Tonga Tsunami Provides Data, Verification for Blast-Generated Global Tsunami Modeling

The January 15, 2022 Hunga Tonga-Hunga Ha'apai volcano explosion provided data for impact tsunami modeling verification

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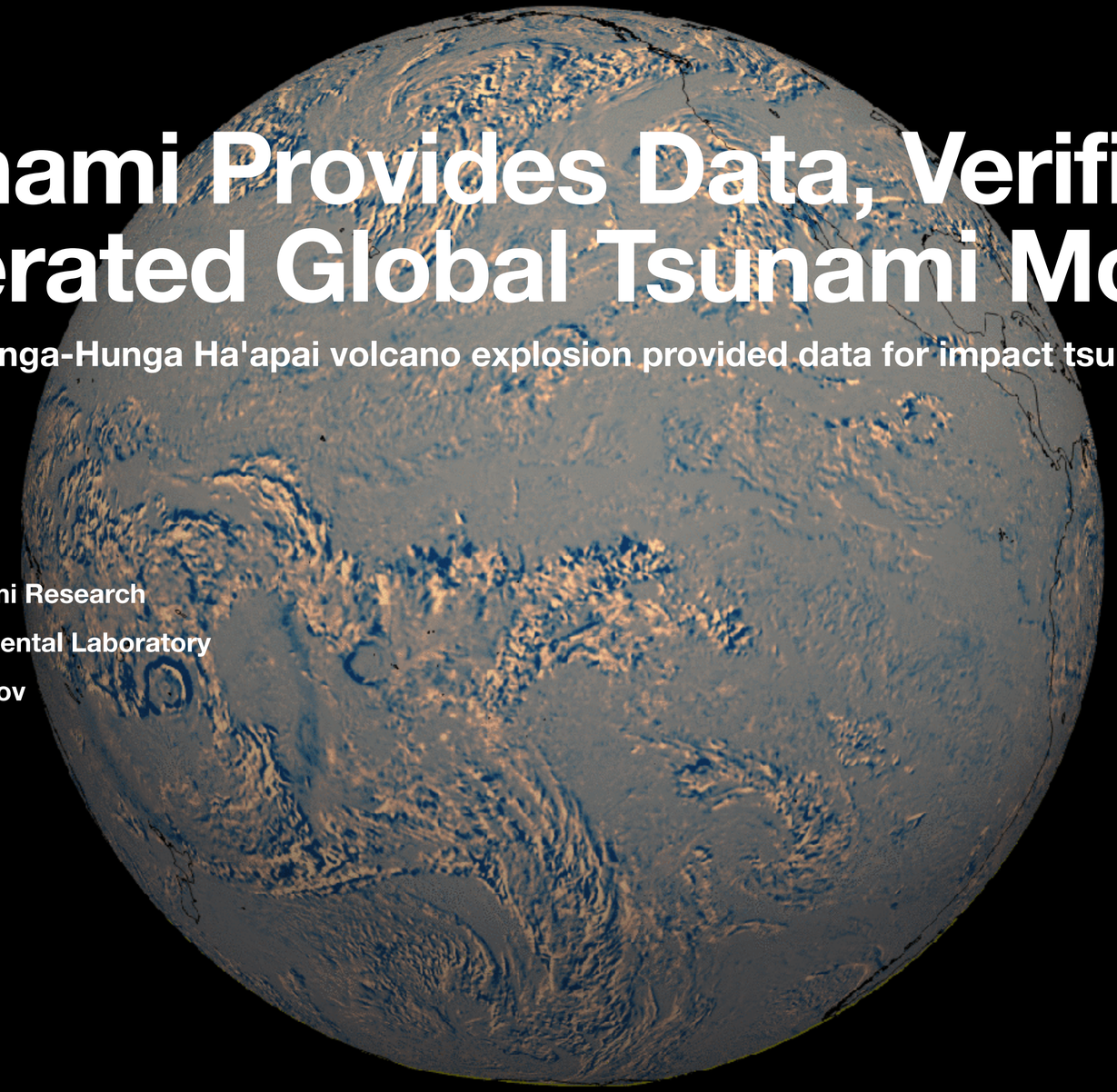
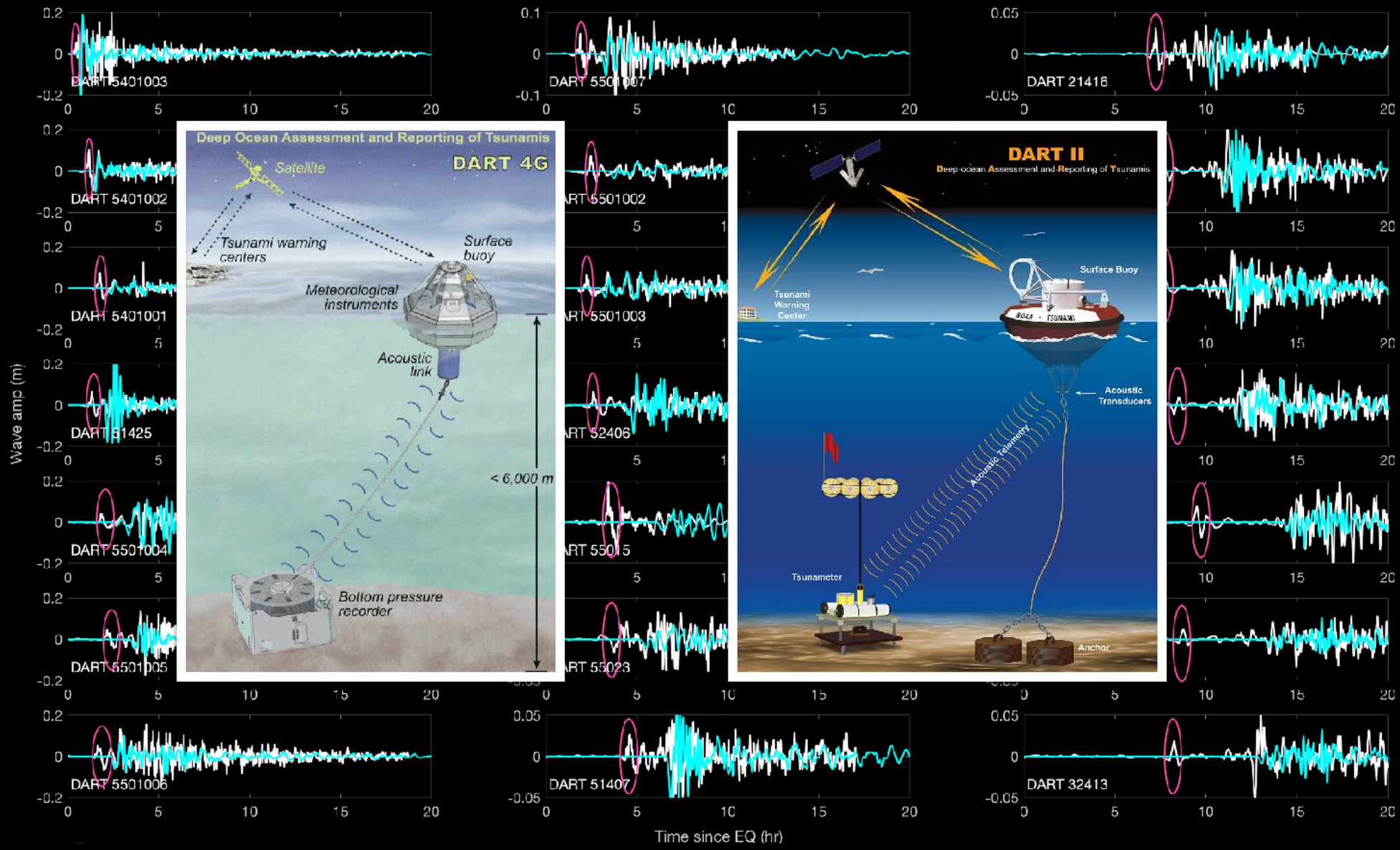
Earth and Planetary Sciences
University of New Mexico
Los Alamos National Laboratory

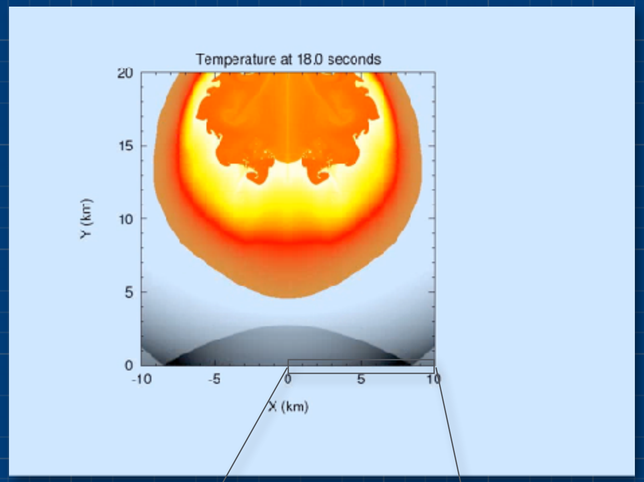


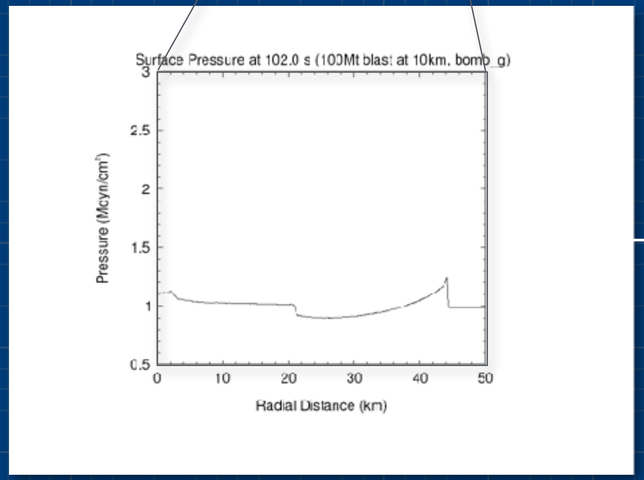
The initial atmospheric response to the eruption was captured by Mathew Barlow using NOAA's GOES-West satellite infrared radiance data (band 13). This sequence is based on images taken 10 minutes apart, and colors show the difference in infrared radiance between each time step.
Credit: Mathew Barlow/University of Massachusetts Lowell.
@MathewABarlow - Environmental, Earth, and Atmospheric Sciences - University of Massachusetts Lowell

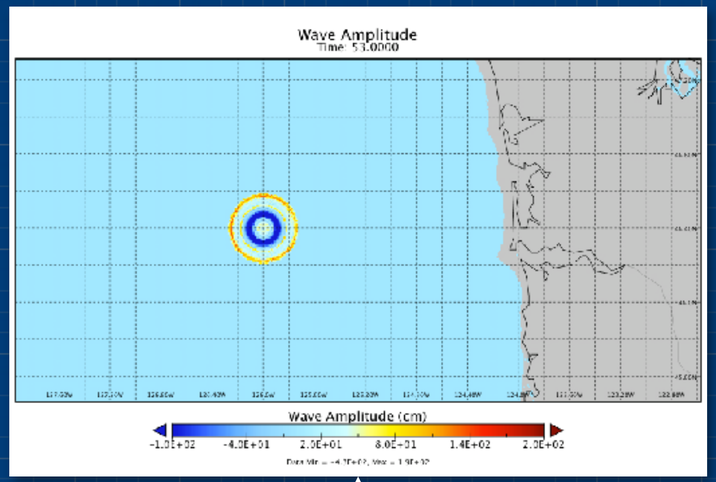
DART records tsunami across the Pacific

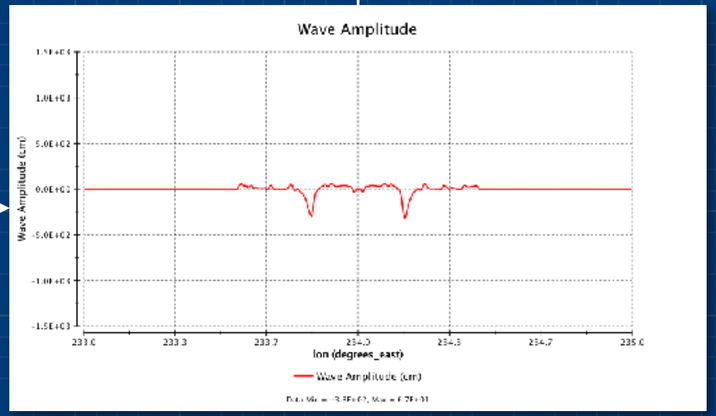


Asteroid Airburst tsunami models



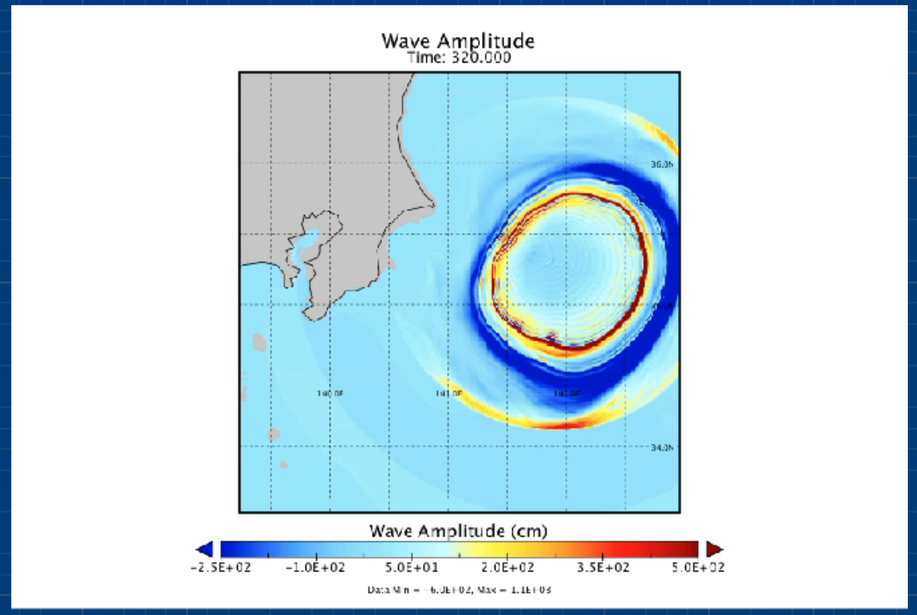




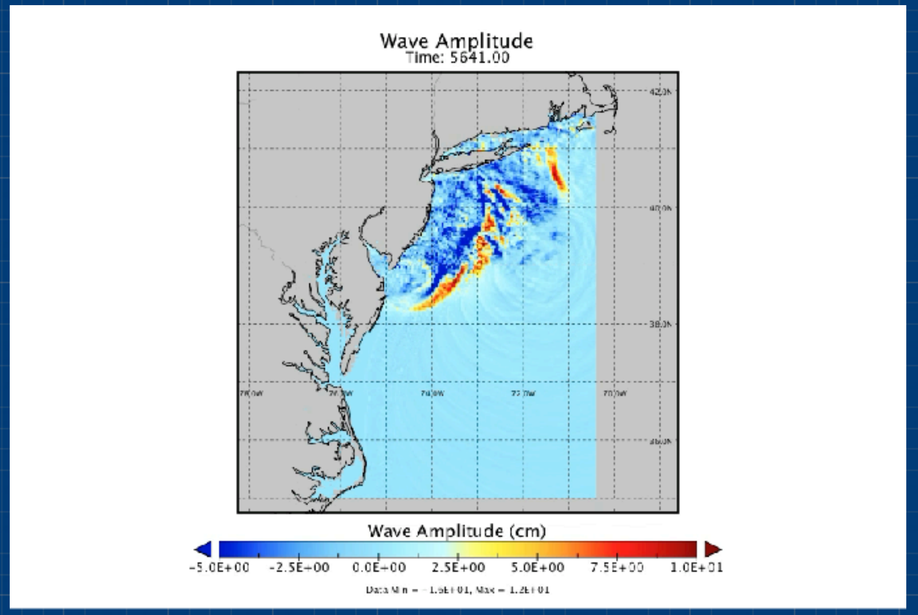


Comparing Two Types of Tsunamis Generated by Pressure-forcing

Proudman Amplification $\eta = \frac{c^2 \eta_s}{c^2 - U^2} = \frac{\eta_s}{1 - F^2}$



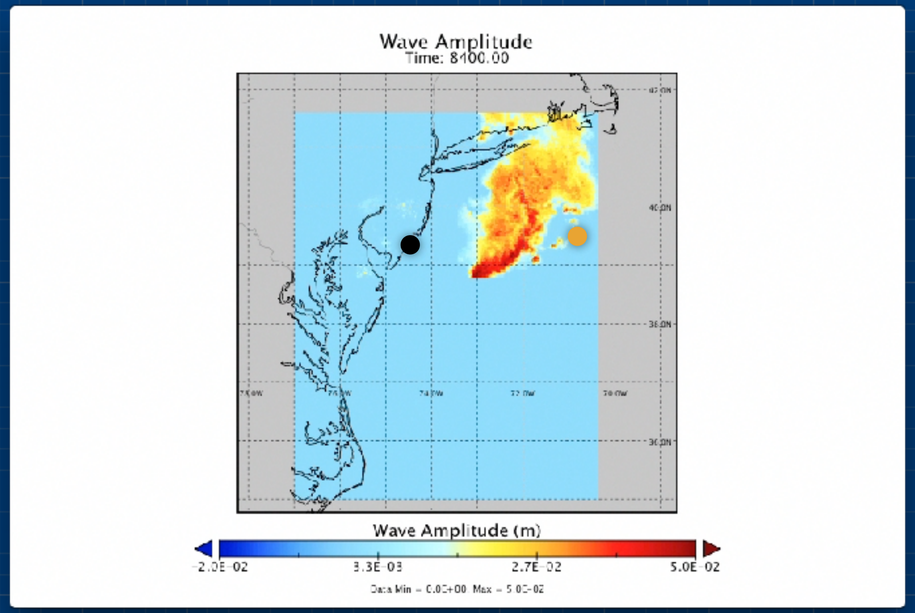
Air blast
over deep water

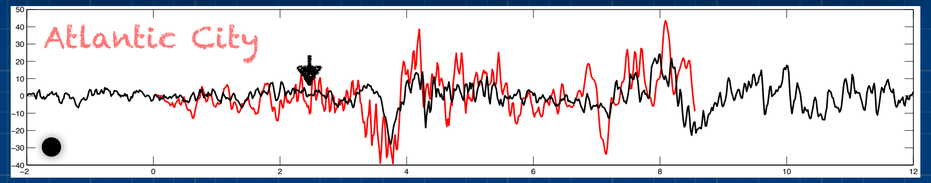


Meteo tsunami
over shallow water

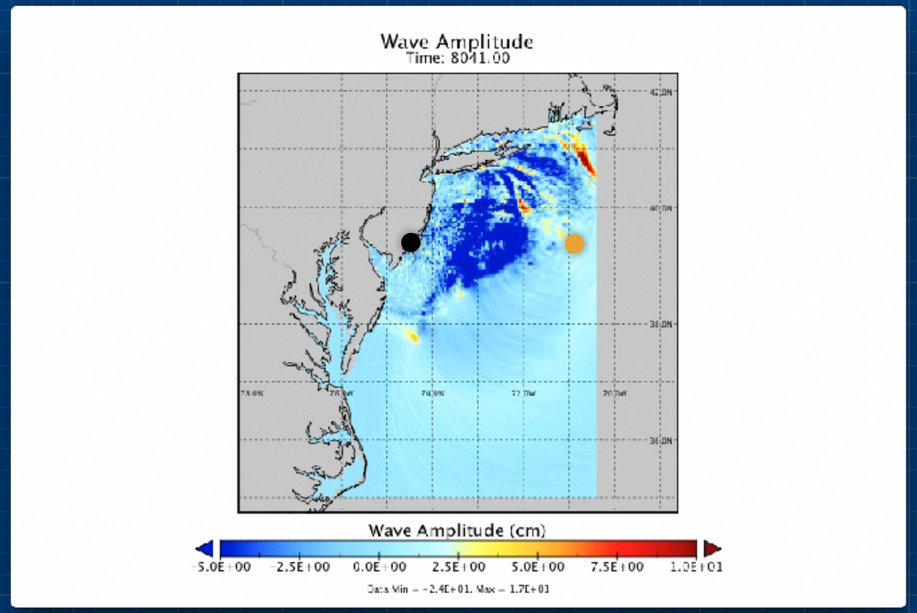
13 June 2013 meteotsunami event

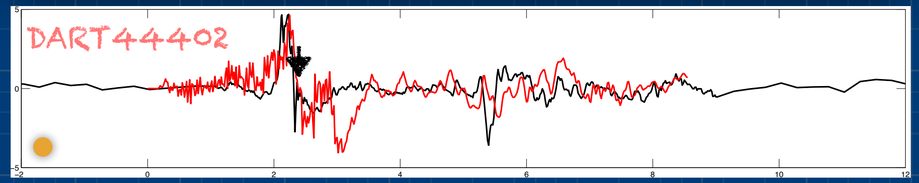
Pressure Forcing



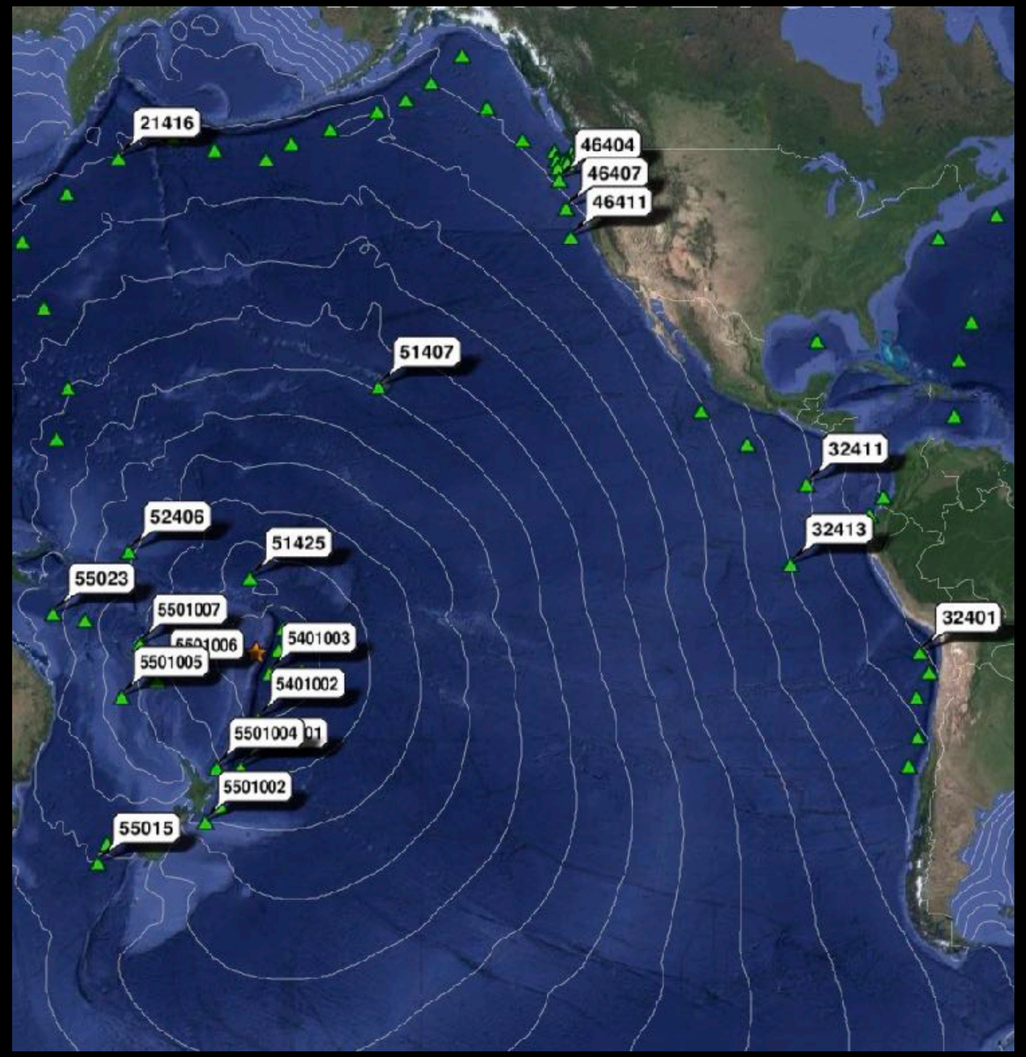


Generated Tsunami



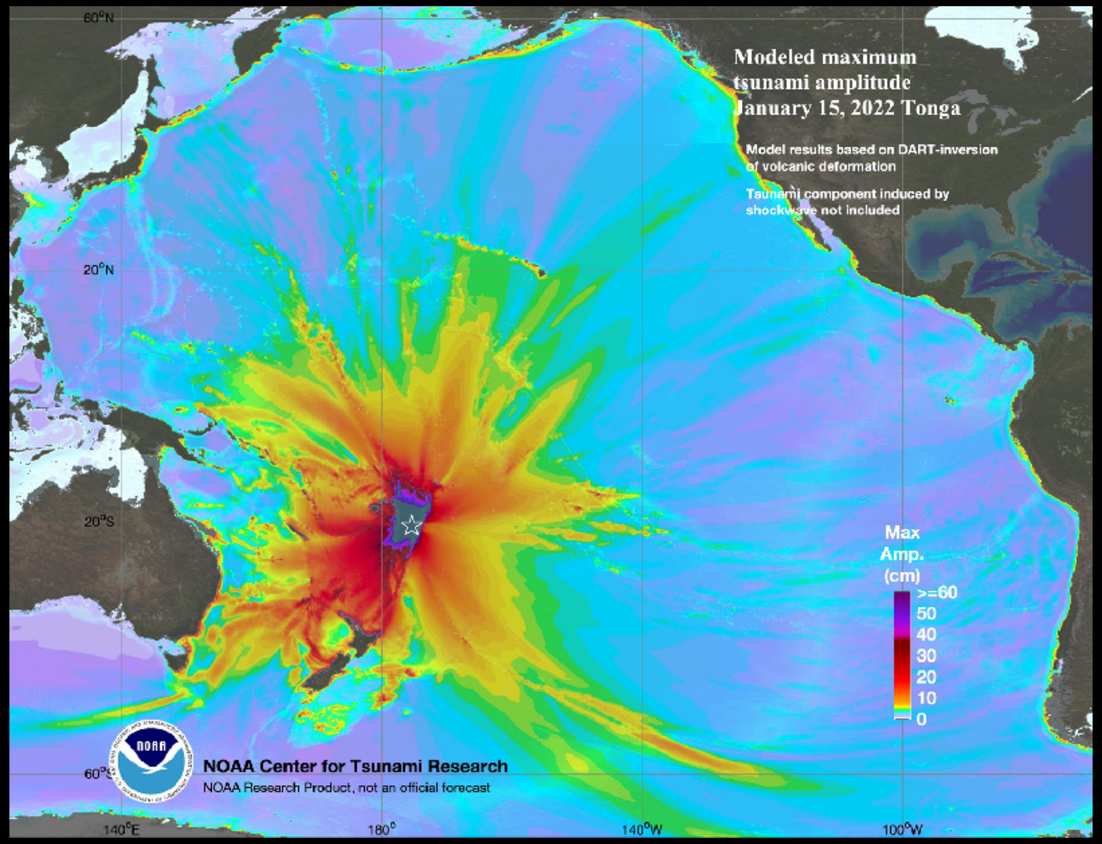


Tonga tsunami recorded at DART around Pacific

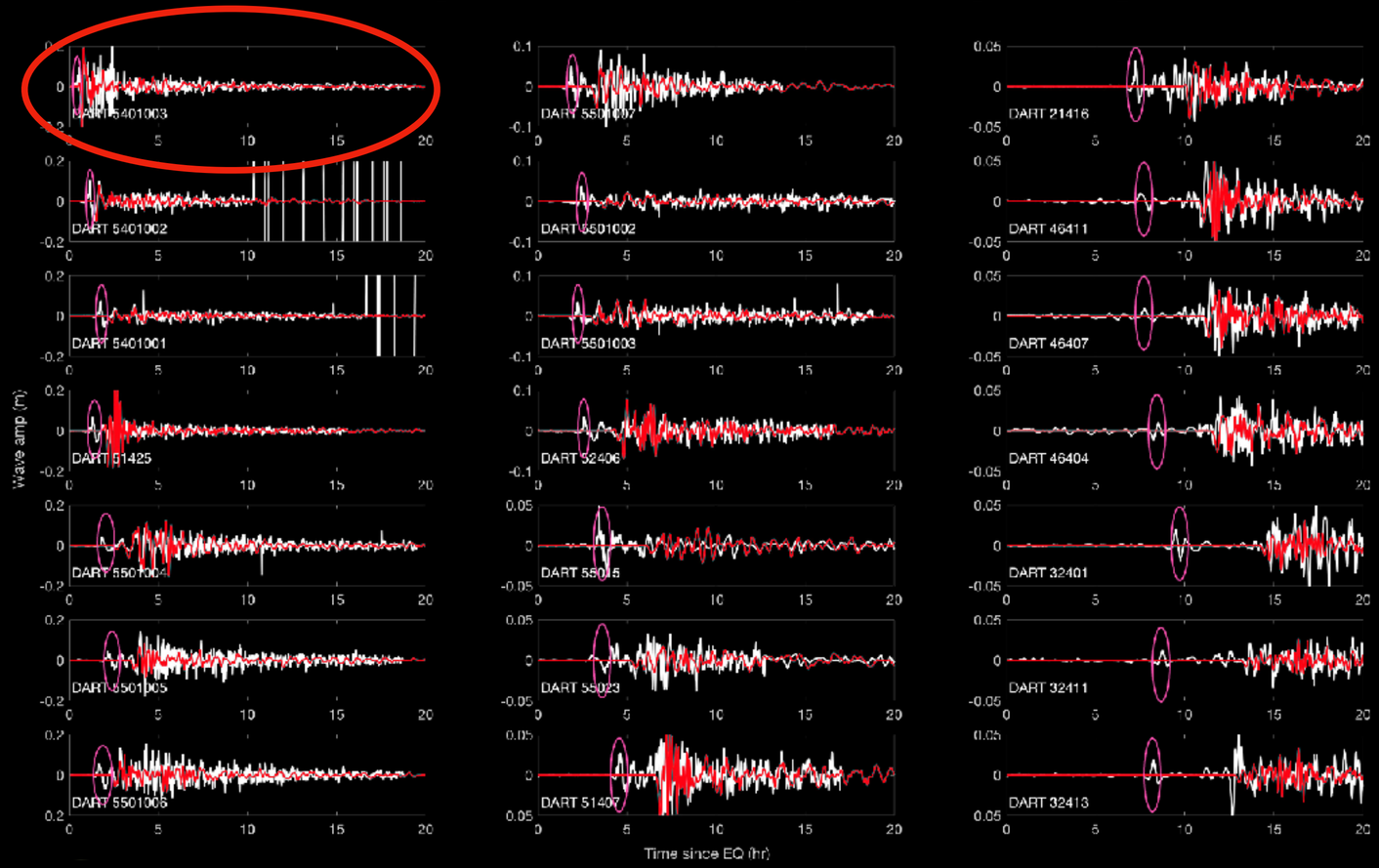


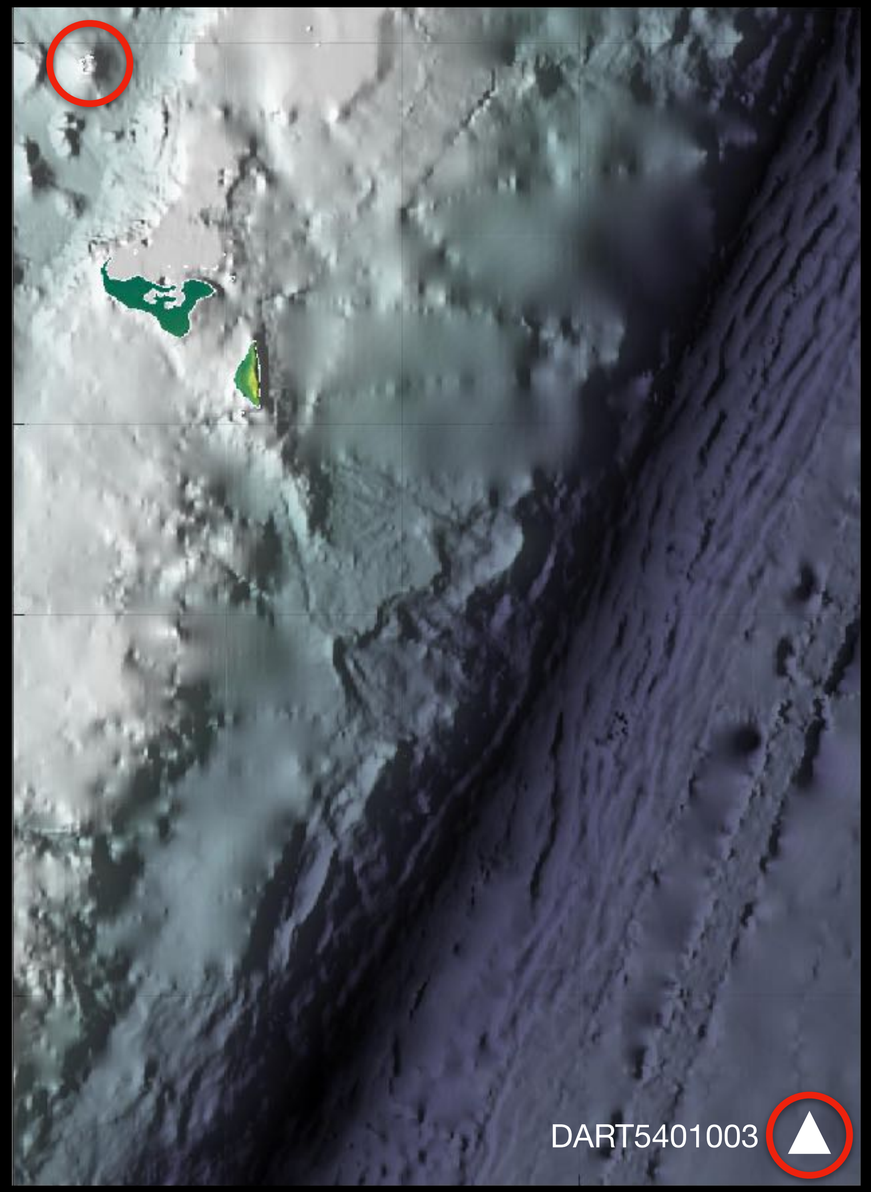
Tonga Initial DART data inversion

Assuming displacement source at the volcano location



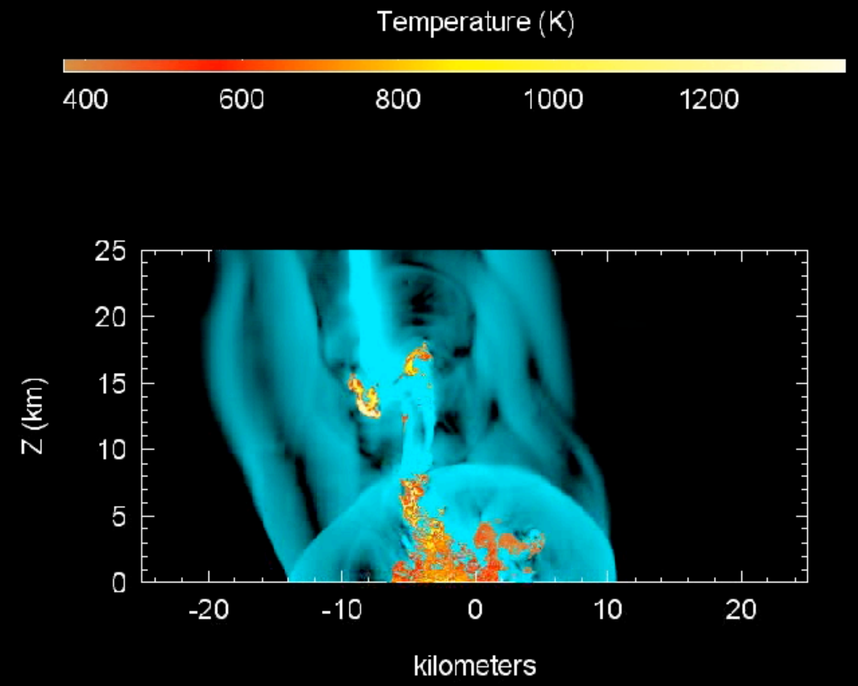
Model inversion results using three DARTs for the January 15, 2022 Tonga volcano-generated event





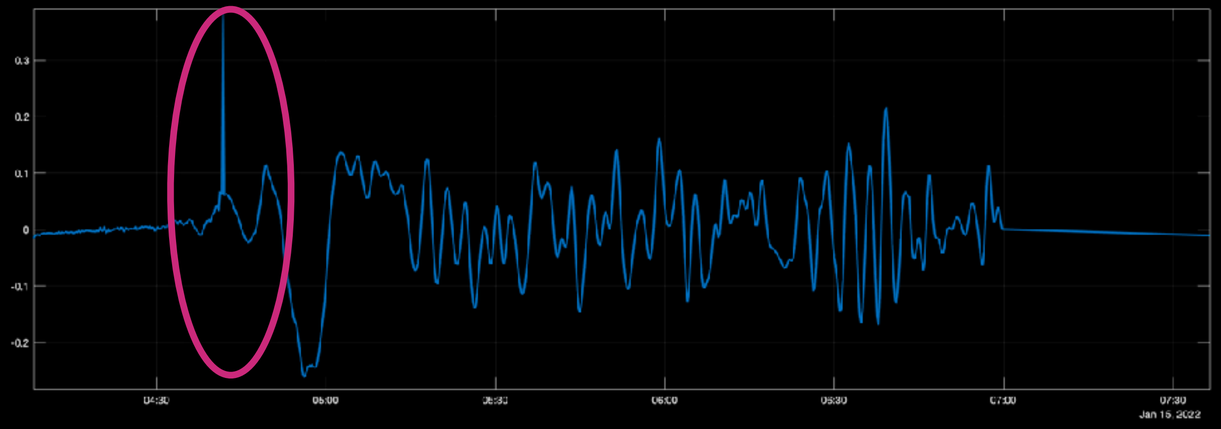
Yield = 250 Mt

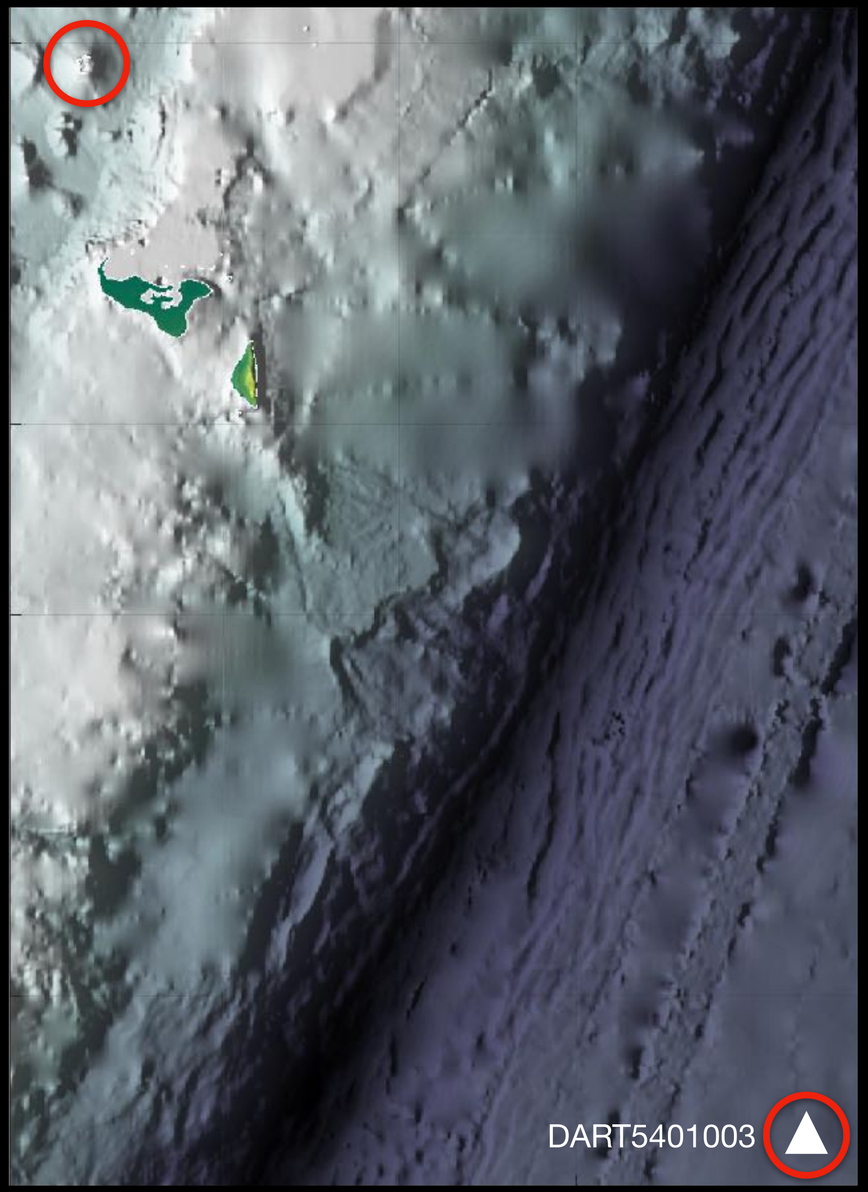
Entry angle = 75°

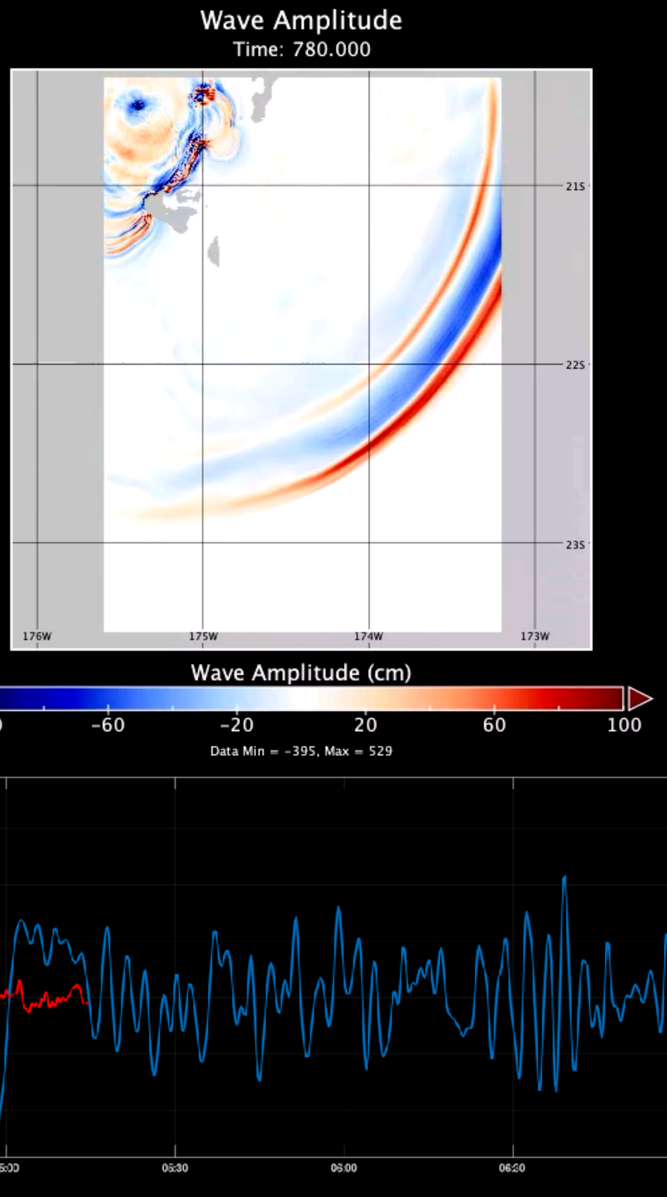


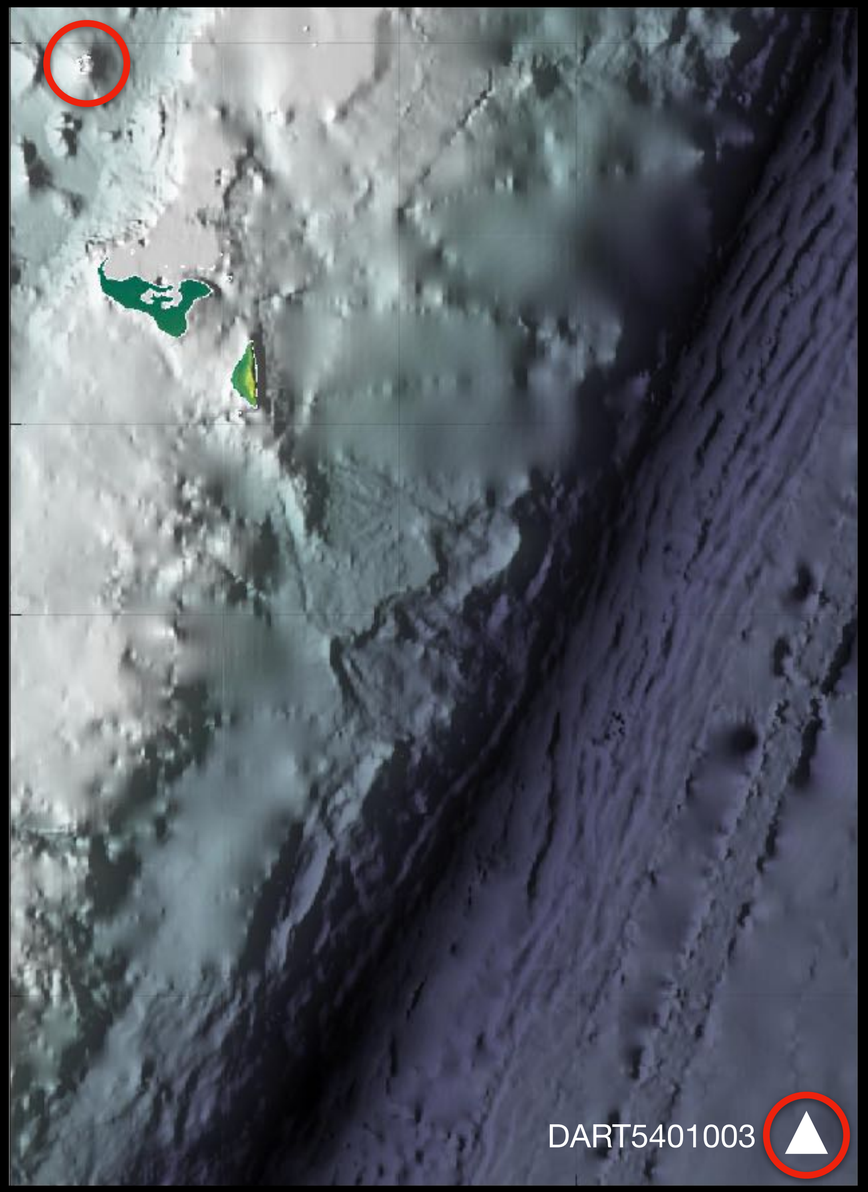
Time = 36.0 s

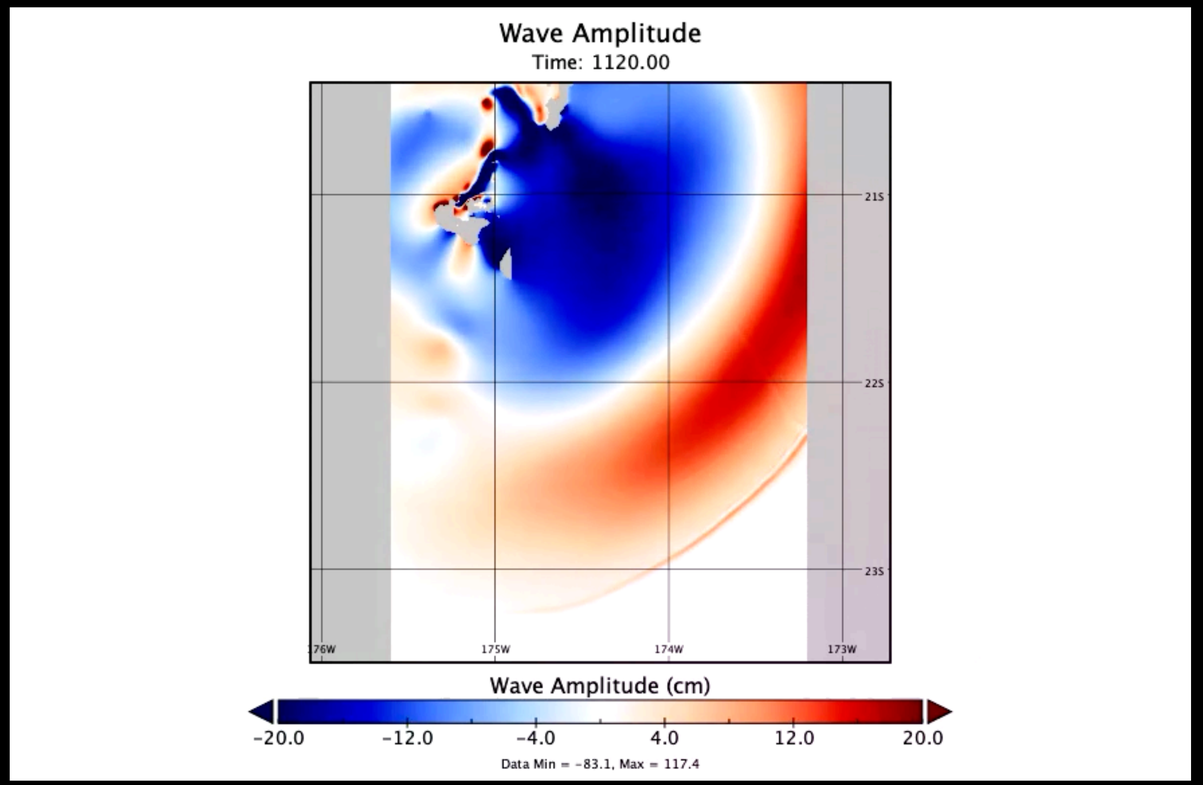
Line source 250mt_i

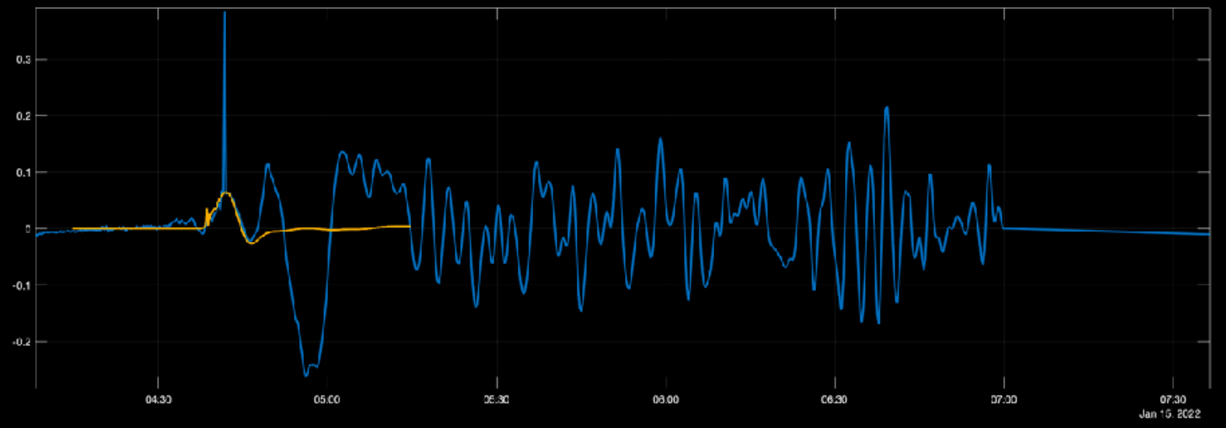


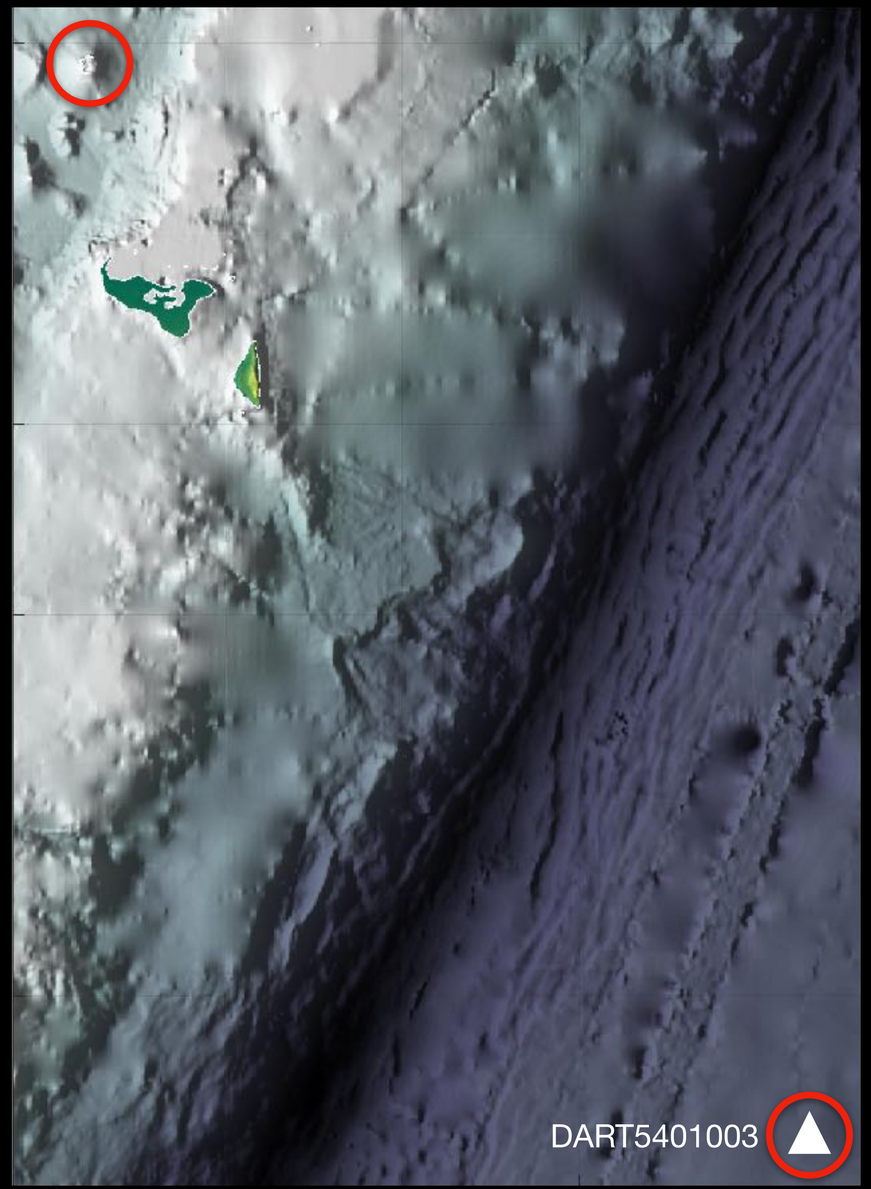

DART5401003

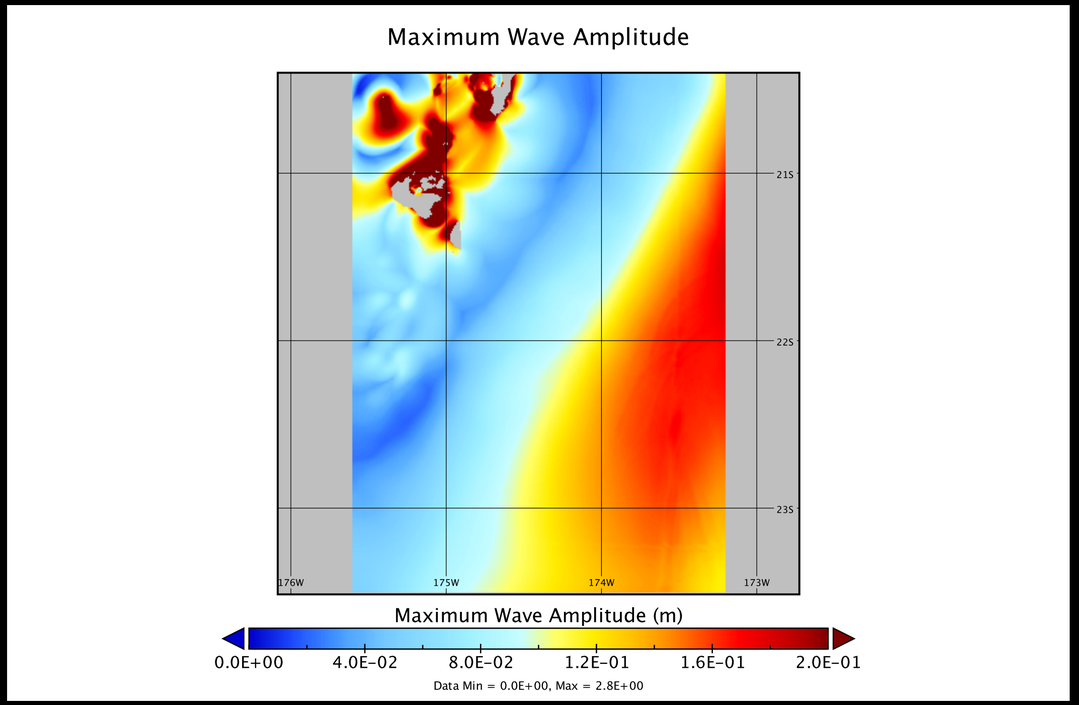

Wave Amplitude
Time: 780.000
21S
22S
23S
176W
175W
174W
173W
Wave Amplitude (cm)
-100
-60
-20
20
60
100
Data Min = -395, Max = 529
0.3
0.2
0.1
0
-0.1
-0.2
04:30
05:00
05:30
06:00
06:30
07:00
07:30
Jan 15, 2022

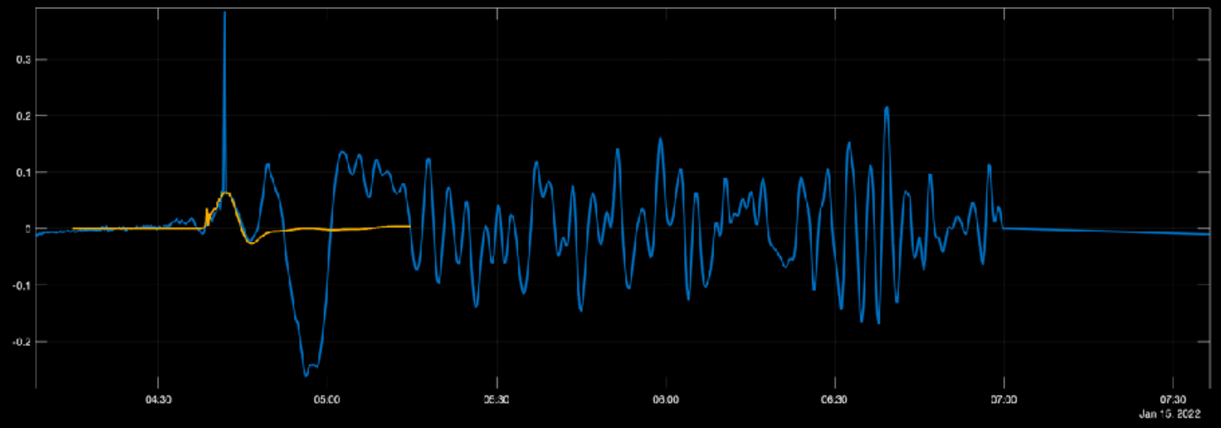

DART5401003


Wave Amplitude
Time: 1120.00
21S
22S
23S
176W
175W
174W
173W
Wave Amplitude (cm)
-20.0
-12.0
-4.0
4.0
12.0
20.0
Data Min = -83.1, Max = 117.4

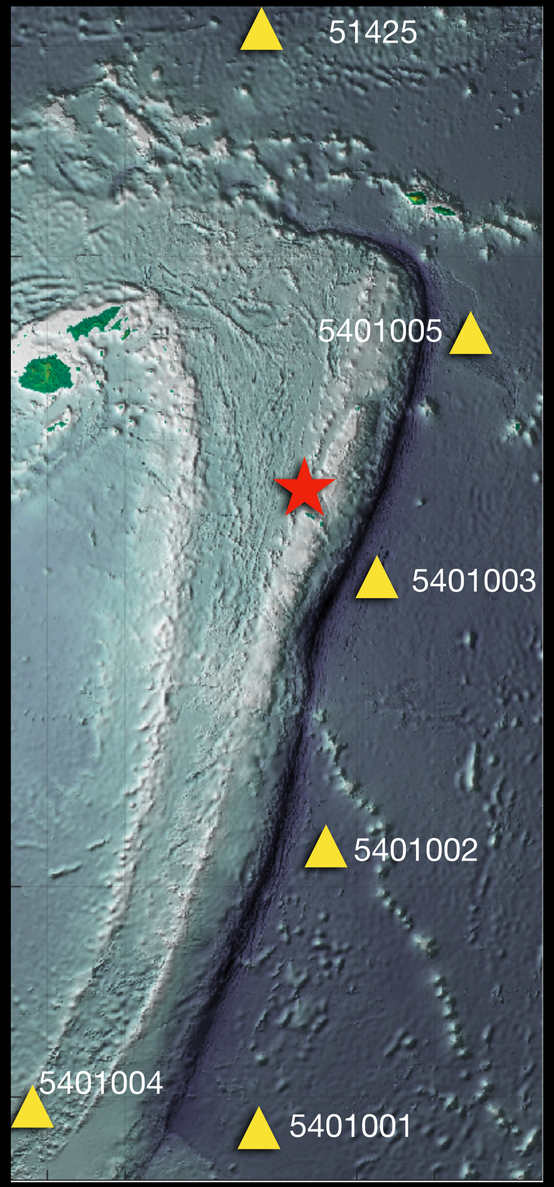

0.3
0.2
0.1
0
-0.1
-0.2
04:30
05:00
05:30
06:00
06:30
07:00
07:30
Jan 15 2022


DART5401003

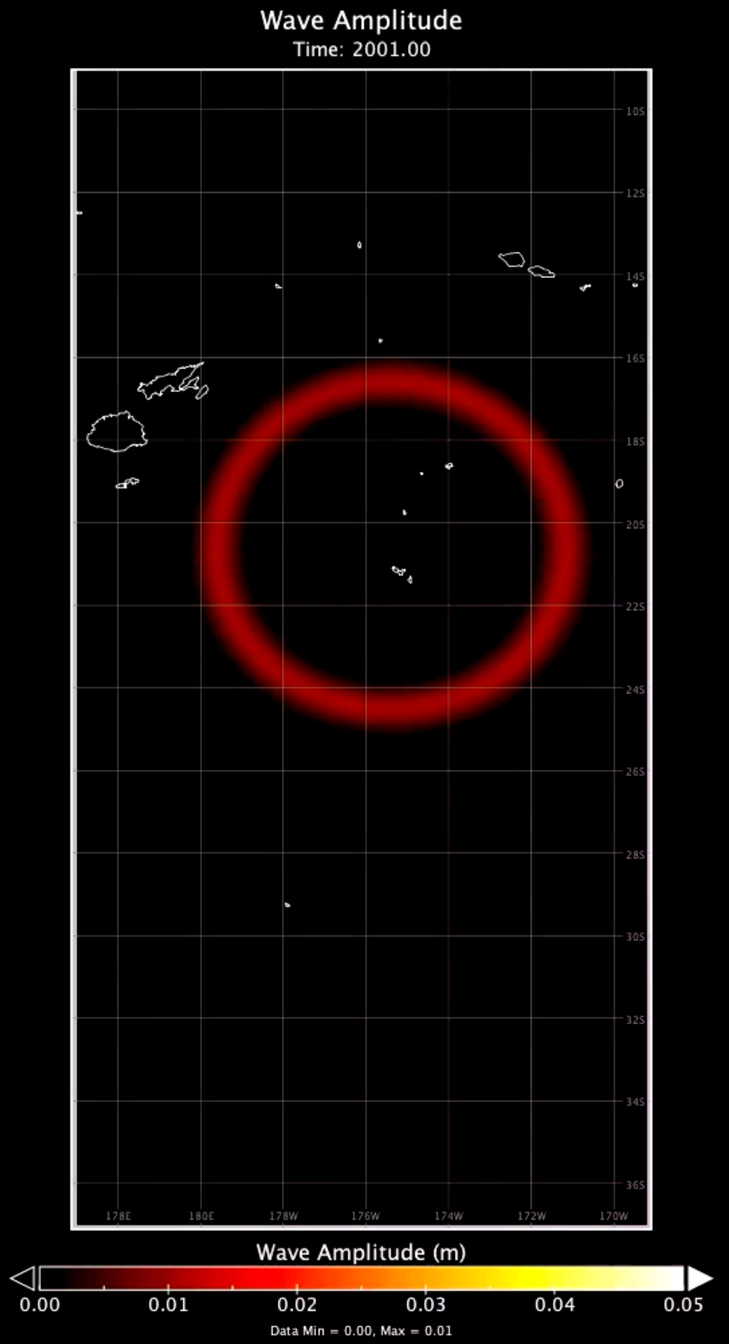

Maximum Wave Amplitude
21S
22S
23S
176W
175W
174W
173W
Maximum Wave Amplitude (m)
0.0E+00
4.0E-02
8.0E-02
1.2E-01
1.6E-01
2.0E-01
Data Min = 0.0E+00, Max = 2.8E+00


0.3
0.2
0.1
0
-0.1
-0.2
04:30
05:00
05:30
06:00
06:30
07:00
07:30
Jan 15 2022

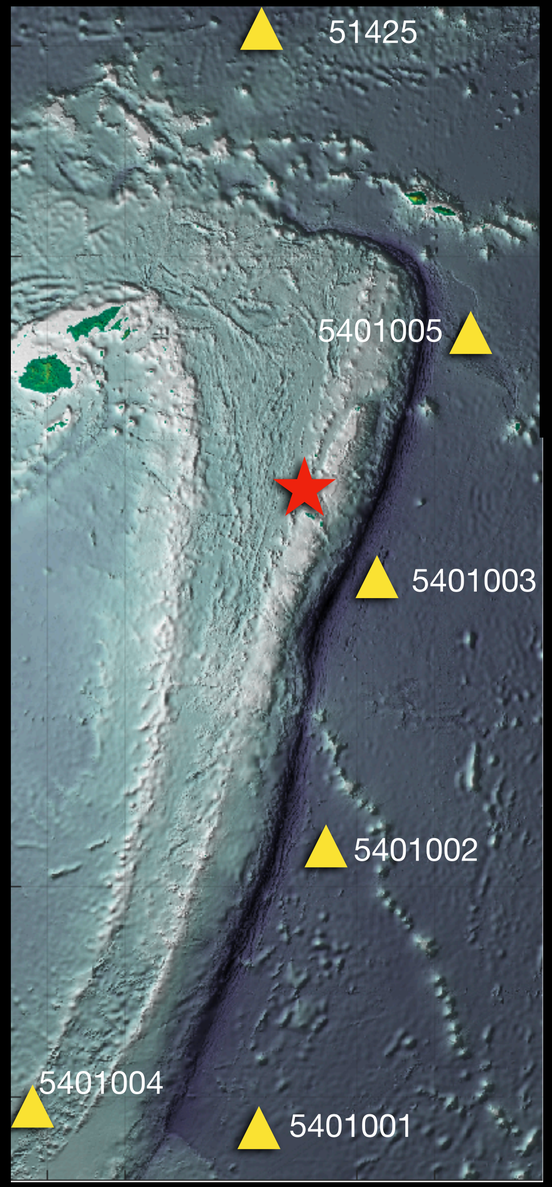
Larger area


51425
5401005
5401003
5401002
5401004
5401001


Wave amp (m)
DART 5401003
DART 5401002
DART 5401001
DART 51425
DART 5501004
DART 5501005
0.2
0
-0.2
0
5
10
15
20


Wave Amplitude
Time: 2001.00
Wave Amplitude (m)
0.00
0.01
0.02
0.03
0.04
0.05
Data Min = 0.00, Max = 0.01

Larger area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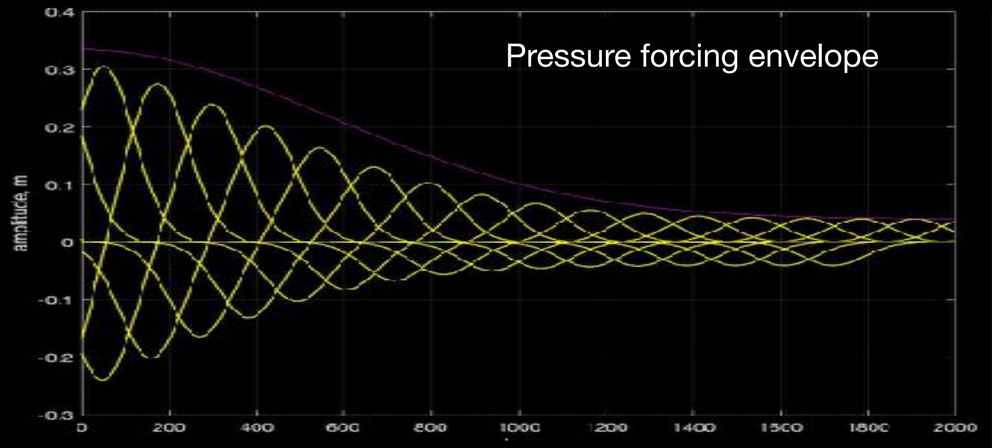
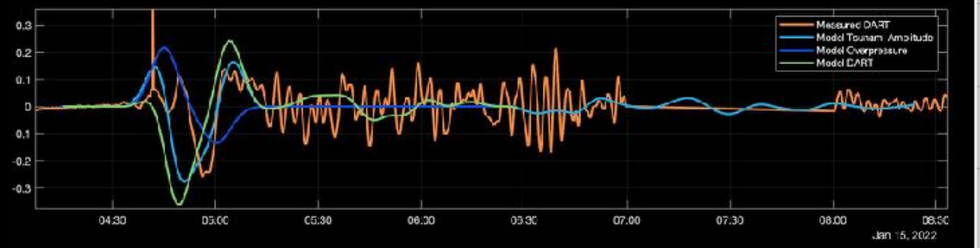
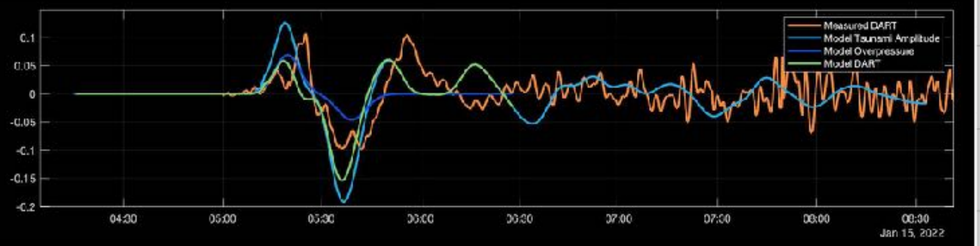
5401005
5401003
5401002
5401004
5401001


Pressure forcing envelope
amplitude, m

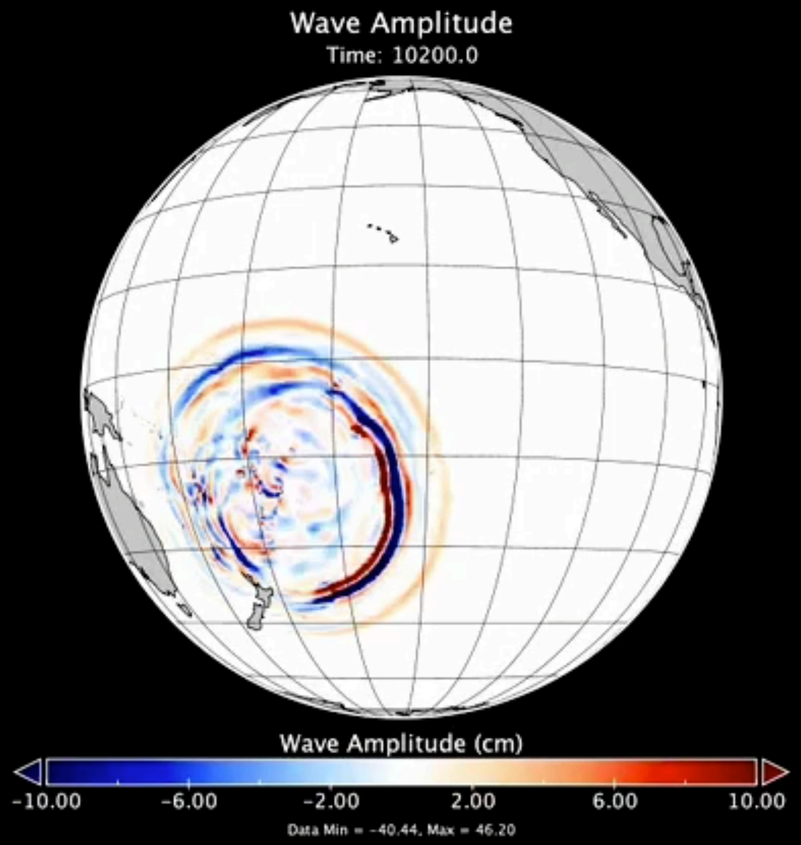

Measured DART
Model Tsunami Amplitude
Model Overpressure
Model DART
Jan 15, 2022


Measured DART
Model Tsunami Amplitude
Model Overpressure
Model DART
Jan 15, 2022

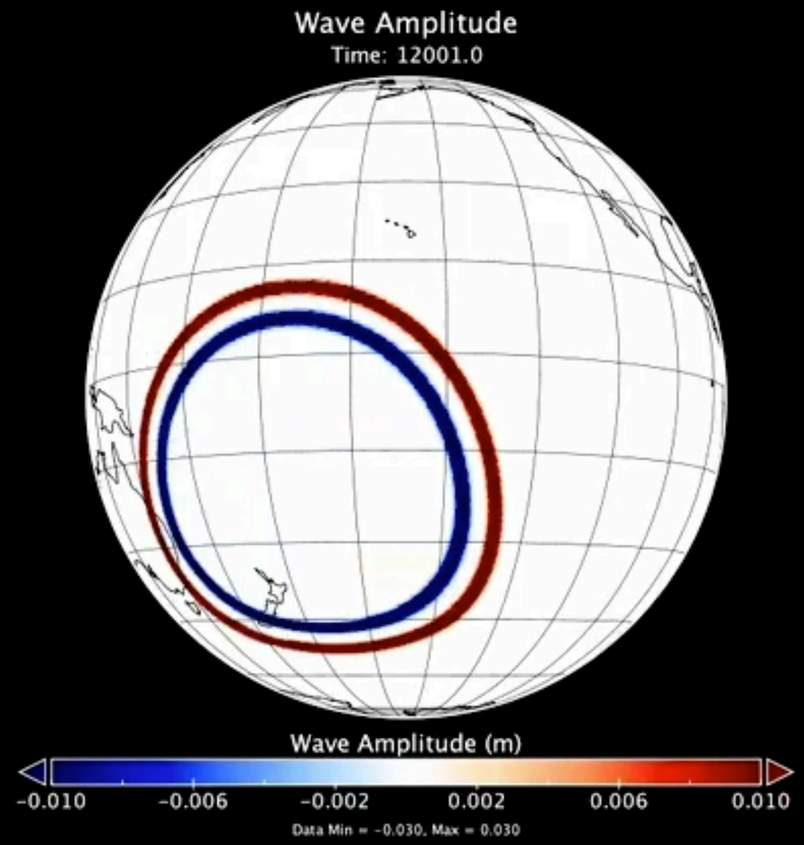

Wave Amplitude
Time: 2001.00
Wave Amplitude (m)
0.00
0.01
0.02
0.03
0.04
0.05
Data Min = 0.00, Max = 0.01

Pacific propagation

Tsunami Amplitudes

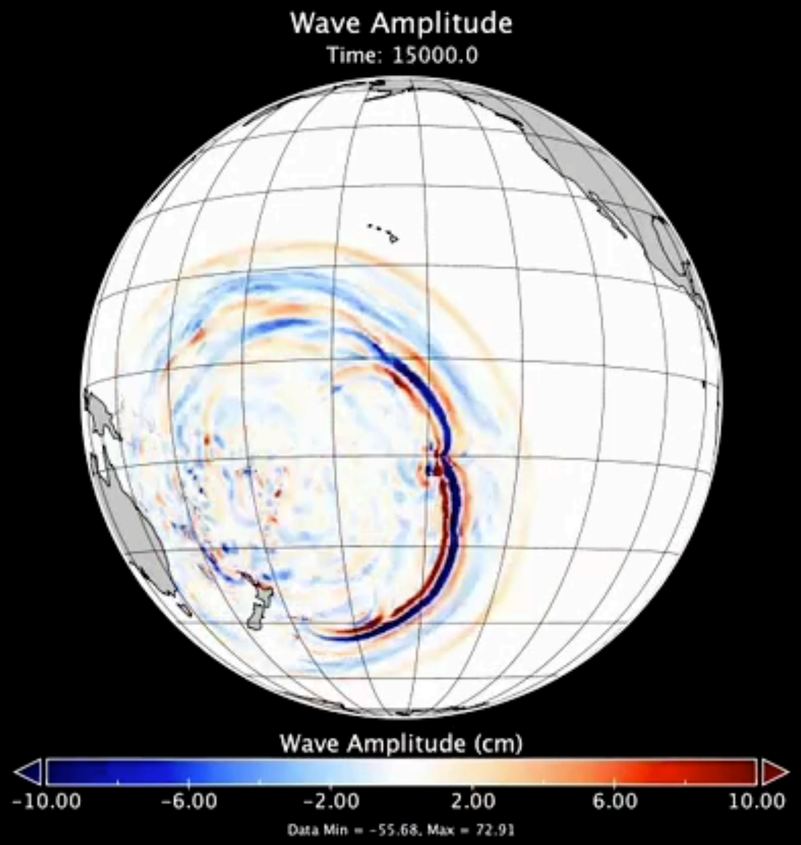


Air Pressure Wave (Gaussian dipole)

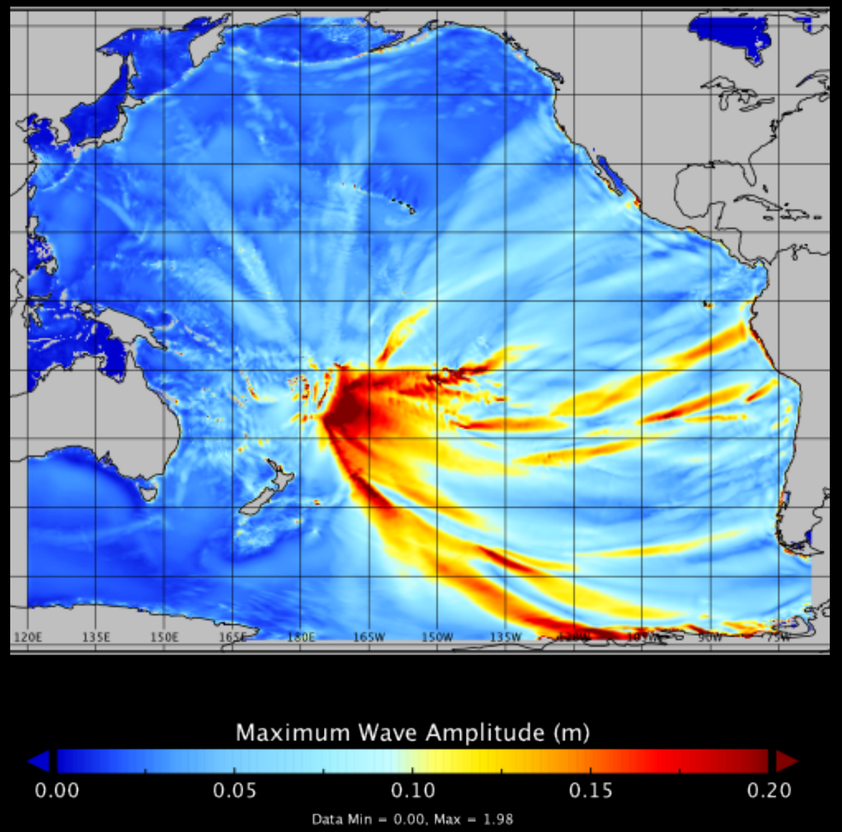


Pacific propagation

Tsunami Amplitudes

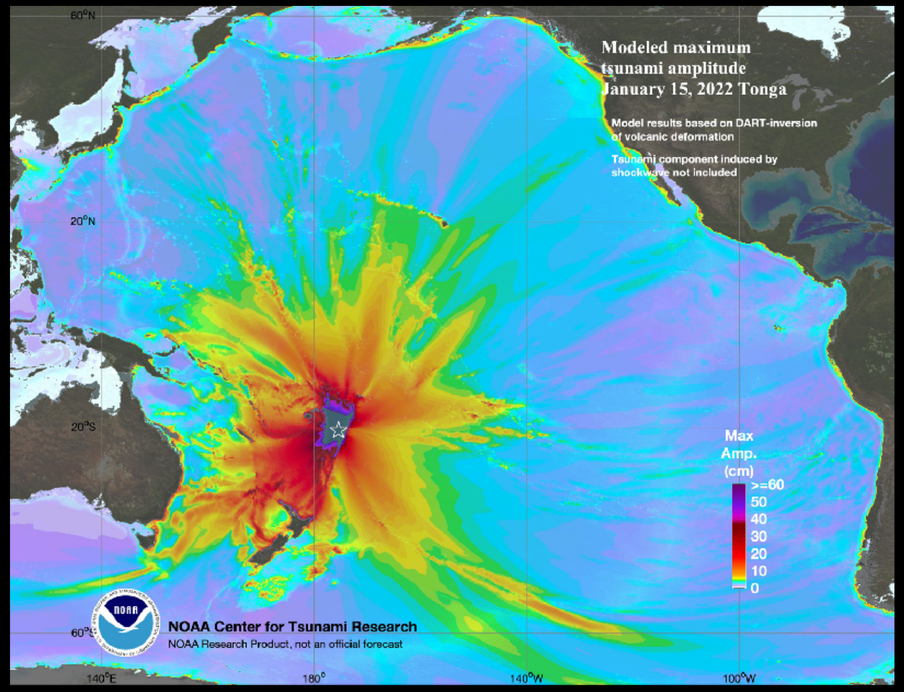


Maximum Computed Tsunami Amplitudes

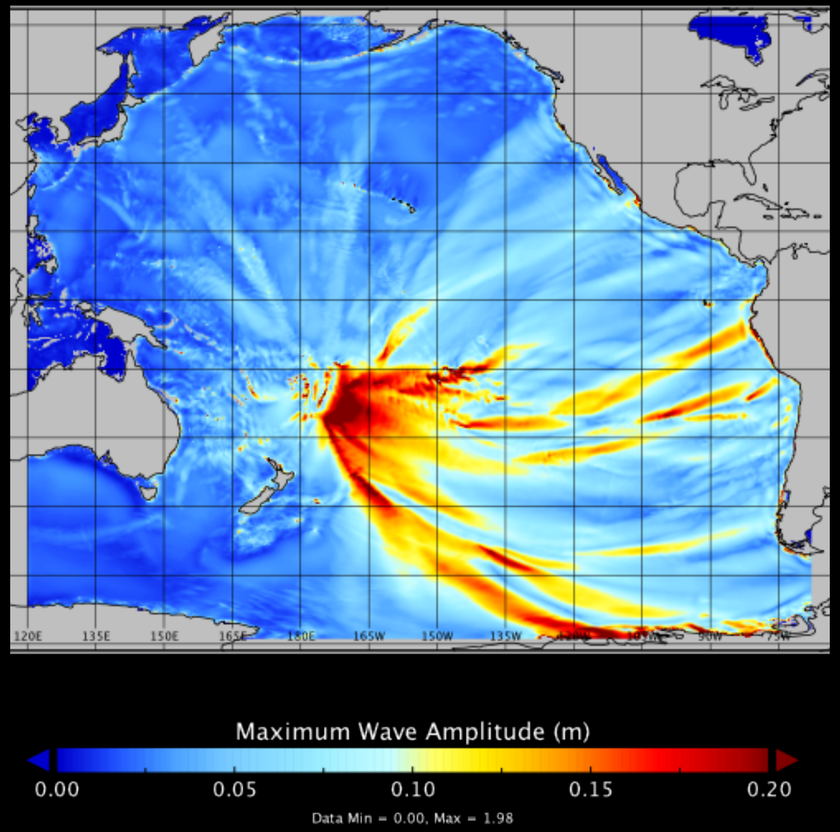


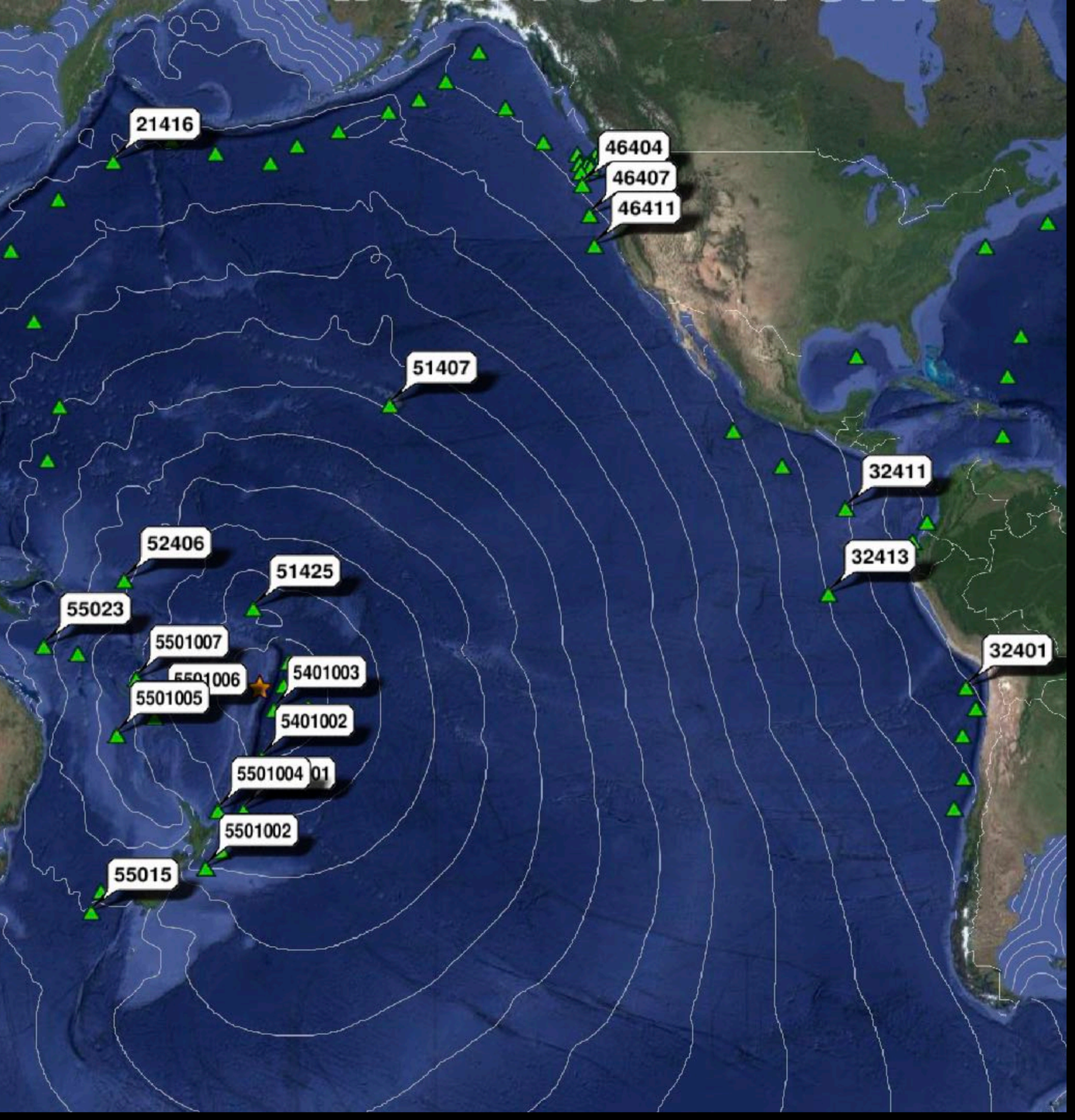
Pacific propagation

Maximum Computed Tsunami Amplitudes
Caldera-centric source



Maximum Computed Tsunami Amplitudes
Air-pressure source




21416
46404
46407
46411
51407
32411
32413
32401
52406
51425
55023
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5501005
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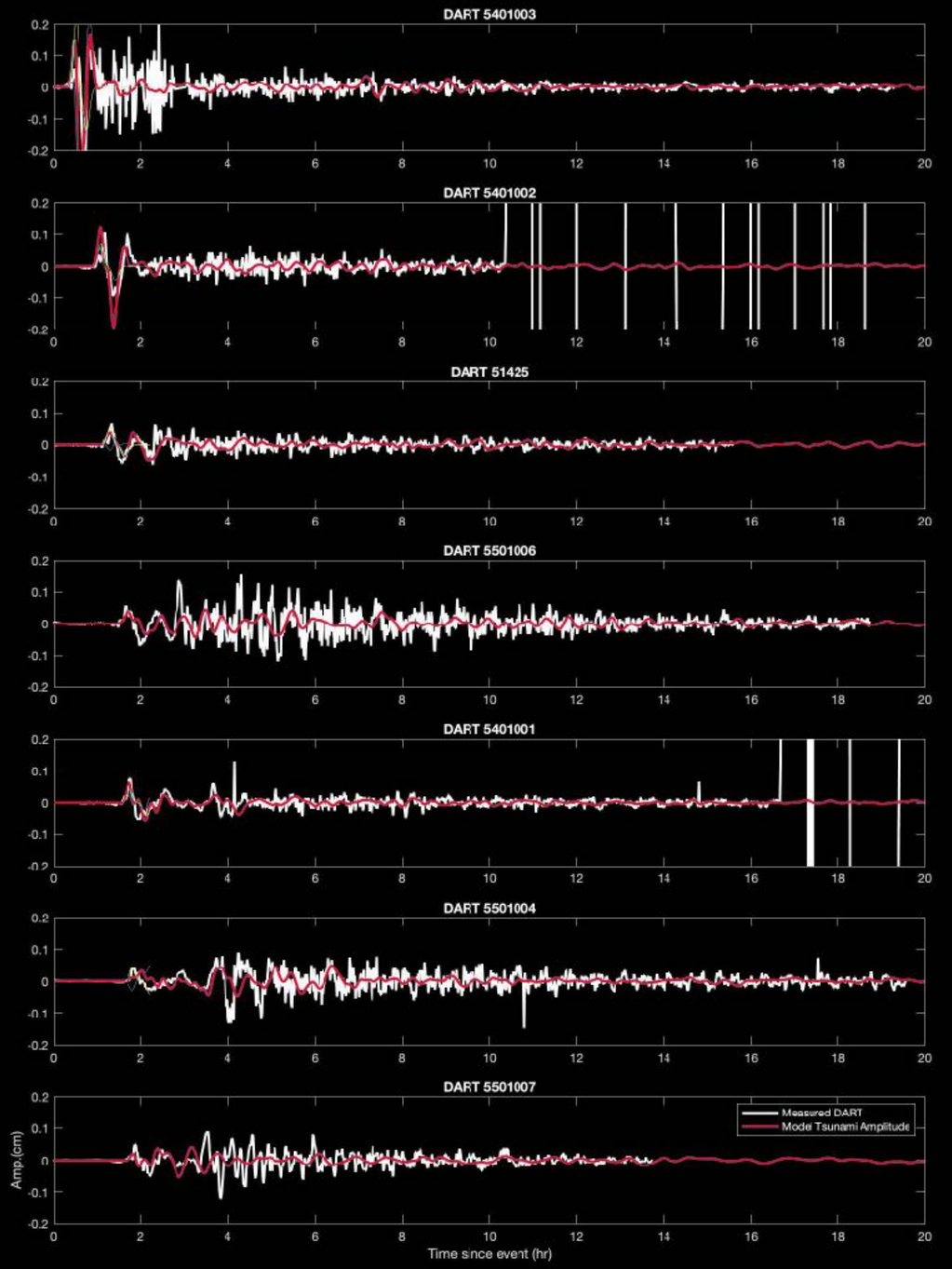
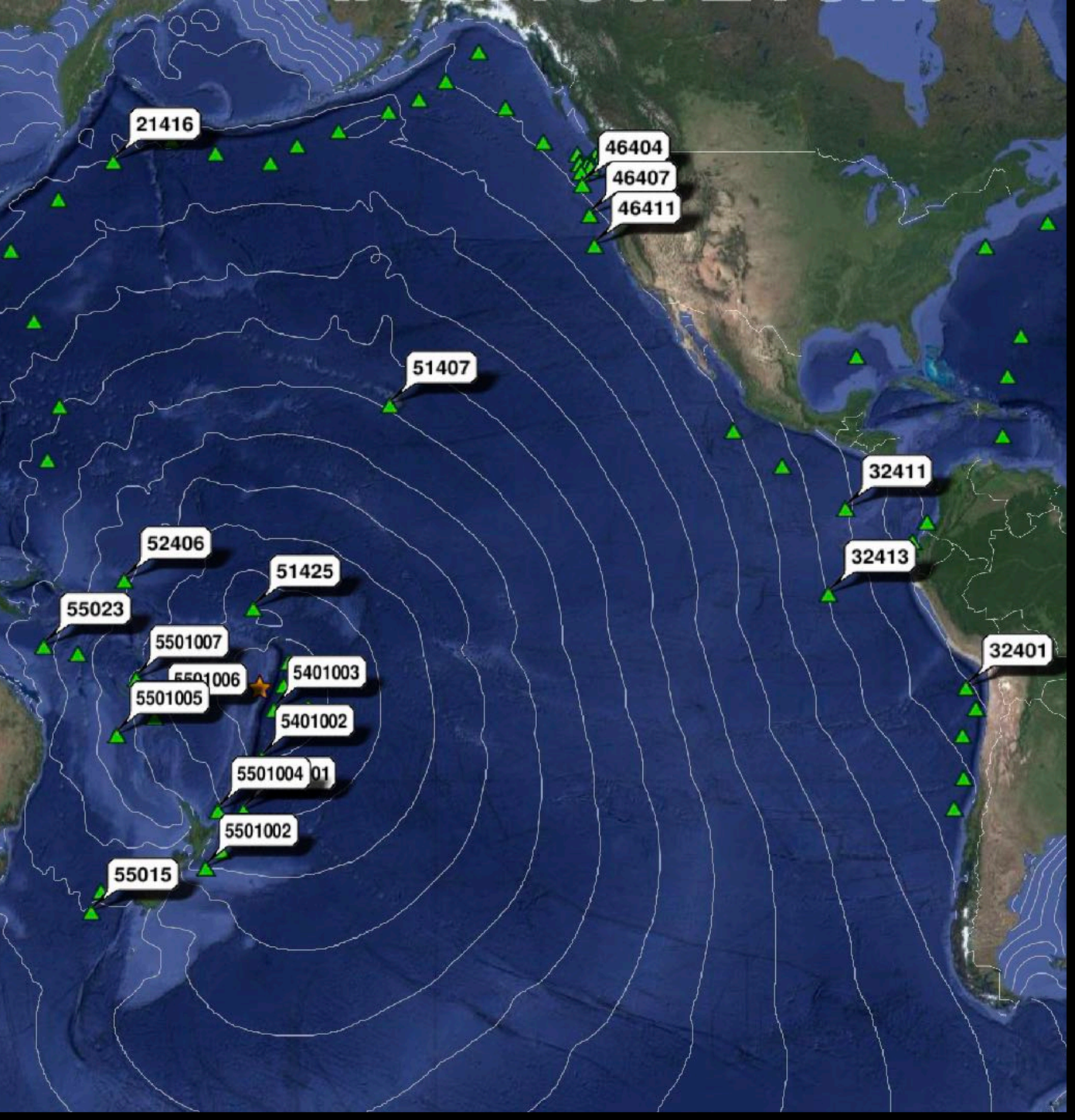
5501002
55015


DART 5401003
DART 5401002
DART 51425
DART 5501006
DART 5401001
DART 5501004
DART 5501007
Measured DART
Model Tsunami Amplitude
Amp (cm)
Time since event (hr)


21416
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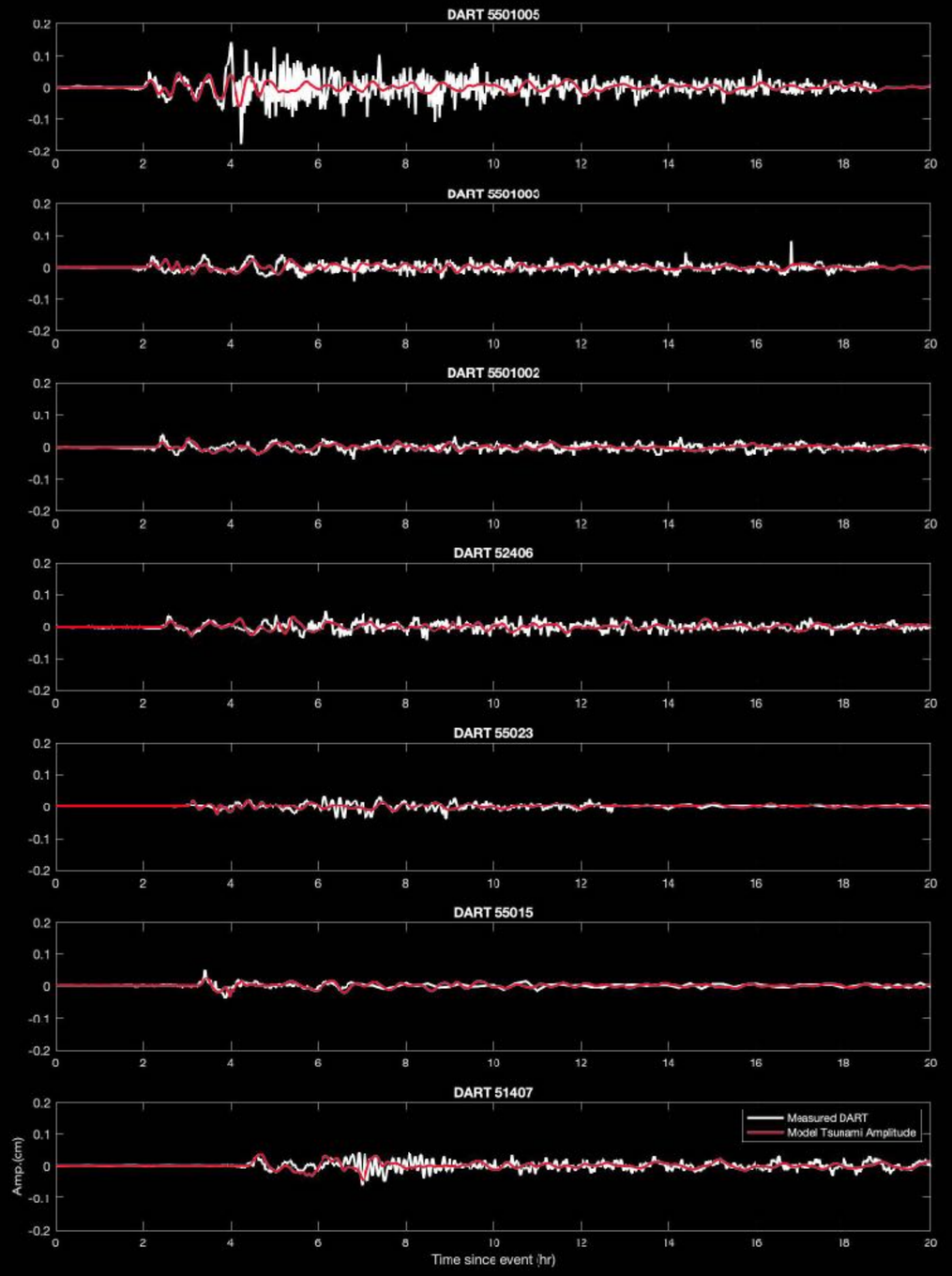
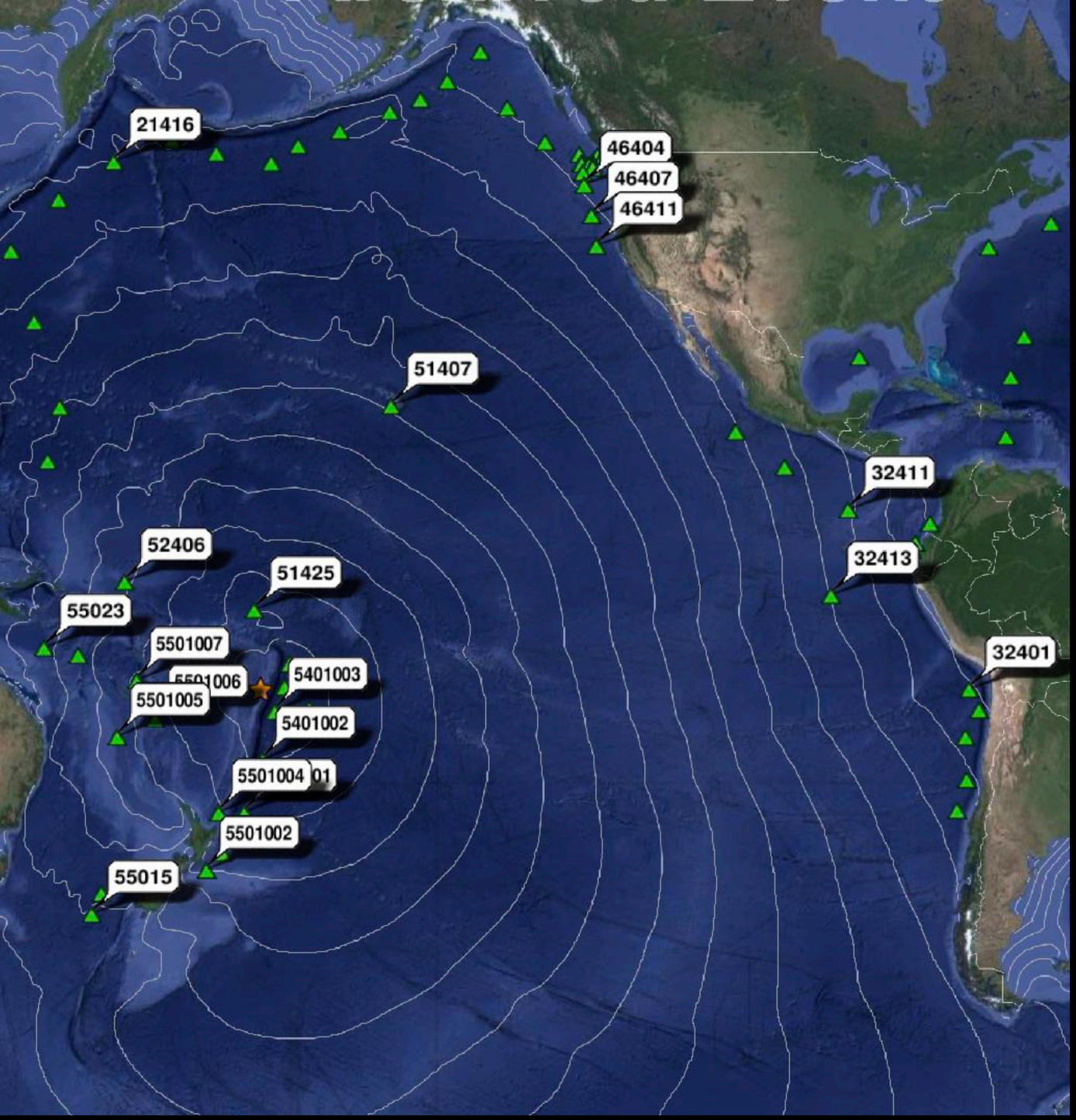
55015


DART 5501005
DART 5501003
DART 5501002
DART 52406
DART 55023
DART 55015
DART 51407
Measured DART
Model Tsunami Amplitude
Amp.(cm)
Time since event (hr)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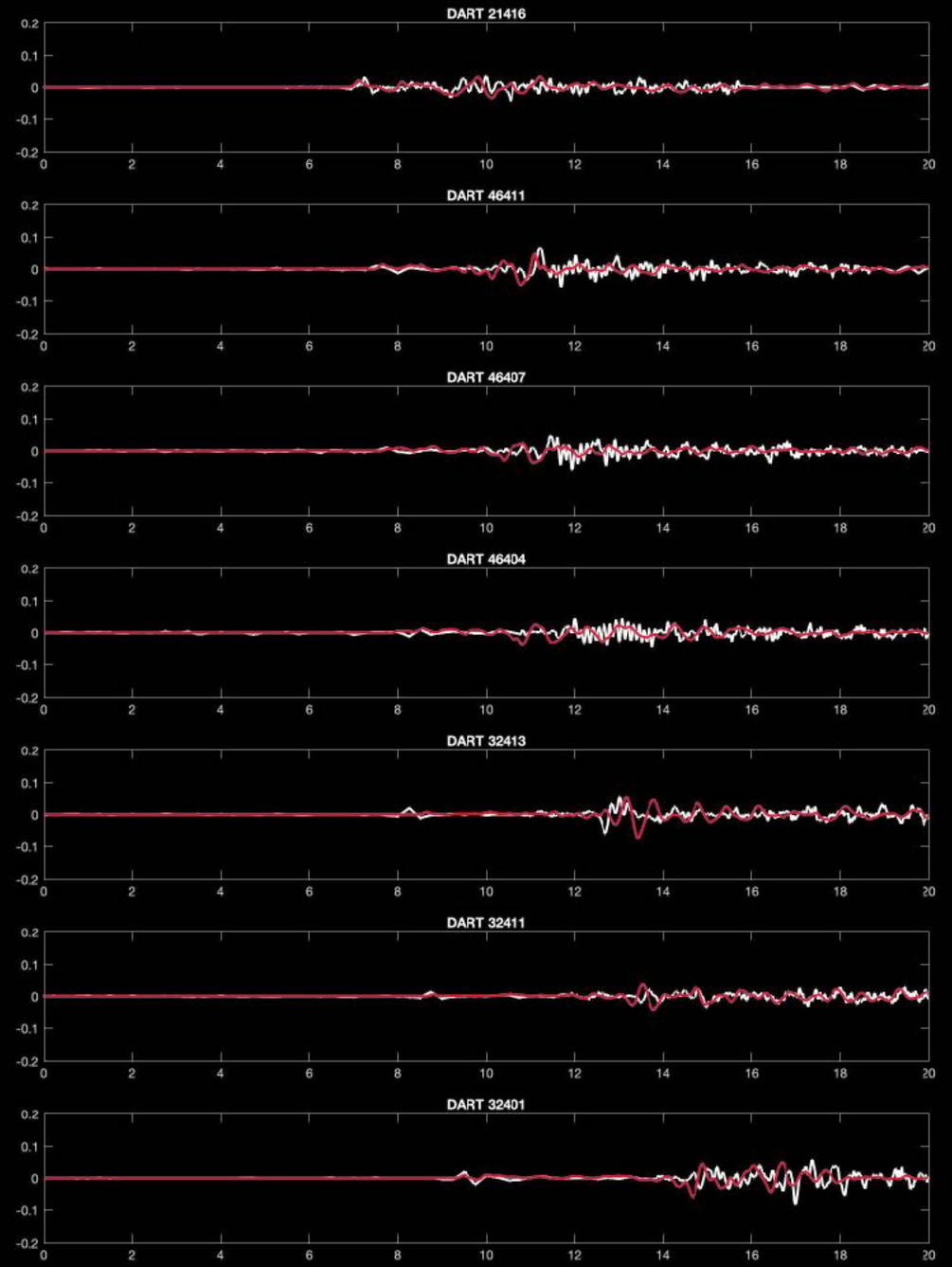
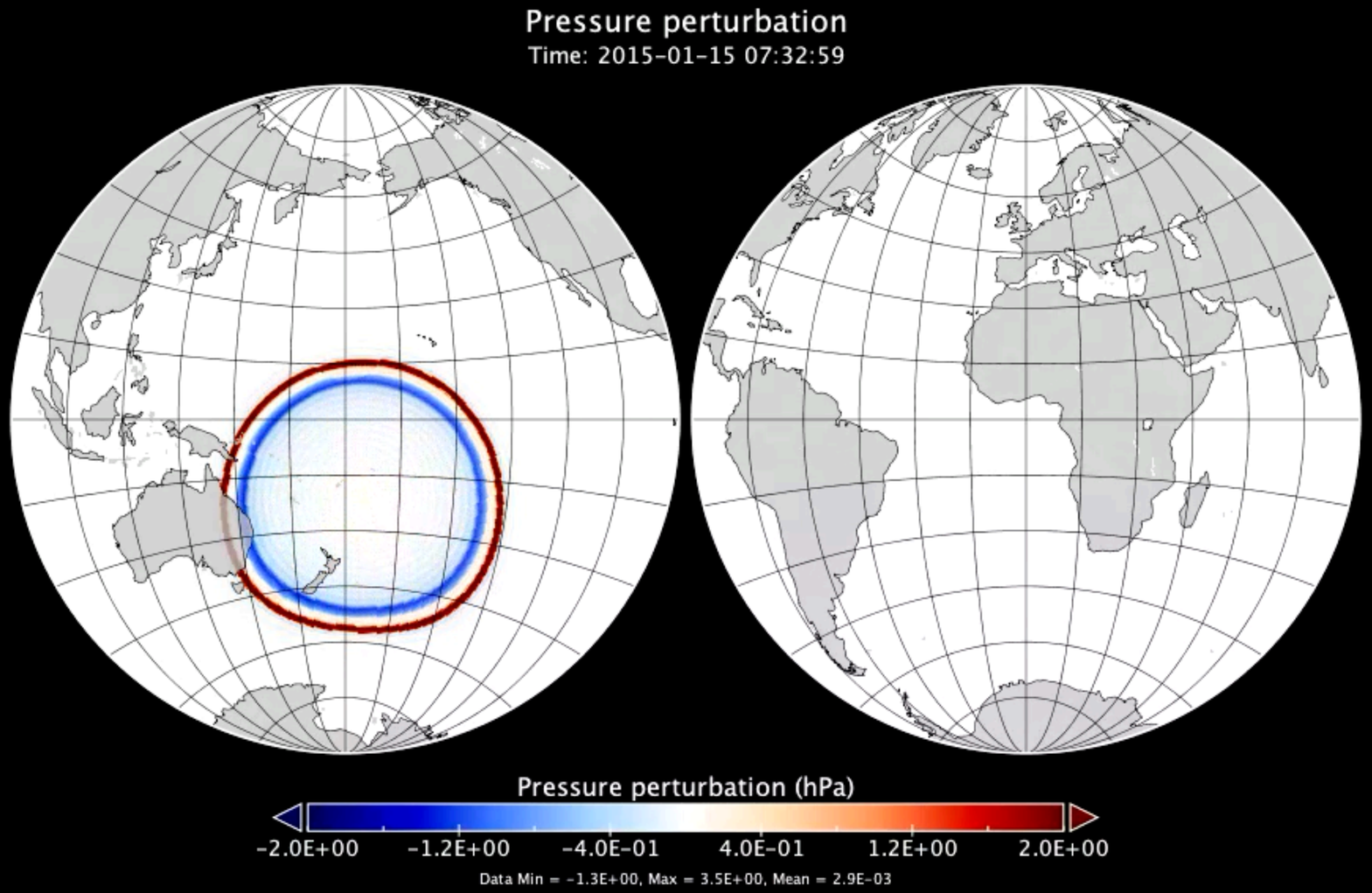
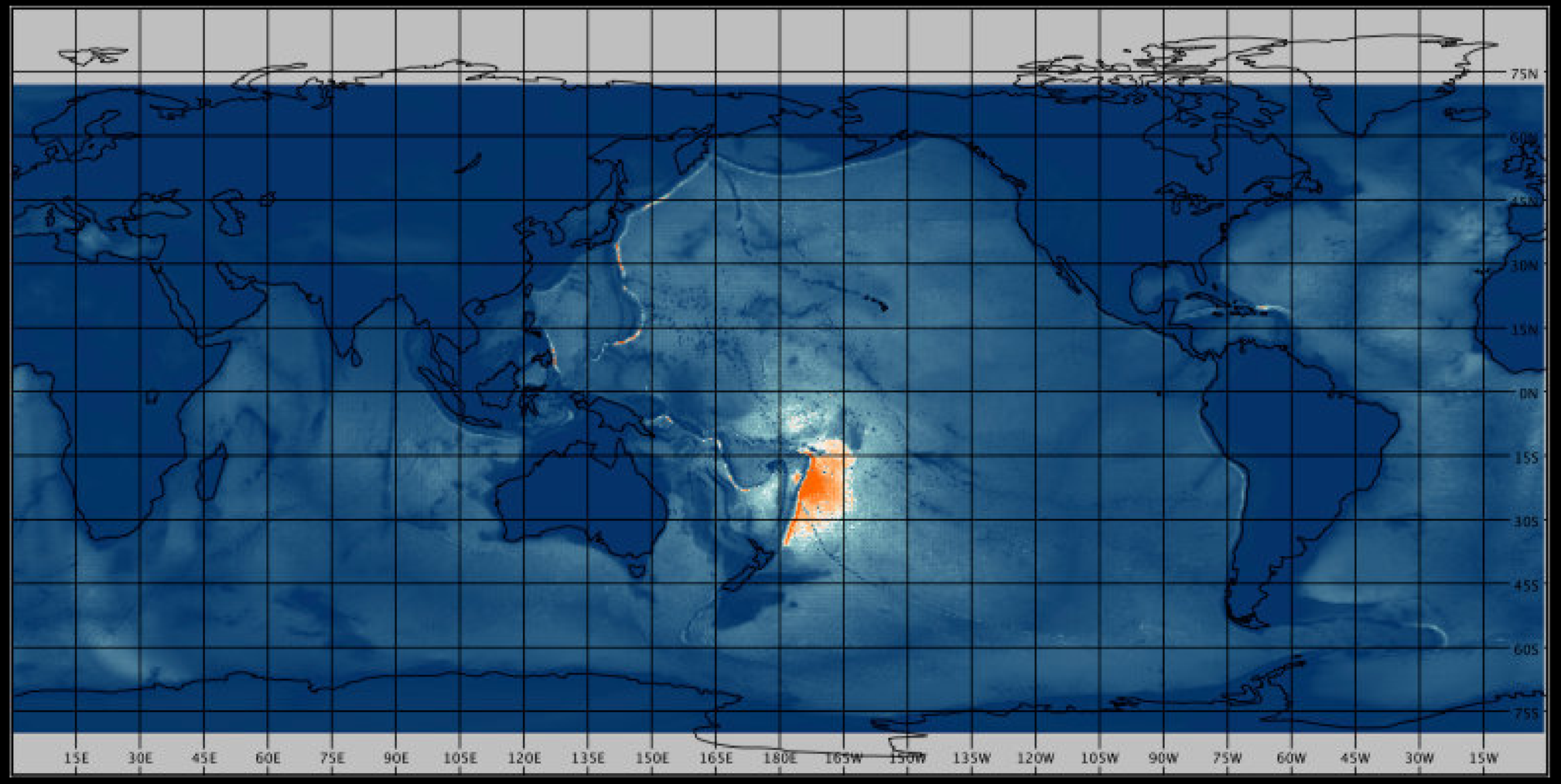

DART 21416
DART 46411
DART 46407
DART 46404
DART 32413
DART 32411
DART 32401

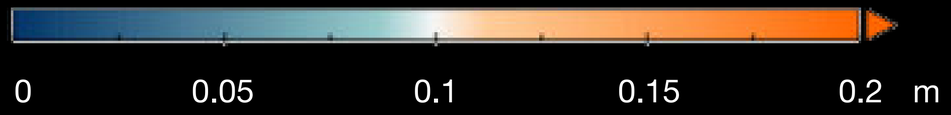
Global propagation



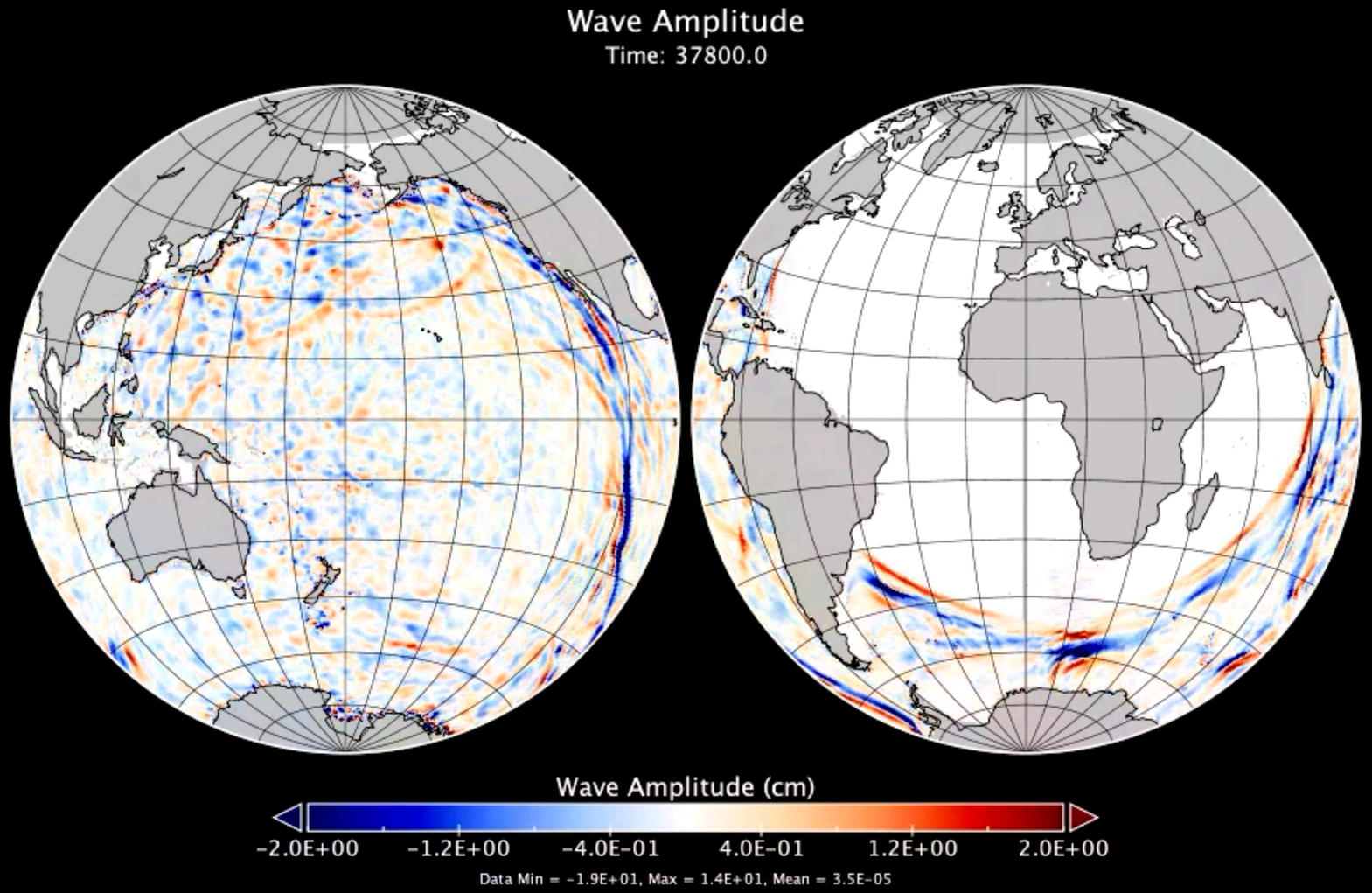
Proudman Amplification



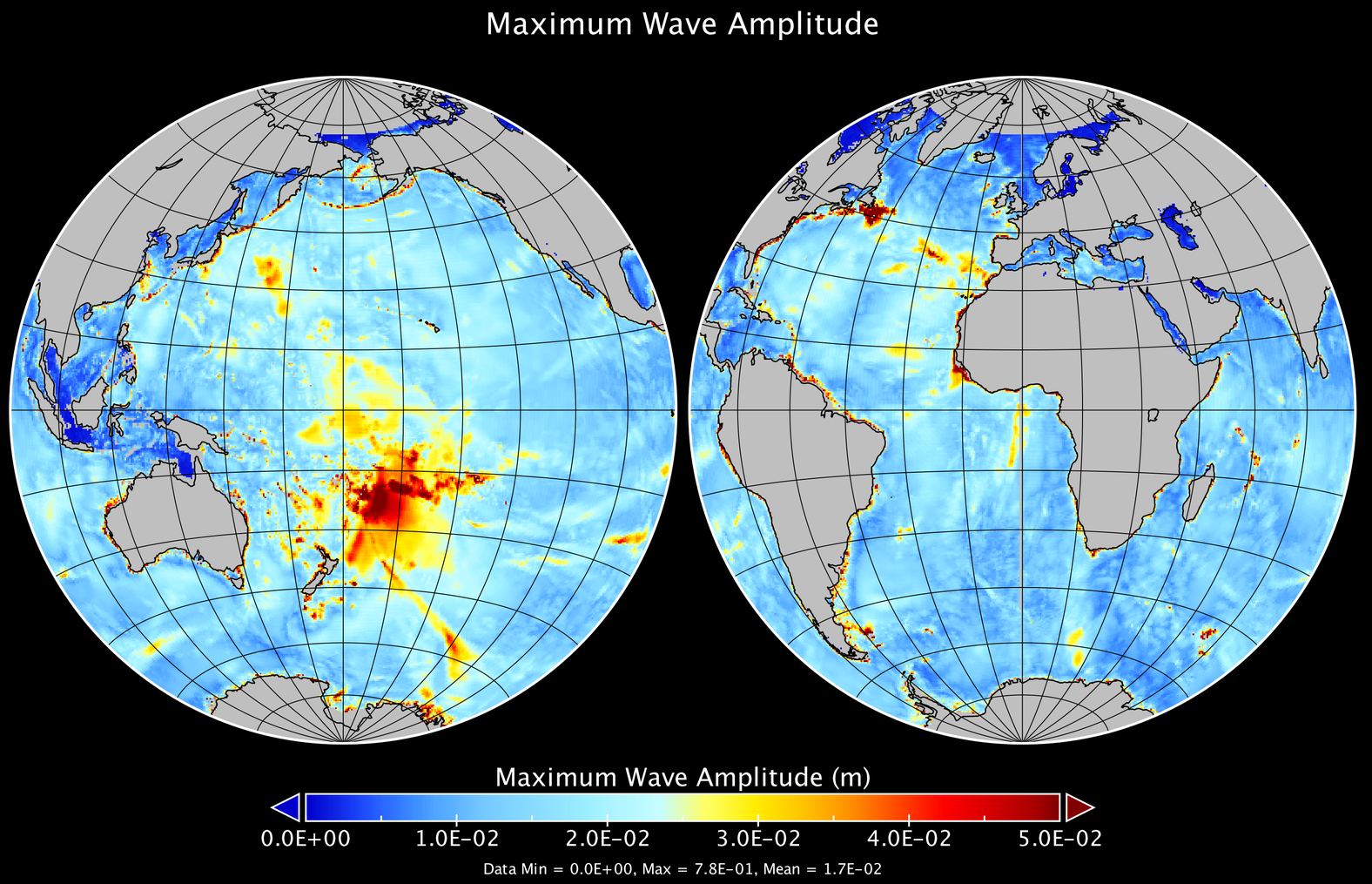
$$\eta = \frac{c^2 \eta_s}{c^2 - U^2} = \frac{\eta_s}{1 - F^2}$$



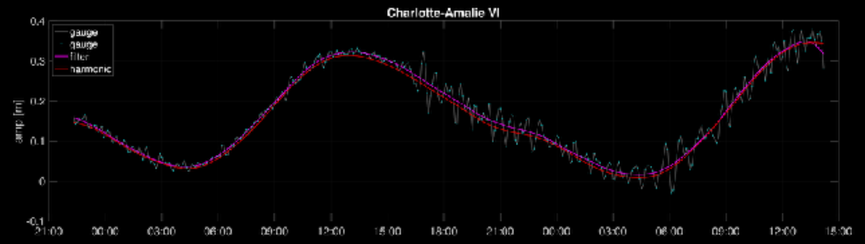
Global propagation

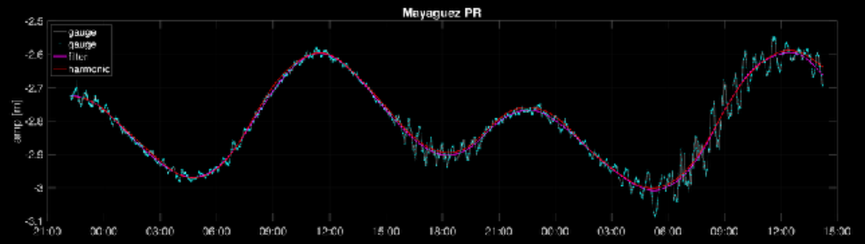


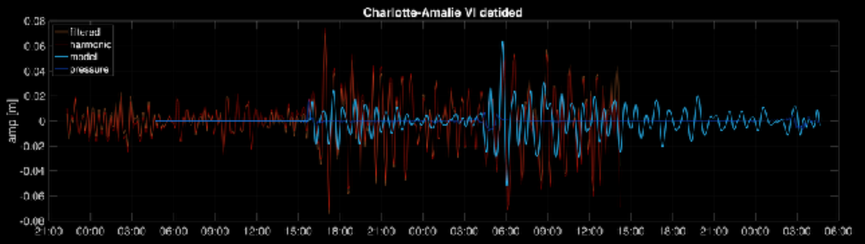
Global propagation

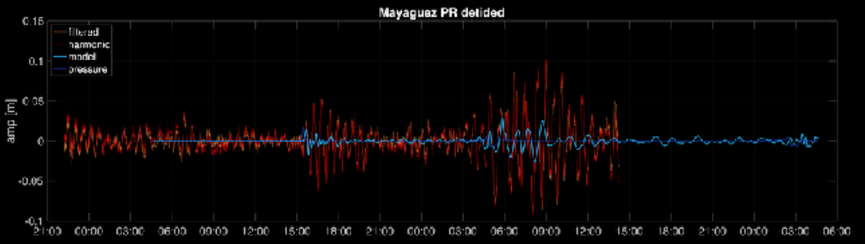


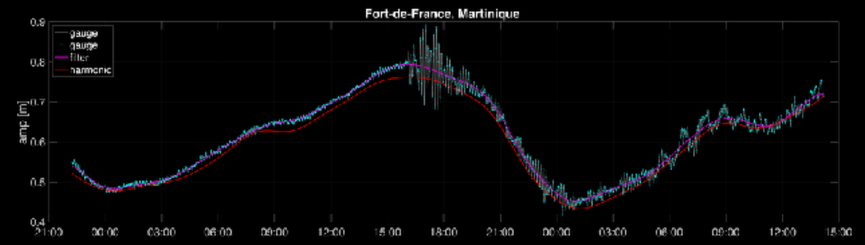
Caribbean coastal gages global run

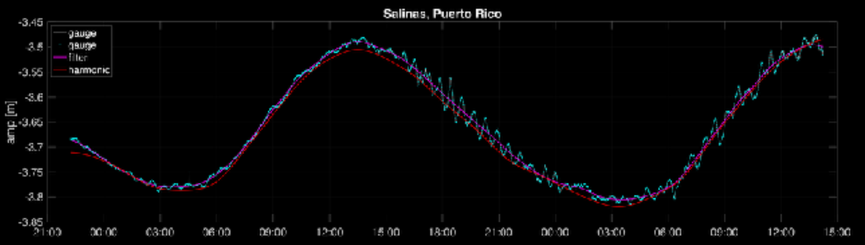


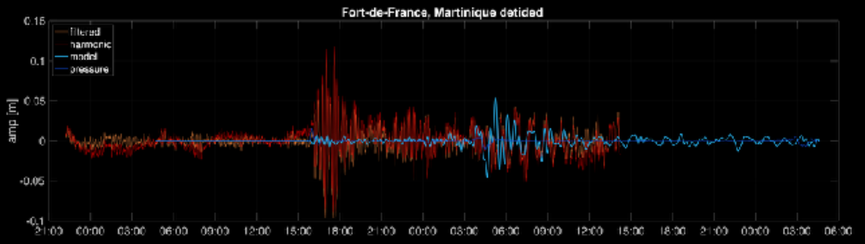


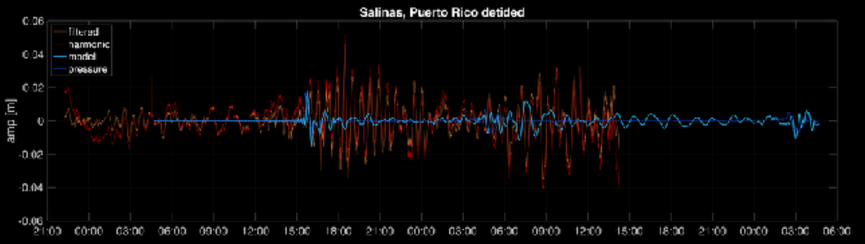




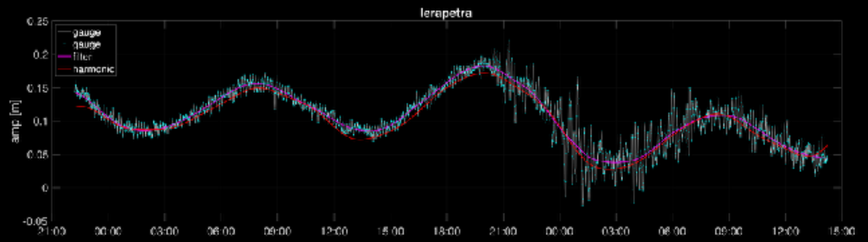


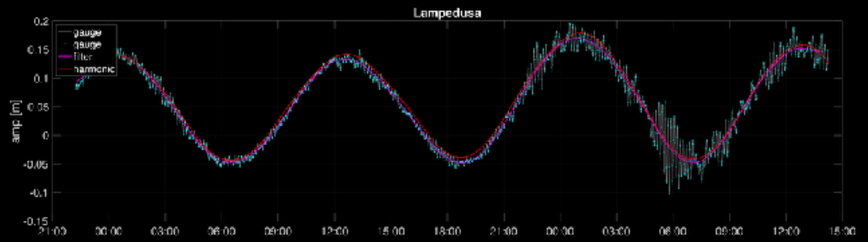


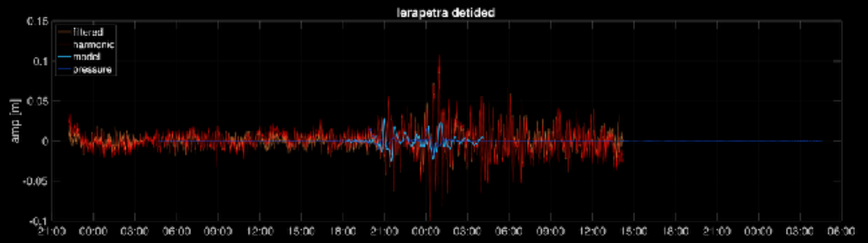


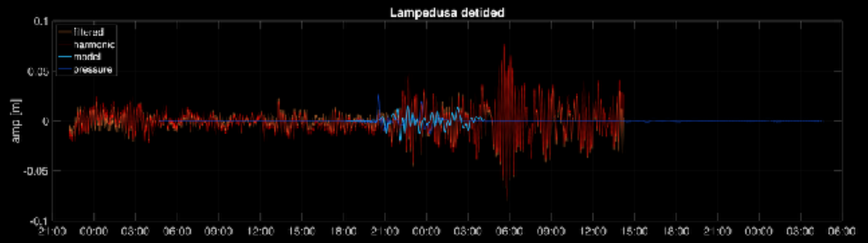


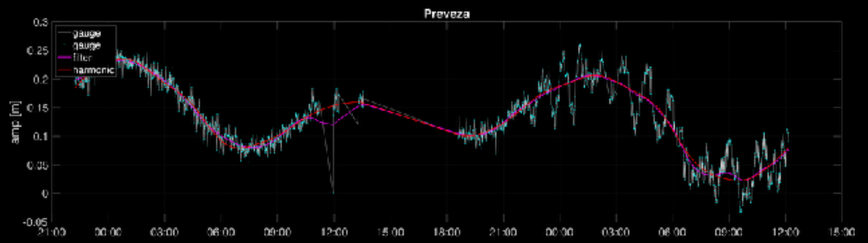
Mediterranean coastal gages

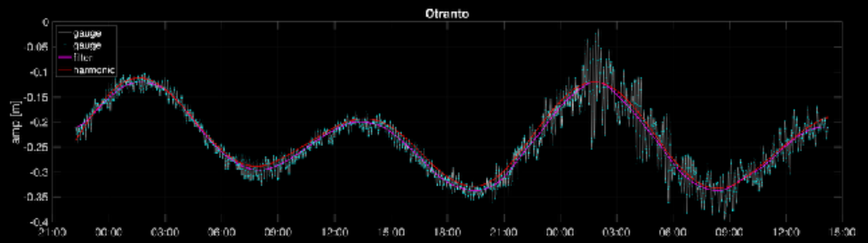


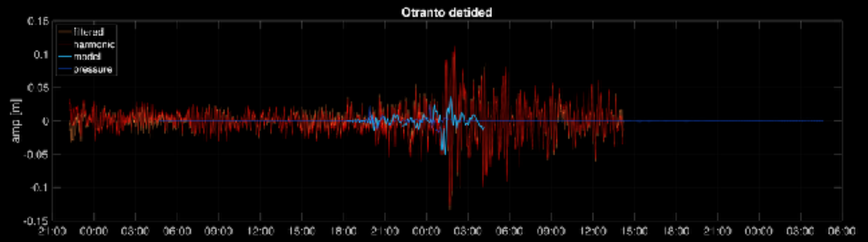




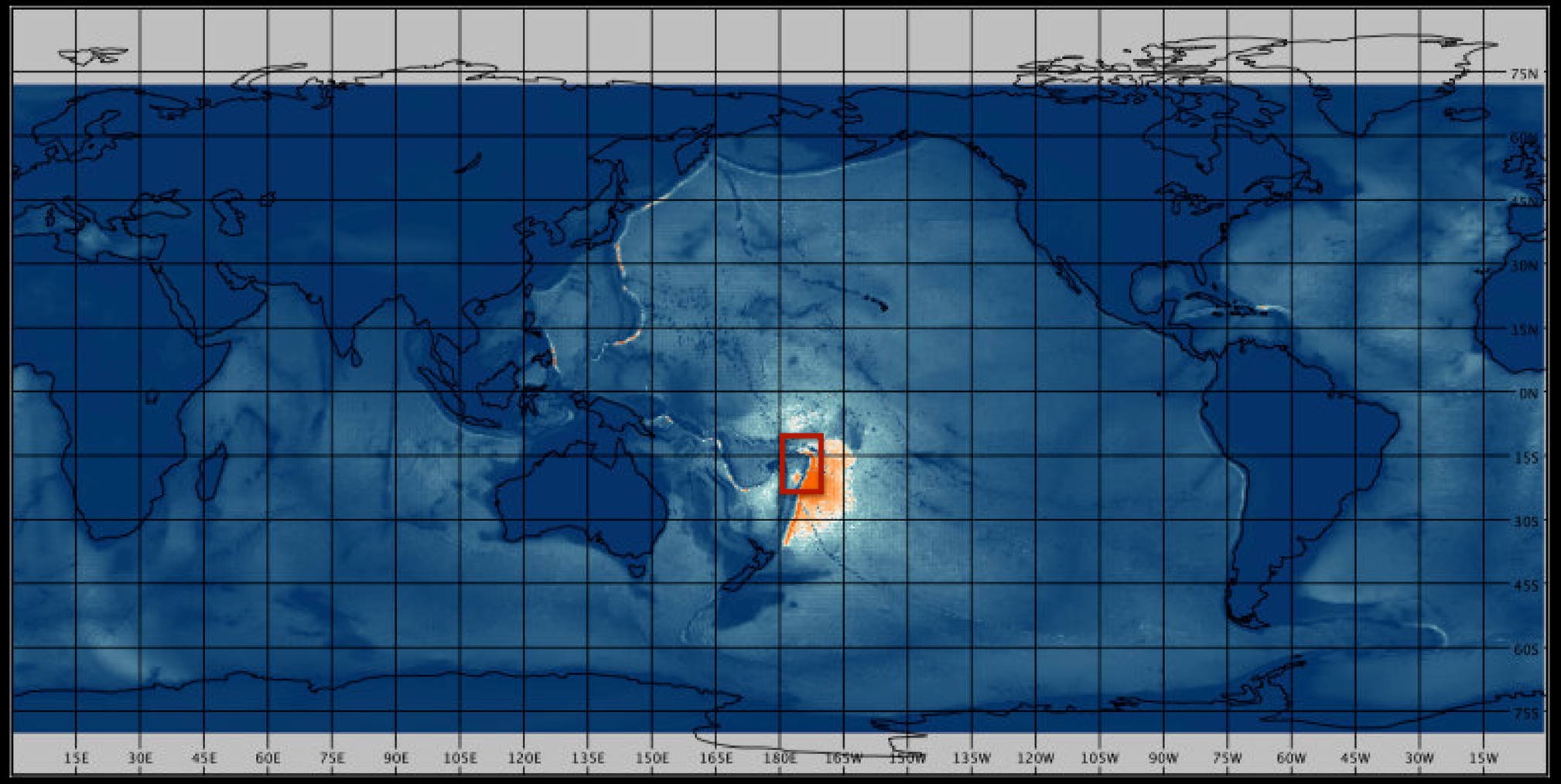




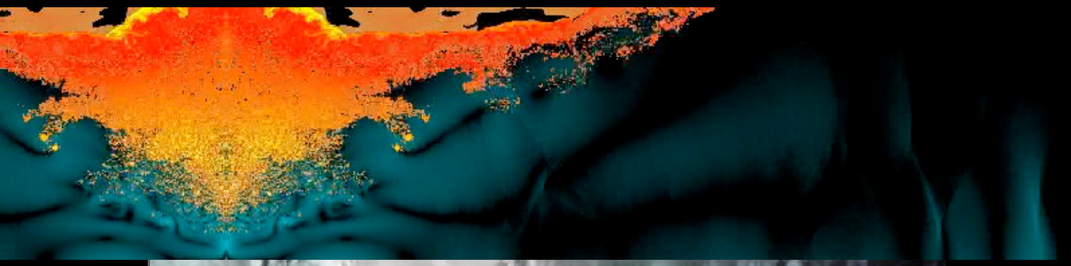


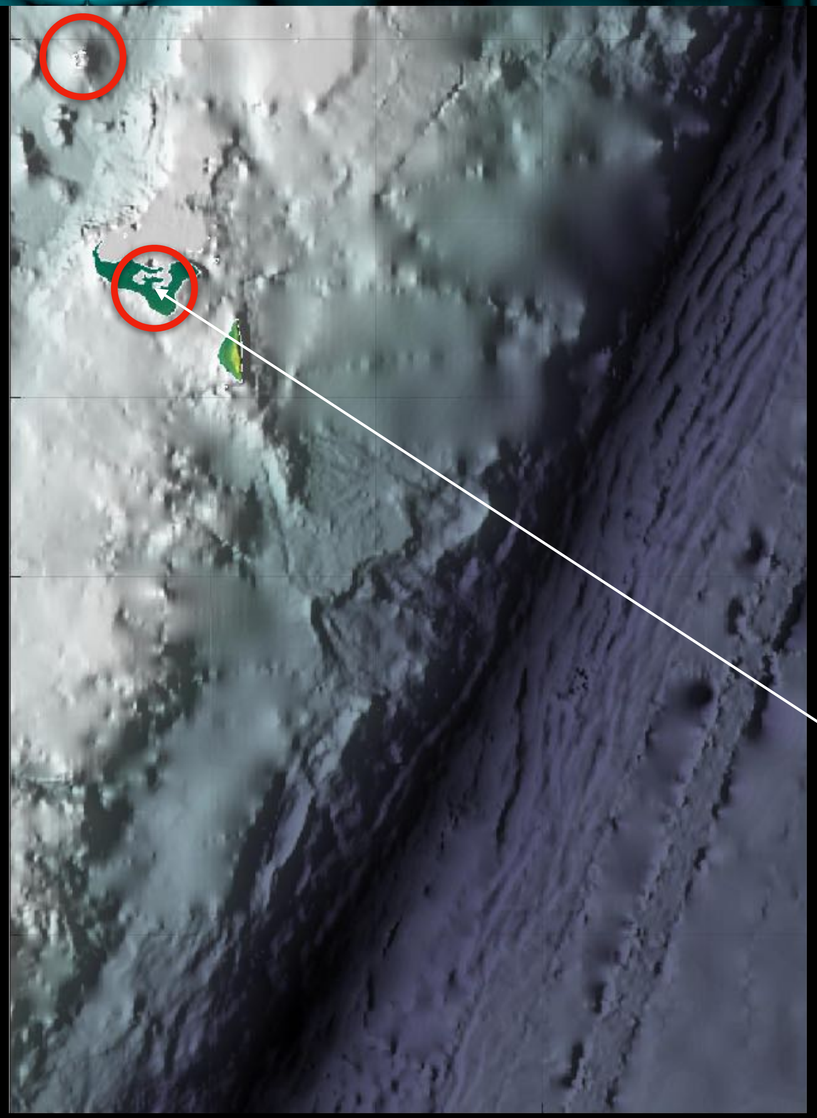


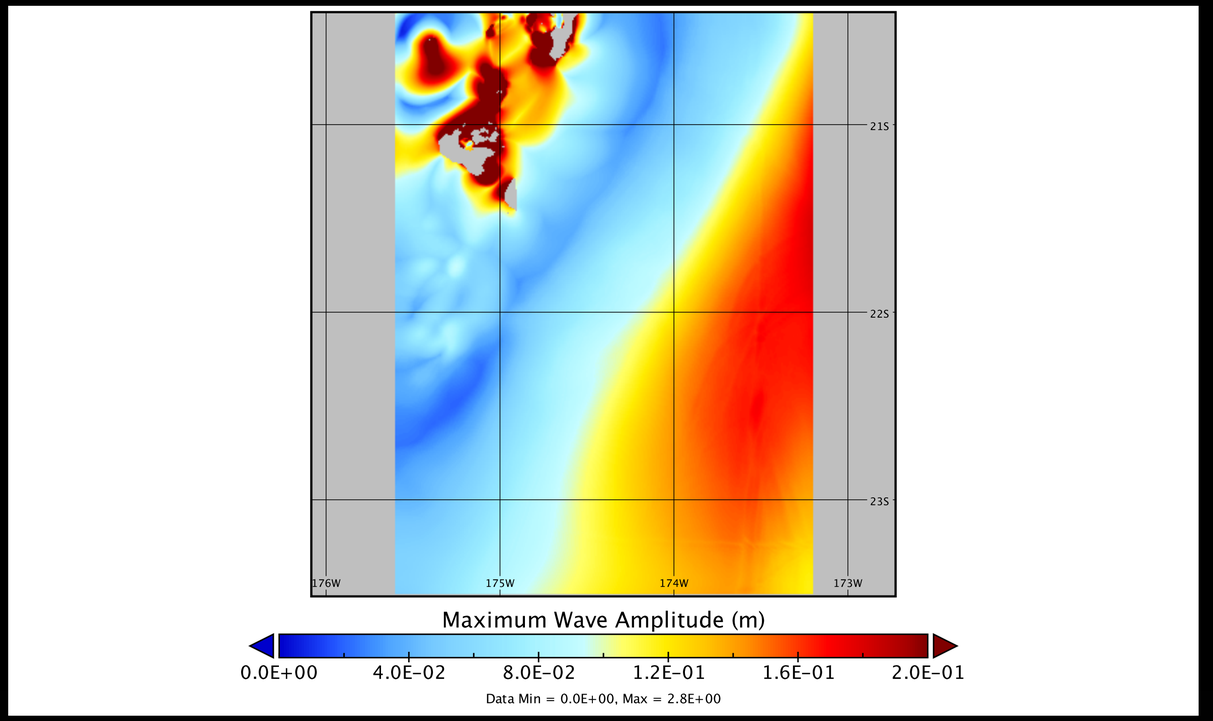
Proudman Amplification for Tonga Explosion

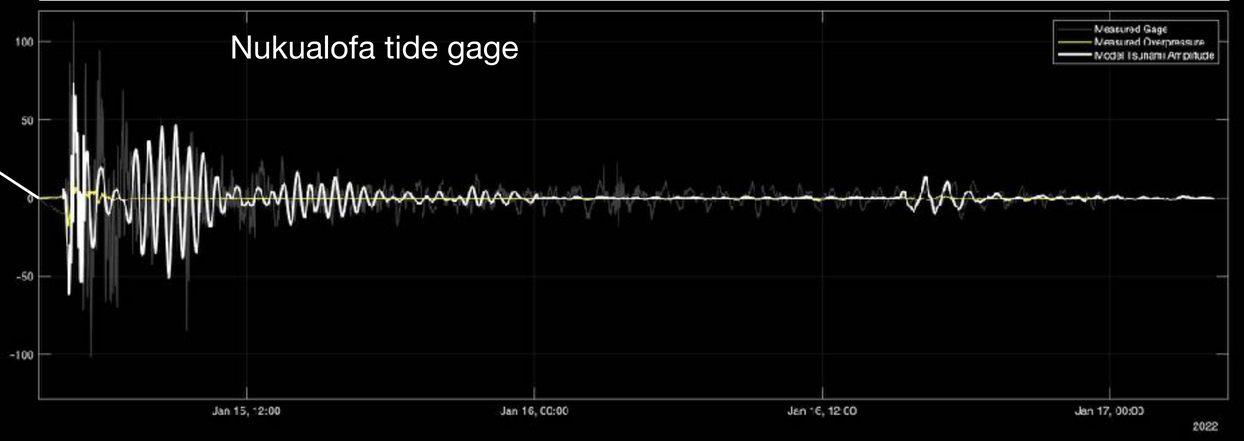


$$\eta = \frac{c^2 \eta_s}{c^2 - U^2} = \frac{\eta_s}{1 - F^2}$$






21S
22S
23S
176W
175W
174W
173W
Maximum Wave Amplitude (m)
0.0E+00
4.0E-02
8.0E-02
1.2E-01
1.6E-01
2.0E-01
Data Min = 0.0E+00, Max = 2.8E+00


Nukualofa tide gage
Measured Gage
Measured Overpressure
Modal Tsunami Amplitude
100
50
0
-50
-100
Jan 15, 12:00
Jan 16, 00:00
Jan 16, 12:00
Jan 17, 00:00
2022

Summary

- Global tsunami from Tonga explosion was generated by the air pressure forcing from Lamb waves
- Tonga event generated ample amount of data for model testing and benchmarking
- Lamb wave generation from an asteroid impact may be a missing mechanism for asteroid tsunami risk assessment