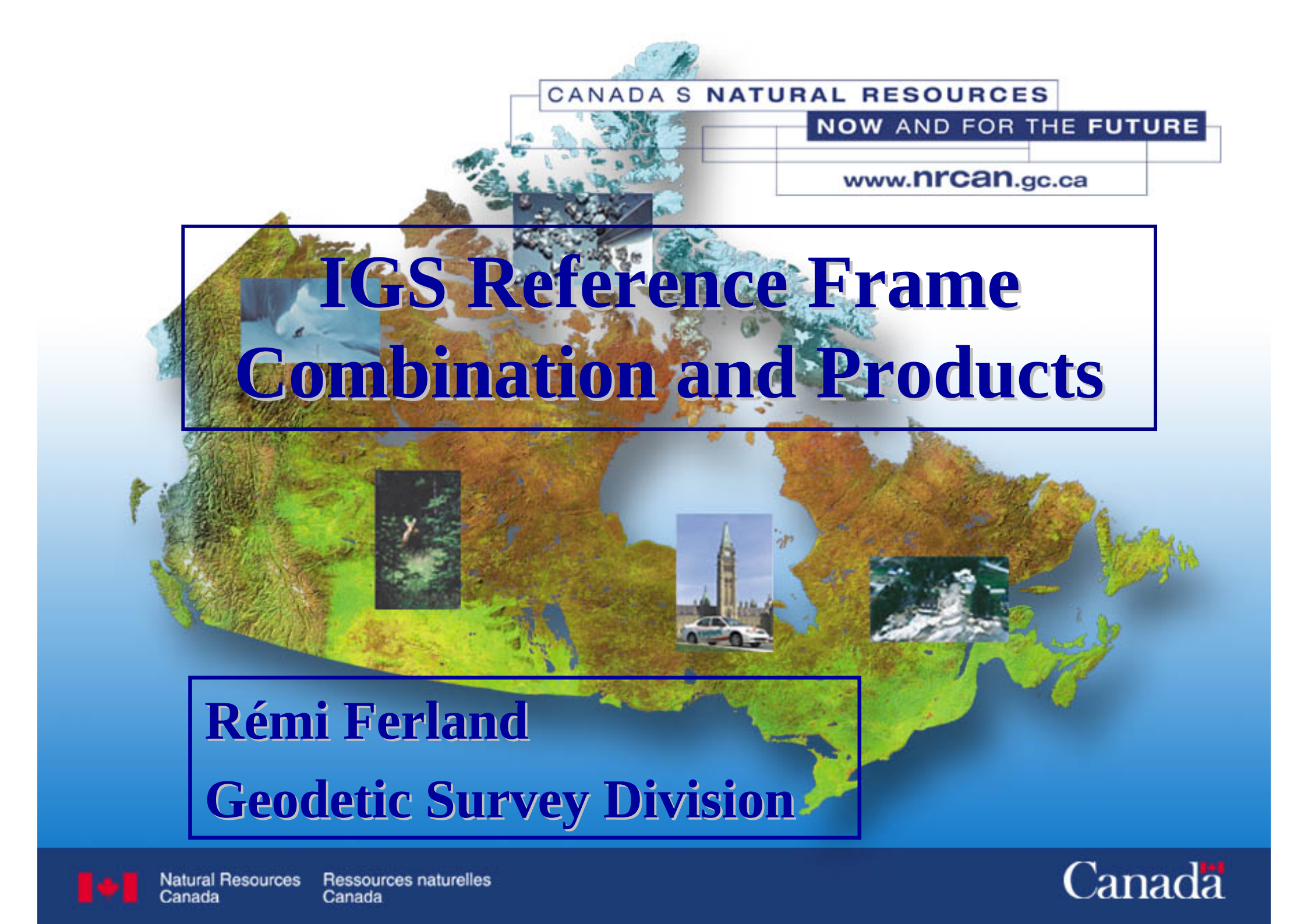




CANADA'S NATURAL RESOURCES

NOW AND FOR THE FUTURE

www.nrcan.gc.ca

IGS Reference Frame Combination and Products

Rémi Ferland
Geodetic Survey Division



Natural Resources
Canada

Ressources naturelles
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Canada



Contents

1. *Reference Frame Working Group*
2. *Weekly Combination Procedure*
3. *ITRF Realizations*
4. *Products*
5. *Maintenance*
6. *Summary*





1. Reference Frame Working Group

- Objectives
- Members
- Timeline



Objectives

- Generate the official solution for:
 - Station coordinates & velocities (~250 stations)
 - Weekly – Cumulative,
 - Earth Rotation Parameters (ERP),
 - Apparent Geocenter.
- For all parameters:
 - Include appropriate covariance information,
 - Alignment to ITRFxx (or IGS realization of ...),
 - Consistency, Reliability & Accuracy.
- Report / Investigate abnormal station coordinate behaviors / discontinuities
- ...



Members +

- AC & GNAAC:

- S. Schear (cod)
- R. Ferland (emr)
- C. Garcia-Martinez (esa)
- G. Gendt (gfz & ACC)
- F. Webb (jpl)
- T. Herring (mit)
- K. Nurutdinov (ncl)
- W. Kass (ngs)
- P. Fang (sio)

- Others:

- R. Neilan (IGSCB)
- A. Moore (Network)
- R. Weber (Ret. ACC)
- J. Kouba (Ret. ACC)
- M. Rothacher (IERS)
- Z. Altamimi (ITRF)
- J. Ray (---)



Timeline

GPS Week	Start Date	Comment
0837	96/01/21	ACs Start Producing SINEX files / ITRF93 / 13 Stations
0978	98/10/04	Start IGS Reference Frame Pilot Project
0999	99/02/28	Preliminary IGS SINEX Combined Products
1021	99/08/01	Use ITRF97 / 51 Stations
1050	00/02/20	Official Combined Products
1065	00/06/04	Use IGS Realization of ITRF97 / 51 Stations
1143	01/12/02	Use IGS Realization of ITRF00 / 54 Stations
1253	04/01/11	Use IGS Realization of ITRF00 / 99 Stations



2. *Combination Procedure*

- AC Processing
- Preprocessing
- Comparisons / Alignment
- Combination:
 - Weekly
 - Cumulative
- Quality Assurance



AC Processing

AC	Software	Comment
cod	Bernese	D.D. / L.S.
emr	Gipsy	U.D. / Kalman
esa	BAHN ...	U.D. / L.S.
gfz	EPOS.P	U.D. / L.S.
jpl	Gipsy	U.D. / Kalman
mit	GAMIT ...	D.D. / L.S.
ngs	Page5	D.D. / L.S.
sio	GAMIT ...	D.D. / L.S.

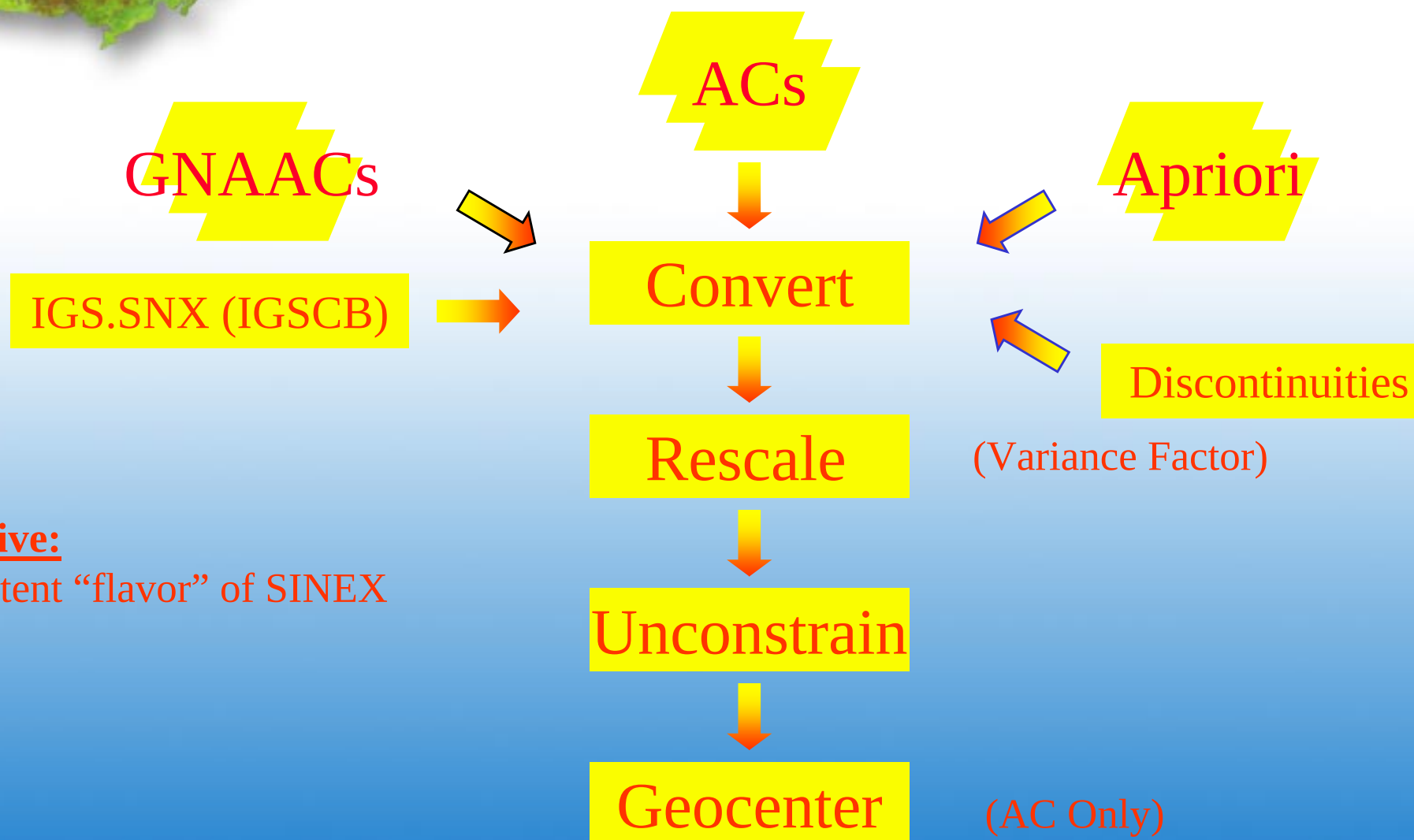
- Independent Software
- Reuse of data
- Evolution:
 - R.D. & Production
 - Synchronization
- Reprocessing ???

U.D. = Undifferenced
 D.D. = Double Differences
 L.S. = Least Squares





Preprocessing

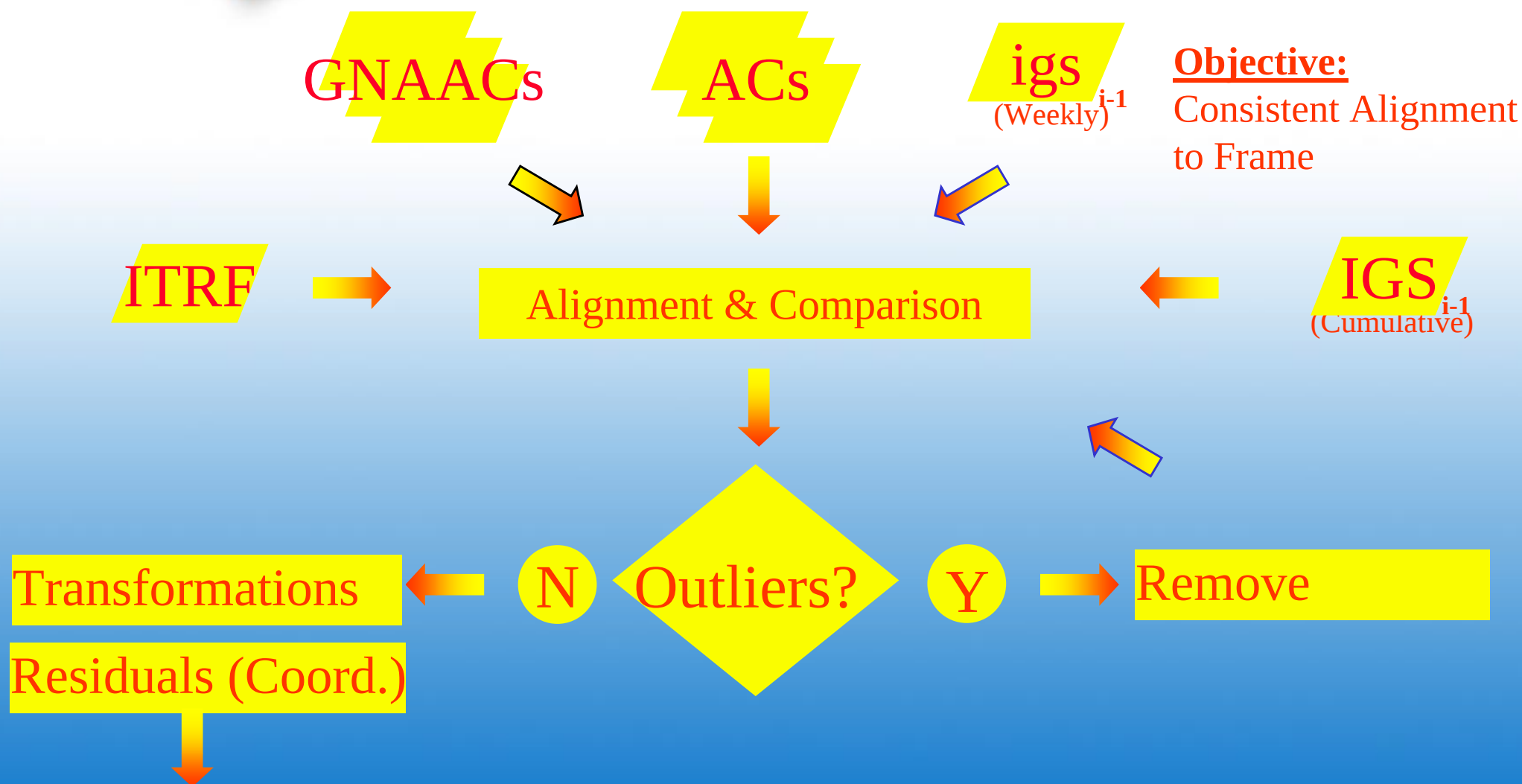


Objective:

Consistent “flavor” of SINEX

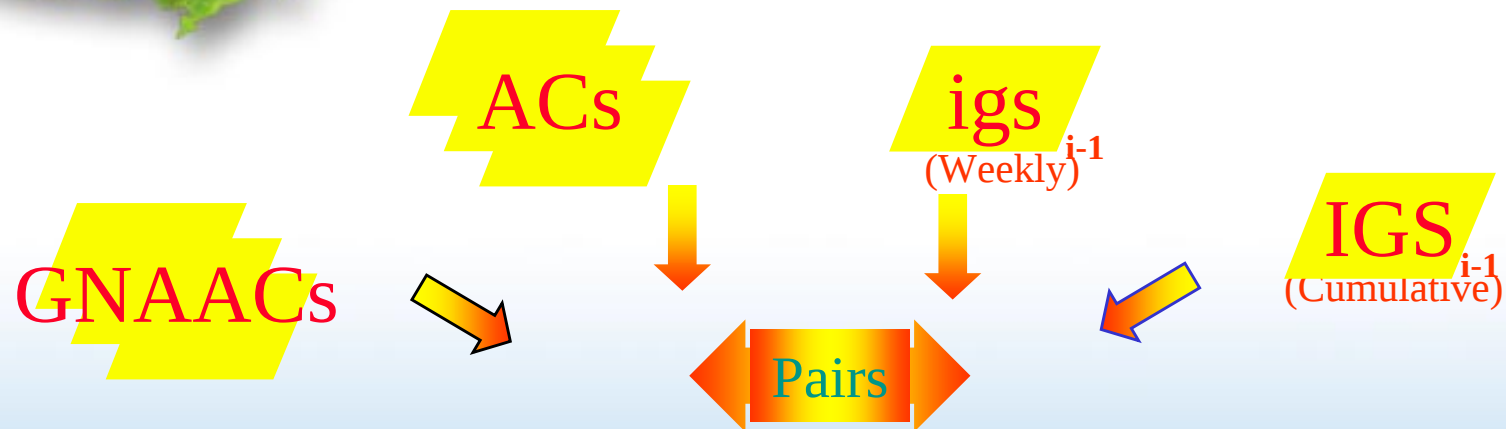


Comparison / Alignment to the Reference Frame



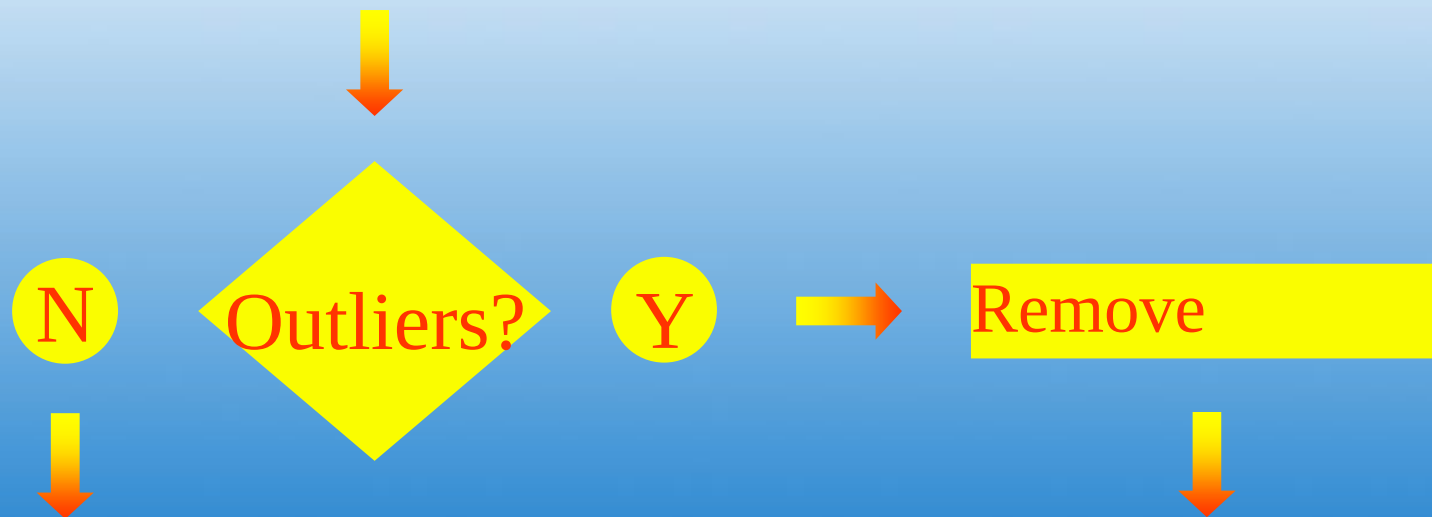


Pairwise Comparison



Objective:

Detection & Removal
of Inconsistencies

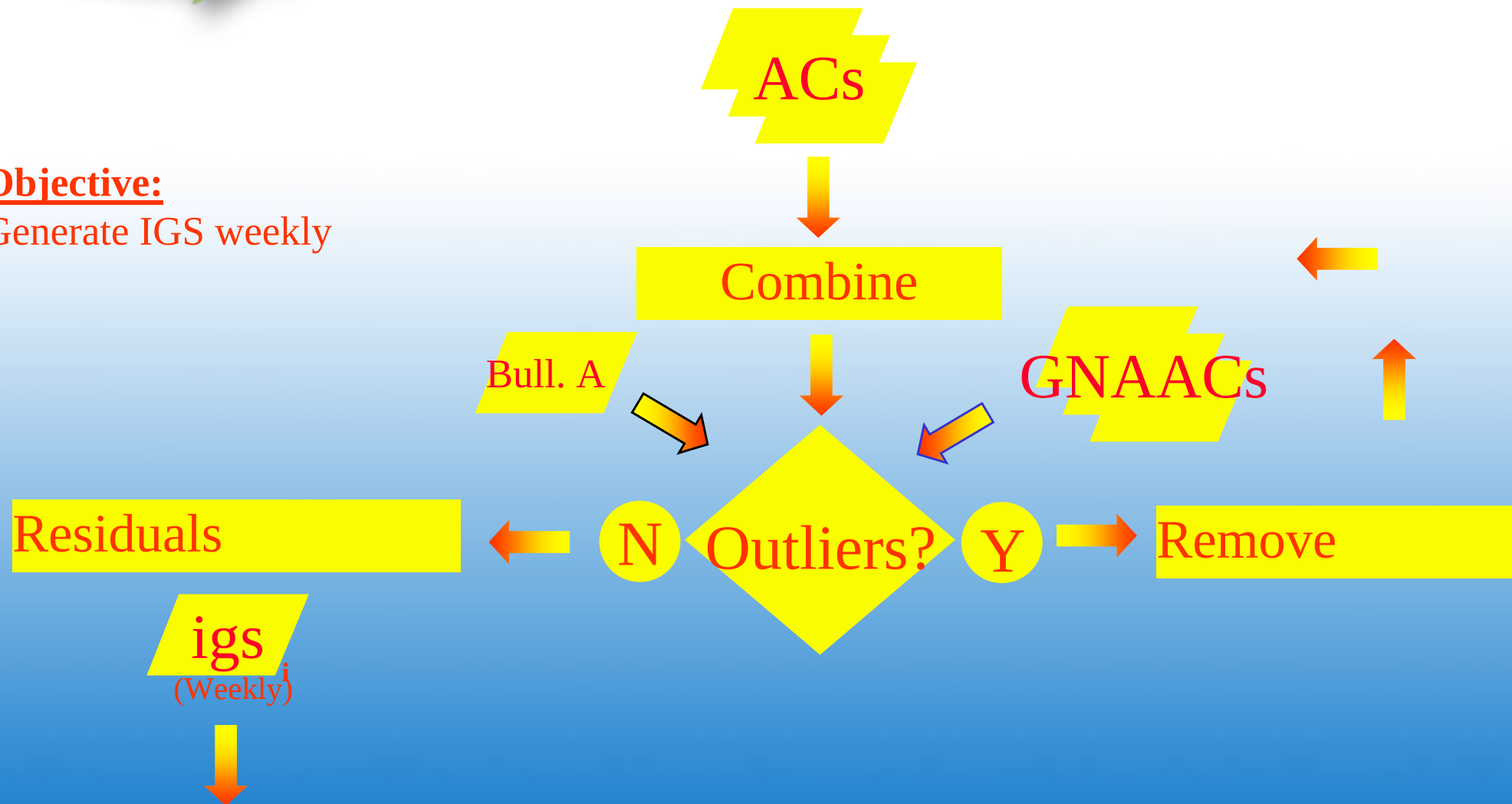




Combination (Weekly Solution)

Objective:

Generate IGS weekly

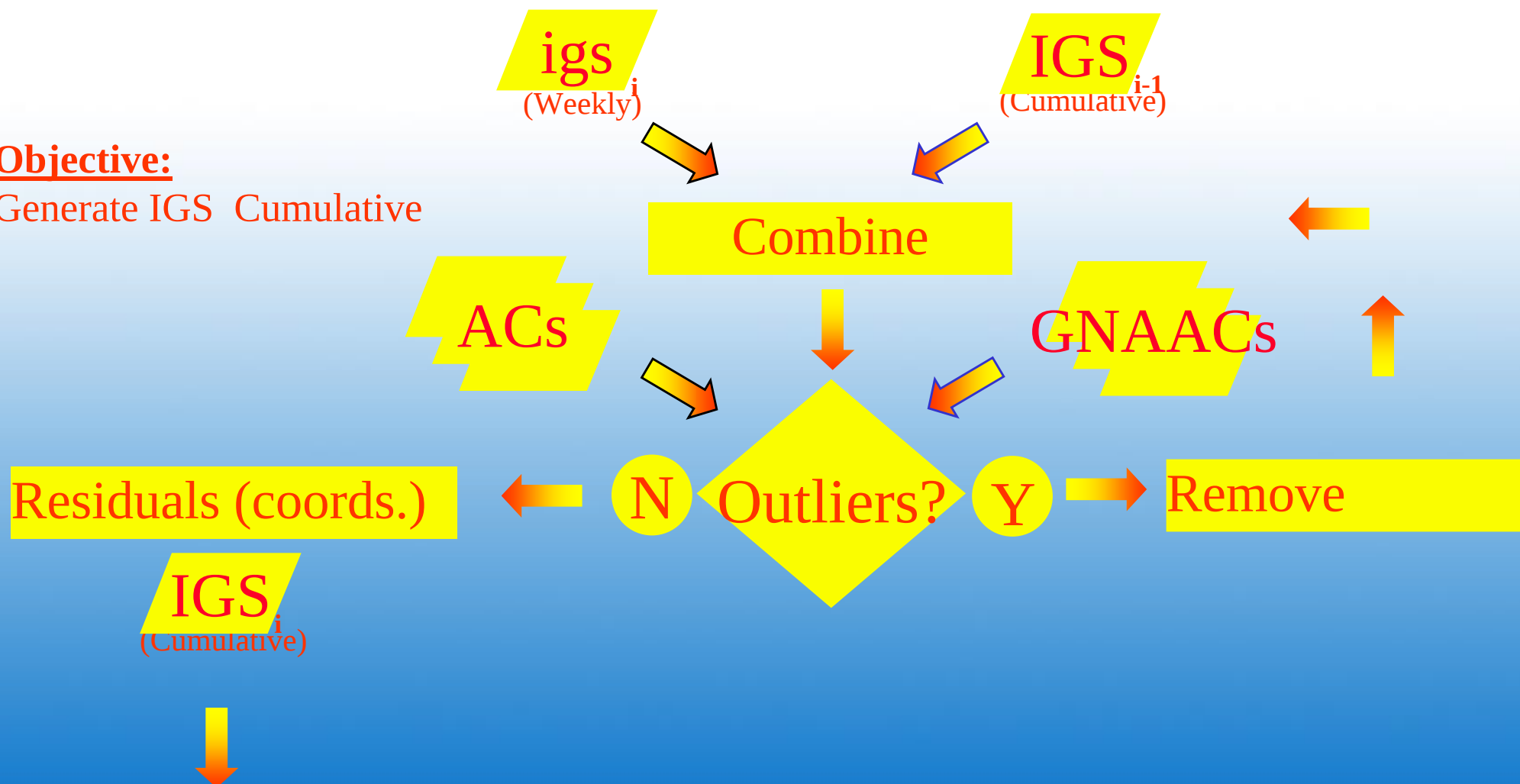




Combination (Cumulative Solution)

Objective:

Generate IGS Cumulative





Combined Parameters

- Coordinates (Weekly Solutions)
 - Corrections for antenna height (where appropriate)
 - Objective: One position/DOME#/Week
 - Some stations removed (No DOME# / No log / Outliers)
- Velocity (Cumulative Solution)
 - No condition imposed at sites with multiple estimates
 - Some Stations removed (No Dome / No Log / Poor Velocity)



Combined Parameters (Cont.)

- Apparent Geocenter
 - Some Implicit AC estimates are excluded
- ERP's (Daily estimates at 12:00:00)
 - LOD Calibrated using Bulletin A (Mireault & al (1999))
 - UT not included
 - Some AC Pole Rates are excluded
 - Continuity condition not removable
- Only Inner Constraints applied



Some Statistics

- Since GPS Weeks 0837 ~ 460 weeks
- AC & GNAAC Solution files ~ 4500
- Weekly Positions Estimates (X,Y,Z)
 - AC & GNAAC ~ 400000
 - IGS ~ 73000



Quality Assurance

- Comparisons:
 - Between ACs
 - With GNAACs independent weekly combination
 - IGS realization of ITRF
 - Previous week IGS solutions (igs_{i-1} , IGS_{i-1})
- Manual checks of the solutions
- Comparisons of IGS_i velocity field with plate motion models (~quarterly).

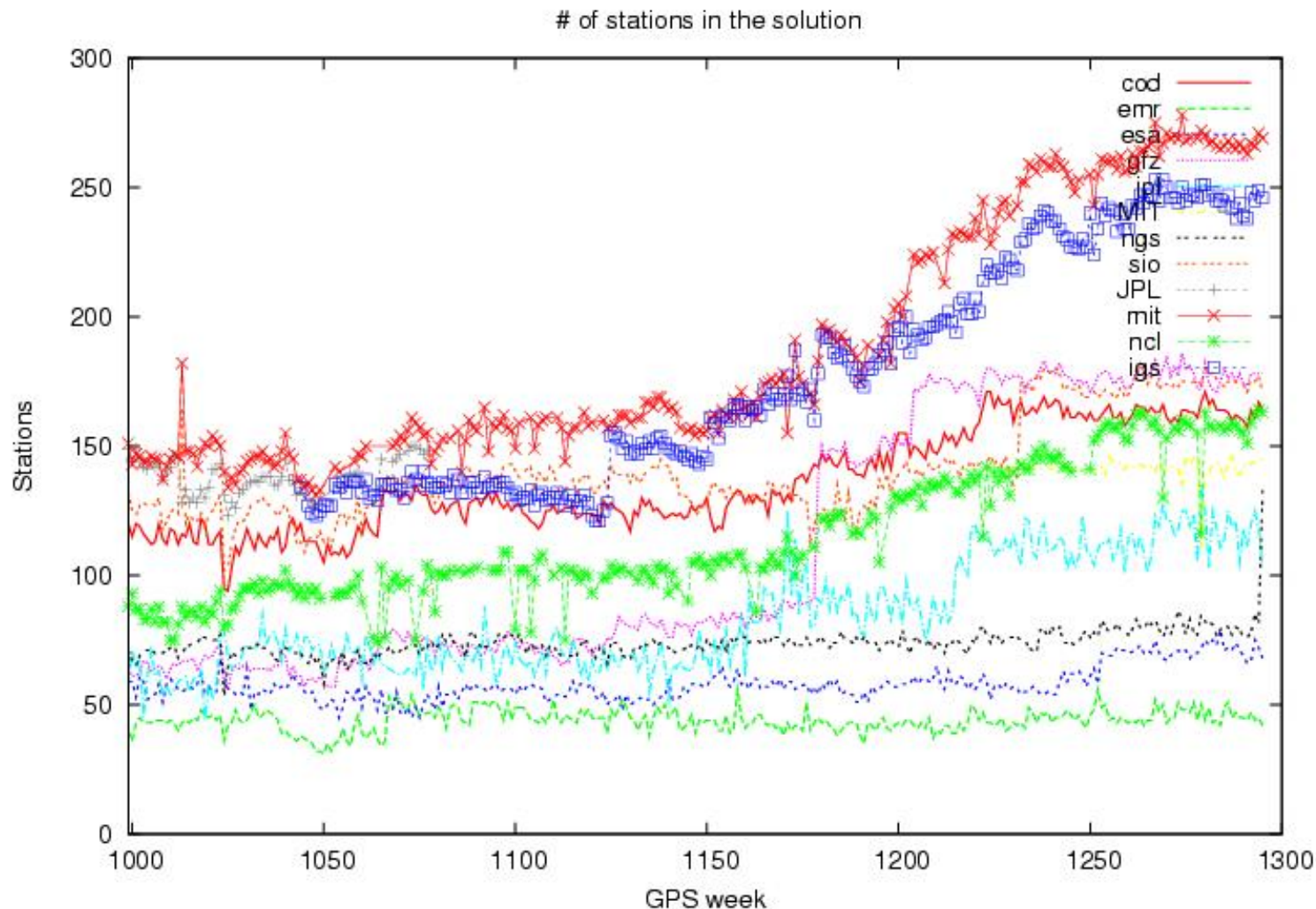


3. *ITRF Realizations*

- AC Stations Analysis Evolution
- ITRF92-93-94
- ITRF96
- ITRF97
- ITRF00
 - IGS00
 - IGb00

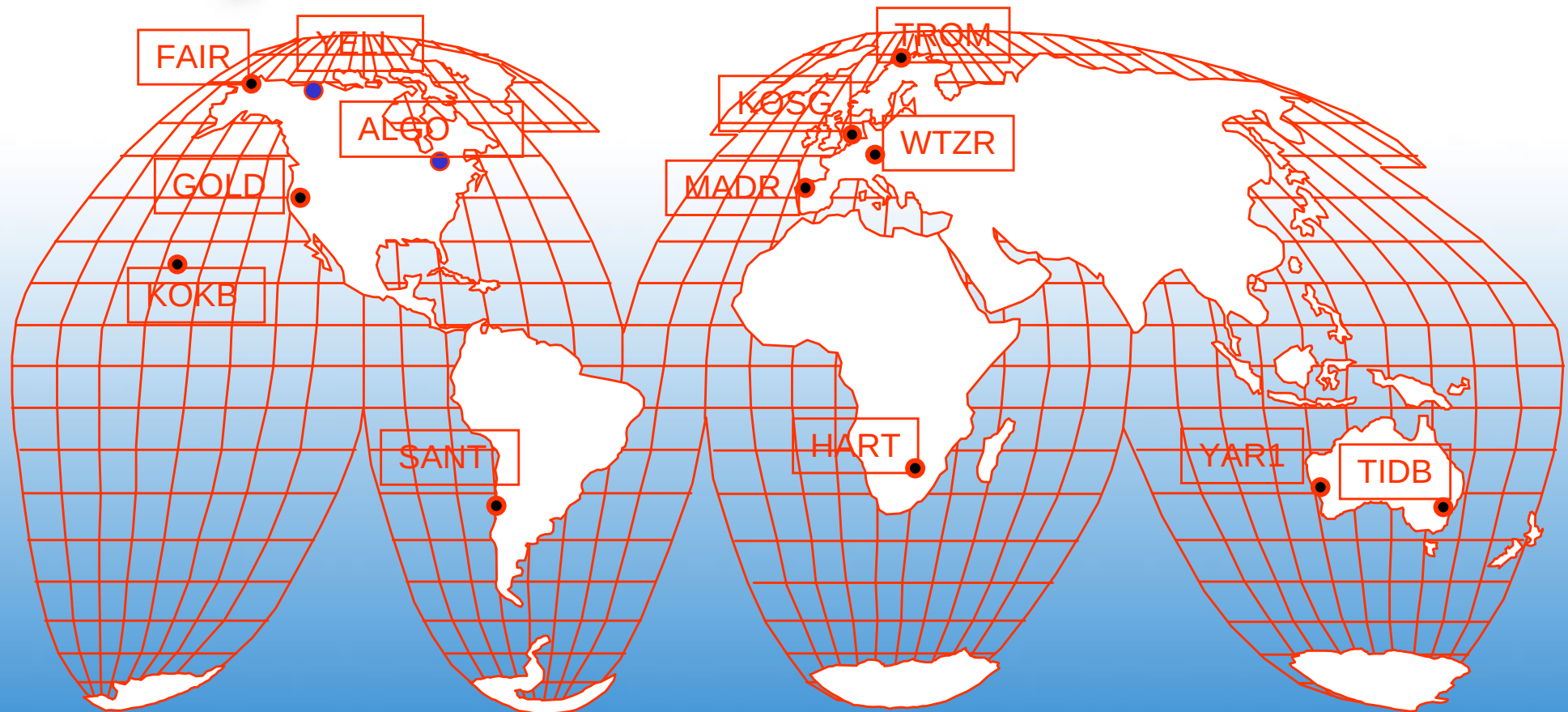


AC/GNAAC/IGS Station Analysis Evolution





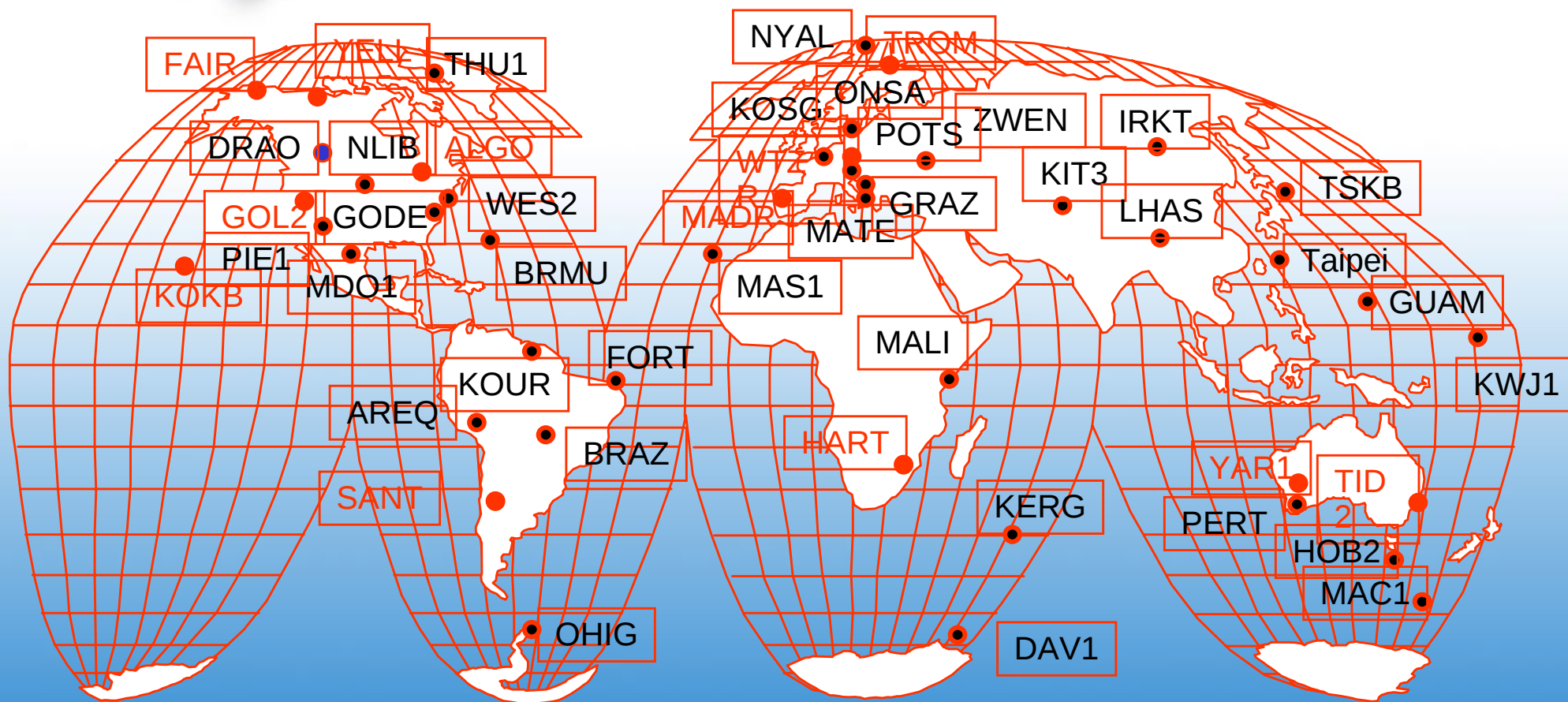
ITRF92-93-94 Stations Used to Align IGS Products



- 13 IGS Global Tracking Sites



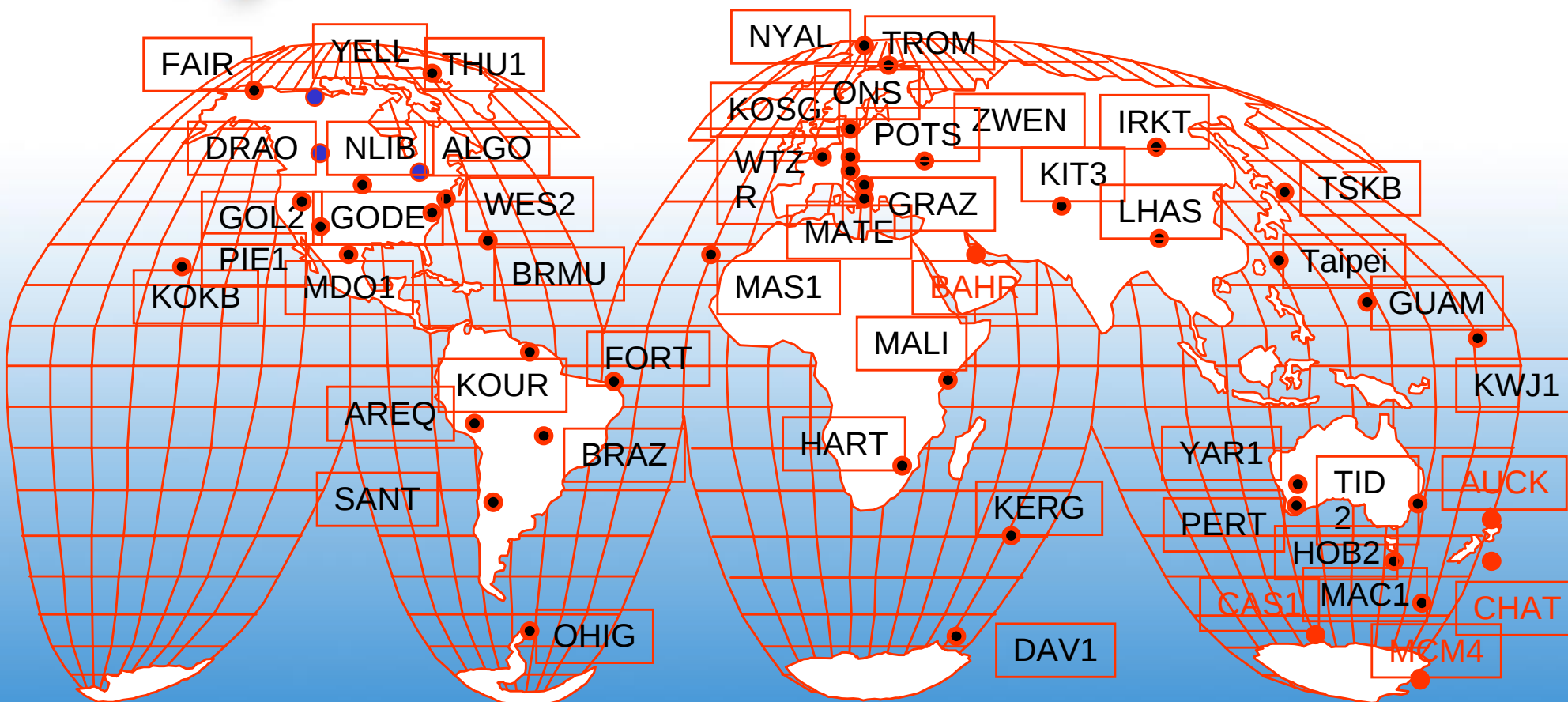
ITRF96 Stations Used to Align IGS Products



- 33 new IGS Global Tracking Sites
- 13 existing Global Tracking Sites

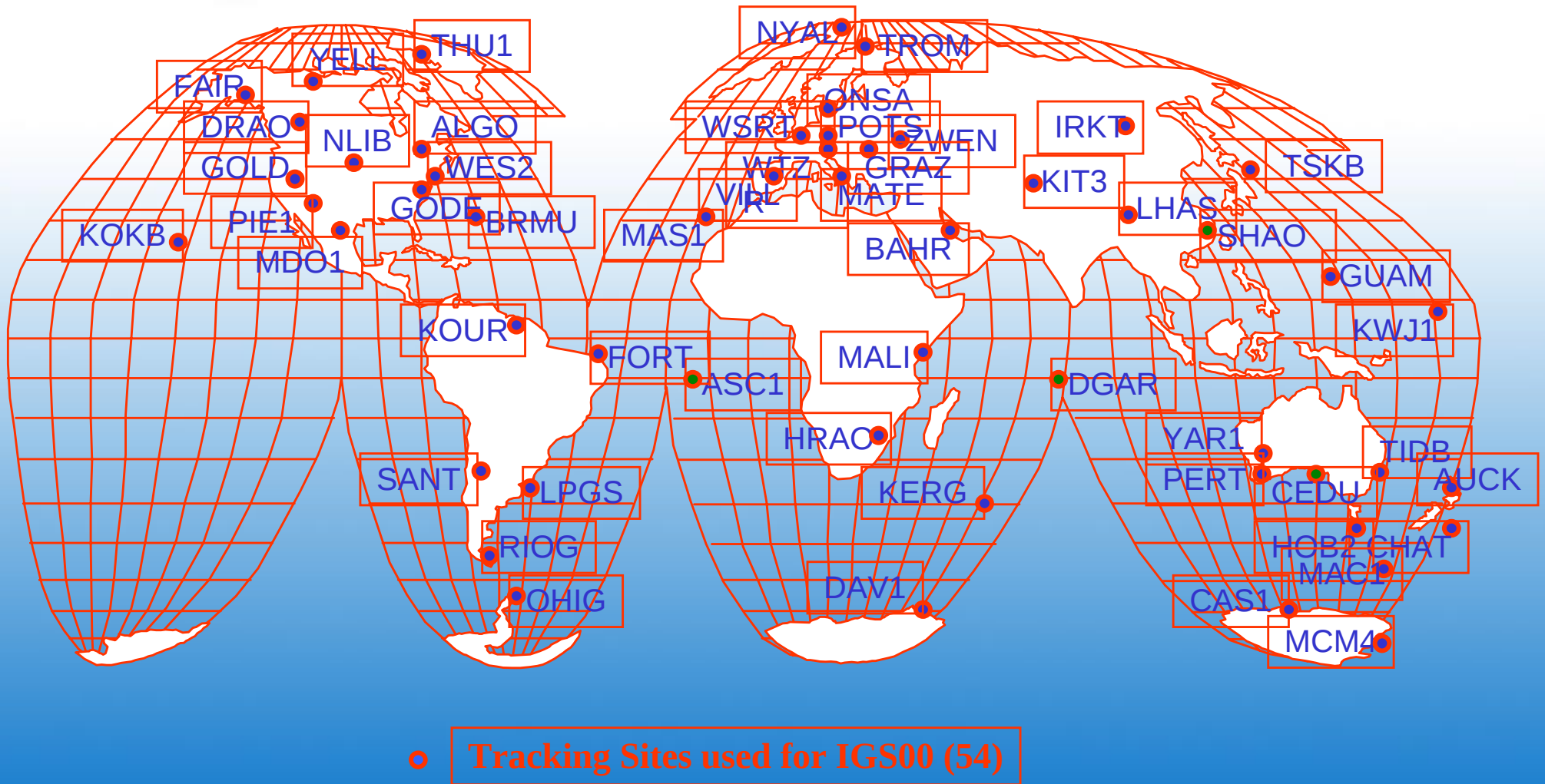


IGS Realization of ITRF97

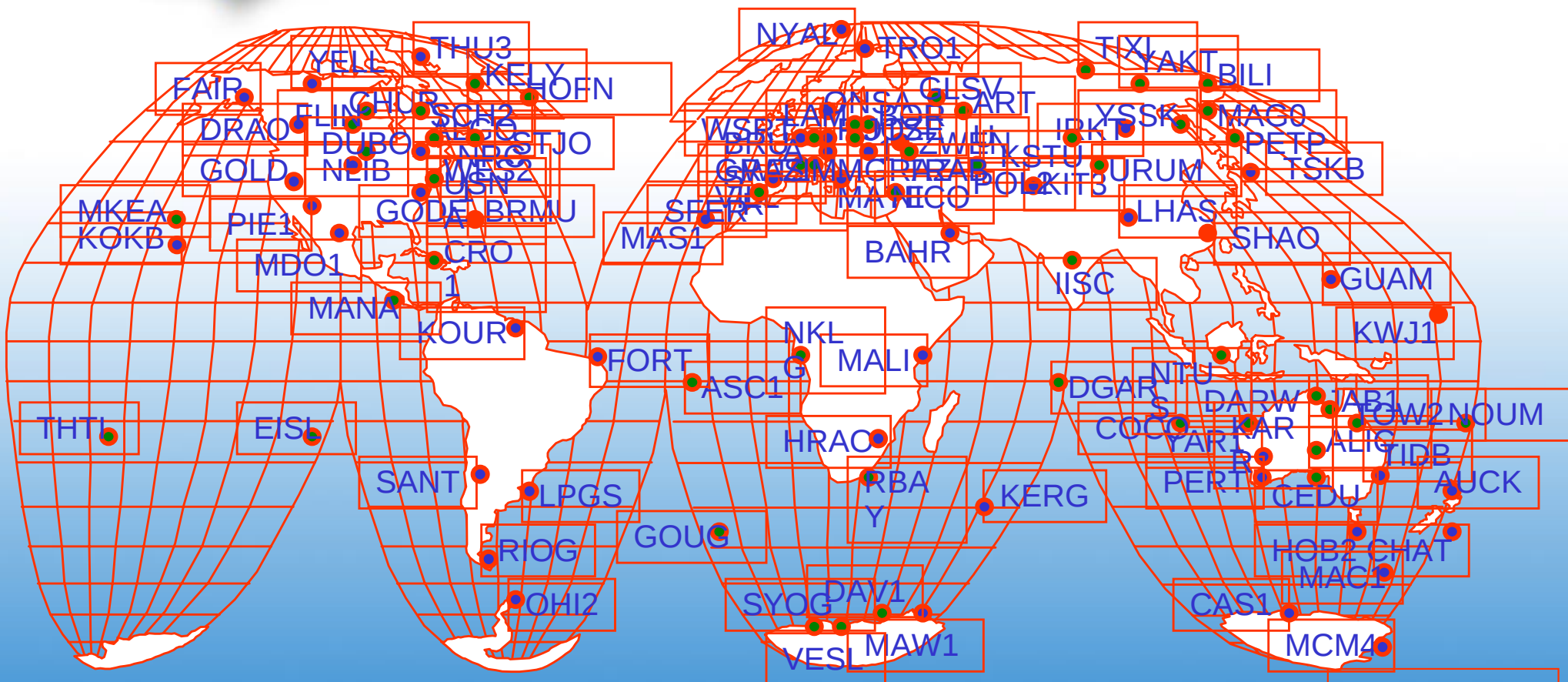


- 46 Existing IGS Global Tracking Sites
- 5 New IGS Global Tracking Sites

IGS00 Realization of ITRF2000



IGb00 Realization of ITRF2000



OHIG → OHI2
THU1 → THU3
TROM → TRO1

- 5 Tracking Sites Removed
- 53 Tracking Sites Added
- 46 Tracking Sites Retained



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4. *Products*

- Types
 - Official
 - Reprocessed
- Derived Products
 - Time Series
 - Tables
 - Graphics
- Availability



Weekly Products

- Stations (~250)
 - Weekly (coordinates)
 - Cumulative (coordinates & velocity)
- Earth rotation parameters (ERP)
 - Daily estimates (weekly & accumulated files)
- Residuals
 - ITRF minus (ACs, GNAACs)
 - igs_i minus (ACs, GNAACs, ITRF(IGS))
 - IGS_i minus (ACs, GNAACs, ITRF(IGS), igs_i)
 - Outliers (summary report only)
 - ERP



Weekly Products (Cont.)

- Summary Report:
 - Variance factor
 - Transformation
 - Residuals statistics (Avg. & STD)
 - Coordinates
 - ERP's
 - Outliers



Weekly Product Summary Report

5) Results:

5-1) AC (Variance Factor)^0.5 estimates:

The residuals used in the estimation of the Variance Factor are the differences between the cumulative combined solution and each AC weekly solution.
 $SF = (\text{Variance Factor})^{0.5} = (\text{Chi}^2/\text{dof})^{0.5}$
 $\text{Final}(SF) = \text{Apriori}(SF) * \text{Apriori}(SF)$

Solution	# sta	#RF	Apriori(SF)	Apriori(SF)	Final(SF)
cod	165	77	25.035	1.007	25.212
emr	42	30	4.003	1.004	4.021
esa	68	54	10.252	1.003	10.284
gfz	178	86	8.935	1.006	8.993
jpl	105	52	5.152	1.005	5.178
MIT	145	70	2.968	1.005	2.983
ngs	133	76	27.269	1.005	27.397
sio	171	85	2.582	1.004	2.592
mit	269	86	1.132	1.006	1.139
ncl	163	88	2.976	1.007	2.997
igs	245	89	1.514	0.933	1.412

5-2) Solution Residuals weighted Average & STD :

5-2-1) With respect to the IGb00 stations:

Solution		Weighted Average (mm)			STD (mm)		
		N	E	U	N	E	U
cod	77	0.8	0.1	-0.3	2.5	2.5	9.1
emr	30	-1.4	-0.3	1.1	3.5	2.8	10.3
esa	54	-0.9	0.4	0.6	4.5	3.2	10.7
gfz	86	-1.0	0.1	-0.4	3.2	3.0	10.1
jpl	52	-0.3	0.1	-0.1	2.7	3.2	10.7
MIT	70	0.1	0.1	0.2	3.8	2.9	9.2
ngs	76	-1.4	0.5	0.7	4.7	4.1	10.9
sio	85	0.2	0.5	-0.3	3.2	3.3	8.7
mit	86	0.3	0.1	0.3	3.0	2.6	8.2
ncl	88	0.1	0.0	0.4	2.9	2.5	7.6

5-2-2) With respect to the Weekly Combination:

Solution		Weighted Average (mm)			STD (mm)		
		N	E	U	N	E	U
cod	163	0.7	0.2	-1.1	1.2	1.3	4.4
emr	42	-1.8	-0.5	2.4	1.7	2.0	6.5
esa	67	-0.6	-0.2	1.1	2.8	2.9	11.8
gfz	173	-1.0	-0.1	-0.6	1.3	1.6	4.5
jpl	104	-0.4	-0.3	-1.0	1.4	1.9	7.6
MIT	131	0.1	-0.1	-1.0	1.4	1.4	4.9
ngs	129	-1.2	0.7	0.4	3.0	4.0	6.8
sio	158	0.5	0.7	-0.1	1.7	2.2	4.8
mit	237	0.4	0.1	-1.2	0.6	0.5	4.4
ncl	160	0.0	-0.1	0.3	0.7	0.5	2.6
ITR	88	0.1	0.2	-0.7	2.5	2.5	7.8

5-2-3) With respect to the Cumulative Combination:

Solution		Weighted Average (mm)			STD (mm)		
		N	E	U	N	E	U
cod	132	0.9	0.4	-1.3	2.3	2.3	7.4
emr	38	-1.8	-0.4	2.3	2.5	2.1	8.3
esa	65	-0.7	0.3	0.9	3.9	3.2	12.2
gfz	160	-1.1	0.0	-0.4	2.6	2.5	7.3
jpl	89	-0.5	-0.3	-1.2	2.1	2.8	9.9
MIT	114	0.1	0.1	-1.2	2.8	2.4	6.9
ngs	120	-0.9	0.6	0.3	4.1	4.1	9.3
sio	148	0.5	0.8	-0.4	2.8	3.3	6.7
mit	179	0.3	0.2	-0.7	2.1	2.1	6.3
ncl	150	0.1	-0.0	0.1	2.4	2.0	5.5
igs	183	-0.2	0.1	-0.1	1.8	1.8	5.7
ITR	93	-0.3	0.0	-0.4	1.1	1.1	3.4

5-3) 7-Parameters Transformation: AC ----> IG80P33_RS99.snrx

5-3-1) Estimates :

Solution	R X (mas)	R Y (mas)	R Z (mas)	T X (mm)	T Y (mm)	T Z (mm)	SCL (ppb)
cod	0.004	0.032	-0.021	14.6	13.9	-3.9	2.81
emr	-0.001	-0.048	0.013	-1.5	12.6	-27.0	3.53
esa	-0.018	-0.019	0.012	-1.1	7.3	0.4	2.44
gfz	0.044	-0.030	0.011	0.4	1.4	-4.7	2.08
jpl	0.150	-0.040	0.105	3.5	8.0	-12.7	1.60
MIT	0.244	-0.108	0.042	4.6	9.2	-7.7	4.44
ngs	0.127	-0.085	0.065	7.3	0.7	-30.9	2.93
sio	-0.050	-0.106	0.025	18.3	3.3	32.6	3.06
mit	-0.003	0.001	-0.018	-0.8	-0.2	-1.8	2.77
ncl	0.041	-0.052	0.001	1.2	1.4	-5.7	2.74

5-3-2) STD :

Solution	R X (mas)	R Y (mas)	R Z (mas)	T X (mm)	T Y (mm)	T Z (mm)	SCL (ppb)
cod	0.045	0.046	0.050	1.2	1.2	1.2	0.18
emr	0.068	0.074	0.082	1.8	1.8	1.8	0.29
esa	0.052	0.055	0.058	1.4	1.4	1.4	0.21
gfz	0.042	0.044	0.048	1.1	1.1	1.1	0.17
jpl	0.054	0.055	0.060	1.4	1.4	1.4	0.22
MIT	0.046	0.048	0.053	1.2	1.2	1.2	0.19
ngs	0.044	0.046	0.050	1.2	1.2	1.2	0.18
sio	0.043	0.045	0.048	1.1	1.1	1.1	0.18
mit	0.042	0.044	0.049	1.1	1.1	1.1	0.17
ncl	0.042	0.043	0.047	1.1	1.1	1.1	0.17

5-4) Geocenter:

	X (mm)	Y (mm)	Z (mm)	s X (mm)	s Y (mm)	s Z (mm)
igs	7.9	8.9	-9.1	3.4	3.5	4.7

5-5) ERP Residuals Weighted Average & STD :

5-5-1) Weighted Average :

Solution	UT us	LOD us	XPO .01mas	XPOR .01ma/d	YPO .01mas	YPOR .01ma/d
cod	---	14.3	-2.6	---	-2.2	---
emr	---	10.3	2.8	10.8	-4.9	-1.0
esa	---	26.2	3.3	---	6.9	---
gfz	---	9.0	3.2	12.4	0.4	16.8
jpl	---	16.4	-1.5	8.2	1.5	3.8
MIT	---	-4.8	-2.0	1.6	3.4	-0.0
ngs	---	46.6	12.8	---	6.3	---
sio	---	-5.3	2.3	2.5	-3.4	1.6
mit	---	34.4	0.0	0.9	4.2	-0.2
ncl	---	21.5	9.4	---	4.6	---
ITR	---	---	---	---	---	---
BuA	---	13.2	-3.6	3.2	32.7	-0.4

5-5-2) STD :

Solution	UT us	LOD us	XPO .01mas	XPOR .01ma/d	YPO .01mas	YPOR .01ma/d
cod	---	2.7	1.4	---	1.8	---
emr	---	10.2	4.5	16.8	2.0	13.0
esa	---	26.7	3.5	---	4.6	---
gfz	---	4.9	1.9	3.6	3.3	7.5
jpl	---	18.8	2.3	7.2	1.9	6.6
MIT	---	2.5	2.4	10.1	1.6	9.3
ngs	---	6.9	3.8	---	5.2	---
sio	---	3.1	2.2	4.0	0.9	4.7
mit	---	5.1	2.4	4.5	1.0	5.6
ncl	---	1.6	1.3	---	0.6	---
ITR	---	---	---	---	---	---
BuA	---	7.4	6.6	10.1	5.8	8.3

5-6) Outliers:

Thresholds set at 5 sigmas and 50 mm.

Solution	Solution Minus	Station code id soln	N (mm)	E (mm)	U (mm)
jpl12957.snrx	mit1295g.snrx	GUAO A ----	0.4	-0.5	-83.2
jpl12957.snrx	mit1295g.snrx	PETS A ----	0.9	-1.7	-92.1
IGS84P43.snrx	jpl12957.snrx	ASPA A ----	-0.9	4.1	-42.9
IGS84P43.snrx	mit1295g.snrx	USUD A ----	13.1	5.6	7.0
IGS84P43.snrx	igs84P1295.snrx	MAG0 A ----	9.3	10.1	-9.3
IGS84P43.snrx	igs84P1295.snrx	MANA A ----	10.3	5.2	5.1
IGS84P43.snrx	igs84P1295.snrx	USUD A ----	12.7	4.7	5.0



Weekly Official Product Availability

- Within 12 days after the end of each GPS week
- CDDIS & SIO
 - Weekly & cumulative SINEX (& ssc) solutions
 - Residuals w.r.t. Frame/Weekly/Cumulative
 - ERP's (weekly & accumulated)
 - Summary
- IGS website (<http://igscb.jpl.nasa.gov/network/list.html>)
 - Residual plots
 - IGS cumulative – weekly
 - Few months



Combination Products Availability (Cont.)

- NRCan (ftp macs.geod.nrcan.gc.ca)
- (cd /pub/requests/sinex/<www>)
- All Official Products Available at CDDIS & SIO
 - + Extended solutions (*.ssc versions)
 - » Weekly 250+ stations
 - » Cumulatives ~430 (Pos. & vel.) + ~40 Pos.
 - Only available for a few days as backup to CDDIS & SIO



Combination Derived Product Availability (Cont.)

- NRCan
 - Latest Iteration of Reprocessed Combined weekly solutions will be made available (CDDIS)
 - Cumulative solution:
 - With all discontinuities (First iteration completed)
 - With discontinuities & Geocenter & ERP's started





Combination Derived Product Availability

- NRCan
 - Tables & plots from Official solutions:
 - Summary (cd /pub/requests/sinex/sum)
 - Coordinates (cd /pub/requests/sinex/coord)
 - Coordinates Resid. (cd /pub/requests/sinex/res)
 - ERPs Residuals (cd /pub/requests/sinex/erp)
 - Tables & plots from Reprocessed solutions:
 - (../sum_r , ../coord_r, ../res_r, ../erp_r)
 - Use most recent realization of ITRF
 - Updated as needed
 - Tables of discontinuities
 - (cd /pub/requests/sinex/discontinuities)
 - Confirmed (~ 650)
 - Probable (~ 150)



Coordinates Residual Tables & Graphics

- Tables
 - Filenames `cd /pub/requests/sinex/res[_r]`
`{sta}_{center}_{cmb}.res`
(See README_res file)
- Graphics
 - Filenames `{sta}_{center}_{cmb}_{axis}.{fmt}`
 - {sta} = Station 4 character ID ~230
 - {center} = ACs , GNAACs , [igs] ~12
 - {cmb} = igs , IGS 2
 - {axis} = N , E , h
 - {fmt} = ps , jpg



Coordinates Residual Tables & Graphics (Cont.)

- Updated within 24 hours after the SINEX weekly combination
- Recent data from {sta}_igs_IGS.res used for IGSCB station residual plots.
- E.g.: <http://igscb.jpl.nasa.gov/network/site/algo.html>



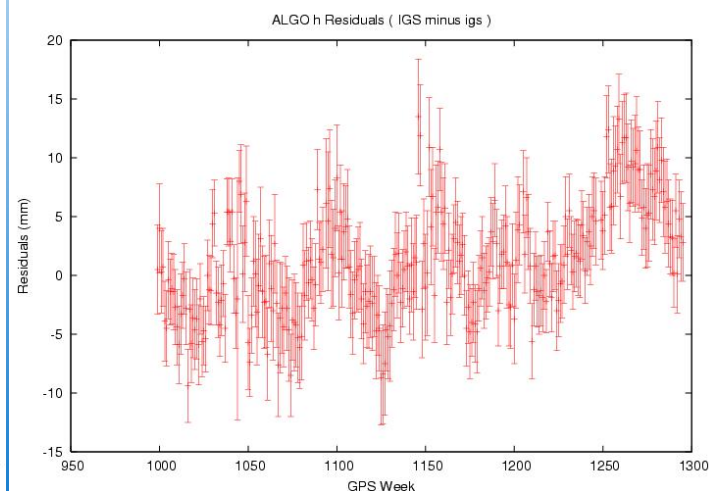
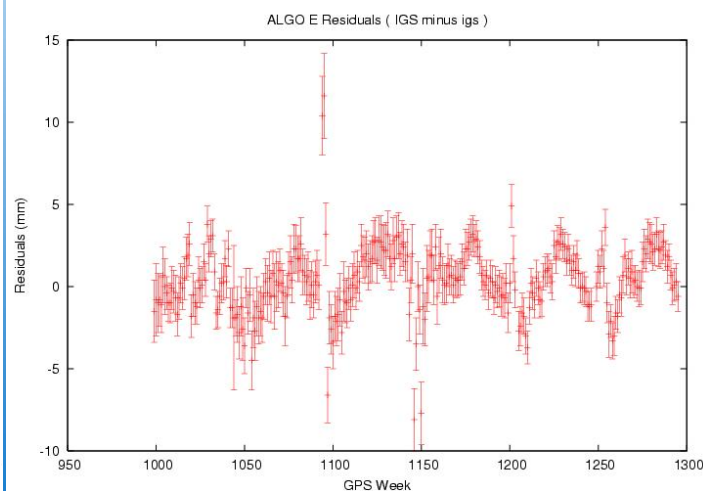
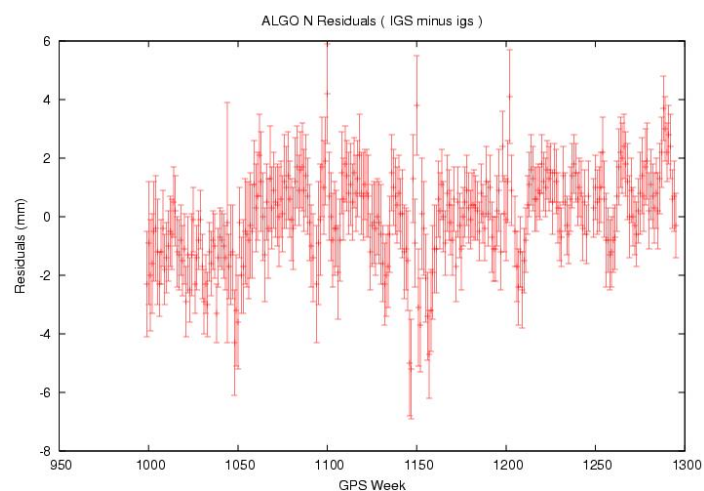


Coordinate Residual Tables & Graphics

res ~4500 tables
res_r ~4700 tables

Example: ALGO

0999	igs	ALGO	-2.3	-1.5	0.5	1.8	1.9	3.8
1000	igs	ALGO	-0.9	-0.8	4.0	2.1	2.2	3.8
1001	igs	ALGO	-2.0	-1.0	0.3	1.9	1.8	3.5
1002	igs	ALGO	-1.6	-0.8	0.7	1.7	1.6	3.3
1003	igs	ALGO	-0.5	-1.1	-3.9	1.7	1.7	3.4
1004	igs	ALGO	-0.4	0.7	-4.5	1.8	1.7	3.2
1005	igs	ALGO	-1.2	0.0	-0.4	1.8	1.7	3.3
1006	igs	ALGO	-2.3	-0.4	-1.4	1.1	1.0	2.8
1007	igs	ALGO	-1.2	-1.0	-1.1	1.1	1.1	3.0
1008	igs	ALGO	-0.4	-1.0	-1.4	1.3	1.2	3.2
1009	igs	ALGO	-1.8	-0.1	-2.7	1.2	1.3	3.2
1010	igs	ALGO	-1.4	-0.3	-4.4	1.2	1.3	3.2
1011	igs	ALGO	-1.0	-0.7	-5.9	1.2	1.4	3.3
1012	igs	ALGO	-0.5	-1.7	-3.3	1.2	1.3	3.4
1013	igs	ALGO	-0.6	-0.7	-1.7	1.2	1.3	2.8
1014	igs	ALGO	0.5	0.2	-0.3	1.2	1.2	3.0
1015	igs	ALGO	0.2	-0.1	-2.8	1.2	1.3	3.1
1016	igs	ALGO	-1.2	0.5	-9.4	1.2	1.3	3.1
1017	igs	ALGO	-1.3	1.7	-2.9	1.2	1.3	3.4
1018	igs	ALGO	-0.8	1.9	-5.8	1.2	1.3	3.3
1019	igs	ALGO	-1.5	2.6	-3.6	1.2	1.3	3.4
1020	igs	ALGO	-1.1	-1.8	-4.6	1.2	1.3	3.4
1021	igs	ALGO	-2.9	-0.5	-3.7	1.2	1.3	3.4
1022	igs	ALGO	-1.3	-1.0	-5.9	1.3	1.3	3.4
1023	igs	ALGO	-2.5	-1.2	-2.0	1.1	1.1	3.0
1024	igs	ALGO	-1.3	0.4	-5.6	1.4	1.4	3.0
1025	igs	ALGO	-0.1	-0.1	-4.7	1.1	1.2	2.9
.....								
1272	igs	ALGO	-0.3	0.0	4.9	1.0	0.9	3.2
1273	igs	ALGO	-0.6	-0.1	5.8	1.1	1.1	3.6
1274	igs	ALGO	0.2	-0.1	4.0	1.1	1.0	3.4
1275	igs	ALGO	0.8	1.5	5.1	1.4	1.2	4.4
1276	igs	ALGO	1.4	2.3	5.3	1.3	1.2	4.1
1277	igs	ALGO	0.7	2.0	8.6	1.2	1.1	3.8
1278	igs	ALGO	1.7	2.9	7.3	1.3	1.2	4.3
1279	igs	ALGO	1.9	2.7	6.7	1.3	1.2	4.1
1280	igs	ALGO	0.2	2.6	8.9	1.3	1.2	4.2
1281	igs	ALGO	1.1	2.1	10.9	1.2	1.1	3.9
1282	igs	ALGO	0.7	2.3	8.1	1.1	1.0	3.6
1283	igs	ALGO	0.3	3.2	9.8	1.2	1.0	3.6
1284	igs	ALGO	0.8	2.3	7.1	1.2	1.1	3.8
1285	igs	ALGO	0.2	2.2	5.8	1.3	1.1	3.9
1286	igs	ALGO	1.3	2.4	6.3	1.2	1.0	3.6
1287	igs	ALGO	2.2	2.7	4.4	1.2	1.1	3.7
1288	igs	ALGO	3.7	1.9	3.3	1.1	0.9	3.2
1289	igs	ALGO	3.0	1.2	3.2	1.1	1.0	3.2
1290	igs	ALGO	2.2	1.8	0.2	1.0	0.8	2.9
1291	igs	ALGO	2.8	0.7	5.5	1.0	0.9	3.1
1292	igs	ALGO	2.4	-0.1	0.1	1.1	1.0	3.3
1293	igs	ALGO	0.6	0.1	4.8	1.0	1.0	3.3
1294	igs	ALGO	0.7	0.3	3.3	1.2	1.1	3.8
1295	igs	ALGO	-0.3	-0.6	2.8	1.1	0.9	3.3





Coordinate Tables & Graphics

- Tables
 - Filenames `cd /pub/requests/sinex/coord[_r]`
`{sta}_{center}.{coor}`
 - Format (See: README_coord)
- Graphics
 - Filenames `{sta}_{center}_{axis}.{fmt}`
 - {sta} = Station 4 character ID
 - {center} = igs (final)
= igs, ACs , GNAACs (reprocessed)
 - {coor} = xyz , plh , utm
 - {axis} = X , Y , Z / P , L , h / N , E , h
 - {fmt} = ps , jpg



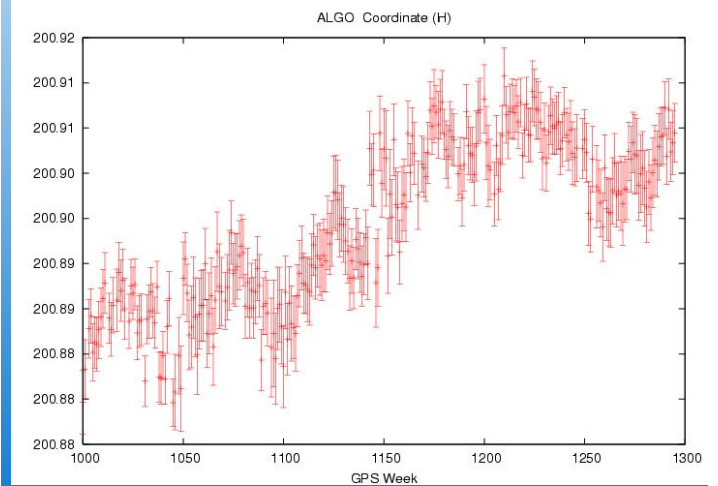
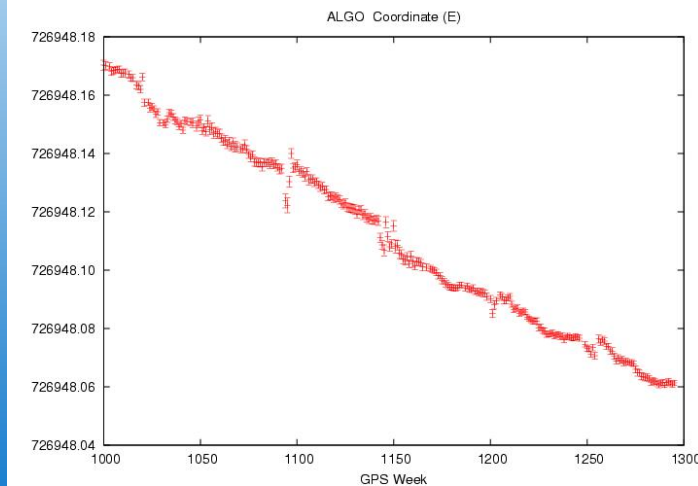
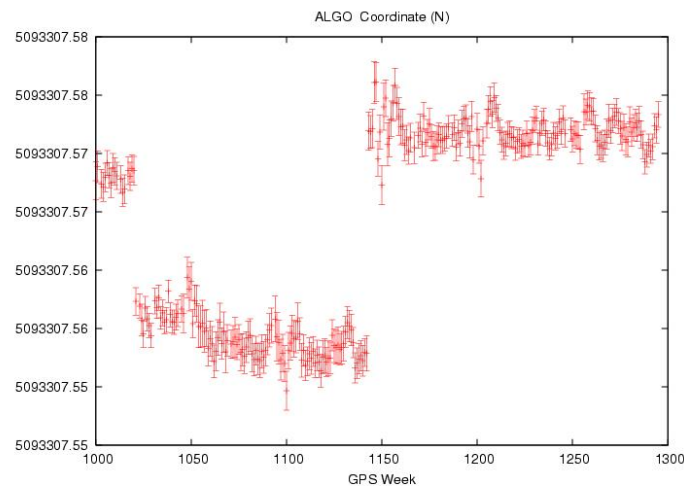
Coordinate Tables & Graphics

coord ~360 tables
coord_r ~3200 tables

Example: ALGO

```
ALGO A ---- 51347.96926 1800 3 5093307572680094E+7 726948170332098098E+6 20887964265421032E+3 1651279E-2 1716515E-2 3549723E-2
ALGO A ---- 51254.93962 1801 3 50933075738691240E+7 72694817021005810E+6 20888330035749822E+3 1382194E-2 1395833E-2 3259587E-2
ALGO A ---- 51268.97192 1803 3 50933075723996357E+7 72694816983458539E+6 20888777932524881E+3 1239759E-2 1255887E-2 3229398E-2
ALGO A ---- 51275.91256 1804 3 50933075721406997E+7 7269481689599322E+6 2088921732548824E+3 1249915E-2 1268839E-2 3015291E-2
ALGO A ---- 51282.95563 1805 3 50933075729415621E+7 72694816838922945E+6 20888519193511456E+3 1217586E-2 1397038E-2 3161436E-2
ALGO A ---- 51289.92563 1806 3 50933075741859804E+7 72694816848745278E+6 20888627536315470E+3 1064643E-2 1027194E-2 2845606E-2
ALGO A ---- 51296.91684 1807 3 50933075731244664E+7 72694816803921436E+6 2088965999387908E+3 1064970E-2 1062895E-2 2964491E-2
ALGO A ---- 51303.96516 1808 3 50933075724568715E+7 72694816873260851E+6 20888766342122107E+3 1249915E-2 1226612E-2 3160406E-2
ALGO A ---- 51310.93272 1809 3 50933075737726436E+7 72694816744896431E+6 20888907561451196E+3 1224566E-2 1257255E-2 3244692E-2
ALGO A ---- 51317.92450 1810 3 50933075734745267E+7 72694816748474531E+6 2088910938886944E+3 1172277E-2 1259871E-2 3244195E-2
ALGO A ---- 51324.87381 1811 3 50933075730867838E+7 72694816763780934E+6 20889287232991346E+3 1174686E-2 1397564E-2 3335046E-2
ALGO A ---- 51338.92671 1813 3 50933075727847254E+7 72694816708943259E+6 20888894787896424E+3 1193141E-2 1259834E-2 276837E-2
ALGO A ---- 51345.95953 1814 3 50933075716734677E+7 72694816599428343E+6 20888771278034468E+3 1180180E-2 1189372E-2 296767E-2
ALGO A ---- 51352.98809 1815 3 50933075715333075E+7 72694816596330446E+6 2088938596969277E+3 1222311E-2 1250086E-2 306888E-2
ALGO A ---- 51366.94918 1817 3 50933075735169025E+7 72694816354551014E+6 20889094839083874E+3 1190369E-2 1279095E-2 3437662E-2
ALGO A ---- 51373.92849 1818 3 50933075730446883E+7 72694816308108512E+6 20889404891803806E+3 1284564E-2 1276139E-2 3275236E-2
ALGO A ---- 51380.98661 1819 3 50933075736965746E+7 72694816302342312E+6 20889200248902211E+3 1176578E-2 1383355E-2 3468758E-2
ALGO A ---- 51387.95197 1820 3 50933075735174896E+7 72694816618589684E+6 20889317823387682E+3 1231903E-2 127362E-2 3392904E-2
```

```
ALGO A ---- 53075.49990 1261 4 50933075785969775E+7 72694807382538891E+6 20990105839911848E+3 1138685E-2 1034955E-2 3488951E-2
ALGO A ---- 53082.37491 1262 4 50933075771530373E+7 72694807231594389E+6 20990062633949466E+3 1150794E-2 1069286E-2 3649464E-2
ALGO A ---- 53089.37491 1263 4 50933075761461993E+7 72694807226110693E+6 2099006110681766E+3 1252676E-2 1142961E-2 3826879E-2
ALGO A ---- 53096.37491 1264 4 50933075756595516E+7 72694807044514173E+6 209903059516149E+3 1161493E-2 1095788E-2 3663108E-2
ALGO A ---- 53103.37491 1265 4 50933075757457194E+7 72694806889526988E+6 2099069845328801E+3 1174334E-2 1018208E-2 3294528E-2
ALGO A ---- 53118.37491 1266 4 50933075754585154E+7 7269480688887628E+6 20990257146116346E+3 1143934E-2 1091139E-2 3538404E-2
ALGO A ---- 53117.37491 1267 4 50933075759462844E+7 72694806899215179E+6 2099030279815684E+3 105231E-2 987721E-3 3254329E-2
ALGO A ---- 53124.37491 1268 4 50933075766521161E+7 72694806923066351E+6 20990276084653424E+3 1280922E-2 1169491E-2 4089525E-2
ALGO A ---- 53131.37491 1269 4 50933075777873346E+7 72694806847646157E+6 2099016895949683E+3 1435118E-2 1316844E-2 4597916E-2
ALGO A ---- 53138.37491 1270 4 50933075769638854E+7 72694806816528138E+6 209901525164286128E+3 1113778E-2 1016115E-2 363767E-2
ALGO A ---- 53145.37491 1271 4 50933075778497755E+7 72694806841212278E+6 20990319105796515E+3 1043538E-2 9393496E-2 3339843E-2
ALGO A ---- 53152.37491 1272 4 50933075781973665E+7 72694806844845588E+6 2099074206562971E+3 1060399E-2 9305541E-2 3197611E-2
ALGO A ---- 53159.37491 1273 4 50933075785974863E+7 72694806821459474E+6 2099065556771788E+3 1144988E-2 1095303E-2 3626846E-2
ALGO A ---- 53166.37491 1274 4 50933075777874113E+7 72694806792568854E+6 20990838835574868E+3 1069782E-2 9651118E-2 3367152E-2
ALGO A ---- 53173.37491 1275 4 50933075771481441E+7 72694806596364150E+6 20990709938989201E+3 1358976E-2 1245770E-2 4460391E-2
ALGO A ---- 53180.37491 1276 4 50933075764961345E+7 72694806489651363E+6 209906913525174968E+3 1249188E-2 1197207E-2 4114241E-2
ALGO A ---- 53187.37491 1277 4 50933075771895060E+7 72694806480890151E+6 20990367779694497E+3 1208744E-2 1166680E-2 3838714E-2
ALGO A ---- 53194.37491 1278 4 50933075761915473E+7 72694806368888131E+6 20990496635623276E+3 1326514E-2 1203446E-2 4322935E-2
ALGO A ---- 53201.37491 1279 4 5093307575951820E+7 72694806148846206E+6 2099055927872323E+3 1272408E-2 1153586E-2 4052207E-2
ALGO A ---- 53208.37491 1280 4 5093307577712327E+7 72694806317980878E+6 2099032355163991E+3 1282152E-2 1171922E-2 4198974E-2
ALGO A ---- 53215.37491 1281 4 50933075768221076E+7 72694806336278493E+6 2099012795999895E+3 1224966E-2 1083247E-2 3915295E-2
ALGO A ---- 53222.37491 1282 4 5093307572308610E+7 72694806238073827E+6 20990484642411314E+3 1134217E-2 9909140E-2 350838E-2
ALGO A ---- 53229.37491 1283 4 50933075776366265E+7 72694806157451464E+6 20990230403374880E+3 1152524E-2 1003733E-2 363739E-2
ALGO A ---- 53236.37491 1284 4 5093307572450380E+7 72694806210887112E+6 20990583286759585E+3 1227153E-2 1075838E-2 3847178E-2
ALGO A ---- 53243.37491 1285 4 5093307577842346E+7 72694806184123747E+6 209906142444875674E+3 1253618E-2 1072409E-2 3884347E-2
ALGO A ---- 53250.37491 1286 4 50933075766440602E+7 72694806131825333E+6 20990600539659768E+3 1166897E-2 1024024E-2 3630596E-2
ALGO A ---- 53257.37491 1287 4 50933075757416998E+7 72694806078239618E+6 20990793737862598E+3 1184113E-2 1081430E-2 3662163E-2
ALGO A ---- 53264.37491 1288 4 50933075742877842E+7 72694806127823026E+6 20990801350505044E+3 1047813E-2 913598E-2 3218334E-2
ALGO A ---- 53271.37491 1289 4 50933075749137382E+7 72694806155533087E+6 20990915381870226E+3 1076710E-2 9503761E-2 3154946E-2
ALGO A ---- 53278.37491 1290 4 50933075756848795E+7 7269480605898818E+6 20991221644449979E+3 9750200E-2 8346944E-2 2920426E-2
ALGO A ---- 53285.37491 1291 4 50933075751844857E+7 72694806141524727E+6 2099068585194753E+3 1086820E-2 889483E-2 312827E-2
ALGO A ---- 53292.37491 1292 4 50933075755742741E+7 72694806182847832E+6 2099120799740764E+3 1091740E-2 9625766E-2 333307E-2
ALGO A ---- 53299.49991 1293 4 50933075773731488E+7 72694806128765889E+6 20990737298773840E+3 1035535E-2 9480897E-2 3273815E-2
ALGO A ---- 53306.37491 1294 4 5093307570364788E+7 72694806085721762E+6 2099083840877133E+3 1125294E-2 1007078E-2 352363E-2
ALGO A ---- 53313.49992 1295 4 50933075783424340E+7 726948061283818221E+6 20990946752391755E+3 1089696E-2 8943345E-2 3255671E-2
```





ERP Residual Tables & Graphics

- Tables
 - Filenames
 - Format
 - Graphics
 - Filenames
 - {erp}
 - {center}
 - {cmb}
 - {axis}
 - {fmt}
- `cd /pub/requests/sinex/erp[_r]
{erp}_{center}_{cmb}.res
(See README_res_erp)`
- `{erp}_{center}_{cmb}_{axis}.{fmt}`
= LOD , XPO , YPO , XPOR , YPOR
= ACs , GNAACs , [igs]
= igs
= e
= ps , jpg



ERP Residuals Tables & Graphics

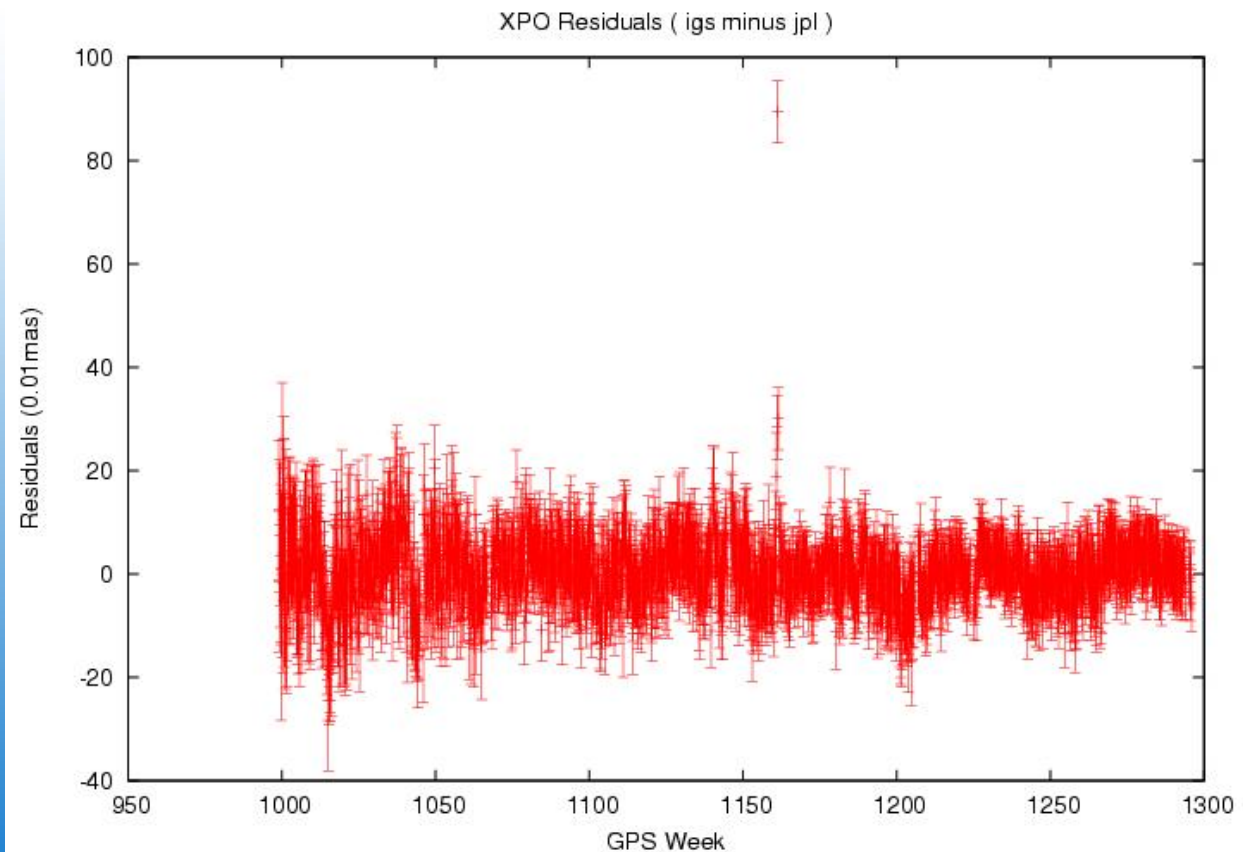
Example: jpl

0999.07	jpl	XPO	12.3	13.5
0999.21	jpl	XPO	-1.4	13.7
0999.36	jpl	XPO	9.4	12.8
0999.50	jpl	XPO	7.6	13.7
0999.64	jpl	XPO	3.5	13.8
0999.79	jpl	XPO	-13.7	14.6
0999.93	jpl	XPO	1.2	14.4
1000.07	jpl	XPO	0.0	16.1
1000.21	jpl	XPO	20.5	16.5
1000.36	jpl	XPO	-1.8	17.4
1000.50	jpl	XPO	10.4	15.6
1000.64	jpl	XPO	14.6	15.9
1000.79	jpl	XPO	9.1	17.1
1000.93	jpl	XPO	0.2	18.2
1001.07	jpl	XPO	4.4	11.3
1001.21	jpl	XPO	-11.1	11.2
1001.36	jpl	XPO	12.8	11.3
1001.50	jpl	XPO	-10.6	12.5
1001.64	jpl	XPO	-10.6	11.2
1001.79	jpl	XPO	-5.4	11.5
1001.93	jpl	XPO	2.2	10.8
1002.07	jpl	XPO	11.9	10.5
1002.21	jpl	XPO	3.5	11.3
1002.36	jpl	XPO	11.5	10.5
1002.50	jpl	XPO	-2.8	10.9
1002.64	jpl	XPO	6.9	10.9
1002.79	jpl	XPO	12.5	10.2
1002.93	jpl	XPO	-3.9	9.5

1292.07	jpl	XPO	0.9	6.2
1292.21	jpl	XPO	-0.7	6.4
1292.36	jpl	XPO	0.6	6.4
1292.50	jpl	XPO	-1.8	6.3
1292.64	jpl	XPO	-1.2	6.2
1292.79	jpl	XPO	-1.6	6.3
1292.93	jpl	XPO	-2.9	6.1
1293.07	jpl	XPO	1.8	5.4
1293.21	jpl	XPO	0.9	5.3
1293.36	jpl	XPO	3.6	5.4
1293.50	jpl	XPO	3.2	5.3
1293.64	jpl	XPO	1.2	5.5
1293.79	jpl	XPO	2.5	5.5
1293.93	jpl	XPO	-3.5	5.3
1295.07	jpl	XPO	1.1	5.4
1295.21	jpl	XPO	-0.8	5.5
1295.36	jpl	XPO	-0.3	5.4
1295.50	jpl	XPO	-1.5	5.5
1295.64	jpl	XPO	-3.6	5.4
1295.79	jpl	XPO	0.8	5.5
1295.93	jpl	XPO	-5.7	5.5

erp ~40 tables

erp_r ~40 tables





Summary Tables & Graphics

- Tables
 - Filenames `cd /pub/requests/sinex/sum[_r]`
 - Format `{sect}_{center}.sum`
(See README_sum File)
- Graphics
 - Filename `{sect}_{center}_{col}.{fmt}`
 - {sect} = 5-1 , 5-[23]-[123] , 5-4 , 5-5-[12]
 - {center} = ACs , GNAACs , [igs]
 - {col} = Various (See README_sum File)
 - {fmt} = ps , jpg



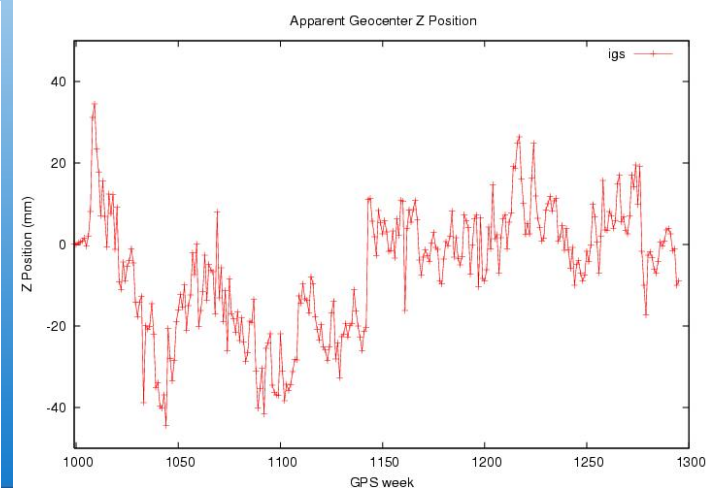
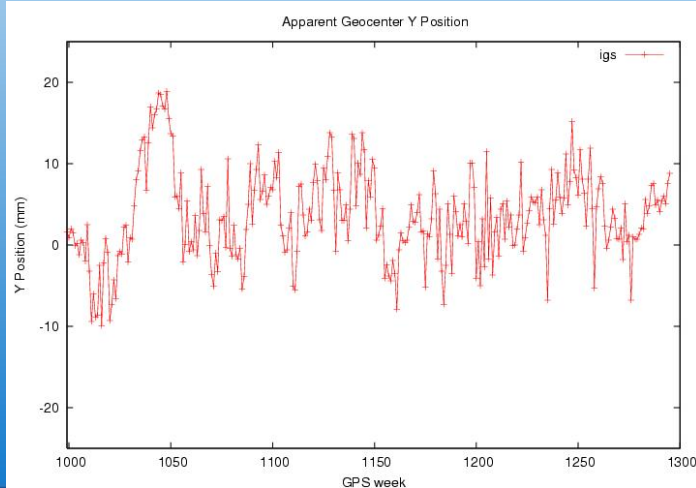
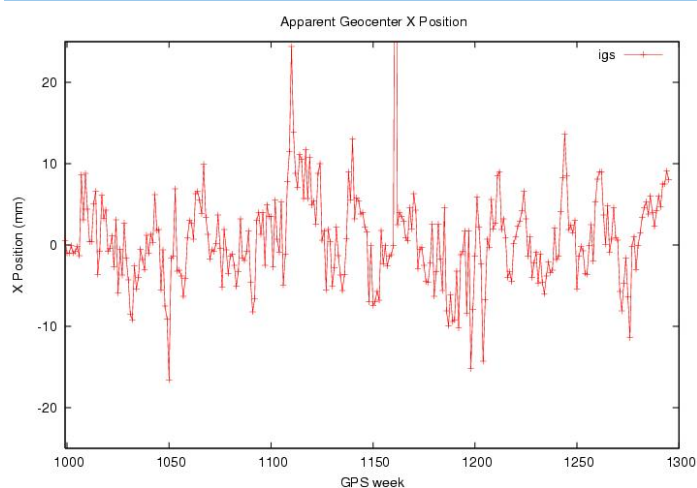
Summary Tables & Graphics

sum ~100 tables
sum_r ~100 tables

Example: Section 5-4
(Apparent Geocenter)

5-4) Geocenter:

	X (mm)	Y (mm)	Z (mm)	s X (mm)	s Y (mm)	s Z (mm)
igs99P0999.sum igs	0.5	1.6	0.2	1.9	1.9	2.0
igs99P1000.sum igs	-1.0	0.9	0.0	2.3	2.2	2.3
igs99P1001.sum igs	-1.0	2.0	0.4	1.8	1.8	2.2
igs99P1002.sum igs	-0.1	1.5	0.6	1.7	1.7	1.9
igs99P1003.sum igs	-1.0	-0.1	0.9	1.6	1.7	1.9
igs99P1004.sum igs	-0.8	0.2	1.6	1.6	1.7	1.9
igs99P1005.sum igs	-0.2	-1.2	-0.4	1.6	1.8	1.7
igs99P1006.sum igs	-1.3	0.6	2.1	1.0	1.0	1.2
igs99P1007.sum igs	8.6	0.3	8.1	4.8	4.8	6.7
igs99P1008.sum igs	3.1	-2.0	31.2	4.8	4.7	7.1
igs99P1009.sum igs	8.8	2.5	34.5	5.1	5.0	7.4
igs99P1010.sum igs	4.4	-3.2	23.4	4.8	4.7	7.1
igs99P1011.sum igs	0.4	-9.4	17.8	4.6	4.6	7.3
igs99P1012.sum igs	0.4	-6.0	7.1	4.8	4.7	7.0
igs99P1013.sum igs	5.1	-8.9	15.6	4.8	4.7	7.0
igs99P1014.sum igs	6.6	-8.6	6.9	5.4	5.2	6.7
igs99P1015.sum igs	-3.6	-2.5	-0.6	5.2	5.1	7.5
igs99P1016.sum igs	-0.8	-9.9	12.4	5.6	5.4	7.9
igs99P1017.sum igs	6.1	-2.2	7.6	4.9	4.8	7.0
igs99P1018.sum igs	3.3	0.8	12.2	4.8	4.7	7.1
igs99P1019.sum igs	4.3	-0.9	-1.2	5.3	5.2	8.5
igs99P1020.sum igs	-0.8	-9.3	9.1	5.1	5.0	7.3
.....						
igs04P1270.sum igs	0.6	0.7	2.6	1.5	2.0	3.9
igs04P1271.sum igs	-5.7	2.1	7.0	1.7	1.7	3.6
igs04P1272.sum igs	-8.1	-1.8	17.1	1.4	1.7	3.4
igs04P1273.sum igs	-4.7	5.1	14.1	1.4	1.6	4.3
igs04P1274.sum igs	-1.6	0.4	19.5	1.7	1.8	3.5
igs04P1275.sum igs	-6.4	1.2	9.8	2.1	2.3	4.5
igs04P1276.sum igs	-11.4	-6.8	19.1	1.8	2.1	4.1
igs04P1277.sum igs	-0.2	1.0	-1.7	3.6	3.6	4.8
igs04P1278.sum igs	1.0	0.7	-10.0	3.8	3.9	5.2
igs04P1279.sum igs	-3.0	0.7	-17.3	3.5	3.6	4.8
igs04P1280.sum igs	-0.1	1.3	-2.6	3.6	3.7	4.9
igs04P1281.sum igs	1.5	2.1	-1.8	3.4	3.5	4.7
igs04P1282.sum igs	3.4	2.0	-3.2	3.1	3.2	4.4
igs04P1283.sum igs	4.6	5.6	-6.1	3.2	3.3	4.6
igs04P1284.sum igs	5.3	3.9	-7.1	3.4	3.5	4.9
igs04P1285.sum igs	3.8	4.8	-4.1	3.6	3.6	5.1
igs04P1286.sum igs	6.0	7.3	0.6	3.4	3.4	4.6
igs04P1287.sum igs	4.0	7.6	-0.4	3.4	3.4	4.4
igs04P1288.sum igs	2.3	4.9	0.9	3.1	3.1	4.1
igs04P1289.sum igs	4.2	5.5	3.6	3.0	3.1	4.2
igs04P1290.sum igs	6.0	4.1	3.9	2.9	2.9	4.1
igs04P1291.sum igs	4.7	5.4	2.6	3.0	3.1	4.6
igs04P1292.sum igs	7.5	6.0	-1.5	3.1	3.2	4.6
igs04P1293.sum igs	7.5	5.1	-1.0	3.1	3.1	4.3
igs04P1294.sum igs	9.1	7.6	-10.0	3.3	3.4	4.6
igs04P1295.sum igs	8.0	8.8	-9.0	3.0	3.0	4.0





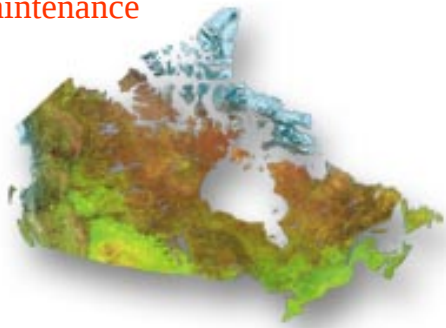
Products Accuracy

Product	Accuracy
Position (N,E / H)	3 / 6 mm
Velocity (N,E / H)	2 / 3 mm/y
Pole Position	0.05 mas
Pole Rate	0.2 mas/d
LOD	0.02 ms
Geocenter (X,Y / Z)	6 / 10 mm

- Latency - 12 Days
- Stations - Weekly
- Geocenter - Weekly
- ERP's - Daily

Accumulated ERP's available in [igs00p02.erp](#)





5. Maintenance

- Discontinuities
- AC solutions constraints
- AC modeling differences
- Reprocessing
- Effects weighting strategy in RF alignment
- Add estimation IGS weekly scale factor
- ACs ...
- ACC ...

Bern IGS Workshop



Natural Resources
Canada

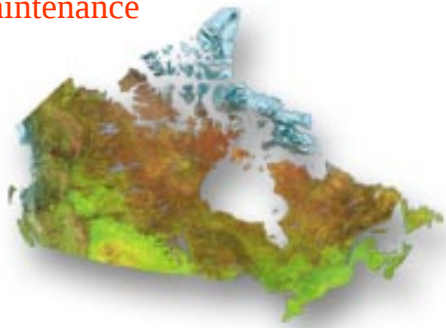
Ressources naturelles
Canada

Canada



Stations Position Discontinuities

- Sources used:
 - IGS / JPL / MIT / SIO
 - IGS logs & earthquake events (USGS)
- Tables:
 - Extension of SINEX format
 - Confirmed discontinuities (~ 650)
 - Probable discontinuities (~ 150)



Discontinuities Issue

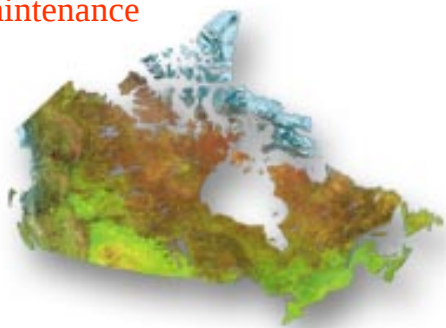
- Multiple solutions for a DOME #
- For collocates sites
 - Which solution to use to connect the local survey?
 - Which solution best “describe” the physical marker?
 - First one / most recent one / best fit ???
 - Should any be used?



AC Solution

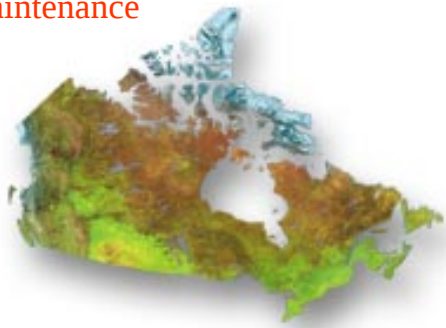
Apriori Constraints

- Objective:
 - Assess the effect of direct and indirect apriori constraints on the AC weekly SINEX solutions
- Methodology:
 - Used GPS Week 1268 - 1269 - 1270
 - With AC production solutions:
 - Review / Unconstrain / Compare
 - Most ACs provided unconstrained solution
 - Compare with production solutions



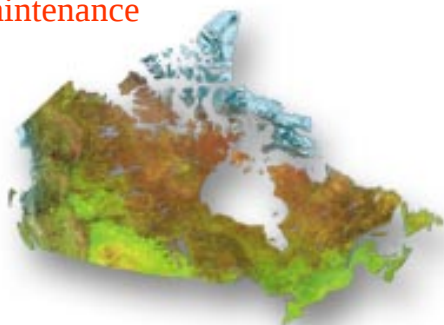
Apriori Constraint in AC Production Solutions

AC	Constraint	Comment
COD	Loose Coordinates Loose ERP's	Continuity Condition on pole Rate – Not removable Occasionally singular
EMR	Inner Rotation	
ESA	Inner Rotation & TZ UT	Continuity Condition on pole Rate – Not removable Occasionally singular
GFZ	Loose coordinates & pole & rates & UT & LOD	Constraints on apparent geocenter – Not removable Occasionally singular
JPL	None	
MIT	Loose coordinates & pole & rates & UT & LOD	
NGS	Loose coordinates Inner Rotation & UT	Continuity Condition on pole Rate – Not removable
SIO	Loose coordinates & pole & rates & UT & LOD	



Effect of Unconstraining AC Production Solutions

R.M.S.	1268	1269	1270
AC	N / E / H (mm) / (mm) / (mm)	N / E / H (mm) / (mm) / (mm)	N / E / H (mm) / (mm) / (mm)
COD	0.0 0.0 0.0	0.1 0.1 0.2	0.0 0.0 0.0
EMR	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0
ESA	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0
GFZ	0.3 0.2 0.7	0.3 0.3 0.8	0.3 0.4 0.9
JPL	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0
MIT	0.0 0.1 0.1	0.0 0.1 0.1	0.1 0.2 0.4
NGS	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0
SIO	0.4 0.2 0.6	0.3 0.2 0.5	0.1 0.1 0.6

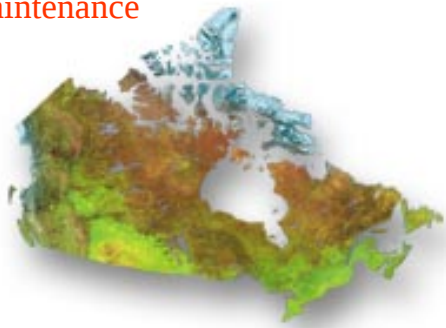


Effect of Direct & Indirect Constraints on AC Solutions

R.M.S.	1268	1269	1270
AC	N / E / H (mm) / (mm) / (mm)	N / E / H (mm) / (mm) / (mm)	N / E / H (mm) / (mm) / (mm)
COD			
EMR	0.2 0.5 0.8	0.4 0.3 0.9	0.3 0.4 1.0
ESA			
GFZ	0.7 0.3 1.1	0.6 0.4 0.9	0.7 0.5 1.0
JPL	0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0
MIT	0.0 0.1 0.1	0.0 0.1 0.1	0.1 0.2 0.4
NGS			
SIO			

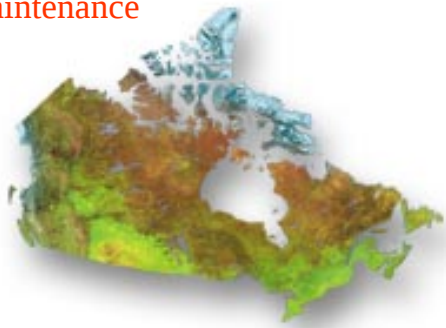
Note: Unconstrained Solutions Provided by the ACs





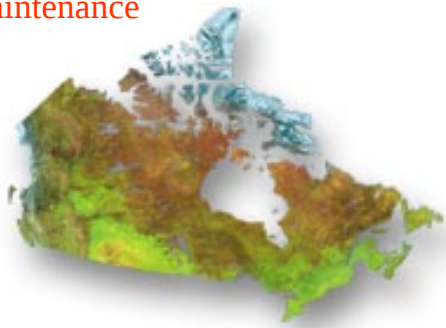
AC Modeling Differences

- Reviewed AC processing strategies
- Identified some differences
 - (e.g.: modeling station displacement)
 - Solid Earth tides
 - Pole tides
 - Ocean loading
 - Estimation strategies
 - ...
- Modeling & estimation changes with time



Improvements in Reprocessed Solutions

- Antenna height
- Modeling
- Refined rejection of marginal station coordinates estimates
- Add discontinuities
- Use most recent realization of the Reference Frame
- ...



Some Constraints

- Limited resources
 - Prioritize activities
- Used as much as possible existing software
 - Sometimes leads to sub-optimal procedures
- Production environment (deadlines)
 - Robust approach



6. *Summary*

- Weekly Production of IGS SINEX solutions
 - Mostly Automated
 - Robust
 - ~250 stations
- Realizations of ITRF
 - Reviews and Maintenance of IGS realizations
 - Convergence between ITRFxx and its IGS realization
- Products
 - Official
 - Tables / Graphics
 - Discontinuities



Summary (Cont.)

- Maintenance
 - Apriori Constraints (~sub-mm effect)
 - AC Modeling
- Acknowledgements
 - WG members
 - ACs & GNAACs
 - IGS
 - Agencies responsible for station installation & maintenance
 - data&product centers
 - IGS management

