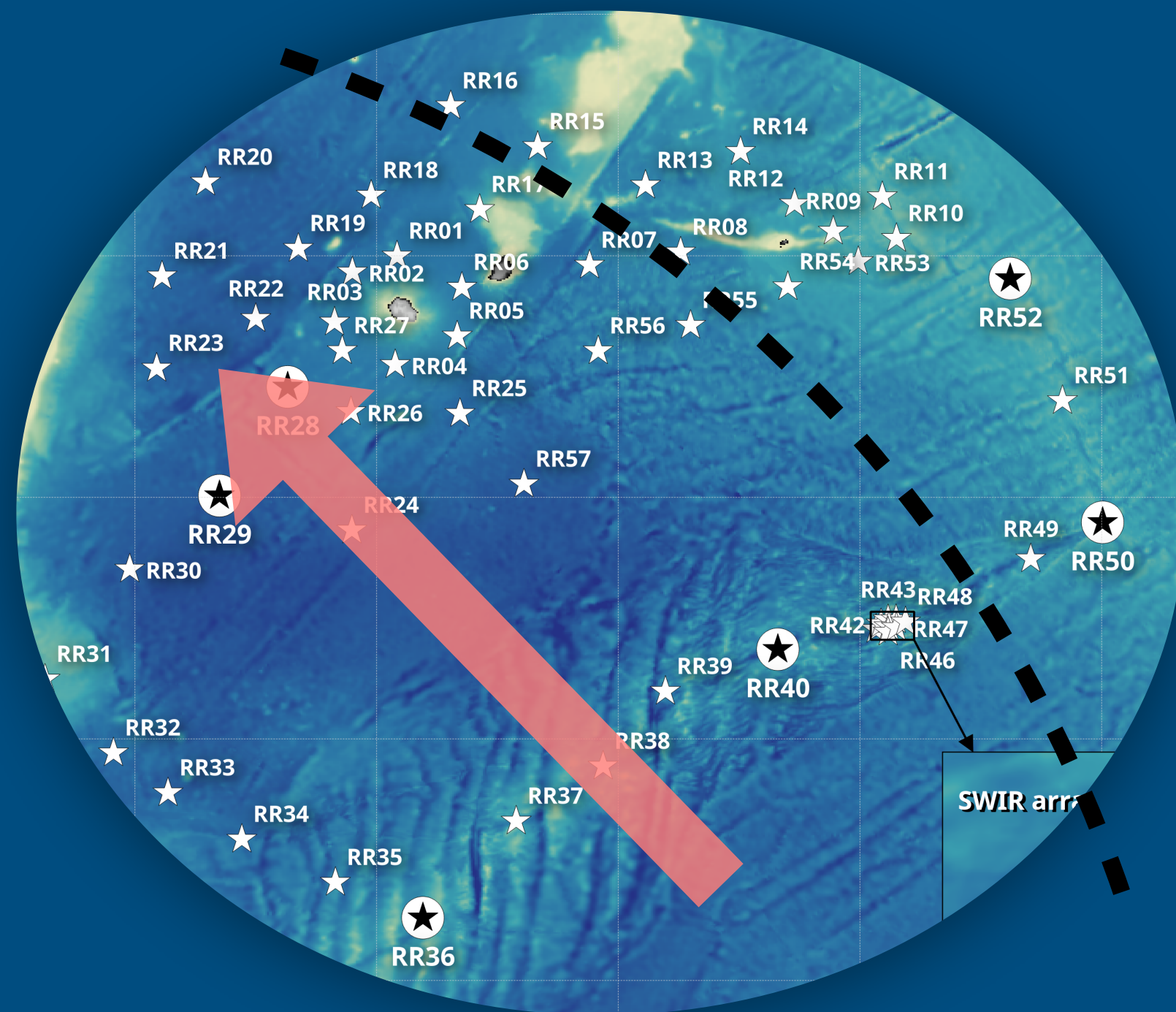


# From large temporal and spatial scales...

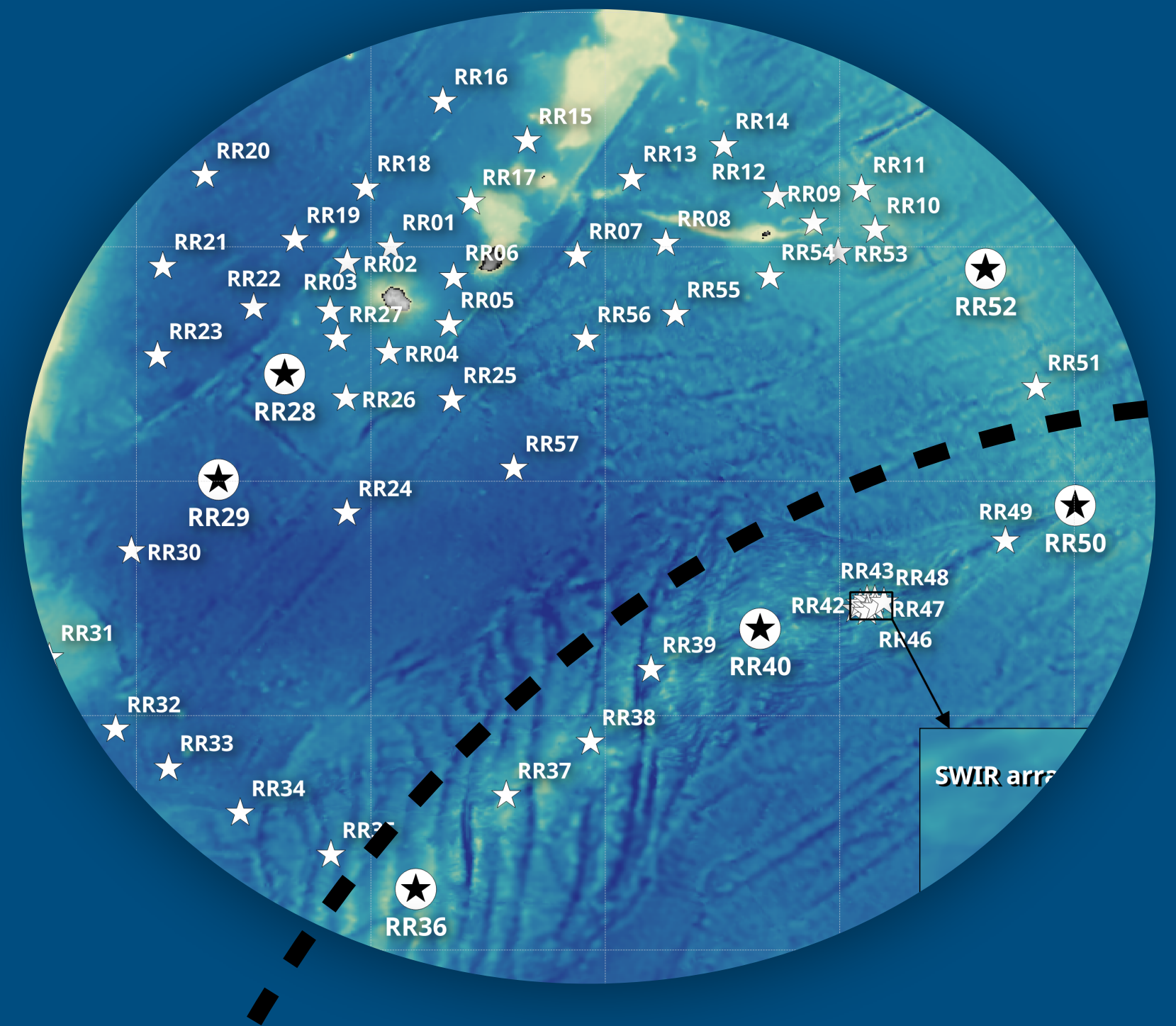


Madagascar pygmy  
blue whale

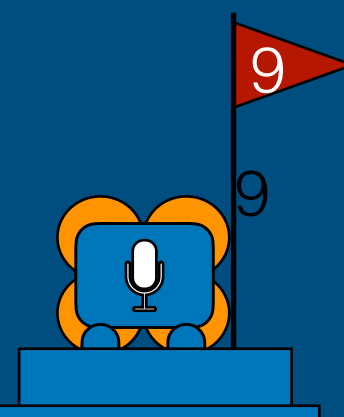
P-call or spot call



March -> June



April -> December

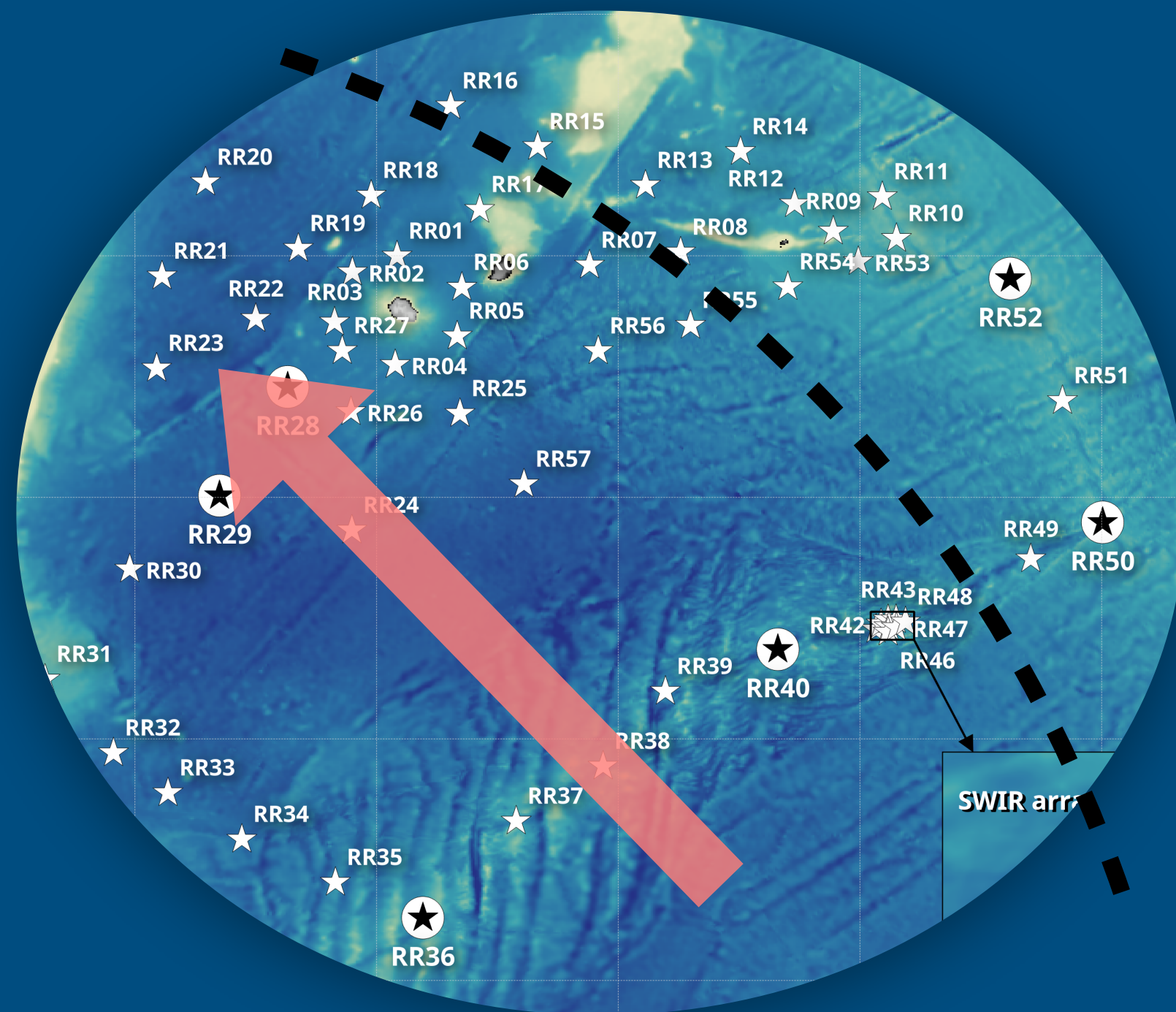




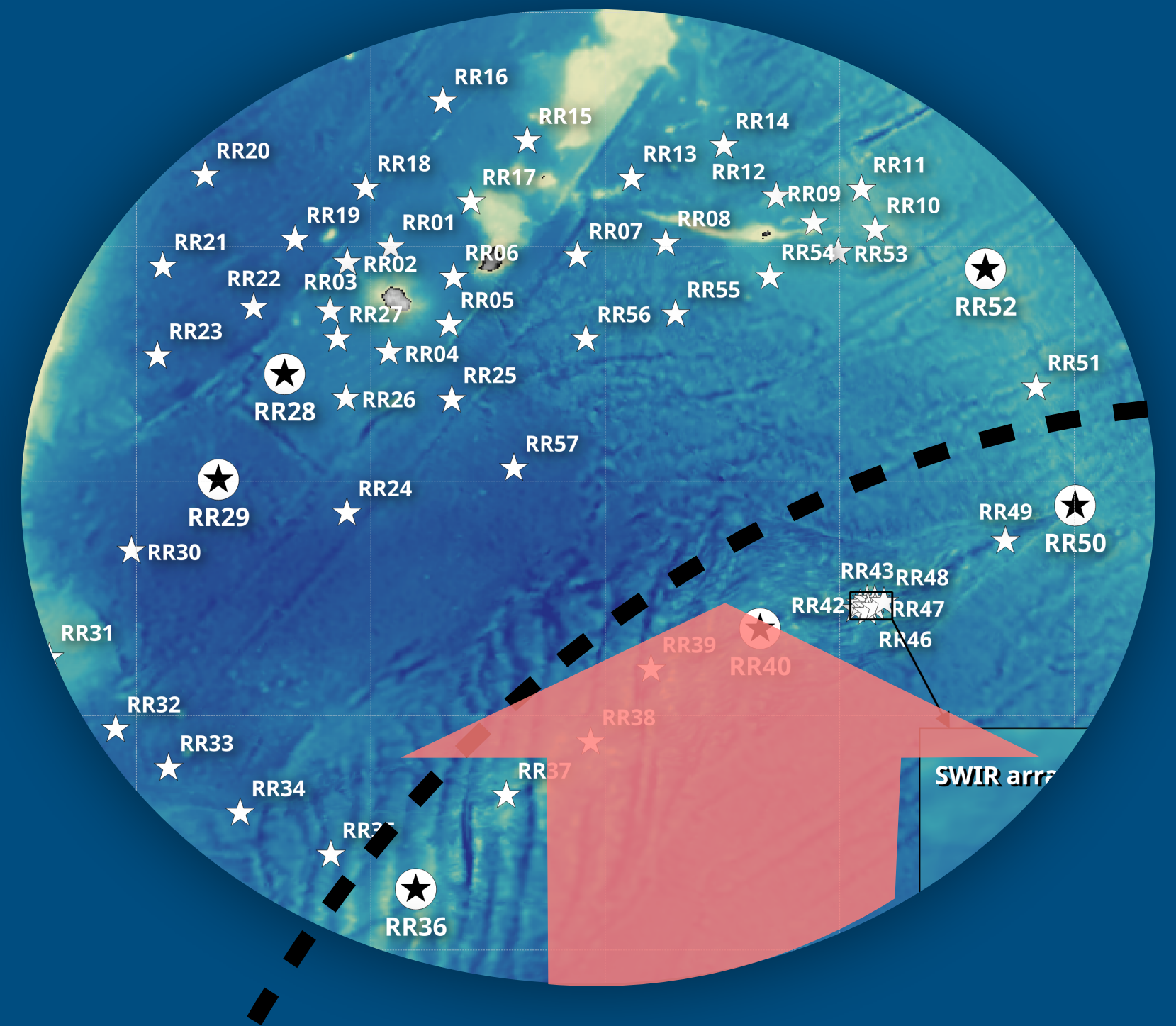
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Madagascar pygmy  
blue whale

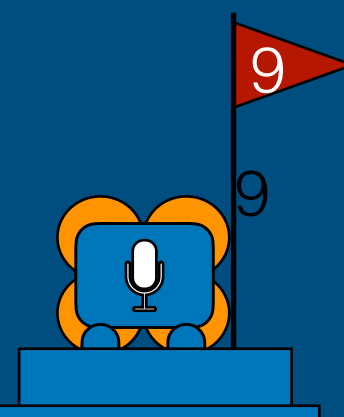
P-call or spot call



March -> June



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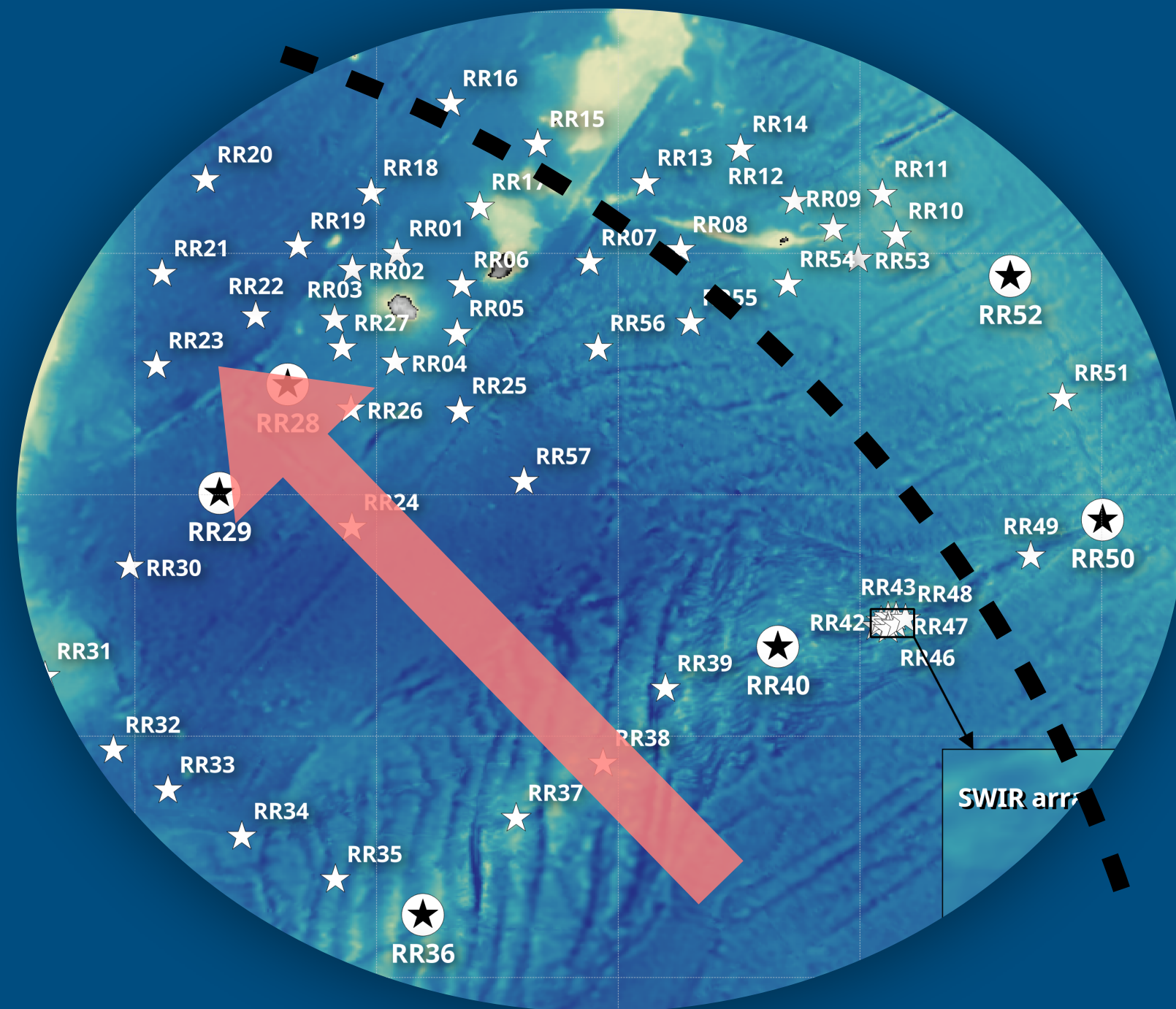
# From large temporal and spatial scales...



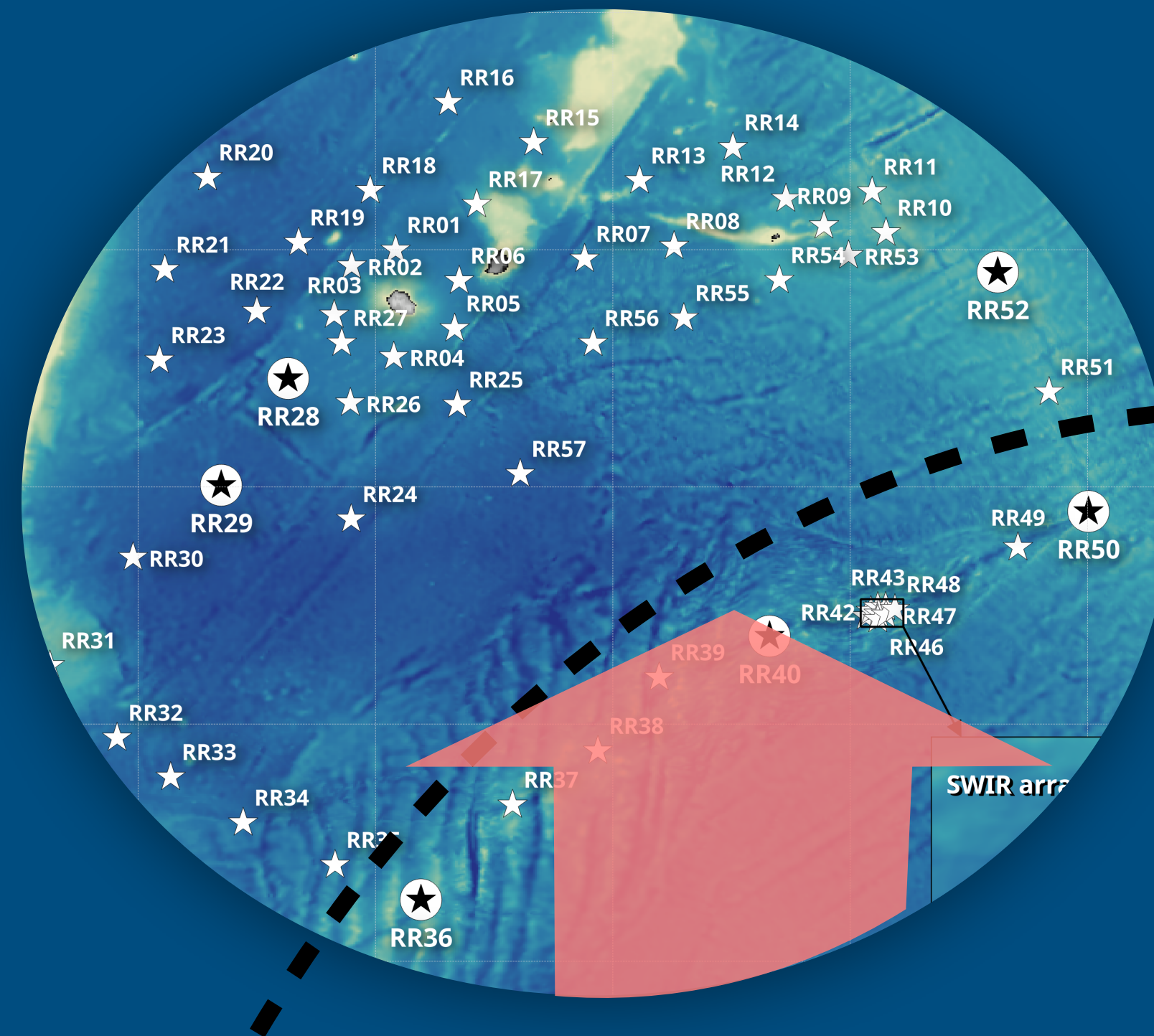
Madagascar pygmy  
blue whale

P-call or spot call

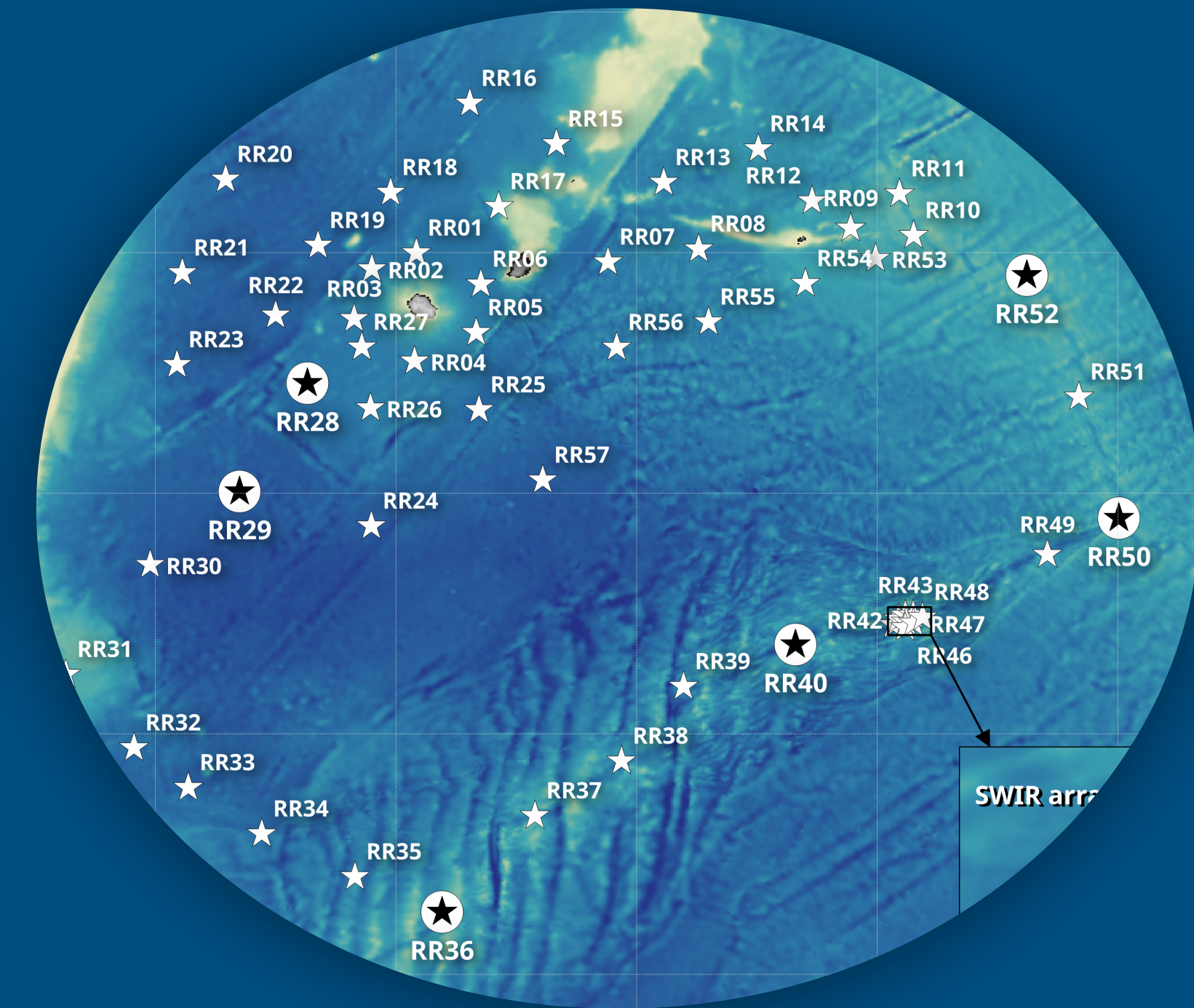
Antarctic blue whale



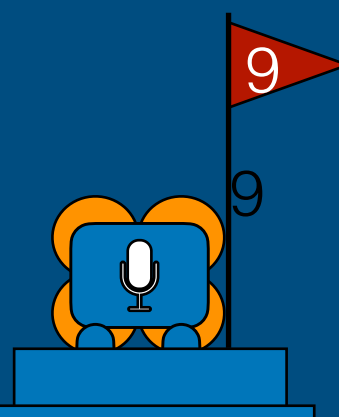
March -> June



April -> December



February -> October





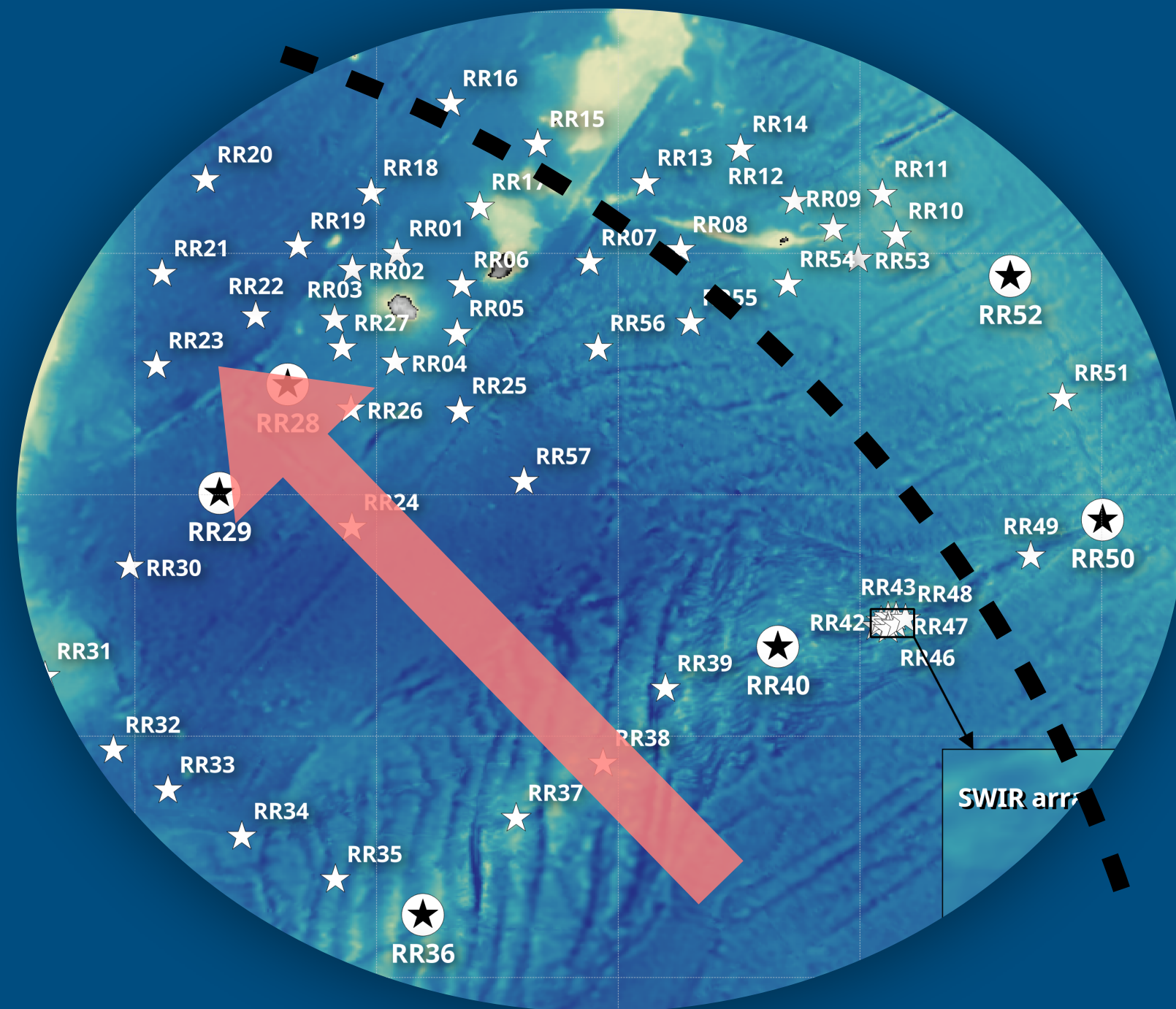
# From large temporal and spatial scales...



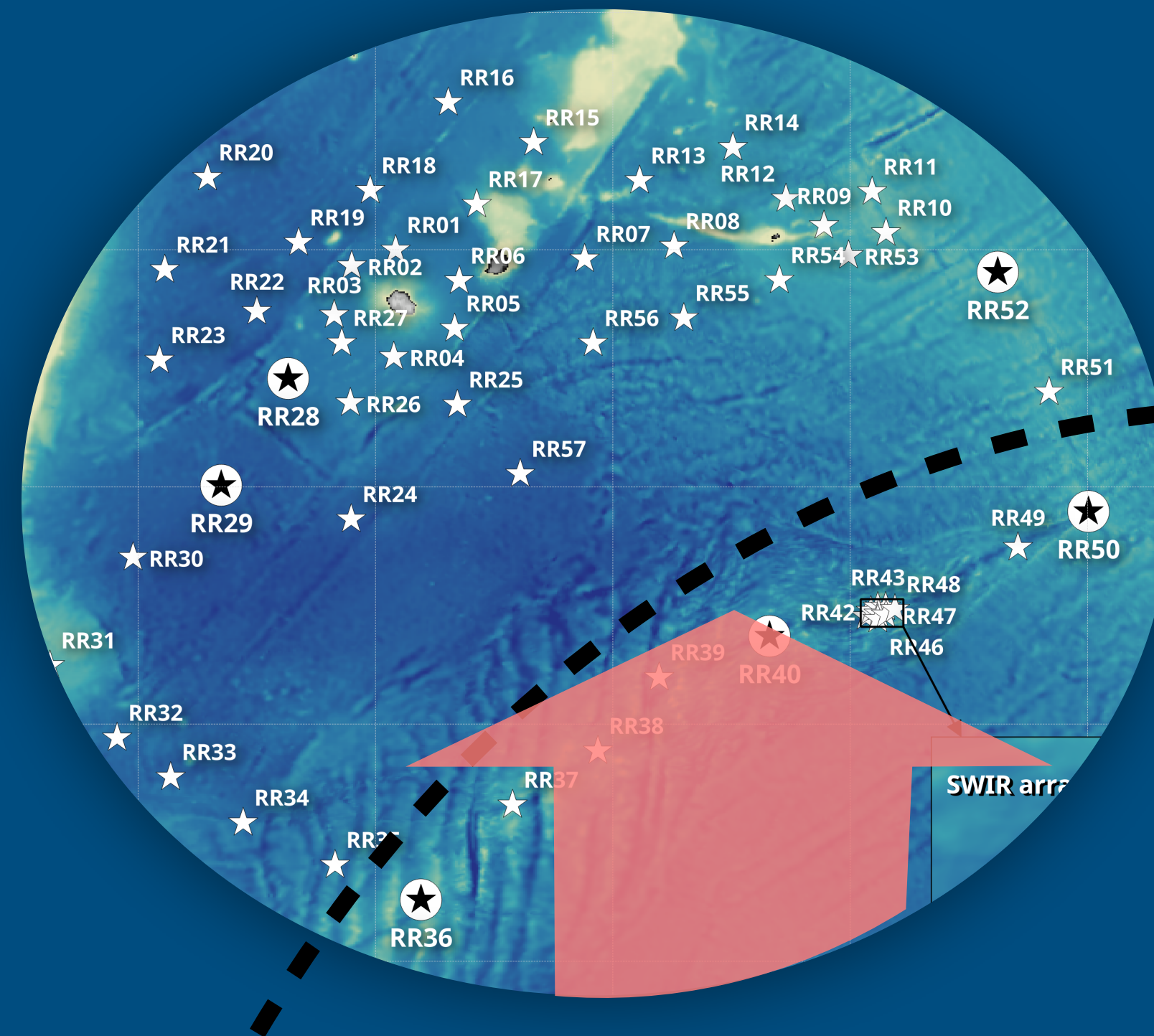
Madagascar pygmy  
blue whale

P-call or spot call

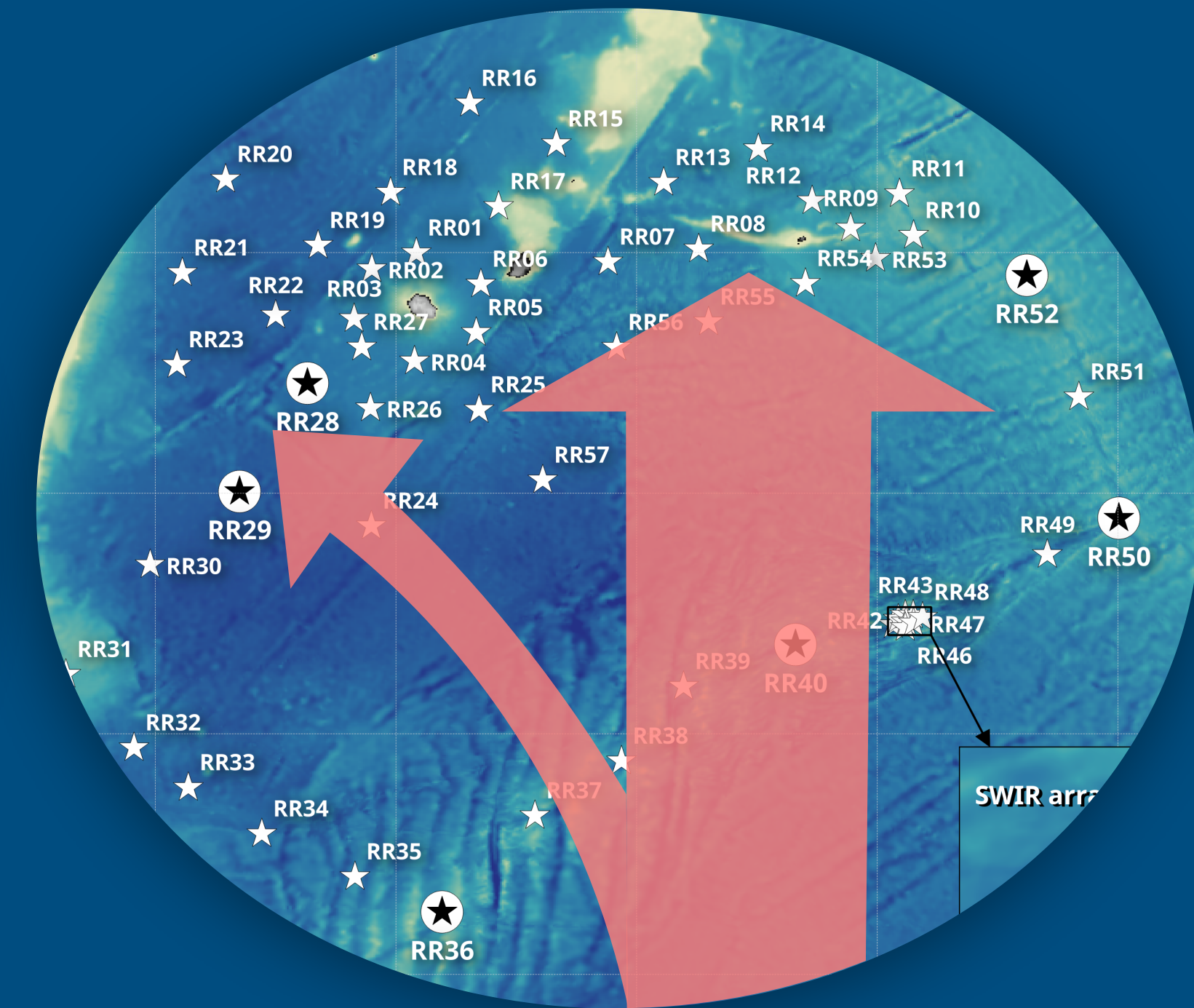
Antarctic blue whale



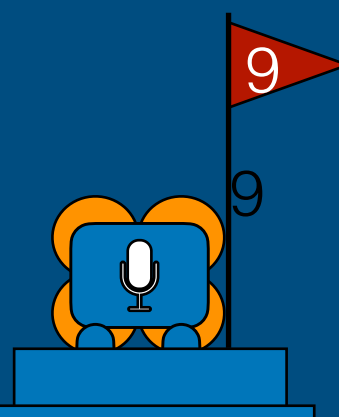
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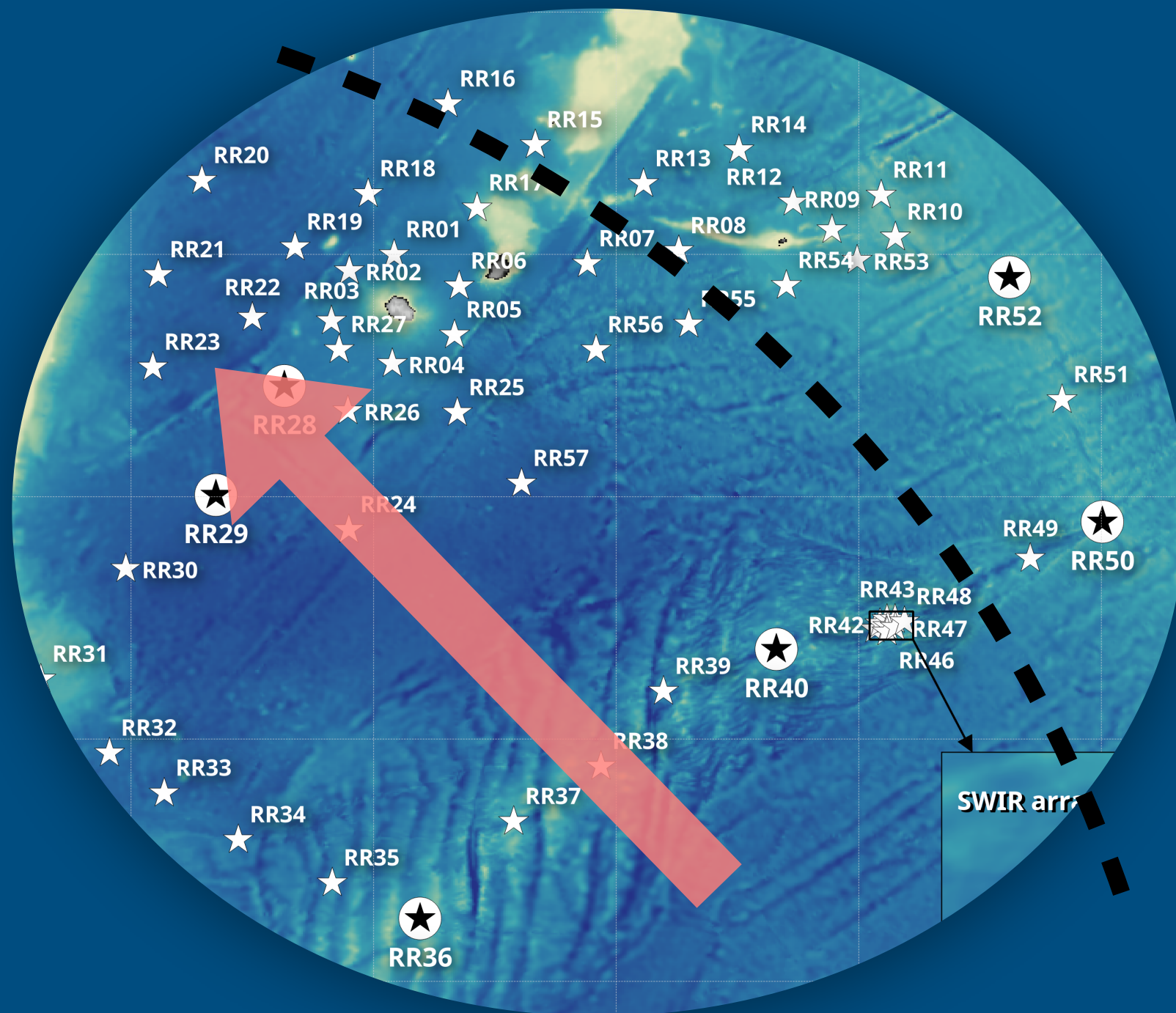
# From large temporal and spatial scales...



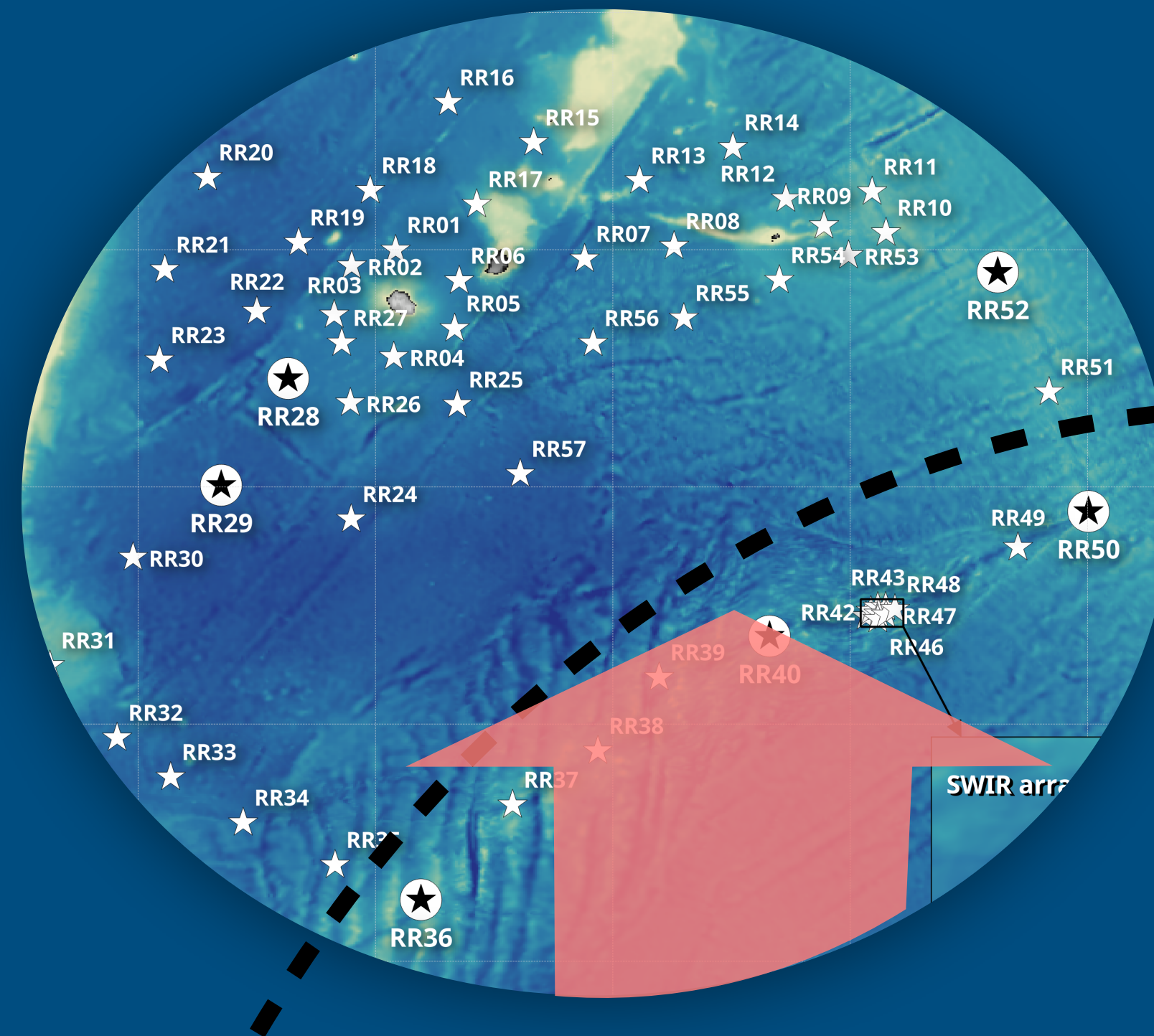
Madagascar pygmy  
blue whale

P-call or spot call

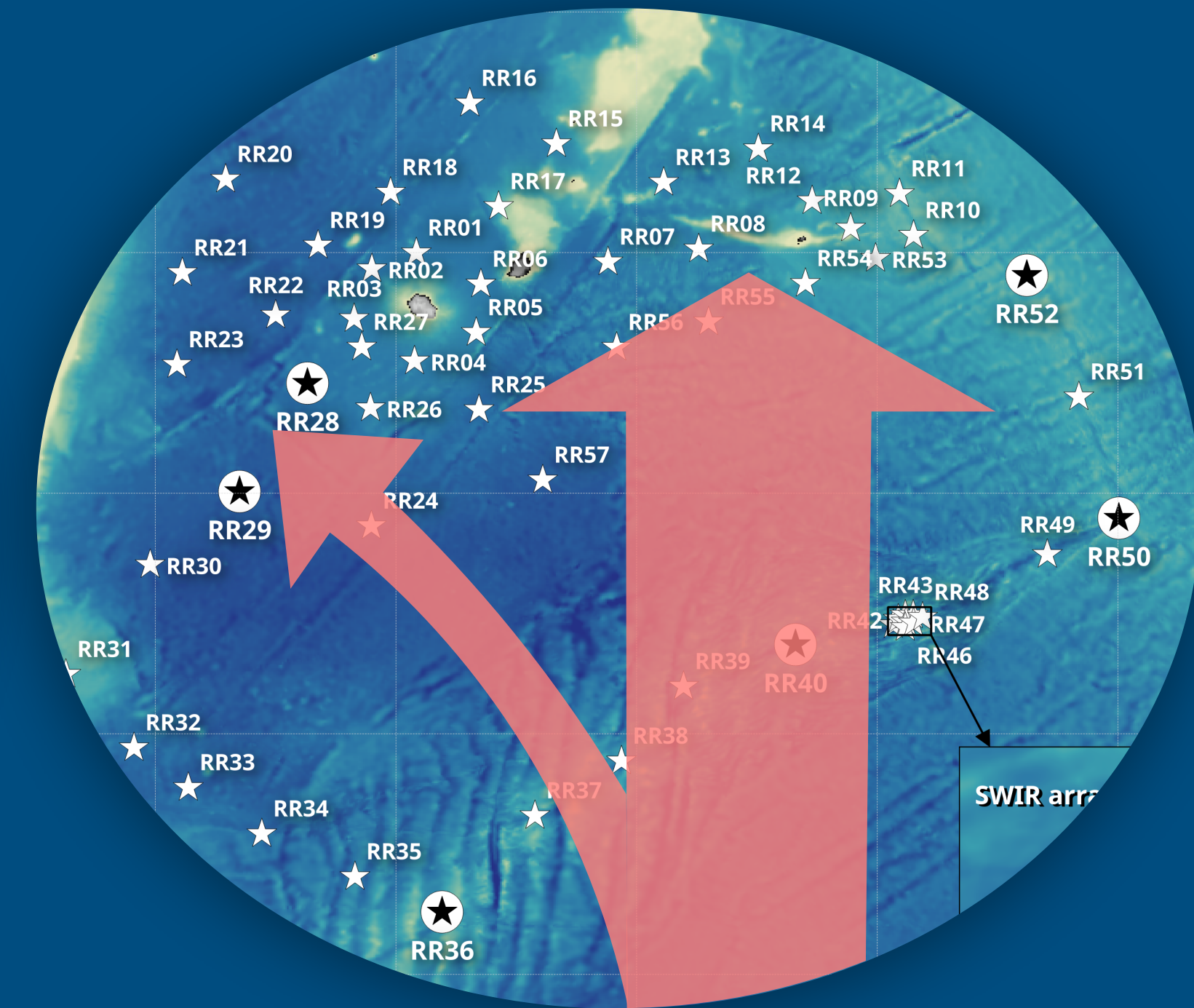
Antarctic blue whale



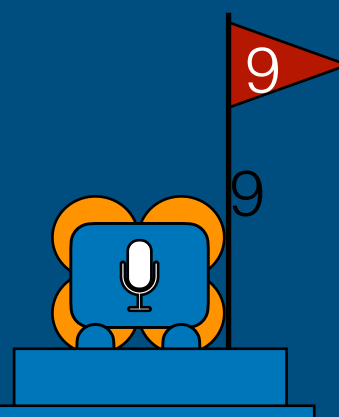
March -> June



April -> December

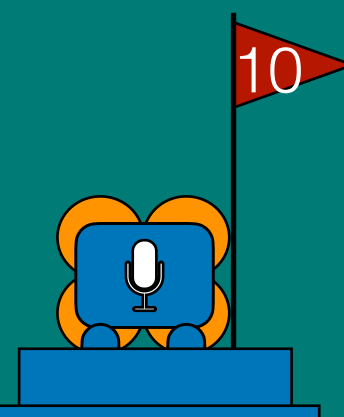
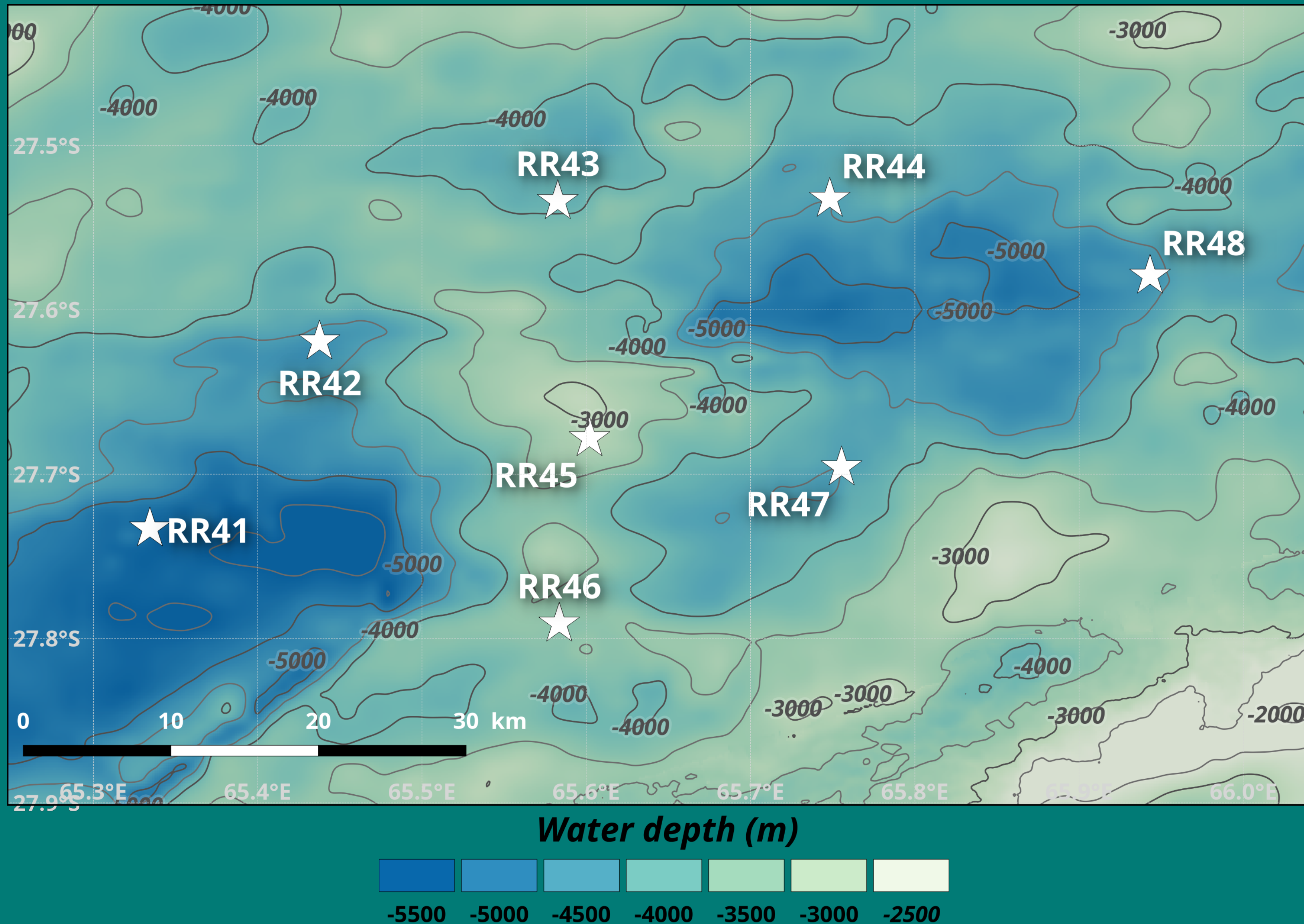


February -> October



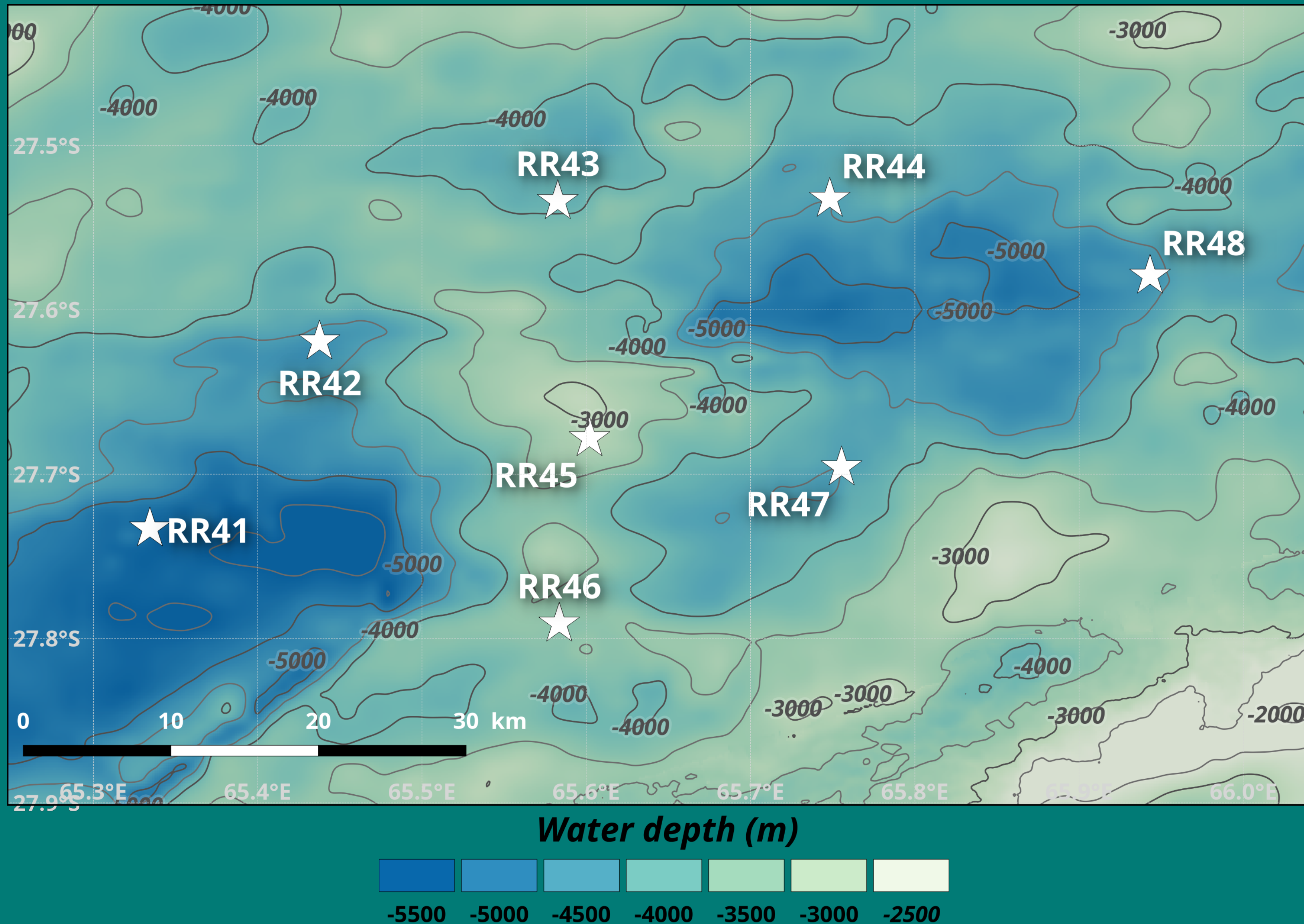


...to smaller scales

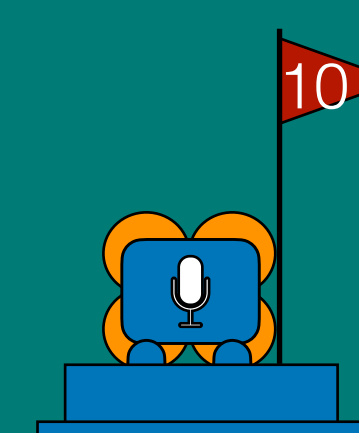
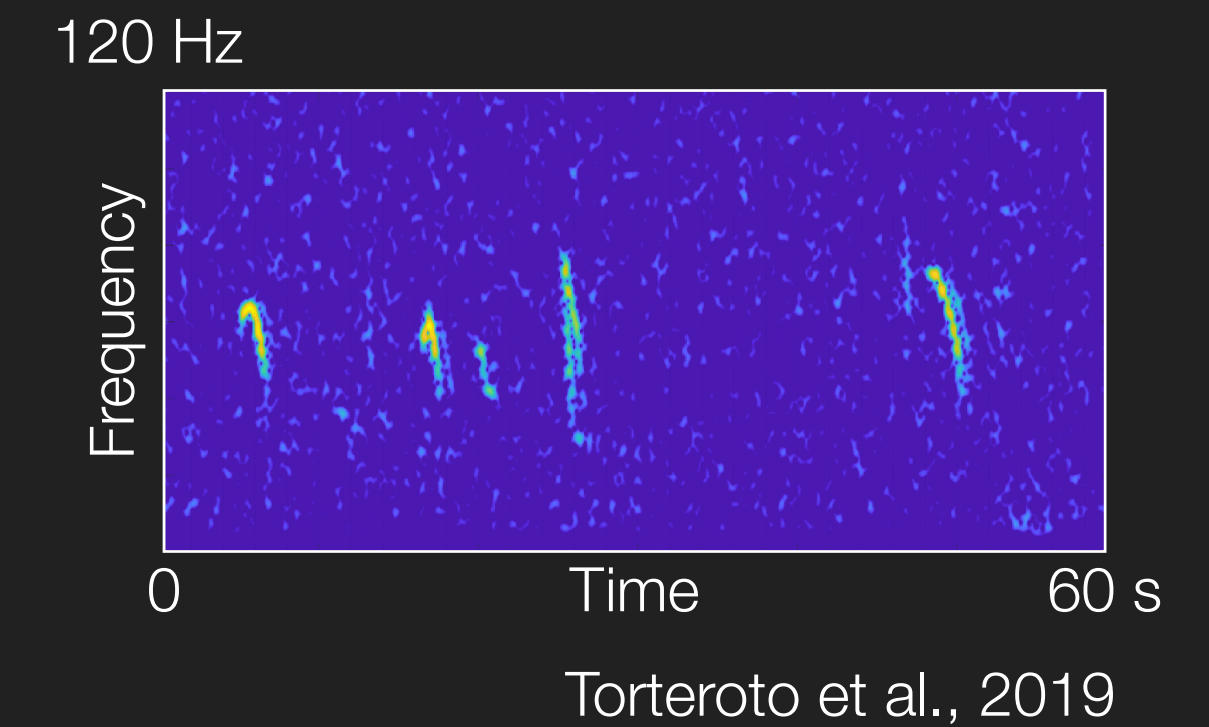
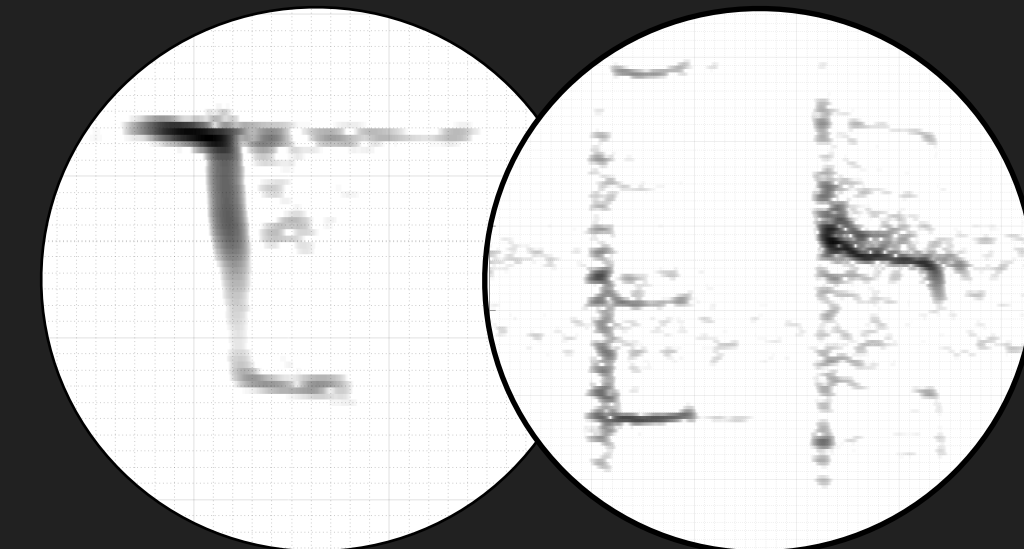




...to smaller scales

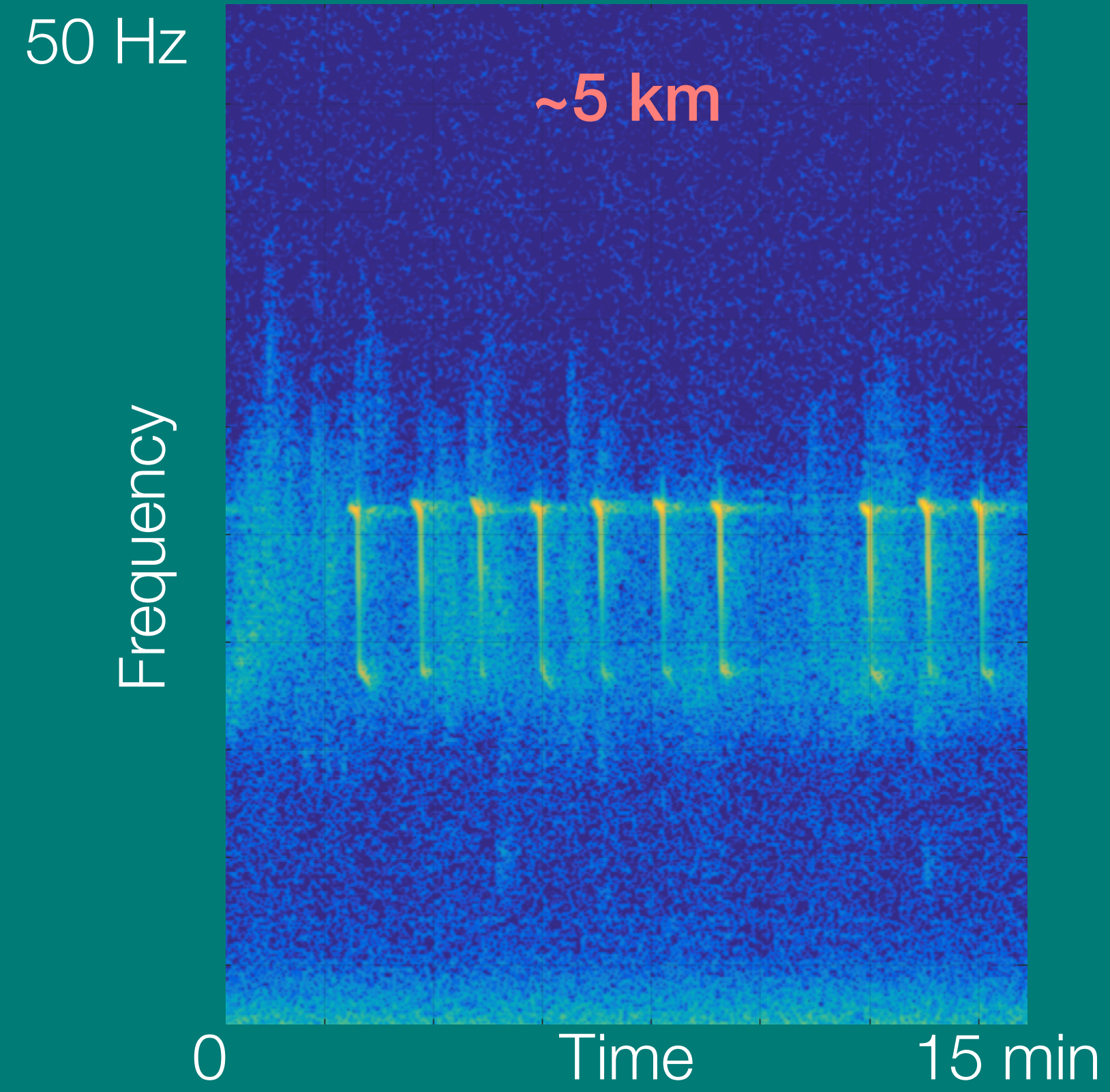


$f_s = 100\text{Hz}$





...to smaller scales





...to smaller scales

50 Hz

Frequency

0

~5 km

Time

15 min

50 Hz

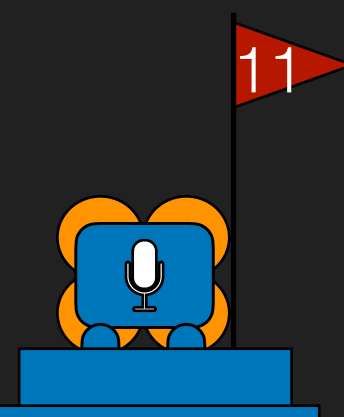
Frequency

0

~100 km

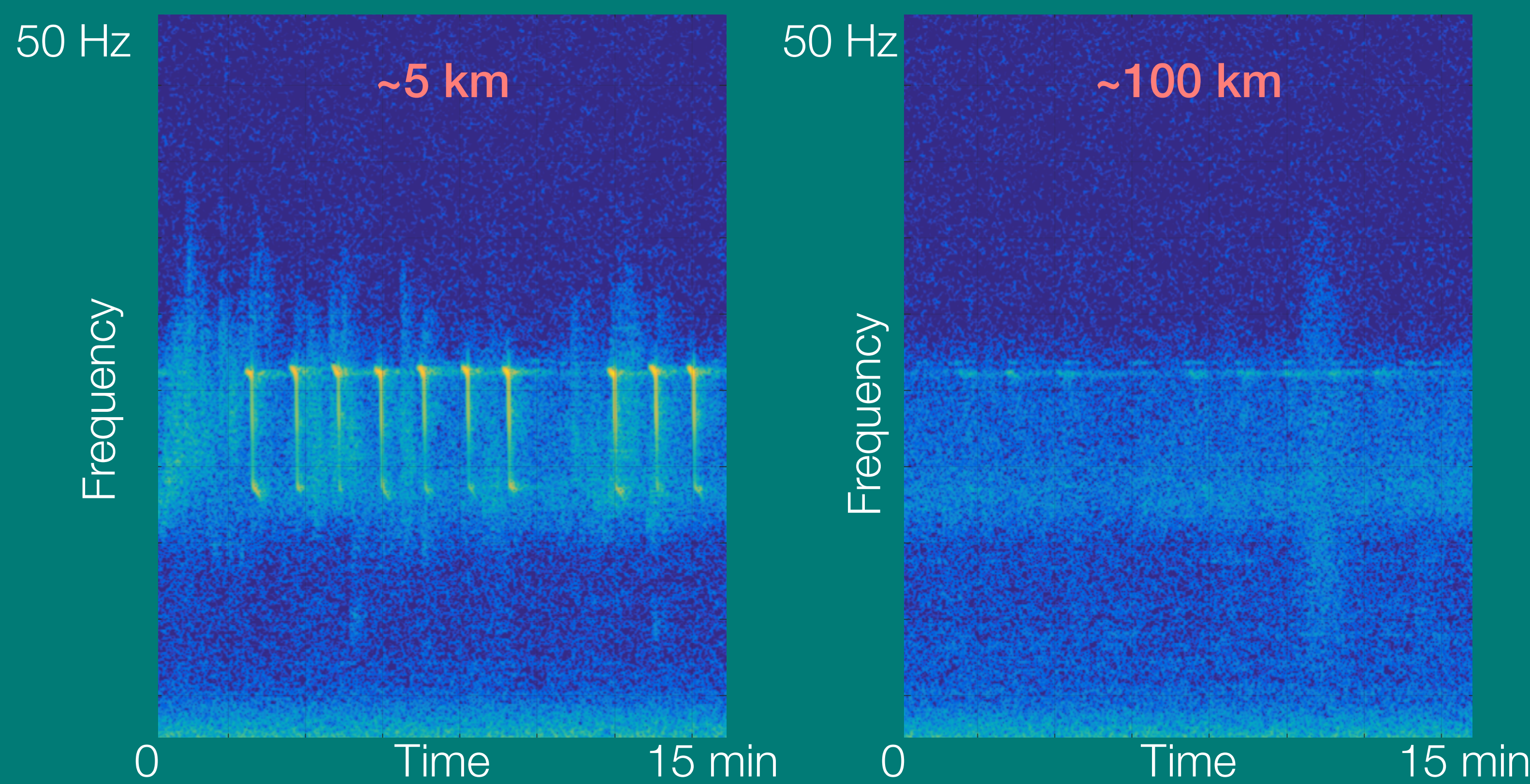
Time

15 min

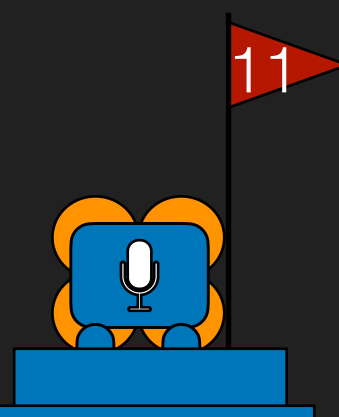




...to smaller scales

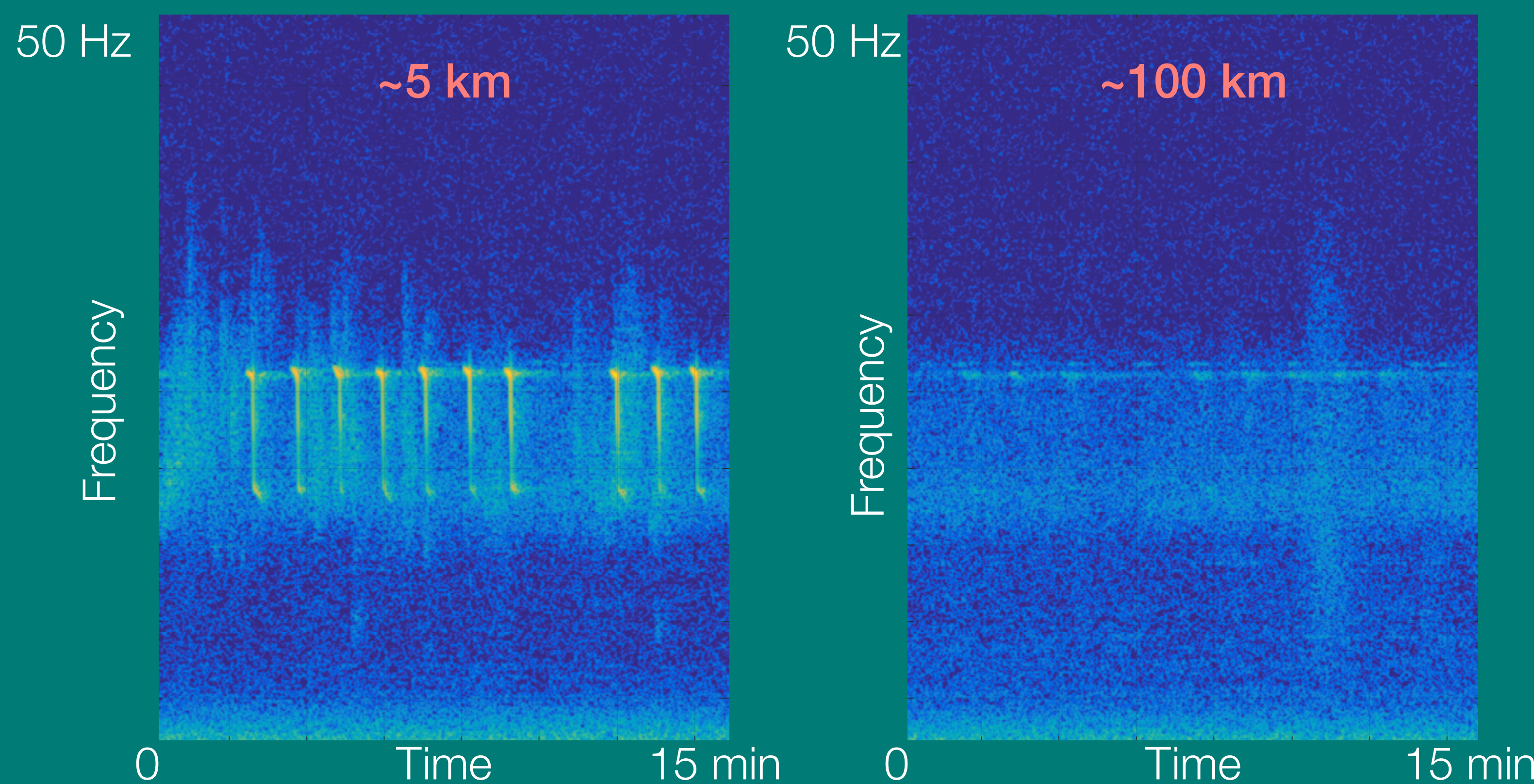


Signals modified by  
propagation channel +  
changing background  
noise





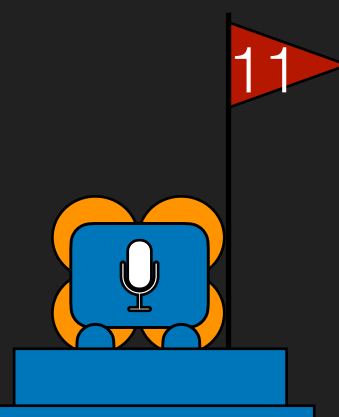
...to smaller scales



Signals modified by  
propagation channel +  
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noise

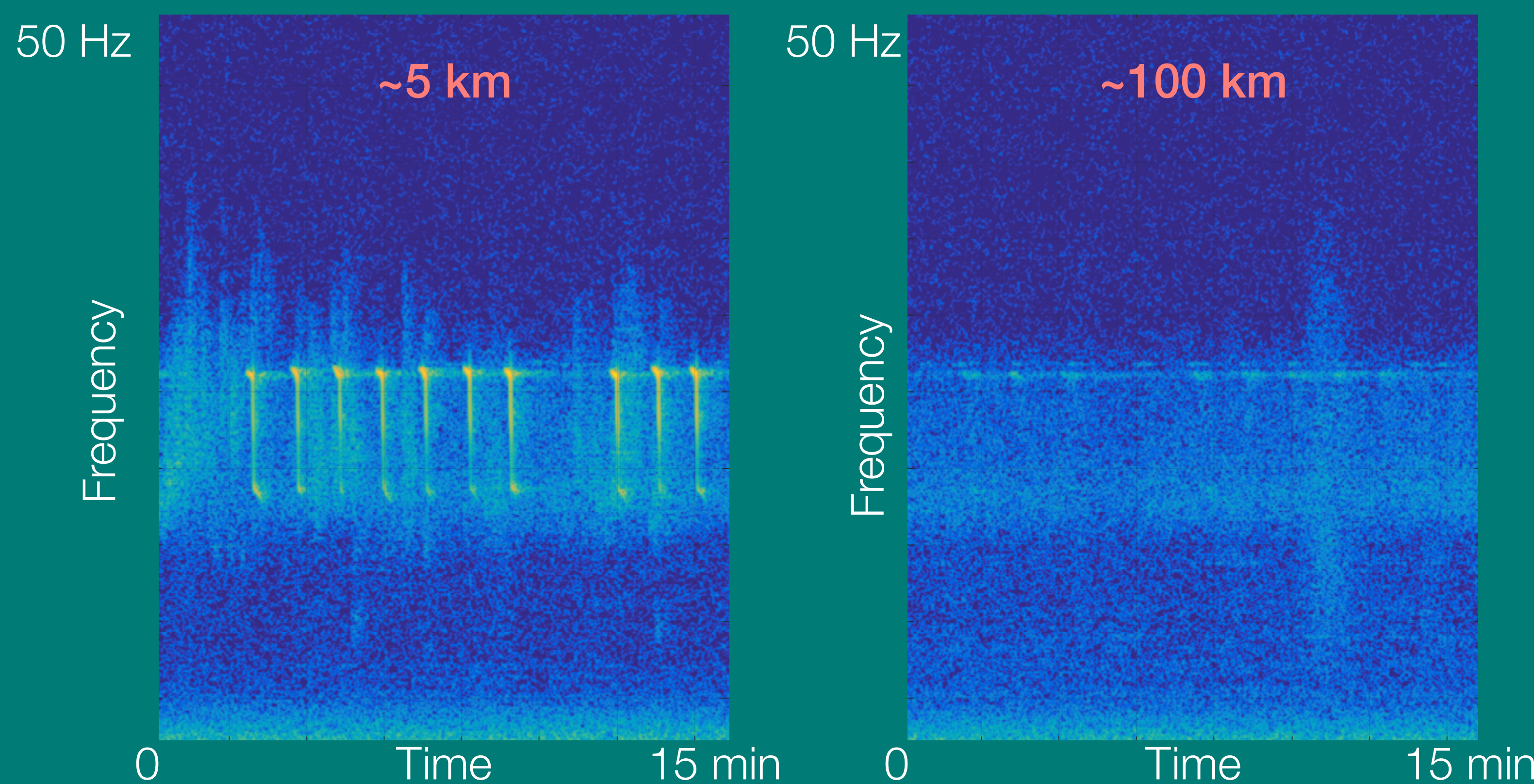


1 month of continuous  
data x 8 OBS  
 $\simeq$  6000h of recording  
(and lots of calls!)





...to smaller scales



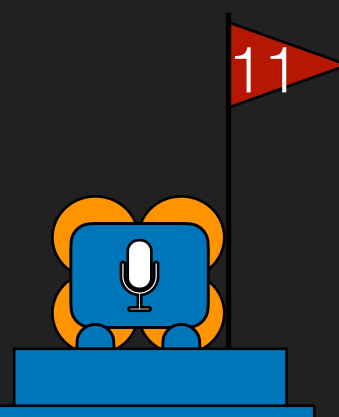
Signals modified by  
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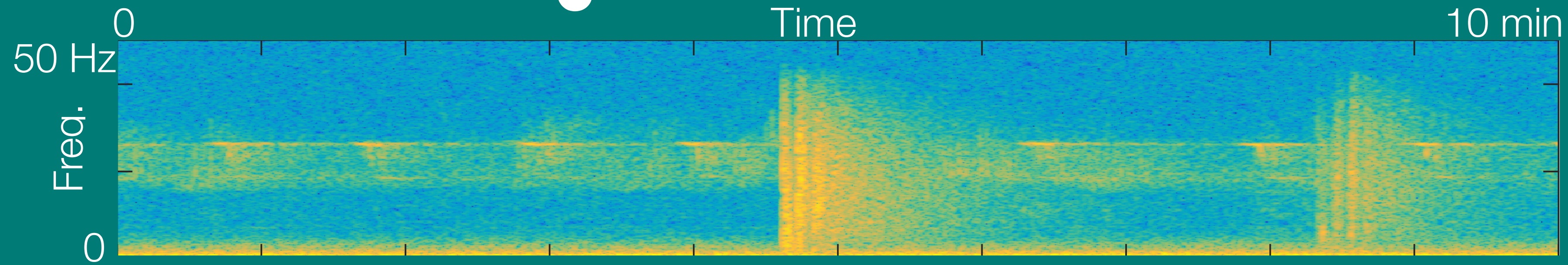


**Robust & controlled  
automatic detection  
methods**



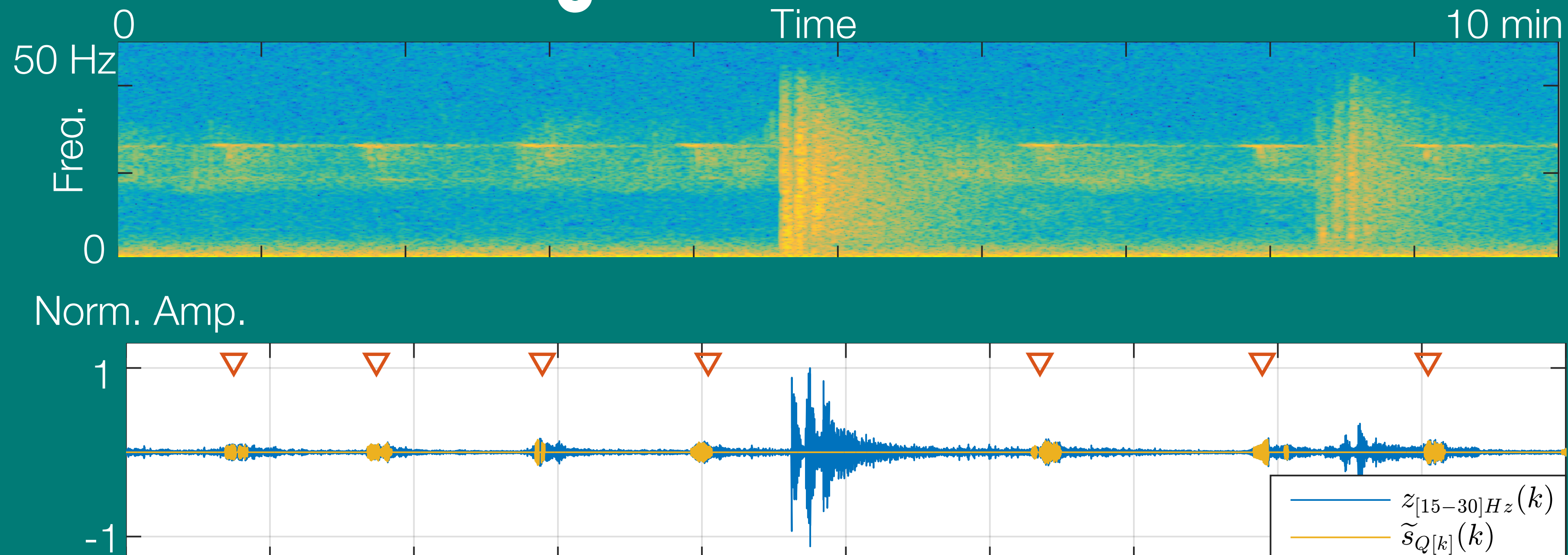


# Stochastic matched filter for the detection of low SNR signals



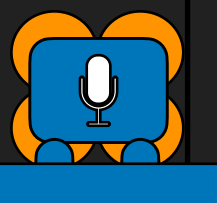
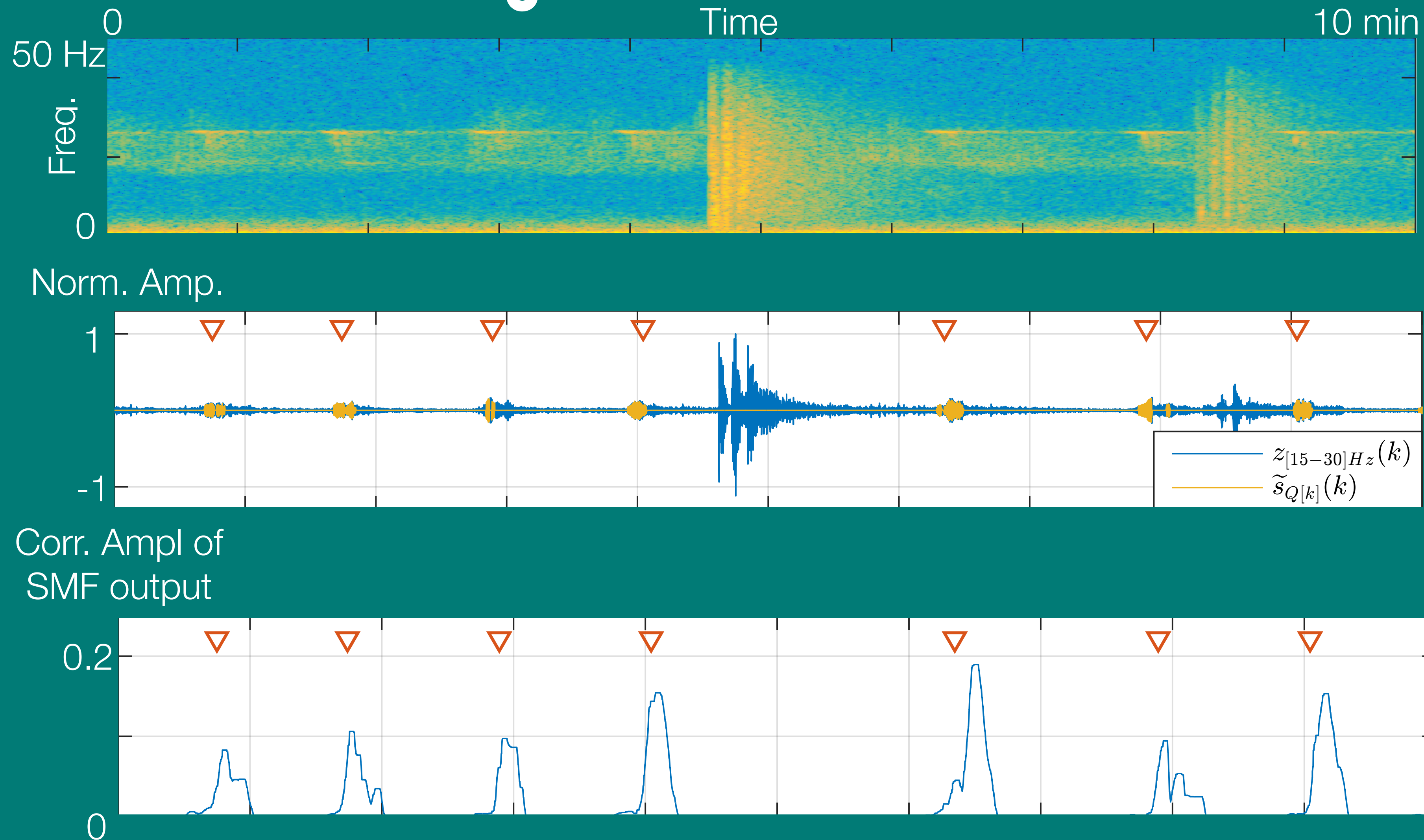


# Stochastic matched filter for the detection of low SNR signals



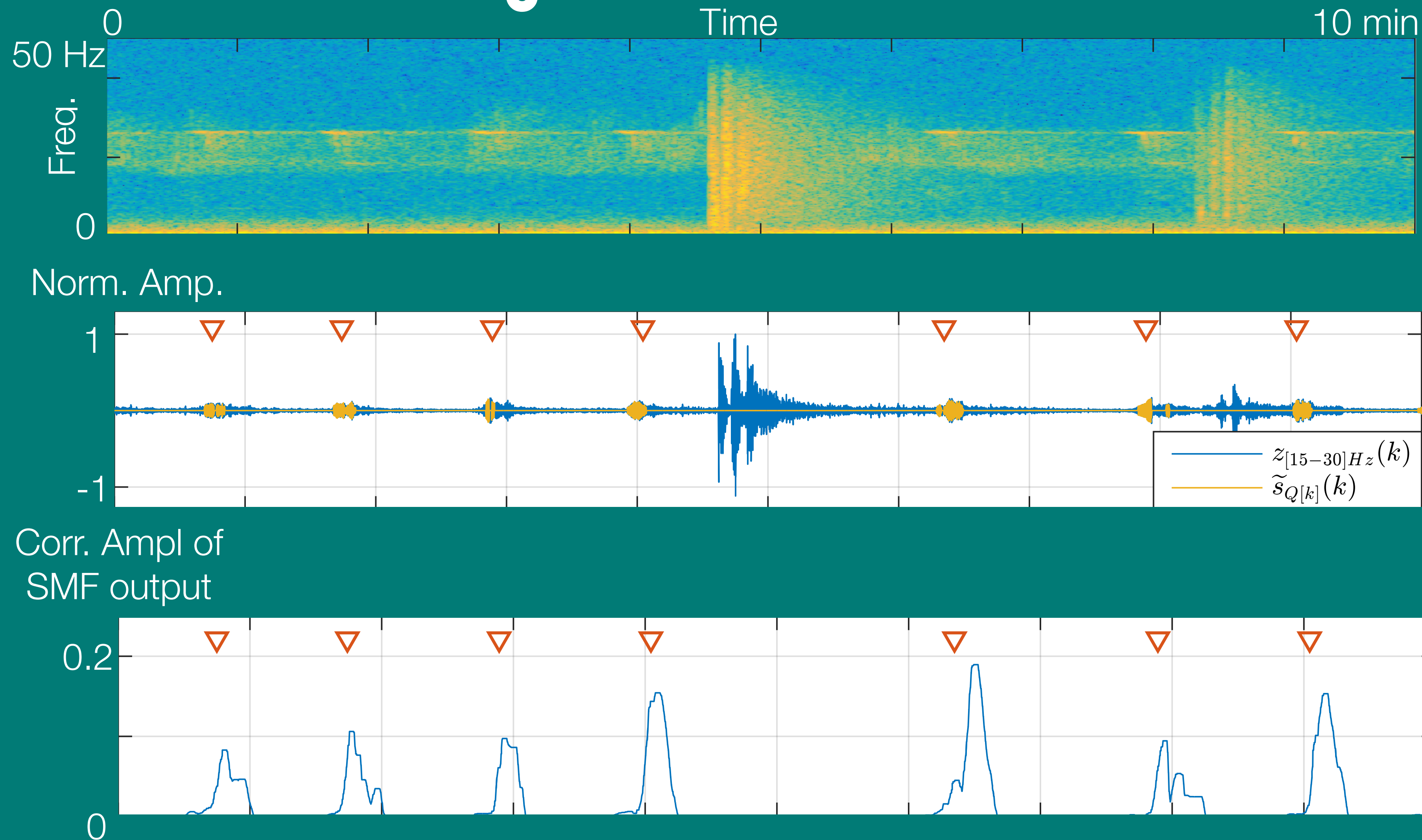


# Stochastic matched filter for the detection of low SNR signals





# Stochastic matched filter for the detection of low SNR signals



## ► Publication

L. Bouffaut, R. Dréo, V. Labat, A. Boudraa and G. Barruol "Passive stochastic matched filter for antarctic blue whale call detection," J. Acoust. Soc. Am, vol. 144, no. 2, pp. 955-965 (2018)

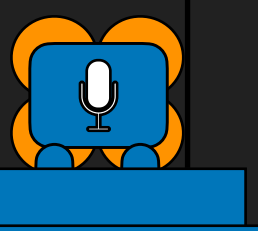
## ► SMF code is available!

[https://leabouffaut.github.io/SMF\\_package/](https://leabouffaut.github.io/SMF_package/)



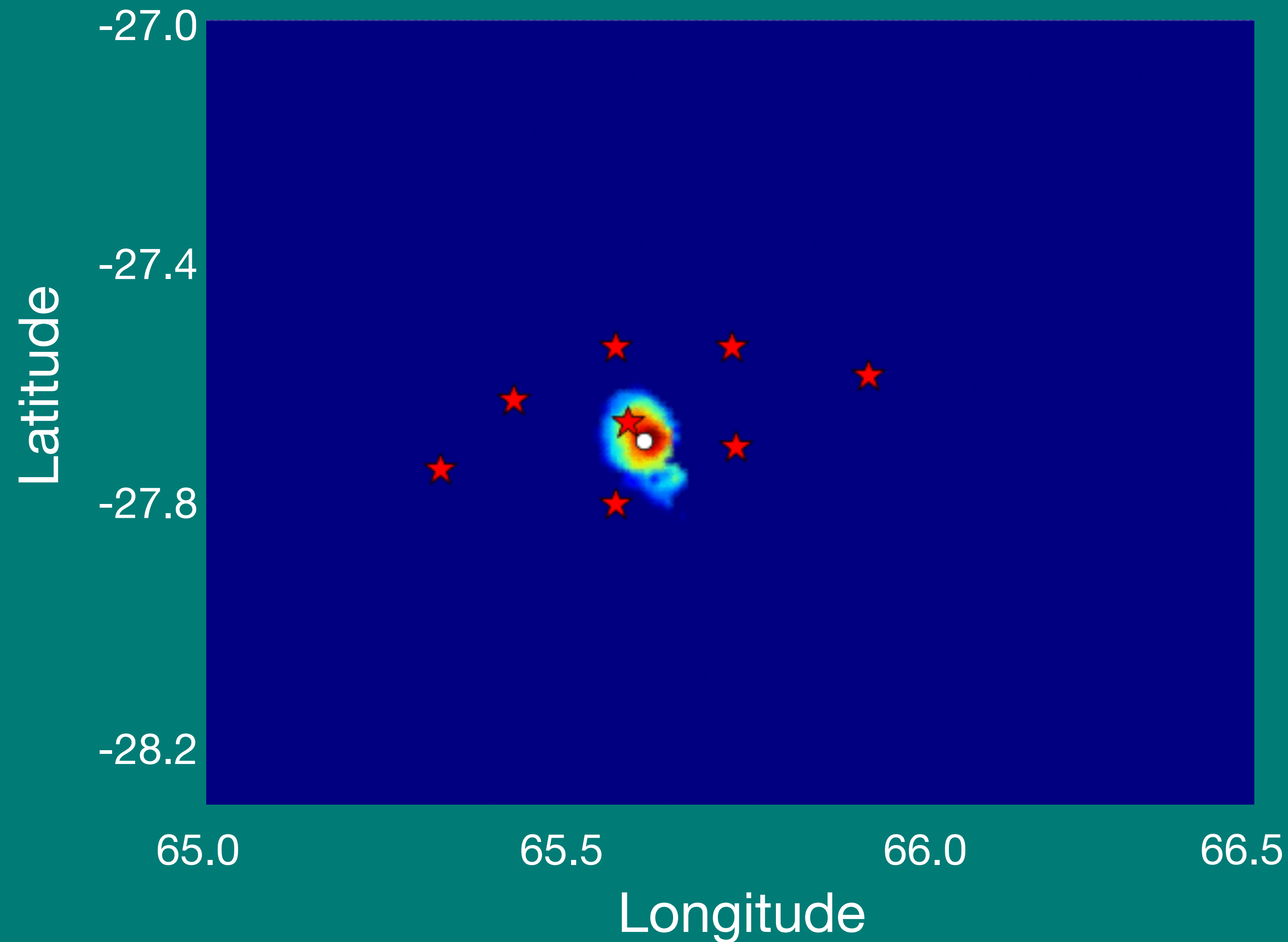
## ► Open source annotated test dataset

<https://doi.org/10.5281/zenodo.3624145>





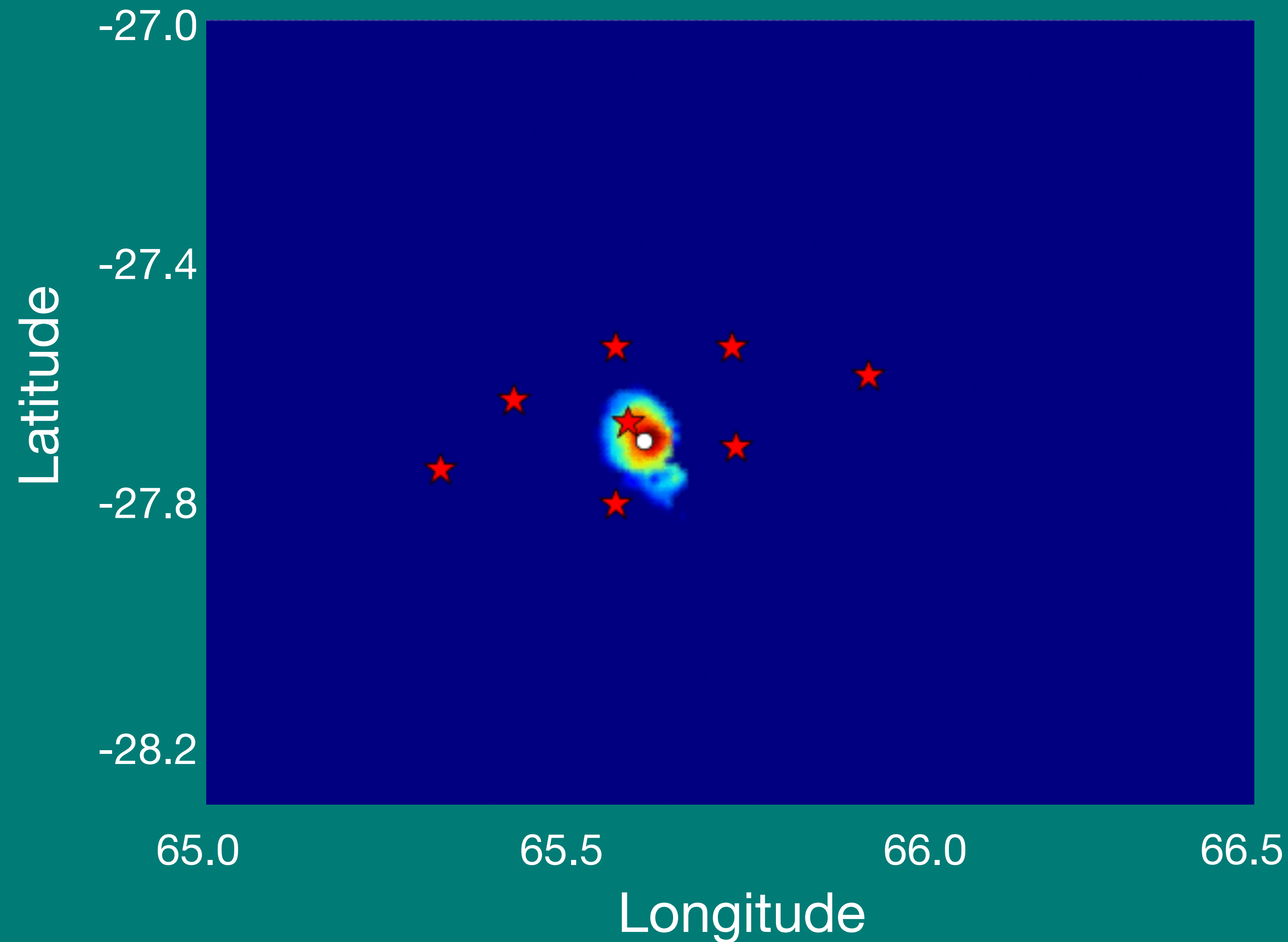
# Tracking of an ABW



R. Dréo, L. Bouffaut, L. Guillon, V. Labat, G. Barruol and A. Boudraa “Antarctic Blue Whale localization with Ocean Bottom Seismometer in Southern Indian Ocean”, *UACE 2017*, Greece, pp. 2-7 (2017).



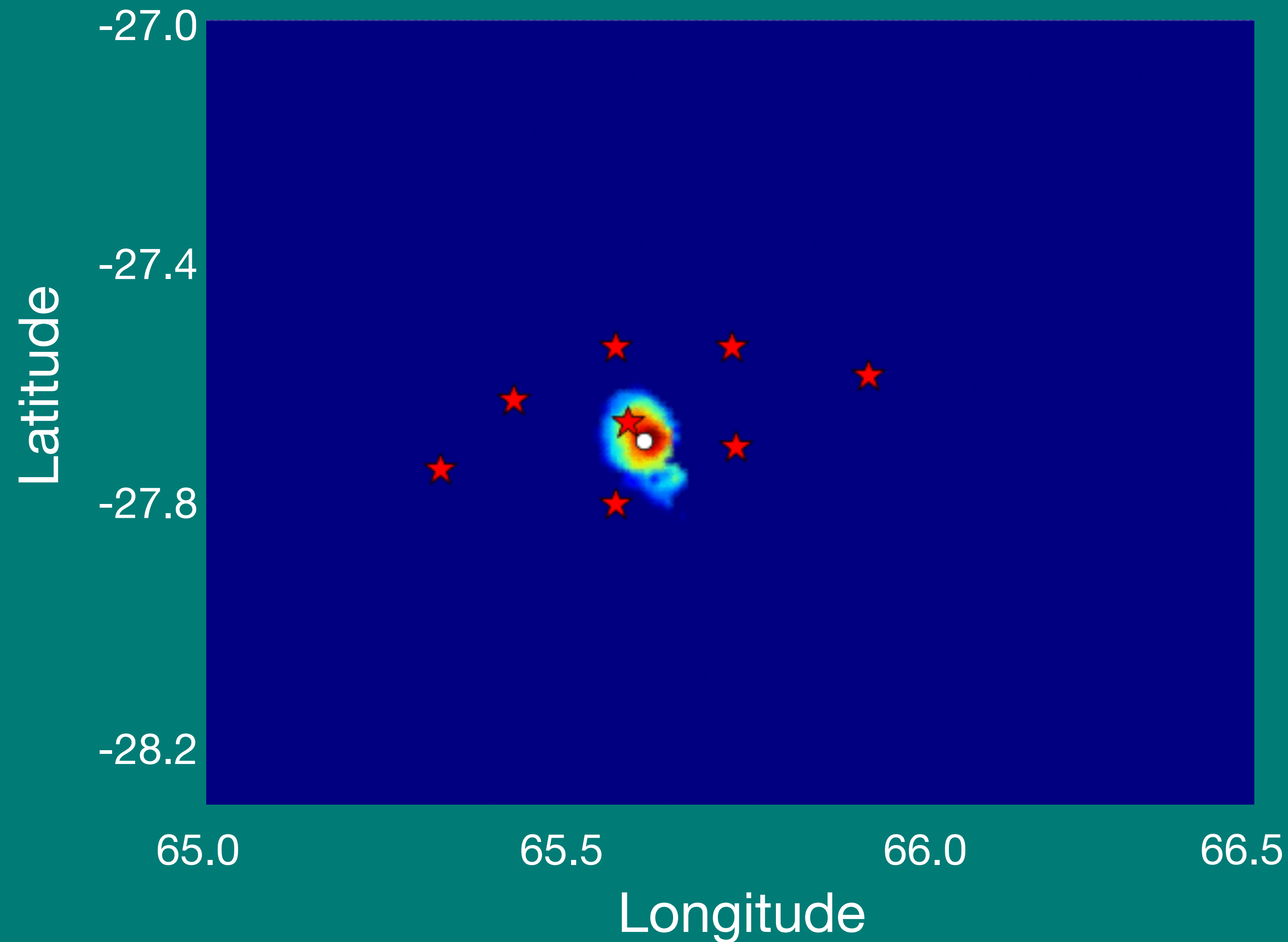
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# Tracking of an ABW

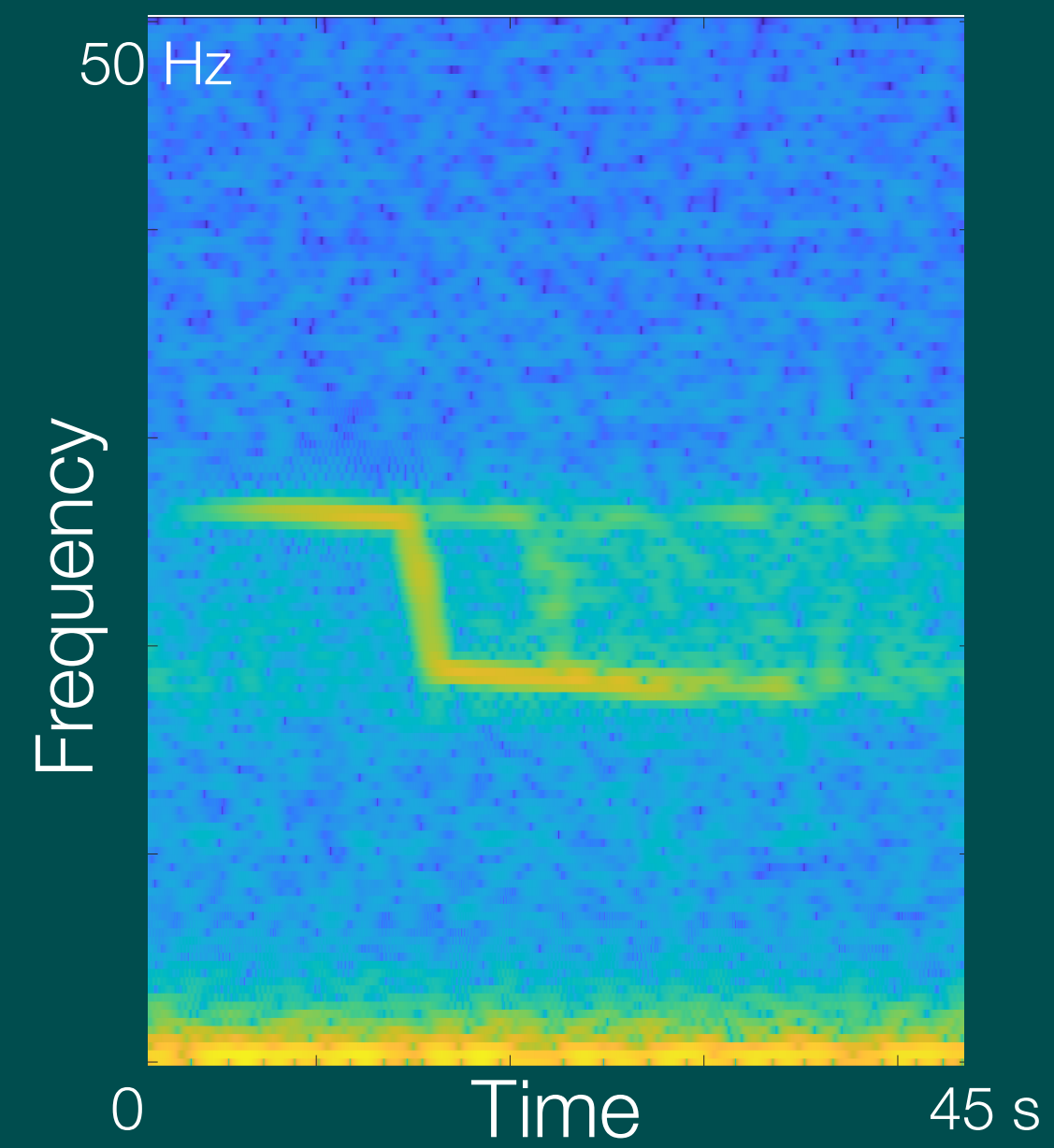


R. Dréo, L. Bouffaut, L. Guillon, V. Labat, G. Barruol and A. Boudraa “Antarctic Blue Whale localization with Ocean Bottom Seismometer in Southern Indian Ocean”, *UACE 2017*, Greece, pp. 2-7 (2017).

**A lot can also be  
done with a  
single  
hydrophone!**

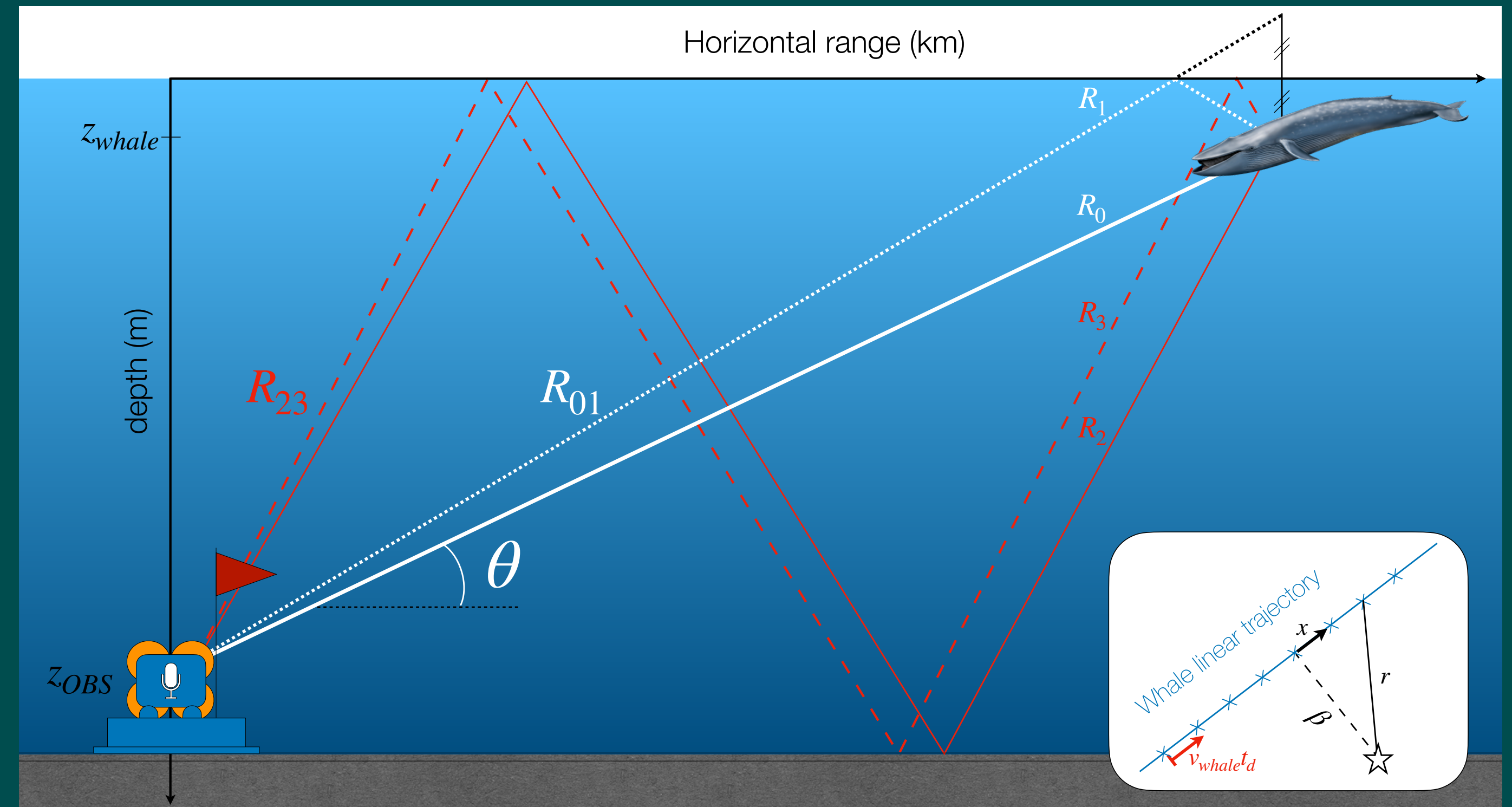
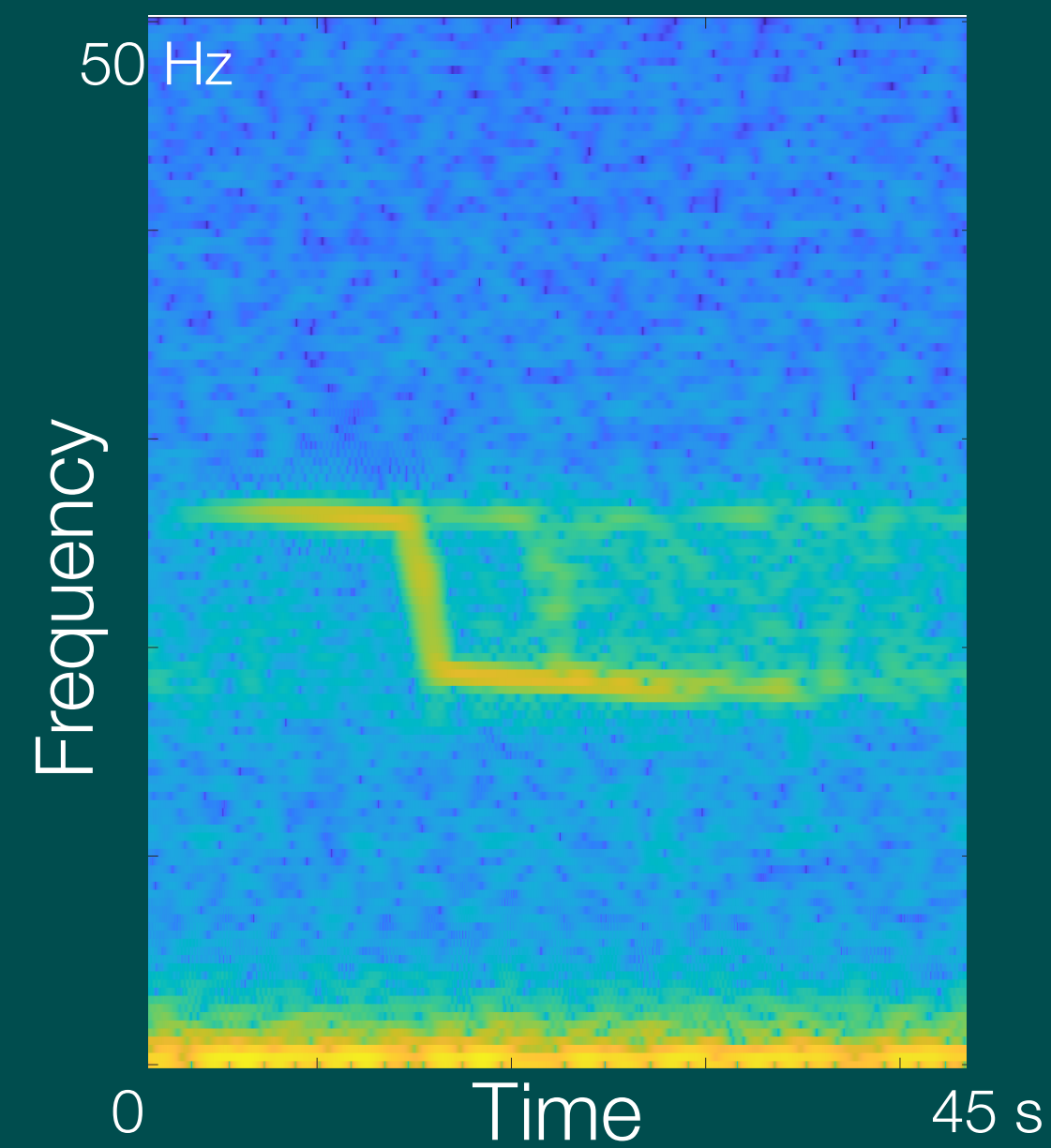


# Blue whale acoustic diving profile



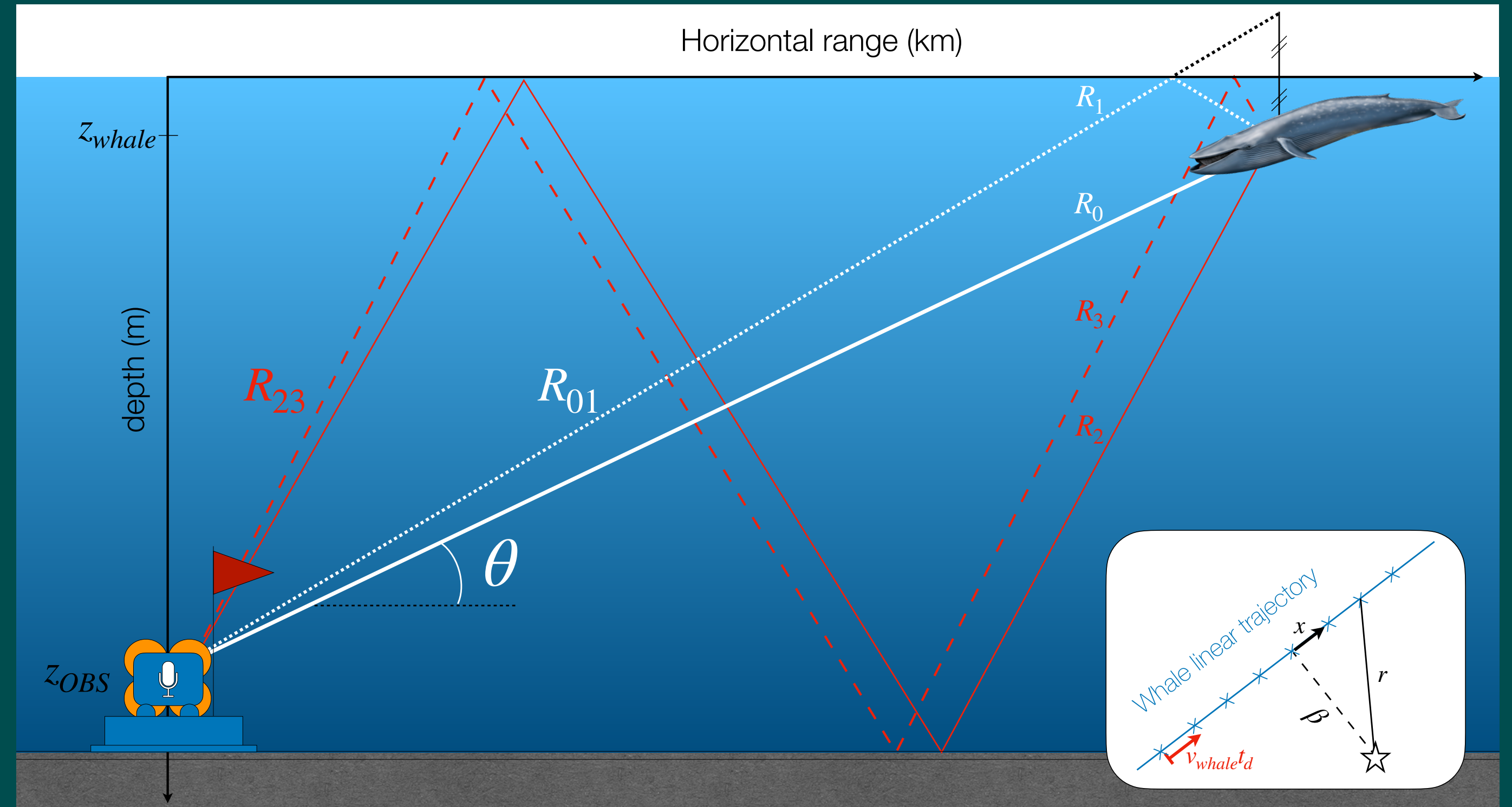
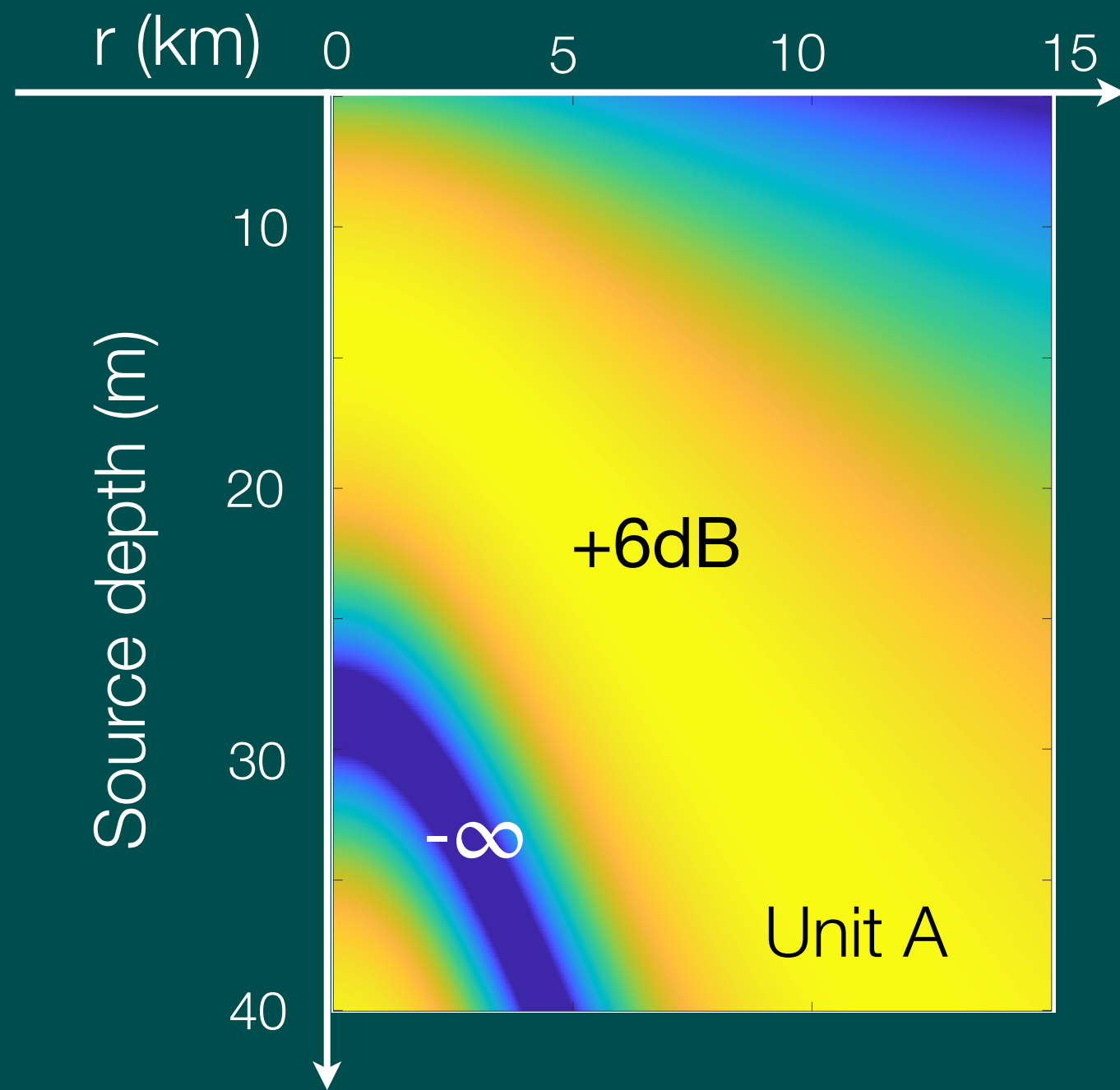


# Blue whale acoustic diving profile



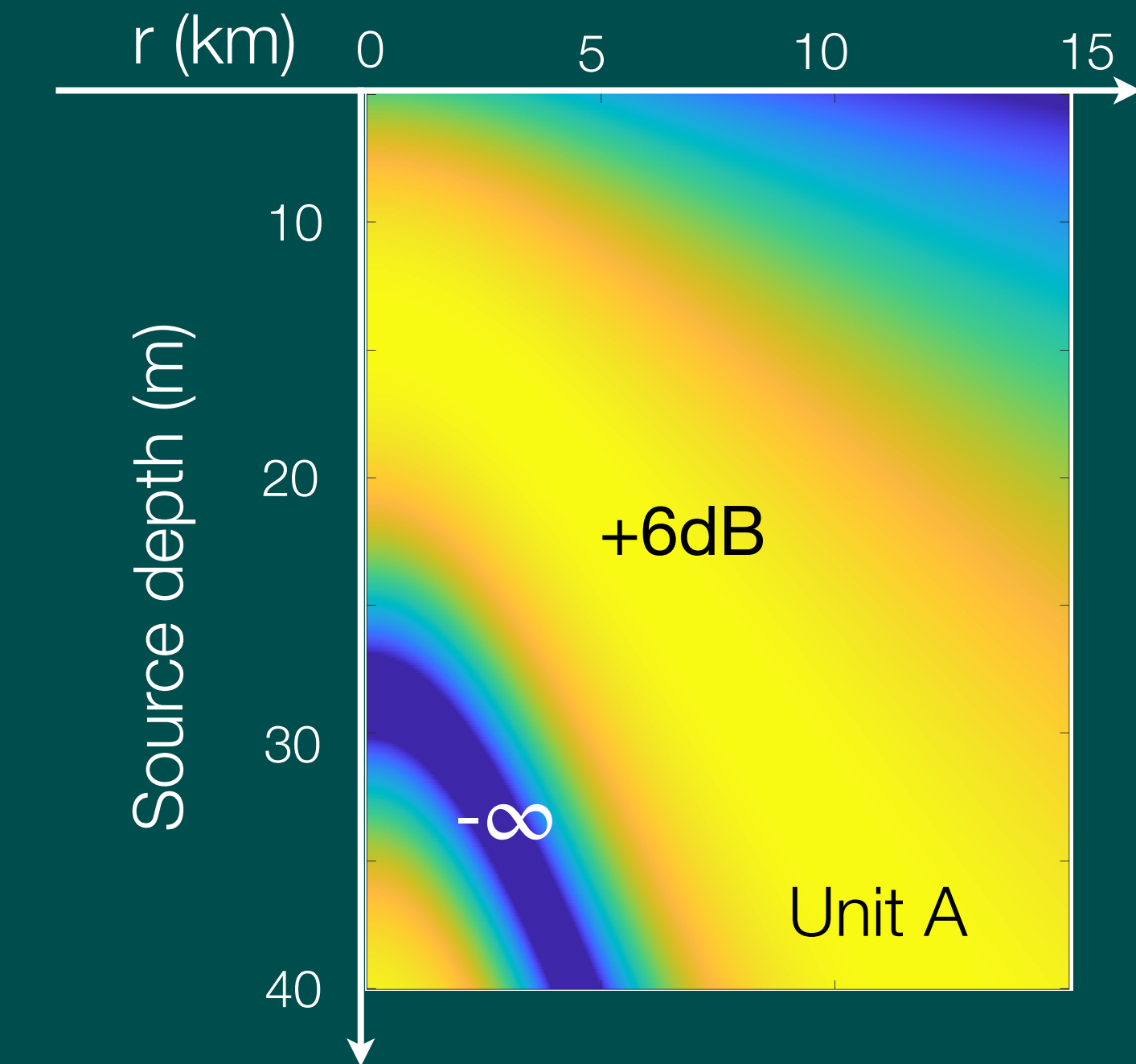


# Blue whale acoustic diving profile

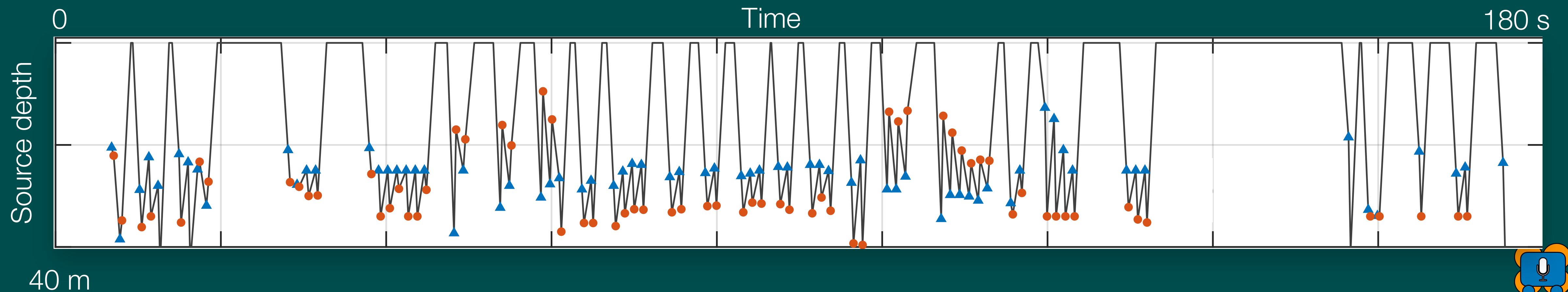




# Blue whale acoustic diving profile

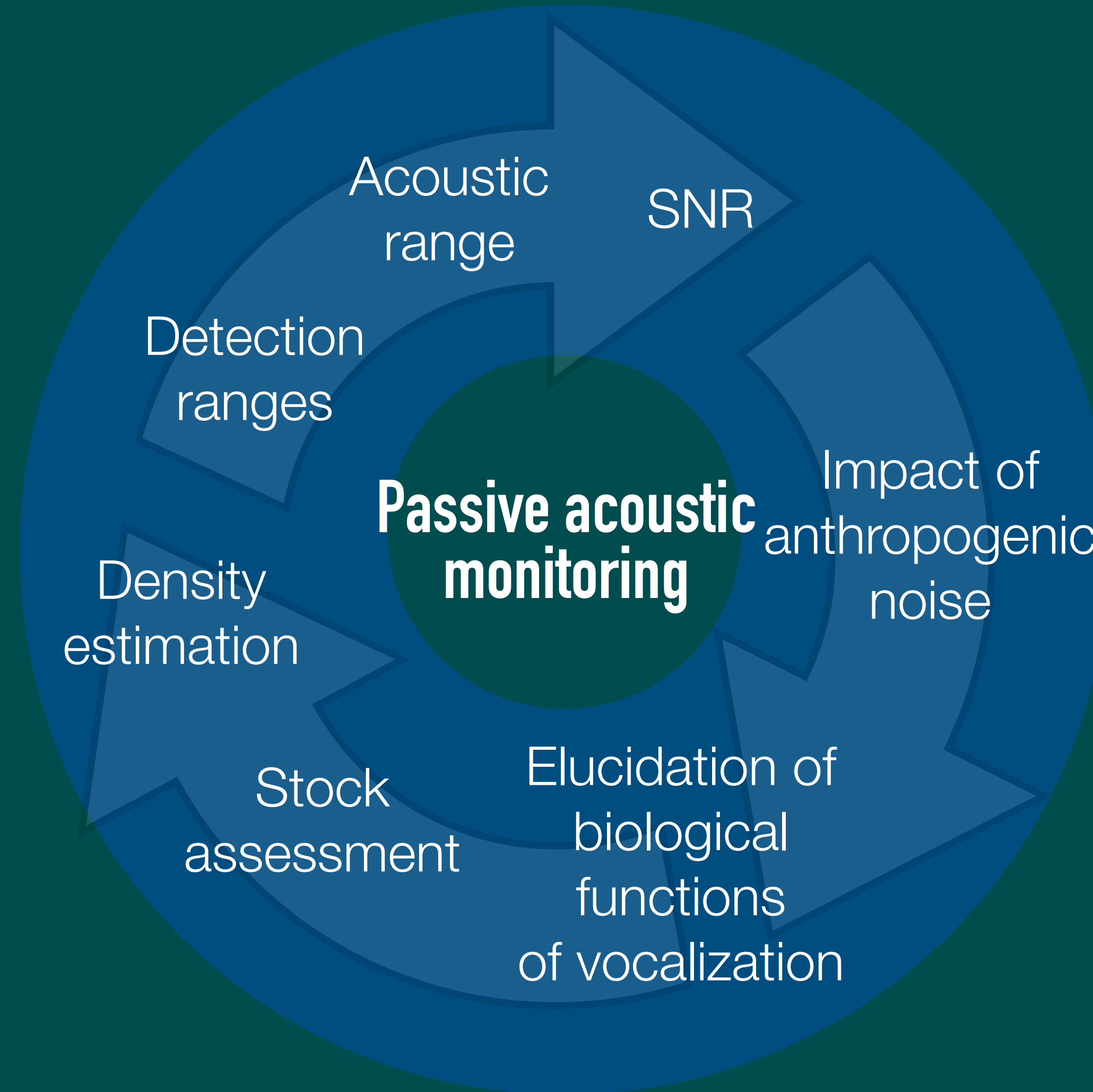


L. Bouffaut, M. Landrø, J. R. Potter  
“Source level and vocalizing depth estimation of two blue whale subspecies in the western Indian Ocean from single sensor observations” J. Acoust. Soc. Am (Under review).





# Conclusions







**Whale, Thank you.**

[lea.bouffaut@ntnu.no](mailto:lea.bouffaut@ntnu.no)



# Question?

**Whale, Thank you.**

lea.bouffaut@ntnu.no