2nd INTERNATIONAL WORKSHOP ON
WAVES, STORM SURGES AND COASTAL HAZARDS
13/Nov/2019

Storm Surge Forecast at Fiji Meteorological Service (FMS)

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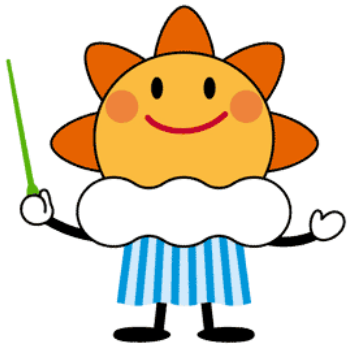
Contents

- Introduction
- Storm surge forecasting system
- Plan of storm surge forecast at FMS
- Summary / Further plan



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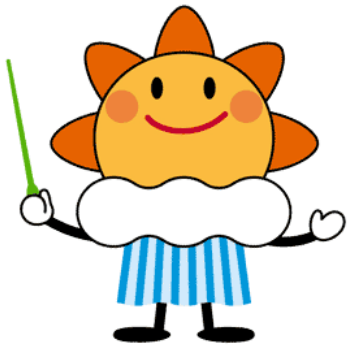
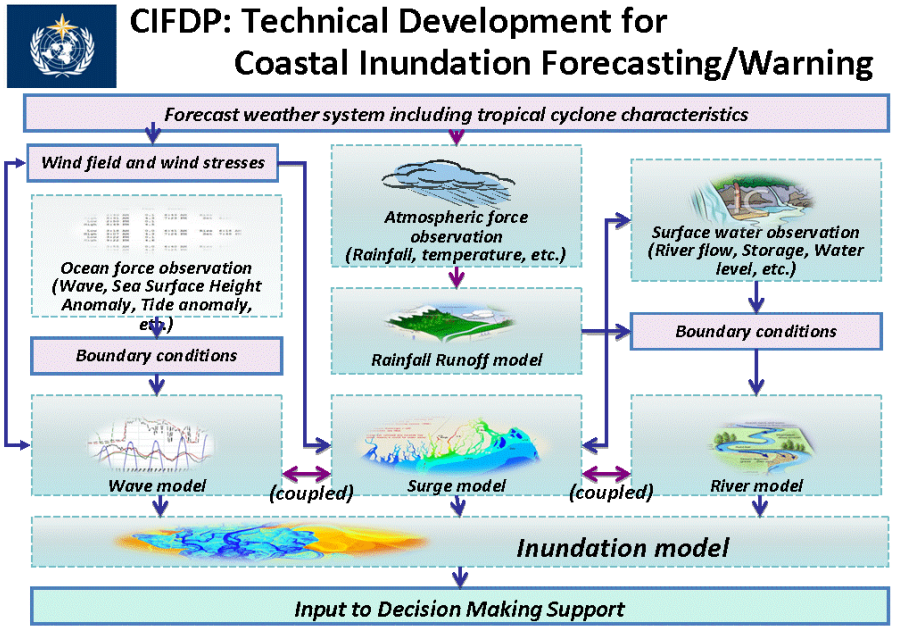
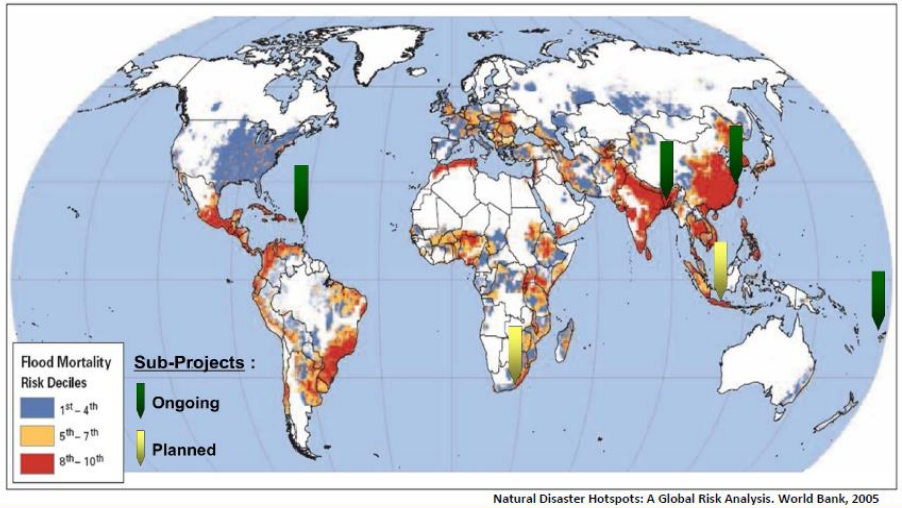


WMO Coastal Inundation Forecast Demonstration Project (CIFDP)

Applying available techniques for integrated operational forecasting/warning

- ✓Assessment of the regional coastal inundation forecasting/warning **capacities**
- ✓Identify **gaps**
- ✓Provide an **overview on the technical aspects** for definition





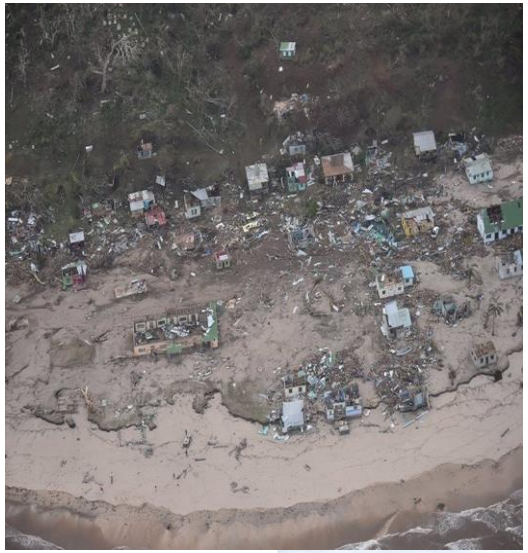
Natural Disaster Hotspots: A Global Risk Analysis. World Bank, 2005

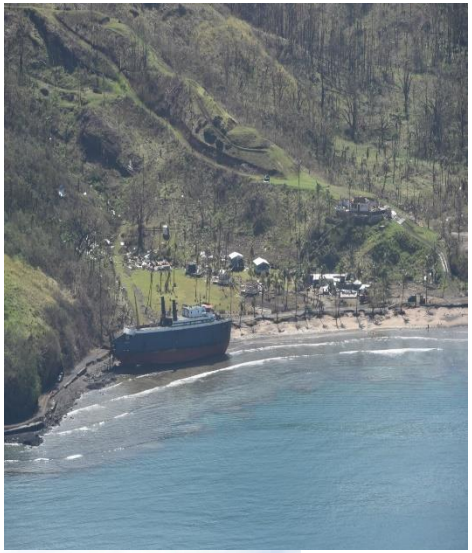
Sub-project：
Bangladesh, Caribbean(Dominica), **Fiji**, Indonesia, Shanghai(China)

Fiji sub-project: 2012-2019

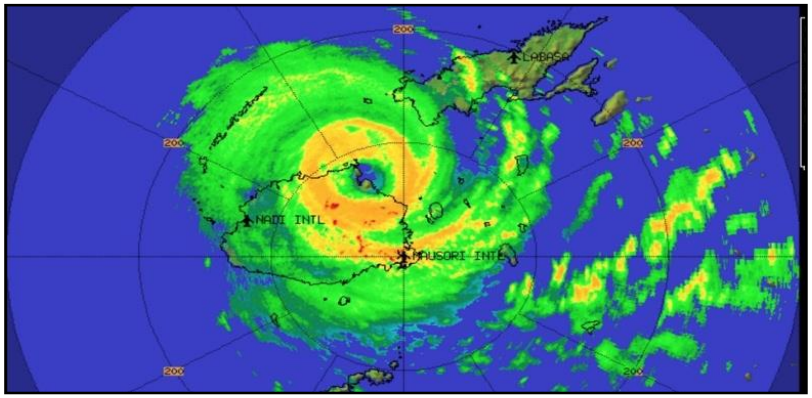
The project will finish soon!

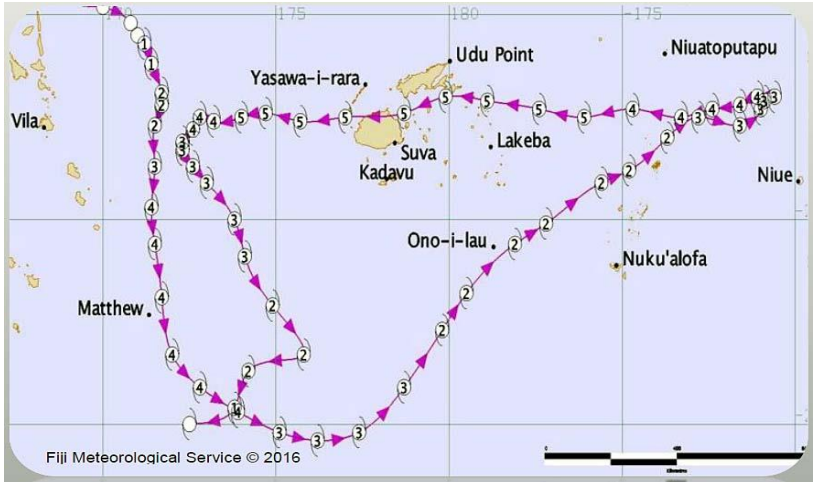
Tropical Cyclone WINSTON





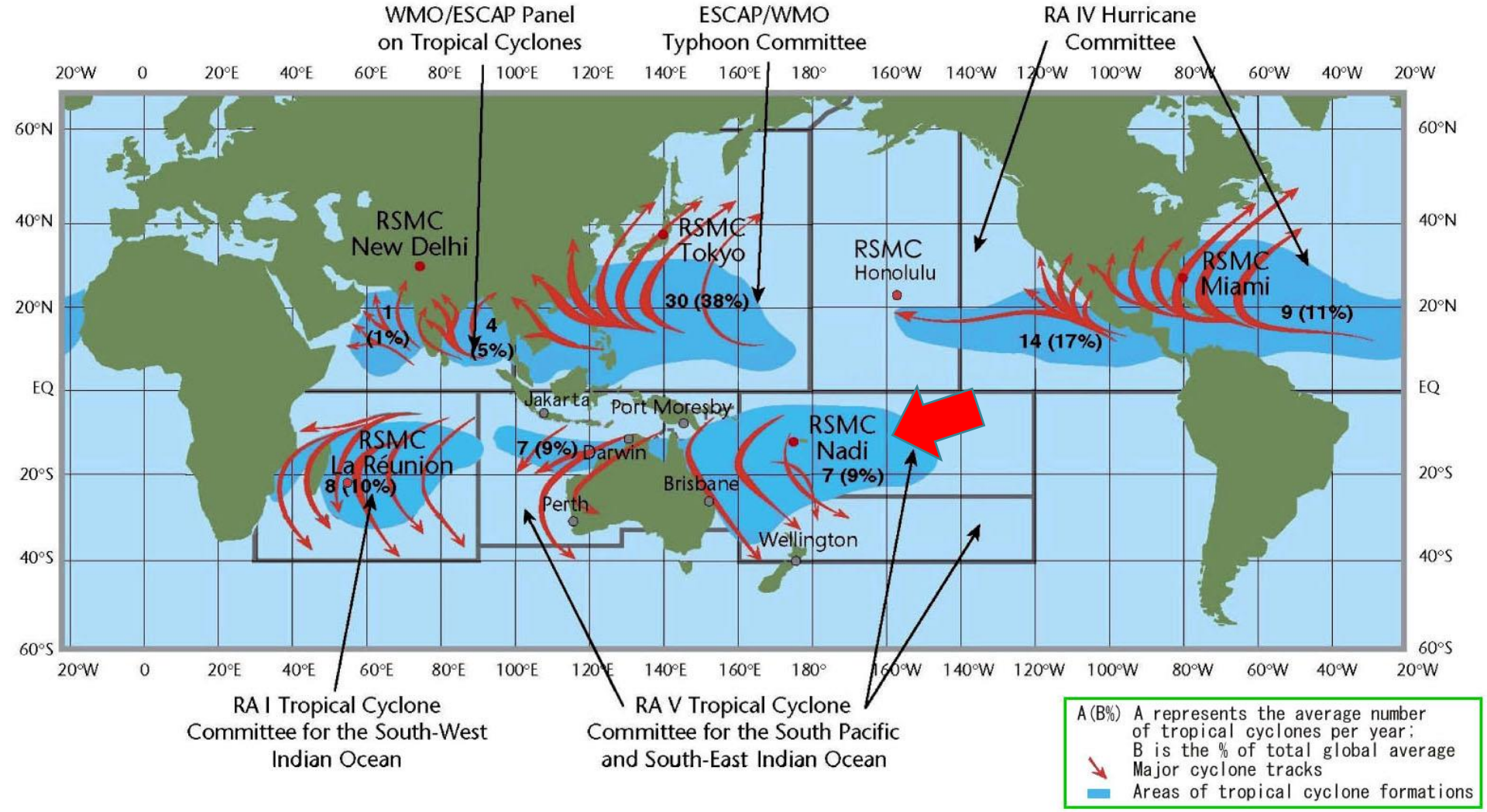
- **Highest winds**
  - 10-min sustained: **233 km/h** (Gust: 306km/h)
  - 1-minute sustained: **285 km/h**
- **Lowest pressure: 929 hPa (mbar)**
- **Storm surges: ~3 m**





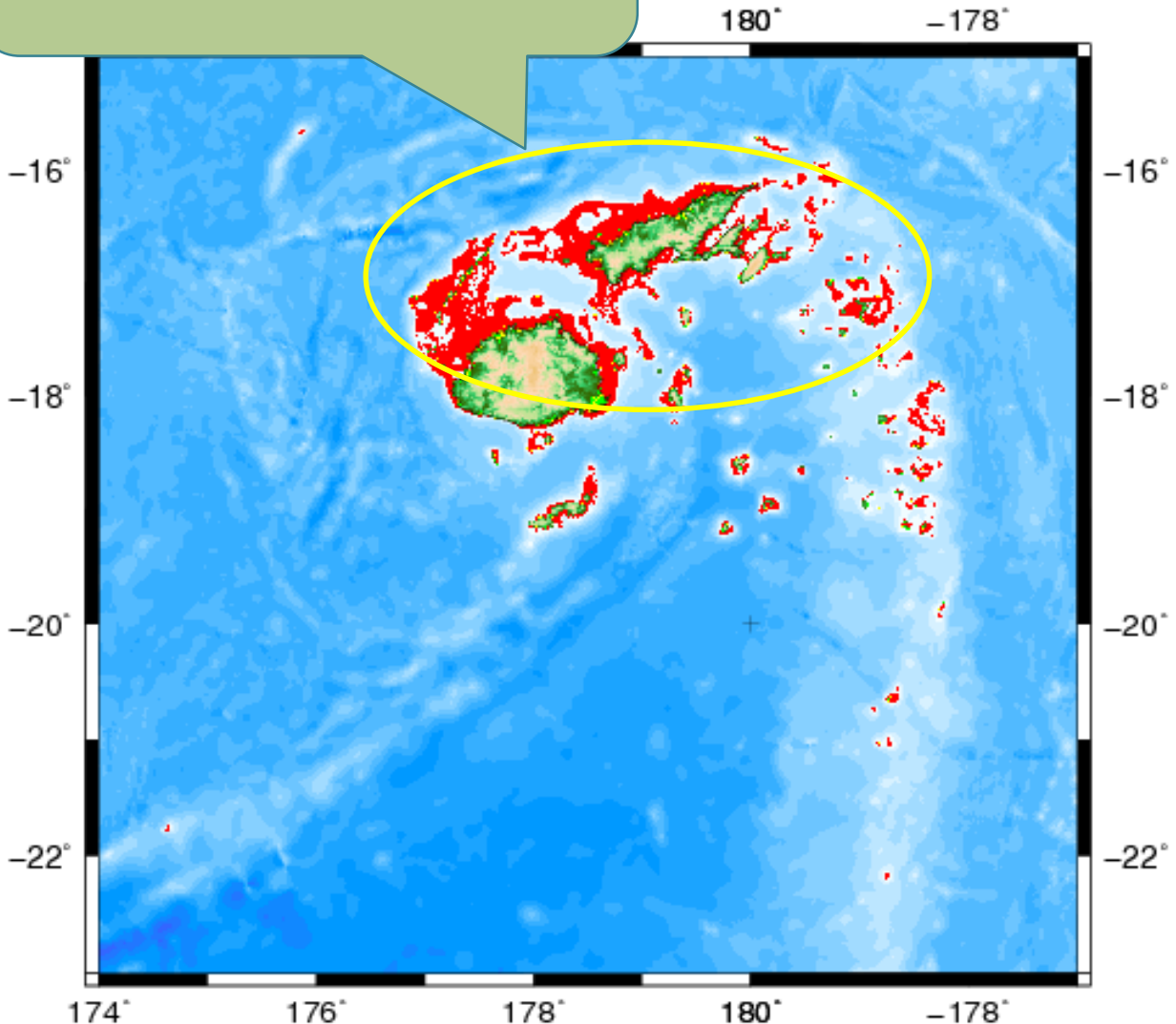
- ✓ **44** Casualties (possibly 2/3 are due to storm surges)
- ✓ **50,000** people in evacuation centers
- ✓ **350,000** people affected (~40% of Fiji pop.)
- ✓ **FJ$2.0 billion** Loss

Regional Specialized Meteorological Centres (RSMCs) of WMO

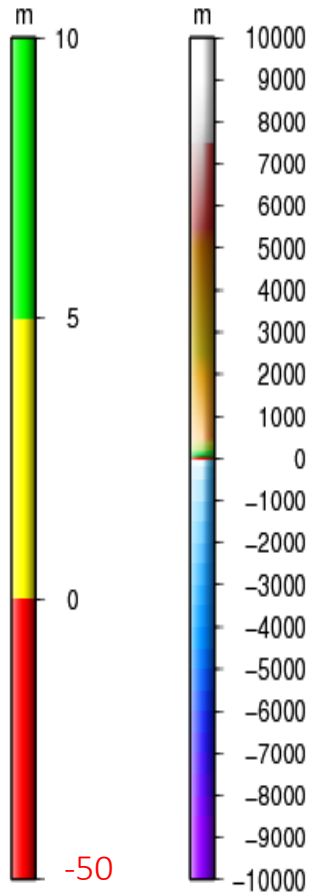


Bathymetry Condition of Fiji

There are shallow water region in north coast of Viti Levu and Vanua Levu.



Water depth and land height



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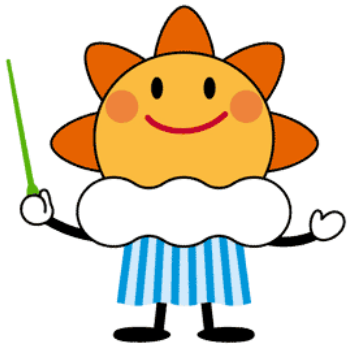
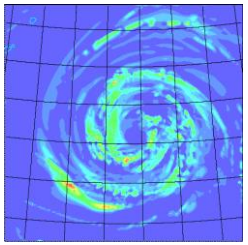


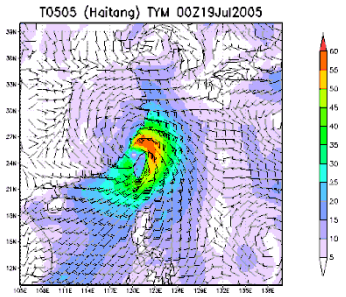
Schematic image of storm surge prediction

Input

tropical cyclone information

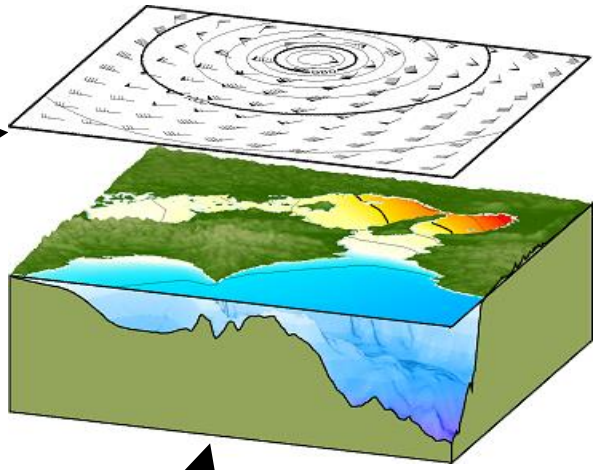


NWP predictions



Storm surge model

- based on two-dimensional shallow water equations



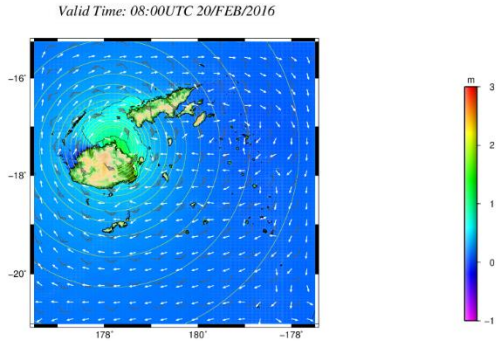
bathymetry

Astronomical tides

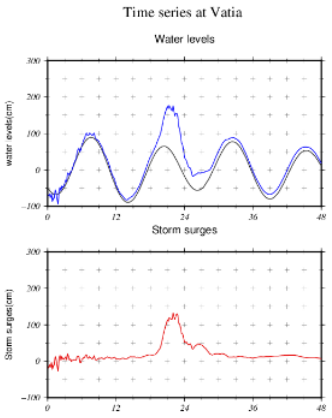
Waves

Products

storm surge map

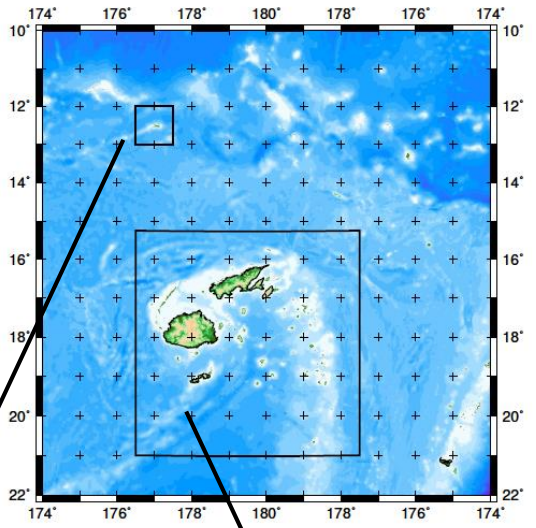


timeseries



Storm surge model for Fiji

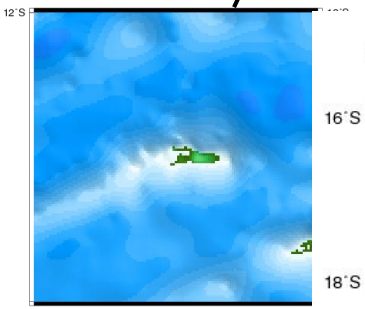
- The model has two domains to cover whole Fiji
  - Fiji main region (1 minute resolution)
  - Rotuma region (30 seconds resolution)
- The model runs 6 times/day if TC exists.
- TC forcing is created from TC analysis/forecast at FMS
  (TC module → TC data → parametric model)
- The 48 hours forecast is conducted.
  (Calculation finishes in 15 minutes at FMS SSM server.)
- Only storm surges are calculated. (Tide is added later*)



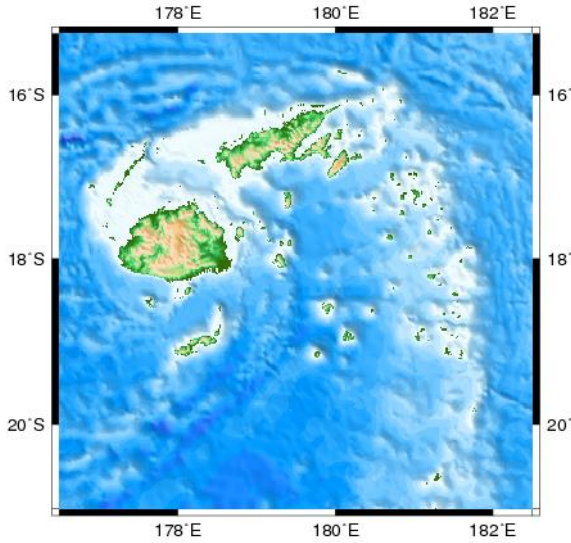
(Sample of TC data)

CYCLONE Ben(1986) Start= 050700 End= 050900
48 hours calculation
6 hourly data

date	Pc	lon	lat	r0	Coef	Pfar
050700	950	176.09	-13.16	10	0.7	1012
050706	950	176.23	-14.38	10	0.7	1012
050712	945	177.84	-15.24	10	0.7	1012
050718	935	179.21	-15.59	10	0.7	1012
050800	930	-179.39	-16.27	10	0.7	1012
050806	930	-177.35	-18.02	10	0.7	1012
050812	940	-175.09	-19.22	10	0.7	1012
050818	950	-172.10	-19.87	10	0.7	1012
050900	960	-169.47	-20.05	10	0.7	1012



Rotuma
(30 seconds)

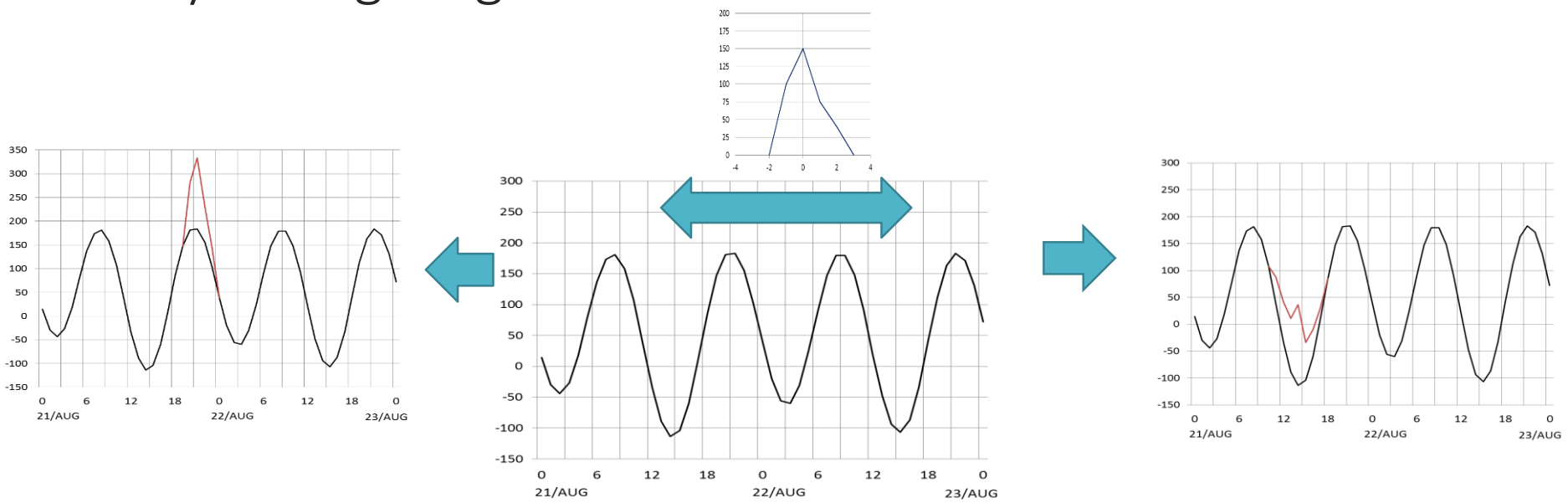


Fiji main (1 minute)

Tide + surge

Strictly speaking, surge and tide are not separable and can not add linearly. However if astronomical tides are not so large as storm surges, which is often the case by tropical cyclones, the linear addition of storm surge and tide gives good estimation.

Moreover, surge errors by TC forecasts is much larger than the error by linear addition. We can easily evaluate worst risk case by sliding surges:



Modification

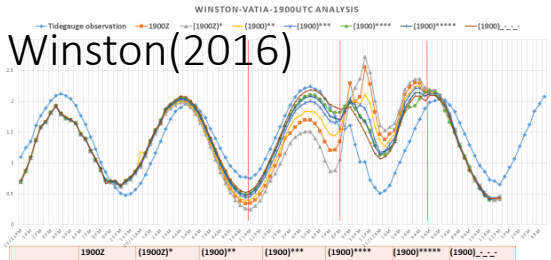
Funaki (2019) conducted storm surge hindcast with several tropical cyclone cases, and verified the predicted values with tide observations.

Based on the results, some coefficients were tuned up.

- Environmental pressure: 1012hPa → 1004 hPa
- Coefficient of symmetric surface winds:

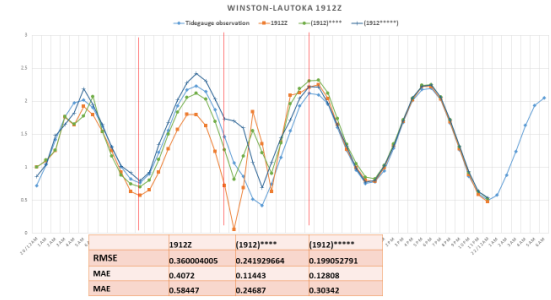
  0.7 (universal constant) → 0.7 – 0.4 domain dependent

Winston(2016)



	1900Z	(1900Z)*	(1900)**	(1900)***	(1900)****	(1900)*****	(1900)_._._.
RMSE	0.494665557	0.578041608	0.421303108	0.365132971	0.339422	0.344235	0.302827
MEAN ERROR	-0.4876	-0.59516	-0.35937	-0.26052	-0.19061538	-0.19584615	-0.12841
MEAN ERROR	0.816461	0.903411	0.701478	0.62315	0.53710556	0.548755556	0.474183

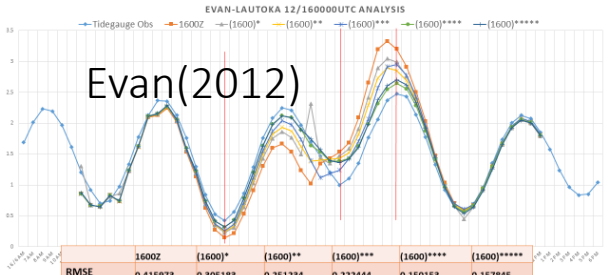
RMSE: 0.49m → 0.33m



	1912Z	(1912)****	(1912)*****
RMSE	0.360004005	0.241929664	0.199052791
MAE	0.4072	0.11443	0.12808
MAE	0.58447	0.24687	0.30342

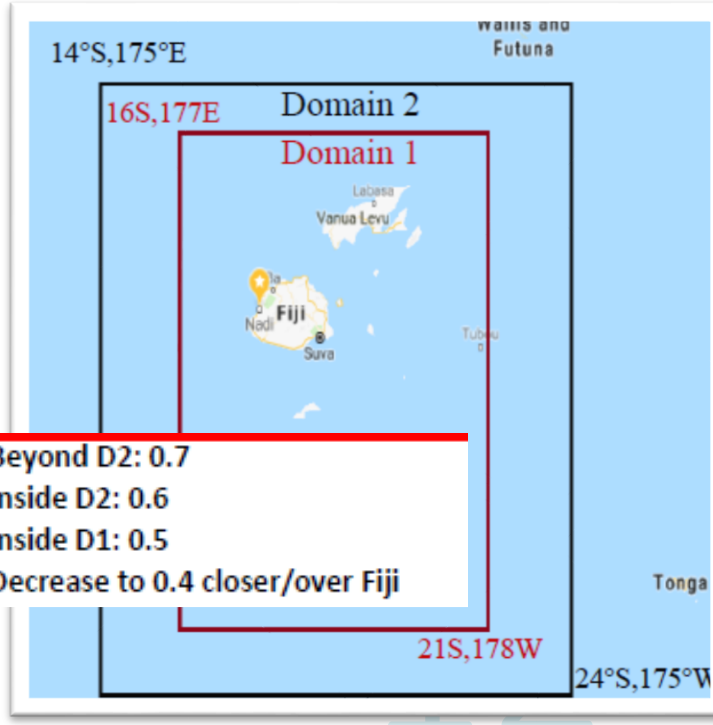
RMSE: 0.36m → 0.12m

Evan(2012)



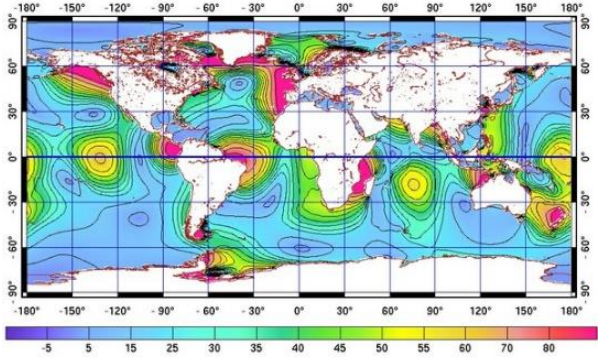
	1600Z	(1600)*	(1600)**	(1600)***	(1600)****	(1600)*****
RMSE	0.415973	0.305183	0.251234	0.222444	0.150153	0.157845
MAE	0.408086	0.2823	0.231871	0.186371	0.106329	0.108471
MAE	0.507586	0.365671	0.289386	0.2278	0.144714	0.146943
MAE	0.793571	0.597686	0.487586	0.392329	0.257243	0.275471

RMSE: 0.41m → 0.15m



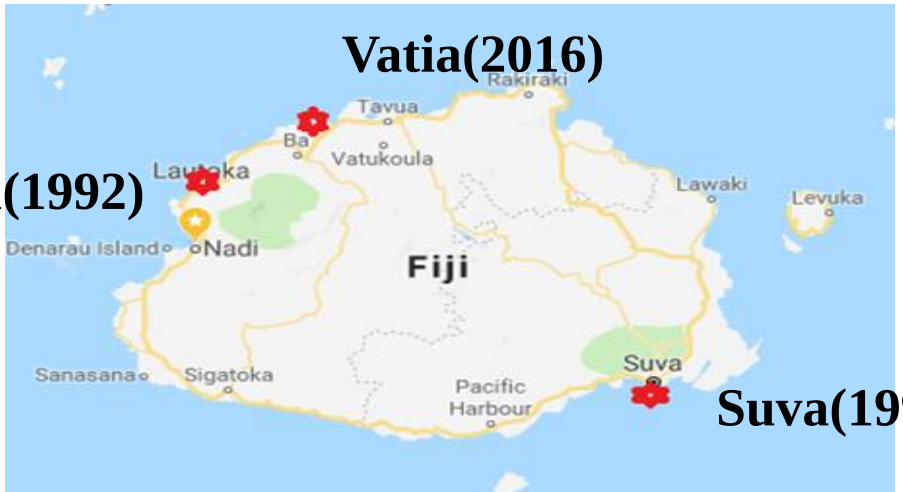
Astronomical Tides

Global Ocean Tide Models: FES2014

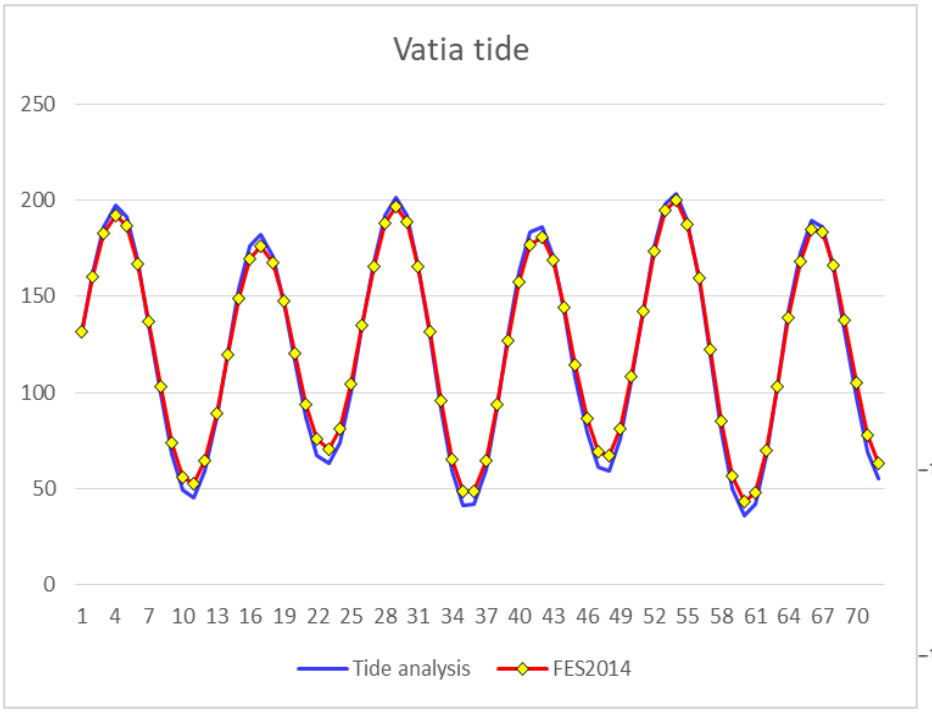


- ✓ Derived from FEM solution
- ✓ Data assimilation (EnOI)
- ✓ Tides are avairavle with 1/16 deg. grids
- ✓ 34 Tidal constituents:
  2N2,EPS2,J1,K1,K2,L2,La2,M2,M3,M4,M6,M8,Mf,MKS2, Mm,MN4,MS4,MSf,MSqm,Mtm,Mu2,N2,N4,Nu2,O1,P1, Q1,R2,S1,S2,S4,Sa,Ssa,T2

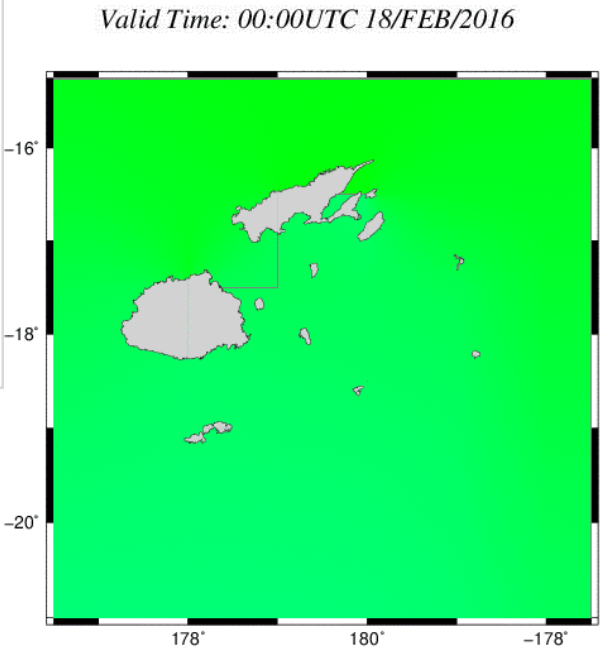
Fiji has three tide stations:



Astronomical Tides by FES2014



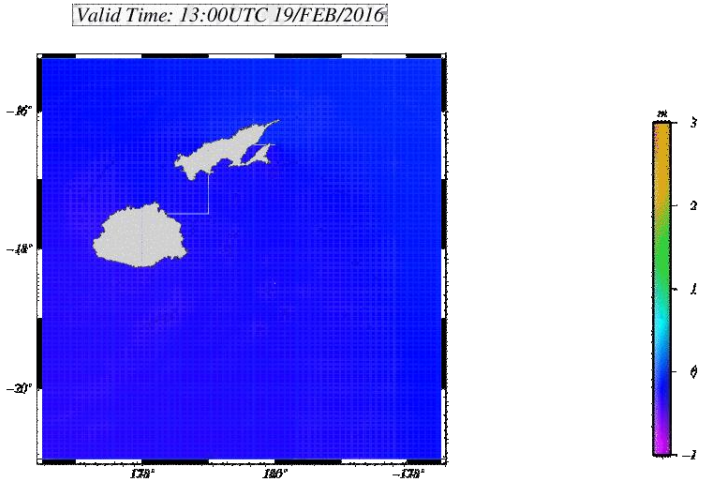
Verification of calculated tides



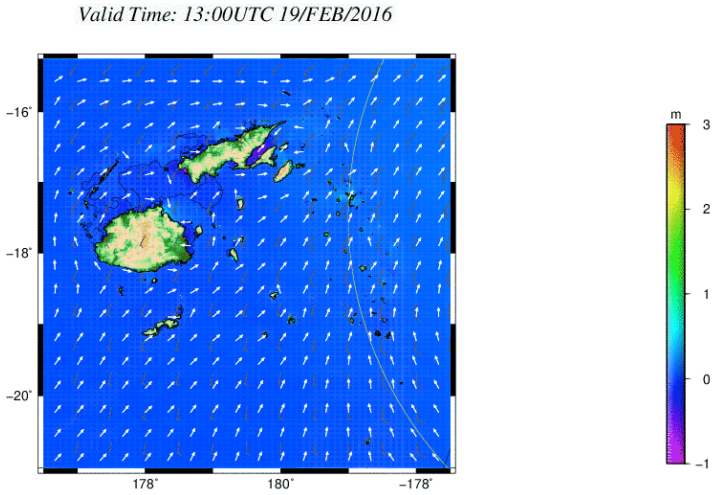
Estimated tides in Fiji SSM region

Simulated water level

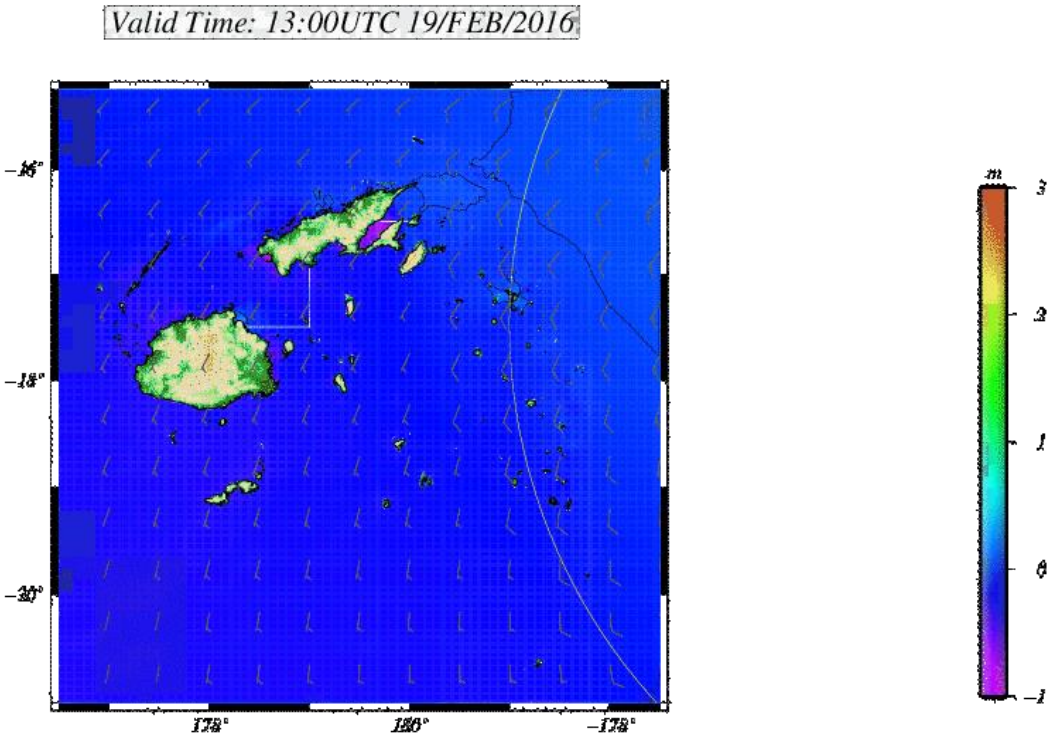
Astronomical tides



Storm surges

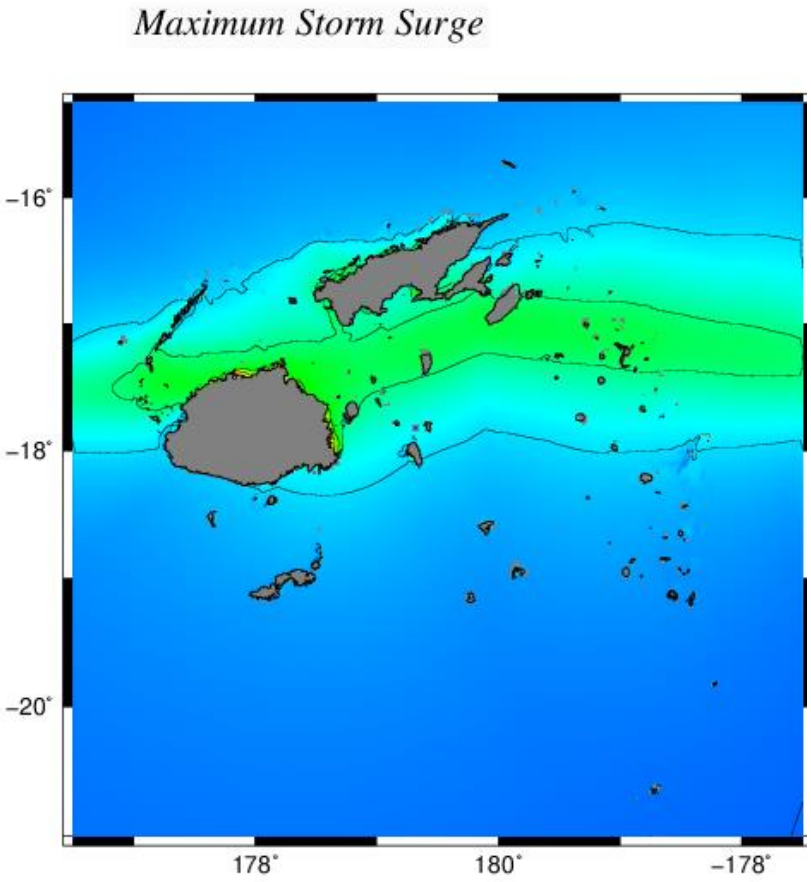


Storm tides

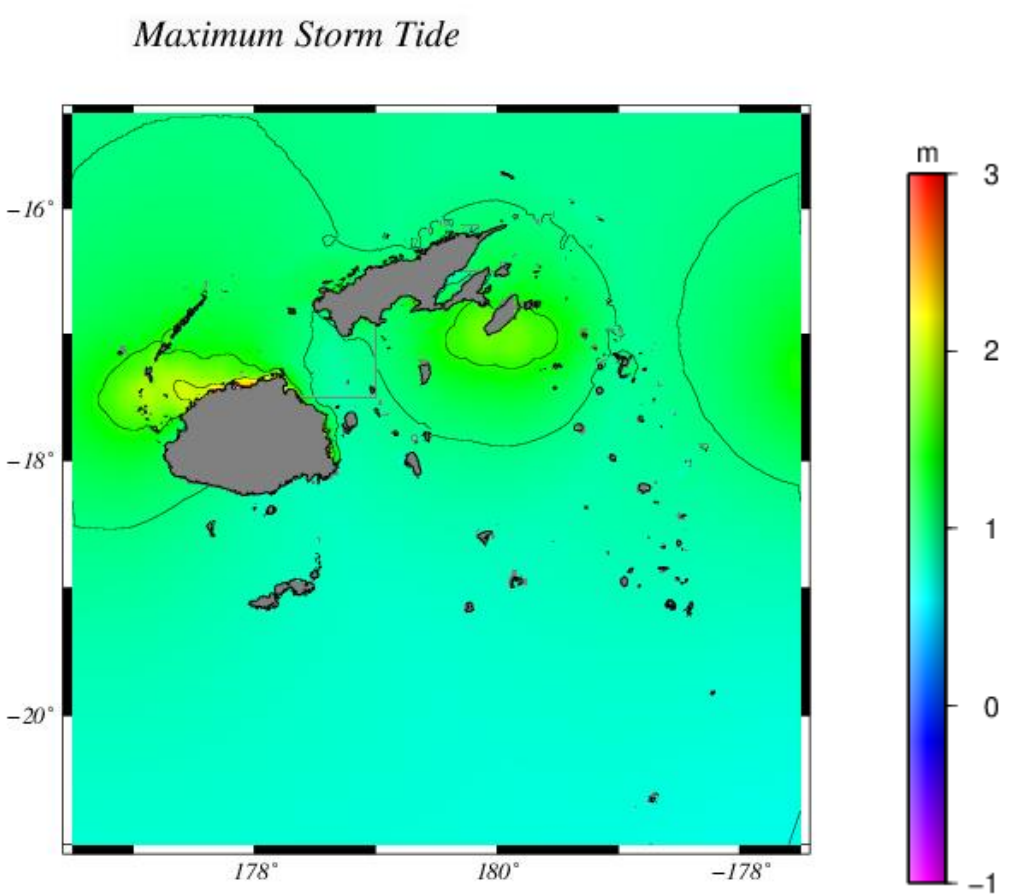


Maximum values in the calculation

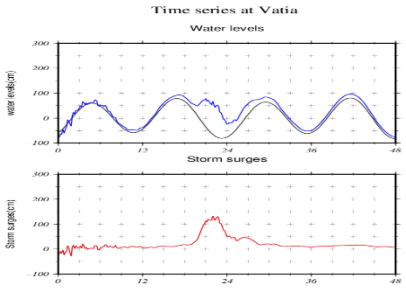
Maximum Storm surges

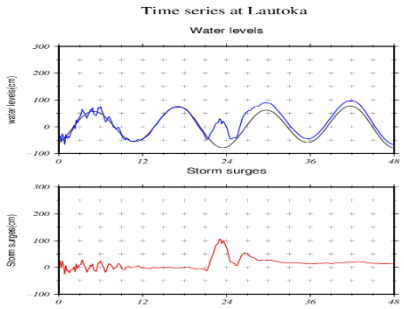


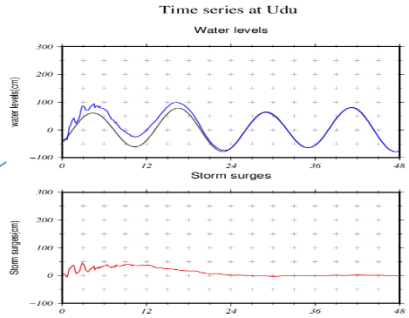
Maximum Storm tides

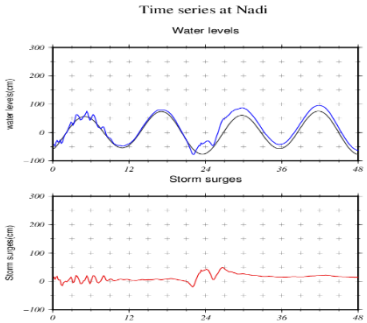


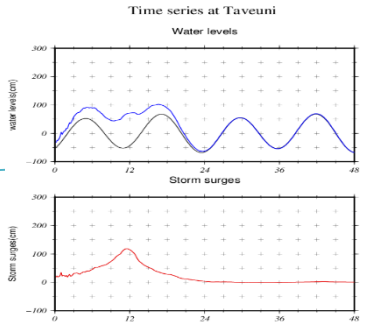
Predicted storm tides at stations

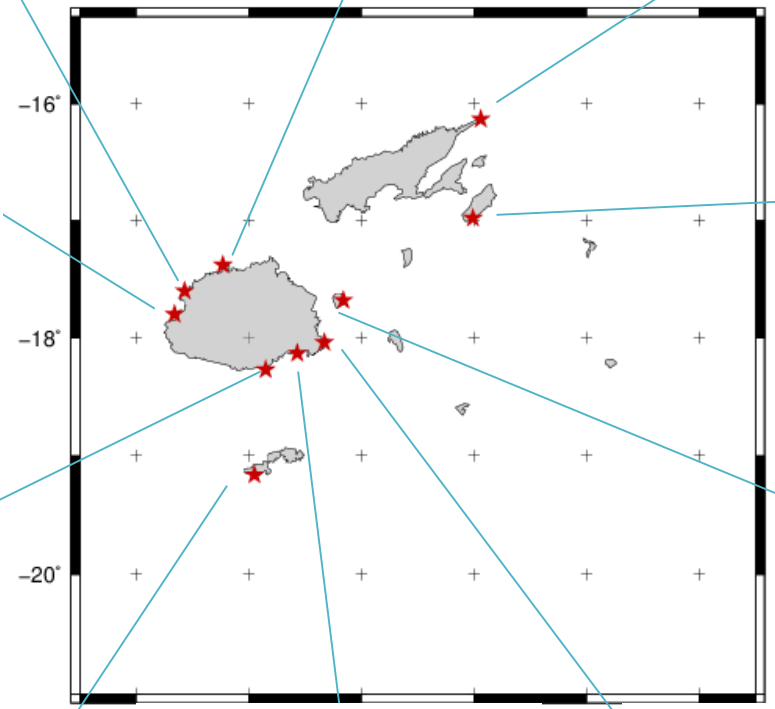


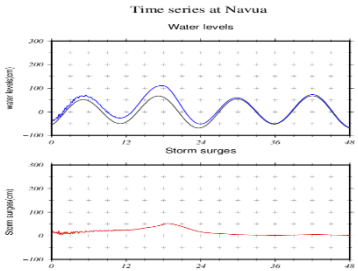


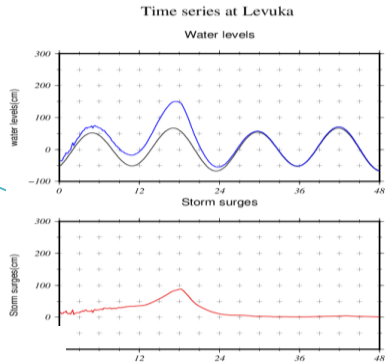


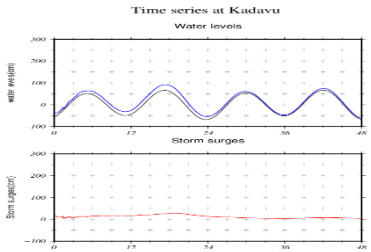


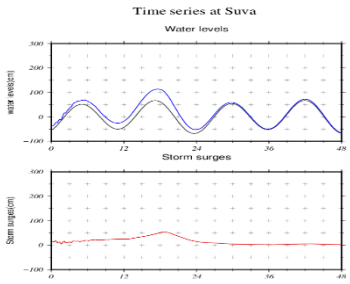


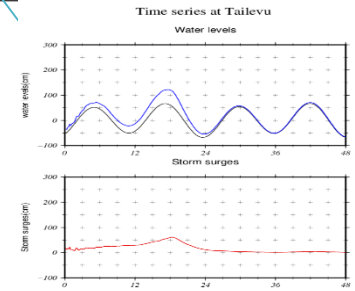












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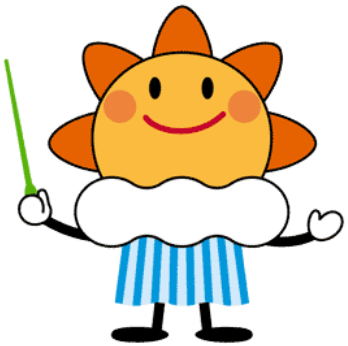


Summary / Future plans

Summary

- ✓ *An operational storm surge forecasting system for FMS was developed.*
- ✓ *The system was installed to a FMS server and is operated by FMS operational staff.*
- ✓ *The operation is supposed to be conducted in this cyclone season.*

Further development plan

- ✓ *Start issuing storm surge warning/advisory*
- ✓ *Introducing multi-scenario storm surge forecasts*
- ✓ *Usage of ocean wave forecasts for evaluating inundation risk*
- ✓ *Integration of predicted data for total water levels*
- ✓ *Development of a wave forecasting system of FMS own.*

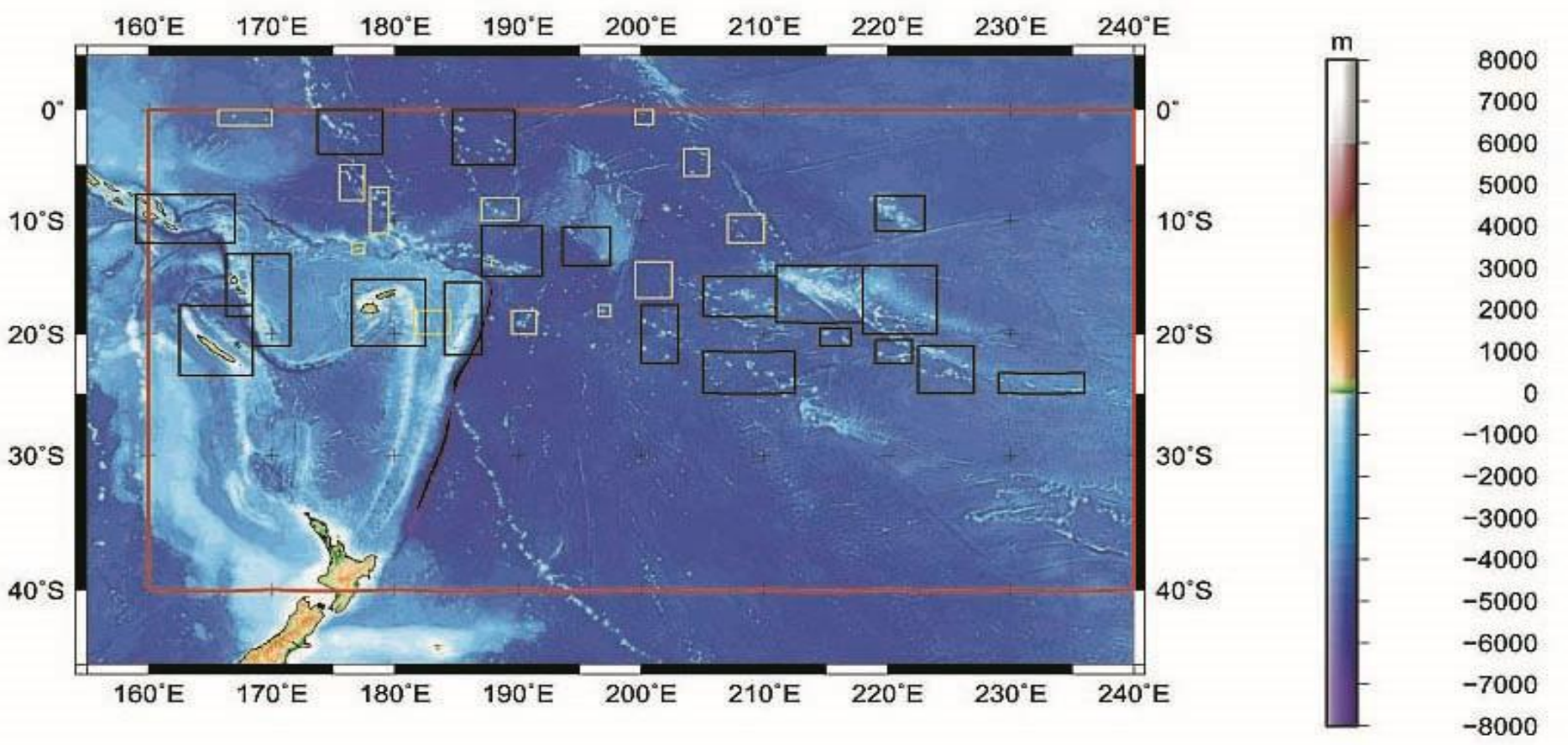
- ✓ *Regional storm surge forecast as RSMC Nadi*

Extension of FMS storm-surge forecast

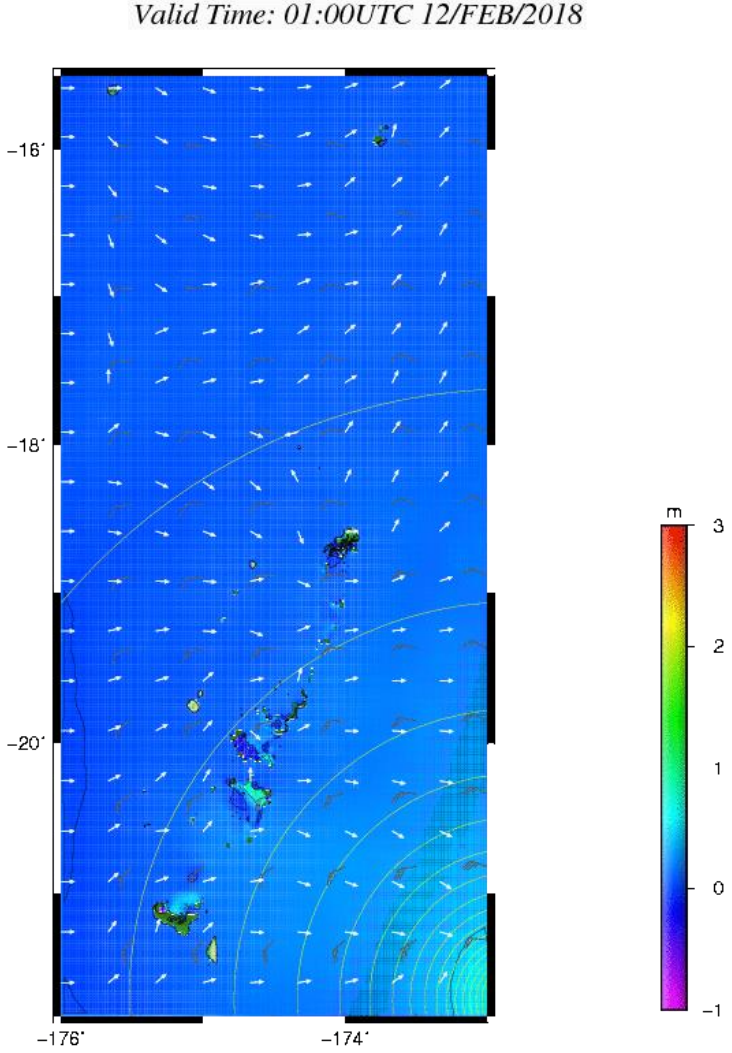
FMS, as **RSMC-Nadi**, is going to start issuing real time storm surge guidance, to member countries in the responsibility area (RA-5).

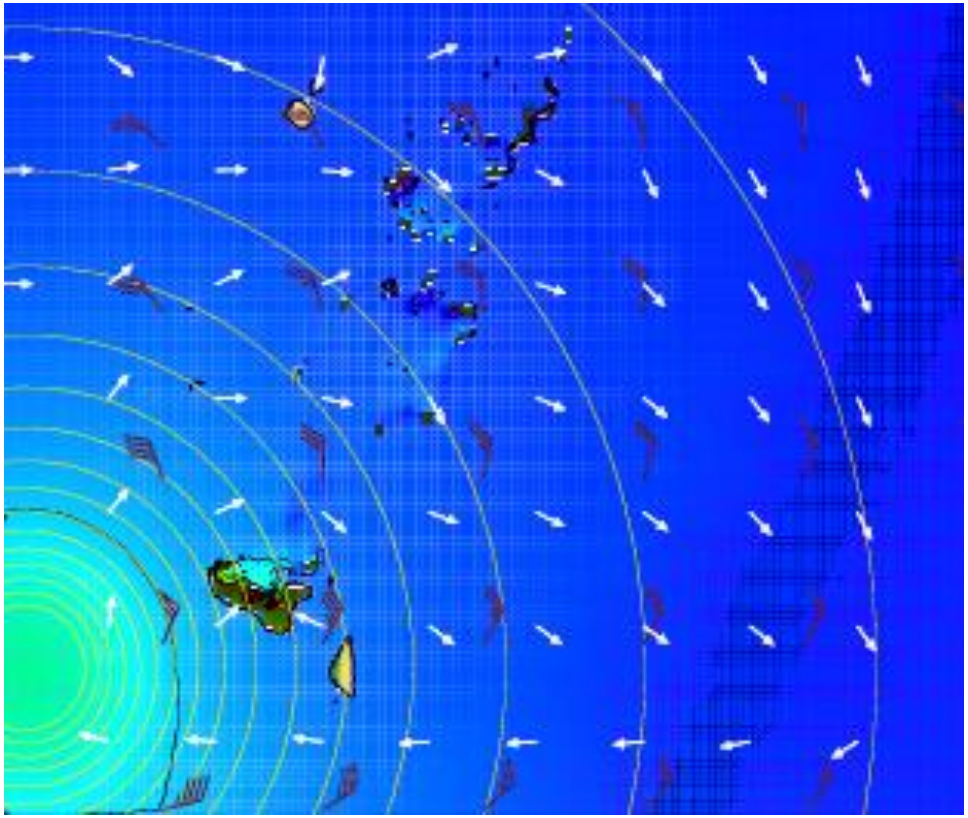
2017 - November : System development
2018 – April : test
2018 November- : operation as trial base

Sub-regions for calculation
□: 1 minute resolution
□: 30 seconds resolution



Simulated storm surges by GITA in 2018





Left: Storm surge animation (14:00 19/Feb – 20:00 20/Feb)
Right: A snapshot of Tonga at 14:00 12/Feb/2018

Thank You for attention!