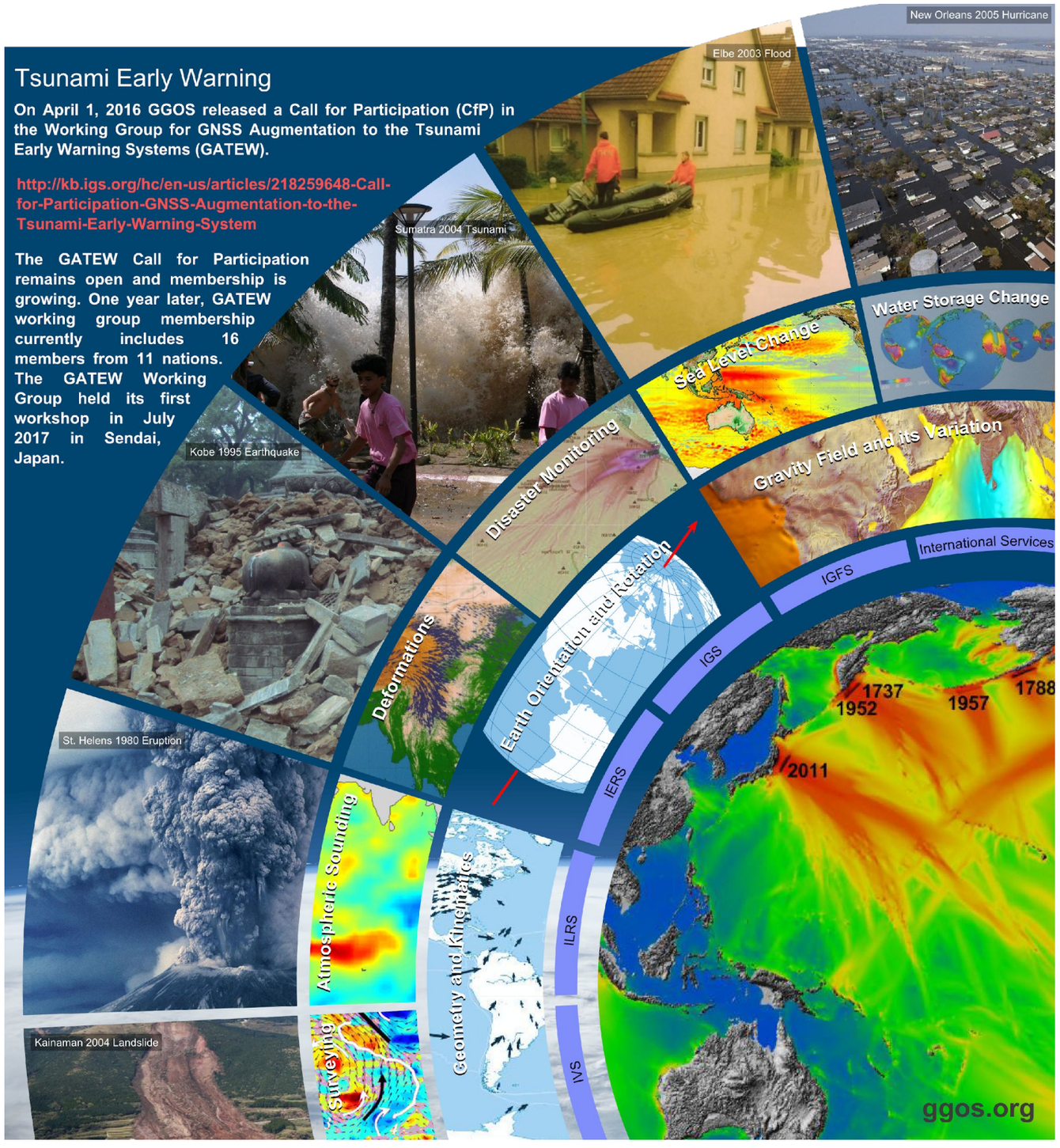


GGOS Global Geodetic Observing System

GNSS Early Warning Systems

John LaBrecque

GGOS Geohazards Focus Area

Union Commission on Geophysical Risk and Sustainability

Center for Space Research

U. Texas @ Austin

Special thanks to:

Elisabetta D'Anastasio GNS, NZ

Siddharth Krishnamoorthy, JPL

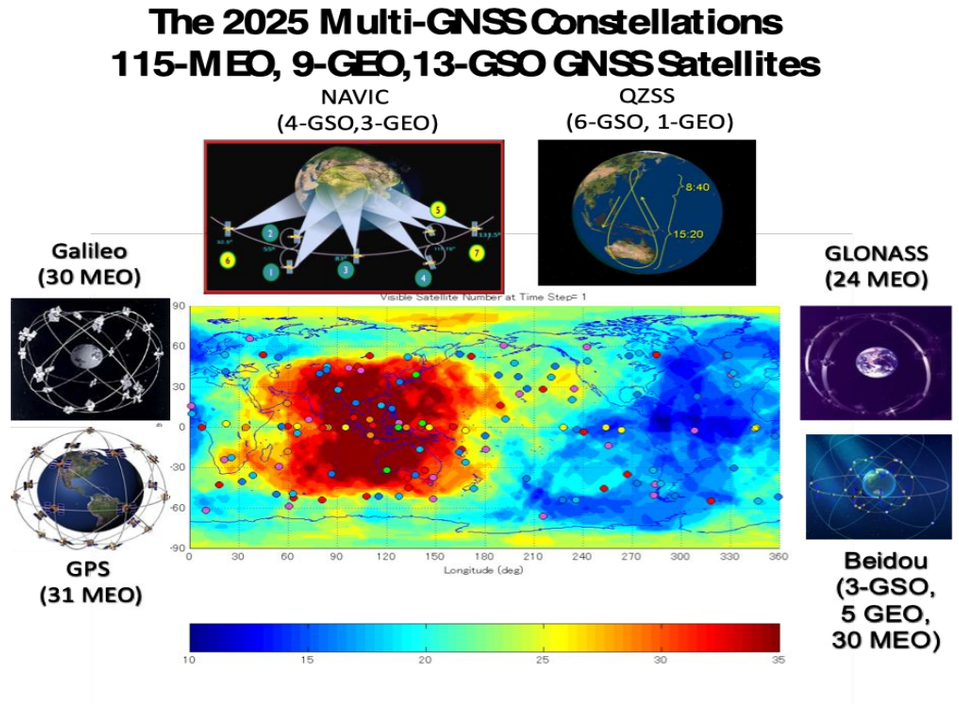
Timothy Melbourne, Central Washington Univ.

Tour de l'iGS Stop 5 Feb 14, 2023

AN EFFICIENT, ACCURATE AND COST EFFECTIVE EARLY WARNING CAPABILITY

- GTEWS is enabled by the GNSS and RNSS constellations of the US Global Positioning System (GPS), the Chinese Beidou, the European Galileo, the Russian GLONASS, the Japanese QuasiZenith Satellite System (QZSS) and the Indian IRNSS/NAVIC regional constellations.

- The QZSS and NAVIC geosynchronous regional constellations (RNSS) improve the stability of Earth surface displacement measurement and increase the stability of ionospheric TEC variation estimates over the Indo-Pacific region.



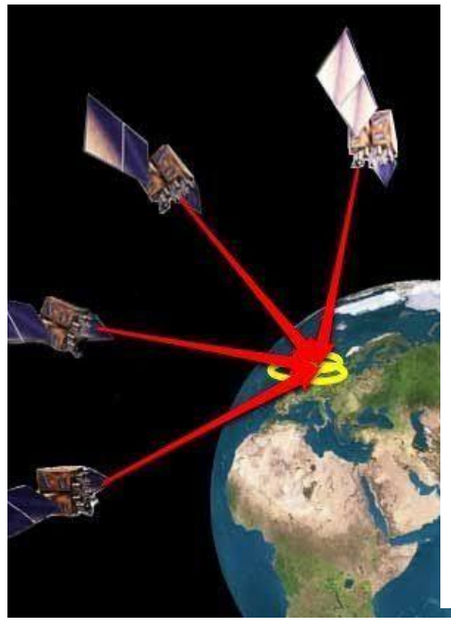
All in view for the Indo-Pacific increases dramatically. (Courtesy S. Kogure)

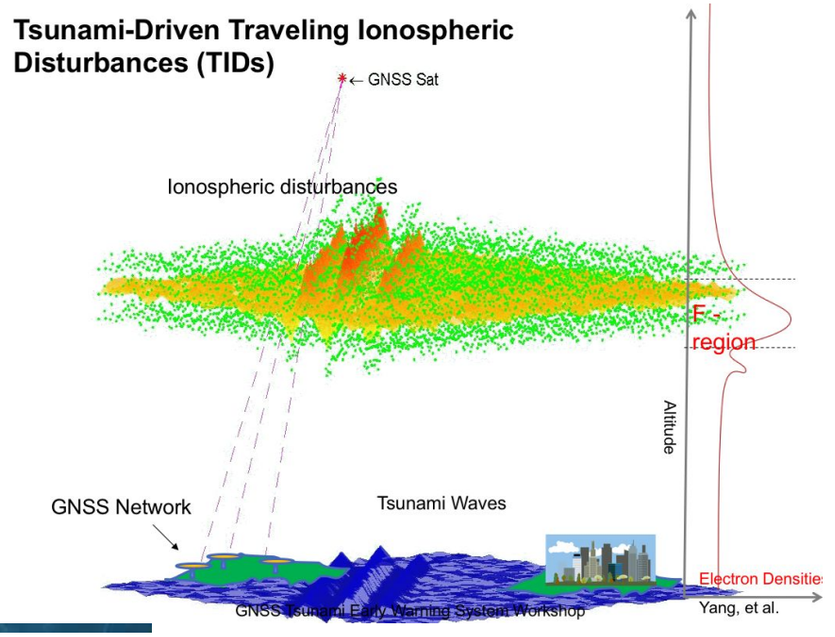
GNSS Tsunami Early Warning System (GTEWS)

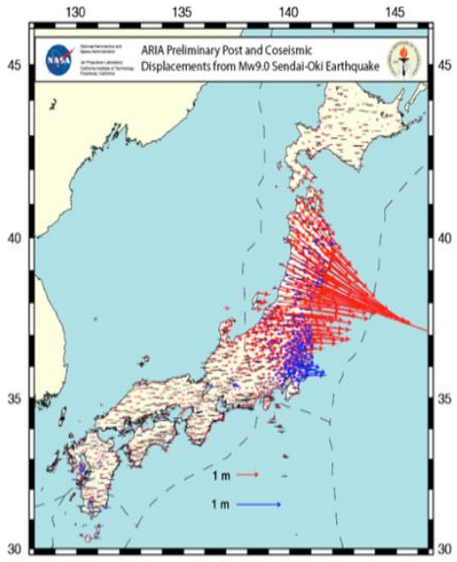
GGOS Global Geodetic Observing System

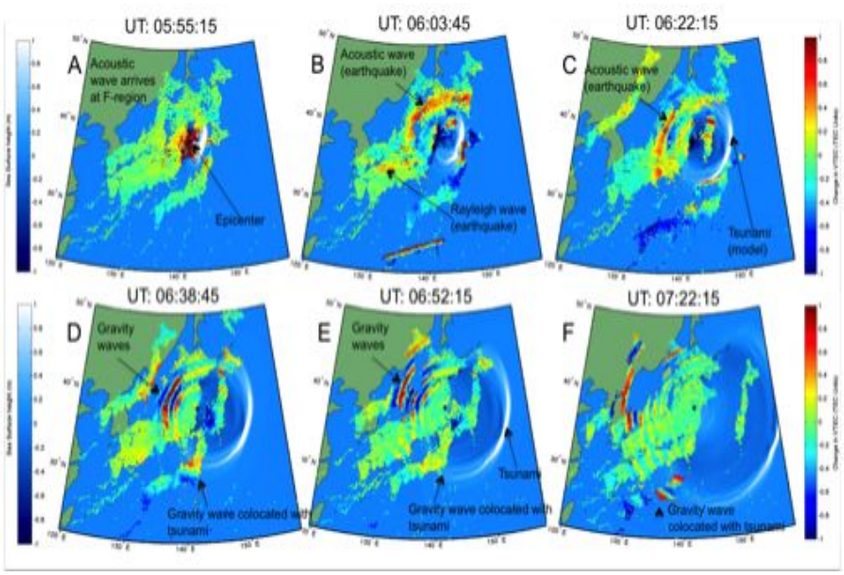
The properly positioned GNSS receivers will measure both the ground displacement and the ionospheric dynamics induced by tsunami formation and propagation. Real time distribution and analysis of these data will provide significant improvements to accuracy, timeliness, and efficiency in tsunami warning. GTEWS is viewed as an augmentation to existing tsunami warning systems. The mesoscale GNSS networks will strengthen environmental monitoring and strengthen disaster risk reduction beyond tsunami risk.

The GTEWS relies upon the development of mesoscale GNSS infrastructure, broadband communication needed for real time data distribution and advanced computational facilities. All of which will advance regional economic development.









IAG Supports the IUGG Call for GTEWS

GGOS Global Geodetic Observing System

2015:

IUGG General Assembly Resolution #4 called for the membership to support the development of an Indo-Pacific effort to implement GNSS augmentations to Tsunami Early Warning Systems (GTEWS).

2016:

Global Geodetic Observing System of the IAG issued a Call for Participation in the GATEW Working Group to support Resolution #4. Today the GATEW includes 18 organizations from 12 nations.

GGOS Working Group on GNSS Augmentation for Tsunami Warning
12 nations - 18 organizations

Country	Organization	Resources	Contact	Email
Australia	GeoScience Australia	Large National Real Time GNSS Network	John Dawson	John.Dawson@ga.gov.au
Chile	U.Chile, Department of Geophysics, CSN	Large National Real time Geodetic and Seismic Network	Sergio Barrientos, Sebastián Riquelme, Juan Baez	sbarrien@dgf.uchile.cl, sebastian@dgf.uchile.cl,jcbaez@csn.uchile.cl
China	GNSS Research Center, Wuhan University	First Real Time Asian Analysis Center	Jianghui Geng	jgeng@whu.edu.cn
China	Shanghai Observatory	Eminent geodetic research organization with strong experience in geodetic infrastructure, analysis and applications.	Shuanggen Jin	sgjin@shao.ac.cn
Colombia	Geological Survey Colombia	Large Real Time GNSS Network, Regional Data Sharing with Brazil, Peru, Panama, Venezuela, COCONet Data Center	Hector Mora	hmora@sgc.gov.co
France	Institut de Physique du Globe de Paris	Strong research in tsunami coupled ionospheric waves and tracking	Giovanni Occhipinti	ninto.a.paris@gmail.com
Germany	GeoForschung Zentrum, Department Geoservices	Strong research and development of GNSS Early Warning including Indonesia and Oman projects	Harald Shuh, Jörn Lauterjung	schuh@gfz-potsdam.de, lau@gfz-potsdam.de
India	Indian National Centre for Ocean Information Services (INCOIS)	INCOIS operates Tsunami Warning Center ESSO and a large array of seismic, tidal guages buoy, GNSS and strong motion accelerometers at sites including the Andaman and Nicobar Islands.	Mrs. Vijaya Sunanda Manneela	shenoi@incois.gov.in, sunanda@incois.gov.in
Italy	University of Rome Geodesy and Geomatics	Initiating research in GNSS Tsunami Warning	Mattia Crespi, Augusto Mazzoni	mattia.crespi@uniroma1.it , augusto.mazzoni@uniroma1.it
Mexico	Instituto de Geofisica, UNAM	Large National GNSS network and analysis system, COCONet Data Center	Enrique Cabral	ecabral@geofisica.unam.mx
New Zealand	GNS Science	Large National Network	Elisabetta D'Anastasion	E.DAnastasio@gns.cri.nz
New Zealand	Land Information New Zealand	Large National Network	Dion Hansen	DHansen@linz.govt.nz
Sri Lanka	Survey Department of Sri Lanka	Strong interest in developing Tsunami Early Warning	P. Sangakkara,Mr A. Dissanayeke	sangakkara@yahoo.com, addsgc@survey.gov.lk
USA	Georgia Tech	Significant focus on subduction zone activity and the generation of tsunamis	Andrew V. Newman	anewman@gatech.edu
USA	Jet Propulsion Laboratory	Real time expertise, Ionospheric mapping, global and operations, earthquake and tsunami warning	Attila Komjathy	attila.komjathy@jpl.nasa.gov
USA	UNAVCO	Global GNSS networks, real time data systems, Global GNSS support	Linda Rowan	rowan@unavco.org
USA	READI Working Group	NASA-NOAA working group developing GNSS Based Tsunami Warning	Yehuda Bock, Timothy Melbourne	ybock@ucsd.edu, tim@Geology.cwu.edu
USA	NASA	NASA Solid Earth Science. Provides funding from GNSS Tsunami Warning development. Cooperating with NOAA in this effort.	Gerald Bawden	gerald.w.bawden@nasa.gov

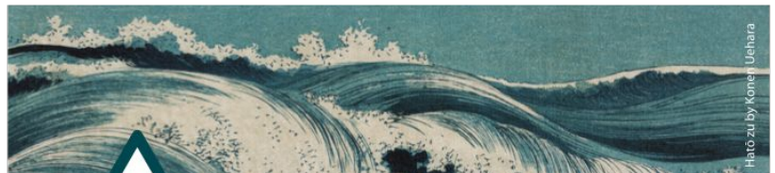
The GTEWS 2017 Workshop

2017:

The GTEWS 2017 workshop reviewed the maturity and utility of GTEWS and provided recommendations for its development. The workshop sought to implement the vision articulated by IUGG 2015 Resolution #4 to encourage broader cooperation within the Indo-Pacific community of APEC economies for the adoption of GTEWS.

2019:

GTEWS 2017 report was published by the Global Assessment Report for 2019 of the UN Office for Disaster Risk Reduction and by the Association of Pacific Rim Universities. The report validates that GTEWS is effective and affordable providing tsunami risk reduction and broad economic benefits to both developing and developed nations. The GTEWS 2017 workshop is aligned with the goals and priorities the UNDRR Sendai Framework for Disaster Risk Reduction 2015-2030 (https://www. unisdr.org/we/coordinate/sendai-framework). GTEWS 2017 workshop recommendations begin with the establishment of a GTEWS Consortium of Principals to support the development of the GTEWS network.



Global Navigation Satellite System to Enhance Tsunami Early Warning Systems

Editors:

John LaBrecque
Center for Space Research, University of Texas
Austin, Texas USA

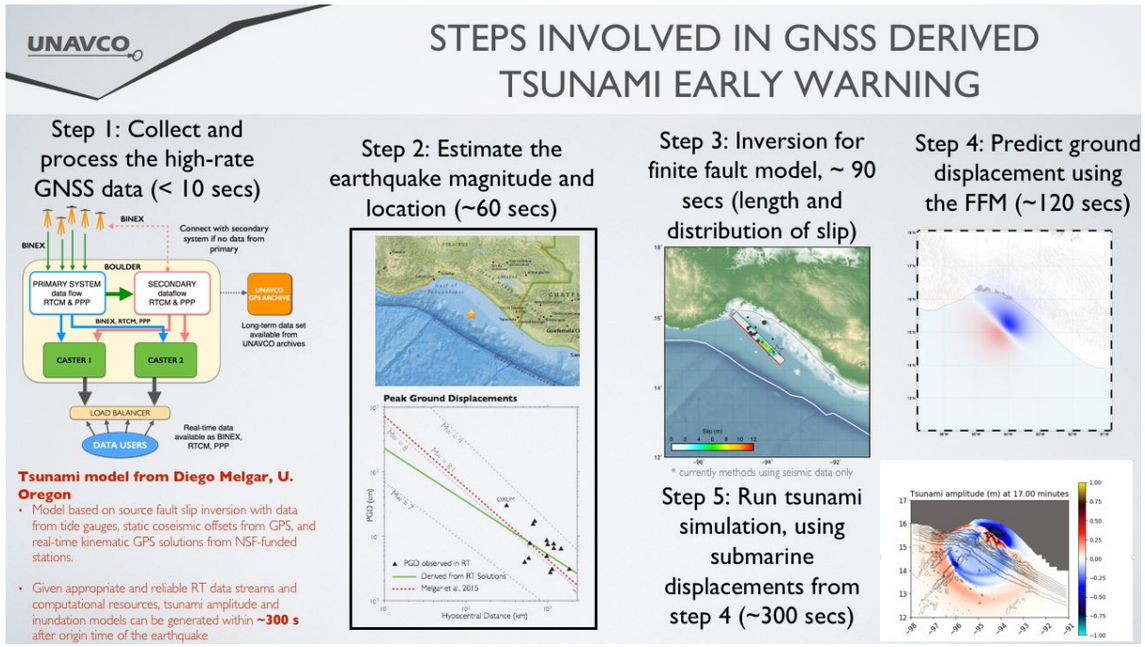
John Rundle
Earth and Planetary Science, University California
Davis, California, USA

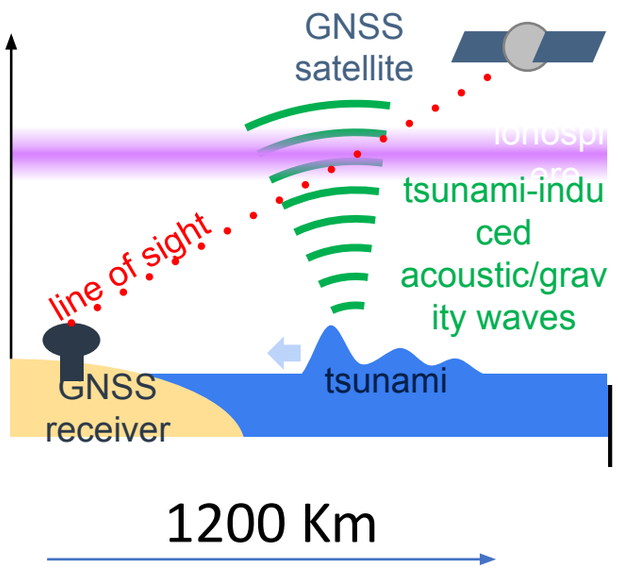
Gerald Bawden
Earth Surface and Interior Focus Area,
Science Mission Directorate, NASA
Washington, DC USA

December 2018

GTEWS Utilizes Displacement and TEC

GGOS Global Geodetic Observing System





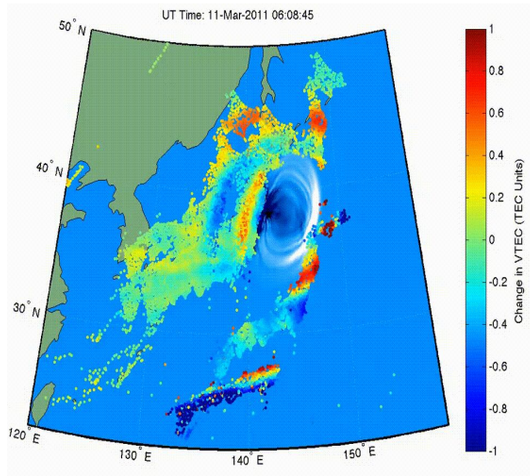


Figure: Ionospheric TEC and sea surface height map for the 2011 Tōhoku-Oki event (Galvan *et al*., 2012).

Displacement measurement allows Prediction

TEC measurements provides Validation and Tracking

Requirements to achieve Pacific GTEWS

GGOS
Global Geodetic
Observing System

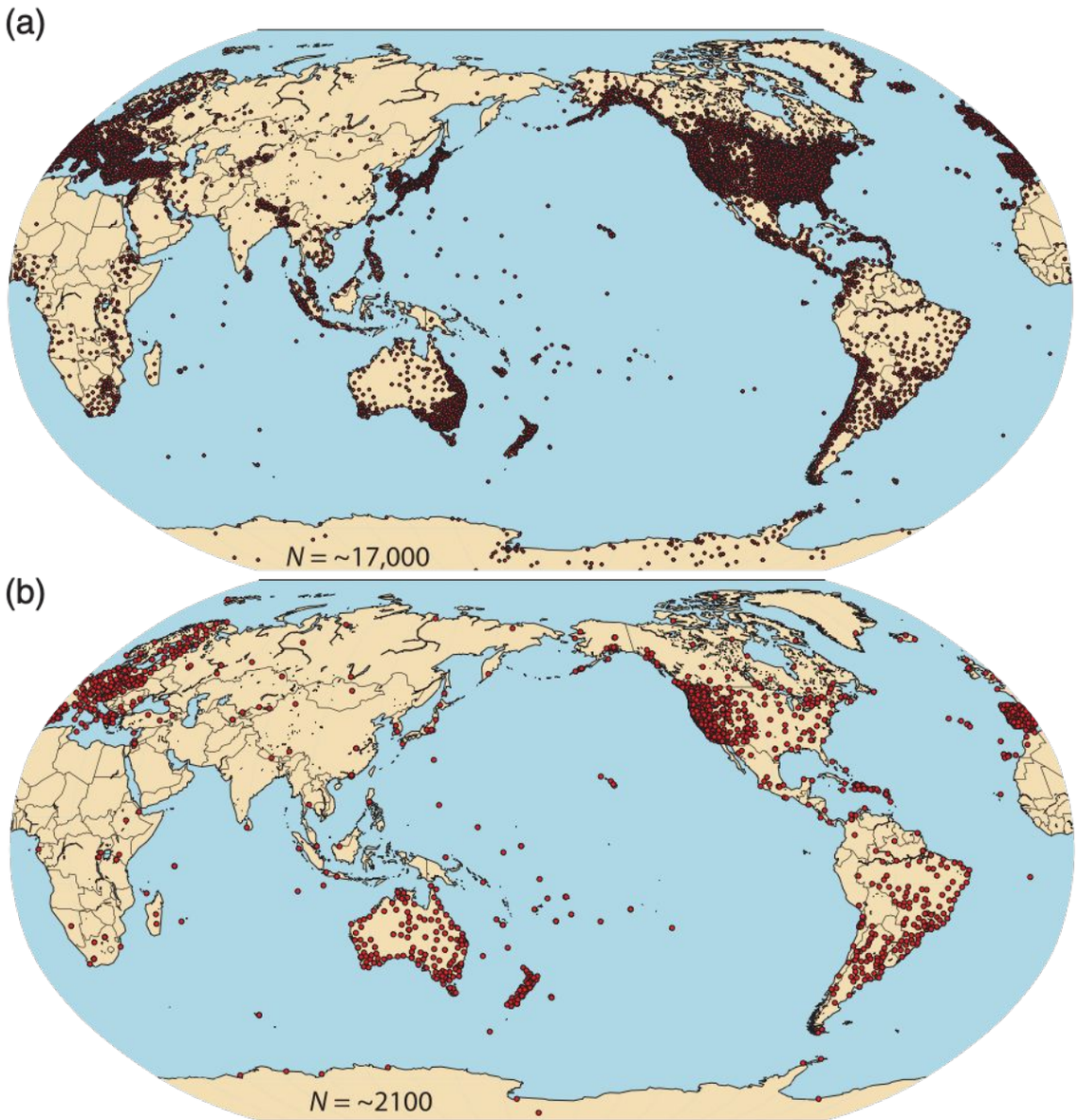
- International collaboration
  Data and software sharing
- Improved GNSS network infrastructure
  Real time multi-GNSS, active maintenance
- Regional Broadband Access
  Satellite coverage for remote areas?
- Integrated computational infrastructure
  Global Cloud computing and regional processing

GTEWS INTERNATIONAL DATA SHARING

The GTEWS 2017 workshop report emphasized the importance of international data sharing of real time GNSS data.

(a) Displays the global distribution of 18,000 GNN data sets.

(b) Real time open streamed GNSS data are significantly reduced in the western Pacific and Oceania.(Melbourne et al.2021)



Global Real Time GNSS Receiver Distribution

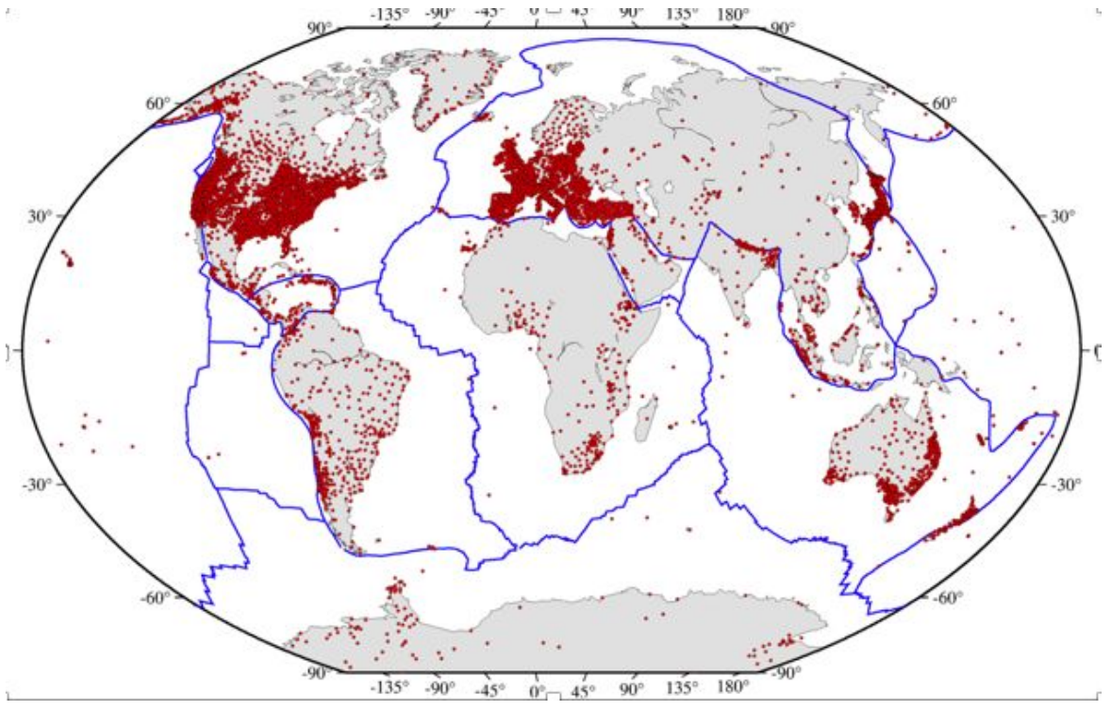
GTEWS-PACIFIC NETWORK REQUIREMENTS

GTEWS-Pacific requires approximately 1700 real time GNSS receivers in optimized locations within the Indo-Pacific Basin.

Displacement: Following Sobolev et al. 2007. GTEWS 2017 workshop recommended three or more receivers every 100 km along the Pacific Ring of Fire (40000 km) to optimally capture fault displacements. (~1200 receivers)

and

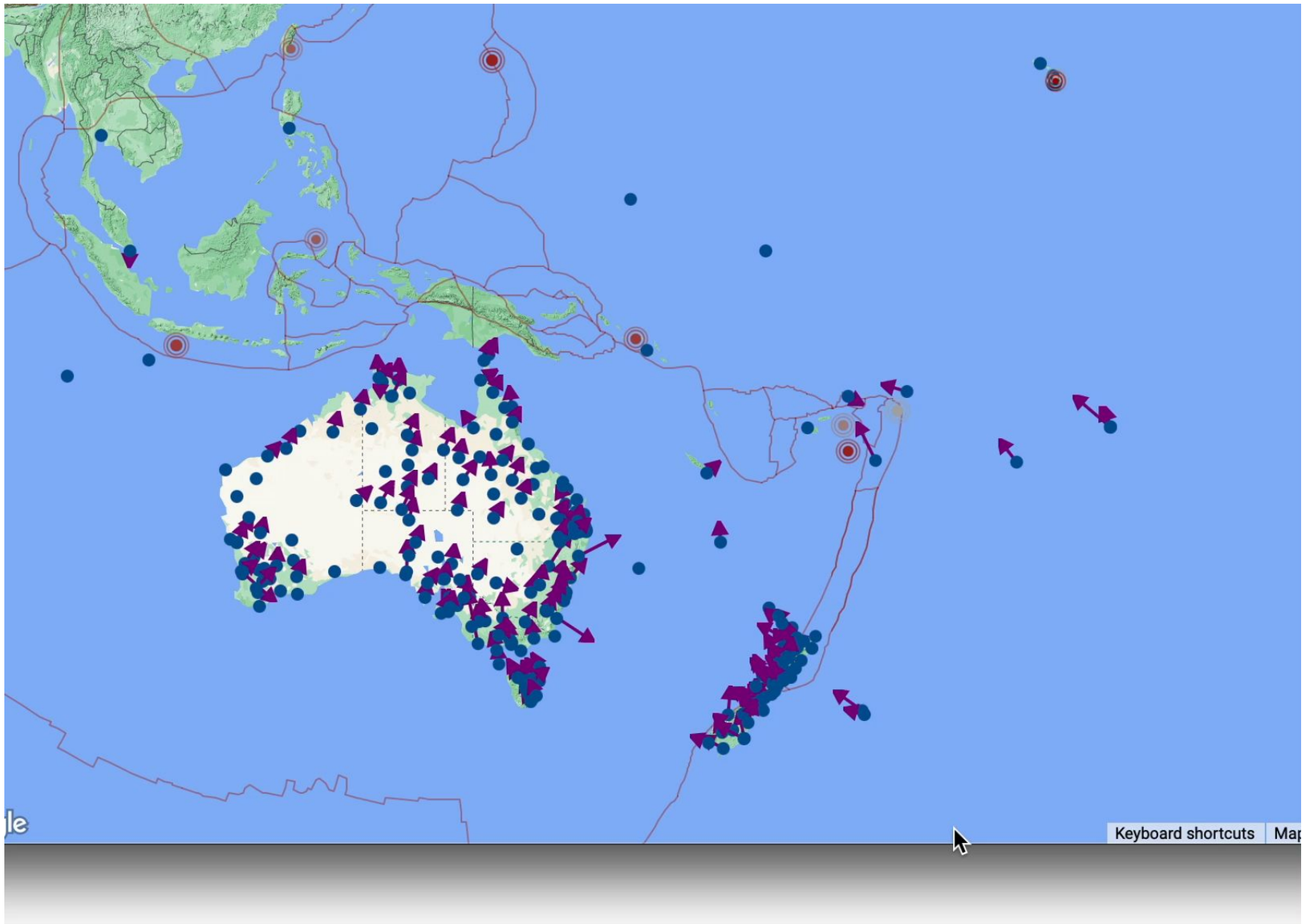
TEC: A mesoscale distribution (200-500km) of GNSS receivers to provide regional measure of ionospheric perturbations- geodetic bracing is not necessary but desired for other applications. (~ 500 receivers). A large percentage of these stations can include upgraded existing GNSS network stations.



Over 18,000 GNSS receivers provide open data access. About 2100 of these receivers stream data in real time. There are more such receivers with restricted data flows to registered users. These open and dark receivers could significantly reduce the GTEWS network development cost.

GPSCOCKPIT REAL TIME DISPLACEMENT

All currently open GNSS streaming for the Oceania. Note the stability of the Australian and New Zealand network measurements and the low density of real time GNSS from much of Oceania. Clearly, a focus upon upgrading the region's GNSS to state of the art real time streaming is required.
Recorded from the [GPScockpit website]
courtesy the Panga Network.

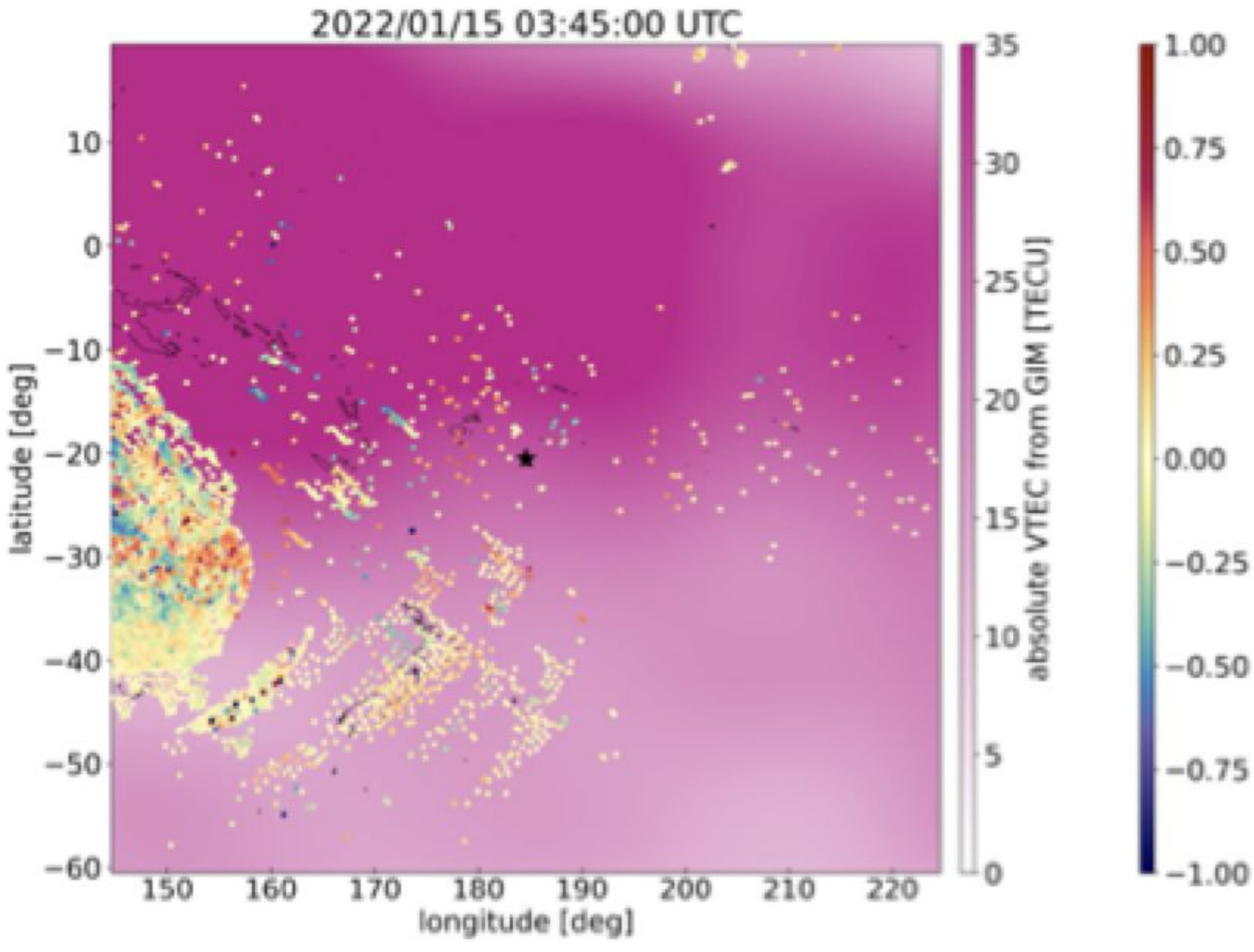


GUARDIAN REAL TIME IONOSPHERIC TEC MONITORING HUNGA TONGA-HUNGA HA'APAI : 15 JANUARY 2022

GGOS Global Geodetic Observing System

[GUARDIAN: A Near Real-Time Ionospheric Monitoring System for Natural Hazards Early Warnings]
Léo Martire, S. Krishnamoorthy, L. J. Romans, B. Szilágyi, P. Vergados, A. W. Moore, A. Komjáthy, Y. E. Bar-Sever, A. B. Craddock, NASA Jet Propulsion Laboratory, California Institute of Technology

- **Background: very-high-rate (2-min) GIM.**
- **Foreground:**
  - calibrated TEC data (30-sec rate),
  - filtered (periods < 60 minutes),
  - for all individual satellite-station links from the stations closest to volcano.



- **0445-0645, above volcano:**
  strong local ionospheric depletion (~15 TECU amplitude) & perturbations.
- **0530-0645, over New-Zealand:**
  main ionospheric signal.
- **0645 onwards, over eastern Australia:**
  enhanced ionospheric activity

Ref: USGS modeling of surface wave dispersion

Online Guardian real time results: *https://guardian.jpl.nasa.gov/*

The Way Forward

- **GTEWS can be implemented using currently available technology and measurement systems.**
- **GTEWS benefits are based upon currently available GNSS signals, commercial GNSS receivers, and analysis algorithms, broadband communications capability such as Generation 4 cell phone networks.**
- **Development of effective GTEWS enhancement for the Indo-Pacific requires:**
  - **Optimization of real time GNSS receiver networks;**
  - **International agreements for the distribution of GNSS real time data;**
  - **Cooperation with disaster reduction and response agencies.**
  - **Development of funding support**

The Way Forward

We propose that the IUGG, GGOS, GEO, and the ICG begin community discussions on the establishment of GTEWS-Oceania as a prototype International cooperative GTEWS.

The objective will be to develop international support and the proper resources to develop and maintain a mesoscale real time GNSS network and analysis capability to provide insure Oceania GTEWS.

- Oceania is currently underserved by real time GNSS infrastructure.
- Oceania is a multi-national region of interest to the international disaster risk reduction community
- Oceania is exposed to multiple geophysical and climate disaster risks that can be addressed by improved GNSS infrastructure.

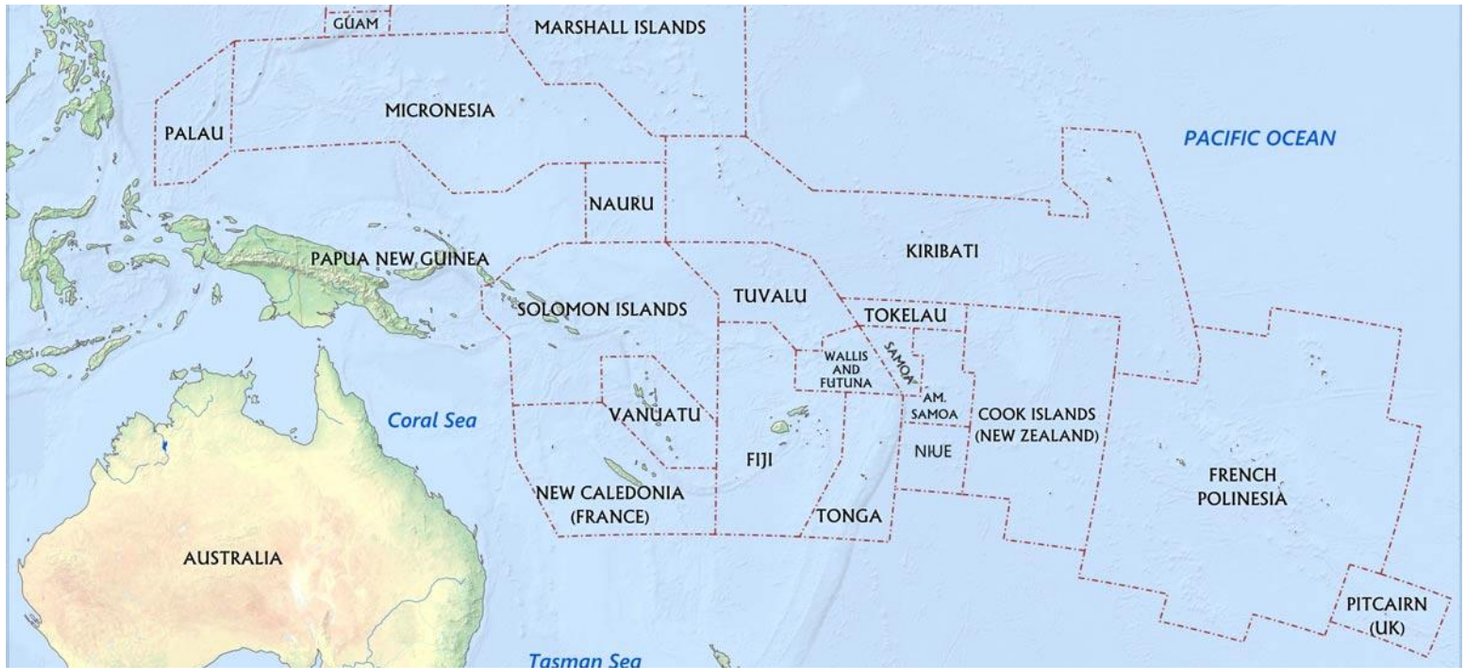
We will begin with monthly virtual meetings of interested principals with the highest priority being the strong participation of those South Pacific nations comprising Oceania.

Please join us in the development of GTEWS-Oceania

First Organizational discussions to begin via Zoom March 1, 2023 at 1 PM (UTC +13) (New Zealand time zone)

Register by sending email to:
jlabrecq@mac.com with the subject "GTEWS_Oceania"
Further notices to follow

Thank you!!!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TOKELAU
WALLIS AND FUTUNA
SAMOA
AM. SAMOA
COOK ISLANDS (NEW ZEALAND)
Coral Sea
VANUATU
NIUE
FIJI
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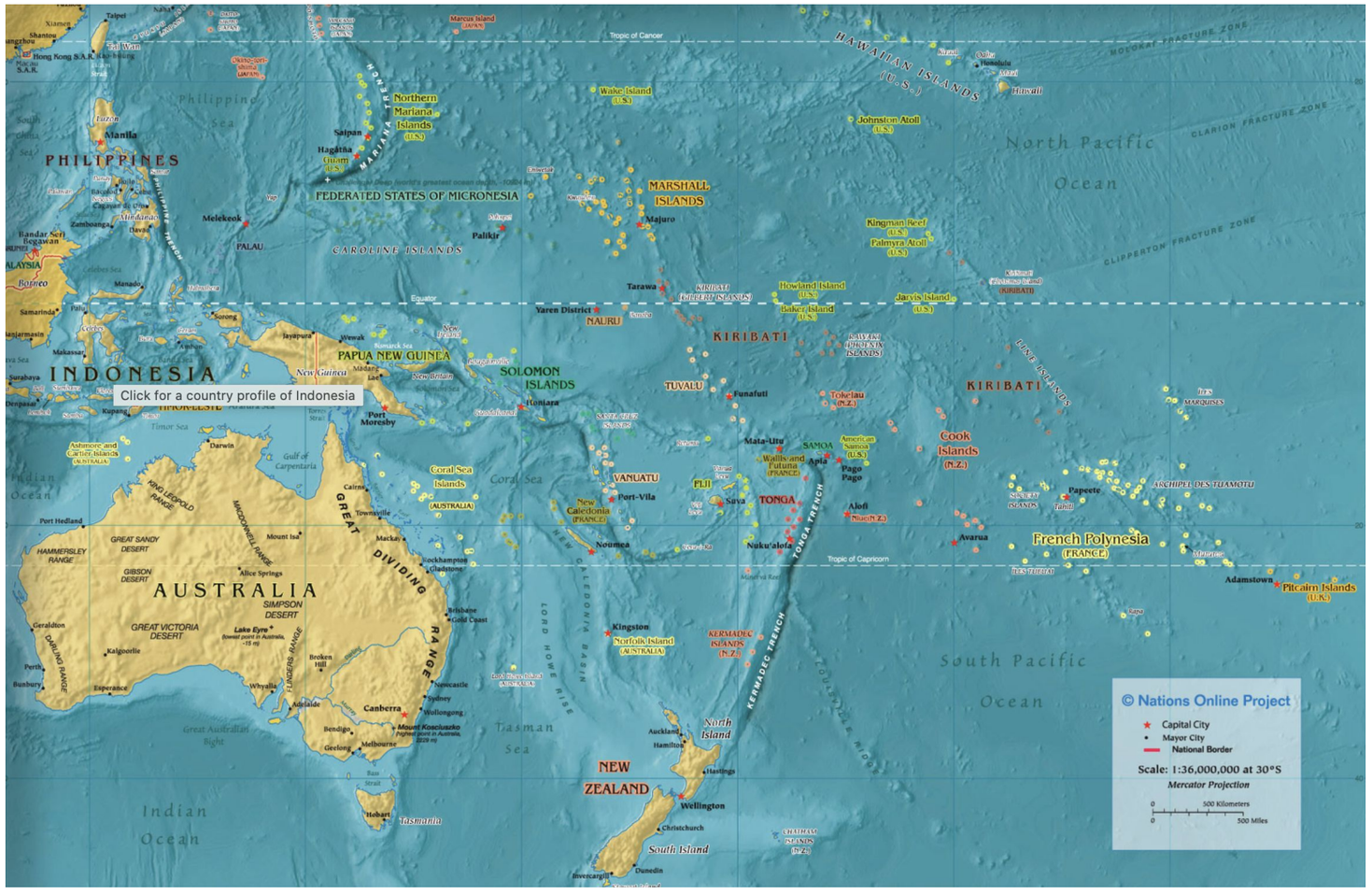
Tasman Sea

OCEANIA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Mercator Projection
500 Kilometers
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