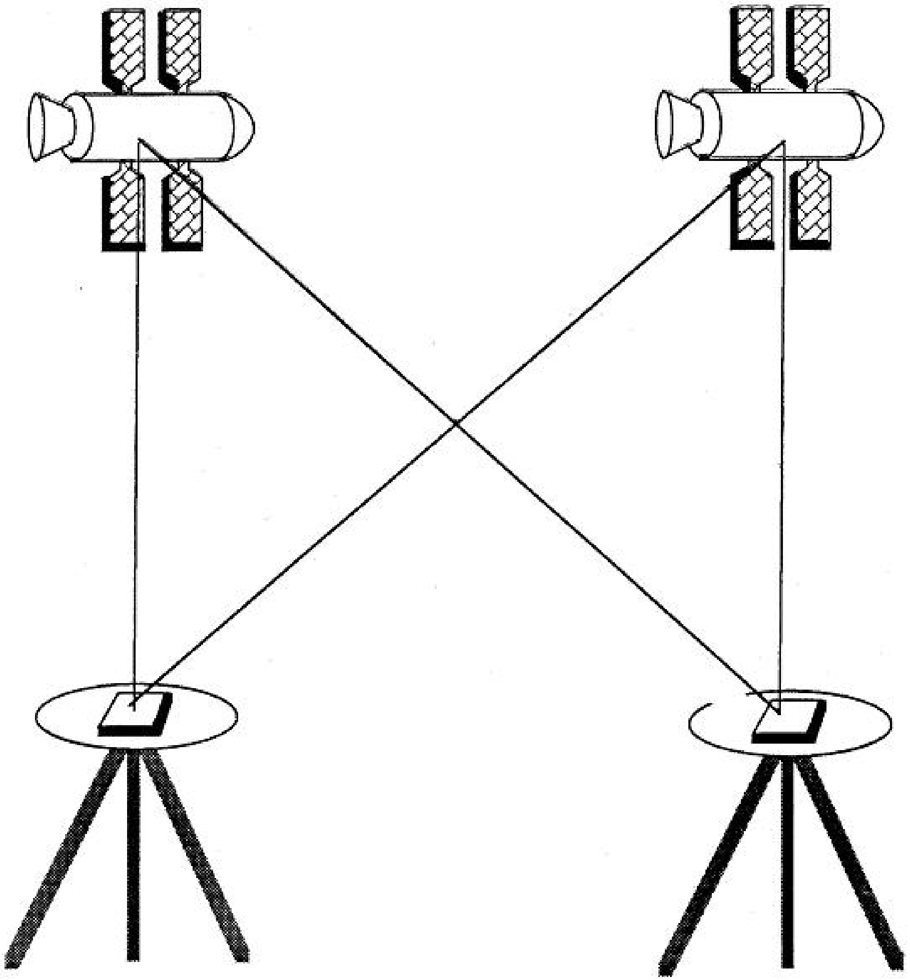
GPS uncertainties

- Relative/ vs. absolute positioning
- Position precision limitations
- Velocity uncertainties
- Accuracy vs. Precision
- Mapping in a reference frame

Double differences



Double differences

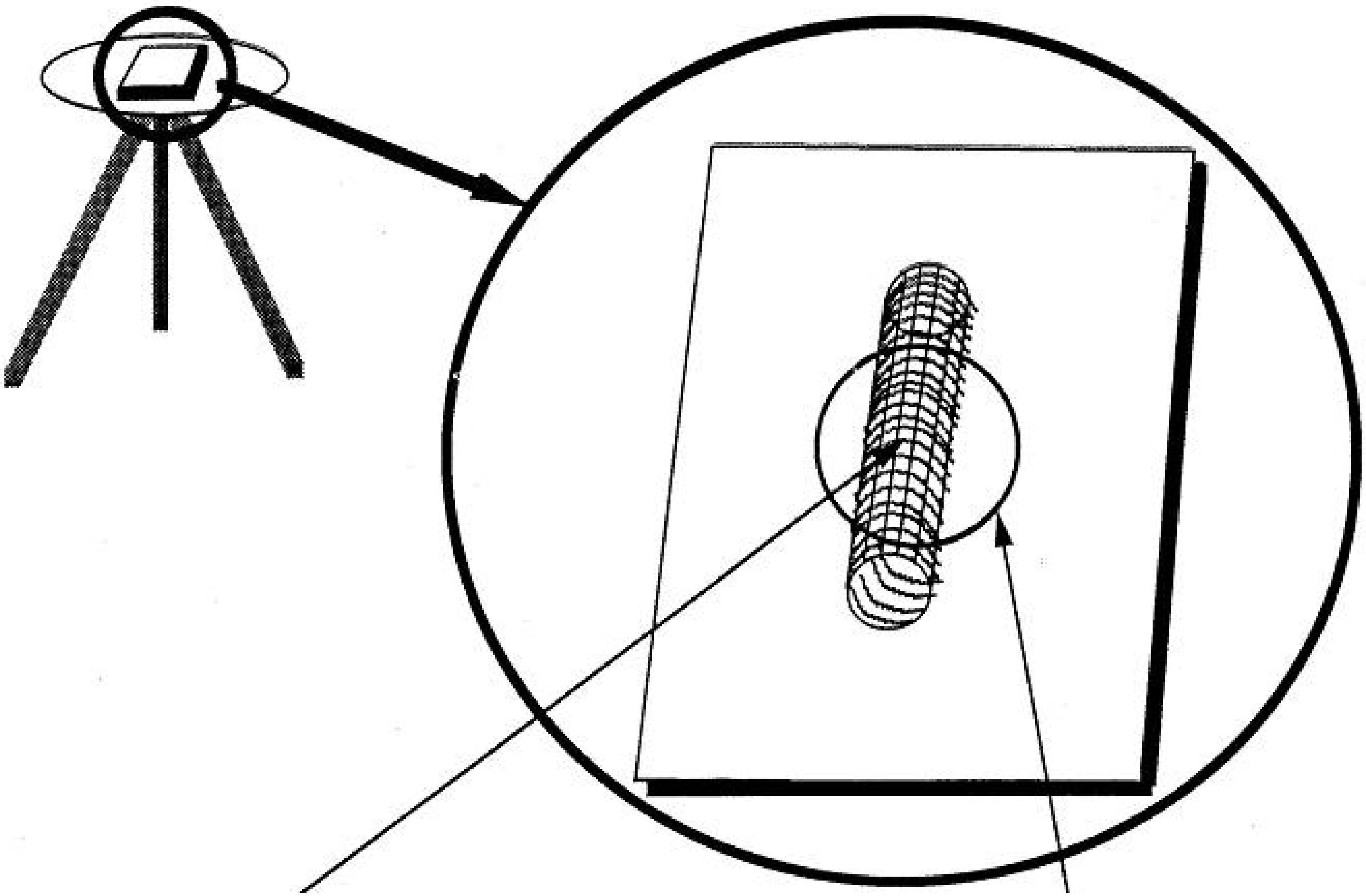
=>

Measurement of point distances = baselines

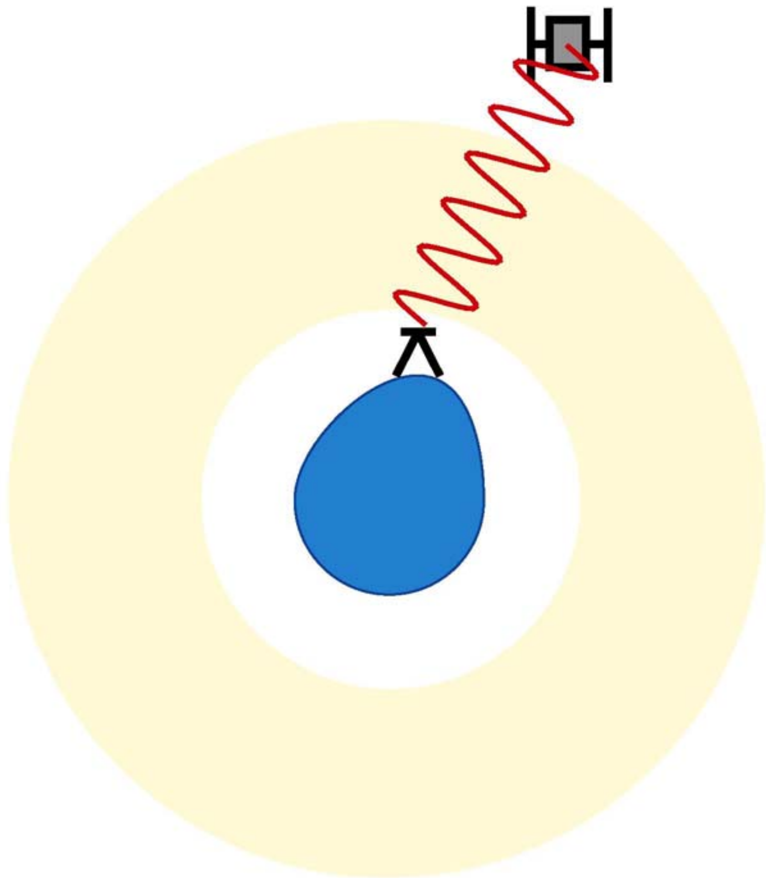
=>

Relative positioning

Phase center offset and variations



Ionosphere sketch



Correct measurement

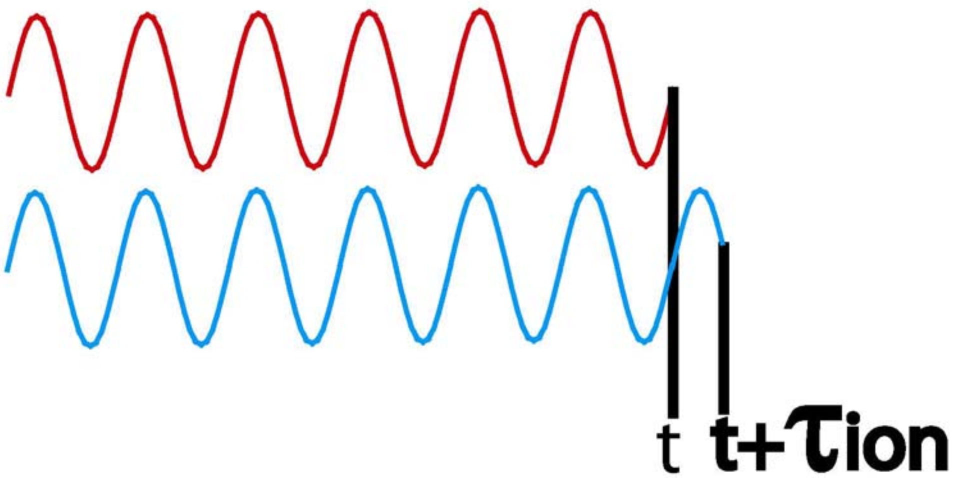
in an empty space

But the ionosphere perturbates propagation of electric wavelength …..

… and corrupts the measured distance

… and the inferred station position

Ionosphere theory



Ionospheric delay τion depends on :

- ionosphere contains in charged particules (ions and electrons) : Ne
- Frequency of the wave going through the ionosphere : f

$$\tau_{ion} = 1.35\ 10^{-7}\ Ne / f^2$$

Ionosphere : solution = dual frequency

Problem : Ne changes with time and is never known

solution : sample the ionosphere with 2 frequencies

$\tau ion_1 = 1.35\ 10^{-7}\ Ne / f_1^2$ $\tau ion_2 = 1.35\ 10^{-7}\ Ne / f_2^2$

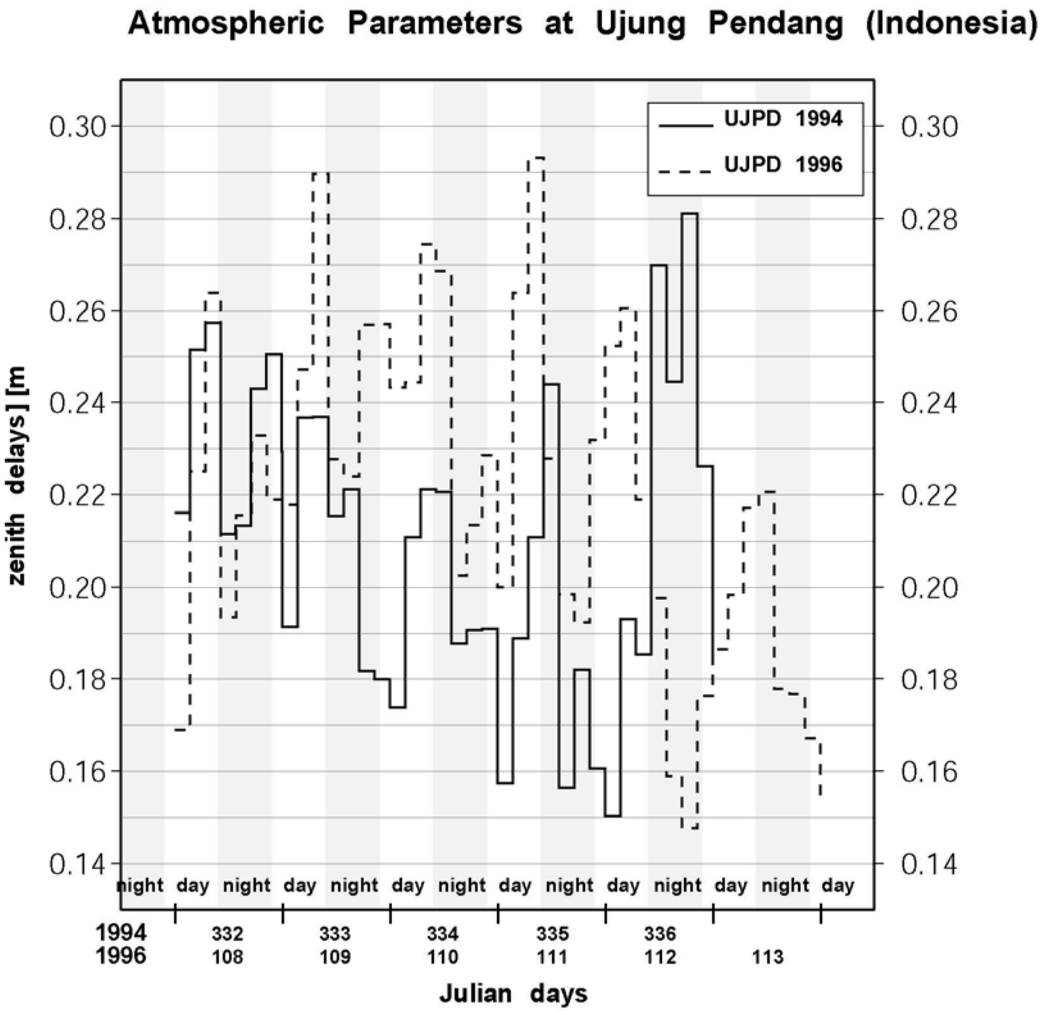
$$\tau ion_2 - \tau ion_1 = 1.35\ 10^{-7}\ Ne\ \ (1/ f_2^2 - 1/ f_1^2\ )$$

$$Ne\ = \left[\tau ion_2 - \tau ion_1\right] /\ 1.35\ 10^{-7}\ (1/ f_2^2 - 1/ f_1^2\ )$$

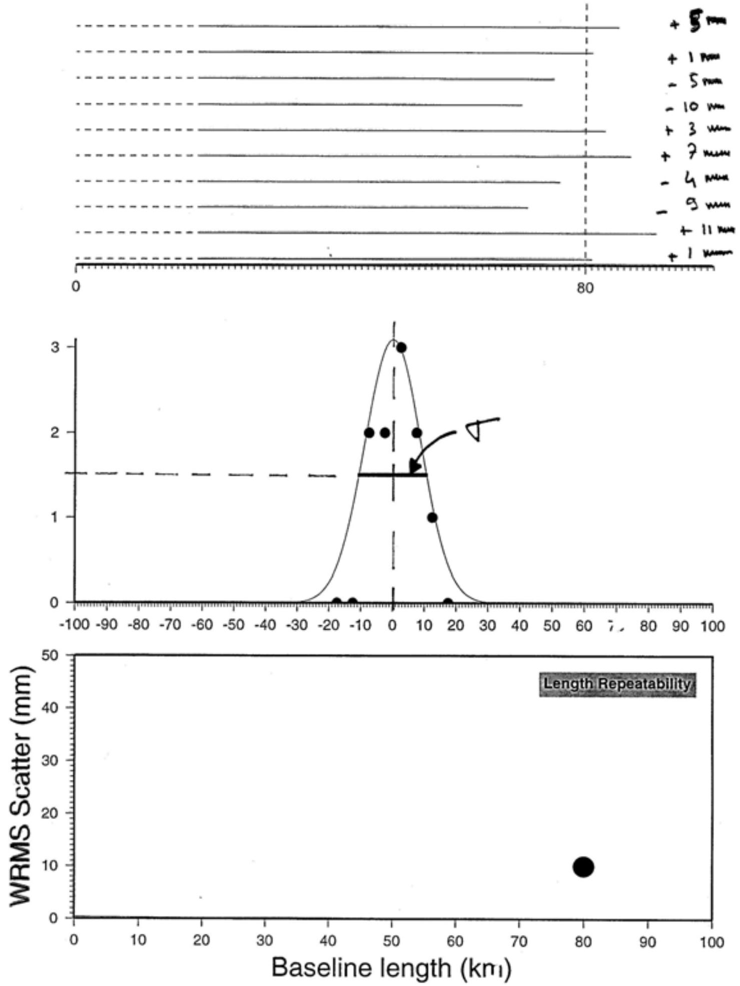
Dual frequency GPS to quantify ionospheric delay

Make ionoosphere TEC maps with GPS

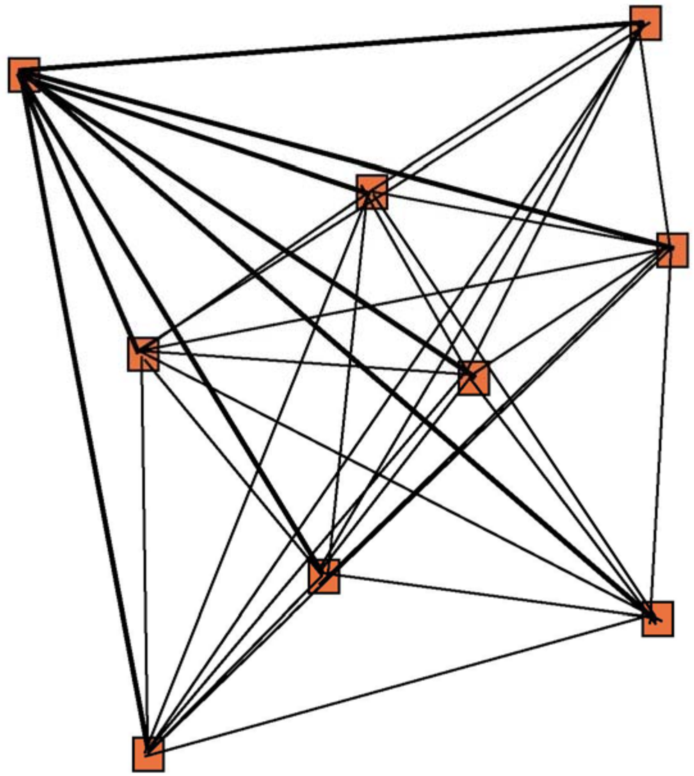
Troposphere



Precision and repeatability



Network repeatabilities



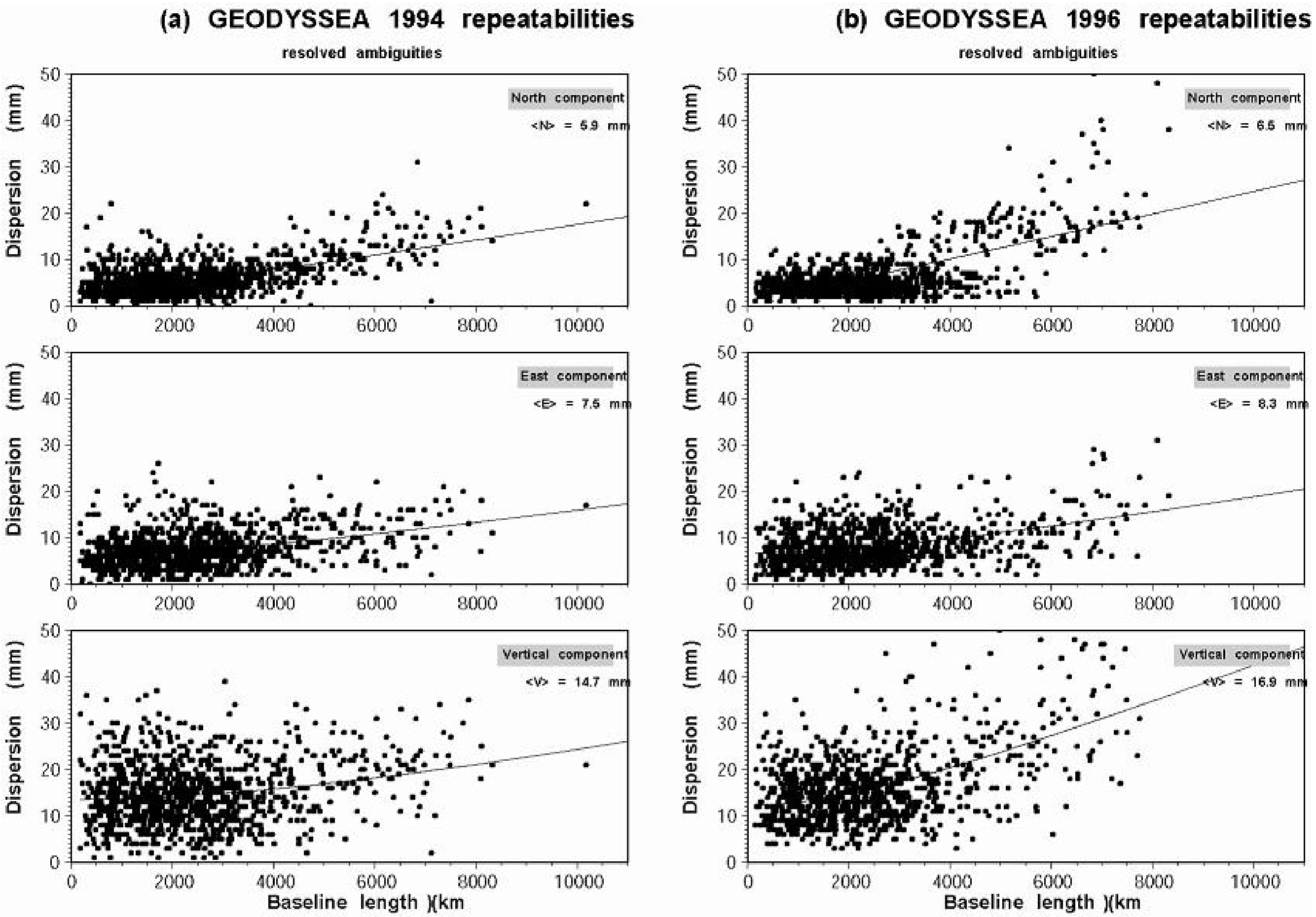
Network of N points
(N=9)

(N-1) (=8) baselines from 1st station to all others

(N-2) (=7) baselines from 2nd station to all others
=> subtotal = (N-1)+(N-2)

total number of baselines
= (N-1)+(N-2)+…+1
= N(N-1)/2 (*36 in that case*)

Typical repeatabilities (60 points => ~1800 bsl)



Repeatabilities are much larger than formal uncertainties !

From position to velocity uncertainty

If one measures position P_1 at time t_1 and P_2 at time t_2 with precision ΔP_1 and ΔP_2, what is the velocity V and its precision ΔV ?

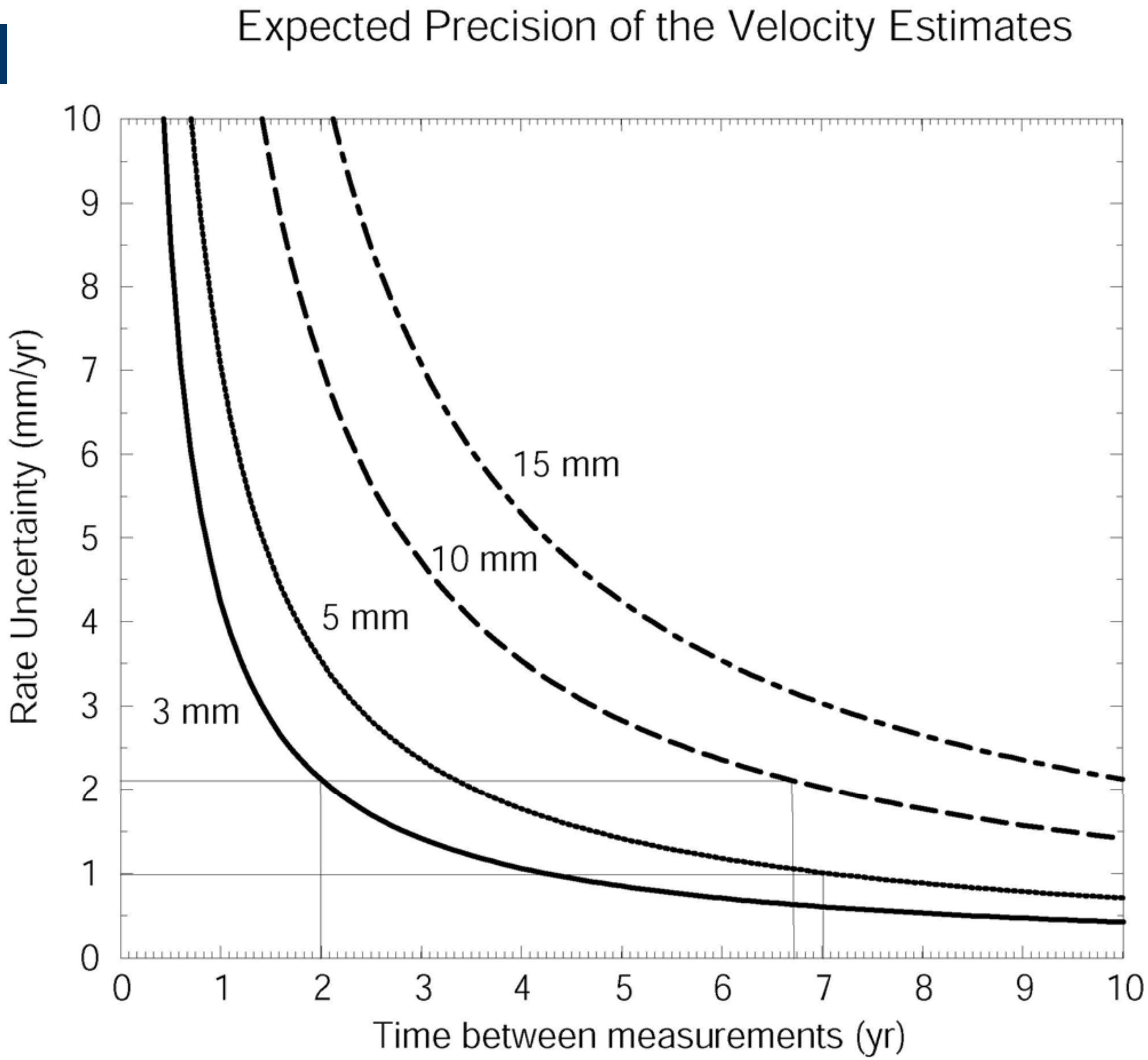
$$\boxed{V = (P_2 - P_1) / (t_2 - t_1)}$$

$$\boxed{\Delta V = (\Delta P_2 \cancel{+} \Delta P_1) / (t_2 - t_1)}$$

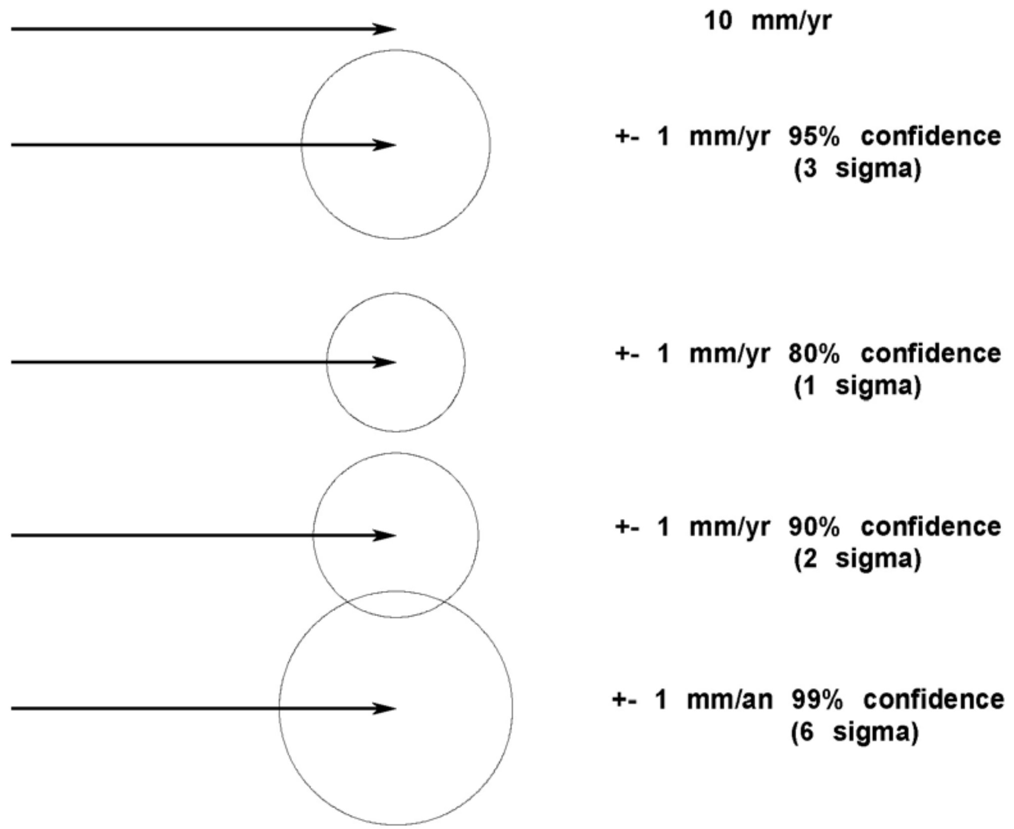
Uncertainties don't add up simply, because sigmas involve probability.

$$\boxed{\Delta V = \left[(\Delta P_2)^2 + (\Delta P_1)^2 \right]^{1/2} / (t_2 - t_1)}$$

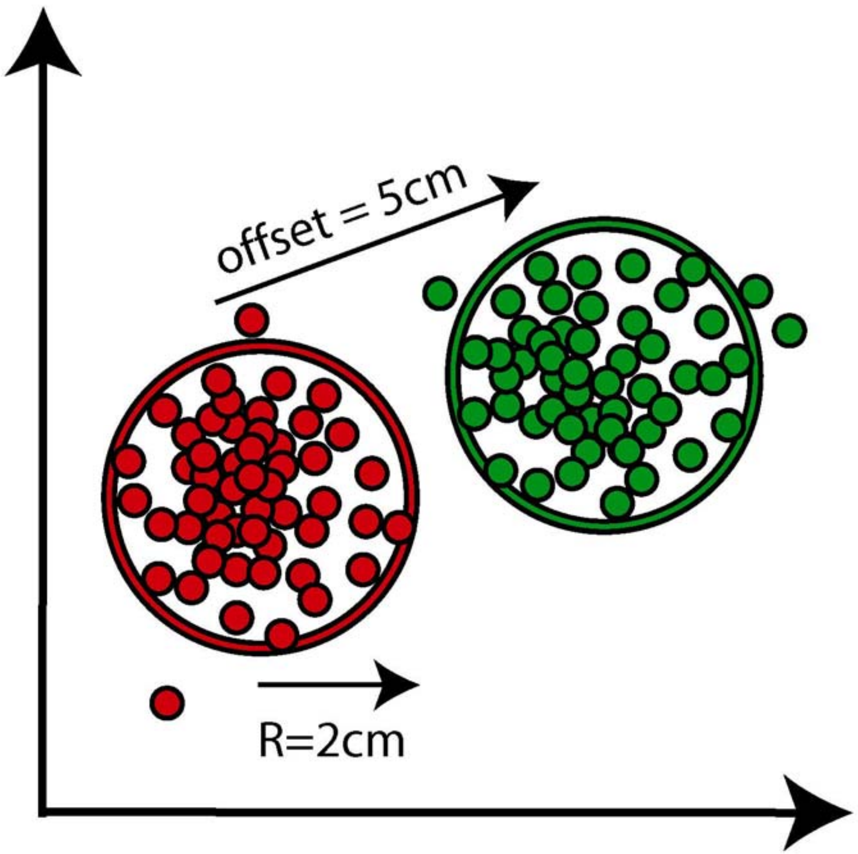
Velocities uncertainties



Velocities ellipses



Accuracy vs. precision (1)



Fix point :
measure 1 hour every 30 s

=> 120 positions

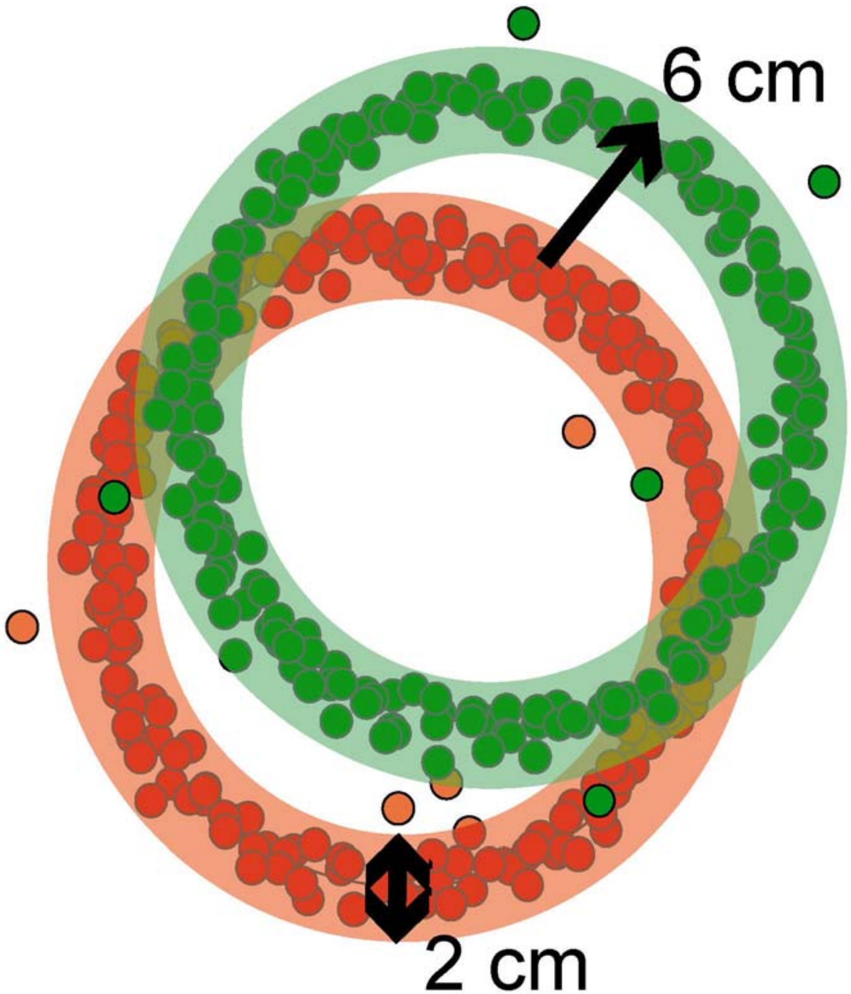
with dispersion ~+/- 2 cm

5 hours later, measure again
1 hour at the same location

=> Same dispersion but
constant offset of 5 cm

Precision = 2 cm
Accuracy = 5 cm

Accuracy vs. precision (2)



Measure path, 1 point every 10s

=> 1 circle with 50 points

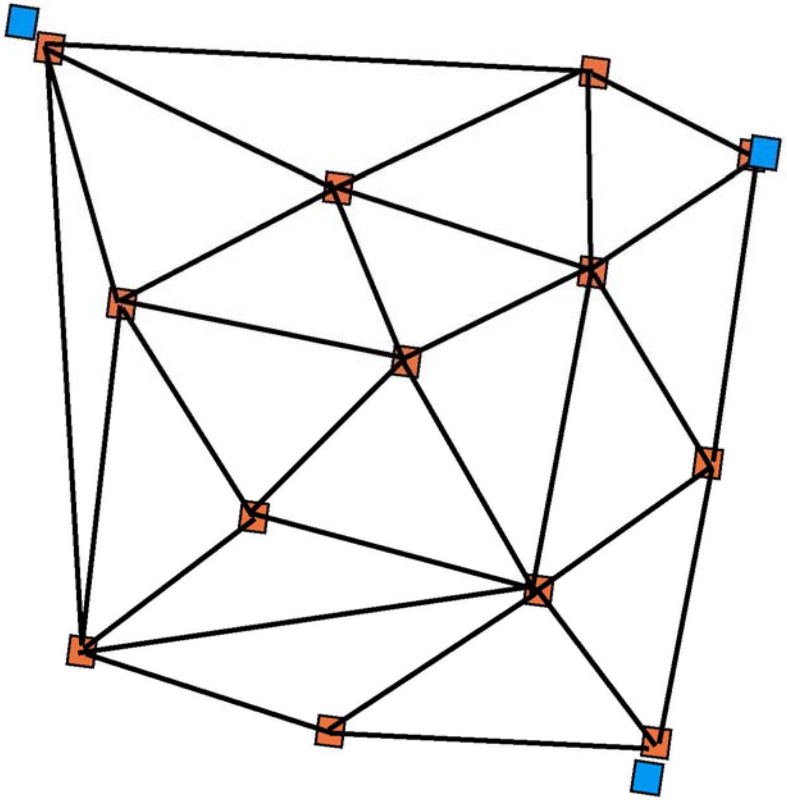
10 circles describe runabout with dispersion ~ 2 cm

Next day, measure again

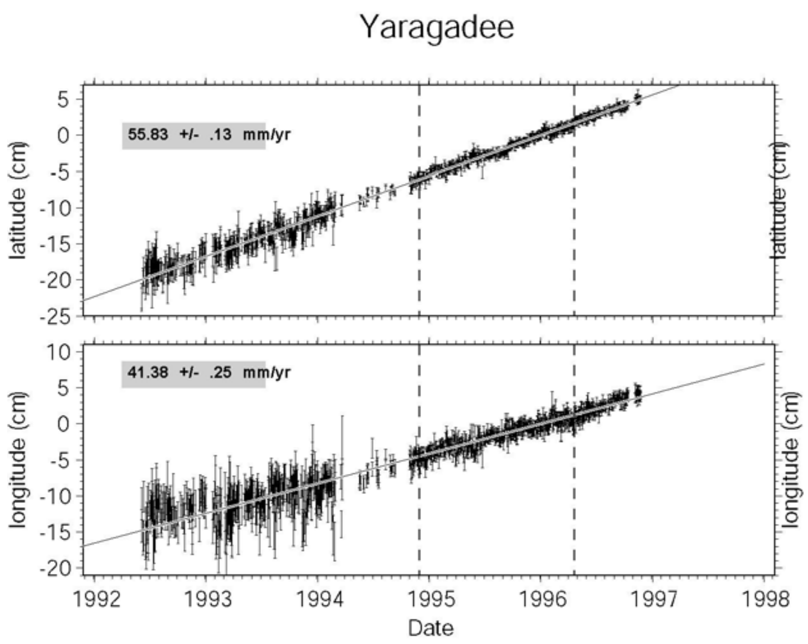
=> Same figure but constant offset of 6 cm

Precision = 2 cm
Accuracy = 6 cm

Mapping in a reference frame (sketch)



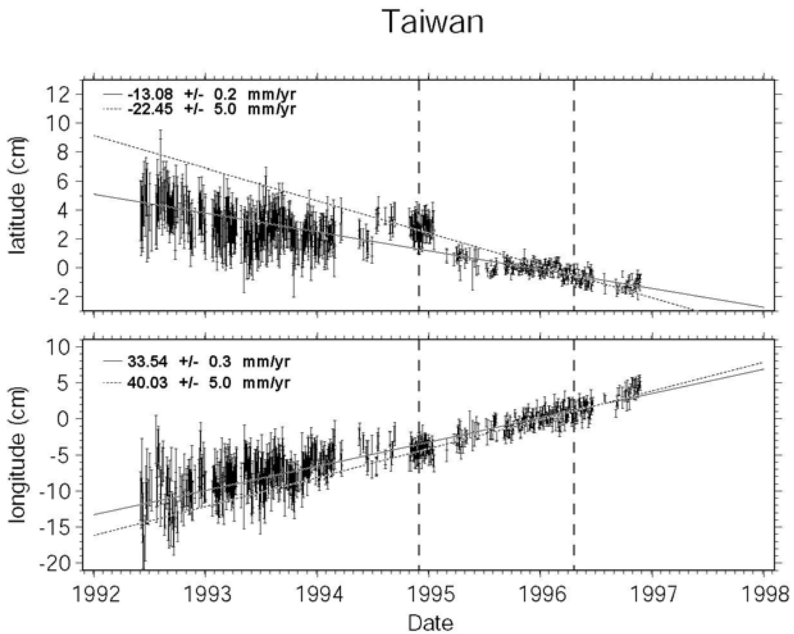
Mapping in a reference frame (1)



Constraining campaign positions (and or velocities) to long term positions (and or velocities) works fine …

… when station displacement is constant with time

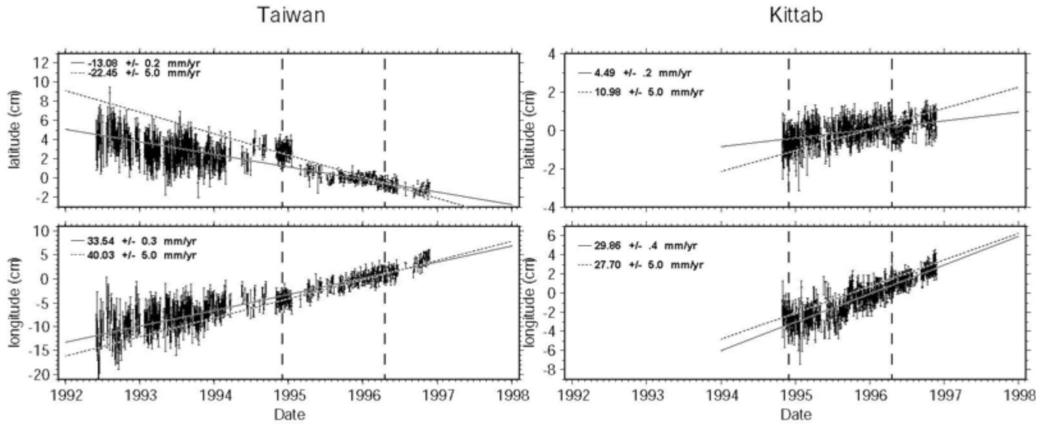
Mapping in a reference frame (2)



Constraining campaign positions (and or velocities) to long term positions (and or velocities) does not work …

… when station displacement is not constant with time

Mapping in a reference frame (3)



some stations are better than others …