Geosciences 2011 Conference
1 December, 2011
Rutherford Hotel, Nelson

Contribution of Warkworth 12m VLBI radio telescope to New Zealand geodesy

Institute for Radio Astronomy and Space Research
Auckland University of Technology

Hiroshi Takiguchi, Sergei Gulyaev,
Tim Natusch, Stuart Weston, Lewis Woodburn

AUT UNIVERSITY

IRASR

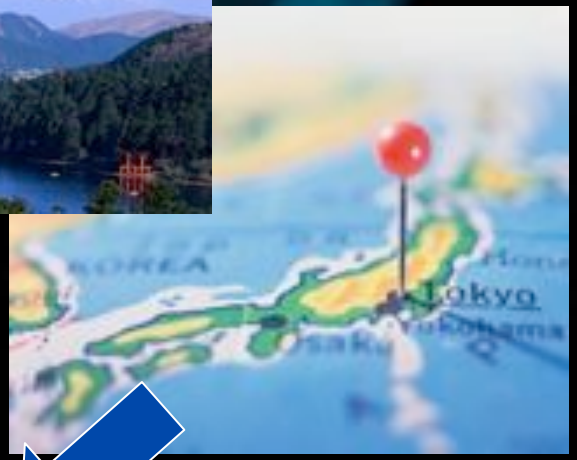
IRASR, AUT

- *Institute for Radio Astronomy and Space Research*
  - Research Activity
    - radio astronomy
    - space science
    - Square Kilometre Array
    - geodesy

12m radio telescope
VLBI technique

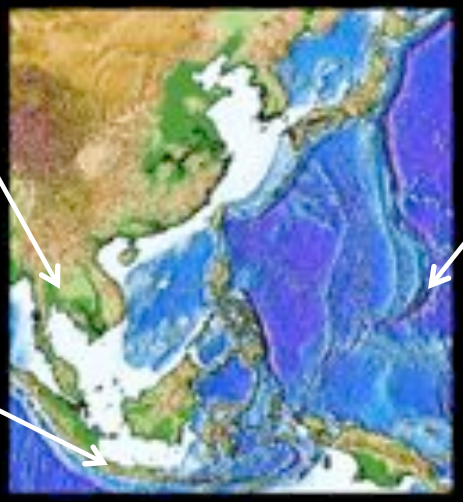
AUT UNIVERSITY IRASR

My Background

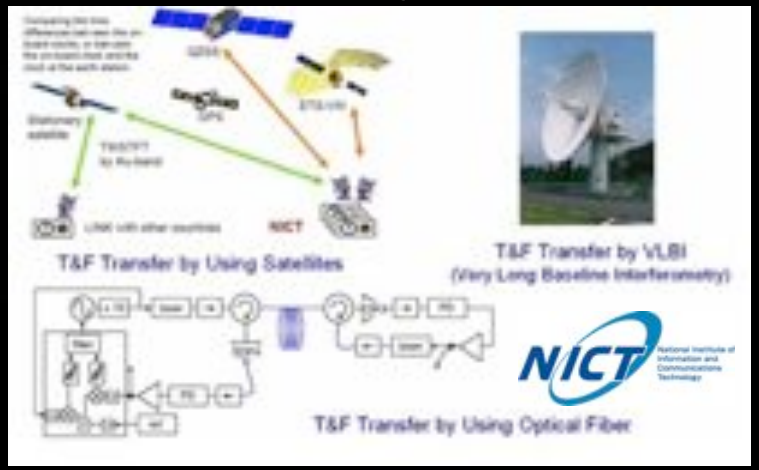


to contribute
to geodetic research

Geodetic Observation



Time and Frequency Transfer



AUT UNIVERSITY

IRASR

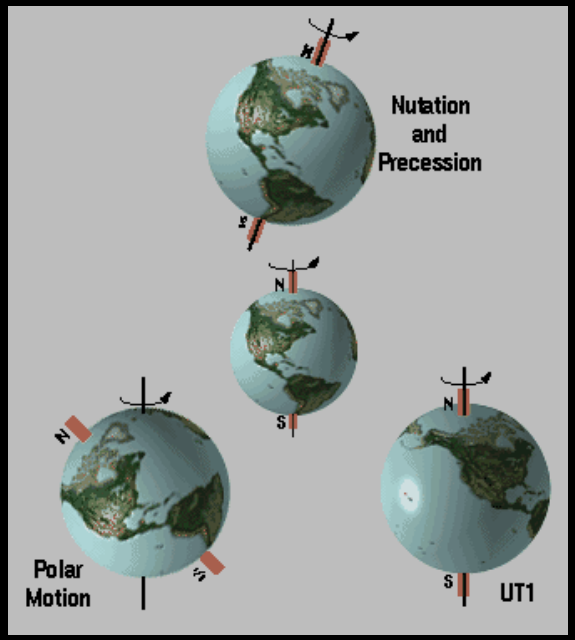
Contents

- Introduction
  - VLBI and AUT radio telescope
- Synergy of VLBI and GNSS
  - the model of Japan
  - GGOS
- To make Warkworth a core site
  - Calculation of the ocean tide loading displacements
- Future Plans

AUT UNIVERSITY IRASR

Introduction VLBI

Very Long Baseline Interferometry



Observational Techniques	Reference Frames		Earth Orientation Parameters			Polar Motion accuracy
	ICRF	ITRF	Pol. Mot.	UT1	Prec. & Nut.	
VLBI	○	○	○	○	○	≤ 0.2 mas
GPS	×	○	○	△	×	0.2 mas
SLR	×	○	○	△	×	$0.3 \sim 0.4$ mas
DORIS	×	○	○	△	×	$1 \sim 2$ mas

VLBI measures the arrival time delay between multiple stations

Introduction

WARK12M

- Launch of New Zealand's **first** & **only** research capable radio telescope
  - 8 October, 2008

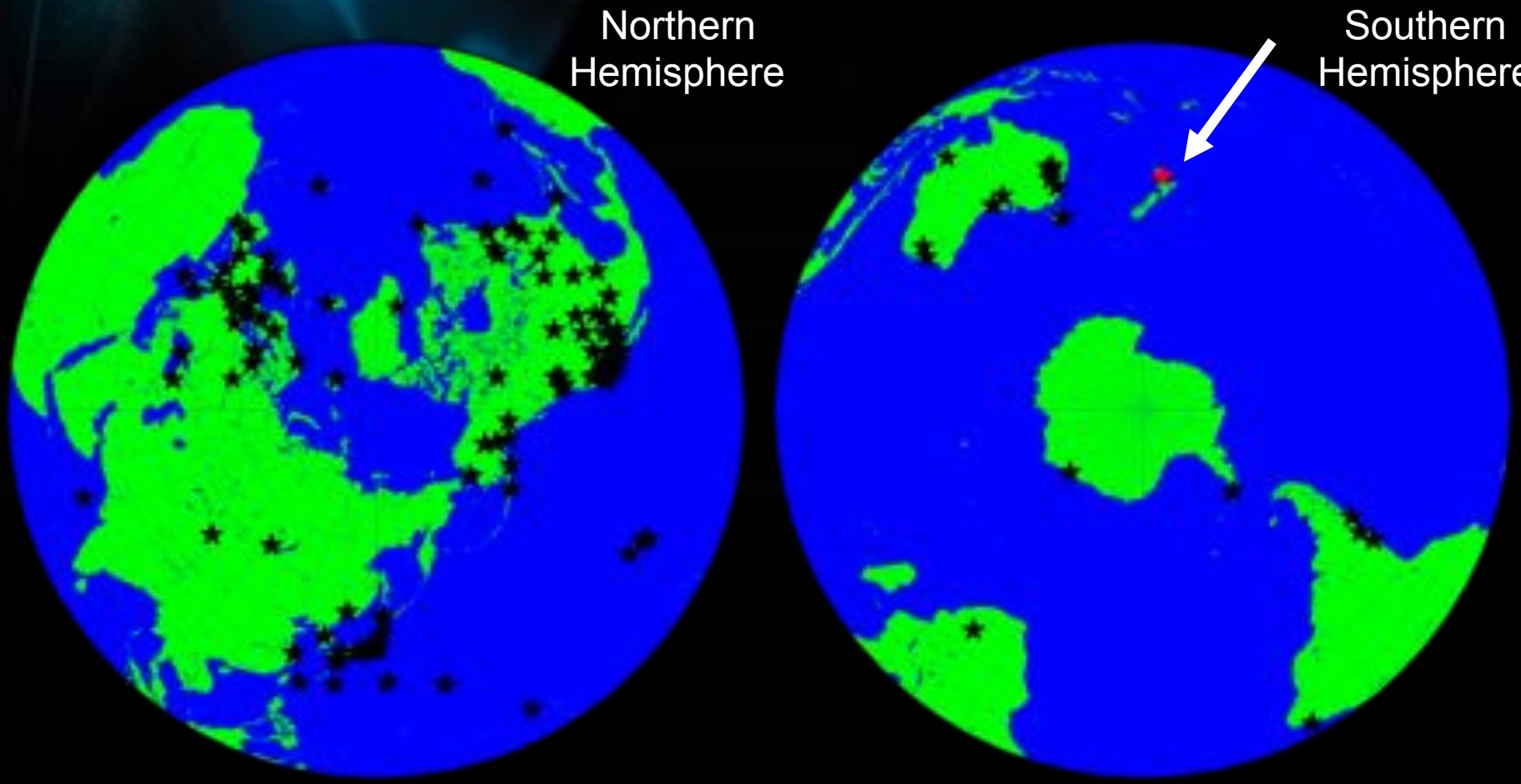
Antenna type	Dual-shaped Cassegrain
Manufacturer	Cobham/Patriot, USA
Main dish Diam.	12.1 m
Secondary refl. Diam.	1.8 m
Focal length	4.538 m
Surface accuracy	0.35 mm
Pointing accuracy	18"
Frequency range	1.4 - 43 GHz
Mount	alt-azimuth
Azimuth axis range	90° ± 270°
Elevation axis range	6° to 88°
Azimuth axis max speed	5°/s
Elevation axis max speed	1°/s

AUT radio telescope is participating in the global IVS sessions regularly.

AUT UNIVERSITY

IRASR

✧ Valuable station of the southern hemisphere



VLBI stations map

Introduction

Space Geodesy @NZ

- before launch of VLBI
  - only GNSS

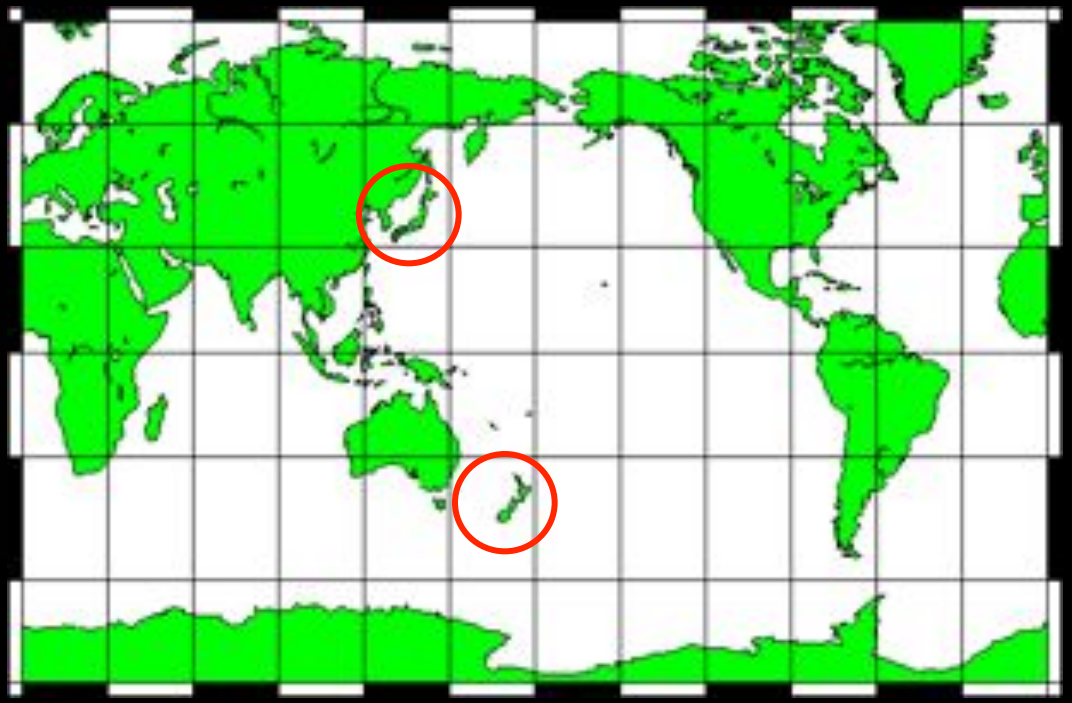
http://www.gns.cri.nz

- **PositioNZ** by *LINZ (Land Information New Zealand)*
  - 31 (2:Chatham Islands, 3: Antarctica)
  - Geodetic system, NZGD2000, surveying, mapping
- **GeoNet** by *Earthquake Commission & GNS Science*
  - to monitor earthquakes, volcanic unrest, land deformation, geothermal activity and tsunami
  - seismometer, accelerometer, tide gauge, sea level pressure
  - GPS : active volcanic activity area, over 100

Synergy of VLBI and GNSS

Synergy of VLBI and GNSS

- Geological situation of New Zealand is similar to **Japan**
  - plate boundaries
  - GPS network
  - Geodetic Datum
  - VLBI



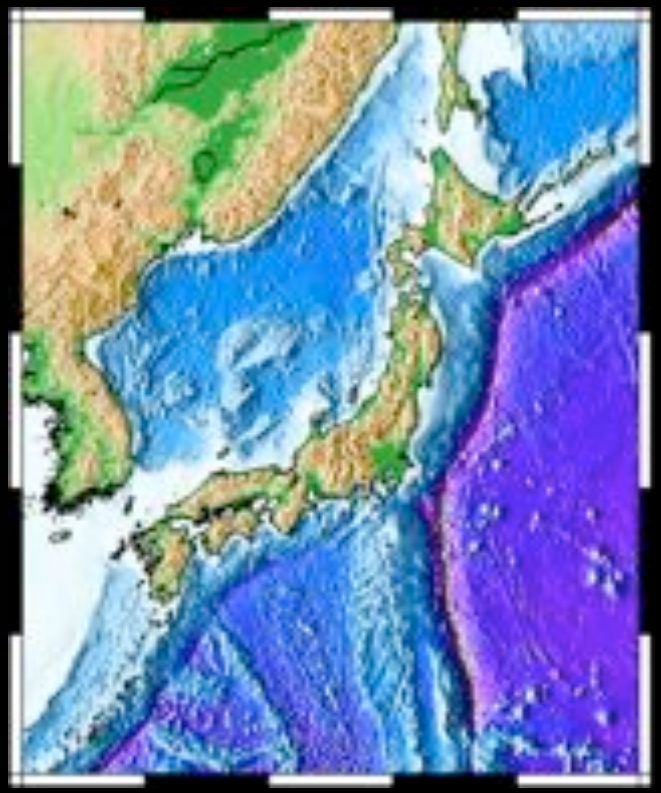
AUT UNIVERSITY IRASR

plate boundary & earthquake

- New Zealand

268,680 km^2

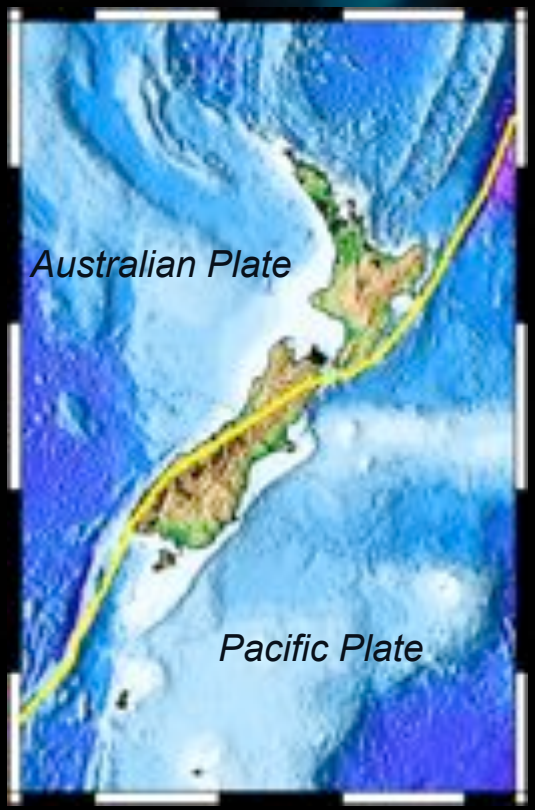
- Japan



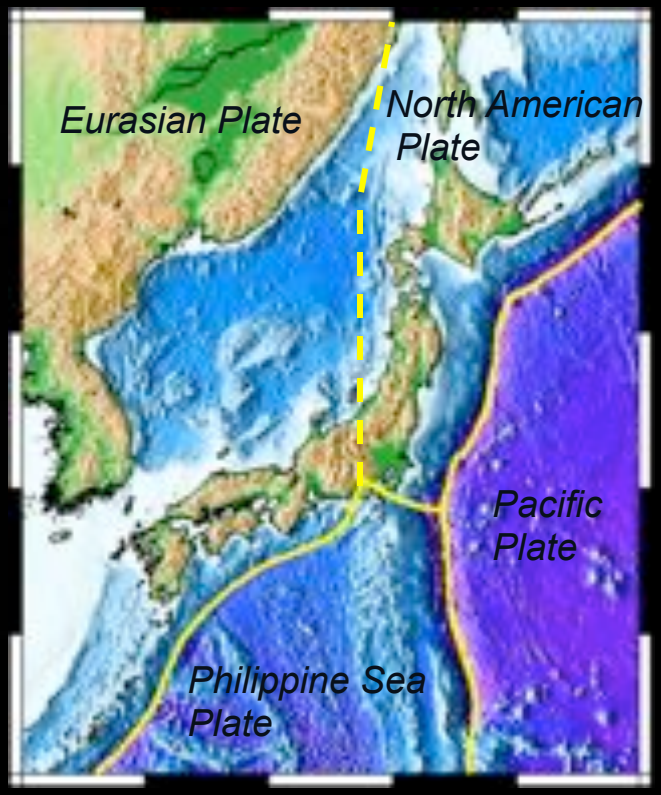
377,914 km^2

plate boundary & earthquake

- New Zealand



- Japan

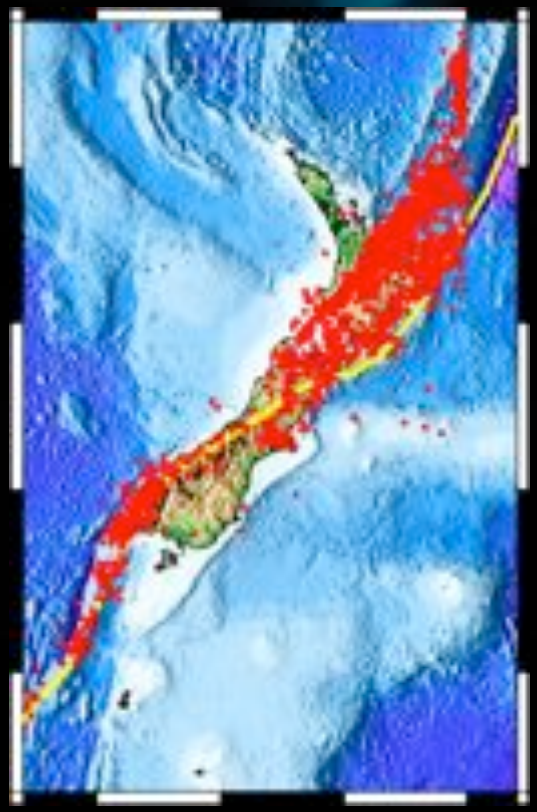


AUT UNIVERSITY

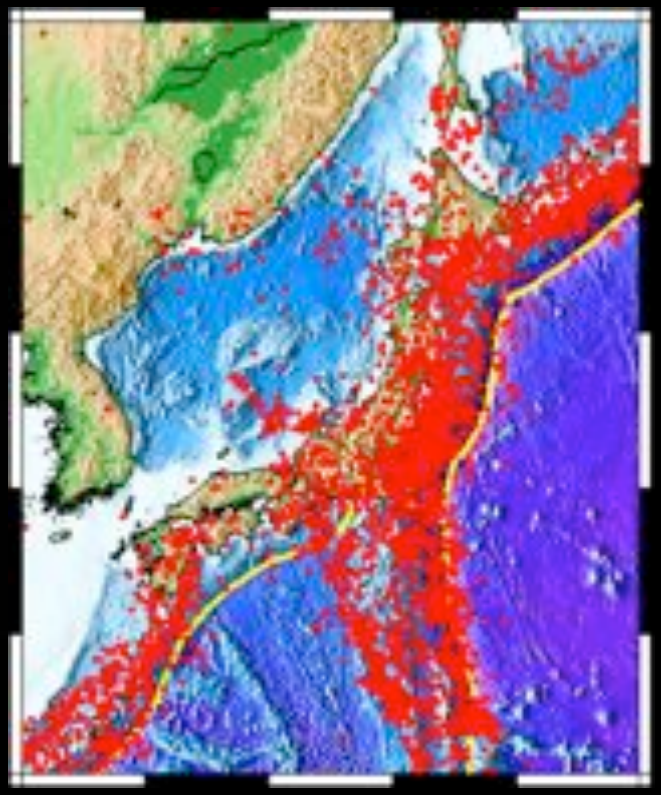
IRASR

plate boundary & earthquake

- New Zealand



- Japan



AUT UNIVERSITY

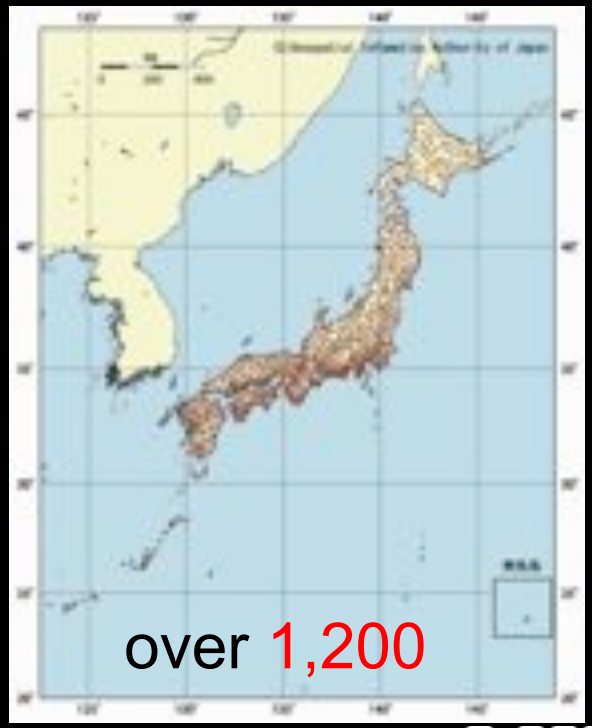
IRASR

GPS network

- New Zealand
  - PositioNZ, GeoNet

http://www.gns.cri.nz

- Japan
  - GEONET (GPS Earth Observation Network System)



http://www.gsi.go.jp
Geospatial Information Authority of Japan (GSI)

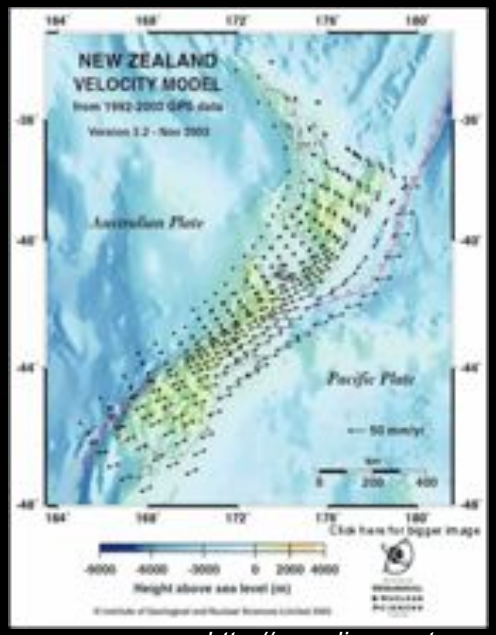
AUT UNIVERSITY

IRASR

Geodetic Datum

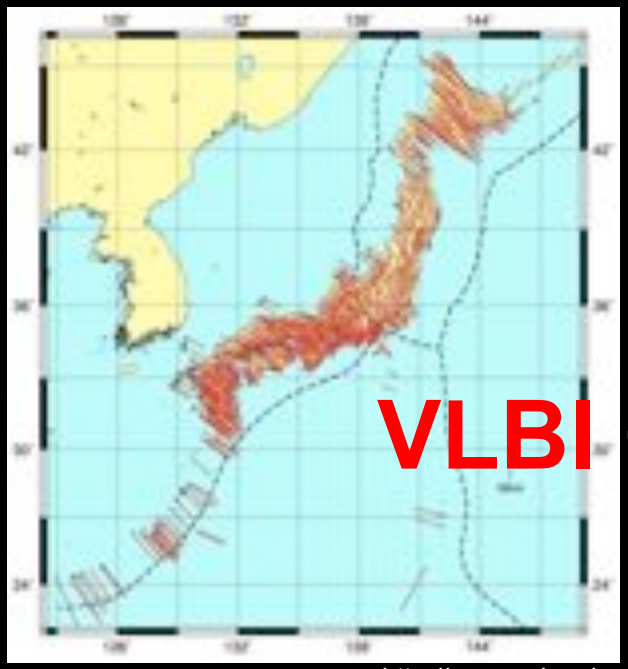
- New Zealand
  - NZGD2000 (1998)
    - ITRF96, 2000.0
    - Semi-dynamic system

GPS



http://www.linz.govt.nz

- Japan
  - JGD2000 (2002)
    - ITRF94, 1997.0
    - Static system
      + Semi-dynamic correction
      (referred New Zealand)



VLBI + GPS

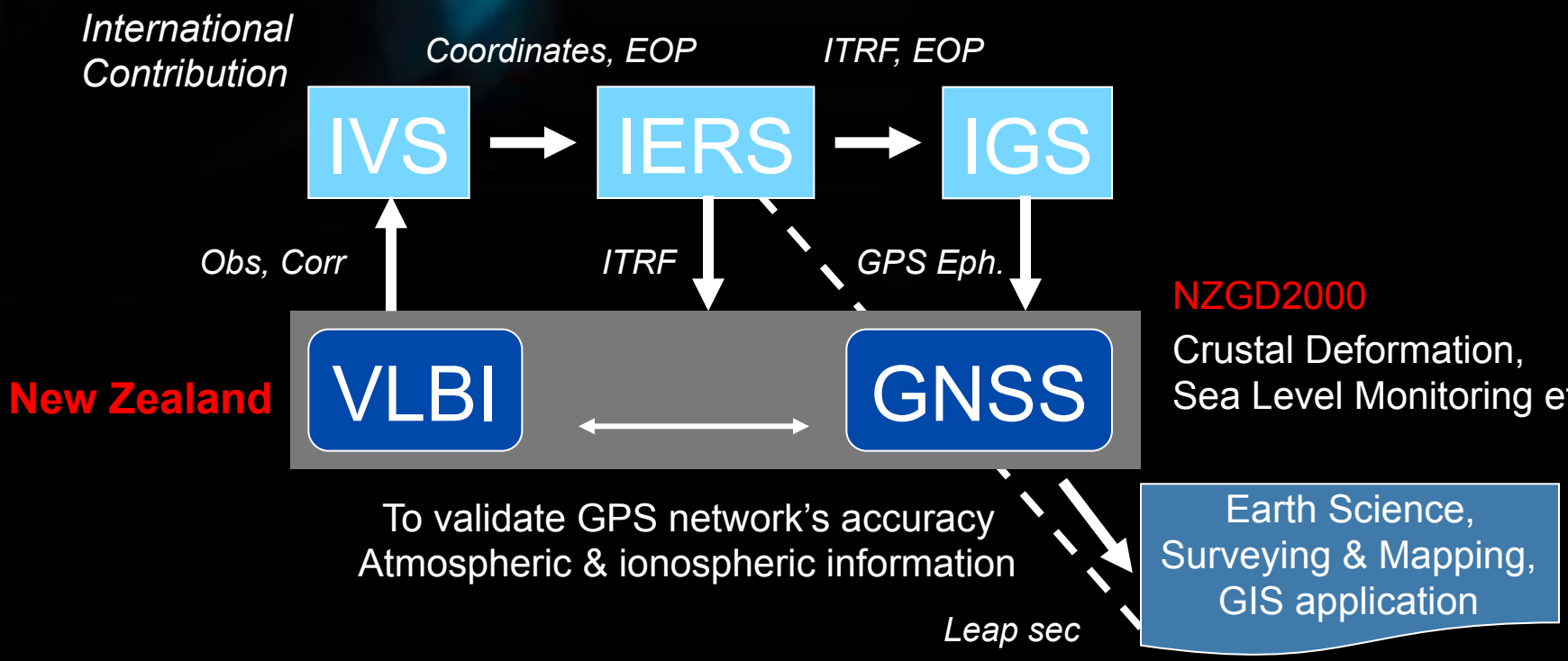
http://www.gsi.go.jp

AUT UNIVERSITY

IRASR

Synergetic relationship between VLBI and GPS

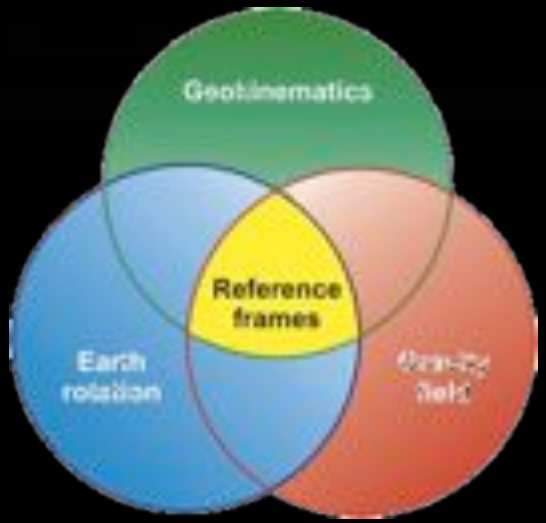
✧ at Japan



Modified after *Tsuji et al. 2003*

Global Geodetic Observing System (GGOS)

- By using Space Geodetic Technique
  1) monitoring the water cycle at global to regional scales
  2) monitoring and modeling sea-level and ice-mass changes
- accuracy : 1 mm, 1mm/yr level



Warkworth

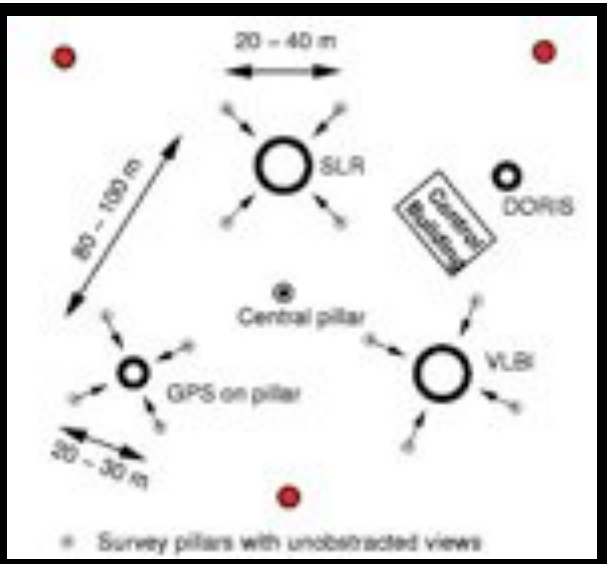
has capability to became a core site

important for GGOS as geographical location

AUT UNIVERSITY IRASR

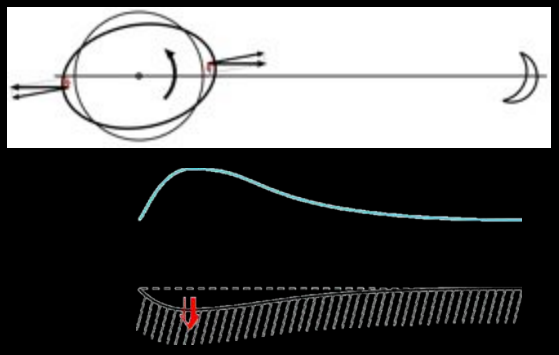
To make a core site

- Stable results
  - Make an appropriate model
    - atmospheric delay
    - *Ocean Tide Loading*
    - environmental loads, etc
  - co-location observation
  - assistance observation
    - Gravity, Groundwater, Soil moisture, etc.
- Cooperation with other institutes
  - LINZ and GNS Science



Ocean Tide Loading

- deformation of the Earth due to the weight of ocean tides



- To calculate site-dependent ocean tidal coefficient

1. global OTL model

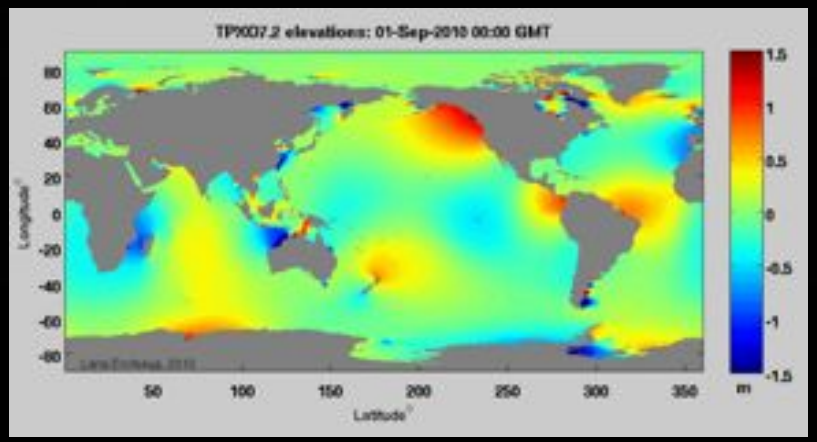


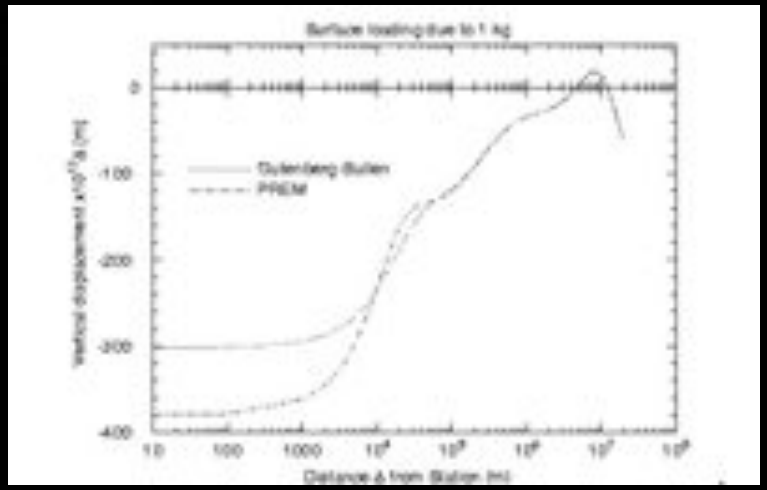
Table 7.6: Ocean tide models available at the automatic loading service.

Model code	Reference	Input	Resolution
Schwiderski	Schwiderski (1980)	Tide gauges	1° × 1°
CSR3.0, CSR4.0	Eanes (1994)	TOPEX/Poseidon altim.	1° × 1°
	Eanes and Bettadpur (1995)	T/P + Le Provost loading	0.5° × 0.5°
TPXO5	Egbert et al. (1994)	inverse hydrodyn. solution from T/P altim.	256 × 512
TPXO6.2	Egbert et al. (2002), see	idem	0.25° × 0.25°
TPXO7.0, TPXO7.1	idem	idem	idem
FES94.1	Le Provost et al. (1994)	numerical model	0.5° × 0.5°
FES95.2	Le Provost et al. (1998)	num. model + assim. altim.	0.5° × 0.5°
FES98	Lefèvre et al. (2000)	num. model + assim. tide gauges	0.25° × 0.25°
FES99	Lefèvre et al. (2002)	numerical model + assim. tide gauges and altim.	0.25° × 0.25°
FES2004	Letellier (2004)	numerical model	0.125° × 0.125°
GOT99.2b, GOT00.2	Ray (1999)	T/P	0.5° × 0.5°
GOT4.7	idem	idem	idem
EOT08a	Savcenko et al. (2008)	Multi-mission altimetry	0.125° × 0.125°
AG08a	Andersen (2008)	Multi-mission altimetry	0.5° × 0.5°
NAO.99b	Matsumoto et al. (2000)	num. + T/P assim.	0.5° × 0.5°

AUT UNIVERSITY IRASR

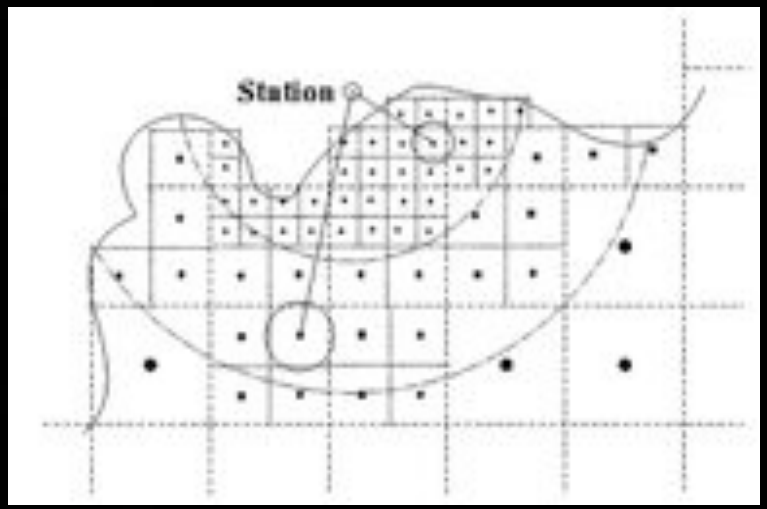
2. The displacement Green's function for Earth model

   determines how much the Earth deforms due to the point load



3. *land-sea grid*

   high-resolution land-sea grid data
   ↓
   GOTIC2 software



4. Convolution [Farrell, 1972]

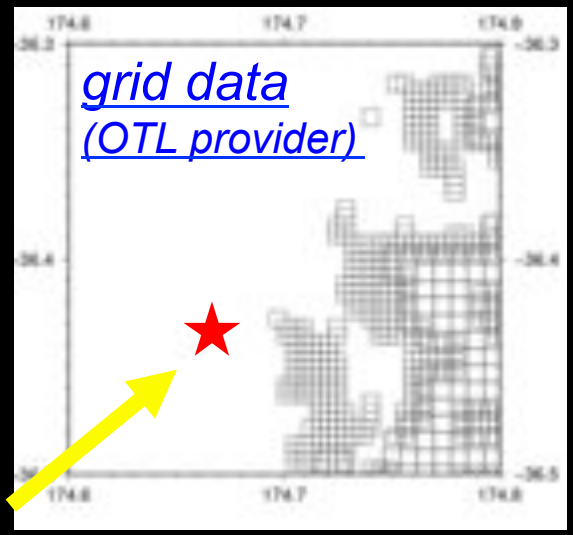
$$L(\theta',\lambda') = \rho \iint H(\theta,\lambda) G_L(\phi) T(\alpha) dS$$

AUT UNIVERSITY

IRASR

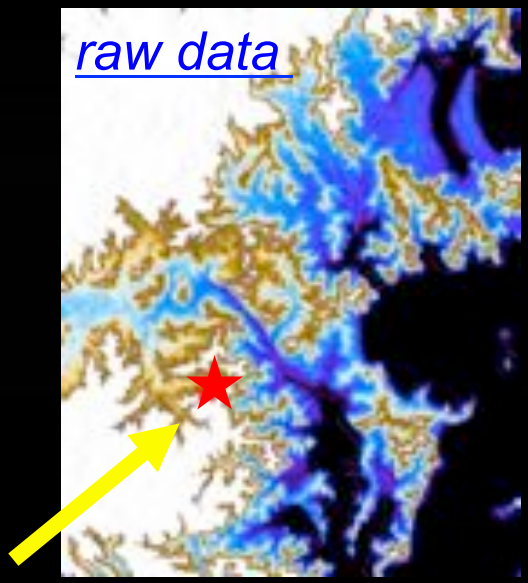
Making land-sea grid from SRTM data

Onsala
OTL provider (coastline resolution, 600m)
http://froste.oso.chalmers.se/loading//index.html

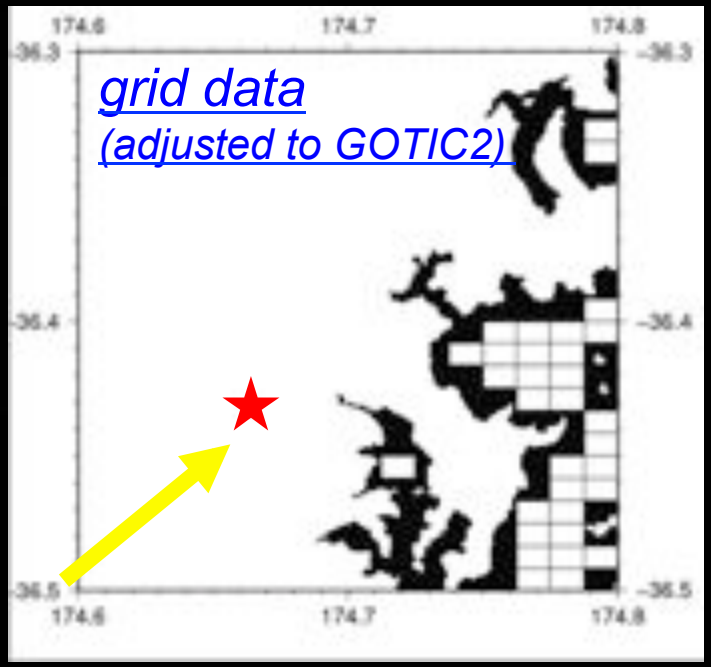


Shuttle Radar Topography Mission
The Mission to Map the World

Version 2 : SRTM1 : US 1 arc-seconds
SRTM3 : World 3 arc-seconds (90m)



Warkworth



AUT UNIVERSITY
IRASR

Calculate OTL displacement

- amplitudes and phases of 11 main tides @Warkworth

software	OTL provider	GOTIC2
OT model	NAO99b	
Earth model	Gutenberg-Bullen	
Land-sea grid	600m	90m

- Calculate OTL displacement
  - c5++ software
  - 1 year (2011) every 12h
  - NS, EW , UP

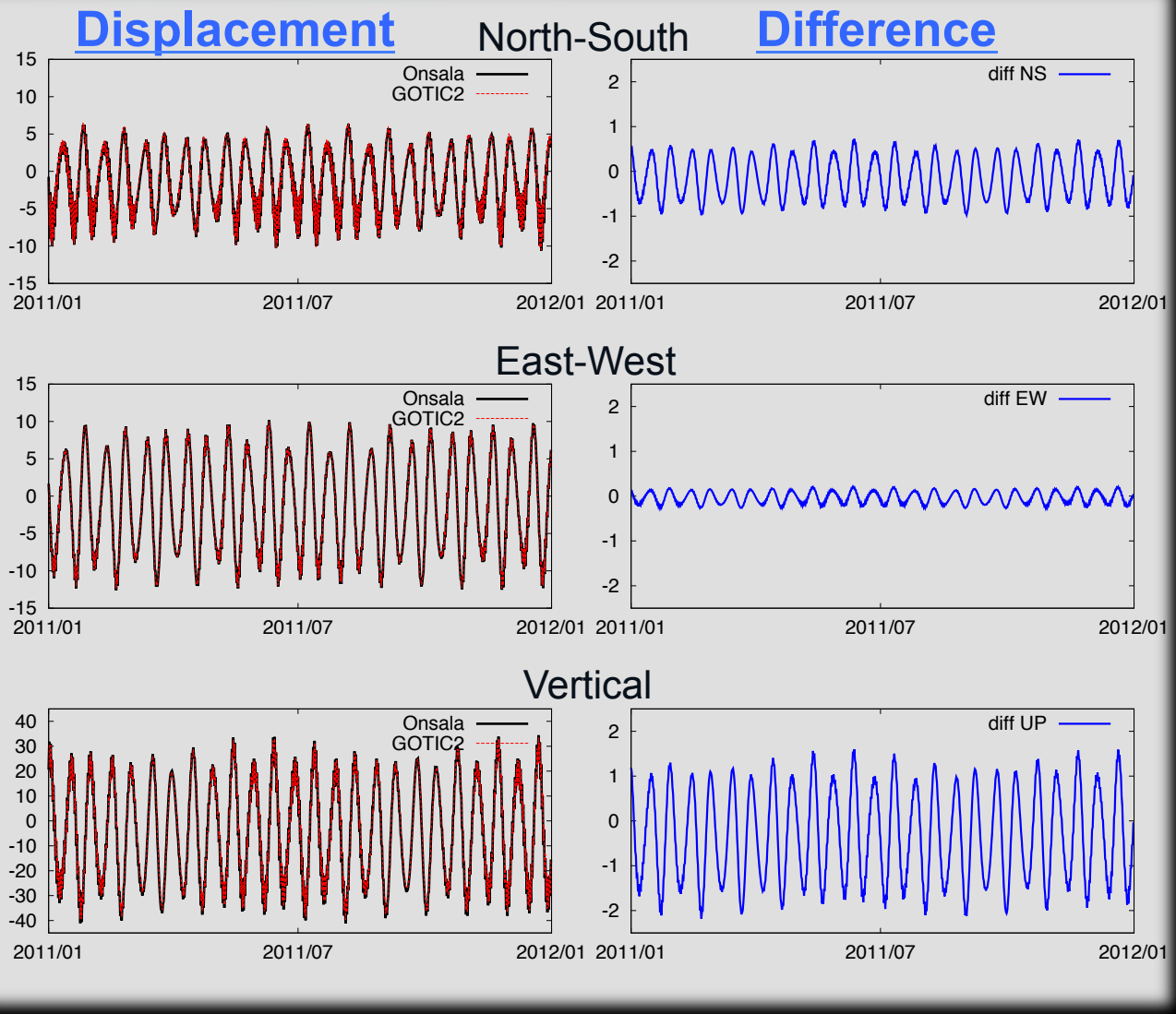
c5++

the new space geodetic analysis software developed at NICT, Hitotsubashi Univ., JAXA and **AUT**

http://www3.nict.go.jp/w/w114/stsi/c5++/

AUT UNIVERSITY IRASR

Results : OTL displacement @Ww



- OTL provider
  - this study
    - IERS Conv. 2003
- NS : ± 1 mm
- EW: ±0.3mm
- Vertical : ± 2 mm

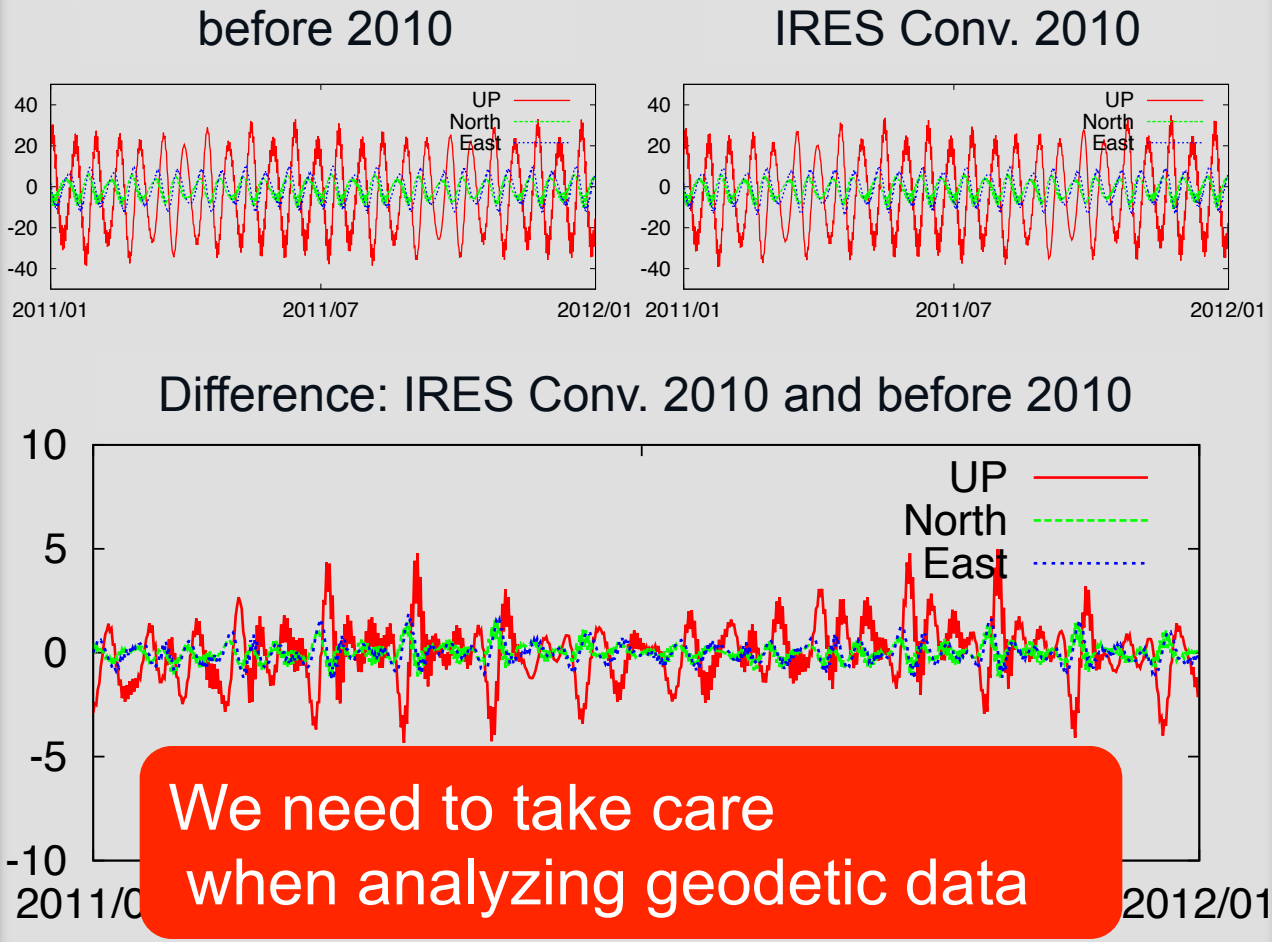
Not small for 1mm accuracy !

Unit: mm

AUT UNIVERSITY IRASR

Difference between IERS Conv. 2010 and before 2010

TPXO 7.2



- Considering number of total constituent tides
- before: 141
- 2010 : 342
  - by spline interpolation of the 11 main tides

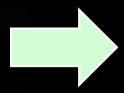
Not small for 1mm accuracy !

Unit: mm

AUT UNIVERSITY IRASR

Conclusion

- AUT radio telescope is ready to contribute to New Zealand geodesy
- Made precise grid data
  - adjusted to GOTIC2
  - resolution : 90m

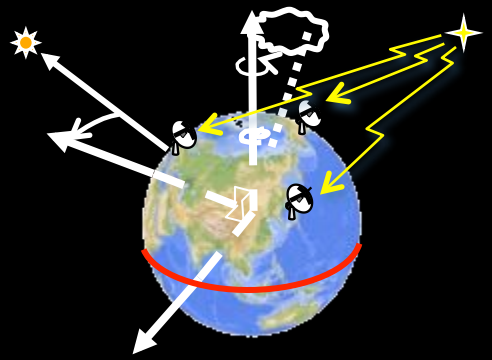


- ✓ apply to geodetic analysis
- ✓ evaluate the effect

- Calculated and compared OTL displacements
  - difference @Warkworth
    - grid data, calculation method
    - not small compared to *1mm accuracy*.

AUT UNIVERSITY IRASR

Future Plans



- Develop new capabilities
  - *Ultra-rapid EOP Measurement*
- Conversion of the 30m antenna

- Periodical co-location observation
  - *GPS and other geodetic techniques*

- New radio telescope @NZ South Island
  - *the application of geodetic research in NZ will be expanded*

AUT UNIVERSITY

IRASR

Thank you very much for your attention.

Thanks to Neville Palmer, Dave Collett, Oleg Titov, Hans-Georg Scherneck,
GOTIC2 and c5++ developer
and

We are new in NZ Geoscience community.

We need
*your **cooperation** and **information**.*

AUT UNIVERSITY
IRASR