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# *JAXA's PPP experiment via QZSS*


***March 13, 2012***

***Japan Aerospace Exploration Agency***

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***PPP-RTK Symposium 2012@Frankfurt***

# Outline



- JAXA's PPP experiment via QZSS
  - Introduction of Multi-GNSS demonstration Campaign
  - The outline of JAXA's PPP experiment via QZSS
  - MGM-net status
  - "MADOCA" development status
  - Kinematic PPP Accuracy
- Summary

# Introduction of Multi-GNSS demonstration Campaign

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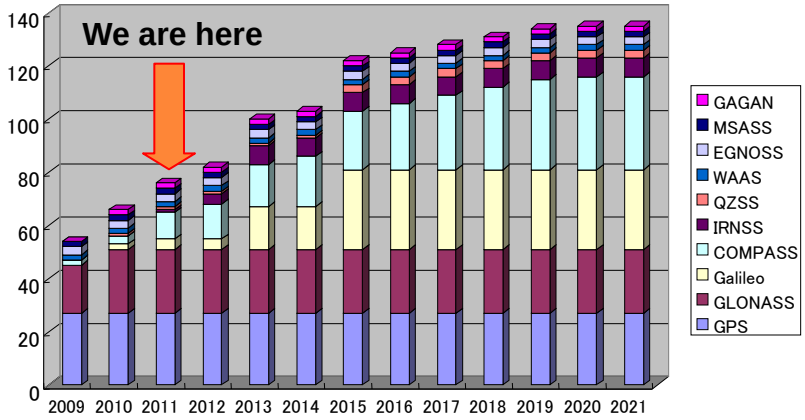
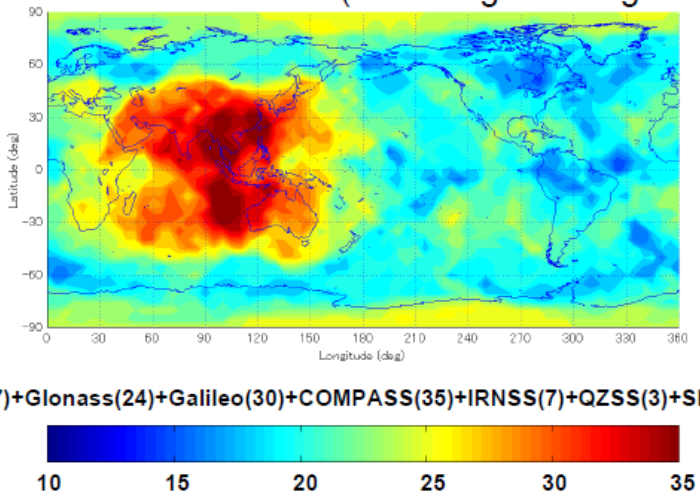
・Background




**Total Number of GNSS Satellites**

Asia Oceania Region is Showcase of New GNSS Era

Visible satellite number (mask angle 30 degrees)




**2020:**

GPS(27)+Glonass(24)+Galileo(30)+COMPASS(35)+IRNSS(7)+QZSS(3)+SBAS(7)




- People in Asia Oceania Region can use multi-GNSS(GPS、Glonass、Galileo、Compass、QZSS、IRNSS）signals earlier than other region in the world.

Offer of various experiment opportunity

**Multi-GNSS Demonstration Campaign**

- Multi-GNSS Asia(MGA) is an organization to promote this campaign.
- This Campaign is a series of activities over a period of five years from 2010.

# Introduction of Multi-GNSS demonstration Campaign

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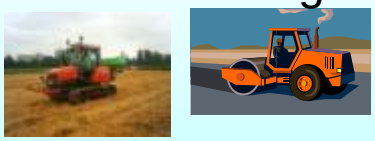
Three main activities of Asia Oceania Multi-GNSS Demonstration Campaign

## Multi-GNSS Monitoring Network

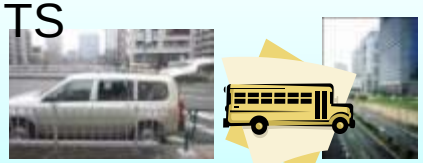
## Application Demonstration

### Disaster Mitigation

### Precise Positioning



### ITS



### LBS

### Others, ionospheric observation etc

## Regional Workshop

3rd Workshop, Nov. 2011 @ Jeju, Korea:

2nd Workshop, Nov. 2010 @ Melbourne, Australia

1st Workshop on GNSS, JAN. 2010, @ Bangkok, Thailand

4th Workshop on GNSS, DEC. 2012, @ Malaysia(TBD)

# The outline of JAXA's PPP experiment via QZSS (PPP experiment using JAXA-LEX signal)

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GPS GLONASS Galileo QZSS : "MICHIBIKI"




navigation signal

Including precise orbit and clock of Multi-GNSS

LEX signal

LEX message

Current target accuracy is less than 10cm.

PPP users

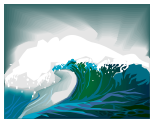
Internet

NTRIP Caster (External server)

(MGM-net etc.) RTCM

Tracking &Control Station (Okinawa)

Multi-GNSS Application Demonstration

LEX message

Data interface

orbit & clock estimation

LEX message generation

RTCM SSR extension

LEX message

MADOCA

LEX message

Master Control Station(MCS)

Tsukuba space center

Various demonstration experiments example :

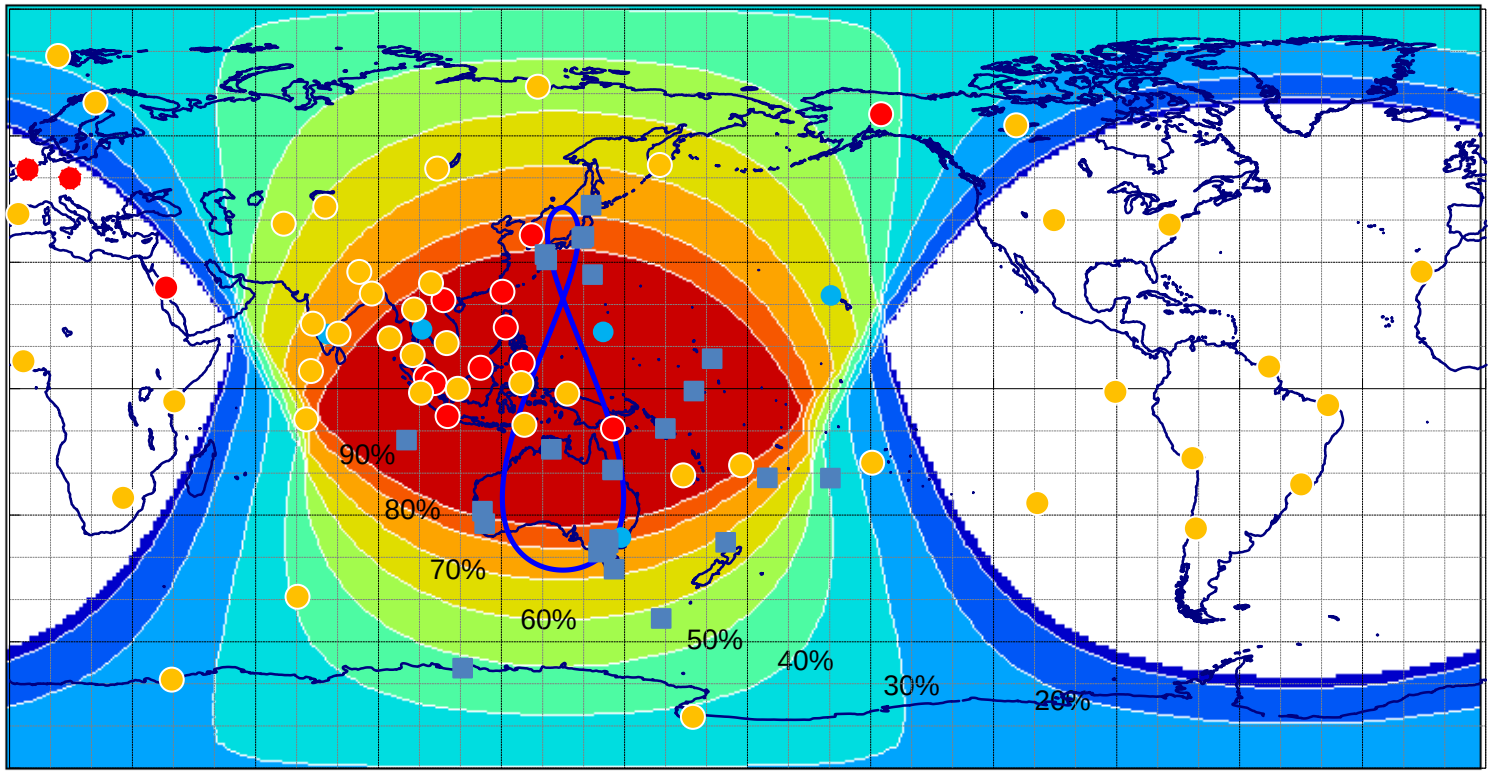
- ditection and warning of Tsunami
- precise agriculture
- estimation of precipitable water
- ・・・

MADOCA: Muliti-gnss Advanced Demonstration tool for Orbit-and-Clock Analysis

# MGM-net Status



- MGM-Net is to be deployed globally aiming to:
  - Improve multi-GNSS including QZSS orbit and clock determination performance
  - Develop and demonstrate Multi-GNSSPPP applications
- 60 sites hosting JAXA's Rx + collaborative networks




Candidate Sites for MGM-net

Selected site  QZSS MS  Candidate site  Site operated by partner organization

# MGM-net Status

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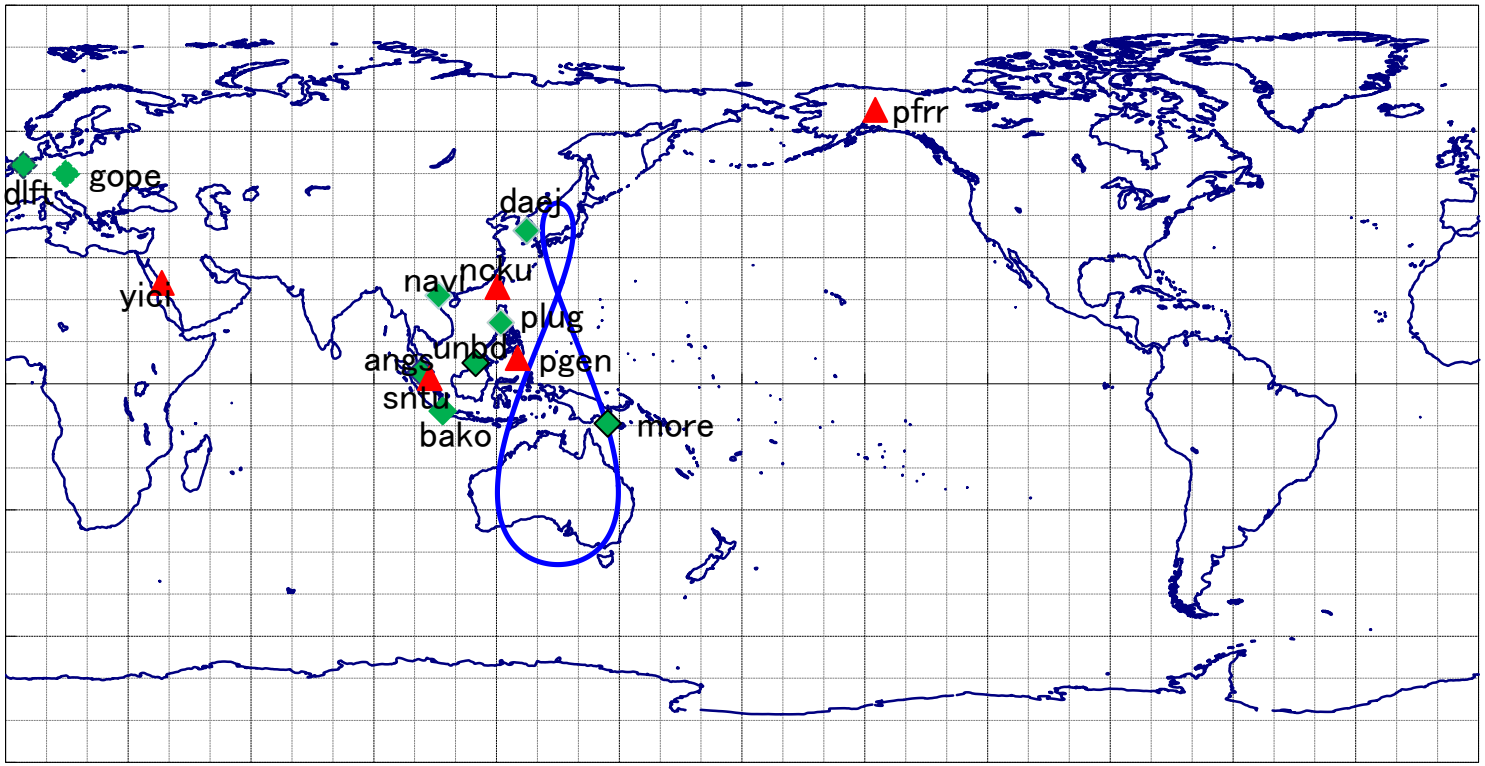


Call for applications of hosting sites for MGM-net was announced twice at the moment.

- As a result, **14 sites were selected as of the beginning of March, 2012**.

  (Korea, Philippines(2), Papua New Guinea, Malaysia, Czech, Netherlands, Indonesia, Vietnam, Bulnei, Taiwan, Singapore, Saudi Arabia, USA

- 14 sites including applications from Nigeria , Indonesia and so on have been still under selection process.
- Continuous call is to be requested until enough number of sites will be joined .

# MGM-net Status
# （Cooperation among Networks）

∞∞∞∞∞∞∞∞∞Quasi-Zenith Satellite System ∞∞∞∞∞∞∞∞∞Quasi-Zenith Satellite System ∞∞∞∞∞∞∞∞∞Quasi-Zenith Satellite System ∞∞∞∞∞∞∞∞∞

## Participation into IGS M-GEX project

- 8 sites in Asia were registered to IGS M-GEX project.
- The Installation at the site is now being prepared, after installation and new RINEX format (ver.3.02) including QZSS is released, data collected those sites will be provided to M-GEX project

## Collaboration with other network

- MGM-Net welcome participation using own multi-constellation tracking receiver and antenna.

  Geoscinece Australia (GA), Land Information New Zealand (LINZ), Curtin University, EGNOS Data Collection Network (EDCN), GPSnet Victoria

- Data share, co-location of Rx, and cross evaluation of POD

  Cooperation with DLR, ESOC and CNES are being prepared formal joint research agreement.

# MGM-net Status

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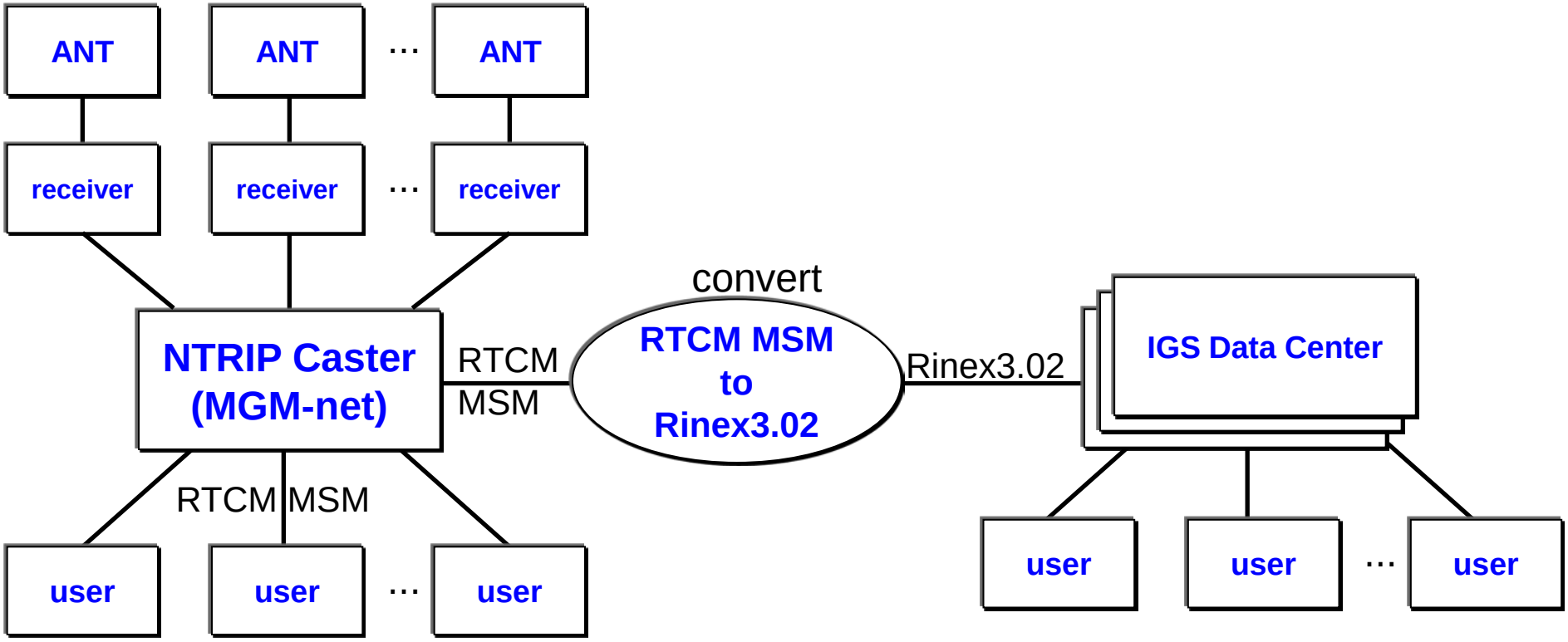
- Data interface in MGM-net

MGM-net a*dopt same philosophy as IGS project*




Realtime data(RTCM MSM) will be shared among participating organizations.

Off-line data(RINEX3.02) will be shared through IGS data center.

# “MADOCA” Development Status



■**Development Plan of MADOCA**

- **2011: Off-line orbit and clock estimation of GPS/GLONASS/QZSS**
- **2012: Off-line / Realtime orbit and clock estimation of GPS/GLONASS/GALILEO/QZSS**

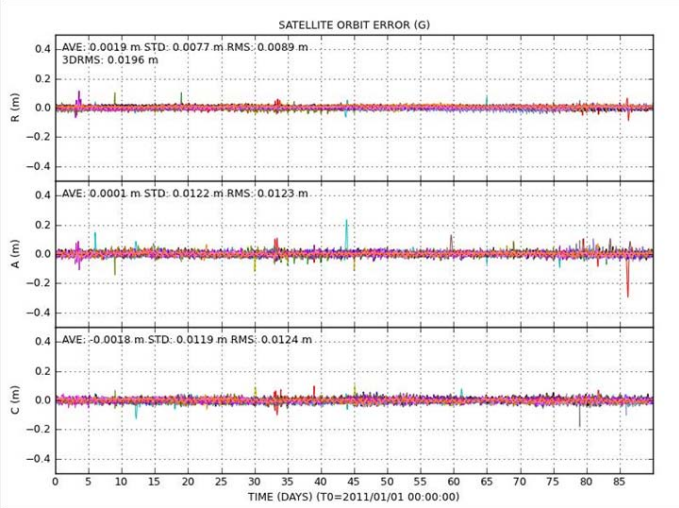
**・MADOCA is developed by cooperation with NEC and Tokyo Univercity of Marine Science and Technology.**

The main Model/Setting of MADOCA

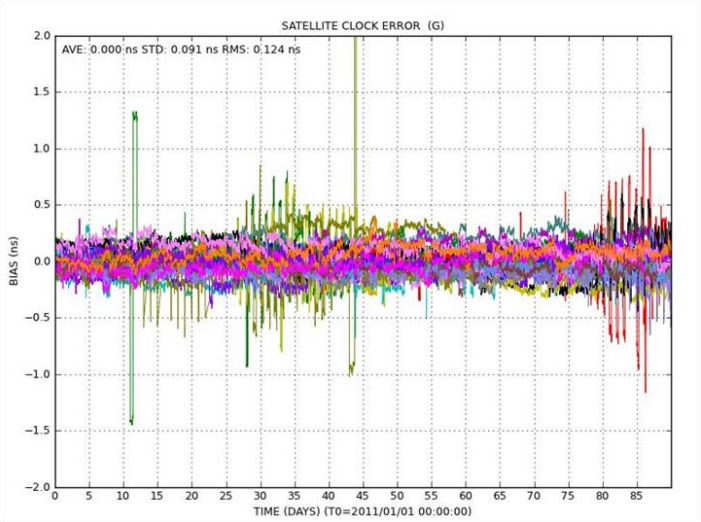
| Option | Model/Setting | Option | Model/Setting |
|---|---|---|---|
| OBS Type | ZD-Carrier-Phase | Tidal Correction | IERS2010+FES2004 |
| Data Span | 3H+24H+3H | 3rd-Body | S+M+V+J(DE421) |
| Data Interval | 300s | Satellite Attitude | prec |
| Elevation Mask | 10 deg | SRP Parameters | mdby |
| Navi-System | GPS,Glonass | ODE solver | RK4(Step=60sec) |
| Excluded Sats | - | Station Position | IGS SINEX,1mm |
| Meas. Noise | 3mm/sqrt(sin(el)) | Site Disp. | IERS2010+FES2004 |
| Nutation | IAU2000A(SOFA) | Troposphere | GPT+GMF |
| Initial EOP | IGS ERP | Tropos. param. | ZTD+Grad,every 2H |
| Geopotential | EGM96(Nmax=12) | Ambiguity | Fixed(<6000km) |

# “MADOCA” Development Status






**GPS** orbit accuracy compared by IGS final




**GPS** clock accuracy compared by IGS final

The performance of MADOCA reaches almost as same as IGS analysis centers.

**GPS** orbit/clock Error comparison with IGS Analysis Centers

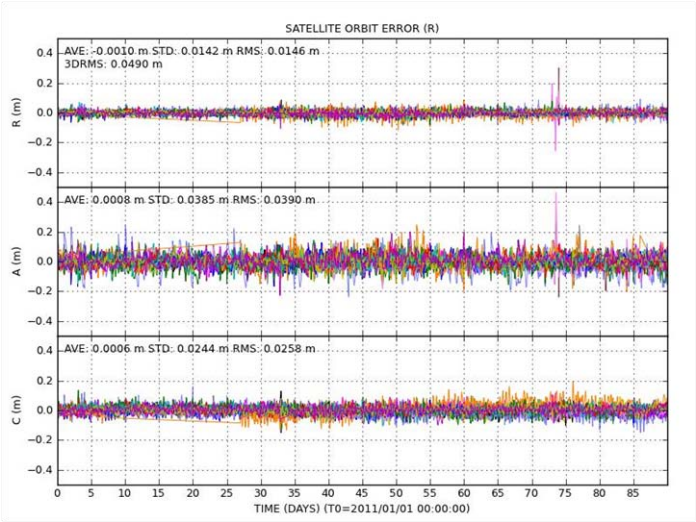
| IGS AC | Analysis Software | # of Station | GPS Orbit Error (cm) | | | | Clock Error (ns) | |
|---|---|---|---|---|---|---|---|---|
| | | | Radial | Along-Track | Cross-Track | 3D | STD-Dev | RMS |
| ESA | NAPEOS 3.5 | 110 | 0.92 | 1.14 | 1.02 | 1.79 | 0.112 | 0.159 |
| - | MADOCA 0.3.0 | 77 | 0.89 | 1.23 | 1.24 | 1.96 | 0.091 | 0.124 |
| CODE | Bernese 5.1 | 231 | 0.98 | 1.48 | 1.22 | 2.16 | 0.064 | 0.085 |
| NGS | arc, orb, pages, gpscom | 199 | 0.93 | 1.59 | 1.49 | 2.37 | - | - |
| MIT | GAMIT 10.33, GLOBK 5.16 | 263 | 1.31 | 1.79 | 1.47 | 2.66 | 0.178 | 0.223 |
| GFZ | EPOS.P.V2 | 191 | 1.16 | 1.92 | 1.91 | 2.95 | 0.086 | 0.103 |
| NRCan | GIPSY/OASIS-II 5.0 | 91 | 2.64 | 1.73 | 1.78 | 3.62 | 0.121 | 0.143 |
| SIO | GAMIT 10.20, GLOBK 5.08 | 258 | 2.61 | 1.95 | 1.76 | 3.7 | - | - |
| JPL | GIPSY/OASIS-II 5.0 | 142 | 2.78 | 1.78 | 2.17 | 3.95 | 0.113 | 0.2 |
| GRG | GINS, DYNAMO | 134 | 2.58 | 3.13 | 1.98 | 4.51 | 0.167 | 0.206 |

**31 GPS satellites,2011/1/1-3/31,errors wrt IGS Final**

# “MADOCA” Development Status



The performance of MADOCA reaches almost as same as IGS analysis centers.



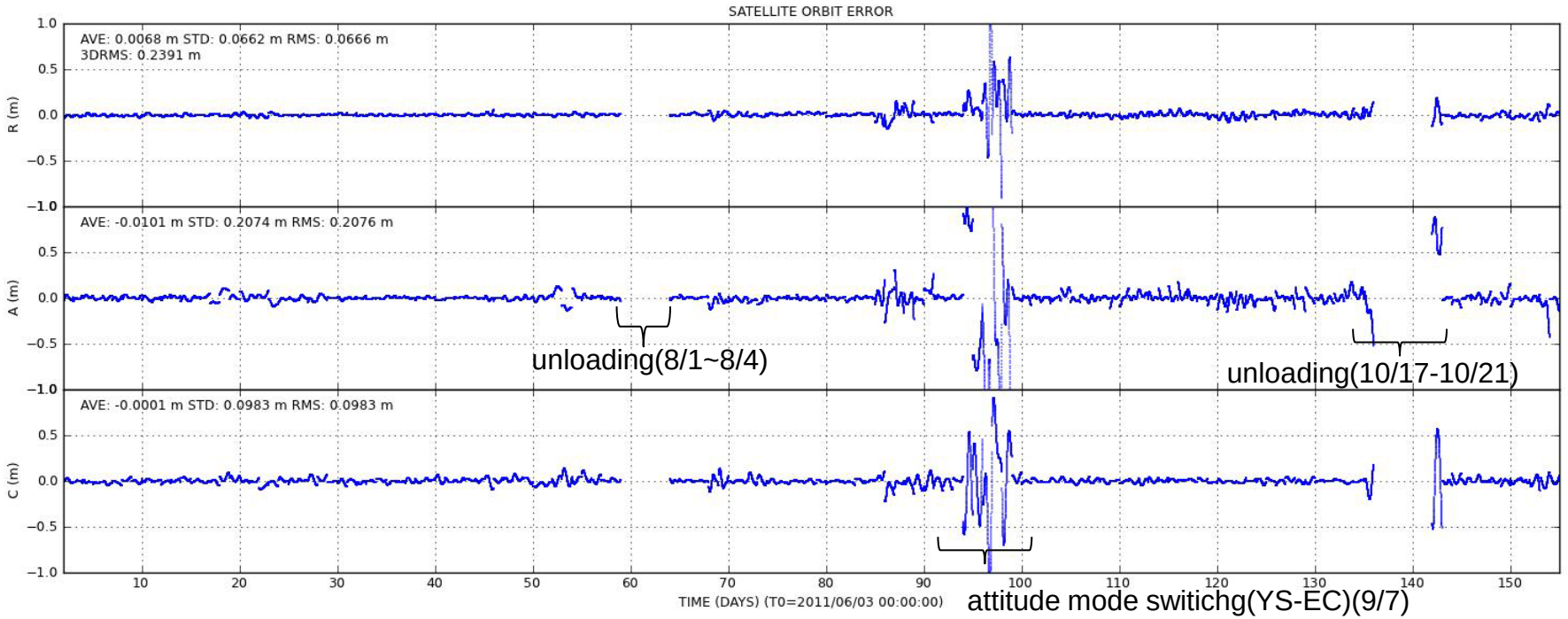

**GLONASS** orbit accuracy compared by IGS final

**GLONASS** orbit Error comparison with IGS Analysis Centers

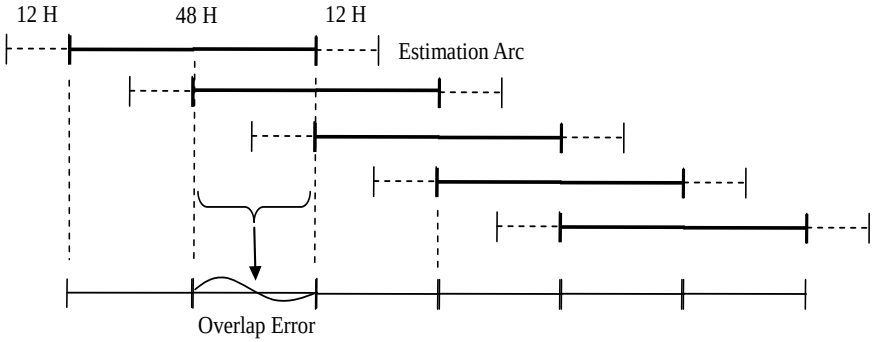
| IGS AC | Analysis Software | # of Station | GLONASS Orbit Error (cm) | | | | Clock Error (ns) | |
|---|---|---|---|---|---|---|---|---|
| | | | Radial | Along-Track | Cross-Track | 3D | STD-Dev | RMS |
| CODE | Bernese 5.1 | 231 | 1.21 | 3.02 | 2.34 | 4.01 | - | - |
| ESA | NAPEOS 3.5 | 110 | 1.46 | 3.19 | 2.2 | 4.14 | - | - |
| - | MADOCA 0.3.0 | 77 | 1.46 | 3.9 | 2.58 | 4.9 | - | - |
| IAC | STARK, POLAR | ? | 2.41 | 5.22 | 2.84 | 6.41 | - | - |
| BKG | Bernese 5.1 | 139 | 2.12 | 7.53 | 3.22 | 8.47 | - | - |
| GFZ | EPOS.P.V2 | 191 | 4.4 | 22.62 | 3.04 | 23.25 | - | - |
| GRG | GINS, DYNAMO | 134 | 4.12 | 21.38 | 5.77 | 22.52 | - | - |
| MCC | STARK, POLAR | ? | 4.31 | 21.11 | 19.95 | 29.37 | - | - |

**22 GLONASS satellites,2011/1/1-3/31,errors wrt IGS Final**

# “MADOCA” Development Status




QZSS-1, 2011/6/3-2011/11/2, 12H+48H+12H arc, 24H orbit overlap error




QZSS orbit overlap error evaluation

・Accuracy of QZSS by 24H overlap errors will be within about 6cm(3DRMS) except for unloading and such as EC-YS attitude mode change of QZSS unique.

・With regard to evaluation of QZSS, JAXA will carry out as follows.
- cross-validation with other agencies such as the DLR etc.
- evaluation of orbit accuracy using SLR data.

# Kinematic-PPP Accuracy

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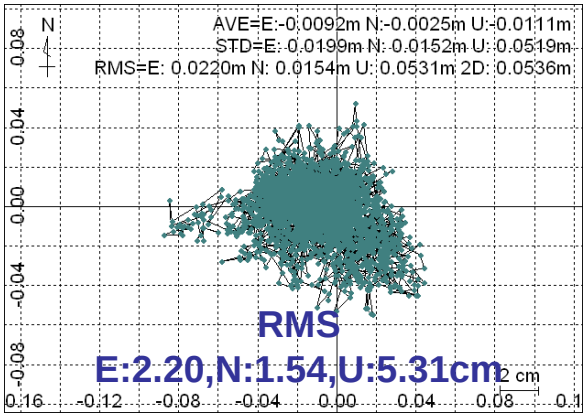
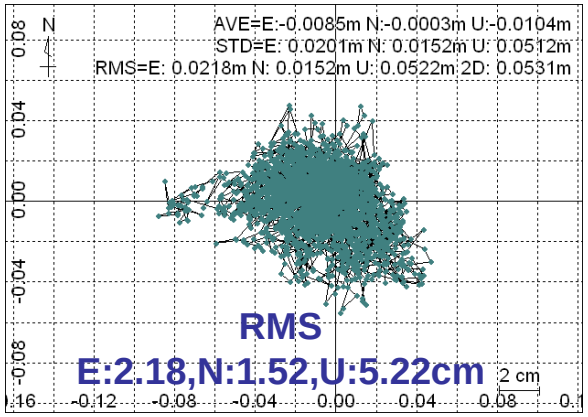
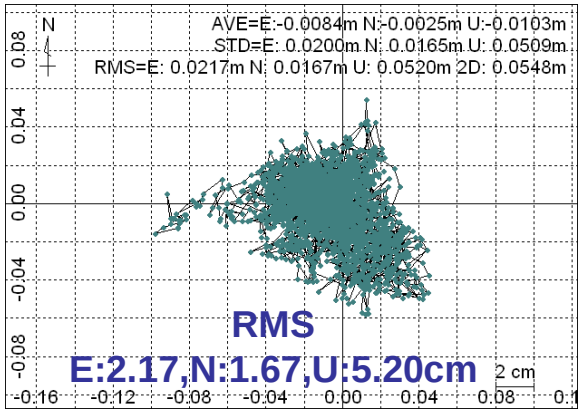
## IGS Final(GPS)



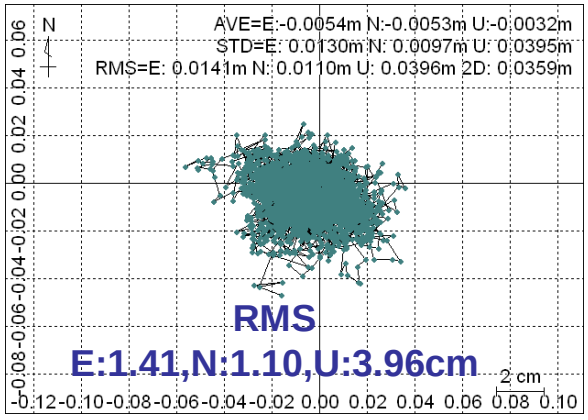

## ESA(GPS)



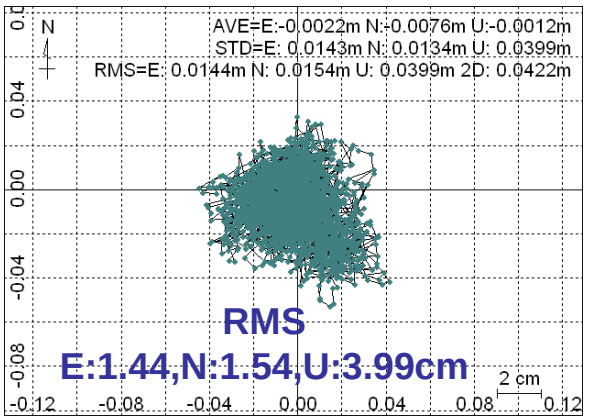

## MADOCA(GPS)




## ESA(GPS+GLONASS)




## MADOCA(GPS+GLONASS)




Processing conditions
- EL mask : 10deg
- Ionosphere correction : Dual Frequency
- Troposphere correction : Estimated ZTD+grad
- Ephemeris/clock : IGS,ESA Final/MADOCA

coordinate origin
→Average of 24H static PPP by IGS final

IGS CNMR by RTKPOST v.2.4.1
2011/3/1 0:00:00-23:59:30 GPST,Interval 30sec
(first 1H solutions are omitted for convergence)

# Kinematic-PPP Accuracy

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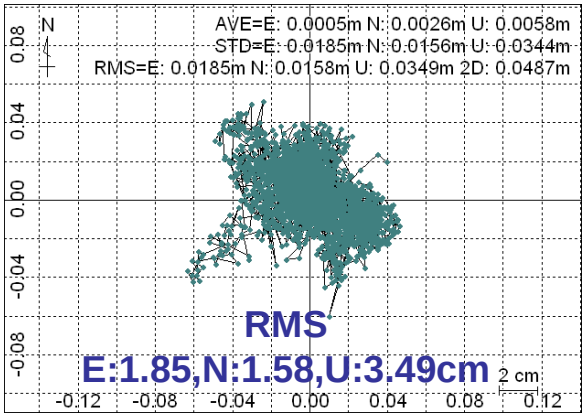
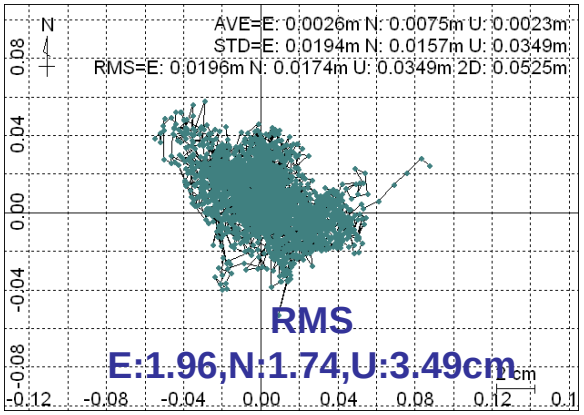
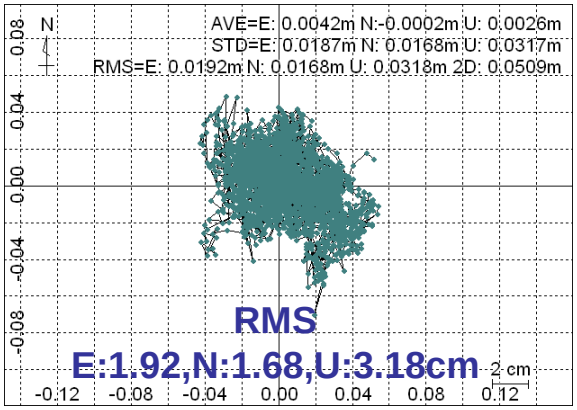
## IGS Final(GPS)




## ESA(GPS)




## MADOCA(GPS)

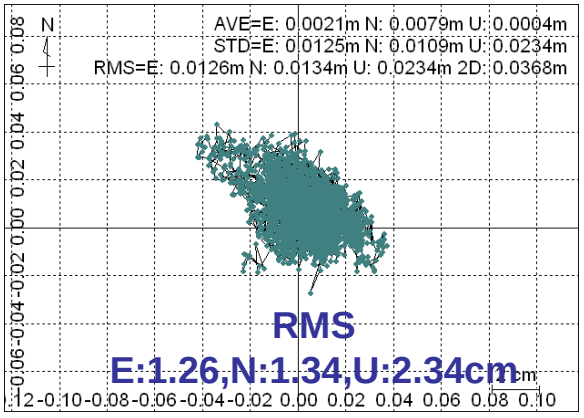



Processing conditions
- EL mask : 10deg
- Ionosphere correction : Dual Frequency
- Troposphere correction : Estimated ZTD+grad
- Ephemeris/clock : IGS,ESA Final/MADOCA

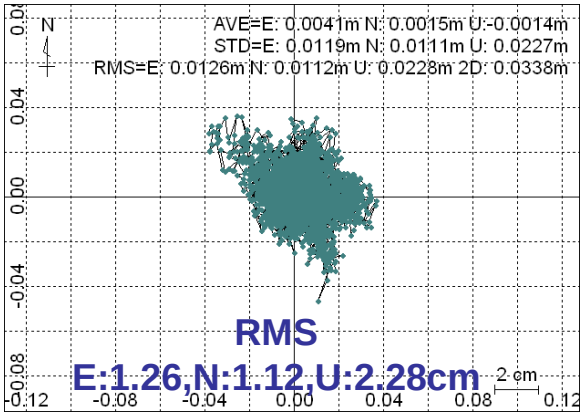
coordinate origin
→Average of 24H static PPP by IGS final

The PPP accuracy improves by adding GLONASS.

## ESA(GPS+GLONASS)




## MADOCA(GPS+GLONASS)




IGS WTZZ by RTKPOST v.2.4.1
2011/3/1 0:00:00-23:59:30 GPST,Interval 30sec
(first 1H solutions are omitted for convergence)

# Kinematic-PPP Accuracy by QZSS-LEX

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In particular, it shows marked improvement about vertical direction accuracy.

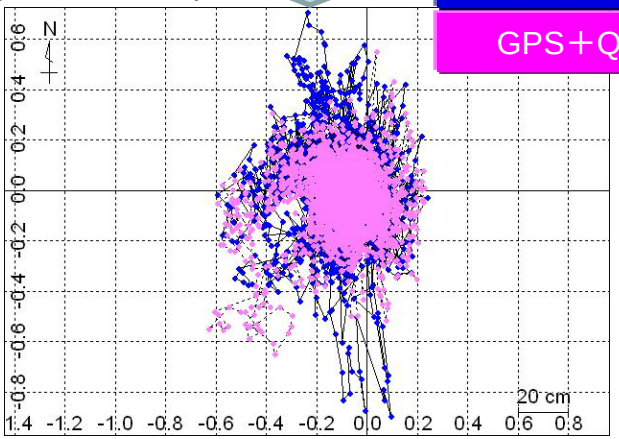
| Date/Time(GPST) | RMS Error(cm) | | | |
|---|---|---|---|---|
| | GPS only | | GPS+QZS | |
| | Horizontal | Vertical | Horizontal | Vertical |
| 2011/6/24 0:00-23:59 | 21.39 | 31.42 | 19.97 | 25.54 |
| 2011/6/25 0:00-23:59 | 23.47 | 42.56 | 20.03 | 26.05 |
| 2011/6/26 0:00-23:59 | 23.07 | 34.34 | 20.71 | 26.28 |

Processing conditions
- Place : Tsukuba (QZS operation facility)
- interval : 30sec
- EL mask : 15deg
- Ionosphere correction : Dual Frequency
- Troposphere correction : Estimated ZTD
- Ephemeris/clock : QZSS LEX

(example : 2011/6/26)

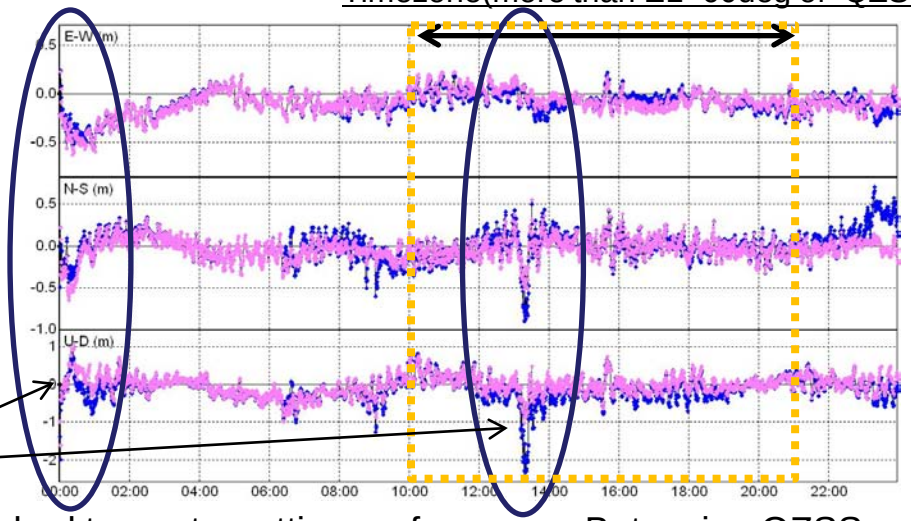
GPS only

GPS＋QZS




coordinate origin→Average of 24H static PPP by IGS final

Timezone(more than EL=60deg of QZSS)




The PPP accuracy improves by adding QZSS.

- Kinematic PPP accuracy using QZSS-LEX has not reached to our targetting performance. But, using QZSS signal the improvement of PPP acuracy in bad DOP condition was observed.
- Following actions are required for achieiving our final goal of real-time PPP experiment using QZSS LEX.
  - Increment of the number of MS as well as get better observation geometry, i.e., MGM-net deployment
  - More presice POD capability for multiple constellations, i.e., MADOCA
  - LEX message modification, more frequent clock update, initial phase offset for PPP-AR and so on

# Summary

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- JAXA is planning real-time PPP experiment by using QZSS-LEX message from 2013.
- The real-time PPP experiment is to be conducted as one of Asia-Oceania Multi-GNSS Demonstration Campaign.
- JAXA is establishing MGM-net deployment under the international cooperation and developing multi-GNSS POD tool, MADOCA, as infrastructure required for the PPP experiment.
  - MGM-net: 14 sites selected. JAXA will continue activity of call for application for hosting site under cooperation with IGS etc.
  - MADOCA: off-line function of GPS, GLONASS and QZSS was developed.
    For the further performance improvement, models and parameters tuning process will be required.
    Real-time function towards PPP experiment will be developed in 2012.
- PPP-AR technique is to be adopted for further accuracy improvement. LEX message will be modified to more suitable format for real-time PPP.
- If you have any interests in our demonstration campaign activity,
  - ✓ please visit MGA website: www.multignss.asia

# *Our Planet from QZS-1 'MICHIBIKI'*

Souvenir from Michibiki / Earth

QZ-vision

JAXA

This wallpaper can be downloaded
from QZ-vision website(http://qz-vision.jaxa.jp/)

***Thank you for your attention***