Influence of station referencing on the quality of EOP time series

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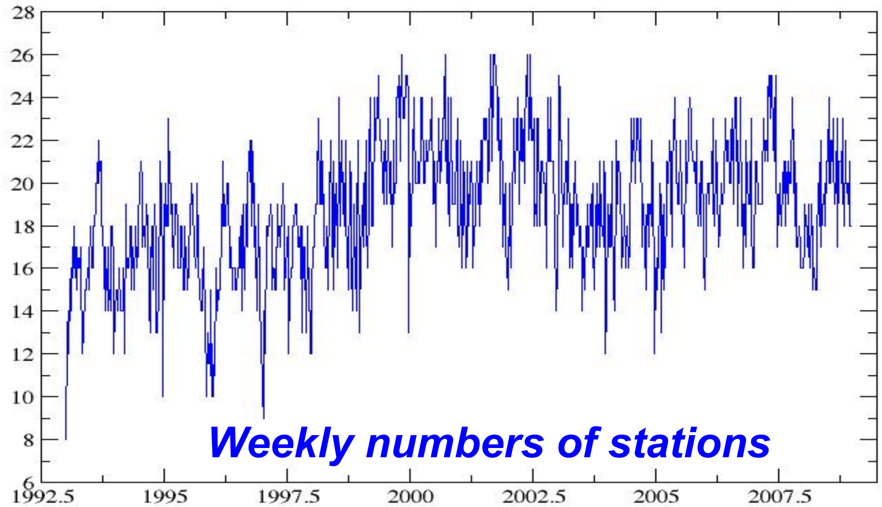
Data used

Data used (1/2)

Solution v23 of ILRS analysis centre ASI used for this work.
Weekly station positions and daily EOP (x_p, y_p and LOD) and possible range biases computed with loose constraints.
834 weeks (between 1993/01/03 and 2008/12/27 ~ 16 years) considered.
77 stations present over the time period.
Median weekly number of stations = 19 *(minimum =8, maximum =26)*.

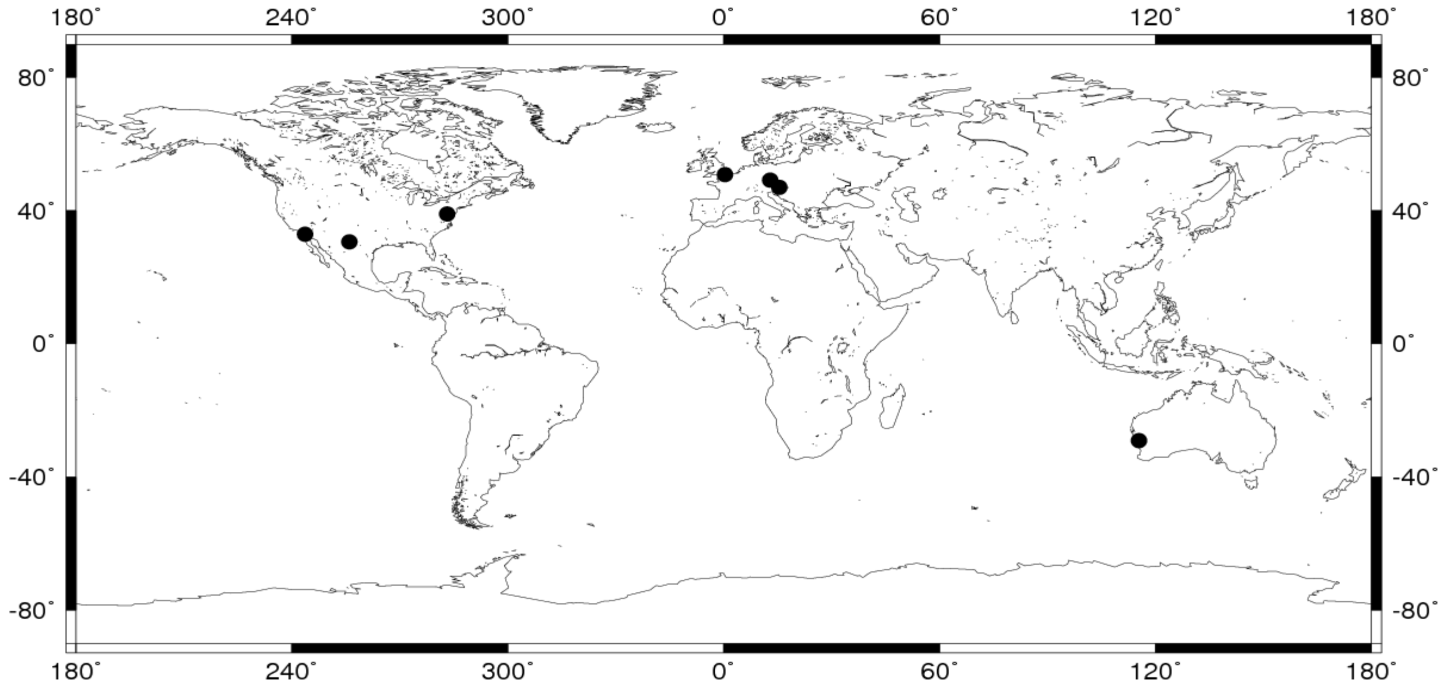


For this study, use ITRF2008 and IERS 05 C04 EOP series as references.

Data used (2/2)

ILRS analysis centre ASI v23 solution

Presence *P* = (Number of weeks of presence / 834) * 100

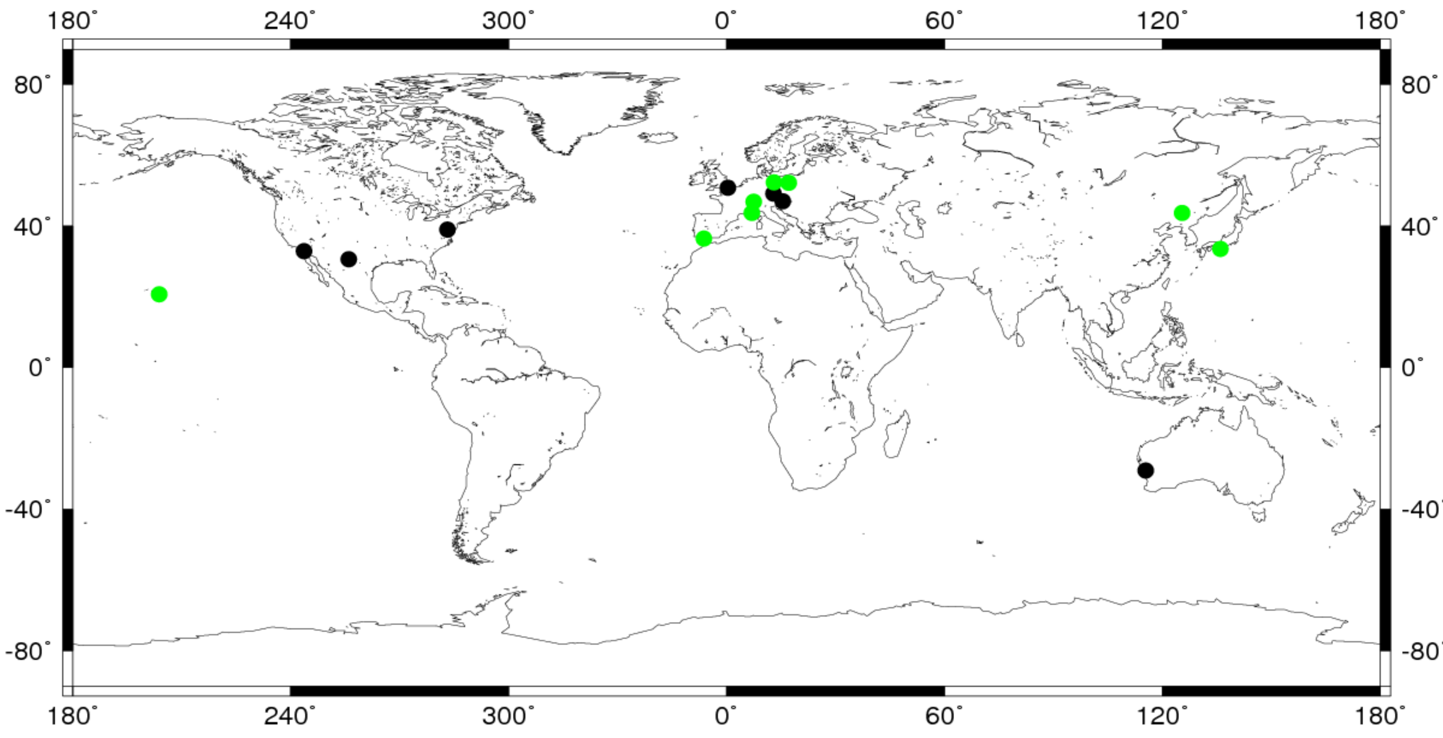


75 % ≤ *P* ≤ 100 % → 7 stations

Data used (2/2)

ILRS analysis centre ASI v23 solution

Presence *P* = (Number of weeks of presence / 834) * 100

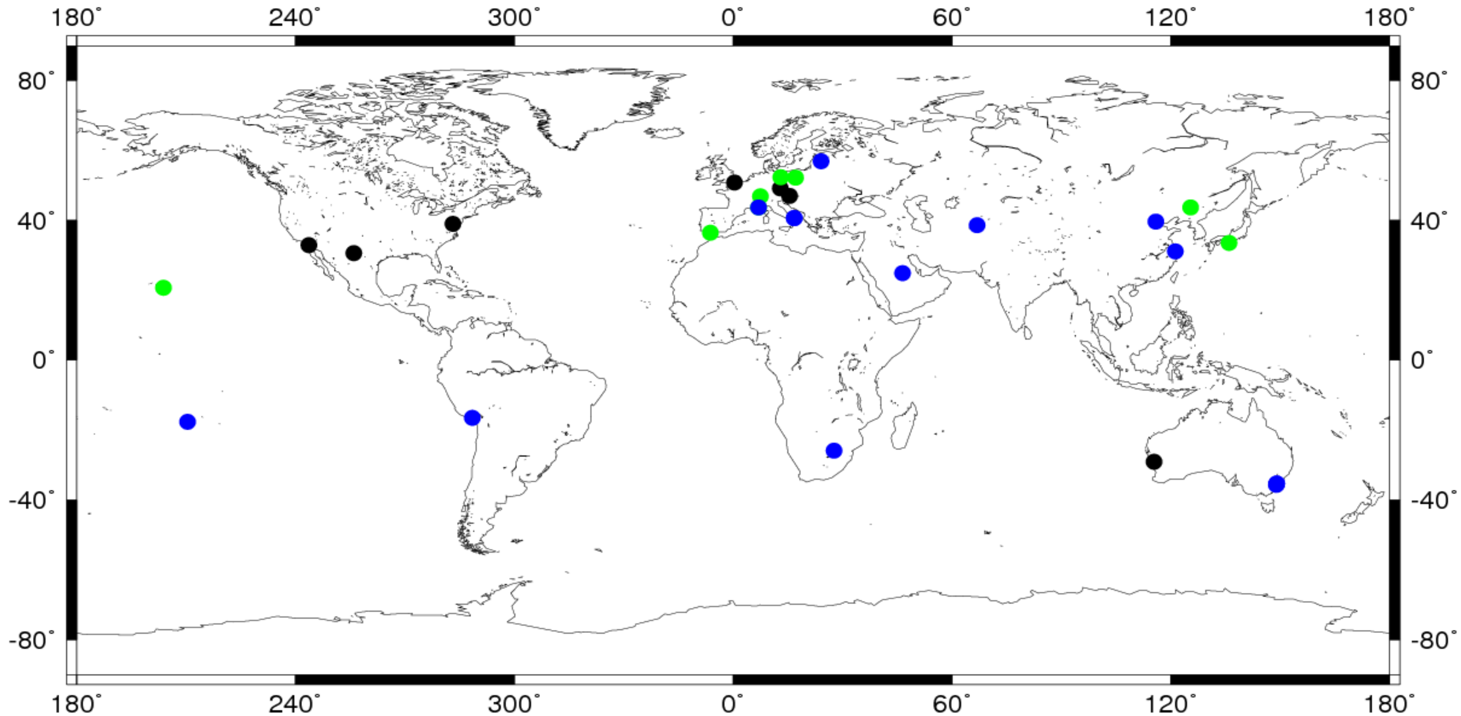


50 % ≤ *P* ≤ 75 % → + 8 stations (15 stations)

Data used (2/2)

ILRS analysis centre ASI v23 solution

Presence *P* = (Number of weeks of presence / 834) * 100

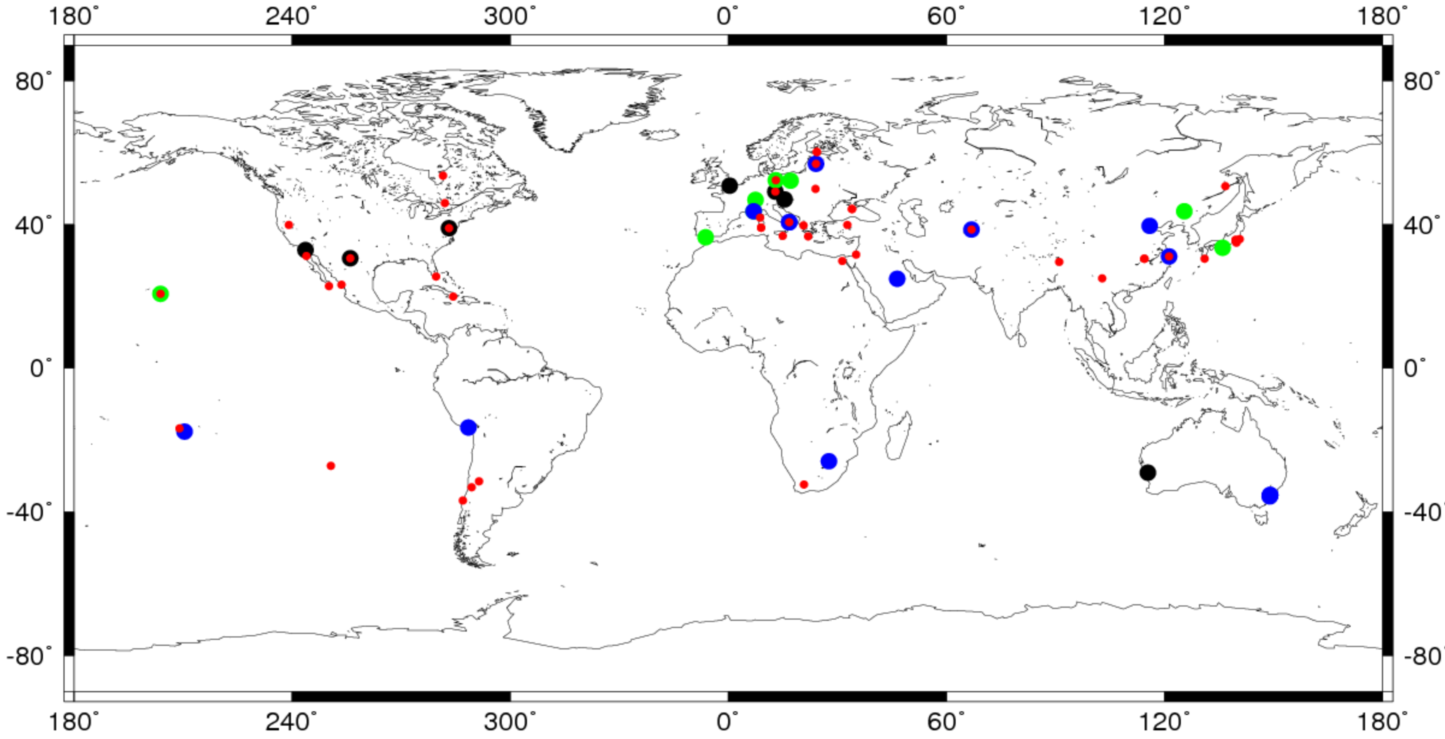


25 % ≤ *P* ≤ 50 % → + 14 stations (29 stations)

Data used (2/2)

ILRS analysis centre ASI v23 solution

Presence *P* = (Number of weeks of presence / 834) * 100



***P* ≤ 25 % → + 48 stations (77 stations)**

→ Dynamical feature of the SLR network

Terrestrial frames and EOP

Terrestrial frames and EOP (1/3)

One of the primary tasks of the IERS = to ensure consistency between ITRF, ICRF, and EOP.

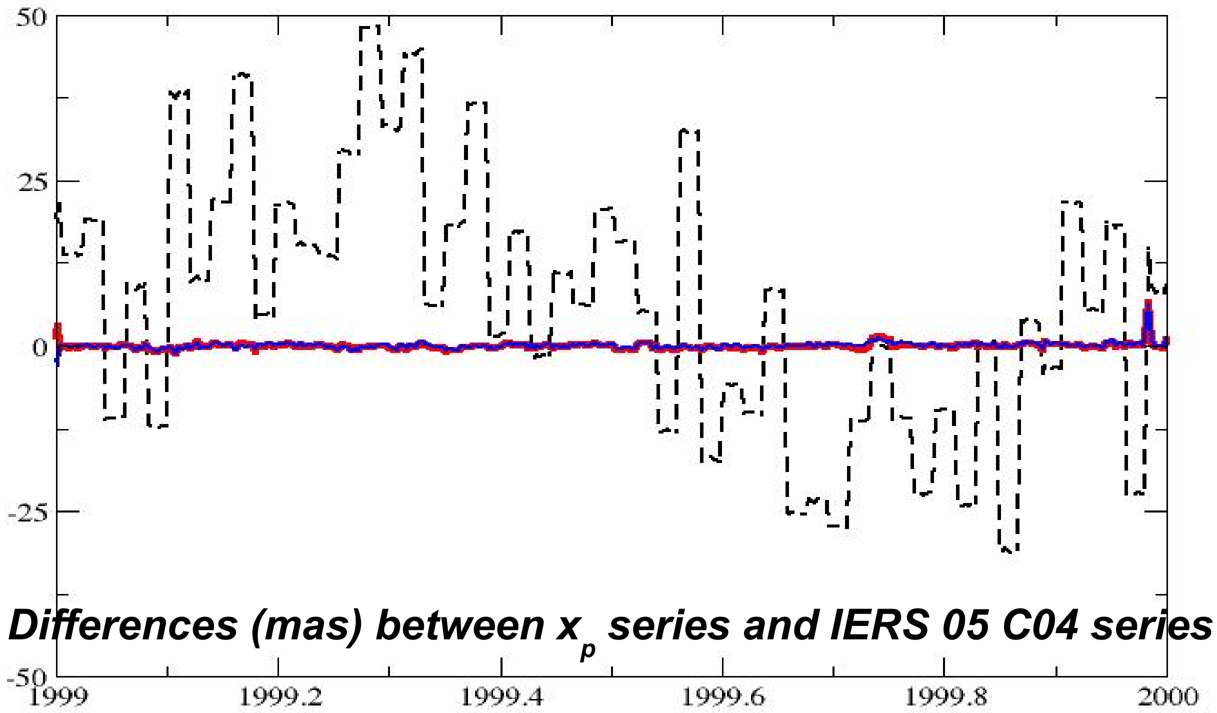
Several ways to reference station position time series with respect to a given TRF → Influence on the EOP time series (through orientation).

Two ways of referencing EOP :

- Definition of orientation of weekly TF wrt ITRF = make rotations equal to zero → EOP are directly "aligned".

- Estimation of 7-parameter transformations between weekly TF and ITRF → EOP are "aligned" with estimated rotations.

Terrestrial frames and EOP (2/3)



Differences (mas) between x_p series and IERS 05 C04 series

- - - Original x_p series (loose orientation for weekly TF).

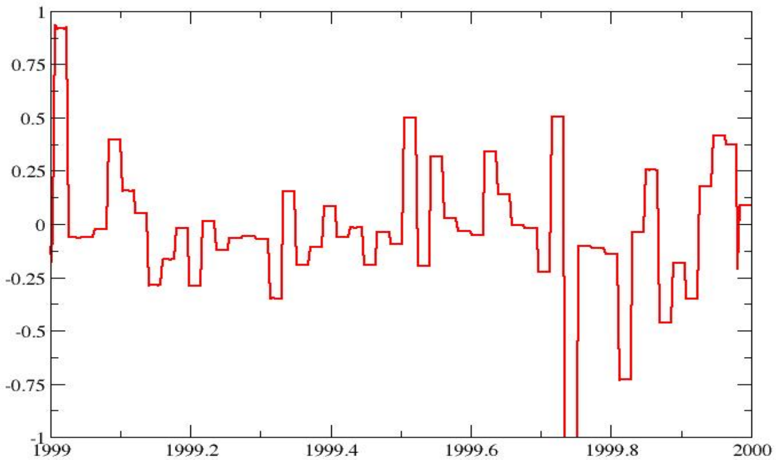
—— x_p series aligned with null rotations of weekly TF wrt ITRF.

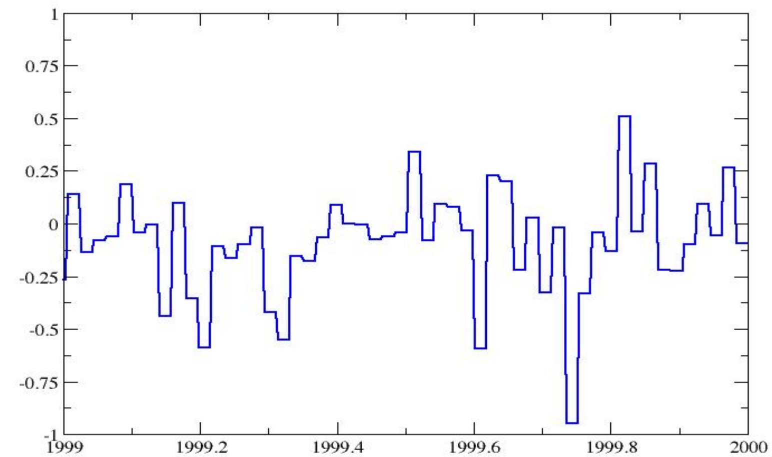
—— x_p series aligned with rotations estimated between weekly TF and ITRF.

Terrestrial frames and EOP (3/3)

Use of 2 networks for orientation definition and transformation estimation:
ALL = all stations available each week (cf. previous map).
ILRS = ILRS AWG core station network.

Differences (mas) between x_p series computed with ALL and ILRS networks





Diff. x_p series aligned with null rotations of weekly TF wrt ITRF.
Diff. x_p series aligned with rotations estimated between weekly TF and ITRF.

→ Network used for station/EOP referencing of great importance.
Goal of this work = find weekly sub-networks for referencing to guarantee stability of EOP series (use of Genetic Algorithms).

Genetic Algorithms

Genetic Algorithms (1/2)

Principle

Context :

Maximization of function $f(x_1,\ldots x_n)$ over $[a_1,b_1]x\ldots x[a_n,b_n]$ (f=objective function)

Solution encoding *(binary encoding example)* :

Each parameter x_i transformed into binary vector of length l_i

$$x_i \rightarrow \begin{vmatrix} 0 & 0 & 1 & 0 & \cdots & 1 & 1 & 0 & 1 \end{vmatrix}$$ (l_i depends on desired precision for x_i)

All encodings are merged into a global binary vector

$$\begin{vmatrix} x_1 & \cdots & x_n \end{vmatrix} \rightarrow \begin{vmatrix} 0_1 & 1_1 & \cdots_1 & 1_1 & 1_1 & \cdots & 0_n & 1_n & 0_n & 0_n & \cdots & 0_n & 1_n & 1_n & 1_n \end{vmatrix}$$

1 coding = 1 possible solution = 1 individual = 1 chromosome = 1 genotype

True values coded by a genotype = 1 phenotype

1 digit (0 ou 1) = 1 gene (with such encoding, $nbrgen=l_1+\ldots+l_n$)

Initial Population :

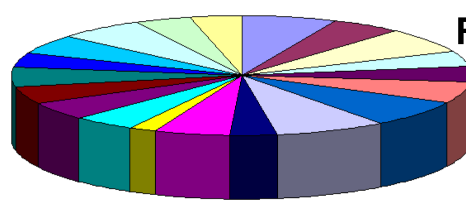
1 population of size m = m chromosomes = m individuals { $ind_1,\ldots,ind_m$ }

Initial population created by randomly setting the nbrgen genes of the m individuals

Evaluation and selection *(roulette wheel example)* :

Evaluation of current population = computation of m values $f_j=f(x_1^j,\ldots,x_n^j)$

$$F = \sum_{j=1}^{m} f_j \rightarrow p_j = \frac{f_j}{F} \rightarrow$$



Roulette wheel launched m times

→ Selection of m individuals = Intermediate population for crossovers and mutations

Genetic Algorithms (2/2)

Genetic operators

Crossover *(one-point crossover example)* :

Crossover probability p_c setted

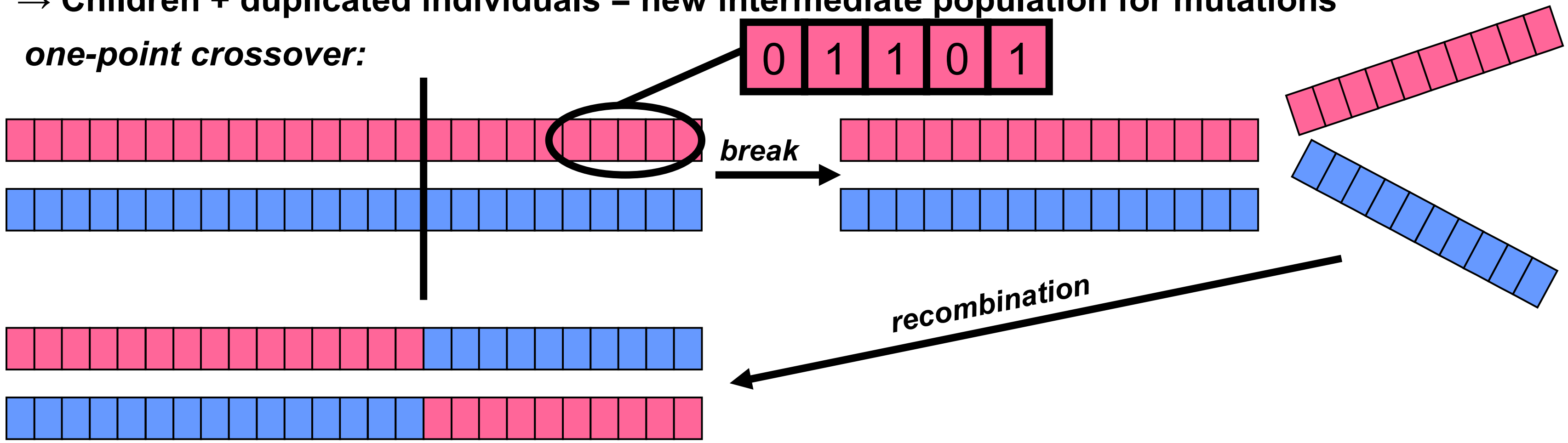
Each individual of the intermediate population is tested wrt p_c

→ Sub population of parents (other individuals are directly duplicated)

→ Crossovers → sub population of children replacing sub population of parents

→ Children + duplicated individuals = new intermediate population for mutations

one-point crossover:

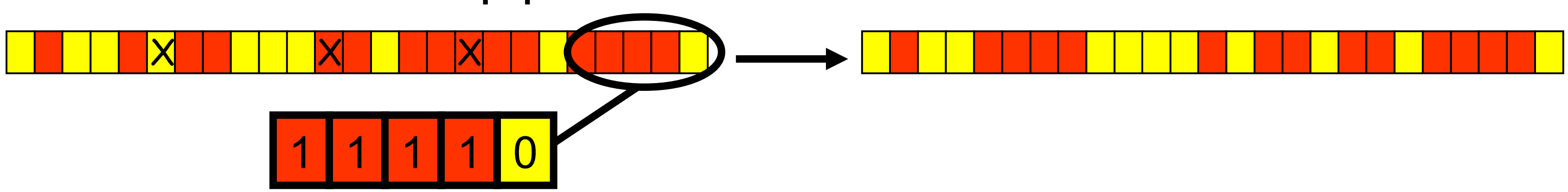


Mutation :

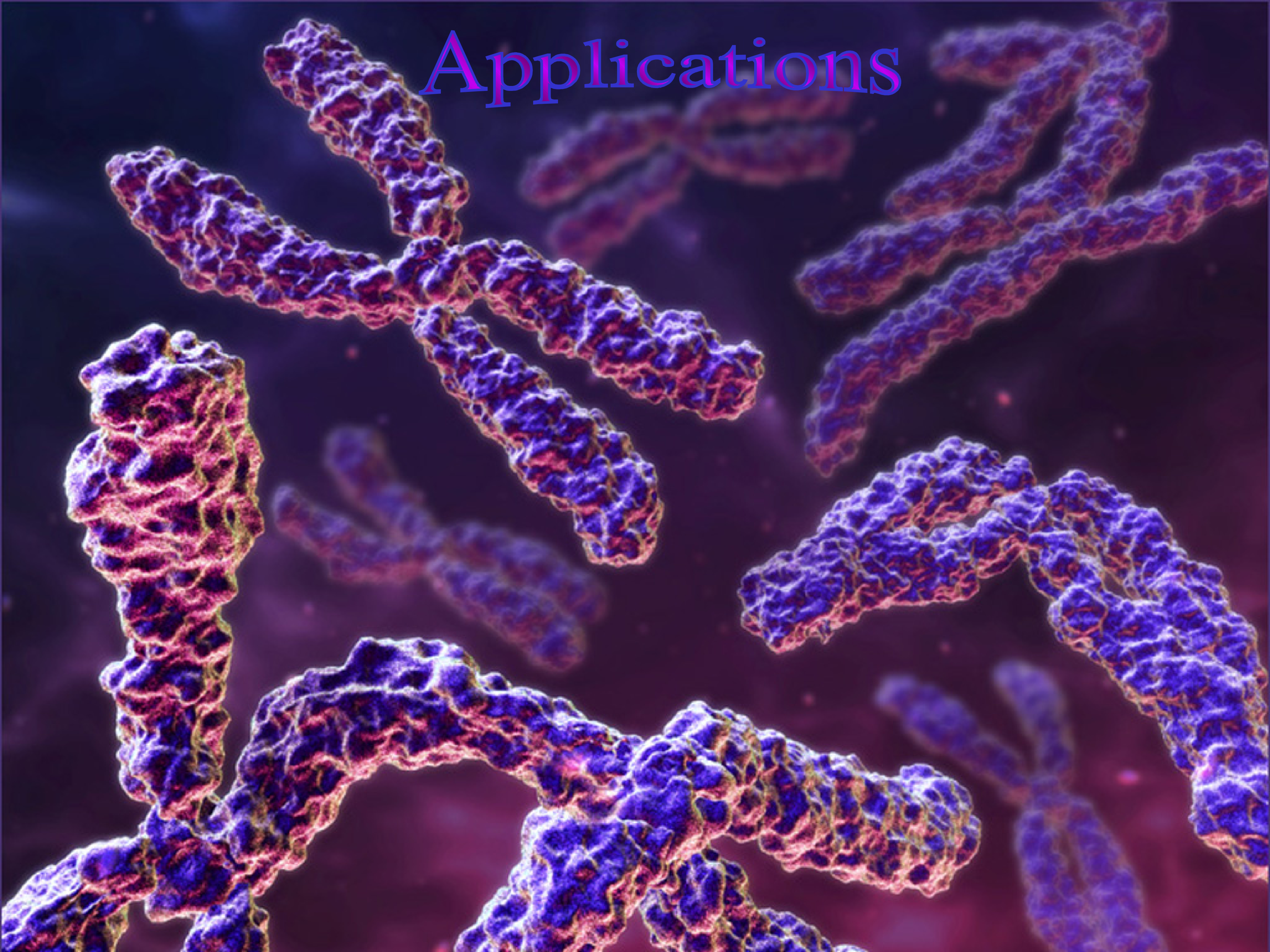
Mutation probability p_m setted

Each gene of each individual of the intermediate population is tested wrt p_m

→ Mutations → new current population for evaluation and selection



Applications



Genetically Modified Networks (1/5)

First computation – Orientation definition

Rotations of weekly TF made equal to zero wrt ITRF2008 with station sub-networks.

Method detailed in [Coulot et al., J Geod, 2010].

Multi objective Genetic Algorithms used to find, each week, optimal station sub-network to align orientation of TF wrt ITRF2008.
Optimization objectives = Reference System Effects for three rotations deduced from variance-covariance matrices of solutions so-obtained.
1 chromosome = 1 possible network
0 = station not used – 1 = station used

Networks so found = GMN (Genetically Modified Networks).

Genetically Modified Networks (2/5)

First computation – Results

Table = Differences between EOP series produced with three networks and the IERS 05 C04 series.

ALL = All stations available each week.
ILRS = ILRS AWG core station network.
GMN = Genetically Modified Networks.

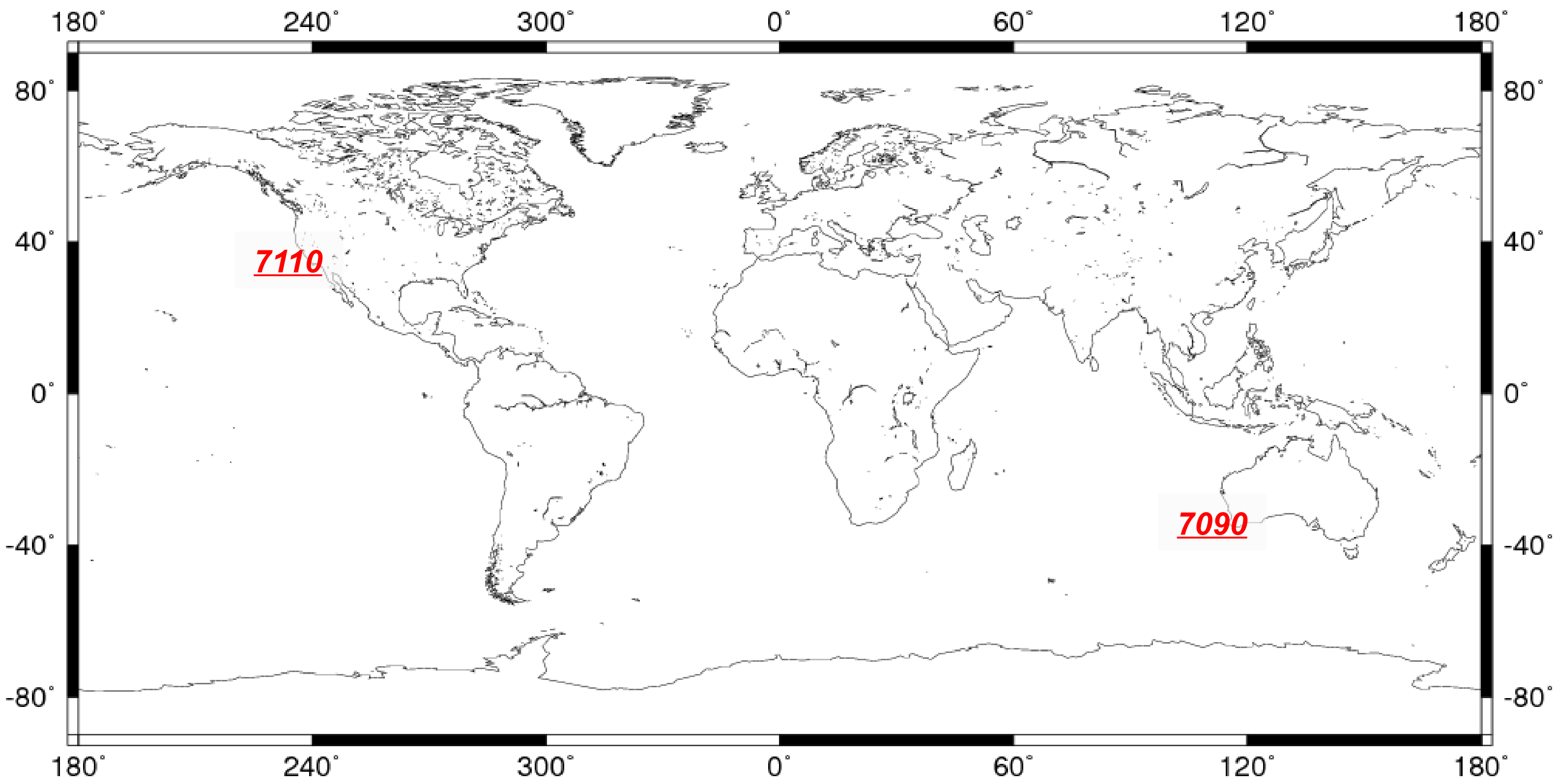
µas	ALL	ILRS	GMNo
x_p Mean St. Dev. RMS	-53 315 319	-62 287 294	-41 261 264
y_p Mean St. Dev. RMS	-21 309 309	-22 265 266	-13 241 241

→ Gains of 25-30 µas (9-10 %) for RMS wrt ILRS network.

= 50 % of accuracy of 05 C04 series [Bizouard and Gambis, 2009].

Genetically Modified Networks (3/5)

First computation – Mean network



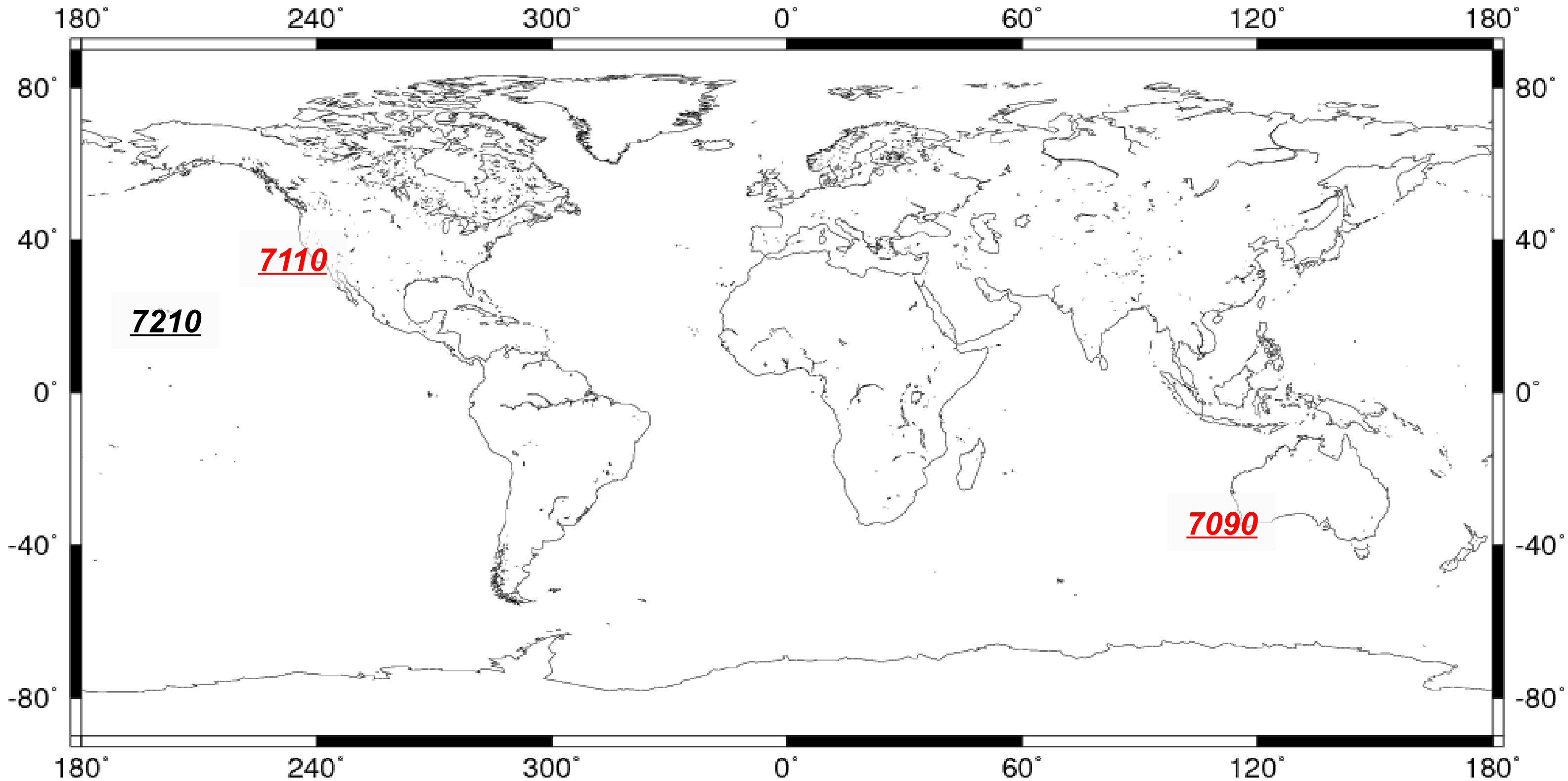
Legend of the map

(C≥75)&(P≥75)

Map = "Mean" network emerging from the weekly GMN.
Two criteria used for each station involved (%)
- Presence *P* = (Total occurrence in ASI sol.) / 834
- Choice *C* = (Occurrence in GMN) / (Total occurrence in ASI sol.)
The ILRS core stations are underlined.

Genetically Modified Networks (3/5)

First computation – Mean network

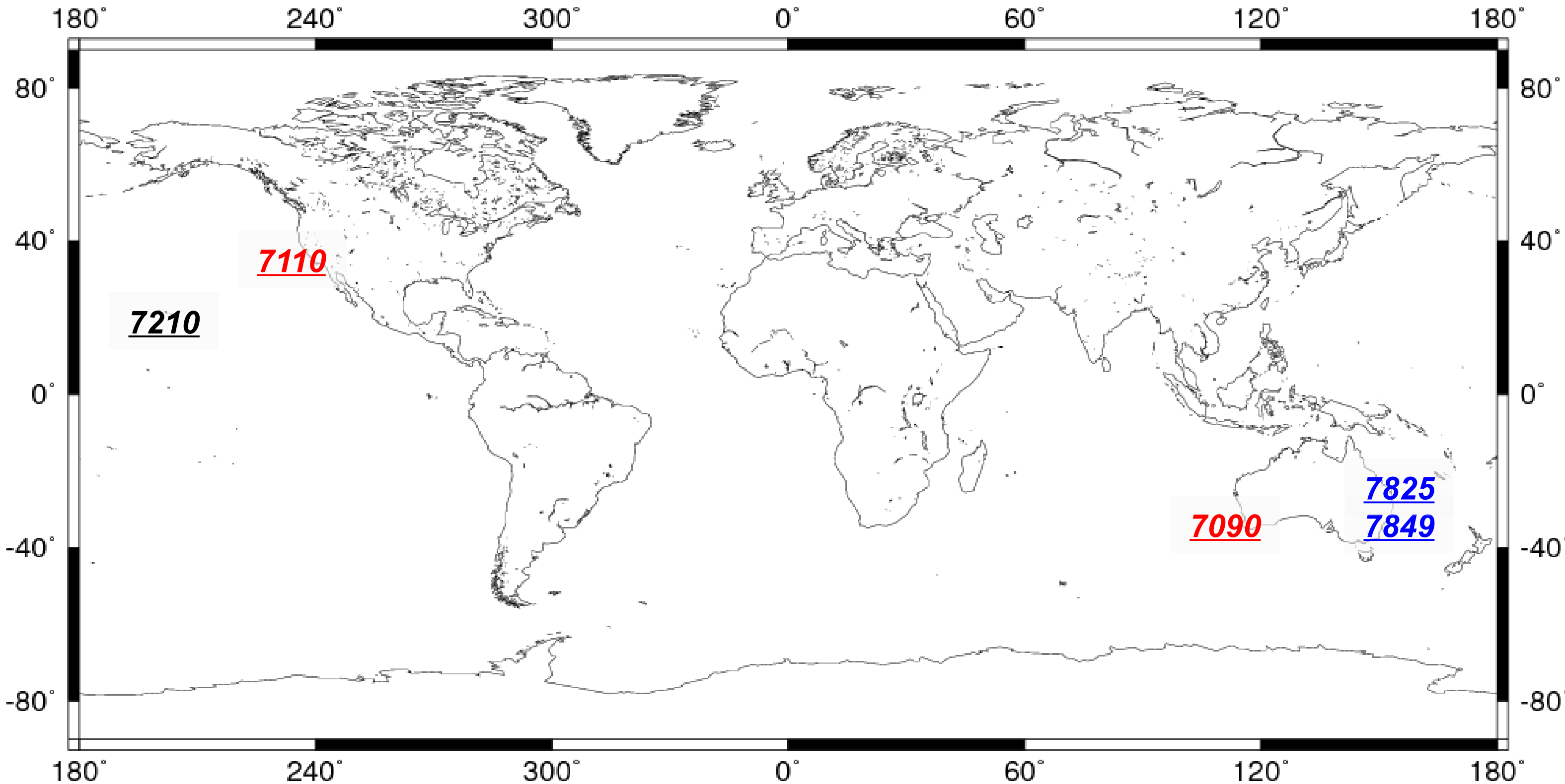


Legend of the map

(C≥75)&(P≥75) *(C≥75)&(75>P≥50)*

Genetically Modified Networks (3/5)

First computation – Mean network

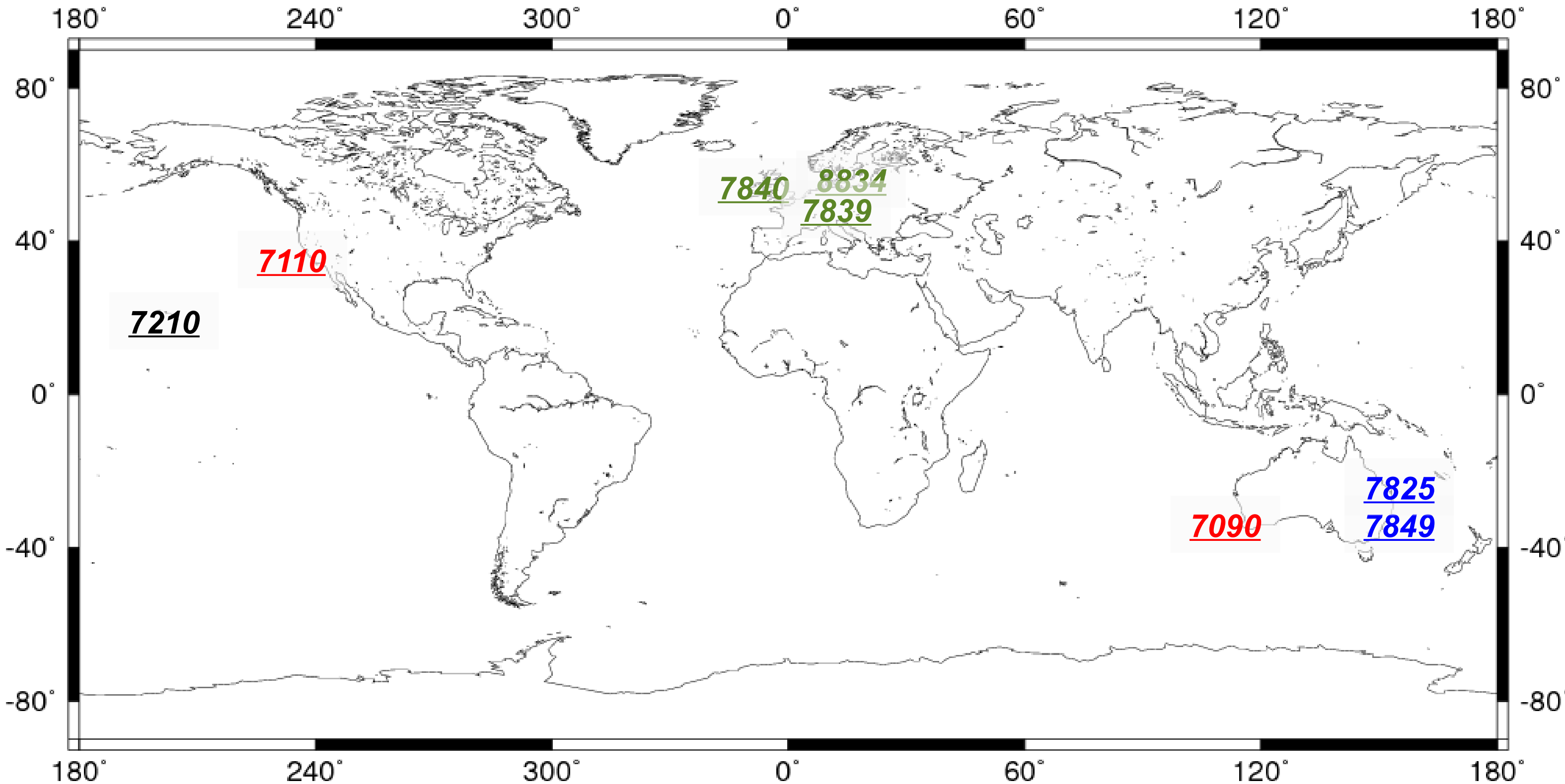


Legend of the map

(C≥75)&(P≥75) *(C≥75)&(75>P≥50)* *(C≥75)&(50>P≥25)*

Genetically Modified Networks (3/5)

First computation – Mean network

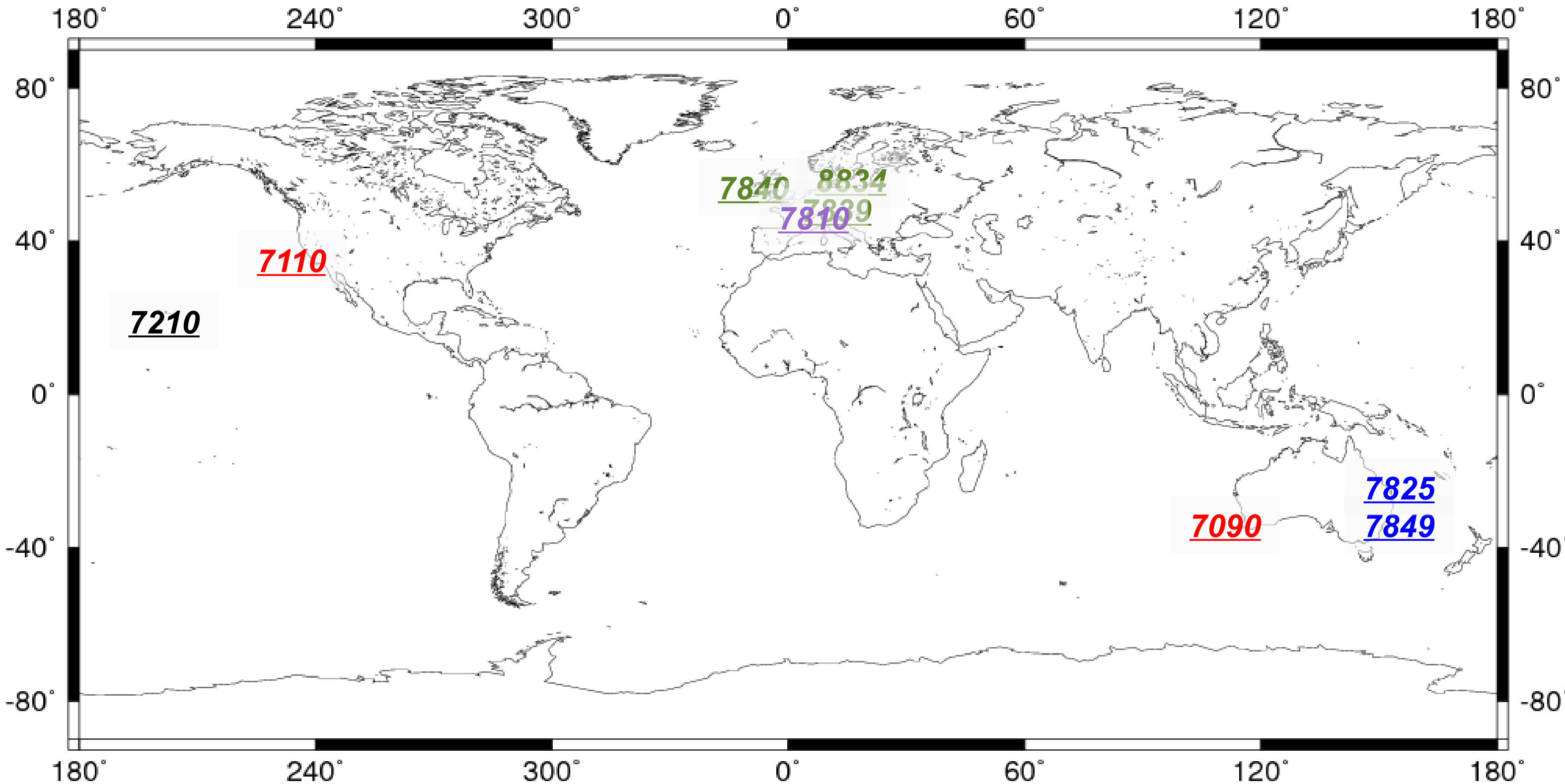


Legend of the map

(C≥75)&(P≥75) *(C≥75)&(75>P≥50)* *(C≥75)&(50>P≥25)*
(75>C≥50)&(P≥75)

Genetically Modified Networks (3/5)

First computation – Mean network



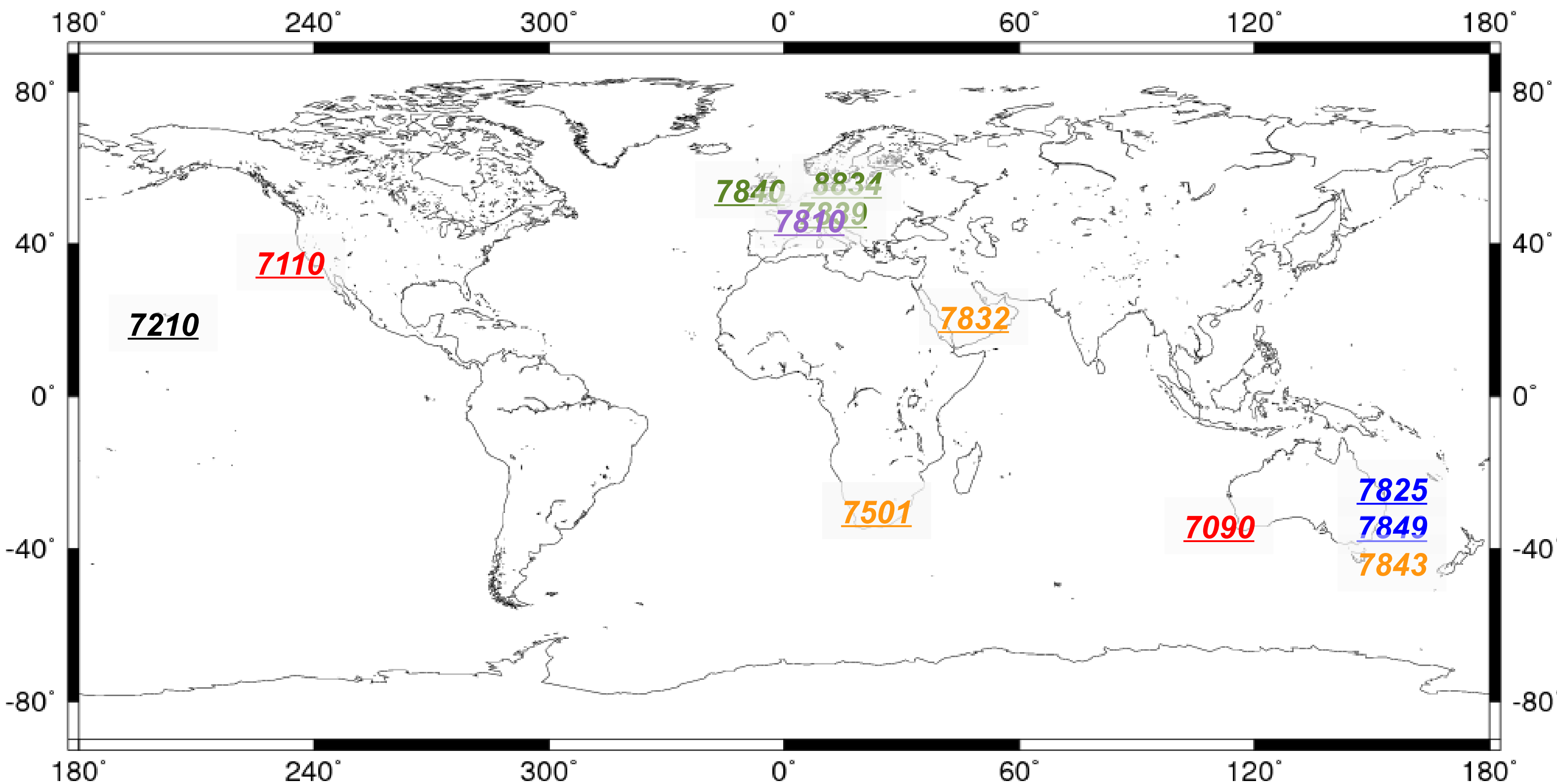
Legend of the map

(C≥75)&(P≥75) *(C≥75)&(75>P≥50)* *(C≥75)&(50>P≥25)*

(75>C≥50)&(P≥75) *(75>C≥50)&(75>P≥50)*

Genetically Modified Networks (3/5)

First computation – Mean network

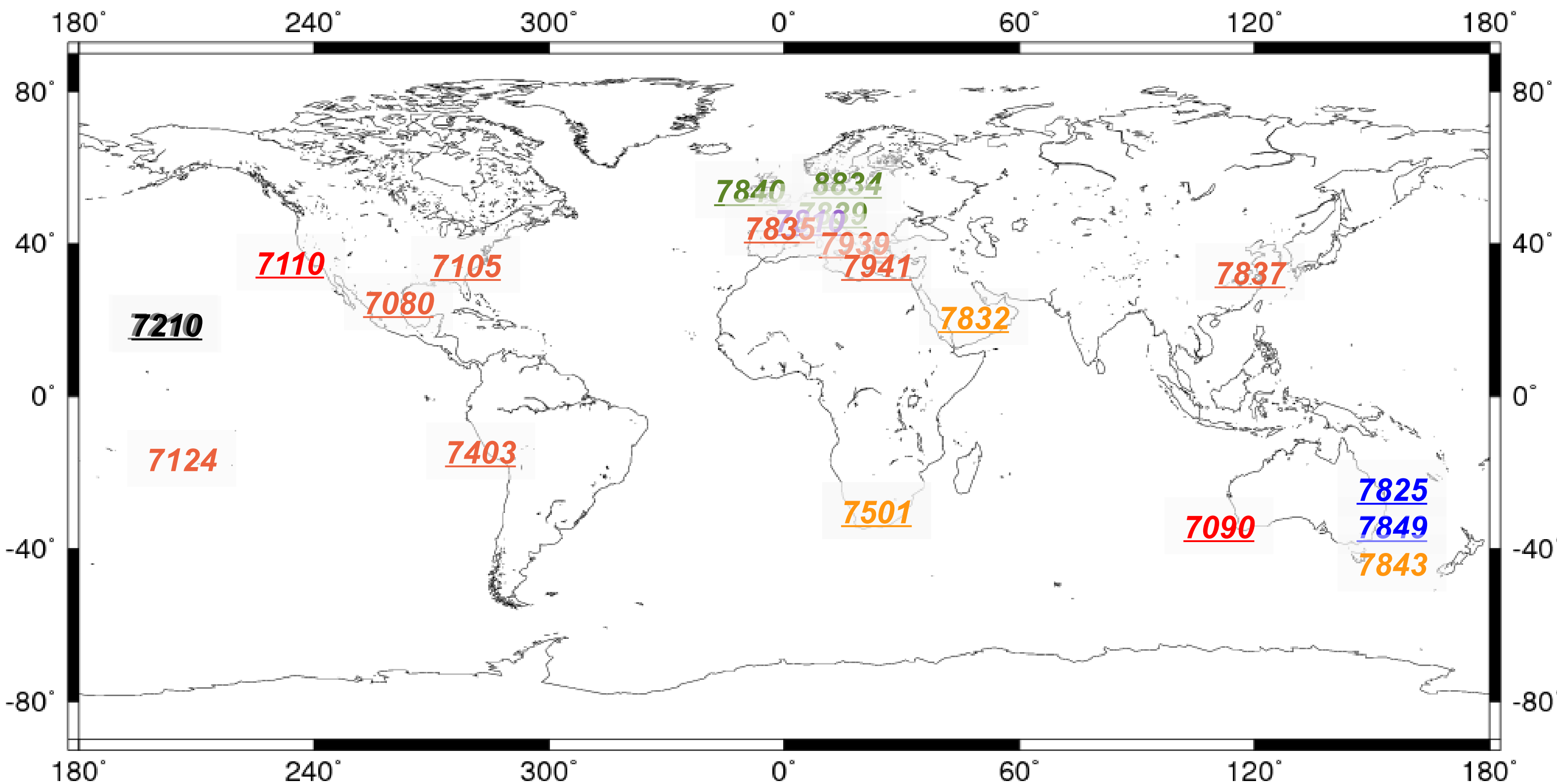


Legend of the map

(C≥75)&(P≥75) *(C≥75)&(75>P≥50)* *(C≥75)&(50>P≥25)*
(75>C≥50)&(P≥75) *(75>C≥50)&(75>P≥50)* *(75>C≥50)&(50>P≥25)*

Genetically Modified Networks (3/5)

First computation – Mean network

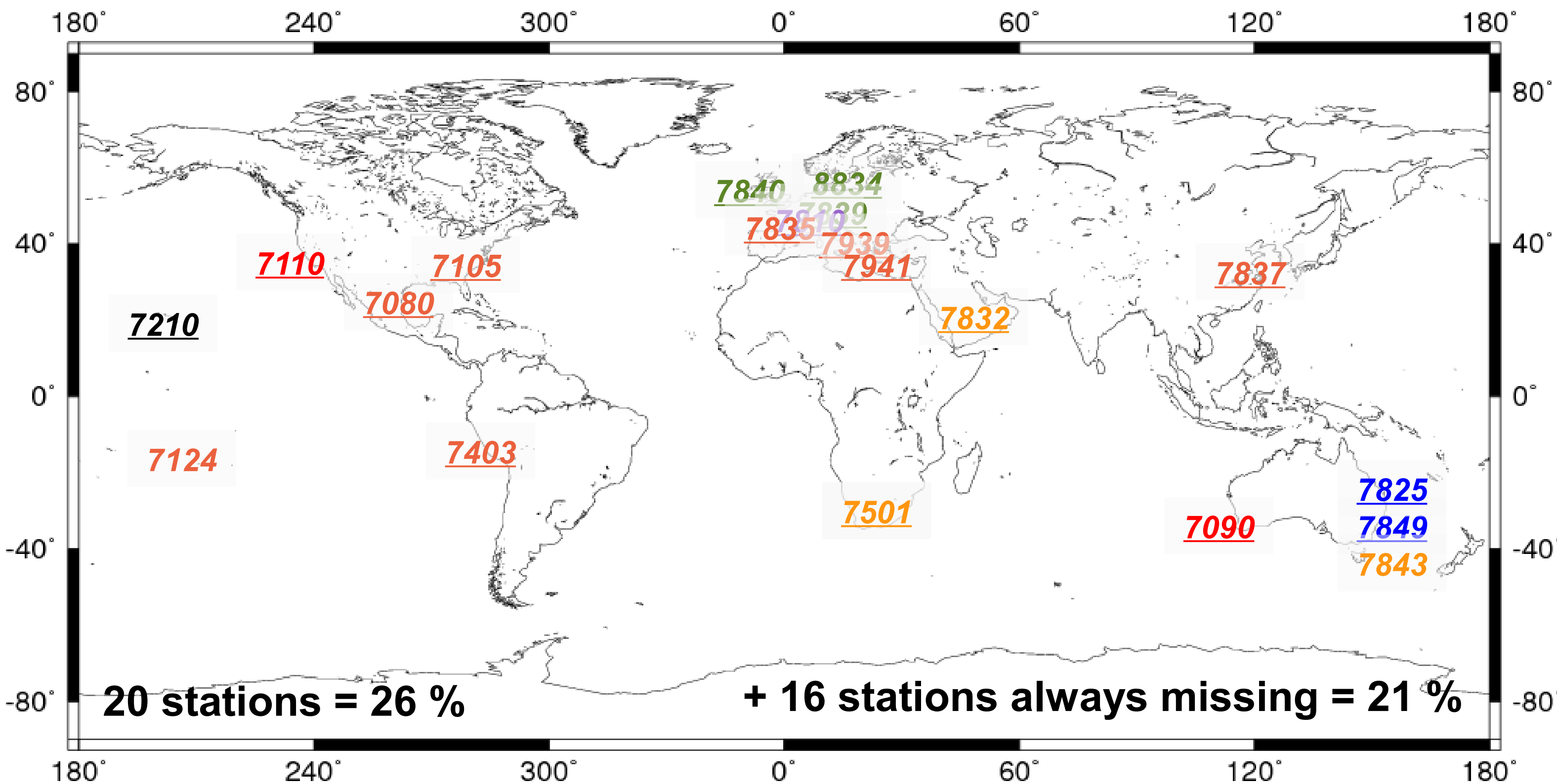


Legend of the map

(C≥75)&(P≥75) *(C≥75)&(75>P≥50)* *(C≥75)&(50>P≥25)*
(75>C≥50)&(P≥75) *(75>C≥50)&(75>P≥50)* *(75>C≥50)&(50>P≥25)*
(50>C≥25)&(P≥25)

Genetically Modified Networks (3/5)

First computation – Mean network



→ A majority of stations used by GMN belongs to ILRS AWG list of core stations.

<u>BUT</u> strength of GMN = their dynamical feature.

Genetically Modified Networks (4/5)

Second computation – Orientation definition – Station weighting

Rotations of weekly TF made equal to zero wrt ITRF2008 with a weighting of all available stations (between 0. and 1.).

Multi objective Genetic Algorithms used to find, each week, optimal station weighting to align orientation of TF wrt ITRF2008.
Same optimization objectives than those previously used.
1 chromosome = 1 vector of weights per station between 0. and 1.

µas	ALL	ILRS	GMNo	GMNw
x_p Mean	-53	-62	-41	-40
St. Dev.	315	287	261	254
RMS	319	294	264	257
y_p Mean	-21	-22	-13	-18
St. Dev.	309	265	241	234
RMS	309	266	241	235

Slight improvement for RMS (6-7 µas) wrt GMN o.

Genetically Modified Networks (5/5)

Third computation – 7-parameter transformations

!! Preliminary results !!

Weekly 7-parameter transformations estimated between weekly TF and ITRF2008 with station sub-networks. EOP aligned with estimated rotations. Multi objective Genetic Algorithms used to find, each week, optimal station sub-network to estimate transformations between TF and ITRF2008.

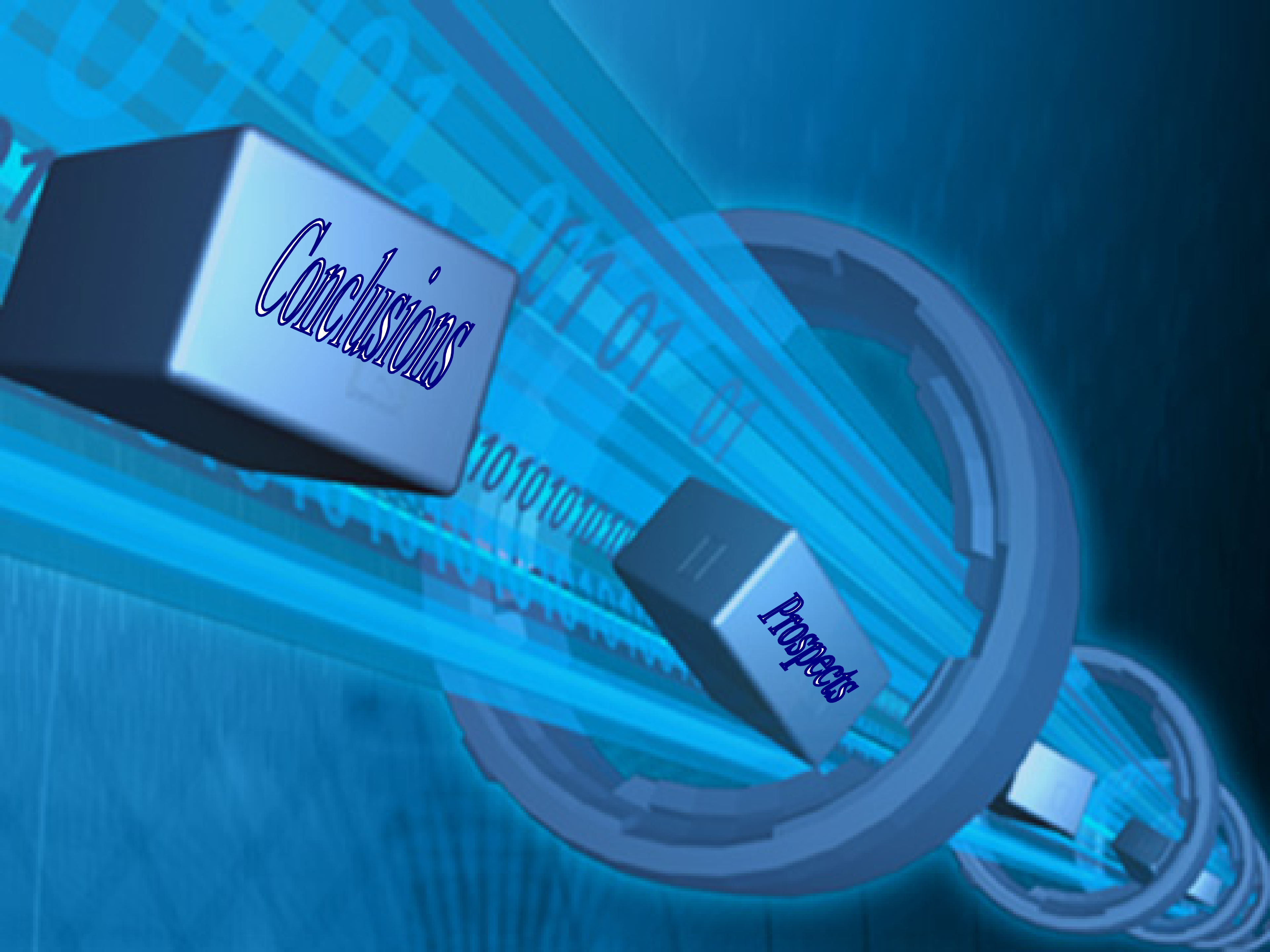
Optimization objectives = RMS of station positions and EOP residuals.

1 chromosome = 1 possible network (0 = station not used – 1 = station used).

µas	ALL	ILRS	GMNt
x_p Mean	-35	-12	-1
St. Dev.	320	283	220
RMS	322	284	220
y_p Mean	-74	-45	0
St. Dev.	309	274	203
RMS	318	278	203

→ Results seem impressive

BUT deep analysis of GMN shows that networks are twisted.


Conclusions
Prospects

Conclusions and prospects

- Many factors may influence the accuracy of EOP series (quality and distribution of the measurements, sensitivity of the technique used, etc.) Among them, it seems that the way the EOP series are referenced is not negligible.

- Impact of the referencing assessed at a 10 % level for SLR.

- Rigourous method to find “core station networks”.

- Regarding GMN for orientation definition, test of hybridization of GA with deterministic methods (Newton's algorithm, for instance).

- Regarding GMN for 7-parameter transformation estimation, search for better suited objectives (based on EOP variabilities at different time scales ?) and study of weight matrices used for estimation.

- Such studies for other space-geodetic techniques.