

Geophysical drivers of non-linear site motion in geodetic station coordinates

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**University of Tasmania
School of Mathematics and Physics**

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Outline

Geodetic background

The need for an accurate
Terrestrial Reference Frame
(TRF)

Deformation of the Earth's surface

Taking into account the motion of
the surface of the Earth

Case study: cyclonic loading

Introducing the effects of tropical cyclone in
Australia

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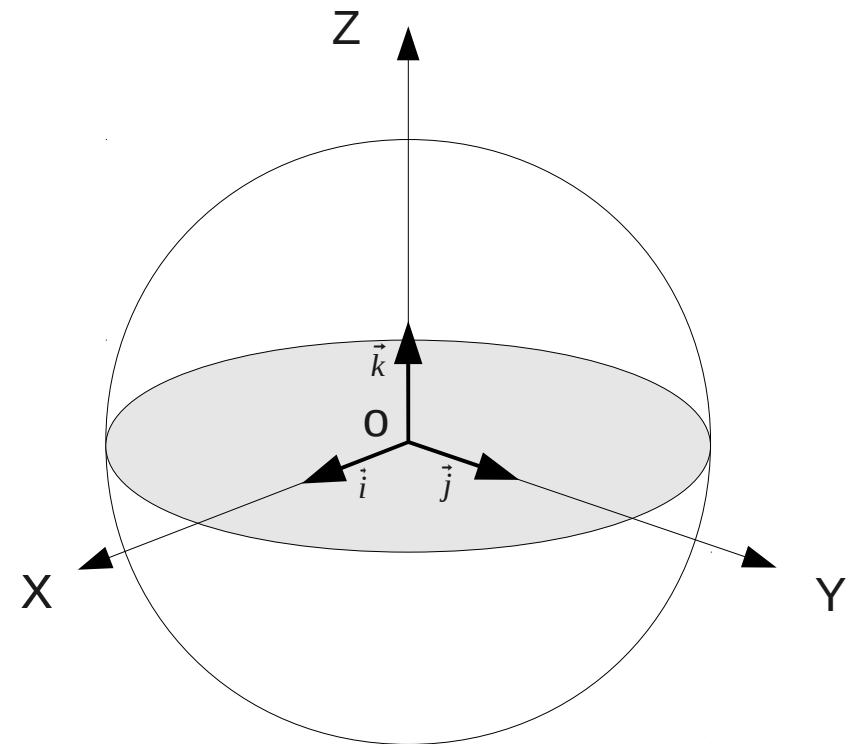
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Terrestrial Reference System (TRS)

What is it ?

A mathematical concept (origin, orientation, scale) for a real Earth



The rotation of the Earth is associated with the rotation of the orthogonal basis

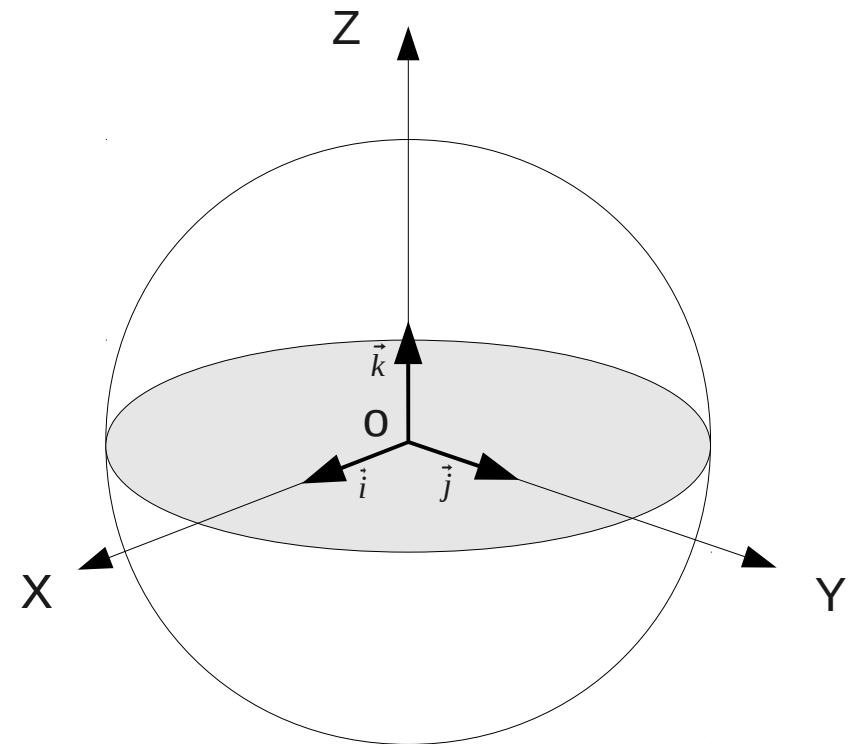
Terrestrial Reference System (TRS)

What is it ?

A mathematical concept (origin, orientation, scale) for a real Earth

What for ?

- mapping, navigation,
- precisely determining satellite orbits,
- quantifying geophysical processes :
 - Earth rotation,
 - Tectonic plate motion,
 - Mean sea level variations,
 - ...

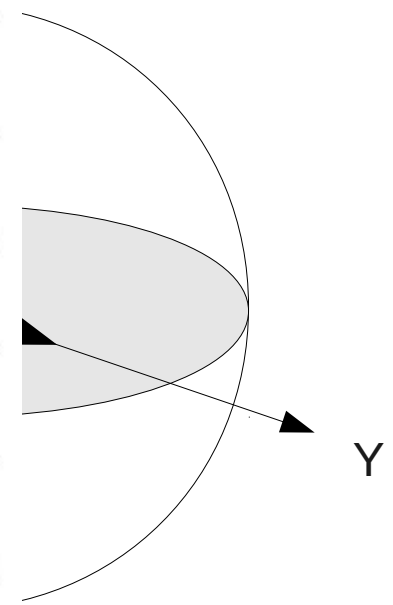
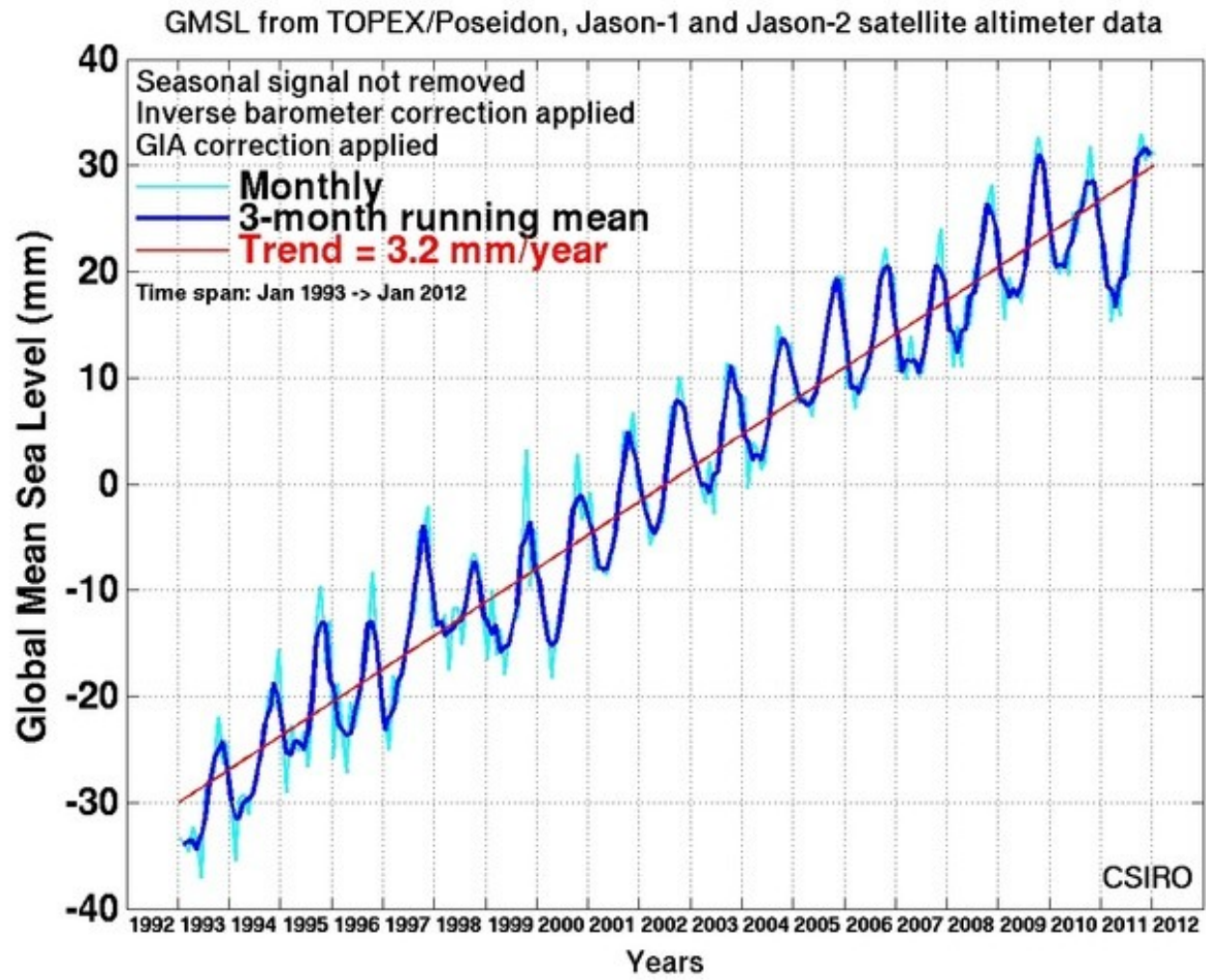


The rotation of the Earth is associated with the rotation of the orthogonal basis

Terrestrial Reference System (TRS)

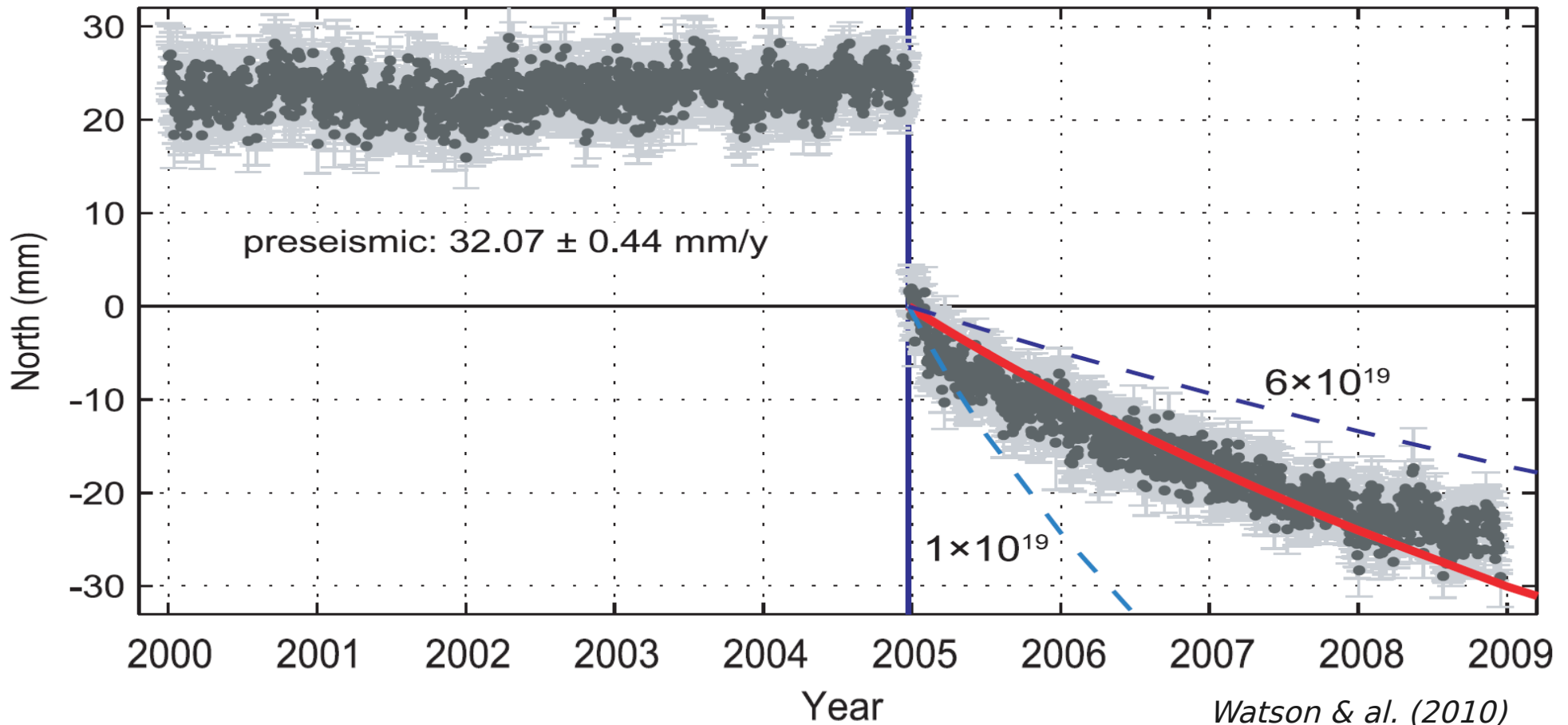
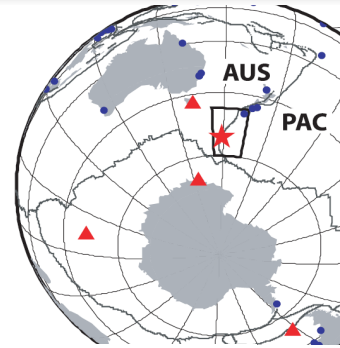
A matter
 orientator

- mapping, n
- precisely de
- quantifying
 - Earth rc
 - Tectonic
 - Mean se
 - ...



the Earth
 with the
 of the
 l basis

Deformation at Macquarie Island after the Mw 8.0 Earthquake (24/12/2004)



Terrestrial Reference Frame (TRF)

**The Earth is not rigid → we can't fix
the vectors of the basis**

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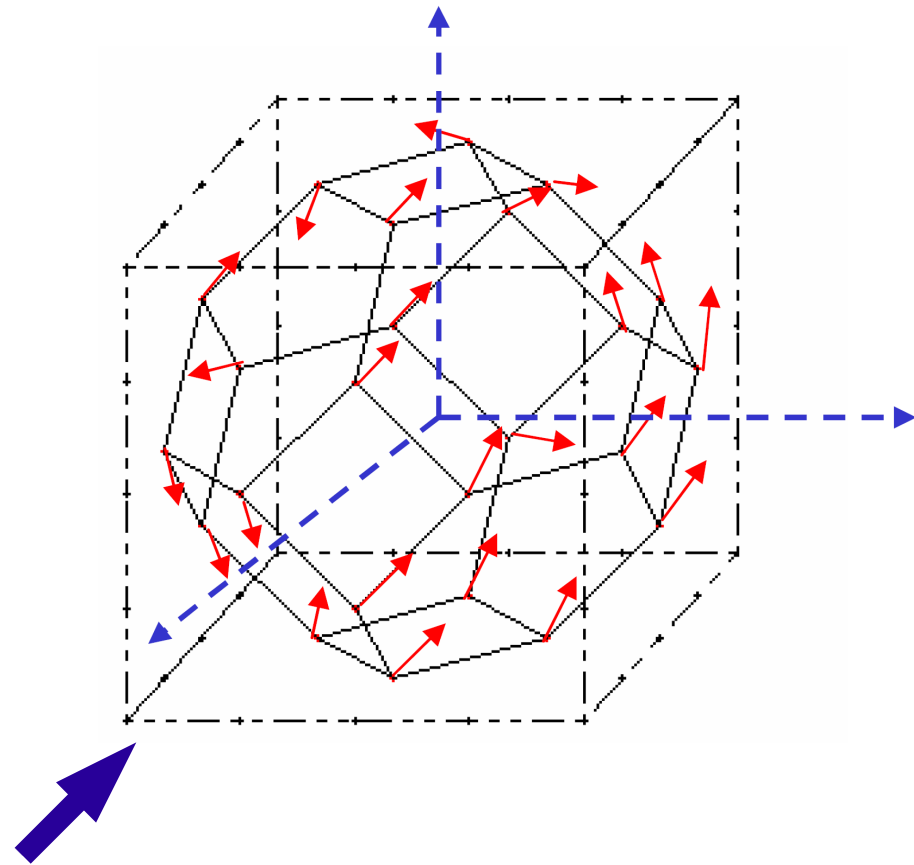
**To obtain a realization of the TRS
we need to know with the best
accuracy the position of sites at
the surface of the Earth at any
single time.**

Terrestrial Reference Frame (TRF)

The Earth is not rigid → we can't fix the vectors of the basis

To obtain a realization of the TRS we need to know with the best accuracy the position of sites at the surface of the Earth at any single time.

TRF = realization of the TRS from data

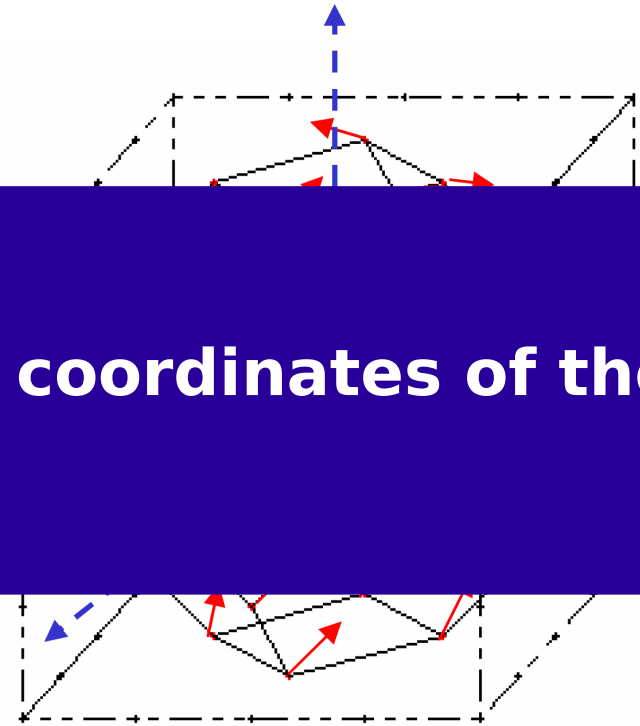


Terrestrial Reference Frame (TRF)

The Earth is not rigid → we can't fix the vectors of the basis

Which data for determining the coordinates of the stations ?

TRF = realization of the TRS from data



Positioning measurements : Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS)



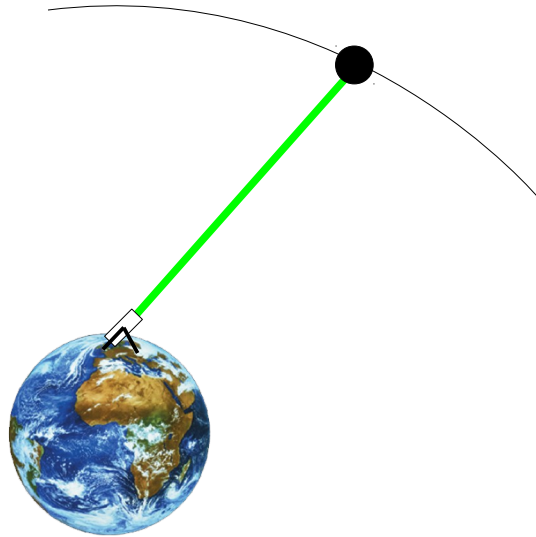
http://geodesie.ign.fr/index.php?page=systeme_doris

The frequency shift of the signal received is used to compute the satellite orbit leading to the position of the transmitters.

Transmitters on the Earth's surface emit a radio signal which is received by antenna on satellites.



Positioning measurements : Satellite Laser Ranging (SLR)

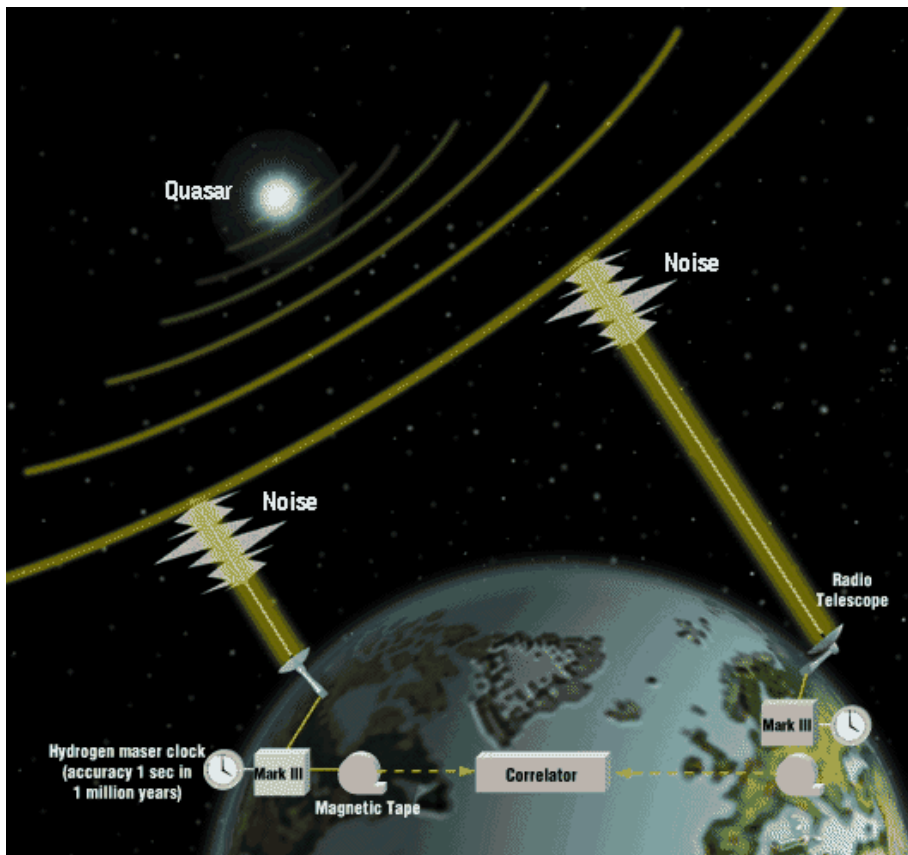


Distance between satellites and a ground based station is obtained by measuring the traveltime of an ultrashort pulse of light.



Positioning measurements : Very Long Baseline Interferometry (VLBI)

Relative positions between two receivers are determined by measuring the difference in the time of arrival of a radio wave from quasars.

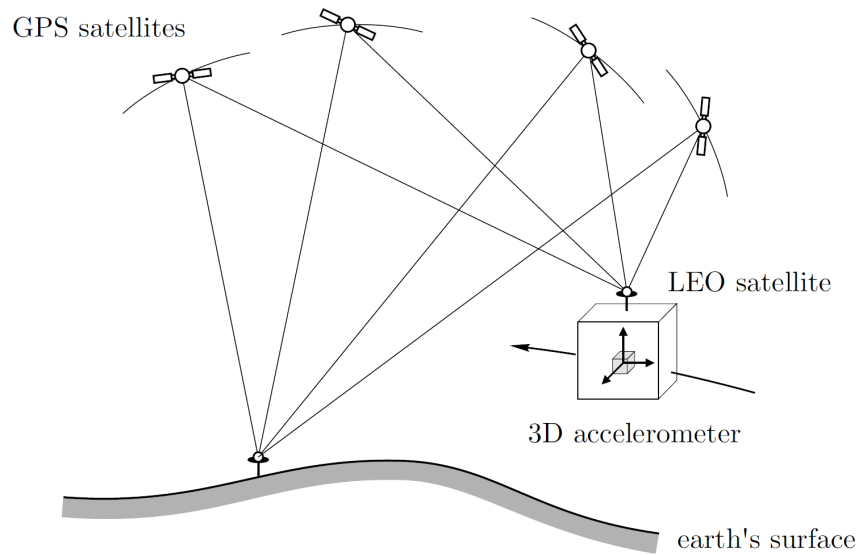


http://eduscol.education.fr/localisation/pedago/geologie/images/vlbi_concept.gif



See next talks by Stas Shabala and
Jamie McCallum

Positioning measurements : Global Positioning System (GPS)



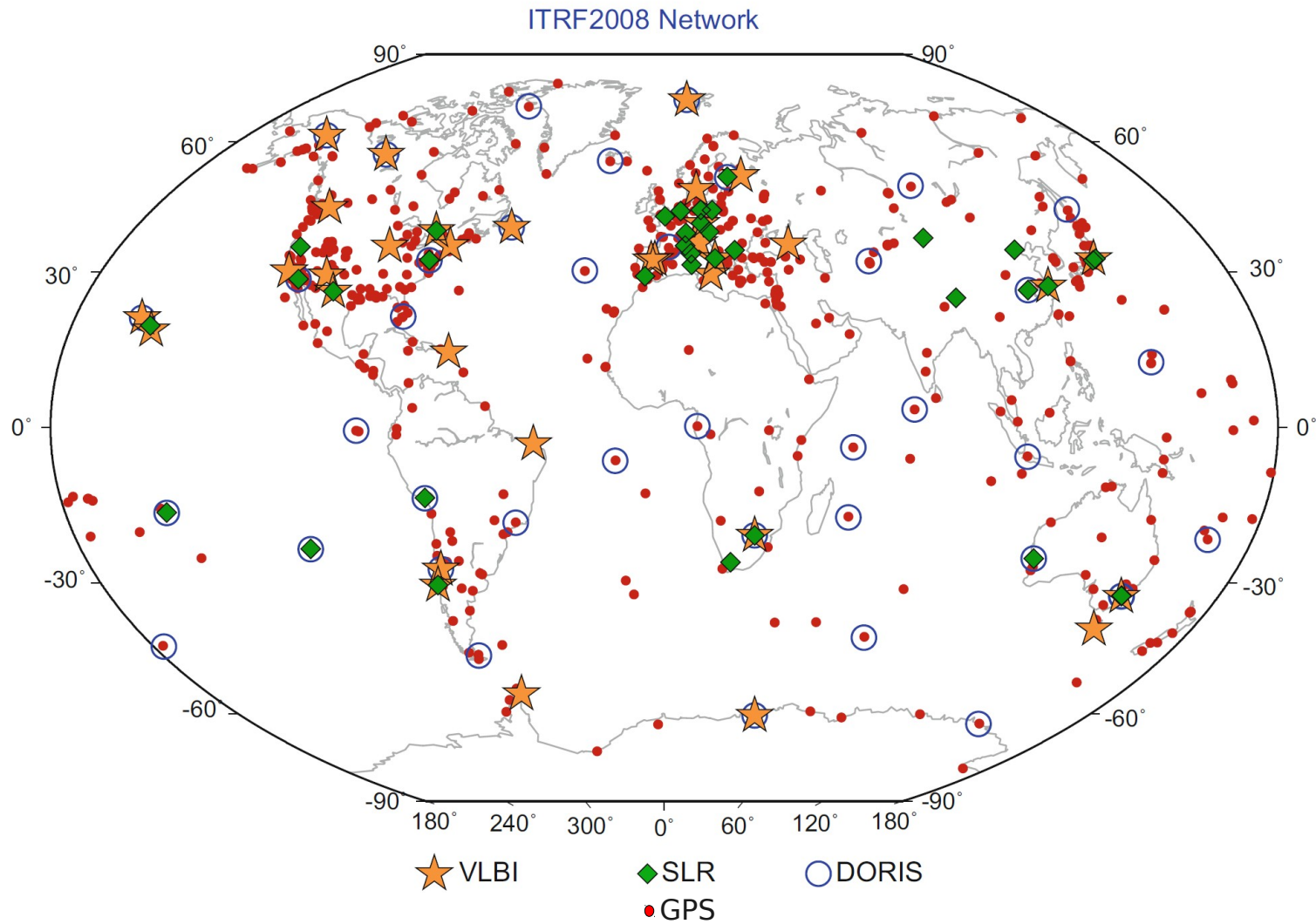
Hofmann-Wellenhof & Moritz (2005)

29 satellites emit microwave signals received by receivers at the Earth's surface.



Blewit (2007)

ITRF 2008 geodetic stations



Altamimi & al. (2011)

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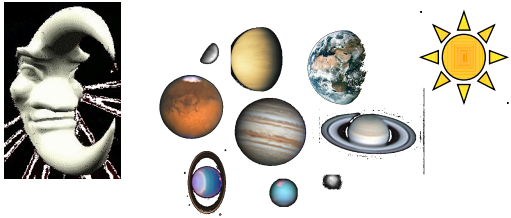
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Geodetic background
Deformation of the Earth's surface
Cyclonic loading

Sources of deformation

External sources
(global, from hours to years)



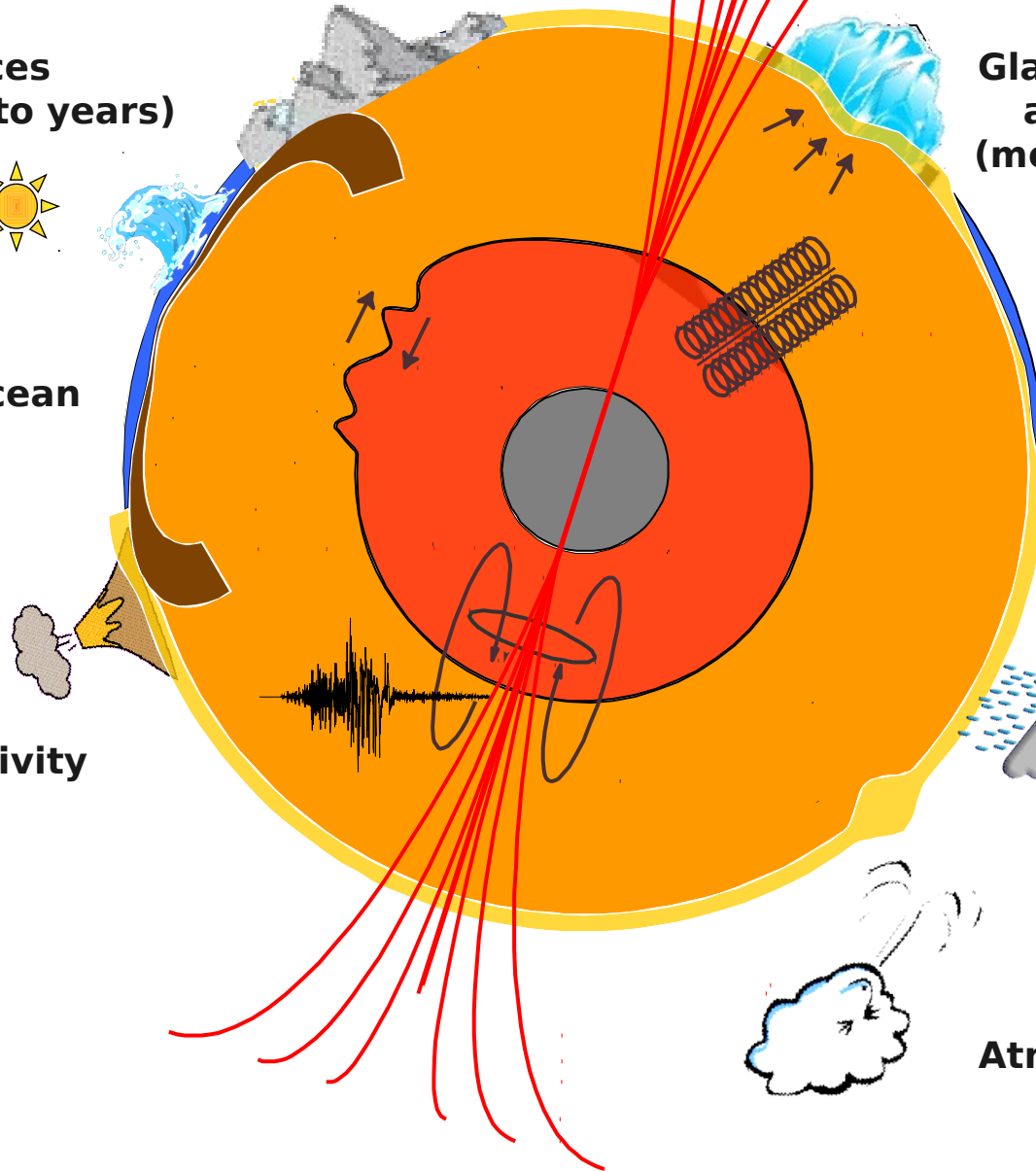
Ocean

Glacial isostatic
adjustment
(mostly secular)

Internal activity

Hydrology
(quasi periodic :
annual, semi-annual)

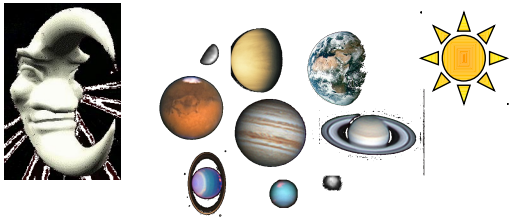
Atmosphere



Geodetic background
Deformation of the Earth's surface
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Sources of deformation

External sources
(global, from hours to years)



Ocean

Glacial isostatic
adjustment
(mostly secular)

different spatial wavelength
And
different time evolution

Internal activity

Hydrology
(quasi periodic :
annual, semi-annual)

Atmosphere

Correcting positioning time series

All the phenomena that are accurately known and cause station displacements are modeled.

Convention of IERS 2004

Ocean tidal loading

Solid Earth tides

Rotational
deformations

Ocean pole tide
loading

Atmospheric loading

Correcting positioning time series

Some important Geophysical effects remain

Non tidal ocean loading

Atmospheric loading

Past and Present-day ice-mass change

Earthquakes

Hydrology

...

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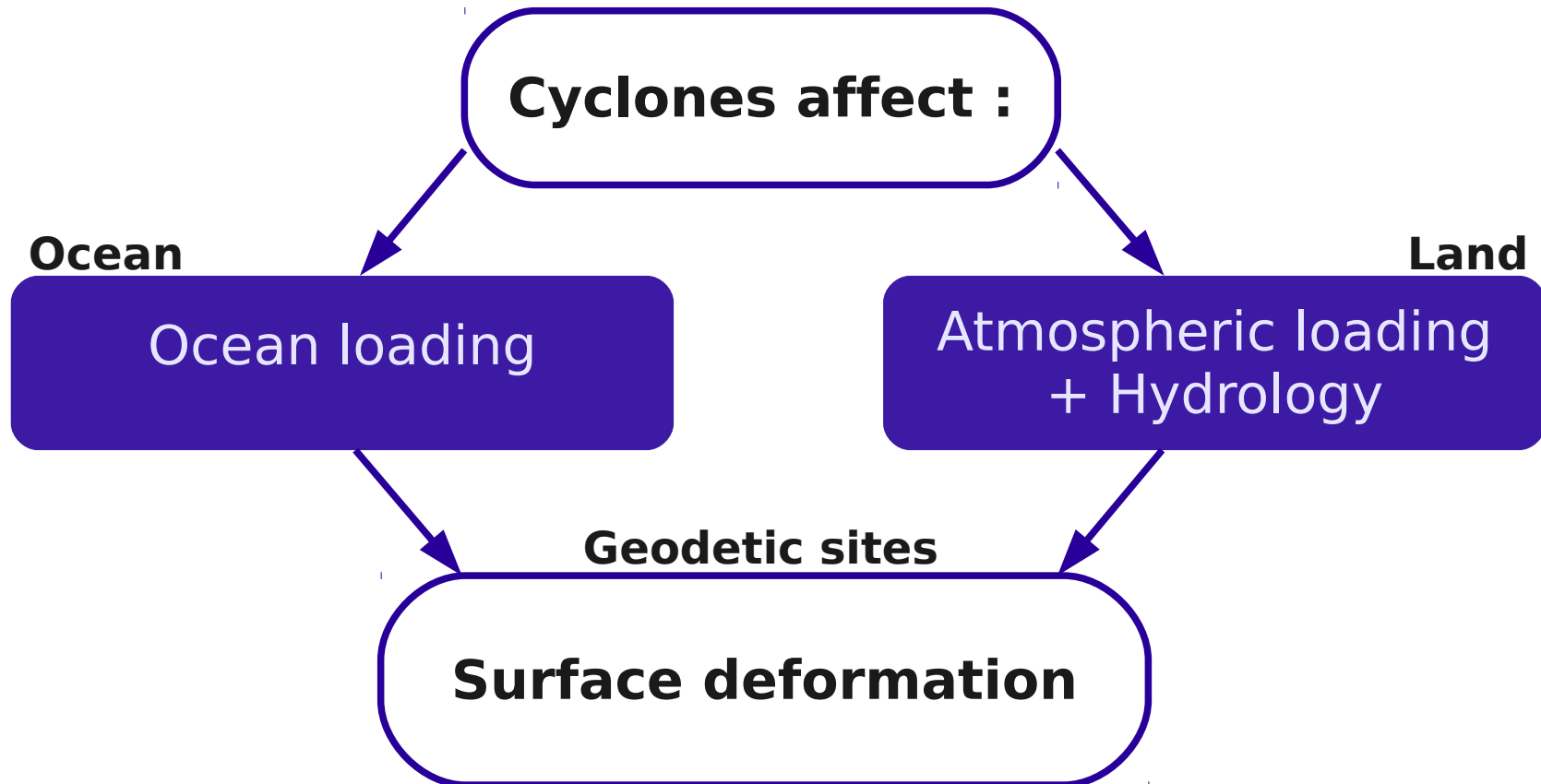
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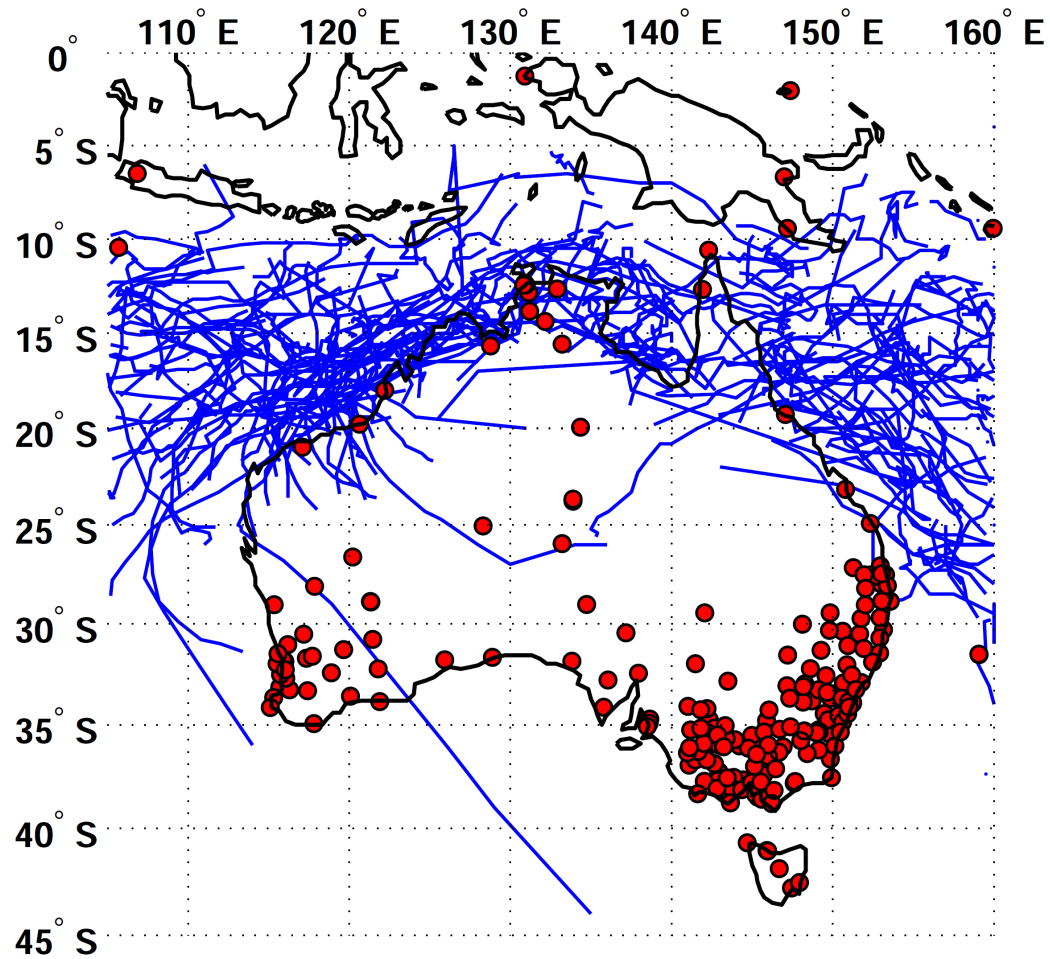
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Effects of tropical cyclones



Tropical cyclones in Australia

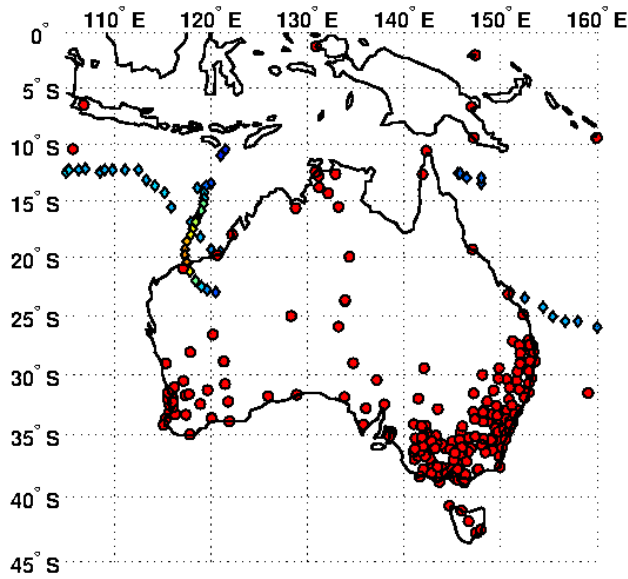
July 1999 - June 2011



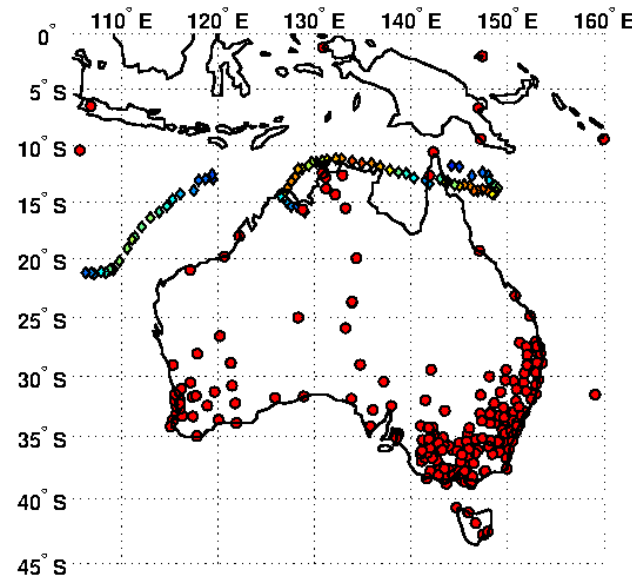
● Geodetic stations

Tropical cyclones in Australia

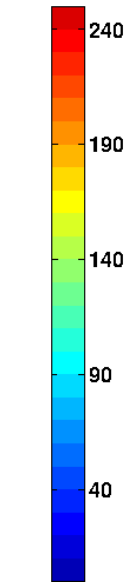
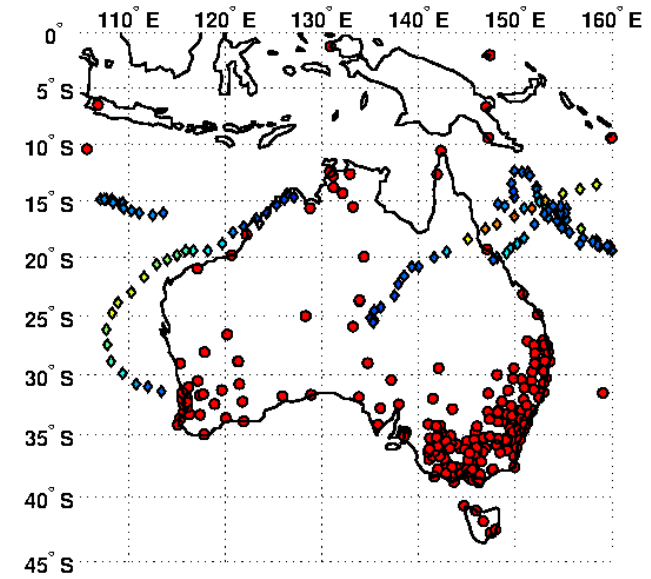
Dec 99 - John



Mar 05 - Ingrid



Jan 11 - Bianca & Yazi



km/h

● Geodetic stations

About positioning times series and cyclones

Coast

How are coastal stations affected ?

Inland

Are inland stations also subject to cyclones' effects ?

About positioning times series and cyclones

**Time
series**

What is a cyclone's geodetic
signature ?
→ space and time

TRF

How is the network affected ?

Data/models

GNSS

AuScope GNSS network

ATML

NCEP : 0.5° or 2.5°, 6h
ERA interim : 0.75°, 6h

NTOL

High resolution of ocean
model (Ivan Haigh)

Preliminary goals

Coastal sites

Estimate the surface deformation induced by tropical cyclones along the Northern Australian coast

Network

Estimate the effects of the surface deformations of tropical cyclones on a GNSS network

Broader goal

Surface deformation induced by tropical cyclones

Effects on stations along the Northern Australian coast

Effects on a GNSS network

Refine ATML and NTOL around the Australian coast

Thank you

Deformation at Macquarie Island after the Mw 8.0 Earthquake (24/12/2004)

