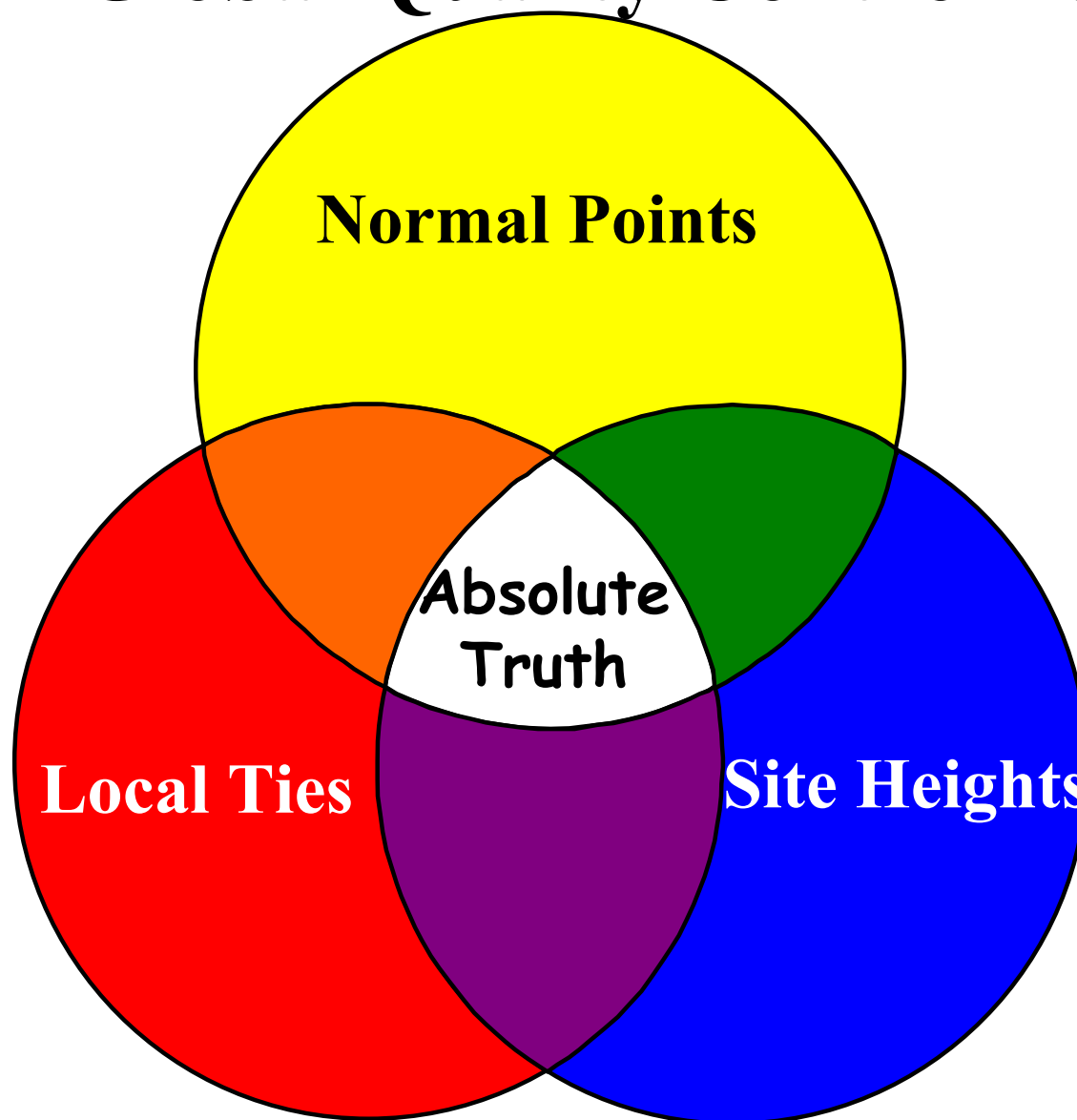


SLR Global Quality Control 2003

(Biases, Heights and Local Ties)

Van Husson (HTSI)
ILRS Central Bureau

SLR Global Quality Control 2003



Outline

- Harmonization of QC Results Status with examples
- New analysis techniques and examples
 - *Collocated Short Arc*
 - *28-day Coordinate Solutions (site height analysis)*
 - *Site Tie Analysis*
- Combination of Techniques

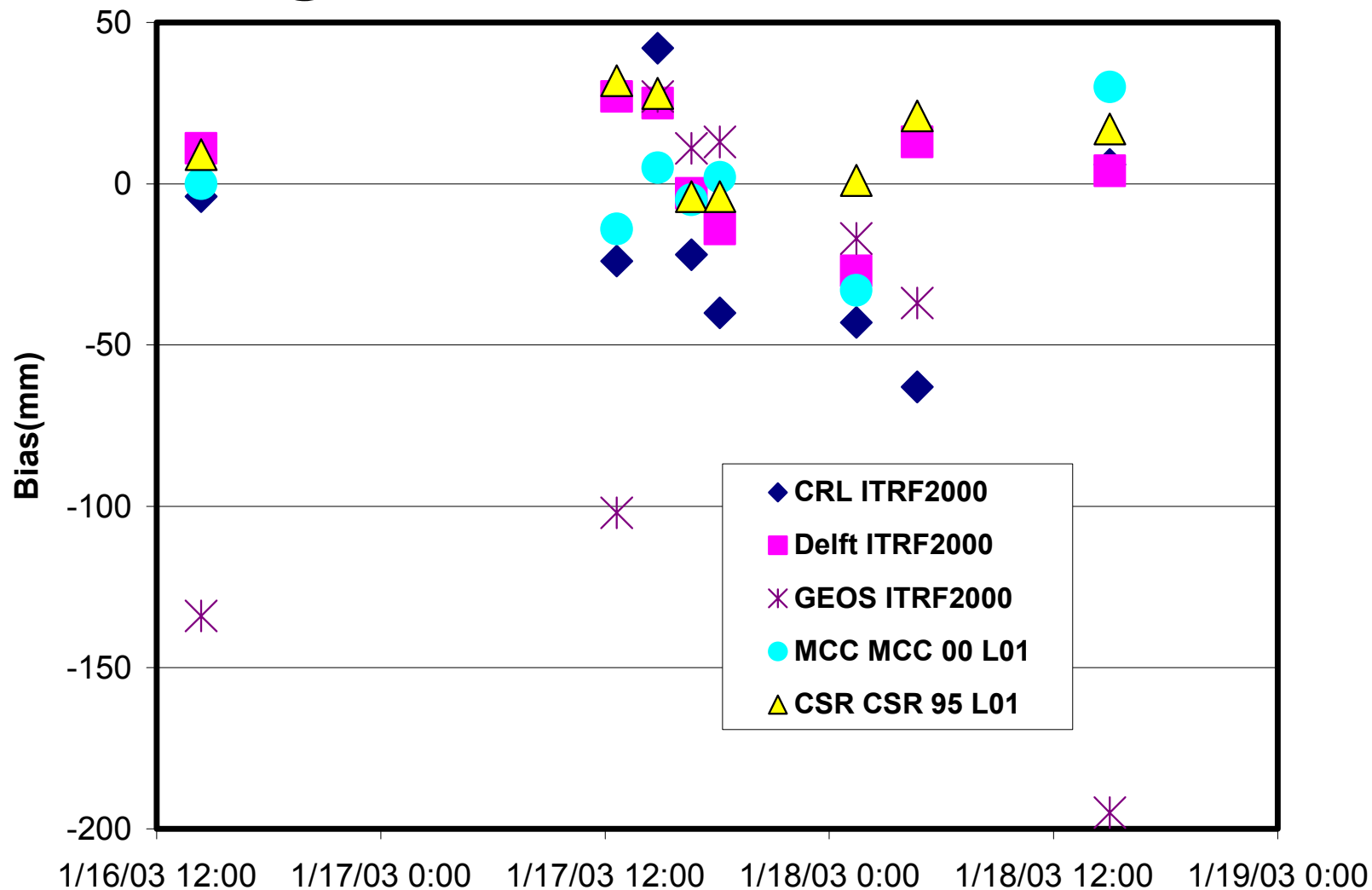
Rationale for Harmonization of QC Results

- The pass-by-pass results can differ significantly between analysis centers
- Different models (e.g. coordinates, location of the pass within the arc, arc length, data weighting, force models, etc.) can and will produce different bias results
- The ILRS stations do not know which report(s) to trust

A Typical Harmonization Example (Yarragadee, 7090)

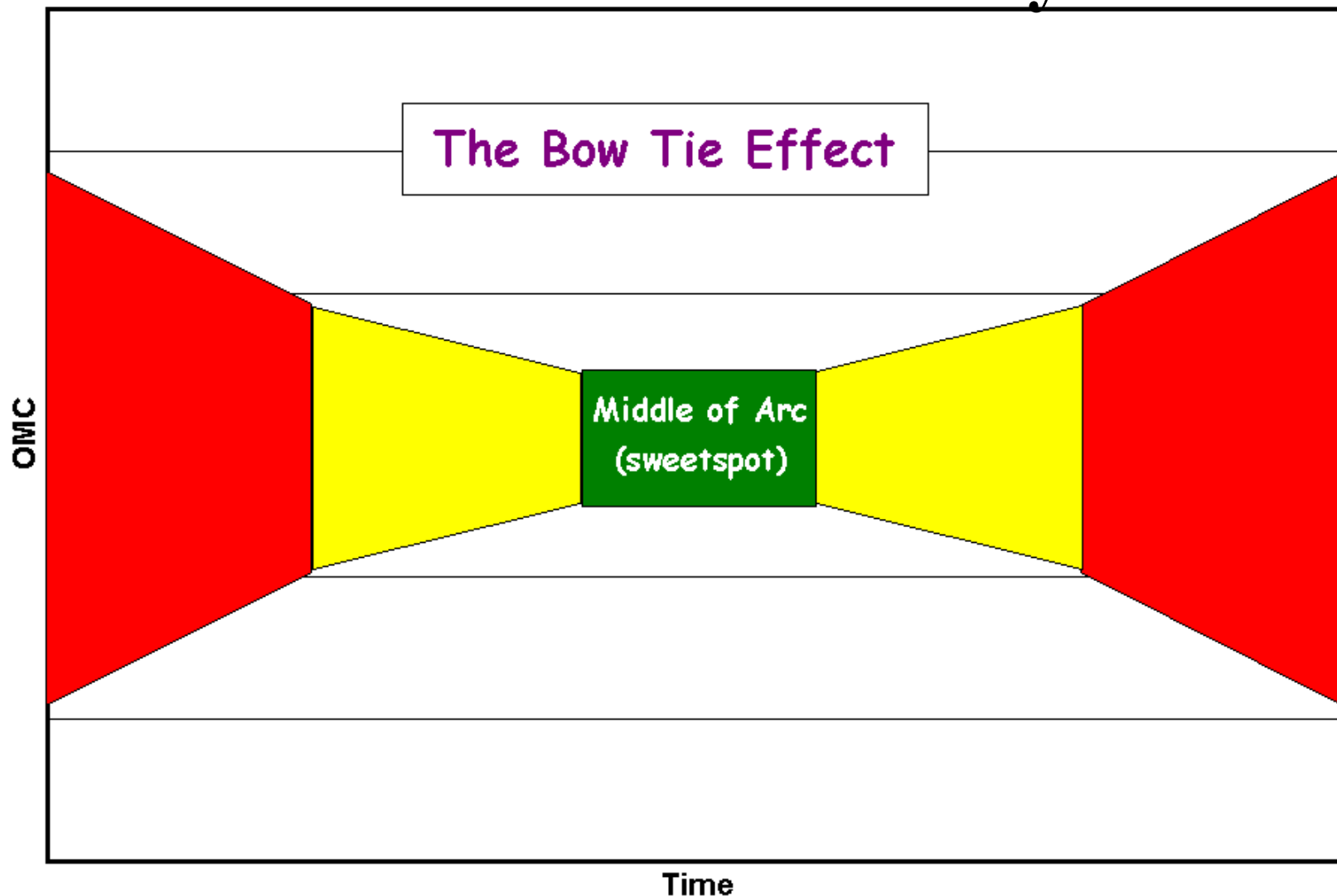
Date	Time	CDP	Satellite	Nps	CRL RB(mm)	Delft RB(mm)	GEOS RB(mm)	MCC RB(mm)	CSR RB(mm)
1/16/03	14:23	7090	L2	14	-4 +- 63	11 +- 14	-134 +- 16	0	9
1/17/03	12:37	7090	L2	13	-24 +- 12	27 +- 14	-102 +- 14	-14	32
1/17/03	14:49	7090	L1	6	42 +- 12	25 +- 23	27 +- 17	5	28
1/17/03	16:37	7090	L2	18	-22 +- 14	-3 +- 13	11 +- 4	-5	-4
1/17/03	18:09	7090	L1	14	-40 +- 259	-14 +- 14	13 +- 8	2	-4
1/18/03	1:27	7090	L2	5	-43 +- 39	-27 +- 82	-17 +- 9	-33	1
1/18/03	4:42	7090	L1	4	-63 +- 174	13 +- 199	-37 +- 18		21
1/18/03	15:01	7090	L2	10	6 +- 14	4 +- 47	-195 +- 13	30	17
mean					-19	5	-54	-2	13
coordinates					ITRF2000	ITRF2000	ITRF2000	MCC 00 L01	CSR 95 L01

Yarragadee Harmonization Results



Delft and CSR have the best agreement.

Realities of Orbital Analysis



The length and the width of the bow tie can vary between ACs.

Harmonization Status

- Six Analysis Centers (AC) provide LAGEOS QC
- Five of these produce ASCII reports (CRL, CSR, Delft, MCC & GEOS)
 - Range and time bias estimates provided for each pass
 - CRL, CSR, MCC, Delft reports sent to SLReport
 - Delft, CRL, GEOS provide error estimates for biases
 - CRL provides Etalon, Stella, Starlette & Ajisai results
 - CRL, MCC provide site met. data
 - MCC and CSR apply a priori biases
- NERC performs automatic daily simultaneous and long arc analyses (web-based and graphical)
 - Simultaneous analysis performed on all satellites
- **Goal - *Develop a single consolidated bias report***

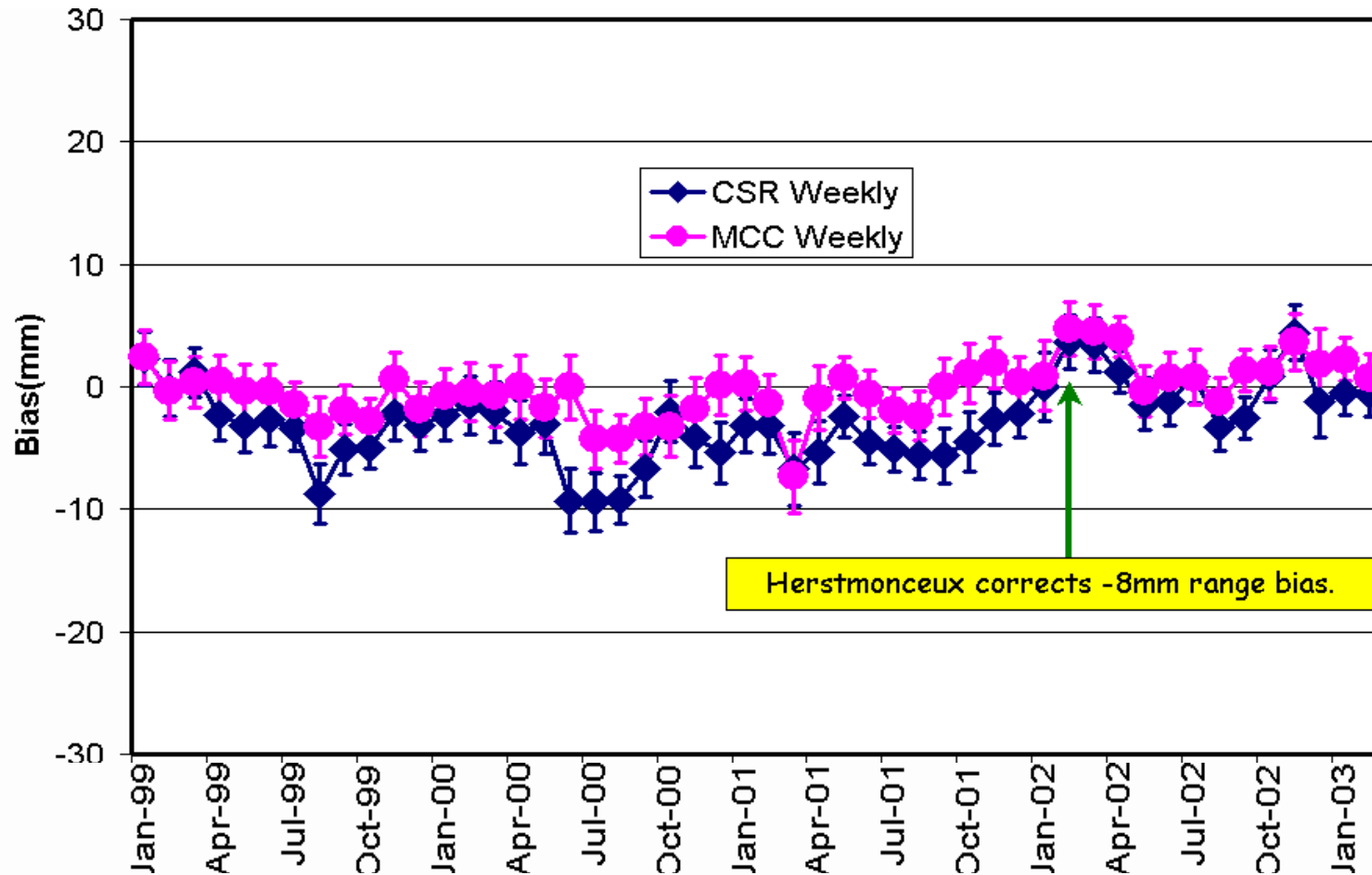
Coordinate Systems

<u>Analysis Center</u>	<u>Coordinates</u>	<u>Implementation</u>
CRL	ITRF2000	2001
CSR	CSR 1995 L01	1995
Delft	ITRF2000	1 January 2003
GEOS	ITRF2000	1 May 2001
MCC	MCC 2000 L01	1 March 2000
NERC	ITRF2000	2001

MCC vs CSR Harmonization **(Jan 1999 to Feb 2003)**

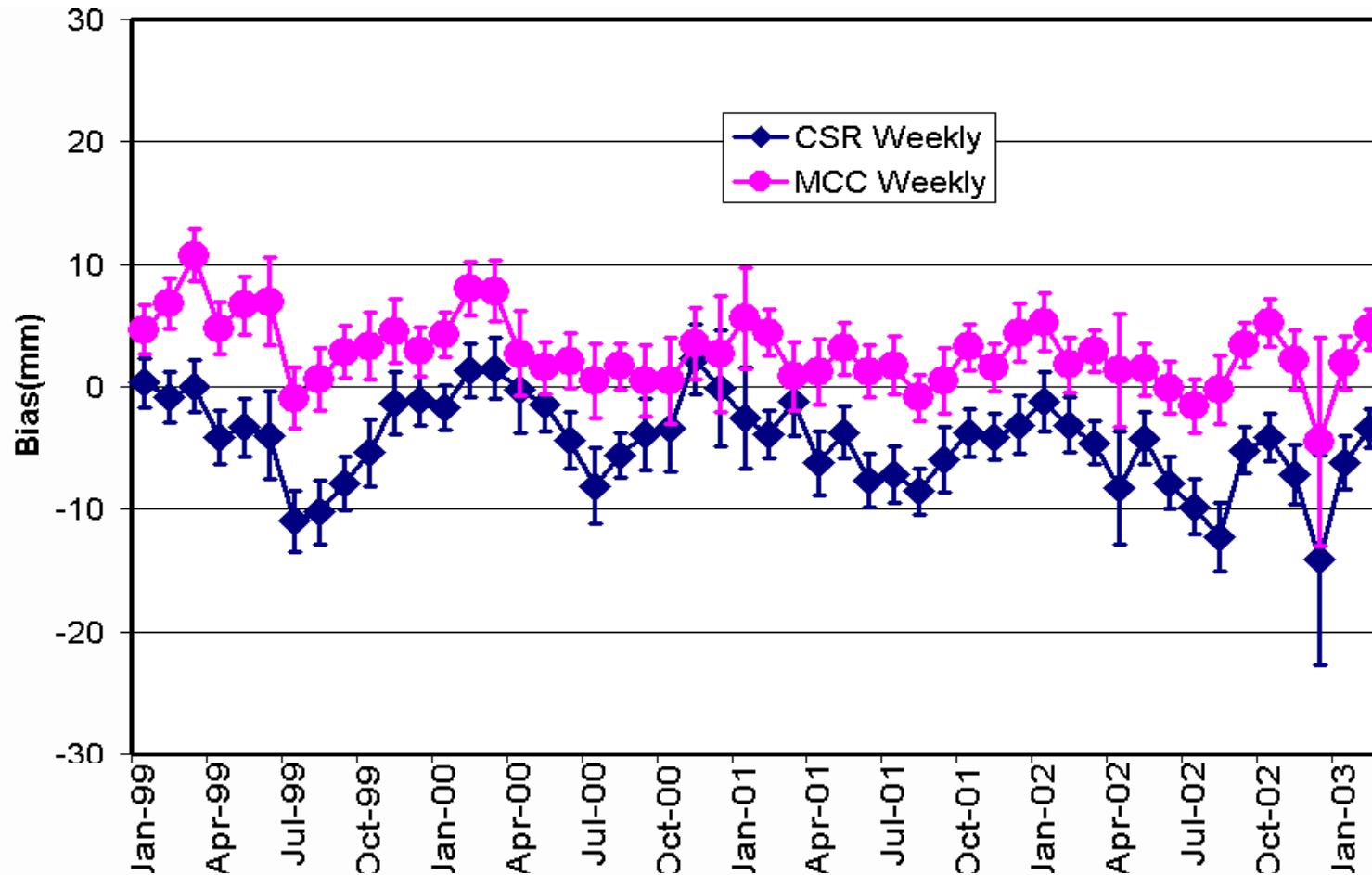
Aggregate Analysis - Monthly

Herstmonceux (7840)



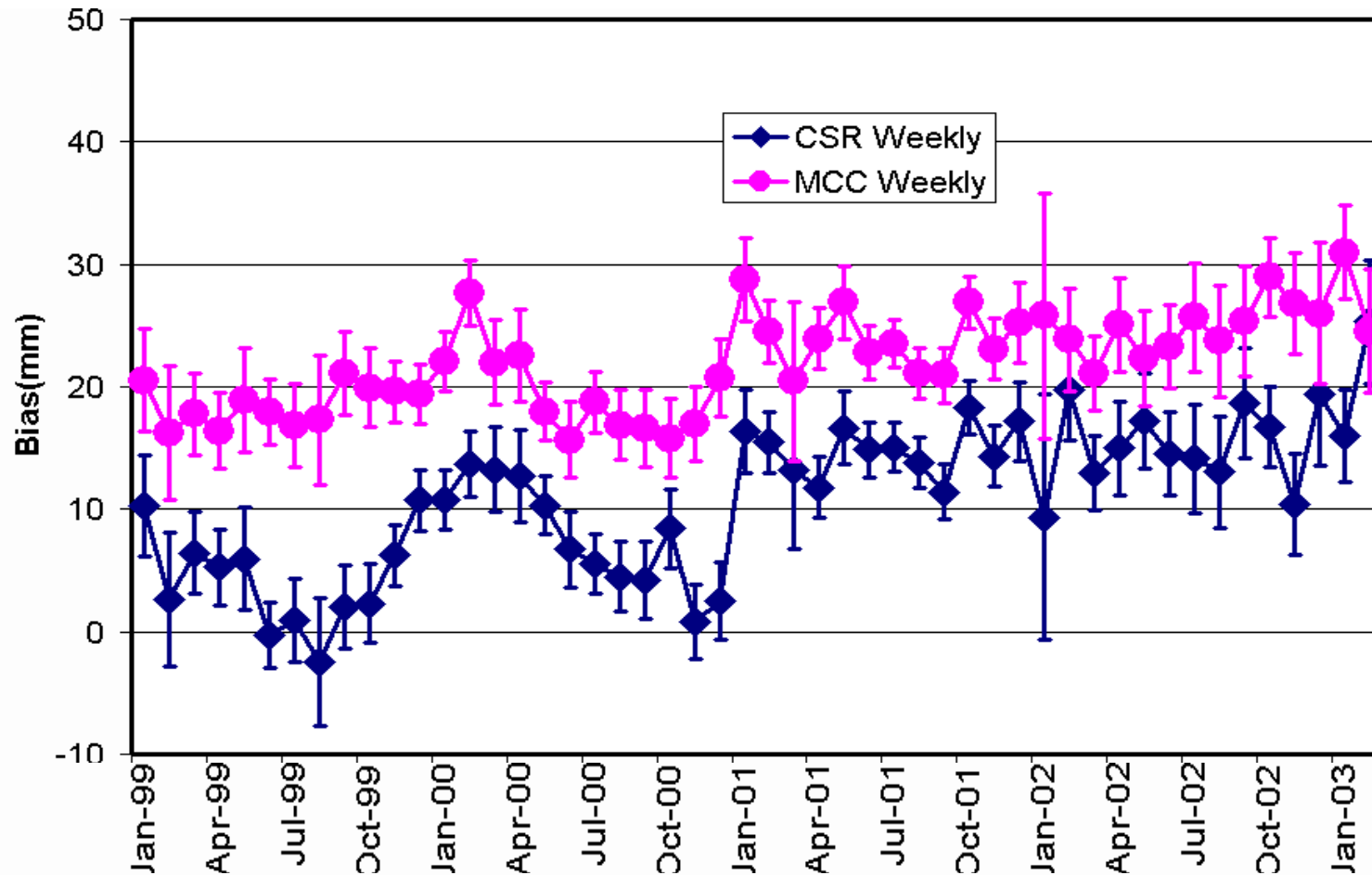
Agreement to the few mm level,
8mm change difficult to discern.

Graz (7839)



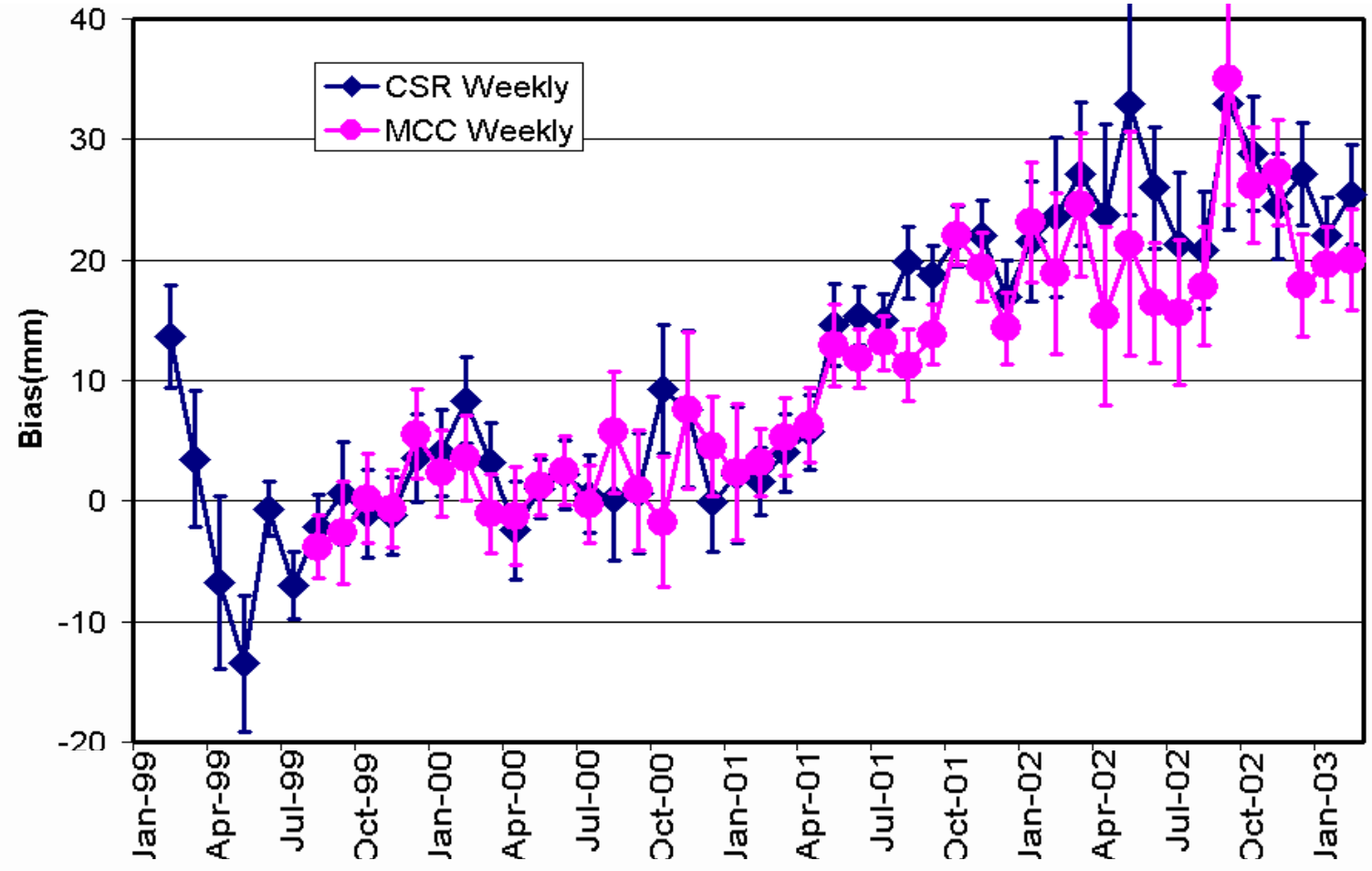
There is an offset between CSR and MCC results.

Grasse (7835)



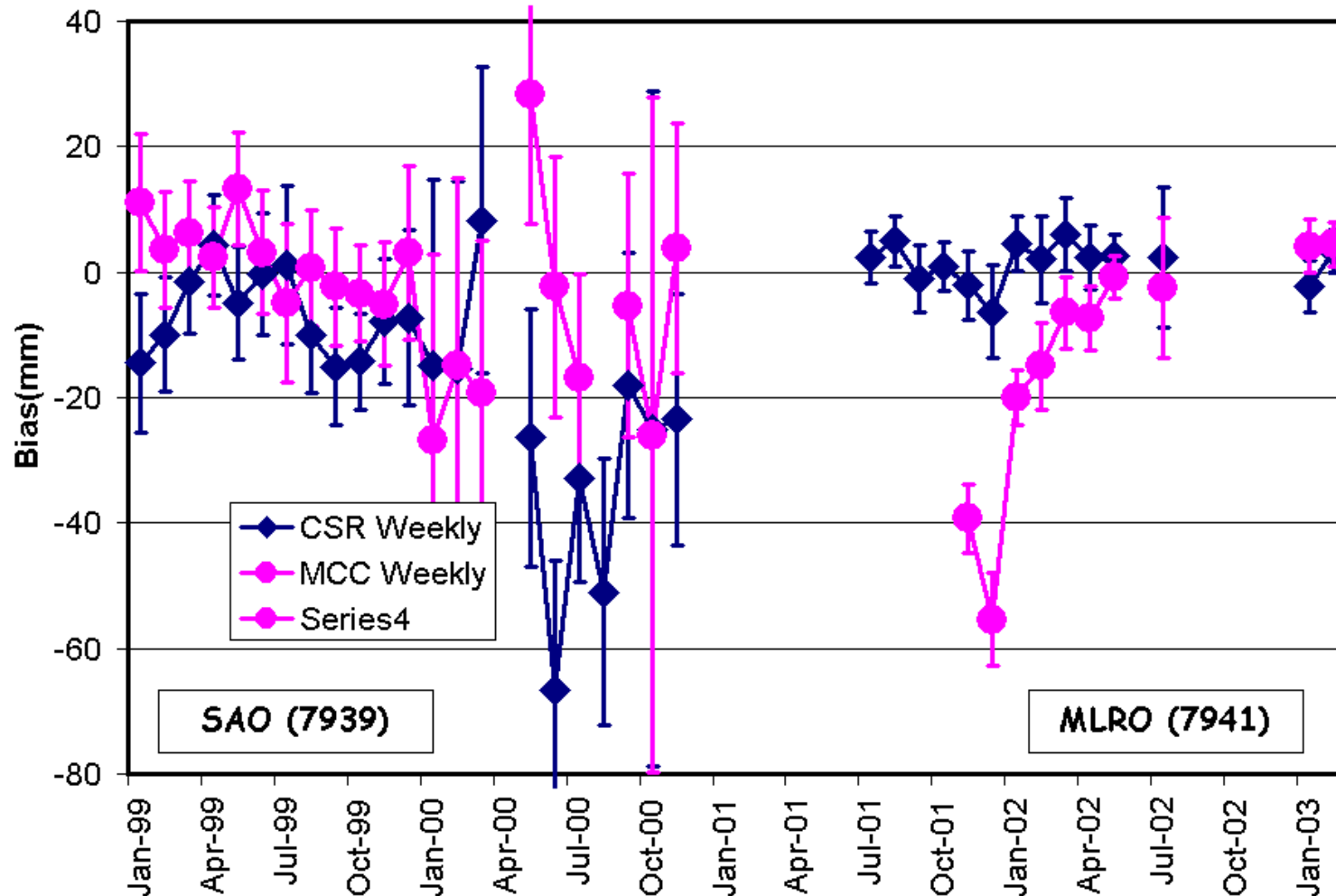
There is an offset between CSR and MCC results. **Bias change** starting in 2001?

Grasse (7845)



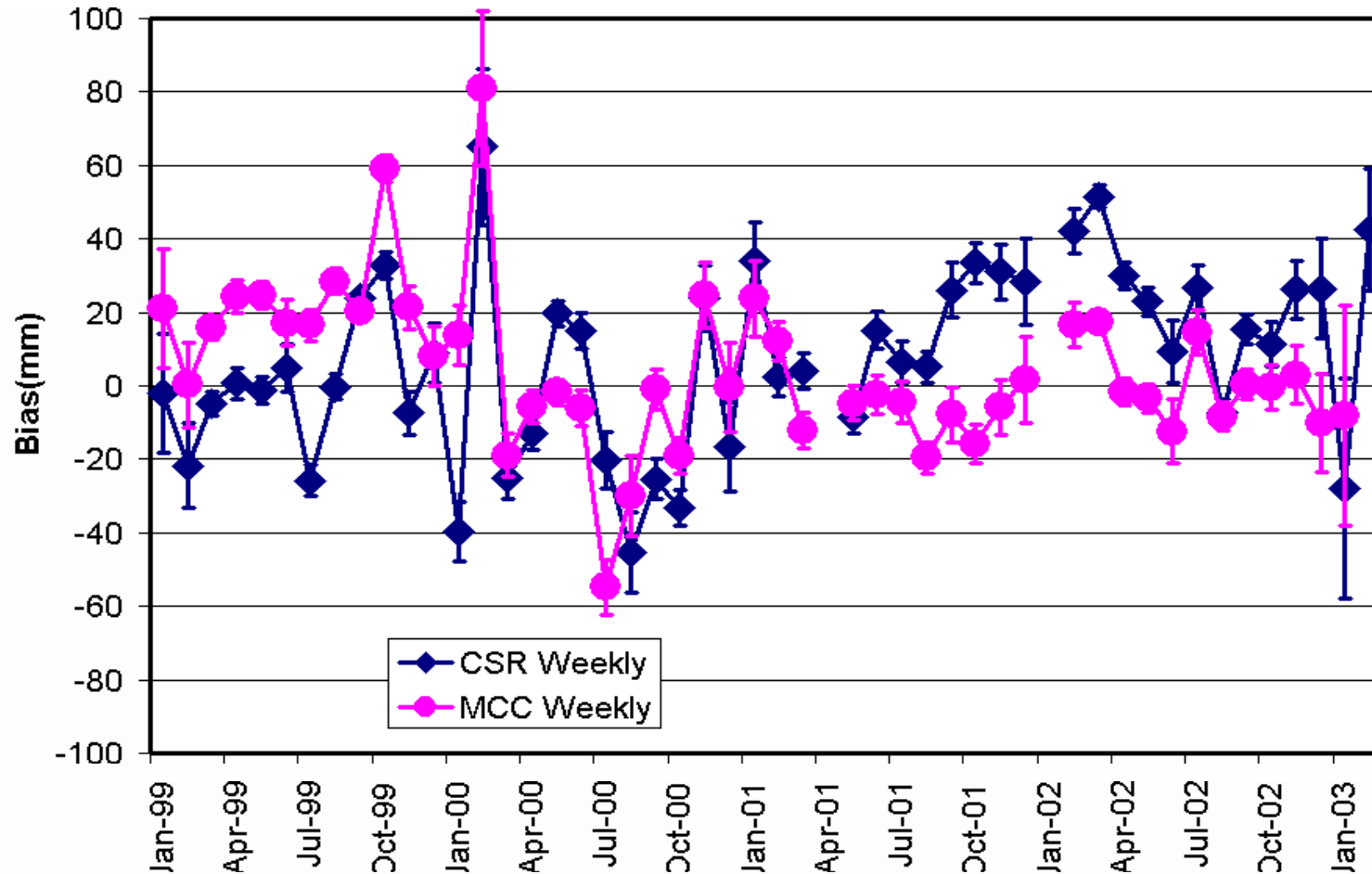
The bias is trending upward.

Matera (7939 & 7941)



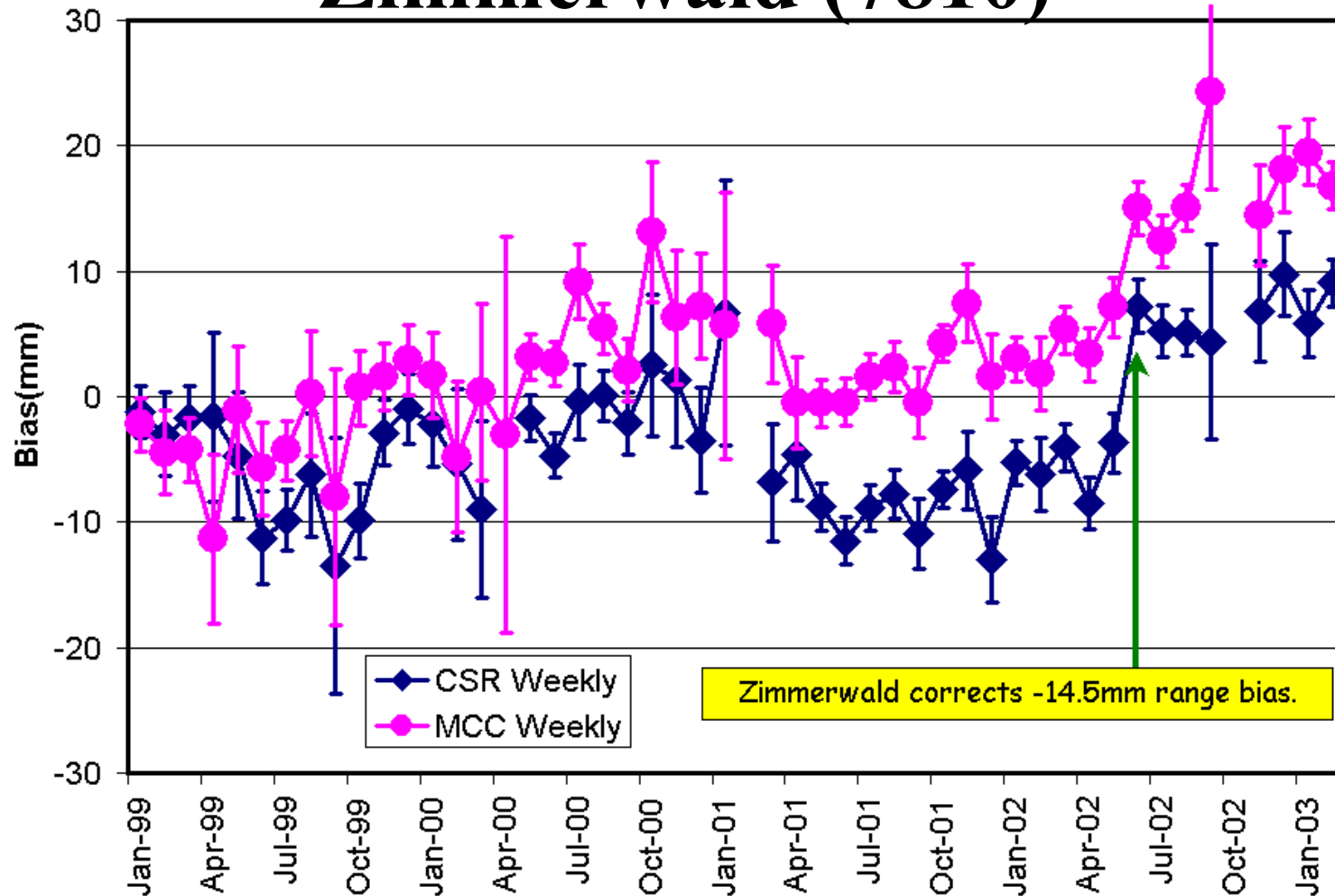
MLRO is much more precise (5mm vs 150mm).

Riga (1884)



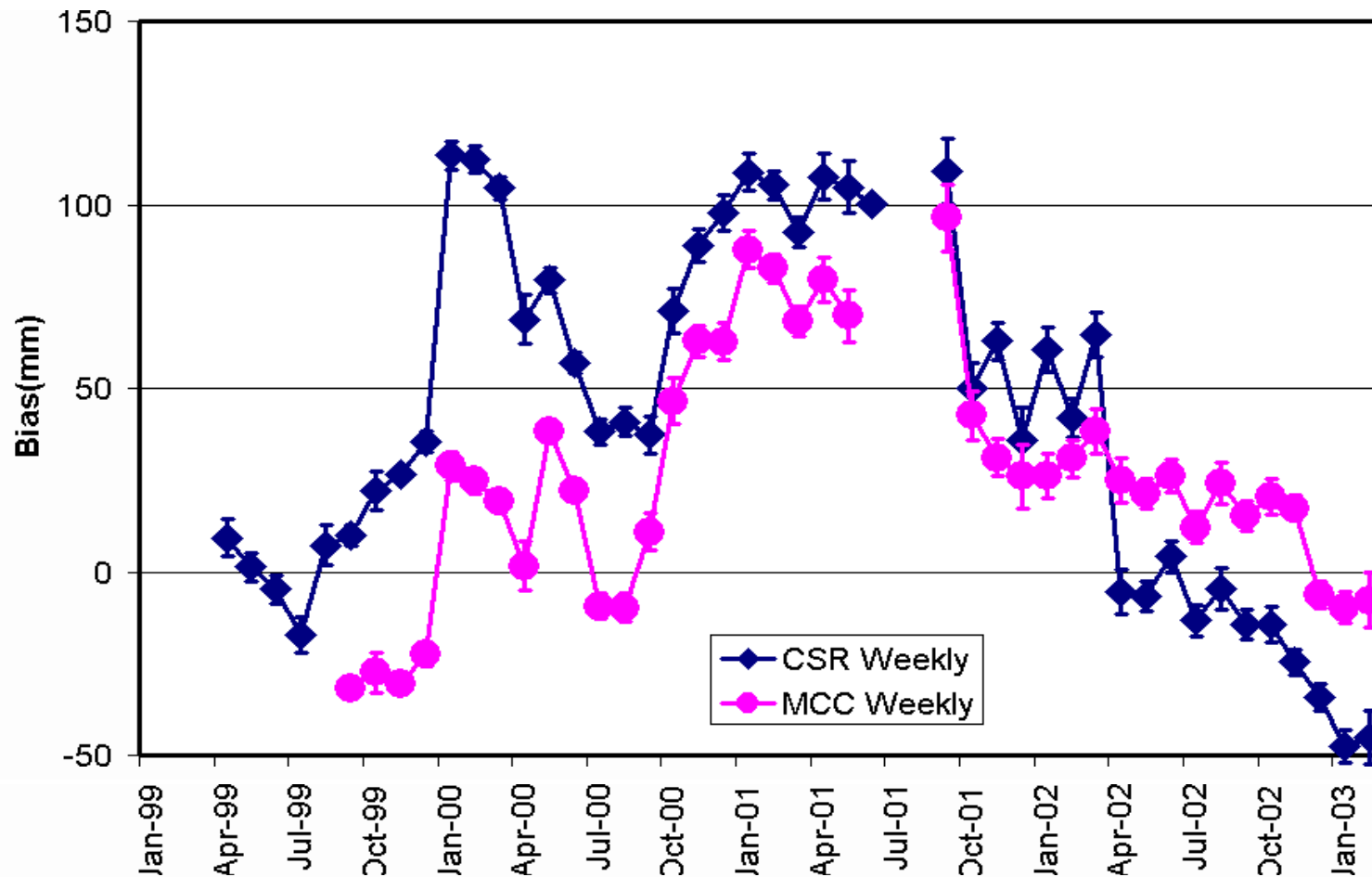
Please not the scale and the apparent changes.

Zimmerwald (7810)



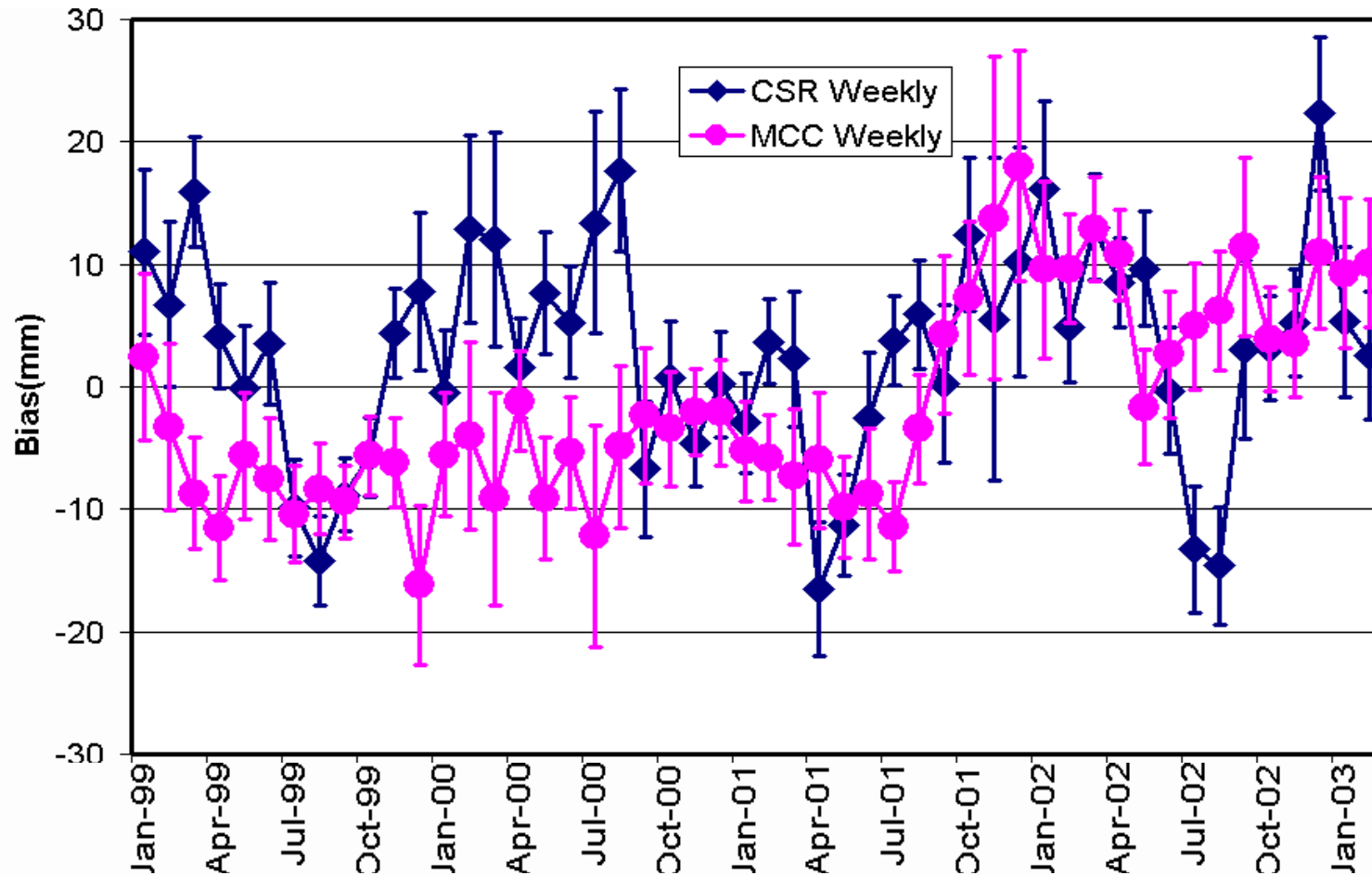
There is an offset between CSR and MCC results. Both results indicate a bias change, **but not 14.5mm?**

San Fernando (7824)



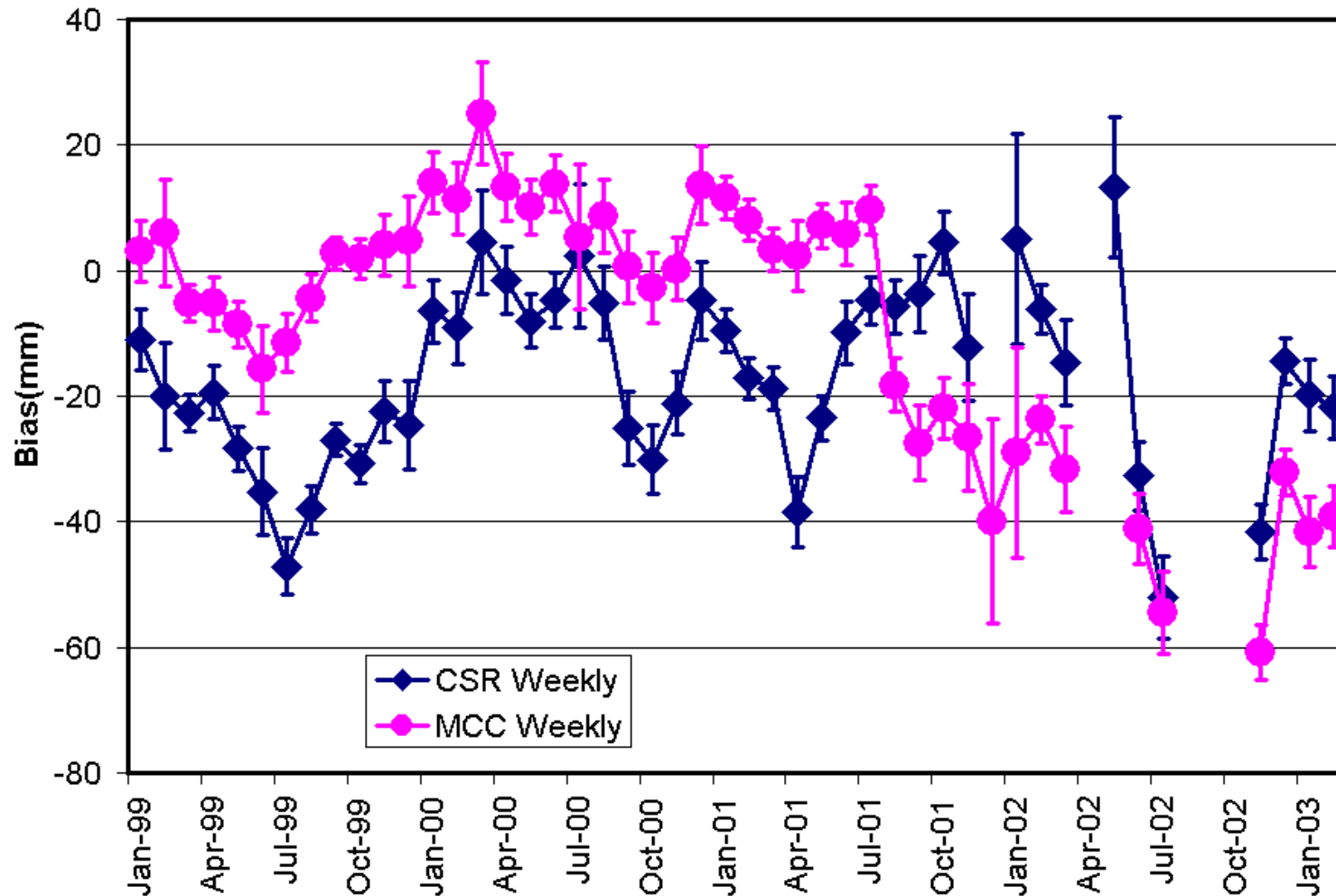
Please not the scale and the apparent changes.

Potsdam (7836)



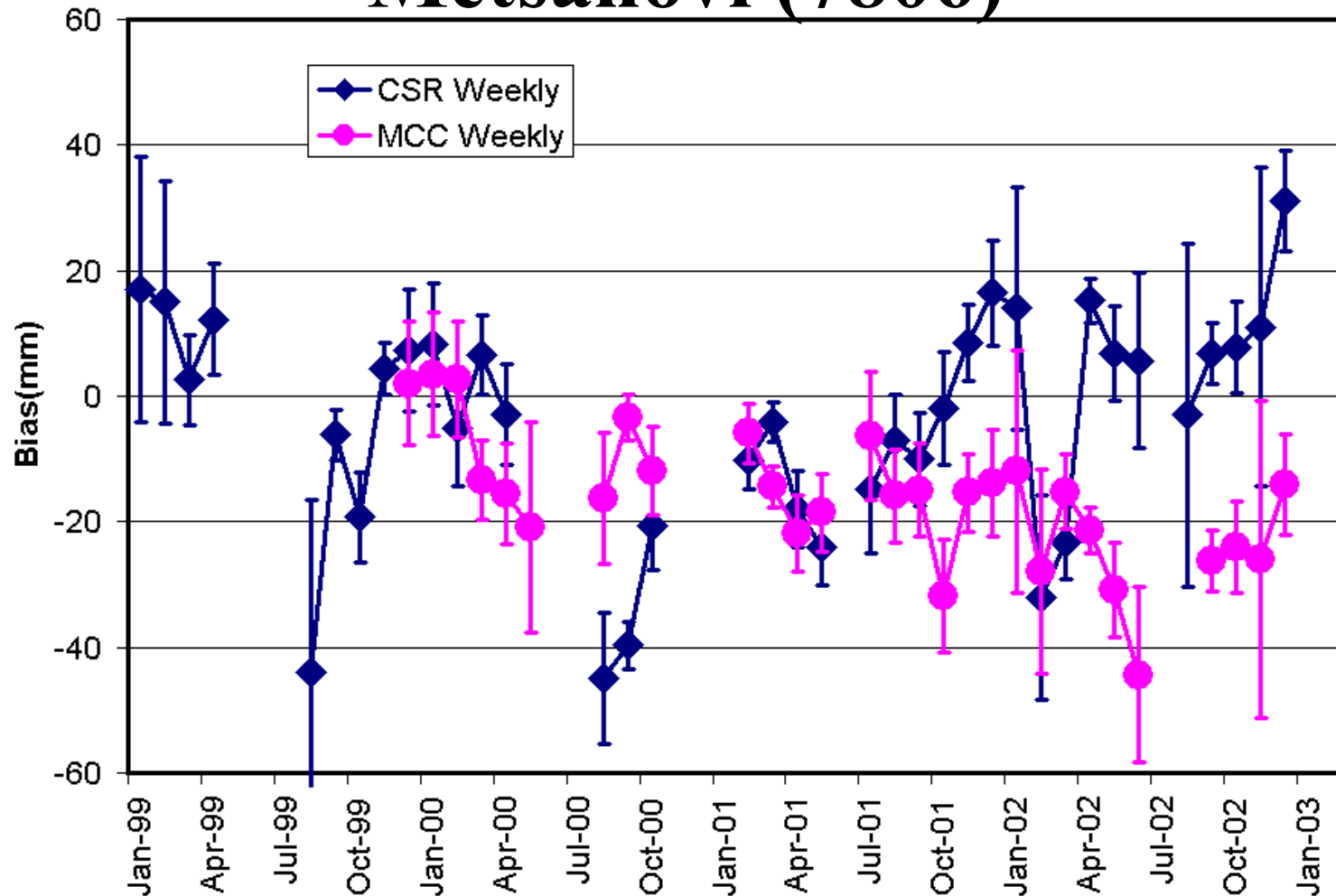
Was there a **change in the bias** in late 2001?

Borowiec(7811)



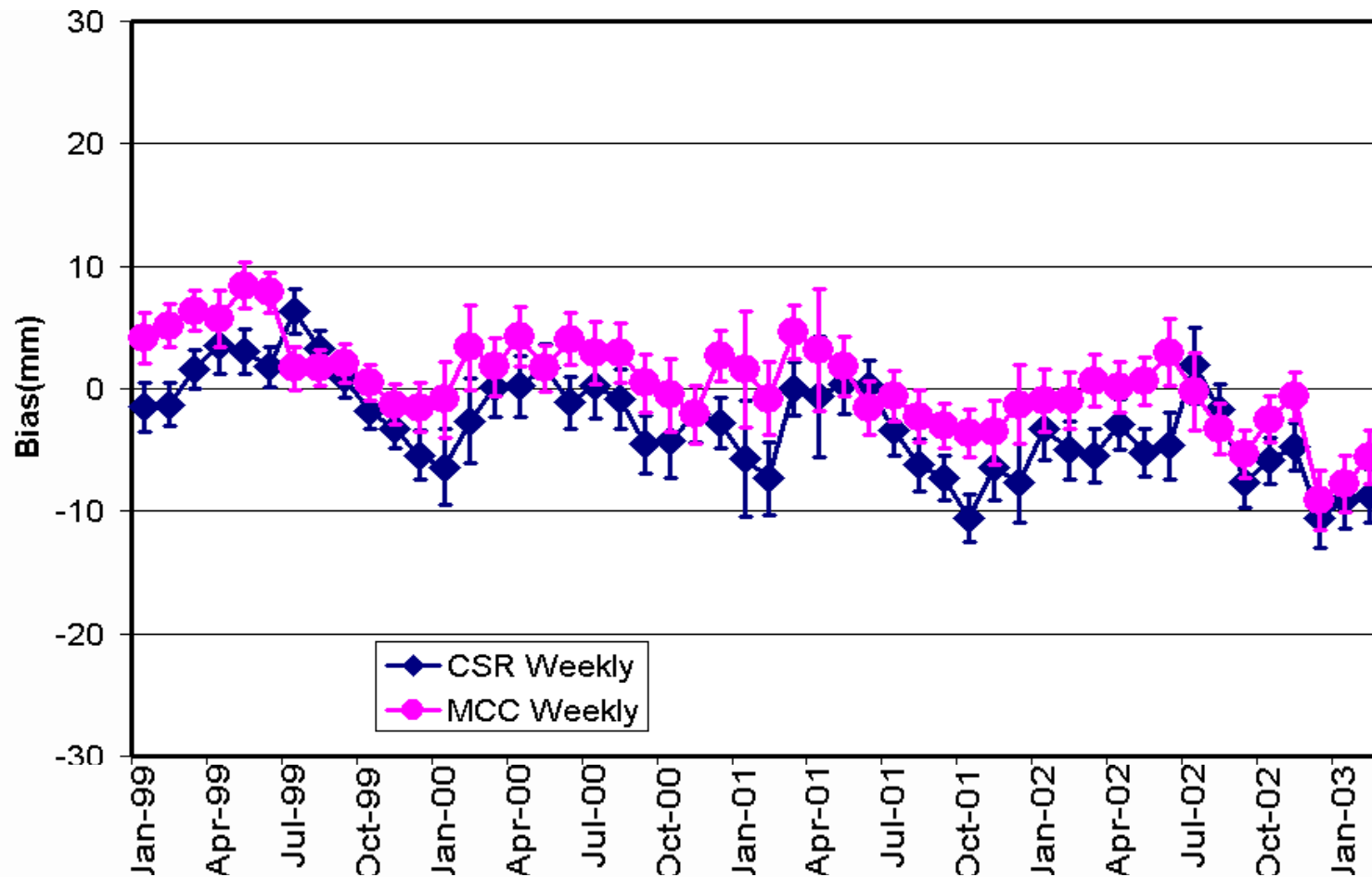
The bias patterns flip flop in July 2001.

Metsahovi (7806)



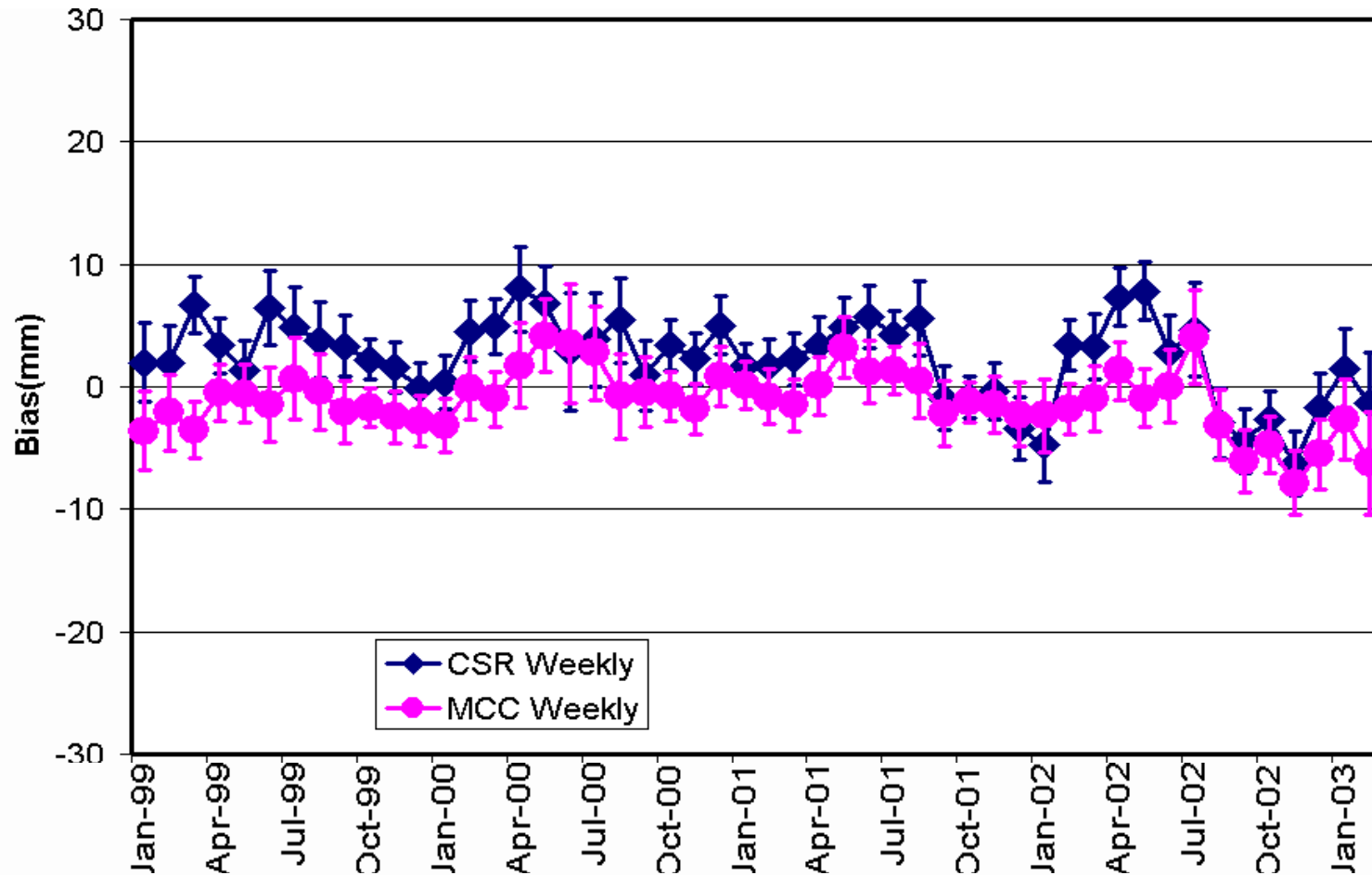
Notice the trend separation in 2002.

Monument Peak (7110)



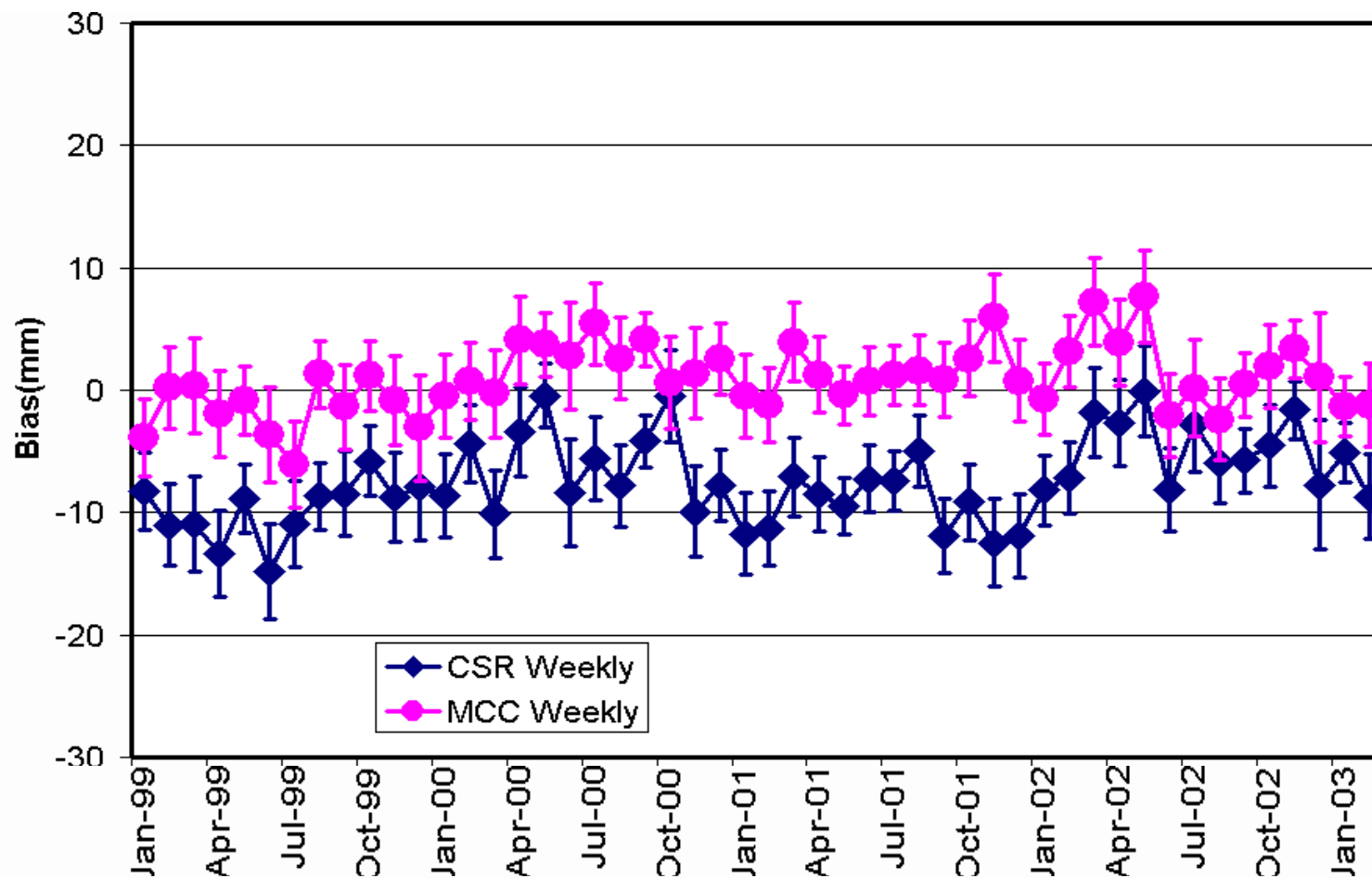
Good agreement between CSR and MCC results.

Greenebelt (7105)

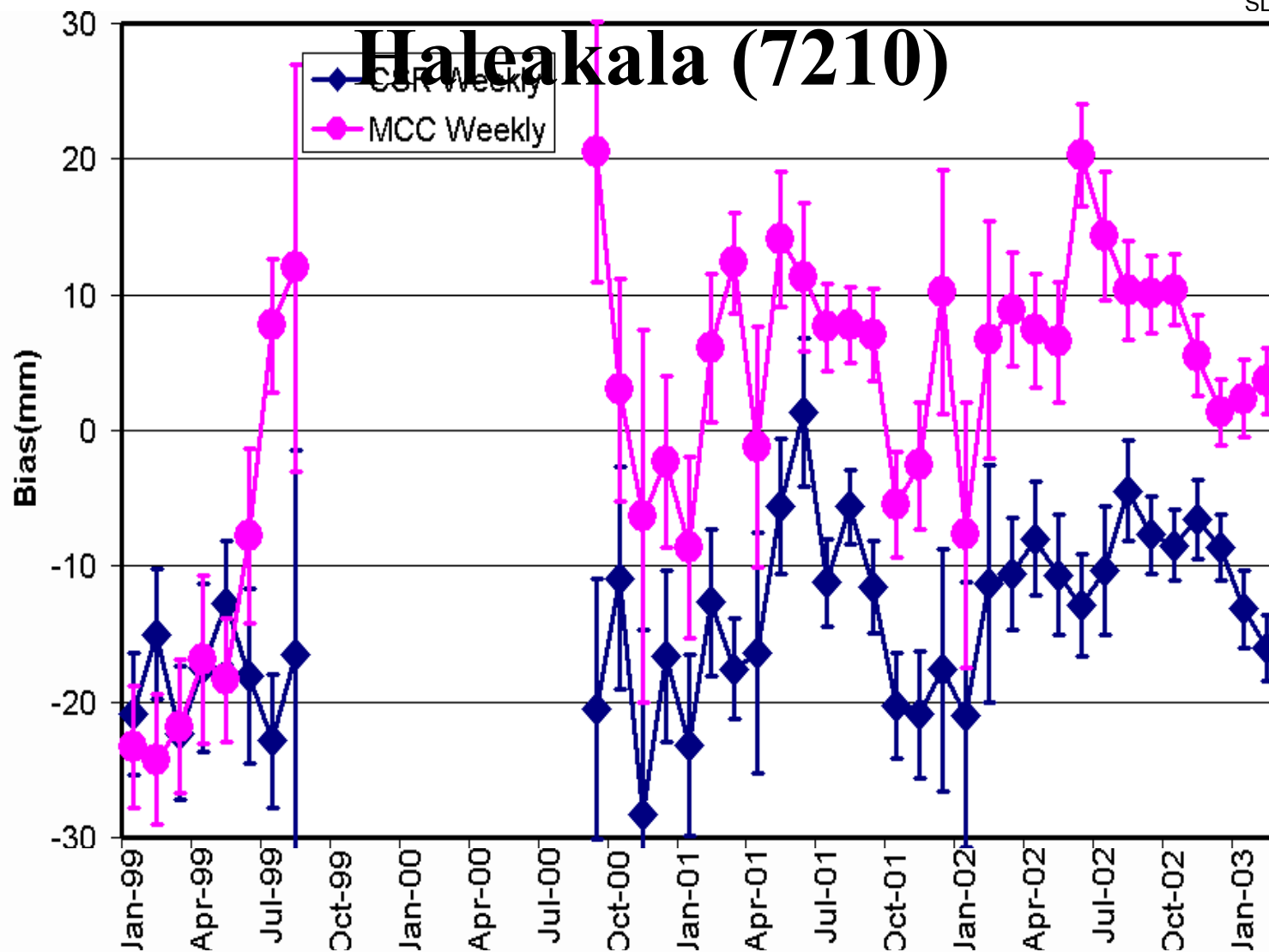


Good agreement between CSR and MCC results.

McDonald (7080)

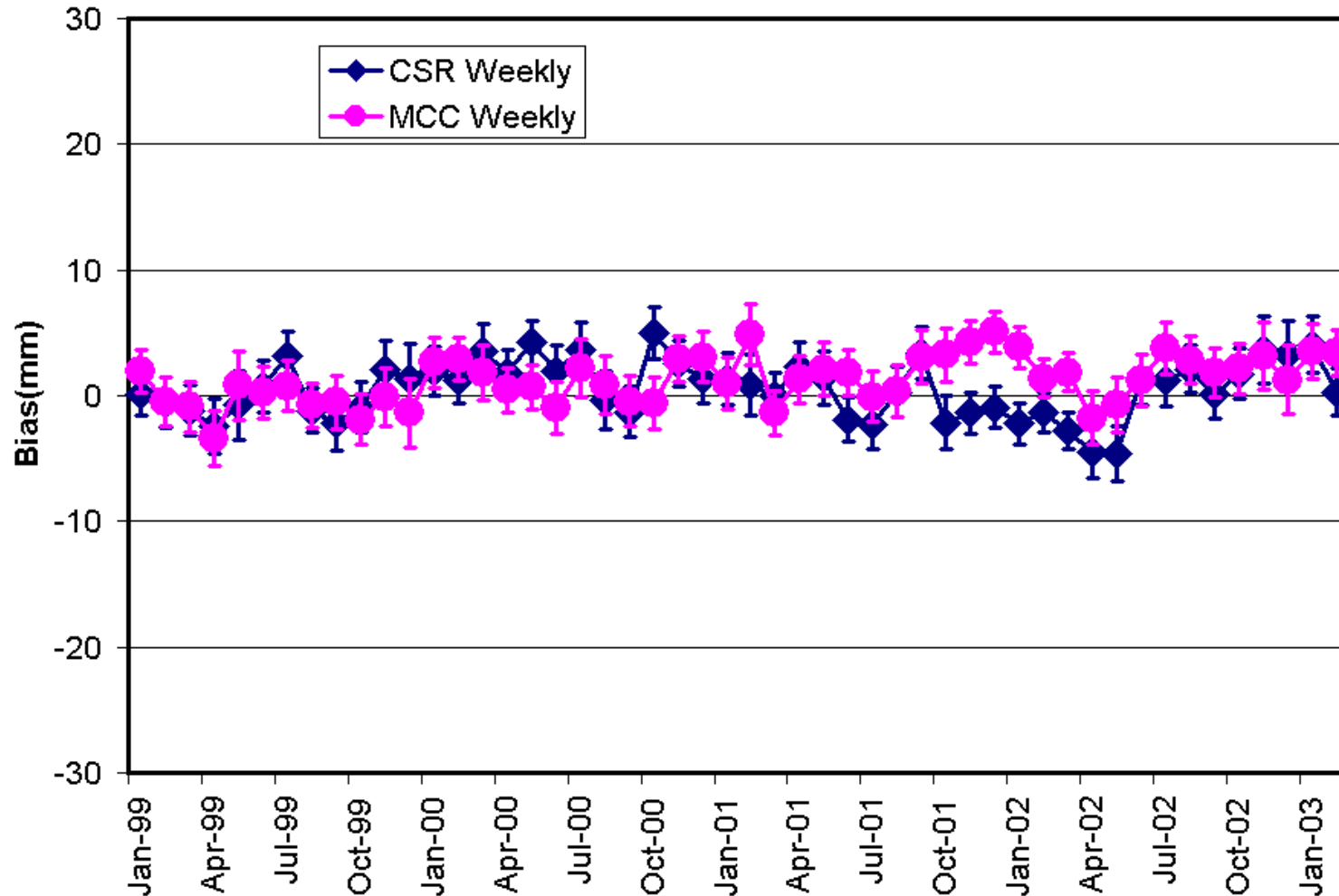


The offset between CSR and MCC results varies with time.



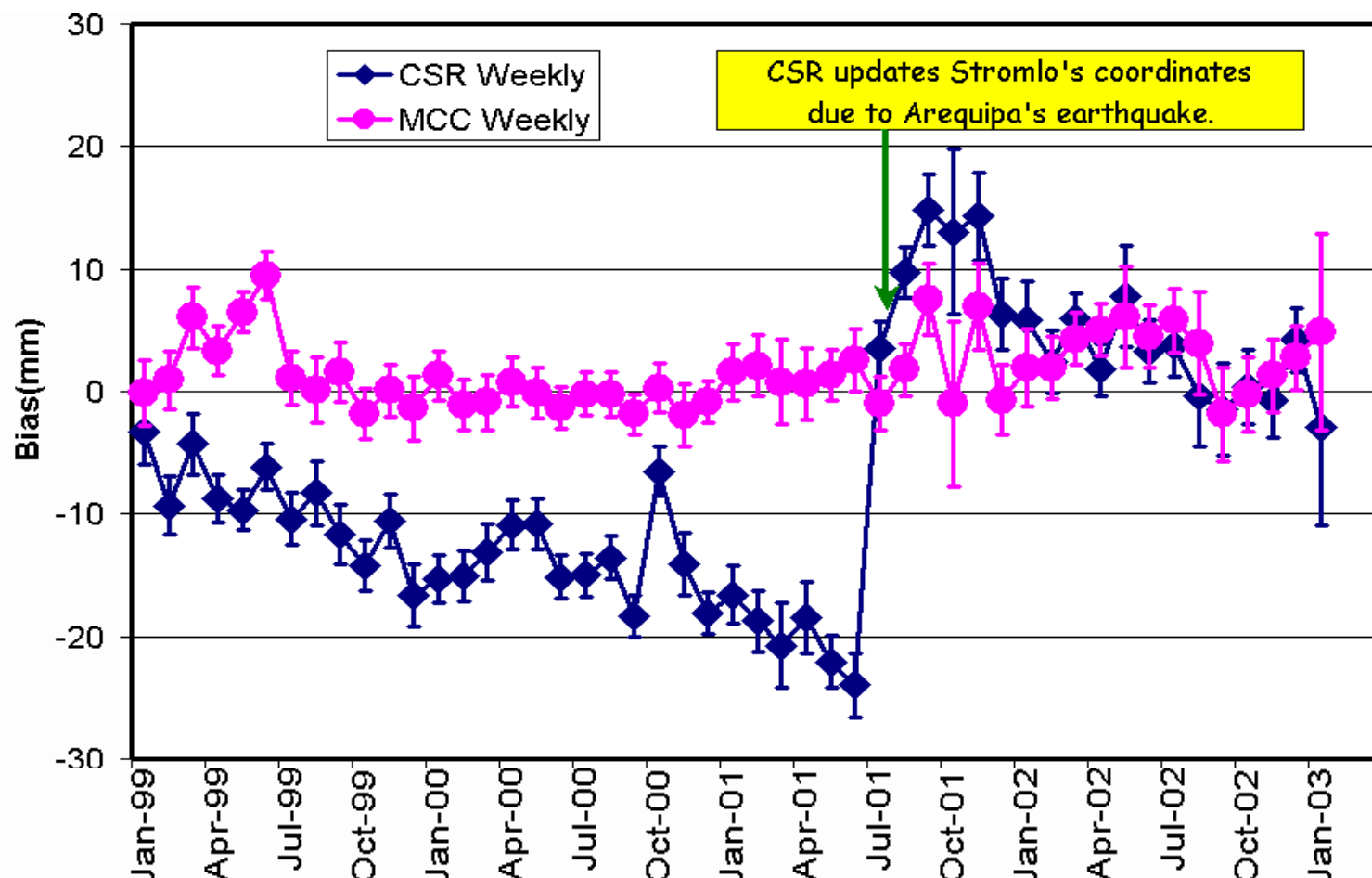
There is a 2cm offset between CSR and MCC results.

Yarragadee (7090)



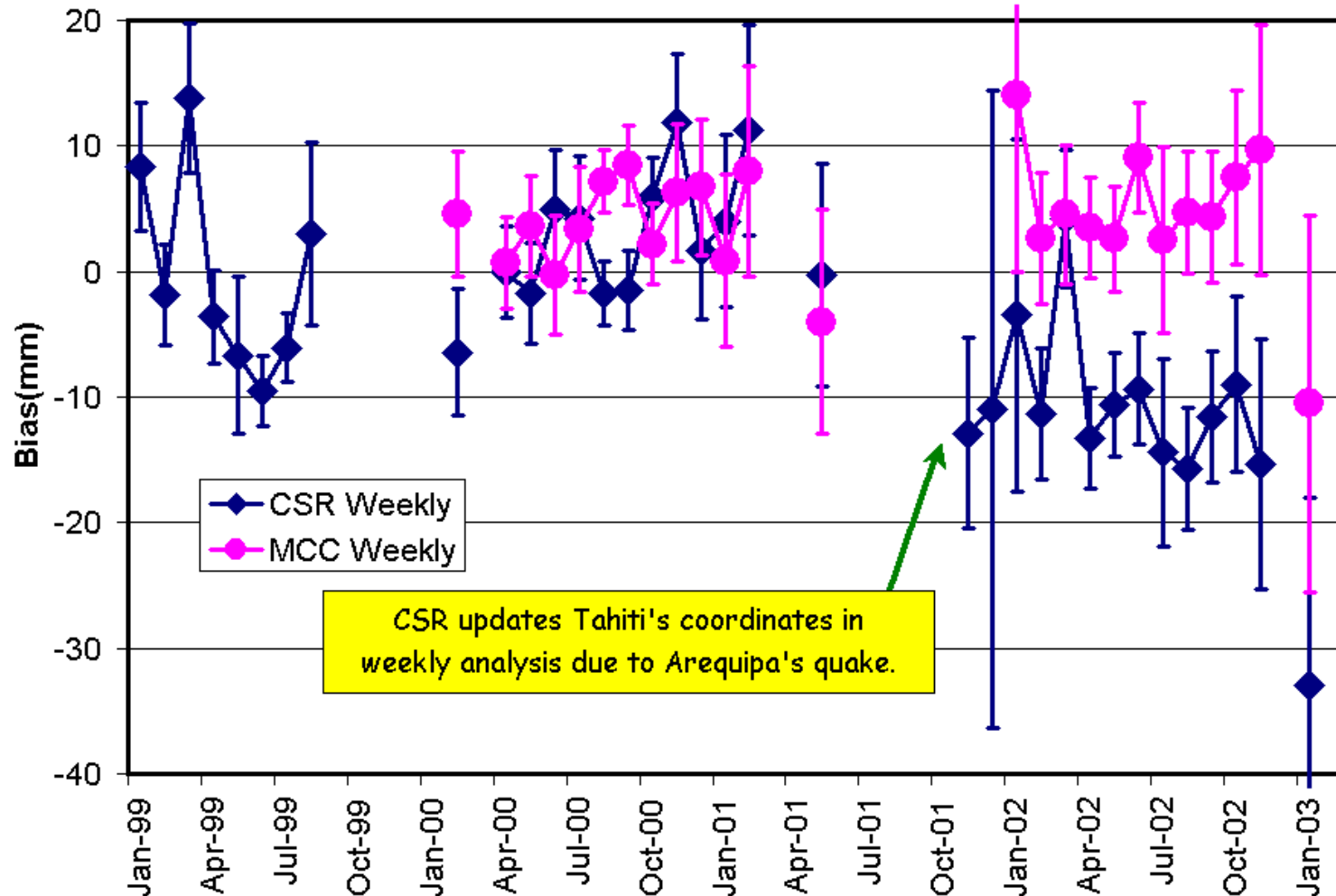
Excellent agreement except for late 2001 early 2002.

Stromlo (7849)



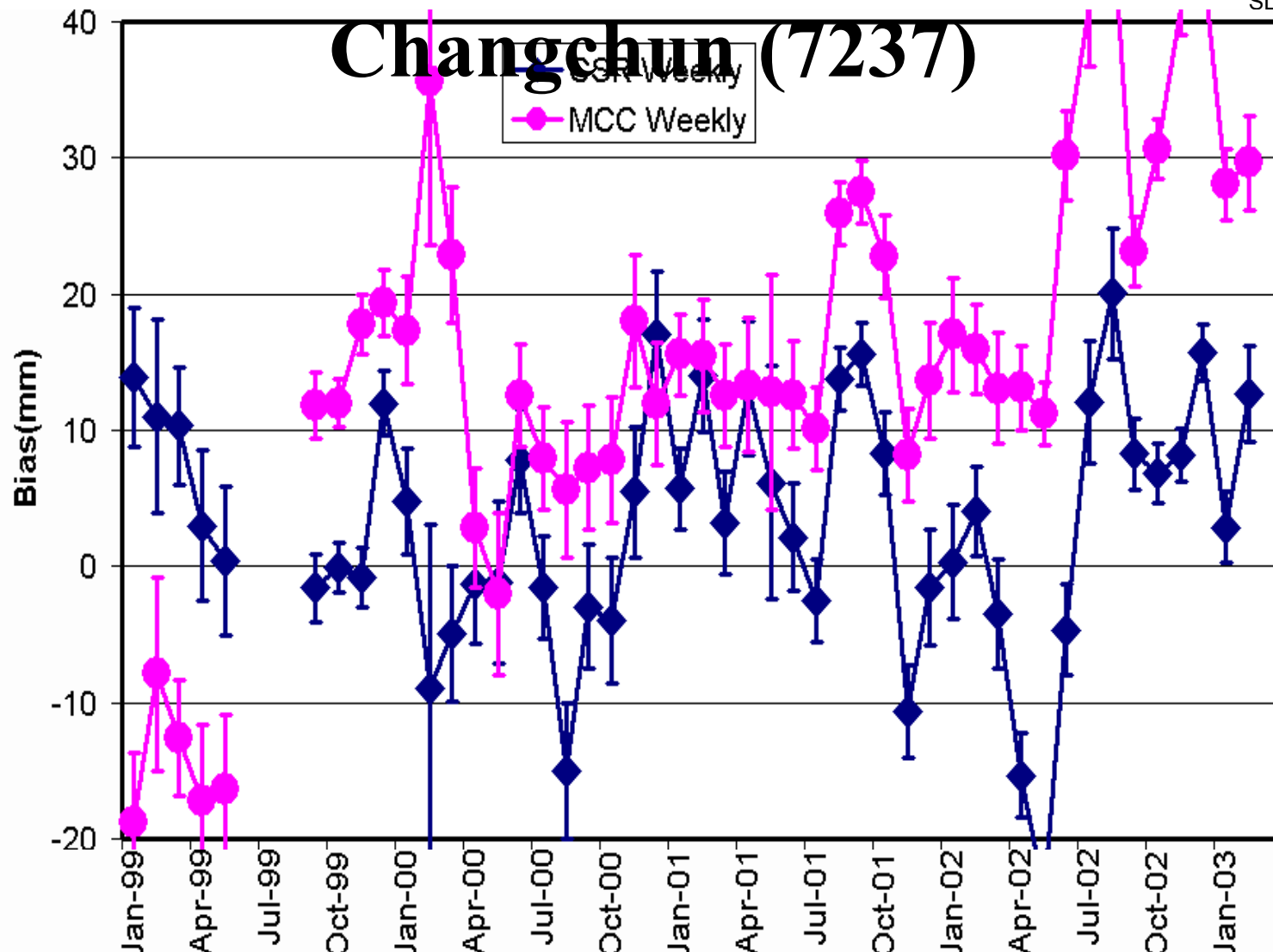
Significant differences between CSR and MCC in 1999-2001, good agreement starting in 2002.

Tahiti (7124)



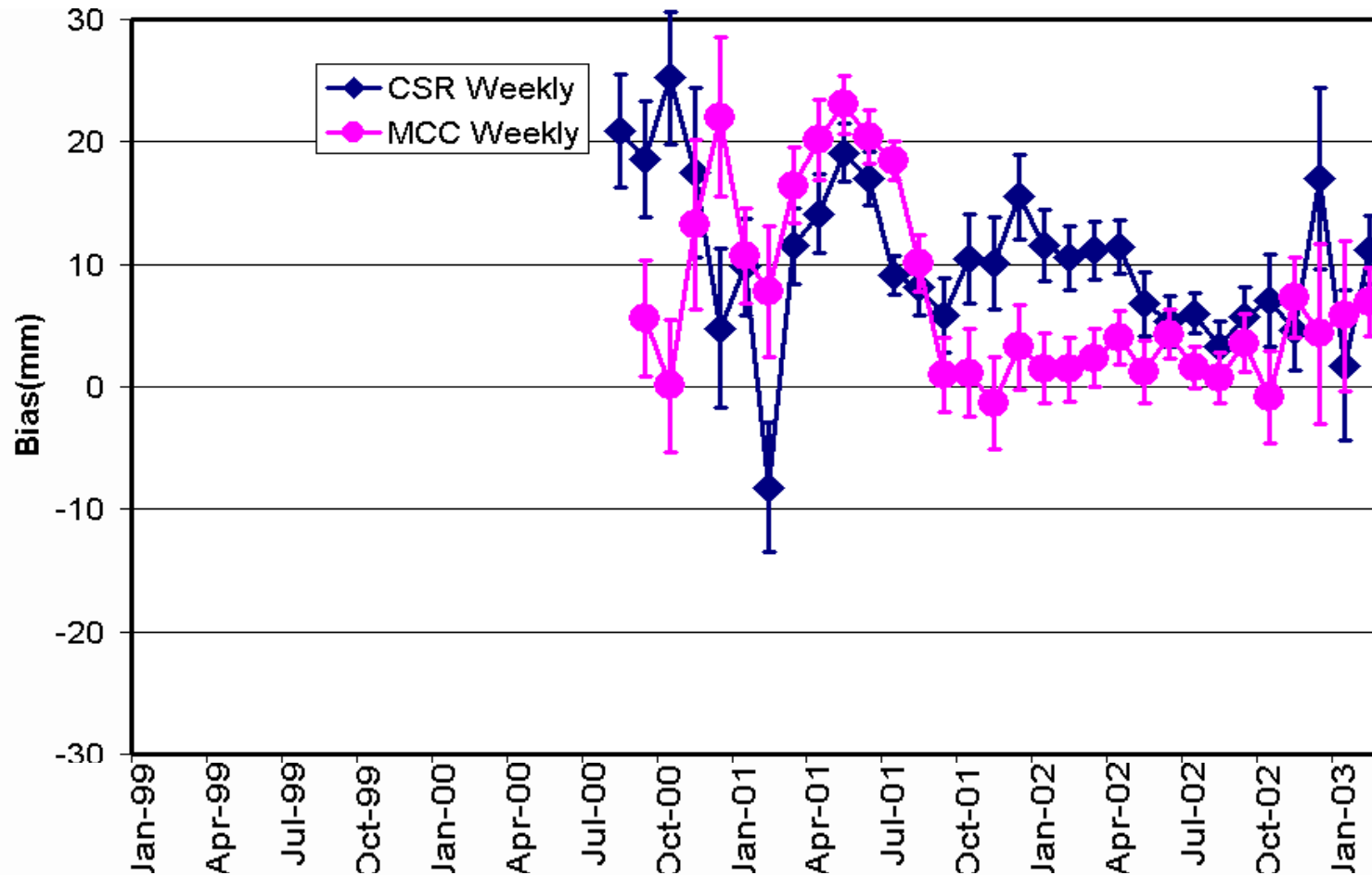
CSR updates Tahiti's coordinates in weekly analysis due to Arequipa's quake.

Coordinate updates have significant influence on the apparent bias.



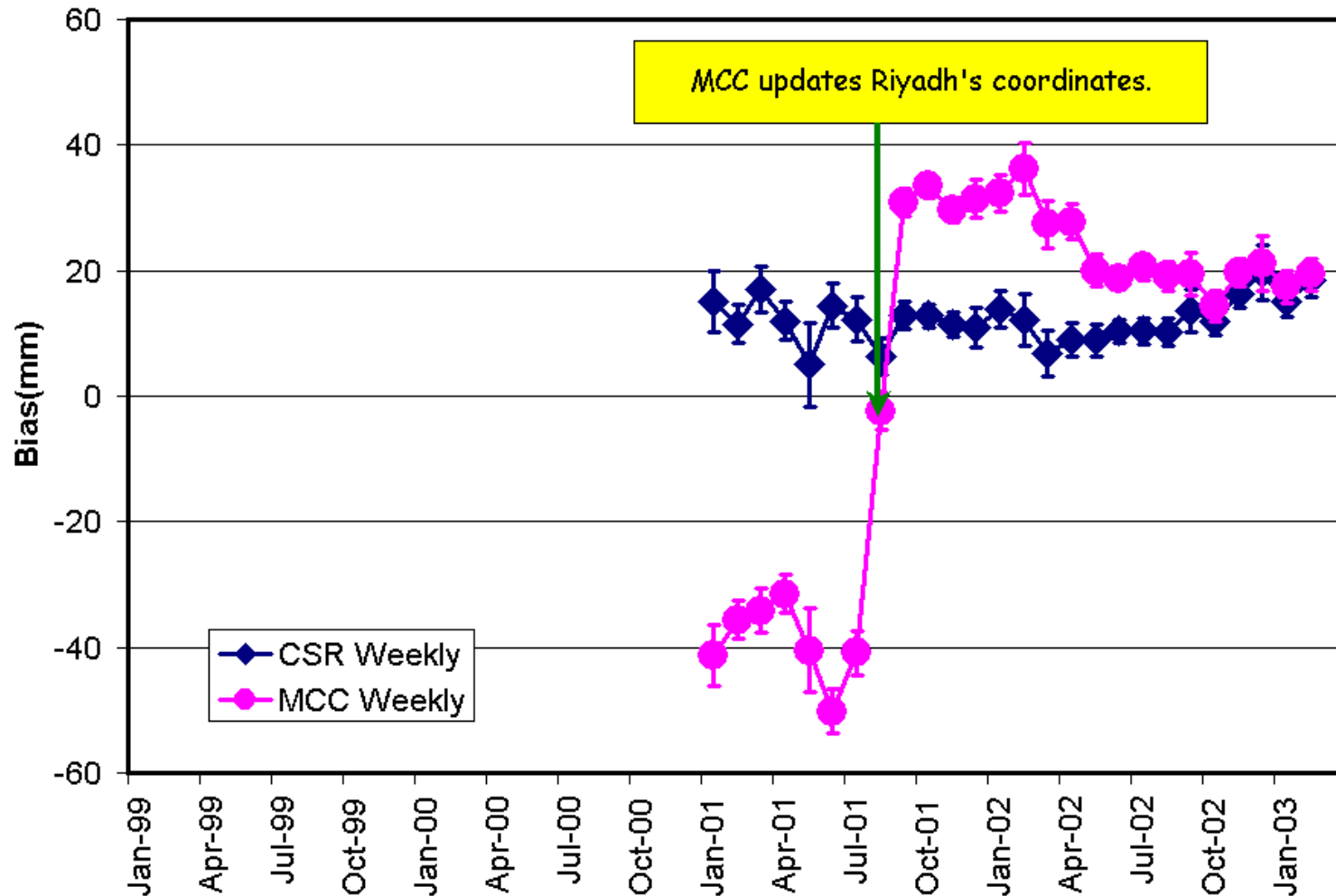
It appears MCC updated Changchun's position in late 1999.

Hartebeesthoek (7501)

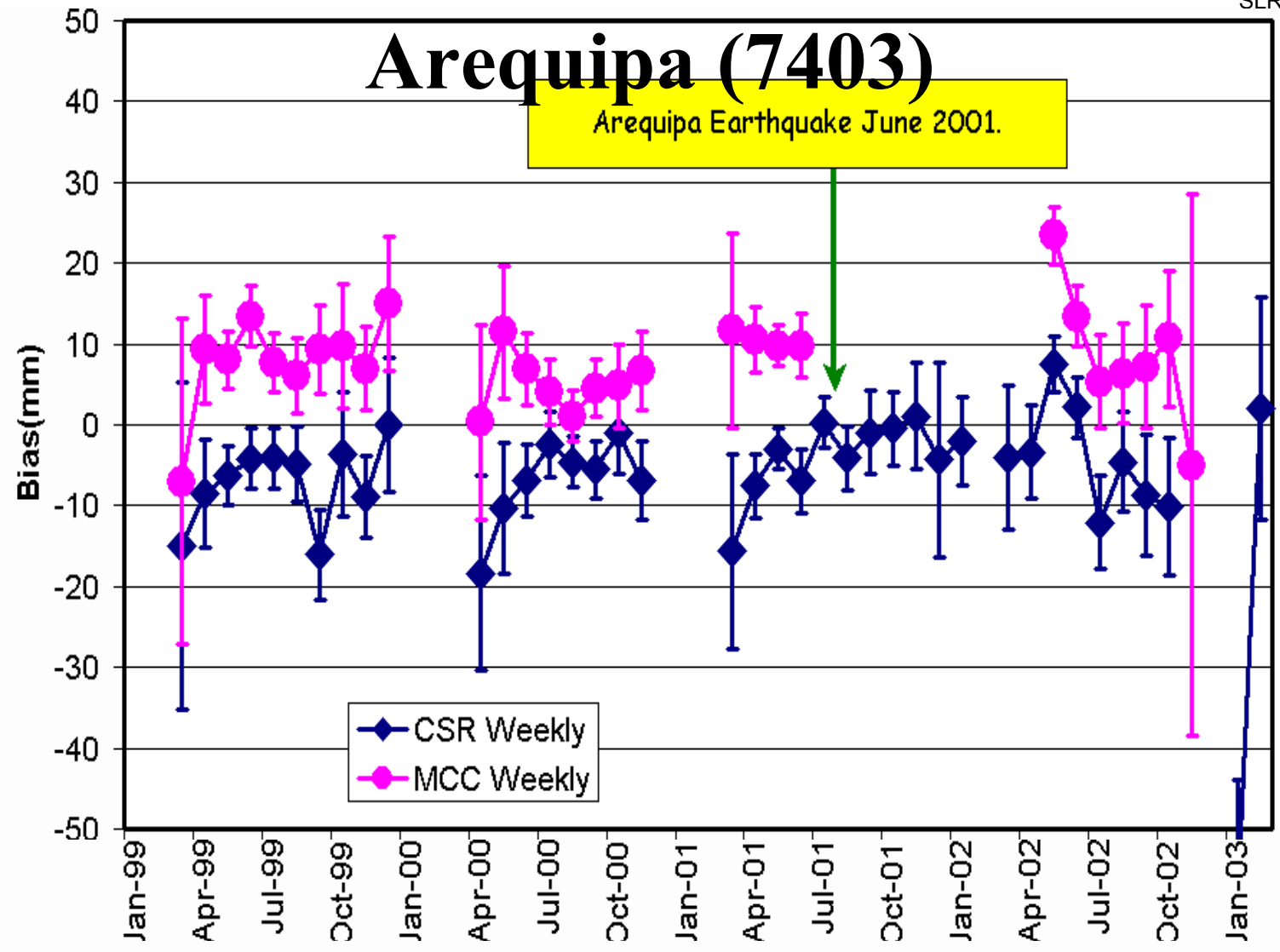


The patterns sometime diverge.

Riyadh (7832)

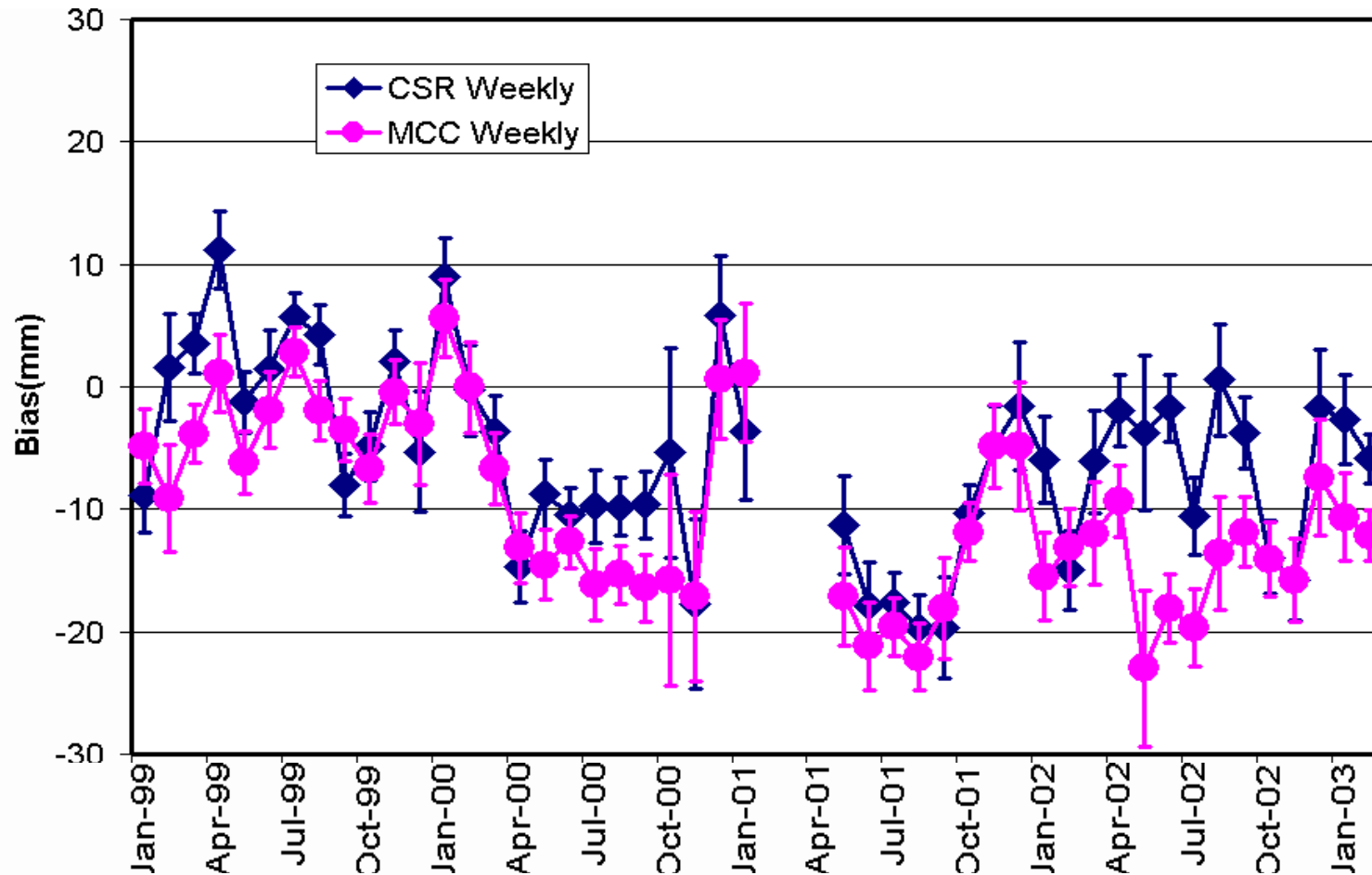


The trends are very different between MCC and CSR.



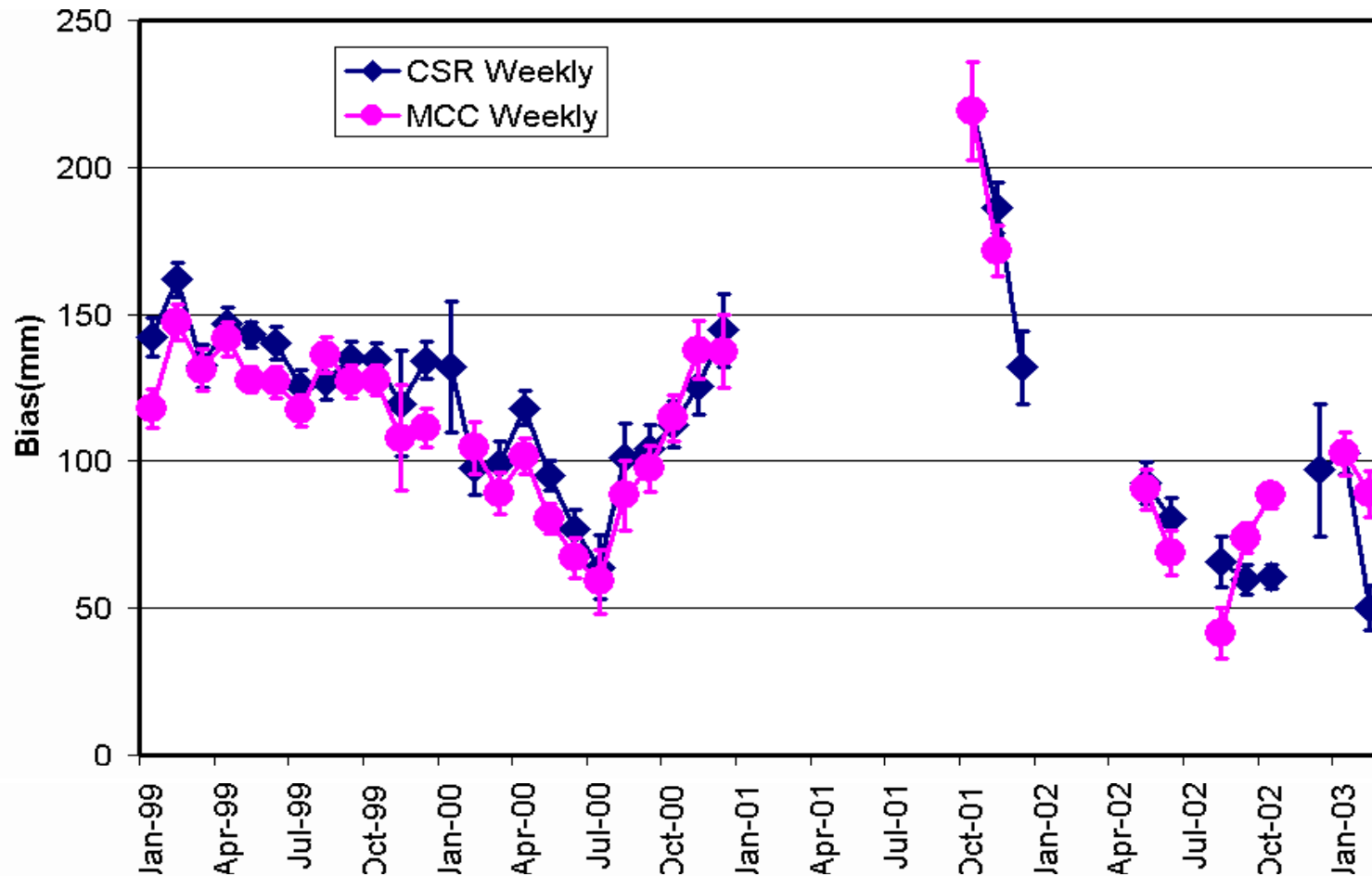
There is an offset between MCC and CSR results.

Wettzell (8834)



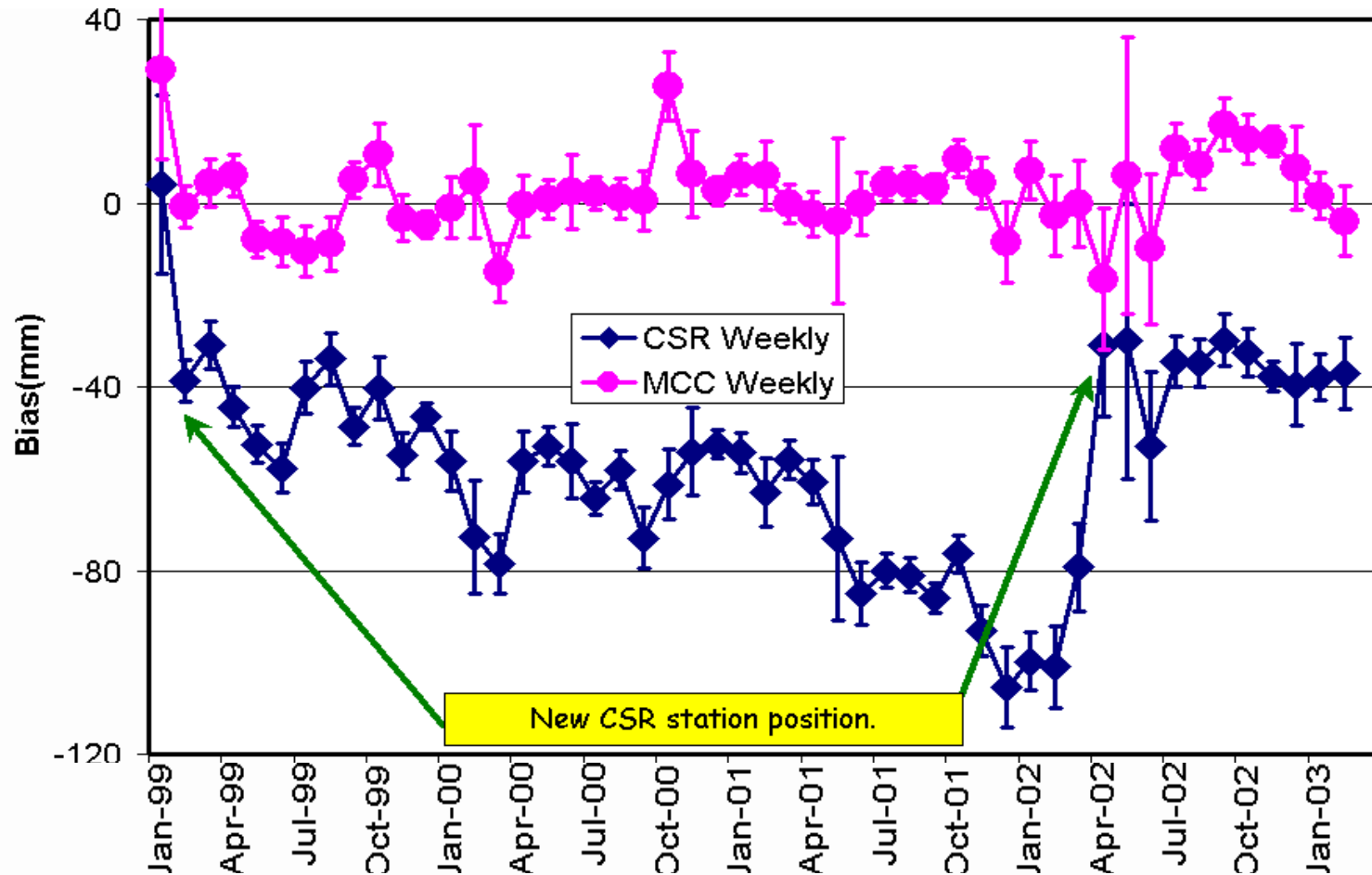
The trends sometimes diverge.

Maidanak (1864)



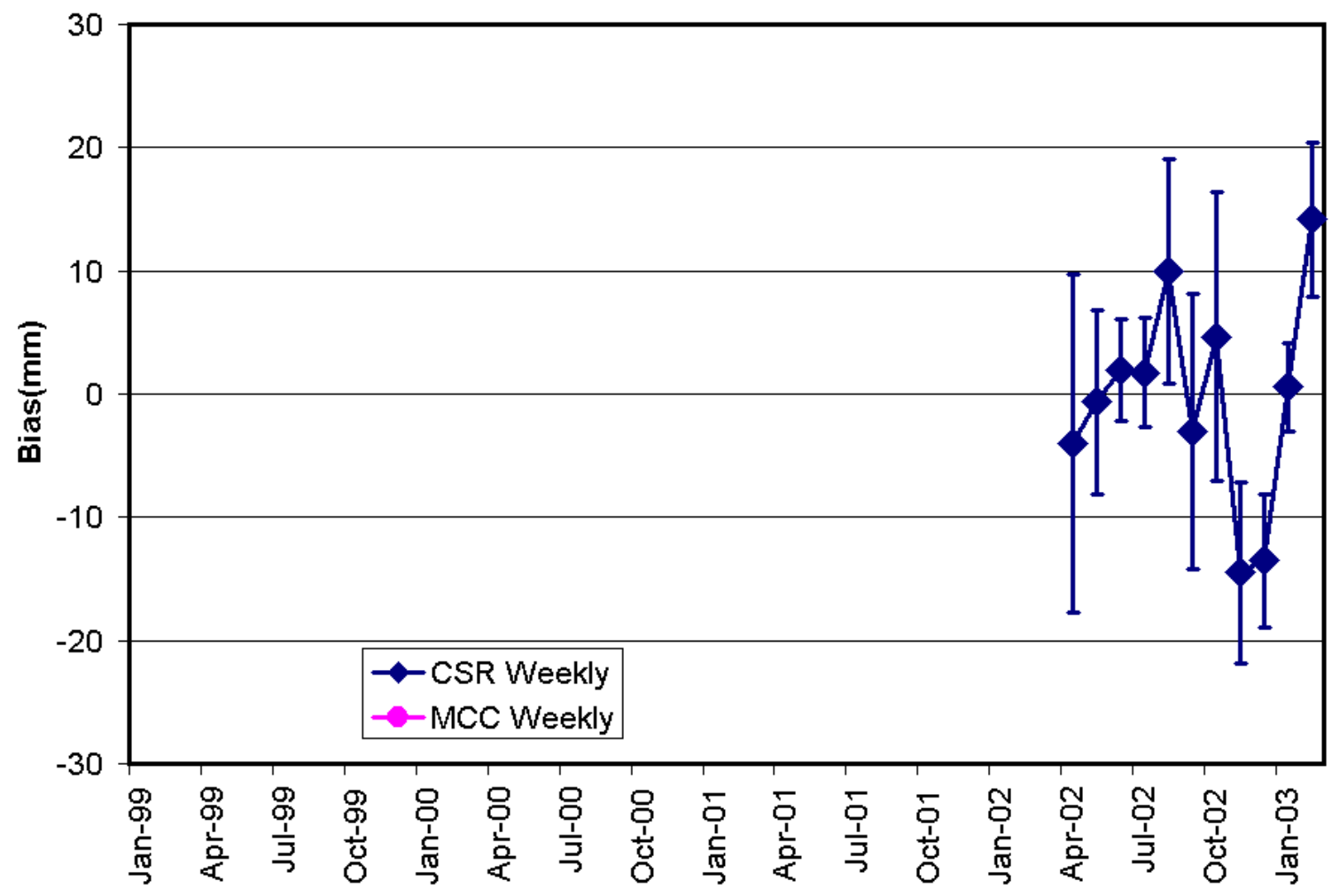
Please note the scale and the big swings.
The trends are nearly identical.

Shanghai (7837)



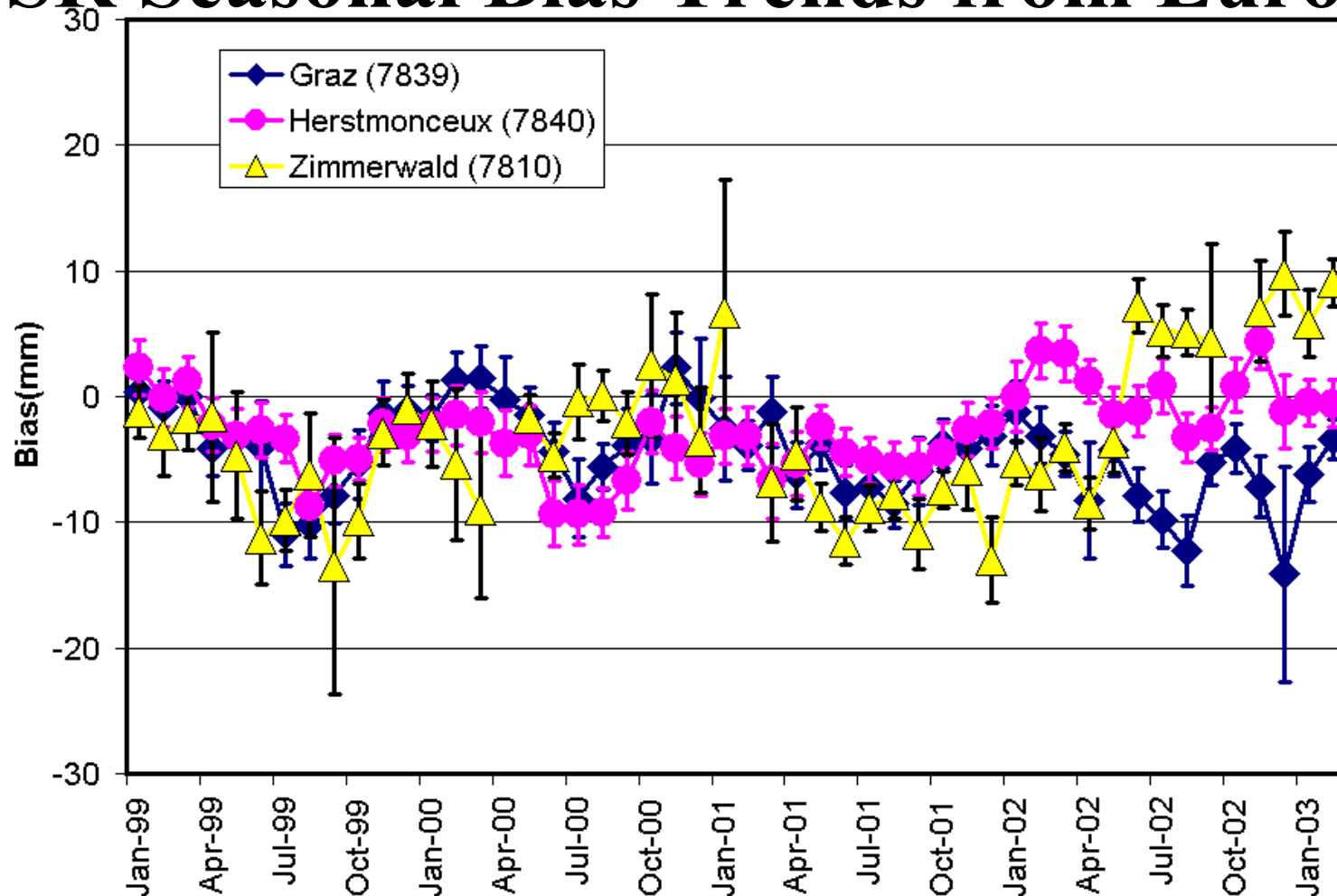
The trends are very different.

Concepcion (7405)



No MCC results.

CSR Seasonal Bias Trends from Europe



The trends from 3 sites track nicely until 2002. CSR, in their weekly analysis, does not estimate geocenter motion.

Summary of MCC & CSR Results

1. There appears to be seasonal signals in the biases.
2. Both Herstmonceux and Zimmerwald corrected known biases, but their site bias results did not indicate the full magnitude of the change.
3. For some sites, the bias magnitudes and trends are sometimes similar, but sometimes very diverse even for the better performing sites.

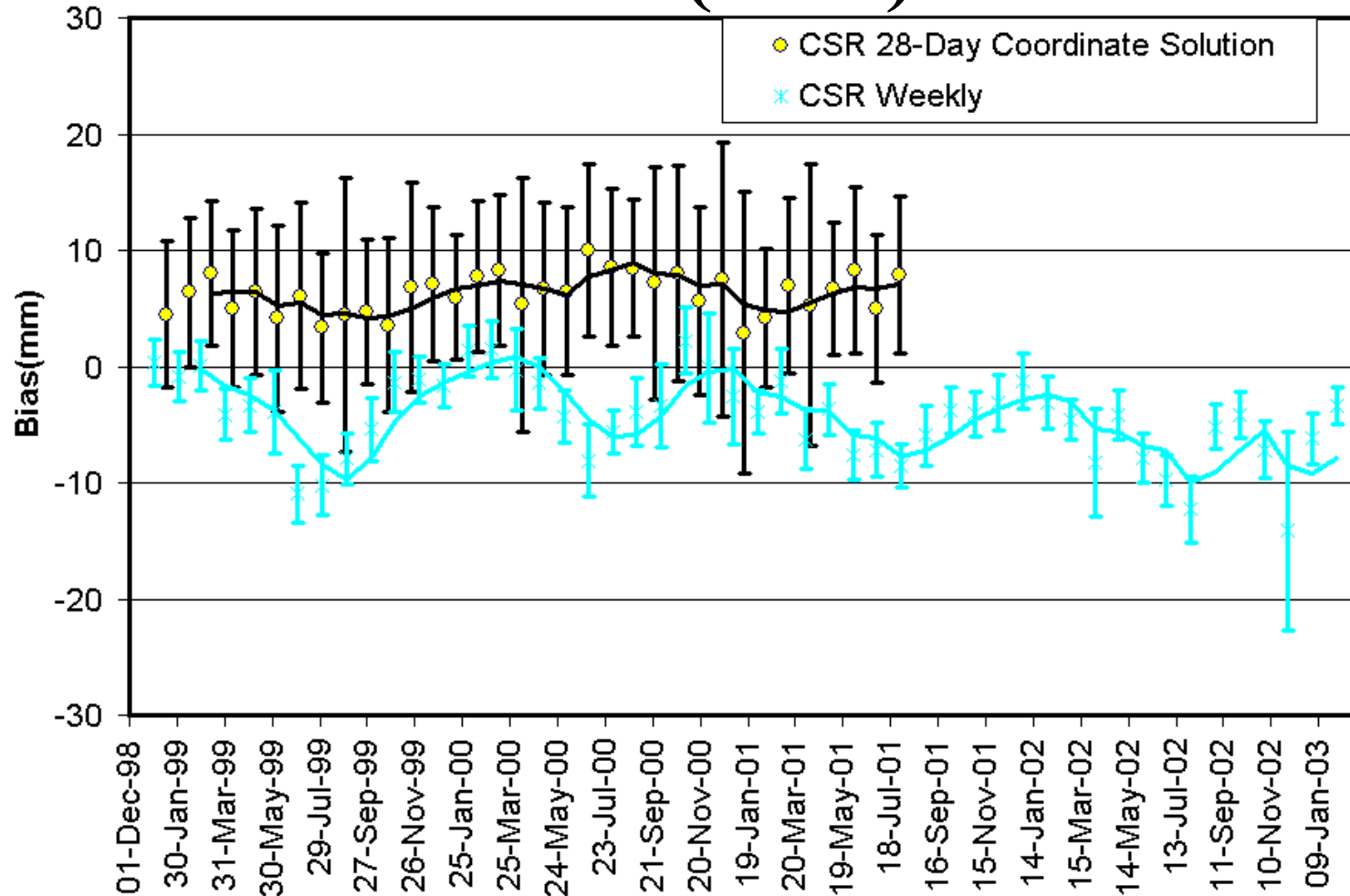
WHY? WHY? WHY?

Let's try to answer these questions.

Bias Trend Comparison

Lets compare the biases from an independent analysis technique (the POS/EOP 28 day coordinate solutions)

Graz (7839)

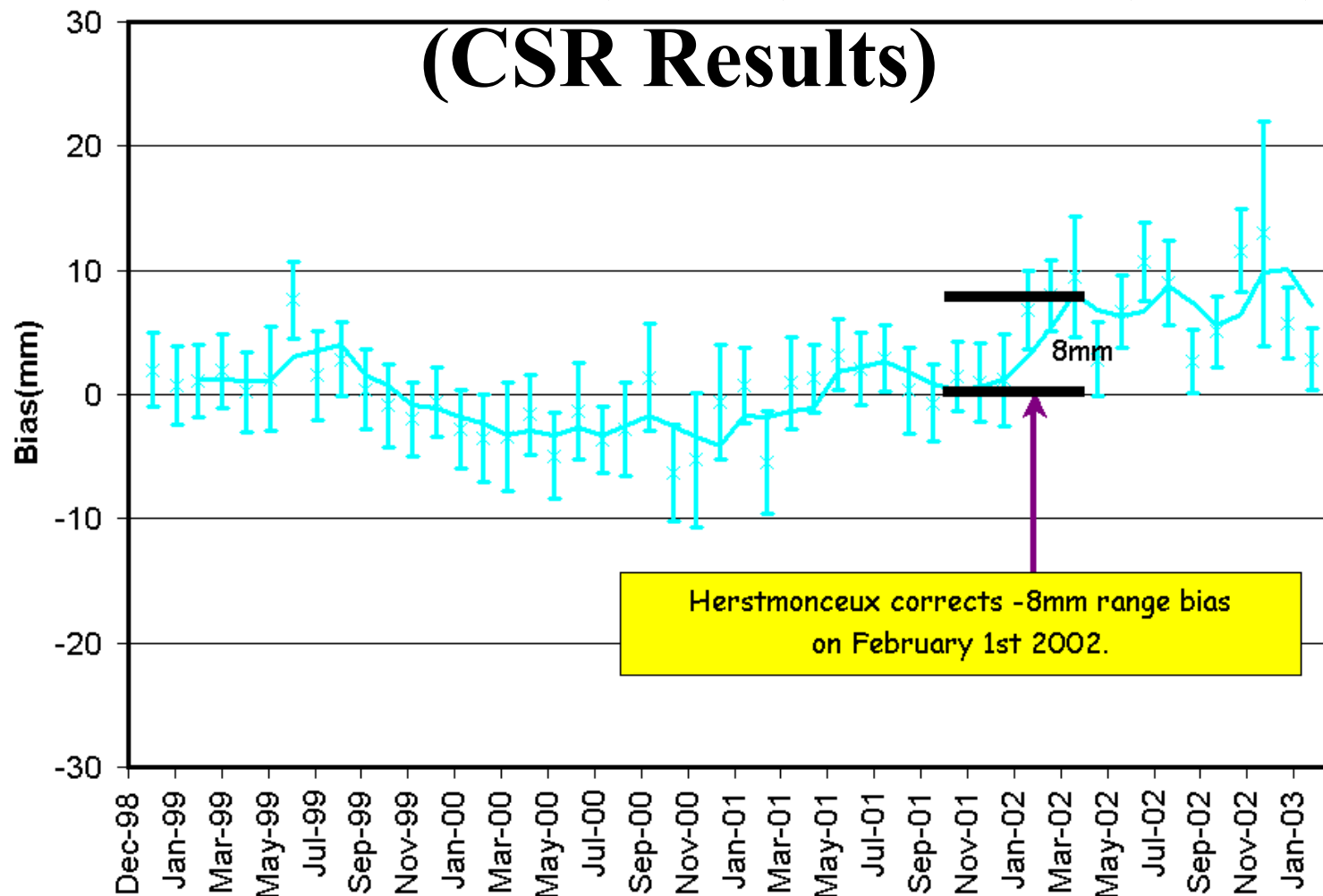


There is an offset. There are seasonal signals in the weekly results. Bias is very stable from CSR 28-day coordinate solution.

New Analysis Technique

- In a given geographic region (i.e. Europe, China, Australia, N. America), let's difference each site monthly bias estimates from a 'trusted' pre-selected site, thereby canceling any seasonal trends (e.g. use Graz as the standard in Europe, Monument Peak in N. America, Stromlo or Yarragadee in Australia)
- This technique could be used to detect a relative bias change between 2 sites
- Let's call this new technique '*Short Arc Collocation*'

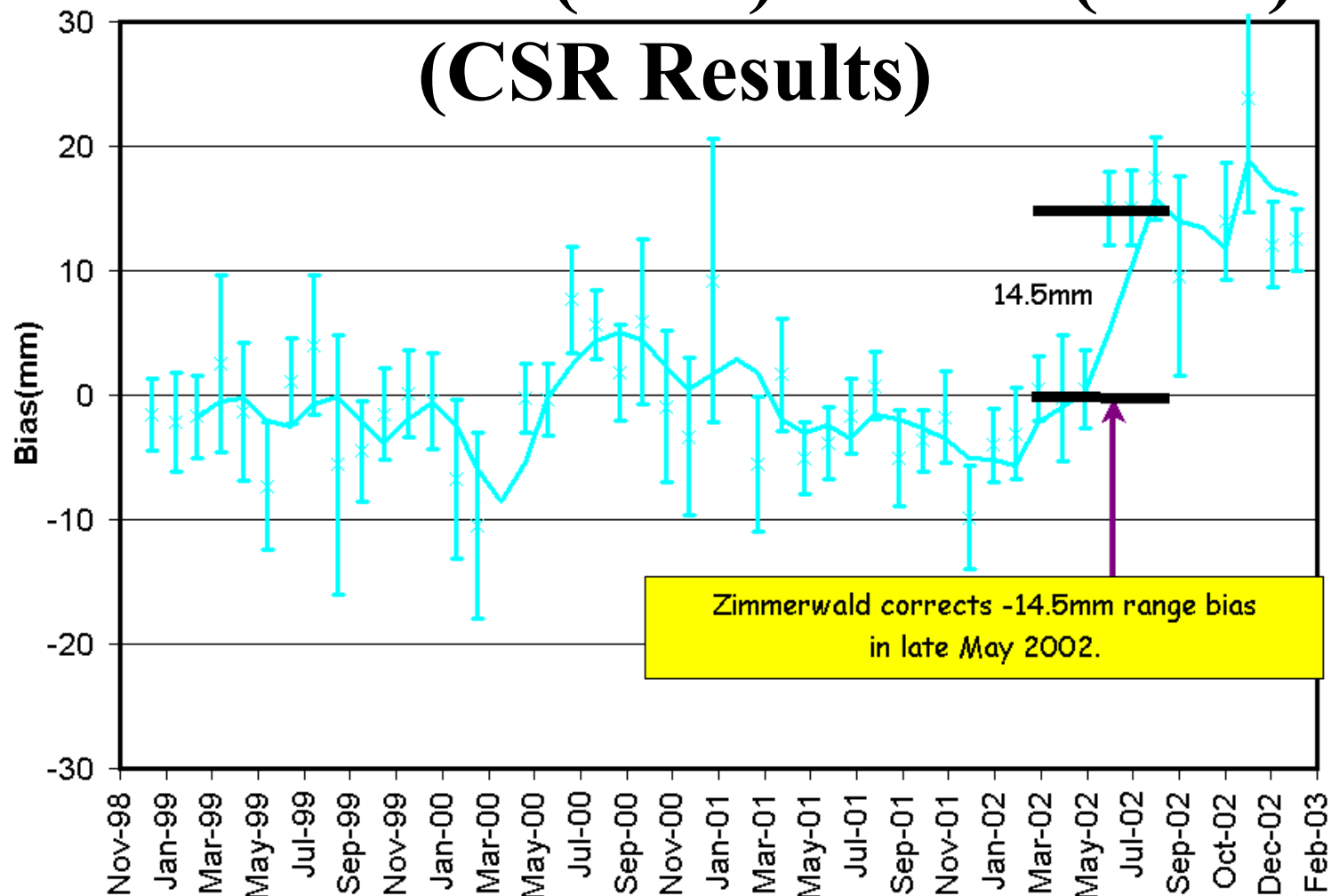
Herstmonceux (7840) – Graz (7839)



The 8mm correction is evident in the difference.
1st Law of ILRS Physics - Conservation of Bias.

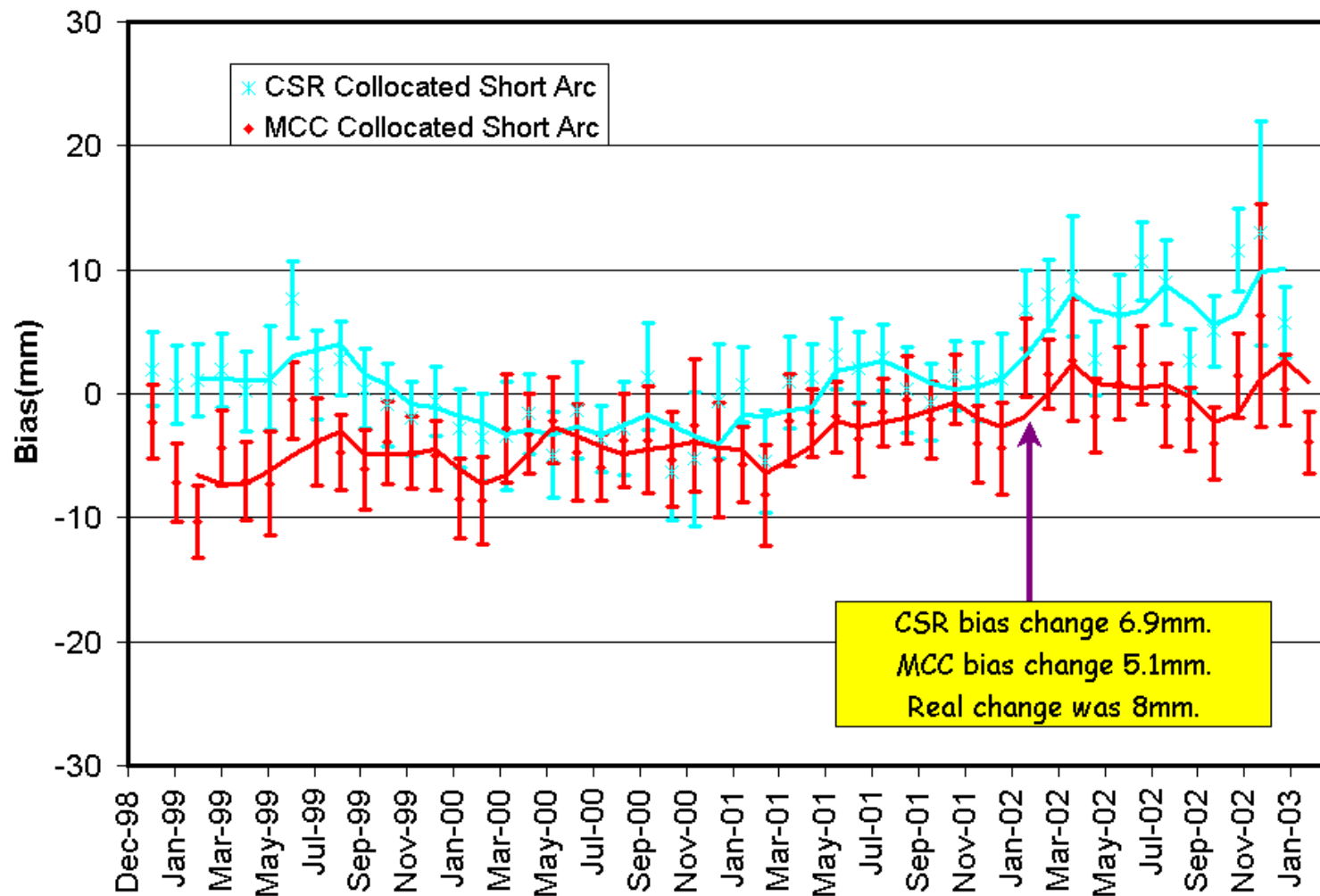
Zimmerwald (7810) – Graz (7839)

(CSR Results)



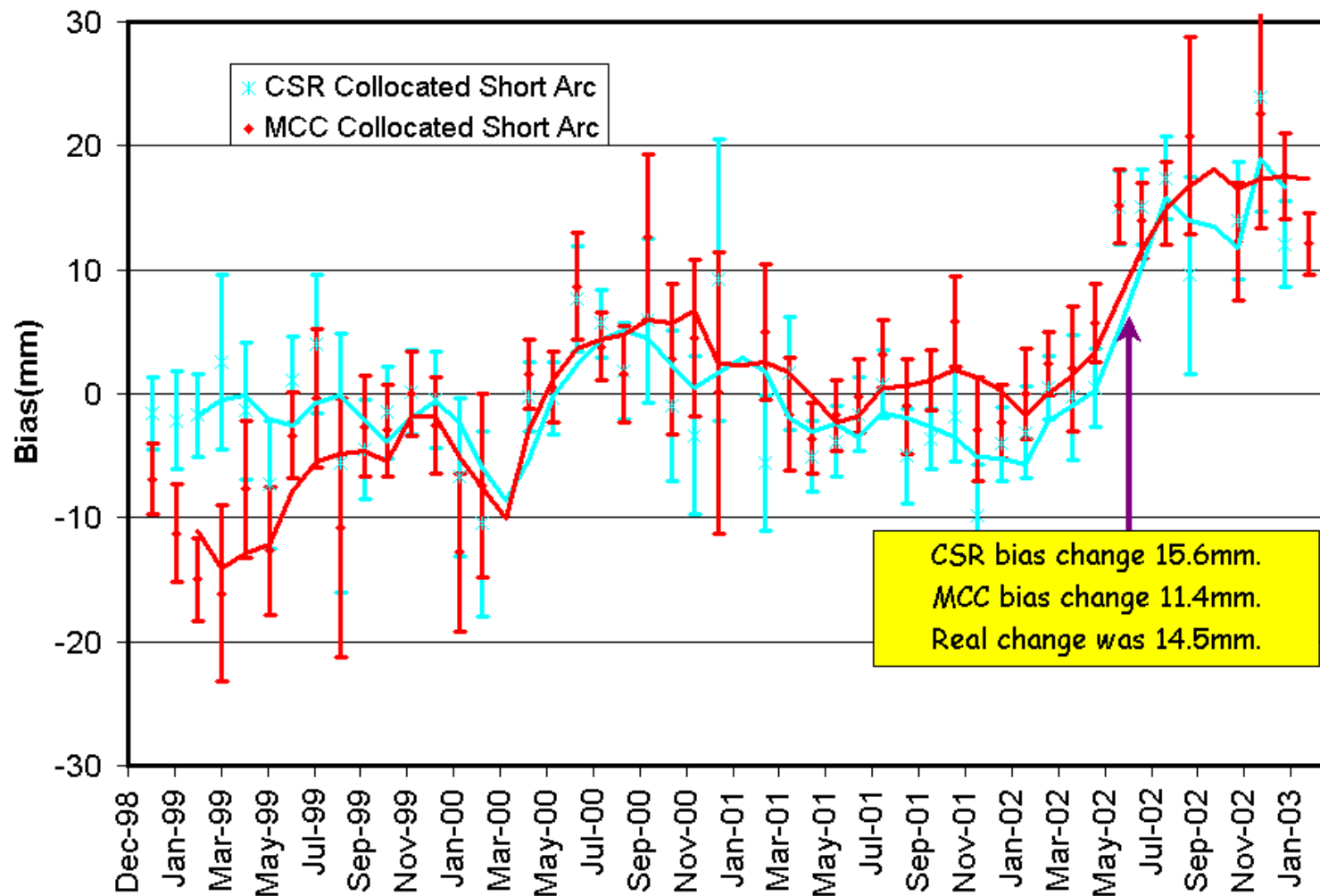
The 14.5mm correction is recovered in CSR analysis.

Herstmonceux (7840) – Graz (7839)



The trends from this technique are different.

Zimmerwald (7810) – Graz (7839)



The trends since late '99 from this technique are similar.

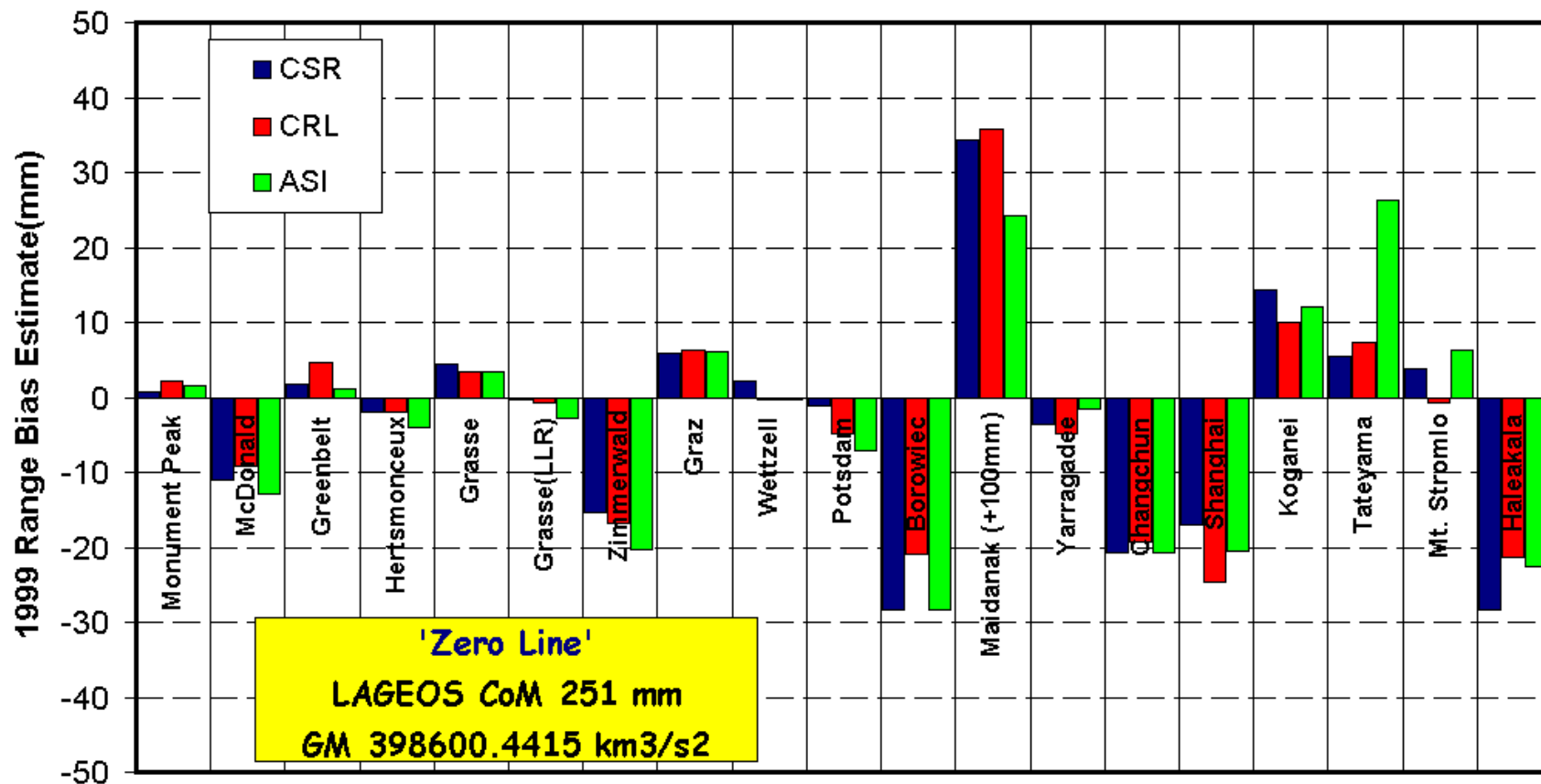
Collocation Short Arc Summary

- CSR and MCC trends are similar, but not exact.
- CSR results more closely recover known errors.
- Thus, *CSR results appear more trustworthy.*

Bias Results from POS/EOP Pilot Project

- Coordinates and range biases estimated every 28-days
- CSR had the most success separating bias from station height in the 28-day POS/EOP solutions.
- If you average these 28-day bias estimates over several months, the results between ACs agree.
- The prime weakness of this bias detection technique is inadequate LAGEOS coverage from sites within the 28-days.
- An advantage of this tool is that any seasonal trends in site heights will be modeled, since the positions are estimated every 28-days (i.e. eliminates seasonal bias trends)

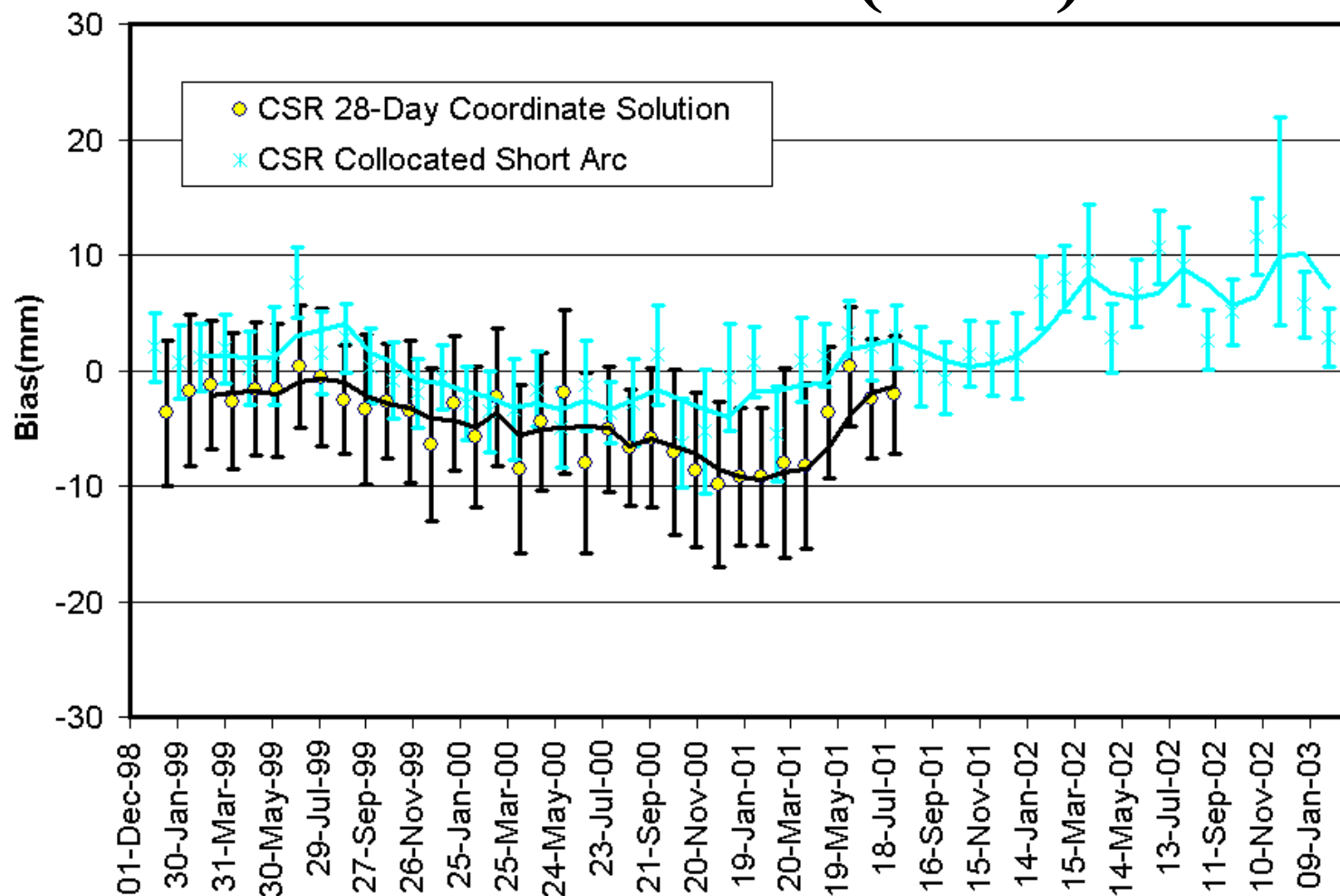
POS/EOP 1999 Bias Estimates



This is much more than coincidence that 3 different groups using 3 different OD packages determine equivalent biases for the global sites. Therefore these bias estimates reflect a higher **'TRUTH'**.

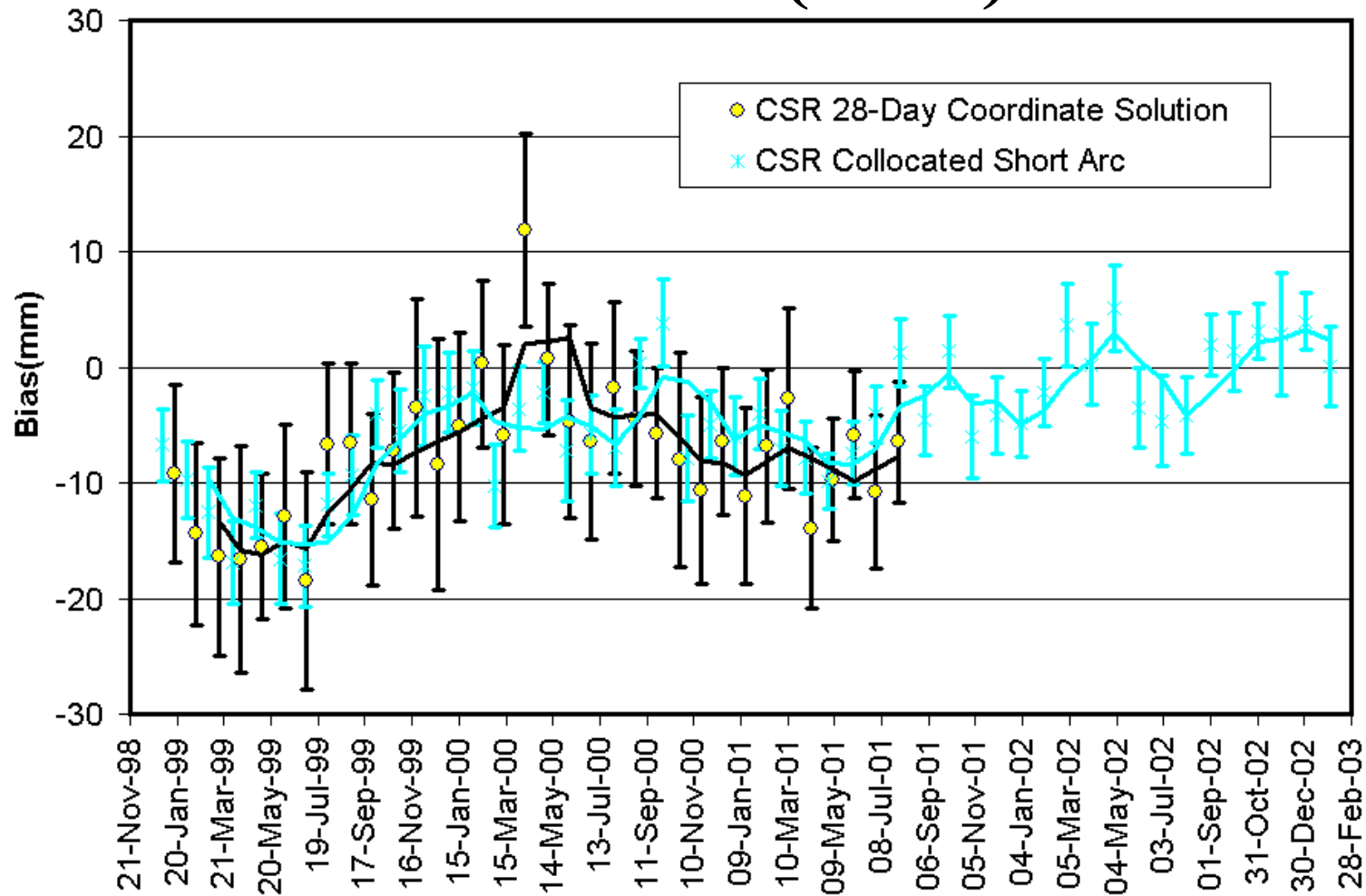
**Comparison of CSR Bias Results from
the *POS/EOP Pilot Project* and from the
*Collocated Short Arc Technique***

Herstmonceux (7840)



An offset exists but the trends are remarkably similar.
Is this drift in Herstmonceux real?

McDonald (7080)

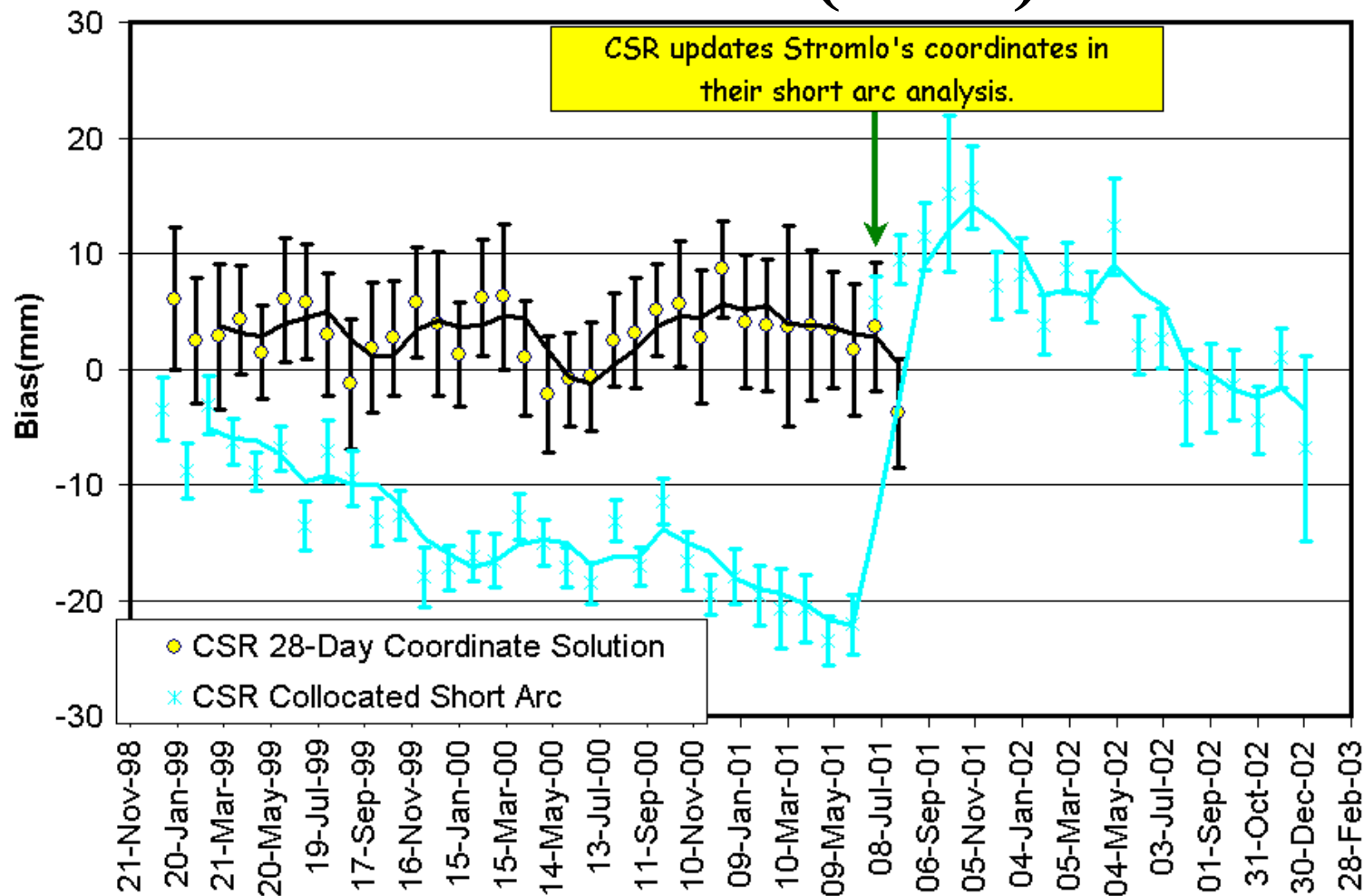


The trends are remarkably similar.
Are these drifts real?

Comparison of the ‘New’ Bias Detection Techniques

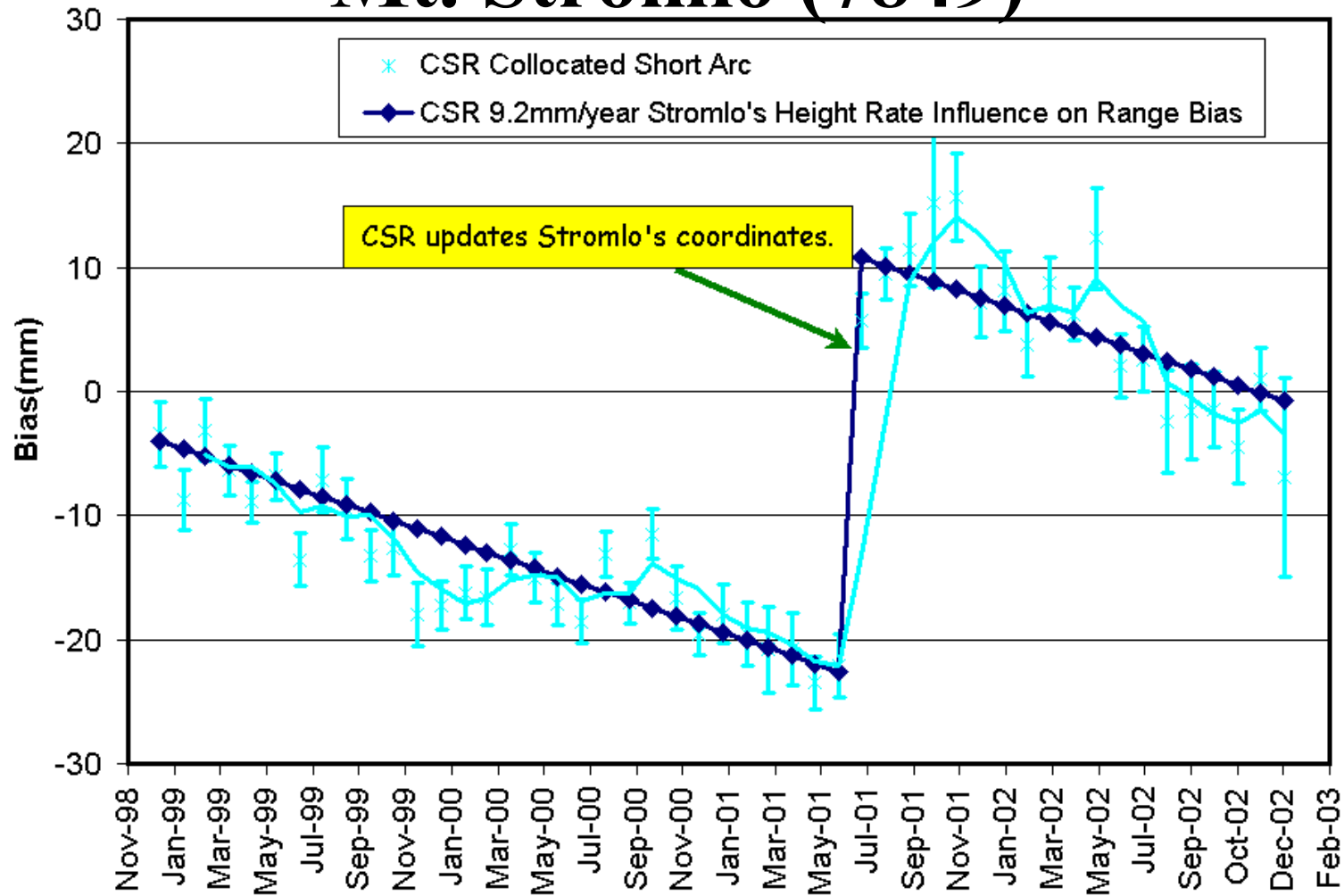
- The collocated short arc technique is capable of recovering known bias changes (e.g. Zimmerwald and Herstmonceux)
- The 28-day coordinate estimation technique provides a sense of ‘*absolute bias*’
- The trends from both technique are very similar, which supports the trends are real.
- You need a known ‘*trusted site*’ for the collocated short arc technique to work.
- But, there is one *potential pitfall* to the collocated short arc technique.

Mt. Stromlo (7849)



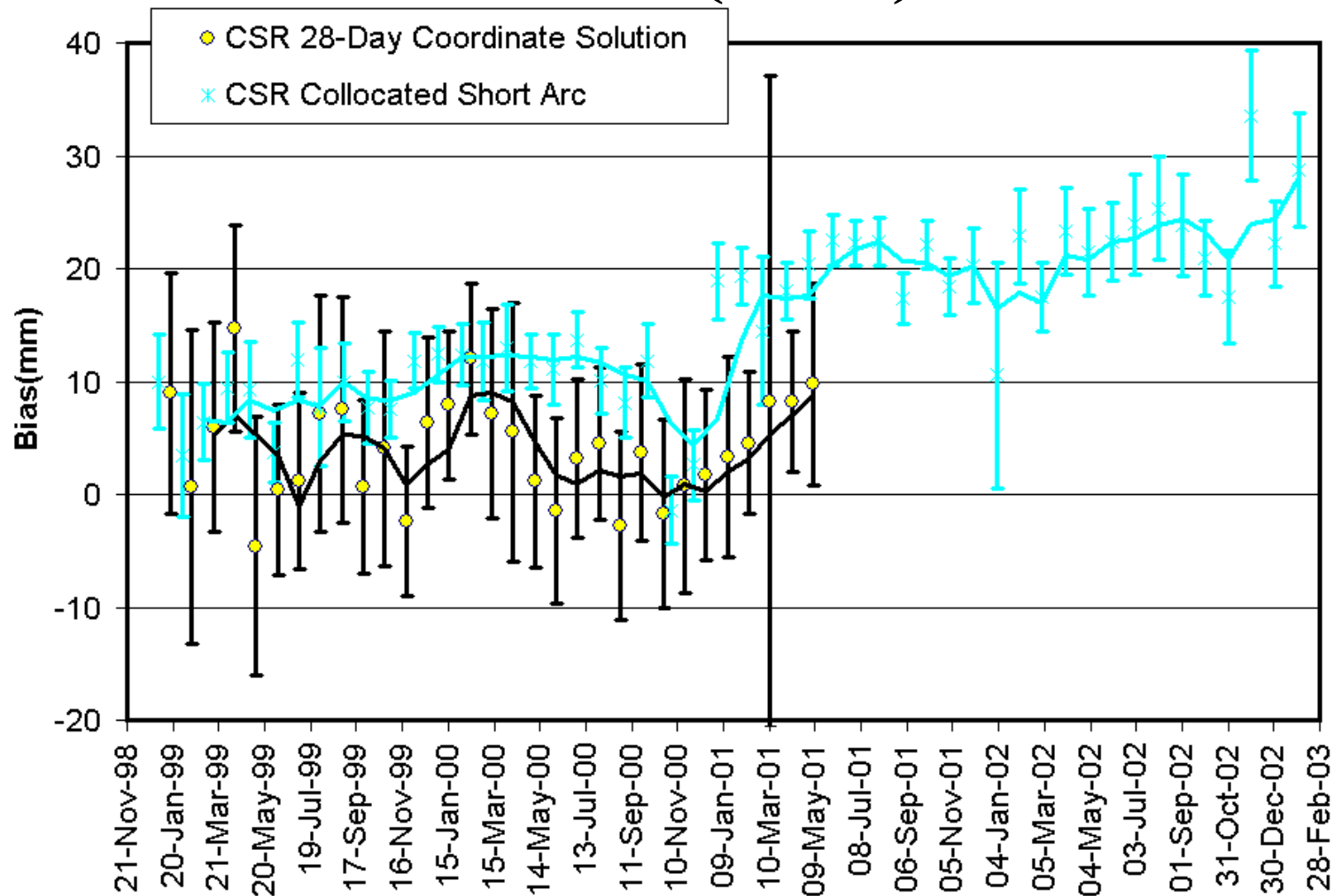
The trends are very different.
What's causing the drift in the Collocated Short Arc?

Mt. Stromlo (7849)



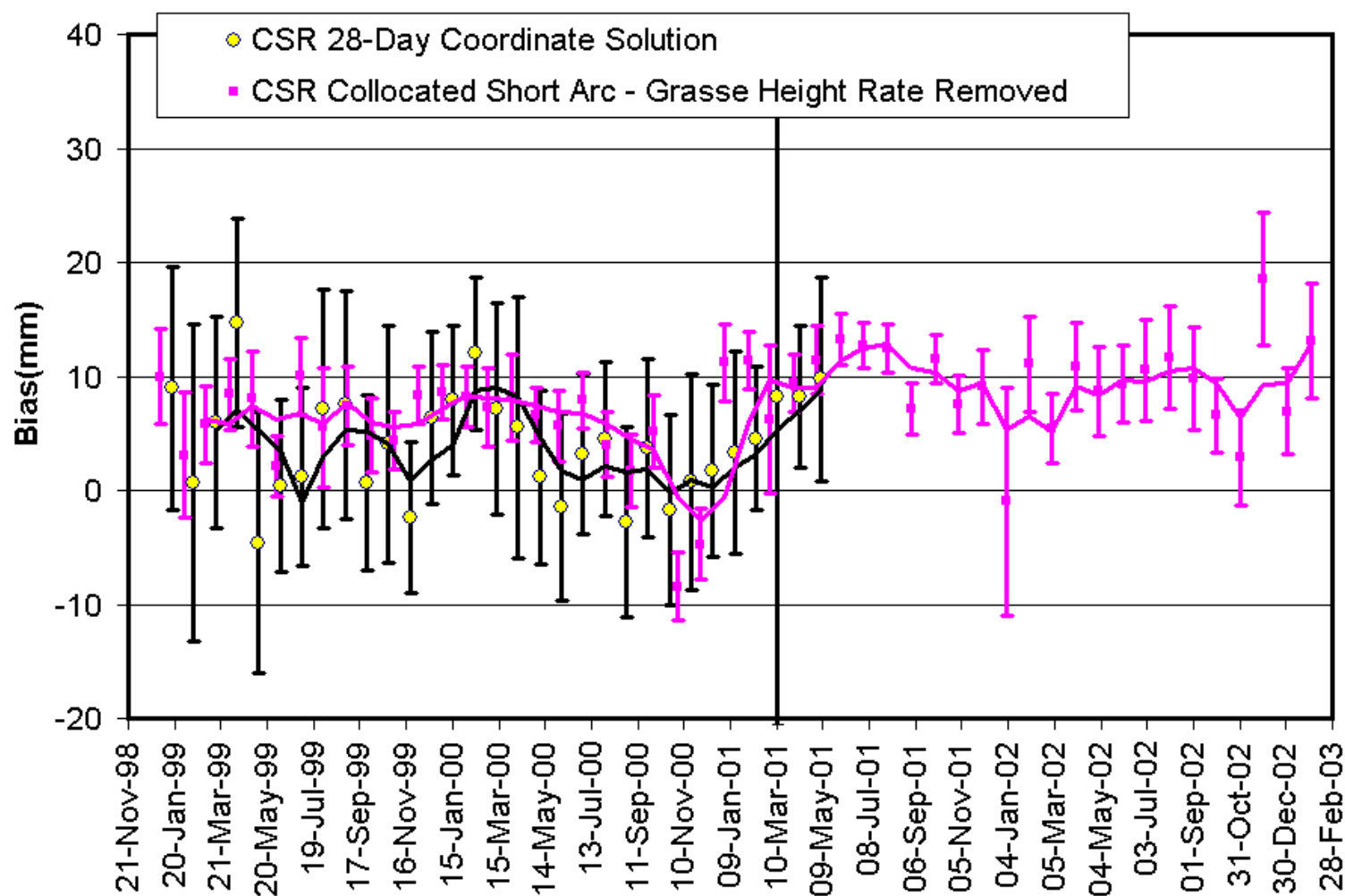
CSR coordinate solution 95L01 has a large Stromlo height rate inducing the apparent drift in the short arc results?

Grasse (7835)



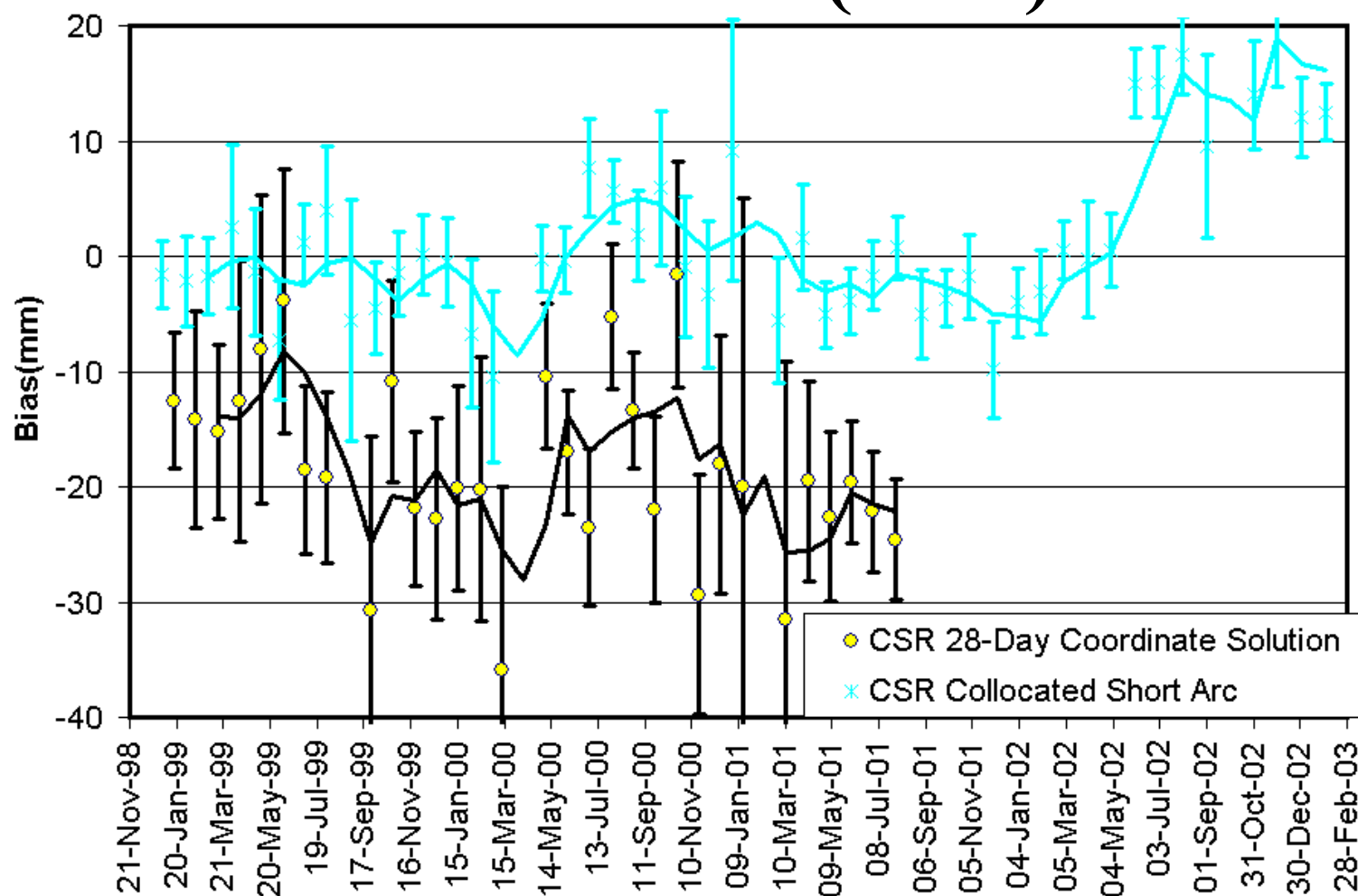
The trends follow, but start to diverge with time.
 CSR 95L01 has a 4.6mm/year height rate for Grasse.

Grasse (7835)



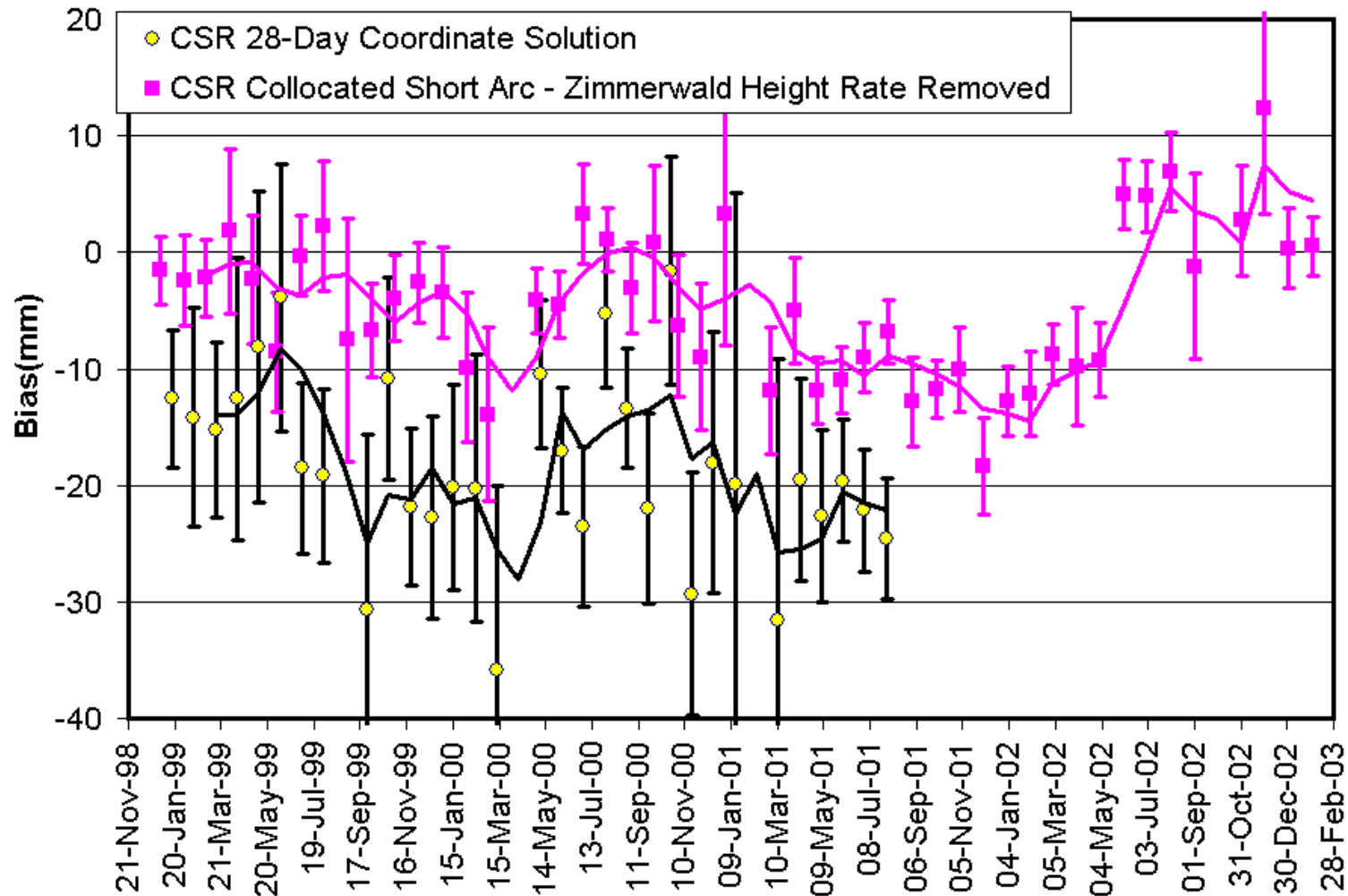
Now the trends are very close. Grasse's bias appears to have changed in early 2001, but has stabilized.

Zimmerwald (7810)



An offset exists, and the trends are diverging with time. CSR 95L01 has a 3.5mm/year height rate for Zimmerwald.

Zimmerwald (7810)



An offset still exists, but the trends are closer.

Suspect Height Rates

CSR 95L01

Stromlo(7849)	-9.5 mm/yr
Simosato(7838)	-5.0 mm/yr
Shanghai(7837)	-5.0 mm/yr
Grasse(7835, 7845)	4.6 mm/yr
Haleakala(7210)	-4.4 mm/yr
Zimmerwald(7810)	3.5 mm/yr

ITRF2000

Beijing(7249)	22 mm/yr
Riyadh(7832)	-17 mm/yr
Komsomolsk(1868)	15 mm/yr
Ajaccio(7848)	-14 mm/yr
Mendeleevo(1870)	9 mm/yr
Riga(1884)	-7 mm/yr
San Fernando(7824)	6 mm/yr
Tahiti(7124)	3 mm/yr

A height rate error as small as 2.4 mm/year will induce an apparent 10mm ($2.4/1.2 * 5$) bias drift in 5 years.

The 'Collocation Short Arc' technique can be improved by modeling suspect height rates.

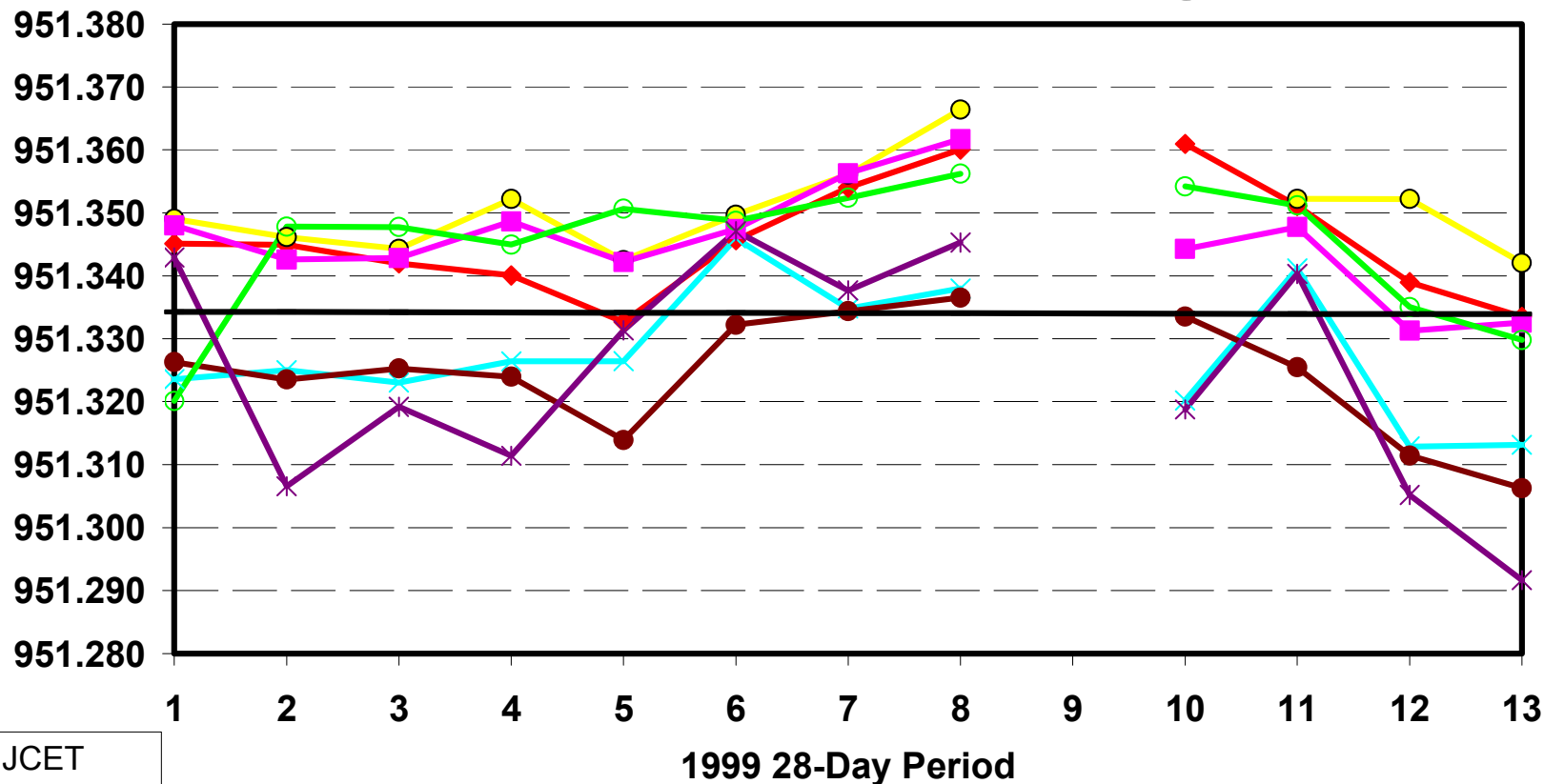
Comparison of Bias Detection Techniques

Technique	Detection Capability	Detection Level(mm)			Orbit Required?	Simultaneity Required?	Station Coordinates
		Pass	Month	3 Months			
System Characterization	Absolute	≤1			NO	NO	NO
Portable Calibration Standard	Absolute	≤1			NO	NO	NO
Collocation	Relative	2 to 4	1 to 2	1	NO	YES	Relative
Simultaneous Arc (NERC)	Relative	10 to 15	5 to 10	3 to 5	YES	YES	Fixed
Short Arc (2-3 days)	Relative	30 to 50	10 to 15	5 to 10	YES	NO	Fixed
28-Day Coordinate Estimation	Absolute	N.A.	3 to 5	2 to 3	YES	NO	Estimated
Collocated Short Arc	Relative	N.A.	2 to 4	1 to 2	YES	NO	Fixed

These detection levels above are **BEST** case (i.e. assumes adequate data from sites with good long term performance history).

Station Height Analysis from POS/EOP Pilot Project and Site Tie Analysis

Zimmerwald (7810) Heights



Several cm divergence in the heights between different analysis centers. **WHY?**

Some ACs assumed no bias and other centers estimated a bias inducing a bi-modal distribution.

Zimmerwald Local Tie Analysis

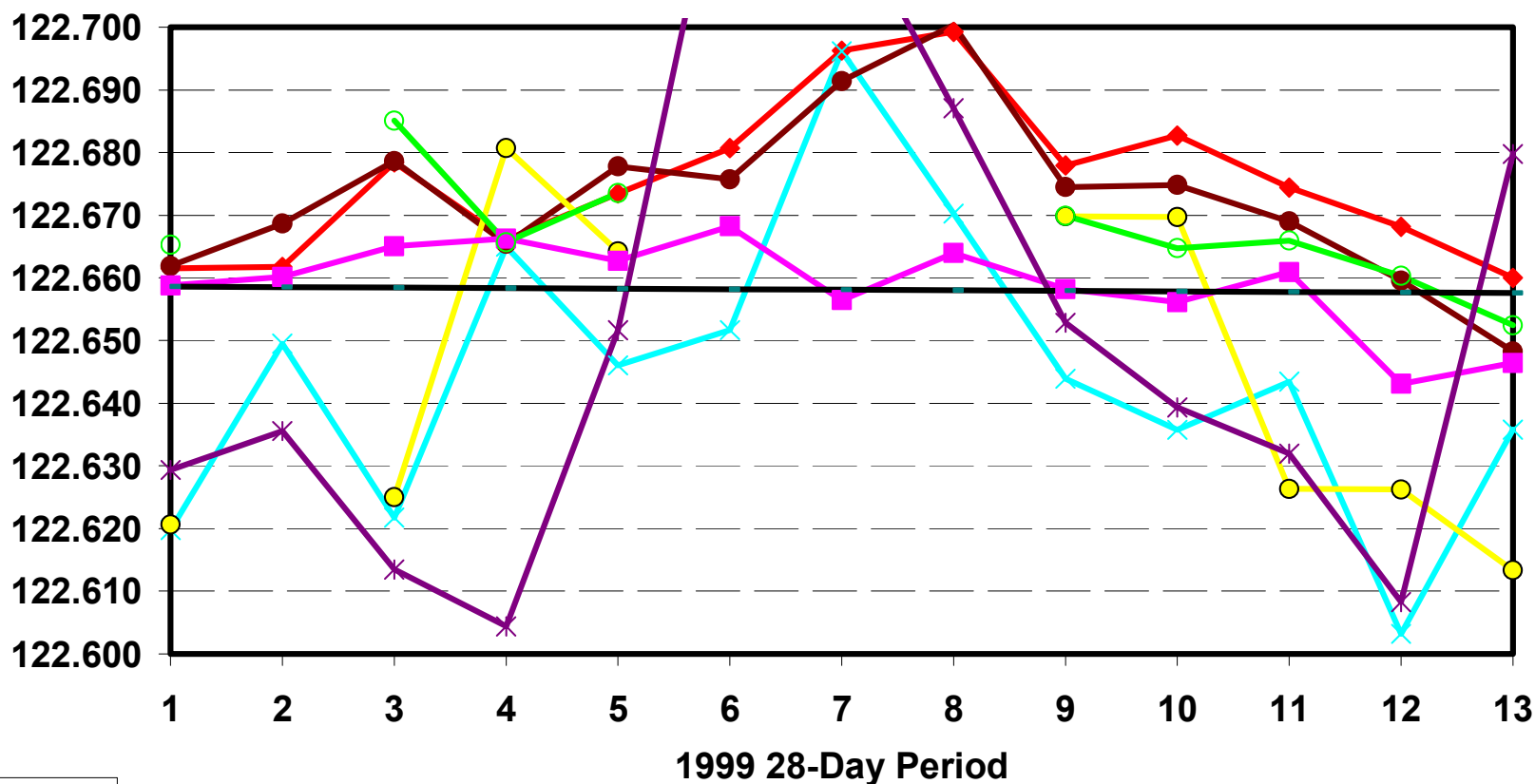
DOMES	Type	Tech.	ID	Source	Epoch	X(m)	Y(m)	Z(m)	N(m)	E(m)	U(m)
14001M004	Position	GPS	ZIMM	ITRF2000	1-Jan-97	4331297.177	567555.732	4633133.840			
14001S007	Position	SLR	7810	ITRF2000	1-Jan-97	4331283.676	567549.743	4633140.267			
M004-S007	Tie		ZIMM-7810	ITRF2000	1-Jan-97	13.501	5.989	-6.427			
M004-S007	Tie		ZIMM-7810	ILRS Site Log	12-Jan-99	13.505	5.986	-6.421			
	Delta			ITRF2000 - Site Tie		-0.004	0.003	-0.006	-0.0015	0.0035	-0.0068

- There is a 0.0068 mm potential error in UP:
 - in the local tie, or
 - the ITRF2000 SLR or GPS position, or
 - all of the above.

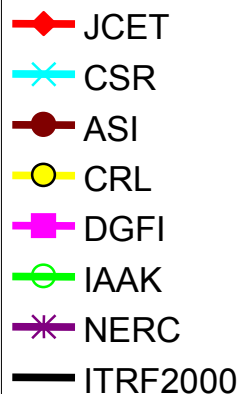
DOMES	Type	Tech.	ID	Source	Epoch	X(m)	Y(m)	Z(m)	N(m)	E(m)	U(m)
14001M004	Position	GPS	ZIMM	ITRF2000	1-Jan-97	4331297.177	567555.732	4633133.840			
14001S007	Position	SLR	7810(sim)	ITRF2000	1-Jan-97	4331283.671	567549.742	4633140.261			
M004-S007	Tie		ZIMM-7810	ITRF2000	1-Jan-97	13.506	5.990	-6.421			
M004-S007	Tie		ZIMM-7810	ILRS Site Log	12-Jan-99	13.505	5.986	-6.421			
	Delta			ITRF2000 - Site Tie		0.001	0.004	0.000	-0.0011	0.0038	0.0010

- Most of this error can be accounted for by an 8mm error in Zimmerwald's 7810 height caused by a known -18mm range bias coupled with different data treatment by the analysis centers.

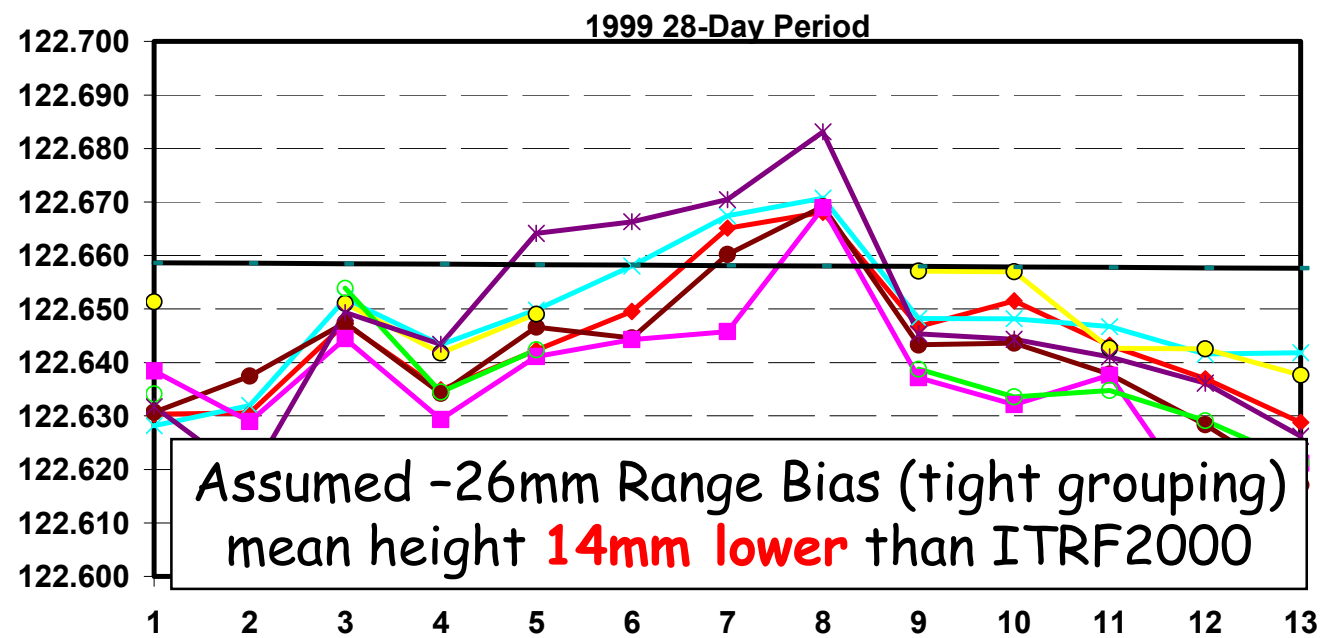
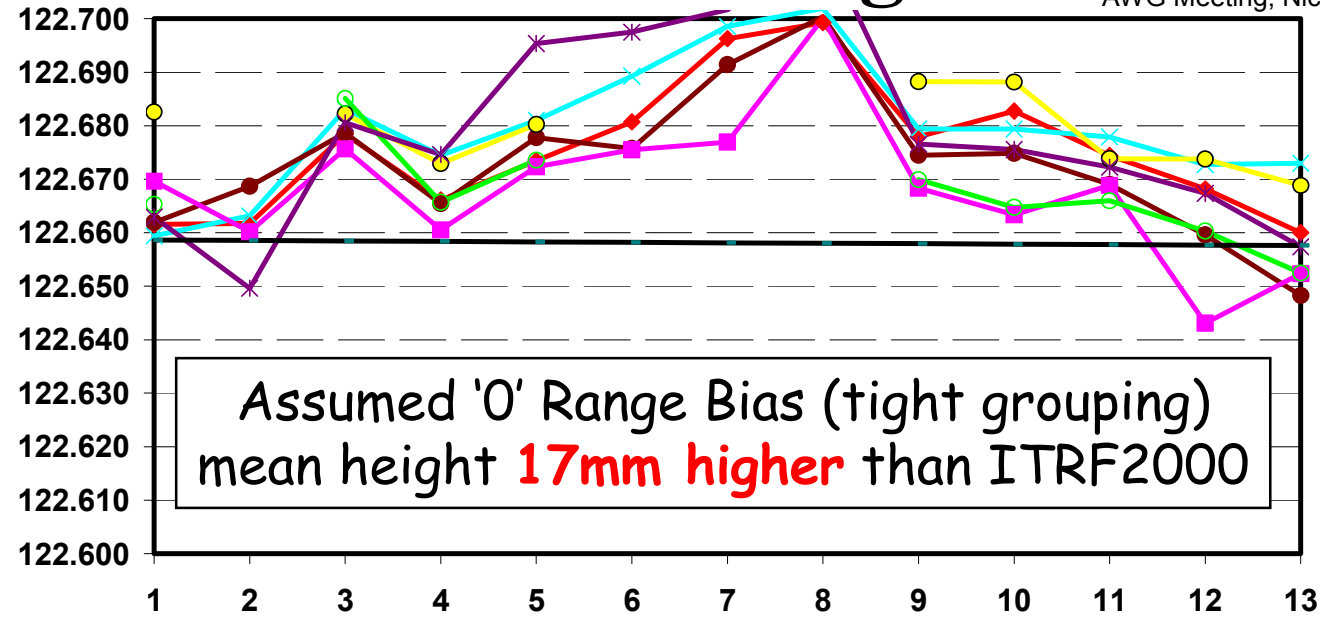
Borowiec(7811)



Several cm divergence in the heights between different analysis centers. **WHY?**
Some ACs assumed no bias and other centers estimated a bias inducing a bi-modal distribution.



Borowiec Heights



Borowiec Local Tie Analysis

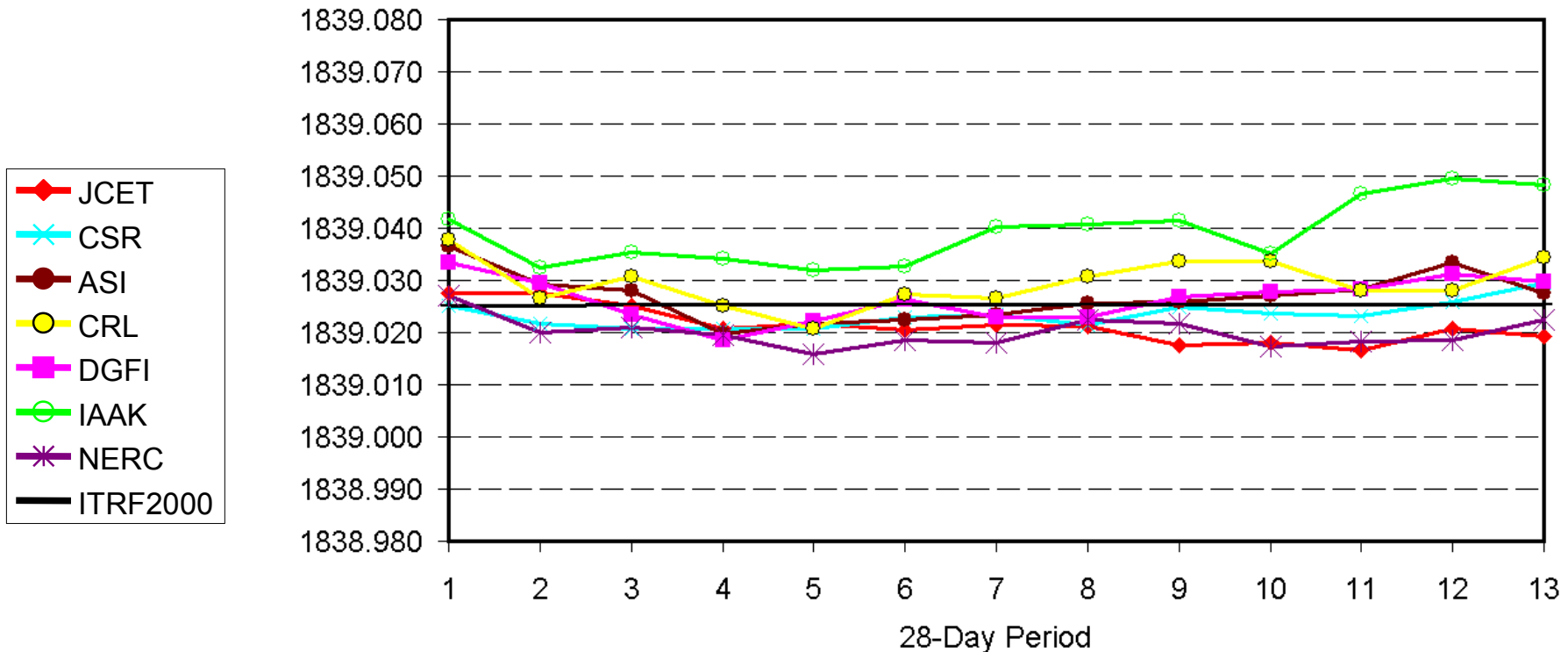
DOMES	Type	Tech.	ID	Source	Epoch	X(m)	Y(m)	Z(m)	N(m)	E(m)	U(m)
12205S001	position	SLR	7811	ITRF2000	1-Jan-97	3738332.834	1148246.491	5021816.035			
12205M002	position	GPS	BOR1	ITRF2000	1-Jan-97	3738358.598	1148173.582	5021815.705			
S001-M002	tie		BOR1-7811	ITRF2000	1-Jan-97	25.764	-72.909	-0.330			
S001-M002	tie		BOR1-7811	ILRS Site Log	1-Jan-94	25.767	-72.908	-0.324			
	Delta		BOR1-7811	ILRS Site Log - ITRF2000		0.003	0.001	0.006	0.0012	0.0001	0.0067

- There is a 0.0067 mm potential error in UP:
 - in the local tie, or
 - the ITRF2000 SLR or GPS position, or
 - all of the above.

DOMES	Type	Tech.	ID	Source	Epoch	X(m)	Y(m)	Z(m)	N(m)	E(m)	U(m)
12205S001	Position	SLR	7811(sim)	ITRF2000	1-Jan-97	3738332.826	1148246.488	5021816.024			
12205M002	position	GPS	BOR1	ITRF2000	1-Jan-97	3738358.598	1148173.582	5021815.705			
S001-M002	tie		BOR1-7811	ITRF2000	1-Jan-97	-25.772	72.906	0.319			
S001-M002	tie		BOR1-7811	ILRS Site Log	1-Jan-94	25.767	-72.908	-0.324			
	Delta			ITRF2000 - Site Tie		-0.005	-0.002	-0.005	0.0012	-0.0004	-0.0072

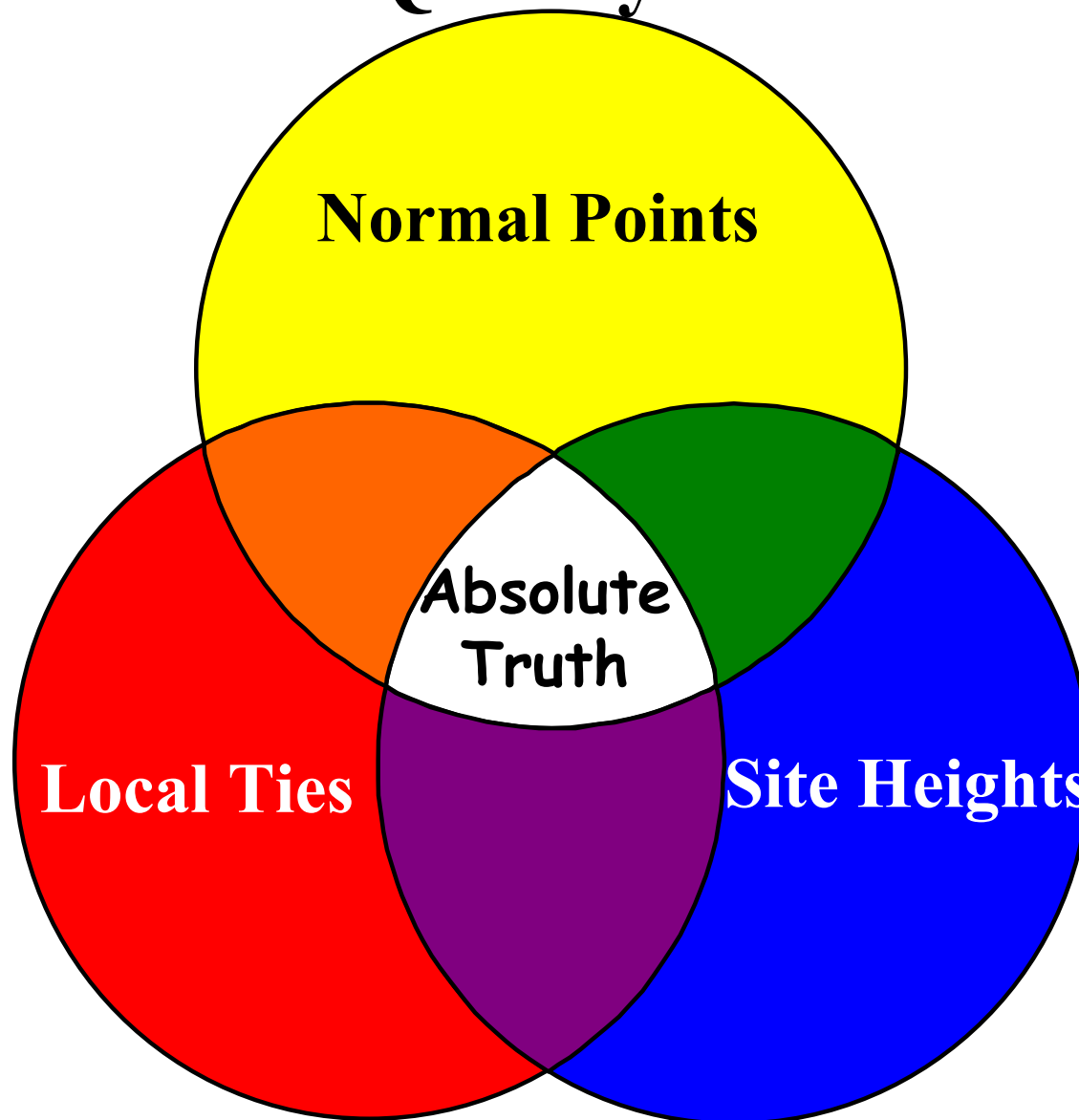
- Unfortunately, this Borowiec height simulation/local tie analysis still points to a potential problem in the local tie and/or BOR1's ITRF2000 site position.

Monument Peaks (7110) Heights



Very tight agreement between the ACs, except IAAK. **WHY?**
Because the Monument Peak (7110)
bias in '99 was near zero. So if you estimate a bias or
not, the height results will be similar. IAAK N. America
heights higher than the other Acs, reason unknown.

SLR Global Quality Control 2003



Conclusions

- The *Collocated Short Arc* technique coupled with the *28-day Coordinate Solution* technique is an excellent way to quality control the global data set to the few mm level in absolute accuracy.
- Apply all known a priori biases in 28-day coordinate solution. Apply site LAGEOS CoM.
- If biases are estimated in the CFP coordinate solutions:
 - Then the heights from each site are in the same reference frame. The frame is absolute.
 - Estimating biases is an excellent QC tool.
 - ***The ‘Dilemma’ is that 28-days is not an adequate data set for most sites to successfully separate height from a range bias, especially for sites that only range at night.***