

# GPS Meteorology in Japan

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*TWAA96*

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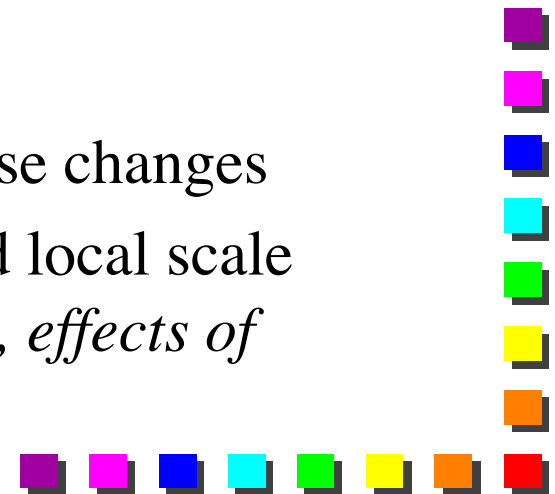
*Kashima, Japan*

*APT&APSG*



# Motivation

- **Wet troposphere delay is crucial source of error for space geodesy (VLBI, GPS, In-SAR, Satellite Altimetry and so on).**
  - Difficulty of accurate vertical positioning
  - Necessity of high spatial and temporal resolution
- **Water vapor plays a key role in meteorological phenomena.**
  - High spatial and temporal variability
  - Large latent heat associated with water's phase changes
  - Insufficient understanding for meso scale and local scale phenomena (*ex. heavy rain fall, severe storm, effects of topography, etc.*)

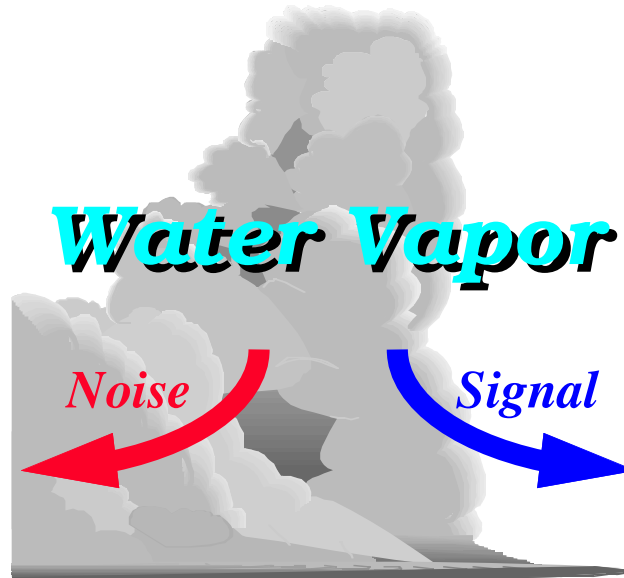


# Scheme of GPS Meteorology in Japan

## Geodesy

### GPS network

- ◆ monitoring crustal deformation
- ◆ monitoring sea level change
- ◆ etc.



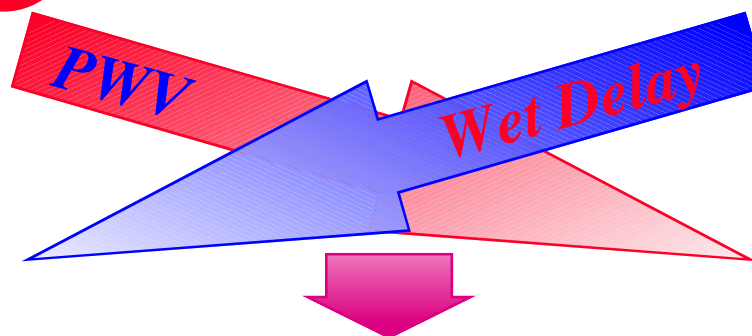
## Meteorology

### Numerical Weather Prediction (NWP)

- ◆ weather prediction
- ◆ research for severe weather
- ◆ etc.

More accurate positioning

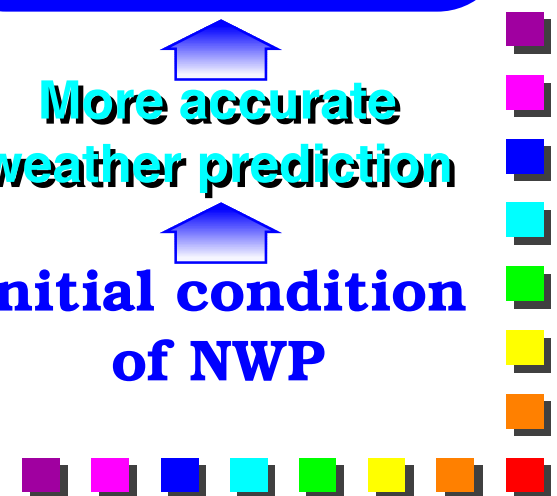
Correction of Wet Delay



Water Vapor Information Database

More accurate weather prediction

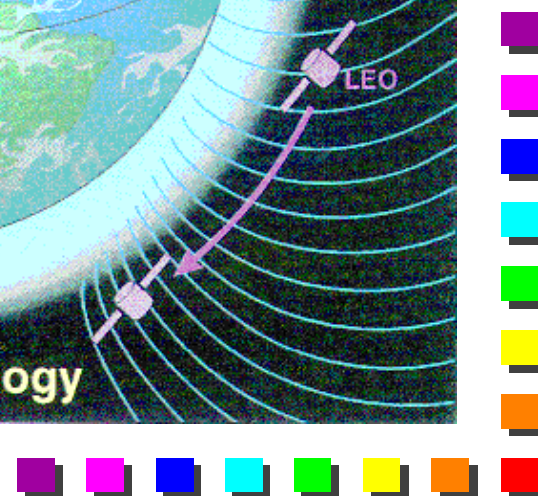
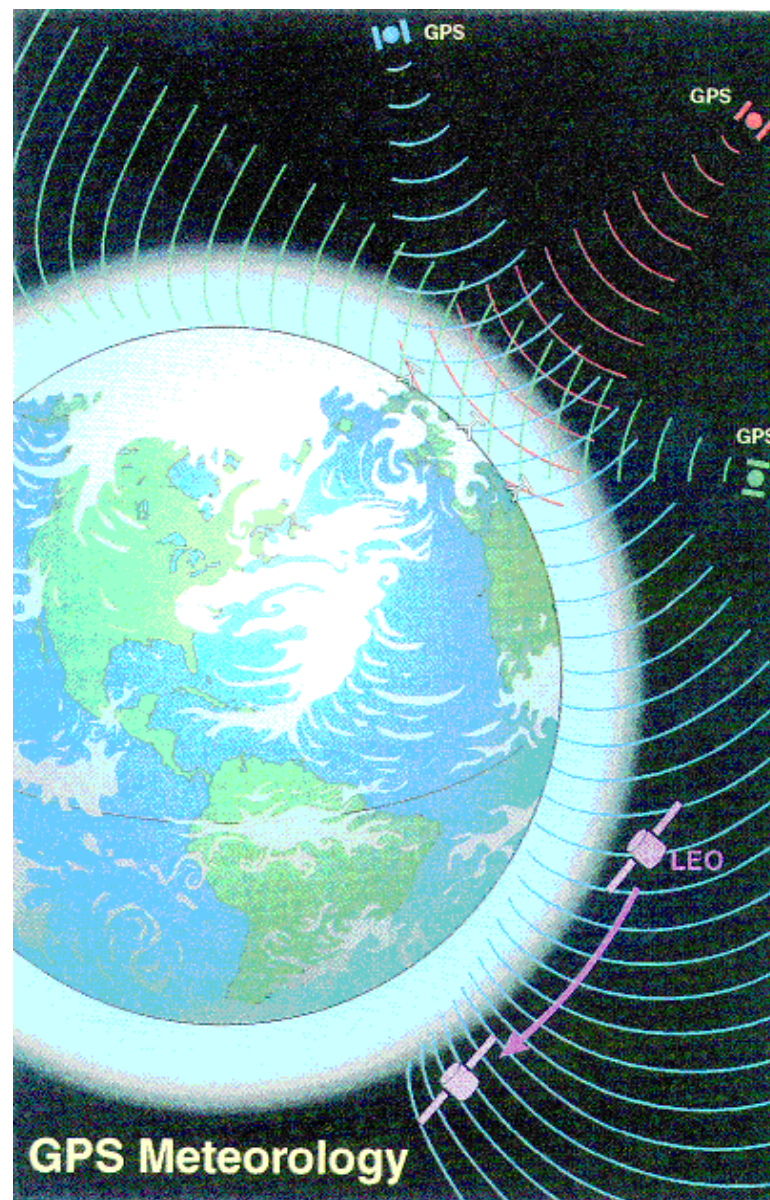
Initial condition of NWP



# Scheme of GPS Meteorology

- Ground-based
- Space-Based

Businger et al.(1996) ->



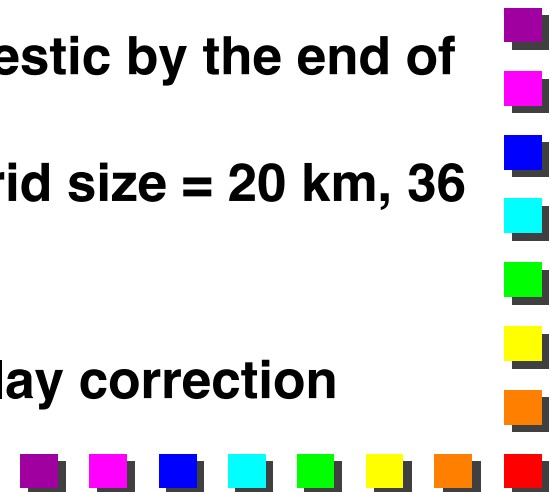
# Outline of Japanese Cooperative Study (1)

## ■ Title

- "Establishment of Water Vapor Information Database by GPS Meteorology and Its Applications to Numerical Weather Prediction, Geodetic Research and Hydrology" is adopted to Feasibility Study in 1996 Japanese budget year, and submitted to Science and Technology Agency (STA) of Japanese Government for five years cooperate study (1997-2001).

## ■ Characteristics

- Dense permanent GPS sites (891 sites in domestic by the end of March, 1997) by GSI
- Dense numerical weather prediction model (grid size = 20 km, 36 vertical levels) by JMA
- GPS receivers as water vapor sensor
- Numerical prediction data for tropospheric delay correction



# Outline of Japanese Cooperative Study (2)

## ■ Goal

- Establishment of Water Vapor Information Database

## ■ Contents

### ■ Evaluate of precipitable water vapor (PWV) by GPS measurements

- Estimate and evaluate GPS PWV
  - Include GPS domestic campaigns
- Study on numerical prediction based on GPS PWV
- Observe GPS PWV in continental and oceanic region

### ■ Study on improvement of precision of space geodesy

- Approach of tropospheric delay correction using numerical prediction data
  - Include GPS domestic campaigns
- Revision of GPS analyzing software

### ■ R&D of GPS water vapor information database

- Development of rapid GPS analyzing technique
- Development of GPS water vapor information database
- Evaluation by meteorological, geodetic, and hydrological users



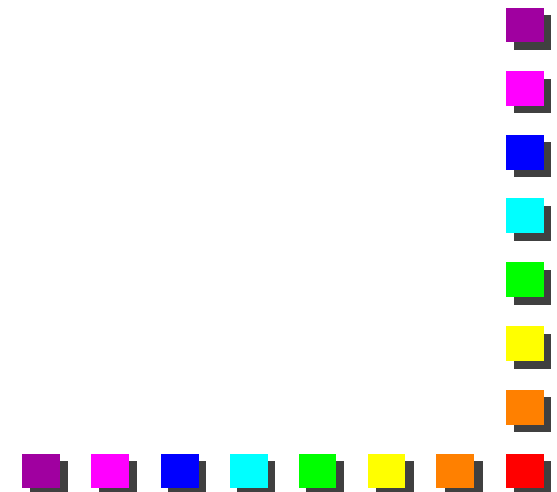
# Japanese Cooperative Study Group

## ■ **Governmental Institutes**

- Geographical Survey Institute (GSI)
- Japan Meteorological Agency (JMA)
- Hydrographic Department of Japan (HDJ)
- Nat. Res. Inst. for Earth Sc. Disaster Prevention (NIED)
- Communications Research Laboratory (CRL)
- Meteorological Research Institute of JMA (MRI)
- National Astronomical Observatory (NAO)
- National Inst. of Agro-Environmental Science
- National Agriculture Research Center

## ■ **Universities**

- Tohoku University
- Fukushima University
- Joetsu University of Education
- Tsukuba University
- Gunma University
- Chiba University
- Earthquake Research Institute, University of Tokyo
- Shizuoka University
- Nagoya University
- Disaster Prevention Research Institute, Kyoto University
- Radio Atmospheric Science Center, Kyoto University
- Kochi University
- Kyushu University
- Nagasaki University
- Kagoshima University



# Prepared Proposals of Cooperative Study at CRL

## ■ Evaluate PWV by GPS

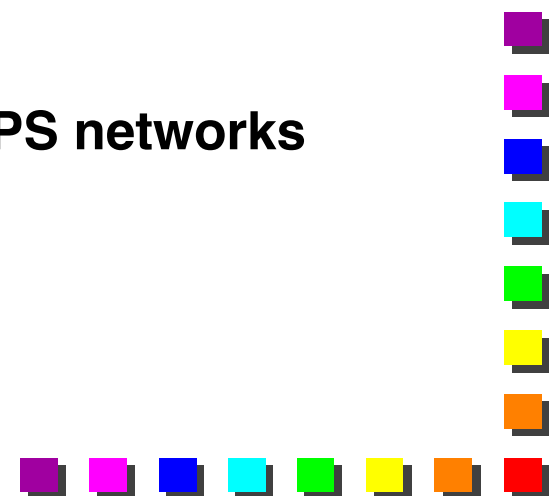
- Investigating temporal scale and spatial dimension of PWV
- Comparison PWV by GPS to WVR observation
- Comparison GPS PWV to numerical prediction data

## ■ R&D of correction method for wet tropospheric delay based on the numerical prediction data

- Japanese domestic and the Western Pacific GPS networks
- VLBI network

## ■ Available data sets

- Japanese GPS data
- numerical prediction data of JMA





# Objectives of GPS Met. at CRL

- **R&D of KSP-VLBI as a water vapor sensor**
  - **real-time**
- **R&D of new method for correcting wet troposphere delay using NWP data**
  - Investigating and considering **Azimuthal Asymmetry of Atmosphere**
  - Evaluating availability of new correction method using NWP data



# Data Analyses

## ■ **Period**

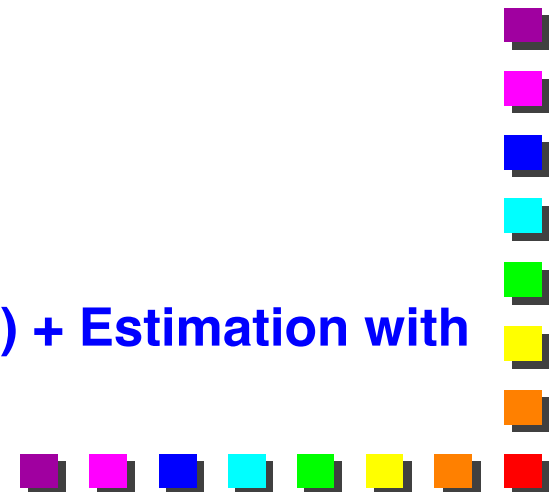
- July 8 - 14, 1996

## ■ **VLBI**

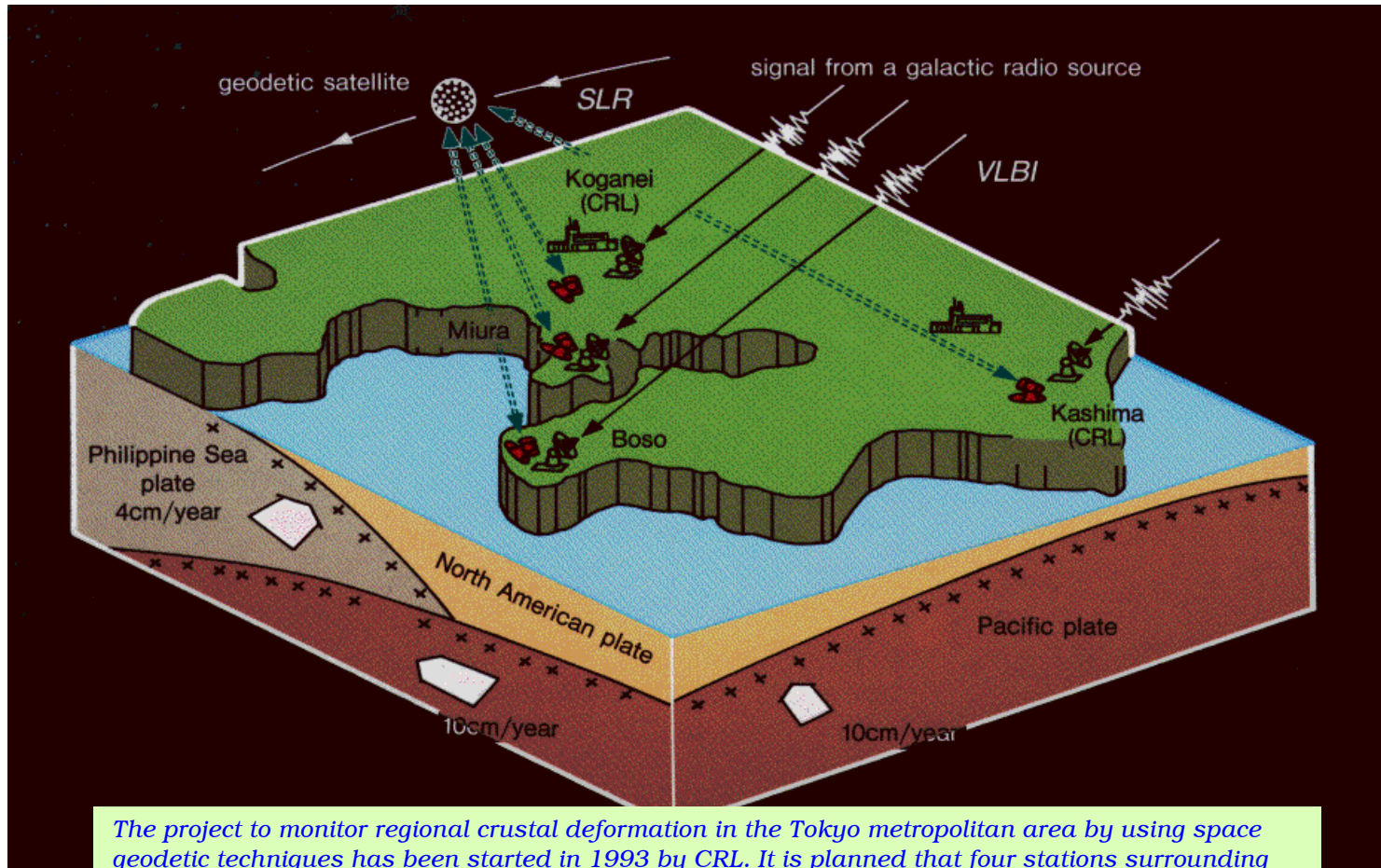
- Data Analysis Software: CALC 8.1 + VLBEST
- Source Coordinates: ICRF94
- Site Coordinates: ITRF94
- Atmospheric Delay: Saastamoinen Model (Dry) + Estimation with 3hrs. interval (Wet)
  - mapping function: MTT mapping function
- Earth Orientation Parameters: EOP90C04 (daily IERS Bulletin values)

## ■ **GPS**

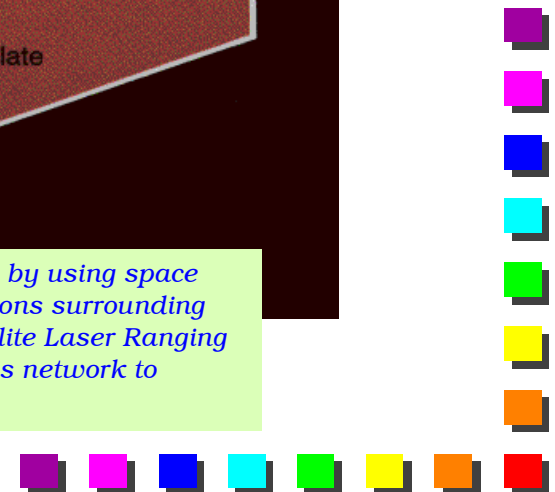
- Data Analysis Software: Bernese 3.4
- Ephemeris: CODE
- Site Coordinates: ITRF94
- Atmospheric Delay : Saastamoinen Model (Dry) + Estimation with 3hrs. interval (Wet)
  - mapping function: Saastamoinen Model



# KSP geodetic network



*The project to monitor regional crustal deformation in the Tokyo metropolitan area by using space geodetic techniques has been started in 1993 by CRL. It is planned that four stations surrounding Tokyo are equipped with both Very Long Baseline Interferometry (VLBI) and Satellite Laser Ranging (SLR) facilities. Daily routine geodetic VLBI/SLR observations are performed in this network to detect precursory crustal movement that may occur pre-seismically.*



# GPS and VLBI Observations at CRL



*Koganei*

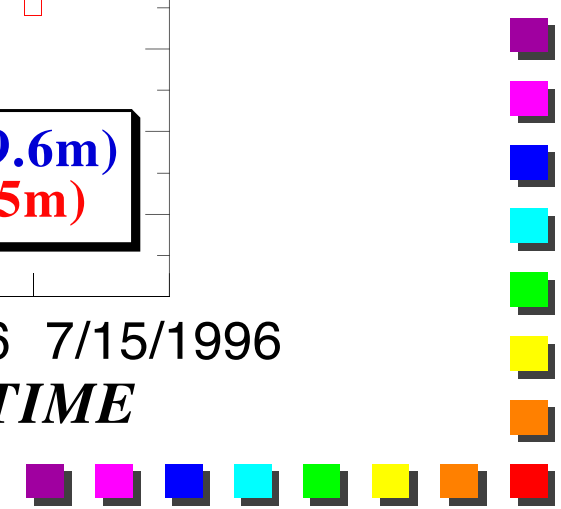
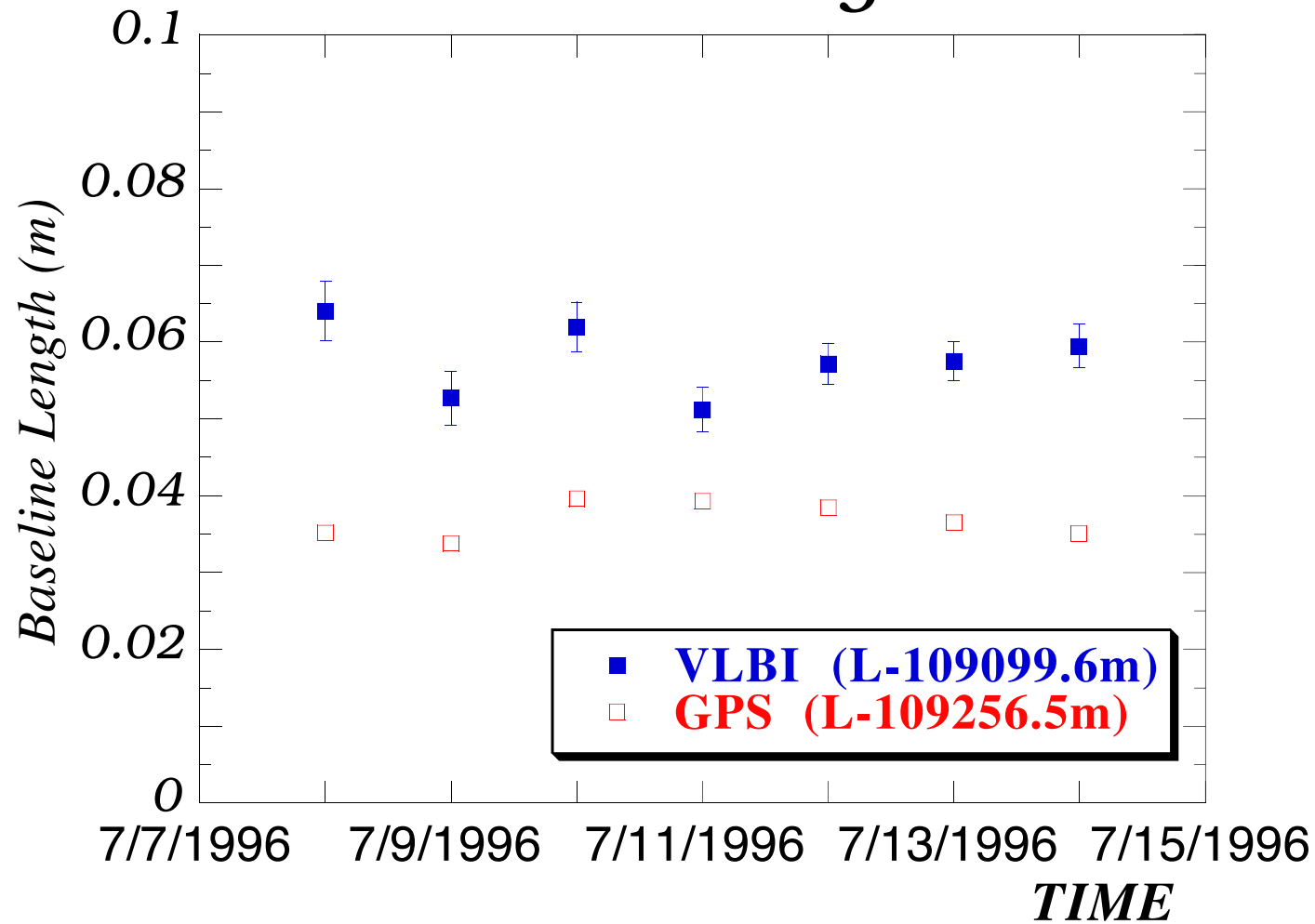


*Kashima*

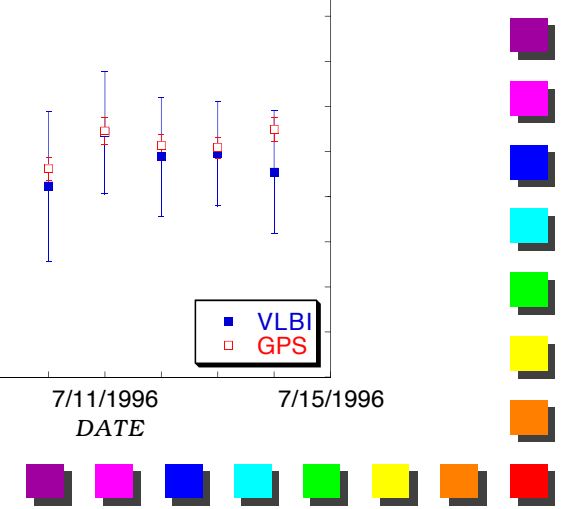
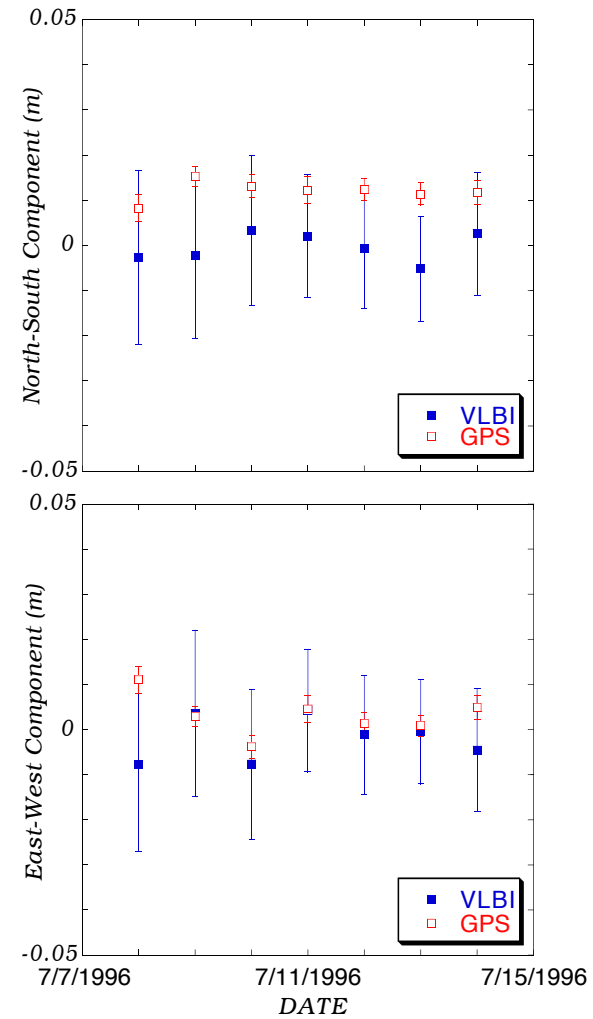
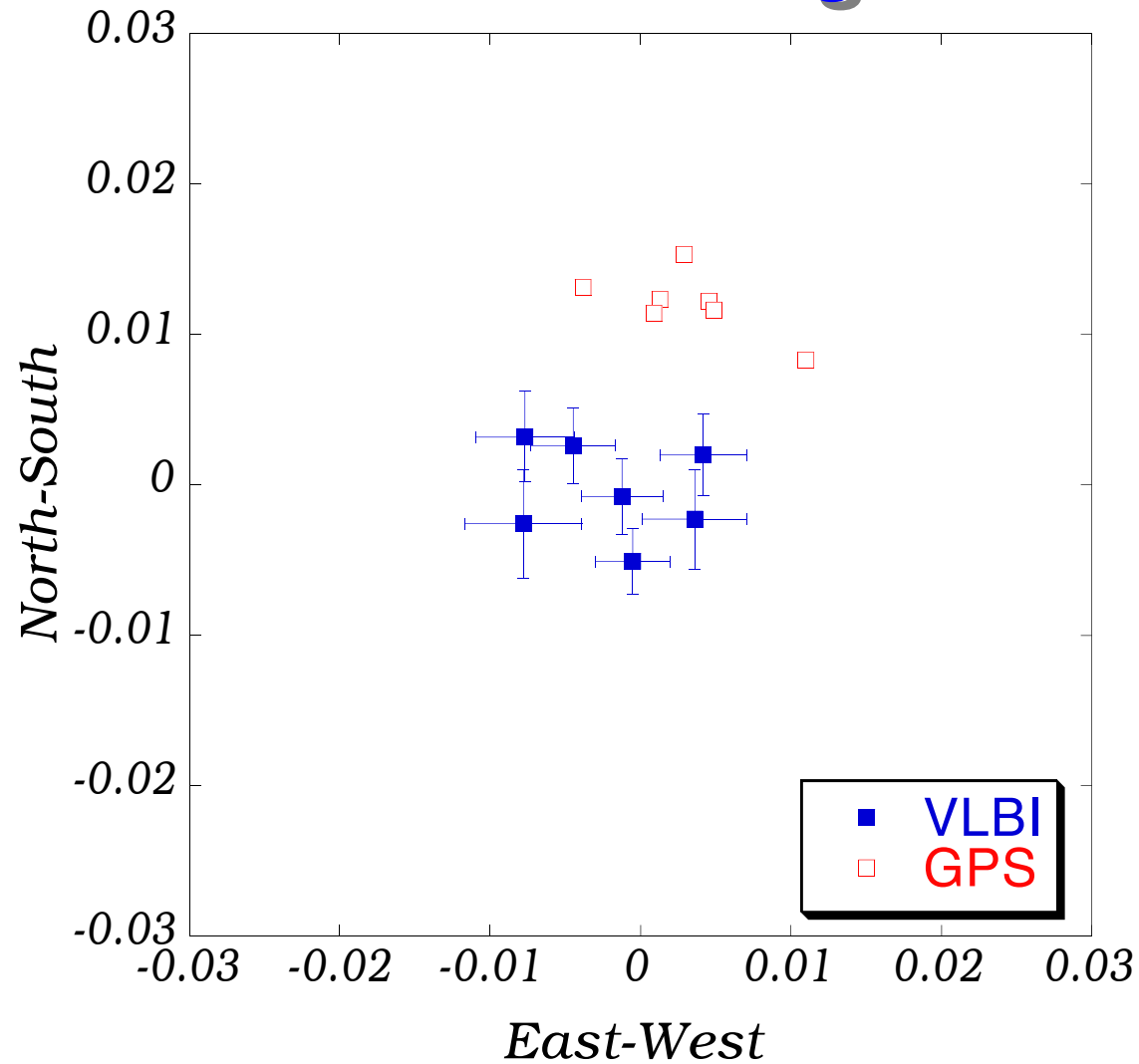


# Baseline Length

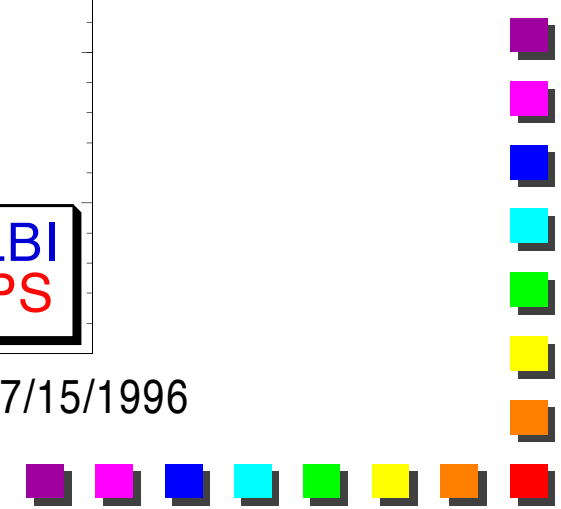
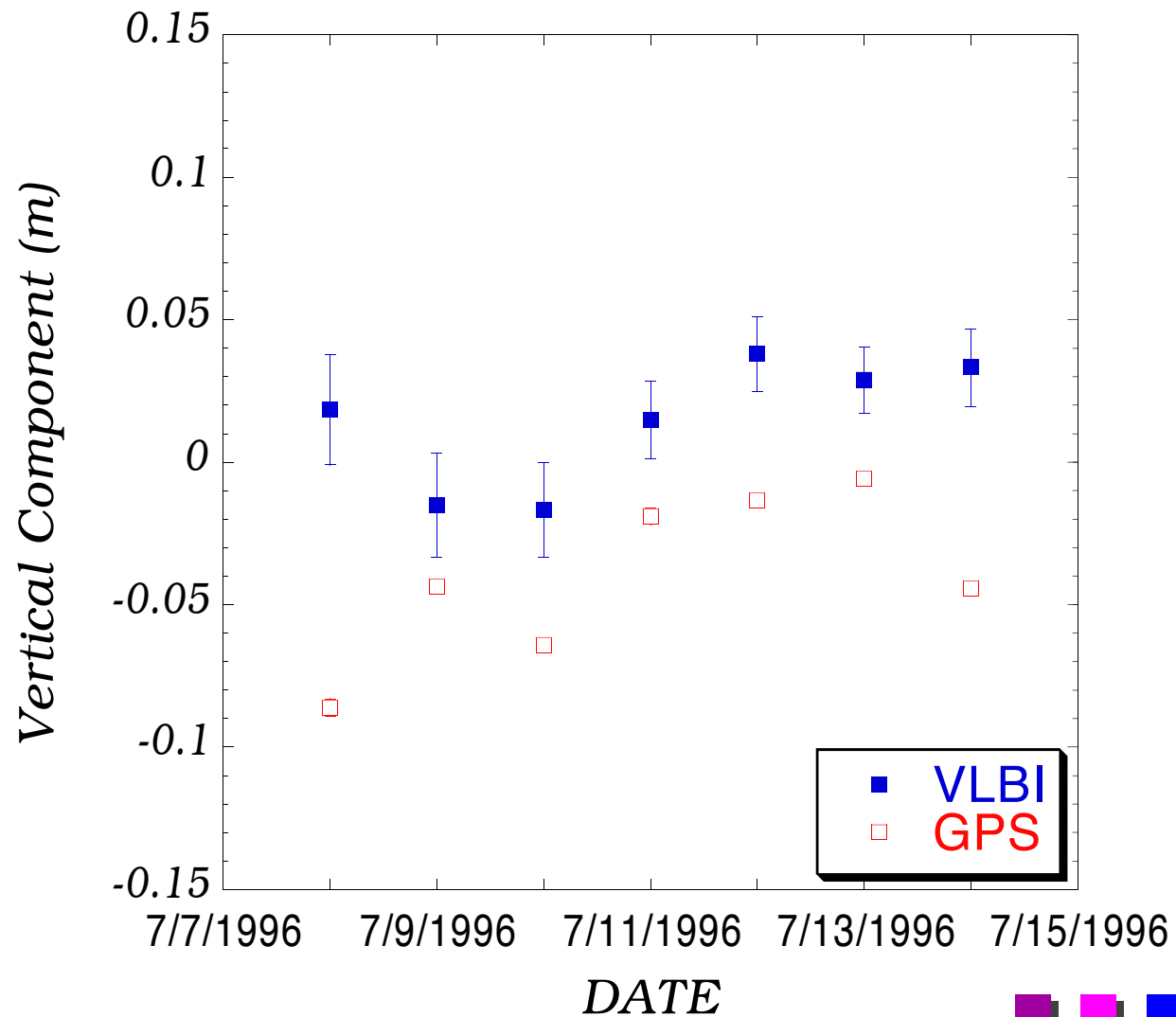
*Kashima - Koganei*

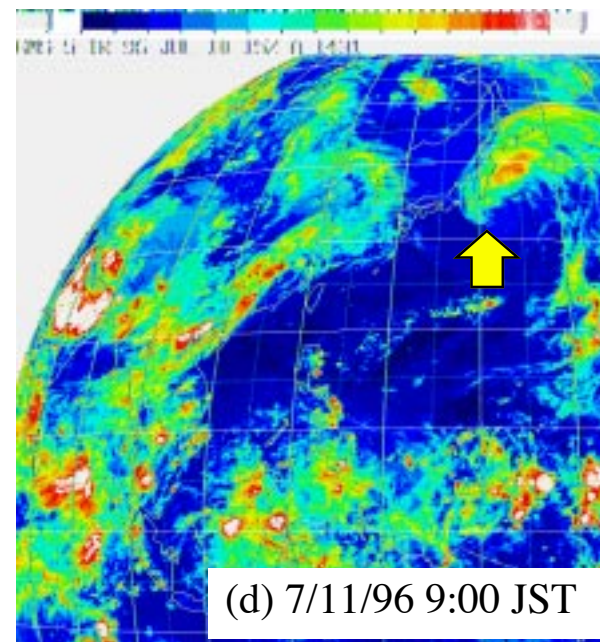
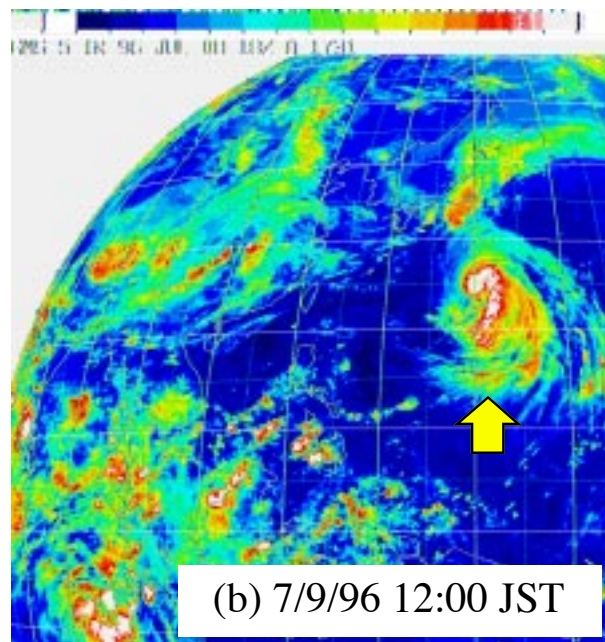
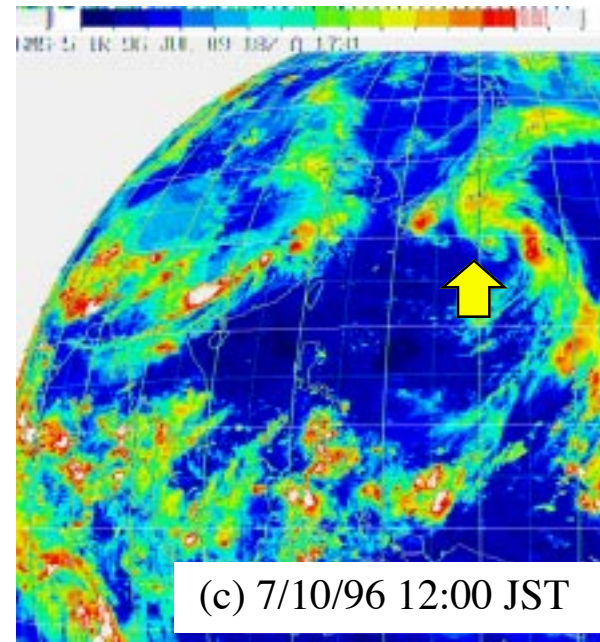
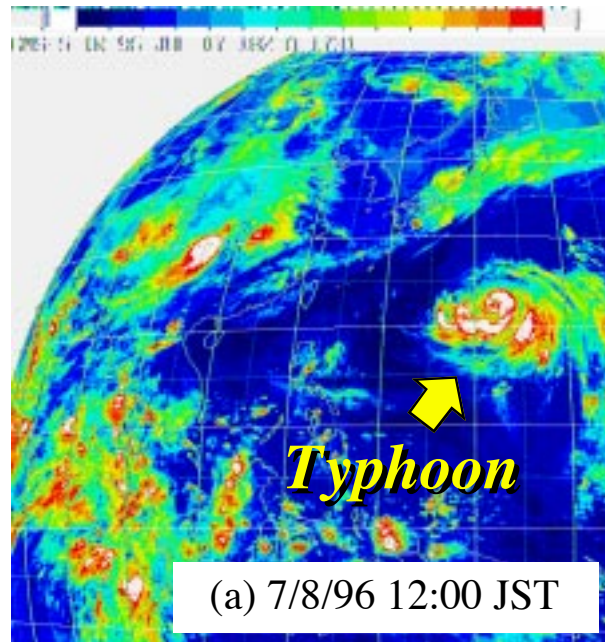


# Horizontal Component of Koganei Site



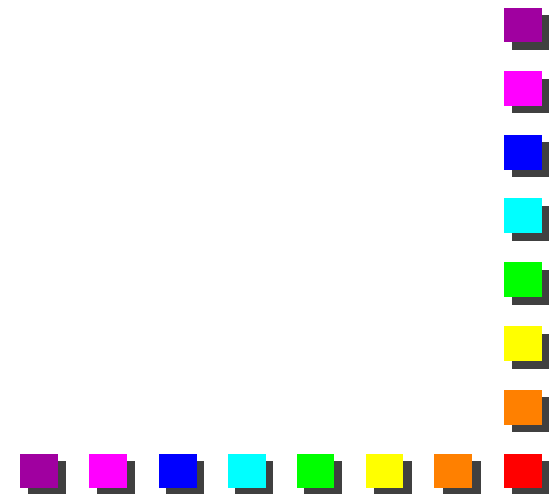
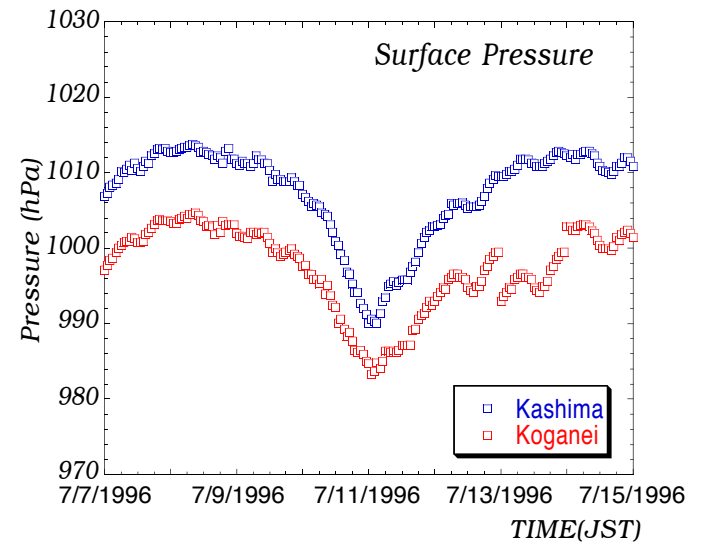
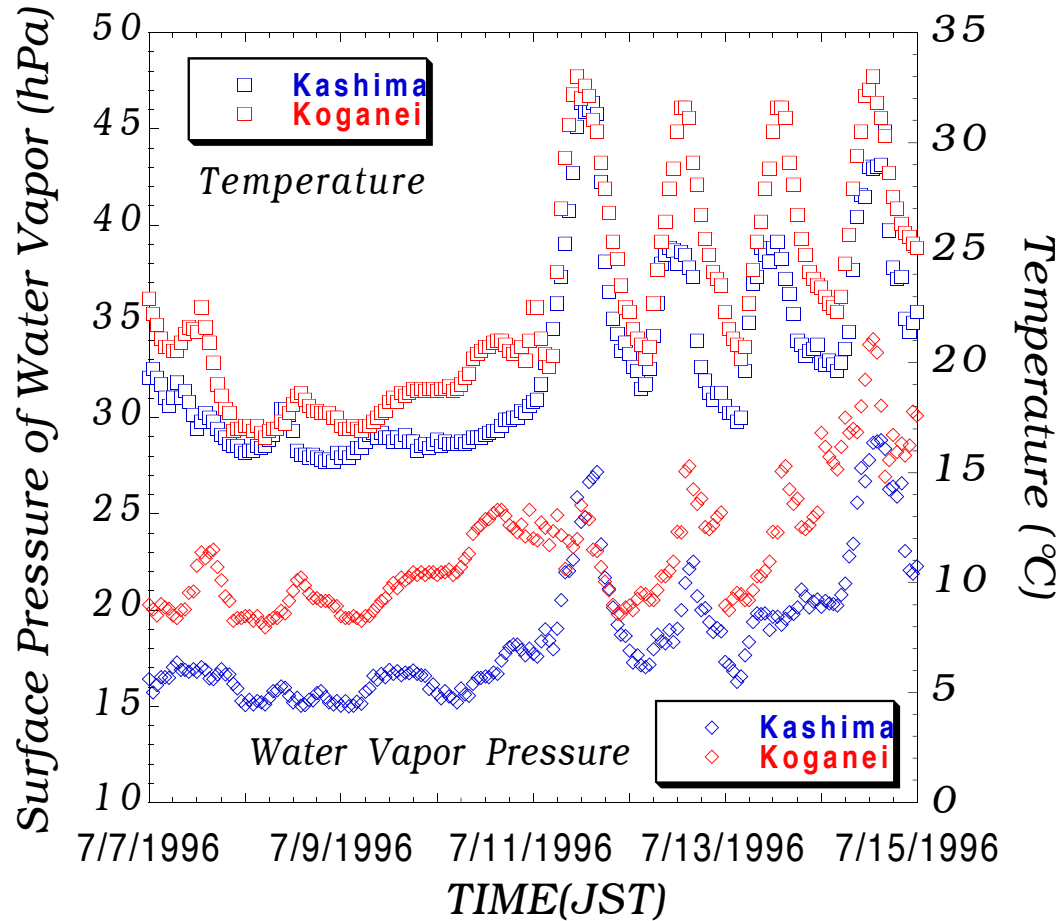
# Vertical Component of Koganei Site



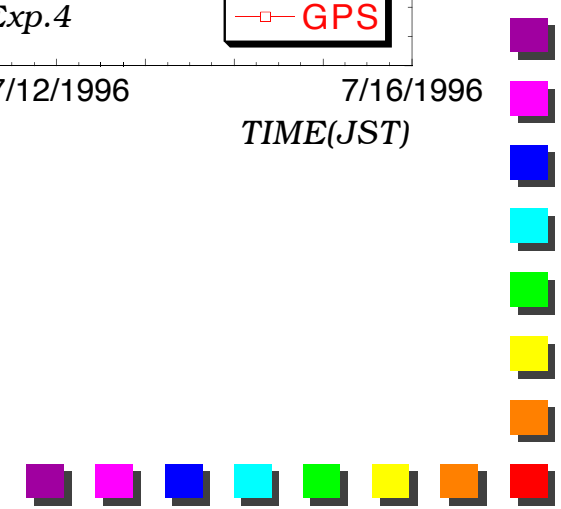
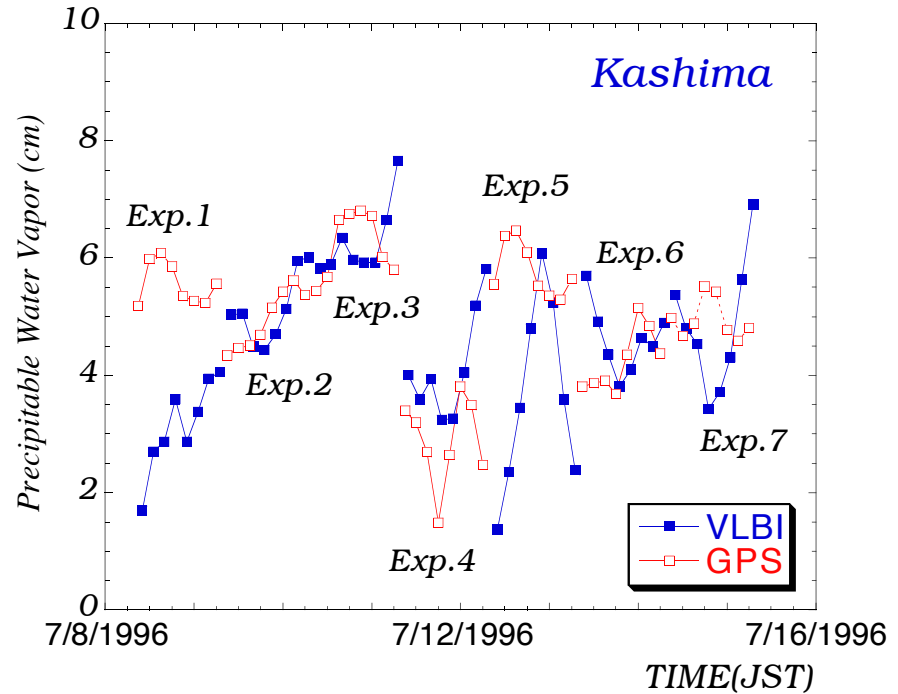
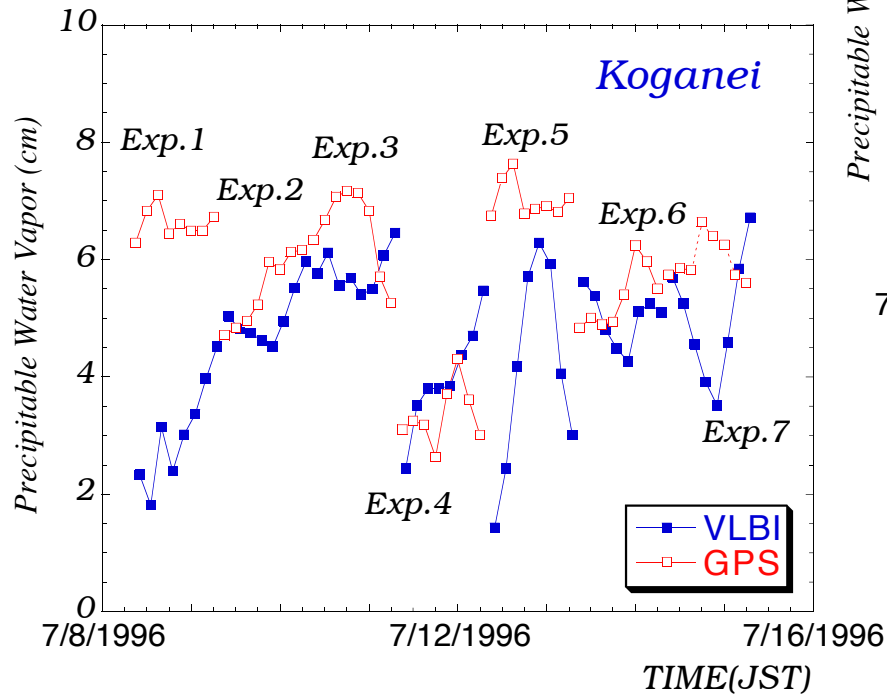
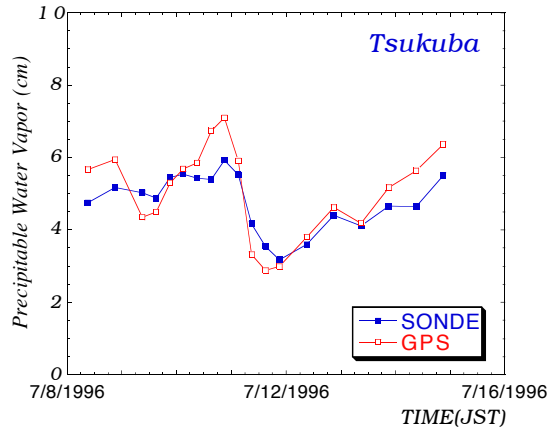




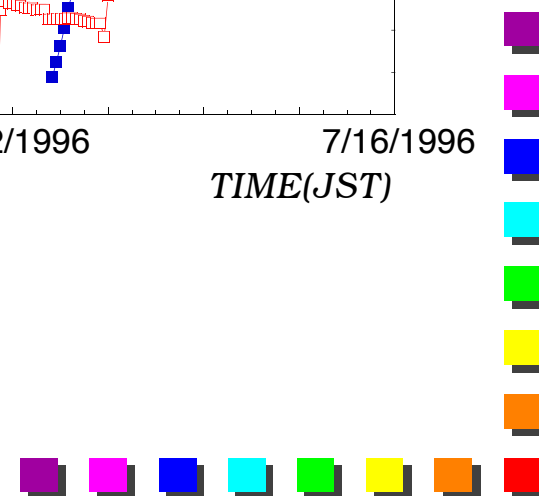
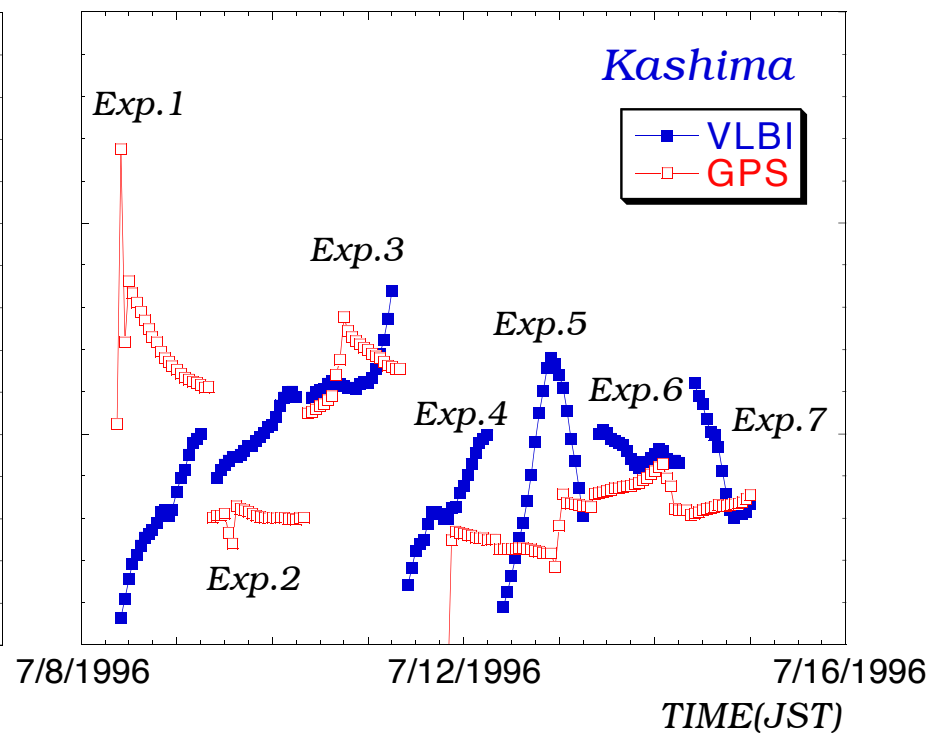
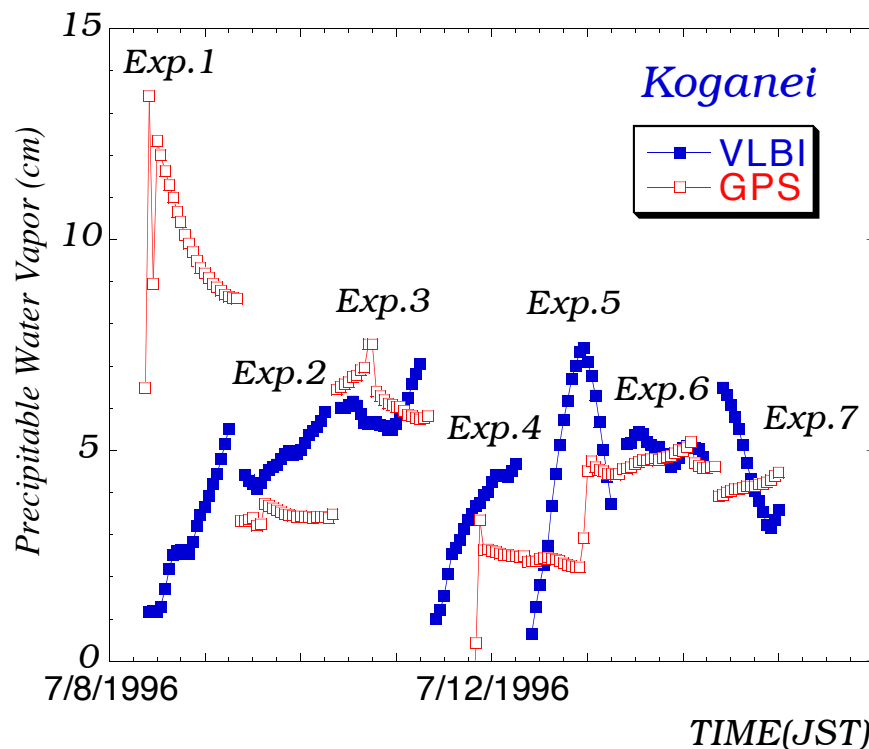
# Surface Meteorology



# PWV estimated by GPS and VLBI



# PWV estimated by GPS and VLBI (1 hour interval)



# Simulation of Positioning Error due to Azimuthal Asymmetry of Wet Troposphere Delay

