Reference Frame in Practice Workshop 2A

A template for the development of a modernised geodetic infrastructure in Pacific Island states

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Chair IAG WG 1.3.2 Deformation Modelling

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United Nations Global Geospatial Information Management – Asia Pacific

Workshop presentation overview

What is geodetic infrastructure used for?

Monumentation and CORS

Network Design and Observations

Data processing and Adjustment

Modelling

Products for Users

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What is geodetic infrastructure used for?

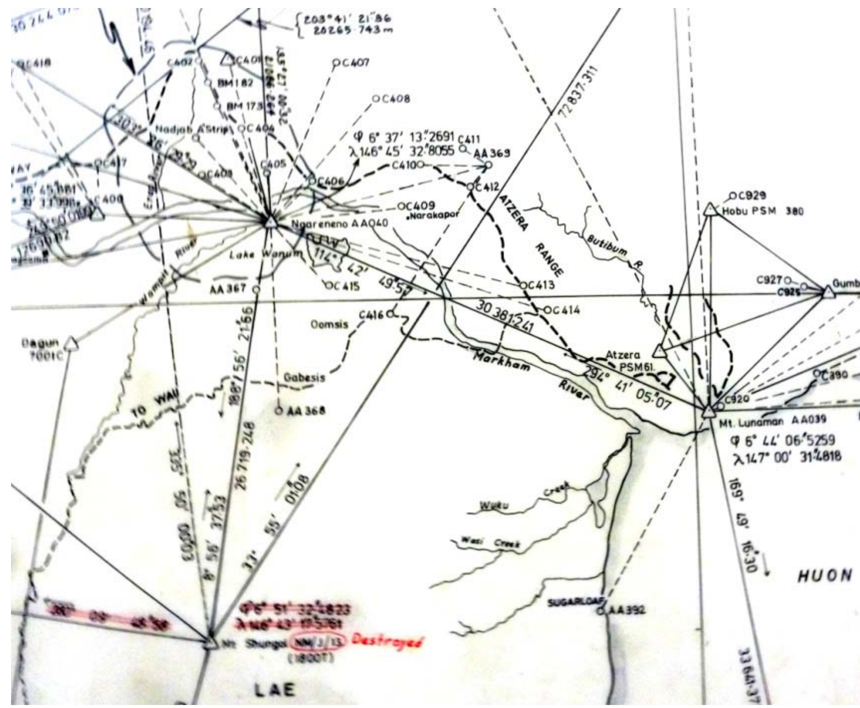
- **Cadastral (including customary land) surveys – define land ownership**
- **Engineering surveys (roads, ports, construction, mining, oil & gas, exploration)**
- **Topographic Mapping & DEM (LiDar ground control and imagery control)**
- **Asset Mapping (e.g. GIS surveys, general features, villages, street map, TLS)**
- **Hazard & environmental monitoring (volcanoes, landslides, subsidence)**
- **Plate tectonics, seismic deformation**
- **Sea level change (e.g. monitoring elevation and stability of Tide Gauges)**
- **Contribution to global and regional geodesy (e.g. GGOS, IGS, APREF)**

Monumentation – Evaluate existing infrastructure

Identify existing primary control stations and levelled benchmarks from earlier survey networks

(e.g. trig stations)

(assess for accessibility, stability, GNSS (sky visibility), utility and proximity to development, cadastral connections)



AGD66 trilateration network, Morobe Province, PNG

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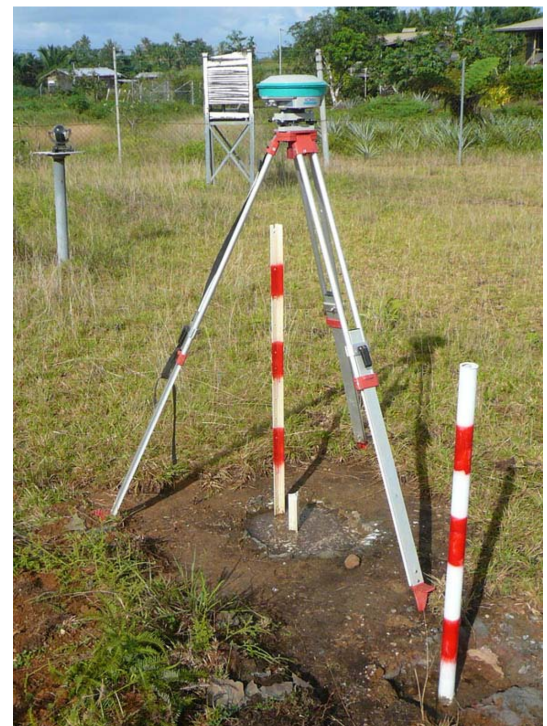
Monumentation – Augment existing infrastructure

Construct new primary geodetic stations at useful places like airports, port facilities (tide gauges), government offices, schools, playing fields, meteorological stations, resource sector camps (secure locations with no land ownership issues and good sky visibility)



Kiunga, Base station, Western Province, Papua New Guinea

Monumentation – Establish CORS

(continuously operating GNSS stations) in main towns and development areas to support RTK/NRTK and local static GNSS surveys. (Consider RTK and static range limitations, mobile network coverage for NTRIP, power supply and UPS backup)

COCO

Cocos Islands

IGS/ ARGN/ APREF pillar

Indian Ocean

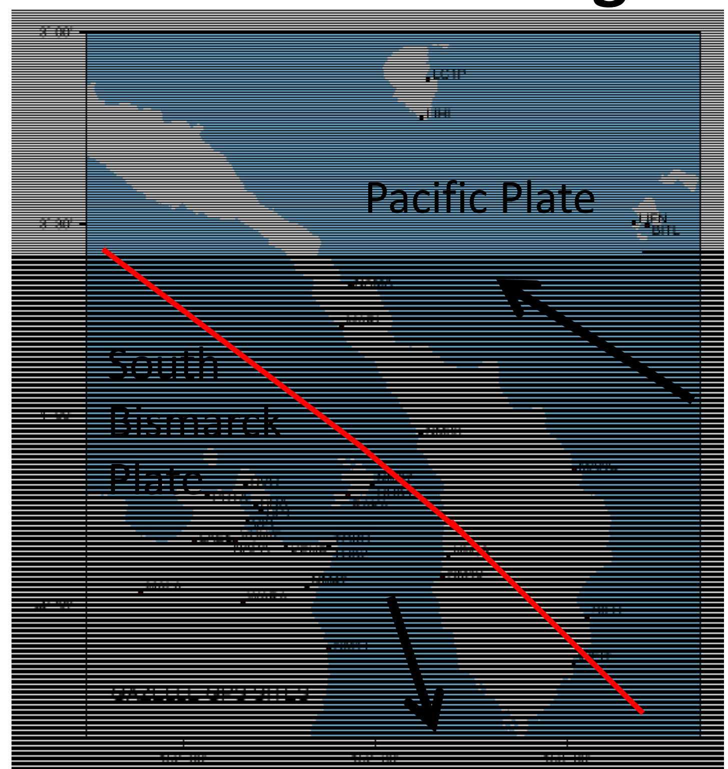
Australia

Monumentation – Tectonic Monitoring

Dense network of geotechnically stable geodetic monuments on either side of plate boundary or active fault zone.

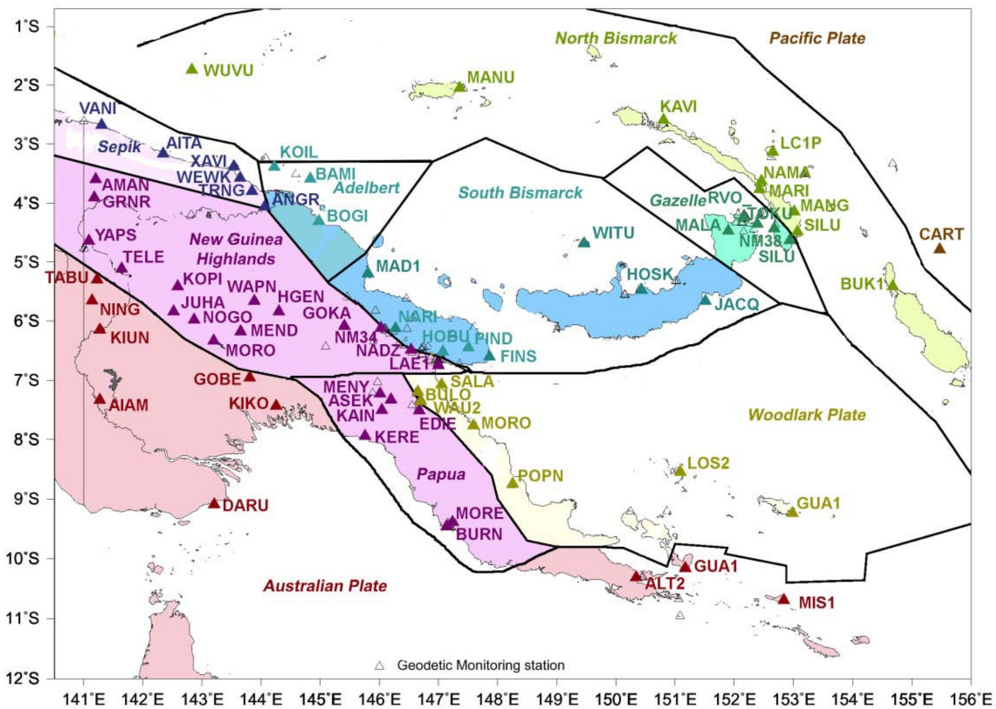
Consider optimum geometry for modelling.

Regular network of stations within rigid portion of plate to enable inversion of plate model.



Southern New Ireland, Papua New Guinea geodynamic monitoring network

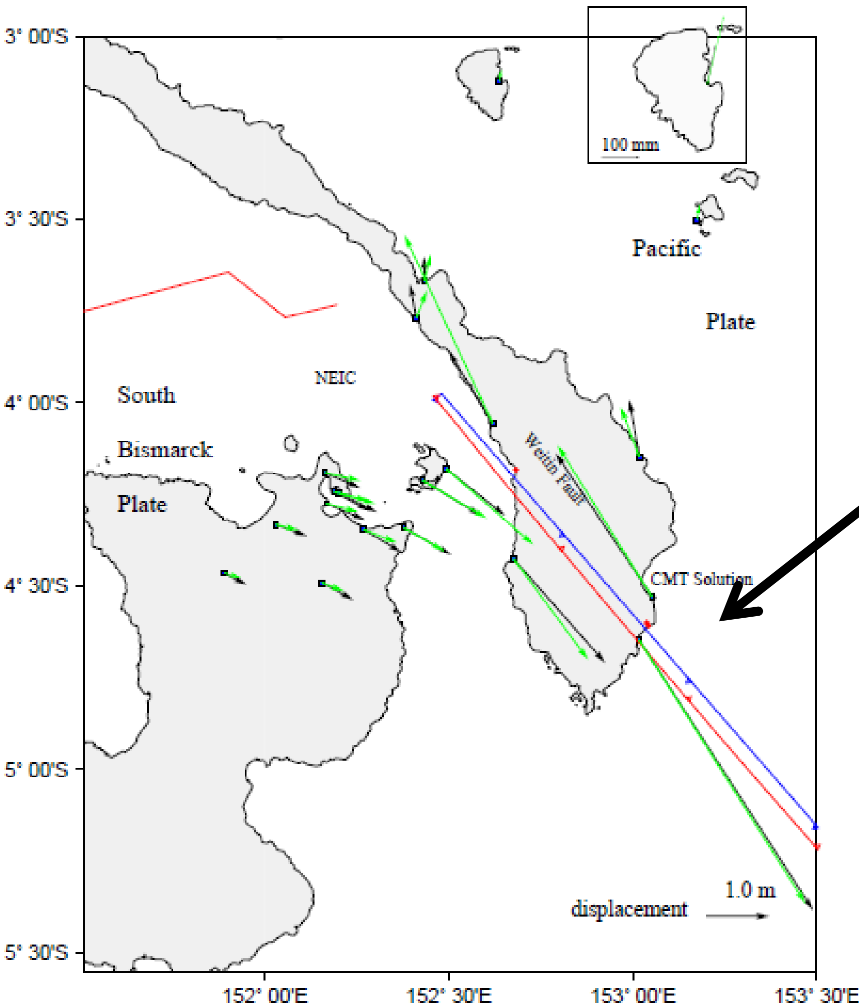
Monumentation – Tectonic Monitoring & sea level



Siting of monitoring stations around each tectonic plate and boundary zone

Tide Gauges well spaced around coastline away from river mouths.

Direct measurement of seismic deformation



Mw8.0 Weitin Fault earthquake,
New Ireland, Papua New Guinea
16th November 2000 (Tregoning, ANU)

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FIG

Other geodetic networks – hazard monitoring

Volcano monitoring networks

Subsidence zones

(e.g. Above underground mining operations, coal-seam gas extraction, groundwater and aquifer abstraction)

Landslide monitoring

Localised deformation monitoring

Co-location with other geodetic sensors

DORIS Beacon

(IDS Network)

Satellite Laser Ranging?

VLBI ?

GNSS Antenna

APREF GNSS Network

Tie and stability check RM

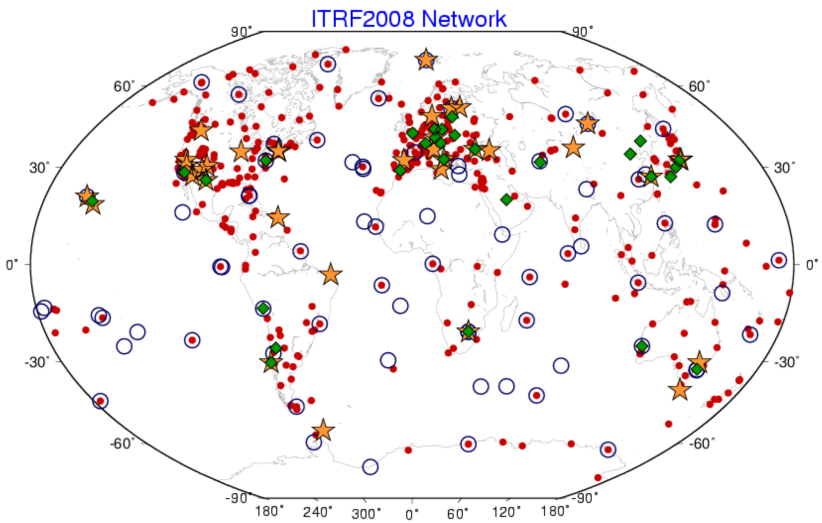
(preferably should be instrument pillar)

Port Moresby DORIS and APREF CORS

Papua New Guinea

Co-location has very significant benefits for global geodesy and ITRF

Contribution to global and regional networks



ITRF (including IGS)

APREF (including SPSLCMP)

(regional densification of ITRF)

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Choice of monument construction

considerations:

Cost & availability of materials

longevity and stability of monument

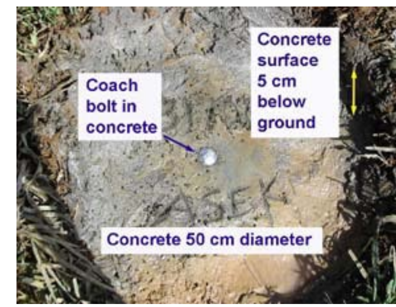
Risk of vanadlism

(e.g. theft of brass plaques!)

Deep footings and reinforcement if possible

Brass Plaque

Stainless steel bolt



Star Picket

Galvanised Iron Pipe

Geodetic pillars

considerations:

Ideal for mining and CORS tie monitoring (already centred for total stations and GNSS antennas)

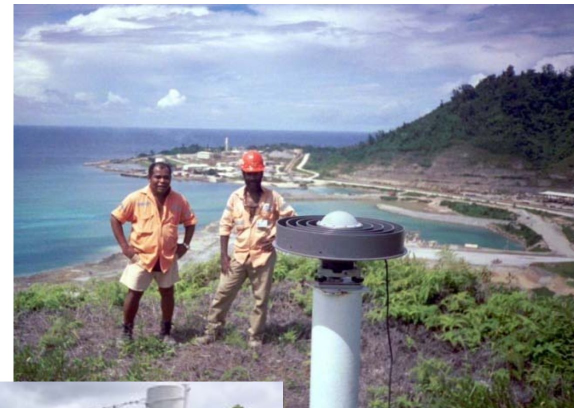
Easily located (of course!)

Requires especially deep and robust footings and reinforcement

Lihir Pillar

New Ireland

PNG



Kiunga GPS base

Western Province

PNG

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Choice of monument siting

Sky view for GNSS observations (under trees is no good!)

Utility – e.g. Is it within range of working area for reliable L1 fixed solution? Intervisibility with other stations for total station use

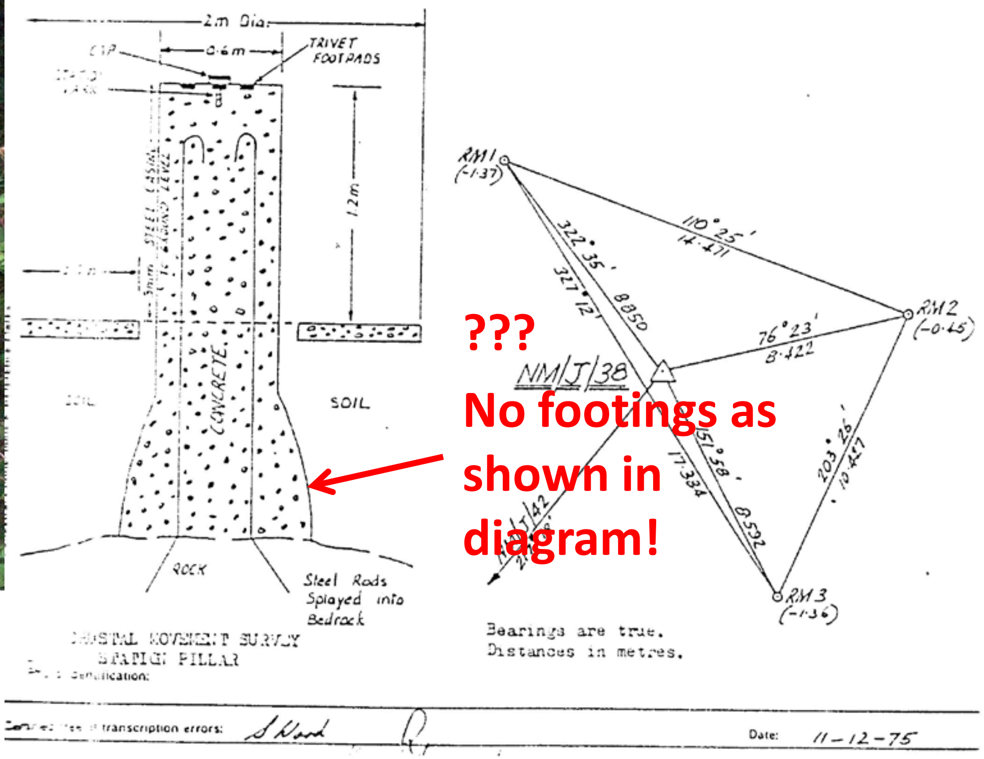
Risk of destruction – located away from possible earthworks or construction, vehicles.

Stability of site – On contiguous bedrock – not floaters!

Avoid clay or deep soils, slopes, edges – requires very deep footings.

Stability of stations!

Tinbal – Crustal Motion Pillar – New Ireland, PNG



???

No footings as shown in diagram!

CORS monuments – good enough?

Roof or tower antenna mount limitations:

Unstable structure?

Strong winds (e.g. cyclones) can induce wind shear deformation

Thermal expansion of structure (e.g. steel tower)

Best construction is a low concrete pillar with very deep footings and reinforcement - tied to bedrock. Requires long curing time.

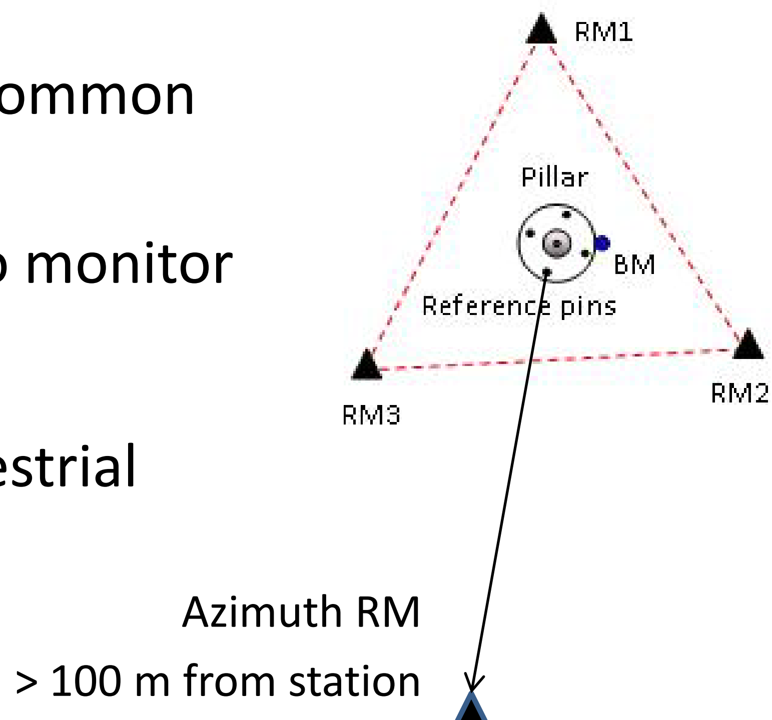
Consider sky visibility and multipath (remove young trees nearby)

Stability monitoring of primary control / CORS

local RM network, low pillars, duplication (redundancy) at common sites, stability of tide gauges.

Redundancy RMs at > 50 m to monitor site stability.

Azimuth RMs to support terrestrial surveys (e.g. cadastral and construction)



Reference Marks and Witness Posts

RMs especially important to verify stability of primary mark (and recovery of main mark if disturbed or vandalised). Constructed to similar standard to main mark (e.g. iron pin in concrete)

Best located within 5 m of main mark and concealed slightly below ground level. 3 marks in a triangle around mark.

Witness post ideally within 50 cm of station. e.g. star picket or galvanised pipe set in concrete. Also consider windsocks at airports (> 5 m away) , rugby goal posts (beyond dead ball line to avoid broken ankles), basketball posts.

Considerations for siting of Tide gauges

Tide Gauges sited away from river mouths – areas of strong wave action or currents

Lower precision sea surface measurements are still useful especially if made over the full tidal cycle
(e.g. by lowering levelling staff or tape from jetty edge)

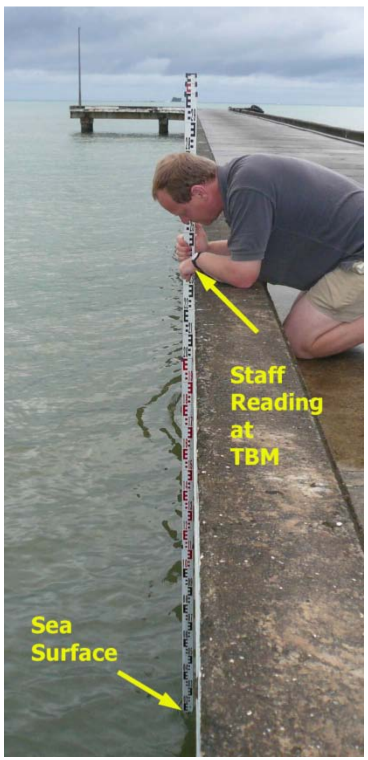
Updated MDT (of the sea) model from satellite altimetry can also be used

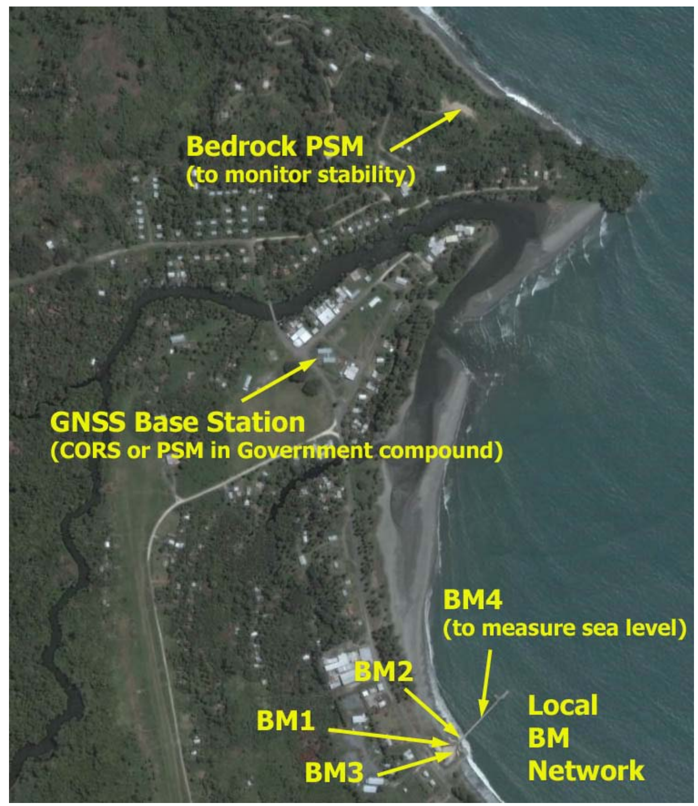
Tide Gauge – monitoring network (1)

Human

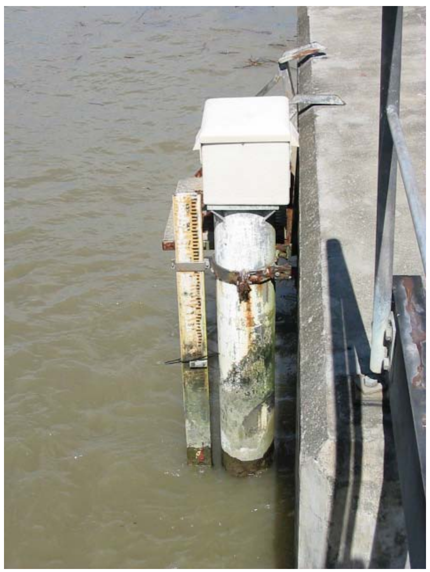
Tide

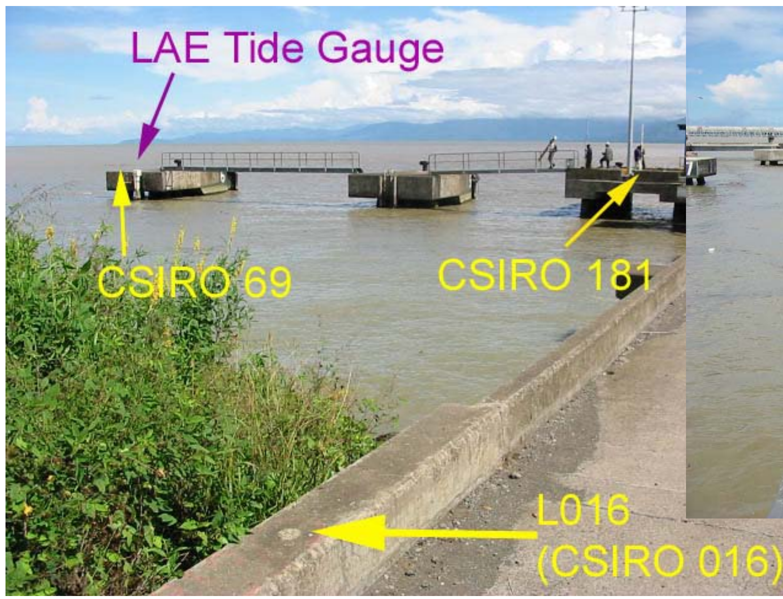
Gauge!





Tide Gauge – monitoring network (2)





Considerations: Subsidence and disturbance to wharf

Slipping of tide gauge zero mark over time – damage

Important to have nearby BM on bed-rock away from wharf

Observations – Choice of equipment

GNSS sensors:

L1 only – limited to 10-15 km for fixed solution or so (cheaper)

L1/L2, L1/L5 – anywhere on the Earth (more expensive)

GPS only, GPS + Glonass, GPS + Galileo,

Beidou(Compass), QZSS .....

Carrier-phase processing not yet fully interoperable

(so multi-GNSS of limited value for static GNSS)

e.g. GPS only fixed solution + Glonass only float solution

Choice of equipment considerations

It's not just about price!

Does the equipment have a good warranty and reputation?

Use a local supplier for warranty and ex- warranty support & repairs – even if it costs more.

(air freight is expensive!)

Is the equipment robust (water proof) for Pacific conditions?

Do other organisations nearby have similar equipment?

Remote area extras: external batteries and cables, spares

Ongoing equipment maintenance budget.

Configuring GNSS for static observations

Does GNSS receiver have a RINEX logging option?

(If not requires software to convert binary observation and nav file to RINEX)

Log all observables (pseudorange, carrier-phase, doppler, SNR)

Choice of epoch interval for data logging:

1 second (Hz) for real-time surveys (e.g. IGS met, LiDar, RTK)

10 seconds (Hz) for rapid-static surveys (< 2 hrs)

30 seconds (Hz) for daily solutions and ITRF connection

GNSS Observations for fiducial network

4 hours of dual-frequency carrier-phase GPS observations can provide 15 mm precision in ITRF (30 mm for ellipsoidal height)

Ideally CORS for continuous measurement! Or campaign style observations:

For fiducial network recommend multi-day observations

(e.g. 2 day or 4 day to moderate unmodelled ocean-tide loading effects – affects vertical precision)

Repeat observations every six months for two to four (or more) years

in order to model station time series in ITRF and average out seasonal (annual) deformation signals e.g. draconitic effect, hydrological loading

GNSS Observations for 2nd order network

GNSS base station running over fiducial station

GNSS rover stations running at stations within radius of 30 km in order to optimise observation time and minimise tropospheric modelling errors.

Observation time 15 minutes to 2 hours depending upon baseline length, Satellite geometry (GDOP), availability and observing conditions (e.g. longer obs required if station near trees or buildings)

Three receivers running concurrently provides baseline loop closure check. Unchecked baseline radiations are dangerous.

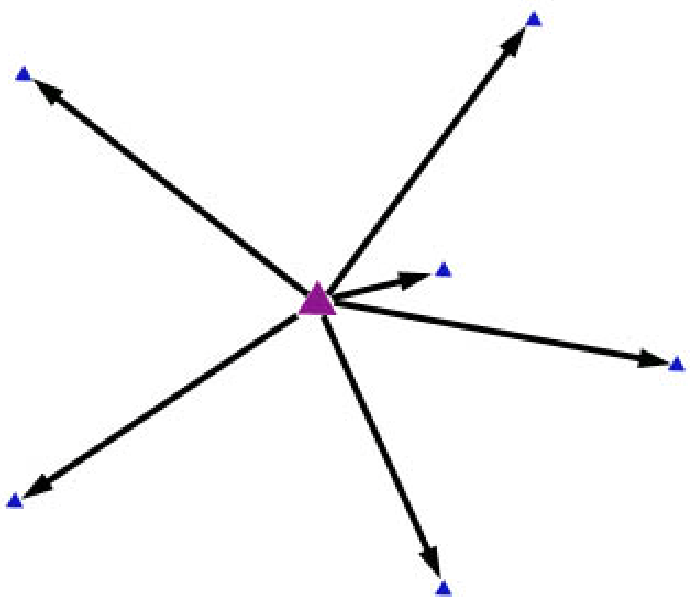
GNSS observations on older datum stations

Important for estimating transformation between old and new datums to enable legacy spatial data (e.g. Topographic and cadastral plans) to be transformed accurately to a new datum.

Observe dense network in urban areas for high precision estimation (and evaluation) of parameters.

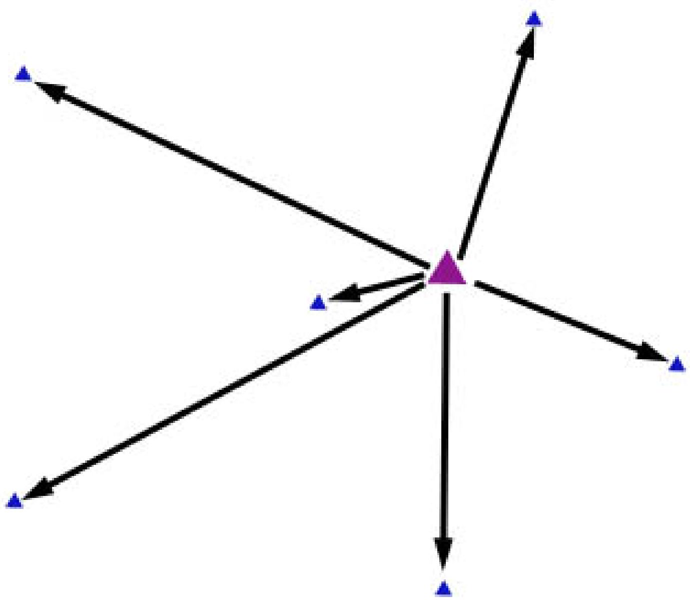
Locate bench marks (with local height datum) in order to estimate offset between geoid model and local height datum surface.

GNSS network (with two receivers)



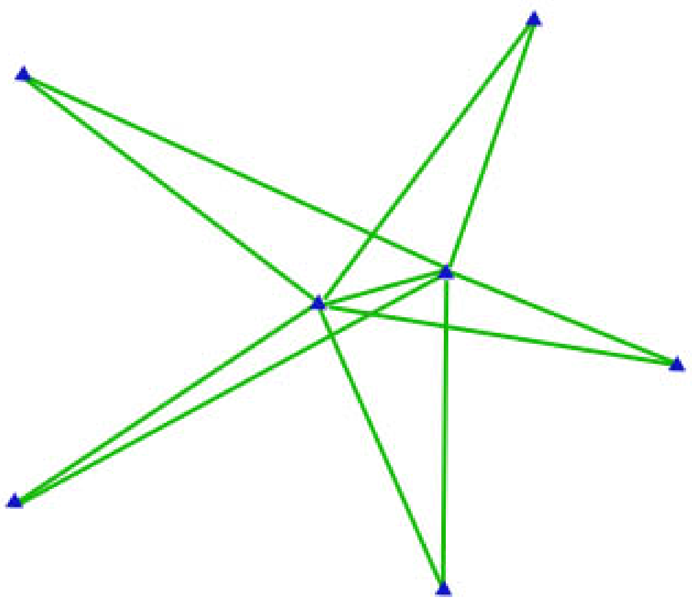
First set of radiations from central base station

GNSS network (with two receivers)



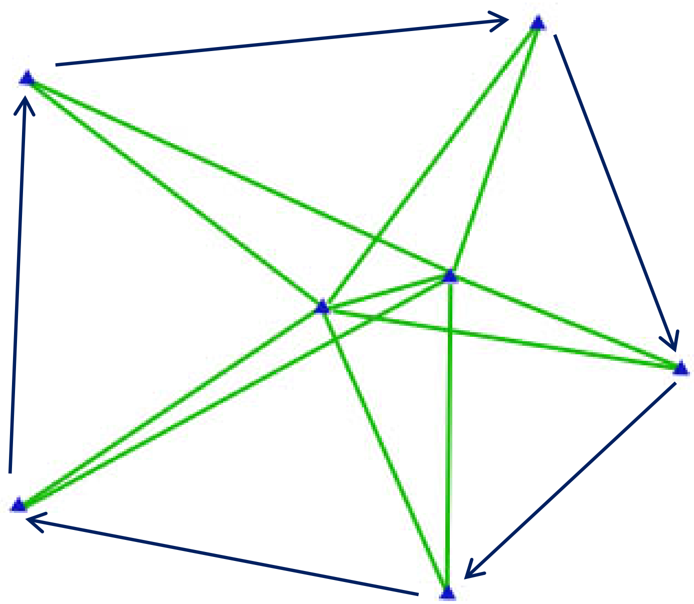
Second set of radiations from central base station

GNSS network (with two receivers)



Network of closed loops

GNSS network (optimum geometry)



Sufficient redundancy and geometry improvement with additional baseline measurements

Antenna height measurements some care needed!

Important checks:

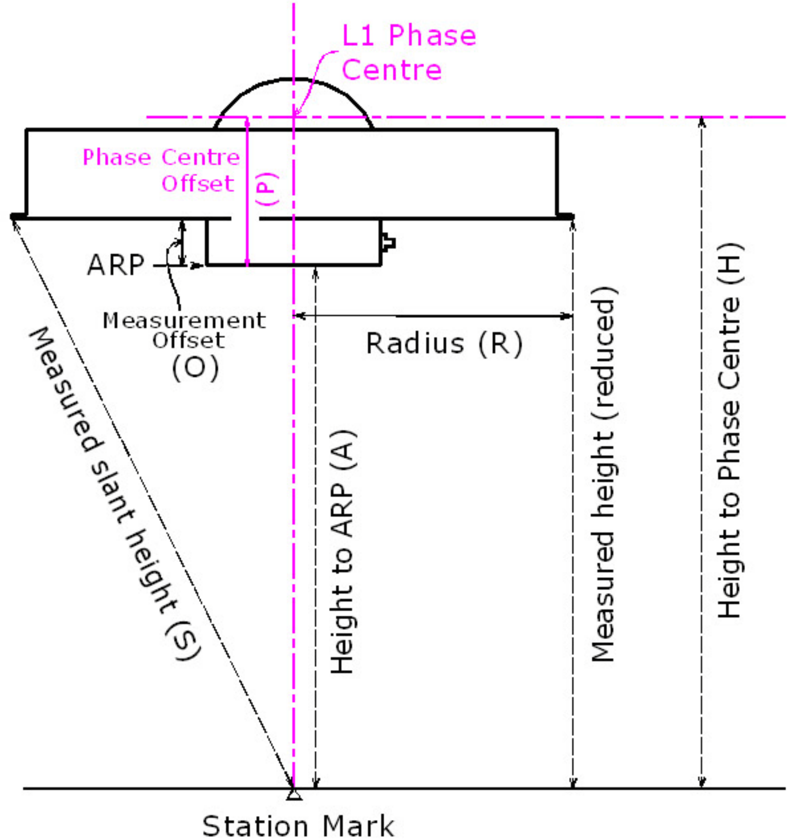
Centering of antenna over station mark

(calibrated optical plummet, plumb-bob check)

Threaded pillar is ideal

Double checking of height measurement start and end of observations with different tapes (use different observers).

Careful note of what is measured on log sheet – also antenna part number

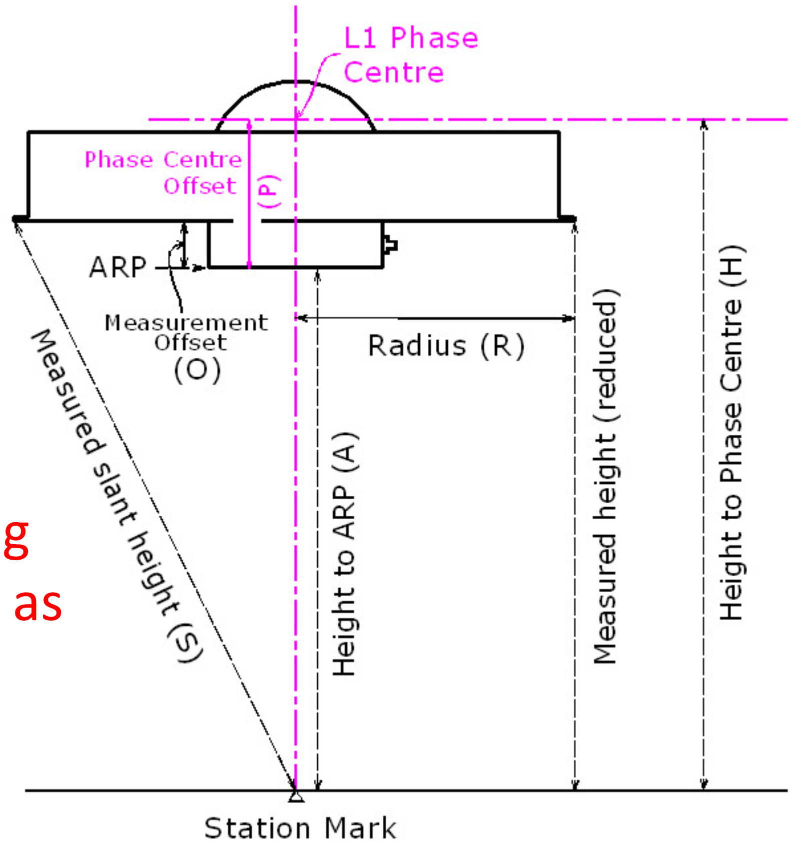


Reduction of slant height measurements

In most instances Antenna Reference Point (ARP) is required for data processing (ARP is usually lowest point on antenna body)

$$A = \sqrt{S^2 - R^2} - O$$

Most common error with GNSS heighting arises from using measured slant height as ARP height & selecting wrong antenna type



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Other geodetic measurements

Total station measurements for site ties, RM surveys,

observations to geodetic control (especially legacy control) under trees.

EDM calibration baselines

Important considerations: using realistic atmospheric corrections in EDM equipment (e.g. atmospheric pressure and temperature – especially important for long EDM measurements and at higher elevations). 90 ppm correction typical at 3000 metre elevation.

Verify prism constant

Levelling ties at tide gauges to monitor stability.

Sea level measurements at tide gauges

Data processing and adjustment

- (1) Choice of software

Can the software do dual-frequency carrier-phase processing?

Can software do network adjustment with weighting options?

Does software support projected coordinates, geoid models?

Can software use IGS precise orbits?

Are different troposheric and ocean-tide loading models selectable?

Multiple licences for field use – support agreement indefinite?

Bernese software (GNSS) – widely used and supported – expensive $$$$

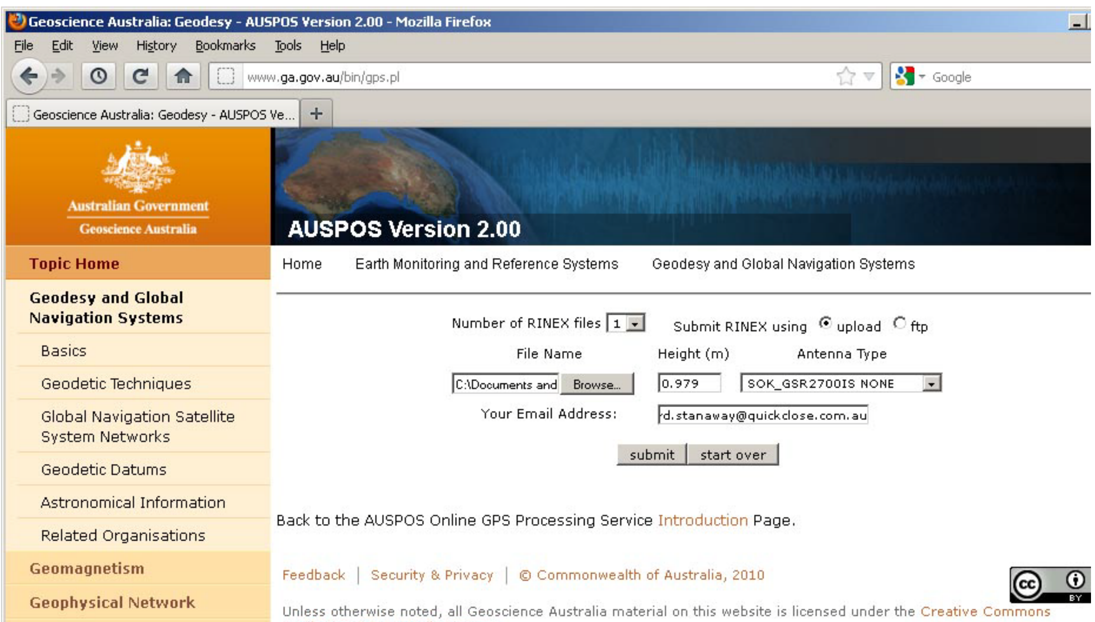
GAMIT/GLOBK (GPS) – less well used, not so user-friendly – but free!

Trimble Business Centre, Leica GO, Topcon Tools – user friendly - $$

RTKLIB – open source

Data processing and adjustment

AUSPOS



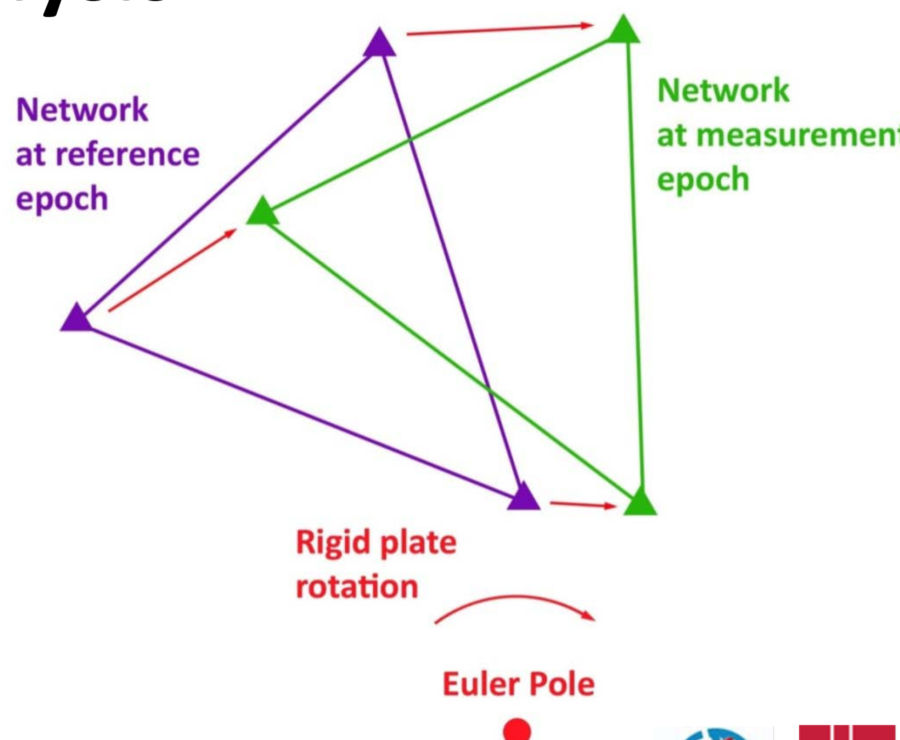
Relatively painless method of data processing!
-Uses Bernese engine
It's free!
ITRF2008 coordinates
EGM2008 elevation
& uncertainty
5 hours data -> 15 mm Hor. & 30 mm Vert.
Wait 3+ days for IGS Rapid orbit

Choice of reference frame for GNSS data analysis

ITRF at mean epoch of measurement!

Overcomes adverse effects of unmodelled localised deformation and plate rotation between reference epoch and epoch of measurement

Convert to local frame/datum after adjustment.



Model station time-series in ITRF to estimate site velocity & reference epoch

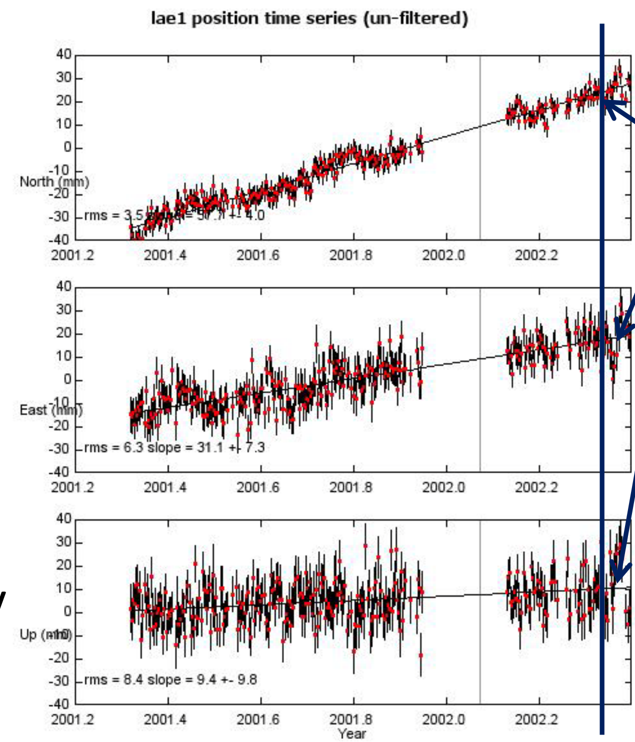
Recommended approach for local datum reference epoch:

Choose epoch near end of timeseries.

1st January (e.g. 2003.0)

Consider reference epochs of adjoining jurisdictions

Unwise to choose epoch too far the future – unless seismic activity and deformation are predictable!



Select reference epoch for local frame (datum) determination

e.g. 2003.0

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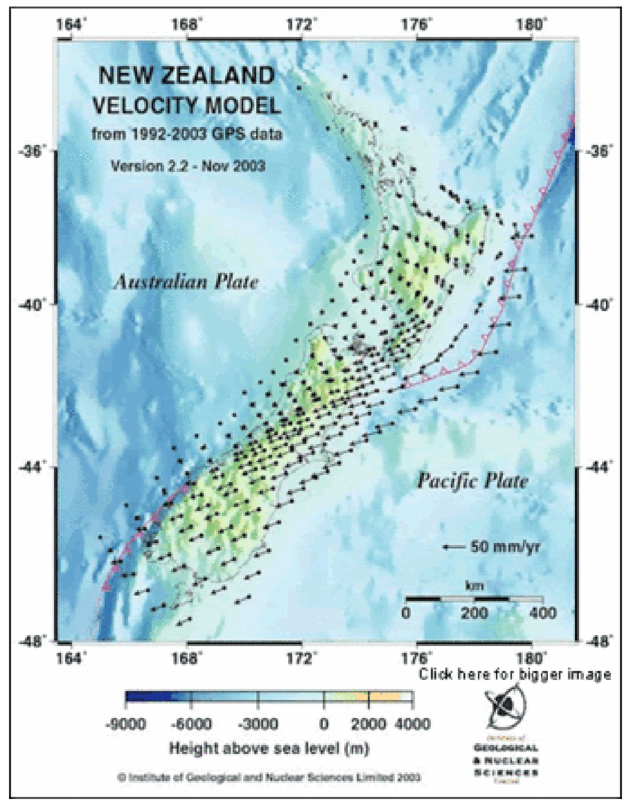
FIG

Develop site velocity (deformation) model

Enables ITRF coordinates at epoch to be propagated to another epoch (e.g. local datum reference epoch)

to model out underlying plate motion.

Alternatively a rigid plate model, 14 parameter, 6 parameter or block shift rate can be derived (e.g. for smaller islands in Pacific located away from plate boundaries)



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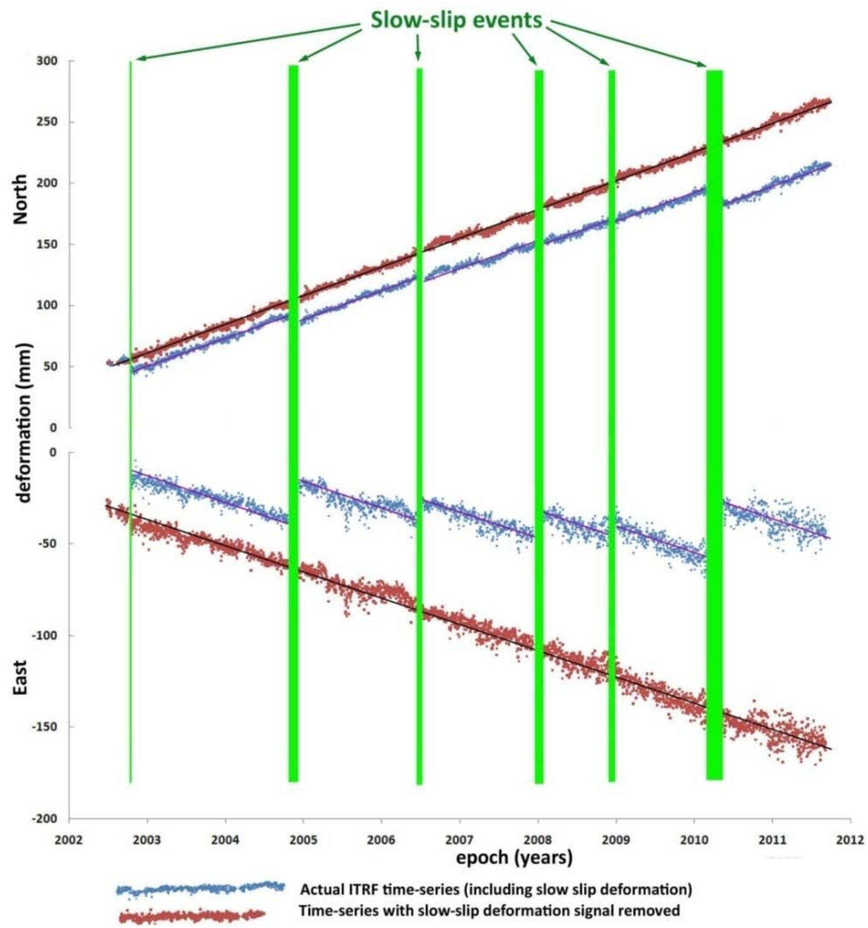
Estimate seismic offsets in time series

Gridded patch models of seismic deformation (including postseismic)

Used in conjunction with linear (interseismic) deformation model.

If postseismic decay is significant, a gridded model of decay coefficients may be required



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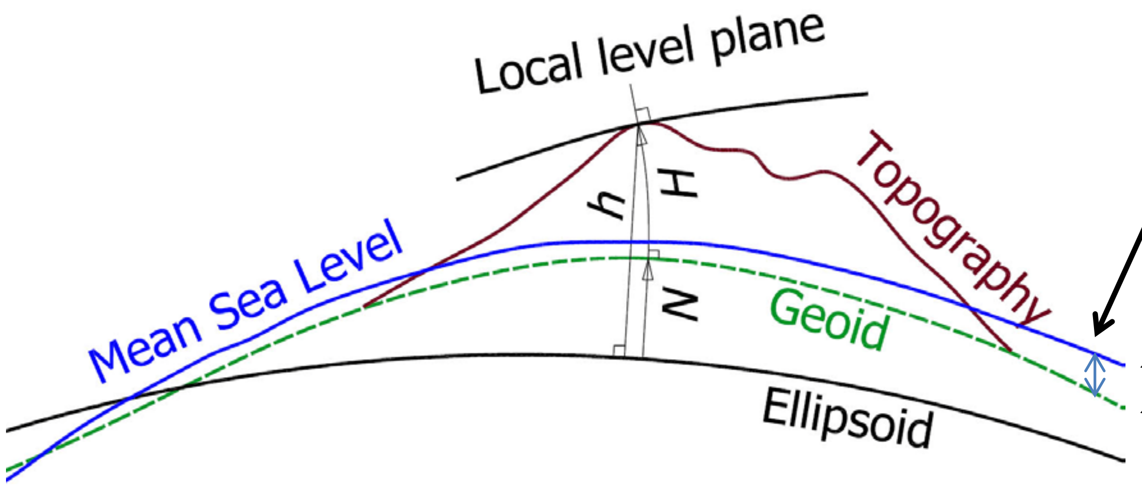
Develop quasigeoid to fit observed MSL



In Pacific region MSL sits between 0.7 m and 1.5 m above the EGM2008 geoid due to thermal expansion

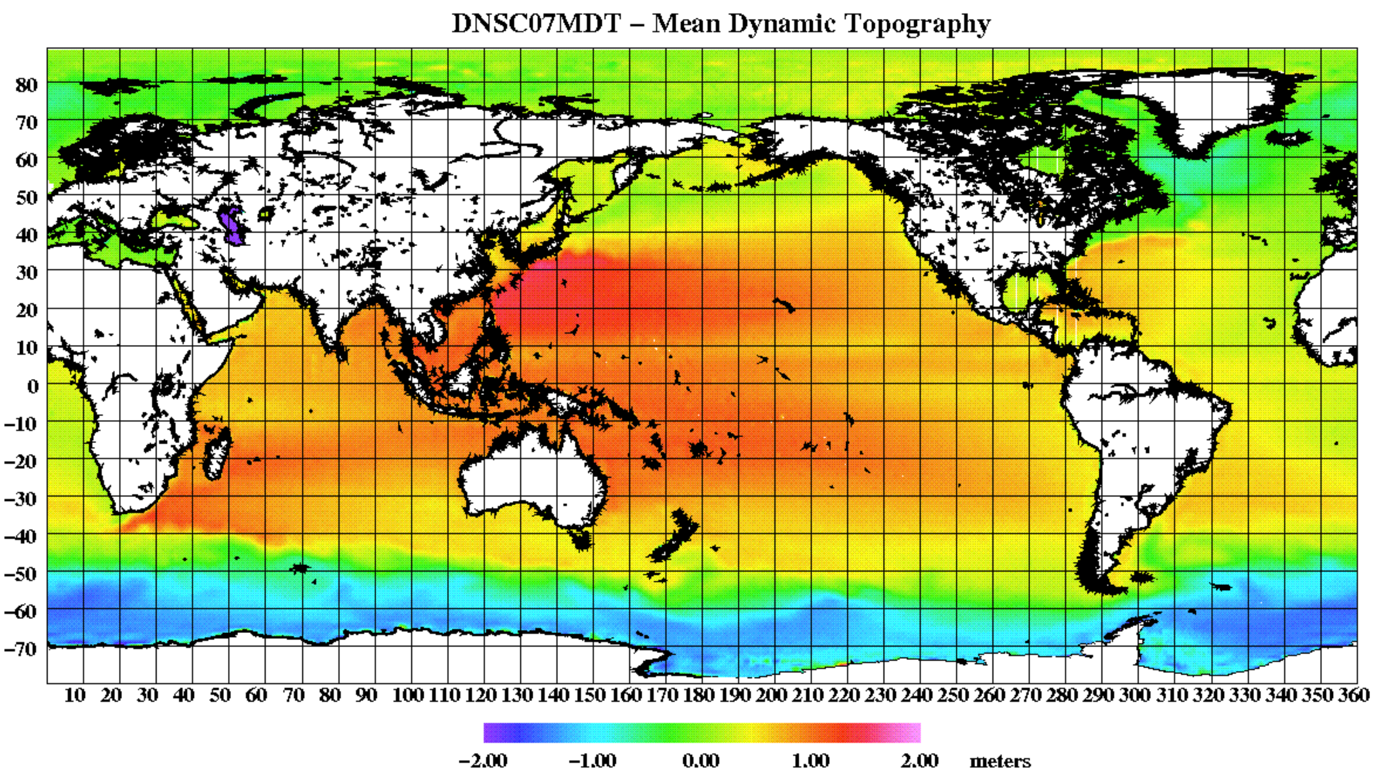
Observed MSL from TG

EGM2008 geoid

Offsets between observed MSL and EGM2008 can be interpolated (e.g. by kriging) and a quasigeoid computed by adding offsets to EGM2008 N values

Other technique – using model of MDT (ocean topography) from altimetry

Difference between MSL and EGM2008



Technical University of Denmark – National Space Institute

Geodetic Adjustment

ITRF2008 at mean epoch of measurement for fiducial network and GNSS baseline processing

↓

Eliminate float or high RMS GNSS baselines
Evaluate weighting of fiducial station coordinates
Older baselines and legacy measurements not recommended

↓

Loop Closure – robustly isolate incorrectly weighted baselines

↓

Run adjustment – tweak apriori and weighting to achieve RV of close to 1

Develop Map Grid related to datum and ellipsoid

UTM typically has large scale factors due to 6 deg wide zone

Often not suitable for cadastral mapping and engineering surveys

Options for best fitting projection to keep scale factors close to 1.00000

Selecting projection surface to coincide with mean elevation of region

Local Transverse Mercator (LTM) (good for most jurisdictions) – Projection can be designed so that LTM bearings are aligned with underlying UTM grid brgs.

Stereographic Projection – Good for large square / circular regions

Lamberts Conformal Conic – Good for higher latitude E-W shaped regions

Compute transformation parameters from old datums

Least squares estimation of transformation parameters by analysis of new datum and old datum coordinates.

Requires robust filtering strategy (e.g. L1 Norm) to isolate “rogue” coordinates and undocumented adjustment and realisation differences.

7-parameter model is the standard approach, but also 3-parameter (small data sets) and distortion grids (e.g. NTv2)

Need to provide parameters to GIS developers (e.g. ESRI and MapInfo) EPSG and other custodians of transformation parameters

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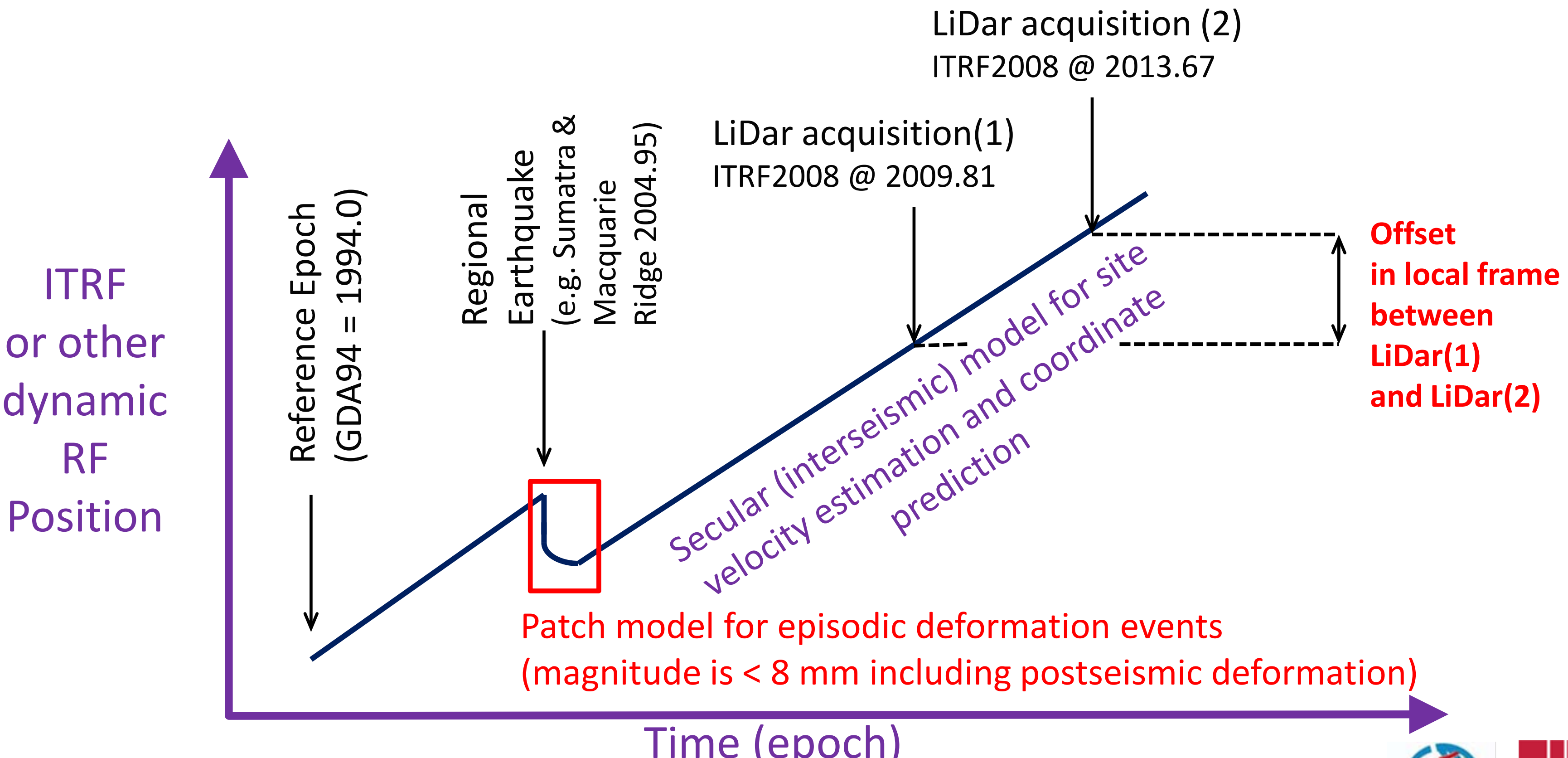
Dynamic datums and data – not a nice marriage!



Promulgation of Datum definition, coordinates, station summaries etc.

Publish datum technical specifications on the web

Station maps, coordinate lists, uncertainties /VCV and station diagrams on web

Online portal for Rinex data from CORS

Subscription access to RT data streaming (e.g. RTK, NTRIP)

New Zealand has a particularly good model for dissemination of geodetic data to users

Example of datum access (New Zealand)

Web-page for data

PositioNZ-RT – real-time data streams

Find out how to access real-time data from PositioNZ stations. more…

Text only version

Clickable map

PositioNZ stations | Velocity Model | Download data

Details | Timeseries | Availability | Photo

Data Access

Details for KAIK

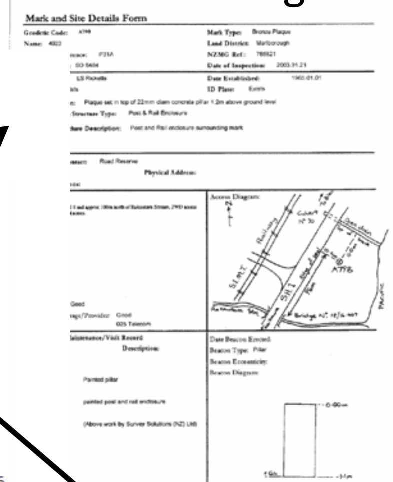
[Info] [Antenna] [Photo] [Notes]

Code:	KAIK
Name:	Kaikoura GPS
DOMES number:	50231M001
Datum:	New Zealand Geodetic Datum 2000
Latitude:	42° 25' 31.68098" S
Longitude:	173° 32' 1.17168" E
Ellipsoidal height:	314.809 m
Mark description:	5/8 thread in centre of 120 mm diameter stainless steel plate set in concrete pillar.
Receiver:	TRIMBLE NETR9 L1/L2+L2C/L5 GLONASS L1/L2 with 2 Maxwell-6 ASIC,
Antenna:	TRM55971.00 Zephyr GNSS Geodetic II - lead-based solder L1/L2/L5/G1/G2/G3/E1/E2/E5ab/E6/Compass
Antenna height:	0.0550

Coordinates and elevation (including historical)

Uncertainty / class / order

Location Diagram

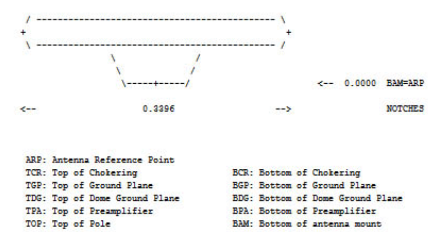


Antenna info

Details for KAIK

[Info] [Antenna] [Photo] [Notes]

Code:	KAIK
Receiver:	TRIMBLE NETR9 L1/L2+L2C/L5 GLONASS L1/L2 with 2 Maxwell-6 ASIC,
Antenna:	TRM55971.00 Zephyr GNSS Geodetic II - lead-based solder L1/L2/L5/G1/G2/G3/E1/E2/E5ab/E6/Compass
Antenna height:	0.0550



Details for KAIK

[Info] [Antenna] [Photo]

Station and mark photos

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Datum access – PNG example

Using Google Earth

Thank You! - Vinaka

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This presentation at:
http://www.quickclose.com.au/figsids.pdf