EXPERIMENTAL RESULTS OF LEX CORRECTIONS USING FARMING MACHINE

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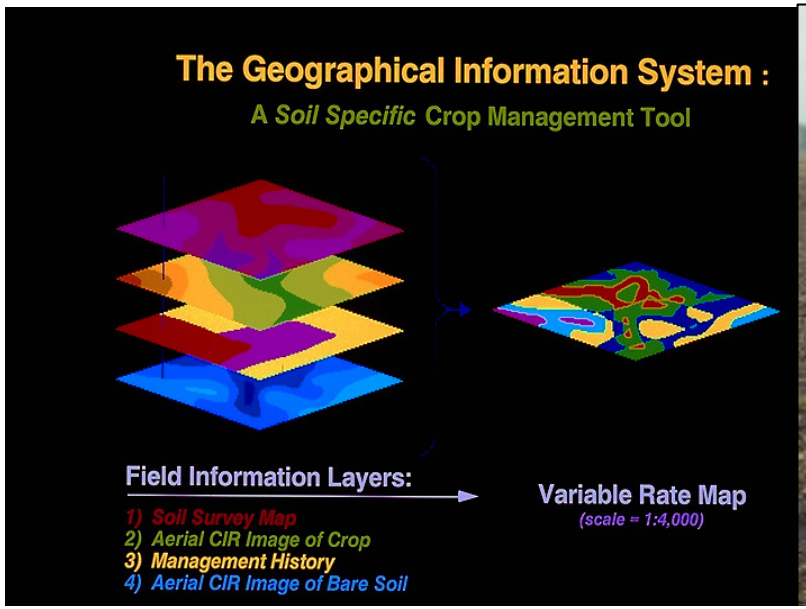
Precision Agriculture

- **Precision Agriculture addresses -**
  - **Production of high-quality foods and feeds at a site-specific (individual) optimized use of resources for production**
  - **Economical and ecological improvements in agricultural production**
- **Precise Positioning with Satellites are effective**

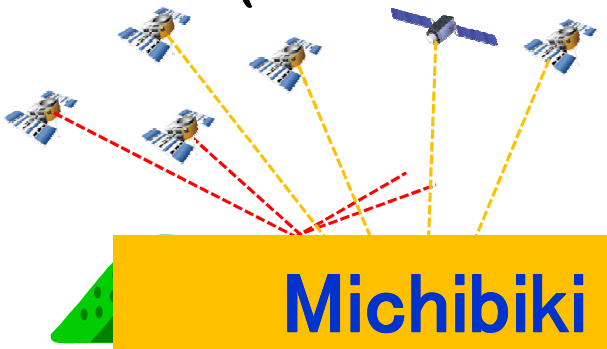
Site Specific

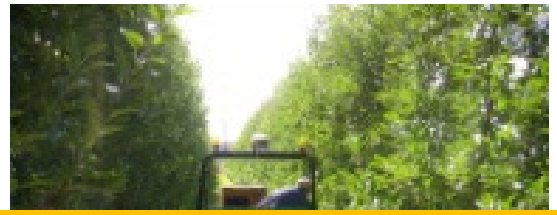


Economical and Ecological Improvements

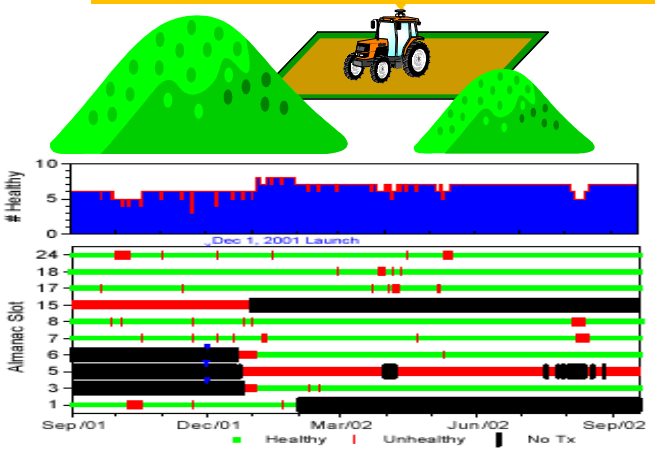
Current issues of GNSS as field navigation sensors

- Cannot be used in any time and any places
- Low Reliability due to limited number of satellites
- Acquisition of Correction data for RTK has problems (Cost and coverage of Cell phone – Packet service area)





Michibiki – QZSS solves those issues



Mission of IT Automated Driving WG

- **Prove QZSS-LEX corrections effect for Autonomous Vehicle Control**
  - **Evaluate LEX Corrections for Vehicle Control Applications such as Farming and Construction Machines (Slow Dynamic Vehicles)**

- **Evaluation of using QZSS-LEX for v precise control**
  - **Geo Spatial Data Maintenance (Field Maintenance)**
  - **Un-manned Operation**
  - **Realize Precision Agriculture using QZSS LEX correction**

Planting rise Robot
(Courtesy National Agricultural Research Center)

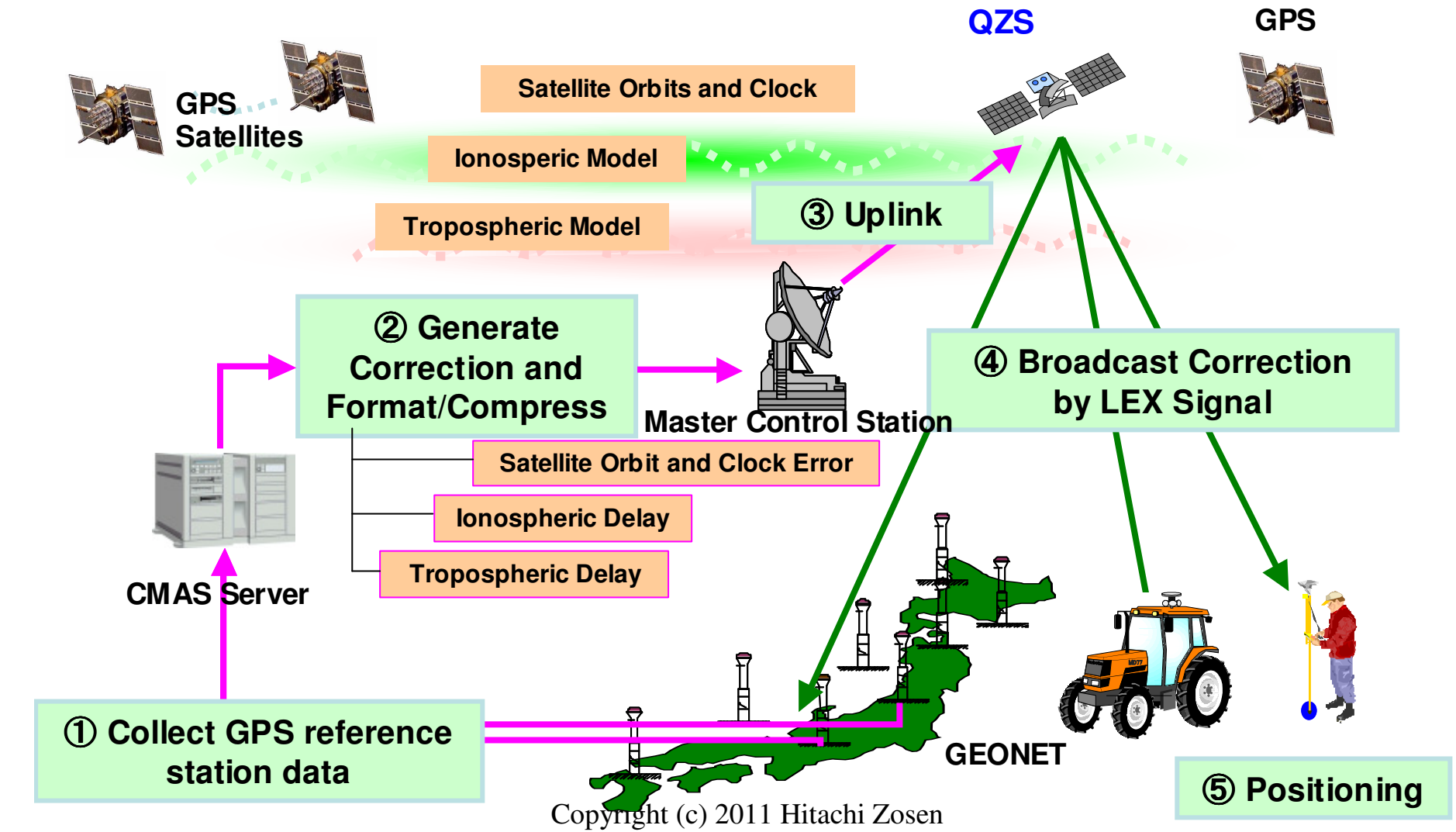
Centimeter Level Augmentation System (CMAS)

- Satellite based high accuracy correction and augmentation system by using QZSS LEX signal to improve Positioning using GPS
  - Broadcast Correction data through QZSS LEX Signal
  - Realize centimeter positioning in real time whole Japan
  - Use L-Band antenna to receive the correction (Can be share with GPS)
  - Static and Dynamic (Kinematic) Survey support in real time
  - Generate corrections using GSI-GEONET GPS network data
  - Base station does not need for Precise Positioning

Space State Representation

- Positioning Method and target accuracy
  - Method: PPP-RTK (Precise Point Positioning) SSR
  - Accuracy in Static: 3cm in Horizontal, 6cm in Vertical
  - Accuracy in Dynamic: 6cm in Horizontal, 12cm in Vertical
  - TTFF(Time To First Fix): Within 60Seconds

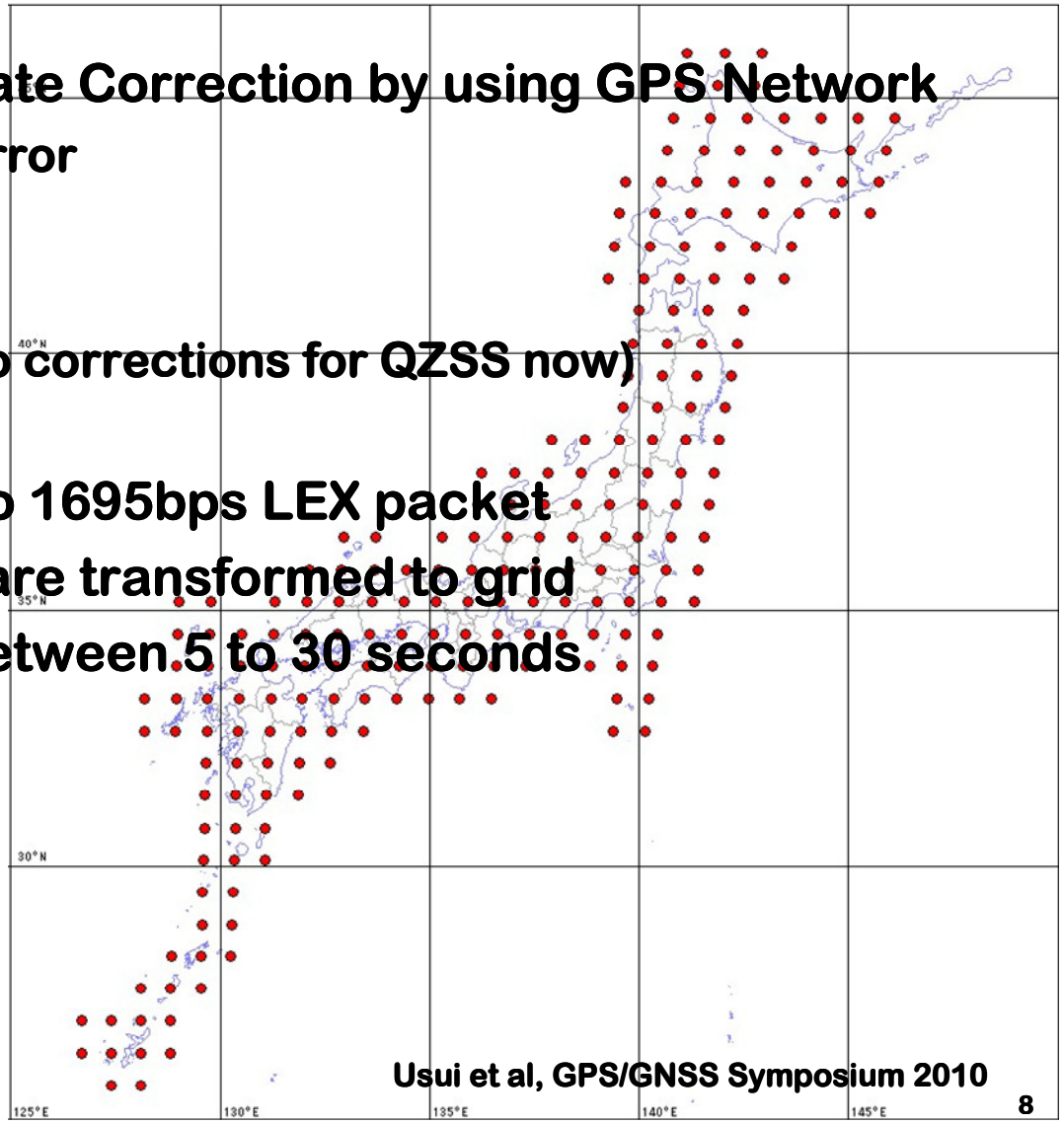
Overview of CMAS



Usui et al, GPS/GNSS Symposium 2010

Estimate and Broadcast Corrections

- Estimate Errors and Generate Correction by using GPS Network
  - Satellite Orbit and Clock Error
  - Ionospheric Error
  - Tropospheric Error
  - For each GPS satellites (No corrections for QZSS now)
- Correction data packed into 1695bps LEX packet
- Location depended errors are transformed to grid
- Update each corrections between 5 to 30 seconds



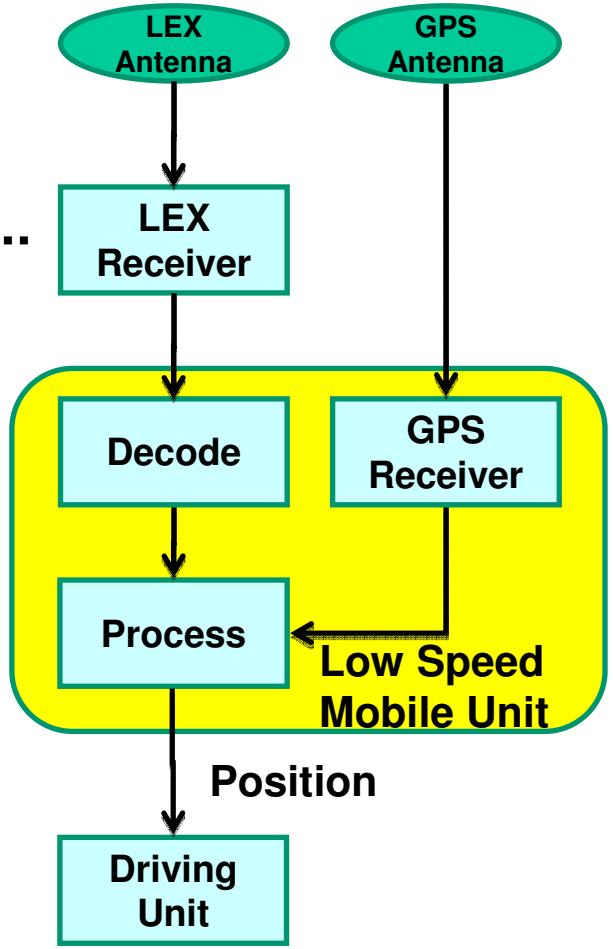
Usui et al, GPS/GNSS Symposium 2010

Slow Dynamic Mobile Unit

- Dual Frequency GPS Carrier Phase Measurement
- Correction data received by LEX Receiver
- Calculate exact correction data based on rough position of unit
- Perform PPP-RTK
- Mode
  - Synchronous mode : High Accuracy with 7 seconds latency
  - Asynchronous mode : Low Accuracy in Real time
- Coordinates are using ITRF system
  - No co-seismic deformation effect
  - Dynamic coordinate transformation needed
    ITRF to Japanese Geodetic Datum (JGD2000)

Slow Dynamic Mobile Unit

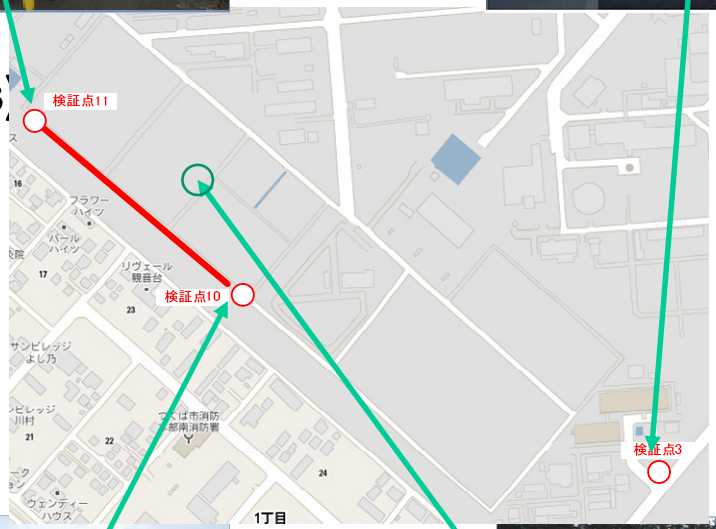
Should be small like this…

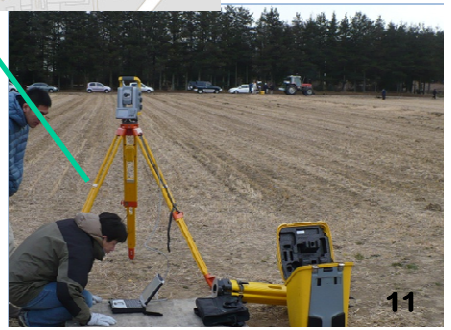


Usui et al, GPS/GNSS Symposium 2010

Experimental Field
National Institute for Rural Engineering

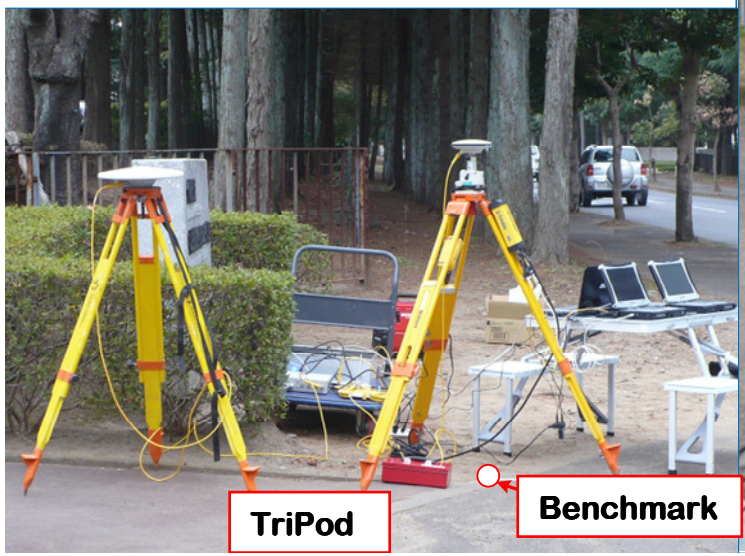
- **Benchmarks**
  - **Post processed GPS Surveying performed by Professional Surveyor**
  - **Three benchmarks used for Static test (Different environments)**
  - **Two benchmarks used for Dynamic test (Straightaway)**

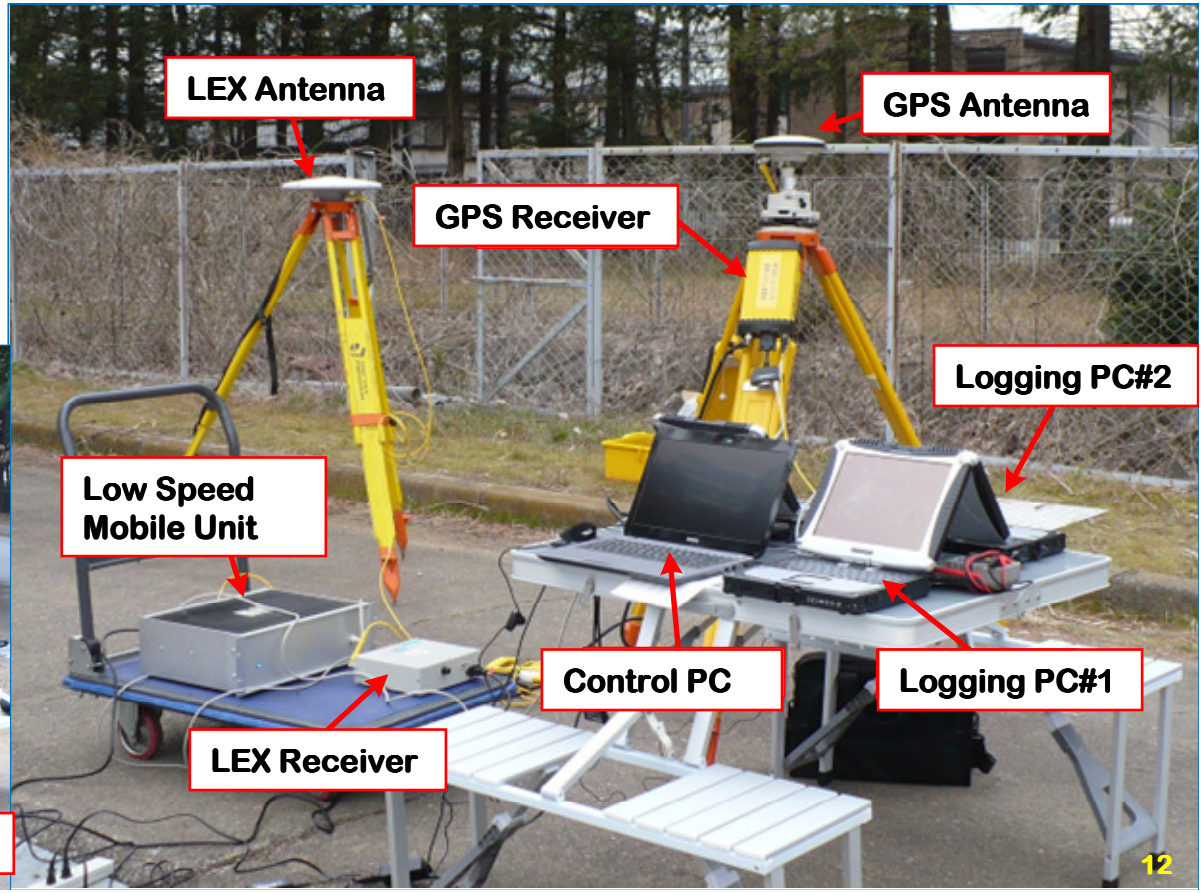




Composition of Static Positioning

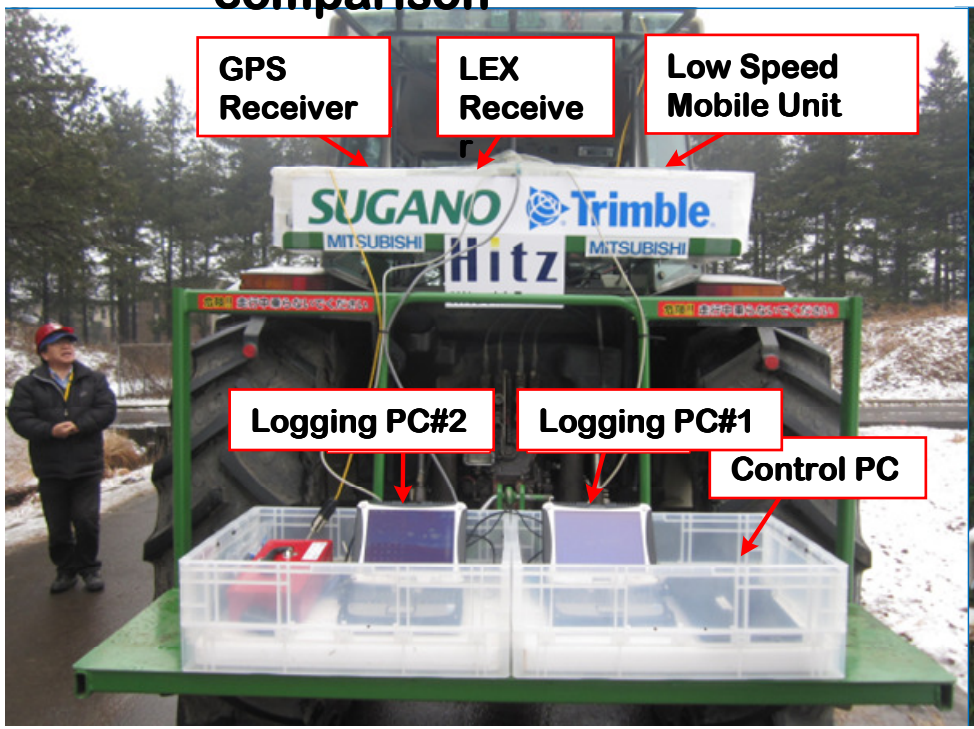
- Equipment Composition for Static Positioning Experiment
  - Share GPS antenna to VRS-RTK and QZSS-LEX positioning
  - VRS data received by Smart-phone (Packet communication)
  - VRS-RTK performed by ordinary GPS receiver's function
  - Comparison with VRS at benchmark

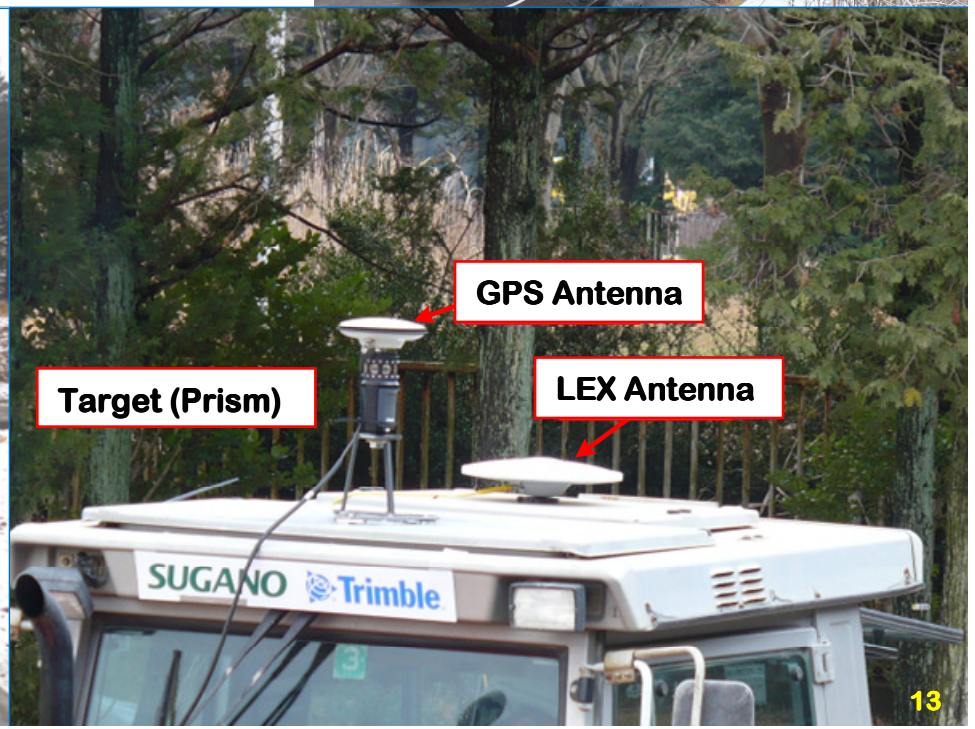




Composition of Dynamic Positioning

- Equipment Composition for Dynamic Positioning Experiment
  - Installed on Tractor
  - Prism (Automatic Laser Tracking) mounted under GPS antenna for Precise comparison
  - Automatic Tracking Total Station used for comparison





Results of Static Positioning

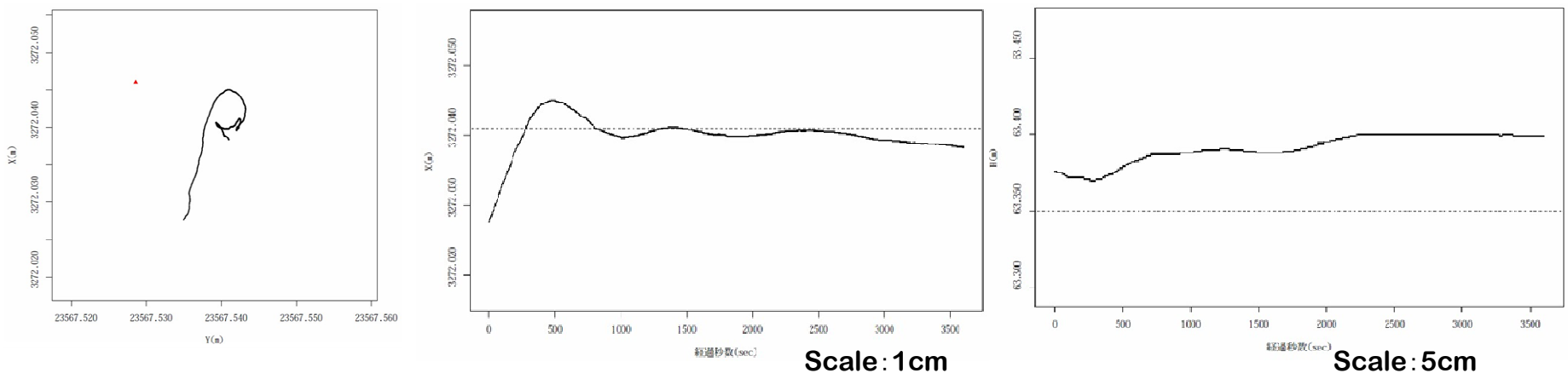
Static Positioning (Open Sky)	
Benchmark	#10
Date and Time	2011/02/08 (TUE) 10:00 - 11:00
Positioning Mode	Synchronous
Update Interval	1Hz

	Fix %	# of Results	# of FIX	Invalid	Float	MissFIX	Missing
LEX (LSMU)	99.97%	3,600	3,599	0	1	0	0
VRS-RTK	100.00%	3,600	3,600	0	0	0	0

		X(m)	Y(m)	H(m)
LEX (LSMU)	Standard Deviation	0.002	0.002	0.009
	RMS Error	0.003	0.007	0.042
	Max Error (Obs.-True)	-0.013	0.009	0.050
VRS-RTK	Standard Deviation	0.005	0.003	0.012
	RMS Error	0.007	0.014	0.024
	Max Error (Obs.-True)	0.023	0.025	0.063

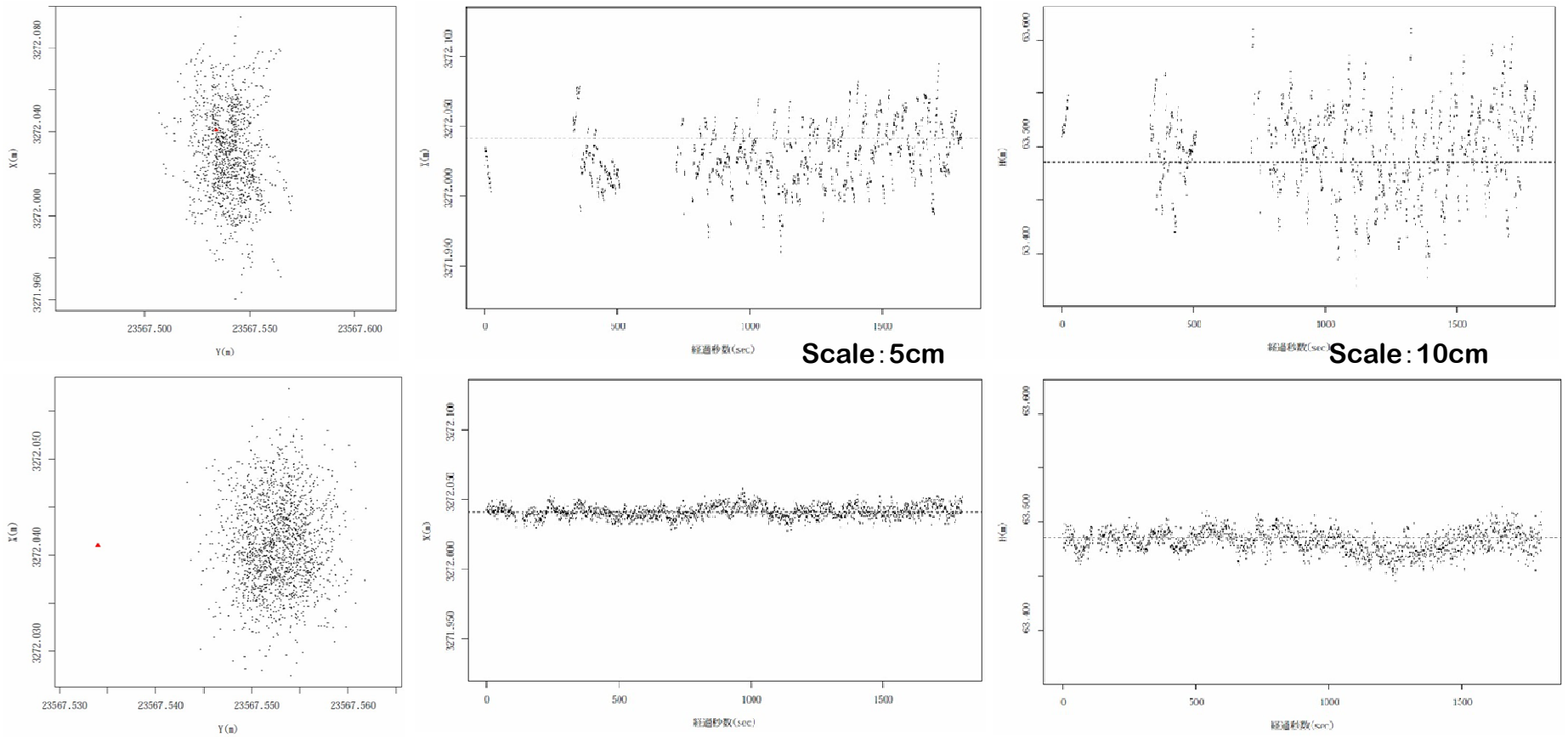
Examples of Static Positioning (Synchronous Mode)

- **Comparison between Low Speed Mobile Unit and VRS-RTK**



Examples of Static Positioning (Asynchronous Mode)

- **Comparison between Low Speed Mobile Unit and VRS-RTK**



Results of Dynamic Positioning

Dynamic Positioning (Good case)	
Benchmark	#10 - #11 Straight Driving
Date and Time	2011/02/09 (WED) 10:00 - 14:00
Positioning Mode	Synchronous
Update Interval	5Hz

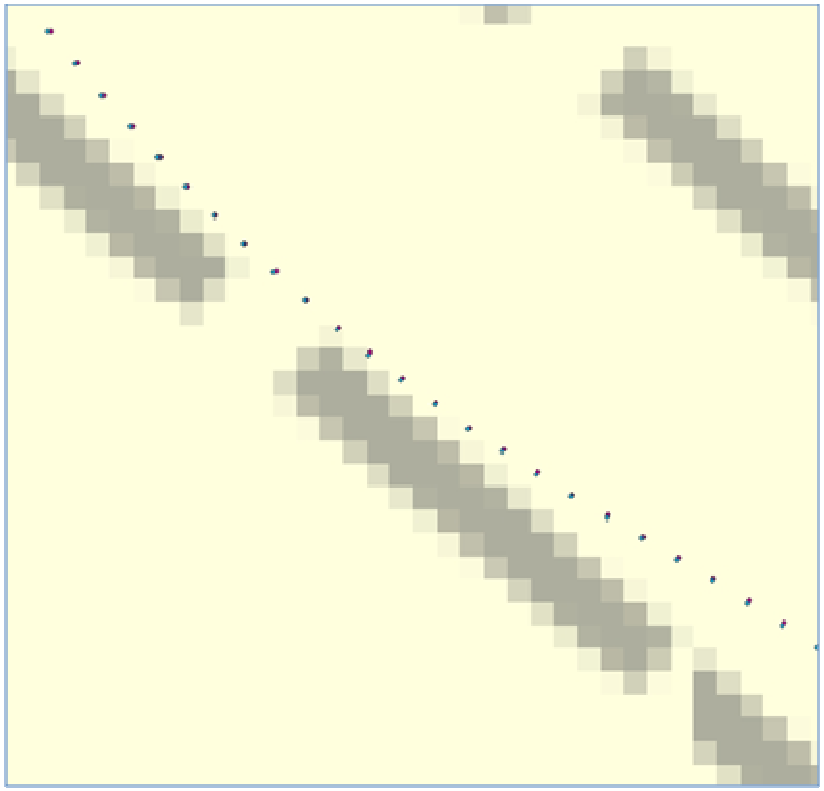
	Fix %	# of Results	# of FIX
LEX (LSMU)	100.00%	1,666	1,666
VRS-RTK	100.00%	1,664	1,664

		X(m)	Y(m)	H(m)
LEX (LSMU)	Standard Deviation	0.005	0.005	0.007
	RMS Error	0.006	0.005	0.029
	Max Error (Obs.-True)	-0.041	0.038	-0.052
VRS-RTK	Standard Deviation	0.007	0.005	0.012
	RMS Error	0.007	0.006	0.016
	Max Error (Obs.-True)	-0.049	0.043	0.043

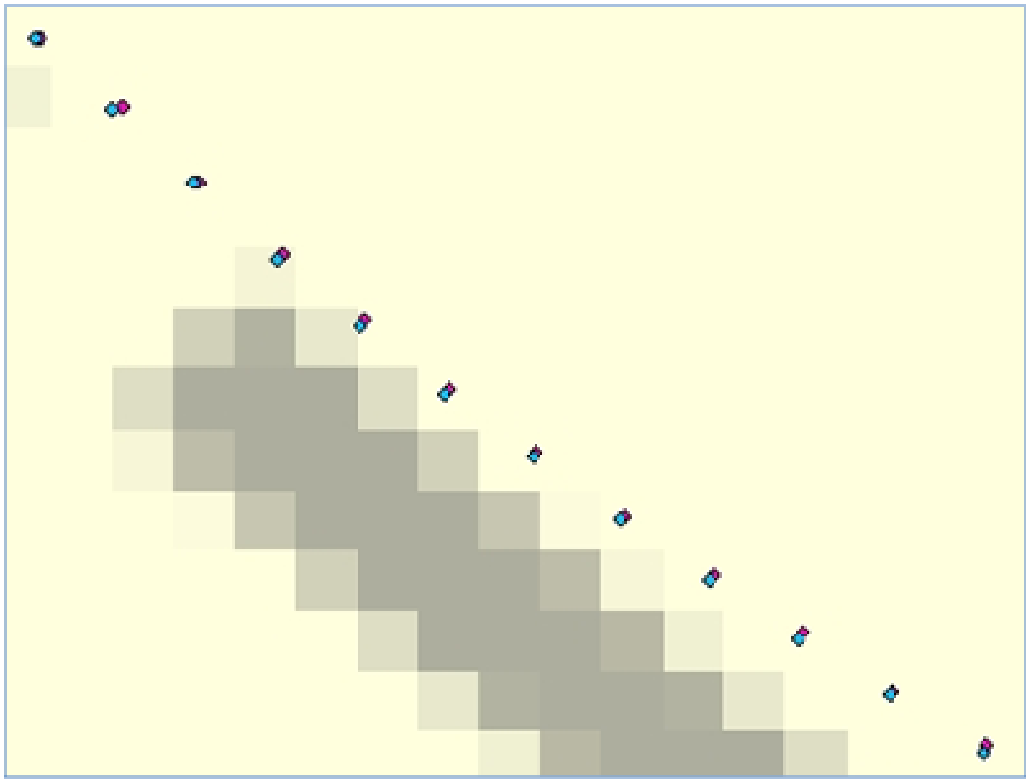
Examples of Dynamic Positioning

- **Zoom up Trajectory (Red: LSMU, Blue:VRS-RTK)**
  In case of Meander Driving (Intervals are around 30cm)

Zoom



More Zoom



Conclusion

- **Effects to use MICHIBIKI-QZSS**
  - **Provide navigation signals and correction data from zenith**
  - **Improve satellite visibility for precise positioning in canyon**
  - **Expand availability to perform precise positioning whole Japan**

- **Broadcast QZSS LEX correction at Asia-Oceania regions are feasible**
  - **Require CORS stations at each region to generate corrections**

- **QZSS LEX correction were performed well with farming machine**
  - **Positioning accuracy of Low Speed Mobile Unit (PPP-RTK with LEX) is similar with VRS-RTK in case of open sky environment**
  - **Some cases caused un-Fixed positioning due to loss of signals**
  - **Precision Agriculture using QZSS LEX will greatly useful to reduce the environmental damage and to increase the productive**


QZSS is not a just supplemental Navigation Satellite
Unique concepts with
- Always on your zenith
- Broadcast HP corrections
Thank you for your attention
This experiment has been conducted by the consignment from the Ministry of Education, Culture, Sports, Science and Technology