

Fast ray-tracing for real-time positioning applications using numerical weather models



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Overview



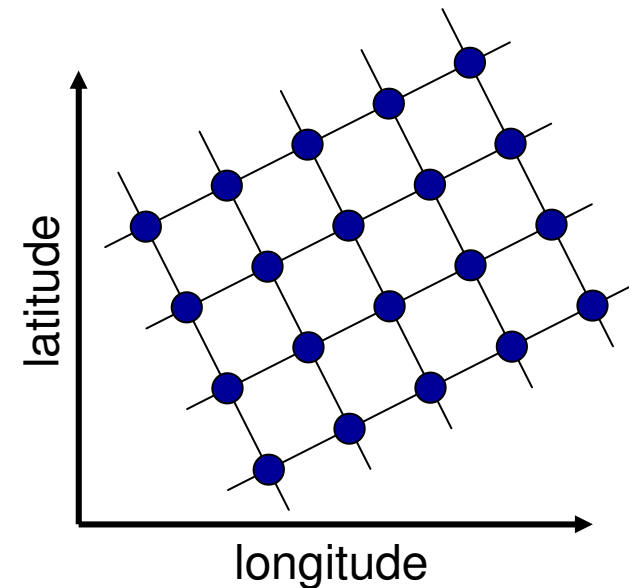
- 1. Numerical weather models (NWM) from JMA**
- 2. Fast ray-tracing through numerical weather models (NMW)**
- 3. Examples**
- 4. KARATS**
- 5. Outlook**

NWM from JMA



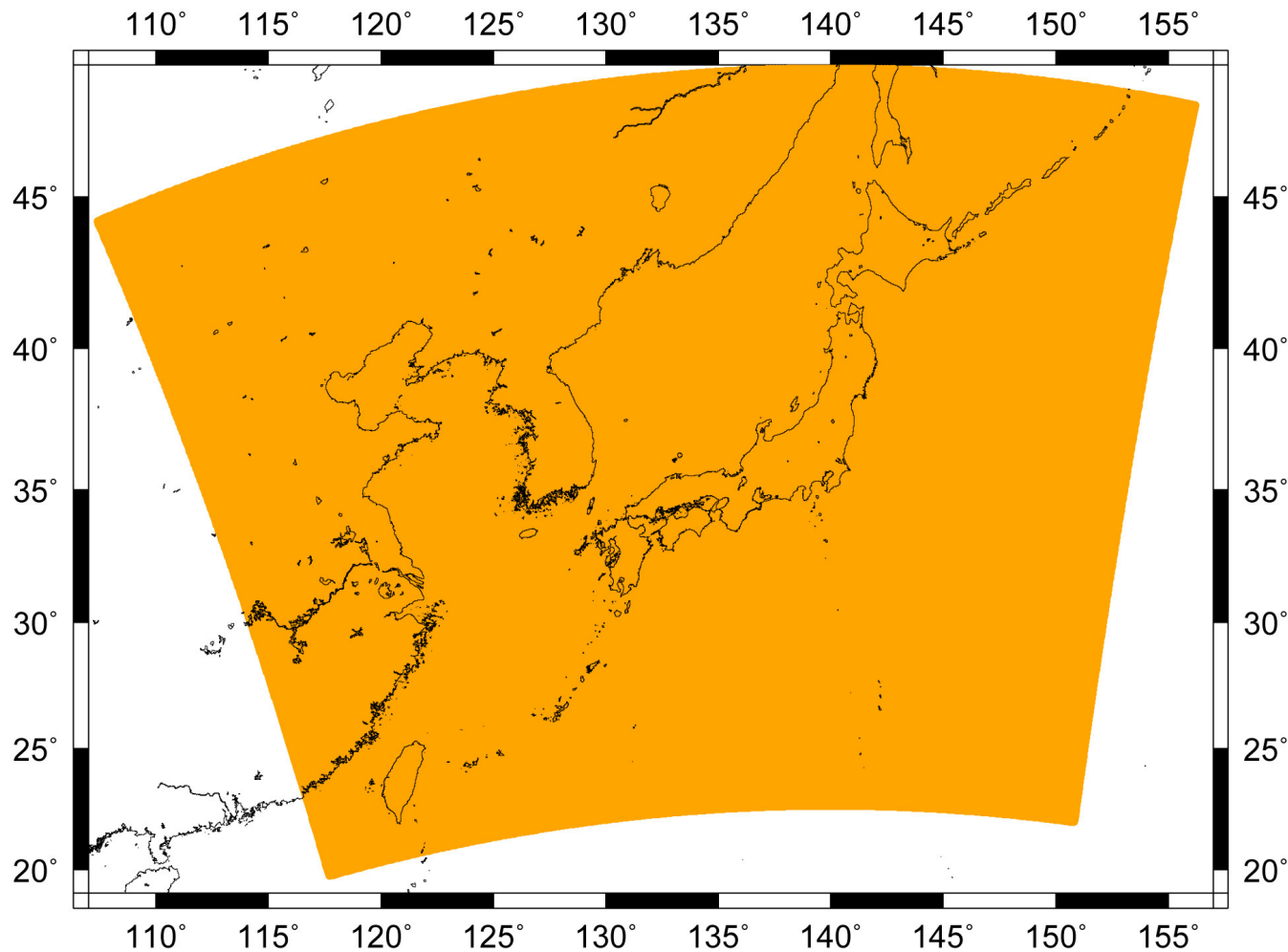
■ JMA provides information about

- Pressure (**P**), temperature (**T**), rel. humidity (which allows to calculate partial pressure of water vapour – **P_v**)
- Refractivity **N** can be used to compute troposphere delay
- Raster width 10km (≈ 0.1 deg)
- 21 pressure levels up to 10mb
- Time resolution: 3 hrs
- BUT:
 - * grid-spacing is not constant in geographical system
 - * Data given at isobaric levels



→ **Re-gridding to permit efficient ray-tracing computations**

Covered region



Boundaries

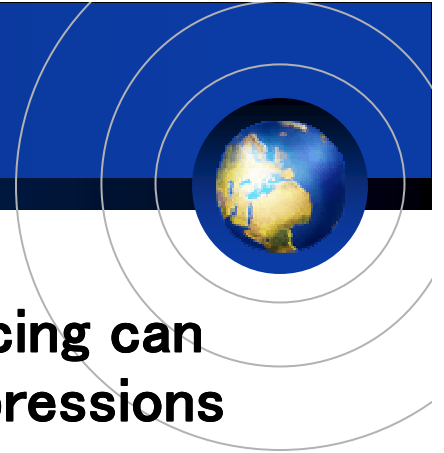
$$\lambda = [107^\circ, 157^\circ]$$

$$\phi = [19^\circ, 49^\circ]$$

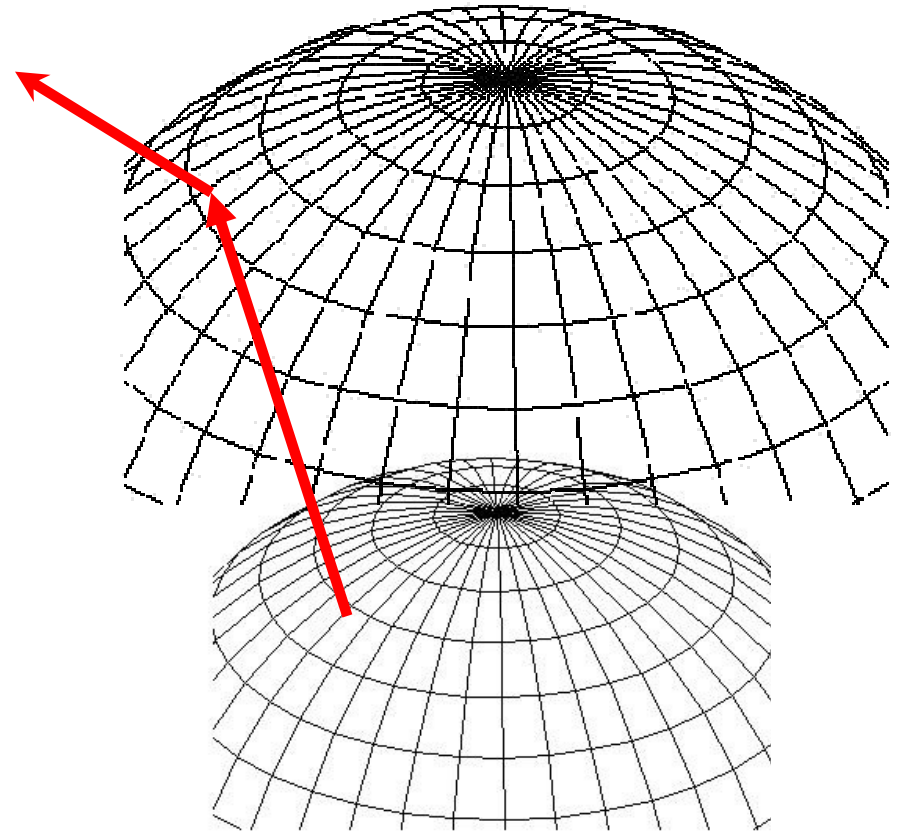
Countries covered:

- Japan (100%)
- Korea (100%)
- Taiwan (100%)
- China (partly)

Ray-tracing



- **Once the data slices have been prepared ray-tracing can be carried out very efficiently using analytical expressions for the calculation of**
 - 3D – intersection points with the slices
 - Delay inside the segments
 - Bending angle due to refractivity gradients
- **Output of total delay, bending angle and ground refractivity**





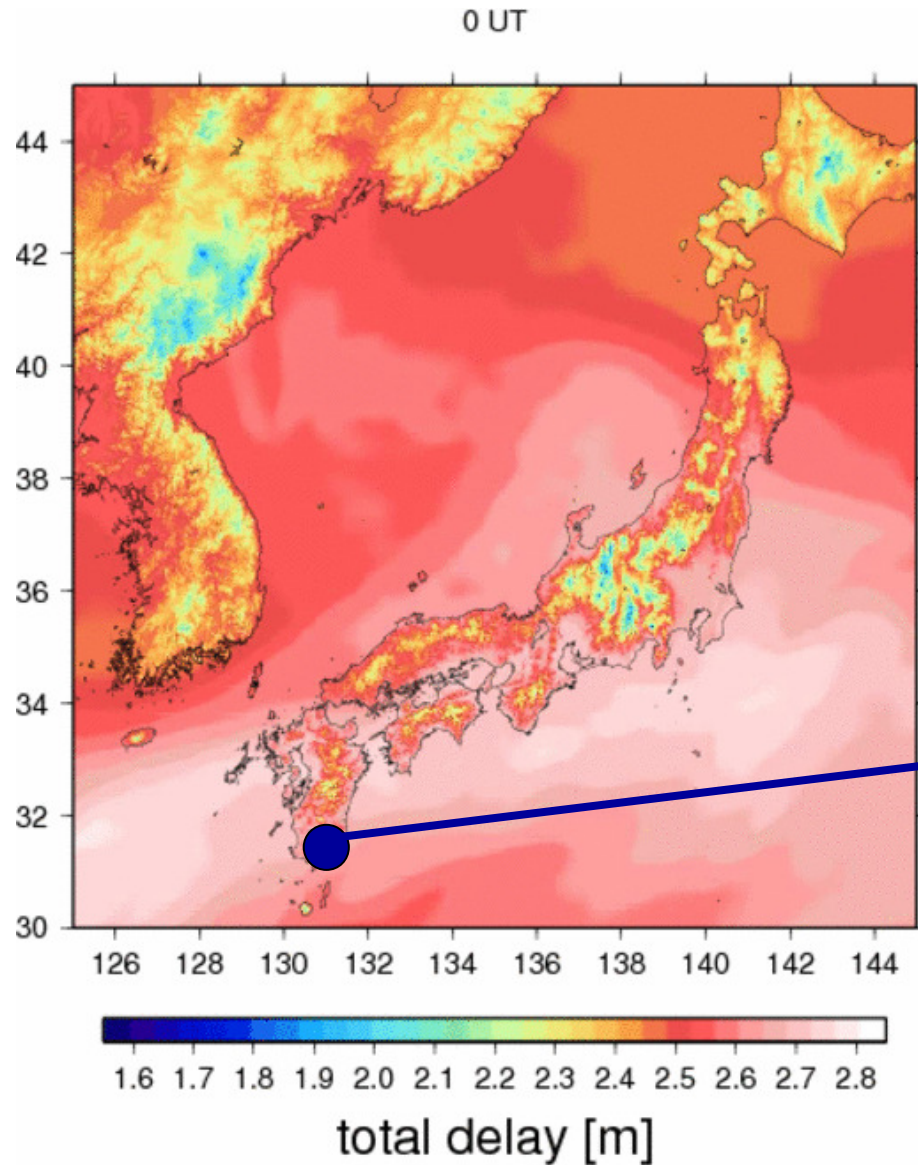
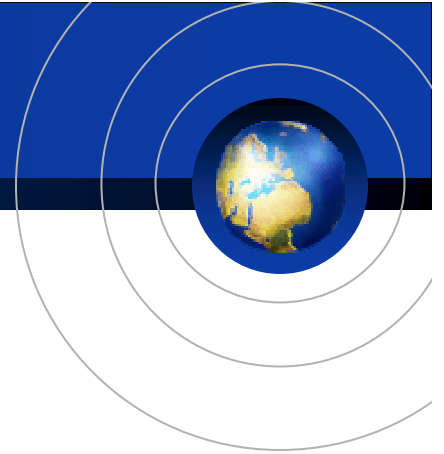
Performance and Results

Speed and data through-put



- **Preparing the data-set (computation of the slices)**
 - computation takes about 30 sec./data-set, has to be done only once, thereafter the slices are stored in binary format for ray-tracing
 - 1 day (i.e. 8 epochs) \approx 800 MB
 - values are represented by integer integer numbers (2 bytes)
- **Ray-tracing through-put (on Pentium D, 3GHz)**
 - About 3 sec. for reading slices
 - **1200 observations / sec. !!!**

Results



July 21, 2006:

- total troposphere zenith delay
- computed from ray-tracing
- complex weather situation

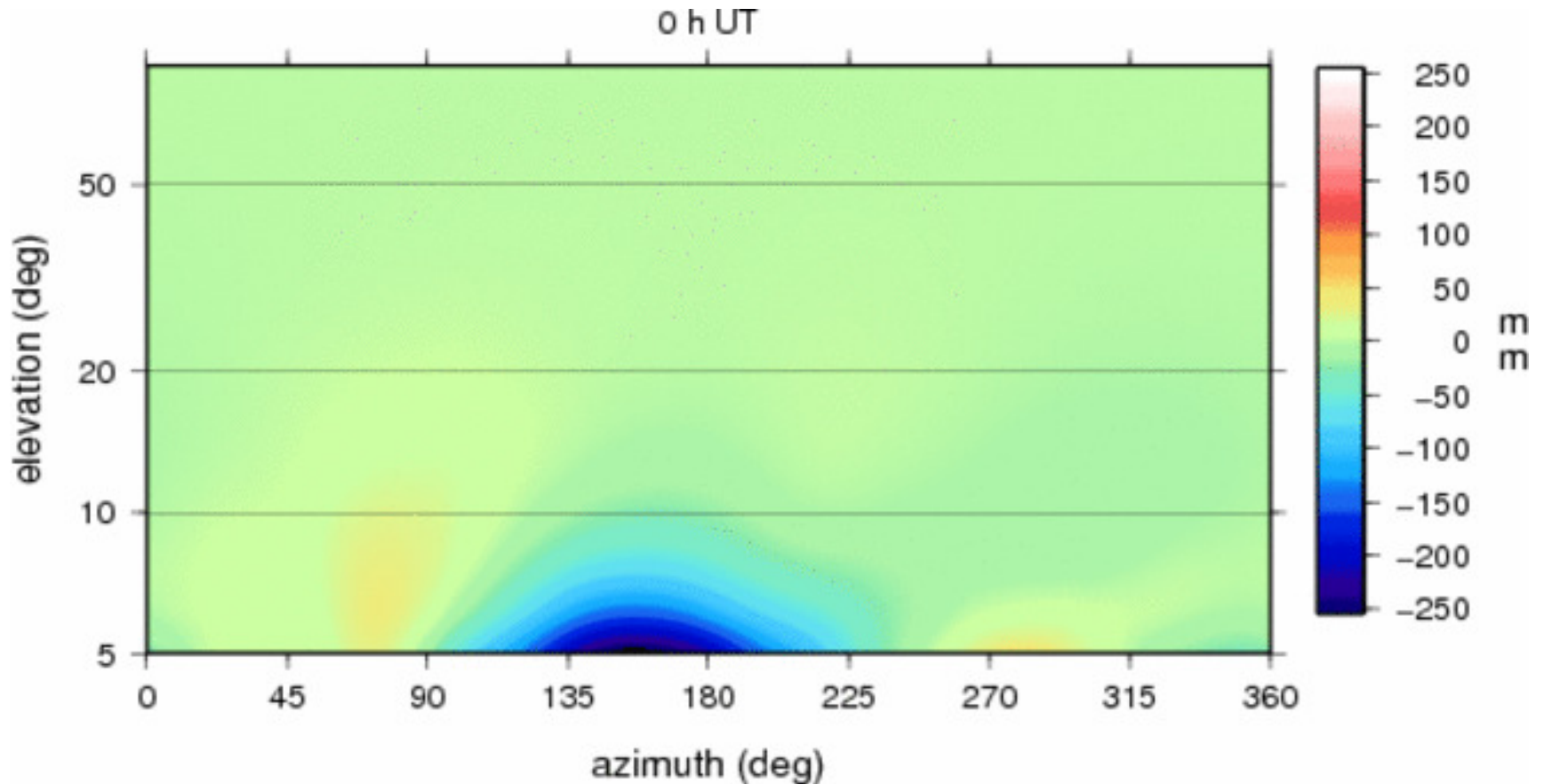
Example:
AIRA (鹿児島)

Results (contd.)



July 21, 2006: Aira

Resid. delay (i.e. the delay excess due to the neglect of asymmetry)

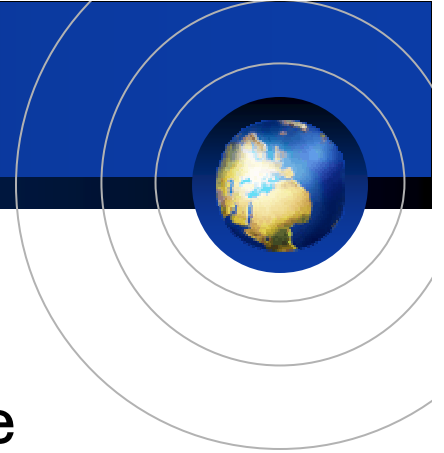


Improvement of (GPS) positions



- **Computed PPP solution using BERNESE 5.0 for station AIRA on July 21st, 2006**
- **First analysis run:**
 - RINEX obs, IGS final clocks + orbits
 - Estimated: station coordinates, clock, troposphere (Niell MF)
- **Second analysis run:**
 - **Troposphere reduced RINEX** file (RINEX handling by GPSTk)
 - IGS final clocks + orbits
 - Estimated: station coordinates, clock, troposphere ($1/\sin(e)$)

Improvement of (GPS) positions ctd.



■ Results:

- Ambiguities can be resolved more reliable
- (more than) 99% of total troposphere are removed due to ray-tracing (estimated troposphere from approach two shows values < 1 cm)
- Troposphere free solution agrees well (difference < 2 mm) with daily GEONET solution, whereas the first solution has larger differences (> 4 mm)
- Clock estimates of both strategies are identical
- Asymmetric contributions are completely removed (verified by estimation of gradients, too)

Improvement of (GPS) positions ctd.



- **Advantage for the user:**

- A simple mapping function ($1/\sin(e)$) can be used to catch the remaining troposphere delay and results are improved, too.

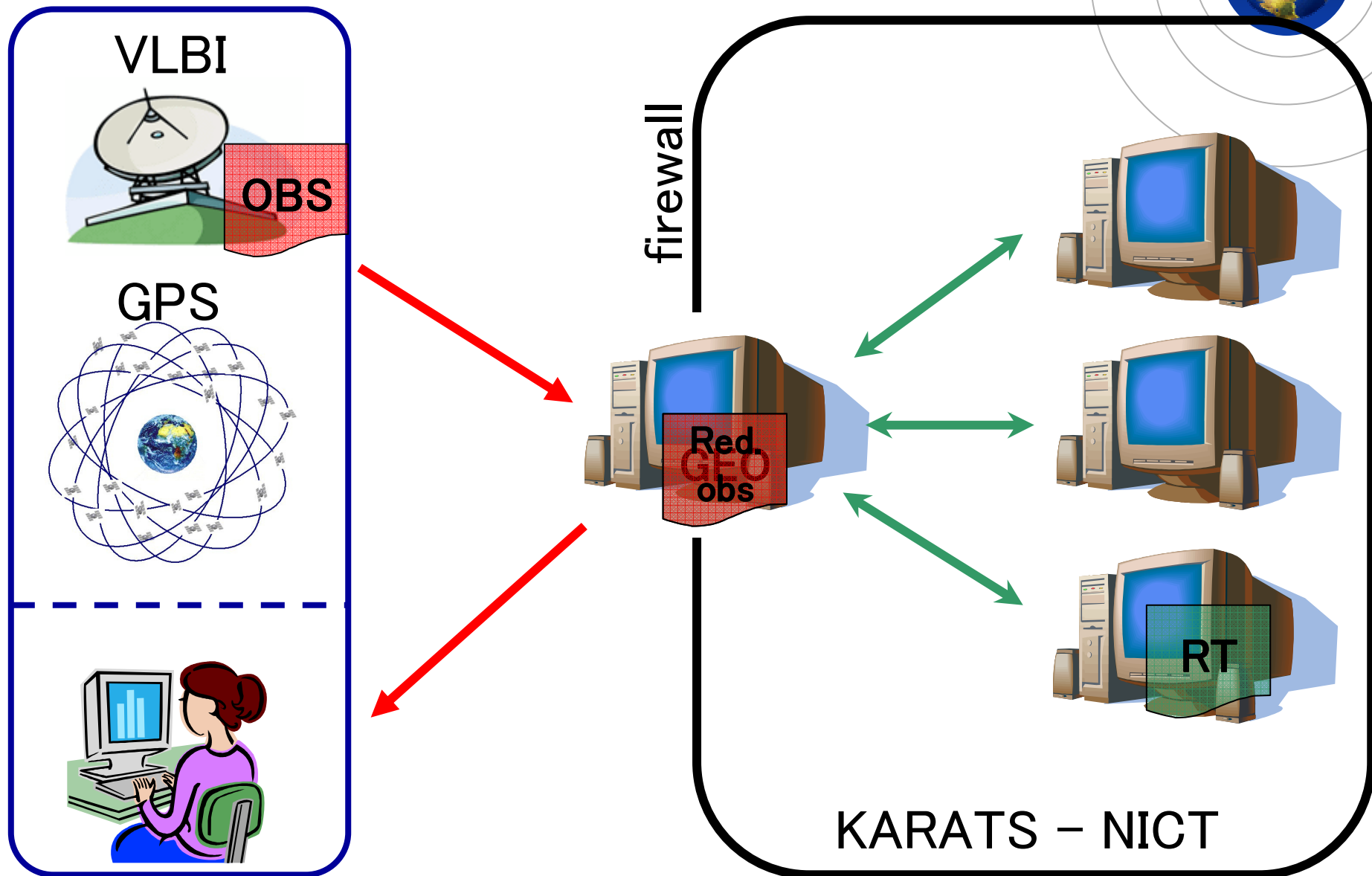
- **But:**

- Needs some changes of common analysis strategy

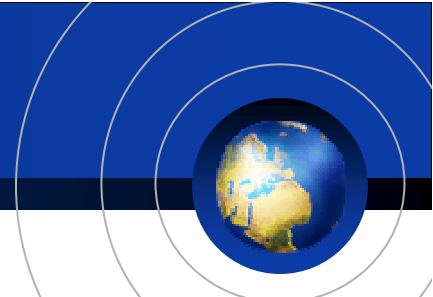
- **Currently:**

- rigorous tests covering longer time-spans and including more stations to obtain significant values of improvements

KARATS processing chain



Planned improvements

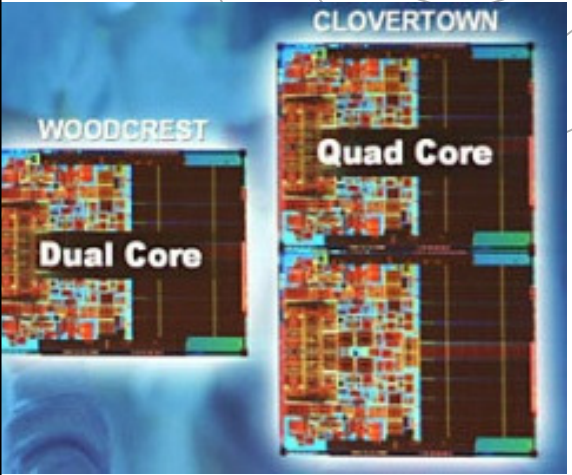


- Optimizing code for dual/multi-core architectures (partially done), will be implemented using **OPENMP™**
- Making usage of parallel processing strategies
- End of year goal is to process all 13000 samples using 1 Hz sampling rate on 4 quad-core machines



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allows to
process in real-time
by 4 quad-core

KAshima Ray-tracing Service (KARATS)



Post-processing mode

- Planned to be operational within the 2nd half of 2007
- Free of charge
- User uploads observation files (GPS, VLBI ...)
- Planned formats to be supported
 - GPS: RINEX
 - VLBI: MK3, FITS (?)
 - Plain text: user provides only geometry
- Expected turn-around time < 1 min / file
- Time coverage of data: TBD

CONTACT



KAshima
RAY-
Tracing
Service
NiCT

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Acknowledgements



Thank you for your attention !



行政法人 日本学術振興会
an Society for the Promotion of Science

NiCT  **Kashima**