IAG / FIG / UNGGIM / UNICG / PhilGEGS

Reference Frame in Practice

Manila, Philippines 21-22 June 2013

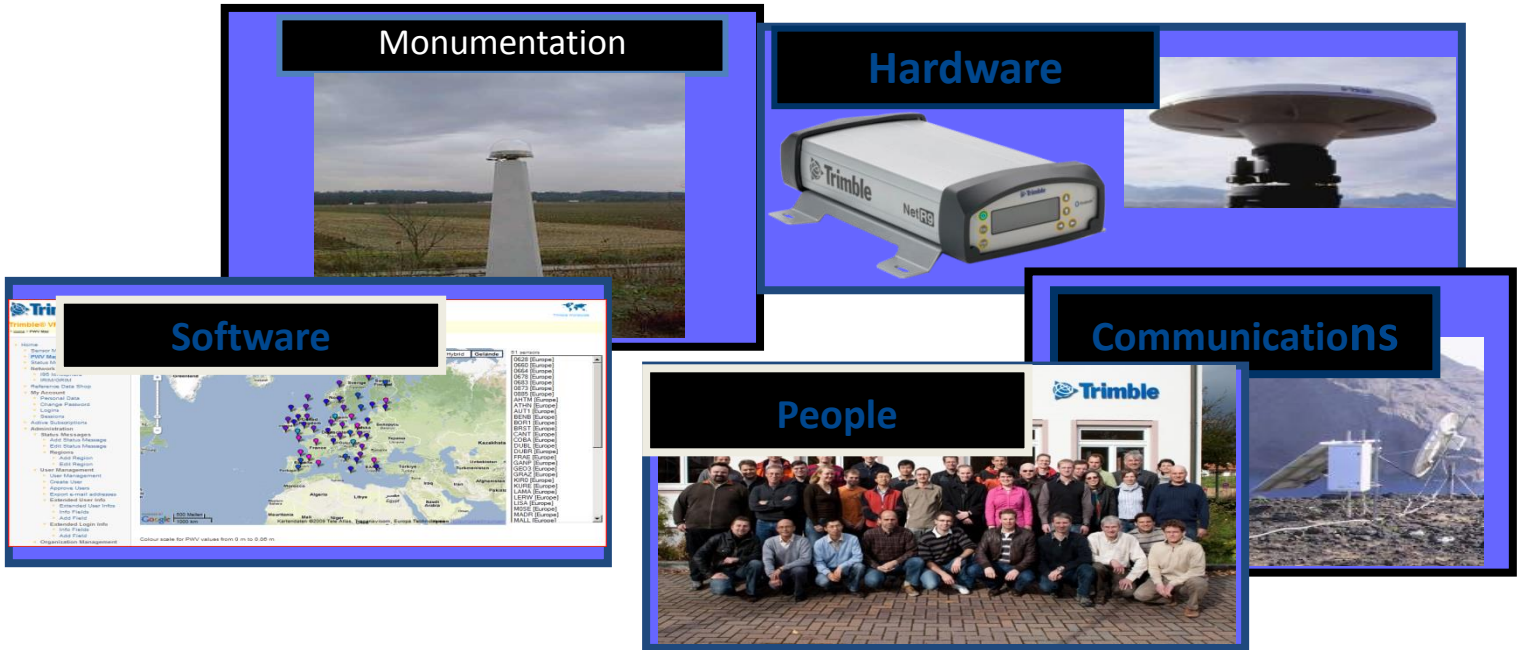
# Trimble's Role in Geodetic Infrastructure

Tan Siew Siong
Worldwide DGPS/DGNSS Sales Manager
Trimble Infrastructure Division
22nd June 2013

Sponsors :

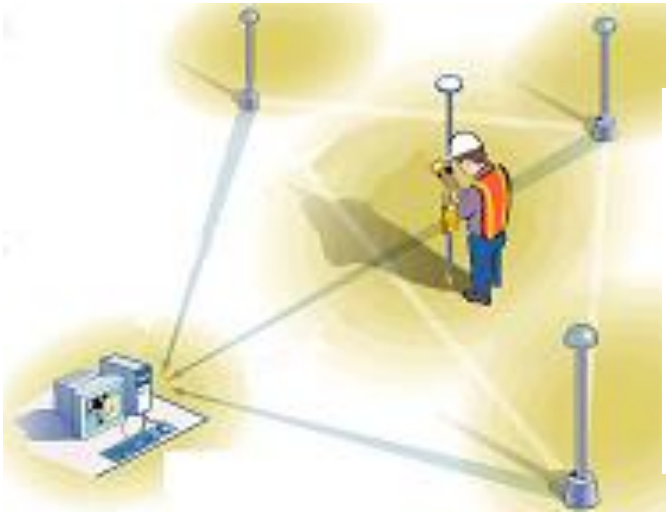
# Trimble's Role in Geodetic Infrastructure

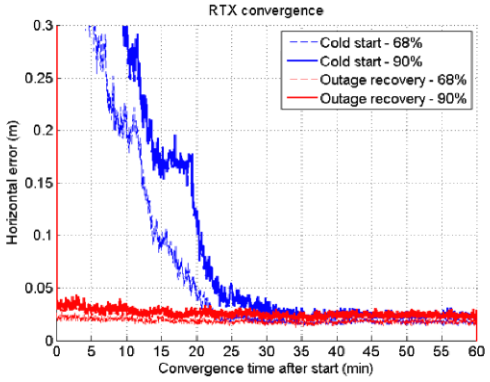
- Provide Future Proof CORS receiver
- Provide Modern & Proven Network CORS app.
- Provide Turnkey Solution
- Provide Innovative Positioning



# The Multi-Role GNSS Infrastructure Geodetic Receiver

- Continuously Operating Reference Station (CORS)
- Mobile Base
- Campaign Receiver
- Scientific Reference Station
- Position Anywhere, Anytime (RTX)

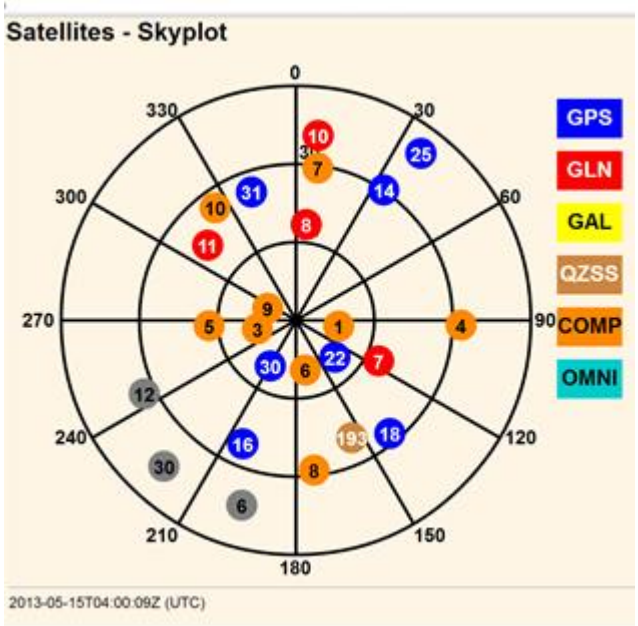



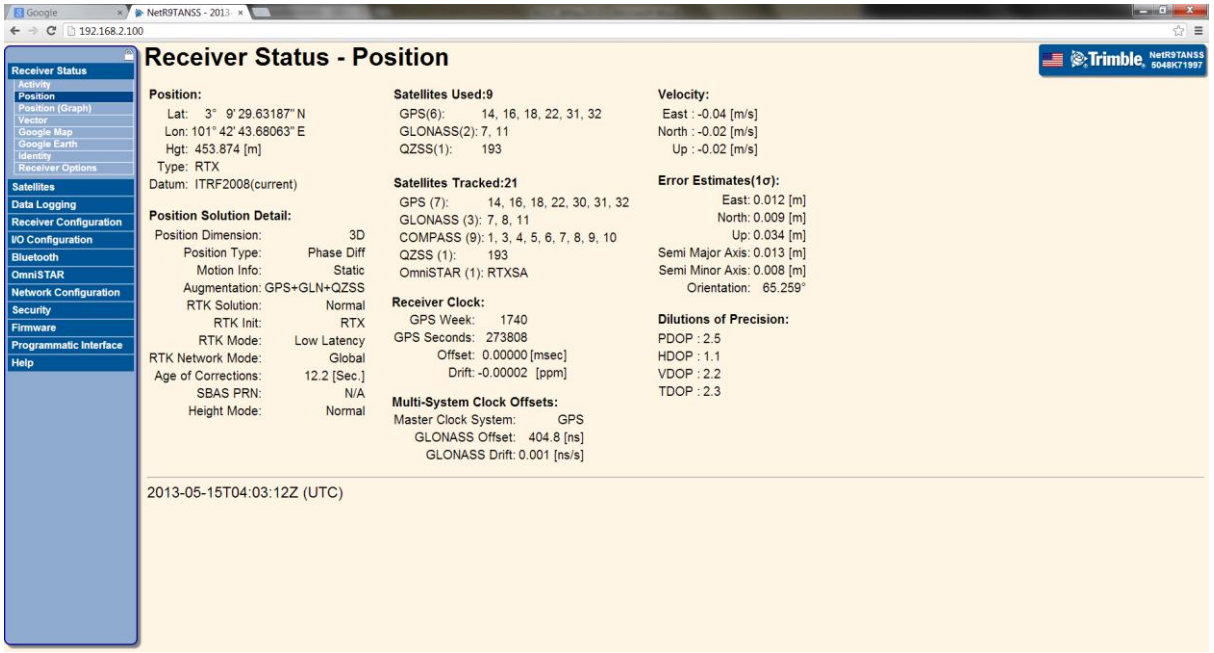



# Trimble NetR9 GNSS Reference Receiver

## Overview

- Enhanced Trimble® R-Track™ technology with Dual Maxwell 6 chipsets
  - 440 channels for unmatched tracking in the industry
- Currently tracks GPS, GLONASS, Galileo, Beidou, QZSS, Onmistar,
  - Chipsets have capacity to handle future signal structures



| FEATURE | NetR9 TI-3 | NetR9 TI-2 | NetR9 TI-1 |
|---|---|---|---|
| Channels | 440 | 440 | 440 |
| Data tracking/storage rate | 1 Hz | 20 Hz | 50 Hz |
| On-board storage size | 0 GB | 4 GB | 8 GB |
| GPS L1/L2 signal processing | ✓ | ✓ | ✓ |
| GPS L2C signal processing | × | ✓ | ✓ |
| GPS L5 signal processing | × | ✓ | ✓ |
| GLONASS signal processing | × | ✓ | ✓ |
| Galileo signal processing | × | × | ✓ |
| Compass signal processing | × | × | ✓ |
| QZSS signal processing | × | × | ✓ |
| CMR/CMR+ Input | × | × | ✓ |
| CMR/CMR+ Output | × | ✓ | ✓ |
| CMRx Input | × | ✓ | ✓ |
| CMRx Output | × | ✓ | ✓ |
| RTCM Input | × | ✓ | ✓ |
| RTCM Output | × | ✓ | ✓ |
| Advanced RTCM Output | × | ✓ | ✓ |
| Event Marker | × | ✓ | ✓ |
| NMEA | × | ✓ | ✓ |
| Bluetooth | × | ✓ | ✓ |
| External USB Support | × | ✓ | ✓ |
| RTK | × | ✓ | ✓ |
| Integrated USB support | × | ✓ | ✓ |
| Programmatic Interface | × | × | ✓ |
| Position Monitoring | ✓ | ✓ | ✓ |
| **RTX Engine** | **X** | **X** | **X** |

# How Trimble Can Assist In Developing Geodetic Infrastructure In The Region

- Provide Turnkey solution; Design, Built, & Operate solution.
- Cloud computing platform, and IT & Comm. consulting.


# Best Practices in GNSS CORS Implementation

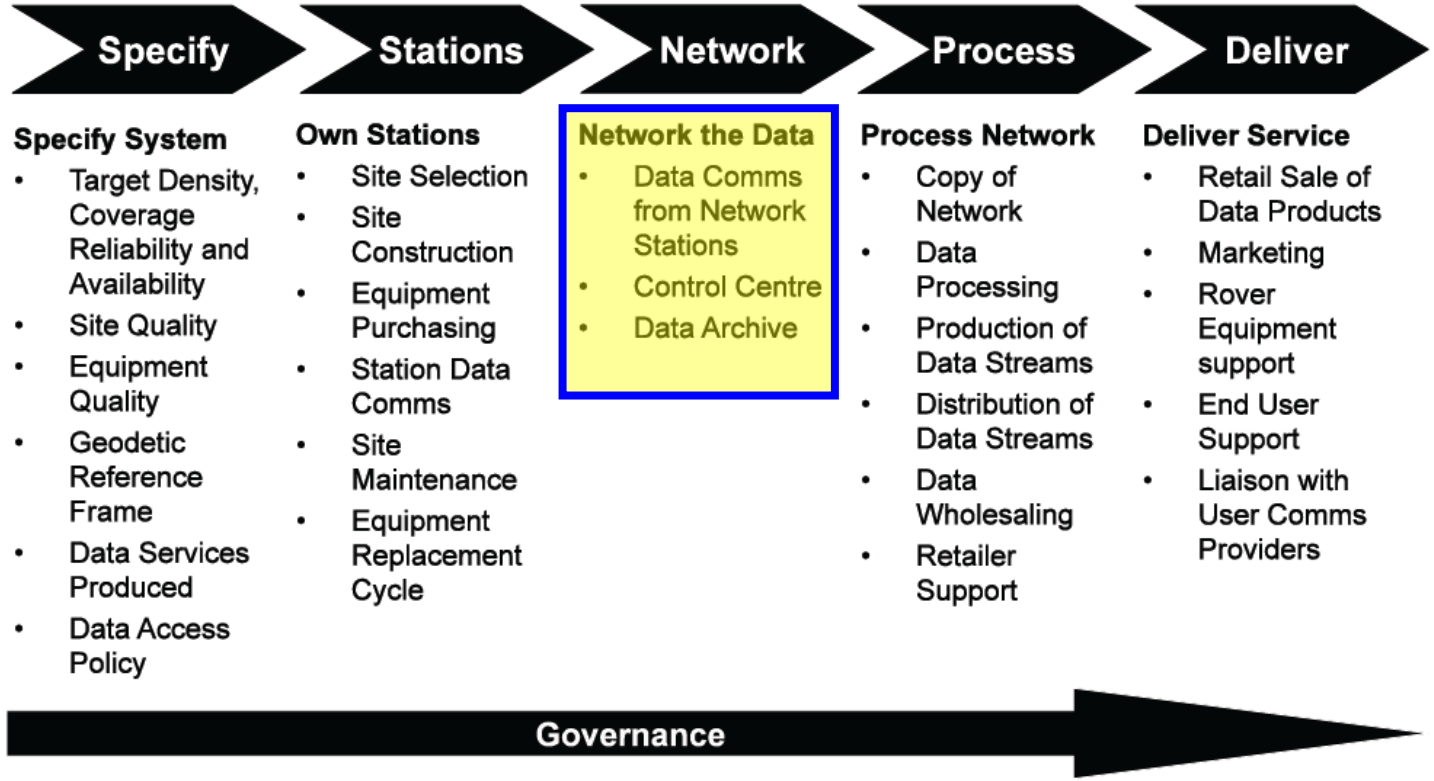
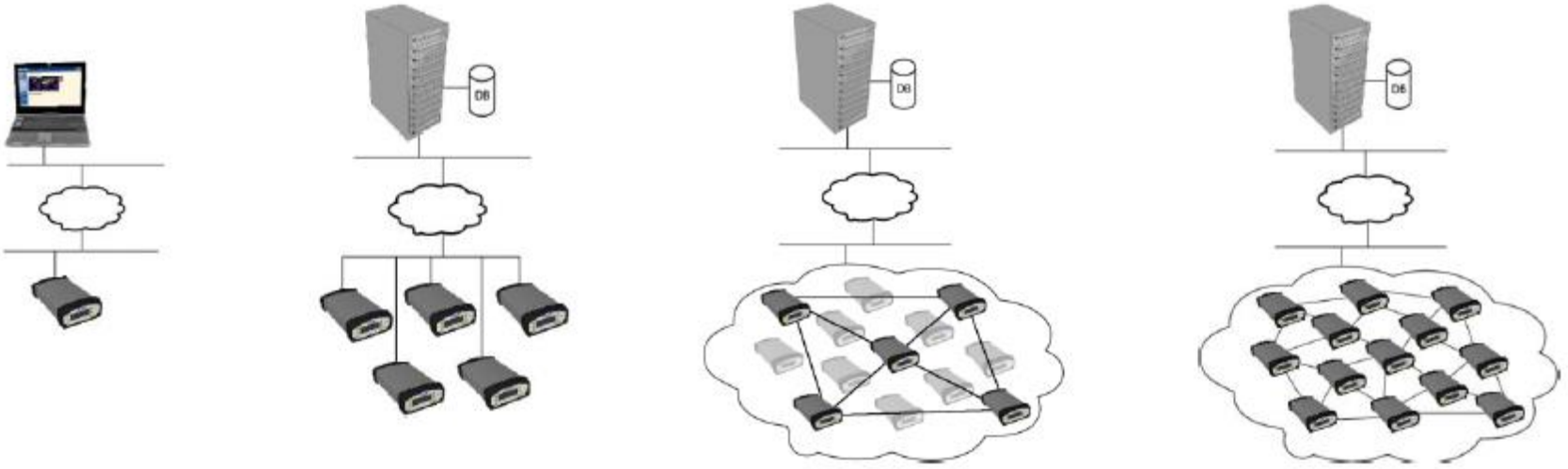



**Figure 1: A Model for Describing Organisational Roles in Precise Positioning Services (Source: Higgins (2008))**

# Real Time GNSS Network - Scalable Approach



Single BASE/CORS
Trimble NetR9

BASE/CORS Array
Trimble Dynamic Control App

SparseVRS Network
Trimble SparseVRS

VRS Network
Trimble VRS³Net App

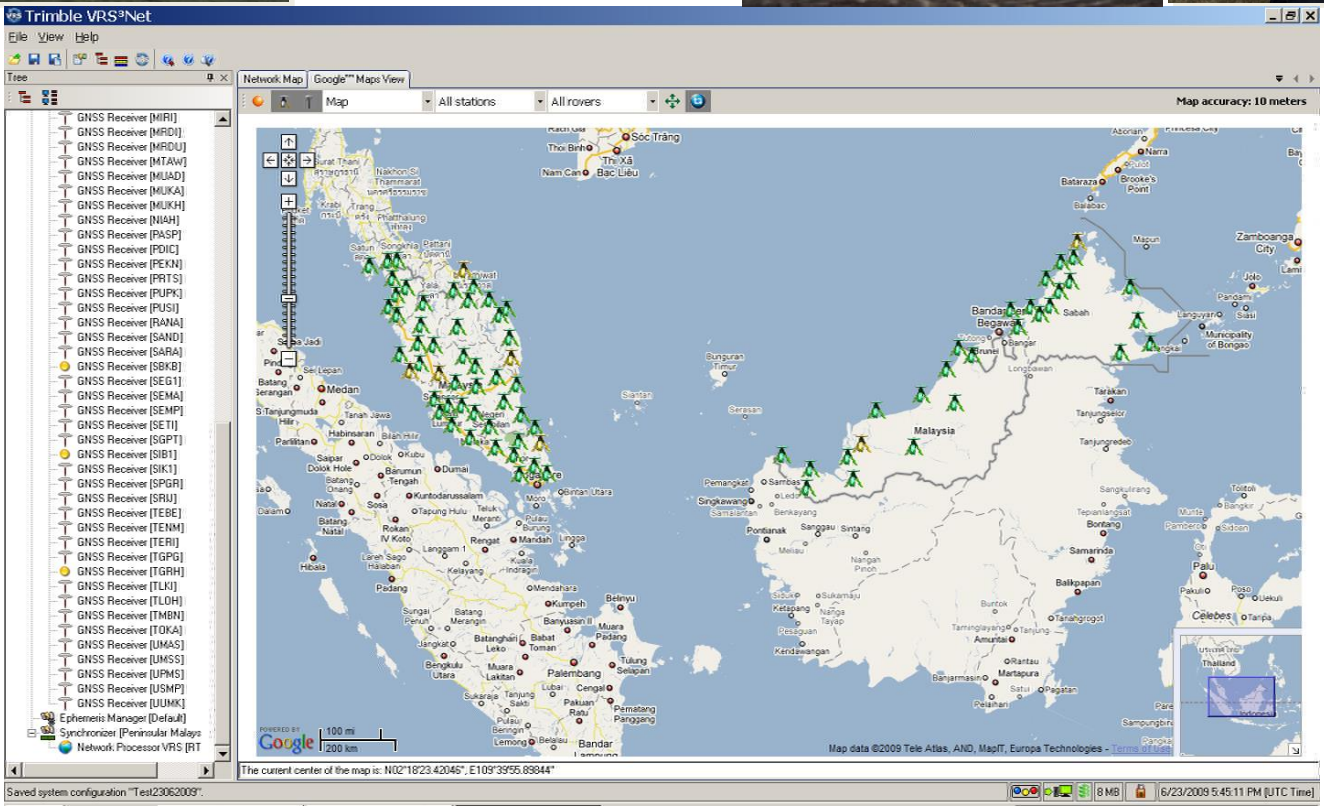
TIC TED TSM TDC sVRS VRS TIM ATMO

TRI RTX RTX-PP TNC iSCOPE TAC TDS TTG

*Software Platform*

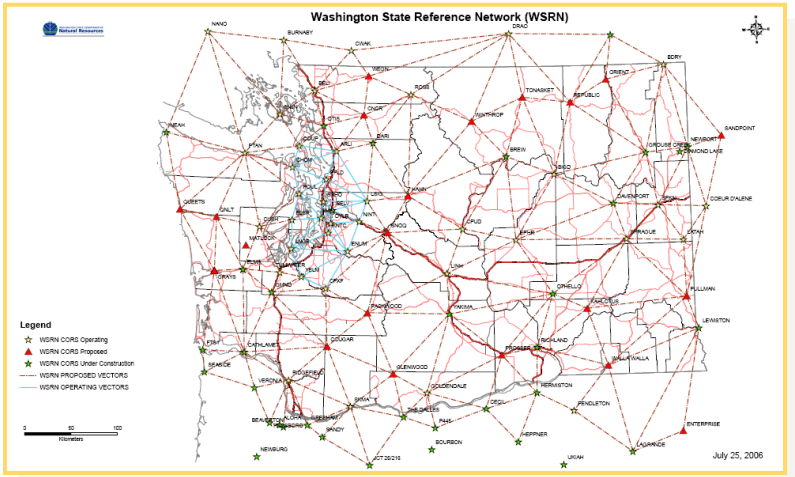
# Foundation for Geodetic Framework

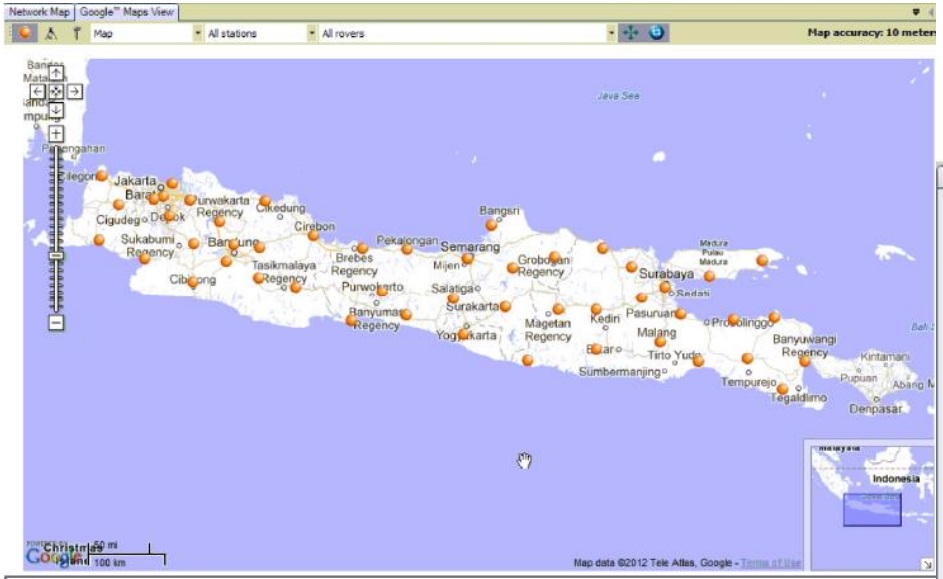


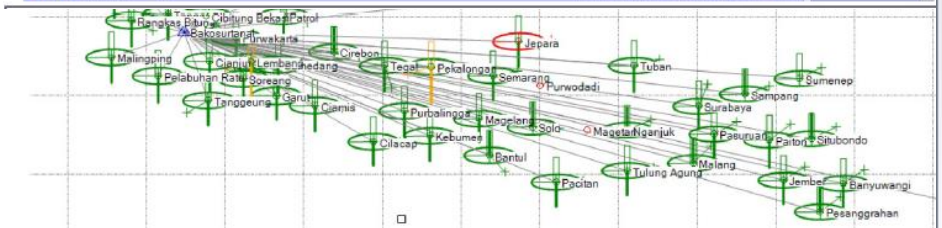



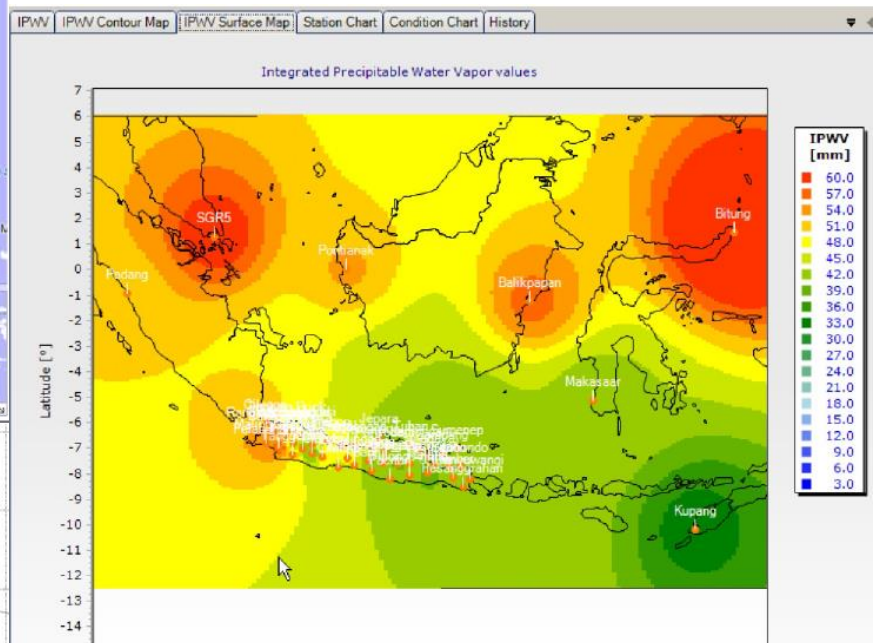
# Multiple use of GNSS Networks

- GNSS network as reference frame
- Positioning with cm-accuracy
- Monitoring
- Meteorology



# Trimble VRS – Cadastral, engineering, etc..

## GPS, GLO, QZSS, Beidou


**1 CONNECT**

Just power up your receiver and connect to the system.

**2 CORRECT**

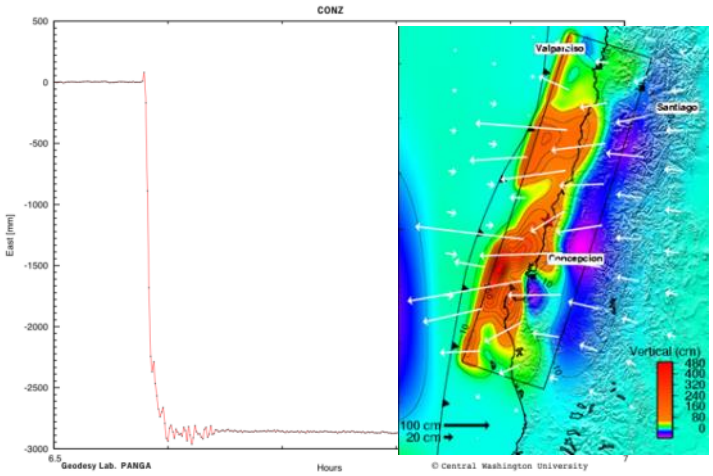
Trimble VRS Now delivers centimetre-accurate corrections tailored for your geographic location.

**3 MEASURE**

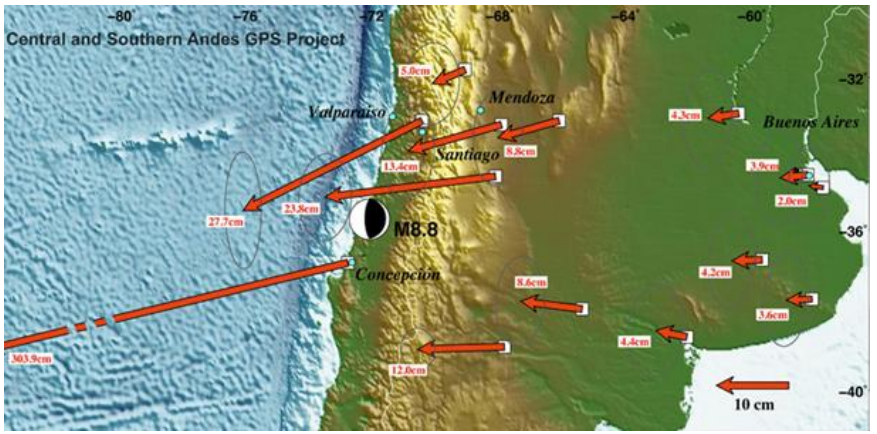
Complete your project without the delay of a field base station setup.

# GNSS – Better Seismic Monitoring

## Earthquakes

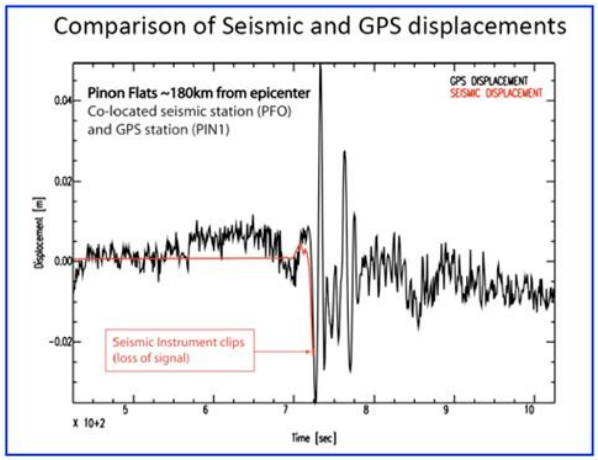



Source - Unavco



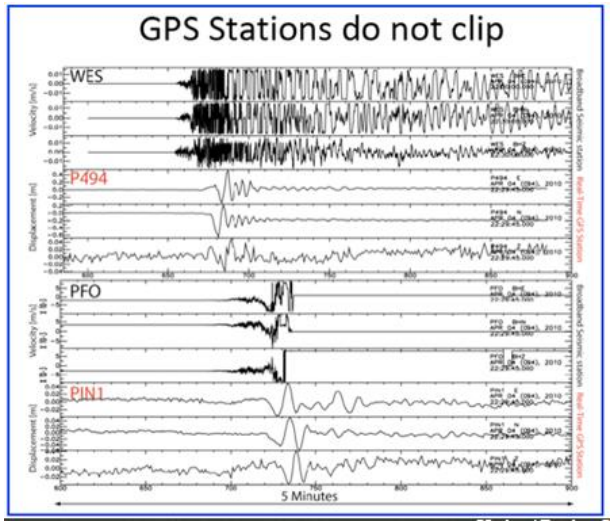

Source - Unavco

**Example of GNSS Derived Displacement - Chilean Quake**



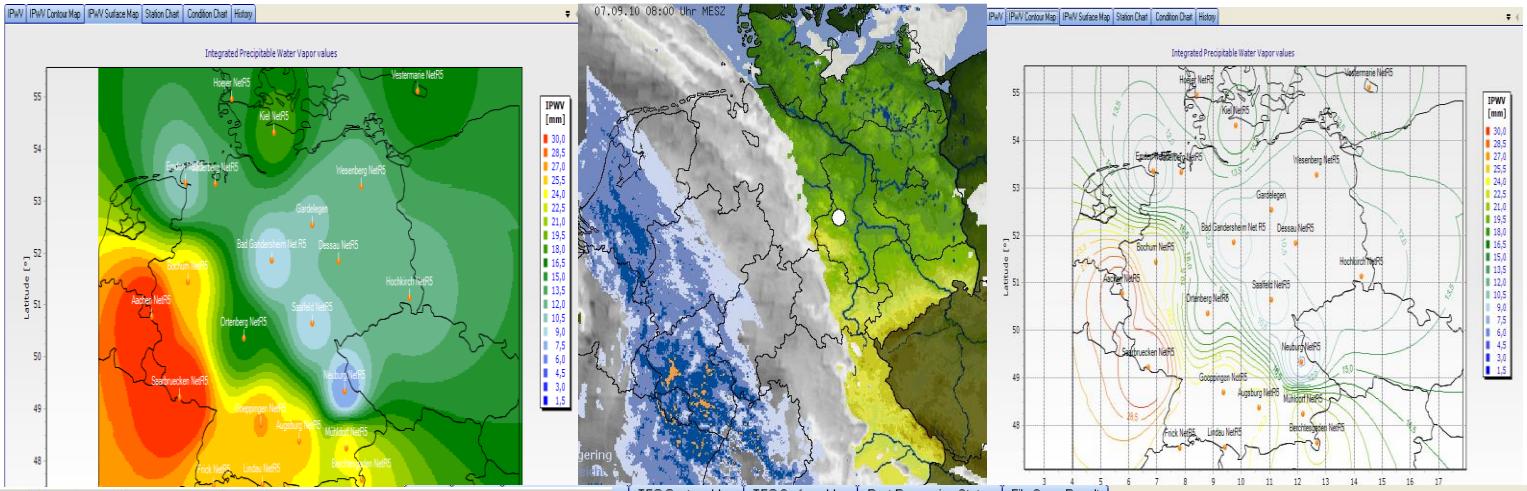

Source - Unavco

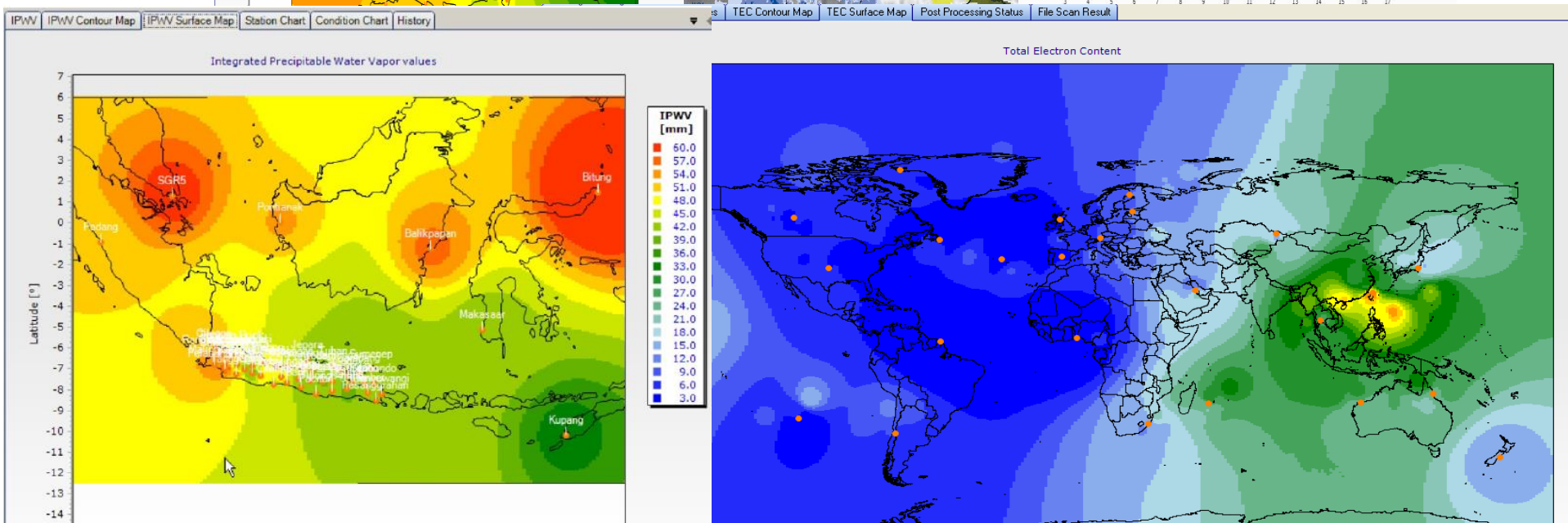
**Example Seismic System Drop-Out and Clipping**




Source - Unavco

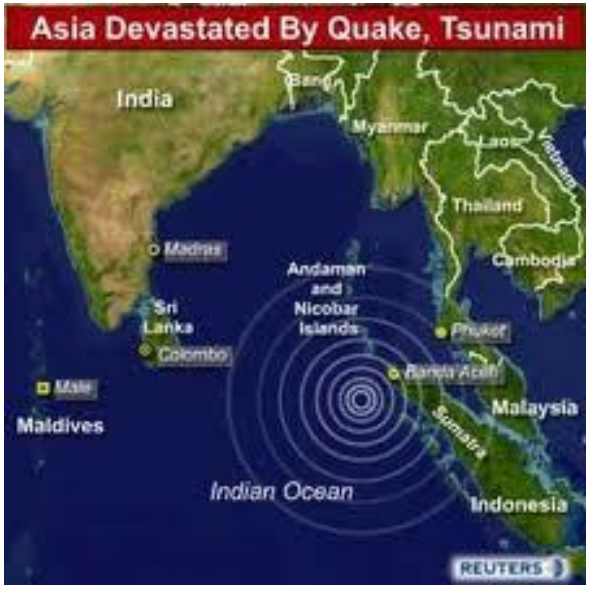
# GNSS - Water Vapor/TEC/Iono

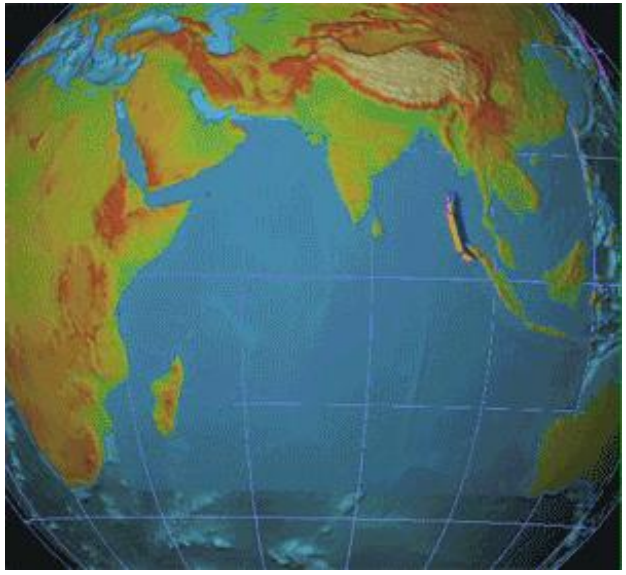


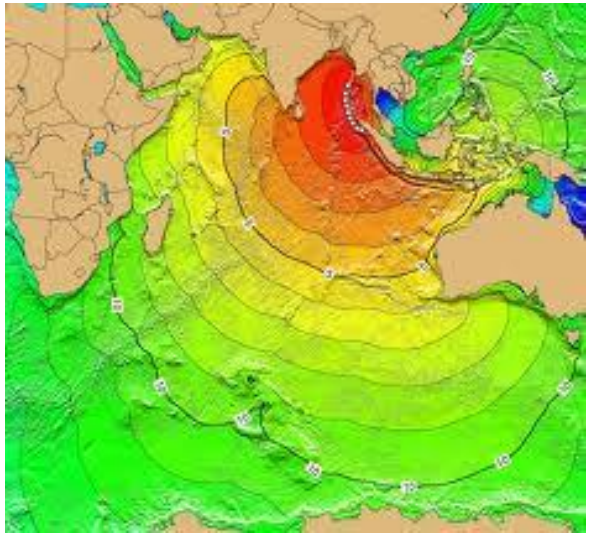



# Trimble's Role in Geodetic Infrastructure

- *What technical advice or applications Trimble can supply to users to manage data in a modern and ever changing geospatial environment, especially with respect numerous geodetic datums / reference systems?*

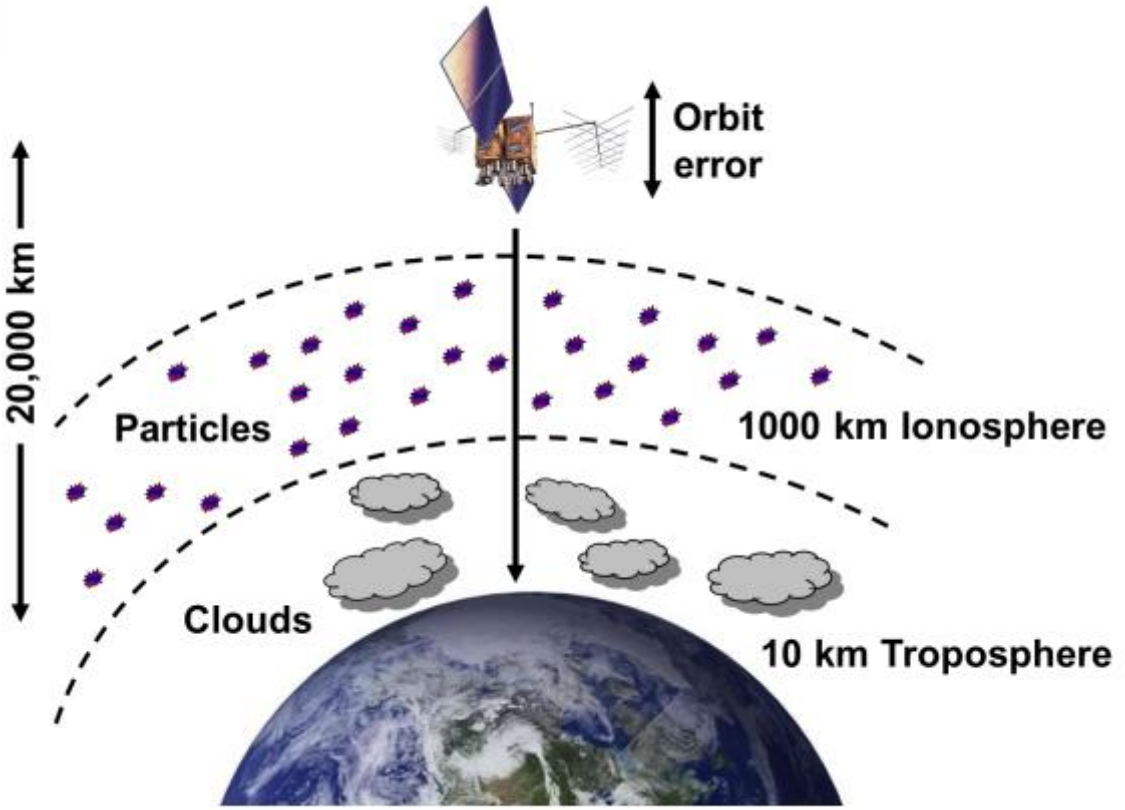




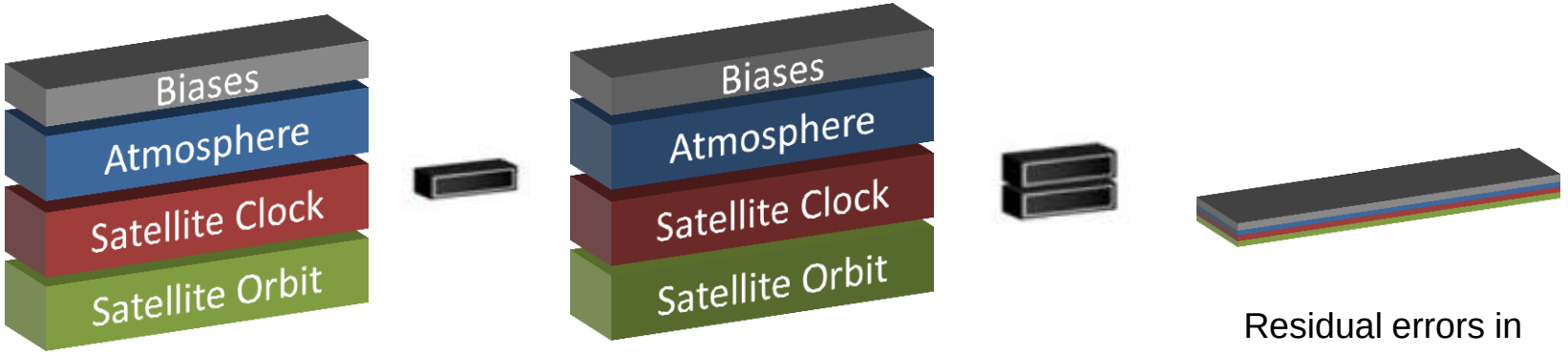
# Trimble RTX Technology

(global)




- **Absolute positioning**
- **ITRF2008**
- **Modeling errors instead of mitigating them by differencing**
  - **Satellite orbit**
  - **Satellite clock**
  - **Atmospheric effects**
- **GPS&GLONASS&QZSS**

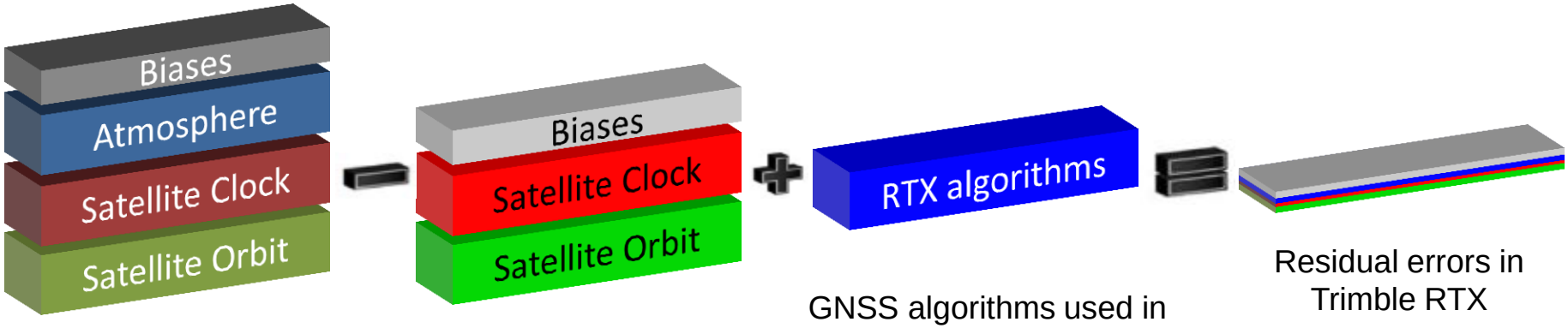
# CenterPoint RTX basics




GNSS errors for the rover

GNSS errors for the reference station / VRS

Residual errors in differential GNSS




GNSS errors for the rover

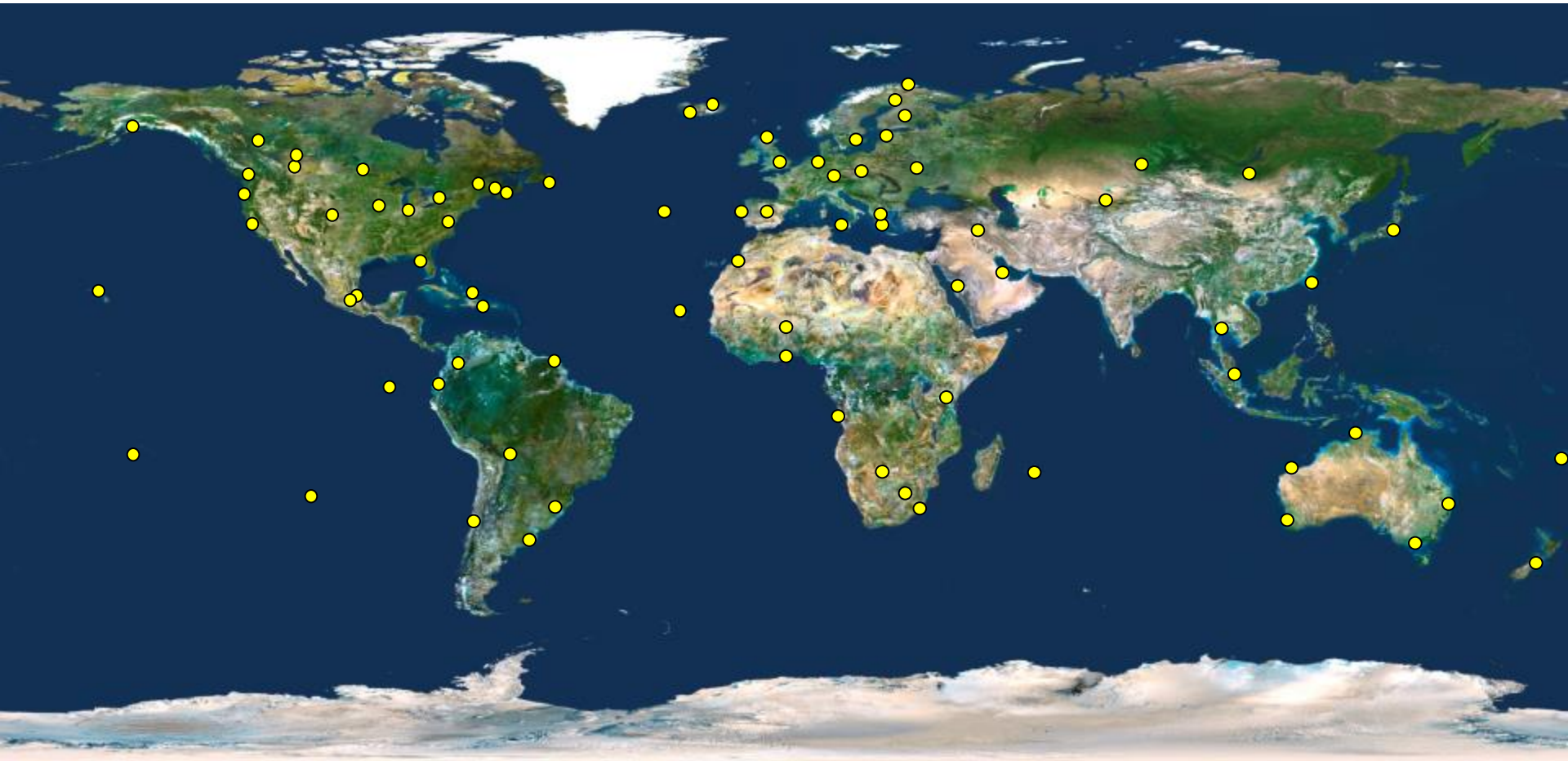
GNSS errors modeled in RTX stream

GNSS algorithms used in RTX

Residual errors in Trimble RTX

# Global Tracking Network

- Tracking network
  - >100 stations in 53 countries
  - Trimble NetR5/NetR9
- Control centers
  - Munich, Germany
  - Ashburn, USA



**Tracking Stations (~100)**

# Trimble CenterPoint RTX™ Service

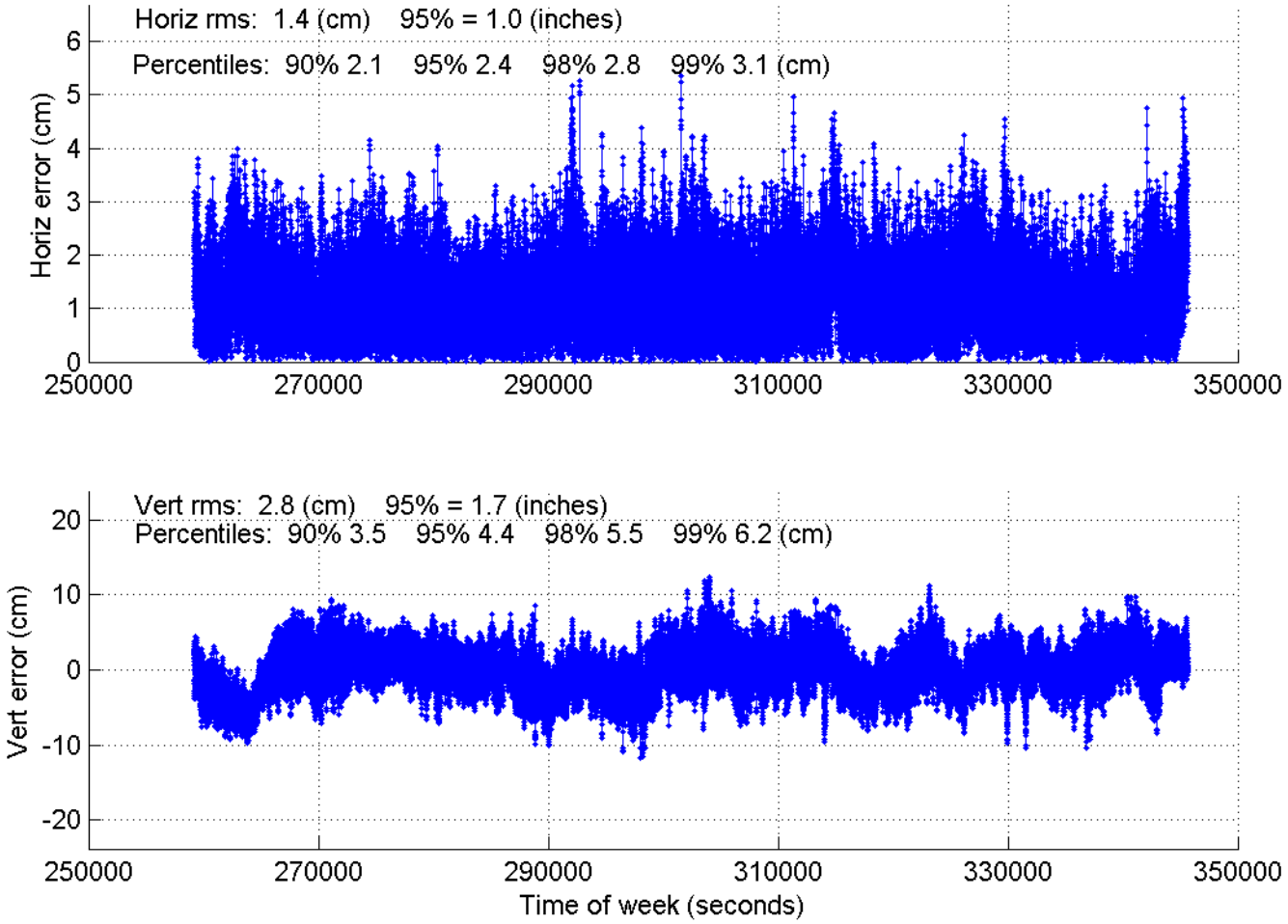
www.trimblertx.com

Satellite & Internet coverage worldwide

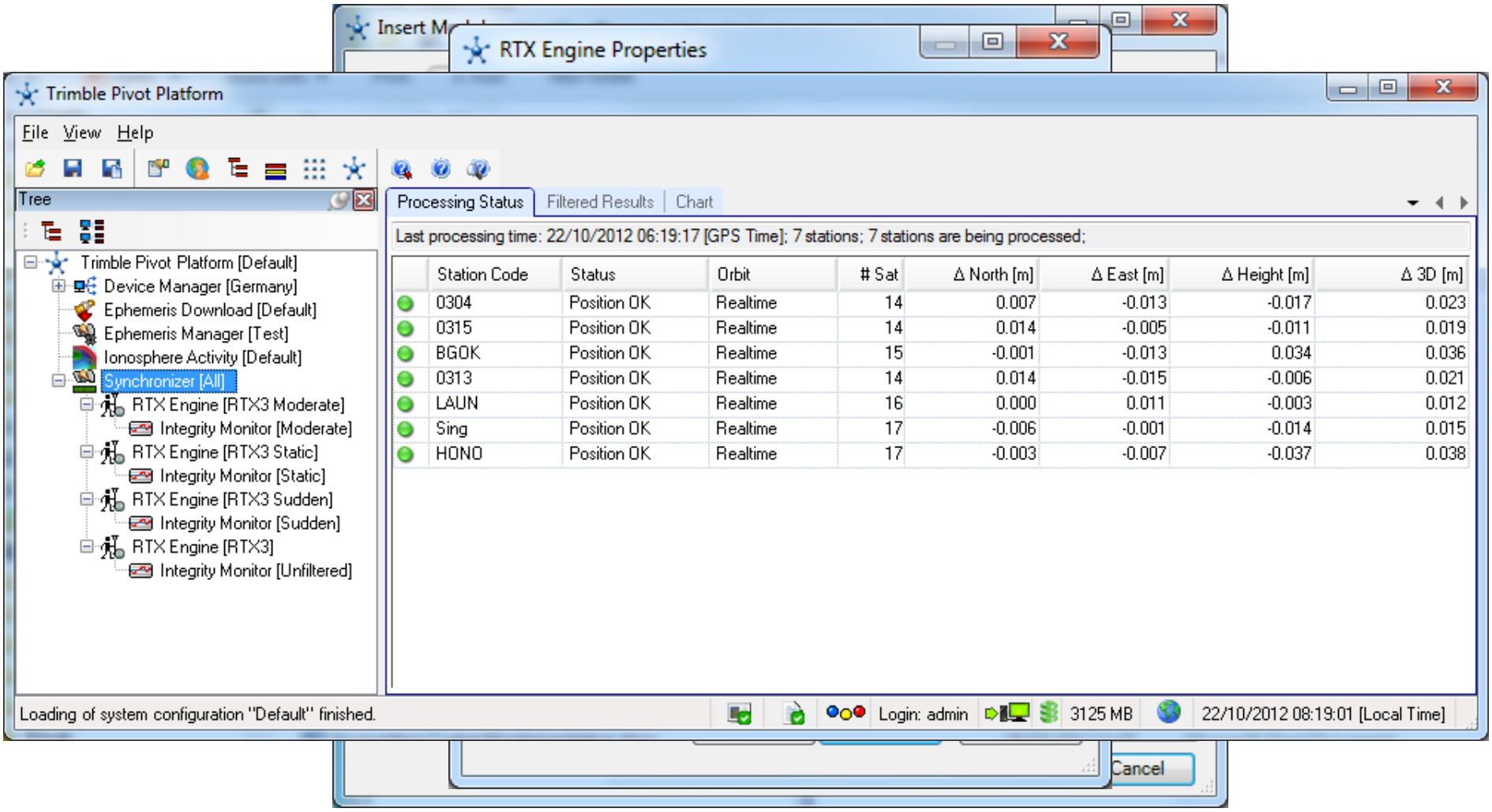

| | |
|---|---|
| JAVAD TRE_G3TH DELTA | 216 channels GPS L1/L2/L2C/L5, GLO L1/L2, GAL E1/E5A |
| JPS LEGACY | GPS/GLONASS dual- or single-frequency receiver, requires external antenna |
| JPS ODYSSEY | GPS/GLONASS dual- or single-frequency receiver, with internal (Legant) flat groundplane antenna |
| JPS REGENCY | GPS/GLONASS dual- or single-frequency receiver, with internal (Regant) chokering antenna |
| LEICA GR10 | 120 channel GPS L1/L2/L5, GLONASS, Galileo, Compass receiver |
| LEICA GRX1200+GNSS | 120 channel GPS L1/L2/L5, GLONASS, Galileo, Compass receiver |
| LEICA GRX1200GGPRO | 14 GPS, 12 GLONASS L1/L2, CORS receiver (RTK out standard) |
| LEICA GRX1200PRO | 12 channel L1/L2 receiver (RTK out standard) |
| RNG FASA+ | L1/L2+L2C/L5 GLONASS L1/L2 GALILEO Maxwell-6 ASIC, eth + SBAS, 440 channel |
| TPS E_GGD | Same as JPS E_GGD: "Legacy E" 160mm Eurocard-based GPS/GLONASS dual frequency receiver |
| TPS GB-1000 | Dual-frequency GPS/GLONASS |
| TPS HIPER_GD | P/N 01-830401-01 Integrated antenna+receiver |
| TPS NETG3 | GPS/GLONASS/Galileo 72 channel receiver |
| TPS NET-G3A | GPS/GLONASS/Galileo 144 channel receiver - Topcon E2G3 GNSS board |

# Trimble RTX Positioning Results

## Real-time Results - 24 hours, 2D RMS: 1.4 cm

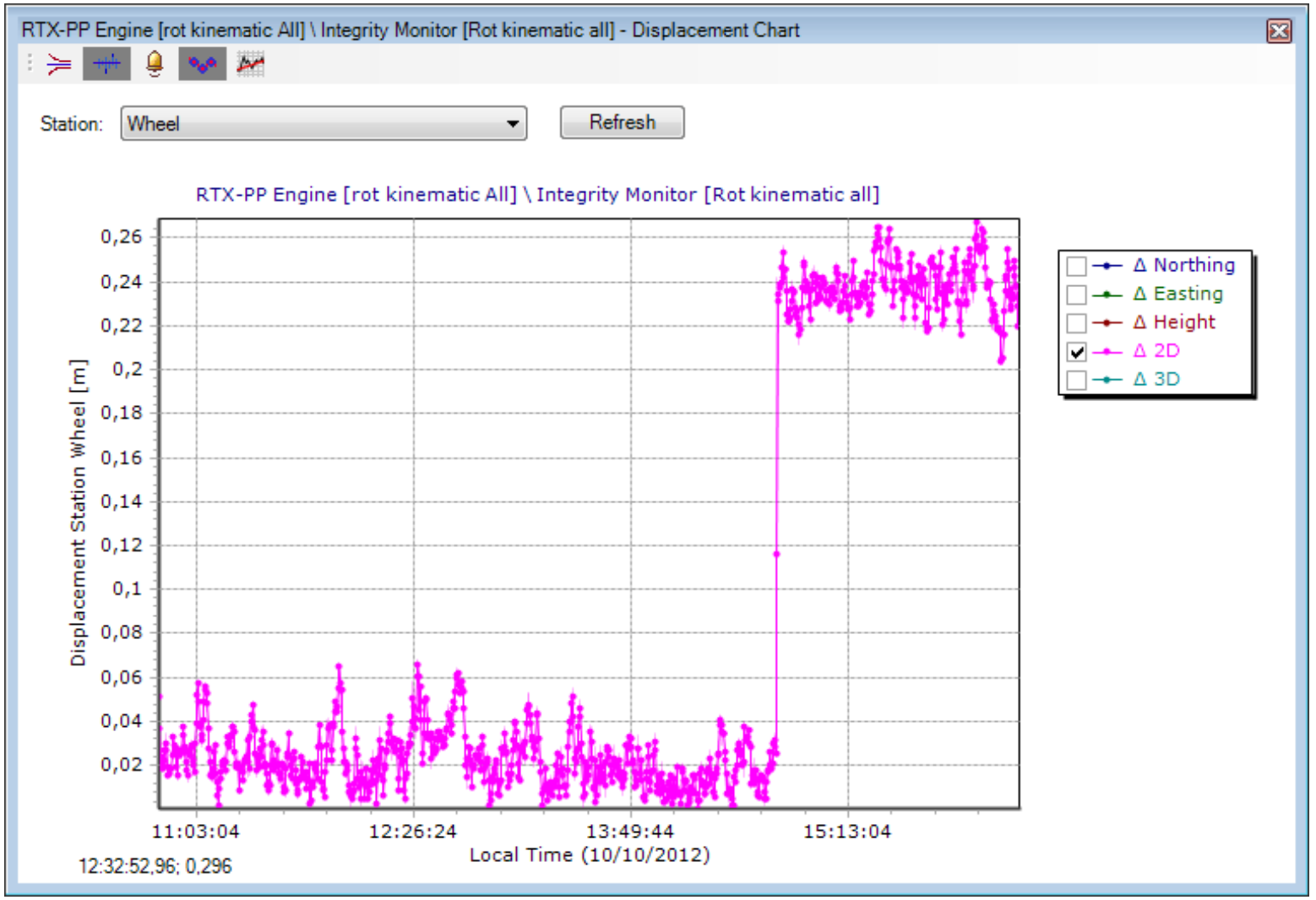


# RTX - Real Time Engine

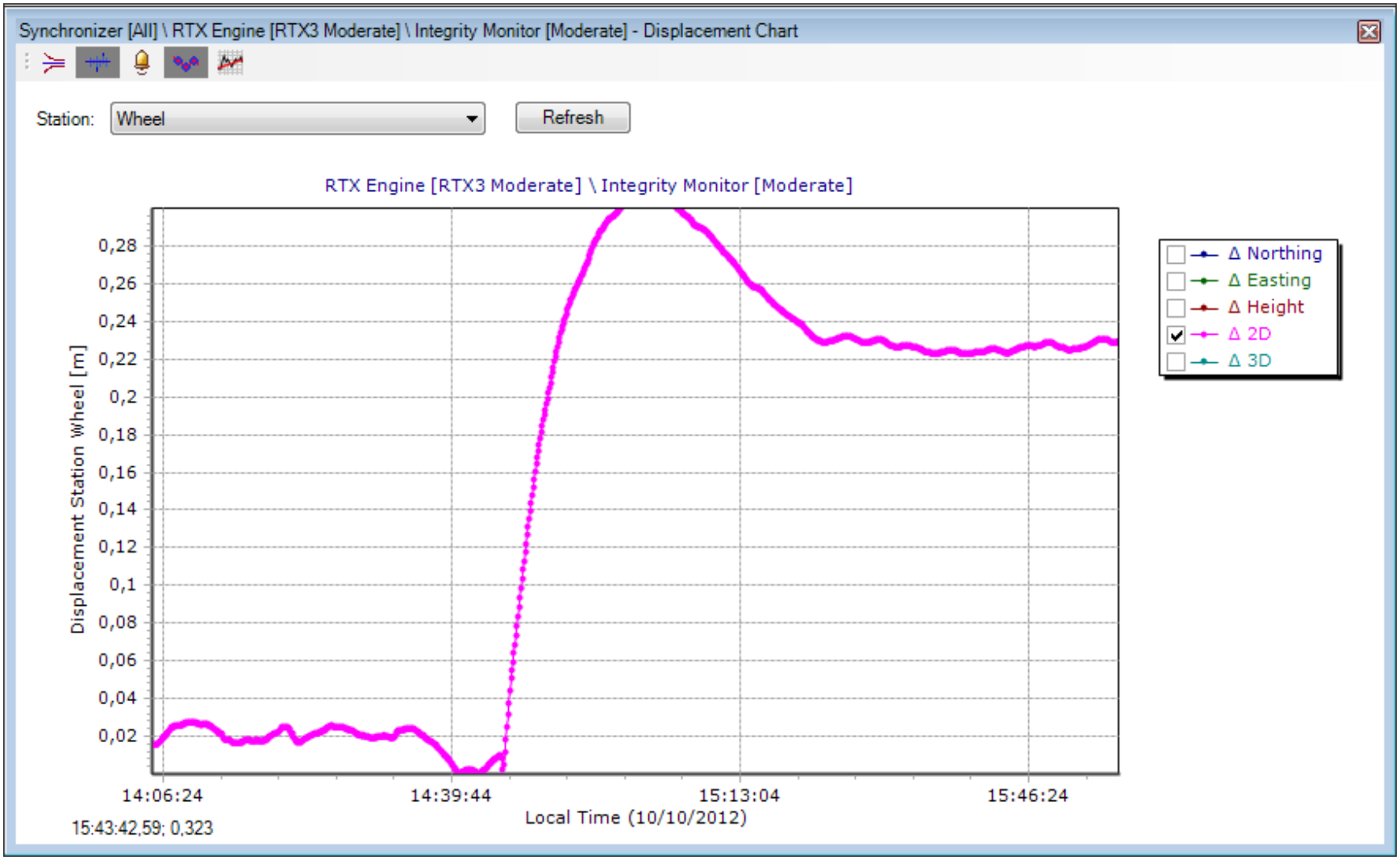


# Motion detection

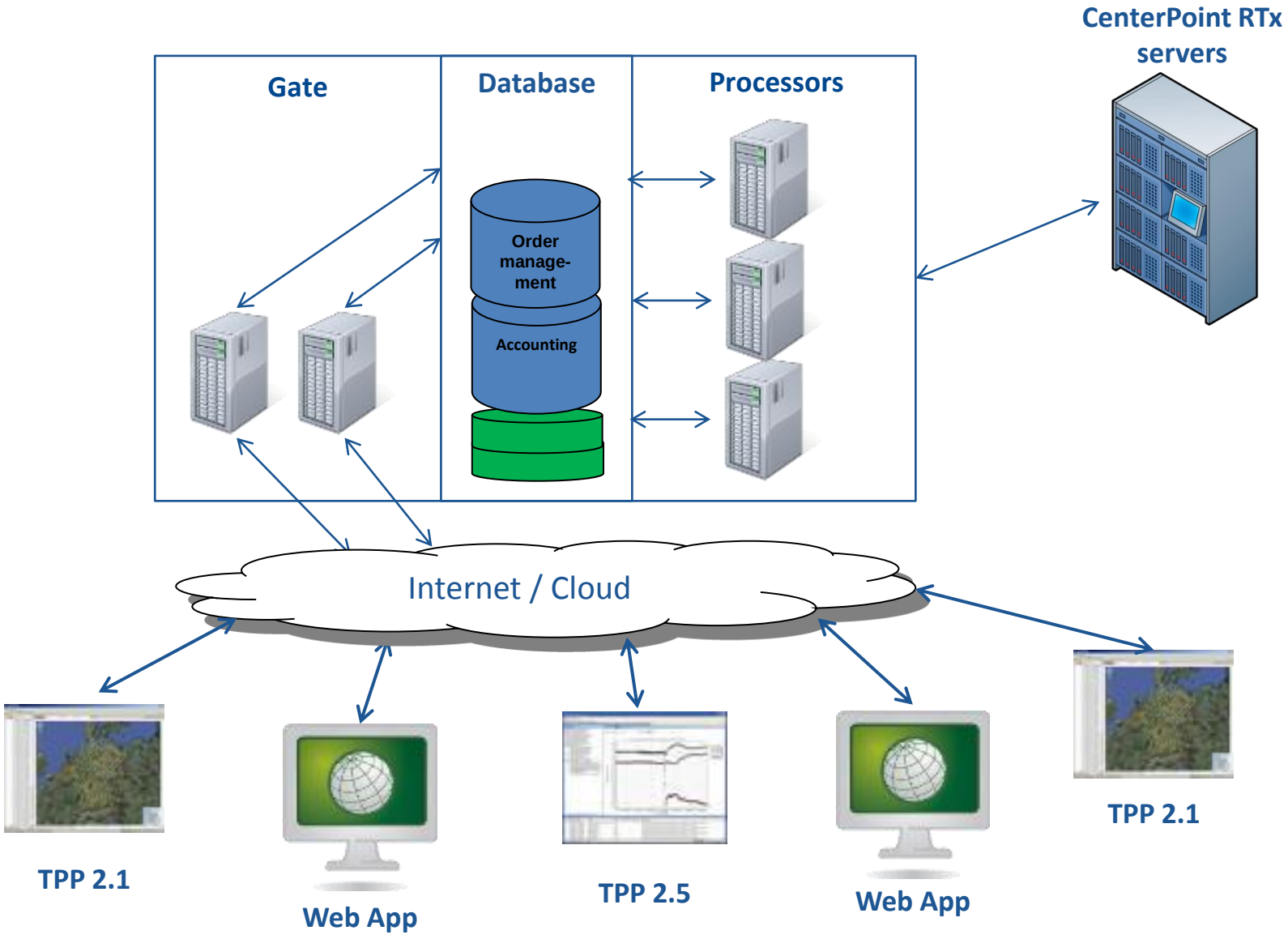
# Motion detection



# Motion detection



# RTX-PP service



# RTX-PP Engine

60 minute expected static accuracy (1 σ)

Horizontal 10 mm Vertical 25 mm

24 hour expected static accuracy (1 σ)

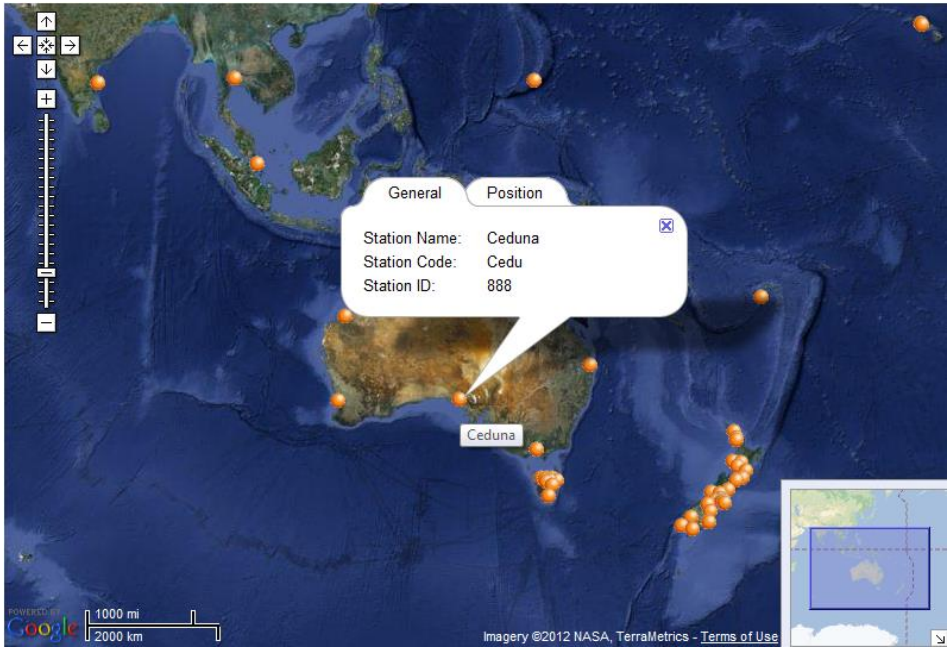
Horizontal 6 mm Vertical 8 mm

# Tectonic Plate Monitoring

Station: Ceduna

Reference: ITRF 2005 (Year 2000)

Observations:
01.01.2012 – 25.10.2012




| Station Data (1) | |
|---|---|
| Station name | Ceduna |
| Station code | CEDU |
| Last modification time [UTC Time] | 10.09.2012 13:27:07 |
| **Position** | |
| Tectonic plate | None |
| X | -3753472.3680 |
| Y | 3912741.0080 |
| Z | -3347960.7180 |
| Velocity X [m/year] | -0.041700 |
| Velocity Y [m/year] | 0.000700 |
| Velocity Z [m/year] | 0.051100 |
| Reference time | 01.01.2000 00:00 |
| **Observer** | |
| Agency | Geoscience Australia |
| Observer | Jens Boehme |
| **Antenna Information** | |
| Antenna calibration | Type calibrated |
| Manufacturer | ROGUE |
| Name | AOAD/M_T NONE |
| Serial number | 194_AUST |
| Antenna height [m] | 0.006 |
| **Receiver Information** | |
| Manufacturer | TRIMBLE |
| Name | TRIMBLE NETR8 |

# Tectonic Plate Monitoring

## Known position / velocity

### IGS

**Position (m)**

x: -3753472.3680
y: 3912741.0080
z: -3347960.7180

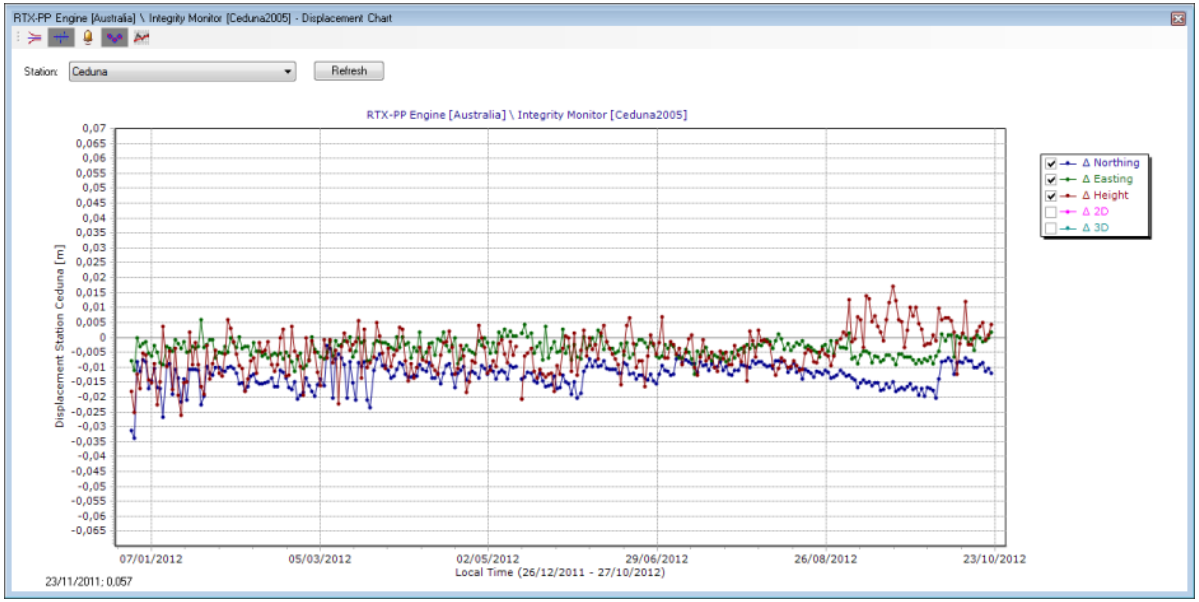
**Velocity (m/year)**

x: -0.0417
y: 0.0007
z: 0.0511

### Pivot RTX-PP

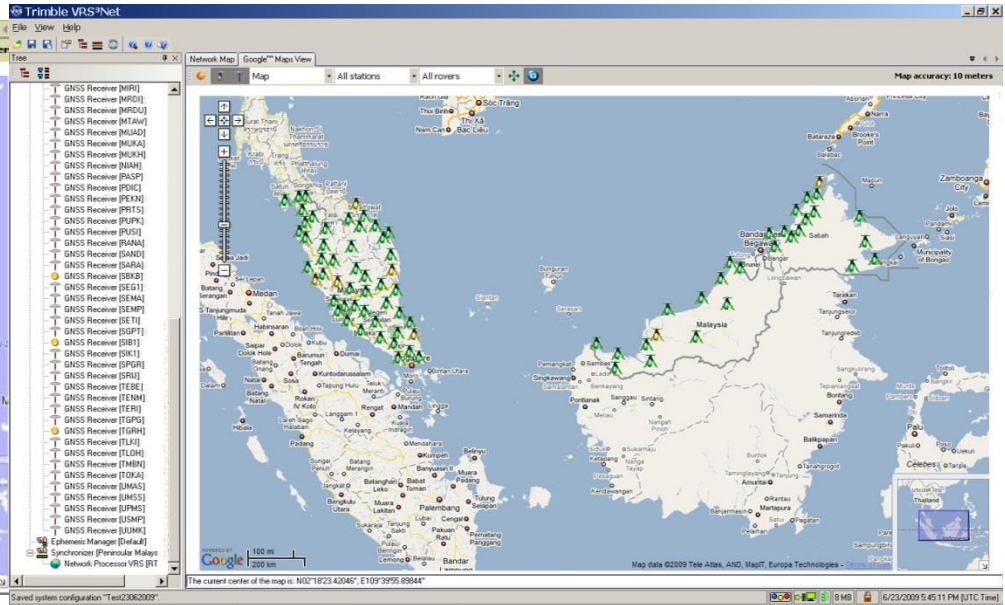
**Position (m)**

x: -3753472.3578
y: 3912741.0027
z: -3347960.7261

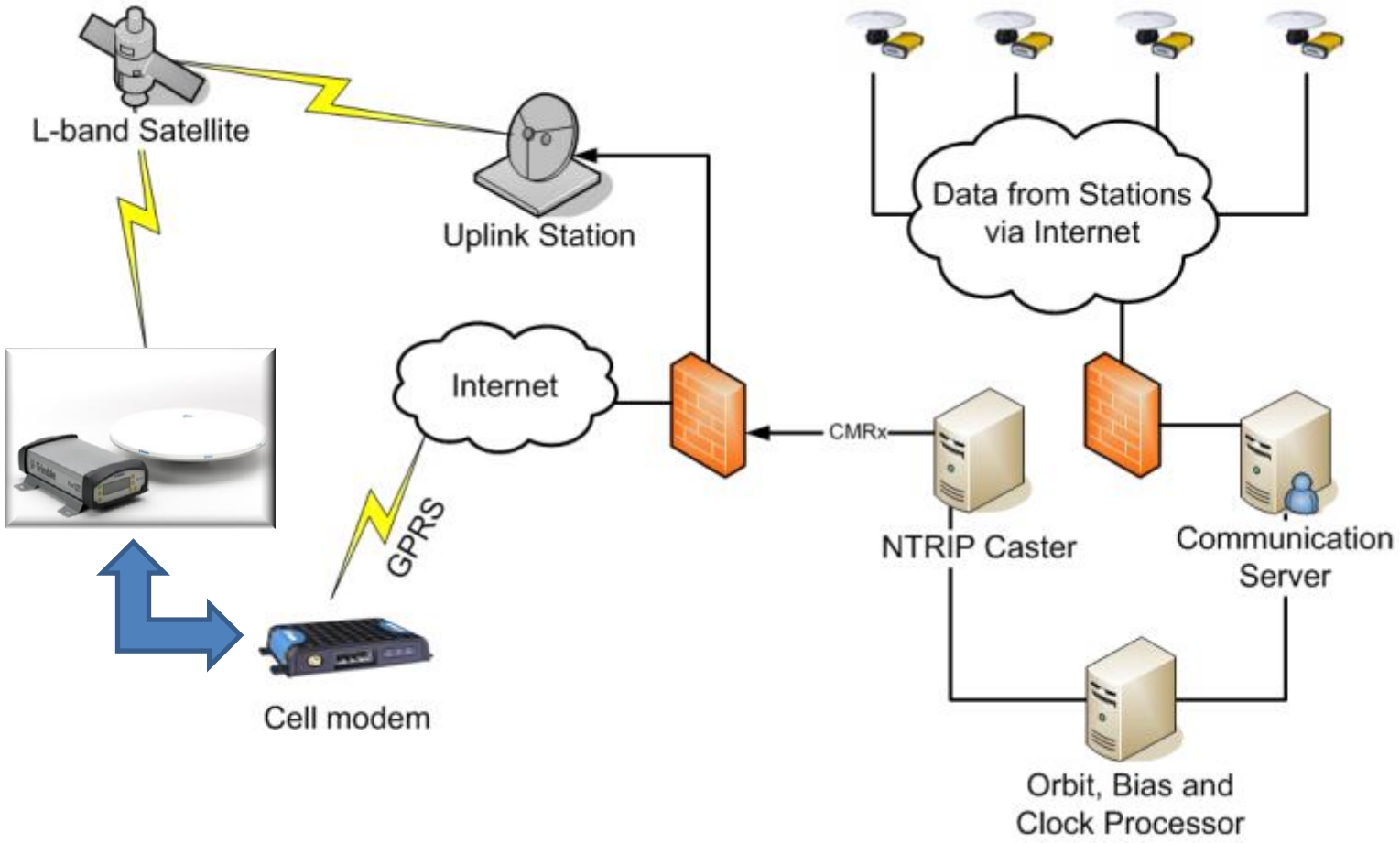


# RTX Clients in Trimble Pivot

- IP driven and post processing service
- Independent from a reference station
- Static and kinematic
- **Absolute coordinate** for monitoring of your network

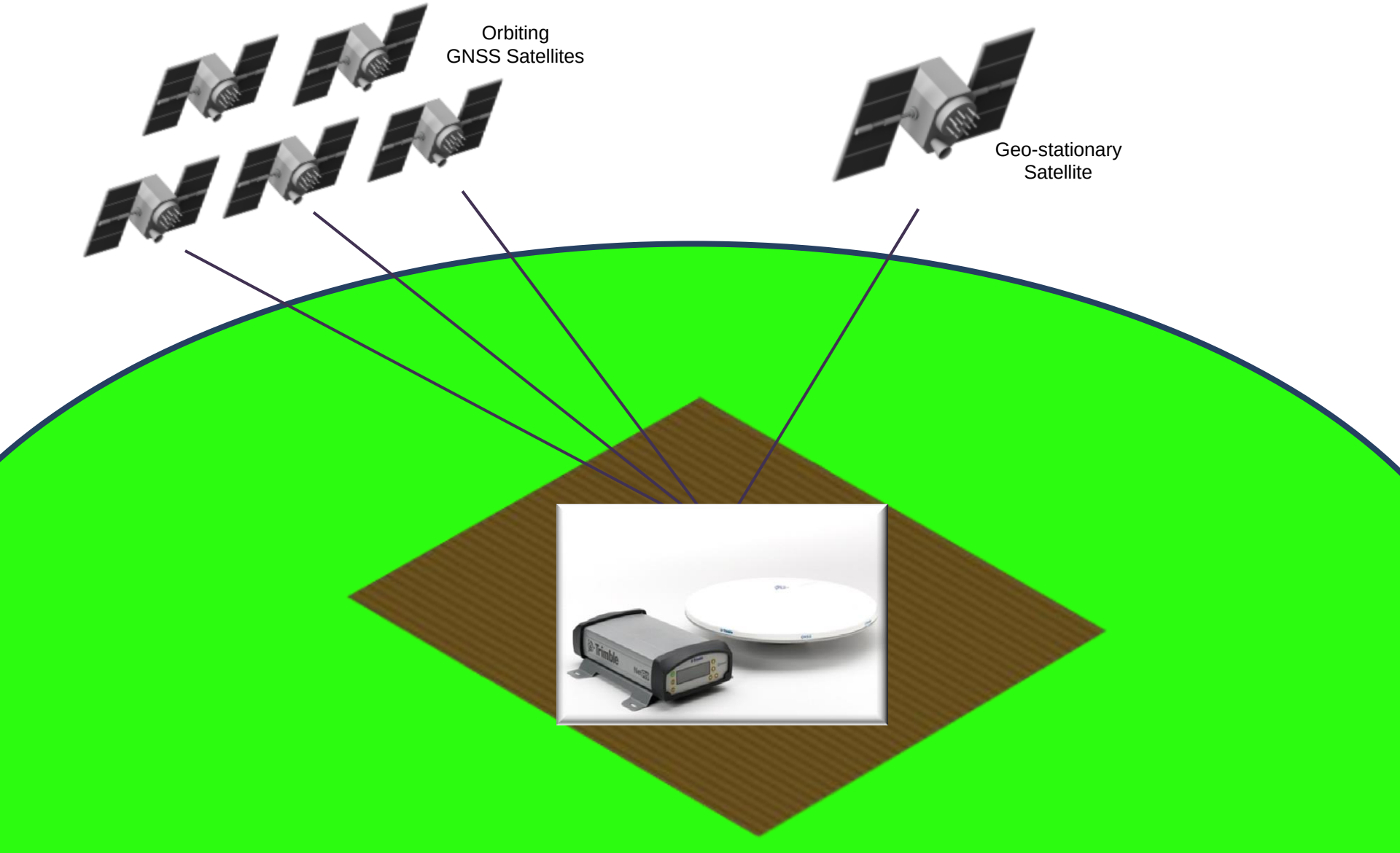



# RTX Rover


L-band Satellite
Uplink Station
Data from Stations via Internet
Internet
CMRx
GPRS
NTRIP Caster
Communication Server
Cell modem
Orbit, Bias and Clock Processor

# Trimble CenterPoint RTX™

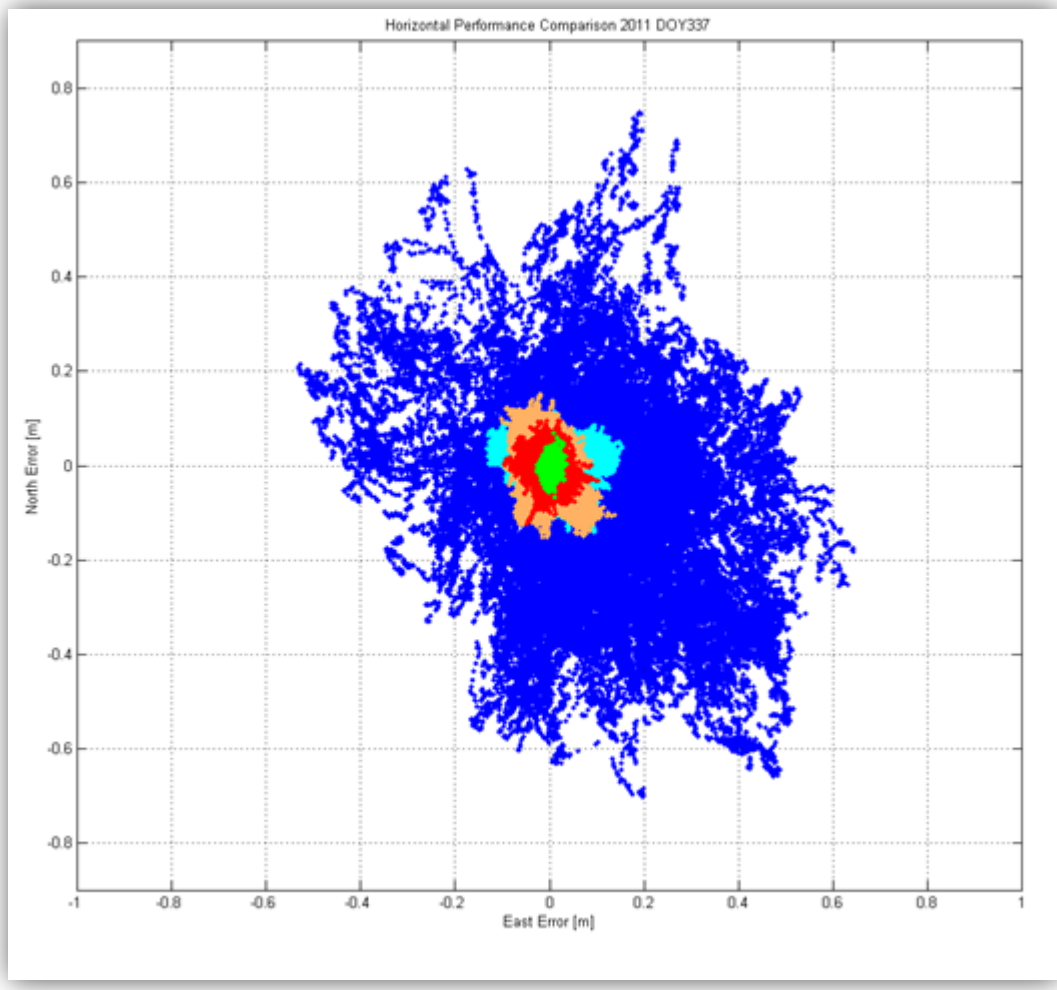
## (via Satellite)



# Data transmission

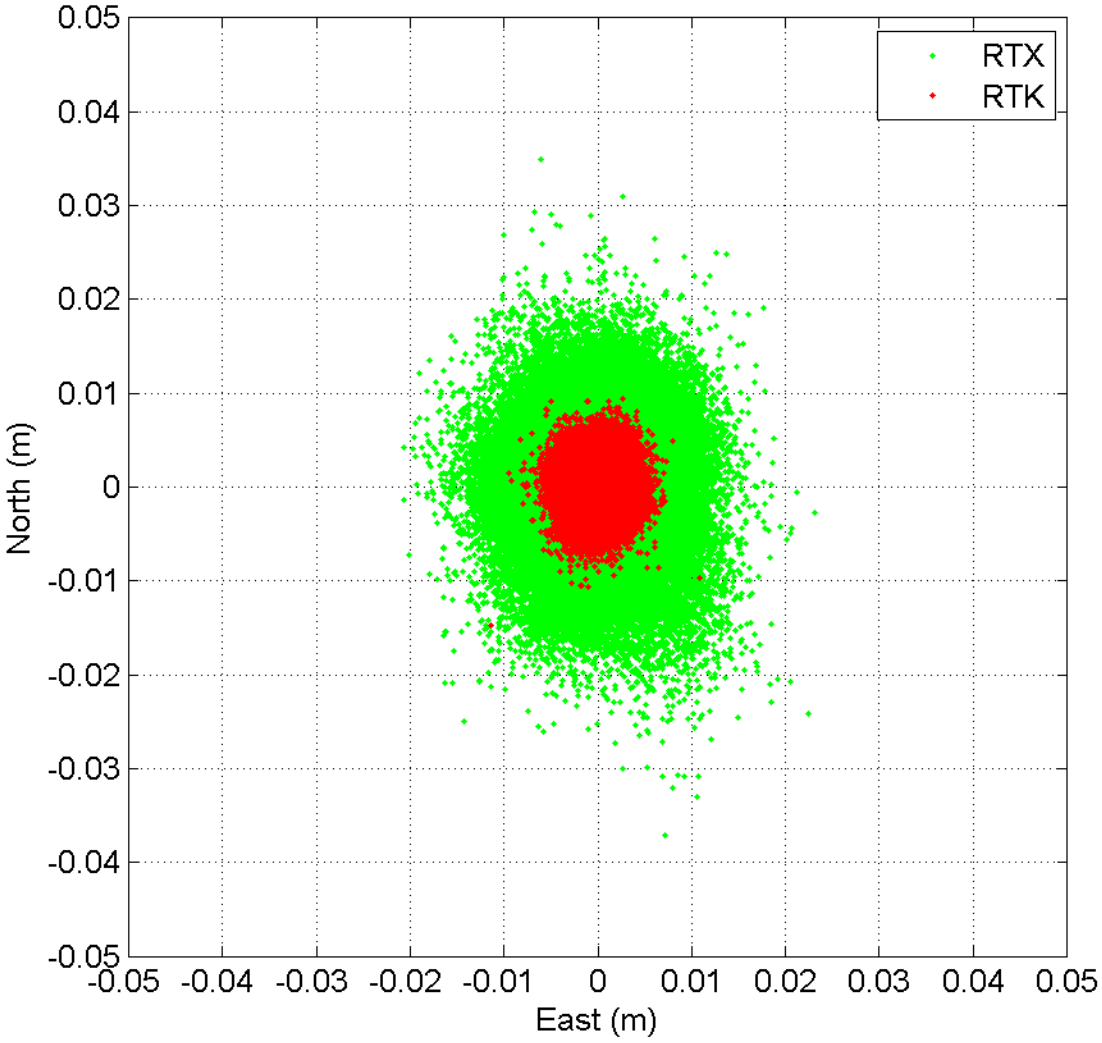
- Real-time global stream (orbits, clocks, etc.)
- GPS, QZSS, and GLONASS
- NTRIP/IP and L-Band delivery
- New messages based on Trimble CMRx technology
  - IODE-free
  - Negligible message inter-dependency
- Bandwidth/Resolution/Update rate
  - 600 bps to cover the Americas
  - 1200 bps for global coverage
  - 1 mm resolution for orbits and clocks
  - 2-4 sec update rate

# Static Accuracy (clear sky)



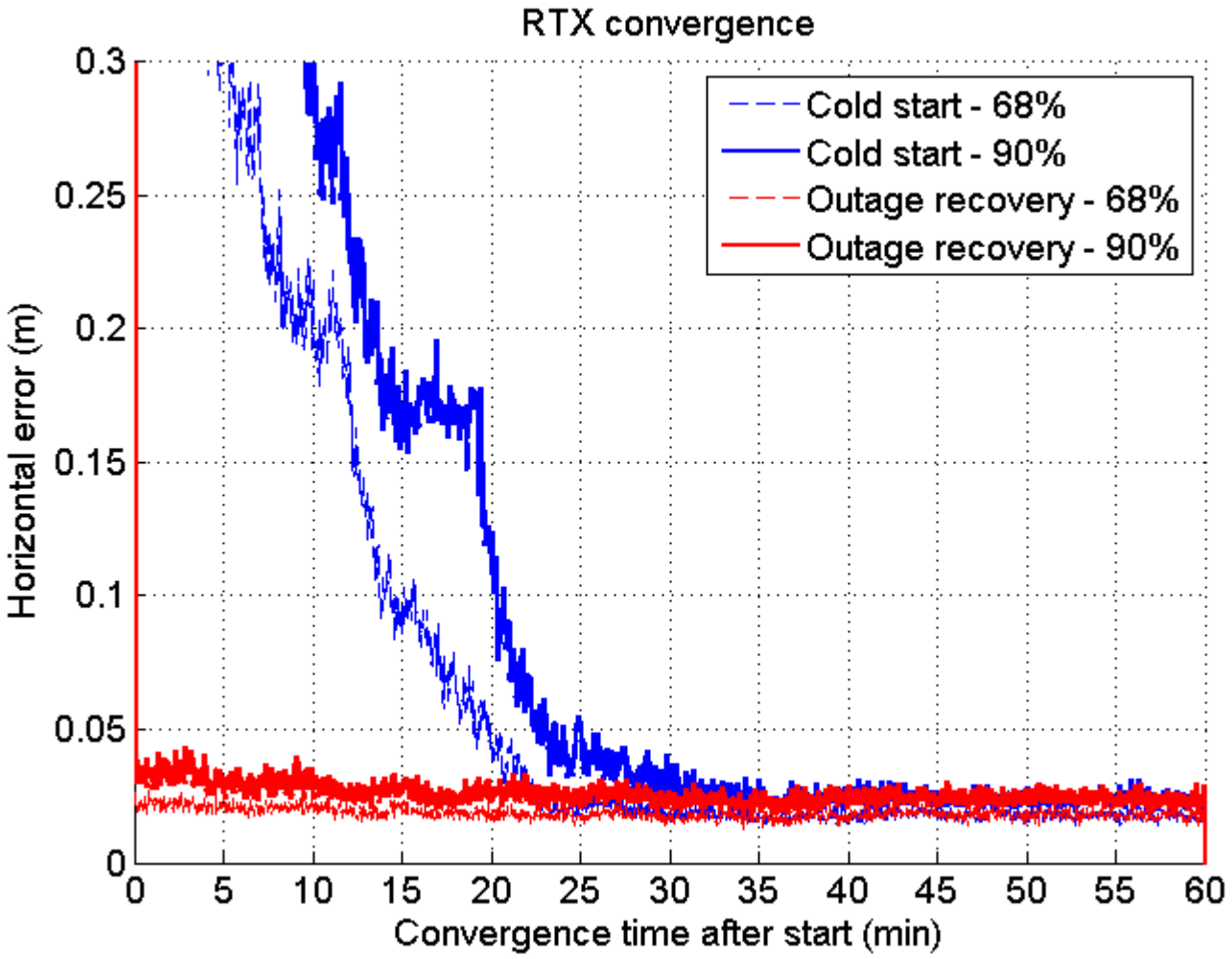

- VBS
- G2
- XP
- HP
- RTX

# RTX vs Short baseline RTK



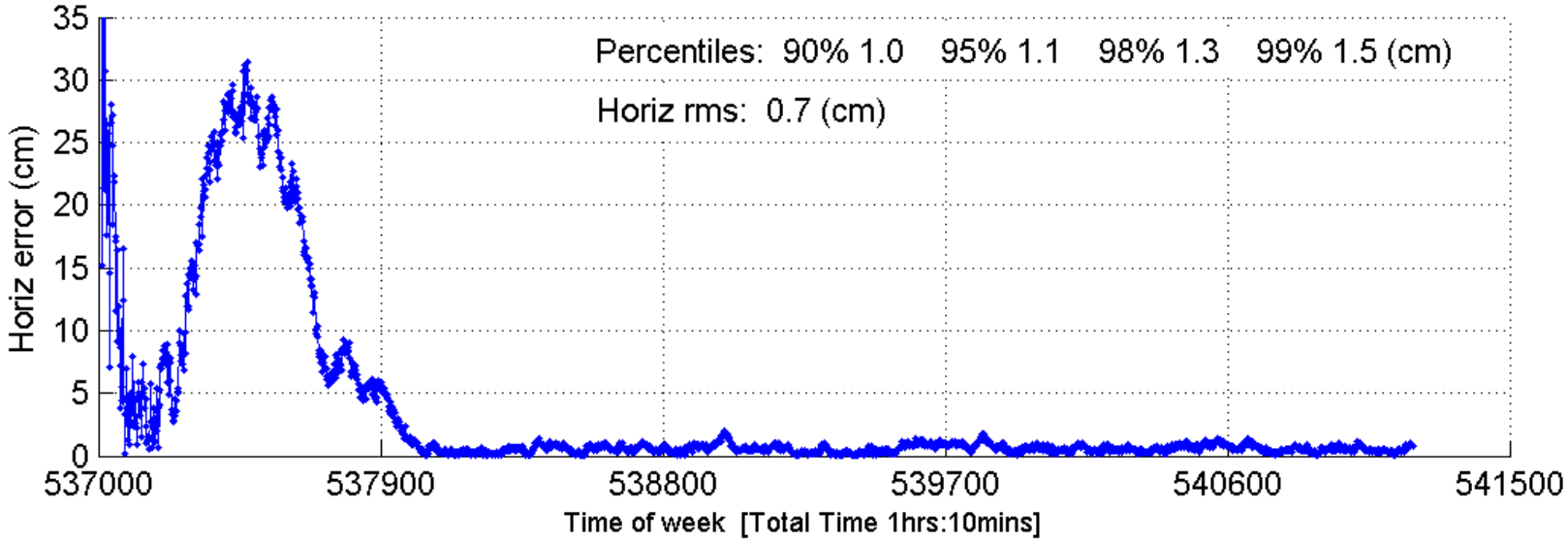
# Convergence Runs

Cold Start and outage recovery, 3-min interruptions every hour

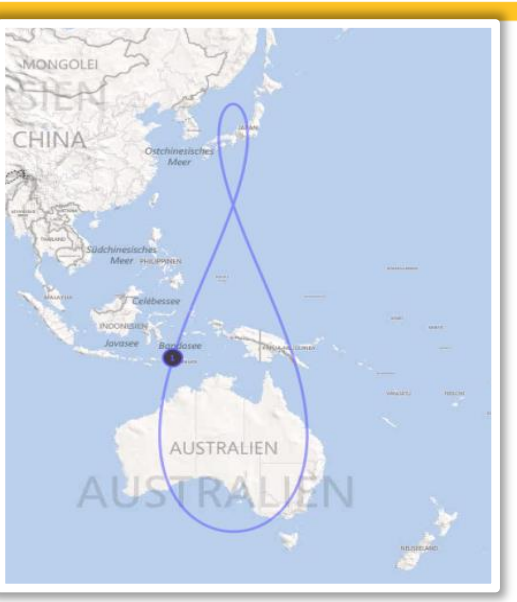


# Position Convergence

## Horizontal Error over 1h 10m

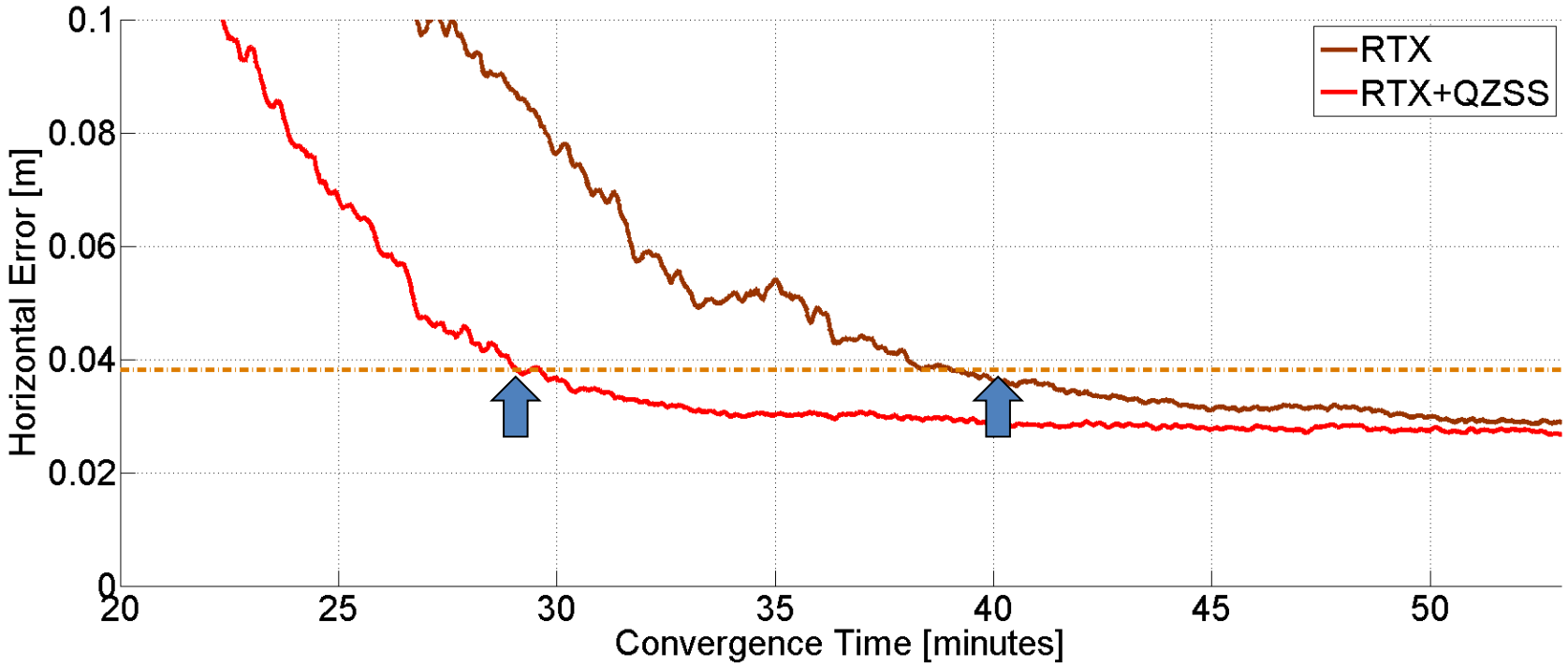



- **Converged to better than 5 cm over 15 minutes**
- **2D RMS after convergence: 7 mm**




# Benefits from QZSS

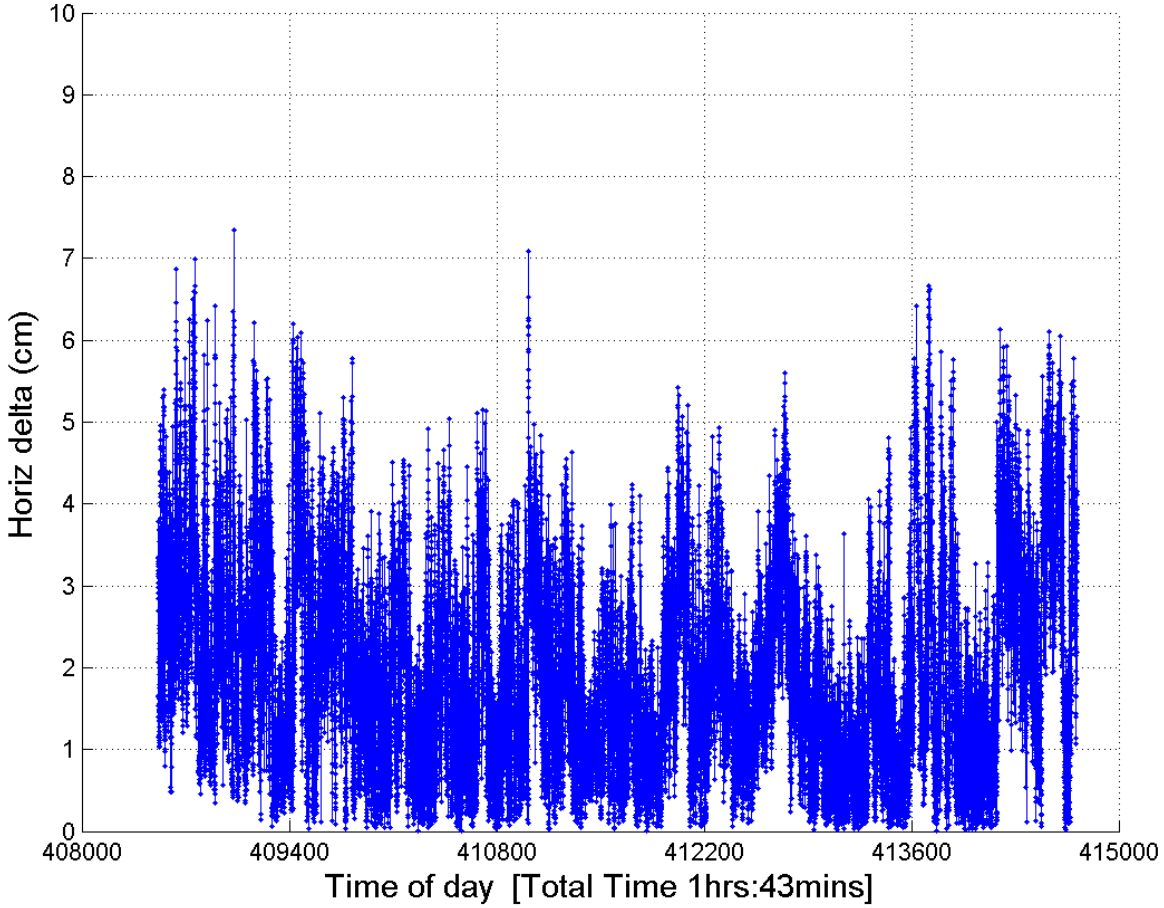
## Convergence Time (95%) out of 1623 Runs



# Dynamic Test

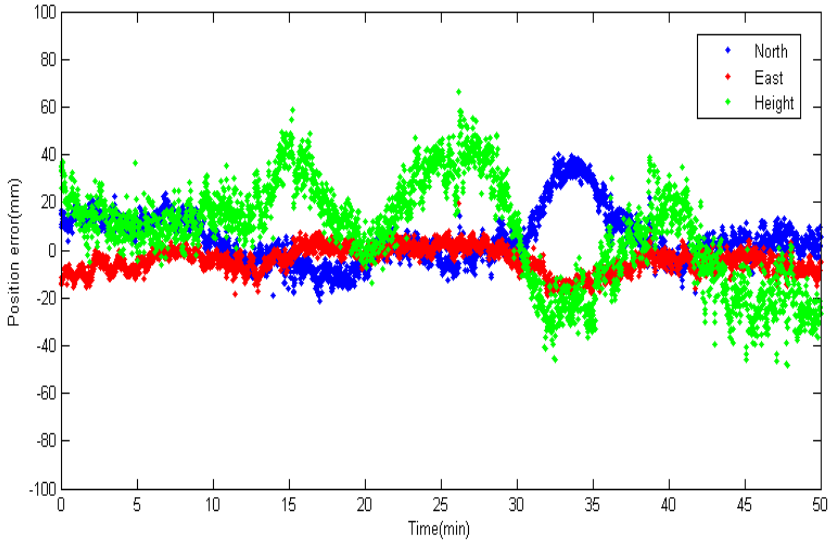

- Illinois, US
- 103 minutes

# Dynamic Test Results



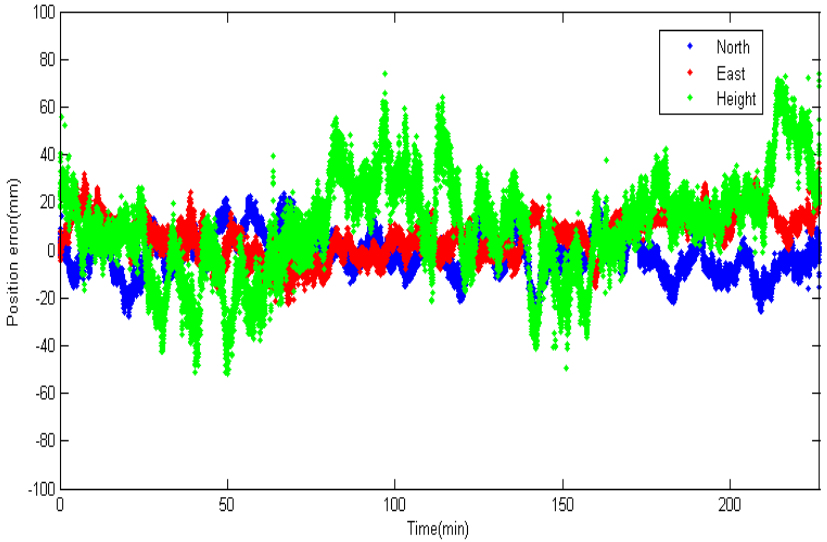

- Comparing with short range RTK
- 2D RMS = 2.3 cm
- 95% = 4.2 cm

# RTX vs RTK (land application)


| | North | East | Up |
|---|---|---|---|
| Mean (mm) | 4.7 | -4.2 | 7.8 |
| σ (mm) | 10.9 | 5.3 | 21.0 |
| RMS (mm) | 11.9 | 6.7 | 22.4 |

# RTX vs RTK (airborne application)

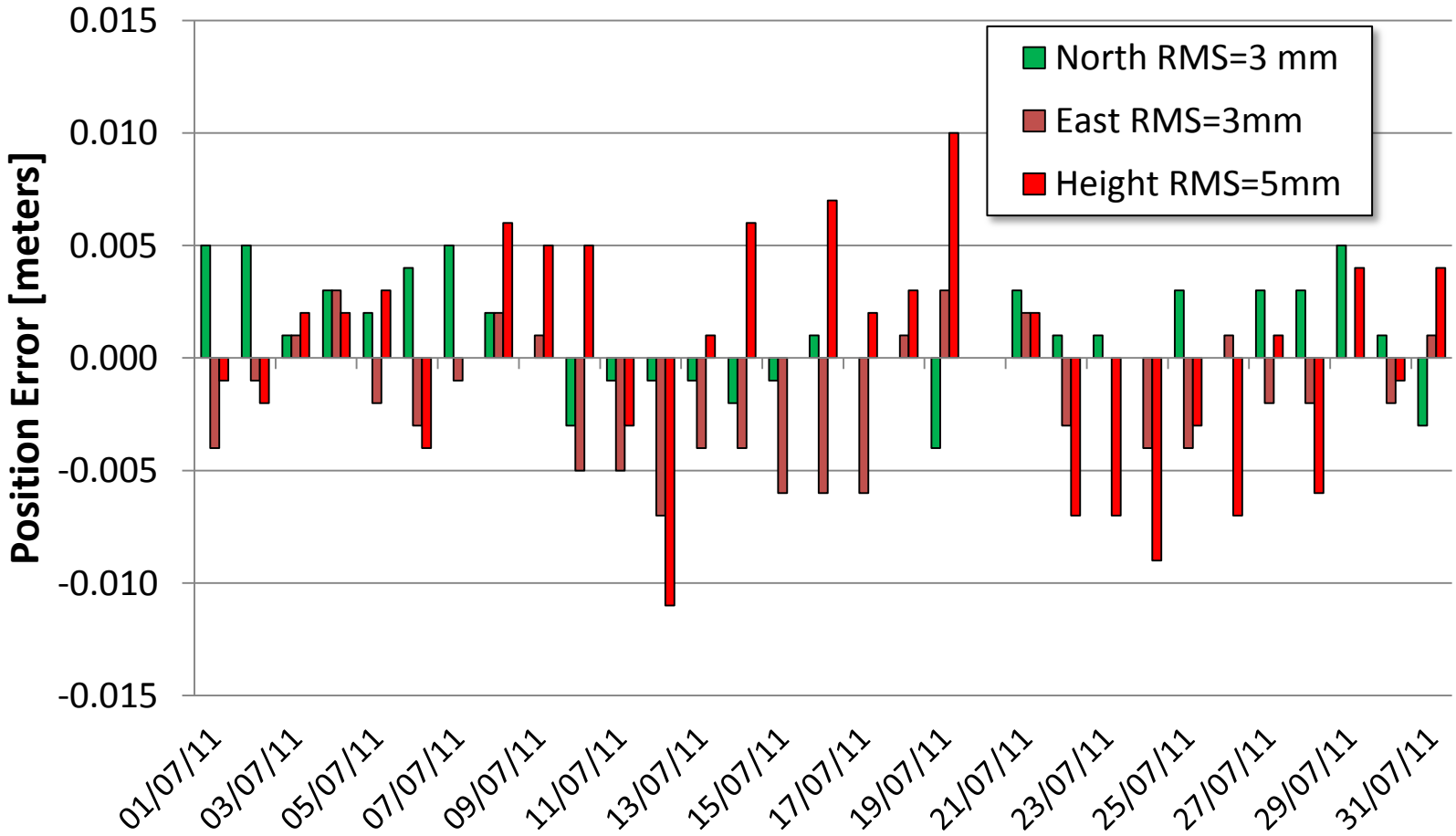




| | North | East | Up |
|---|---|---|---|
| Mean (mm) | -1.5 | 5.7 | 10.1 |
| σ (mm) | 8.5 | 8.6 | 21.2 |
| RMS (mm) | 8.6 | 10.3 | 23.5 |

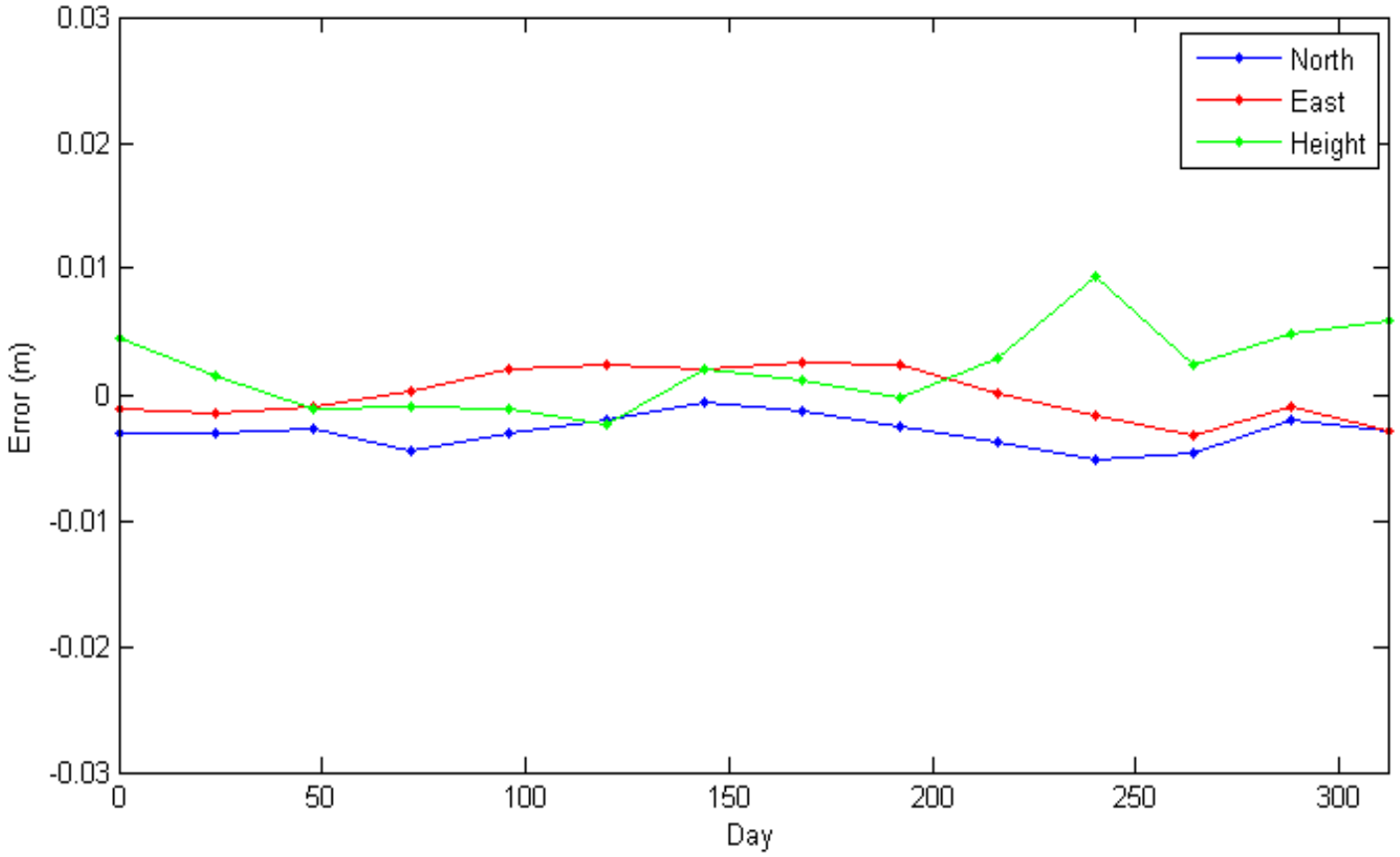
# Post-Processing RTX

Daily results from 31 days in July 2011

www.trimblertx.com



# Static accuracy tests




**24 Hours**

# GNSS Performance Summary

| Method | Horizontal [95%, cm] | Vertical [95%, cm] | Convergence [95%] |
|---|---|---|---|
| RTK < 30 km | 0.8 + 1ppm | 1.5 + 1 ppm | < 10 sec |
| VRS < 70 km | 0.8 + 0.5 ppm | 1.5 + 0.5 ppm | < 10 sec |
| Trimble RTX RT | 4 | 7 | < 30 min |
| Trimble RTX PP | 1 | 2 | 24 hours |

# Summary

- Future Proof NetR9 CORS receiver
- Modern & Proven Trimble PIVOT App
- Turnkey Solution
- RTX – positioning anywhere, anytime.