Detecting the structural variability of cetacean tonal sounds by automatic detection and classification algorithms

Tzu-Hao Lin[1*], Hsin-Yi Yu[1], Chi-Fang Chen[2], Lien-Siang Chou[1]

[1]Institute of Ecology and Evolutionary Biology, National Taiwan University

[2]Department of Engineering Science and Ocean Engineering, National Taiwan University

生態學與演化生物學研究所

Institute of Ecology and Evolutionary Biology, NTU

ECOLOGY & EVOLUTIONARY BIOLOGY

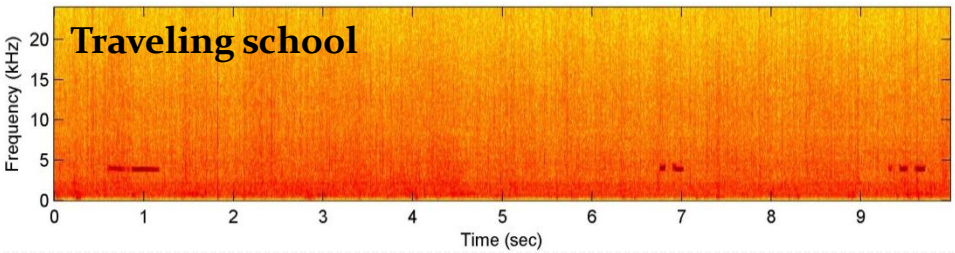
Difficulty in cetacean monitoring

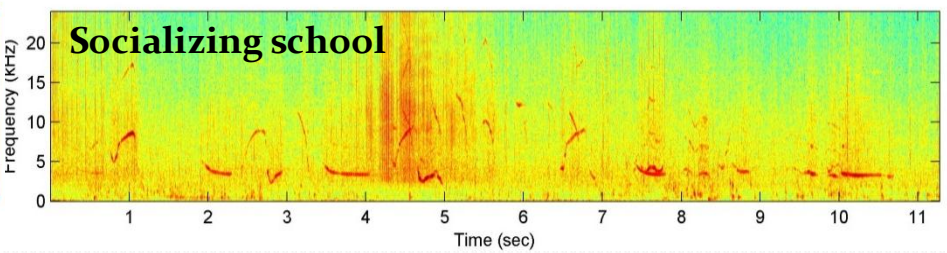
- Habitat utilization of cetaceans
  - **Temporal variation of occurrence and behavior**

- Disadvantage of traditional visual observation
  - Low visibility during nighttime and severe weathers
  - Underwater behavior is not observable

Passive acoustic monitoring

- Marine observatory with acoustic sensors
  - Provide information on the cetacean occurrence and behavior

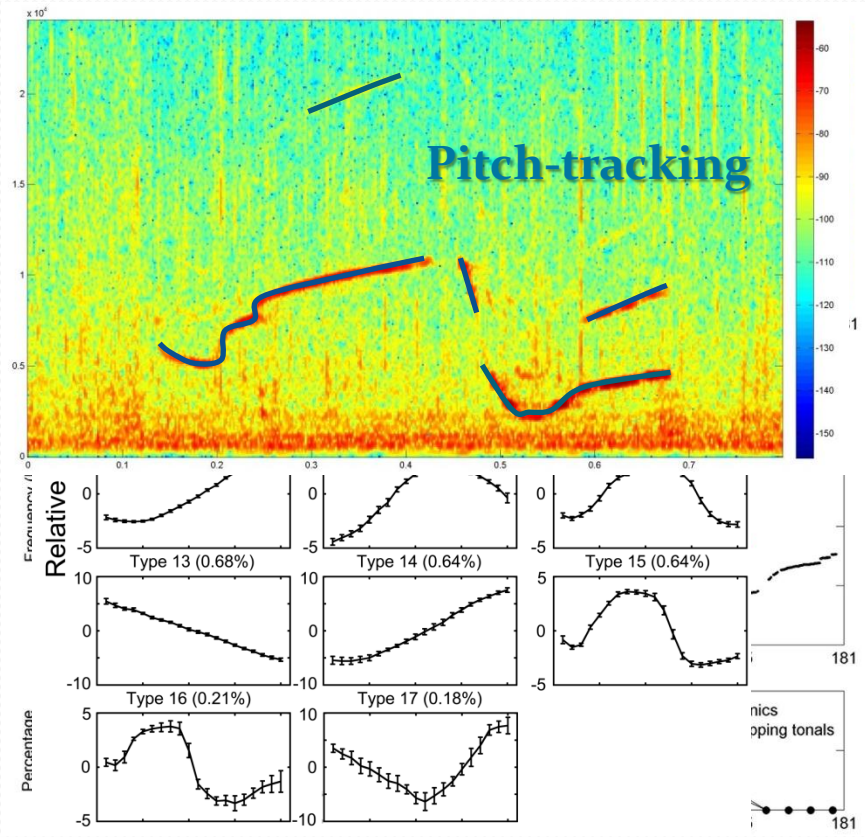




- Cetacean tonal sounds are complex, what's the best solution to examine tonal sound usage?

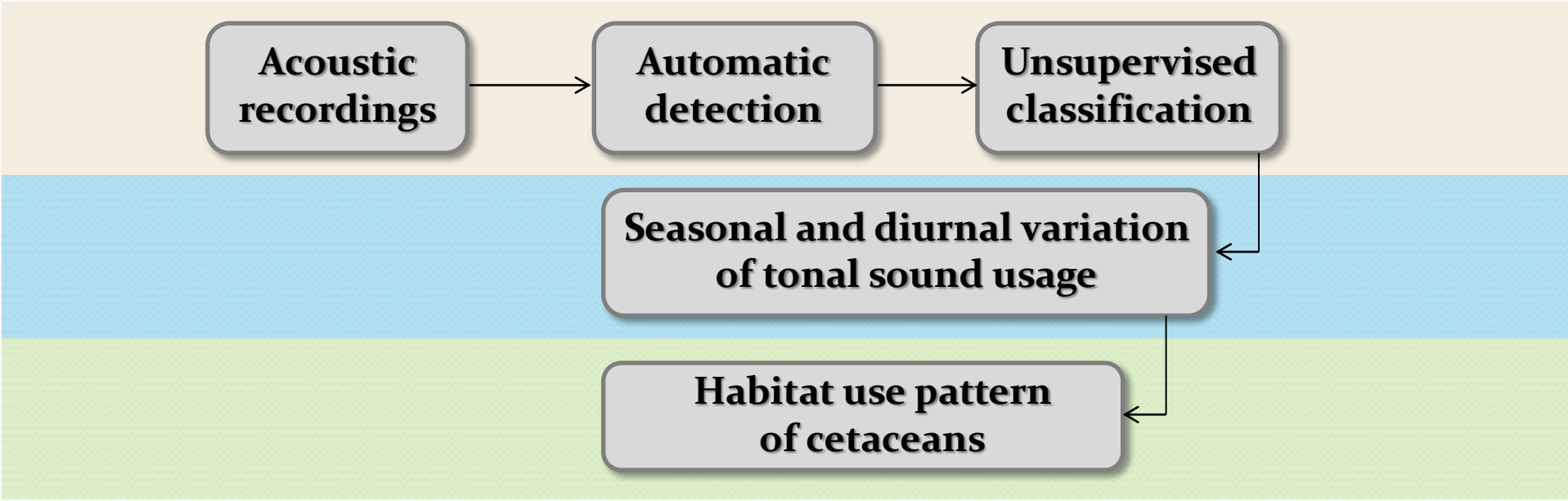
Automatic detection and classification

- Pitch-tracking detector
  (Roch et al. 2011; Mellinger et al. 2011)
  - **Individual contour**
- Unsupervised classification
  (McCowan 1995; Seekings et al. 2010)
  - **Whistle repertoire**
- Local-max detector
  (Zimmer 2011; Lin et al. 2013)
  - **Frequency distribution**
  - **Presence of harmonics & overlapping calls**



Objectives

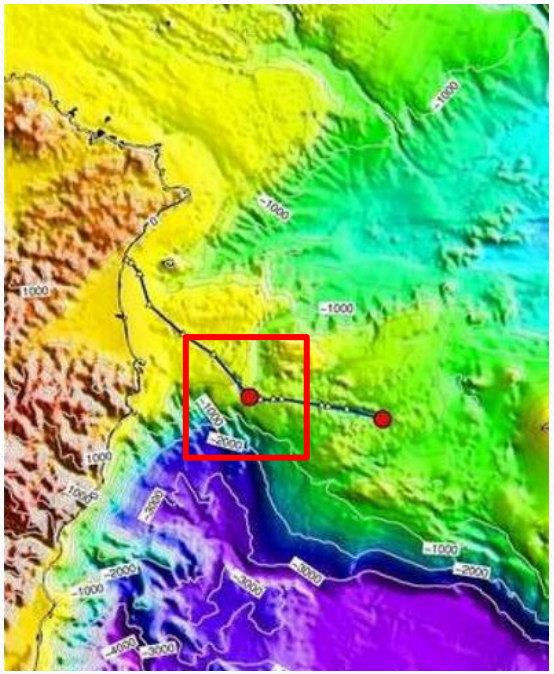
- To examine the **temporal changing pattern of cetacean vocal behavior** from a marine observatory (MACHO)
  - Burst-pulse and whistle

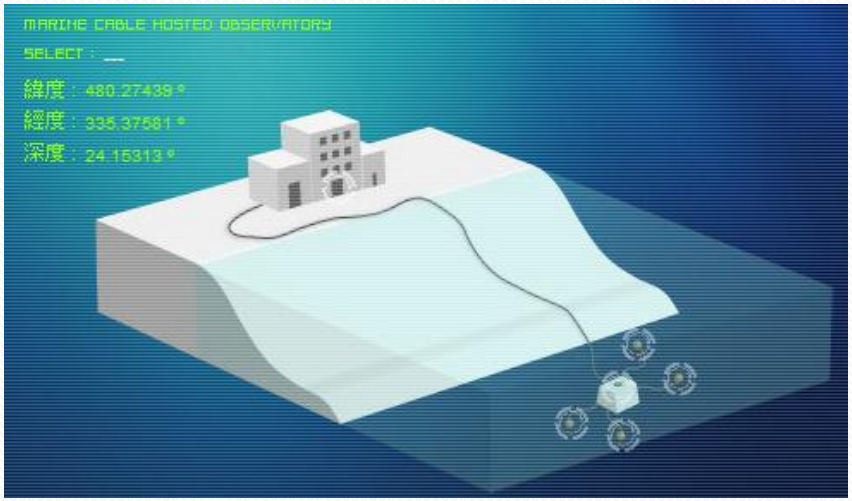


Data collection

MArine Cable Hosted Observatory (MACHO)

- Long-term marine observatory
  - Bottom mounted hydrophone
  - Local water depth: 277 m
  - Sampling rate: 384 kHz

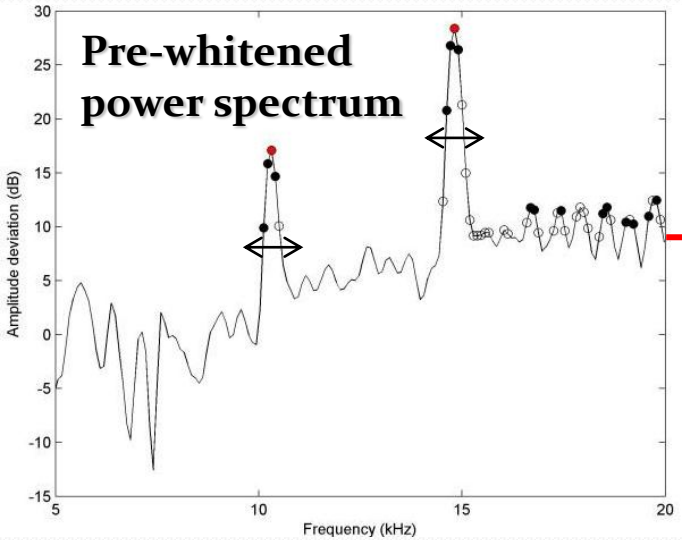




Acoustic data processing

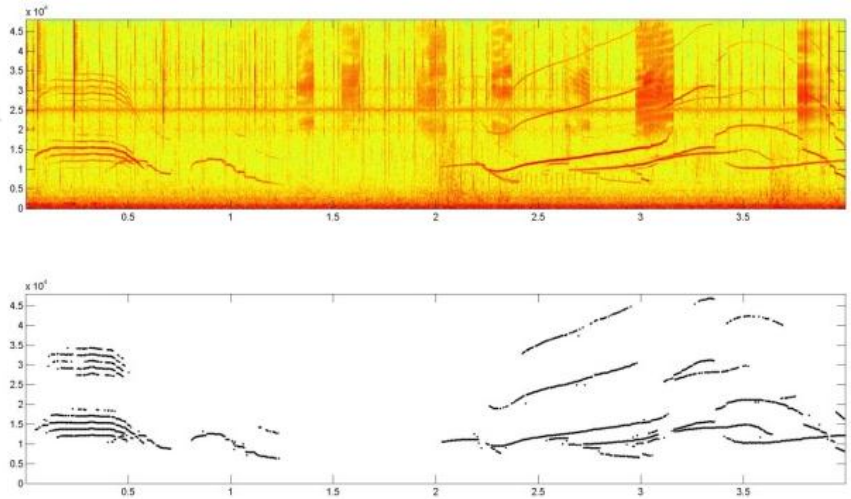
Local-max detector

- Adopted frequency (AF)
  - Local maximum along the frequency axis (Zimmer 2012)
  - Instantaneous frequency bandwidth (Lin et al. 2013)



Spectrogram

Detection result

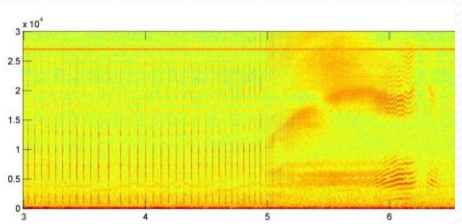


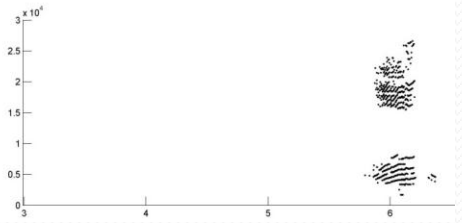
Separation of burst-pulses and harmonics

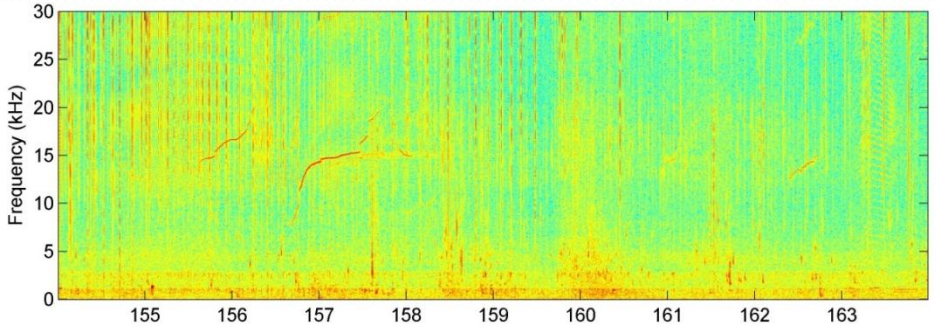
- Burst-pulse
  - Tonal appearance & pulsed structure
  - Density of adopted frequencies

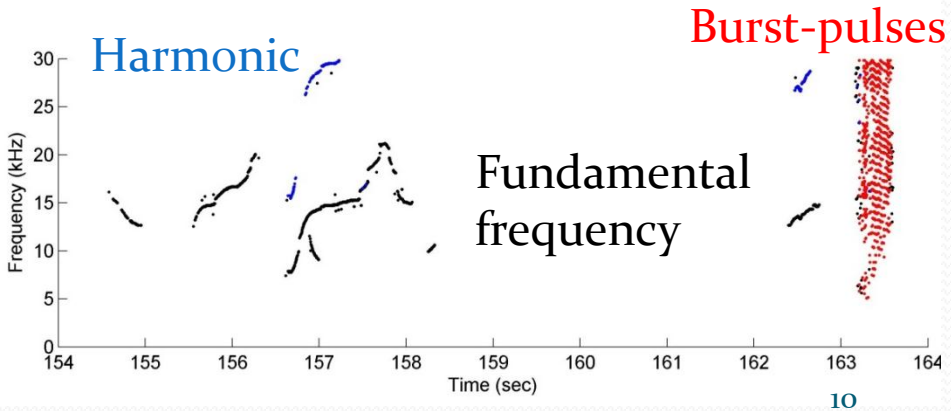
$$\frac{N_{AF}}{N_F N_T}$$

- Harmonic
  - The positive integral multiple of any adopted frequency









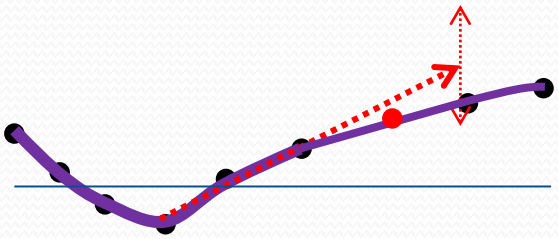
Unsupervised tonal sound classification

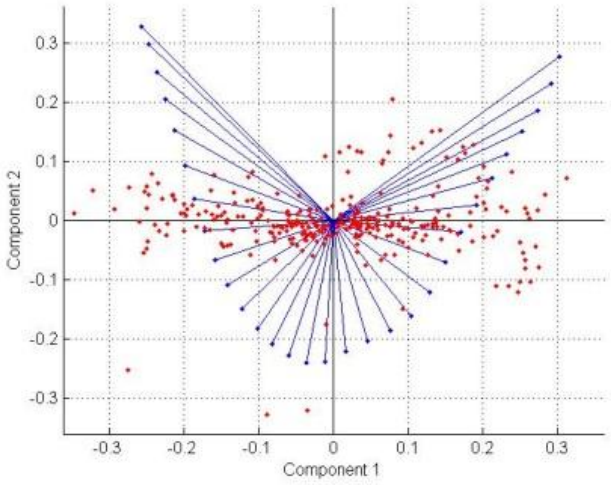
Pitch-tracking
- Extract individual contour from AFs

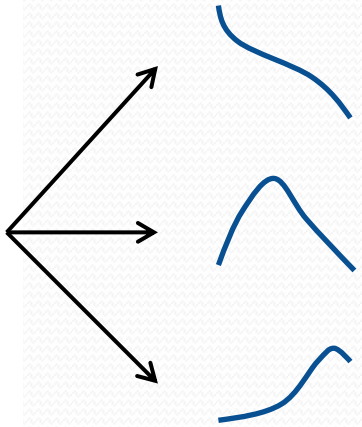
Feature extraction
- 20 frequency points
- Standardize by mean F

PCA
- Reducing feature vectors

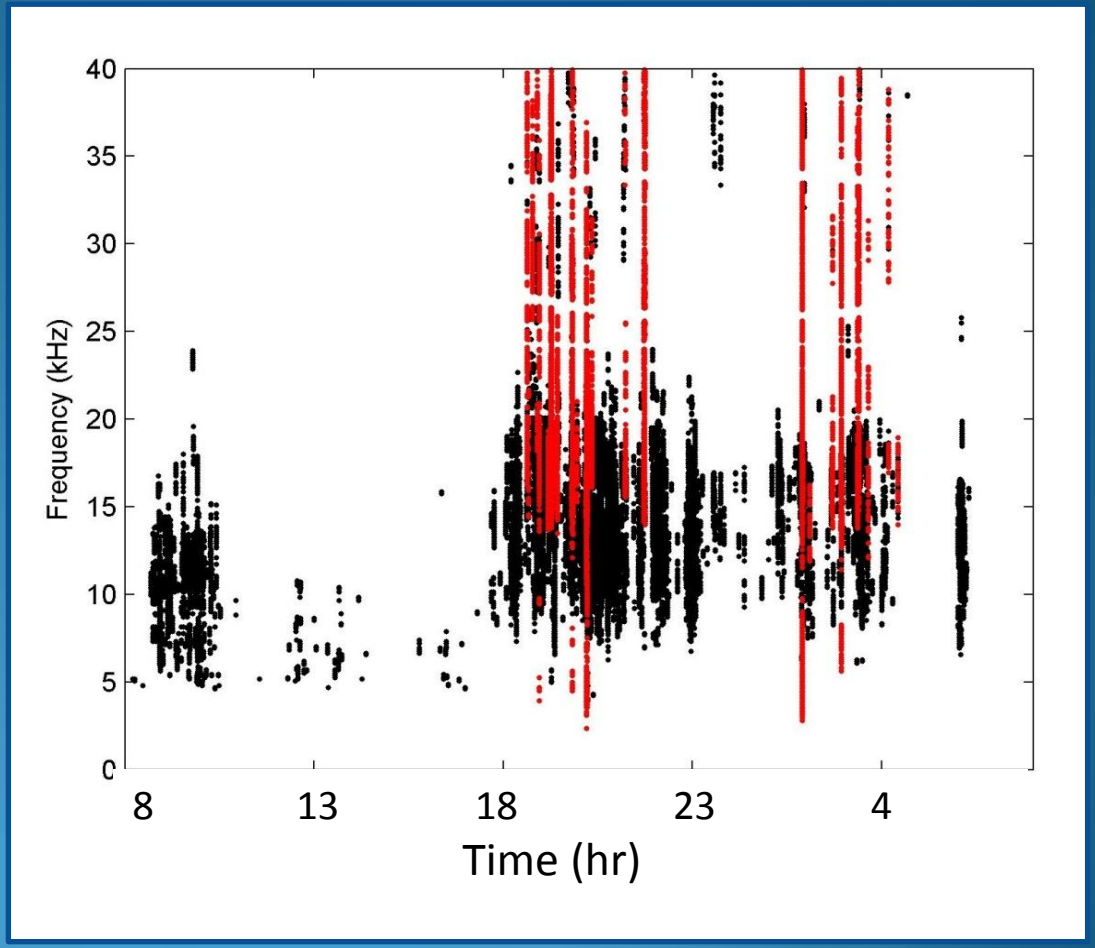
K-means clustering
- Number of clusters explain 99% variance





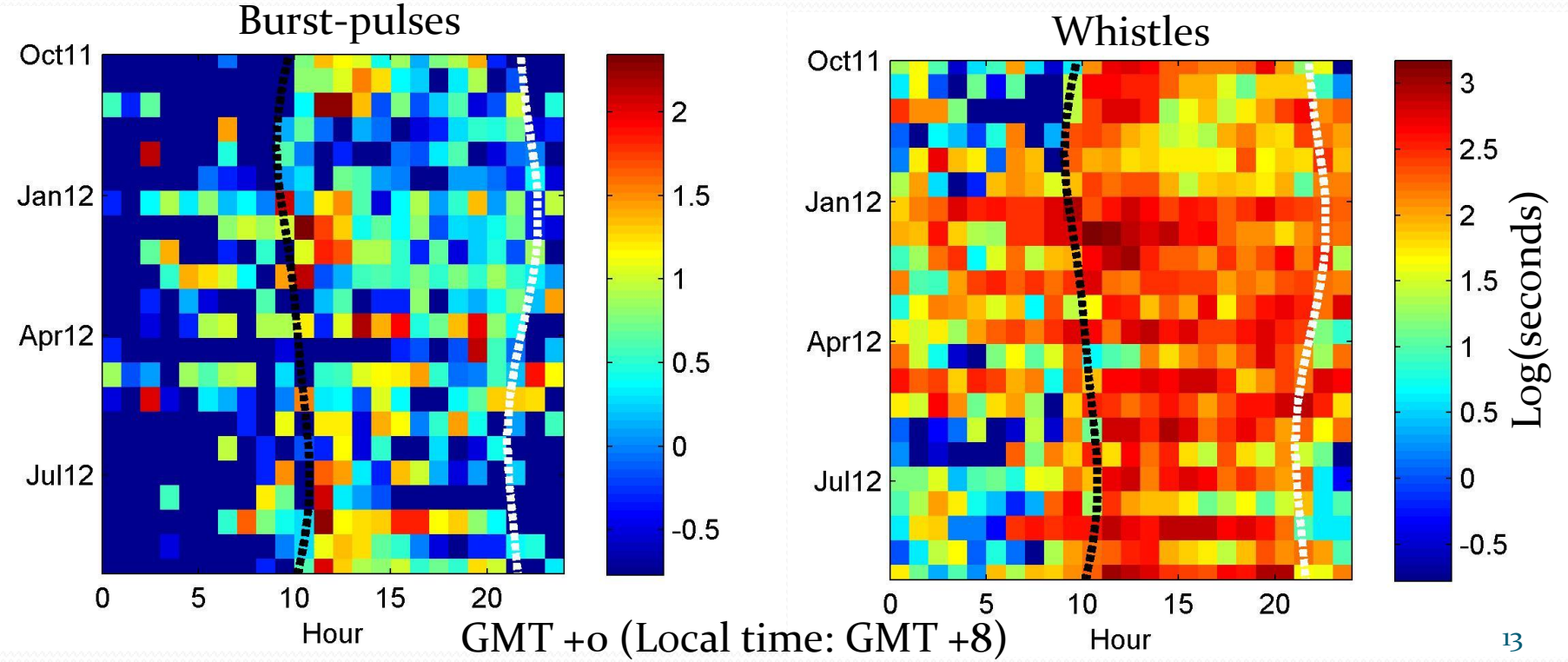


Results



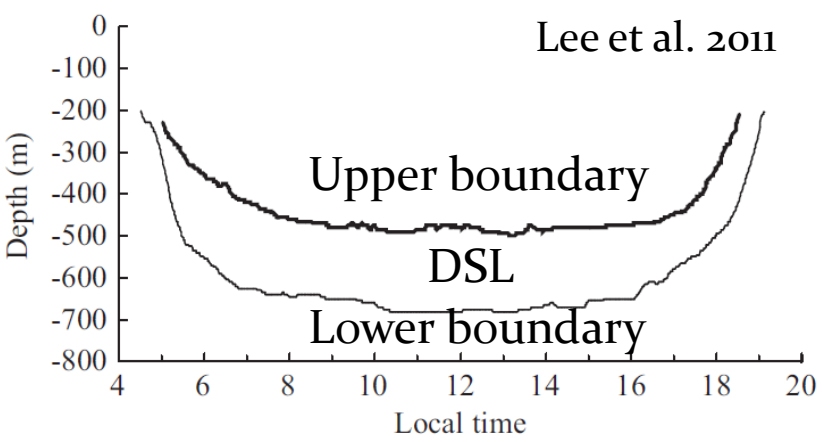
Detection results

- 2011.10.1-2012.9.30: Day 1-6, 16-21 for each month
  - Generalized linear model:
    significant seasonal, diurnal change and interaction



Diurnal variation of cetacean habitat use

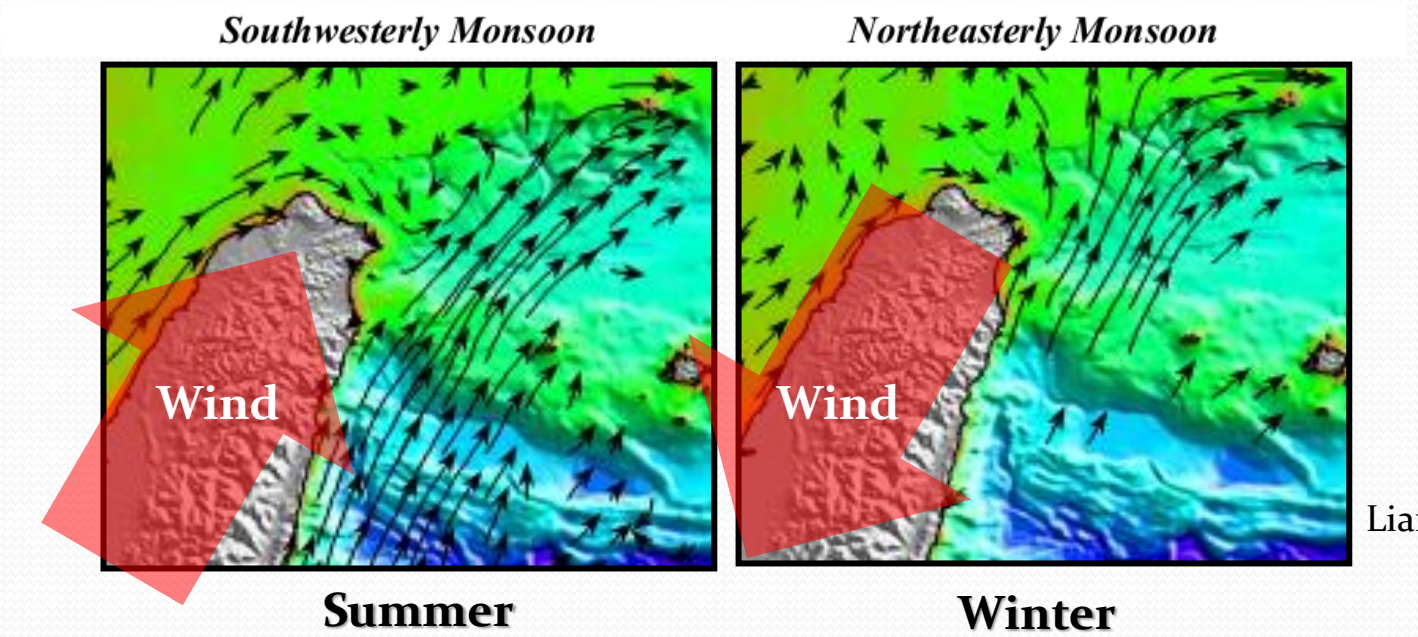
- Odontocetes primarily feed during nighttime
  - Diurnal movement of DSL



- Behavioral change within the diurnal cycle
  - More overlapping calls → Higher group size during nighttime
  - Complex whistle sequence → More social behavior in the afternoon
    - Supported by the preliminary data based on the visual observations

Seasonal variation of cetacean habitat use

- Different species in different seasons
  - Lower AF → **Larger odontocetes during winter-spring**
    Higher AF → **Smaller odontocetes during summer-fall**
- Seasonal change of Kuroshio
  - Upwelling during NE monsoon



Liang et al. 2003

Conclusions

- The structural usage of cetacean tonal sounds can be effectively examined through the automatic detection and classification platform and the multivariate analysis

- Different seasons and daylight periods showed varied composition in species and behaviors
  - Required acoustical database for species recognition and behavioral interpretation
  - Preliminary information on the habitat use pattern of local cetaceans

Acknowledgement

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