Report by IOC/UNESCO TOWS-WG Ad-hoc Team on Meteotsunami
February 2023

Chair: Mike Angove Co-Chair: Dr. Ivica Vilibic

Contributors: Dr. Alexander Rabinovich, Dr. Sebastian Monserrat, Dr. J Sepic, Dr. Vasily Titov, Dr. Emile Okal, Dr. Mohammad Heidarzadeh and Dr. Charitha B. Pattiaratchi.

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The purpose of this report is to:

a) Review current global status and advise on gaps related to MT monitoring and warning systems.

b) Identify guidelines for Standard Operating Procedure (SOP) development to monitor and warn for MTs.

c) Review relationships and coordination required between Tsunami Service Providers/National Tsunami Warning Centers and Regional/National Meteorological Services activities to monitor and warn for MTs

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Key Takeaways:

- At present, **all operational Meteotsunami (MT) alert products are addressed within the standing procedures of National or Regional meteorological services**. This report **does not** consider shock-wave induced tsunamis such as HTTU. The GTWS therefore typically plays either no role, or a supporting role in current MT alerts.

- Meteotsunami (MT) occurrence is common along virtually all coastlines. **Only infrequently does MT pose a significant risk to life and property** and this is typically in areas with particularly strong MT forcing characteristics such as the **Balearic Islands region of the Mediterranean sea**. In these cases specific MT Early Warning Systems (EWS) have been developed that rely heavily on identifying the meteorological parameters necessary for MT development through NWP schemes.

- Outside of dedicated MT EWS', MT alerting procedures are inconsistent and present risks. The **Global Tsunami Warning System can play a supporting role in terms of making direct tsunami detection**, though even when a tsunami is detected by the network, this will not typically be sufficient to fully characterize the tsunami wave field and support precise coastal impact forecasts.

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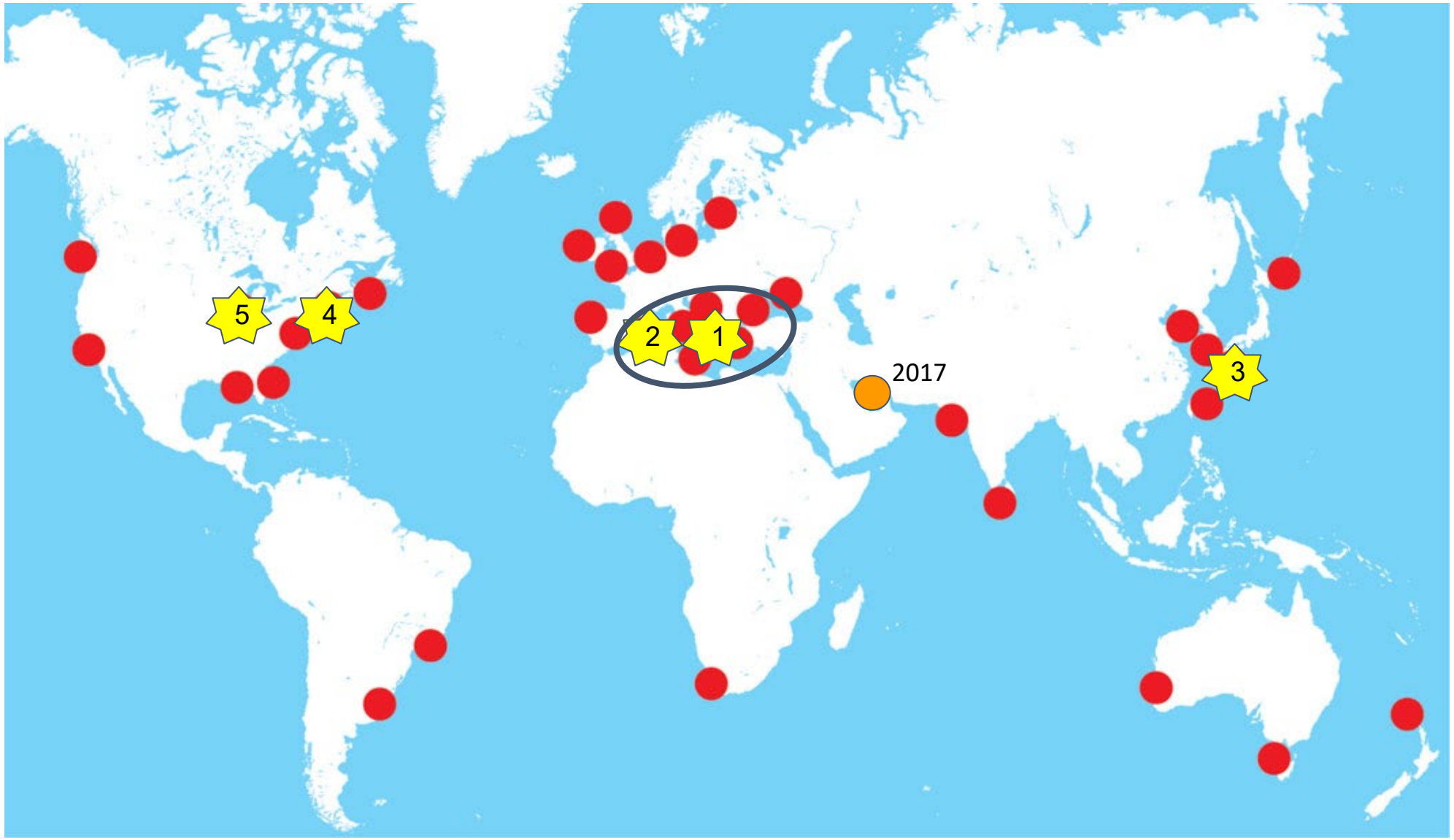
Key Takeaways cont):

- A **future unified system** in which a combination of direct tsunami detection from the ever-expanding global tsunami sensing network and NWP-based MT forecasts is considered worthwhile. Even in areas where well established MT EWS exist, direct MT measurement using tsunami detection instruments would both improve hydrodynamic forecasts as well as reduce false alarms. Outside of MT EWS, the unified system would be equally beneficial in providing Met Services offices with guidance on when to monitor GTWS instruments based on MT cueing algorithms.

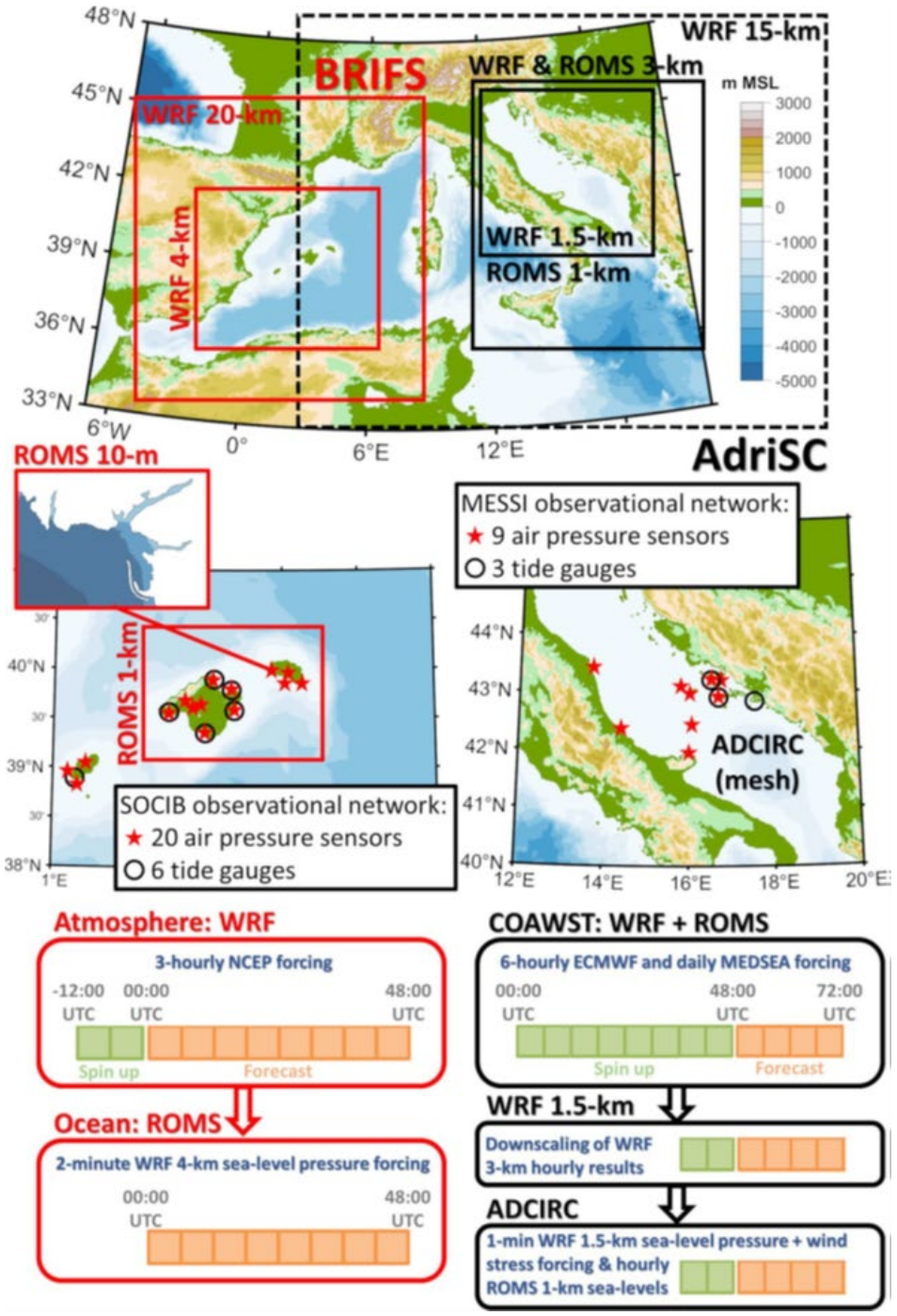
- MT only form under a narrow range of parameters related to water depth and the translational speed of the source disturbance. This makes it possible to thoroughly characterize the MT risk for virtually any coastline in the world. **Local understanding of the MT threat posed to a given coastline is critical** to ensuring the phenomena is addressed through Met services.

Significant MT Occurrences (reported as of 2015)



Mediterranean MT System

Existing meteotsunami monitoring and forecasting systems in the Mediterranean Sea: BRIFS (in red) associated with the SOCIB observational network in the Balearic Islands and AdriSC forecast system (in black) associated with the MESSI observational network in the Adriatic Sea (after Vilibić et al., 2021)



Mediterranean MT System: Tendency for overprediction

Verification of meteotsunami forecast issued by the AEMET experimental rissaga prediction service between 2003 and 2006 (after Jansà and Ramis, 2021).

Verification –through a contingency table- of a sample (2003-2006) of the rissaga prediction service established in 1985 at the Spanish National Meteorological Service

Rissaga	Observed amplitude (when amplitude >= 30 cm)			
Forecast amplitude	30-75 cm	75-150 cm	> 150 cm	total
No forecast (< 30 cm)	4	1	1	6
30-75 cm	2	1	1	4
75-150 cm	9	11	4	24
> 150 cm	1	2	1	4
Total	16	15	7	38

Under-prediction

Correct prediction

Over-prediction

When rissaga (>30 cm) is observed:
Rissaga was not forecast: 16%
Rissaga was forecast: 84%

MT Alerting

Dedicated Systems:

1. *Balearic Islands*
2. *Adriatic Sea*
3. *S. Korean Peninsula*

Key Attributes:

- *High resolution NWP*
- *Met sensing networks*
- *Depth constrained ocean model coupling*
- *Deterministic, Probabilistic…or *qualitative**

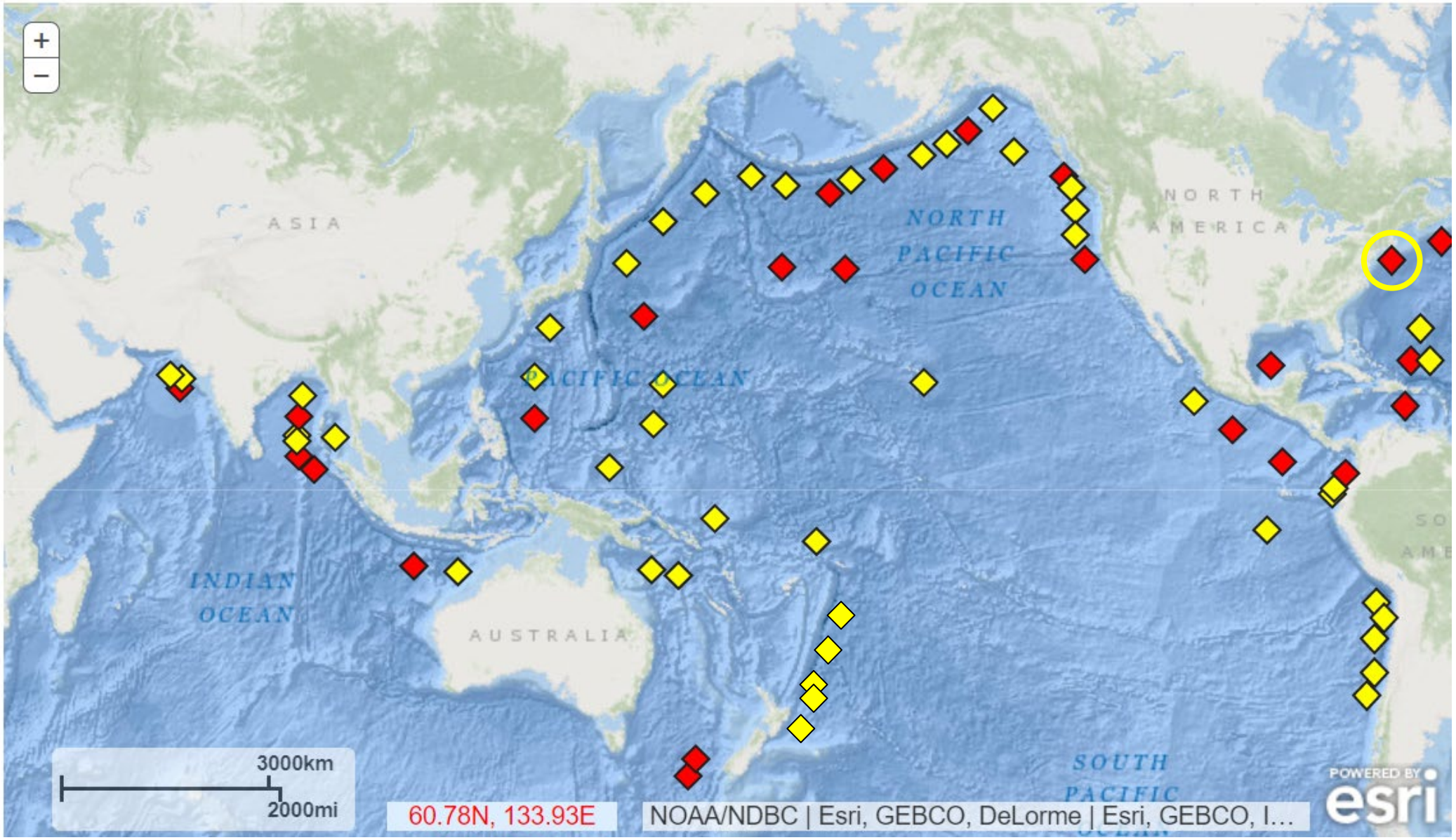
Q: *Is there a role for GTWS/TSP/NTWCs in MT?*

Generized Systems:

All other met services areas address MT as “lesser included” component of coastal flooding eg:

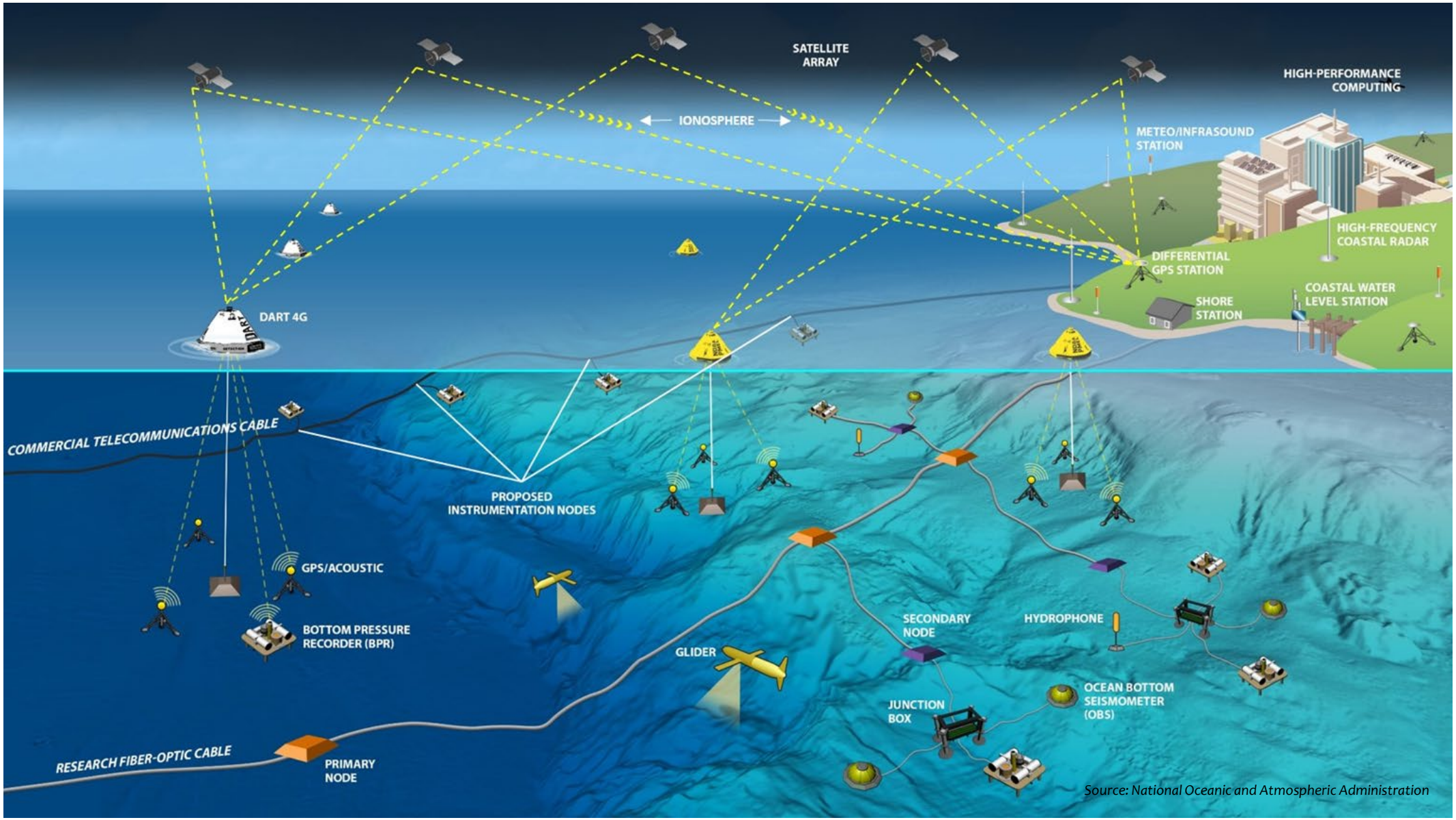
- seiche
- anomalous tides
- MT

Can GTWS be used for MT? Yes…and no



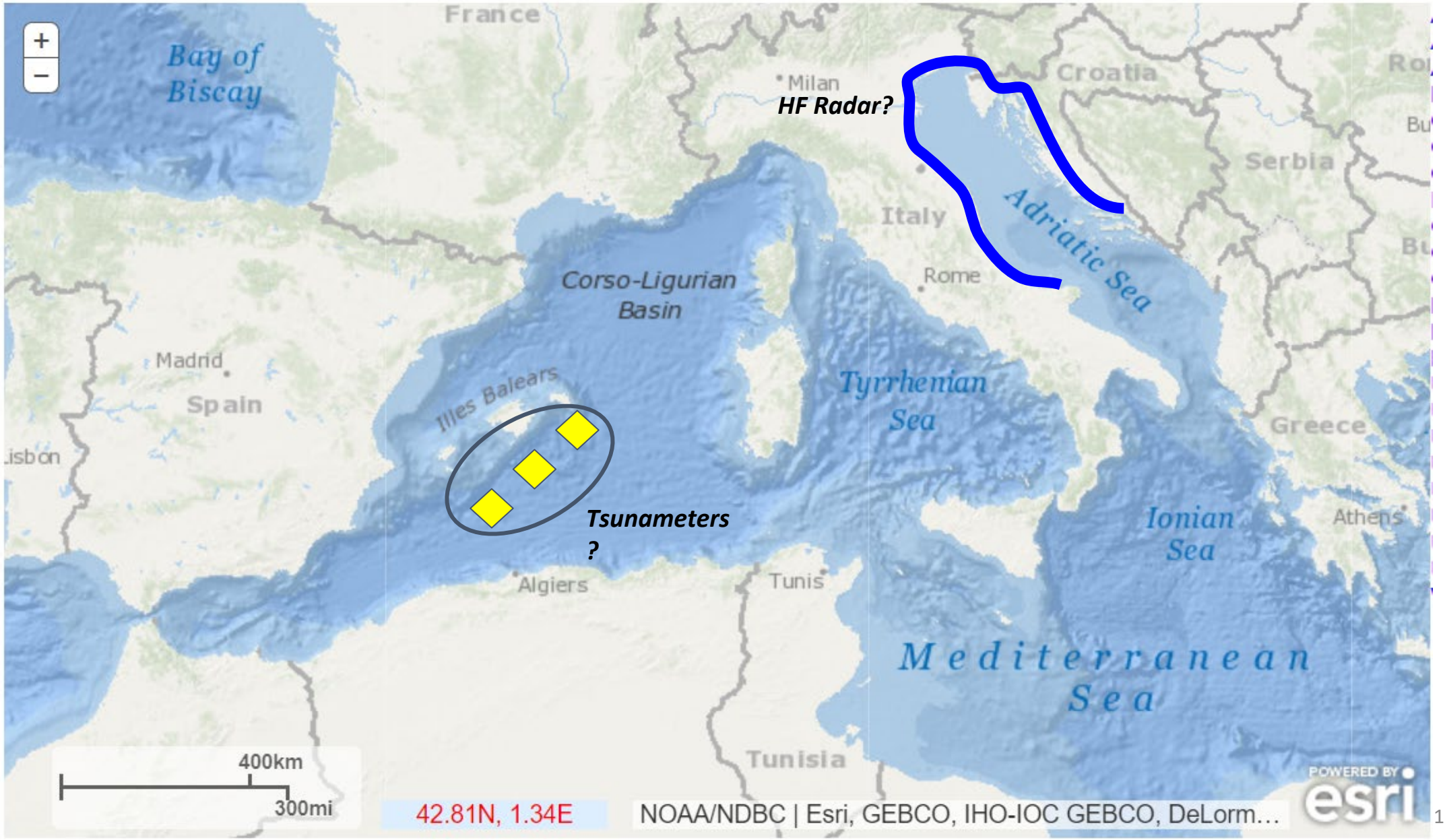
Rethinking Ocean Observations:

Reducing Uncertainty in Global Tsunami Forecasts

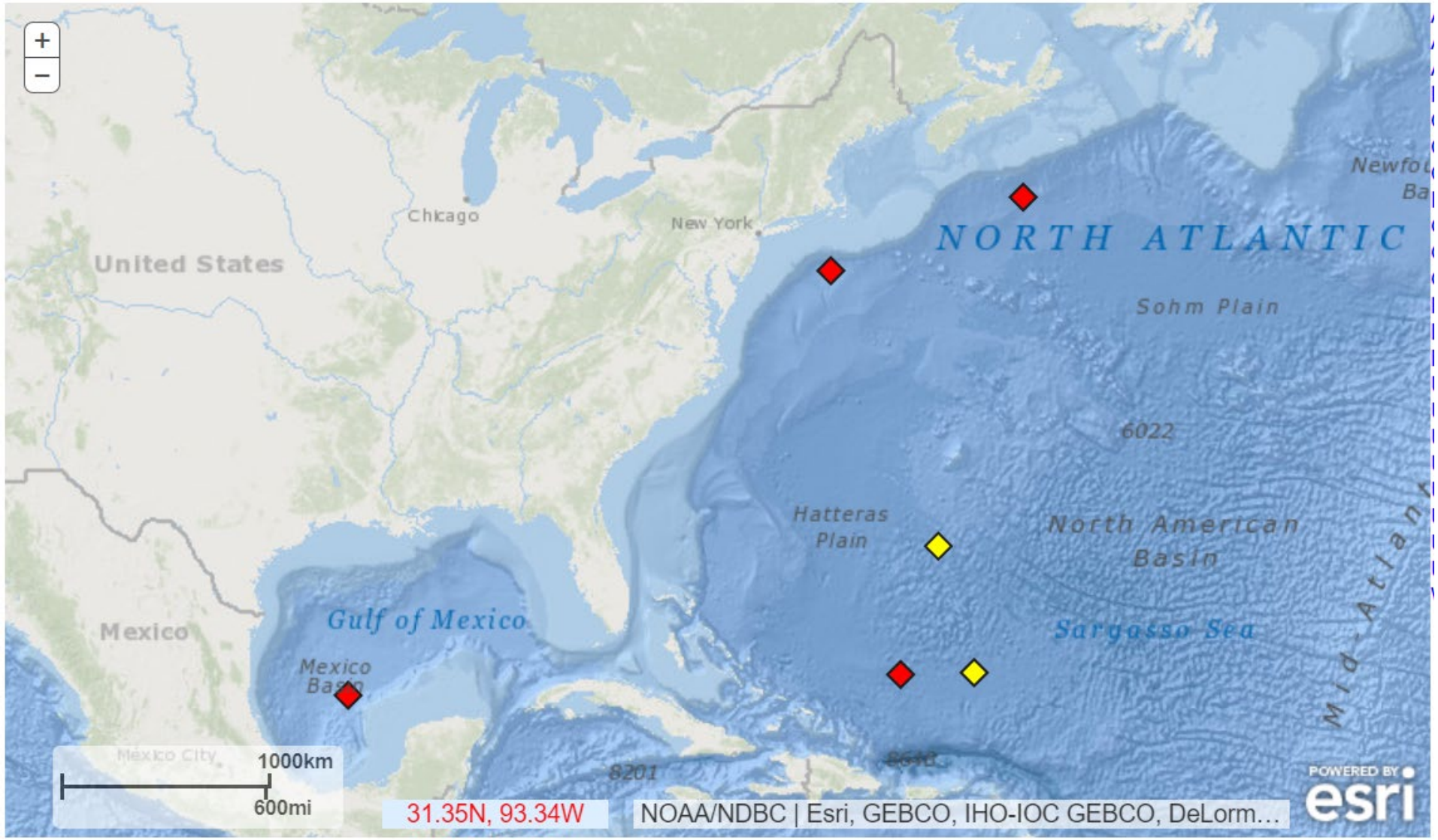


Source: National Oceanic and Atmospheric Administration

Could the GTWS be used for MT? Possibly



Could the GTWS be used for MT? Possibly



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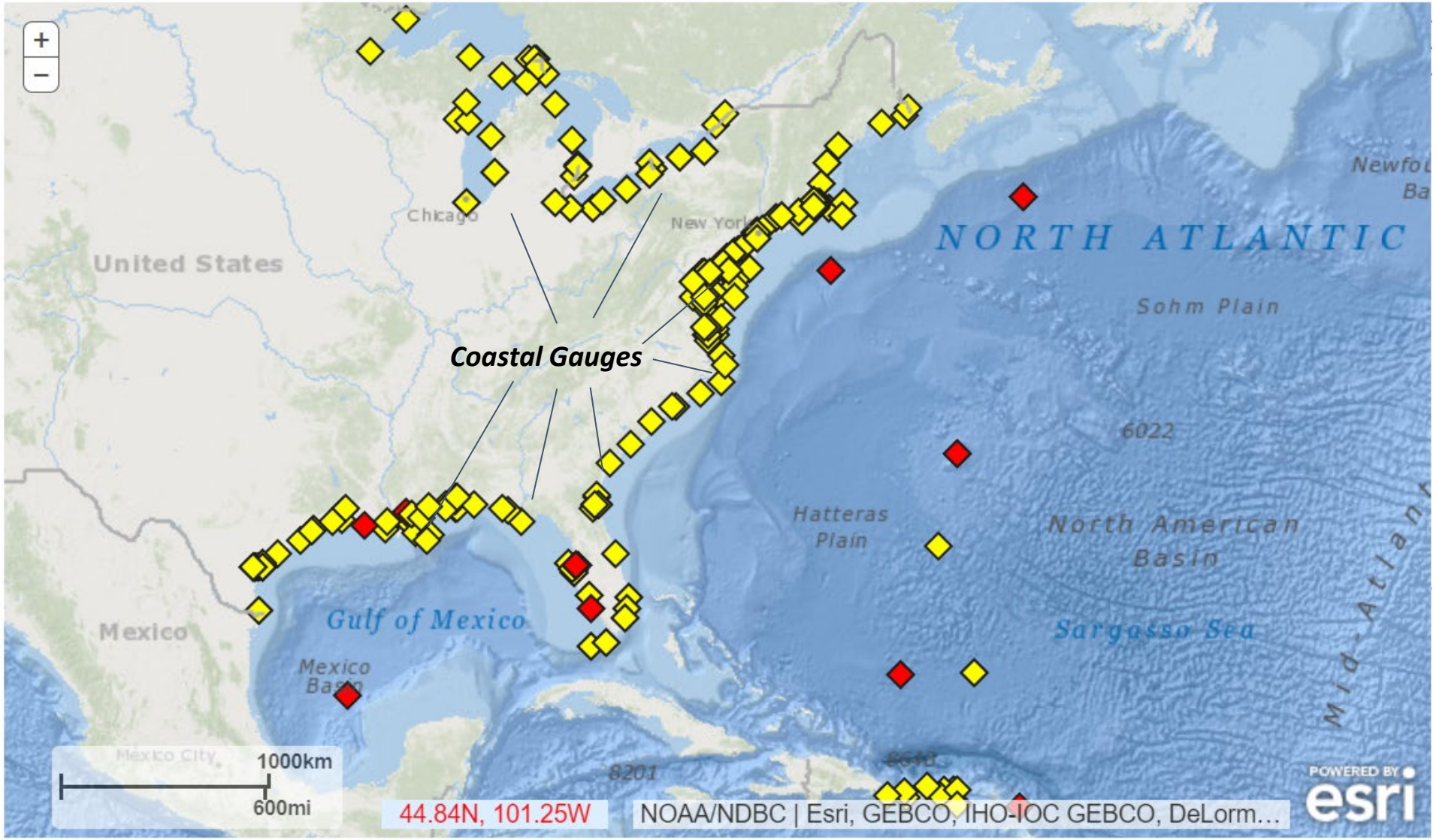

General Standard Operating Procedure Guidance

(i) **Understanding risk**. Member states prone to MT impact should conduct detailed risk assessments to include:

1. Identify areas prone to MT development;
2. Identify types of weather disturbances can create MT in risk-prone areas, and what the seasonal variation is;
3. Determine the range of impact that can be expected from MT, particularly if this an evacuation hazard or a more limited marine impact and;
4. Identify and exercise the the primary mitigation measures available to address these risks.

(ii) **Available Detection networks**: Identify instruments available that can detect MT within area of responsibility including:

1. Meteorological sensors that can identify precursor disturbances
2. Tsunameters that can provide positive detection of MT once formed,
3. Coastal water-level gauges that can verify MT arrival in coastal locations and validate forecasts
4. HF radar that can identify tsunami current velocities in coastal areas (Lipa et al., 2014).

General Standard Operating Procedure Guidance

(iii) **Triggering considerations.** Ensure tsunami detection instruments are tuned to alarm or trigger upon detecting tsunamis. Some guidelines include:

1. Tsunameters trigger on >3cm detection
2. Coastal gauges trigger upon tsunami phase detection
3. Coastal radars (if available) trigger upon tsunami phase detection

(iv) **Communications.** States with at-risk coastal areas should pay careful attention to communications status. This includes ensuring

1. Communications established between detection instruments and warning service support offices (internationally and nationally) and that
2. Regular testing of communications paths, and redundancies identified and conducted

Organizational Relationships and Considerations

Public alerting responsibilities related to MT reside within National and regional met services. The amount of coordination with IOC GTWS or NTWCs varies depending on capability

1. For Dedicated MT EWS', MT is currently treated as met hazard operationally. Areas of WMO/IOC coordination are **primarily training and awareness** and could include:
    a. Semi-annual training exercises jointly facilitated by NEAMTWS and corresponding WMO Met Areas
    b. Summary of MT impacts to TOWS WG by NEAMTWS Chair
    c. Seasonal awareness campaigns facilitated jointly by IOC/WMO with focus on NEAMTWS region

1. For Generalized MT systems, the GTWS can be leveraged to alert responsible met services offices of potential risk. For this to be effective, significant coordination between the GTWS and Met Services on both **operations and education** should be established. Some activities could include:
    a. Annual training exercises between NTWCs and Met Services offices to review MT risks, detection networks and alerting protocols
    b. Regular review and cataloging of events
    c. Wide area awareness and education campaigns as part of IOC TsunamiReady initiatives

Future Unified System?

Finding: *"Immediate improvement of the existing MT warning can be achieved by unifying the generalized and targeted approach for the meteotsunami warning"*

Goal: Combine NWP-based coupled models with direct, high-density, targeted tsunami observations

Pro:

- Reduced false alarms and more accurate forecasts in MT-prone regions
- Comprehensive MT cuing and forecasts in all other zones

Con:

- Potentially high cost v. risk
- Human capital intensive

Who would oversee such a system? WMO? IOC? Both? Neither?

Recommendations

1. **Joint WMO/IOC coordination on MT alerting**. Since responsibility for issuing public alerts related to MT generally falls to National or regional met services offices, a dialogue between the tsunami community and met services is necessary to ensure full exchange of information in support of a robust international alerting standard. **The ad/hoc team on MT strongly recommends this action as a follow-on to this initial report.**

1. **MT consideration in GTWS instrumentation strategy**. Tsunami detection and measurement capabilities are rapidly improving and this is expected to accelerate under the UN Decade of Ocean Science. It is now possible to consider non-seismic tsunami sources in the global instrumentation strategy, including MT. Input from national and regional met services offices would be particularly useful as the GTWS considers a new generation of tsunami detection and measurement networks

1. **Establish Framework for a Unified MT Global System.** Combining the direct tsunami detection capability of the GTWS with the NWP-based algorithms tuned to MT prediction could deliver significant advances in global capability at minimal cost. It is recommended that a working group made up of experts from both systems be formed with the expressed intent of outlining the potential construction of such a system.