



# Combination of the reprocessed IGS Analysis Center SINEX solutions

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Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

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- Combined Products:
  - Coordinates
  - ERP's
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# Introduction

- Main Objective:
  - Improve products consistency to better meet users requirements
- Original SINEX products:
  - AC contribution started in early 1996 (Wk 0837)
  - Combinations:
    - GNAACs (mit & ncl) combination since 1996
    - Pilot Project ~1999 (Wks 0999 – 1049)
    - Official since ~2000 (Wks 1050 – Now)
- Latest SINEX products:
  - Reprocessed:
    - 1994.0 - 2008.0 (Wks 0730 – 1459)
  - Official (Included for completeness):
    - 2008.0 - 2010.1 (Wks 1460 – 1566)





# Contributing Agencies

- co[d1] Center for Orbit Determination in Europe, University of Bern, Switzerland
- em[r1] Natural Resources, Canada
- es[a1] European Space Operations Center, ESA, Germany
- gf[z1] GeoForschungsZentrum, Germany
- gt1 GeoForschungsZentrum, Germany (Tiga)
- jp[l1] Jet Propulsion Laboratory, USA
- mi[t1] Massachusetts Institute of Technology, USA (AC + GNAAC)
- nc[l1] Newcastle, England (GNAAC)
- ng[s1] National Oceanic and Atmospheric Administration / NGS, USA
- pd1 GFZ Potsdam/IPG Dresden, Germany
- si[o1] Scripps Institution of Oceanography, USA
- ul1 University of La Rochelle, France (Tiga)

11 ACs + 2 GNAACS





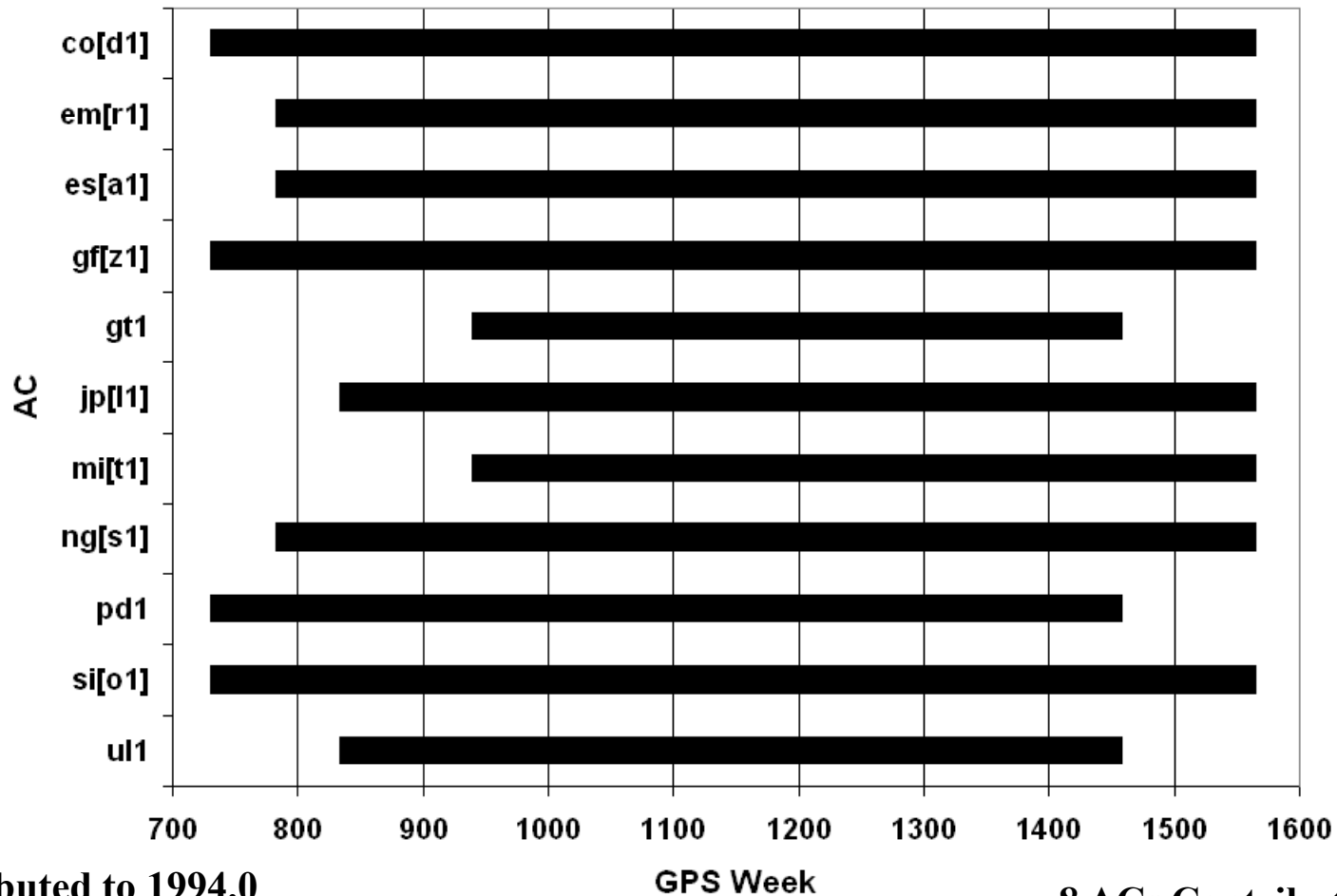
# Contributed Solutions

AC (11)	Software (6)	Data span	# of Stations	Comments
co[d1]	Bernese	1994.0 - 2010.0	322	Excluded ERPs
em[r1]	Gipsy	1995.0 - 2010.0	229	
es[a1]	NAPEOS	1995.0 - 2010.0	418	
gf[z1]	EPOS	1994.0 - 2010.0	299	Excluded apparent geocenter
gt1	EPOS	1998.0 - 2008.0	390	Excluded apparent geocenter
jp[l1]	Gipsy	1996.0 - 2010.0	413	
mi[t1]	Gamit	1998.0 - 2010.0	700	
ng[s1]	Page	1995.0 - 2010.0	436	Excluded pole position (1994.0 - 2000.0)
pd1	Bernese	1994.0 - 2008.0	201	Excluded LOD
si[o1]	Gamit	1994.0 - 2010.0	422	Excluded pole rate (2008-2010)
ul1	Gamit	1996.0 - 2007.0	275	Excluded apparent geocenter (no ERPs)
<b>GNAAC(2)</b>				
MIT		2008.0 - 2010.0	632	Comparison only.
nc[l1]		2000.0 - 2010.0	355	Comparison only





# Weekly AC Contributed Solutions



4 ACs Contributed to 1994.0

GPS Week

8 ACs Contributed to 2010.0

3 ACs Contributed the entire period

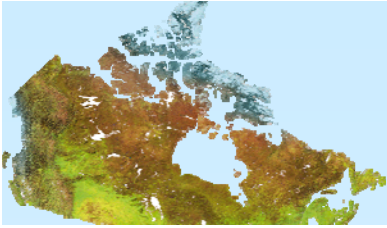
Contribution to ITRF2008 (1997.0 – 2009.5) 492 stations



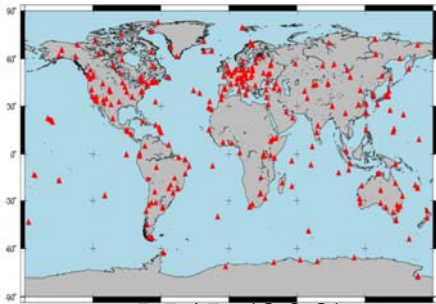
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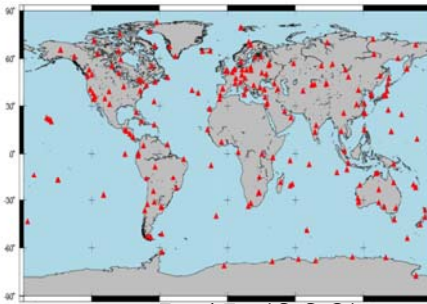
Canada



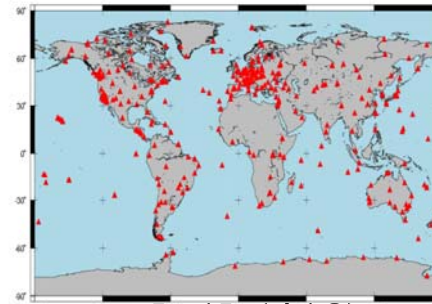
# AC Networks (Total # of stations)



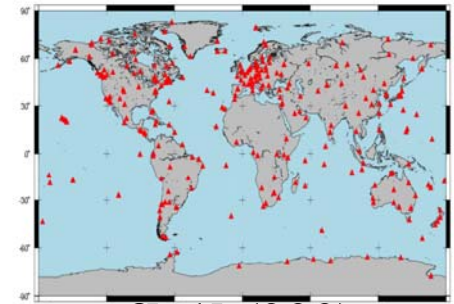
**co[d1] (322)**



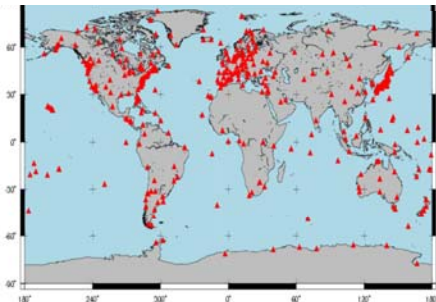
**em[r1] (229)**



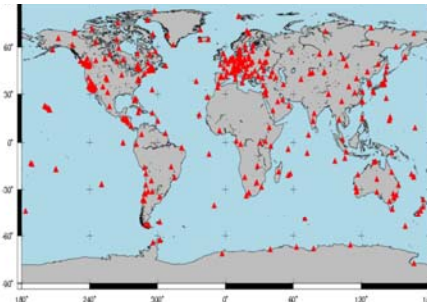
**es[a1] (418)**



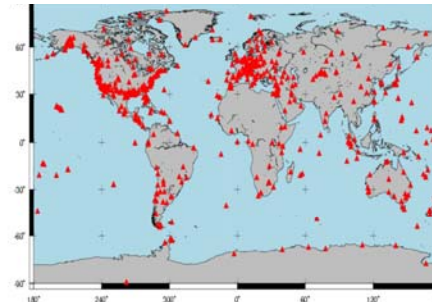
**gf[z1] (299)**



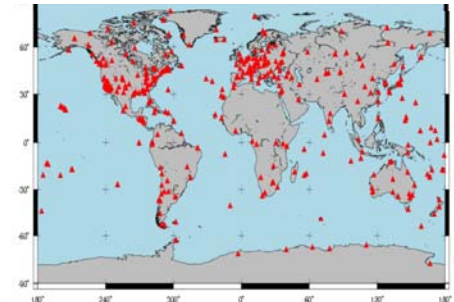
**gt1 (390)**



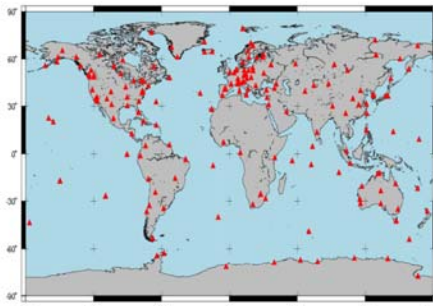
**jp[l1] (413)**



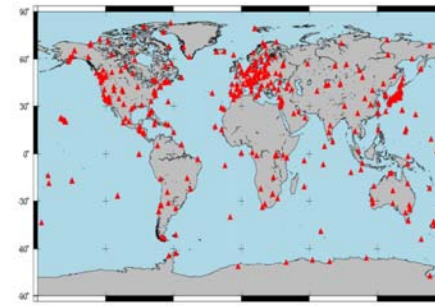
**mi[t1] (700)**



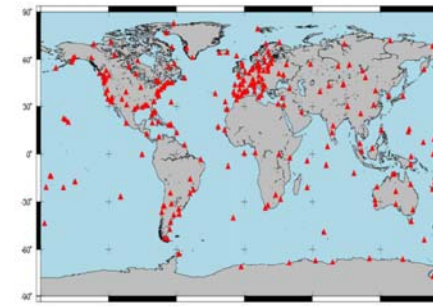
**ng[s1] (436)**



**pd1 (201)**



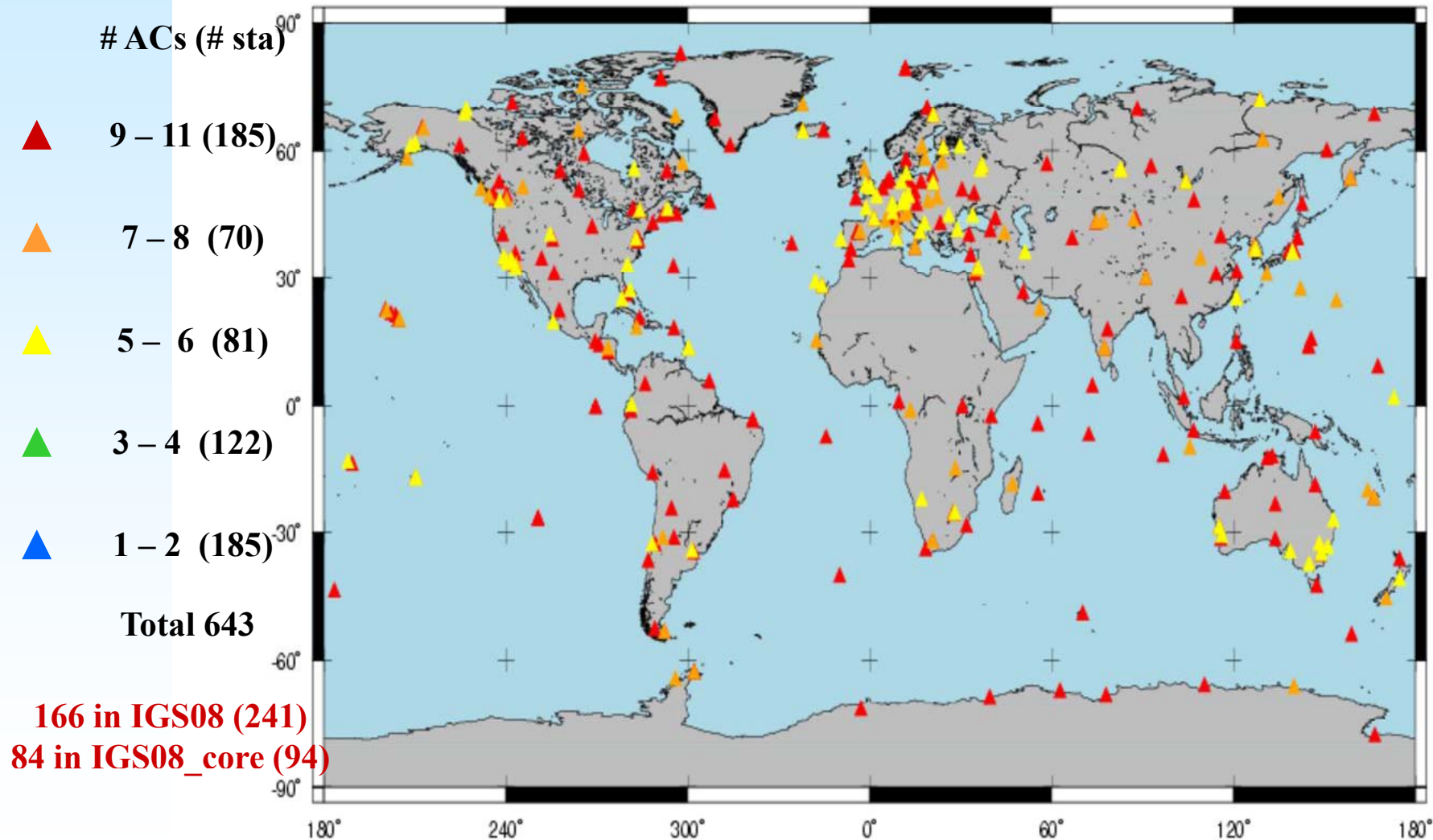
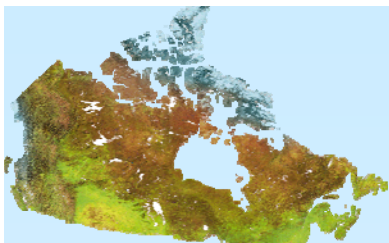
**si[o1] (422)**



**ul1 (275)**



# Stations Usage by the ACs for at least 2 years





# Stations Data Span



Years of Data (# sta)

▲ 14.0 – 16.0 (78)

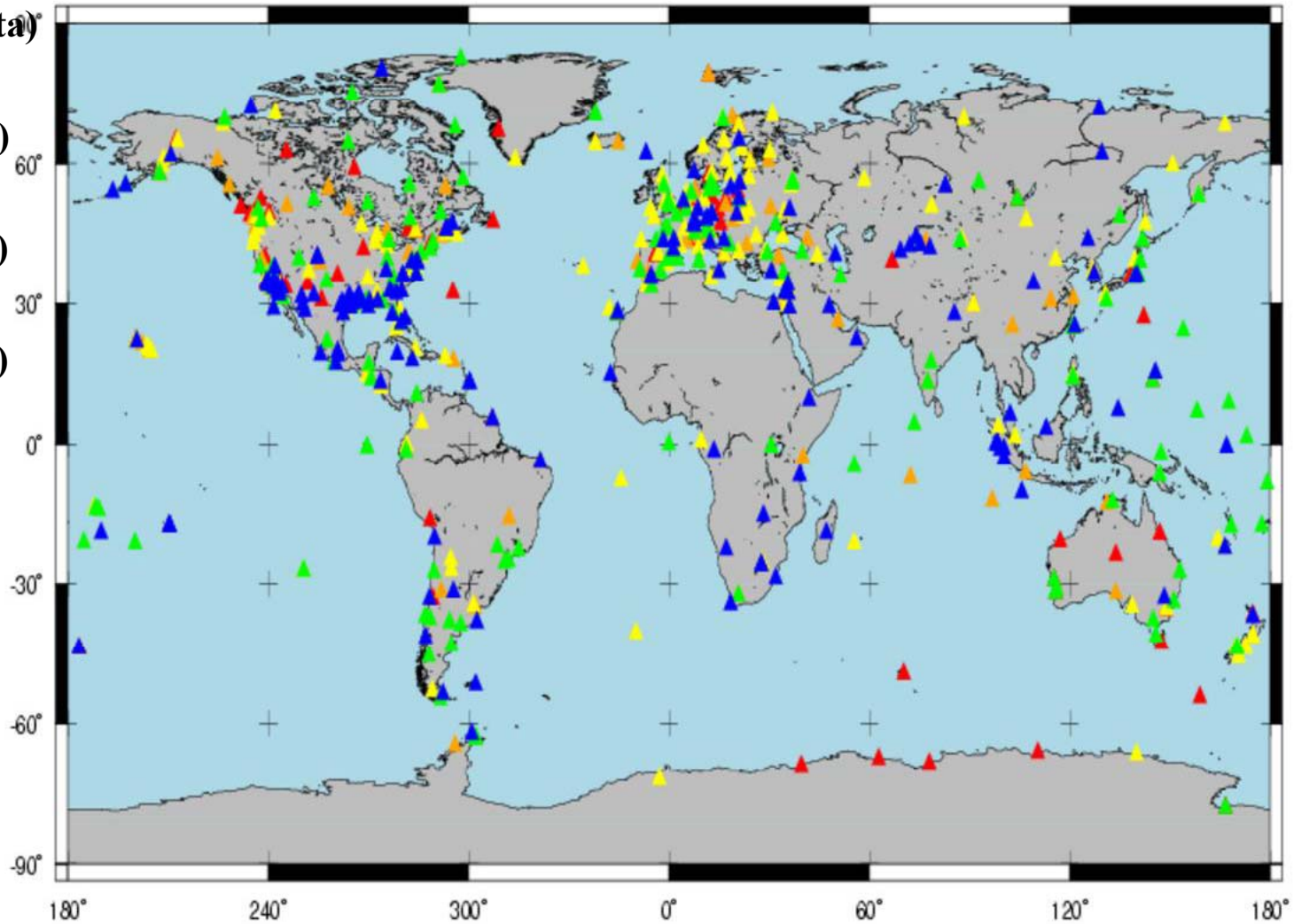
▲ 11.0 – 14.0 (81)

▲ 8.0 – 11.0 (158)

▲ 5.0 – 8.0 (157)

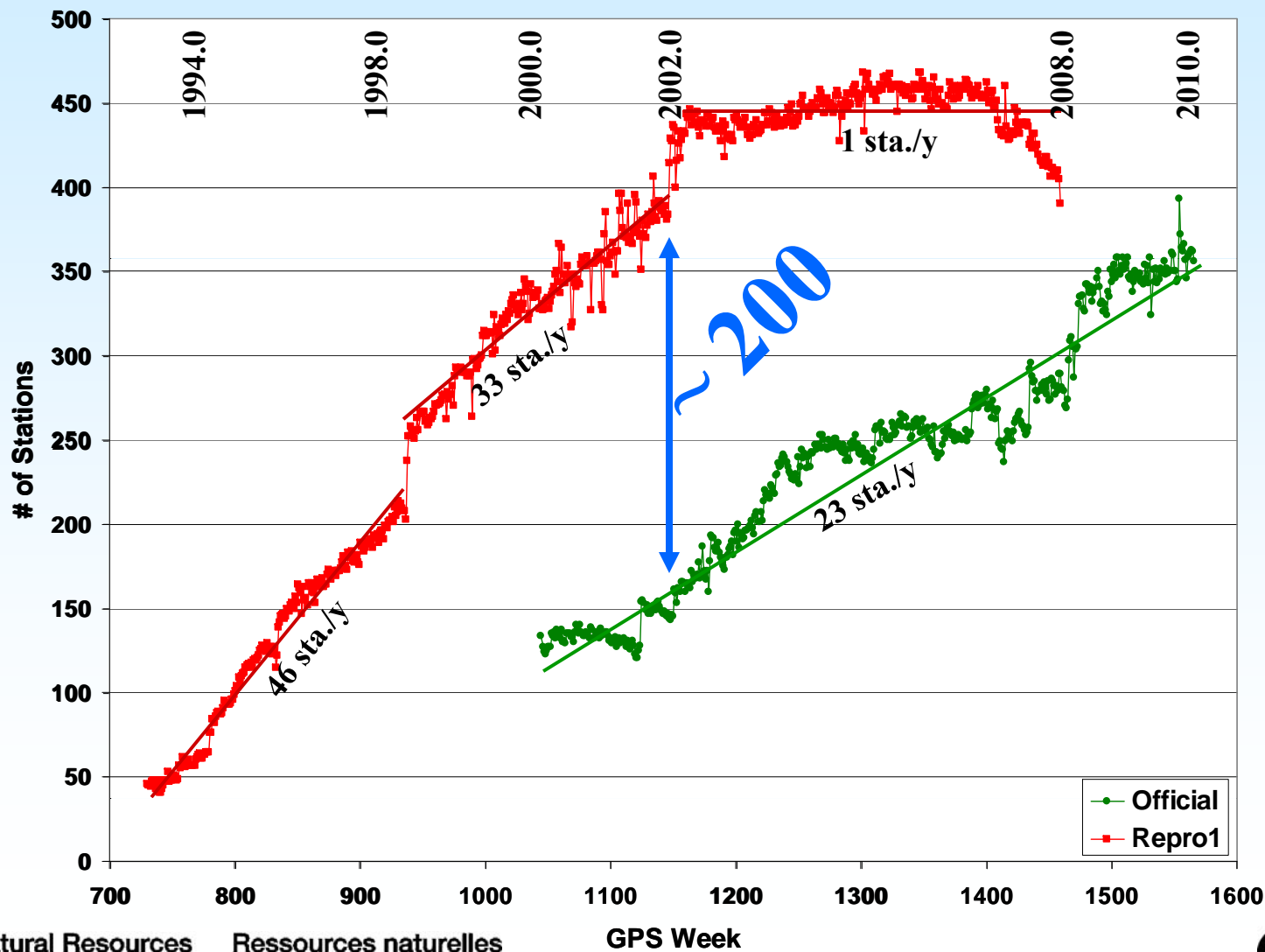
▲ 2.0 – 5.0 (169)

Total 643

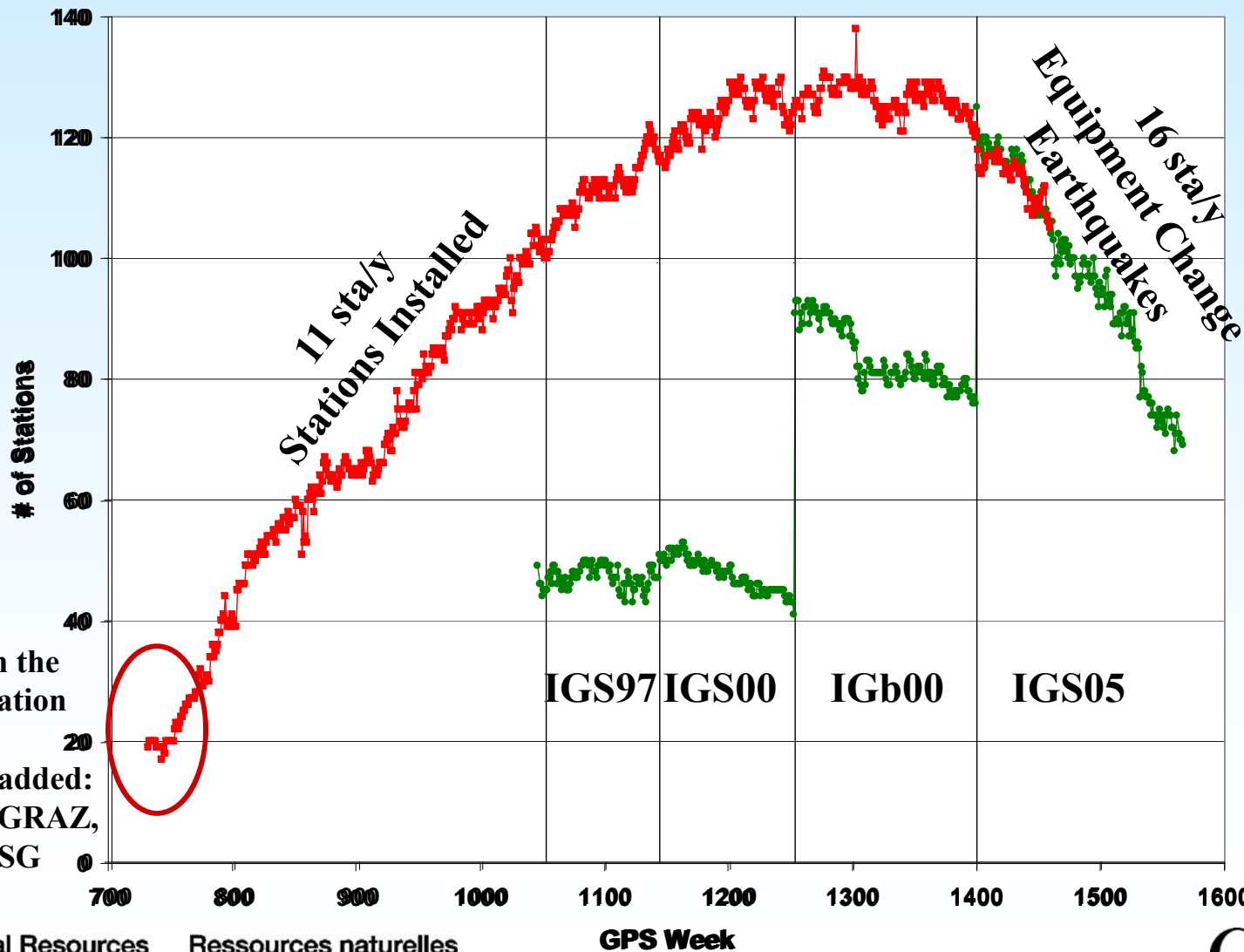




# Stations in the IGS Weekly Combination



# Reference Frame Stations in the Weekly Combinations



To strengthen the Frame Realization for 1994, 5 stations were added: BRMU, FORT, GRAZ, HOLB, KOSG



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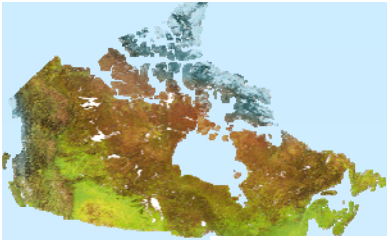
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GPS Week

Canada

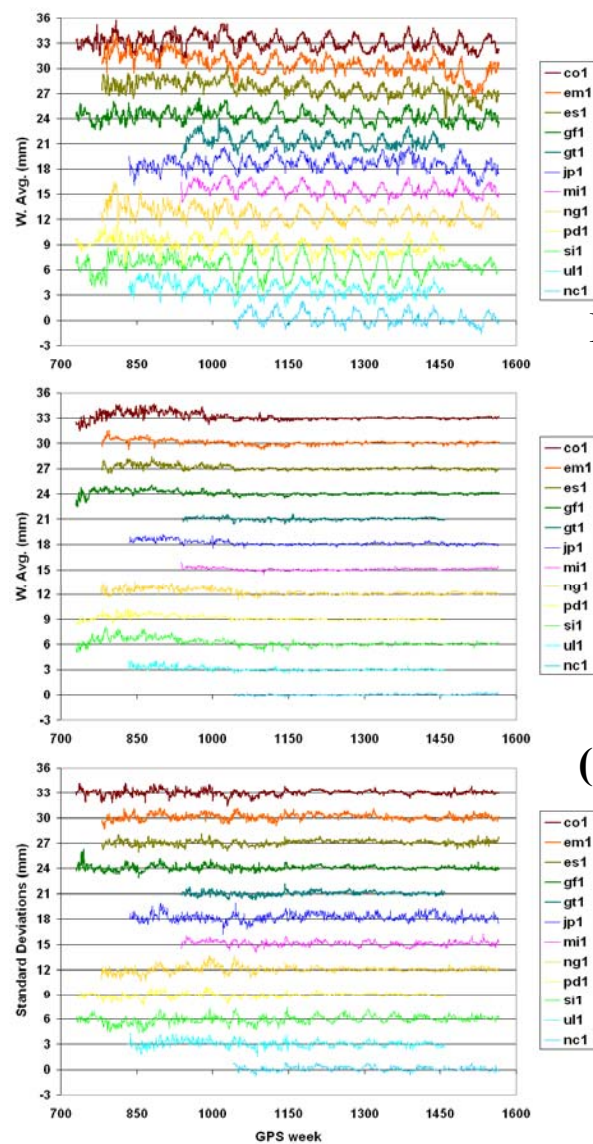
# ACs Coordinates Residuals

## Avg. & Std. w.r.t. IGS05



Annual Signal Amplitude ~1mm

Avg. (mm)



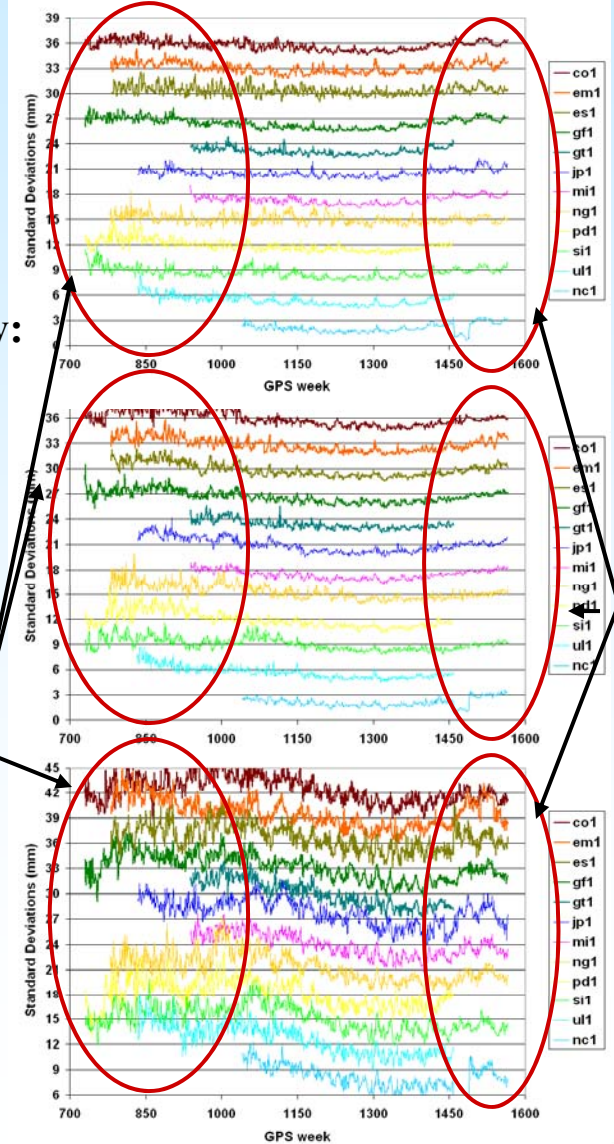
N

Best Consistency:  
N&E ~2.5mm  
H ~7mm

E

Older=noisier (solns. & IGS05)

H



IGS05 Std. (mm)

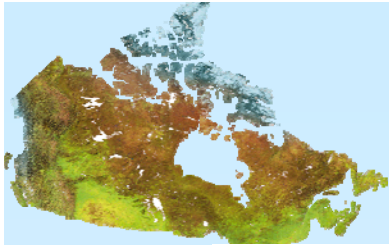


Natural Resources Canada

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Time series shifted by multiples of 3 mm.

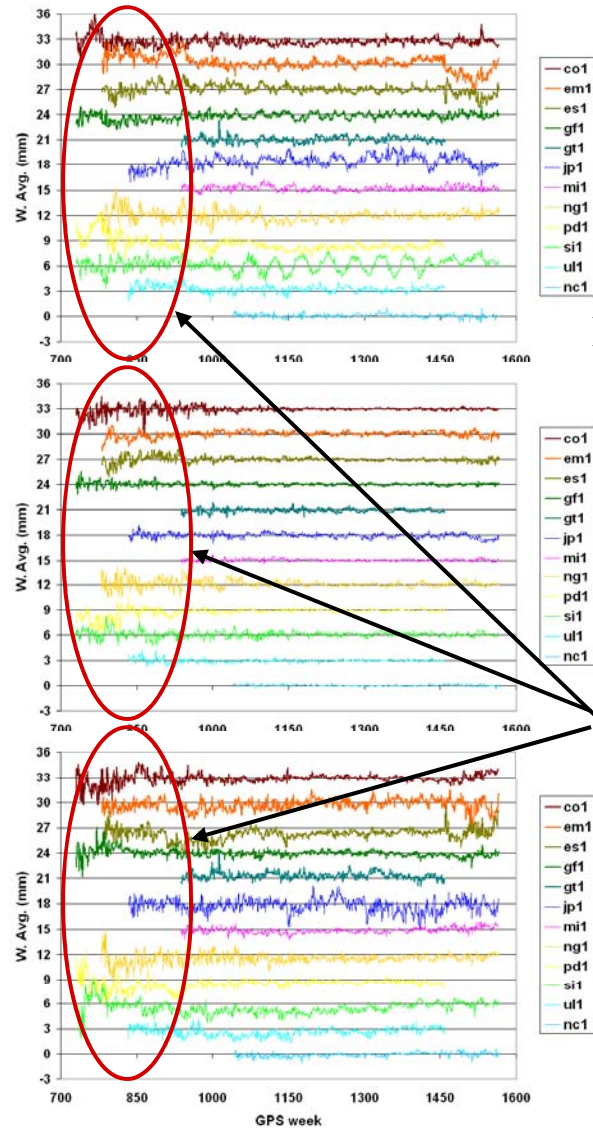




# ACs Coordinates Residuals

## Avg. & Std. w.r.t. IGS Weekly

Avg. (mm)



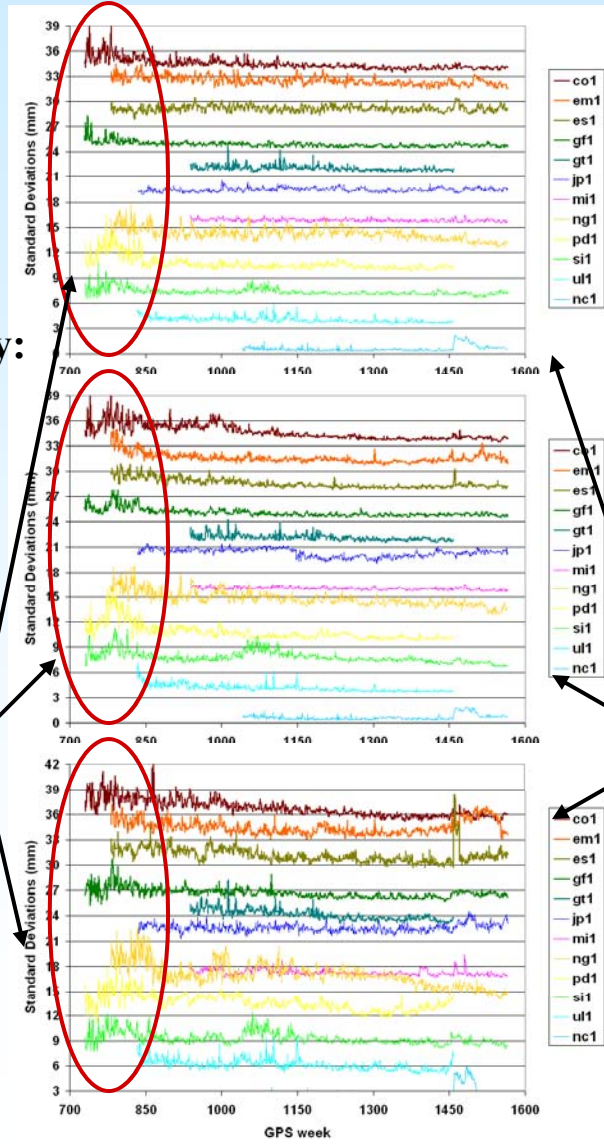
N

Best Consistency:  
N&E ~1mm  
H ~ 2.5 mm

E

Older=noisier

H



Std. (mm)

No AC dominates the combination

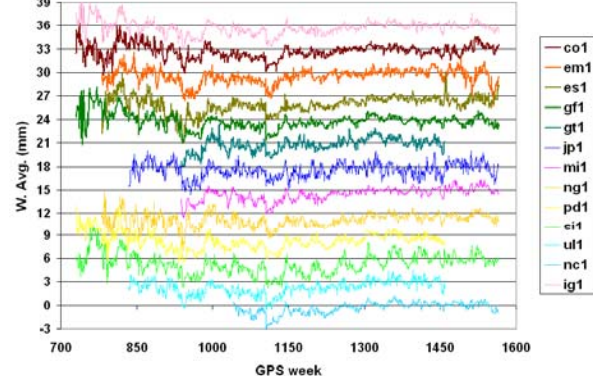
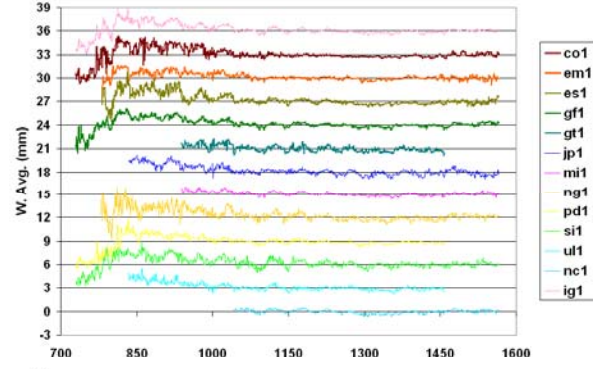
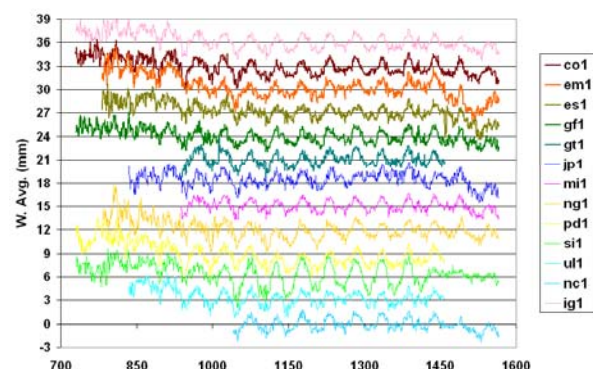


# ACs Coordinates Residuals

## Avg. & Std. w.r.t. IGS Cumulative

Annual  
Signal  
Amplitude  
~1mm

Avg. (mm)

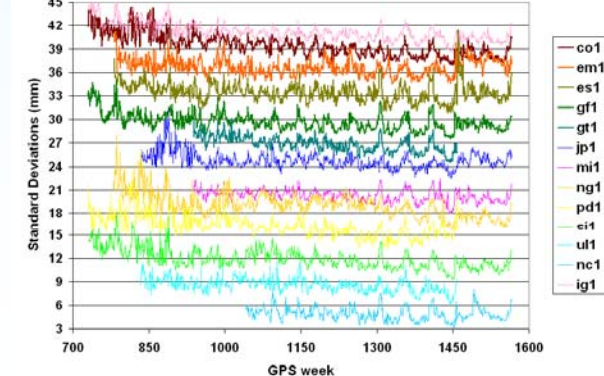
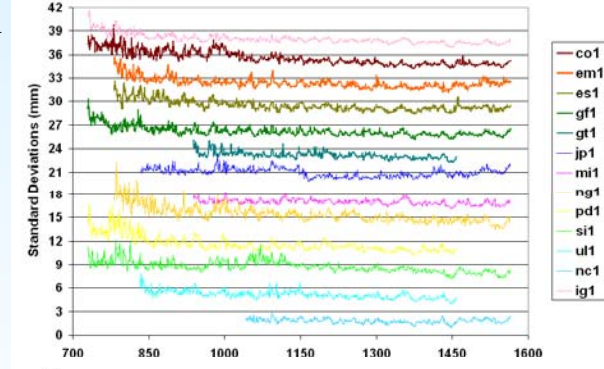
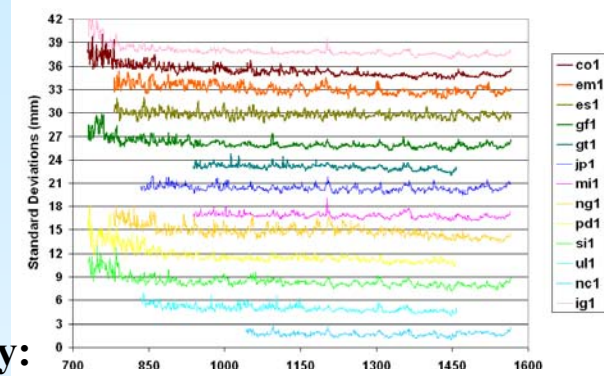


N

Best Consistency:  
N&E ~ 1.5mm  
H ~ 5mm  
Older=noisier  
E

H

Again,  
Older=noisier

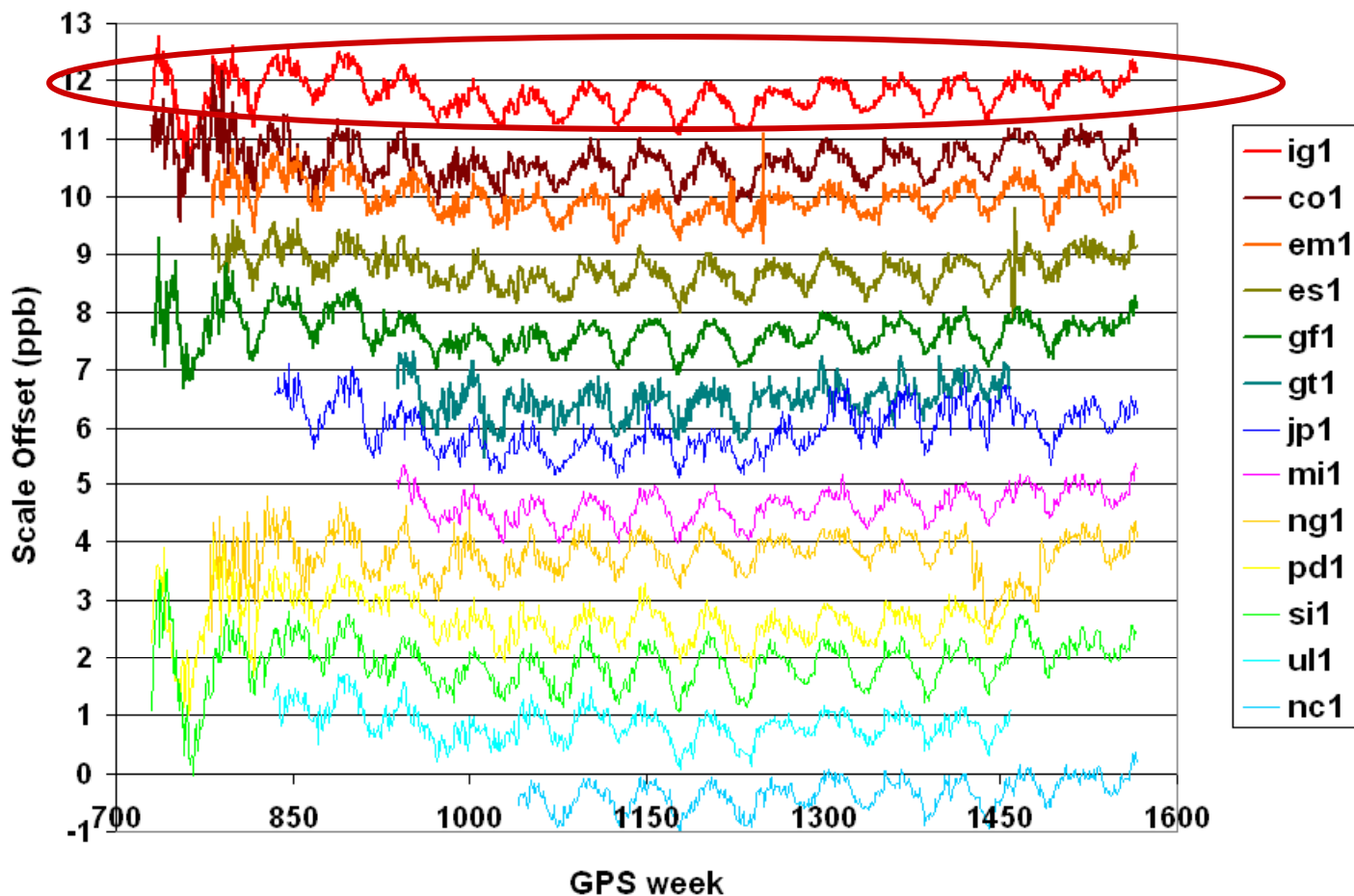


Std. (mm)





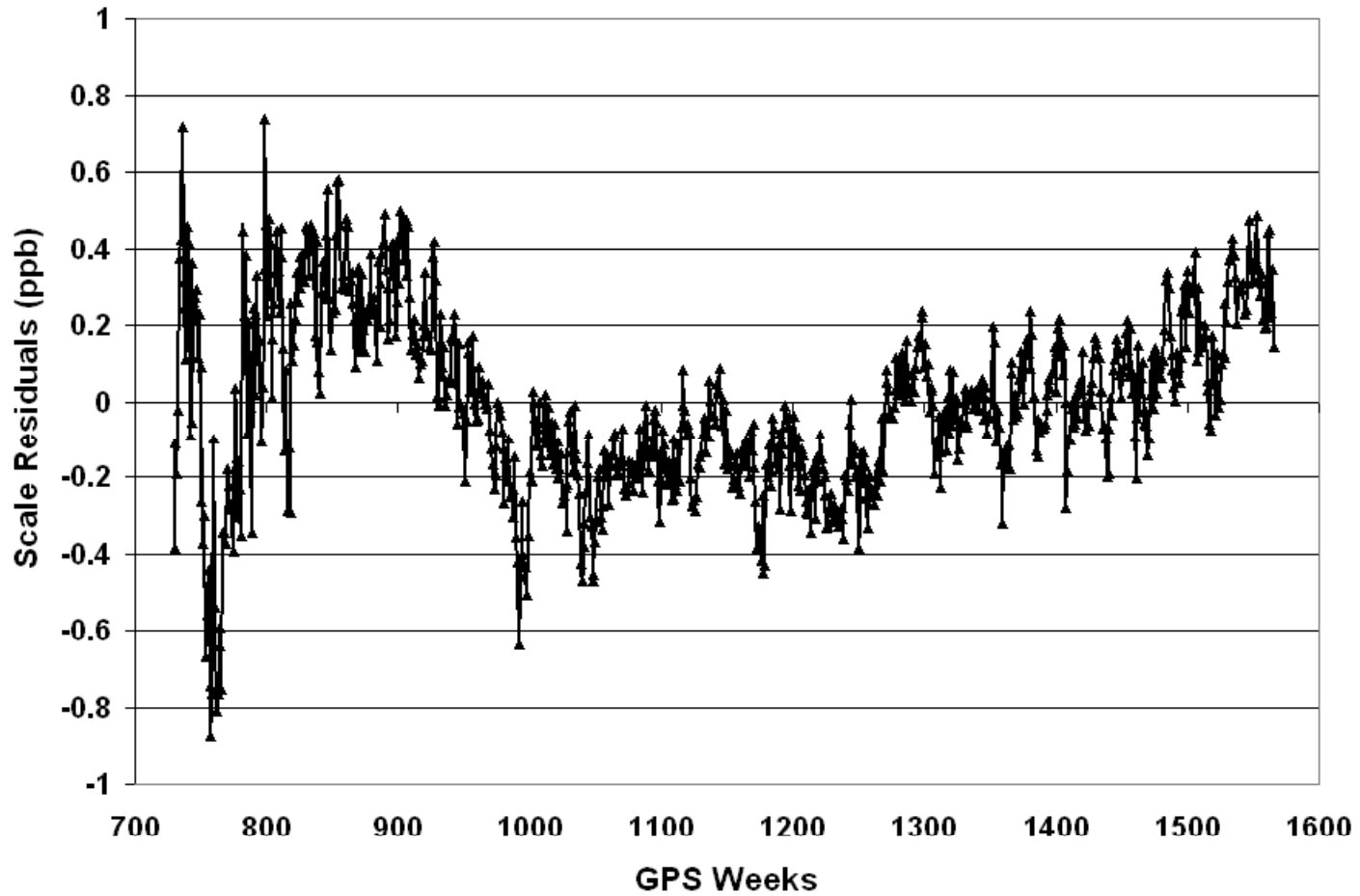
# ACs Scale offset





# IGS Scale Offset

Bias = -0.2ppb  
Drift  $\approx$  0.000 ppb/y  
Annual signal Amplitude = 0.3ppb

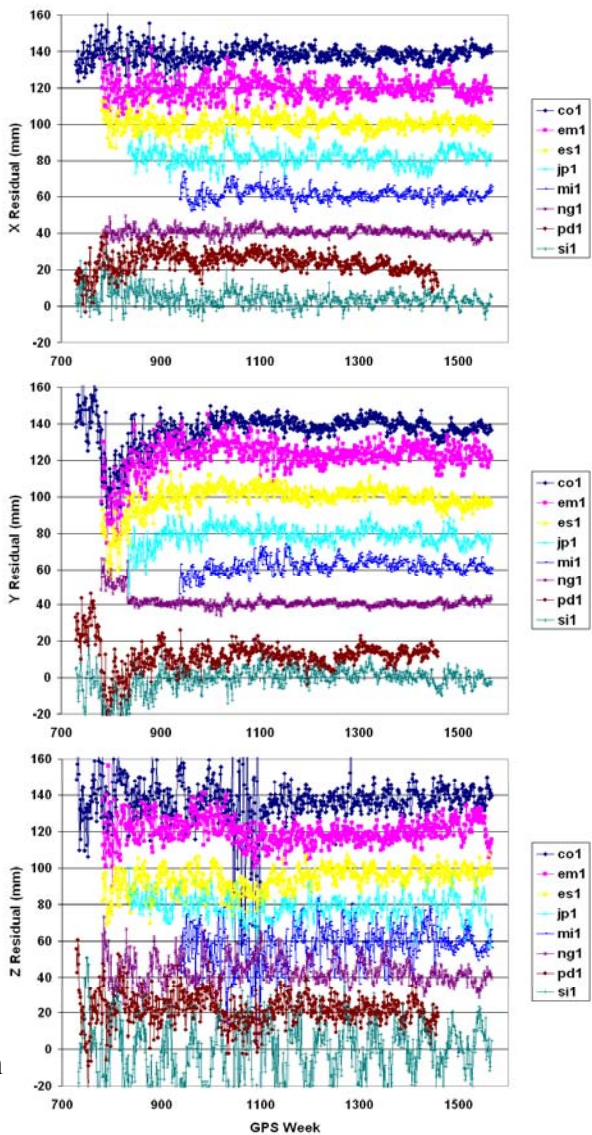




# AC Apparent Geocenter Weekly Residuals and Formal Uncertainty



Residuals (mm)



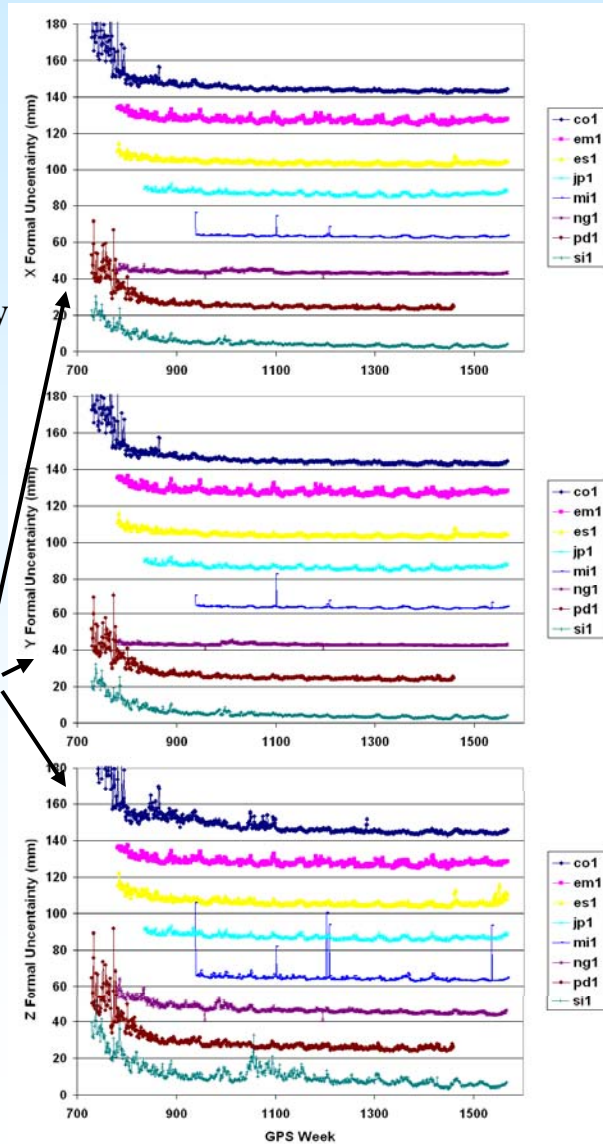
mi1 A~5mm  
ng1 A~7mm  
si1 A~15mm

X

Best Consistency  
X&Y ~1mm  
Z ~3mm  
Older=noisier

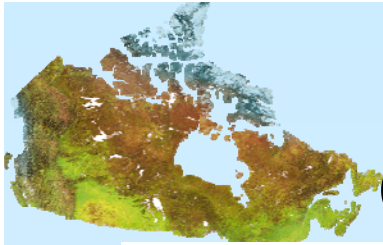
Y

Z  
No AC Dominates  
the Combination



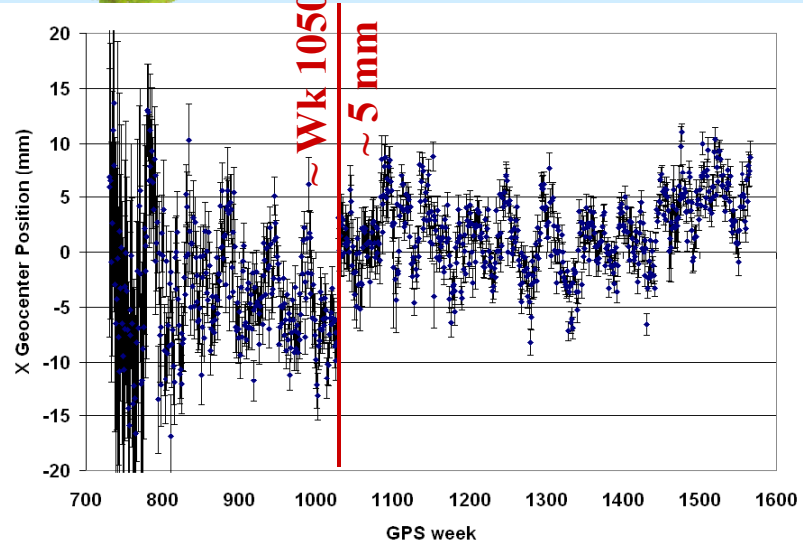
Formal Uncertainty (mm)



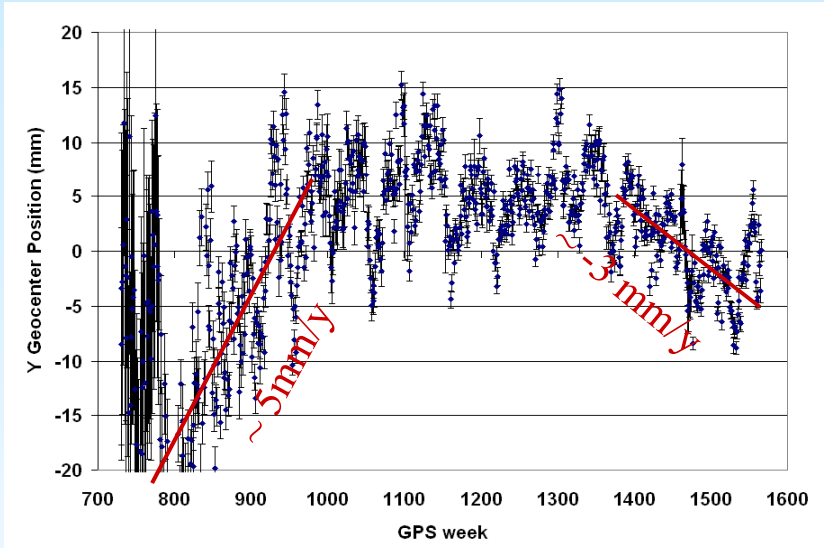


# Combined Apparent Geocenter Position w.r.t. IGS05

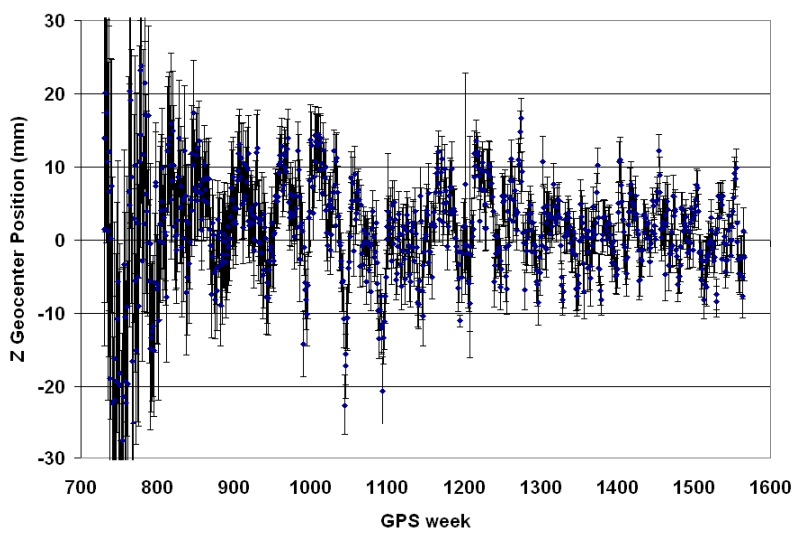
X



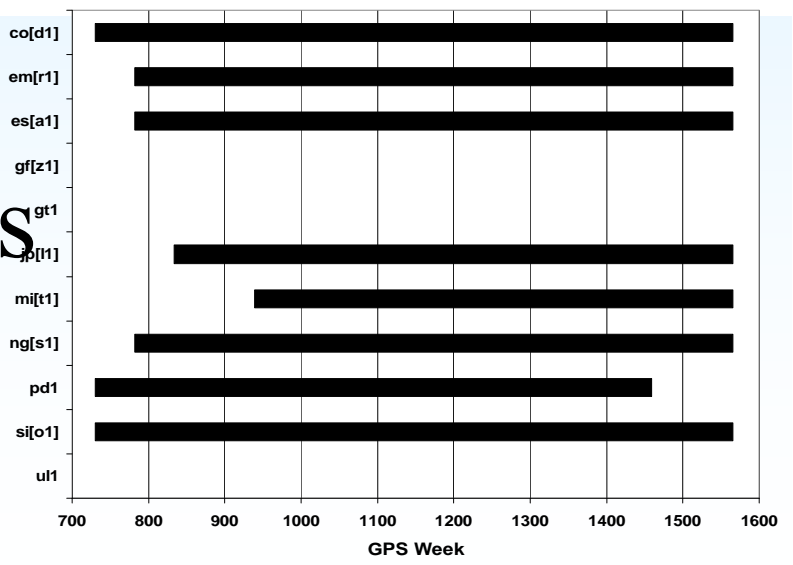
Y



Z



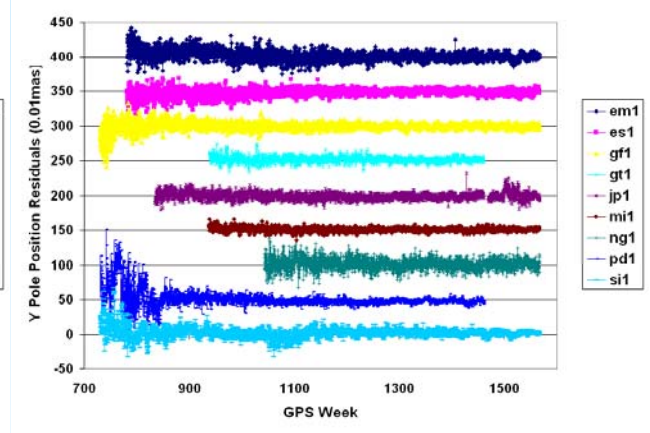
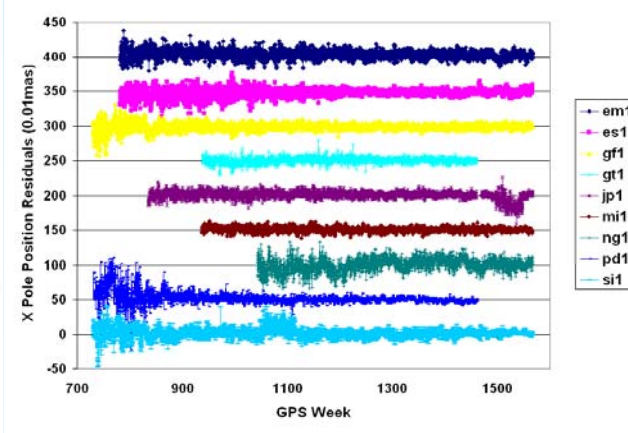
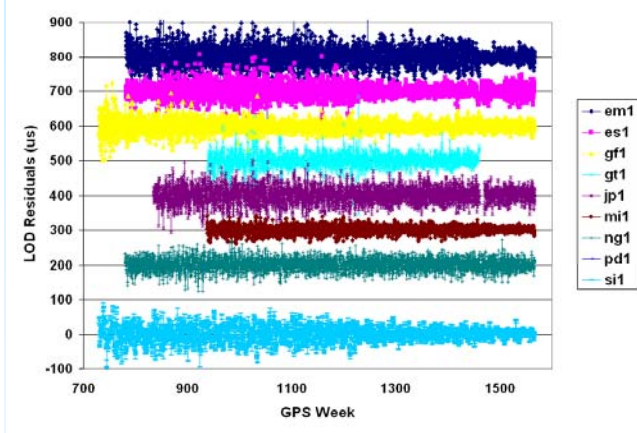
ACS





# ACs Daily ERPs Residuals w.r.t. the IGS Combined

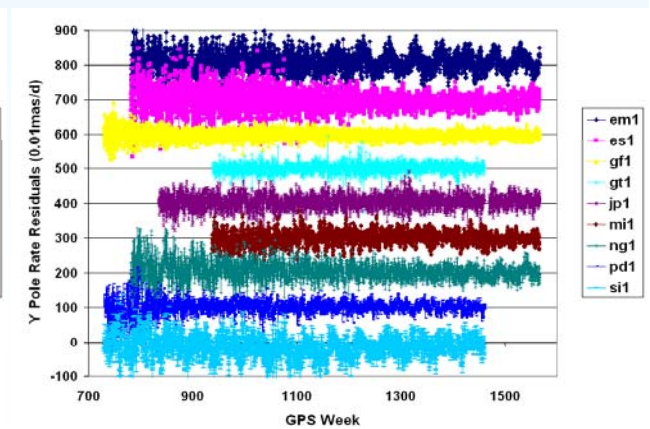
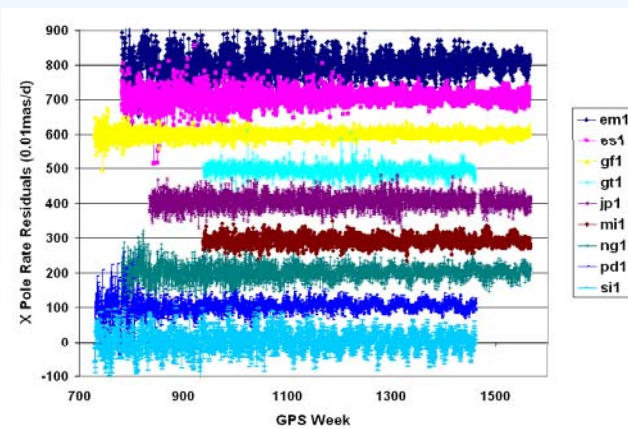
$X_p$   $Y_p$



## $X_{pr}$

## $Y_{pr}$

Consistency:  
 LOD  $\sim 10\mu s$   
 [XY] $_p \sim 0.03mas$   
 [XY] $_{pr} \sim 0.10mas/d$   
 (Older=noisier)





# Daily ERPs STD

	LOD	XPO	XPOR	YPO	YPOR
em1	25.7	5.7	33.4	7.0	26.6
es1	17.3	5.4	21.0	4.8	29.0
gf1	14.9	4.7	10.3	5.5	11.9
gt1	19.2	3.7	13.9	3.8	12.6
jp1	23.0	5.5	18.3	4.6	18.2
mi1	10.0	3.0	13.3	2.6	18.6
ng1	17.0	9.0	20.7	7.6	26.6
pd1		8.9	20.7	12.0	20.4
si1	22.5	7.1	28.6	7.2	31.4

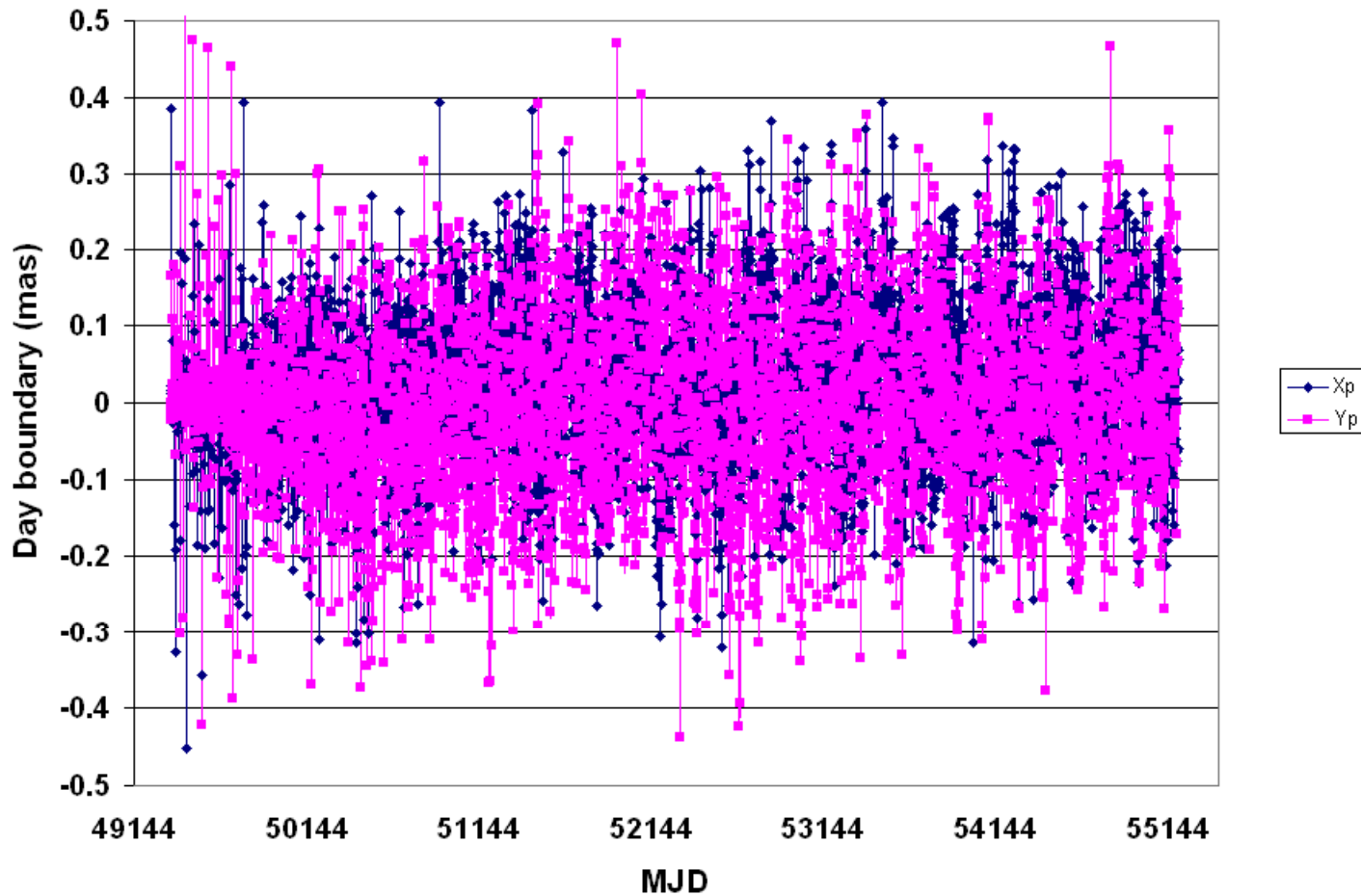
Red = Smallest STD

Green = Largest STD





# Pole Position Misclosure at Day Boundary



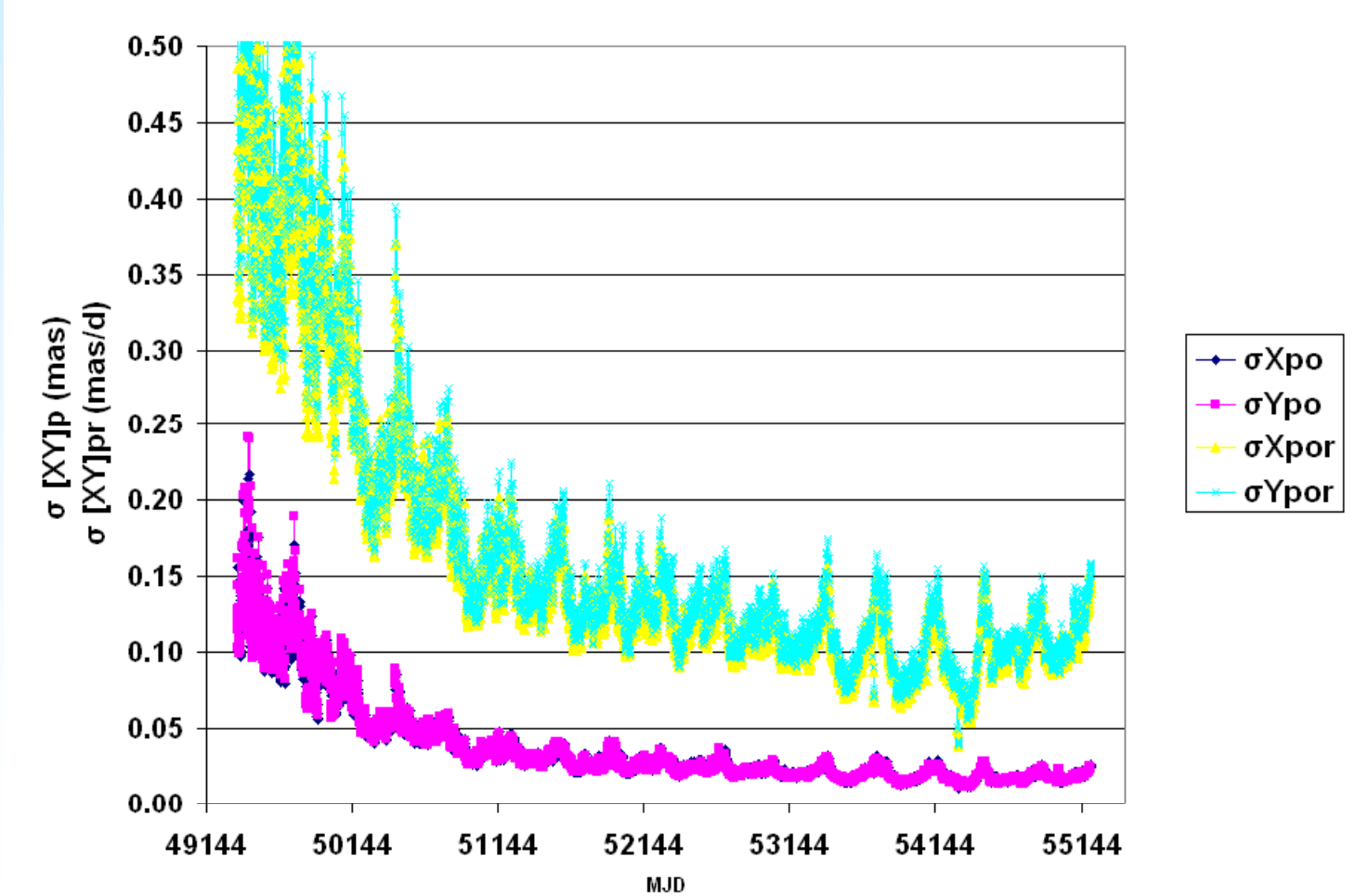
Std

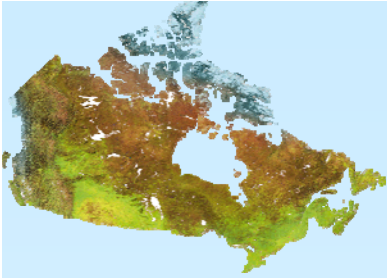
X	0.10 mas
Y	0.11 mas





# Pole Position and Rate Formal Uncertainty





# Summary (1/2)

- Contributors :
  - 11 ACs
  - 2 GNAACs
- Time span:
  - Reprocessed: 1994.0 – 2008.0
  - Official: 2008.0 – 2010.1
  - No significant discontinuity observed at the reprocessed/Official solutions boundary
- Network:
  - All contribution : 900 + stations
  - With 2 years + : 643 stations





# Summary (2/2)

- ACs products best consistency:
  - Coordinates w.r.t.:
    - IGS05 (N-E ~ 2.5 mm, H ~ 7 mm)
    - IGS Weekly (N-E ~ 1 mm, H ~ 2.5 mm)
    - IGS Cumulative (N-E ~ 2 mm, H ~ 5 mm)
  - ERPs:
    - LOD ~ 10us
    - ( [XY]<sub>p</sub> ~ 0.03 mas; [XY]<sub>pr</sub> ~ 0.10mas/d)
  - Geocenter: X & Y ~1 mm Z ~ 3mm
  - Older (pre-1996) solutions consistency substantially worse







# Recommendations

- Improve older combinations (pre-1996)
  - All Acs should contribute (Half have done it)
  - More stations ... if possible.
- All ACs should contribute all parameters
- All contributed Parameters should be unconstrained or at least unconstrainable.





# Acknowledgements

- Co[d1] Center for Orbit Determination in Europe, University of Bern, Switzerland
  - Em[r1] Natural Resources, Canada
  - Es[a1] European Space Operations Center, ESA, Germany
  - gf[z1] GeoForschungsZentrum, Germany
  - gt1 GeoForschungsZentrum, Germany (Tiga)
  - jp[l1] Jet Propulsion Laboratory, USA
  - mi[t1] Massachusetts Institute of Technology, USA (AC + GNAAC)
  - nc[l1] Newcastle, England (GNAAC)
  - ng[s1] National Oceanic and Atmospheric Administration / NGS, USA
  - pd1 GFZ Potsdam/IPG Dresden, Germany
  - si[o1] Scripps Institution of Oceanography, USA
  - ul1 University of La Rochelle, France (Tiga)
- 
- All Data/Products Centers
  - All Agencies and people that contributed station data.

