





ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

Underwater Acoustics in Antarctica

Lars Kindermann – AWI Ocean Acoustics Group

Presented at the Ettore Majorana Foundation and Centre for Scientific Culture
International School Of Ethology, 30th International Workshop, Erice, October 2013
*Cetacean echolocation and outer space neutrinos:
Ethology and physics for an interdisciplinary approach to underwater bioacoustics
and astrophysical particles detection*

One of the most productive ecosystems on earth – during austral summer



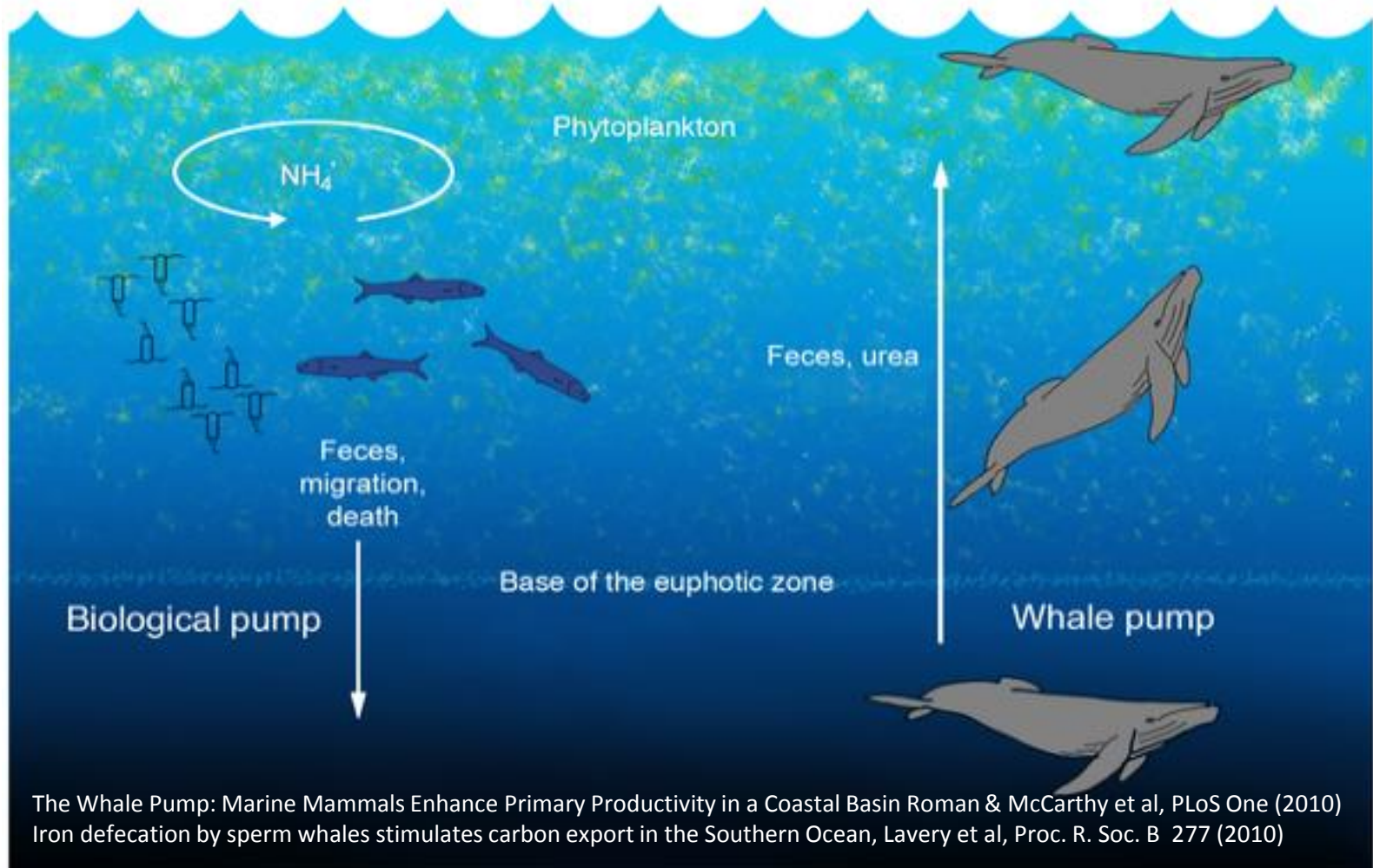




20%-25% of the Southern Oceans CO_2 fixed by primary production is transferred by marine mammals and birds into the atmosphere
(A Major Leak in the Carbon Pump: Huntley et al, Science vol. 253)

Zooplankton, Fish

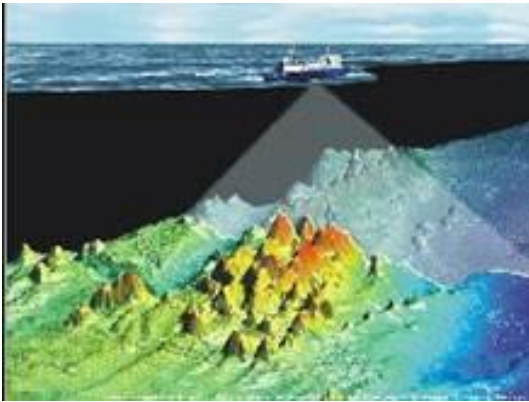
Marine Mammals



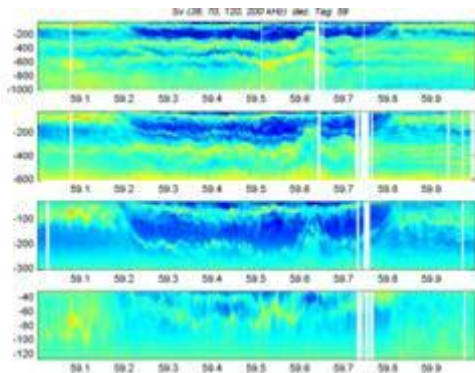
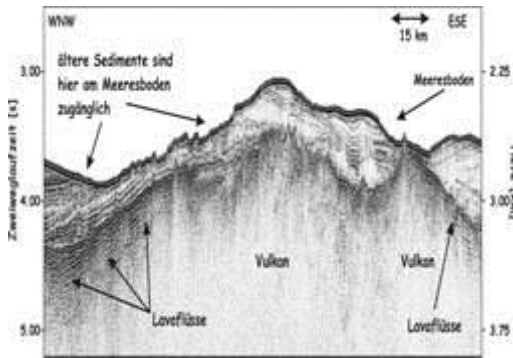
The Whale Pump: Marine Mammals Enhance Primary Productivity in a Coastal Basin Roman & McCarthy et al, PLoS One (2010)
Iron defecation by sperm whales stimulates carbon export in the Southern Ocean, Lavery et al, Proc. R. Soc. B 277 (2010)



Scientific use of Sound on Polarstern

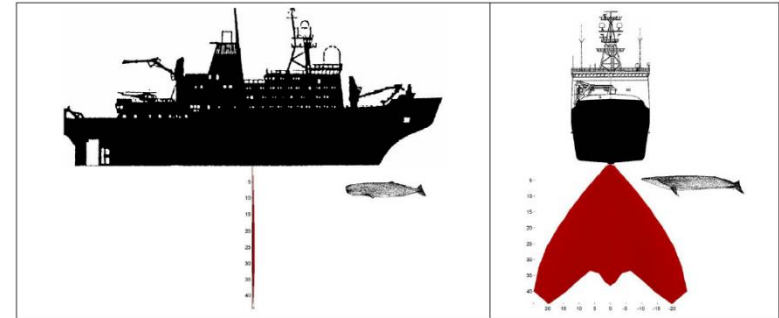
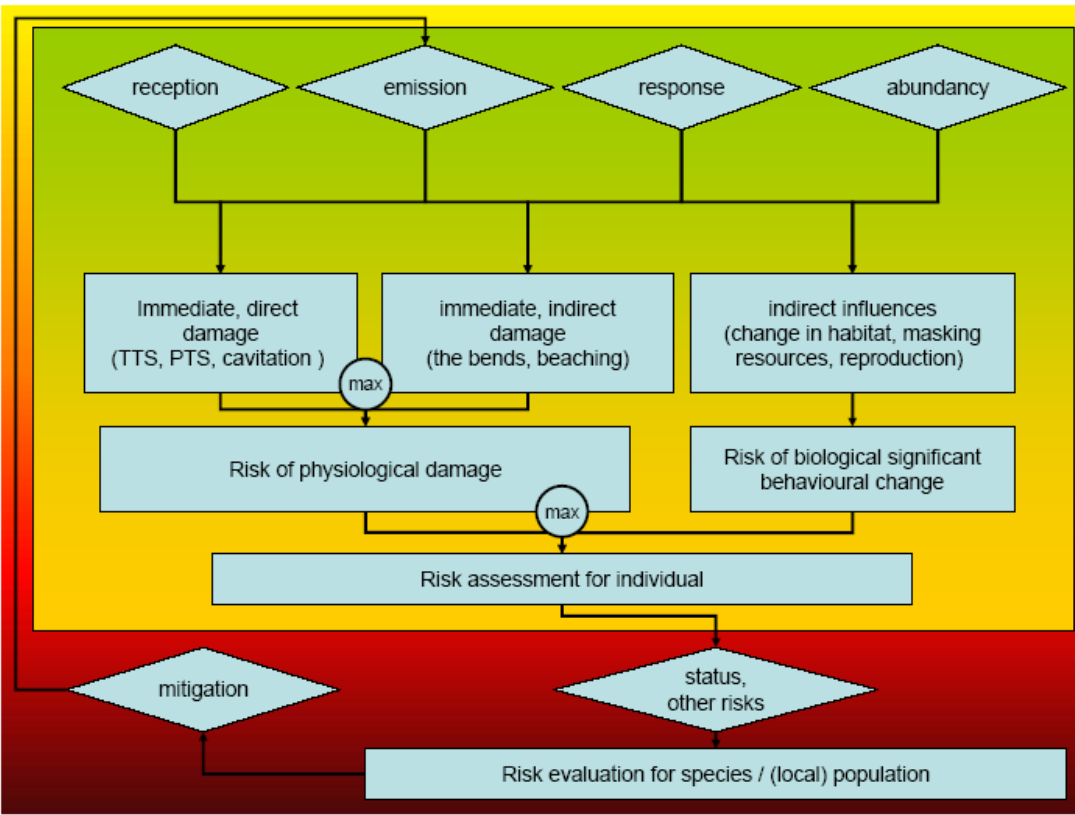


- Hydrosweep / Side scan sonar
 - Fan beam echo-sounder to explore bathymetry
- Parasound
 - Parametric sonar to study upper sediment layers
- Simrad EK 60
 - Fish finding & Krill sonar
- Air-Guns
 - Geophysical studies (not exploration/exploitation)
- Posidonia
 - Underwater navigation

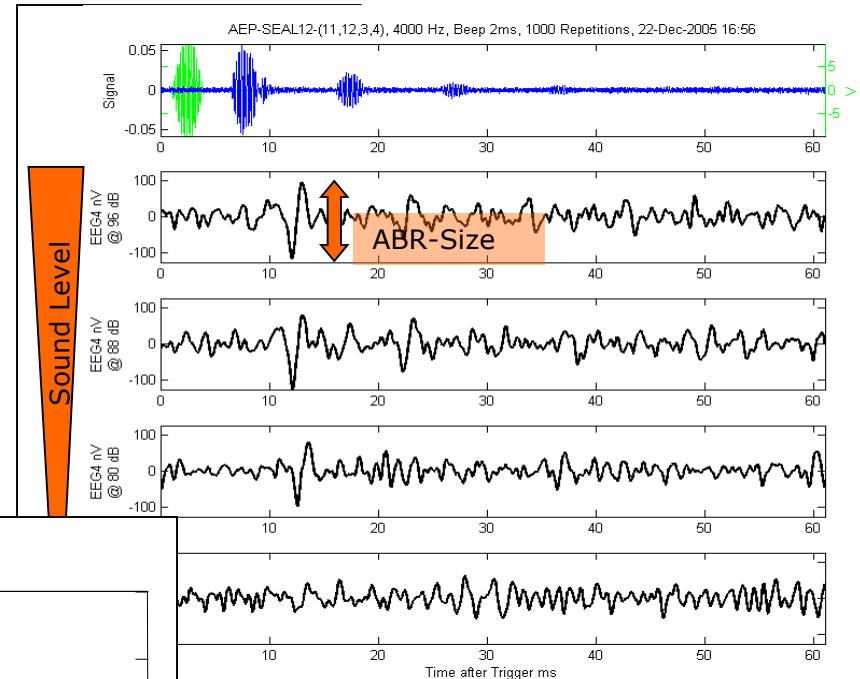


Comprehensive risk assessment for hydro acoustic activities:

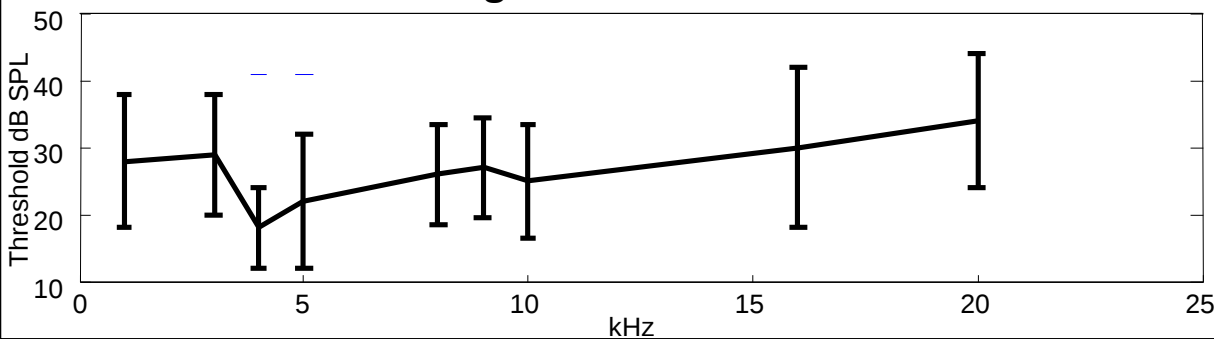
Acquire data from a mostly undisturbed environment



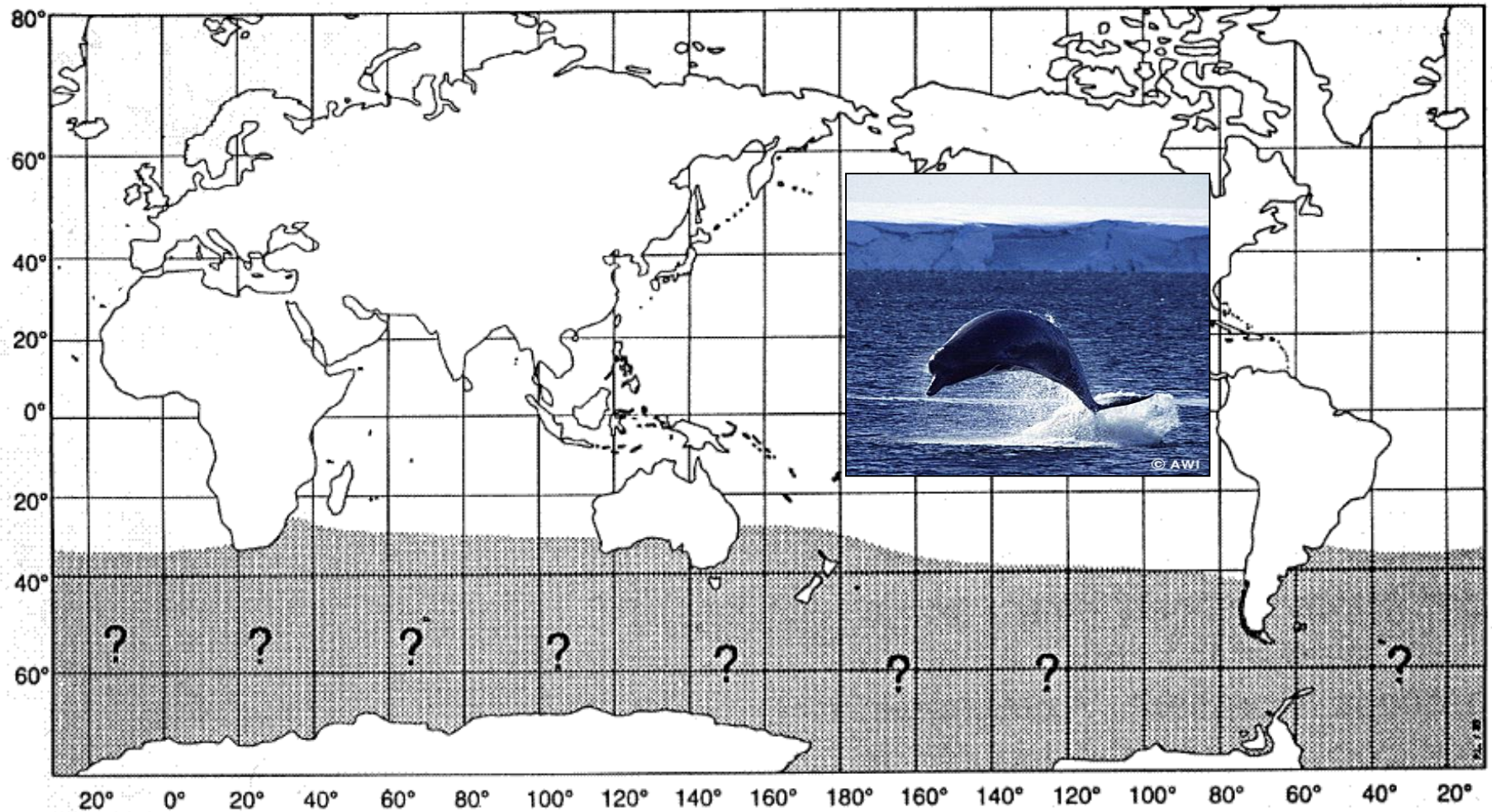
Audiometry of Antarctic Seals, Atka Bay 2005



First Audiogram of Weddell Seals

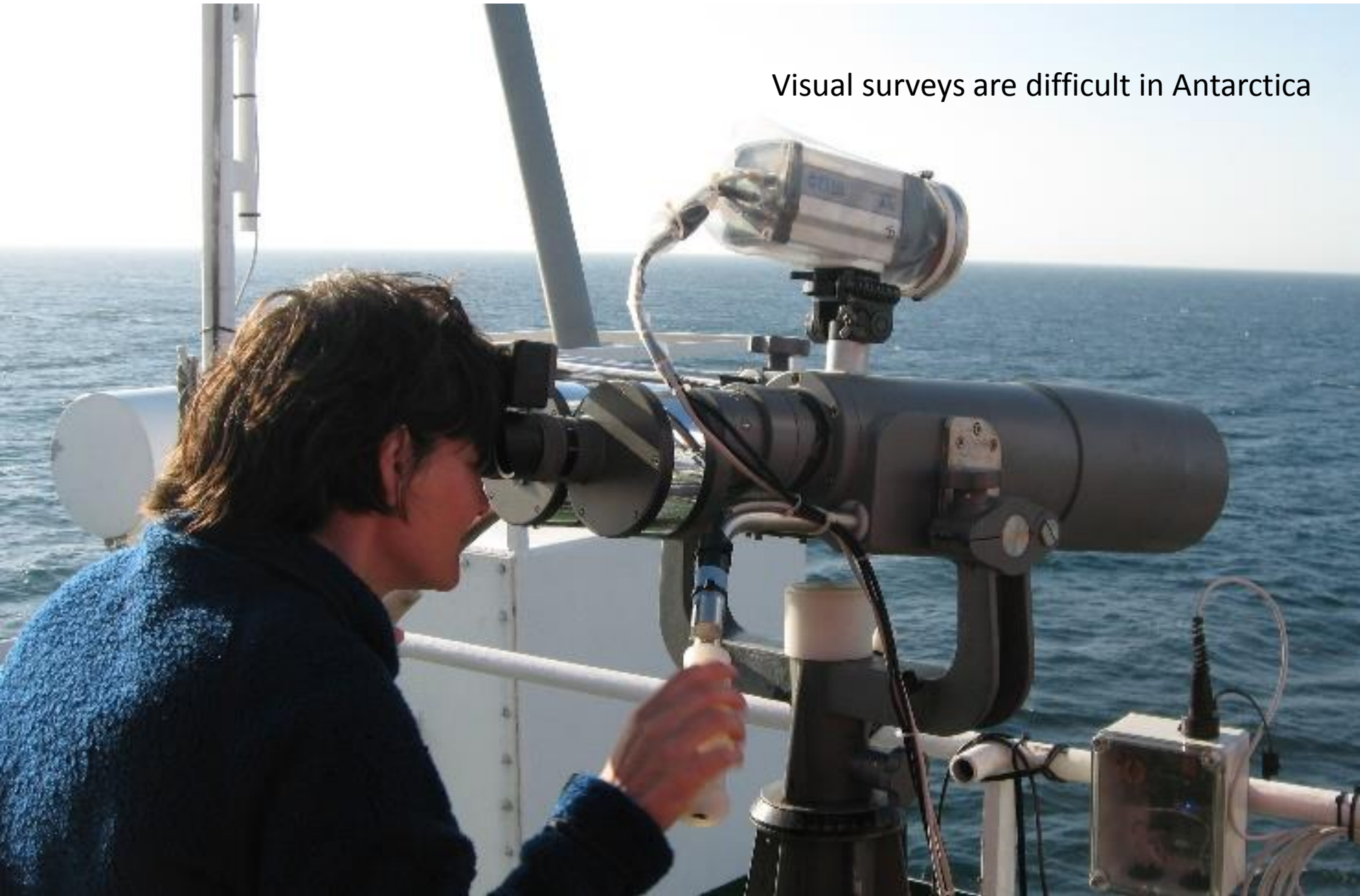


Very limited knowledge of the distribution of many species

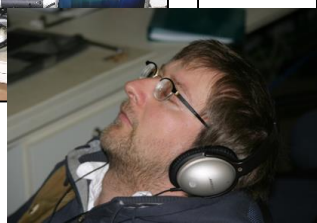
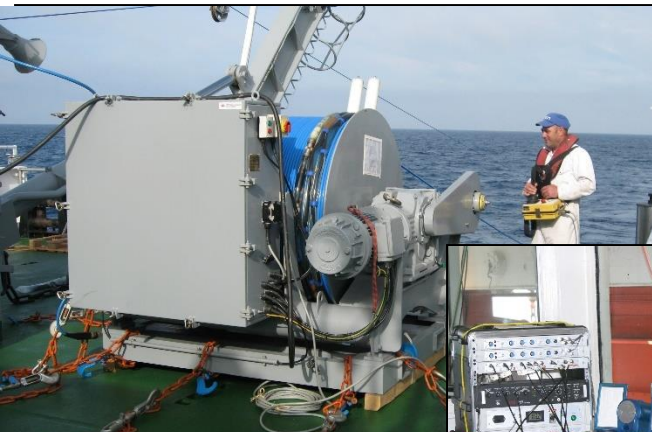
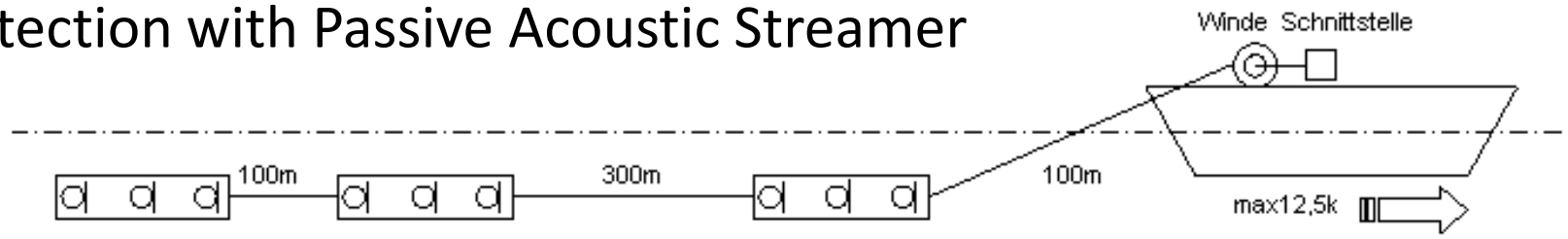


Known distribution of Arnoux's beaked whale (berardius arnuxii)
UN FAO Species Identification Guide: Marine Mammals of the World, 1993

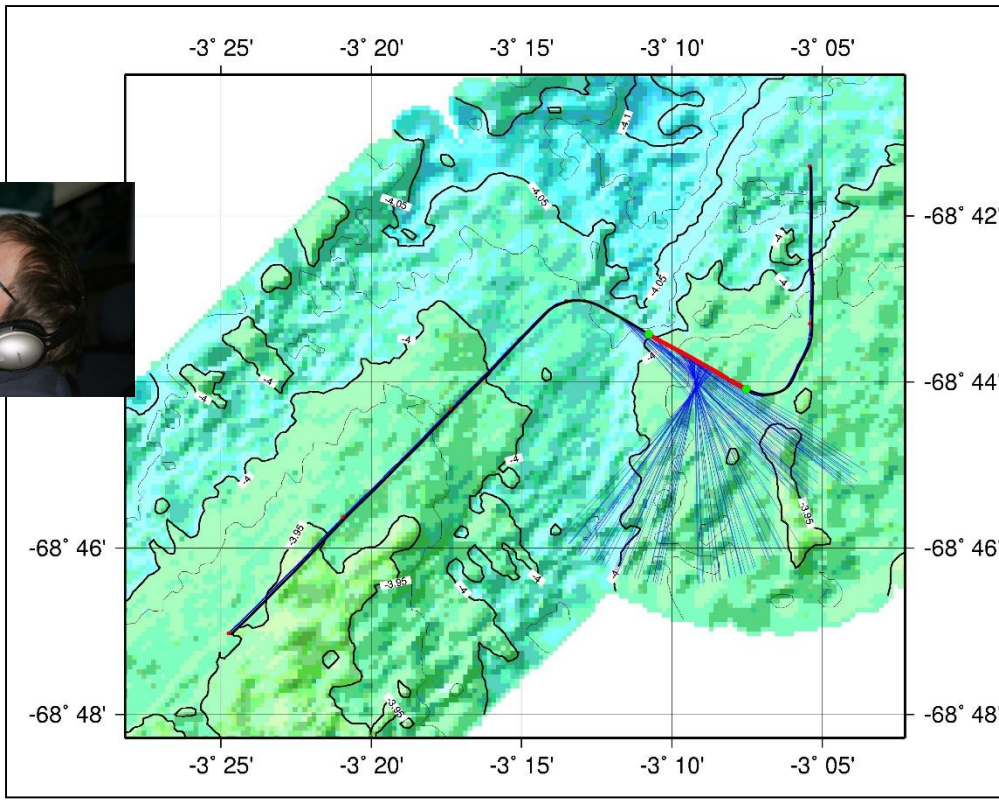
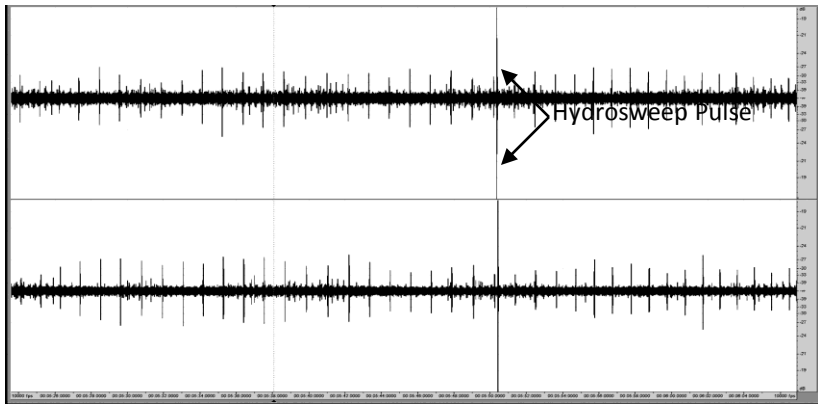
Visual surveys are difficult in Antarctica



Whale Detection with Passive Acoustic Streamer



Sperm Whale Clicks



Deployment of acoustic recorders on ice floes



Recording in the acoustic shadow of large icebergs



Recovery of recorders by helicopter



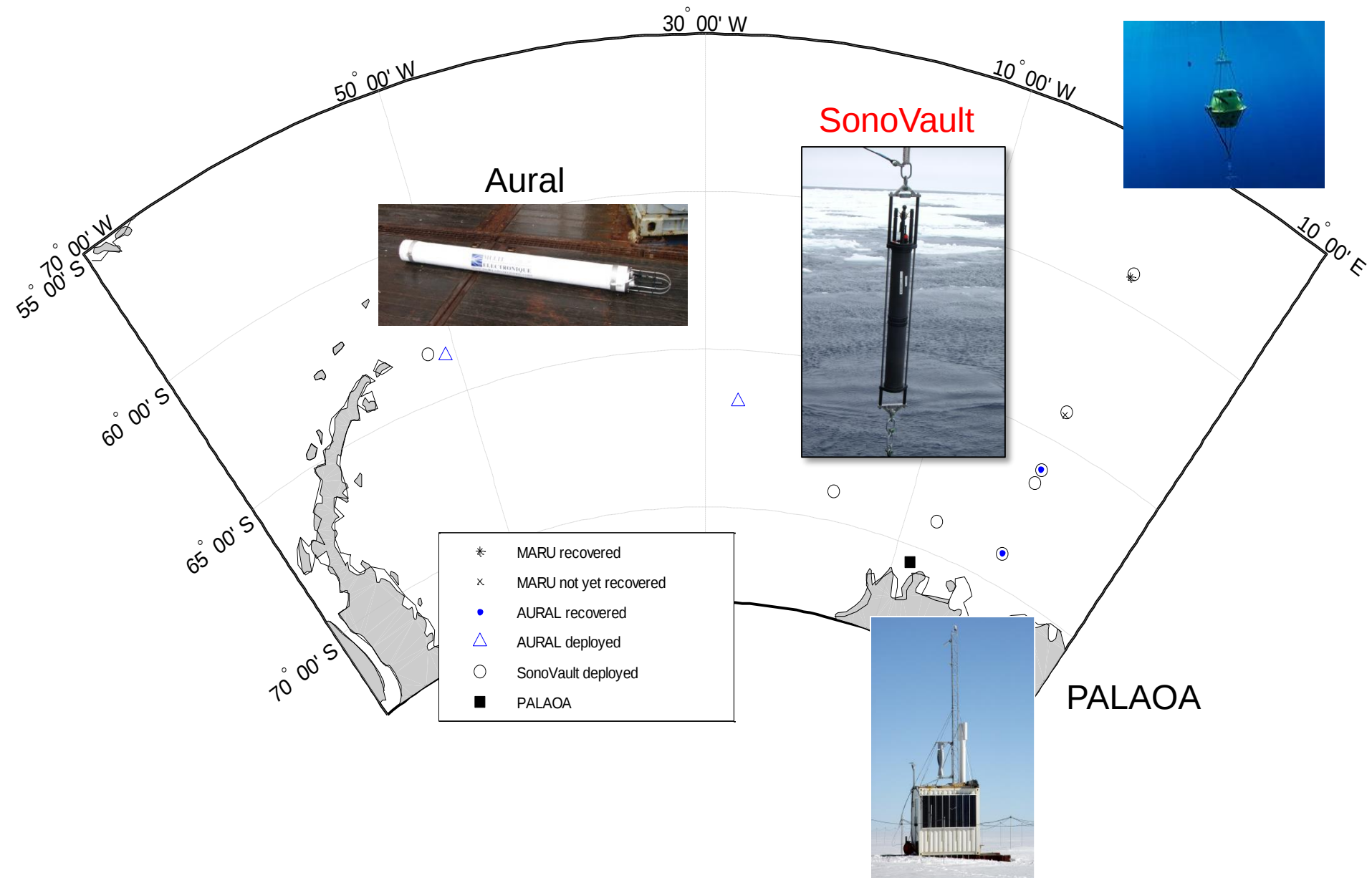
Field recordings to identify species specific calls: Elephant Seals at Adelaide Island



Field recordings to identify species specific calls: Minke Whales in the winterly Weddell Sea



20 Long Term Passive Acoustic Recorders in the Weddell Sea

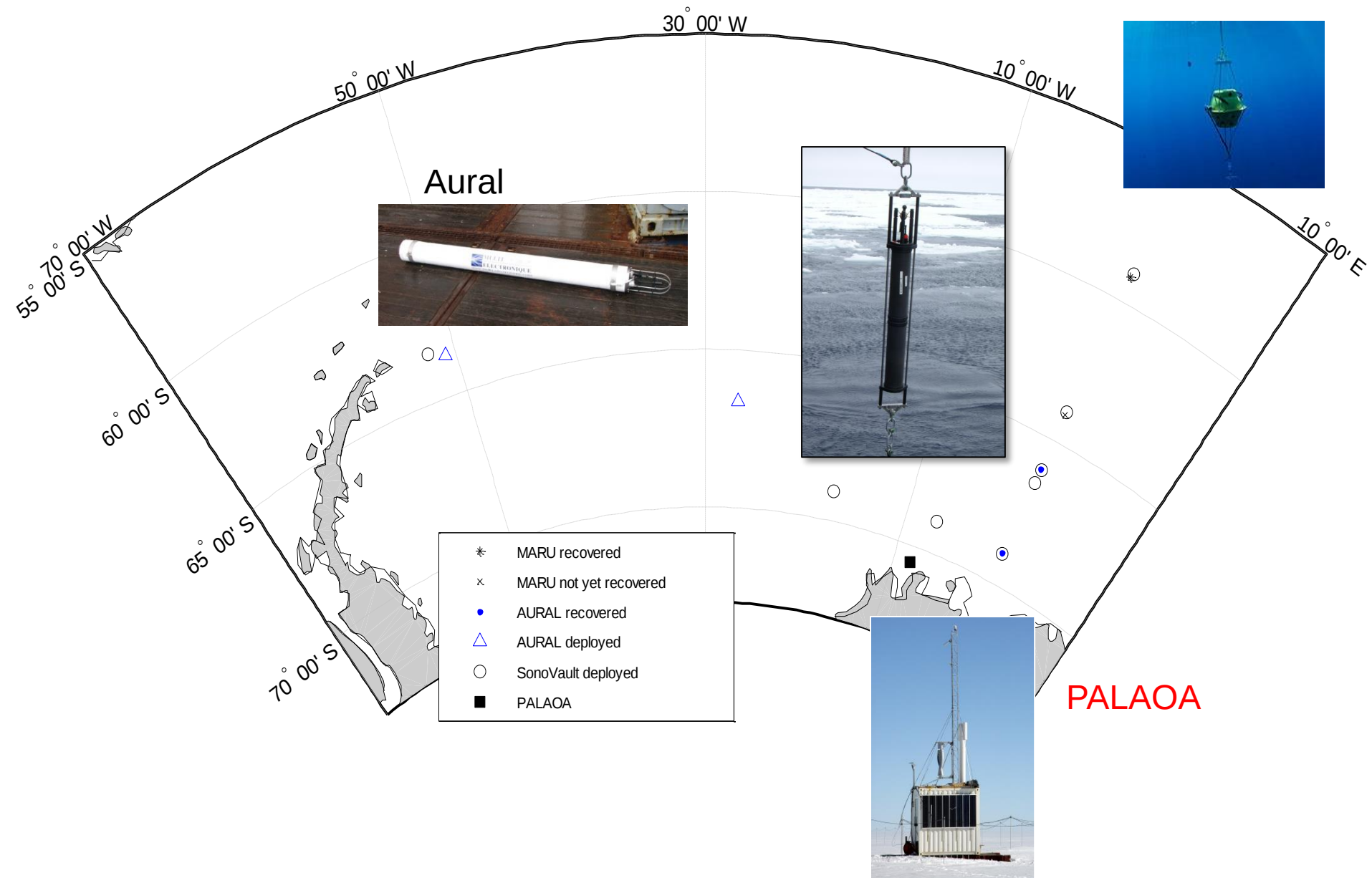


SonoVault Acoustic Recorder

- Calibrated RESON Hydrophone
- 24Bit recording up to 20kHz
ultra sensitive at LF
- 16Bit recording up to 200kHz
for toothed whale clicks
- Rated up to 3000 m (10.000 m option)
- High capacity Lithium primary cell powered
- Up to 4 TB SD card memory
- GPS disciplined clock
- Programmable DSP option
- 5330 Hz / 24Bit -> continuous recording for 3 years



Long Term Passive Acoustic Recorders in the Weddell Sea





Atka Bay
Neumayer Base



Hydrophone 1

Hydrophone 2

PALAOA

Eckström Ice Shelf

PALAOA-S

Neumayer

“Ice finger” at the tip of the Eckström Ice shelf

PALAOA site



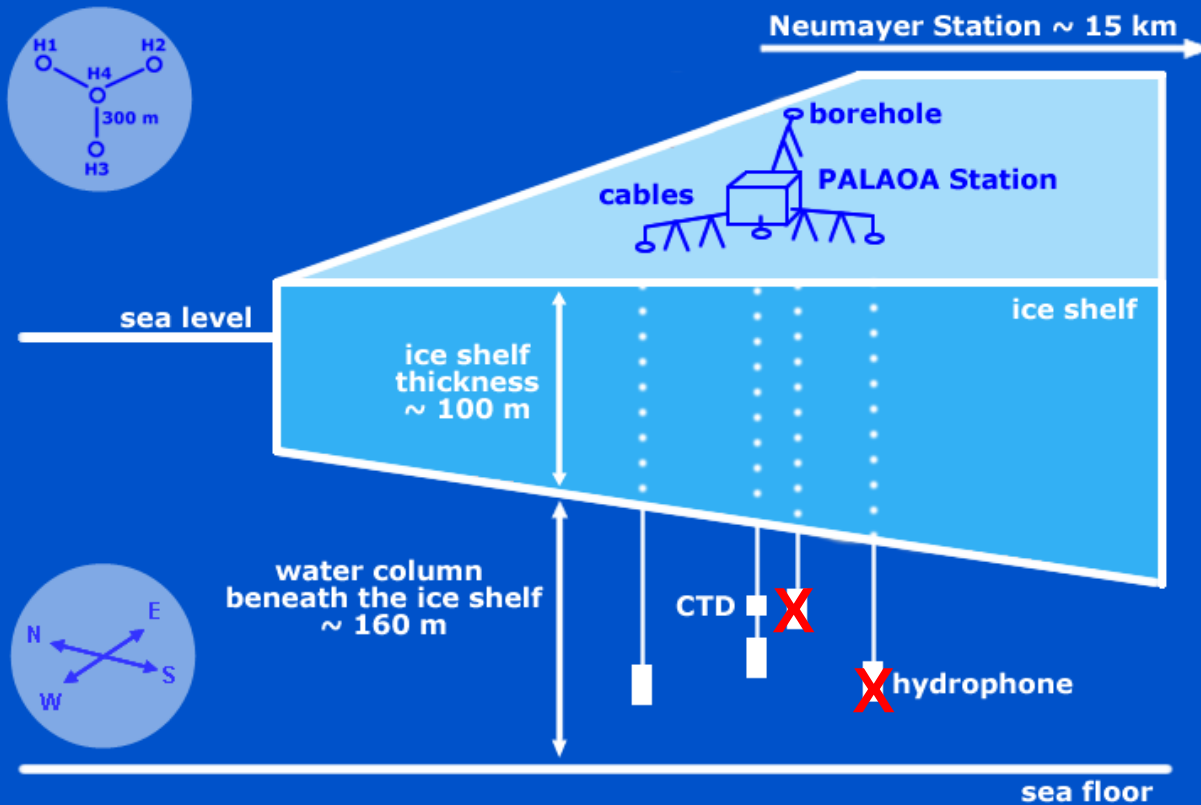
Drilling camp



AWI hot water drilling facility



PALAOA Hydrophone Array



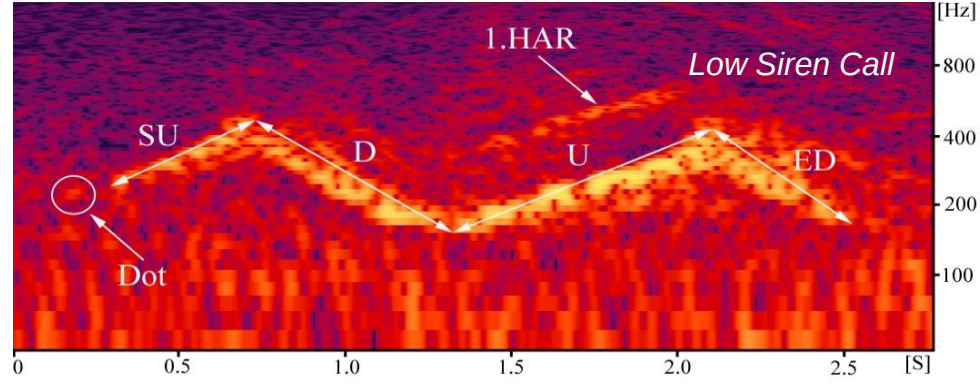
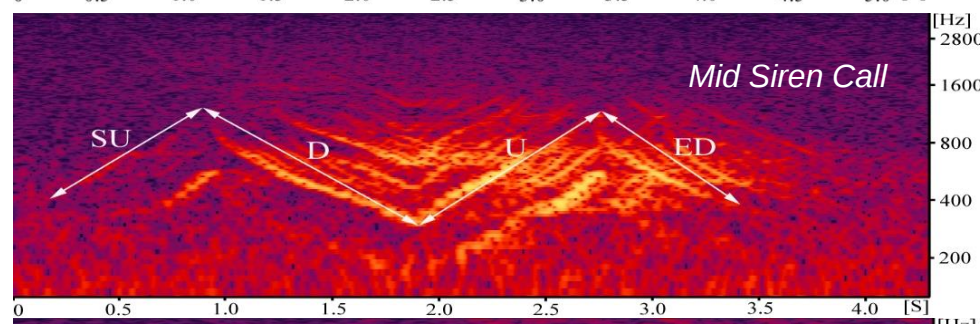
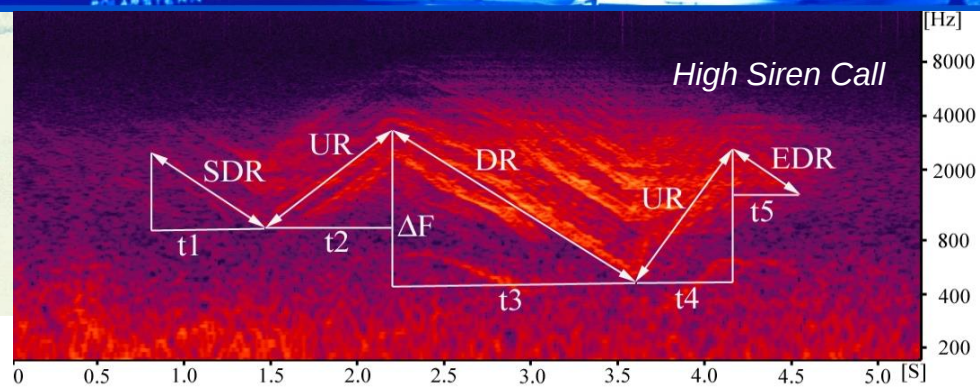
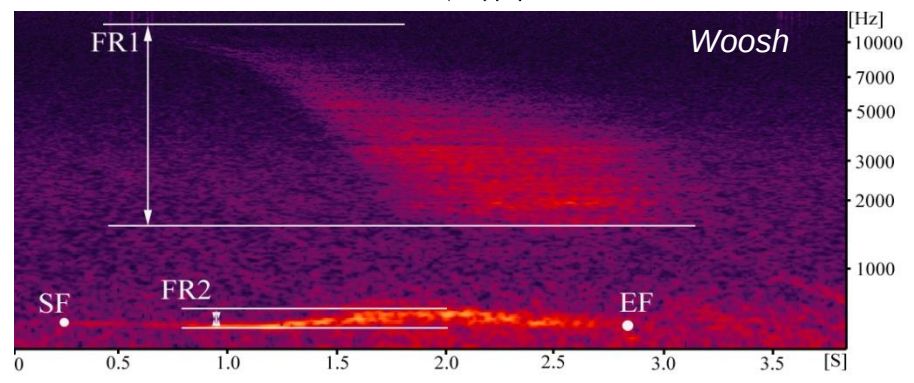
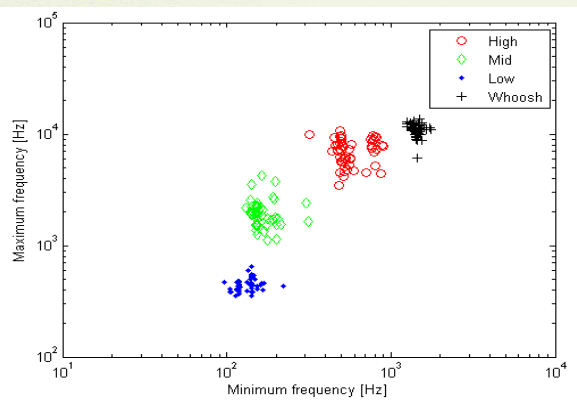
Maintainance every two years

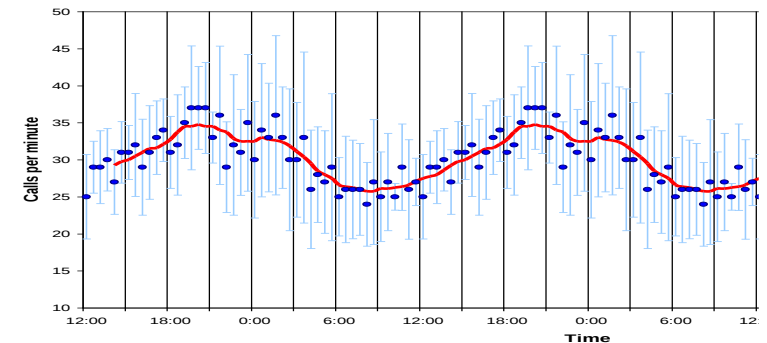




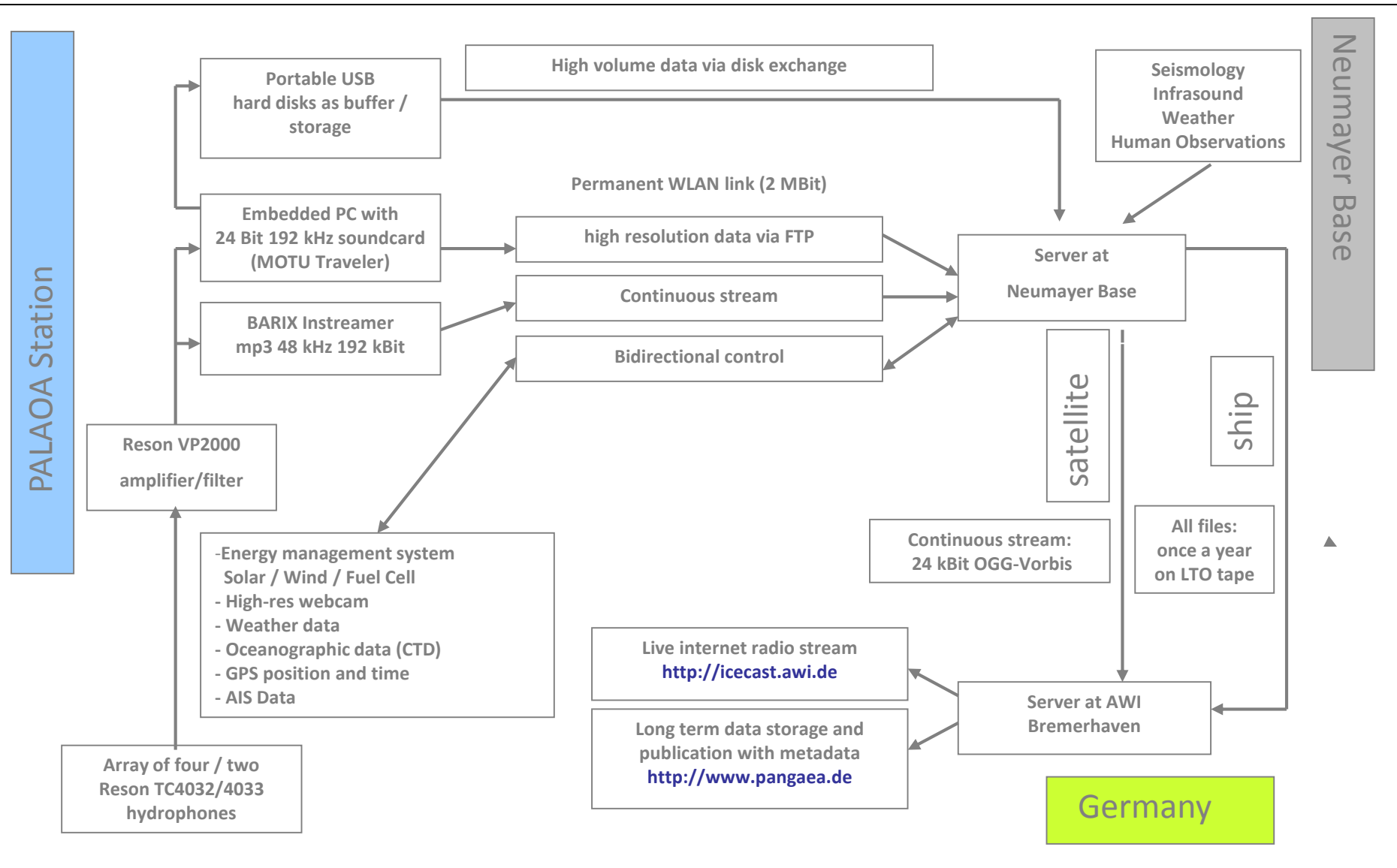


Ross Seals



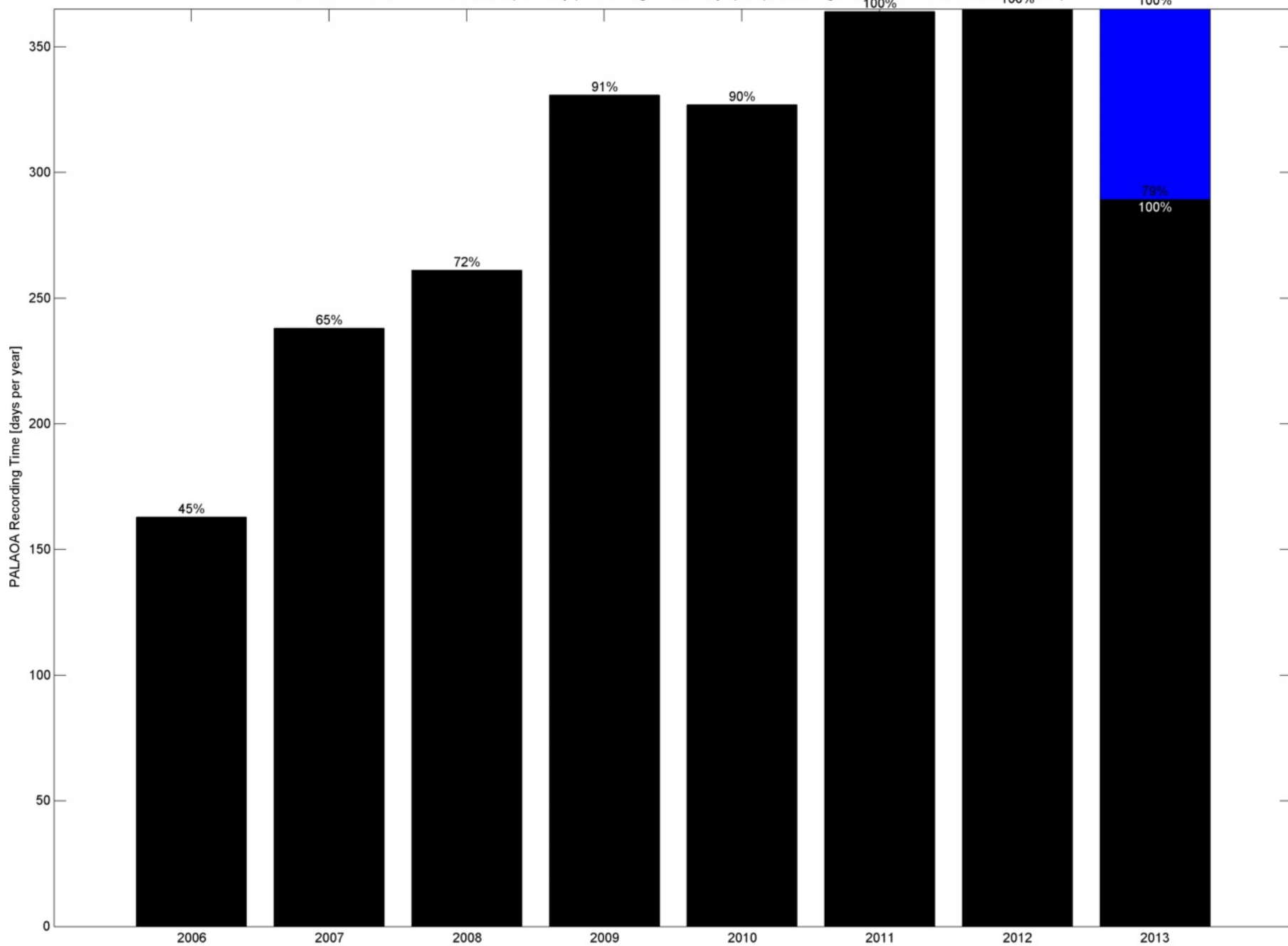


Data and control flow of the PALAOA observatory



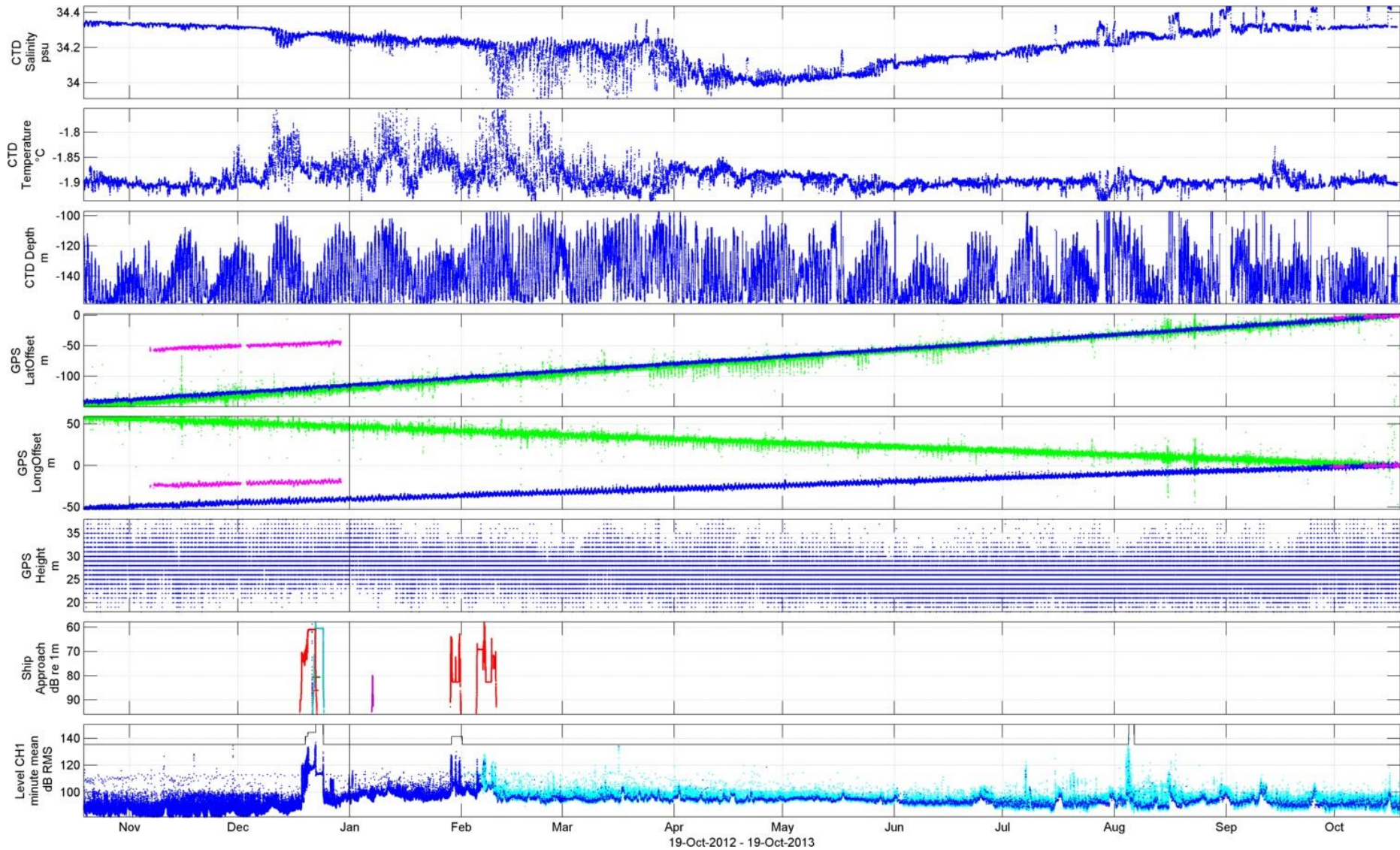
PALAOA 28-Dec-2005 - 17-Oct-2013 (2851 days): Recording on 2471 days (87%), Recording Time: 56137 hours or 2339 days (82%)

PALAOA 01-Oct-2008 - 17-Oct-2013 (1843 days): Recording on 1782 days (97%), Recording Time: 42388 hours or 1766 days (96%)

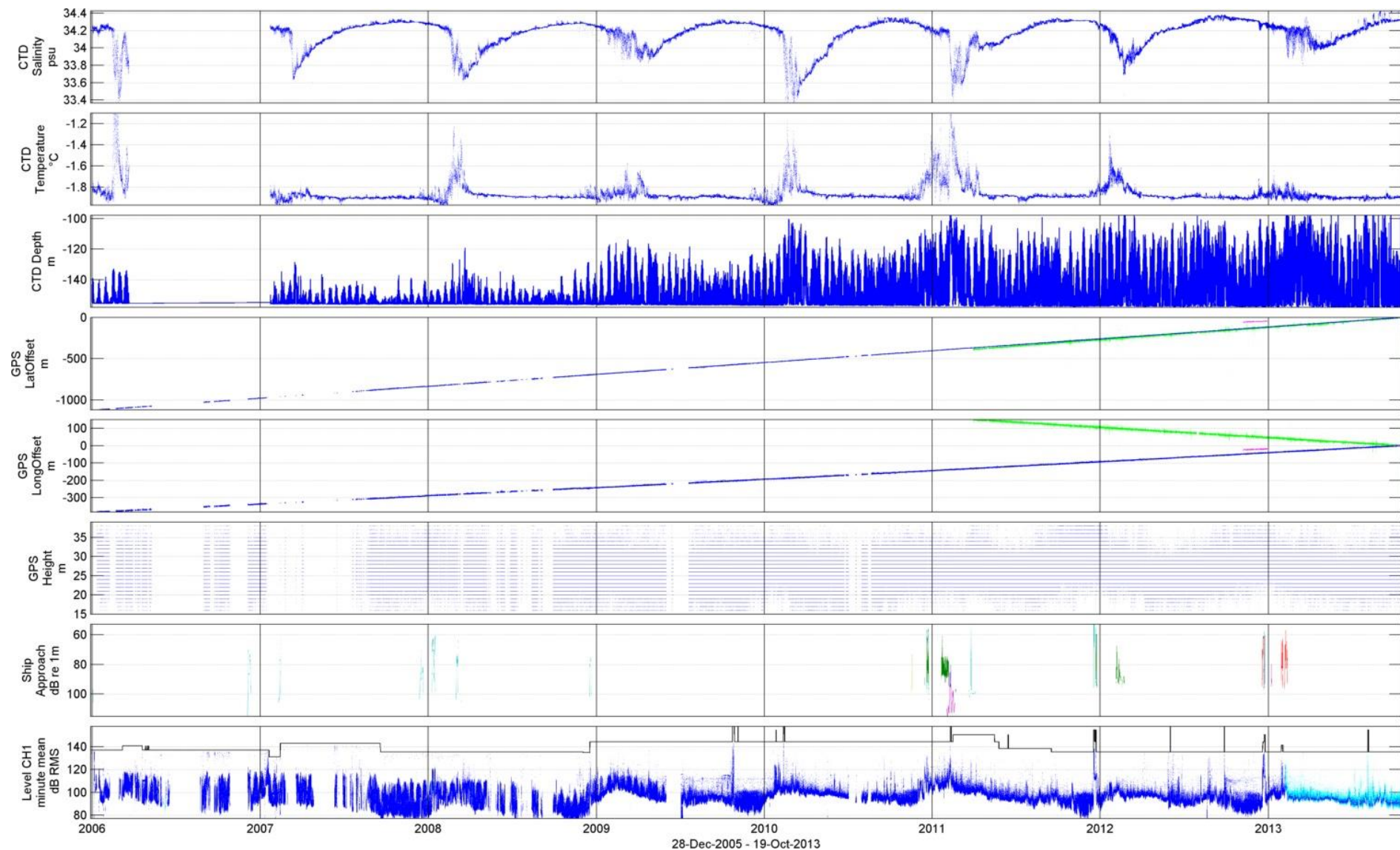


2013 numbers @ Oct-17. Black: uptime till today, percentages relative and in respect to whole year. Blue: optimistic estimation for the whole year

CTD - GPS - AIS – Noise levels: 1 year data



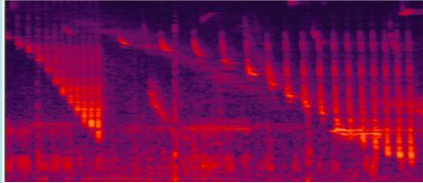
CTD - GPS - AIS – Noise levels: 8 Year data



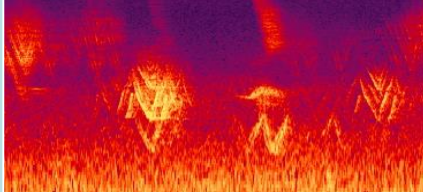
Identified vocalizations in the recordings

Pinnipeds

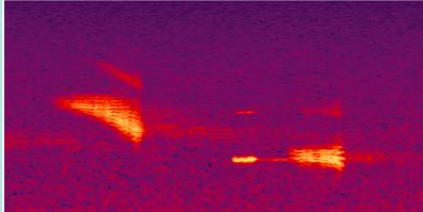
Weddell seal (*Leptonychotes weddellii*)



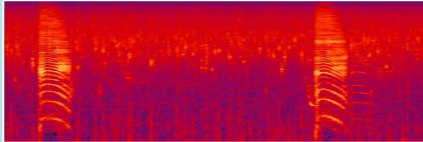
Ross seal (*Ommatophoca rossii*)



leopard seal (*Hydrurga leptonyx*)



crabeater seal (*Lobodon carcinophaga*)

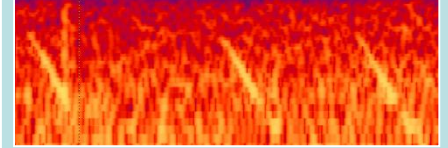


Cetaceans

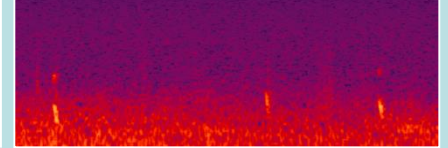
humpback whale (*Megaptera novaeangliae*)



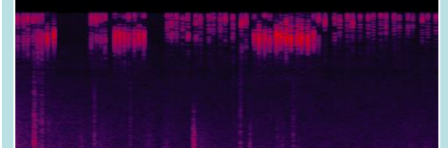
blue whale (*Balaenoptera musculus* spp)



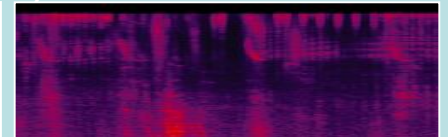
finback whale (*Balaenoptera physalus*)



sperm whale (*Physeter macrocephalus*)

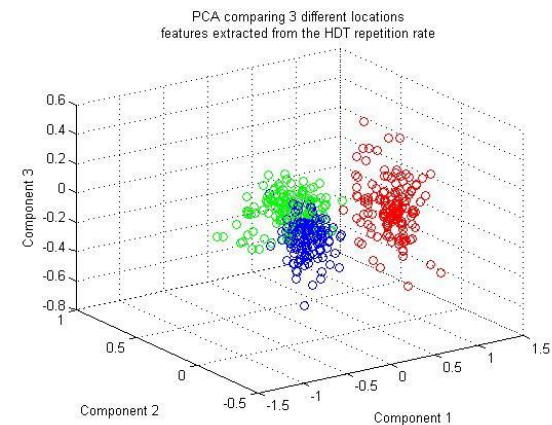
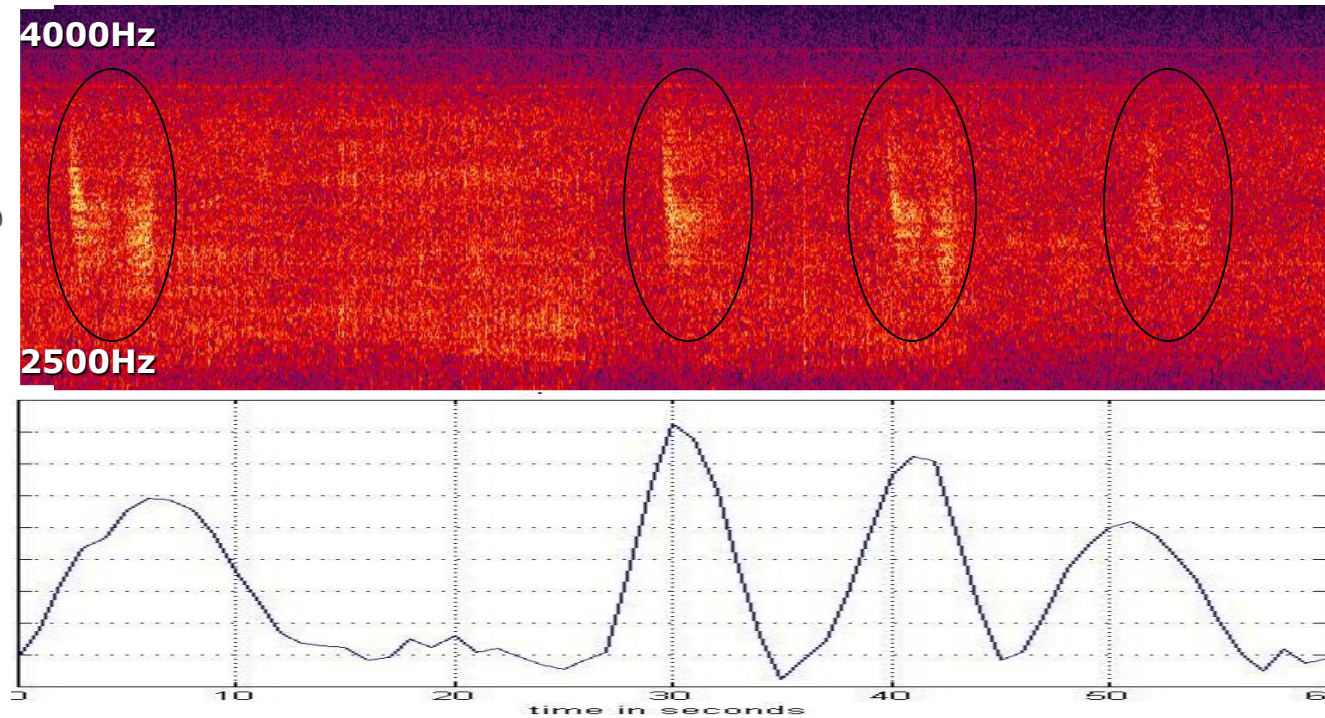


killer whale (*Orcinus orca*)

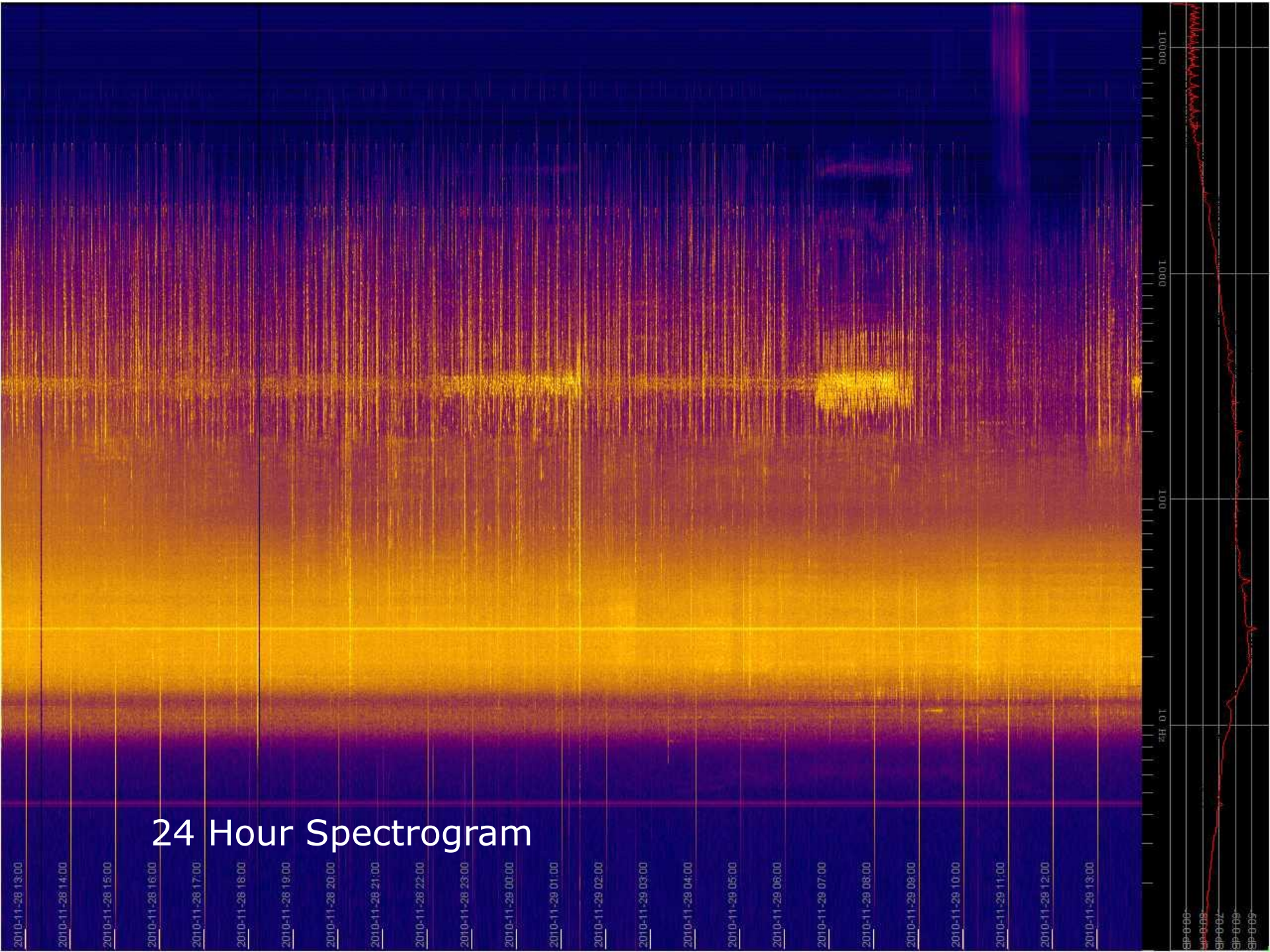




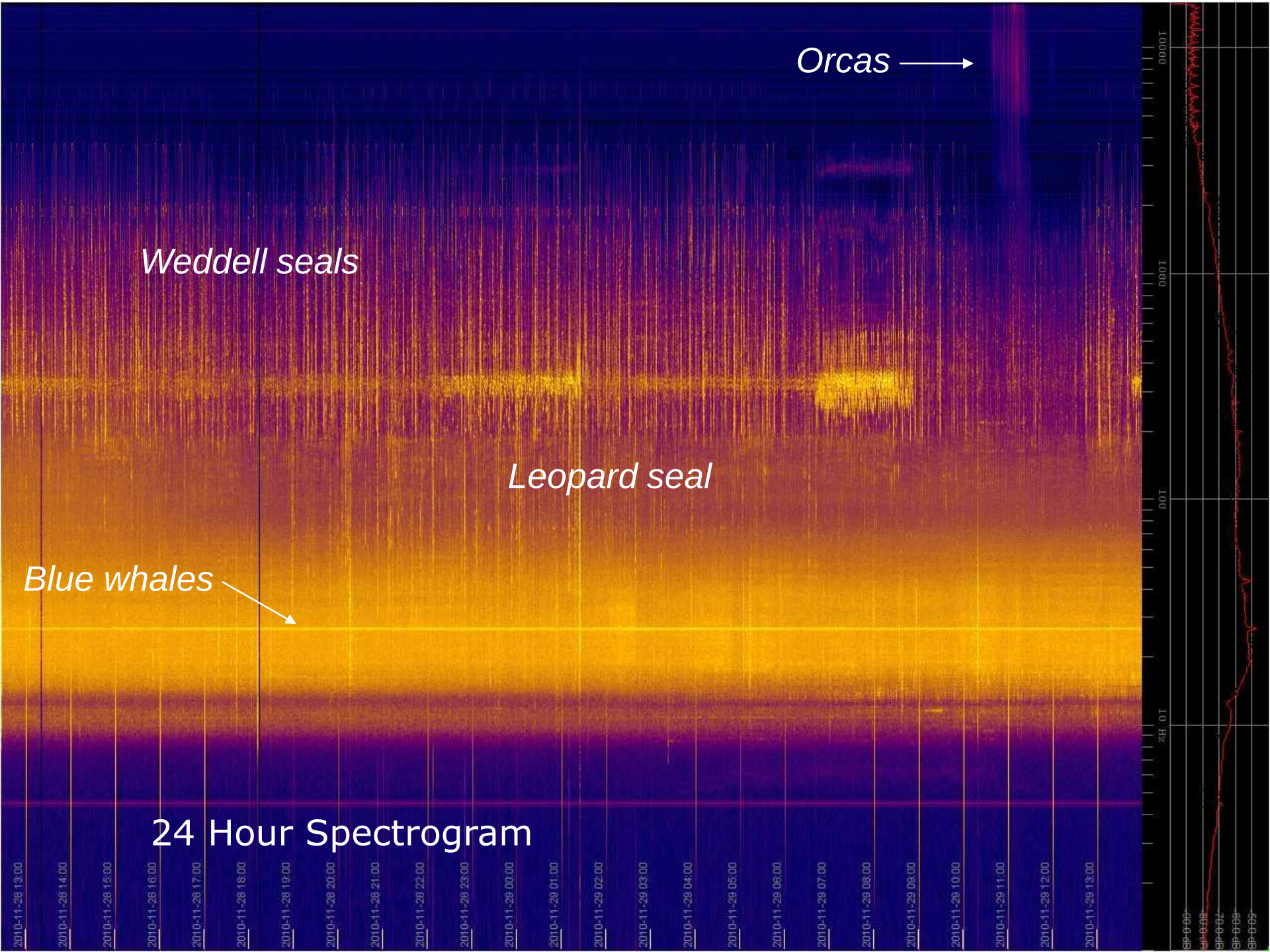
Dialects of Leopard seals



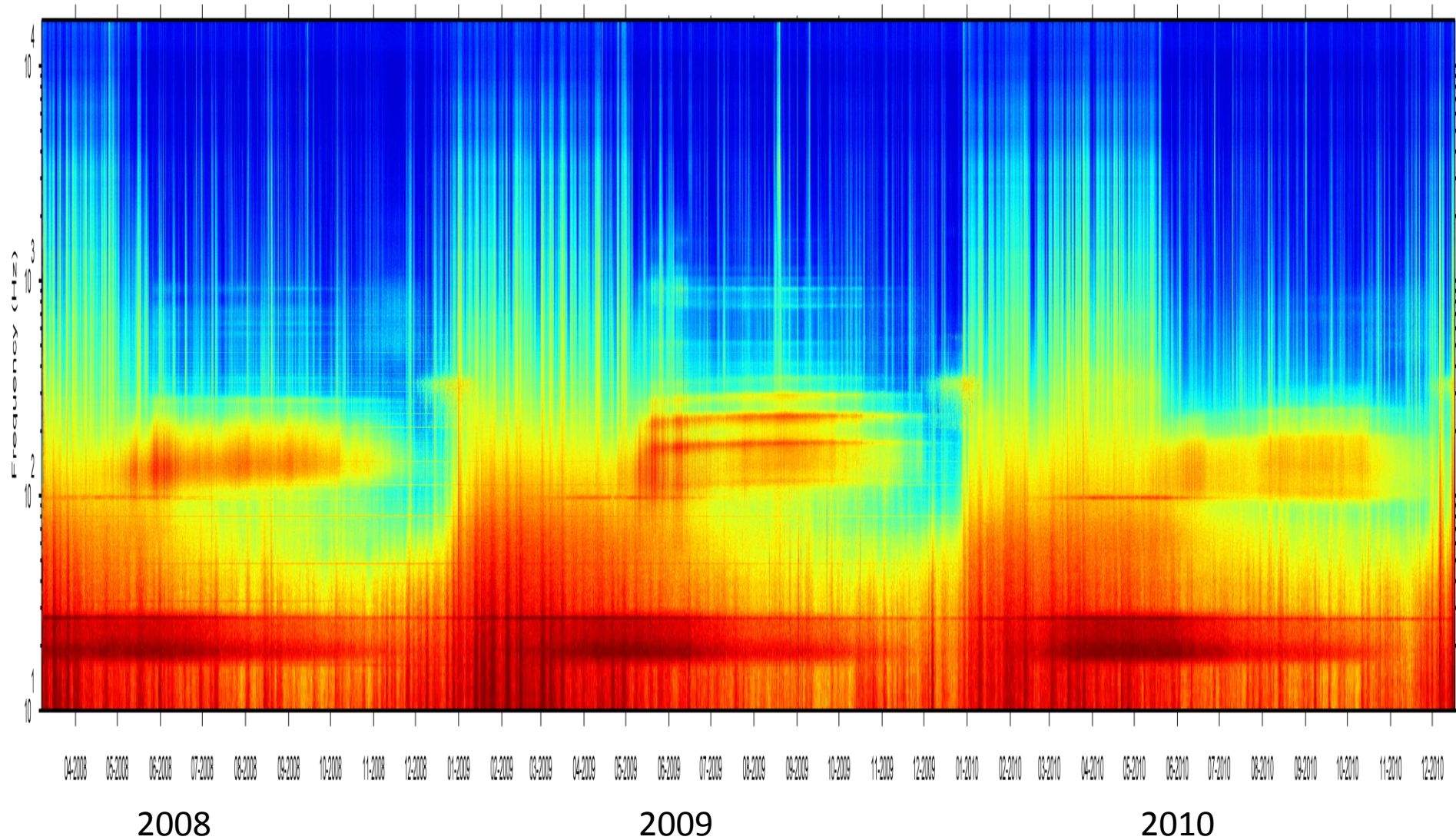
Automatic call detection / classification using a Hidden Markov Model / Neural Network



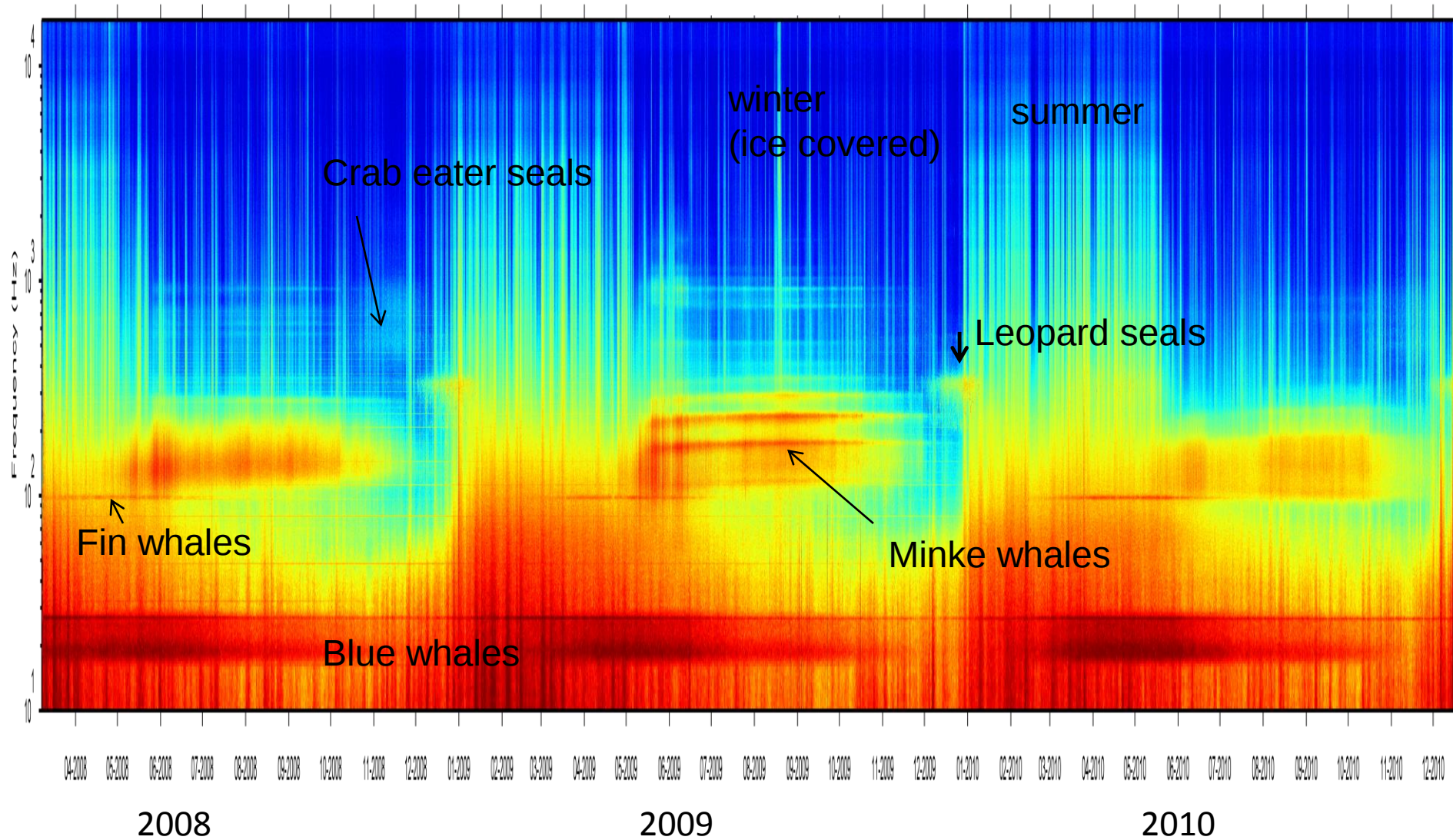
24 Hour Spectrogram



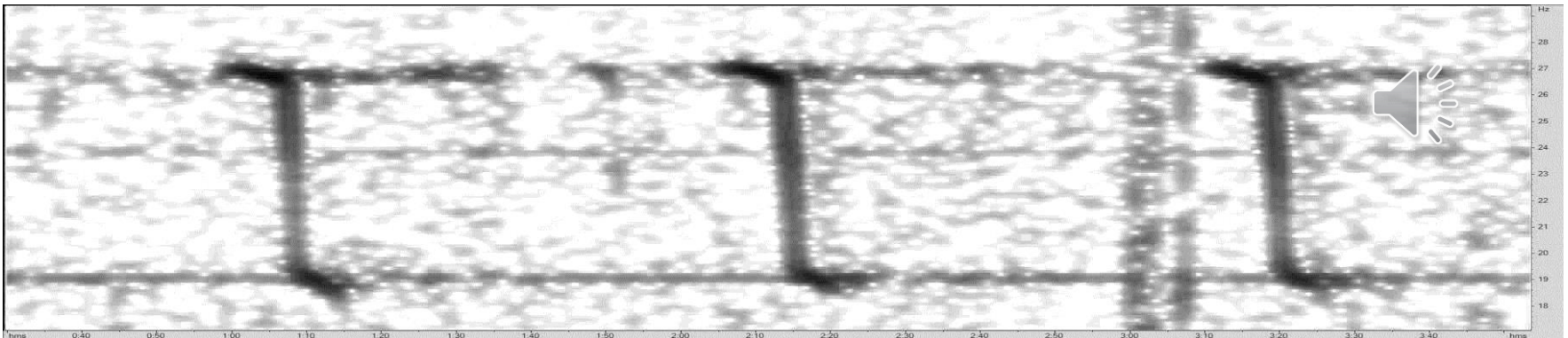
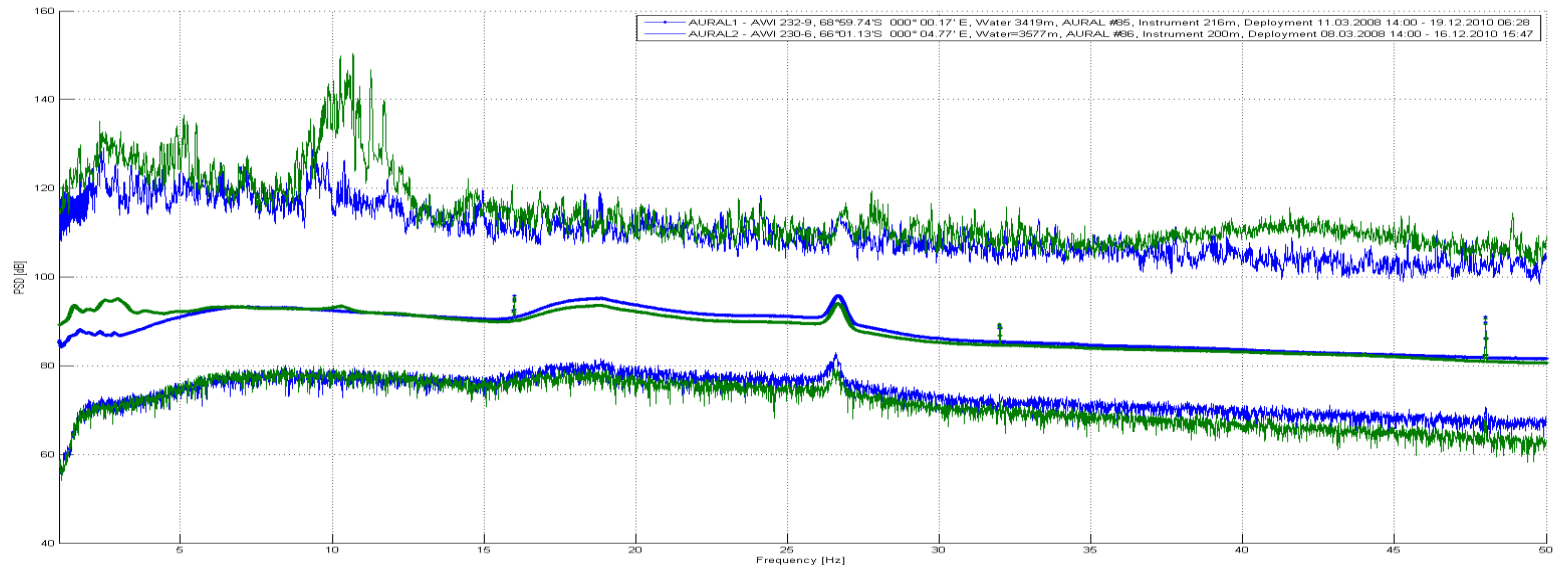
Multi Year Spectrogram



Multi Year Spectrogram

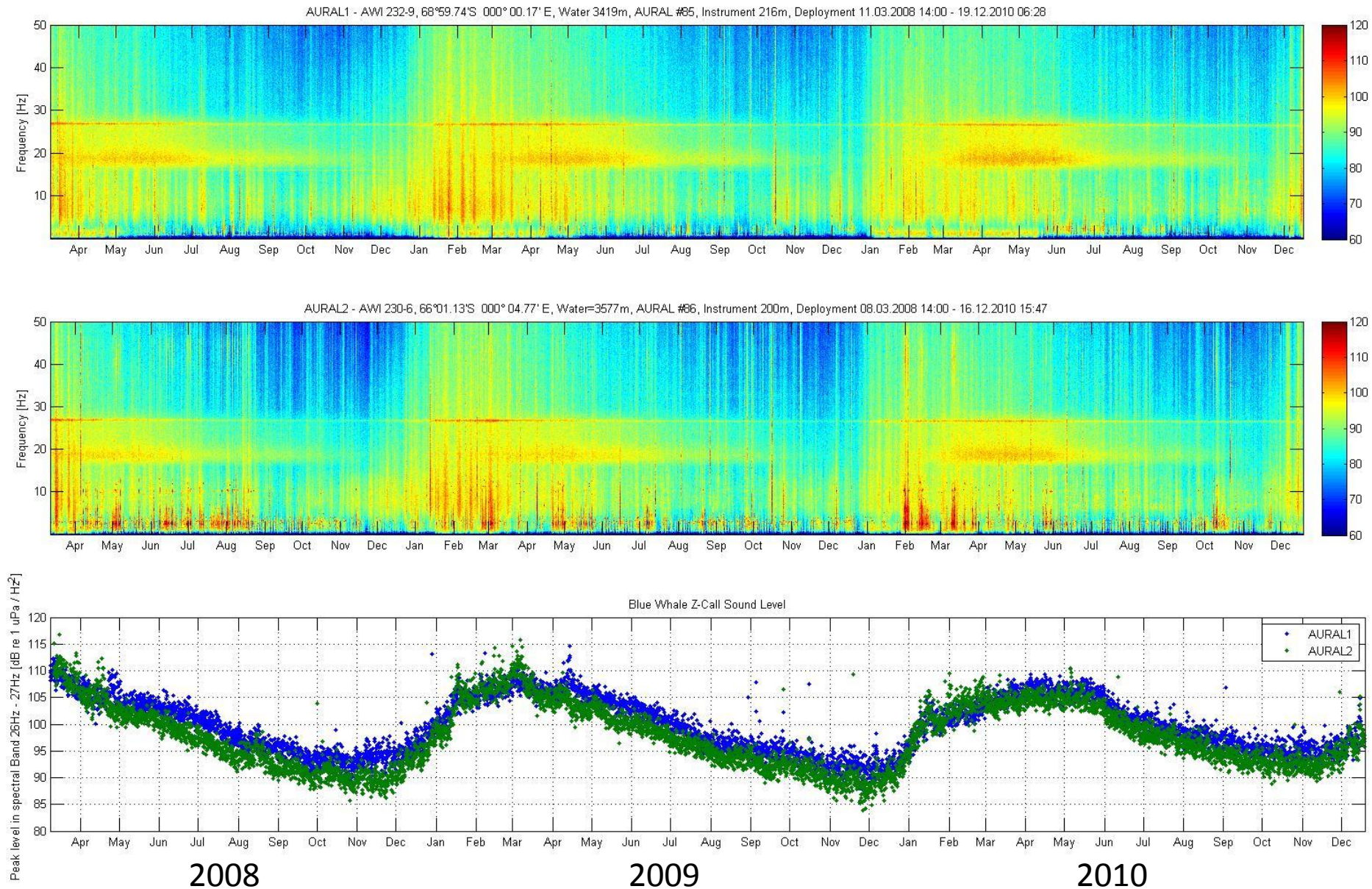


Blue Whale Z-Calls



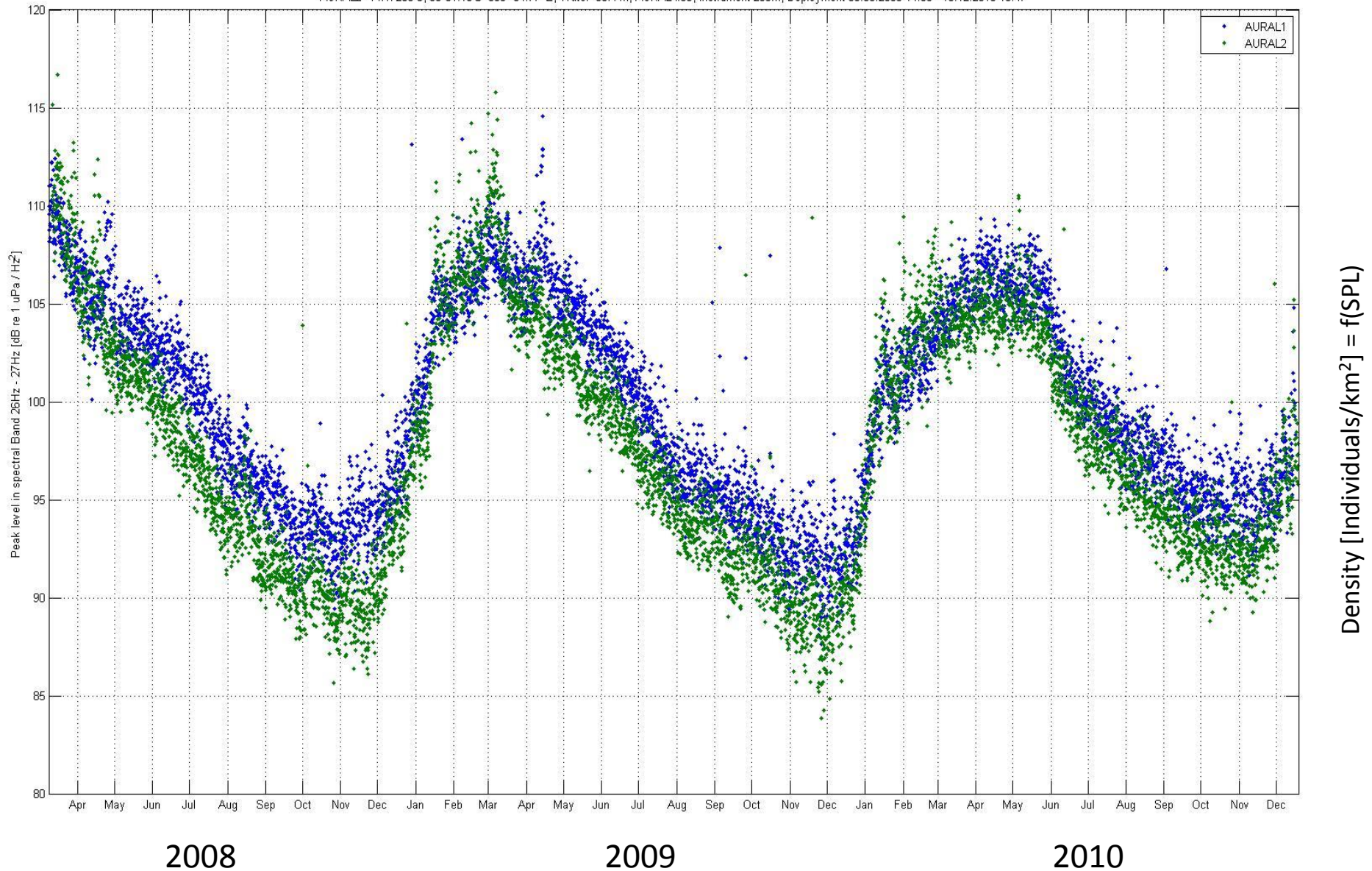
Spectrogram of blue whale "Z"-calls, recorded by MARU#1 on 28.12.2008 17:55

Two recordings at a distance of ~140km reveal migration pattern



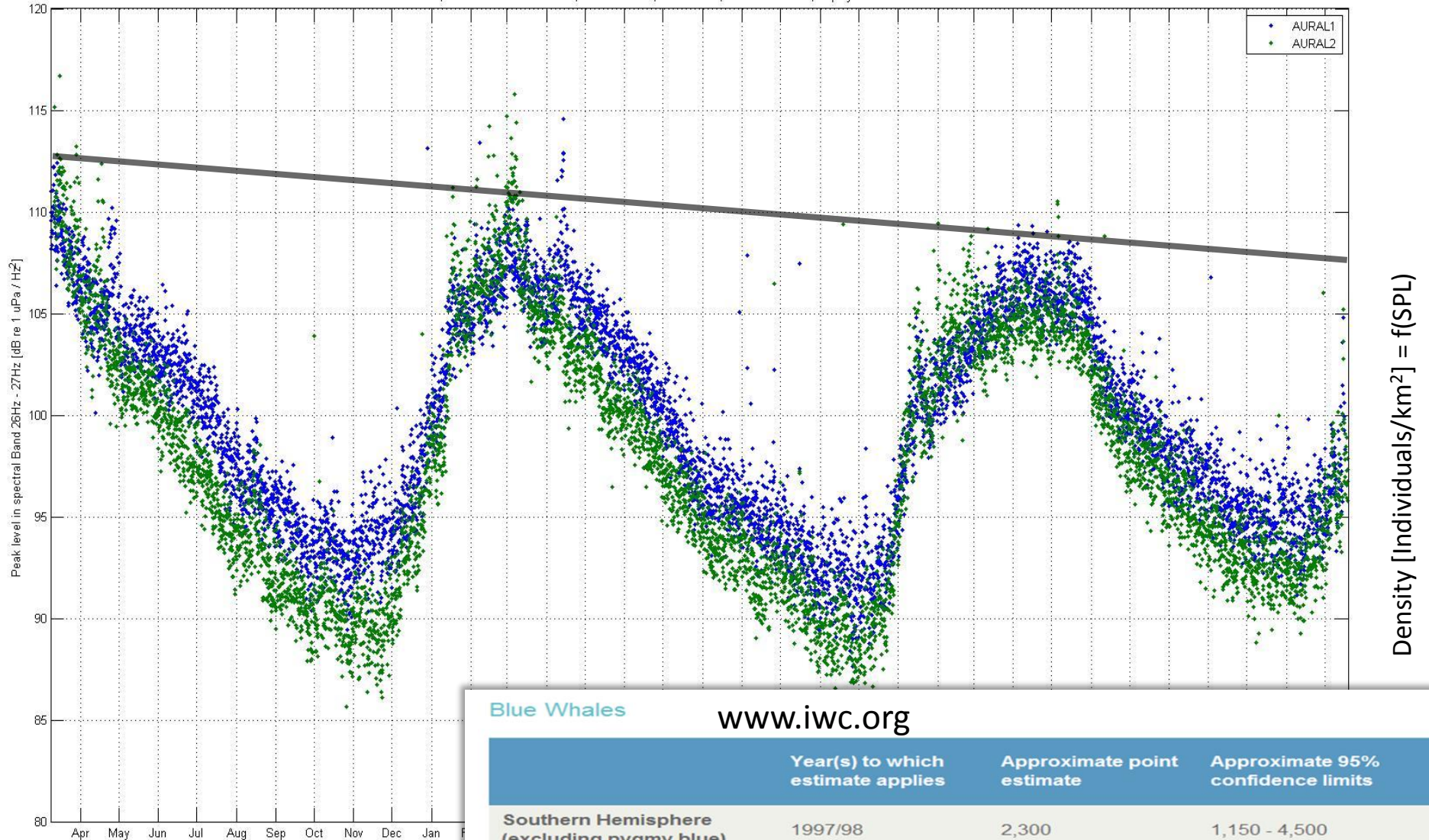
Blue Whale Chorus Intensity

AURAL1 - AWI 232-9, 68°59.74'S 000°00.17' E, Water 3419m, AURAL #85, Instrument 216m, Deployment 11.03.2008 14:00 - 19.12.2010 06:28
AURAL2 - AWI 230-6, 66°01.13'S 000°04.77' E, Water=3577m, AURAL #86, Instrument 200m, Deployment 08.03.2008 14:00 - 16.12.2010 15:47



Blue Whale Chorus Intensity

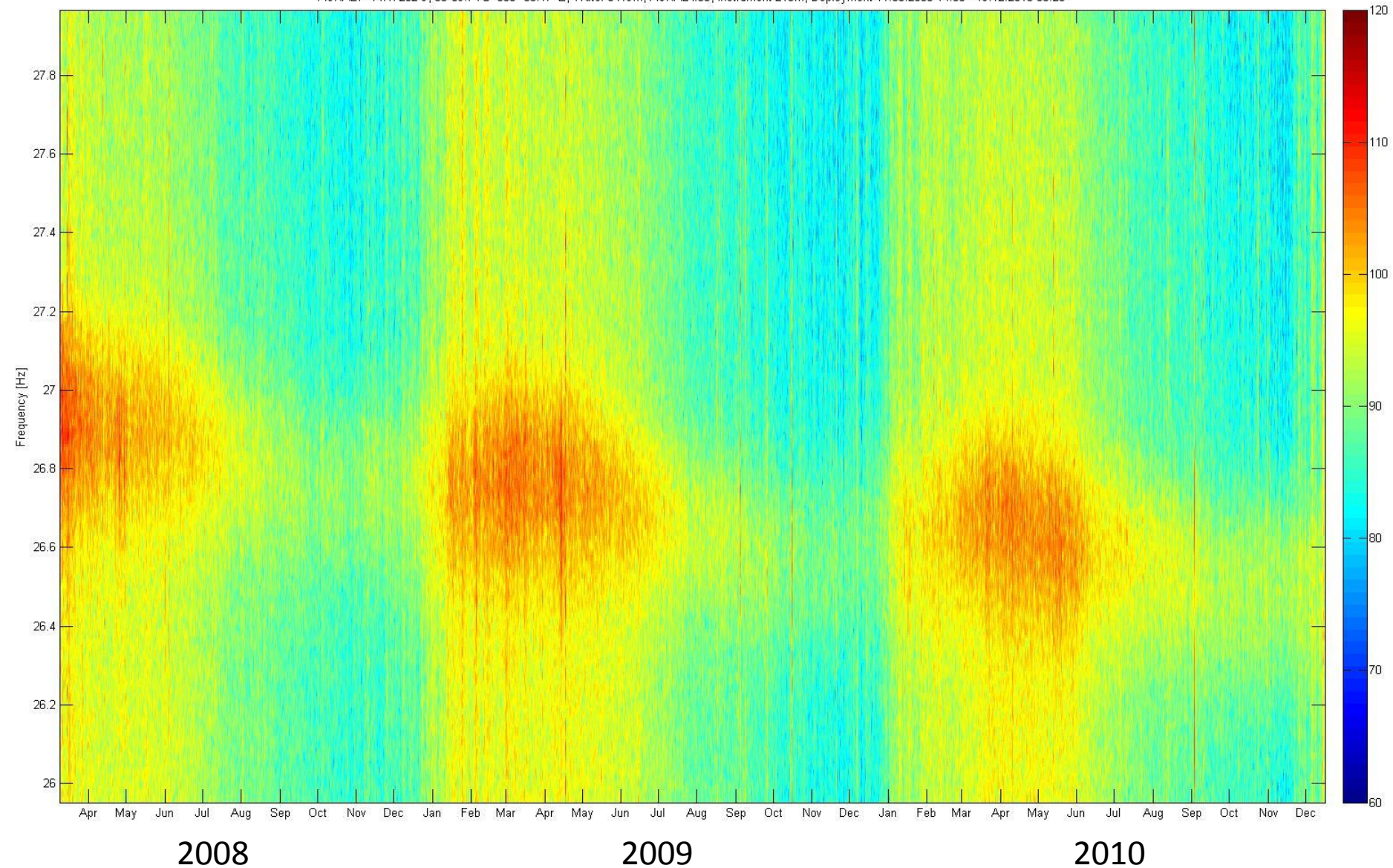
AURAL1 - AWI 232-9, 68°59.74'S 000°00.17' E, Water 3419m, AURAL #85, Instrument 216m, Deployment 11.03.2008 14:00 - 19.12.2010 06:28
 AURAL2 - AWI 230-6, 66°01.13'S 000°04.77' E, Water=3577m, AURAL #86, Instrument 200m, Deployment 08.03.2008 14:00 - 16.12.2010 15:47

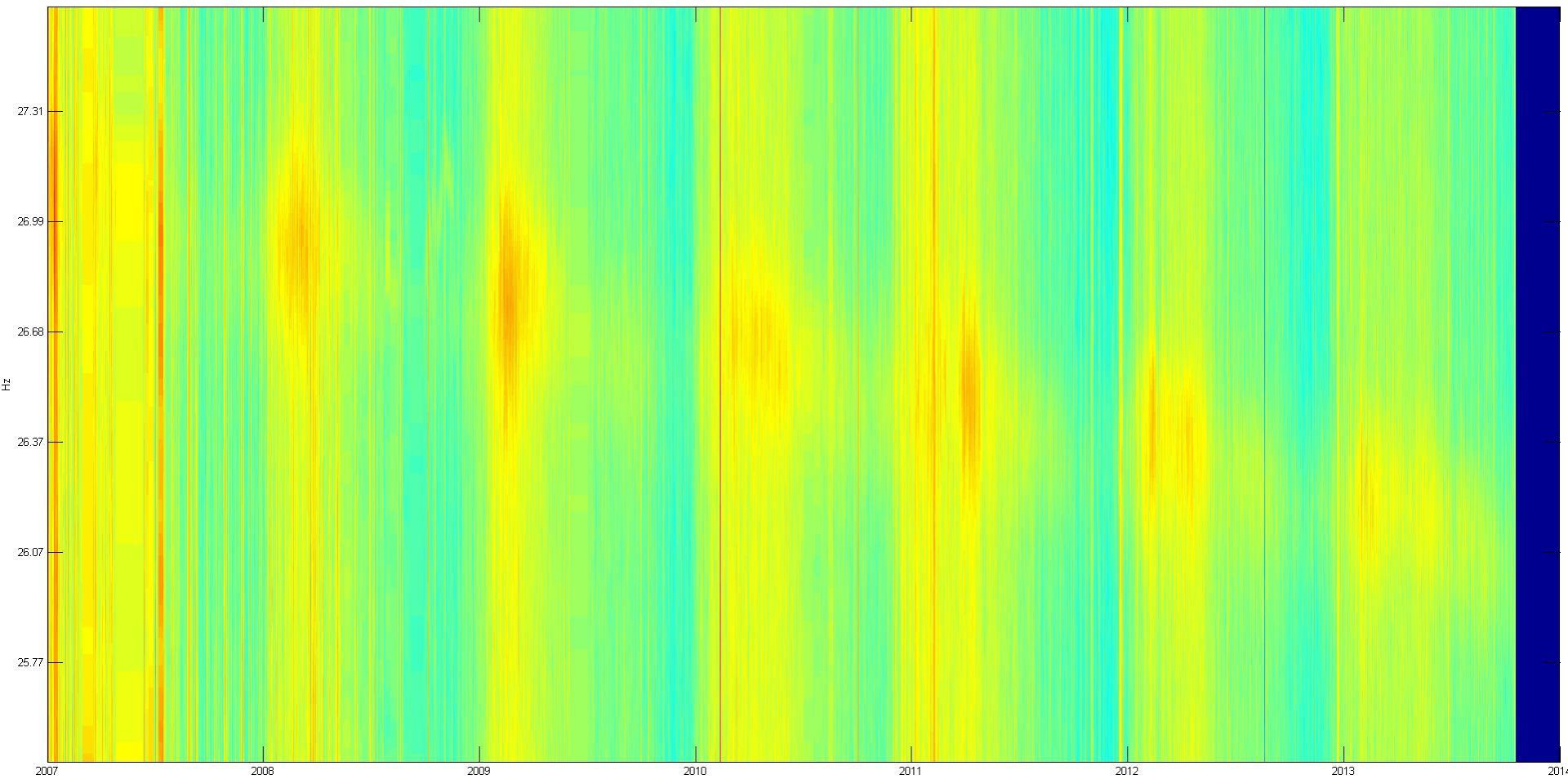


The estimated rate of increase is 8.2% (95% confidence interval 3.8-12.5%) per year between 1978/79 and 2003/04

Decreasing Frequency

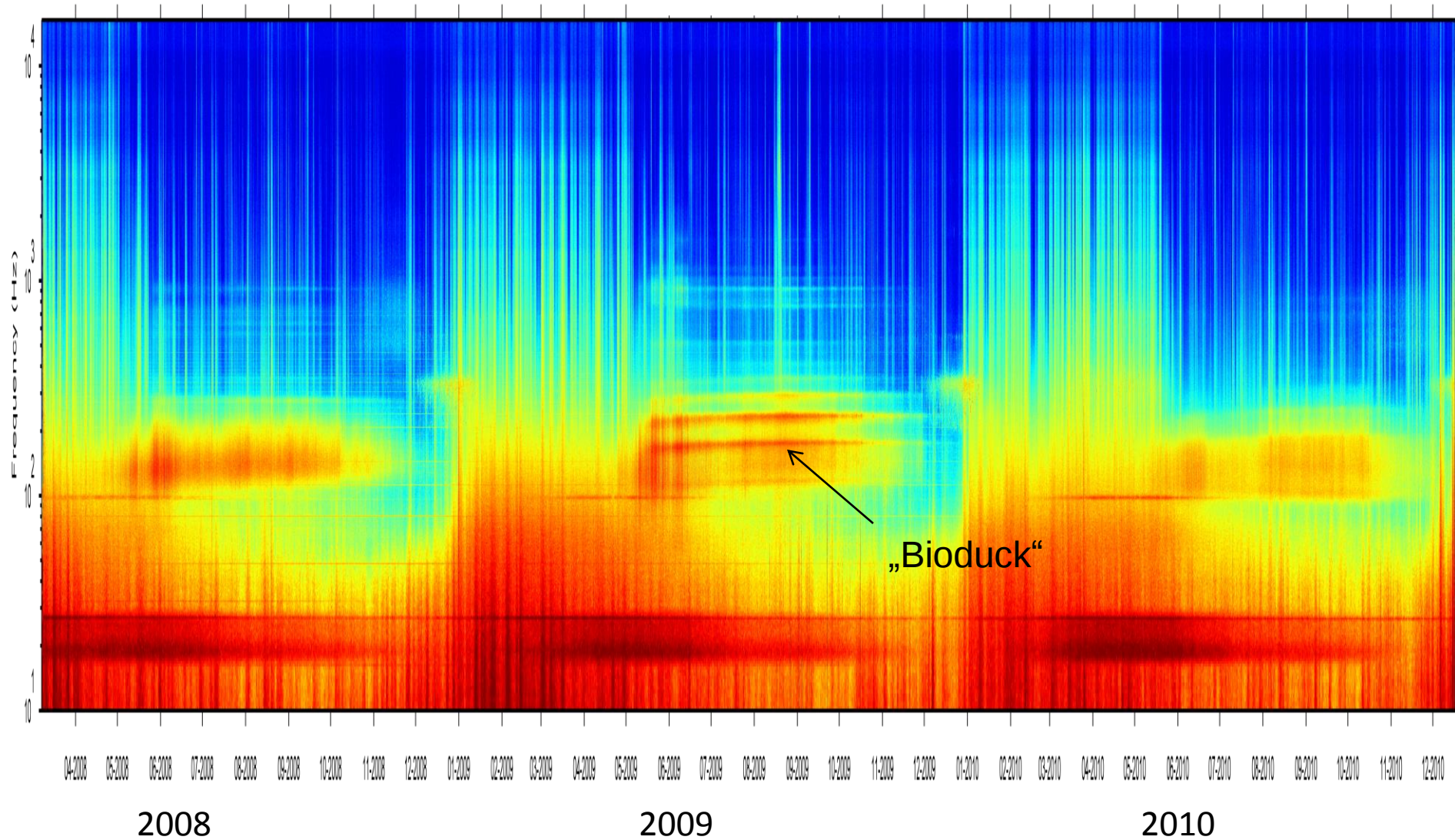
AURAL1 - AWI 232-9, 68°59.74'S 000°00.17'E, Water 3419m, AURAL #85, Instrument 216m, Deployment 11.03.2008 14:00 - 19.12.2010 06:28



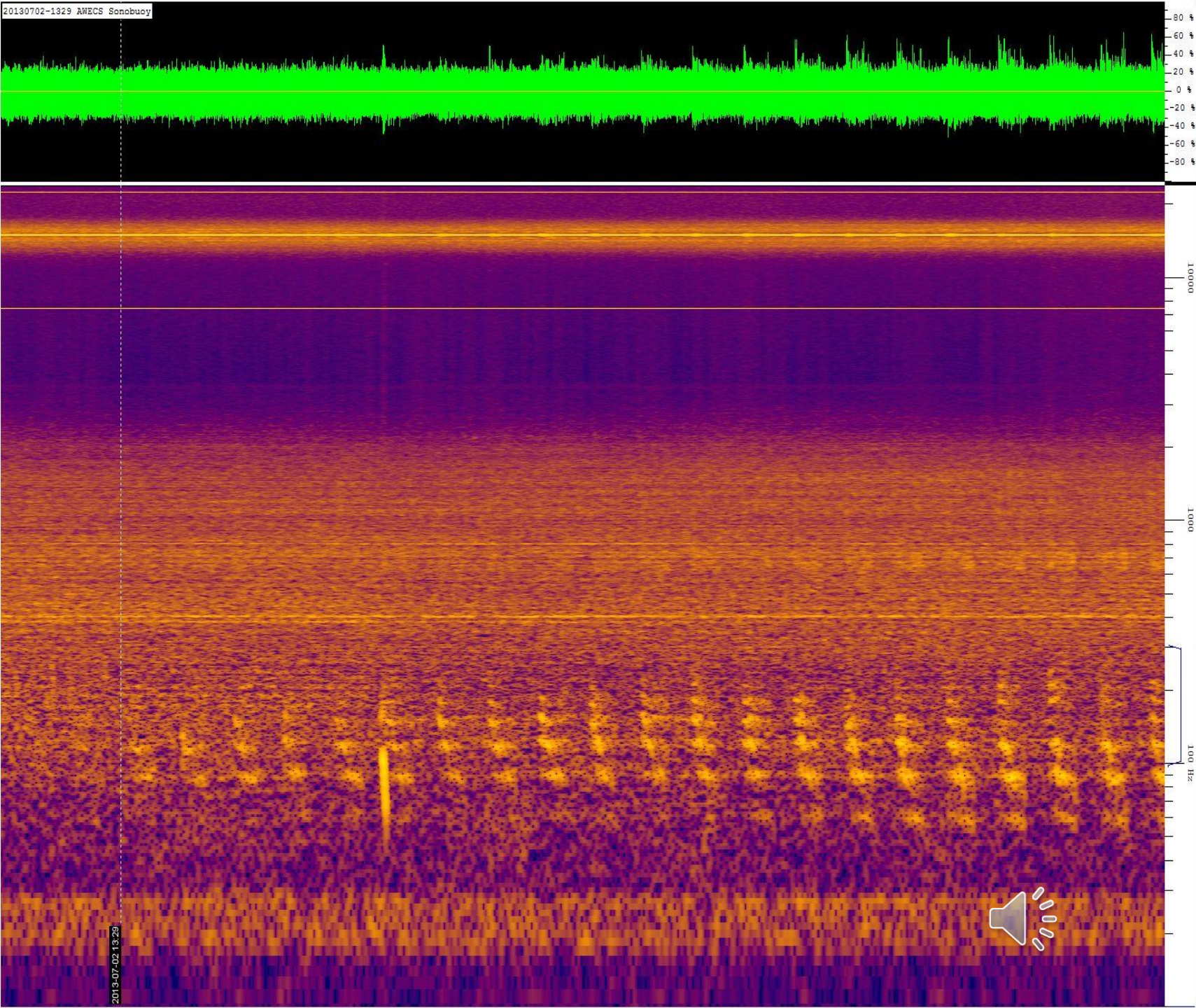


Blue Whale frequency decrease over 7 years: ~ 0.1 Hz / year

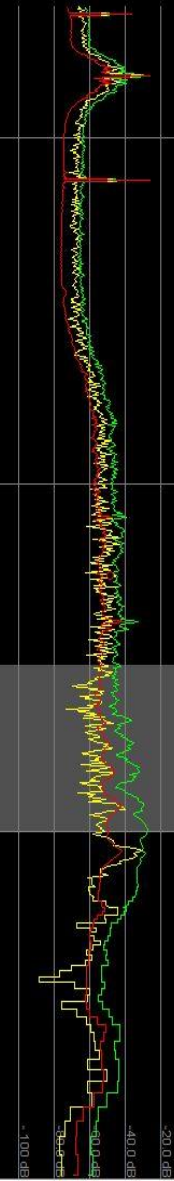
3-Year Spectrogram



20130702-1329 AWZCS Sonobuoy

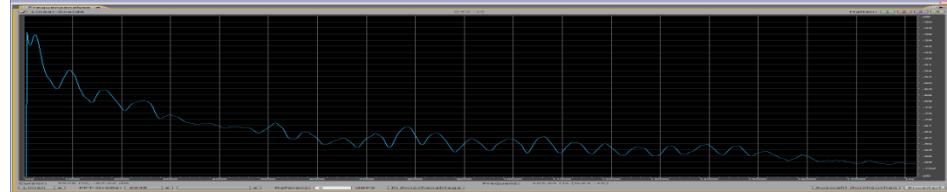
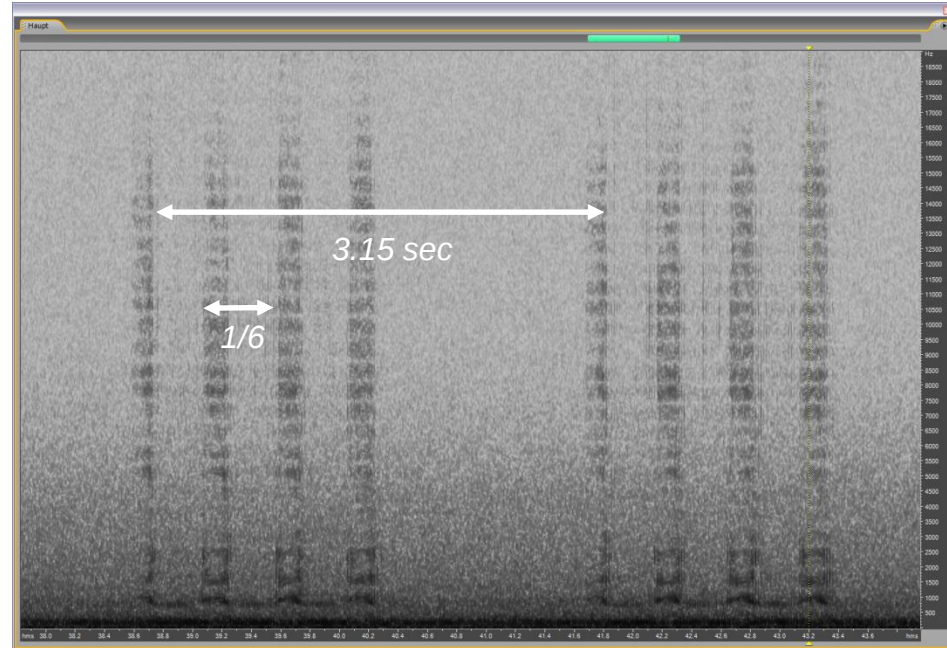
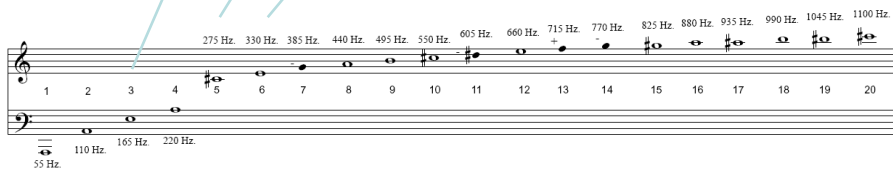
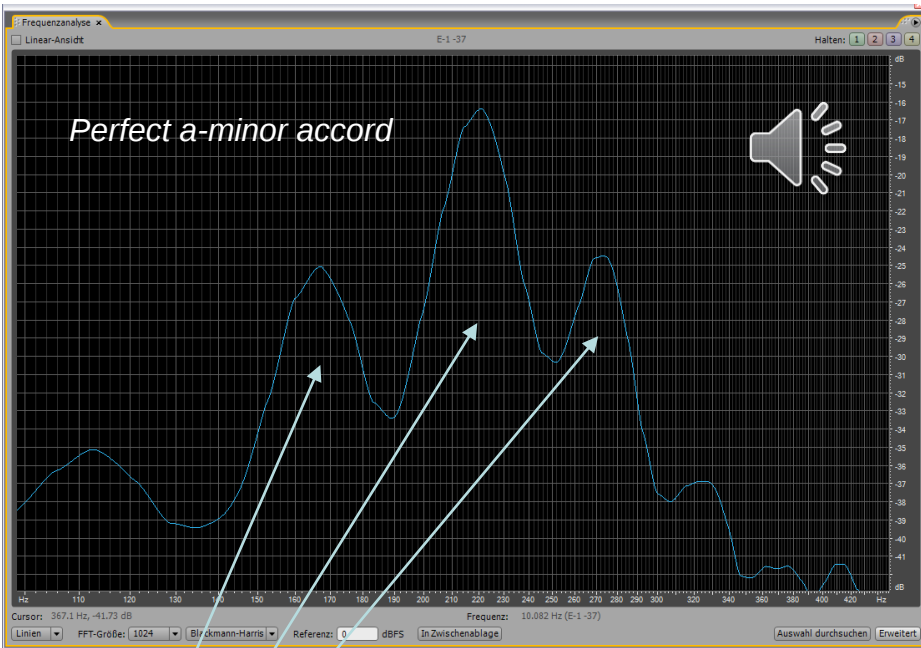


2013-07-02 13:29





A unique vocalisation



Antarctic minke whale
Acurostrata borealis

Size 10 m / weight 20 tons

Population estimate 515.000

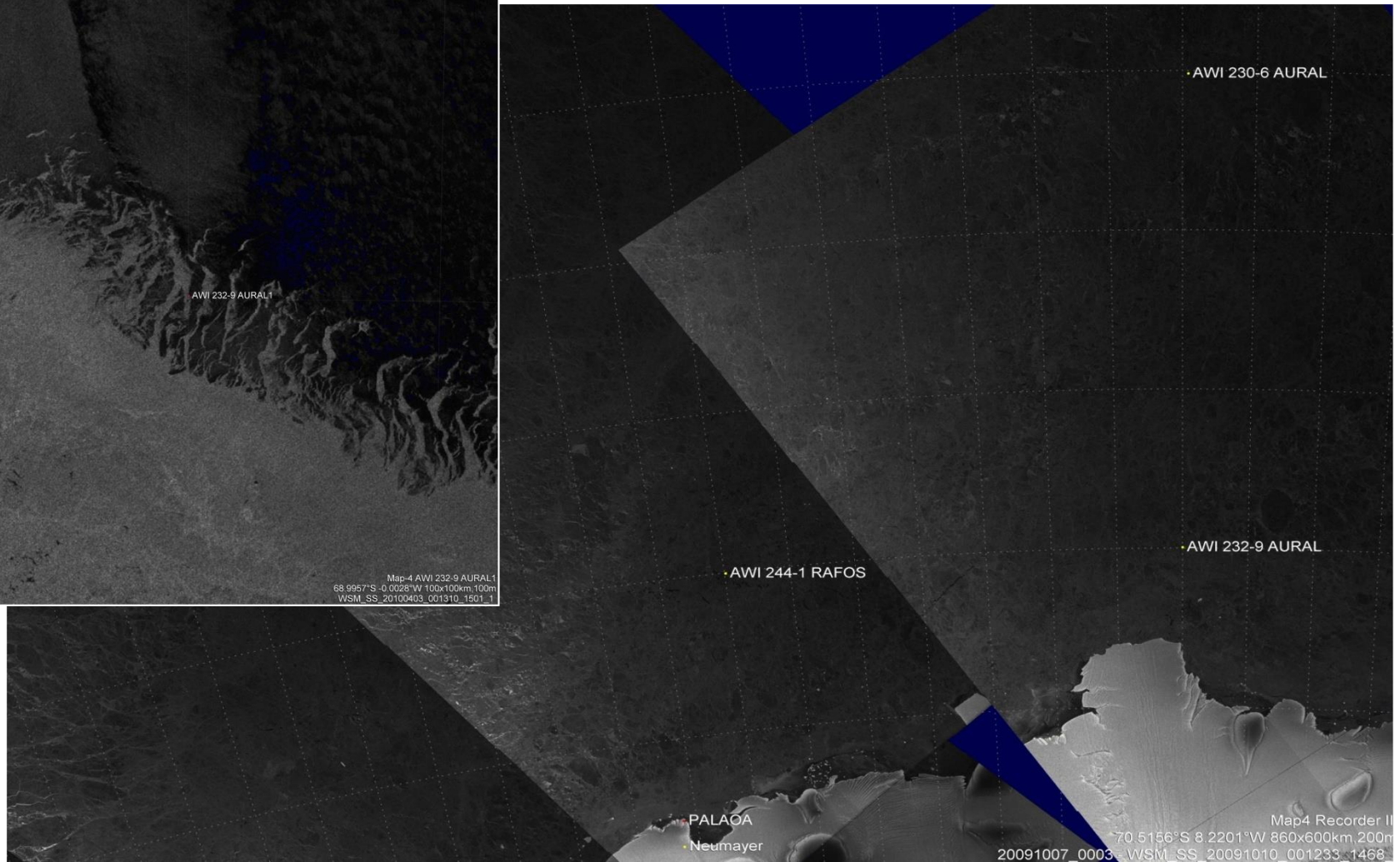
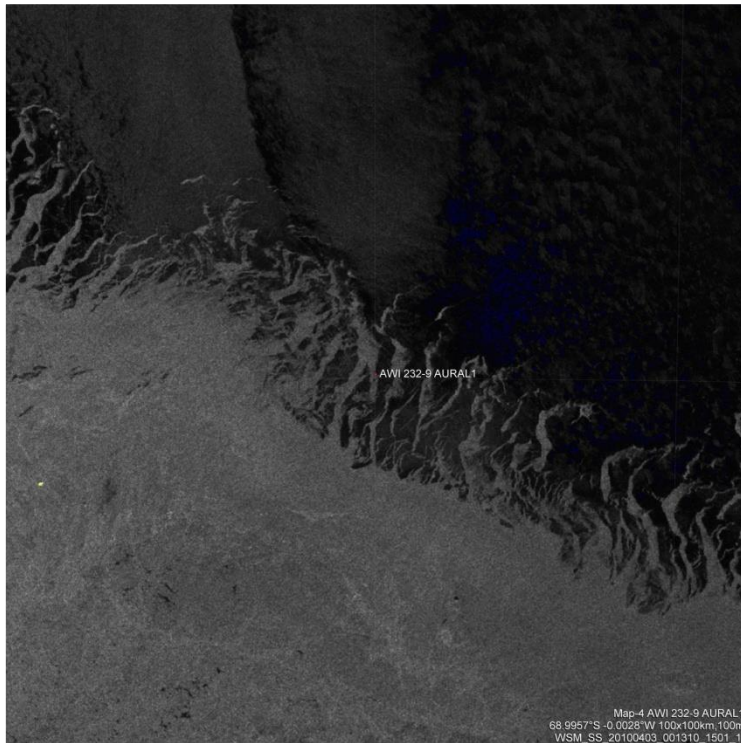


Minke Whales

	Year(s) to which estimate applies	'Best' estimate	Approximate 95% CI
Southern Hemisphere	1985/86-1990/91	720,000	510,000 - 1,010,000
	1992/93-2003/04	515,000	360,000 – 730,000

Local ice situation from ASAR

allows to compare call densities / animal presence between open water and ice cover



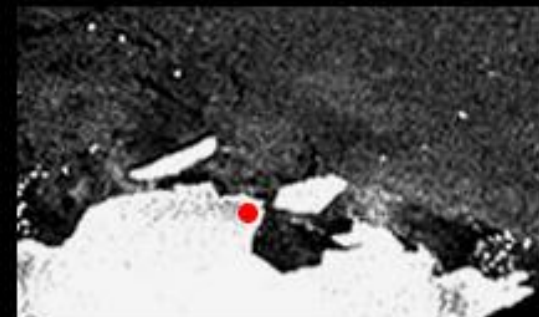
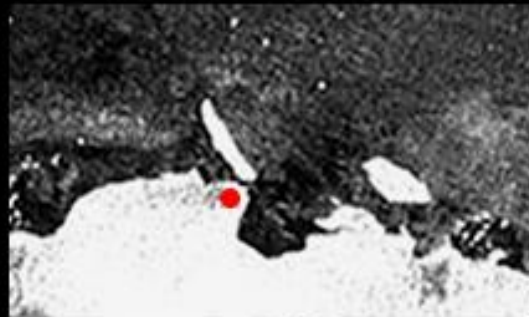
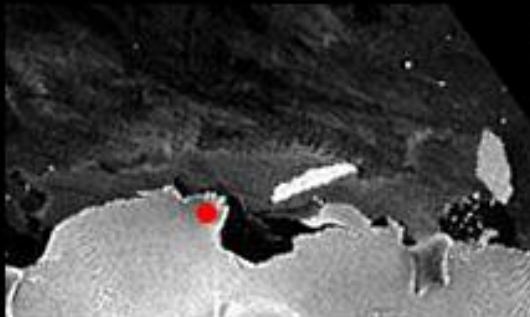
Typical iceberg sound



16.07.2007 - 08:05

19.07.2007 - 08:10

22.07.2007 - 08:15



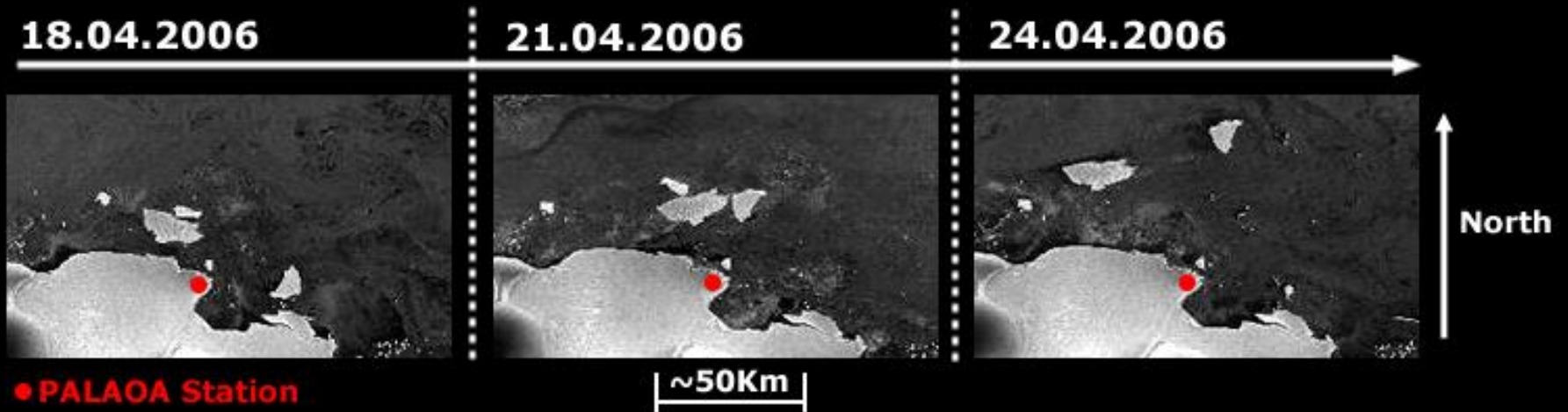
North

● PALAOA Station

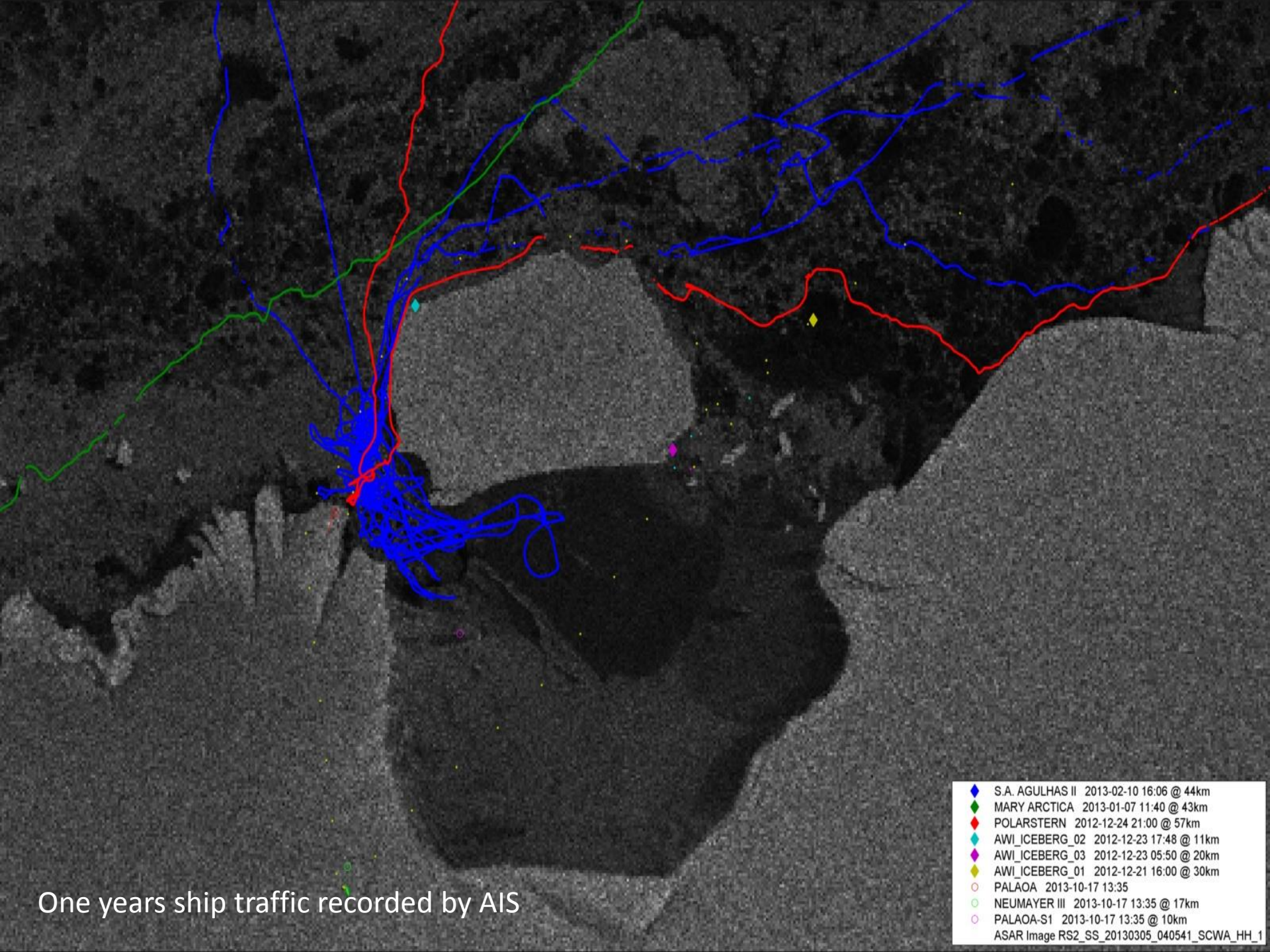
~50Km



Collisions of Icebergs



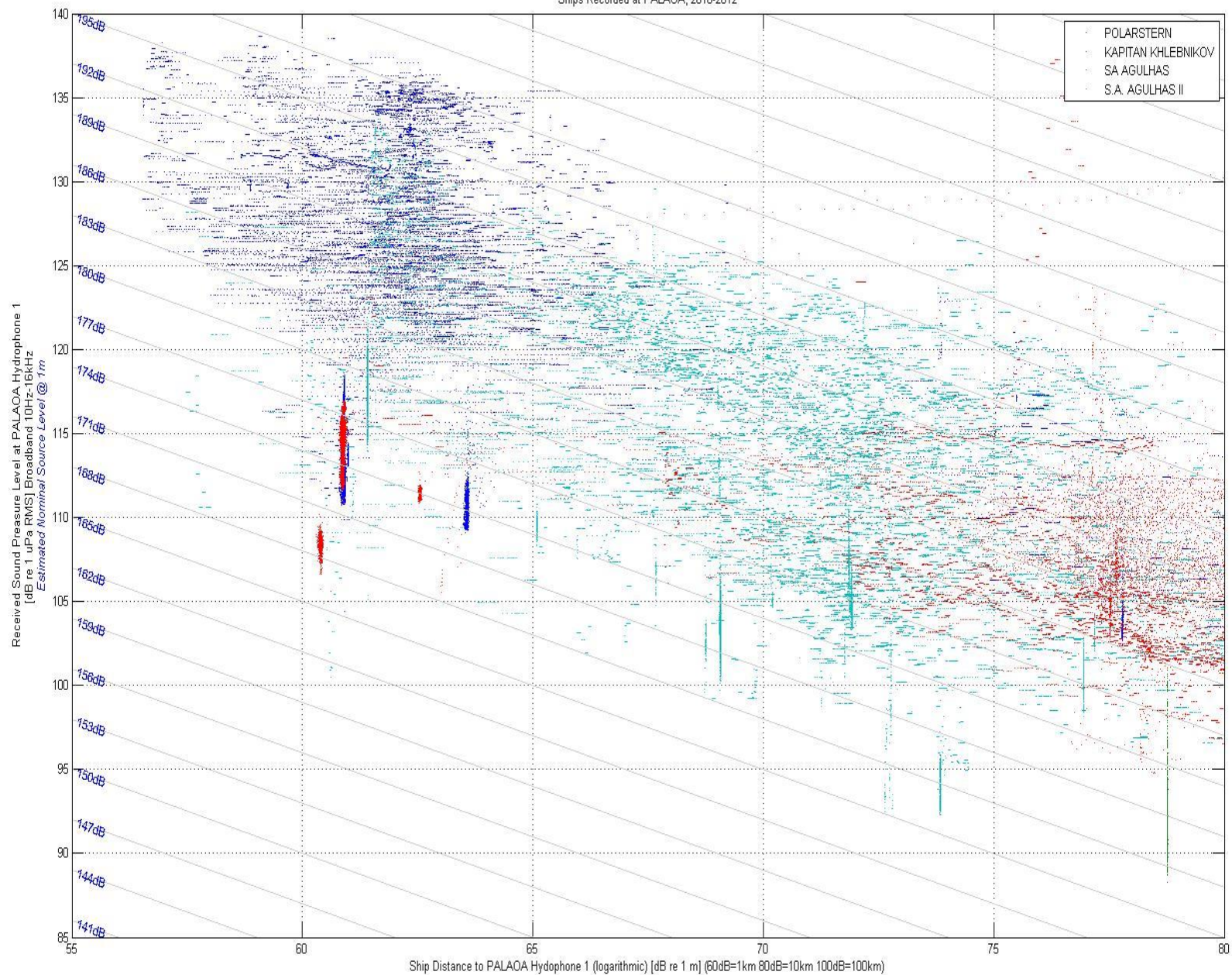
- > 205 dB SPL received level
- ~ 230 dB SPL estimated source level
- ~ 10 min duration



PALAOA



Ships Recorded at PALAOA, 2010-2012





Unknown sounds in the recordings



Open Access Data: www.awi.de/PALAOA

