CENTRE NATIONAL D'ÉTUDES SPATIALES

Receiver positioning with zero-difference integer ambiguity fixing

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Antarctic 2007 campaign

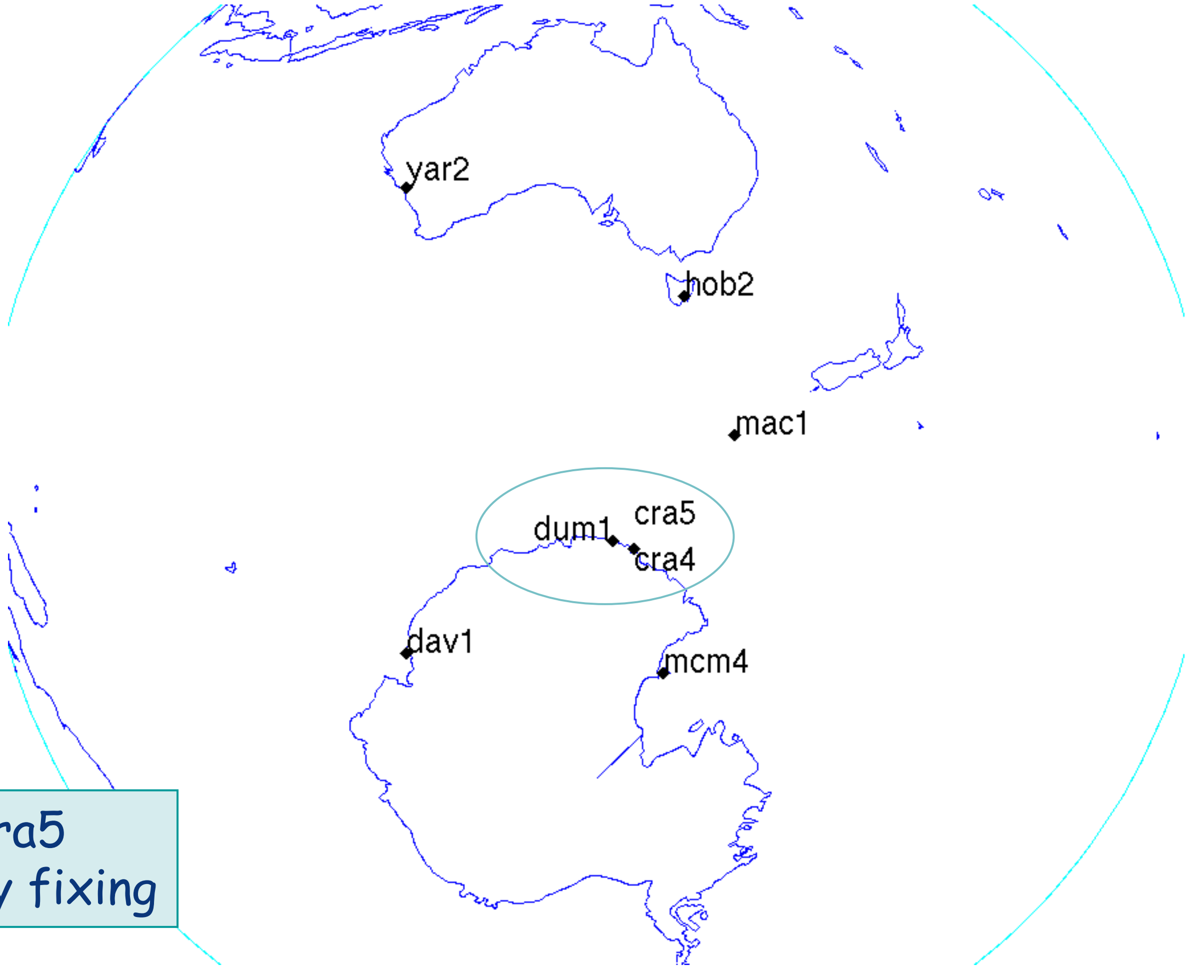
Data from project CRACICE et NIVMER (Benoit Legresy, Laurent Testut, CNRS/LEGOS)
GPS measurements on Mertz glacier in November 2007

Reference IGS stations :

dav1, mcm4, mac1, hob2, yar2
distances 2500-3200 km

User receivers :

dum1 (Dumont d'Urville)
and two receivers on the glacier
cra4, cra5 (distance 3.4 km)
240 km from dum1



Kinematic positioning of cra4, cra5
with zero difference ambiguity fixing

The three equations

Emitter j, receiver i, dual frequency observables P1,P2,L1,L2

Widelane :

$$L_2 - L_1 + f(P_1, P_2) = -N_w + \mu_i(t) - \mu^j$$

$$N_w = N_2 - N_1$$

Phase iono-free :

$$Q_c = D_c + \lambda_c d_{windup} + h_i(t) - h^j(t) - \frac{\lambda_2 N_w}{1-\gamma} - \lambda_c N_1$$

$$\lambda_c \sim 10.7cm$$

Pseudo-range iono-free :

$$P_c = D_c + h_{p,i}(t) - h_p^j(t)$$

Measured quantities on the left, model and unknowns on the right

N_w, N_1 integer ambiguities, constant during a pass

$\mu_i(t), \mu^j$ widelane biases, stable for the emitter, each epoch for the receiver

$h_i(t), h^j(t)$ phase clocks, each epoch (in meters)

$h_{p,i}(t), h_p^j(t)$ pseudo-range clocks, each epoch

remark : $h^j(t) - h_p^j(t)$ is stable enough and can be aligned to be < $\frac{\lambda_c}{2}$

Solution

Similar to double difference processing :

Widelane equation	→	integer Nw emitter and receiver widelane biases
Phase equations Pseudo-range equations	→	integer N1 emitter and receiver phase clocks (emitter and receiver pseudo-range clocks) model parameters

Remark : standard positioning solutions (floating ambiguities)

Phase equations Pseudo-range equations	→	real valued ambiguity emitter and receiver clocks (same clocks are used for phase and pseudo-range) model parameters

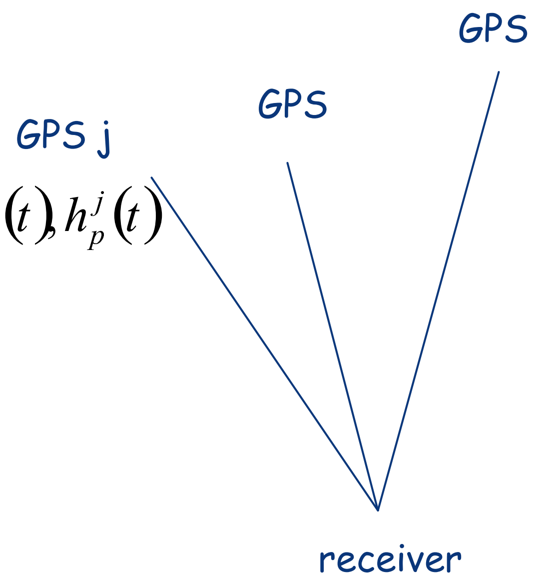
Application to PPP and Kinematic positioning

Network solution (using igs ephemeris)
integer ambiguity fixing :

↓

Satellite data
- widelane biases
- phase clocks
- pseudo-range clocks

$\mu^j, h^j(t), h_p^j(t)$



PPP or kinematic

↓

- receiver widelane ambiguities, integer Nw (using satellite widelane biases)
- adjusted parameters (x,y,z …) with integer N1

Antarctic 2007, network solution

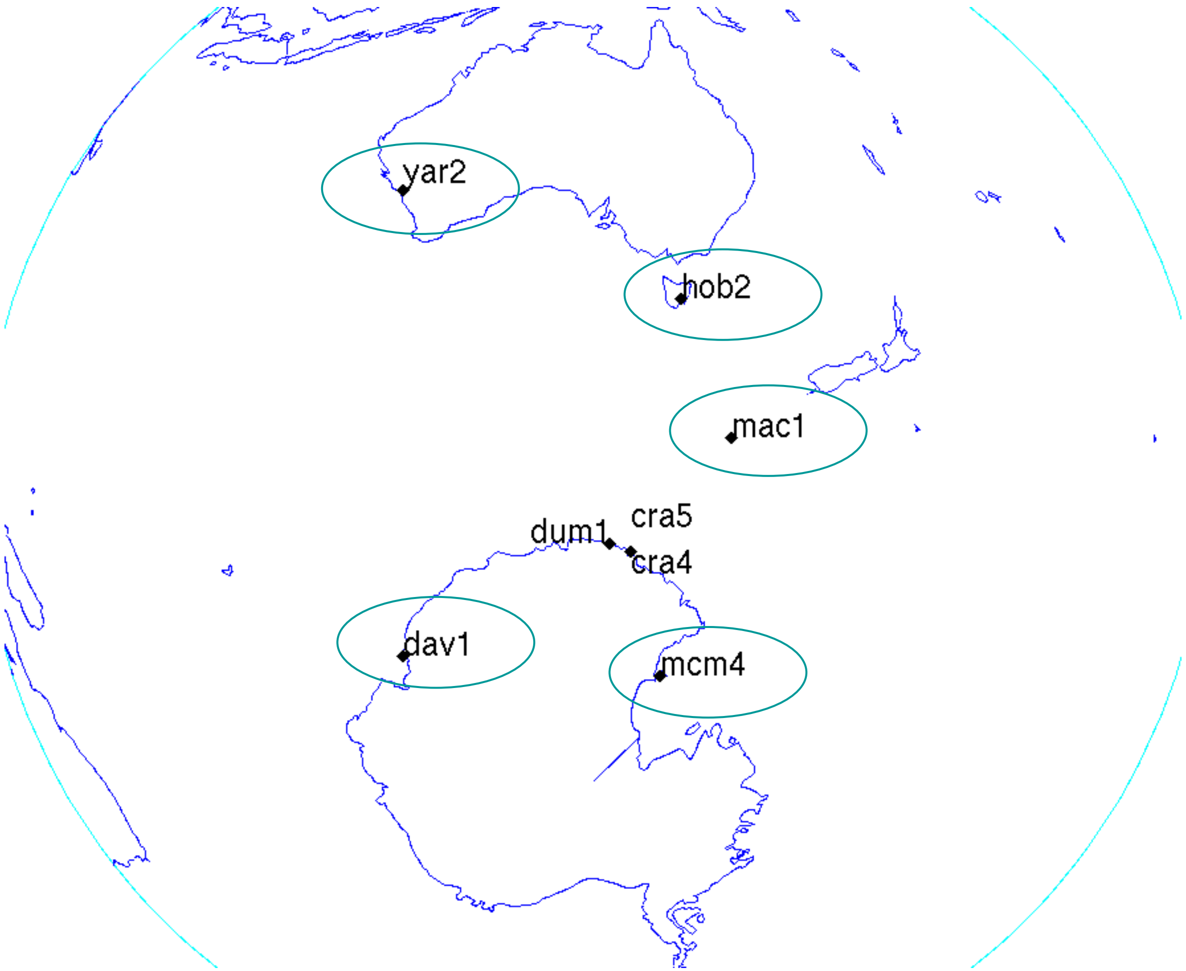
Data from project CRACICE et NIVMER (Benoit Legresy, Laurent Testut, CNRS/LEGOS)
GPS measurements on Mertz glacier in November 2007

Reference IGS stations :

dav1, mcm4, mac1, hob2, yar2
distances 2500-3200 km

↓

Network solution
GPS satellite bias and clocks data
when in visibility



PPP and kinematic positioning

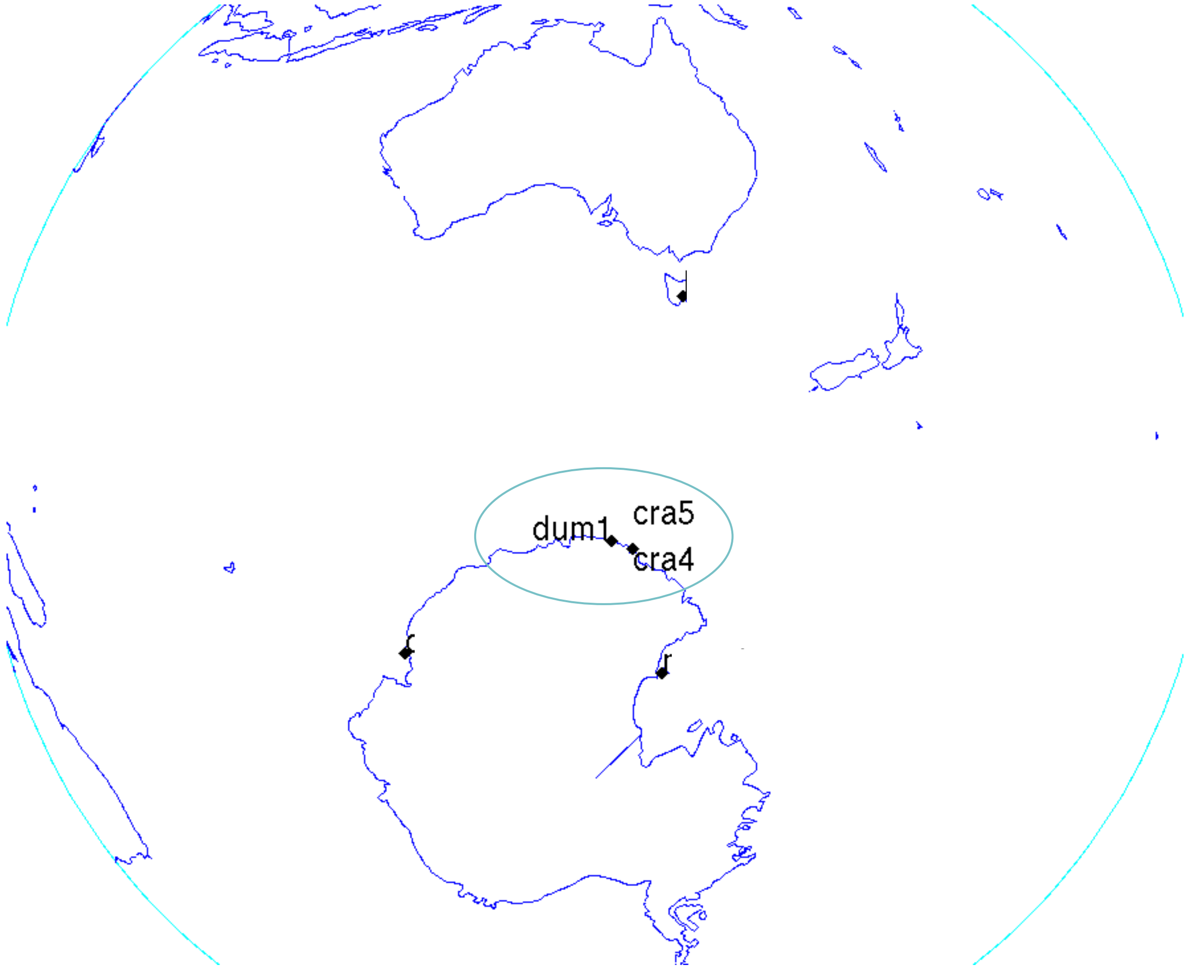
Using the network solution :

dum1 PPP and kinematic positioning
with ambiguity fixing :

- validation of the approach
- expected performance

cra4, cra5 kinematic positioning
with ambiguity fixing :

- independent trajectories
- comparison with short baseline solution
  single frequency
  dual frequency



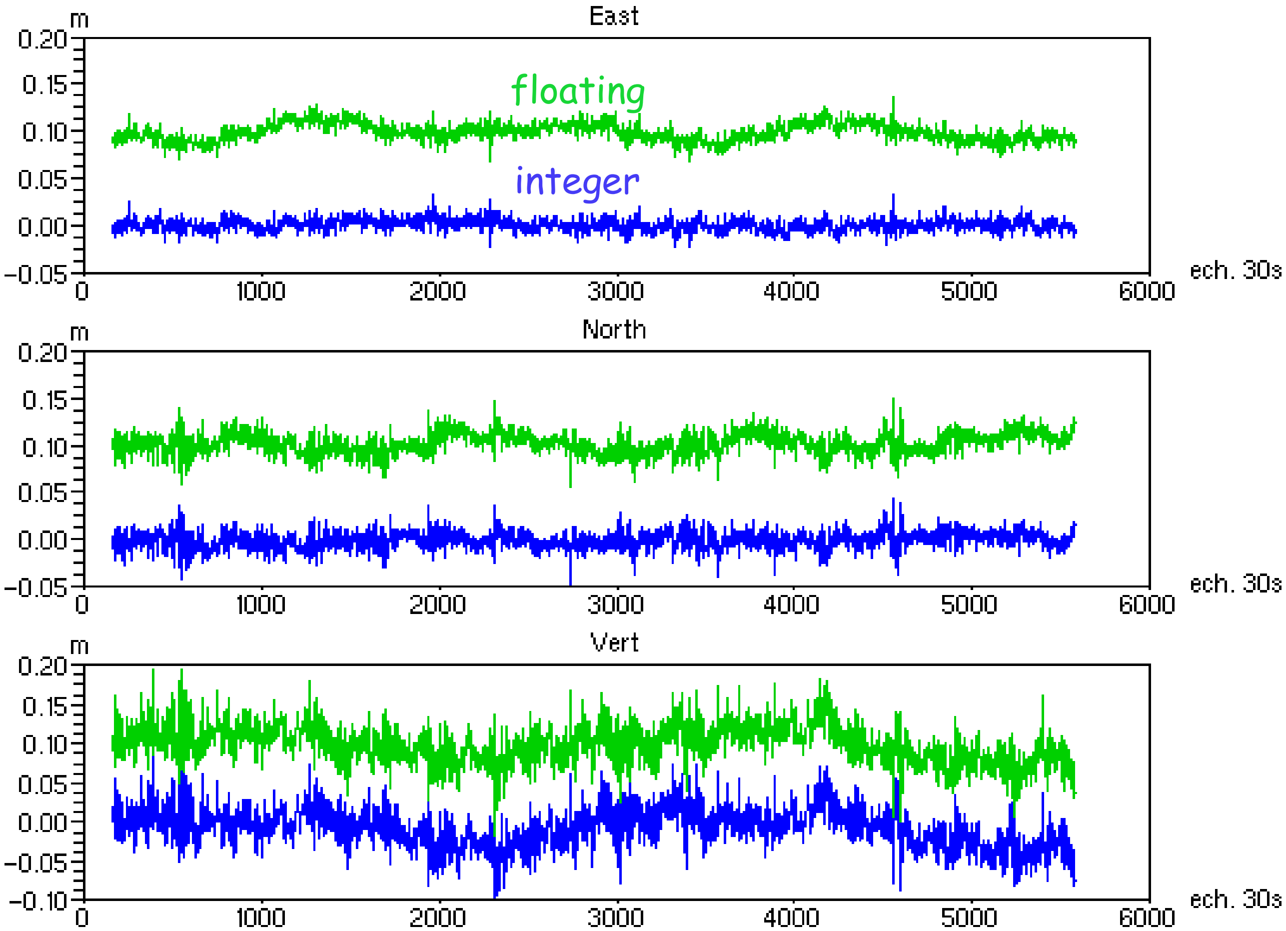
dum1 kinematic positioning results

Solution of :
- x,y,z,t for each 30 s epoch
- troposphere (1 hour segments, with evolution constraints)
- N1

floating or integer N1

dum1	(flo)	(int)
East	10	6
North	11	9
Vert.	24	25

millimeters rms



Remark : no correlations between epochs for positions and clock (this explains the noise ~ 1 cm rms)

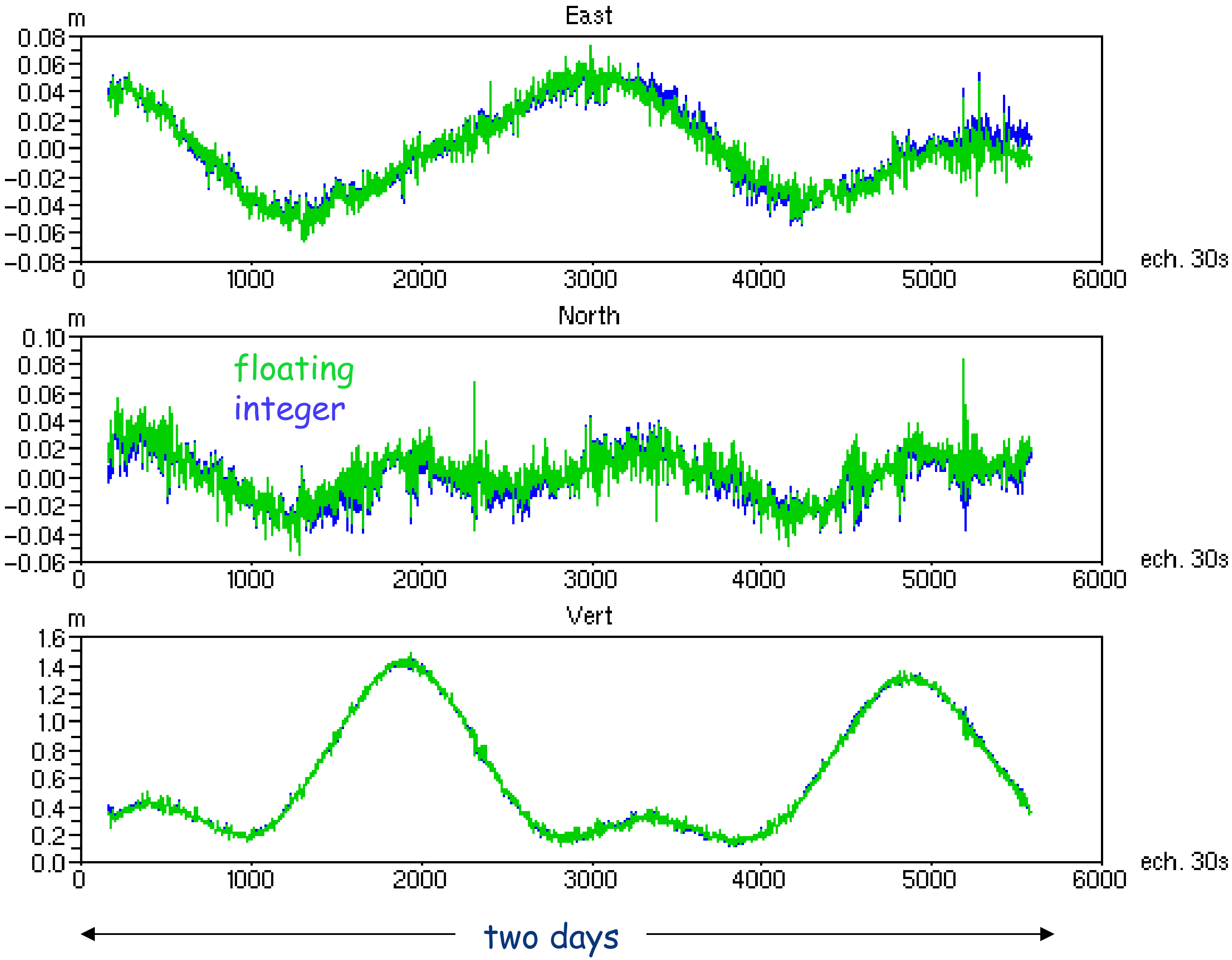
cra4 stochastic positioning

Common linear evolution removed for horizontal data :

East

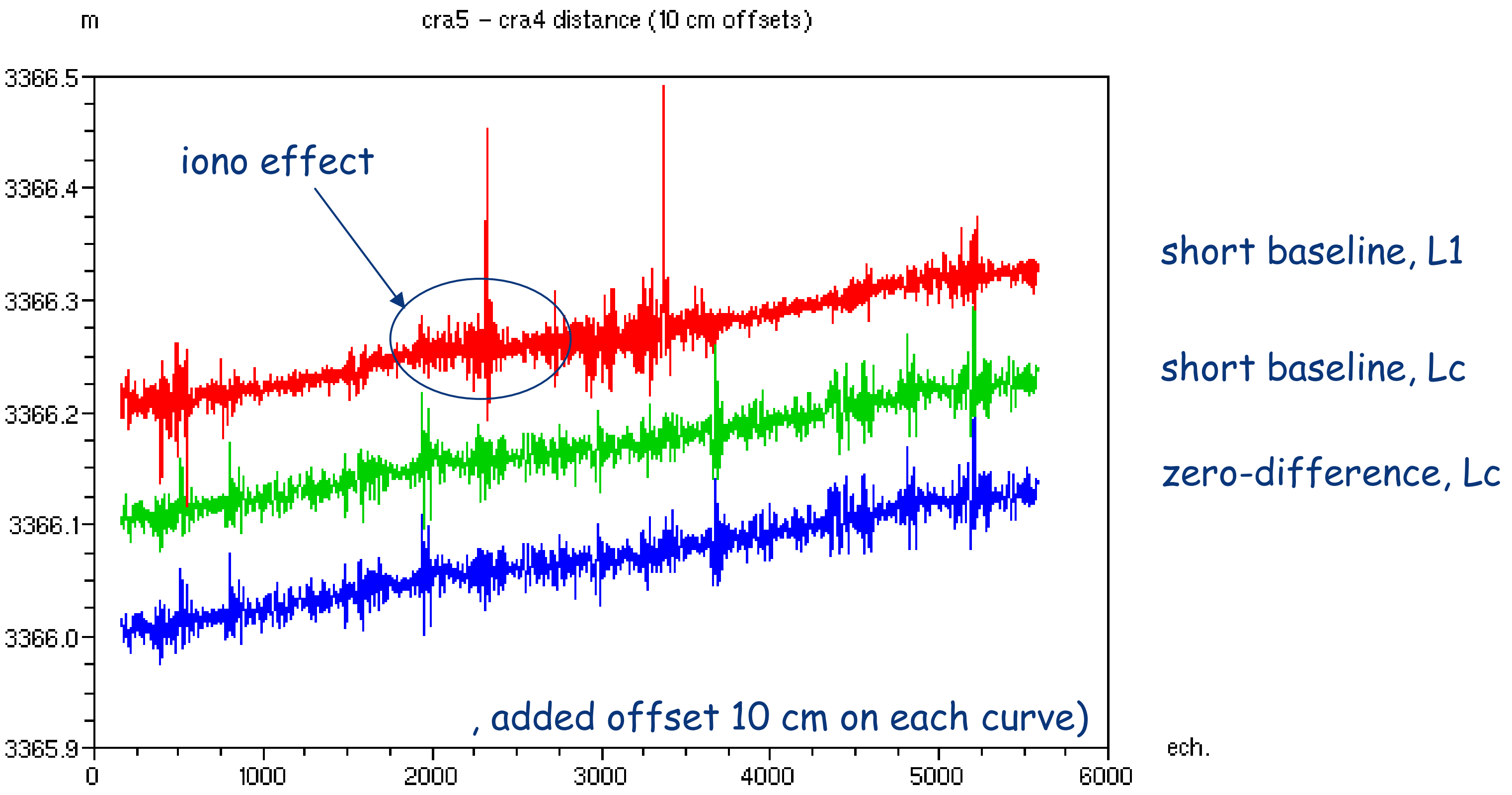
North

Vertical



cra4 and cra5 comparison

comparison with short baseline relative solution, all solutions with integer ambiguity fixing :
- distance between the receivers for
  - L1 and Lc single baseline
  - Lc zero-difference (from previous slide)



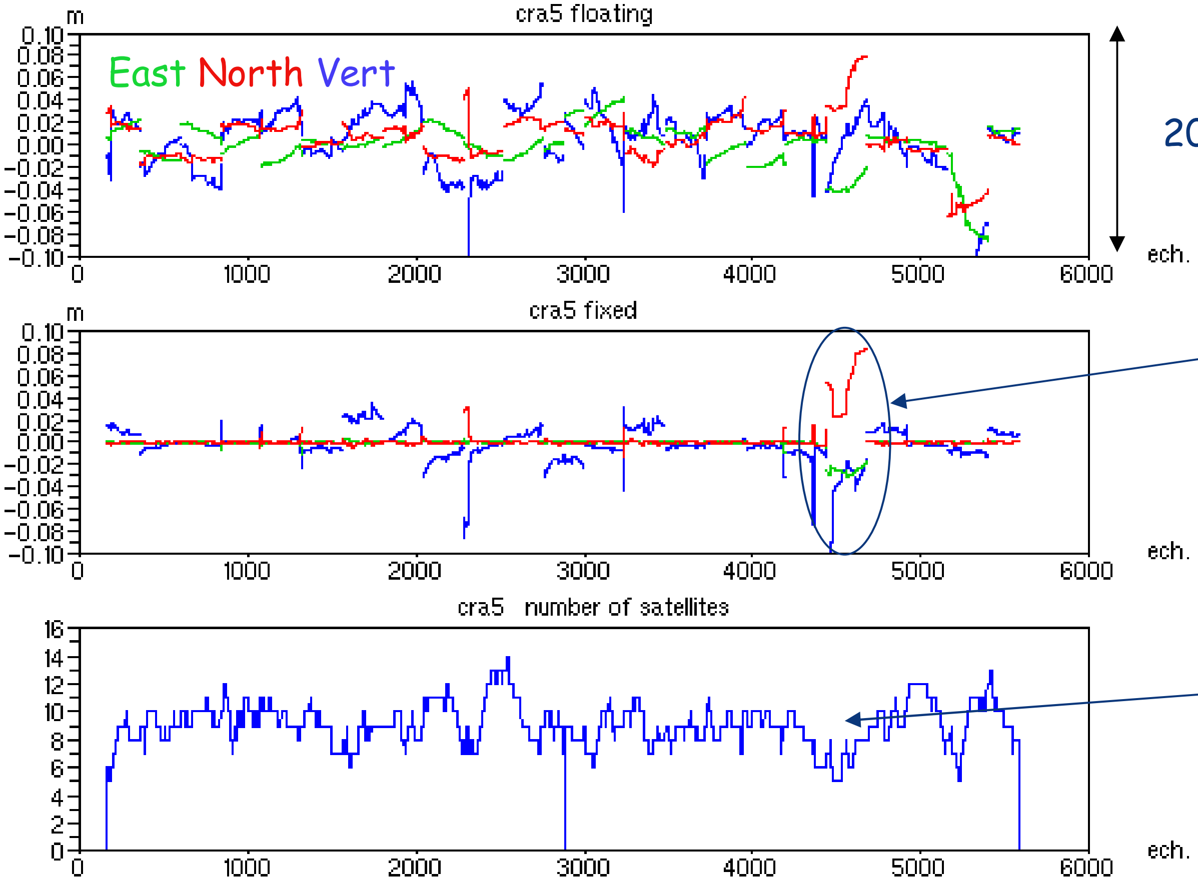
Absolute positioning allows same performance as the short baseline solution (dual frequency)

cra4 and cra5 short duration solutions

Two hours solutions, 30 s, 1 tropo value
comparison with reference for float./int. N1

	Cra4 (flo)	(int)	Cra5 (flo)	(int)
East	22	1	20	5
North	16	2	21	12
Vert.	32	10	36	16

millimeters rms (without ref. solution noise)



ambiguity fixing was not successful (50 %)

it is important to have a maximum number of GPS in visibility

Conclusion

An application of PPP and Kinematic positioning with integer ambiguity fixing
is demonstrated here over a wide area in Antarctic (more than 1000 km)

Algorithms for integer phase clock solutions

over a local or global network
for single receiver positioning applications

Reference network phase clocks with ambiguity fixing produce very good standard solutions
(floating ambiguities for the receiver)

Ambiguity fixing stabilises/improves the solutions for the receiver

limited improvement for long durations w.r.t. floating solution (~one day)
significative improvement for shorter durations (~ two hours)

Other areas (Jason 1 orbits, time transfer, real time) ….

PPP and Kinematic positioning solutions with integer ambiguity fixing
are now possible and efficient

Other results

Jason 1 orbits with ambiguity fixing

very efficient (all receiver passes are very short (below one hour))
common views with complete constellation are much longer than common views with a ground station

ION 2008

Integer Phase clocks and time transfer

continuous GPS time transfer, no drift (known problem in the floating solutions)
connection of overlapping clocks solutions without error

International Journal of Navigation and Observation, special issue, selected papers from TimeNav 2007

Real Time solutions

adjustment of GPS orbits and clocks in real time, improved performance on real time positioning

ION 2009

Thank you for your attention

Summary

Some definitions for zero difference ambiguities

Properties of the solutions
- zeros difference widelane properties
- integer phase clocks
- independent receiver positioning with ambiguity fixing

Example
- Kinematic positioning
  - with ambiguity fixing for LEGOS 2007 Antarctic campaign

Conclusion

Initial observation equations

GPS satellites and receiver biases referenced to ionosphere free combinations

Δh : clocks terms (in meters), one value per epoch
Δh-Δh_p, $\Delta\tau$, $\Delta\tau_p$: biases, 'slow' variations

Clock (ionosphere-free pseudo-range one value per epoch)

tgd

observables

pseudo range

$$P_1 = D_1 + e + \Delta h_p + \Delta\tau_p$$

$$P_2 = D_2 + \gamma e + \Delta h_p + \gamma\Delta\tau_p$$

phase

$$\lambda_1 L_1 = D_1 + \lambda_1 d_{windup} - e + \Delta h + \Delta\tau - \lambda_1 N_1$$

$$\lambda_2 L_2 = D_2 + \lambda_2 d_{windup} - \gamma e + \Delta h + \gamma\Delta\tau - \lambda_2 N_2$$

integer ambiguities

wavelength

models

ionosphere

Clock (ionosphere-free phase one value per epoch)

$$\Delta h = h_i - h^j$$

receiver i
emitter j

Reduced equations

Use of three ionosphere free combinations :

$$\frac{\gamma P_1 - P_2}{\gamma - 1} = D_c + \left(h_{p,i}(t) - h_p^j(t)\right)$$

Pseudo-range
'ionosphere free'

Widelane integer ambiguity

$$L_2 - L_1 + f(P_1, P_2) \cong -(N_2 - N_1) + \mu_i(t) - \mu^j$$

Receiver widelane bias (each epoch)

Emitter widelane bias (stable)

Widelane
'ionosphere free'
'geometry free'

$N_w = N_2 - N_1$ fixed

$$\frac{\gamma\lambda_1 L_1 - \lambda_2 (L_2 + N_w)}{\gamma - 1} = D_c + \lambda_c d_{windup} + \left(h_i(t) - h^j(t)\right) - \lambda_c N_1$$

Phase 'ionosphere free'

$\lambda_c \sim 10.7cm$

Reference network

Reference network solution

Widelane :
identification of satellite and receiver widelane biases, using only the rinex files (no model)
satellite biases : stable over few days
receiver biases : may vary, depending on the receiver environment (thermal effects)
production of a set of fixed widelane ambiguities, for each pass

Pseudo-range and Phase equations : network solution
adjusted parameters
- models if necessary (here, use of IGS precise ephemeris and ITRF stations)
- N1 integer ambiguity per pass
- emitter and receiver clocks (integer phase clocks)

→ Satellite widelane biases (typically daily values)
Satellite clocks at each epoch
allowing N1 ambiguity fixing

Positioning solution with ambiguity fixing

Integer PPP

User receiver

Widelane :

$$L_2 - L_1 + f(P_1, P_2) + \mu^j = -N_w + \mu_i(t)$$

one integer per pass

one value per epoch

Pseudo-range and phase equations : PPP or Kinematic solution

input : satellite ephemeris and integer phase clocks

adjusted parameters

- models (coordinates, troposphere)
- N1 integer ambiguity per pass
- receiver clock

$$\frac{\gamma P_1 - P_2}{\gamma - 1} + h^j(t) = D_c + h_i(t)$$

$$\frac{\gamma \lambda_1 L_1 - \lambda_2 (L_2 + N_w)}{\gamma - 1} + h^j(t) = D_c + \lambda_c d_{windup} + h_i(t) - \lambda_c N_1$$

one integer per pass

Remarks : same equations as for standard PPP but N1 can be fixed to an integer value

code-phase biases have been neglected here

(below 10 cm with these definitions)

cra4 stochastic positioning (1)

East

North

Vertical