The 2010 Haiti earthquake disaster:

The ShakeMap that could have been…

Shahar Shani-Kadmiel[1,2]

Gil Averbuch[1,2], Jelle Assink[2], Pieter Smets[1,2], Läslo Evers[2,1]

[1] **T**U**Delft** Delft University of Technology

[2] Royal Netherlands Meteorological Institute *Ministry of Infrastructure and the Environment*

NWO

The January 12, 2010 M_W 7 Earthquake Disaster in Haiti

Due to the lack of seismometers during the 2010 Haiti earthquake:

Overestimated shaking intensity near the epicenter

Underestimated the extent of potentially damaging shaking

(a) USGS ShakeMap : HAITI REGION
Tue Jan 12, 2010 21:53:10 GMT M 7.0 N18.46 W72.53 Depth: 13.0km ID:2010rja6

Unconstrained by seismometers
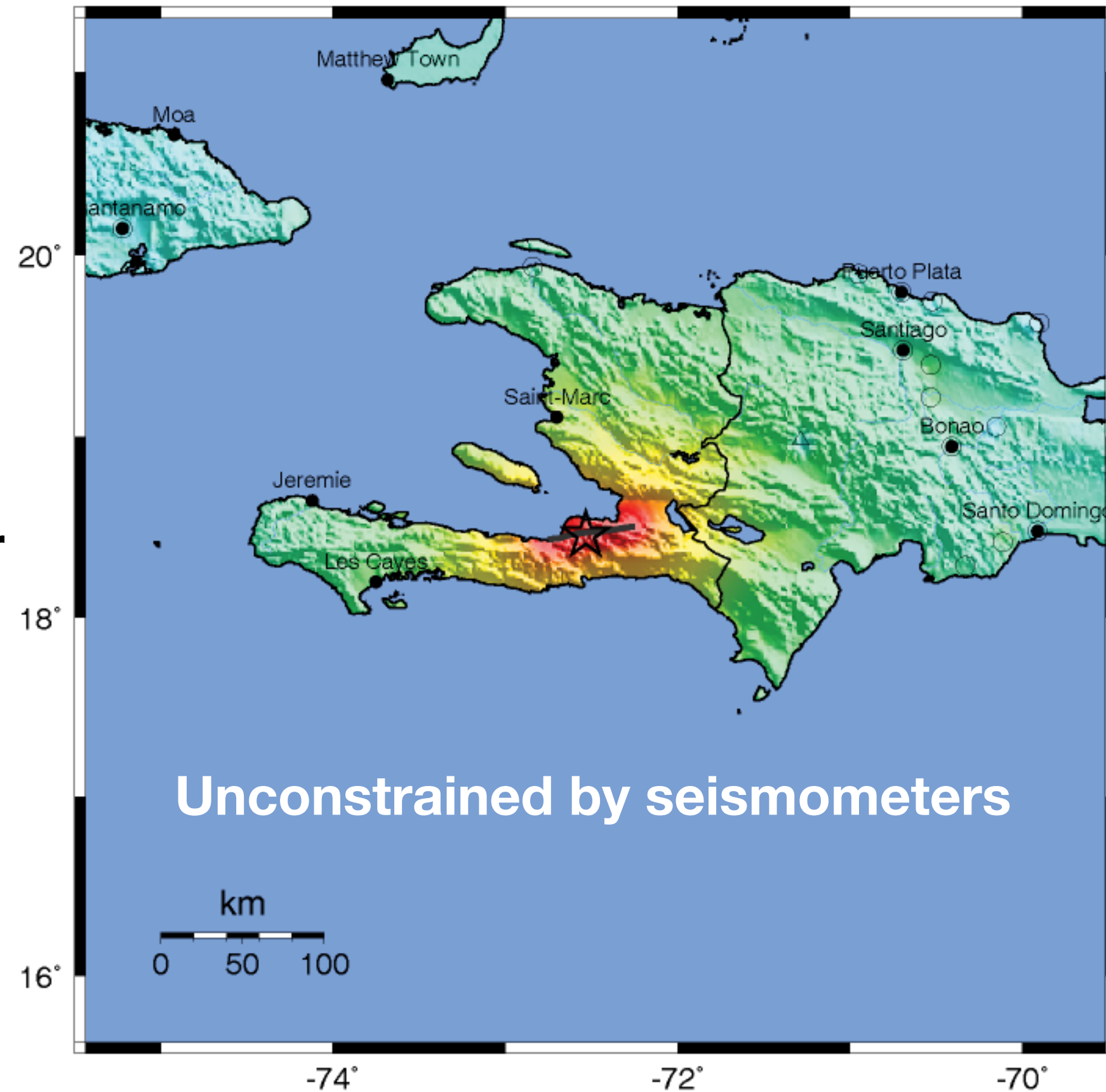
Map Version 7 Processed Wed Jan 13, 2010 06:53:11 PM MST -- NOT REVIEWED BY HUMAN

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

ShakeMap generated more than a day after the earthquake

(b) USGS ShakeMap : Haiti
Jan 12, 2010 21:53:10 UTC M 7.0 N18.46 W72.53 Depth: 13.0km ID:20100112215310

Based on surveyed damage, GMPEs from recorded aftershocks, forward propagation models…
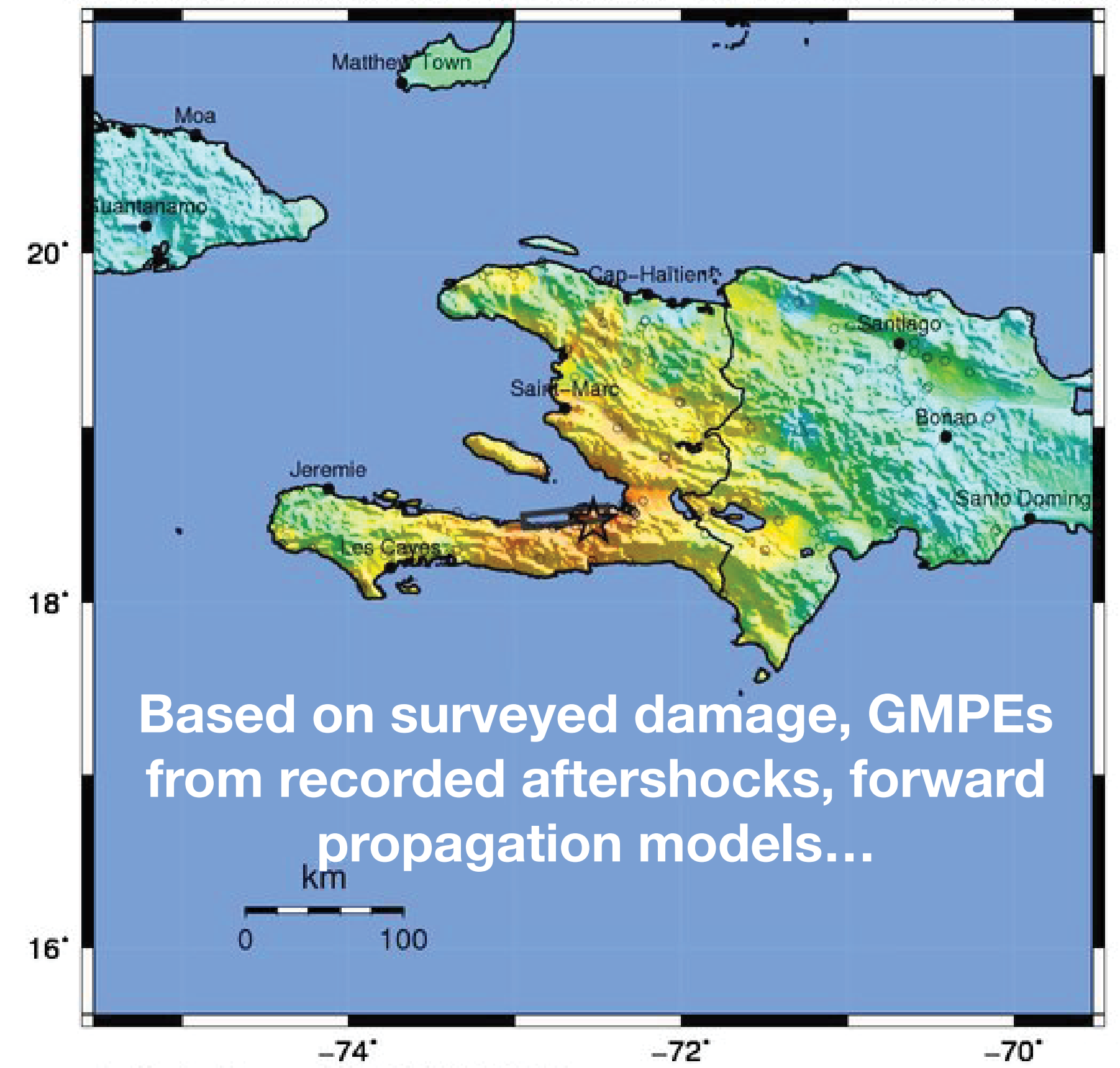
Map Version 1 Processed 2017-01-27 03:39:48 UTC

| PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

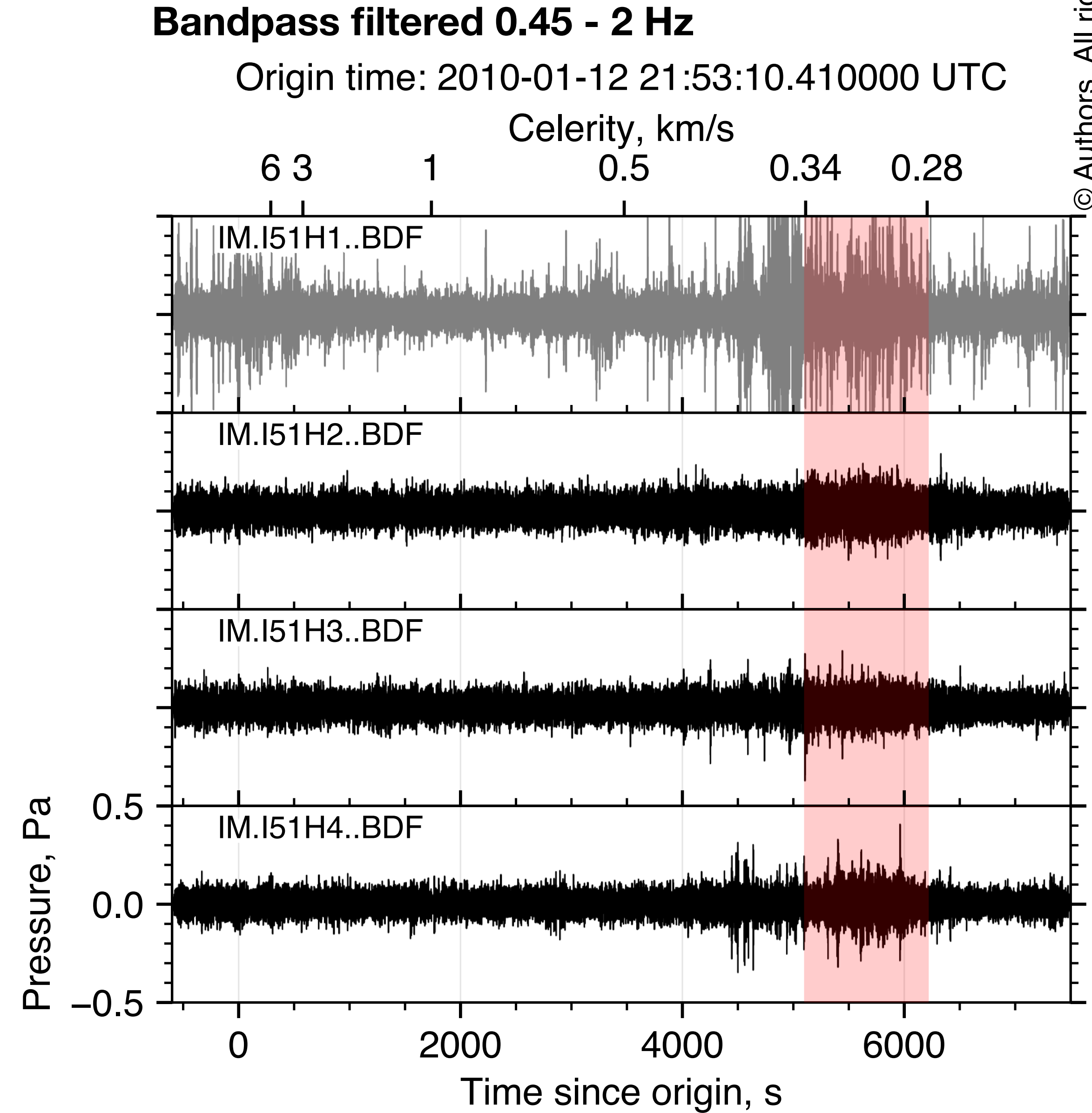Scale based upon Worden et al. (2012)

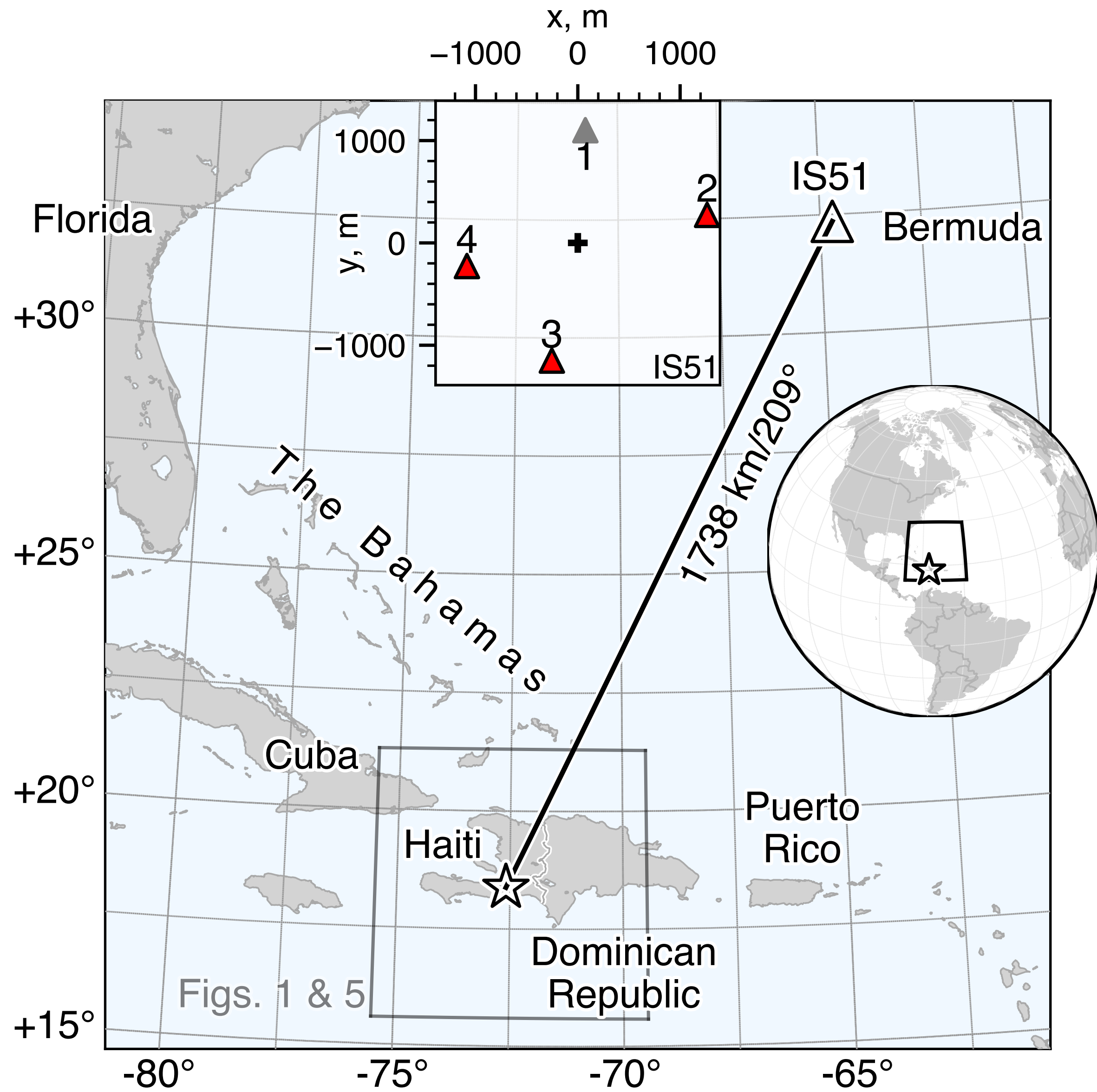**ShakeMap generated more than 7 years after the earthquake**
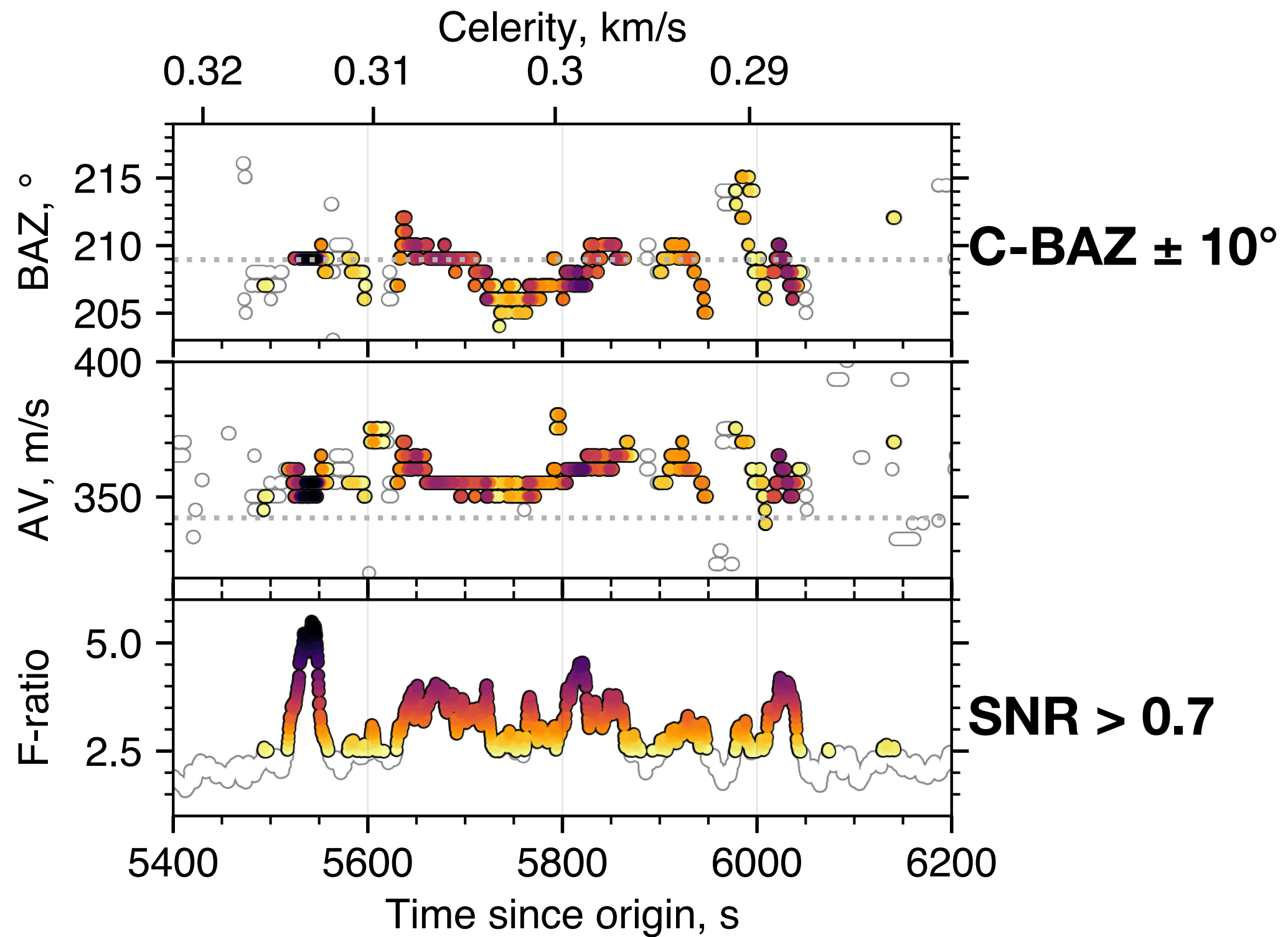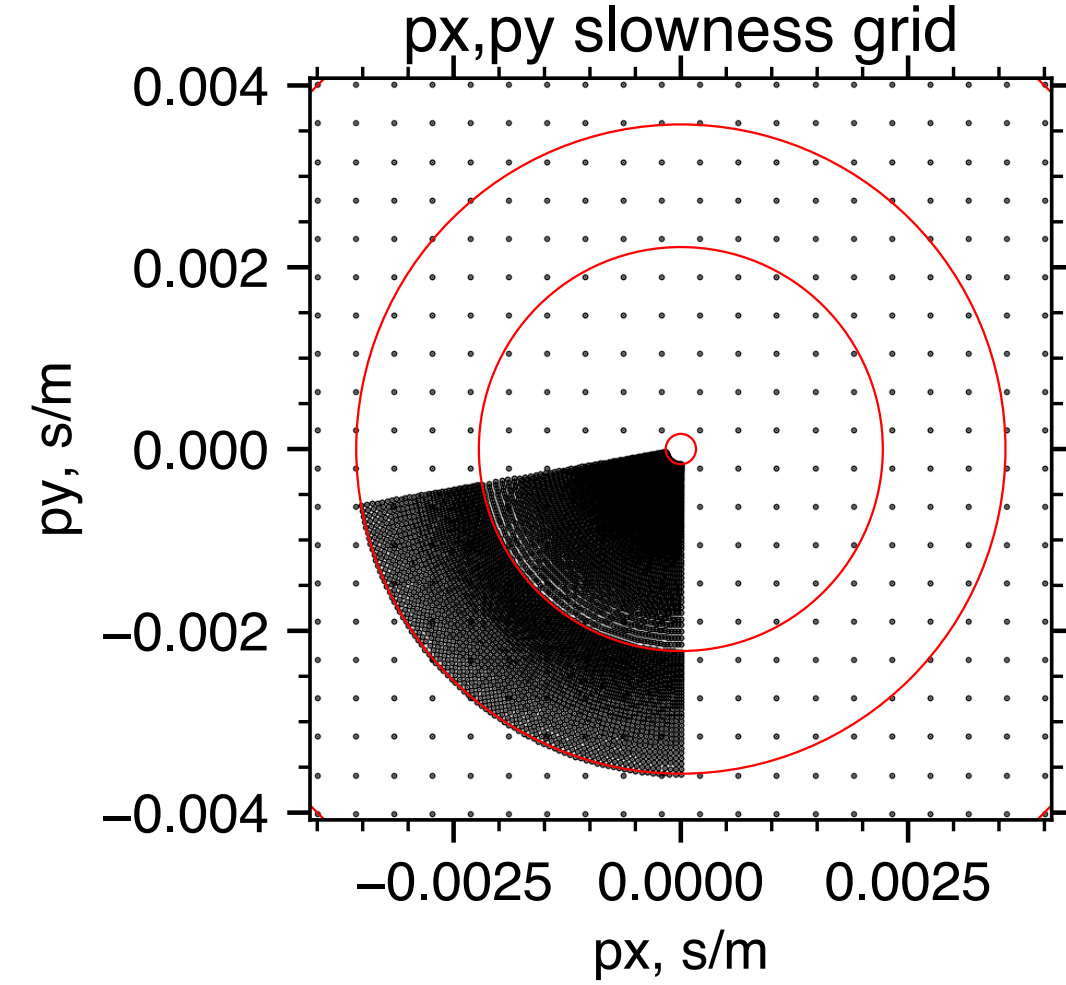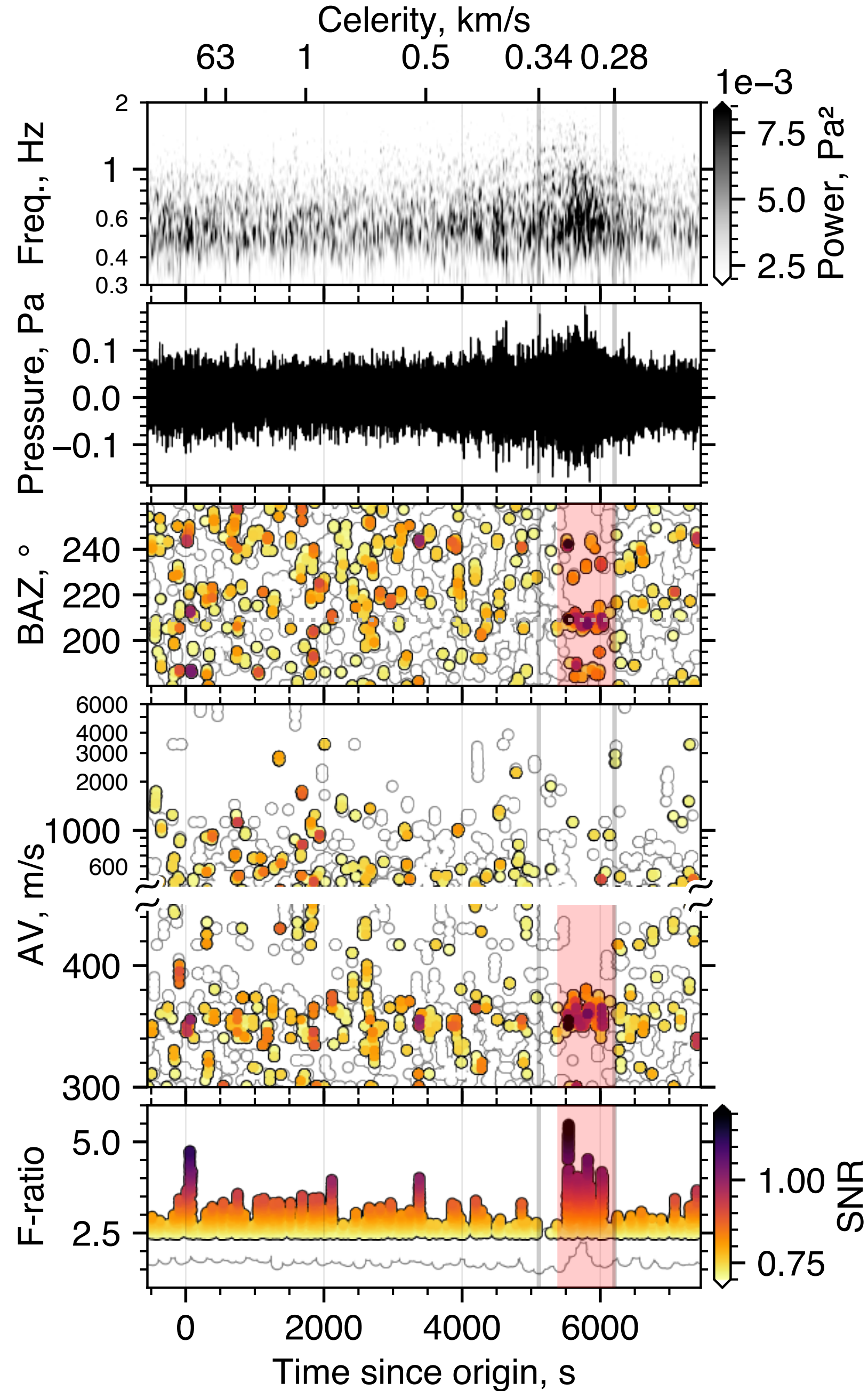
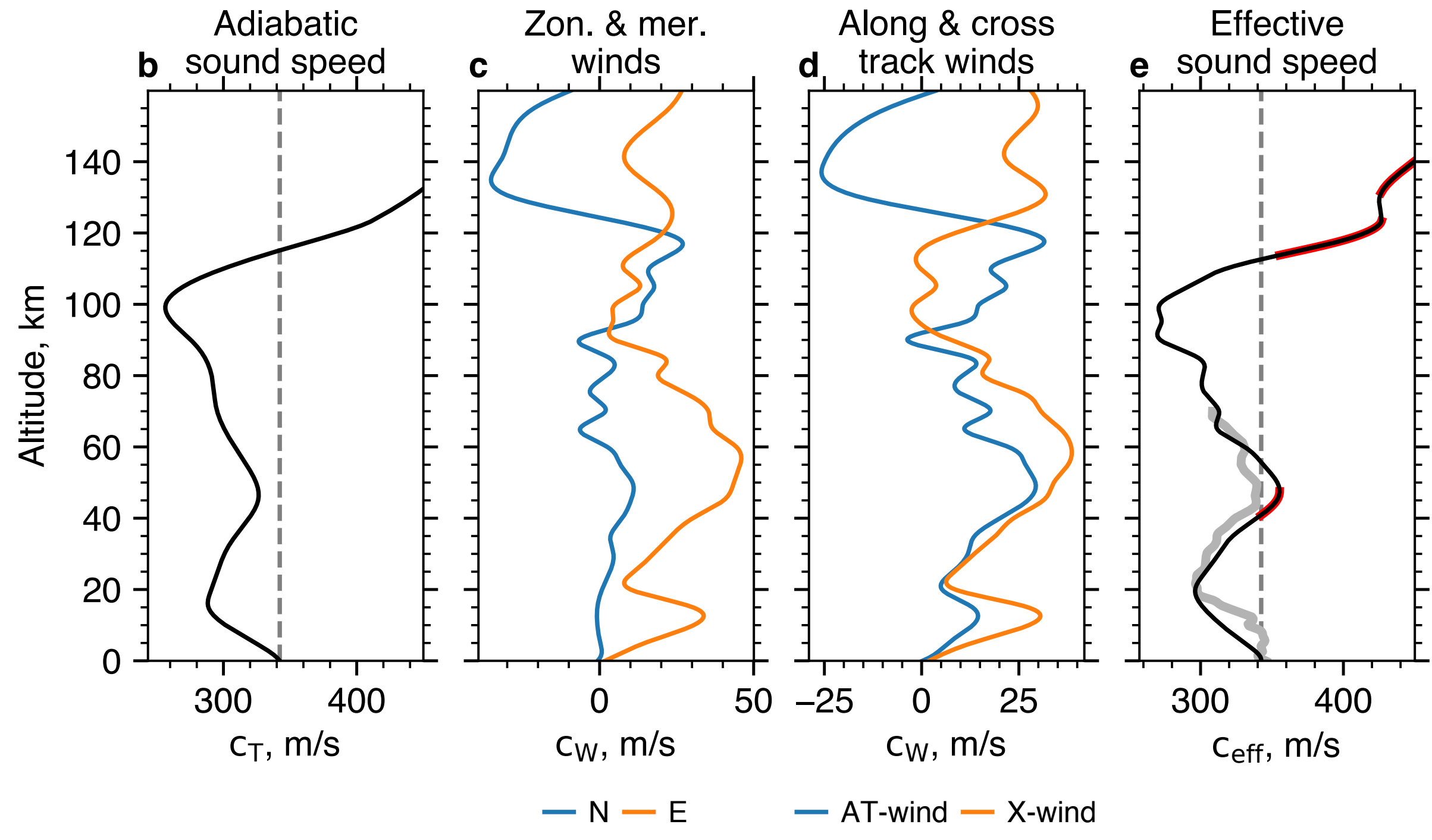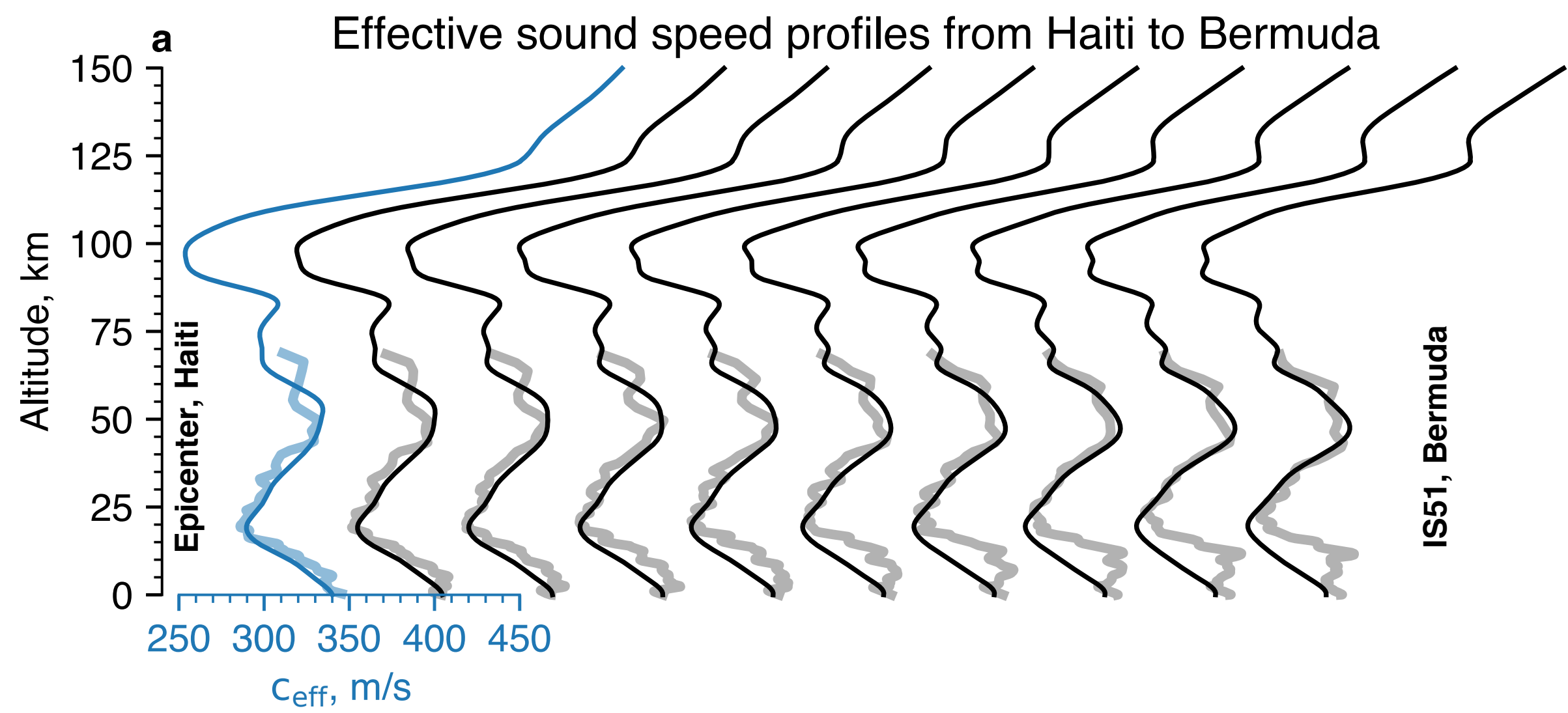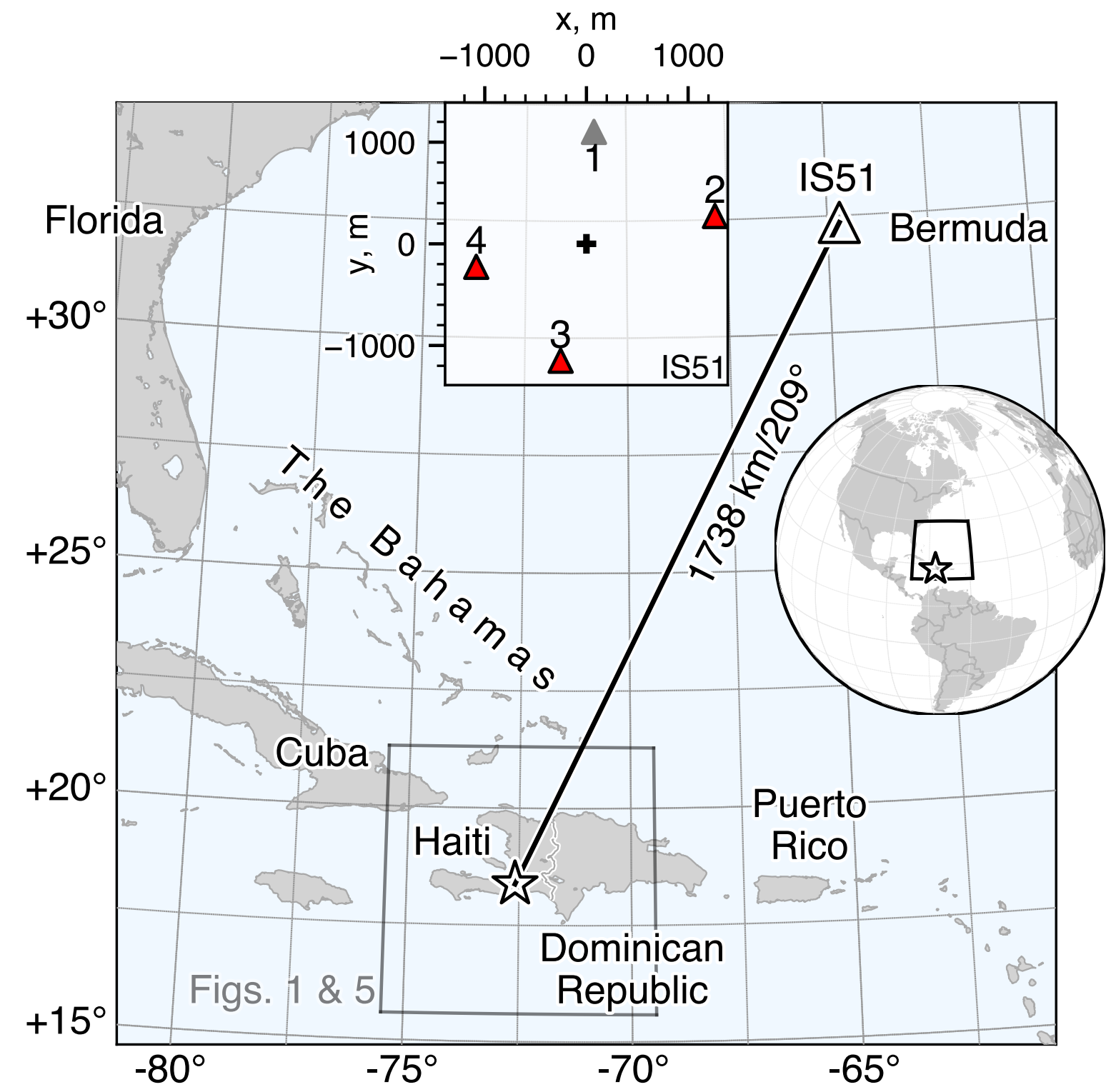# Data Processing
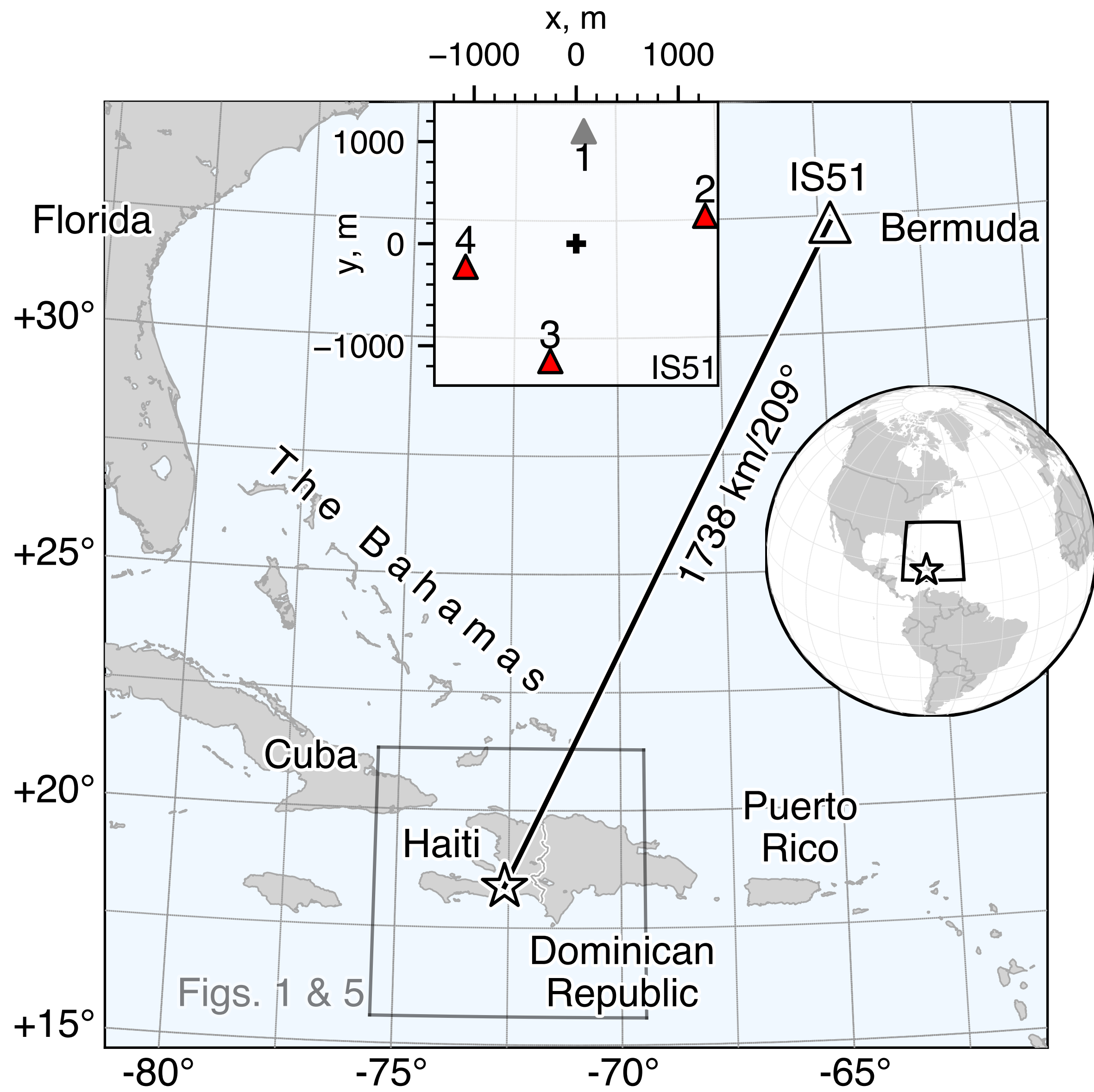
Data Processing
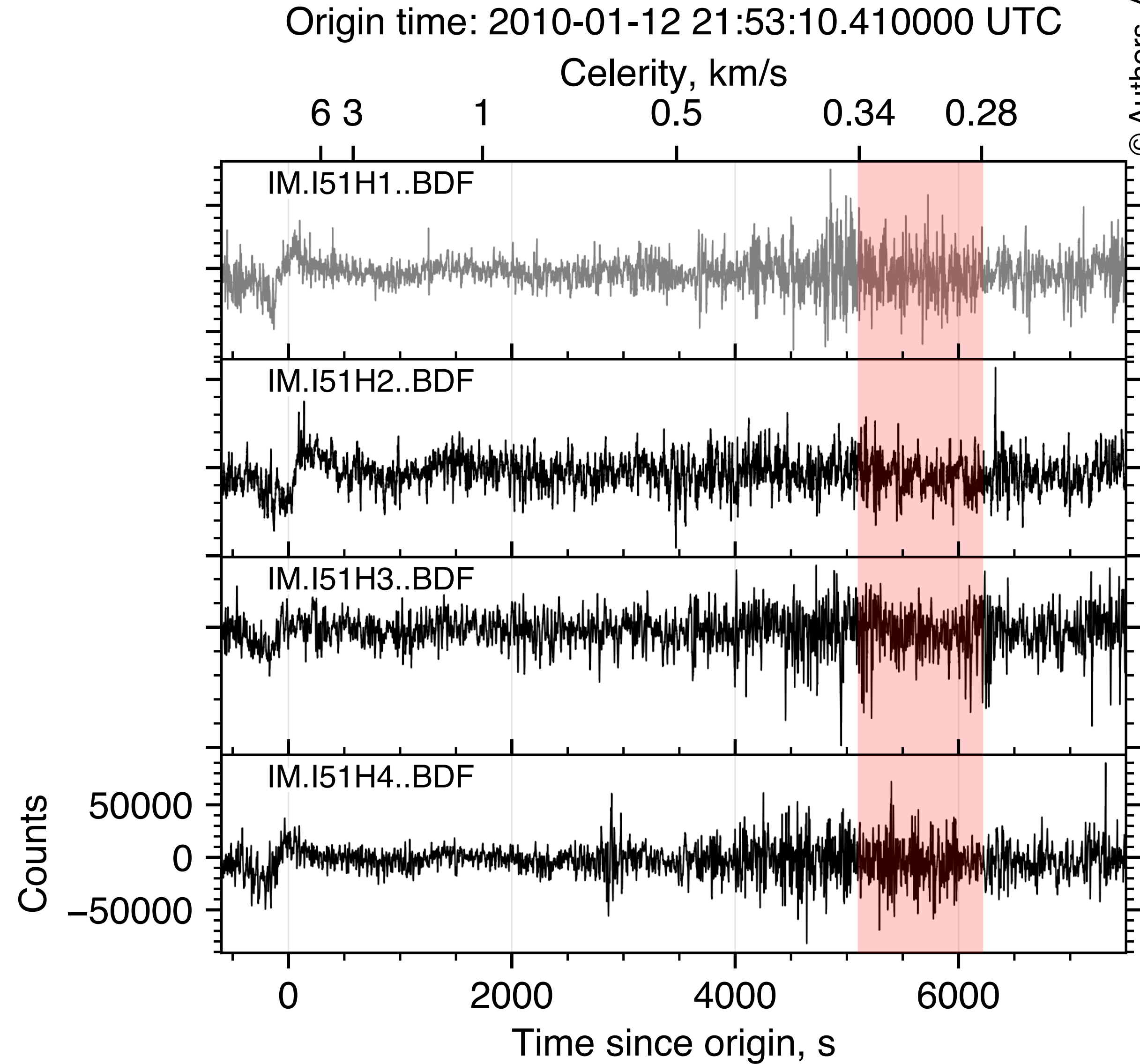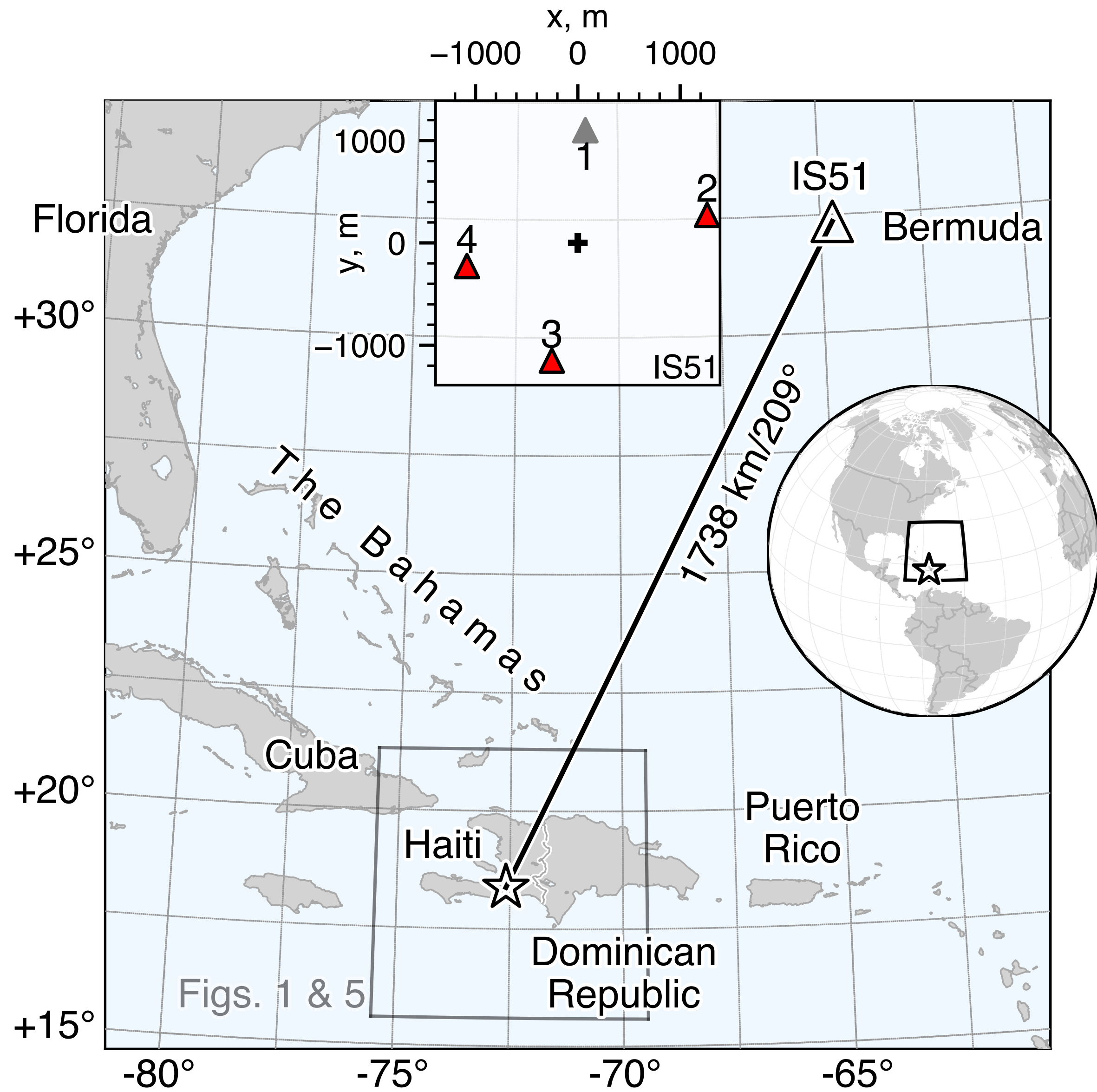
Data Processing

Array: IS51 l 3 elements l event range: 1738 km l event BAZ: 209°
Beamforming: wlen: 30.00 s l overlap: 99% l freq: 0.45 --> 2.00 Hz
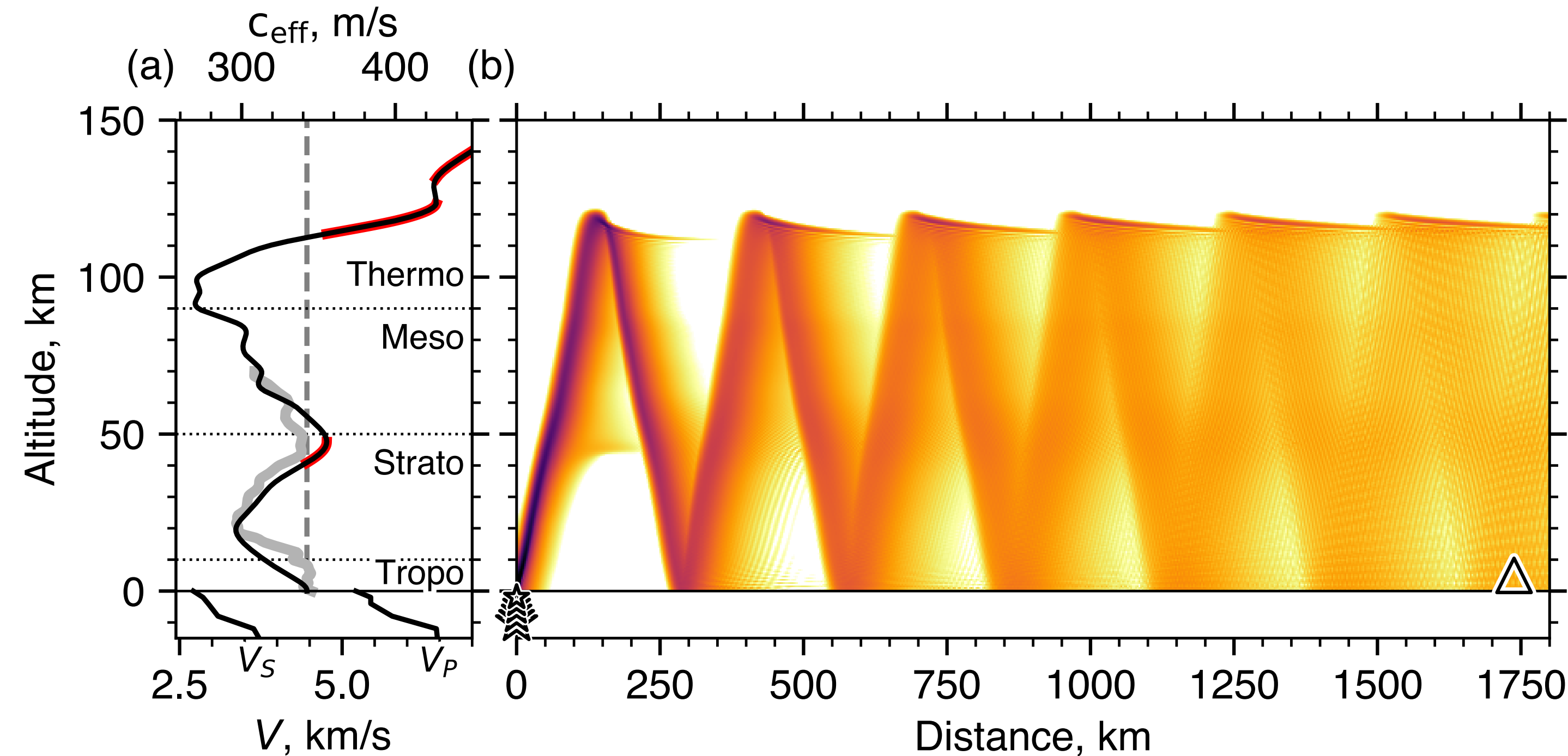Event origin time: 2010-01-12 21:53:10.410000 UTC

px,py slowness grid

C-BAZ ± 10°

SNR > 0.7

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Seismo-Acoustic Coupling and Propagation Conditions

a Effective sound speed profiles from Haiti to Bermuda

b Adiabatic sound speed

c Zon. & mer. winds

d Along & cross track winds

e Effective sound speed

MSIS-00 & HWM14

ERA5 RA ECMWF

N — E — AT-wind — X-wind

Seismo-Acoustic Coupling and Propagation Conditions

Fast Field Program (FFP) Setup:
- **Sources at 10, 8, 6, 4, 2 km depth**
- **f = 0.5 Hz**
- **Modeled velocities: 300 - 450 m/s**

Averbuch et al. ASA2020

Haiti

s2010HAITIx02HAYE
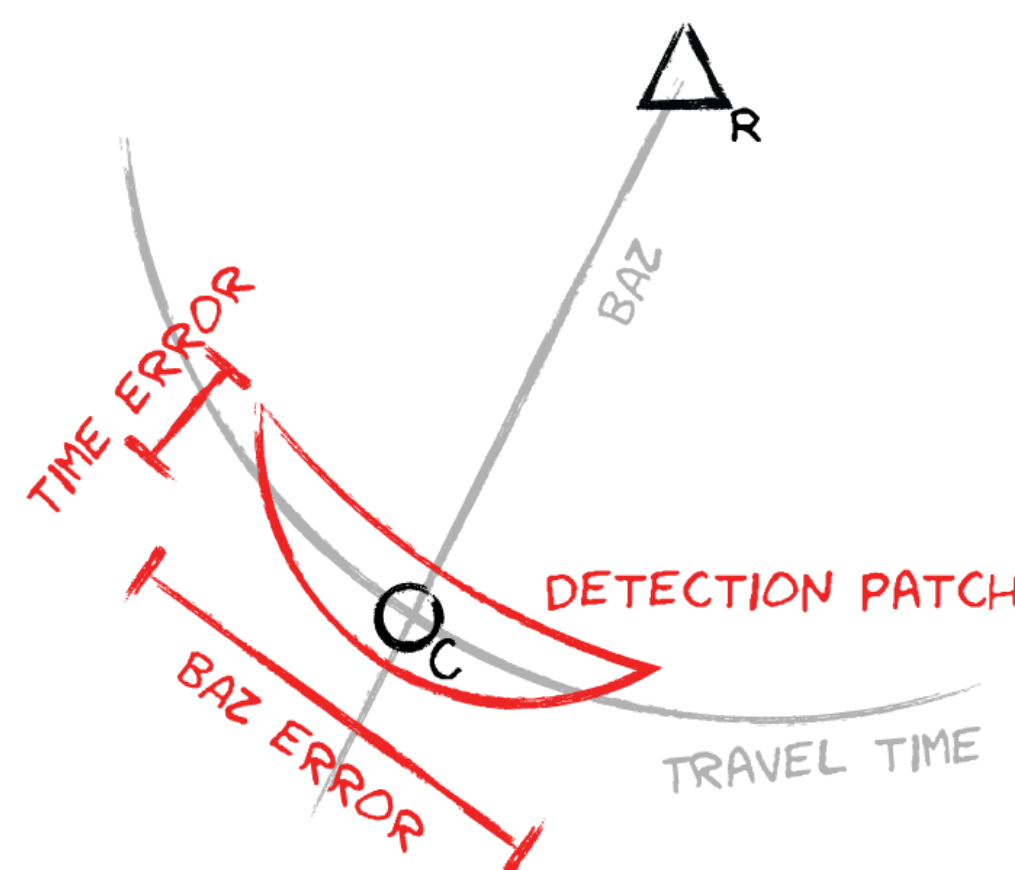Mw 7.0   Mo 3.55e+19
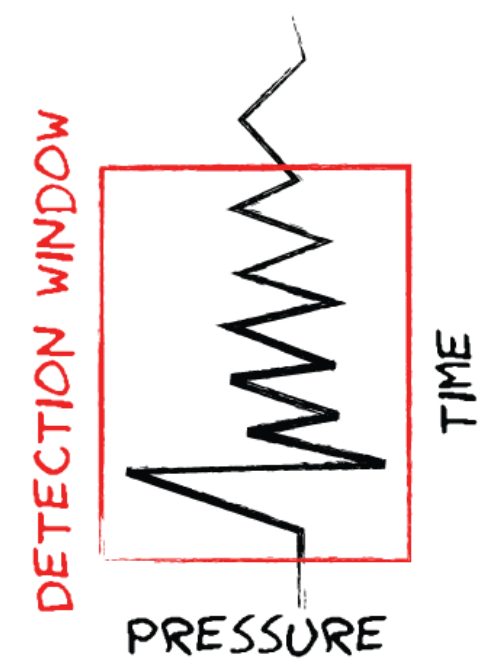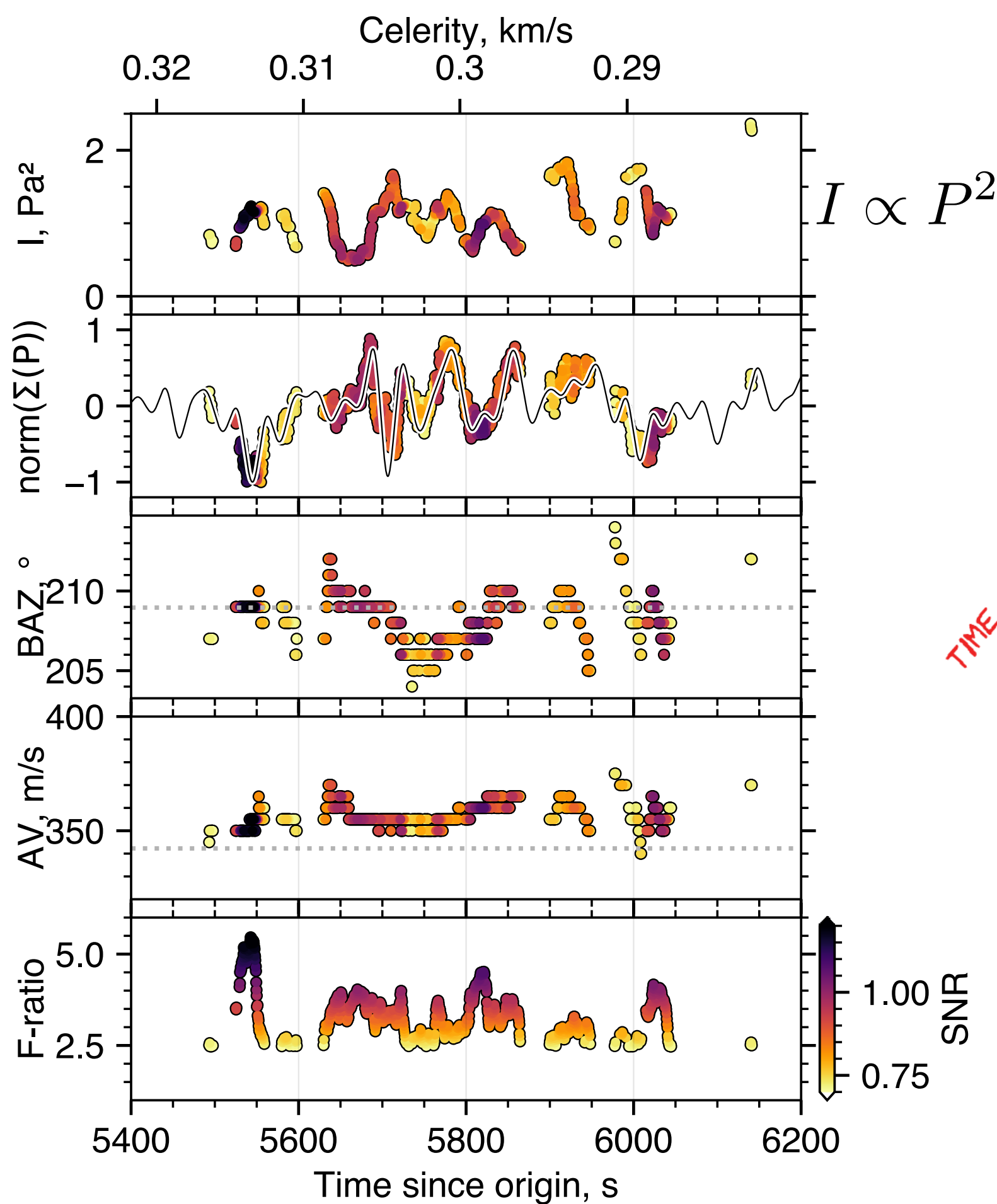Lat/Lon/Dep: 18.51°, -72.53°, 12.2 km
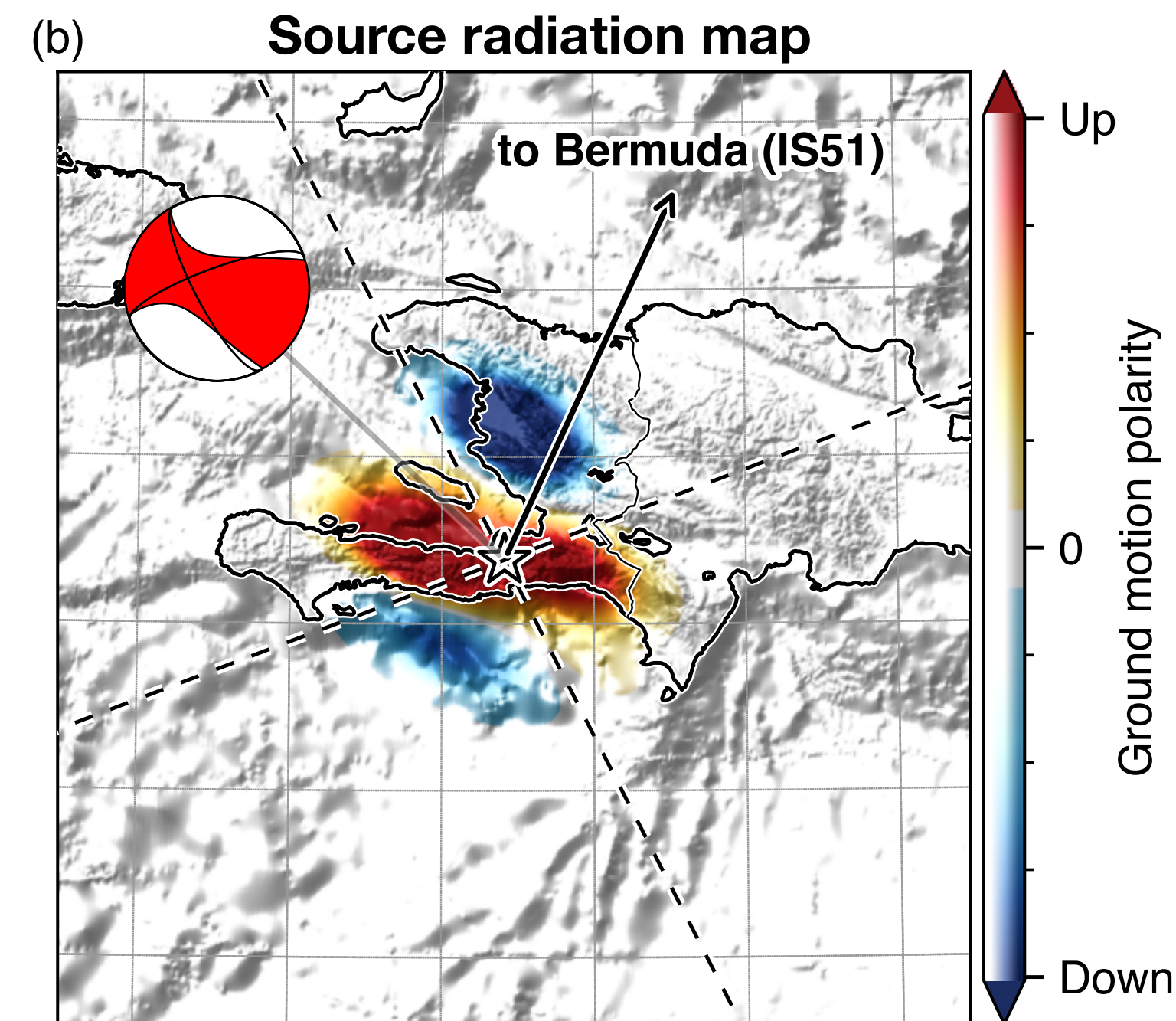*View angle: 9° from North*

Hayes et al. NG2010

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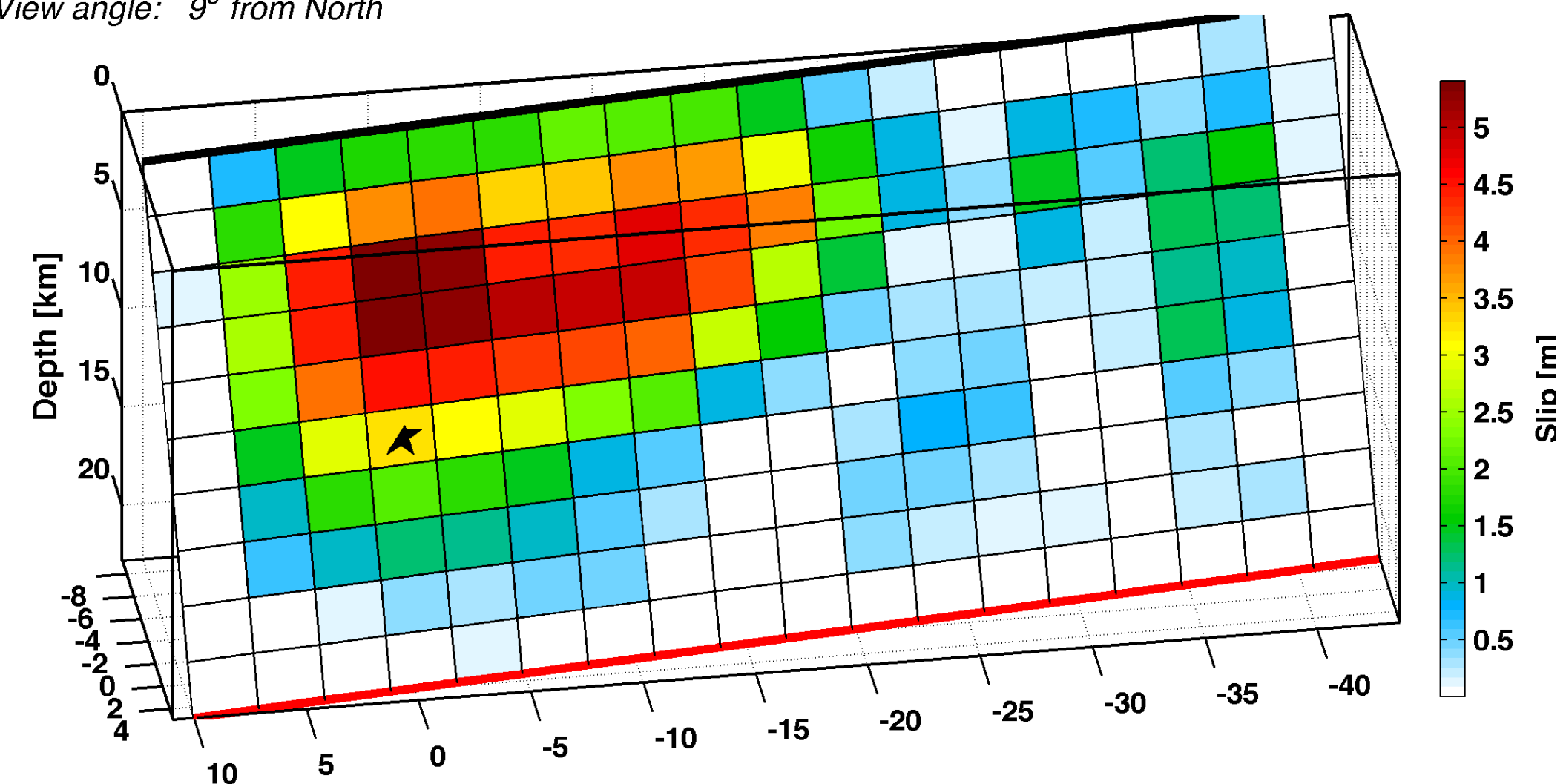
Backprojections

Epicentral infrasound detections

$$I \propto P^2$$

(a) Acousto-ShakeMap

MMI=V of the initial USGS ShakeMap

MMI=V of the updated USGS ShakeMap

(b) Source radiation map

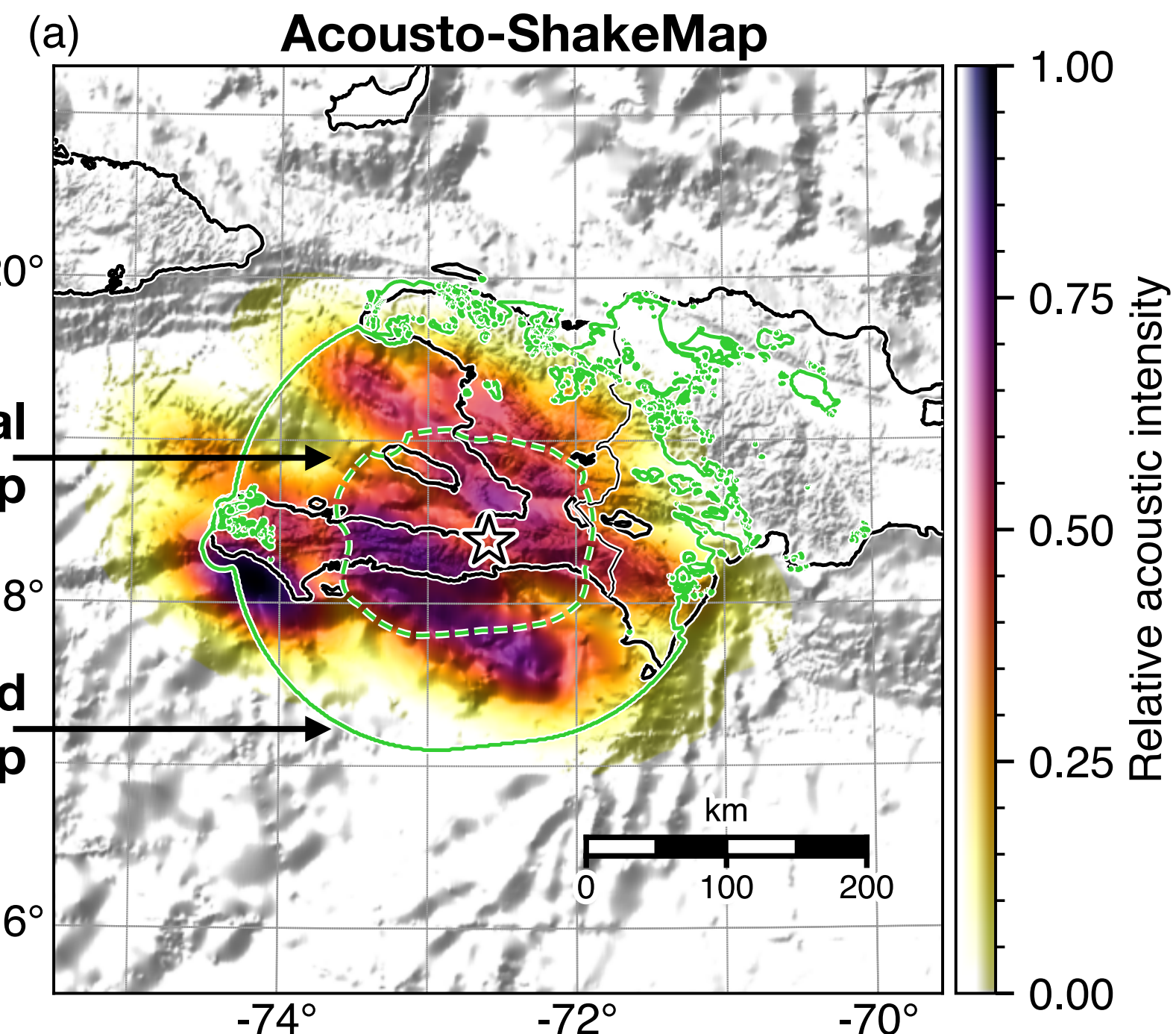to Bermuda (IS51)

Backprojection accounts for:

• Horizontal advection effects from along- and cross-track wind

• Uncertainties with regard to the time of detection and back azimuth

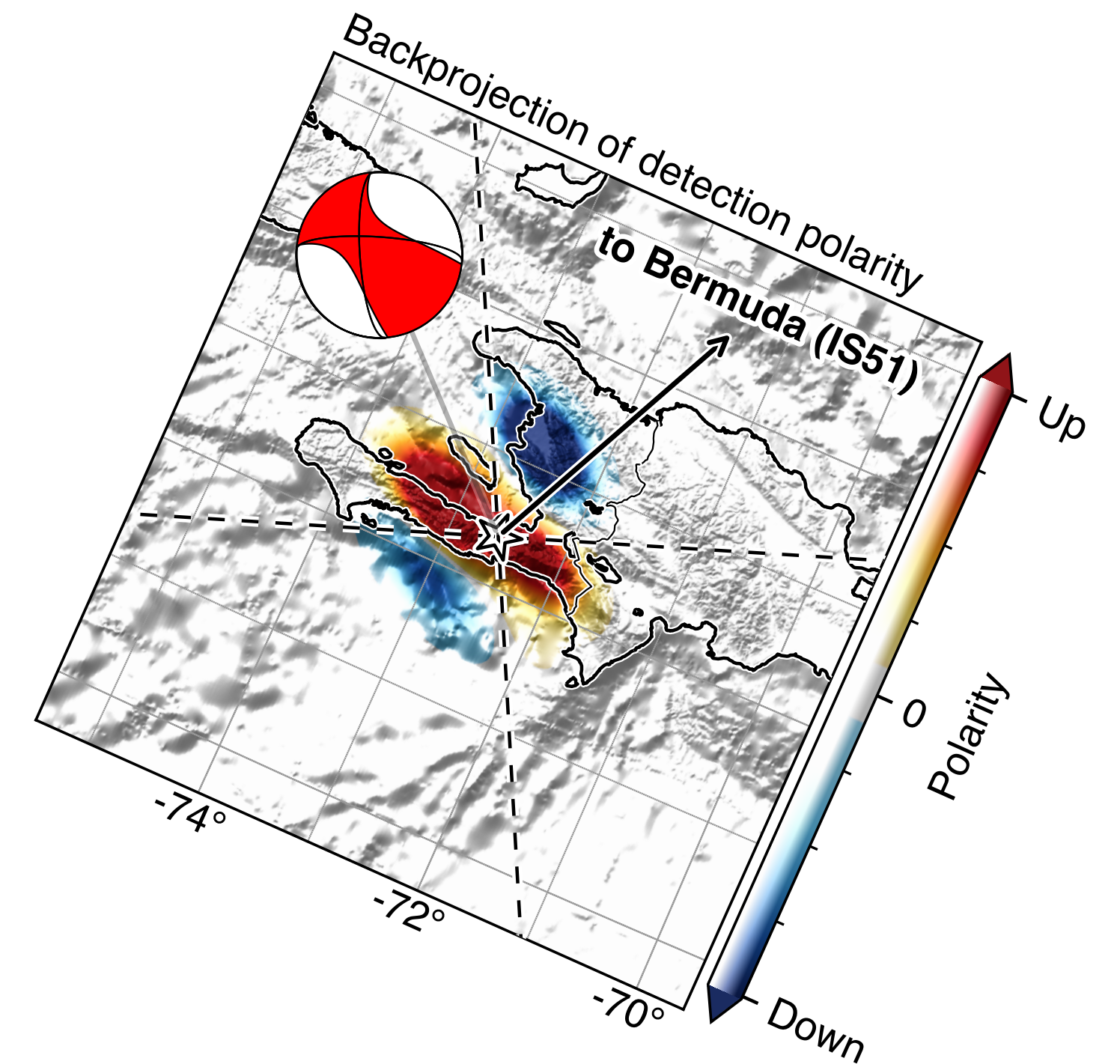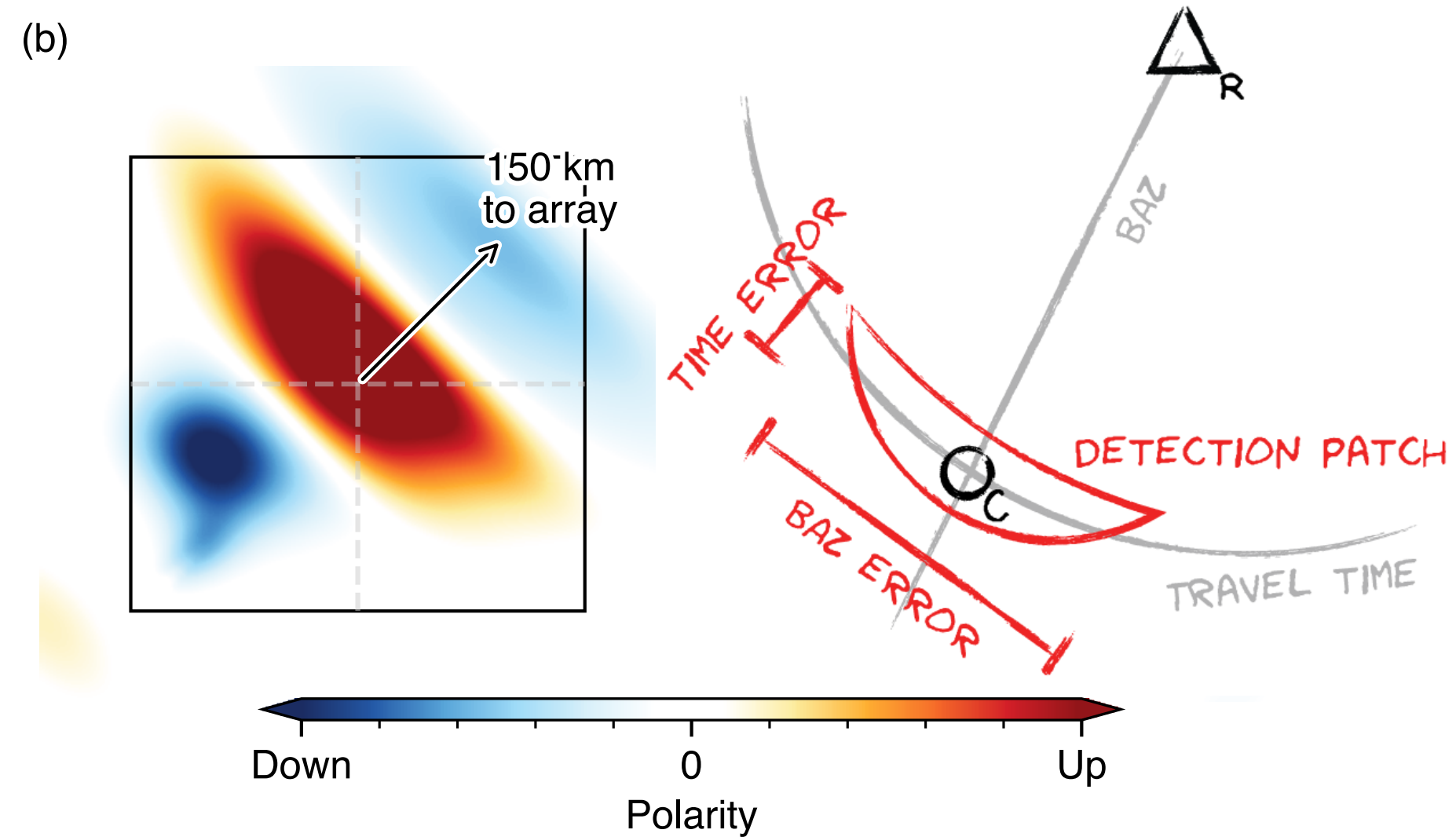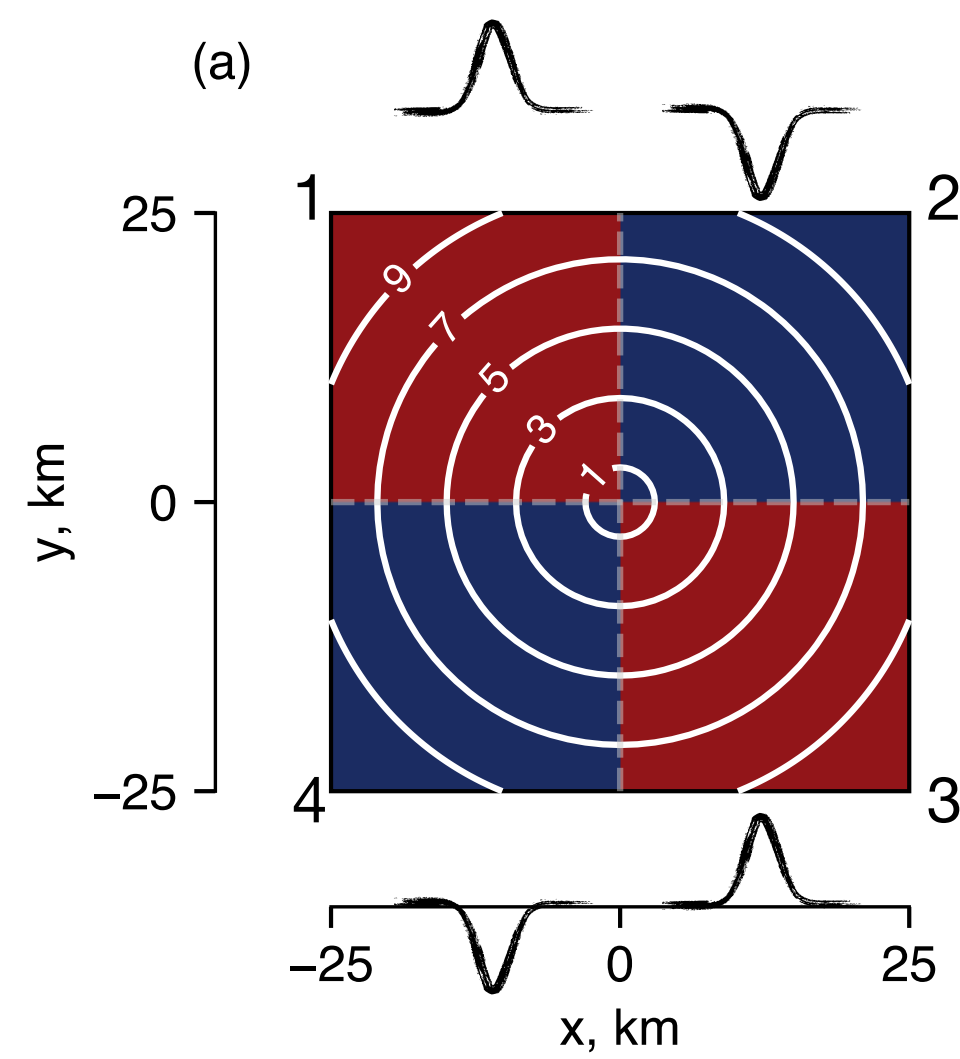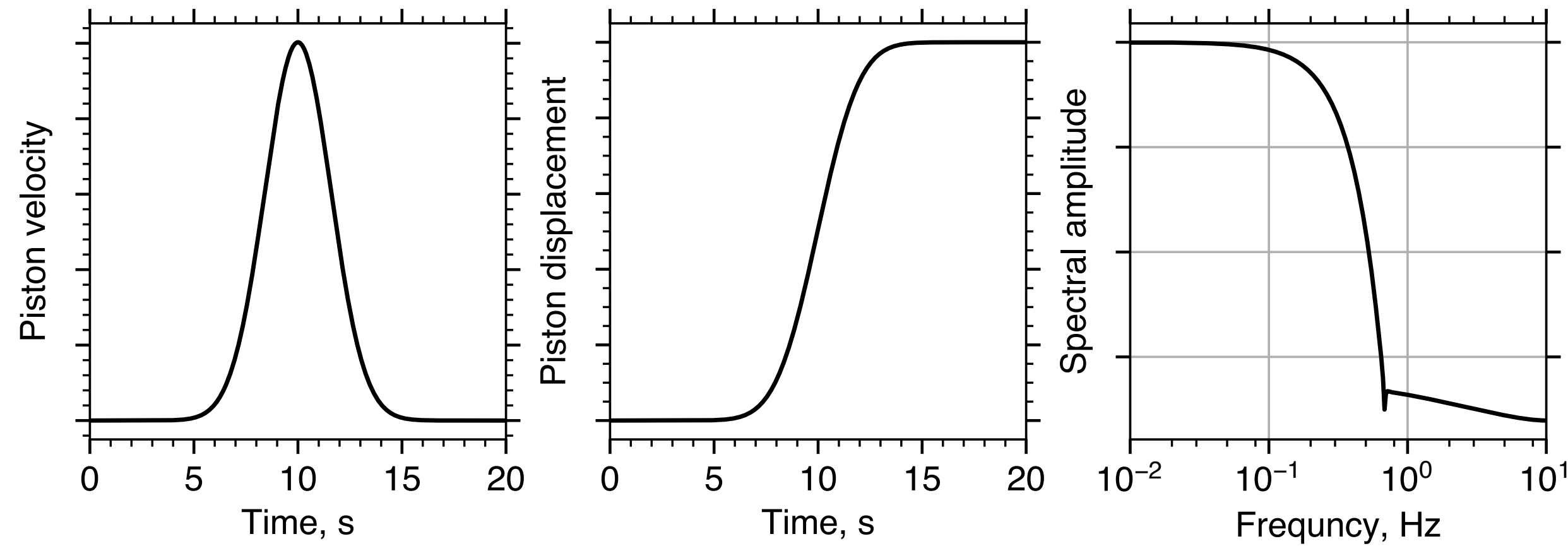**Important:** Back azimuth uncertainty grows with backprojection distance

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50 km extended source discretised to 400 m pistons Gaussian STF, f_c=0.1 Hz moveout velocity of 3 km/s

(a)

(b)

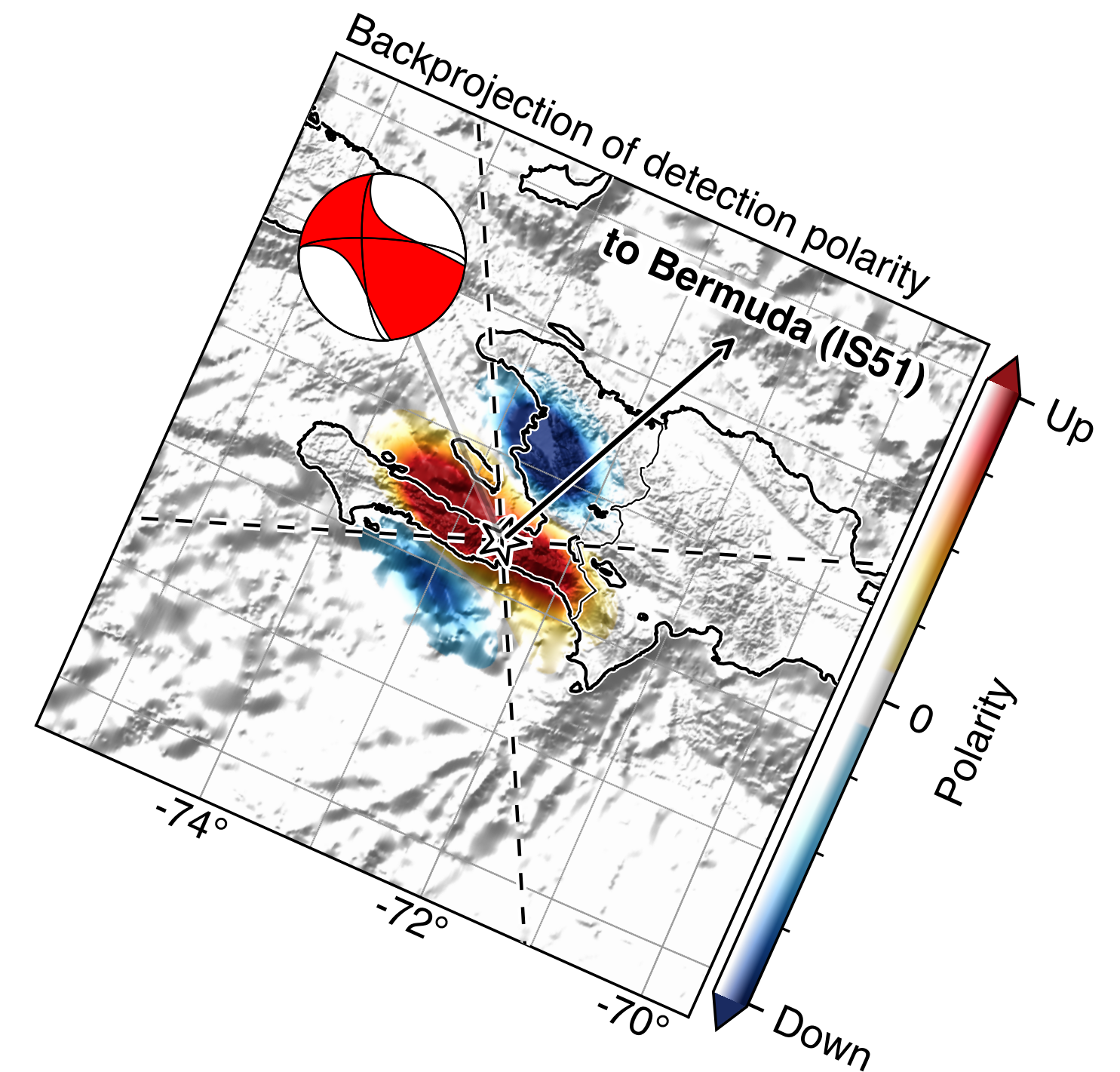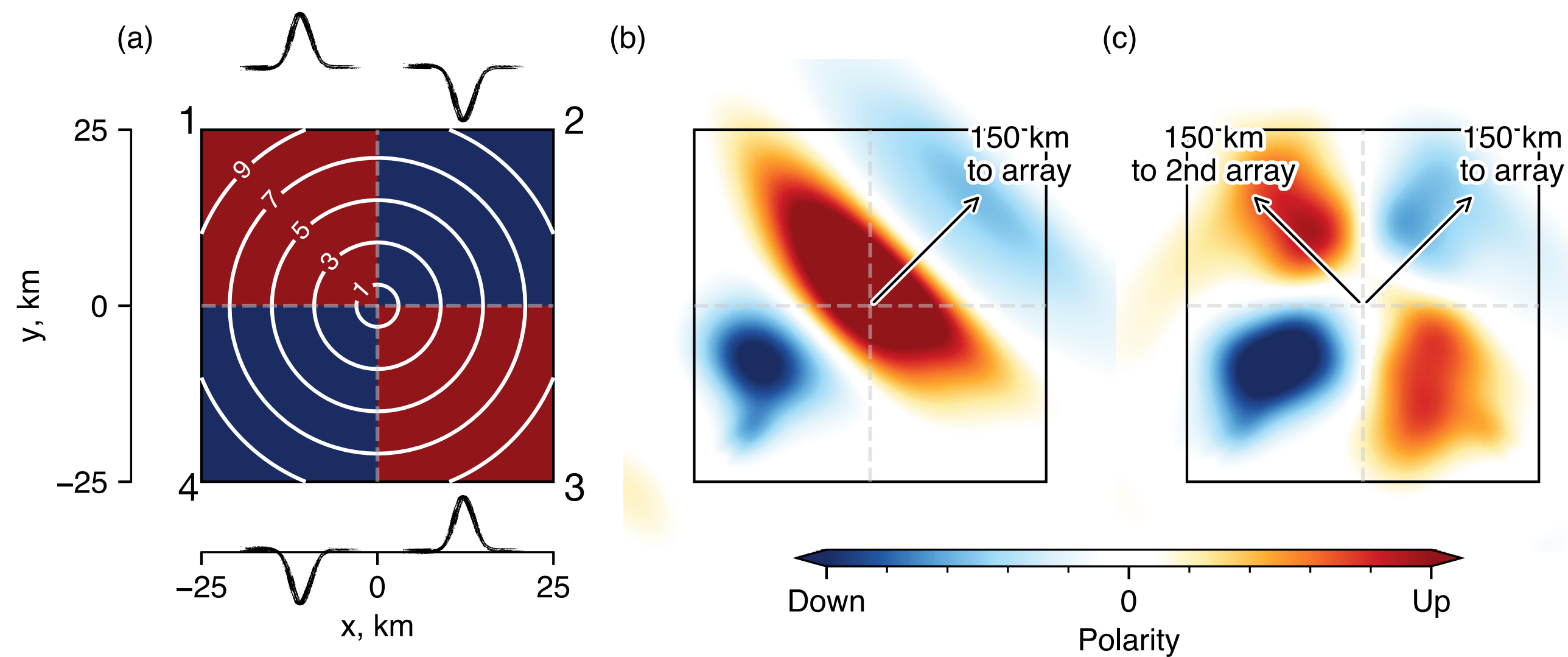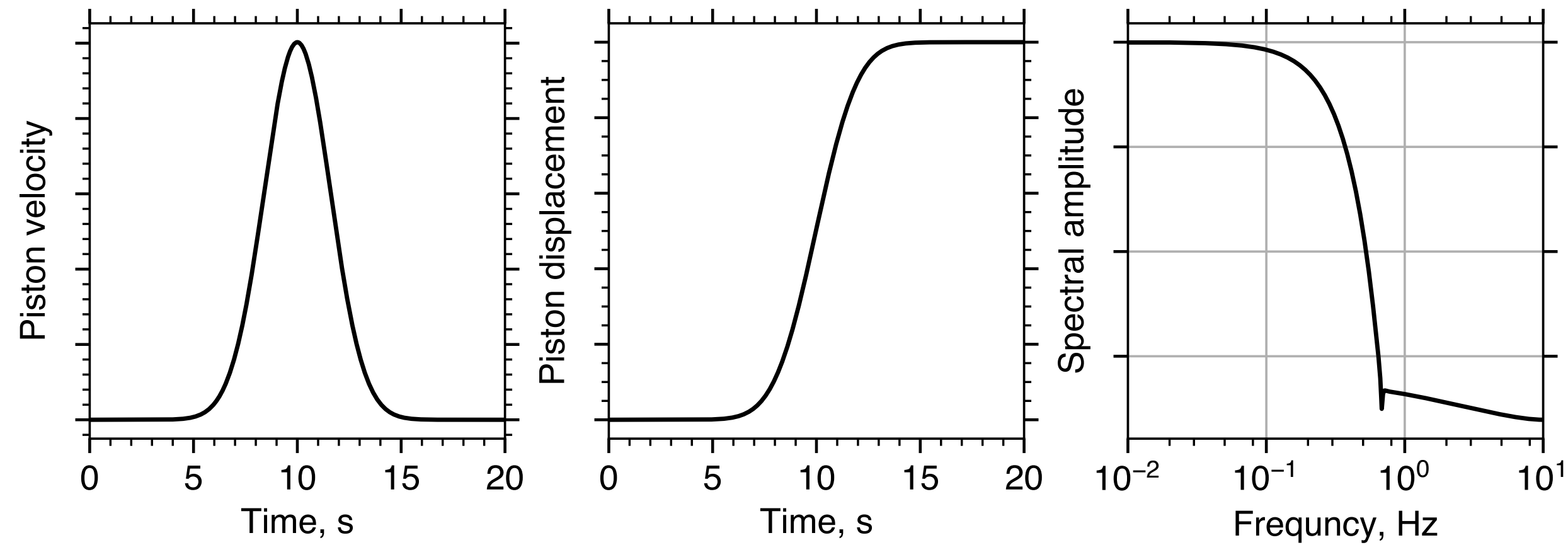# Proof of Concept with the help of Lord Rayleigh

**50 km extended source
discretised to 400 m pistons
Gaussian STF, f_c=0.1 Hz
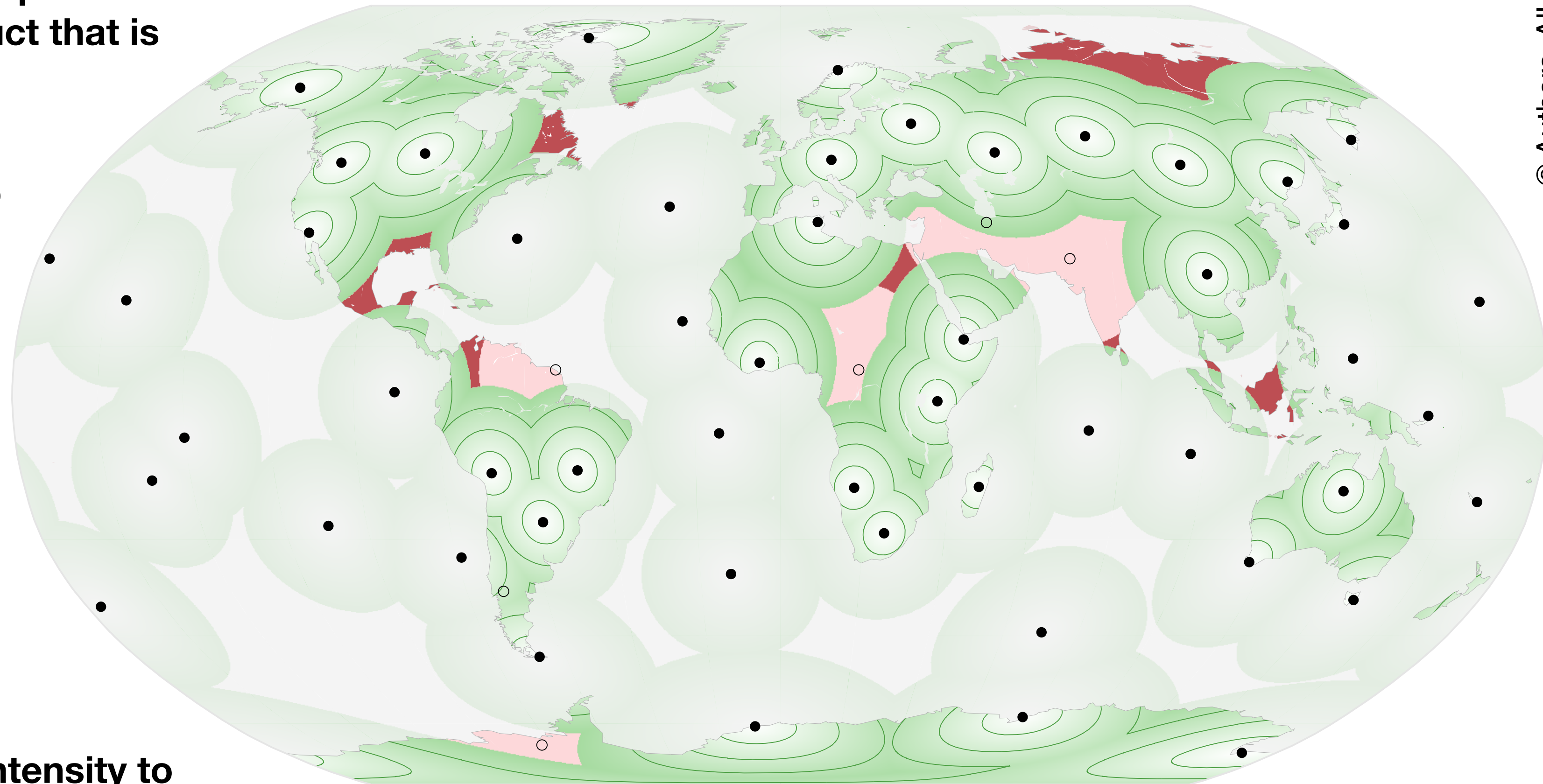moveout velocity of 3 km/s**

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Discussion & Conclusions

- The temperature gradient in the thermosphere makes it so there is always a thermospheric duct that is effective to about 2000 km.

- This means that the existing infrasound stations of the IMS already provide 90% coverage of landmass.

- When the network is complete the coverage will increase to 97%.

- The remaining gaps can be easily covered with nationally operated stations.

Next steps:

3D and 1D raytracing…

Translating measured acoustic pressure intensity to ground motions at the epicenter…

1 **TU**Delft Delft University of Technology

2 Royal Netherlands Meteorological Institute *Ministry of Infrastructure and the Environment*

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