# The Ocean Soundscape Atlas (introduction and maps)

**Pierre Mercure-Boissonnault & Édouard Philippe**
**Université du Québec à Rimouski**

# Context

- The shipping density and ship sizes have increased over the years
  - It adds loads of underwater noise pollution
- Oceanographers suspect that it may contribute to the decline of the endangered marine mammals in Canada (targeted by the Canada's Oceans Protection Plan)
  - North Atlantic Right Whale (NARW)
  - St. Lawrence Estuary Beluga (SLEB)
  - Southern Resident Killer Whale (SRKW)
- Researchers are modeling acoustical maps to verify that hypothesis. However they face some issues:
  - The datasets are huge and difficult to share with other collaborators
  - The datasets are highly multi-dimensional and cannot be put on typical web platforms (such as SLGO).

# The Ocean Soundscape Atlas

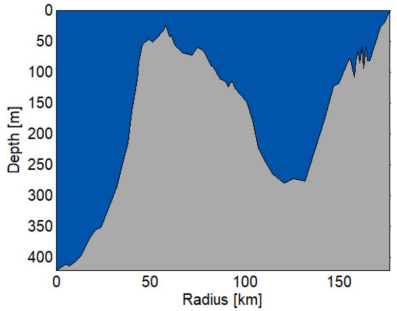
- Web application about underwater acoustic data
  - Browse, visualize and analyze the 3D +T +F data
  - Assessing the effects of noise on marine species
  - Raise the general level of knowledge about underwater acoustics
- Target audience
  - Oceanographers and biologists
  - Decision makers
  - General public
- The Ocean Soundscape Atlas team is made of experts to help optimizing data-production, -management, -quality control and -diffusion.

# What is the ocean soundscape?

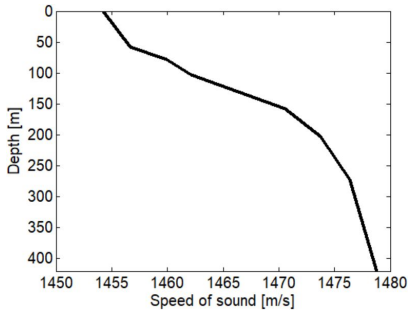
- Anthropophony
  - Shipping
  - Fixed sources : offshore oil platforms, ports, construction sites, etc.
  - Others : sonars, dredging, geophysical surveys, etc.
- Geophony
  - Wind
  - Waves
  - Rain
  - Sea Ice
  - Earthquakes
- Biophony
  - Communication calls
  - Echolocation
  - Other sounds

# Acoustic models - What they do

**Bathymetry profile**




**Water column profiles**

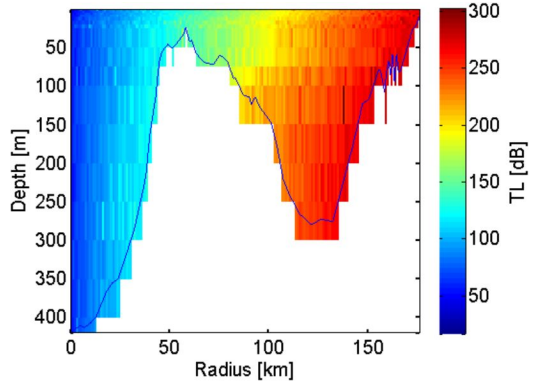



**Bottom properties**

**Model parameters**

**Model**

**Transmission Loss (TL)**




**(RL = SL - TL)**

# Acoustic models - Model types

| Model type | Applications | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Shallow water | | | | Deep water | | | |
| | Low frequency | | High frequency | | Low frequency | | High frequency | |
| | RI | RD | RI | RD | RI | RD | RI | RD |
| Ray theory | ○ | ○ | ◑ | ● | ◑ | ◑ | ● | ● |
| Normal mode | ● | ◑ | ● | ◑ | ● | ◑ | ◑ | ○ |
| Multipath expansion | ○ | ○ | ◑ | ◑ | ◑ | ◑ | ● | ◑ |
| Fast field | ● | ◑ | ● | ◑ | ● | ◑ | ◑ | ◑ |
| Parabolic equation | ◑ | ● | ○ | ○ | ◑ | ● | ◑ | ◑ |

Low frequency (<500 Hz)
High frequency (>500 Hz)

RI: range-independent environment
RD: range-dependent environment

● Modeling approach is both applicable (physically) and practical (computationally)

◑ Limitations in accuracy or in speed of execution

○ Neither applicable or practical

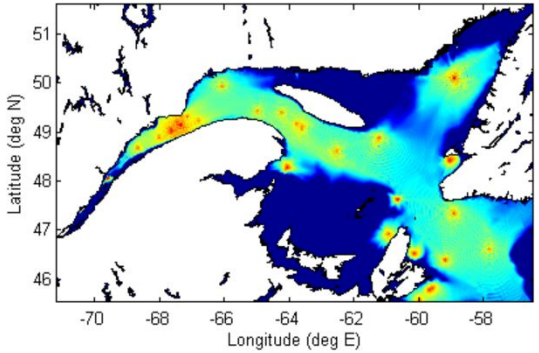
P. C. Etter, "Advanced applications for underwater acoustic modeling", Advances in Acoustics and Vibration Volume 2012 (2012).

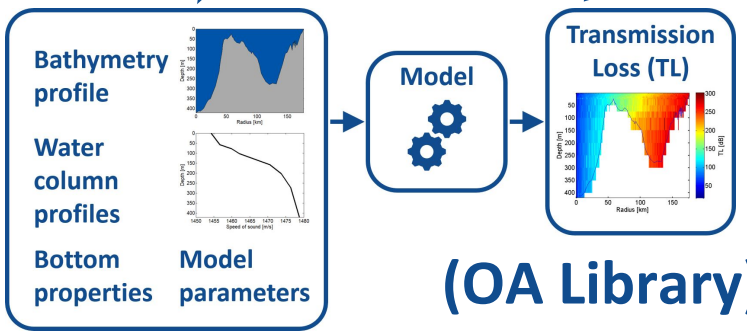
# Shipping noise maps – Ramdam

- Bathymetry map
- Temperature & salinity data
- Bottom prop. maps
- AIS data
- SL model (Simard et al. 2016)

**Ramdam (Matlab) Nx2D - 3D**
(Aulanier et al. 2016)

**Sound pressure level maps**



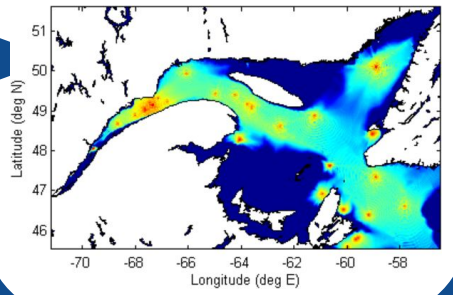




(OA Library)

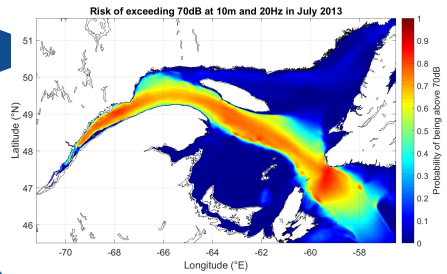
# Shipping noise maps – Ramdam

**Ramdam (Matlab) Nx2D - 3D**
(Aulanier et al. 2016)

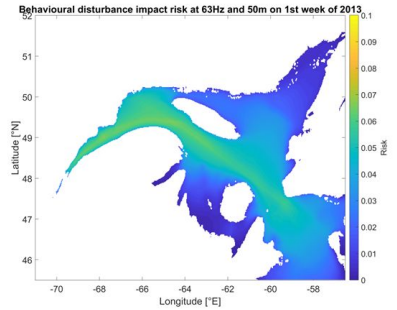
**Sound pressure level maps**




**Probabilistic maps**

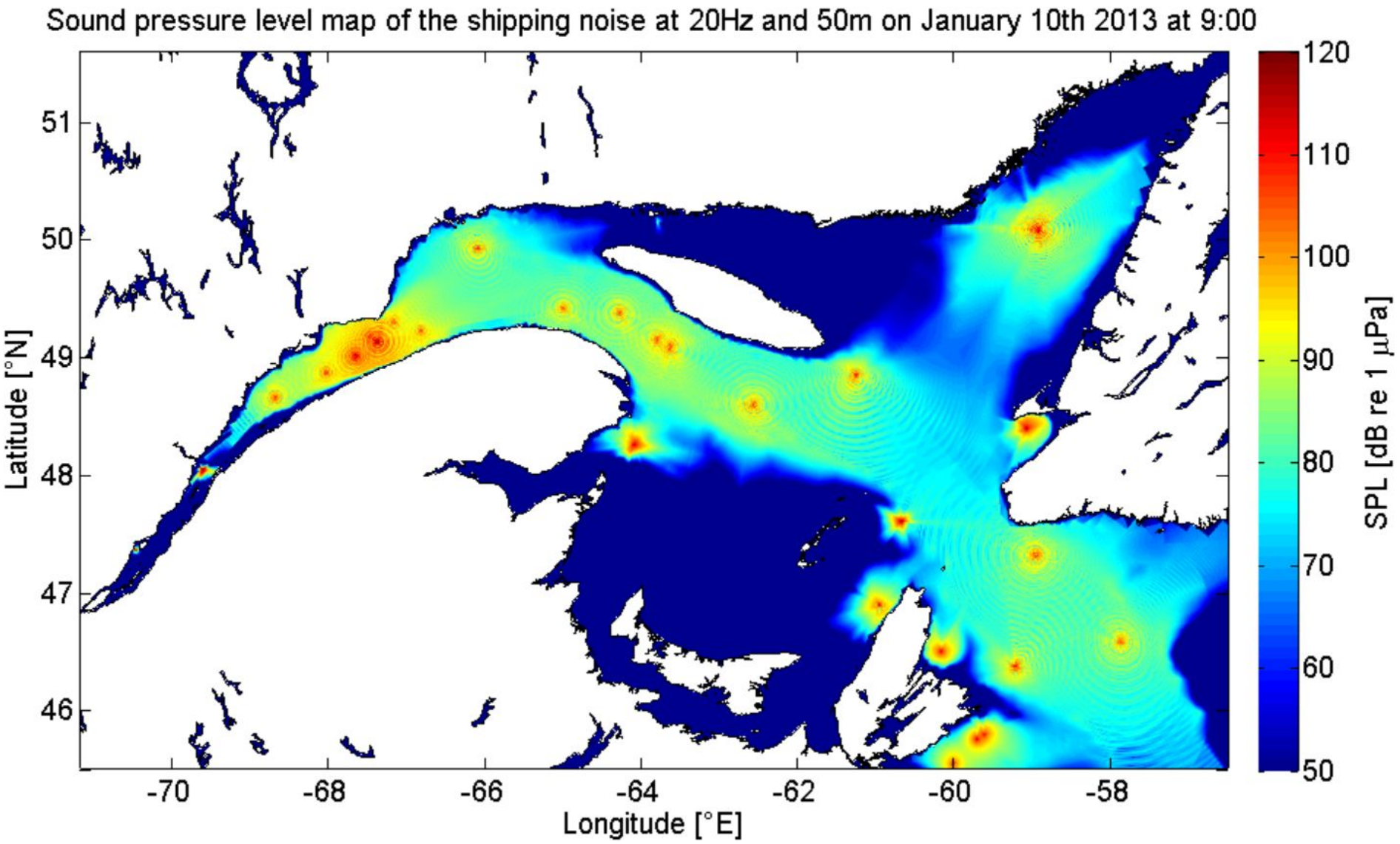



**Impact risk maps**

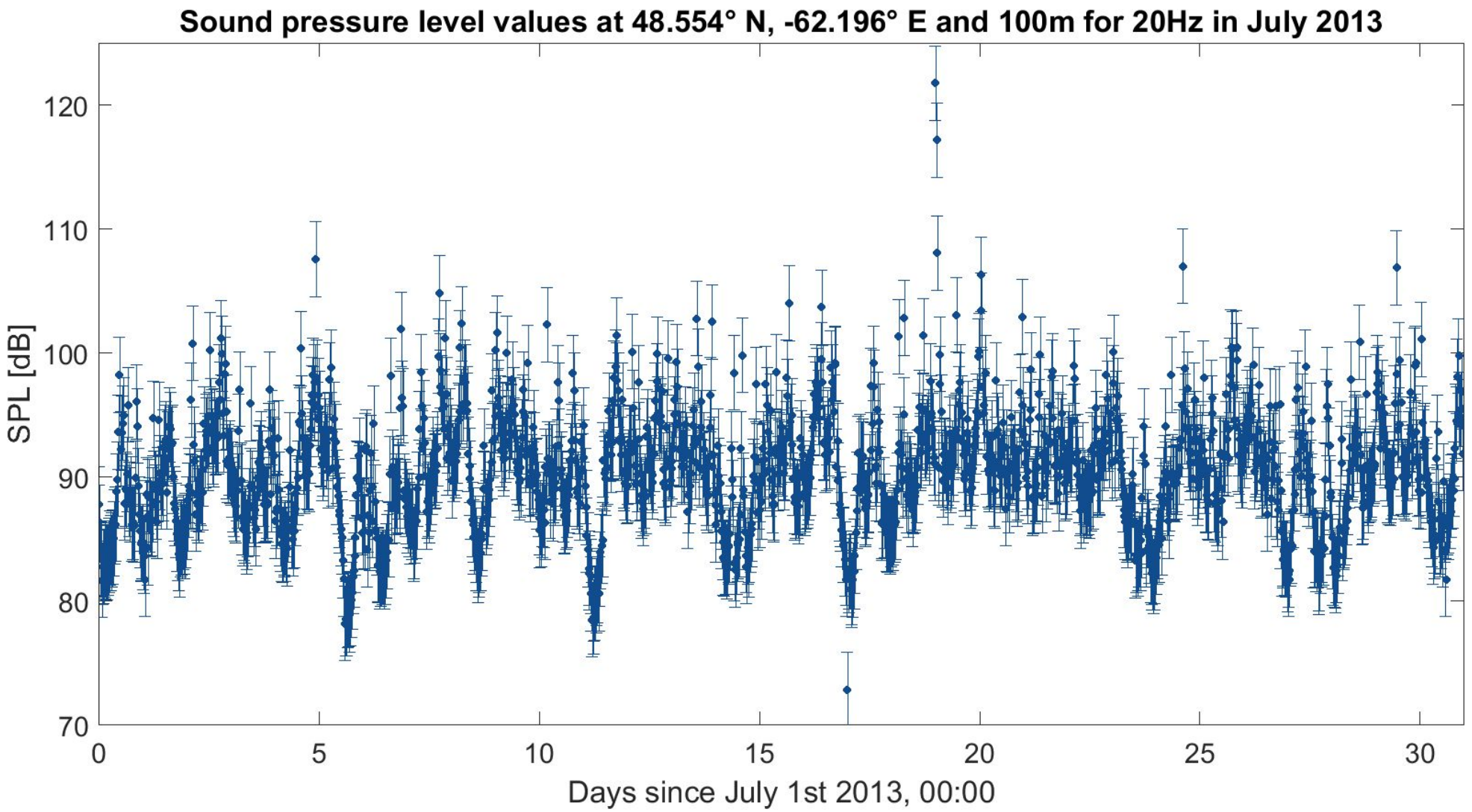



**Validation**

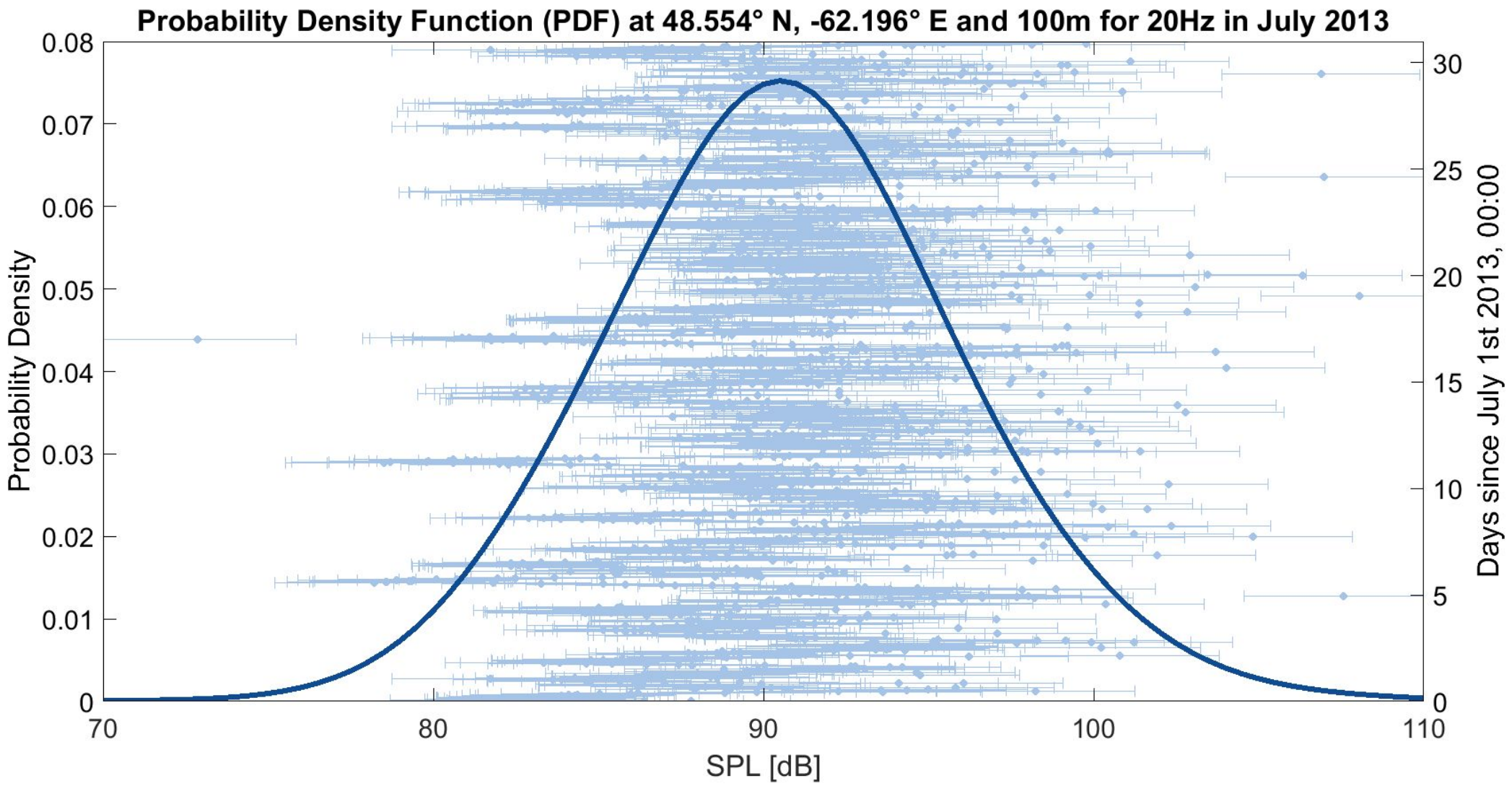
# Shipping noise maps – Timestep



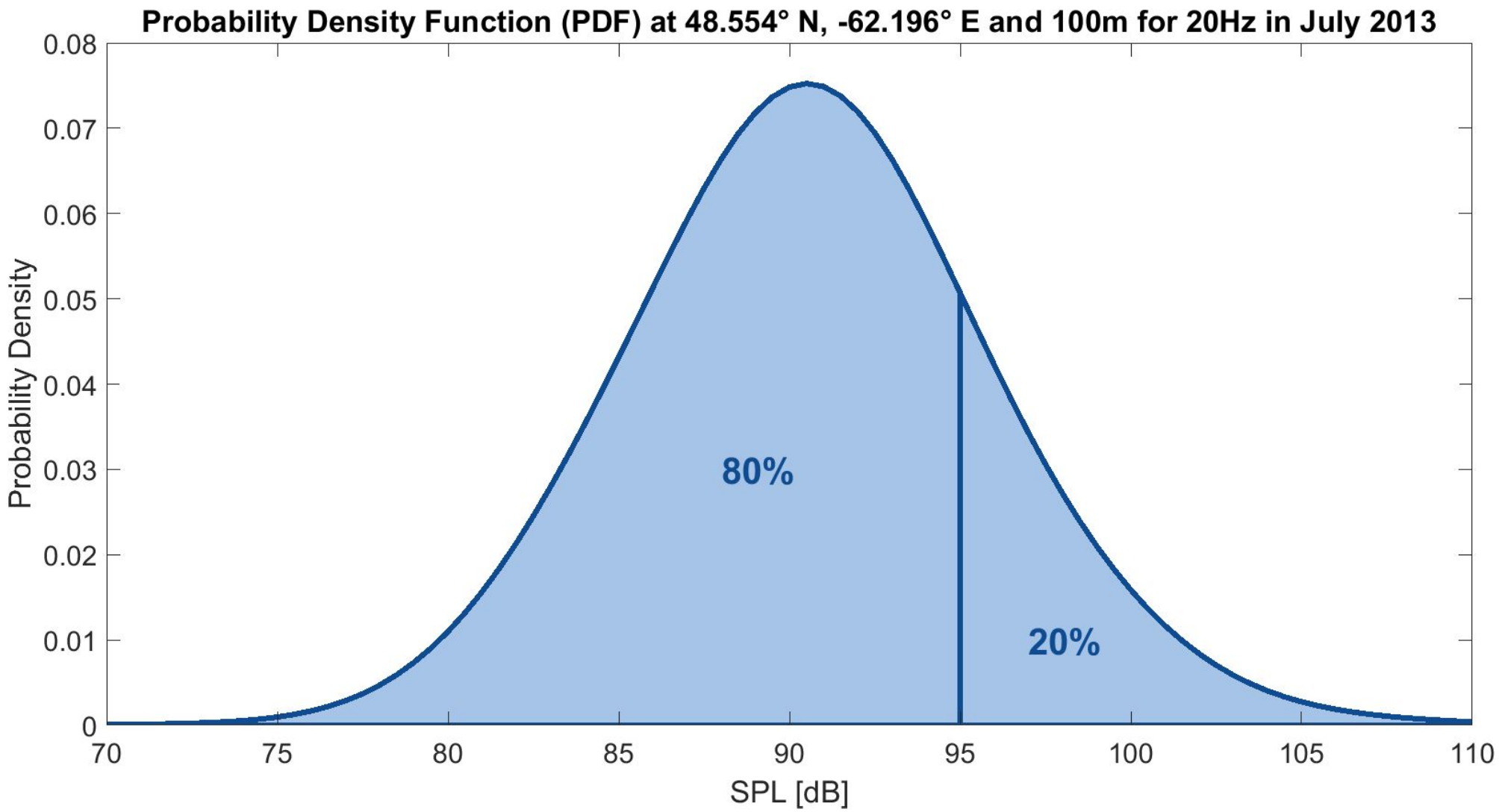
# Statistics : Variability



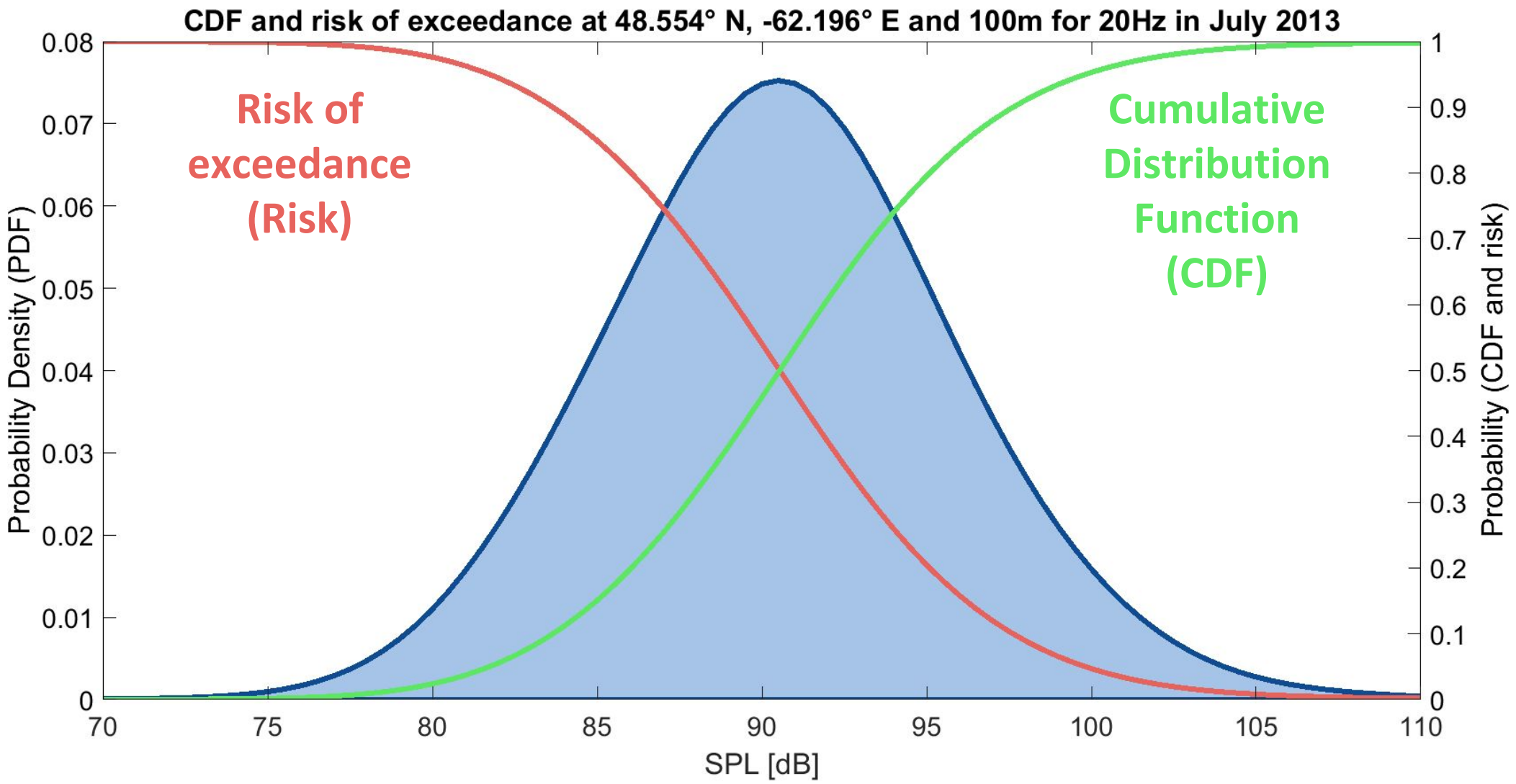
# Statistics : PDF



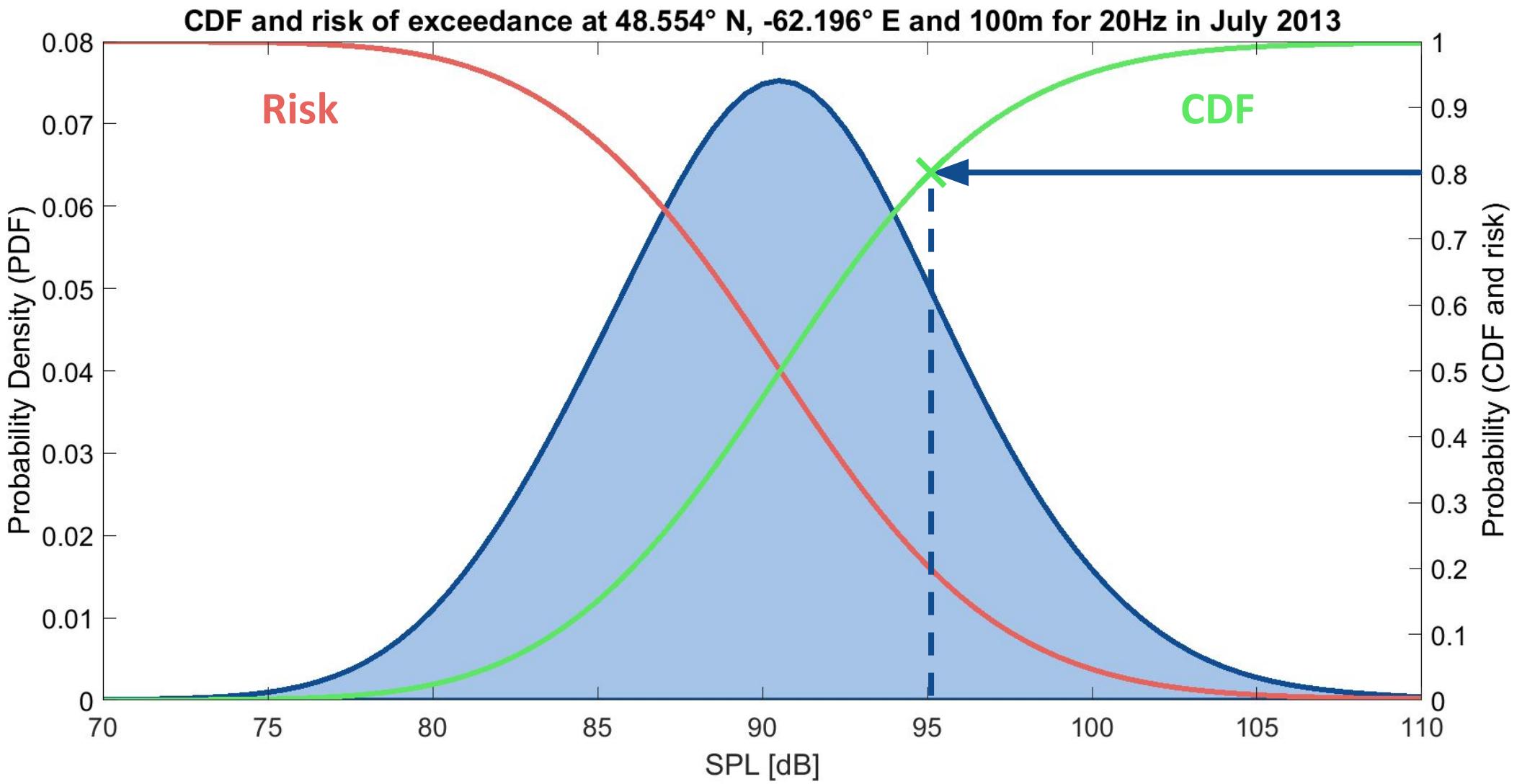
# Statistics : PDF



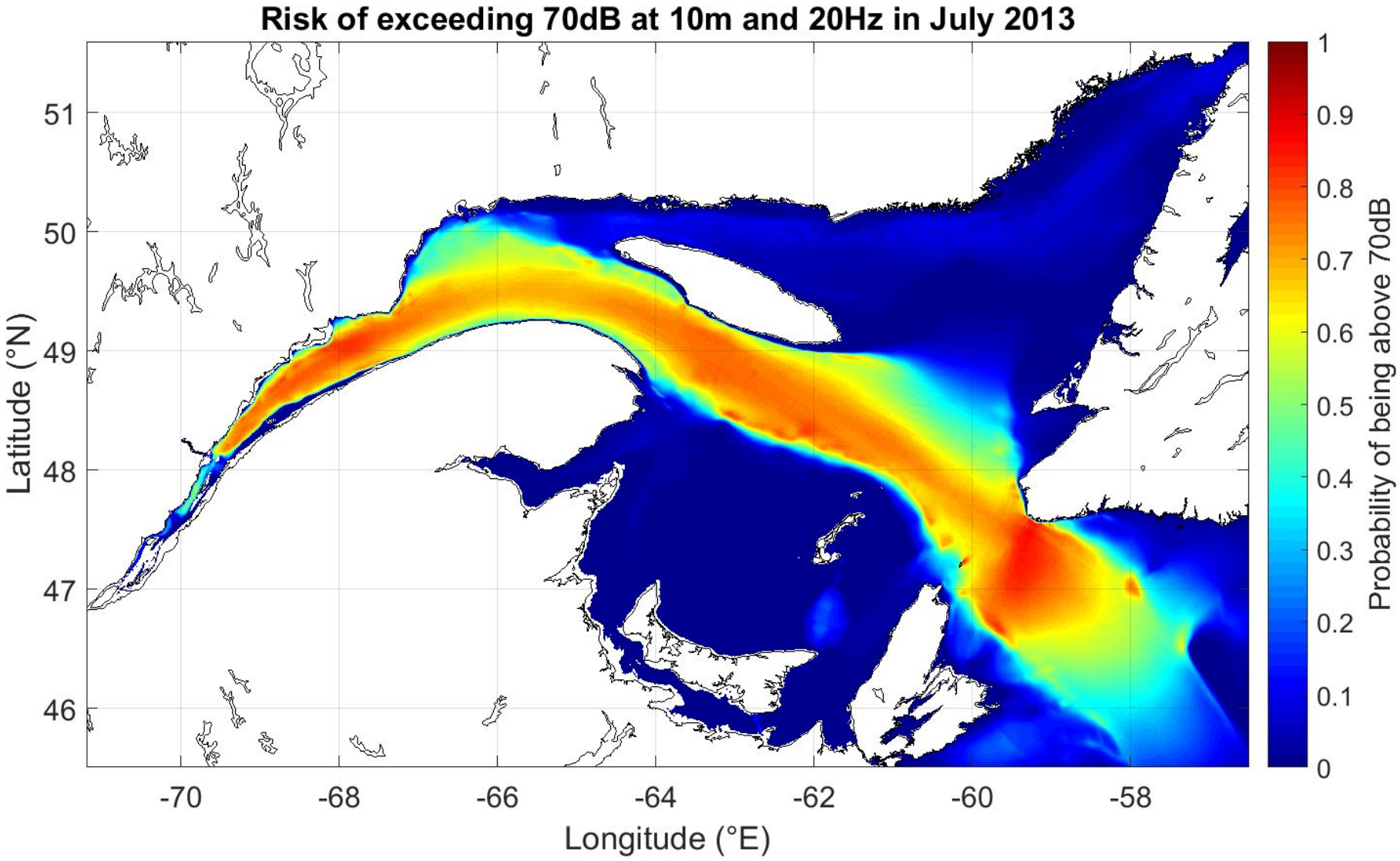
# Statistics : CDF and risk



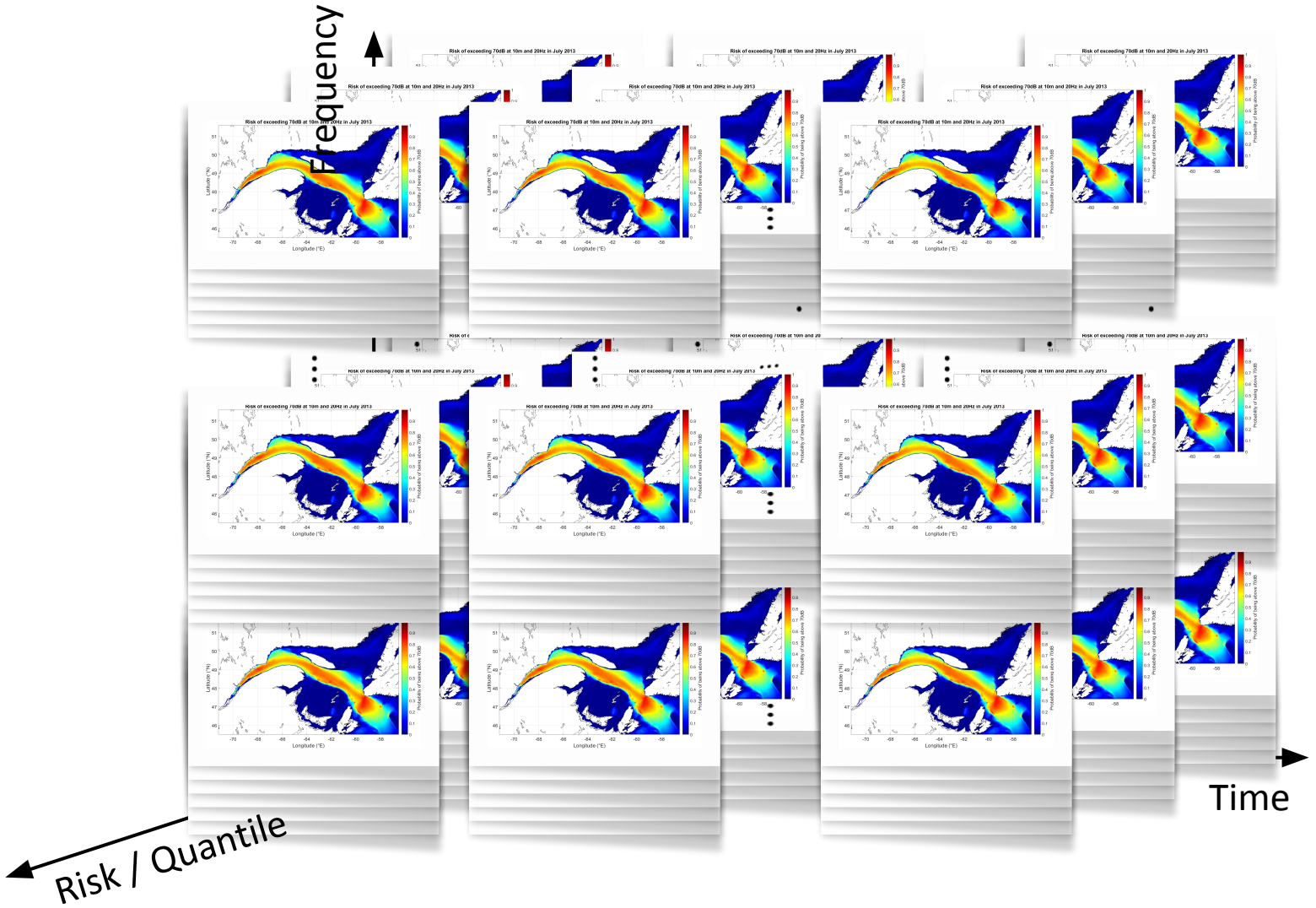
# Statistics : Quantiles using the CDF



# Risk map of shipping noise



# Dimensions and file size issues



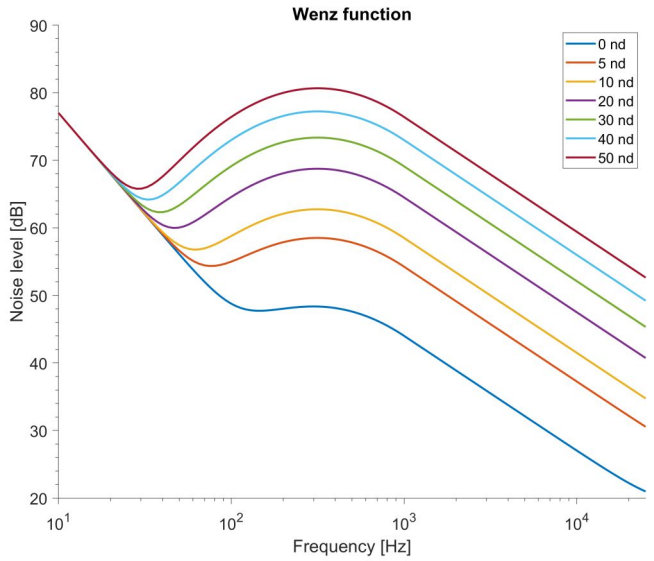

1 map (30 arcsec grid spacing)
x 21 Depths
x 365 Days
x 11 Frequencies
x 632 Risk & Quant.
≈ 50 million maps
≈ 25-30 TB
For 1 source type, 1 year and 1 region

# Geophony

**Geophony**

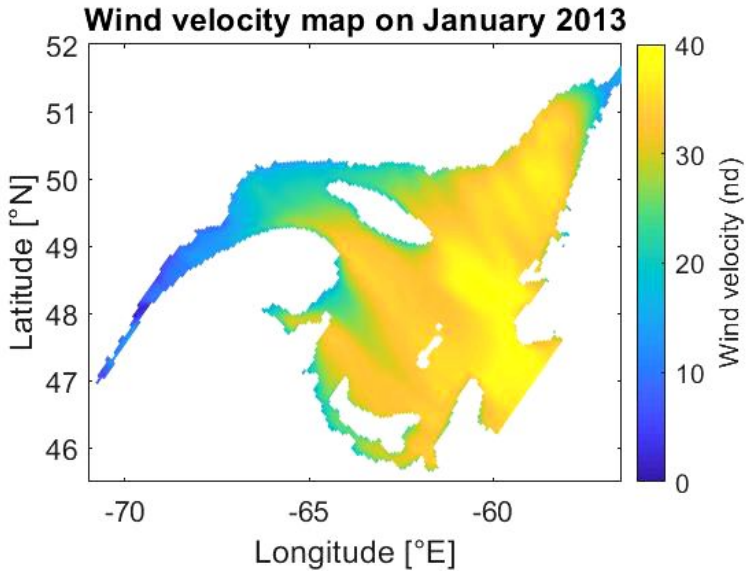
- **Wind**
- **Waves**
- ~~Rain~~
- ~~Sea Ice~~
- ~~Earthquakes~~

## Wenz (1962)

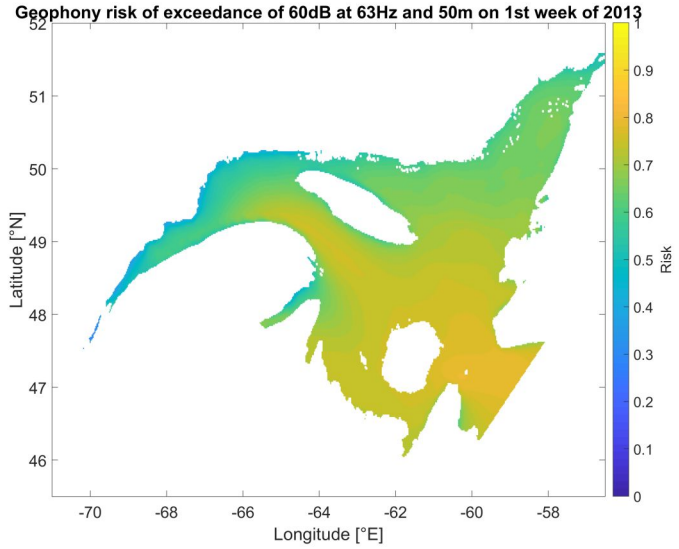



Chi-square distribution k=2

## Wind velocity

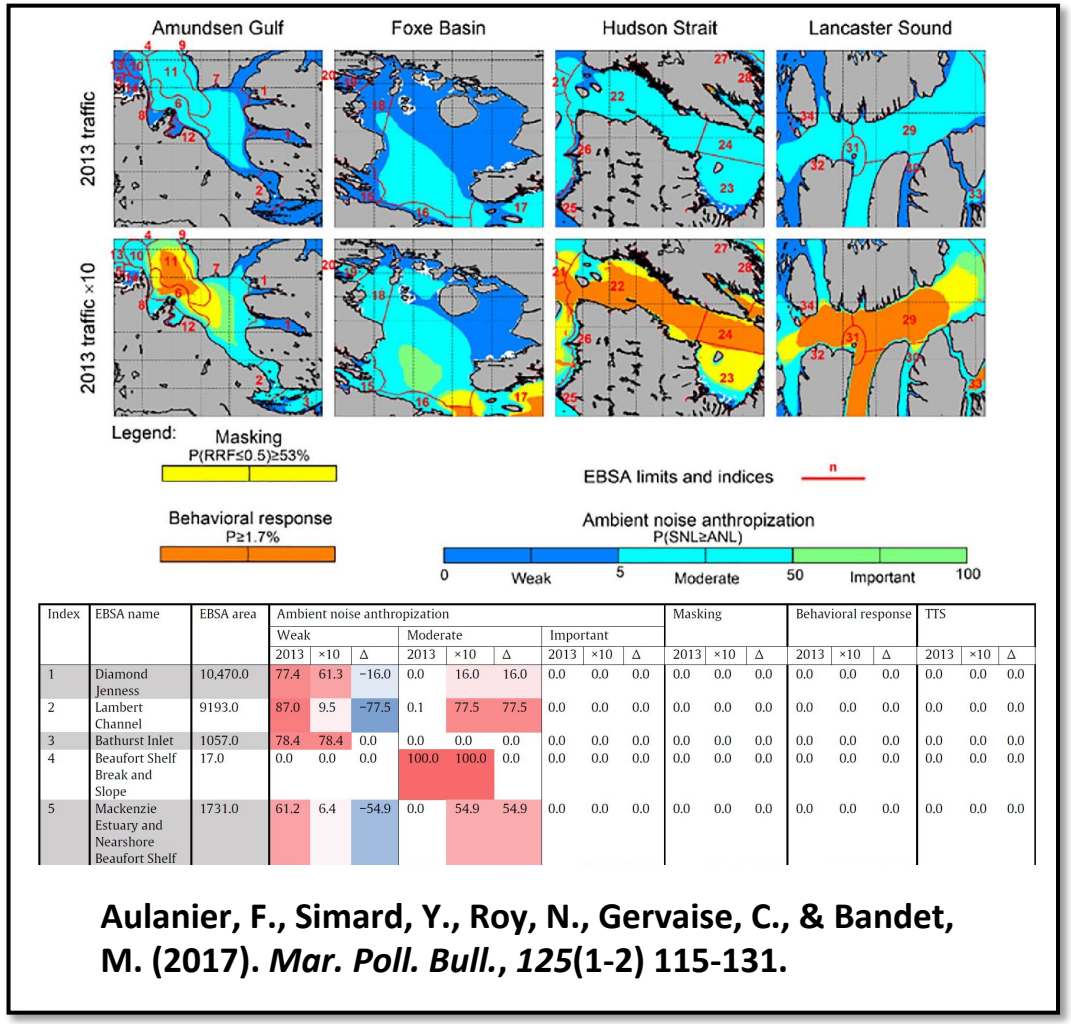



## Geophony risk of exceedance



# Risk assessment at habitat scale using various risk metrics

- Anthropization: P(shipping noise > Ambient Noise Levels) (= SN exceed.)
- Audibility: P(shipping noise > audiogram) (= SN audibility exceedance)
- Masking: P(shipping noise > comm., echolocation received signals)
- Behavioral responses: P(shipping noise elicit a behavioral response)
- Physiological responses: P(SN elicit physiological effect) PCoD
- Auditory impairments (TTS, PTS): P(shipping noise exceed TTS/PTS thresholds)




| Index | EBSA name | EBSA area | Ambient noise anthropization | | | | | | | | | Masking | | | Behavioral response | | | TTS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Weak | | | Moderate | | | Important | | | | | | | | | | | |
| | | | 2013 | ×10 | Δ | 2013 | ×10 | Δ | 2013 | ×10 | Δ | 2013 | ×10 | Δ | 2013 | ×10 | Δ | 2013 | ×10 | Δ |
| 1 | Diamond Jenness | 10,470.0 | 77.4 | 61.3 | −16.0 | 0.0 | 16.0 | 16.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | Lambert Channel | 9193.0 | 87.0 | 9.5 | −77.5 | 0.1 | 77.5 | 77.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | Bathurst Inlet | 1057.0 | 78.4 | 78.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | Beaufort Shelf Break and Slope | 17.0 | 0.0 | 0.0 | 0.0 | 100.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | Mackenzie Estuary and Nearshore Beaufort Shelf | 1731.0 | 61.2 | 6.4 | −54.9 | 0.0 | 54.9 | 54.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

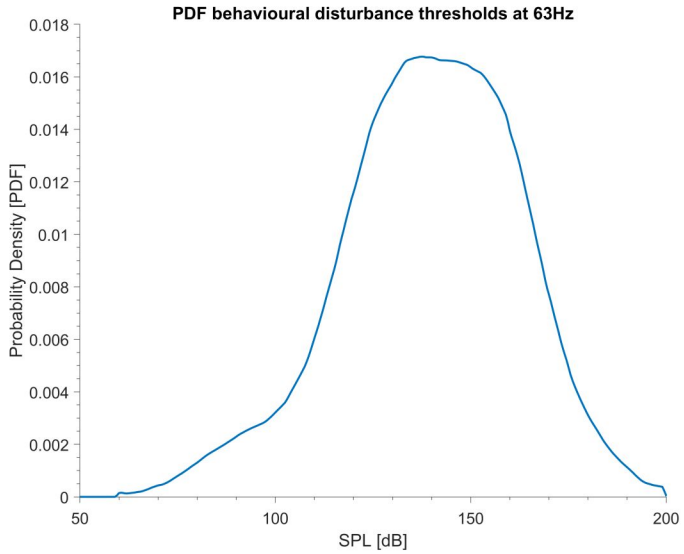
**Aulanier, F., Simard, Y., Roy, N., Gervaise, C., & Bandet, M. (2017). *Mar. Poll. Bull.*, *125*(1-2) 115-131.**

# Impact risk

**Impact risk**

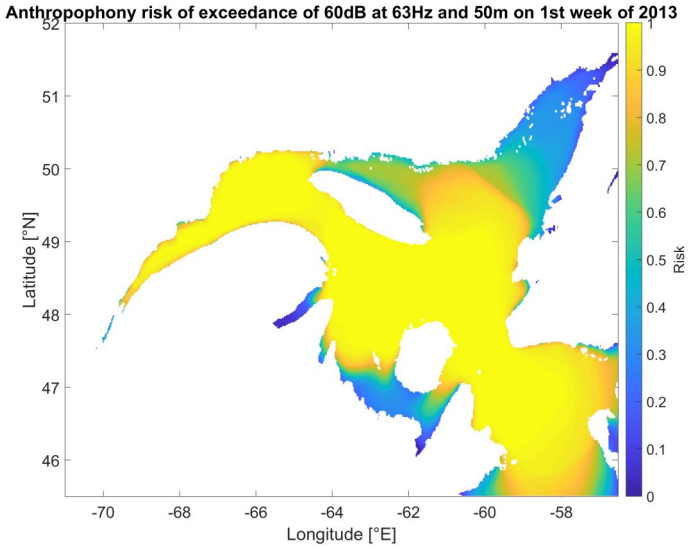
- **Behavioural disturbance**
- Sea state noise masking
- Reduction of detection / comm. range
- Temporary hearing loss

## Behavioural disturbance

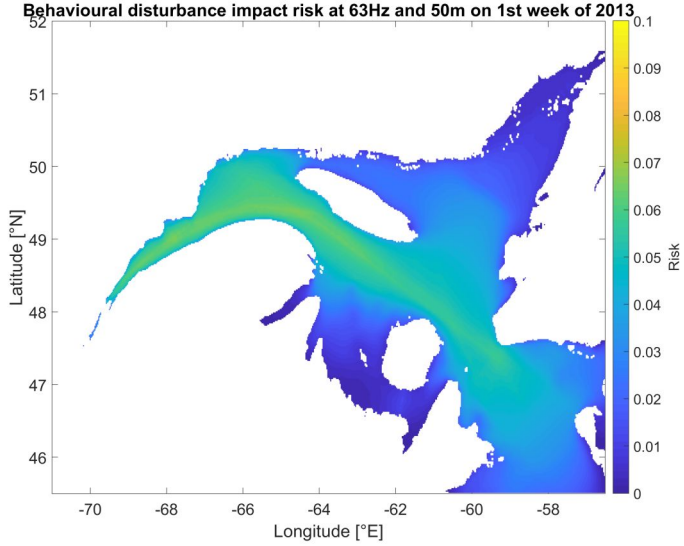



(Gomez et al. 2016) modified

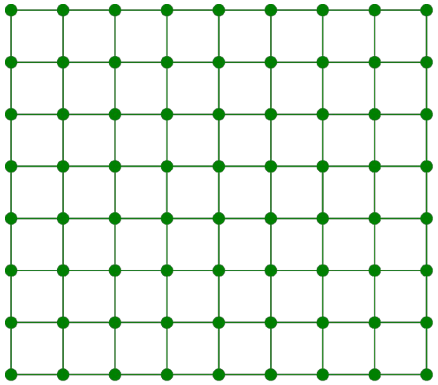
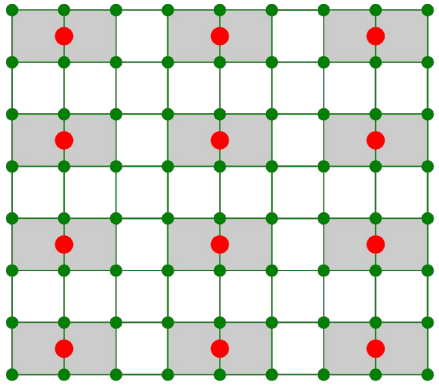
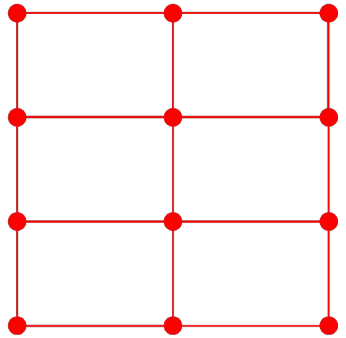
## Anthropophony risk of exceedance



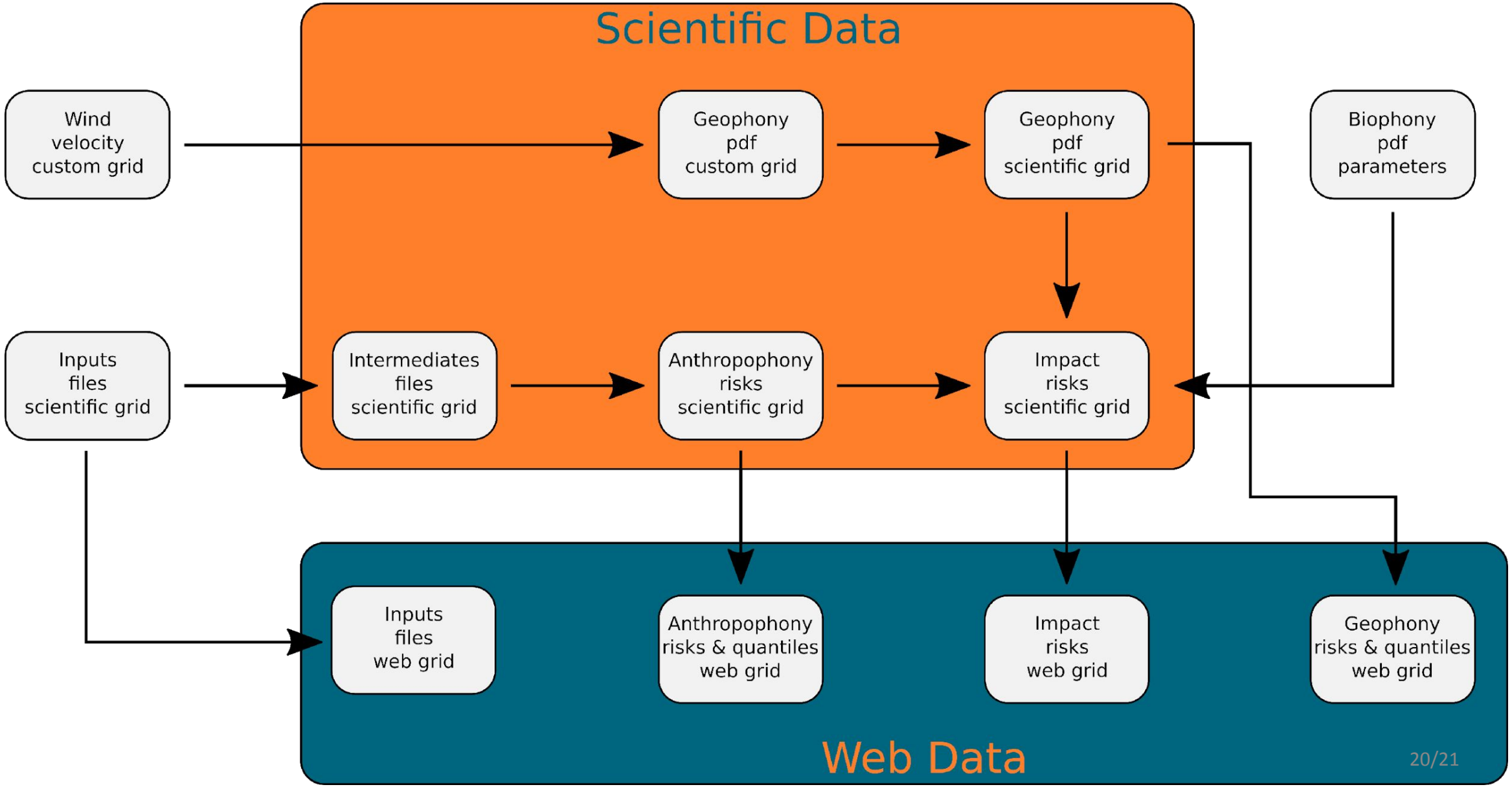

## Behavioural disturbance impact risk



# Reduction for web data

| | Scientific | | Web |
|---|---|---|---|
| Grid |  Initial grid 9x8 |  Transformation 3x2 |  Final grid 3x4 |
| Storage data in netCDF | Double (64 bits) | → | Single (32 bits) |
| Depths | 21 layers | → | 10 layers |
| Risk of exceedance | 531 SPL | → | 13 SPL |
| Quantile | 101 percentiles | → | 13 percentiles |
| Anthropophony risk | ≈ 30 TB | → Storage reduction | ≈ 50 GB |

# Summary


Scientific Data
Wind velocity custom grid
Geophony pdf custom grid
Geophony pdf scientific grid
Biophony pdf parameters
Inputs files scientific grid
Intermediates files scientific grid
Anthropophony risks scientific grid
Impact risks scientific grid
Inputs files web grid
Anthropophony risks & quantiles web grid
Impact risks web grid
Geophony risks & quantiles web grid
Web Data

# Thank you!

- Stay tuned for the next Soundscape Atlas presentation with Patrice Lebel!

# Partners of the project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FISHERIES AND OCEANS

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St. Lawrence
Global Observatory

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