Ray-traced tropospheric total slant delays for GNSS processing

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Content

1. Ray-tracing
2. Baseline solutions / GEONET
3. Precise point positioning (PPP)
4. Conclusions / outlook

KAshima Ray-tracing Tools (KARAT)

A set of programs written in C++, which

- ***handle NWM from Japan Meteorological Agency (JMA)***
- ***read RINEX data and compute observing geometry using orbit information***
- ***ray-trace each observation and correct L1, L2, P1, P2 and C/A for total troposphere delay***
- ***support multi-processor/multi-core architectures using OpenMP™***

KARAT ray-tracing modes

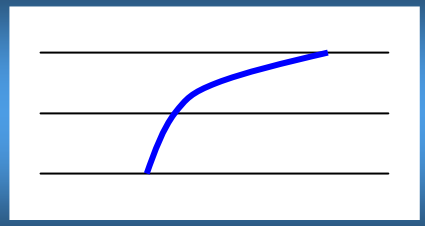
- SPEED +

+ ACCURACY -

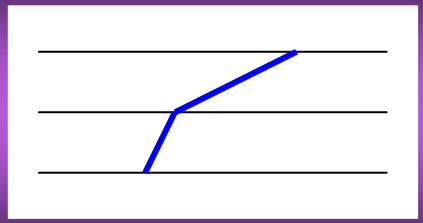
3D Eikonal solver (gives also out-of- plane component)

$$\frac{d}{ds}\left[n(\vec{r})\frac{d\vec{r}}{ds} \right] = \nabla n(\vec{r})$$

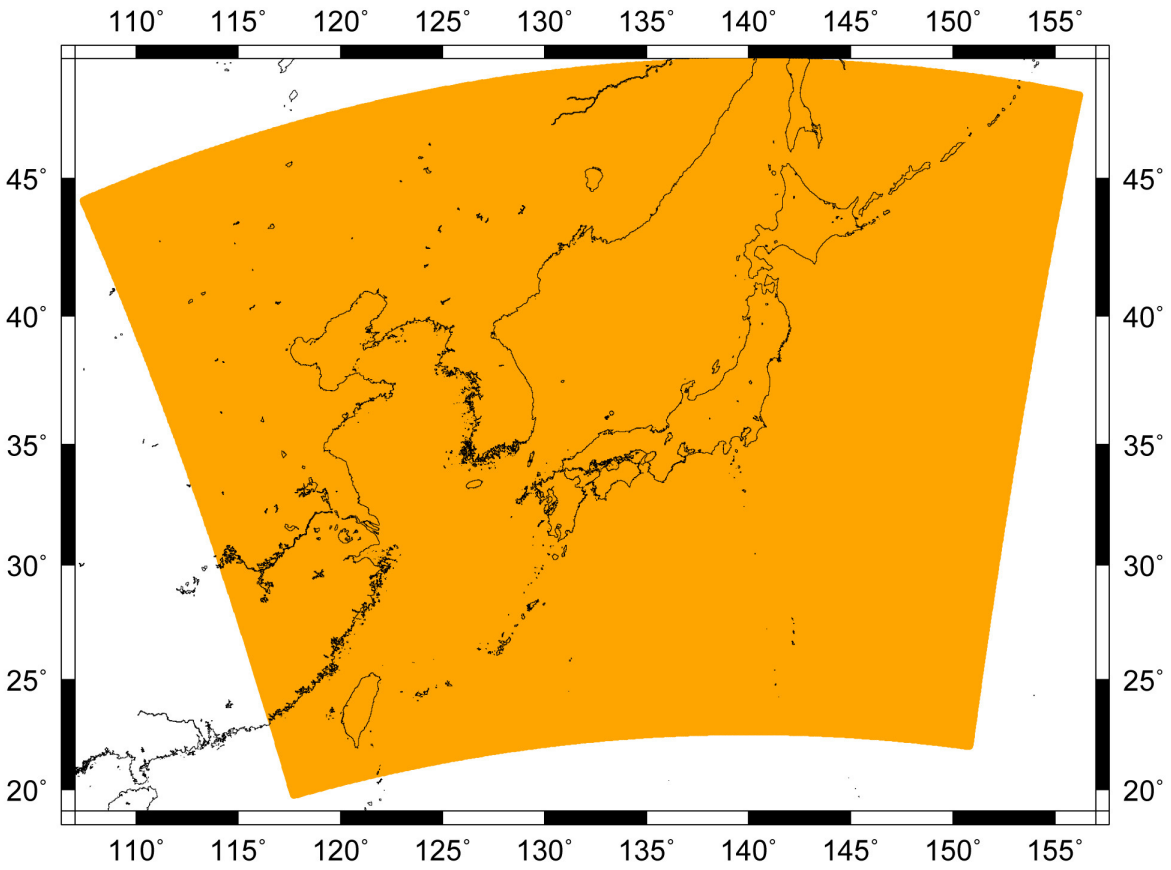
Thayer approx. (bending between layers, plane of const. azimuth)



Piece-wise linear (bending at layer, plane of const. azimuth)



JMA meso-scale NWM

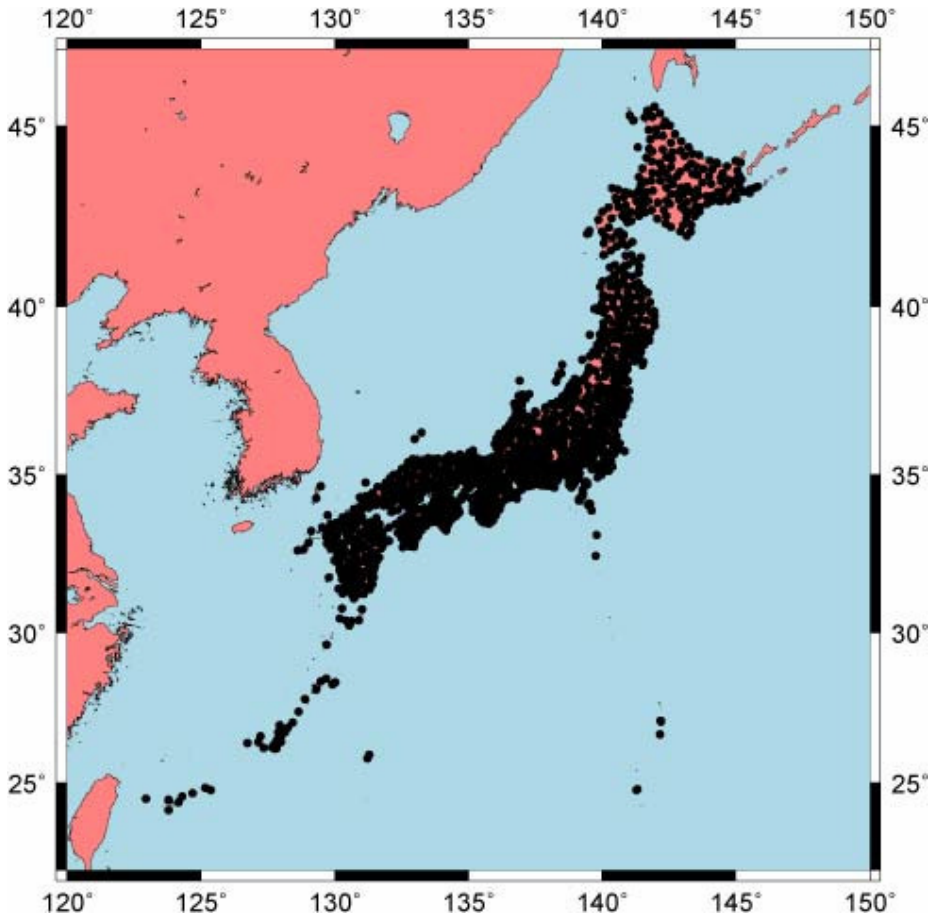


Horiz. Res.:
0.1 x 0.1 deg.

Time res.:
3hrs

Countries covered:
- **Japan (100%)**
- **Korea (100%)**
- **Taiwan (100%)**
- **China (partly)**

GEONET receiver network

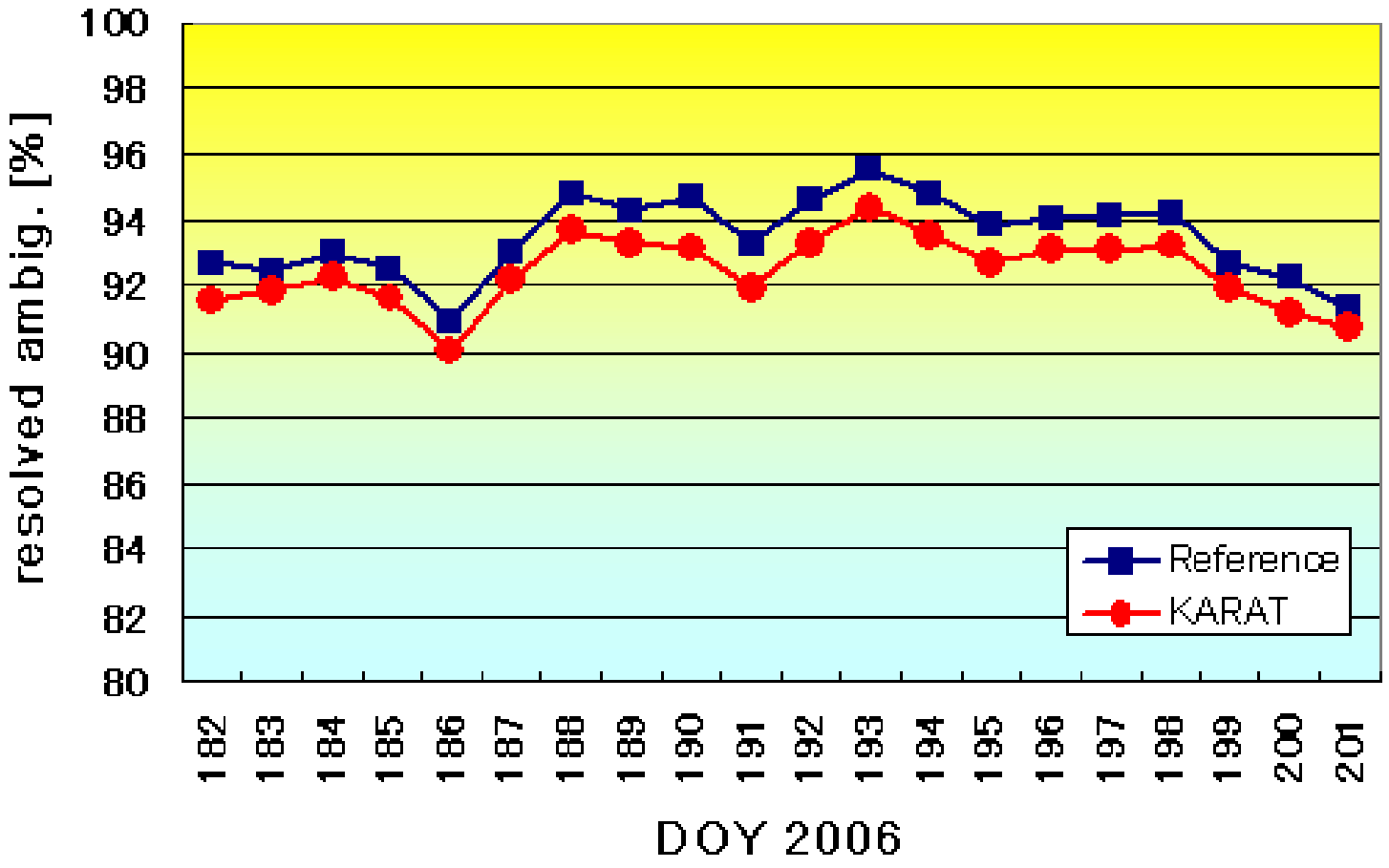


~1360 receivers within Japan, operated and analyzed routinely by the Geographical Survey Institute (GSI)

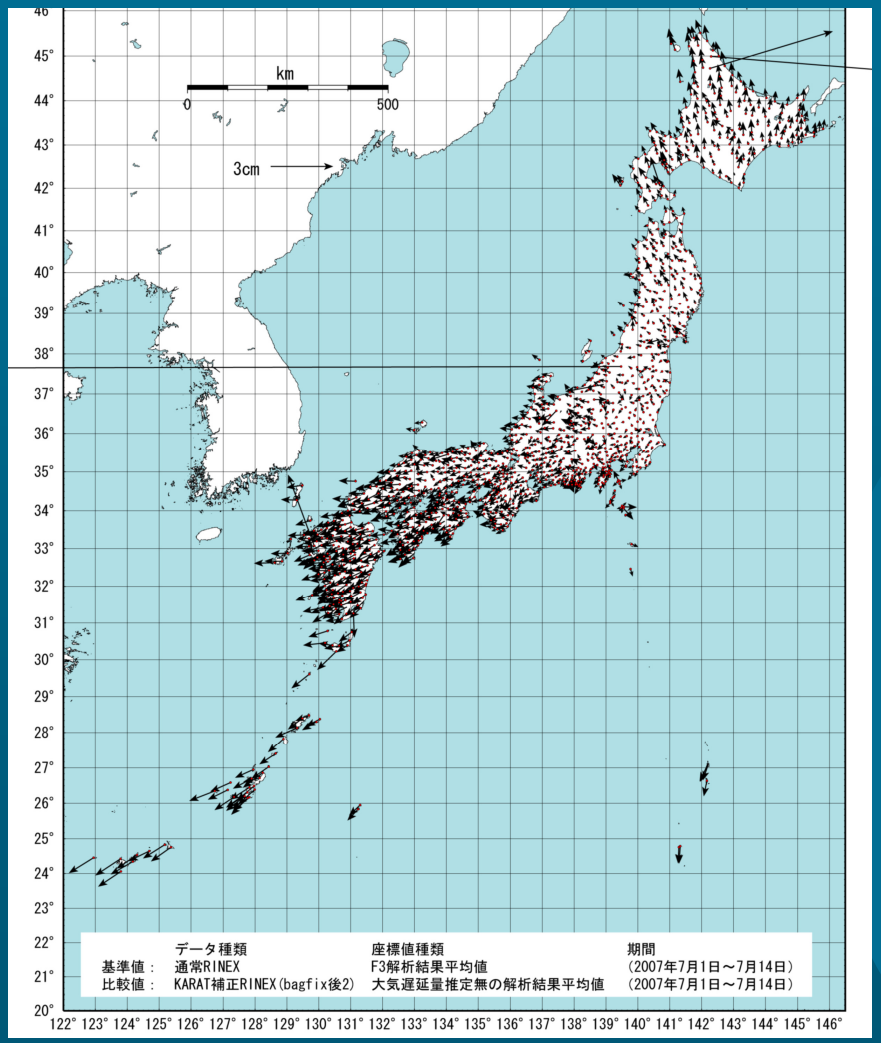
Processing strategy

- Data from July 1st, 2006 – August 31st, 2006
- ~ 1.6 billion observations (~ 83000 RINEX files), ray-traced in 7 days on 5 PCs
- Reduced RINEX files were analyzed with GSI's PC cluster running BERNESE 5.0
- Troposphere estimation + a-priori models turned OFF in all modules
- Comparison to reference solution (orig. RINEX, NMF + gradients)

Ambiguity resolution performance

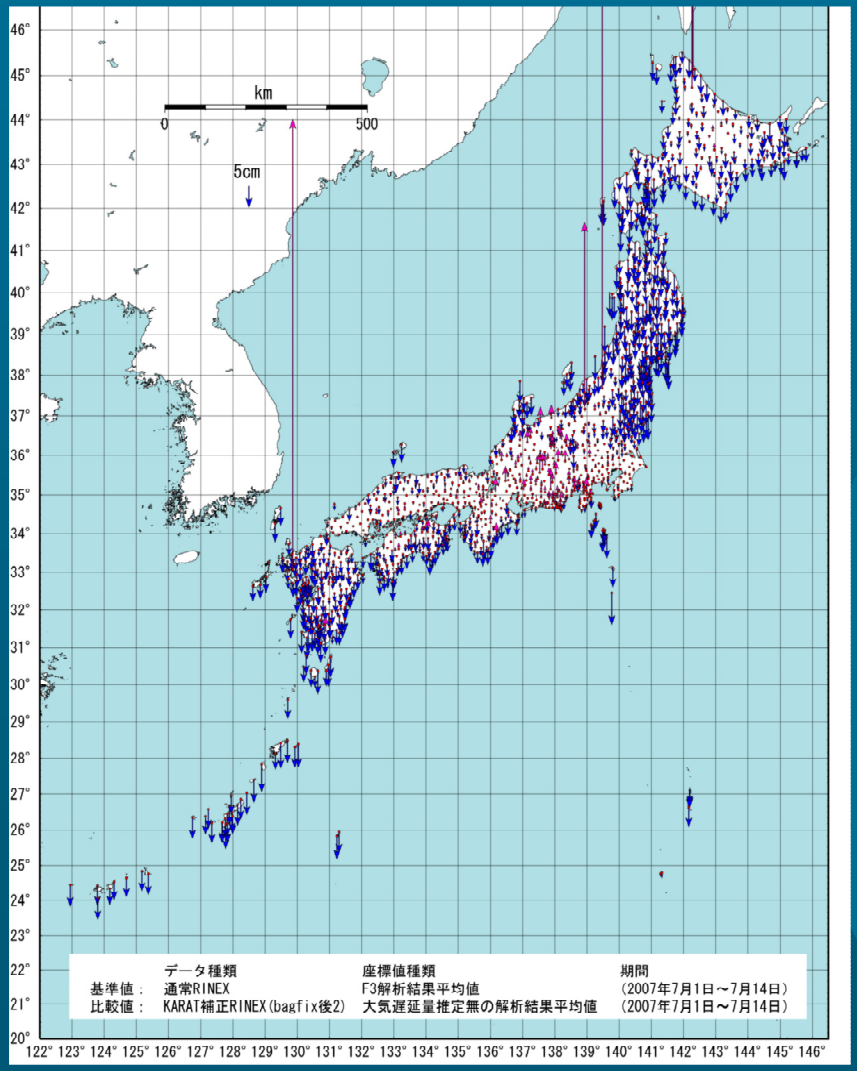


Horizontal diff. (w.r.t reference sol.)



Mean differences
July 1st –
July 14th, 2006

Vertical diff. (w.r.t reference sol.)



Mean differences
July 1st –
July 14th, 2006

PPP + resid. troposphere estimation

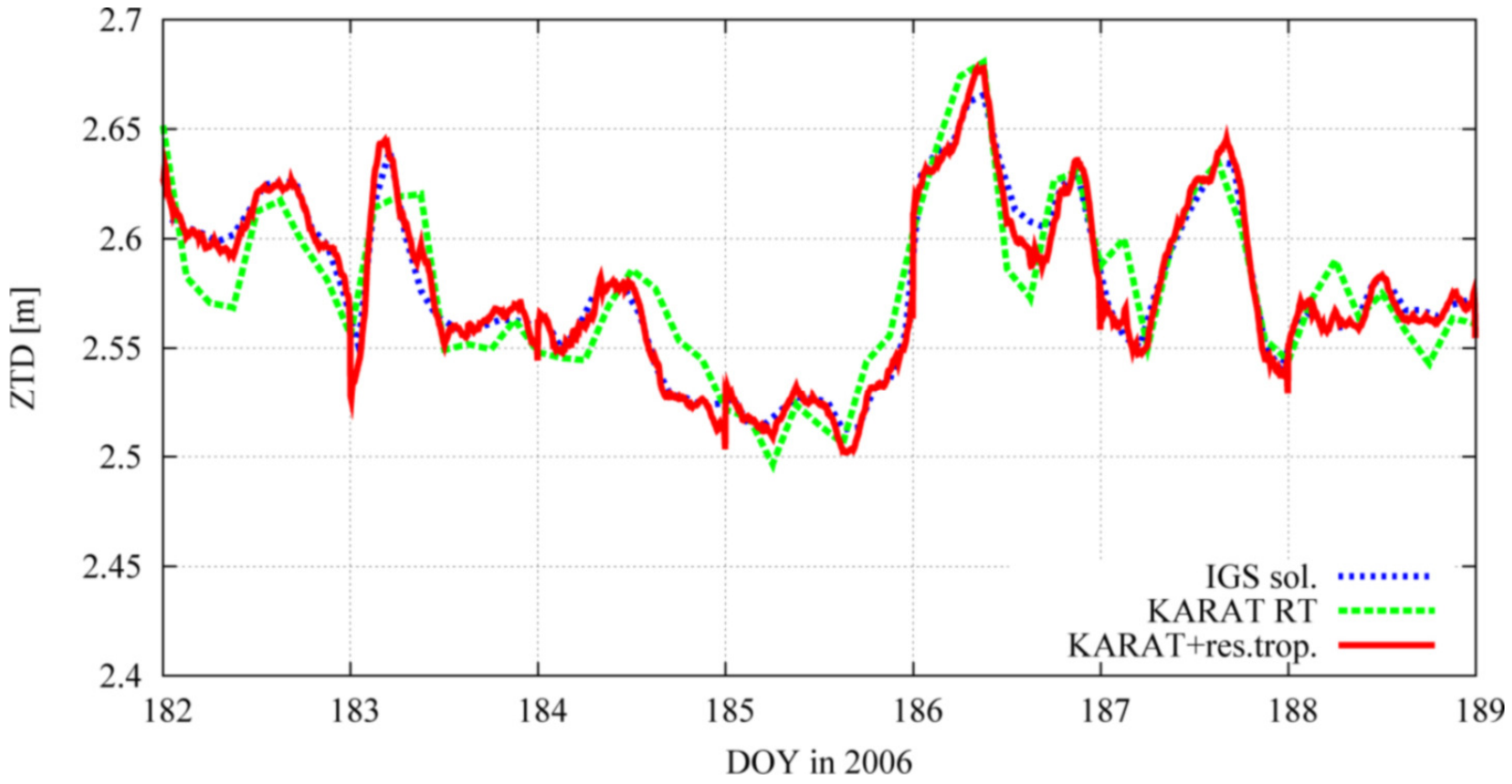
- GPSTOOLS V0.6.3
- TSKB, July 1st – July 14th, 2006
- Kalman filter (Fwd.+Bwd.)
- 5 min interv., 24h, +/- 12 h overlap
- Cut-off elevation angle 10 deg
- Residual troposphere modeled by simple 1/sin(el) MF
- A-priori ZHD = 0
- Comparison to IGS final solution and standard PPP (GMF+gradients)

PPP results - position

[mm]	Standard	KARAT
Mean ΔE / ΔN / ΔU w.r.t. IGS0b	-4.3 / -3.8 / -14.9	-4.5 / -3.6 / -15.4
E / N / U repeat.	3.0 / 3.8 / 3.9	3.1 / 4.2 / 4.5
R.M.S. of residuals	11.8	9.8

Described in: Hobiger et al., Ray-traced troposphere slant delays for precise point positioning, to be submitted to GRL, 2007.

PPP results - troposphere



Station TSKB

Conclusions

- Numerical weather models are accurate by about 99% of total delay
- Estimation of residual ZTD by a simple mapping function is still necessary
- Many analysis packages don't allow estimation of troposphere with zero a-priori values
- Stochastic models need to be revised when ray-traced data is applied

Outlook

- Benefits from reduction of unknowns (no gradient estimation)
- BUT: Ray-traced ZTDs are needed (in order to obtain absolute values from computed residual troposphere delays)
- Cooperate with weather agencies, iterative process: ray-tracing $\rightarrow$ analysis $\rightarrow$ update weather model $\rightarrow$ ray-tracing $\rightarrow$ analysis $\rightarrow$ …
- Provide an online ray-tracing service for the user who uploads data and receives "troposphere free" observations

www.nict.go.jp

Thank you for your attention !