Bear Brook Watershed in Maine, USA

Twenty Four Years and Counting

Stephen A. Norton – Earth Sciences

Ivan J. Fernandez – Plant, Soil, and Environmental Sciences

Lindsey Rustad – U. S. Forest Service

Tomas Navrátil – Czech Academy of Sciences

March 2011

Norwegian Institute for Water Research

Lillehammer, Norway

1865 THE UNIVERSITY OF MAINE

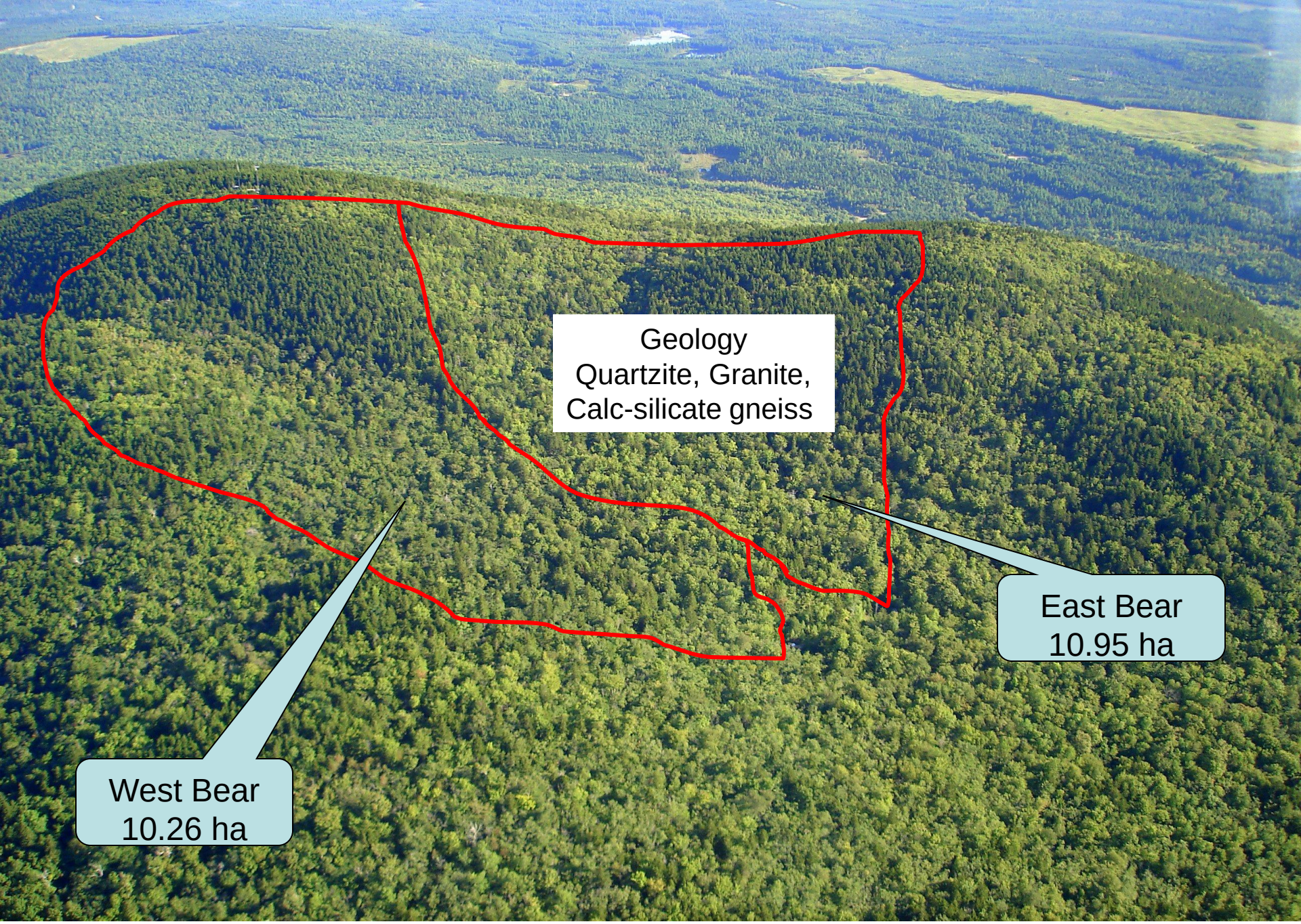
Bear Brook Watershed in Maine

NSF

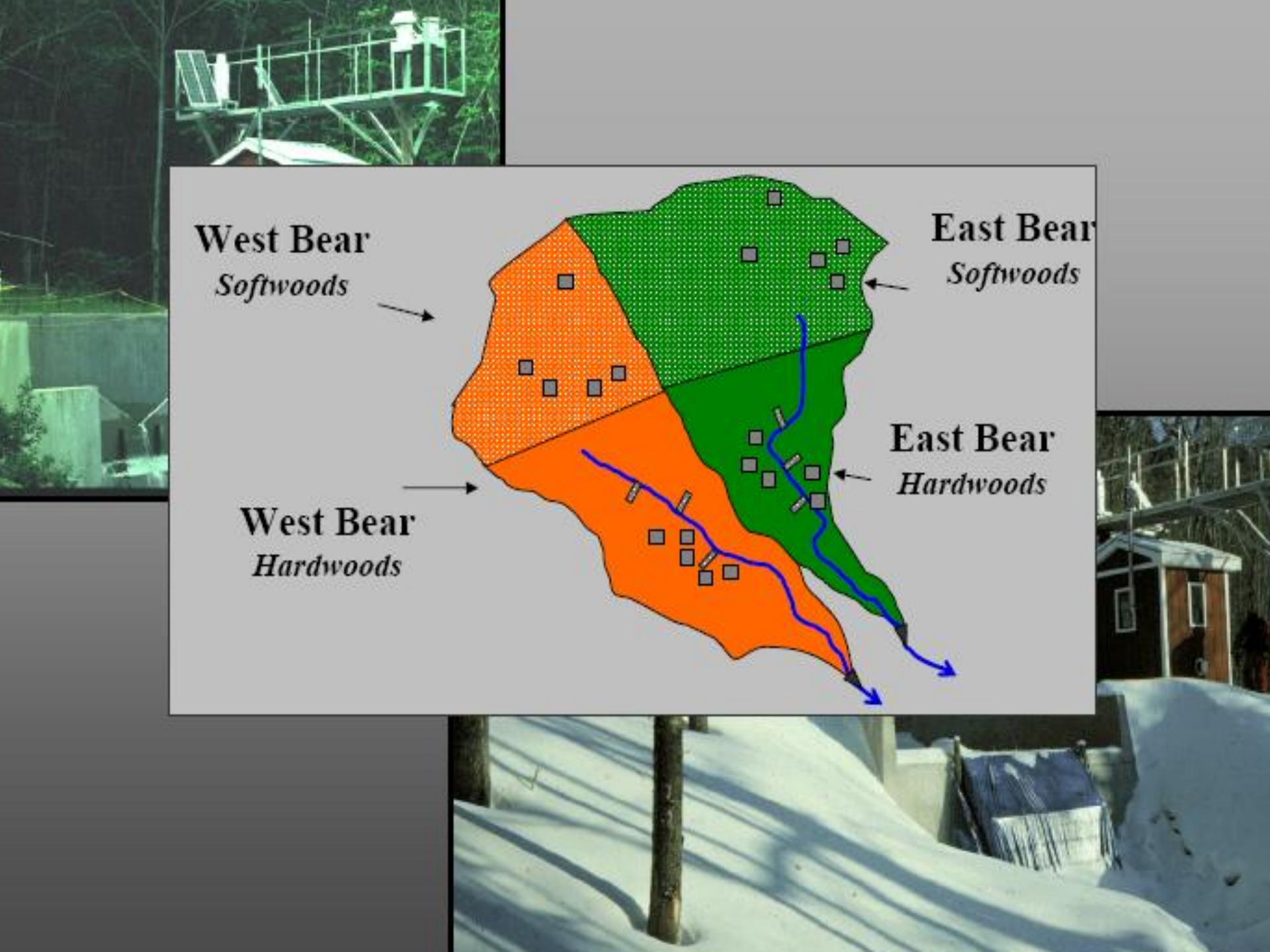
Bear Brook Watershed in Maine

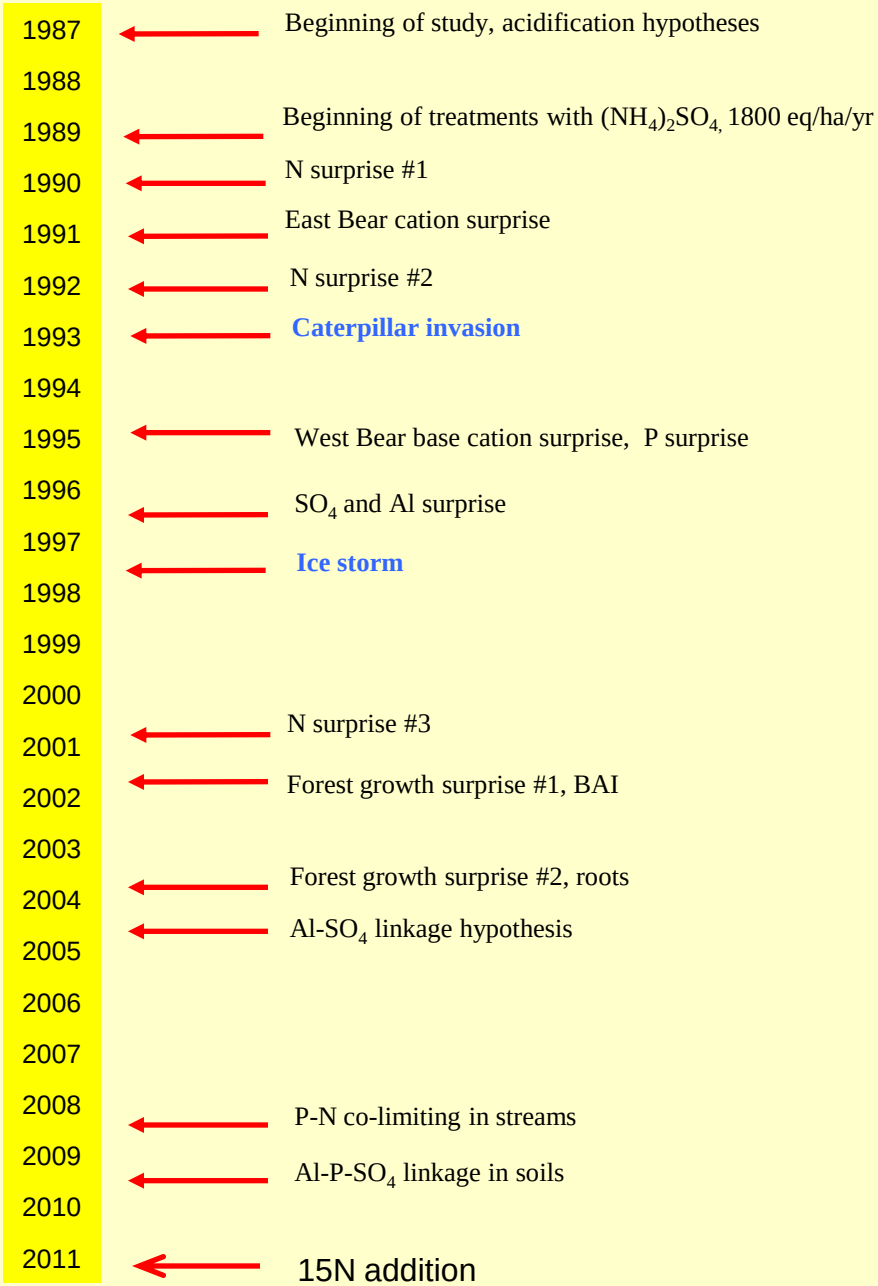
Twenty four years and counting

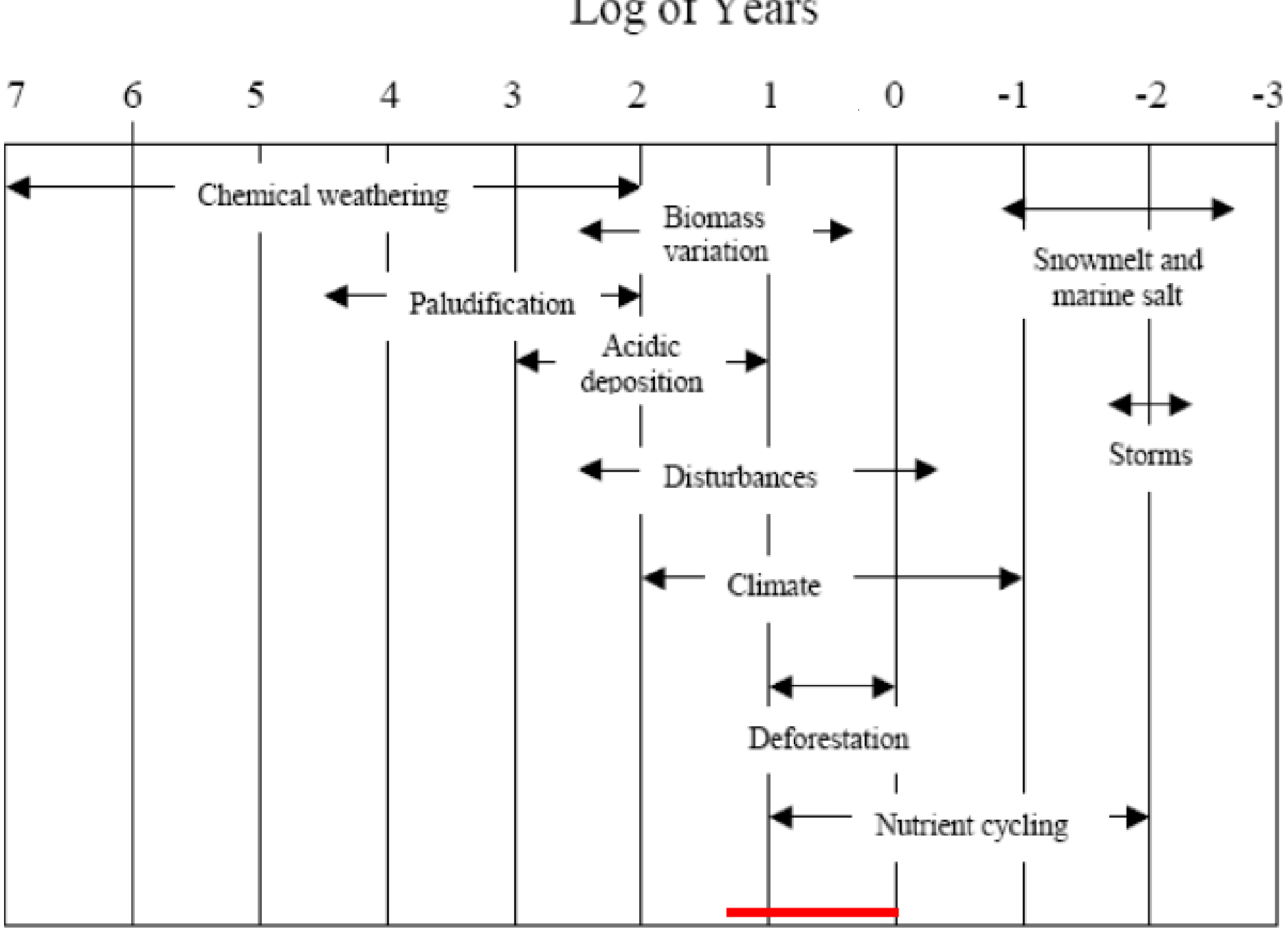
NSF

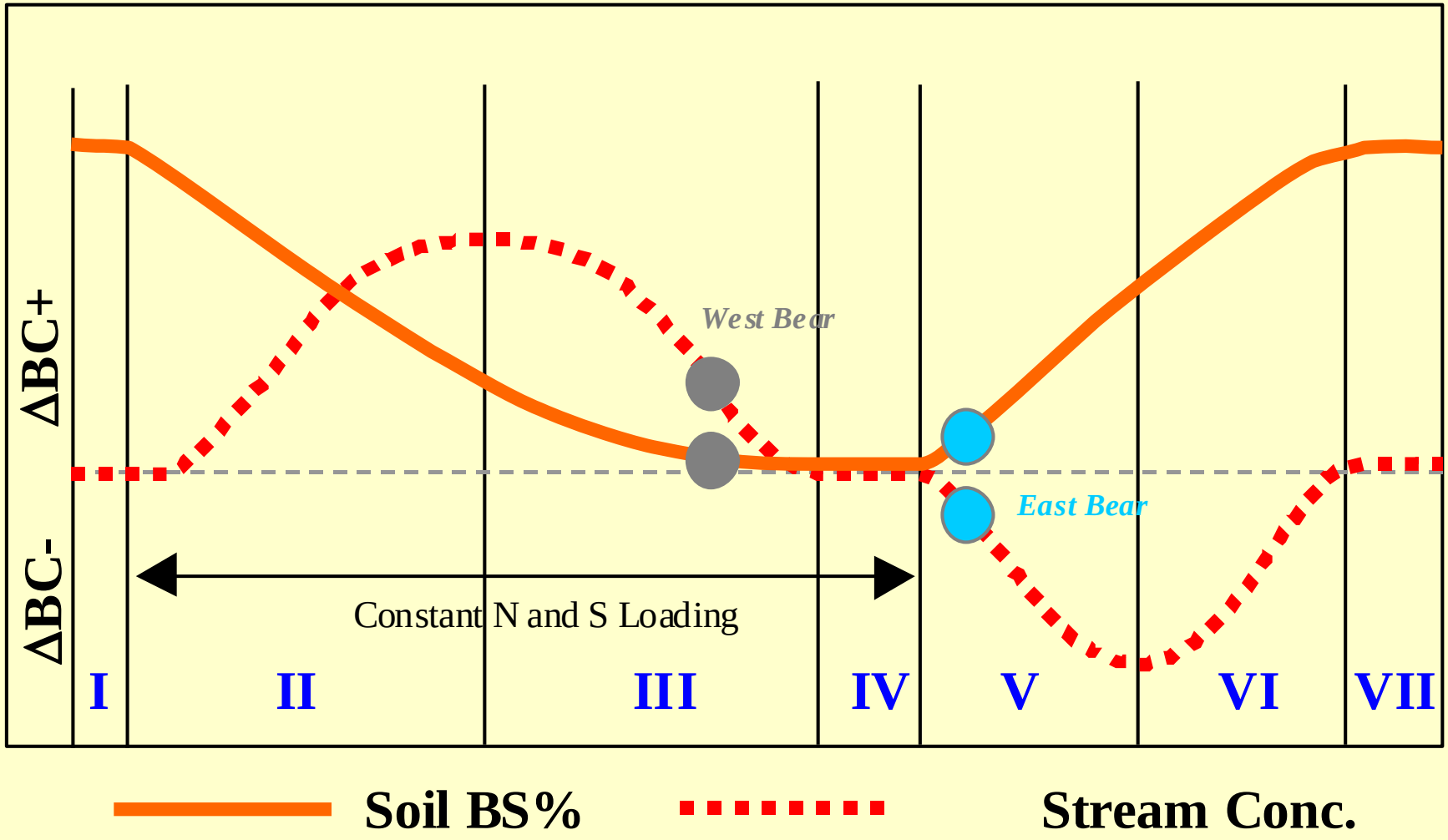


From G. Bruce Wiersma


West Bear
Softwoods
East Bear
Softwoods
East Bear
Hardwoods
West Bear
Hardwoods


1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Beginning of study, acidification hypotheses
Beginning of treatments with $(NH_4)_2SO_4$, 1800 eq/ha/yr
N surprise #1
East Bear cation surprise
N surprise #2
Caterpillar invasion
West Bear base cation surprise, P surprise
SO_4 and Al surprise
Ice storm
N surprise #3
Forest growth surprise #1, BAI
Forest growth surprise #2, roots
Al-SO_4 linkage hypothesis
P-N co-limiting in streams
Al-P-SO_4 linkage in soils
15N addition

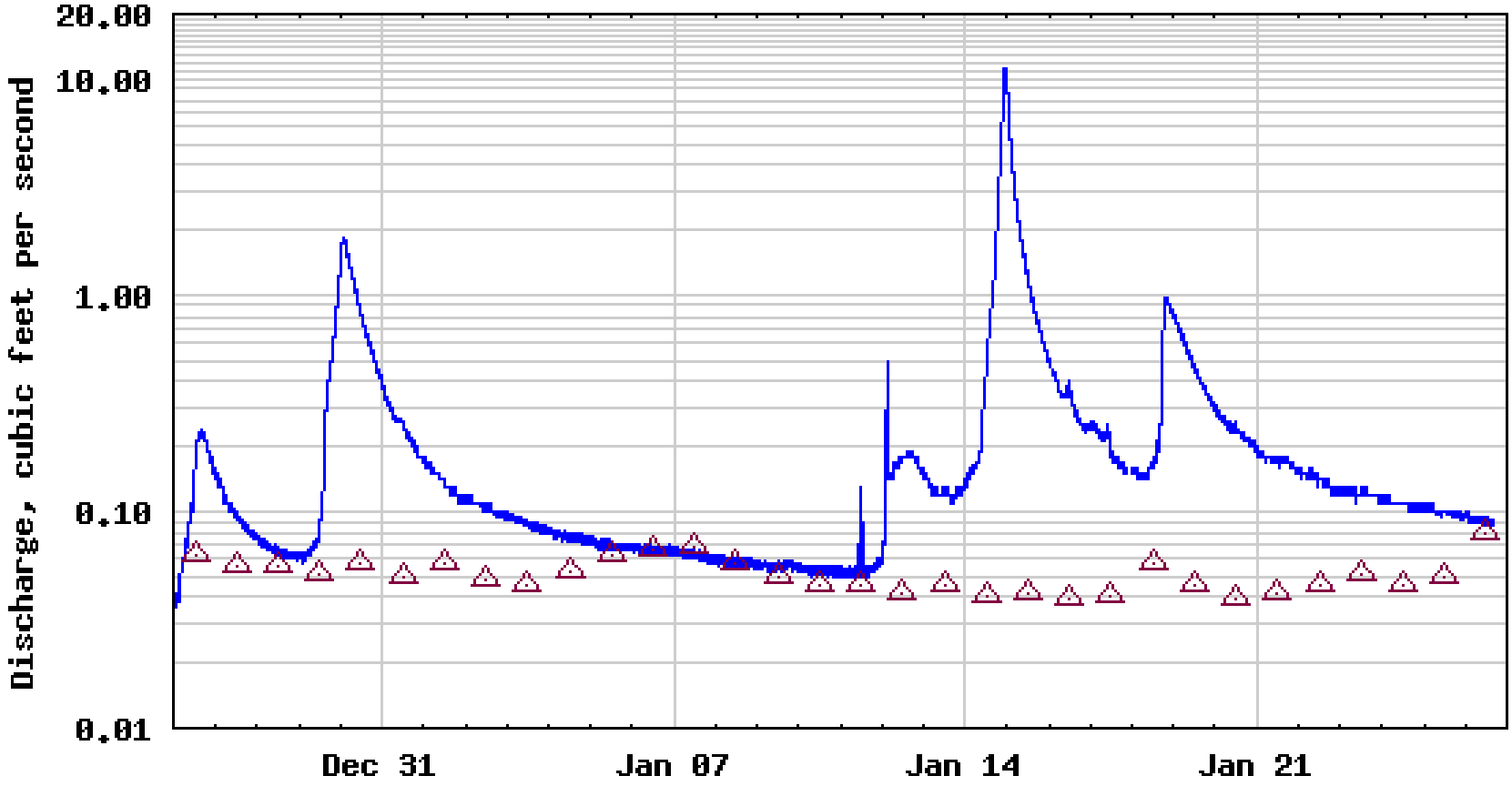

Log of Years
7
6
5
4
3
2
1
0
-1
-2
-3
Chemical weathering
Biomass variation
Snowmelt and marine salt
Paludification
Acidic deposition
Storms
Disturbances
Climate
Deforestation
Nutrient cycling



Modified after Galloway et al. 1983

USGS

USGS 01022295 West Br Bear Brook near Beddington, Maine



---------- EXPLANATION ----------

DISCHARGE

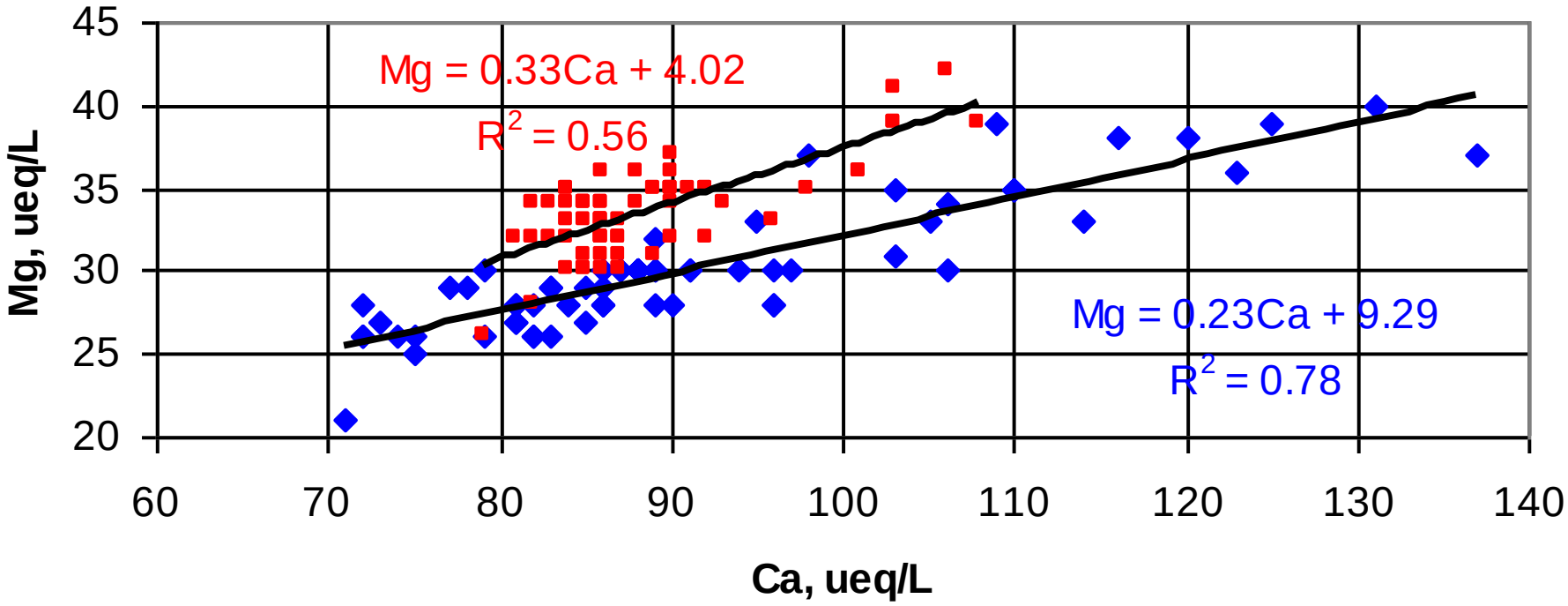
MEDIAN DAILY STREAMFLOW BASED ON 16 YEARS OF RECORD

Provisional Data Subject to Revision

- Initiated November, 1989
- 1800 eq ha^{-1} yr^{-1} $(NH_4)_2SO_4$, or 25.2 and 28.8 kg ha^{-1} yr^{-1} N and S
- Added in 6 bi-monthly applications

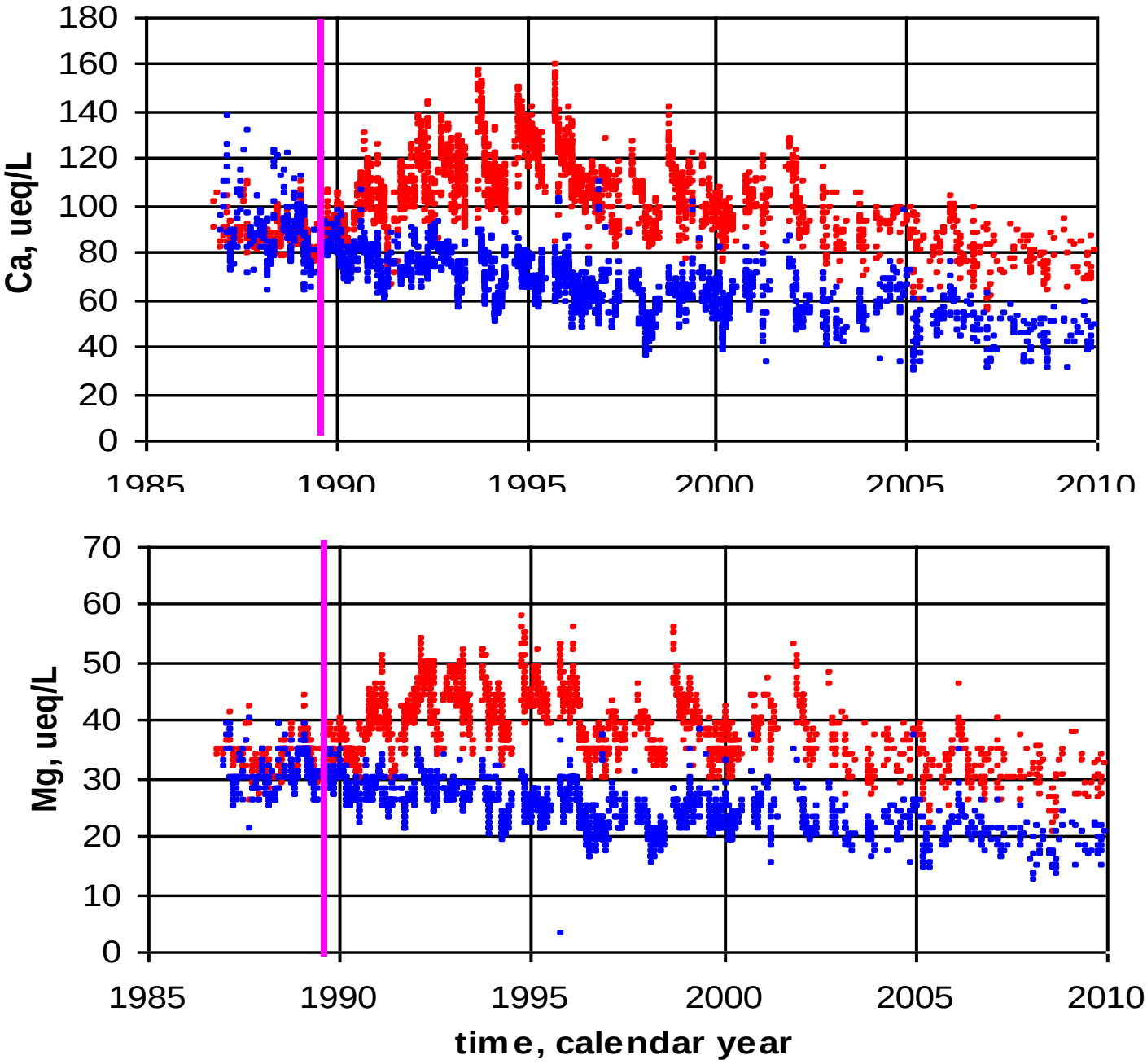
Base Cation Surprises

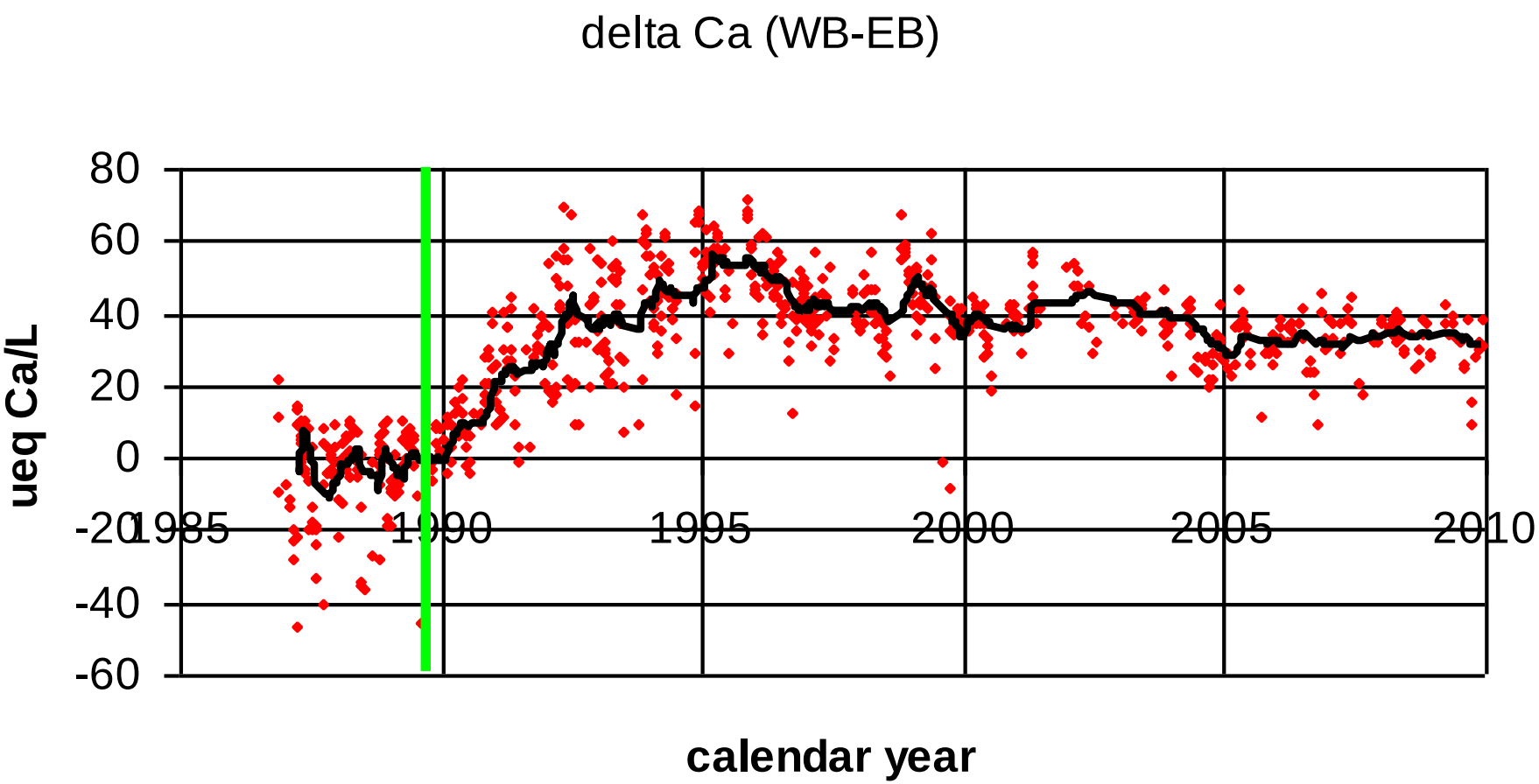
East and West Bear Brooks, 1987

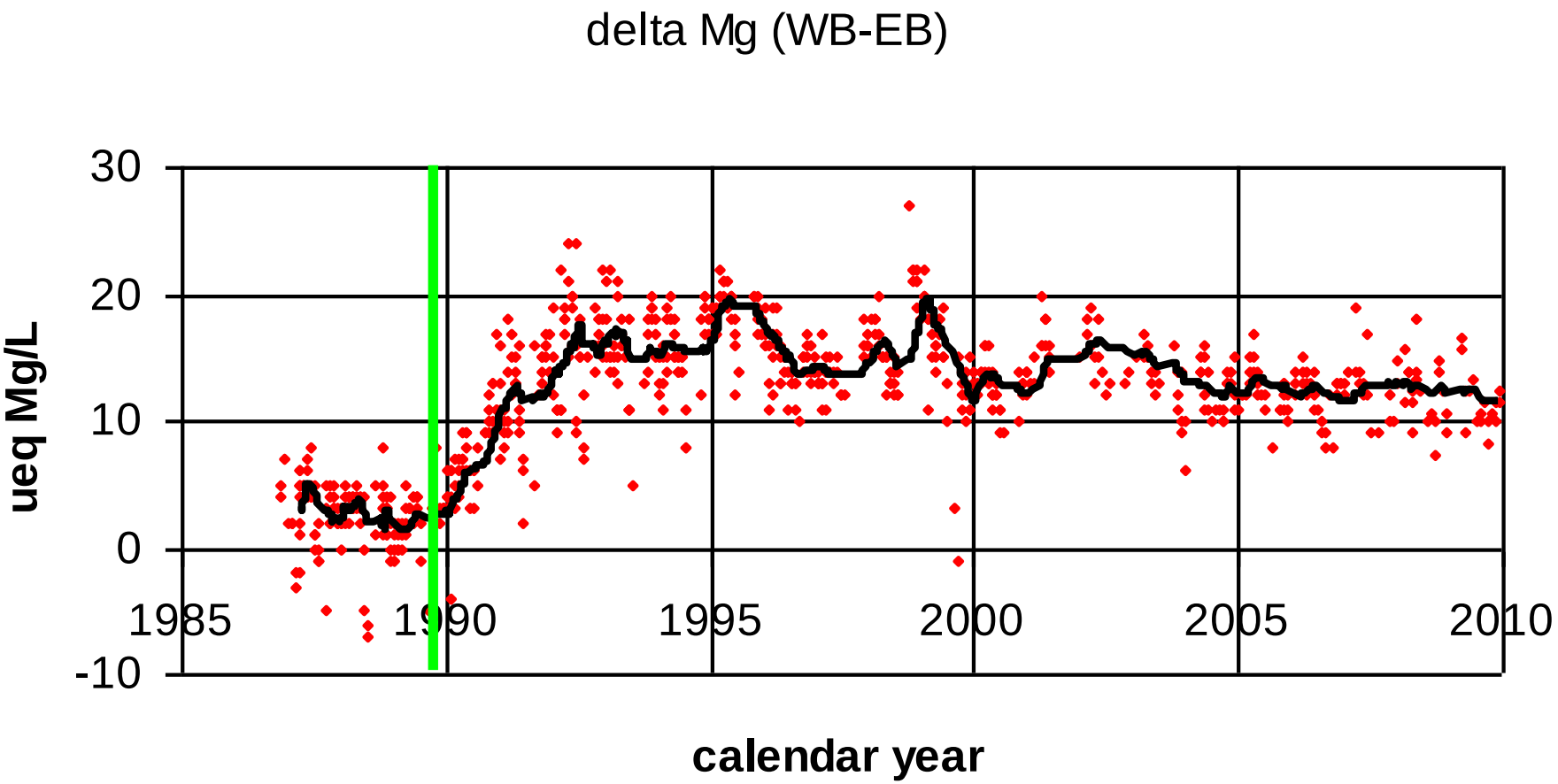


West Bear

East Bear

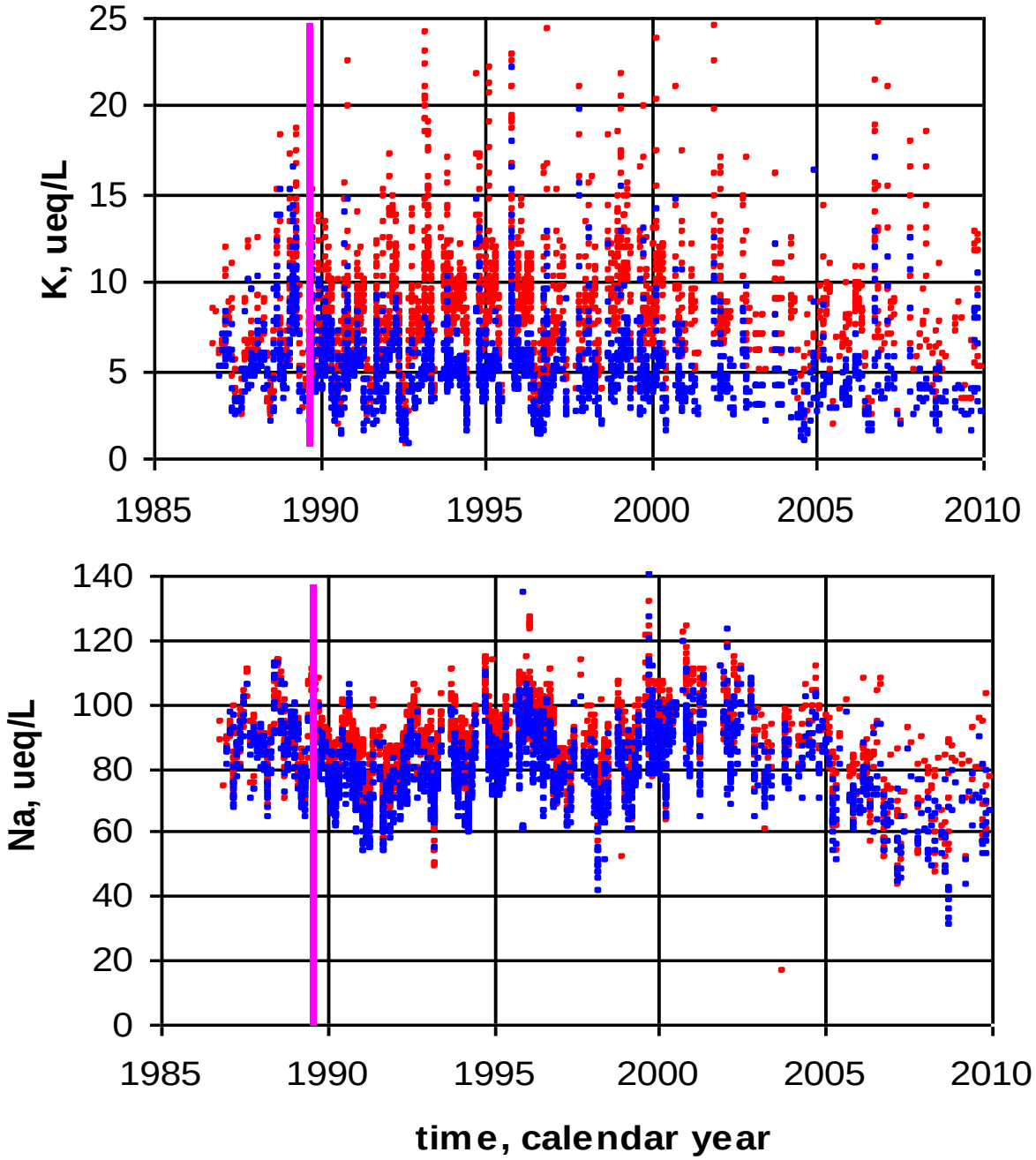


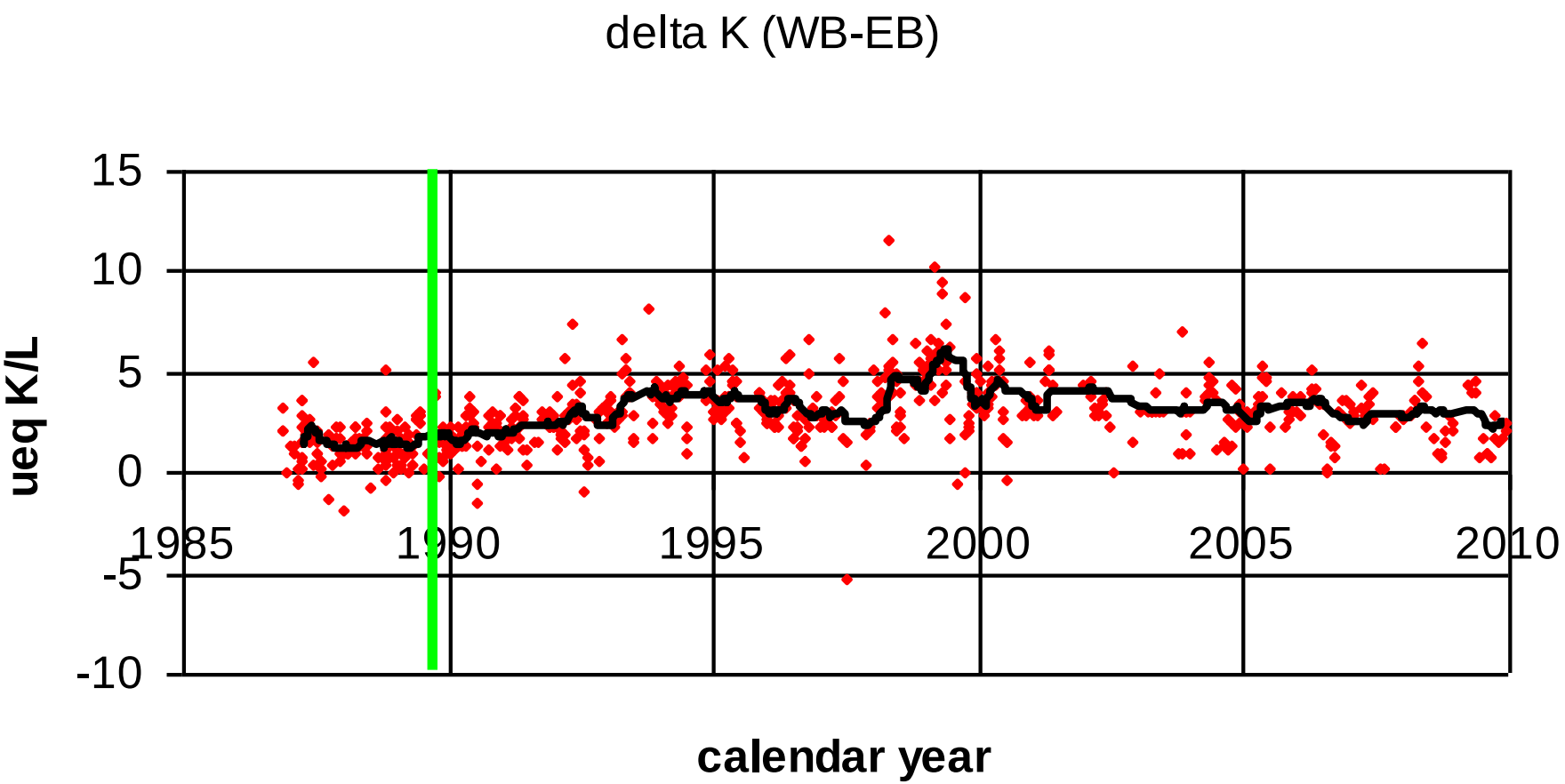

delta Ca (WB-EB)
80
60
40
20
0
-20
-40
-60
1985
1990
1995
2000
2005
2010
ueq Ca/L
calendar year

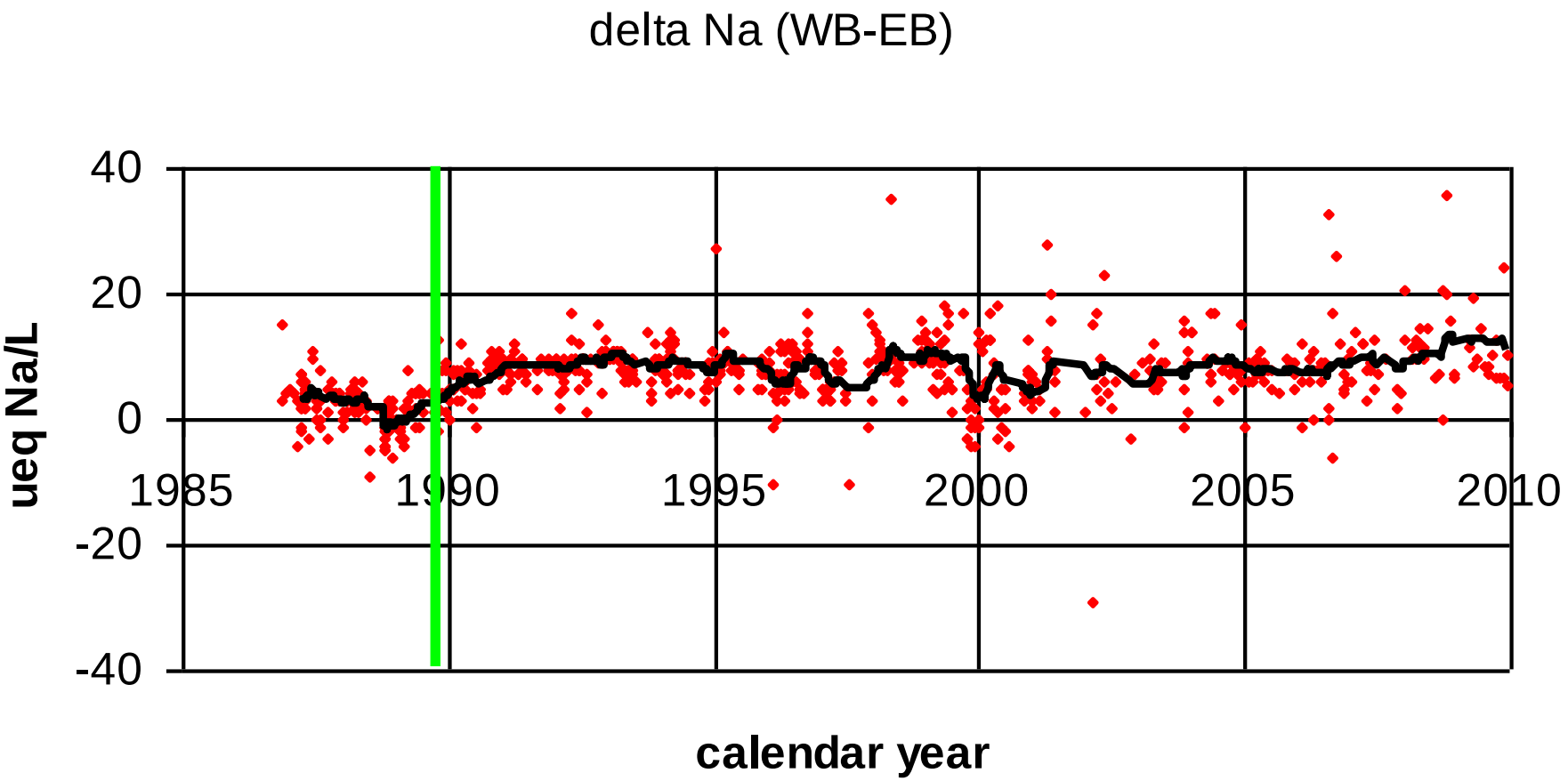

delta Mg (WB-EB)
30
20
10
0
-10
1985
1990
1995
2000
2005
2010
ueq Mg/L
calendar year

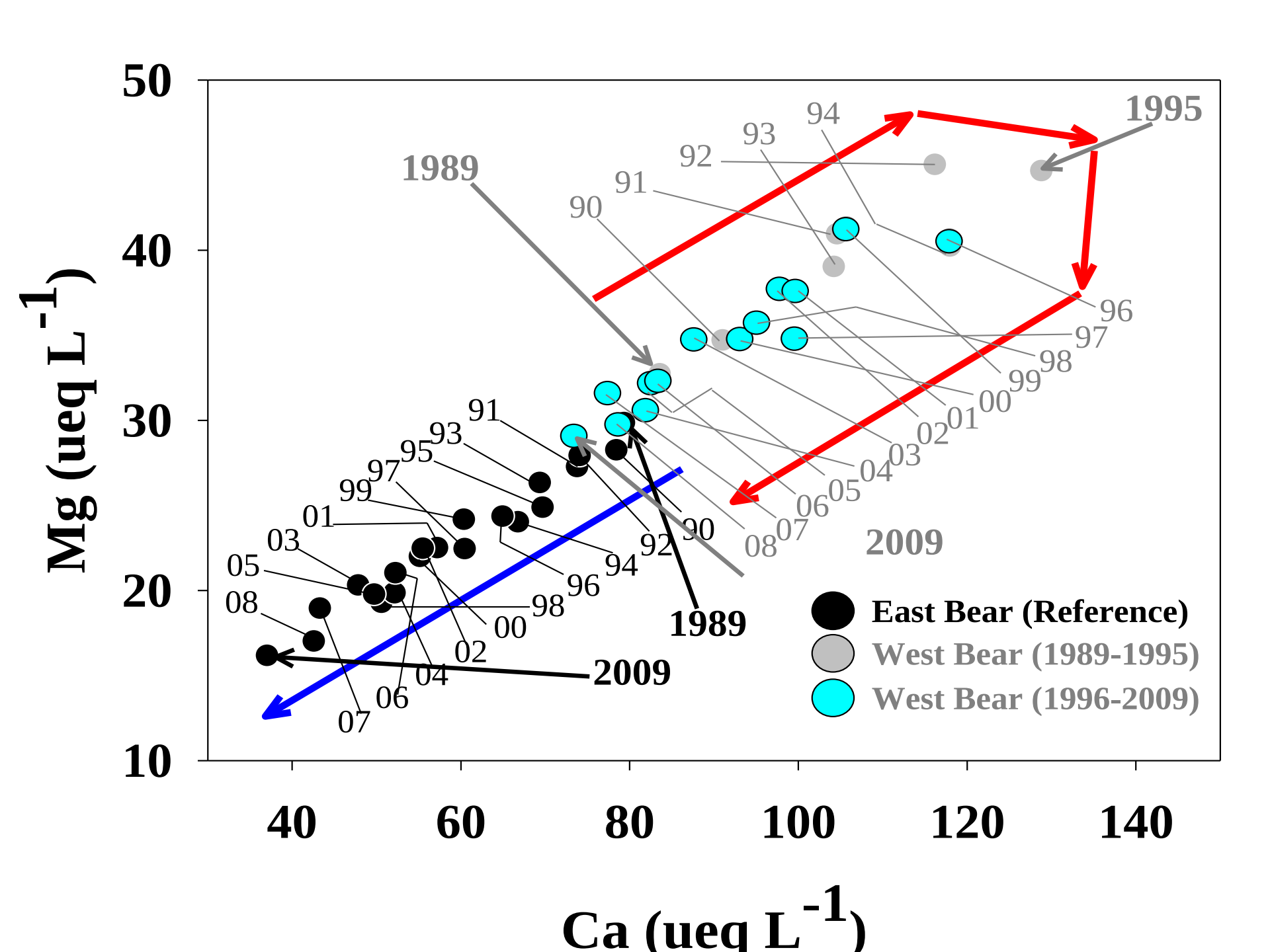
West Bear

East Bear

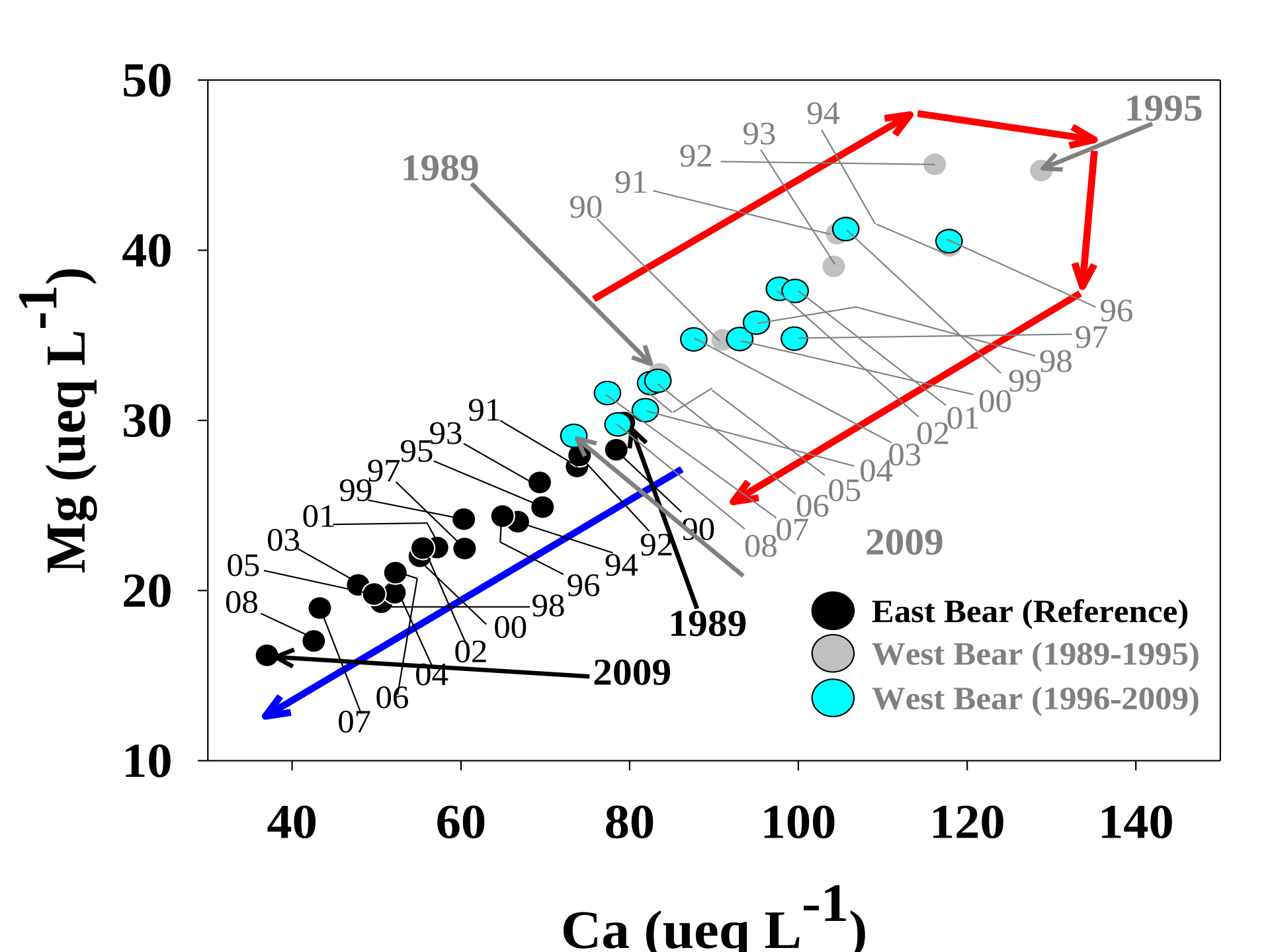



delta K (WB-EB)
15
10
5
0
-5
-10
ueq K/L
1985
1990
1995
2000
2005
2010
calendar year


delta Na (WB-EB)
40
20
0
-20
-40
1985
1990
1995
2000
2005
2010
ueq Na/L
calendar year


50
40
30
20
10
Mg (ueq L-1)
40
60
80
100
120
140
Ca (ueq L-1)
1989
1995
2009
1989
2009
East Bear (Reference)
West Bear (1989-1995)
West Bear (1996-2009)
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07
08


January
1998


50
40
30
20
10
Mg (ueq L-1)
40
60
80
100
120
140
Ca (ueq L-1)
1989
1995
2009
1989
2009
East Bear (Reference)
West Bear (1989-1995)
West Bear (1996-2009)
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07
08

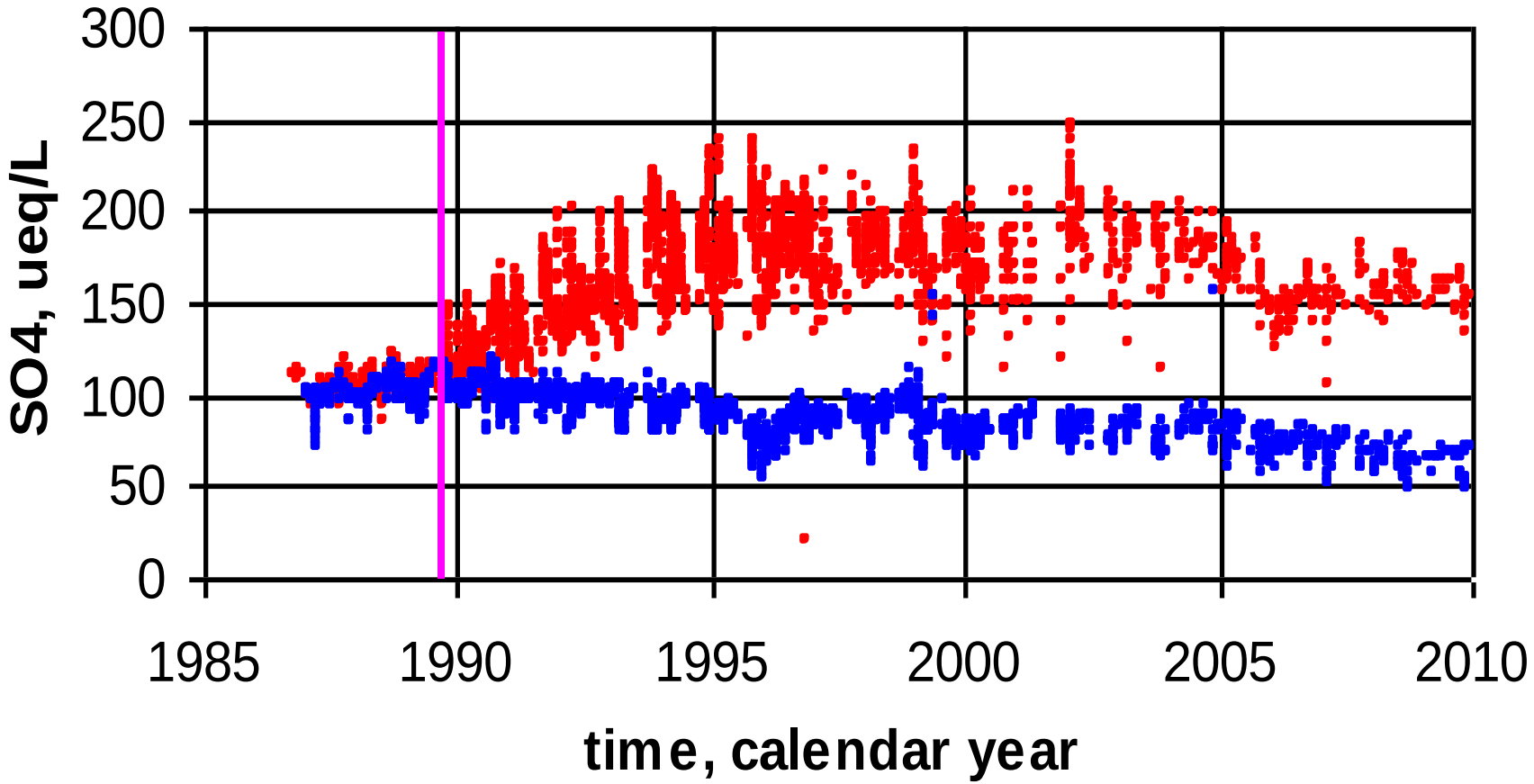
Cumulative Excess Stream Ca Export = 55 kg ha^{-1}

Adjusted West Bear Exchangeable Ca Loss = 47 kg ha^{-1}

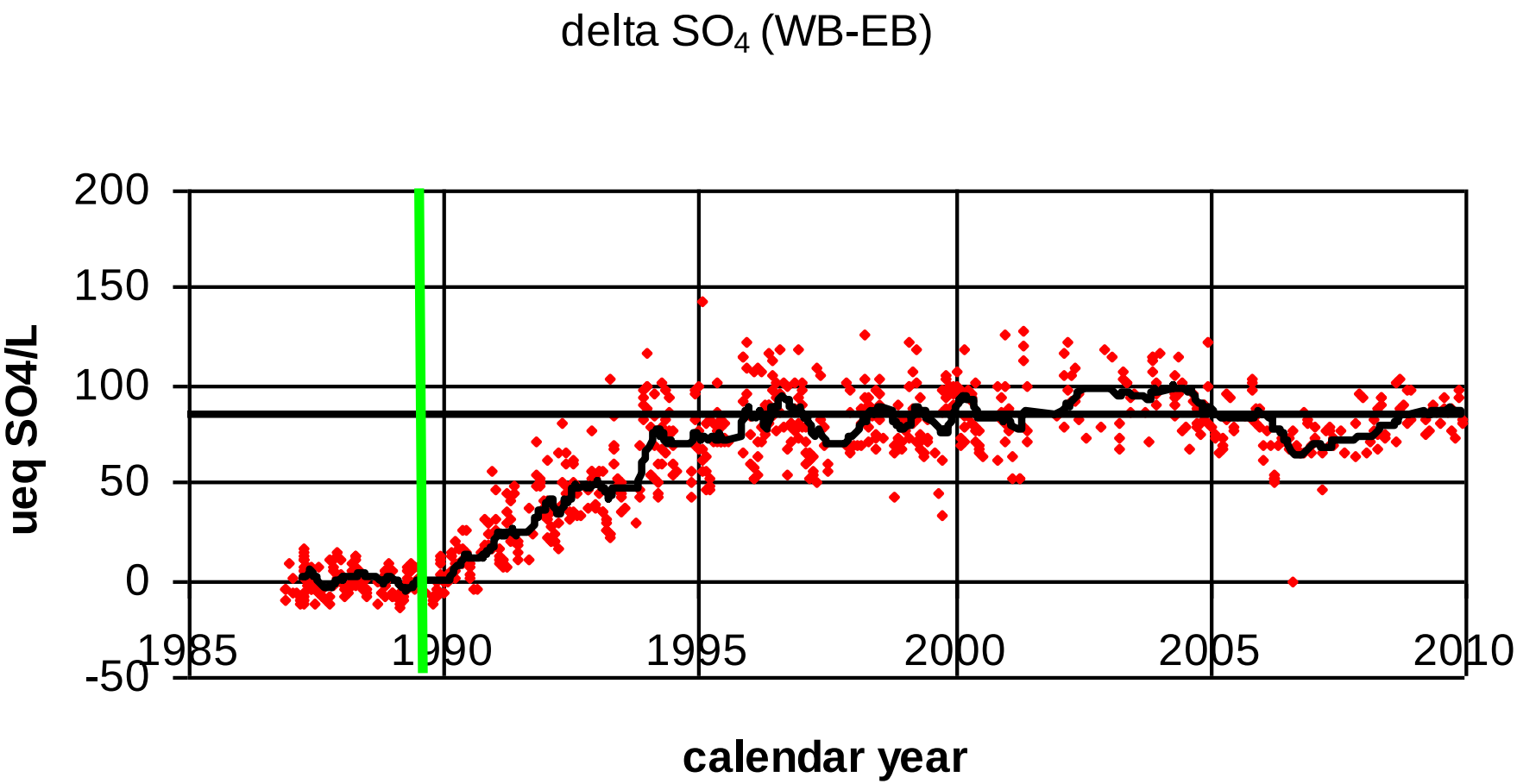
MAGIC Predicted Soil Exchangeable Ca Loss = 45 kg ha^{-1}

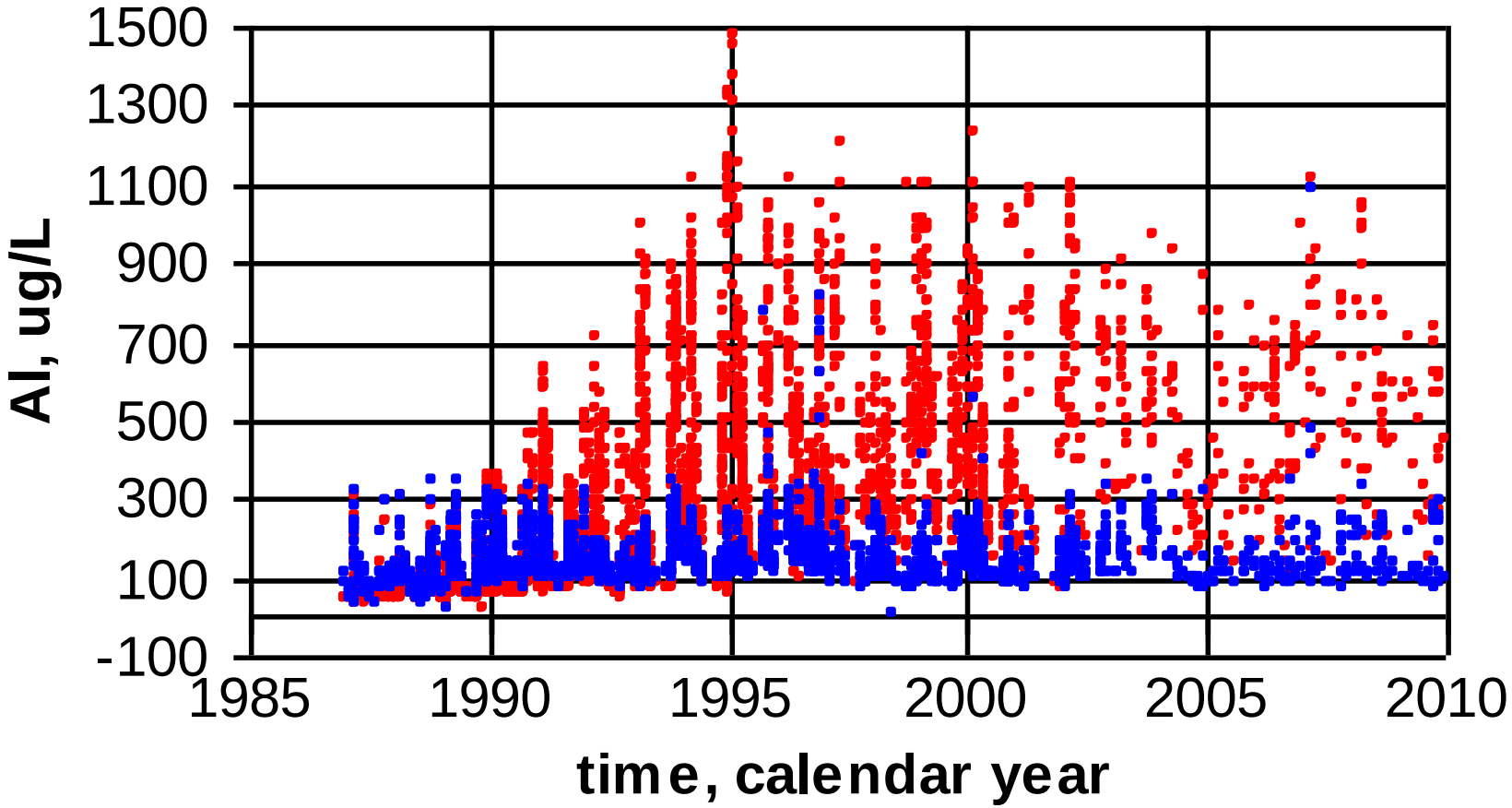
Fernandez et al. 2003

Sulfate Surprises

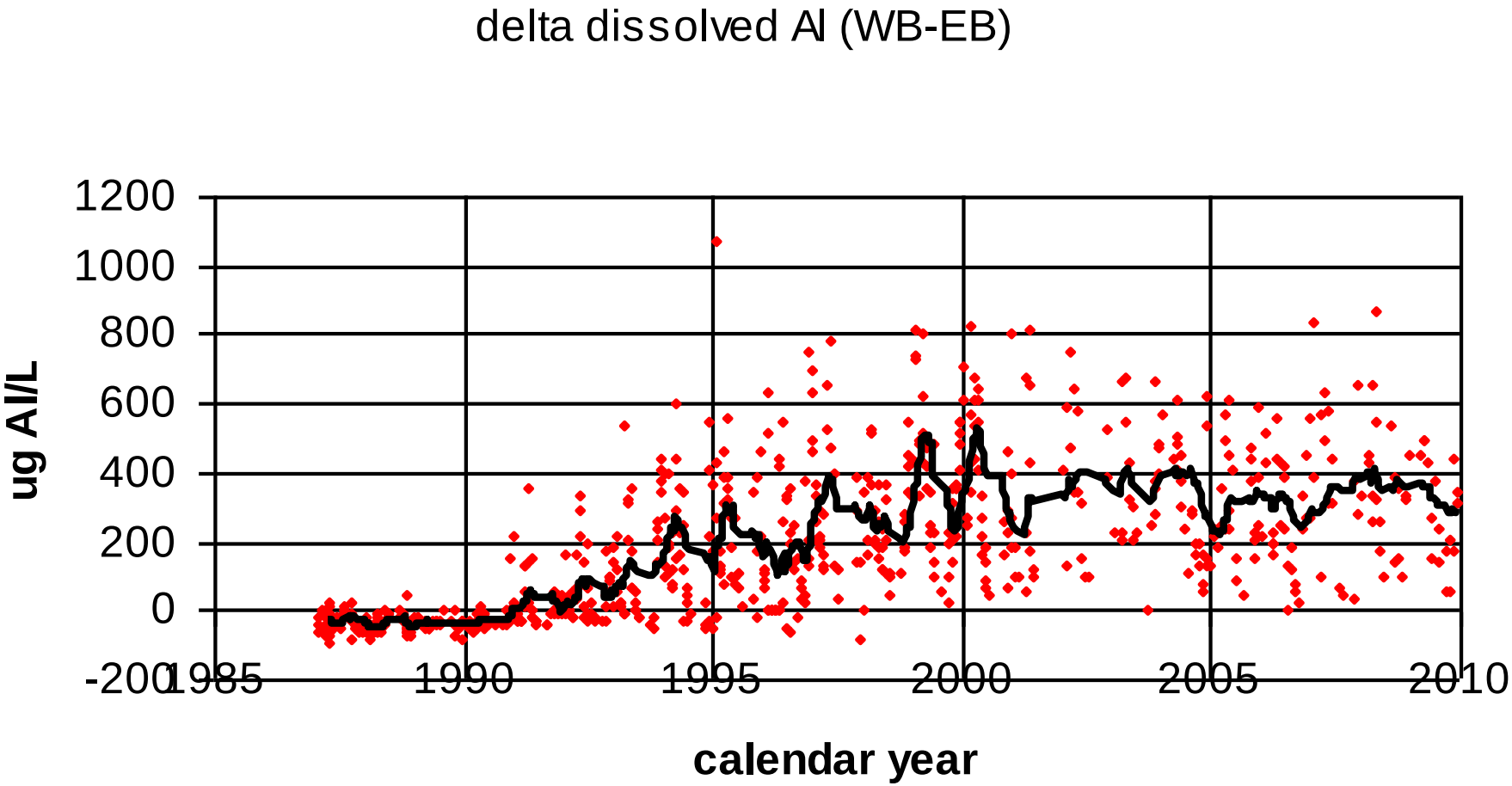


West Bear, East Bear


delta SO_4 (WB-EB)
200
150
100
50
0
-50
ueq SO4/L
1985
1990
1995
2000
2005
2010
calendar year



West Bear, East Bear


delta dissolved Al (WB-EB)
ug Al/L
1200
1000
800
600
400
200
0
-200
1985
1990
1995
2000
2005
2010
calendar year

Alunite = $K(Al)_3(SO_4)_2(OH)_6$

Gibbsite or amorphous equivalent = $Al(OH)_3$

Saturation Index (SI)

SI = log{(Activity Quotient)/(Equilibrium Constant)}

e.g.,

$NaCl = Na^{+1} + Cl^{-1}$

$K_{eq} = (Na^{+1})(Cl^{-1})$, where parentheses denote activity

$= 10^{+1.54}$ at $25^{o}C = K_{eq}$

$SI = \log \{(Na^{+1})(Cl^{-1})/(K_{eq})\}$

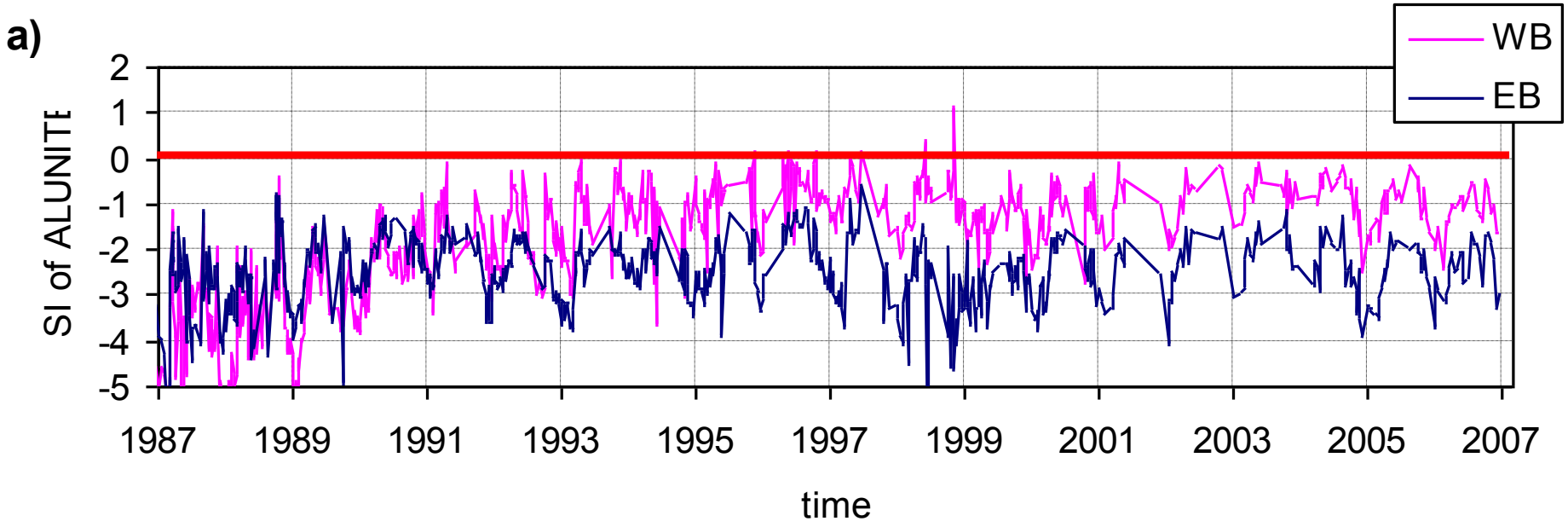
if SI = 0, saturation prevails

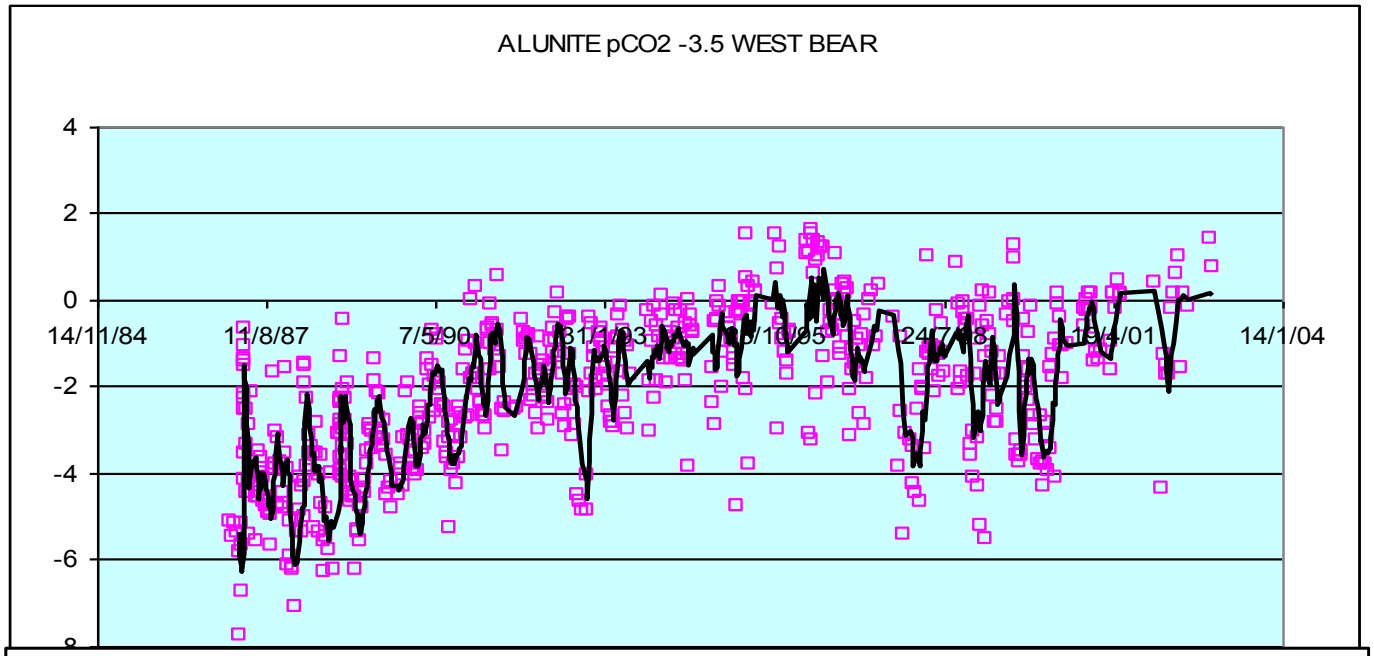
If SI > 0, solution is supersaturated

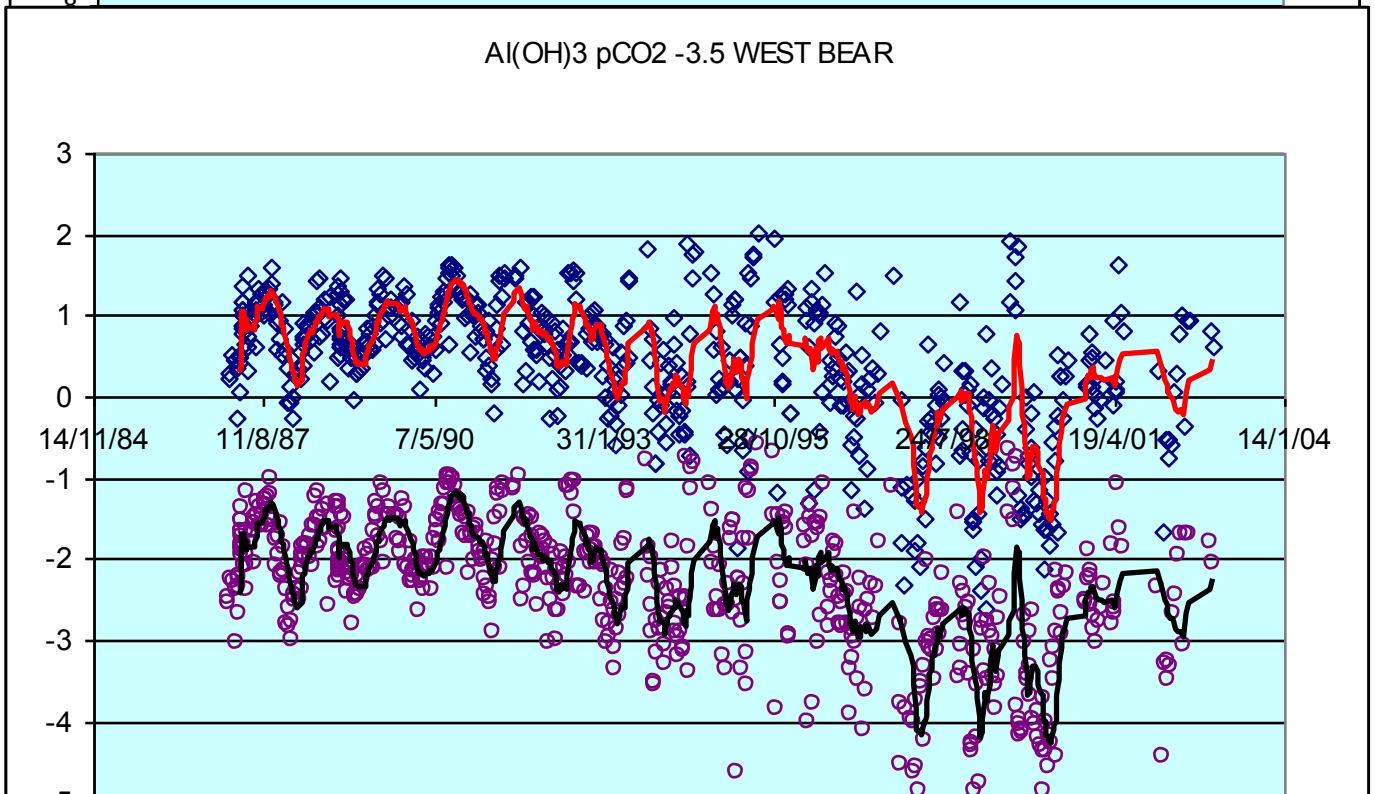
If SI < 0, solution is undersaturated

(All adjusted for T, PCO_2, and ionic strength)

SI for alunite
weekly samples

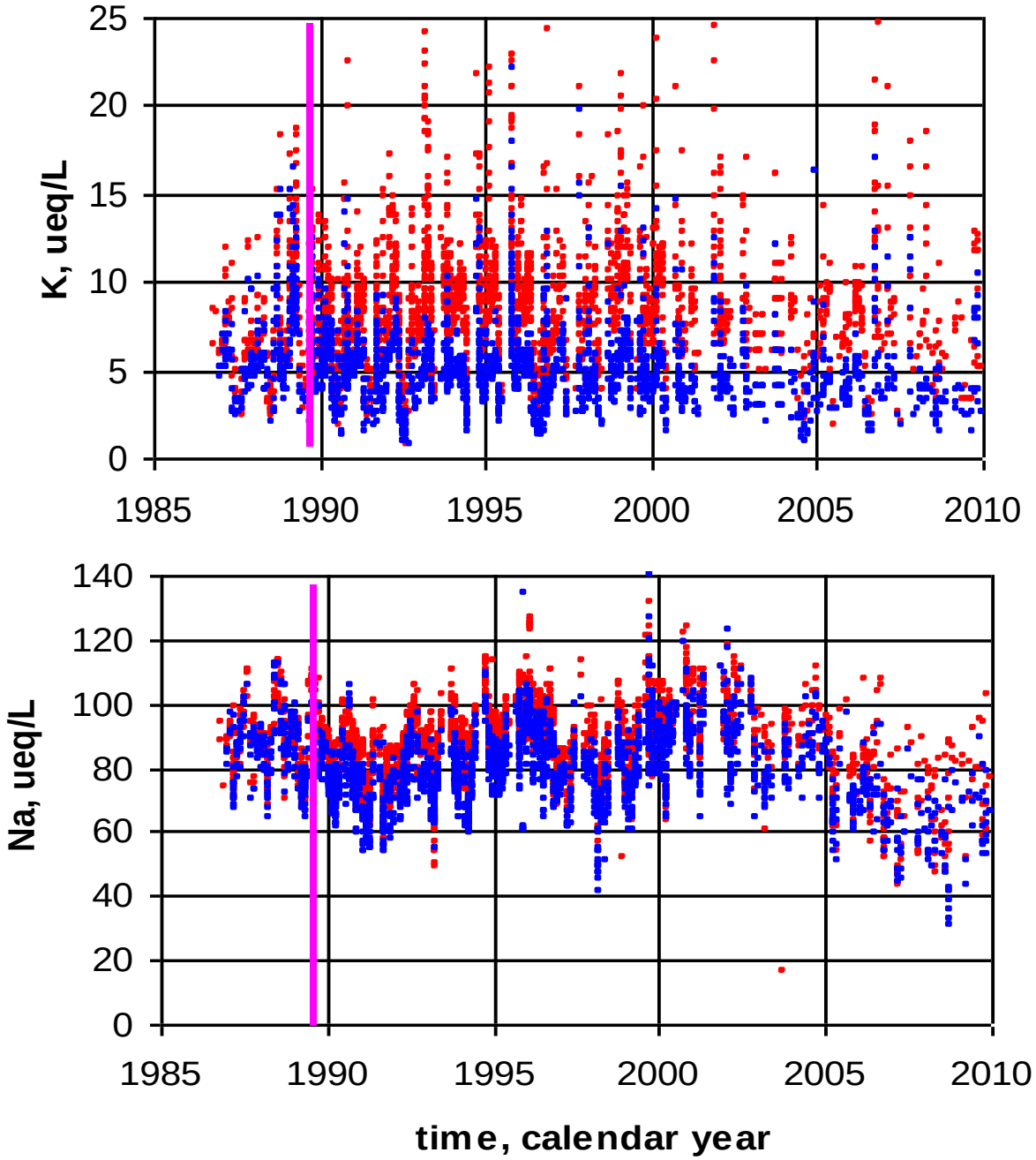


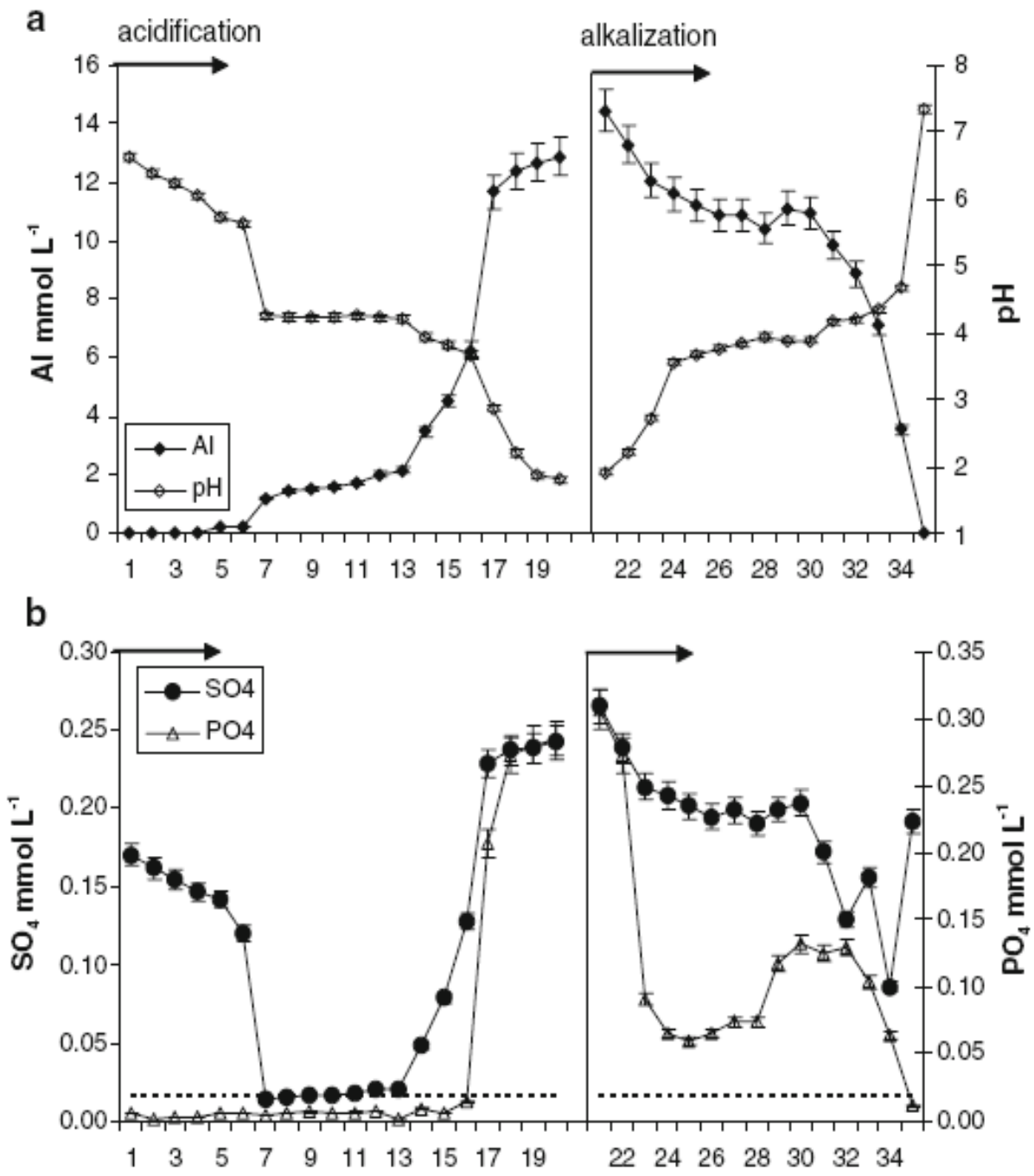

ALUNITE pCO2 -3.5 WEST BEAR
4
2
0
-2
-4
-6
14/11/84
11/8/87
7/5/90
14/1/04


Al(OH)3 pCO2 -3.5 WEST BEAR
3
2
1
0
-1
-2
-3
-4
14/11/84
11/8/87
7/5/90
31/1/93
28/10/95
24/7/98
19/4/01
14/1/04

West Bear

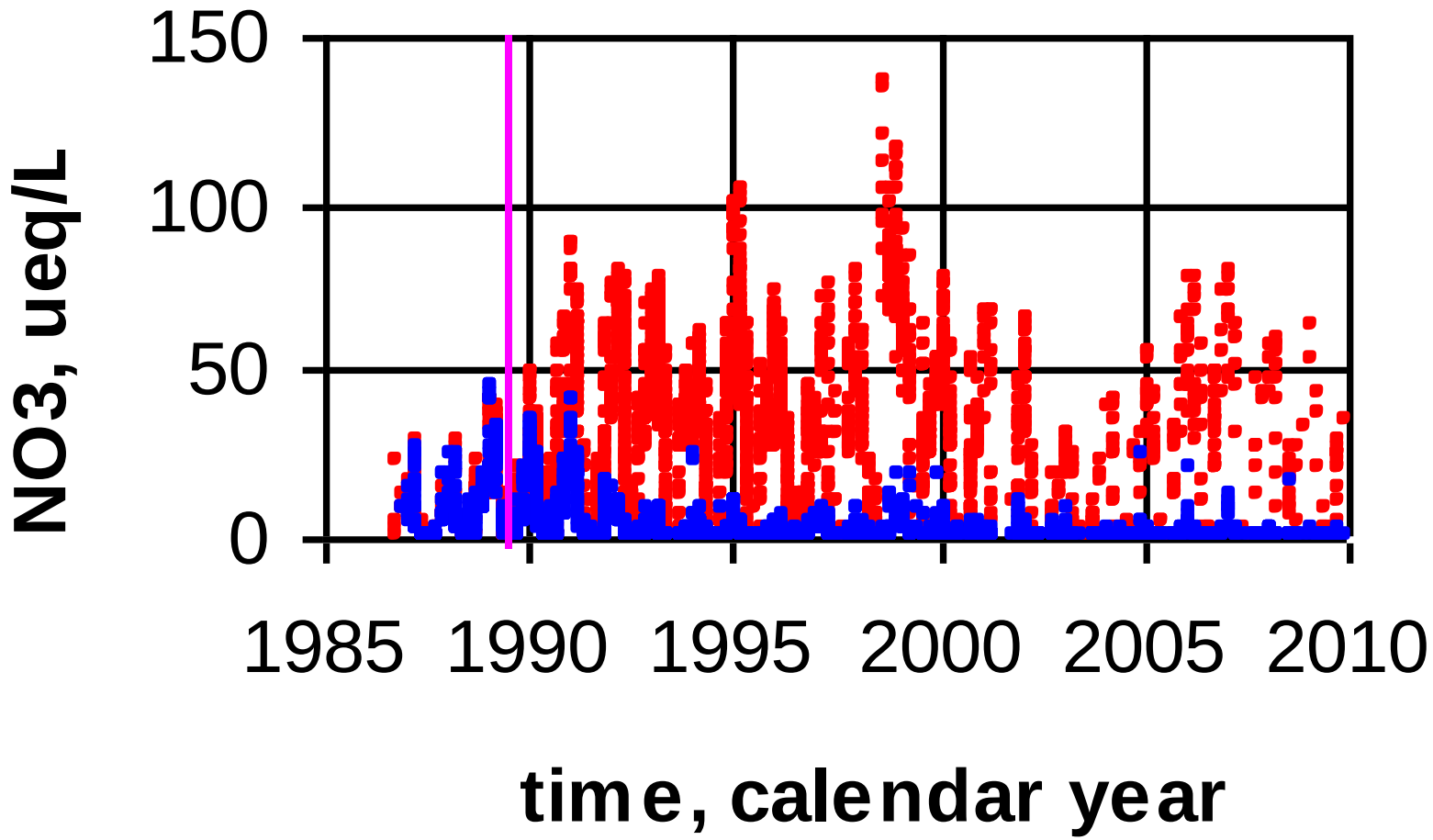
East Bear



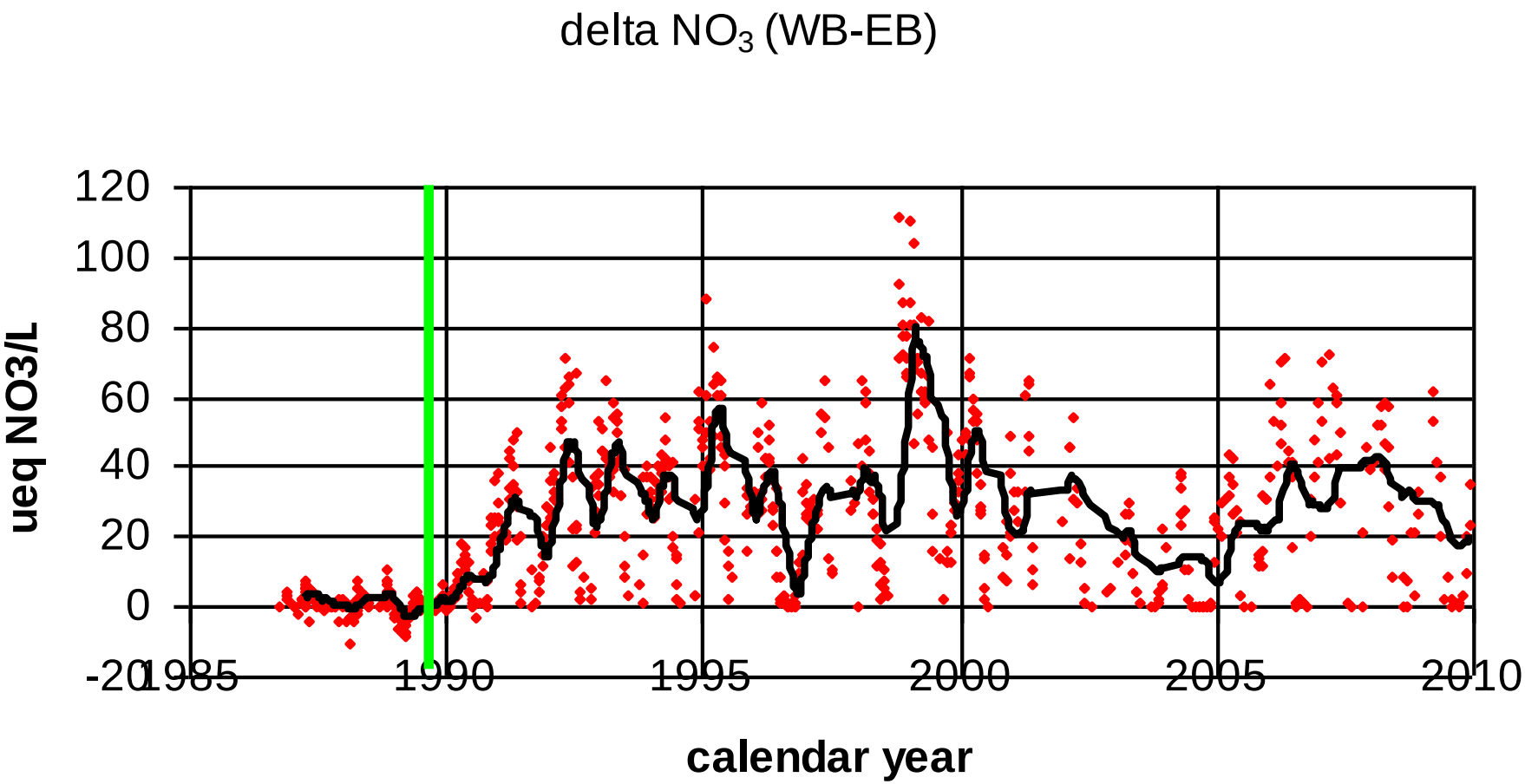


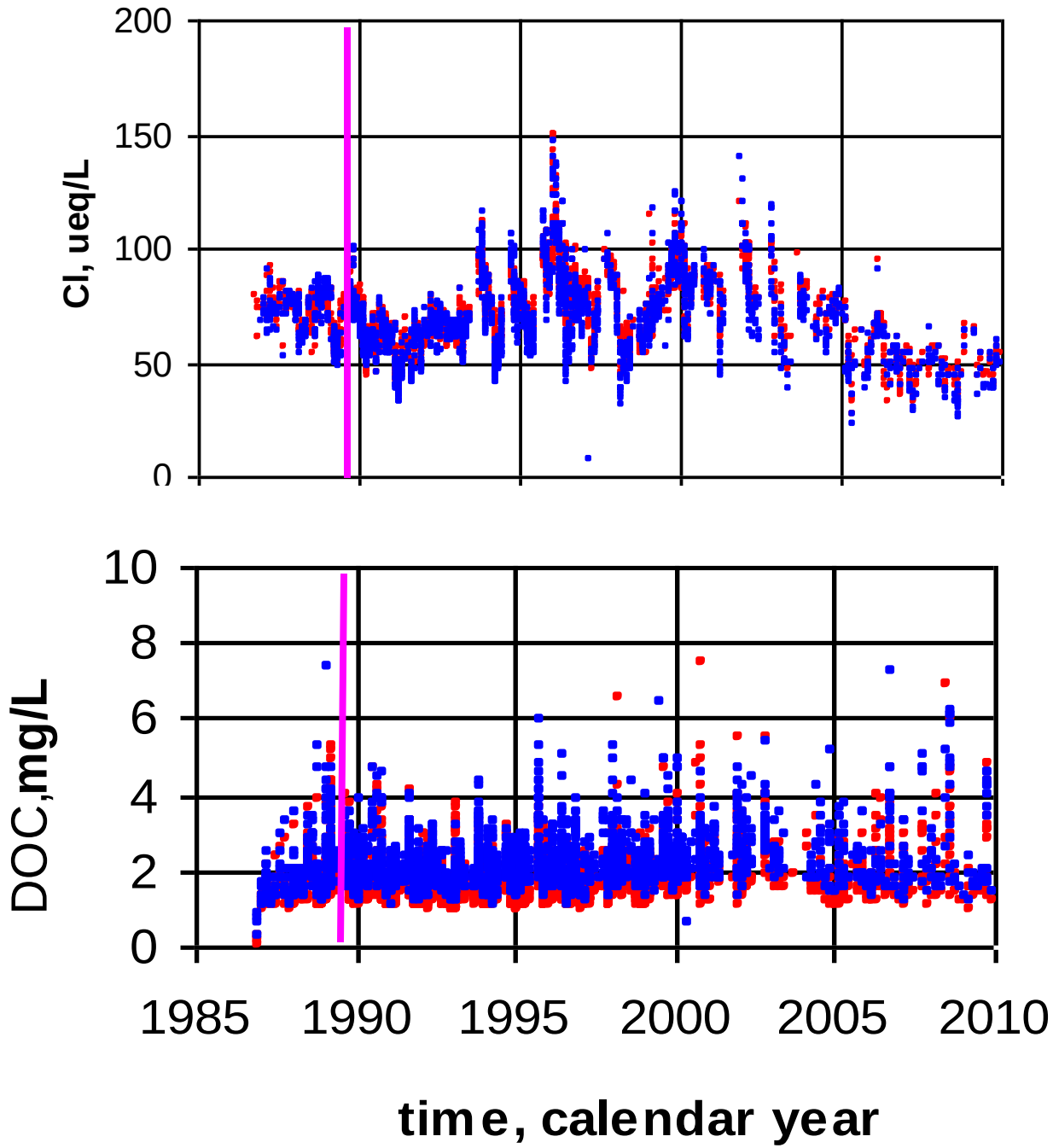
Navrátil et al., 2008

Nitrate Surprises



West Bear, East Bear

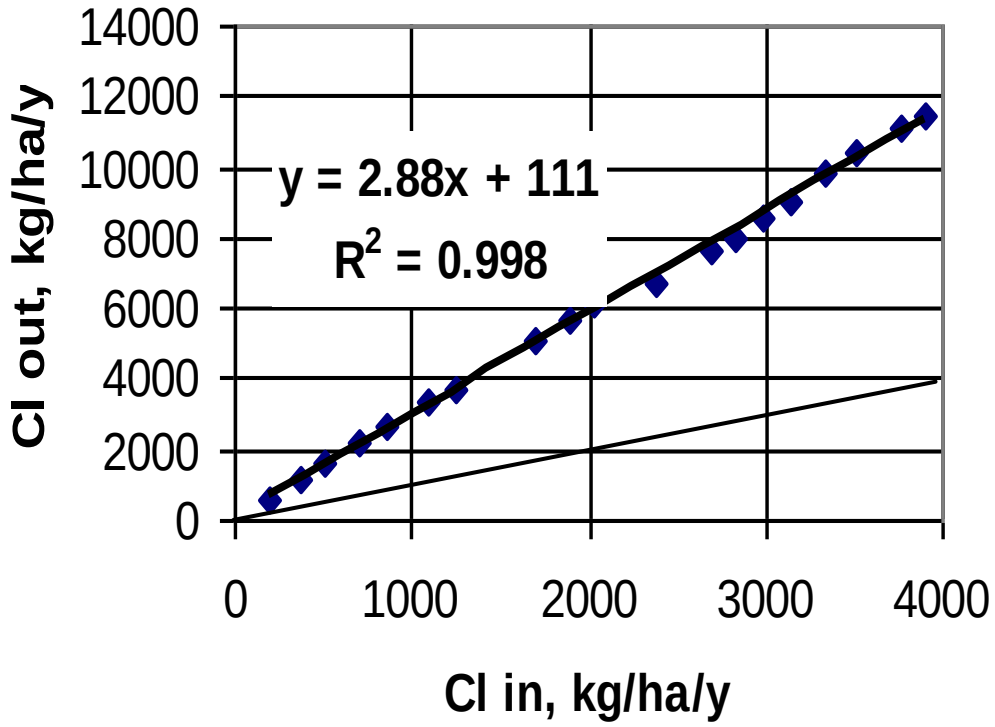

delta NO3 (WB-EB)
120
100
80
60
40
20
0
-20
ueq NO3/L
1985
1990
1995
2000
2005
2010
calendar year


200
150
100
50
0
Cl, ueq/L
10
8
6
4
2
0
DOC,mg/L
1985
1990
1995
2000
2005
2010
time, calendar year

East Bear

1987-2007

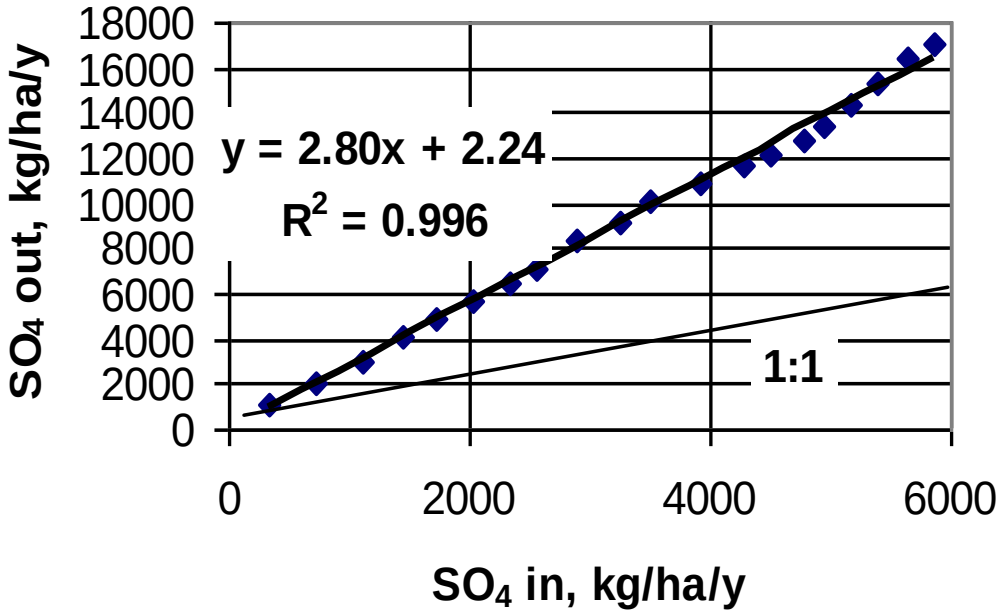
Chloride budget



East Bear

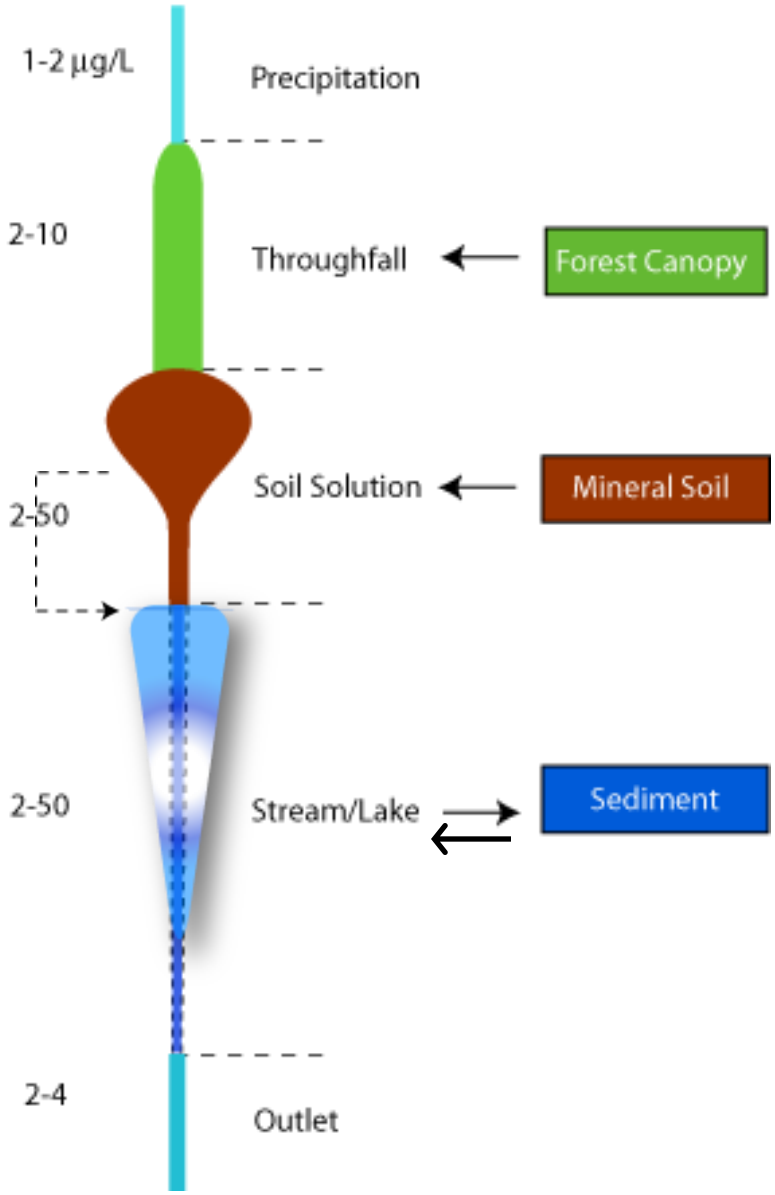
1987-2007

Sulfate budget

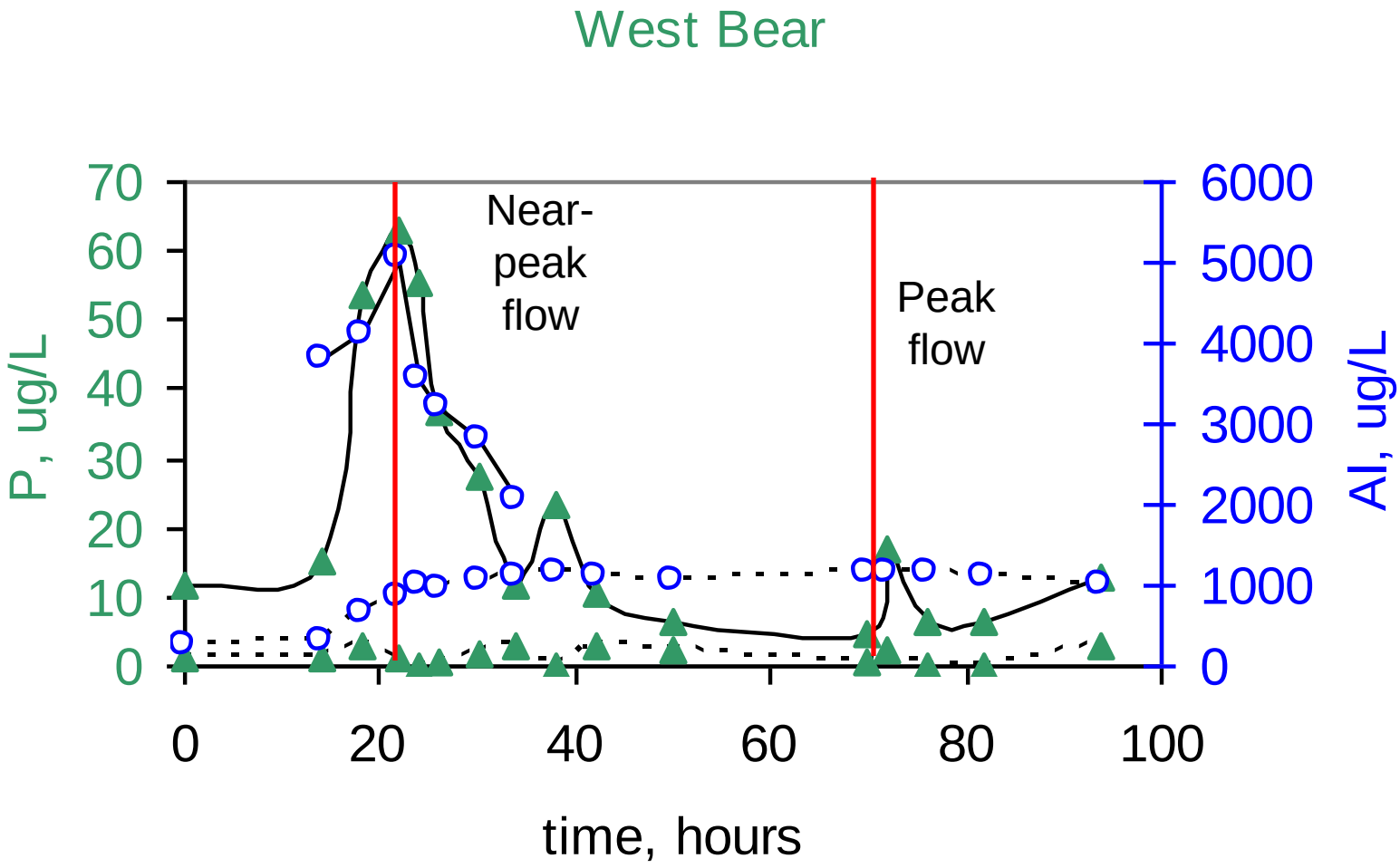


Phosphorus Surprises

Low/High Flow Concentration



Phosphorus concentration in water



modified from Roy et al. 1999

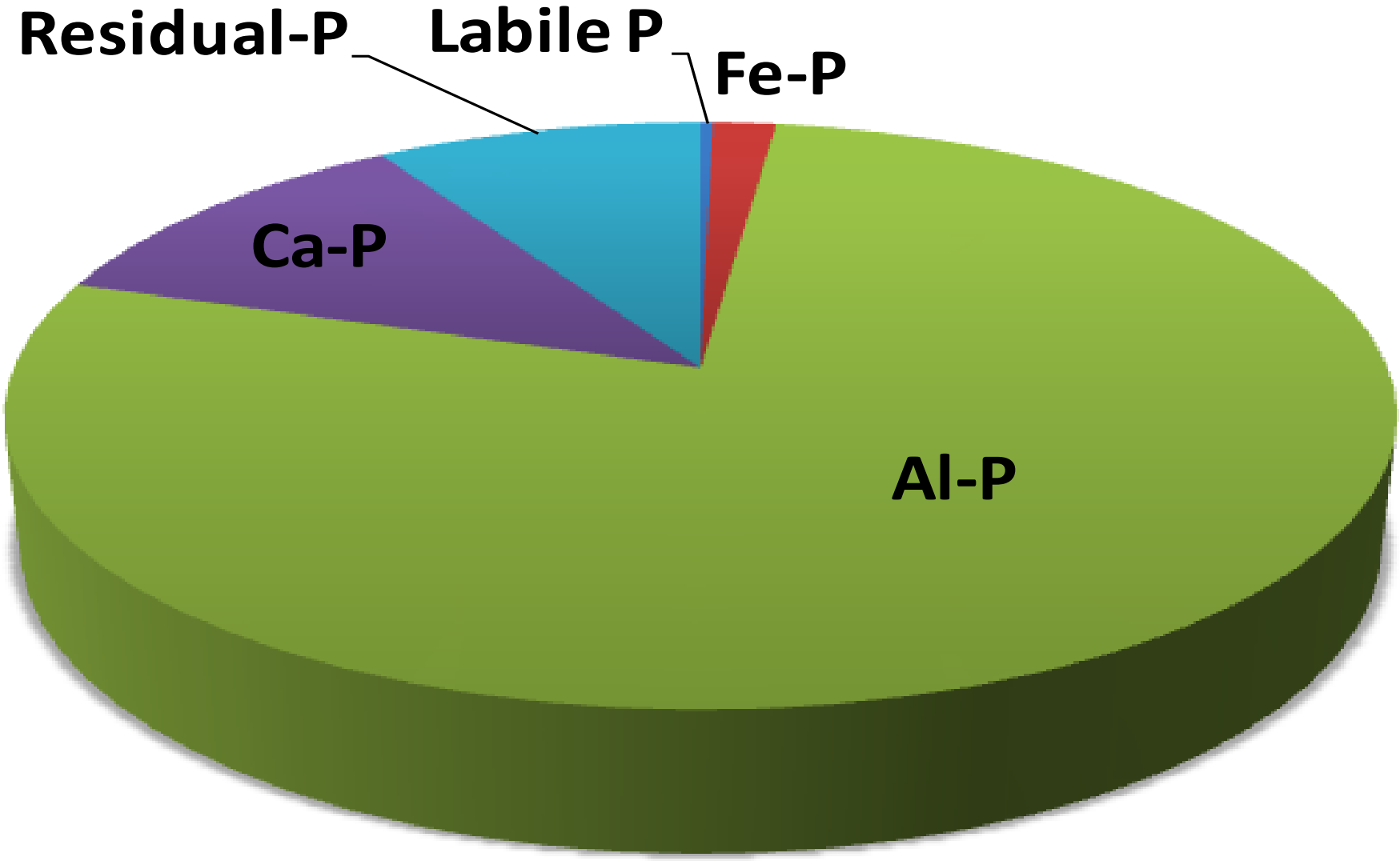
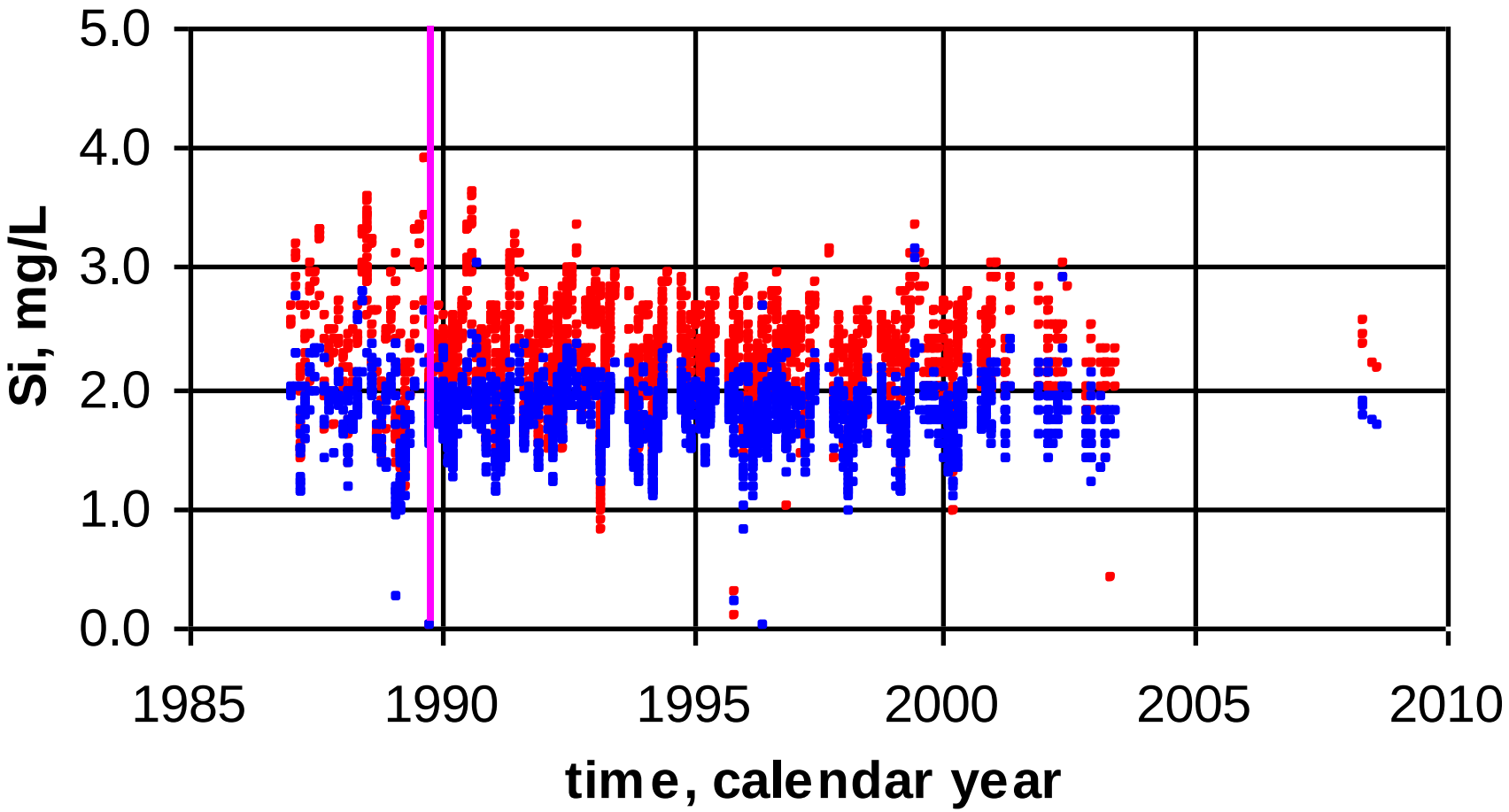
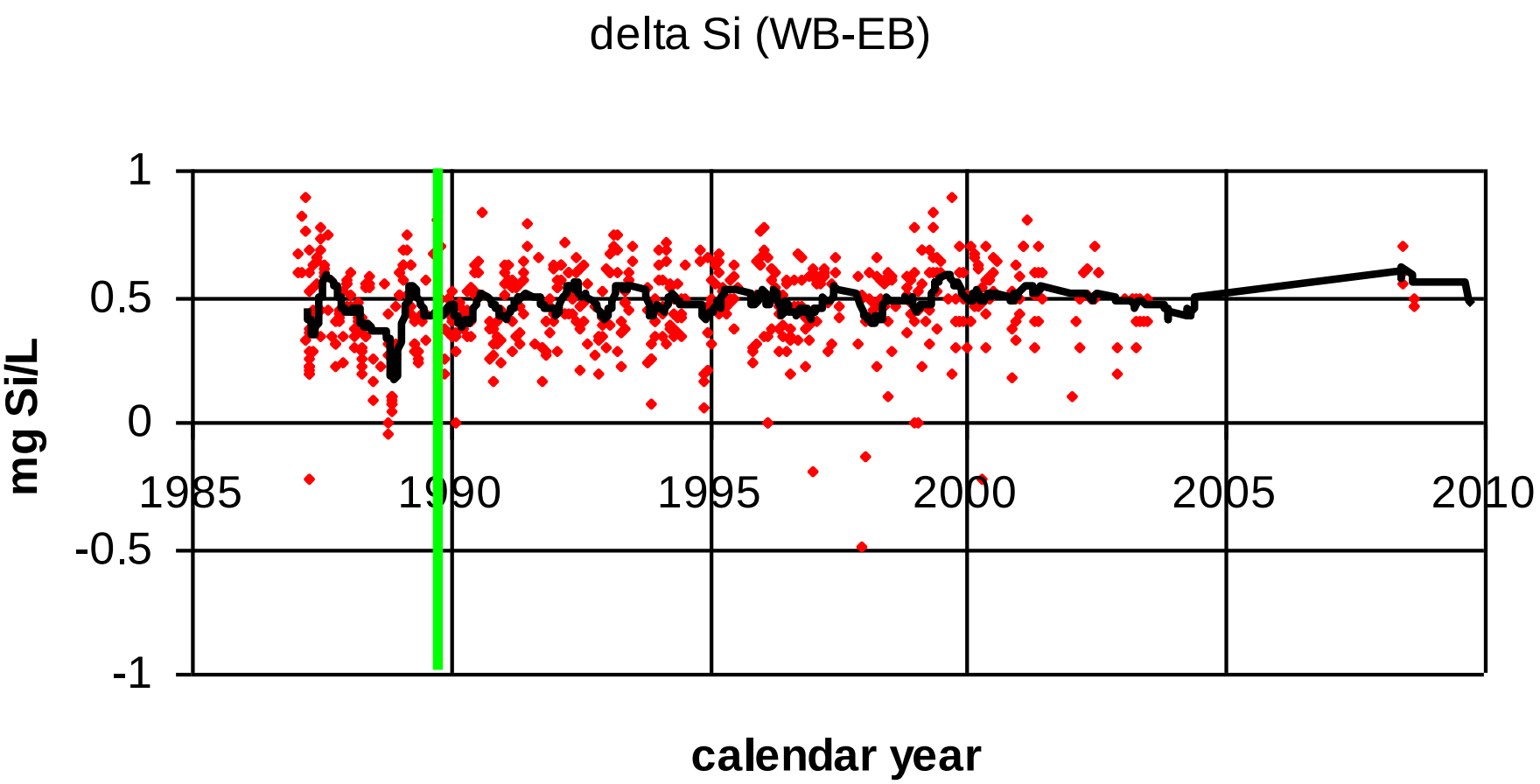
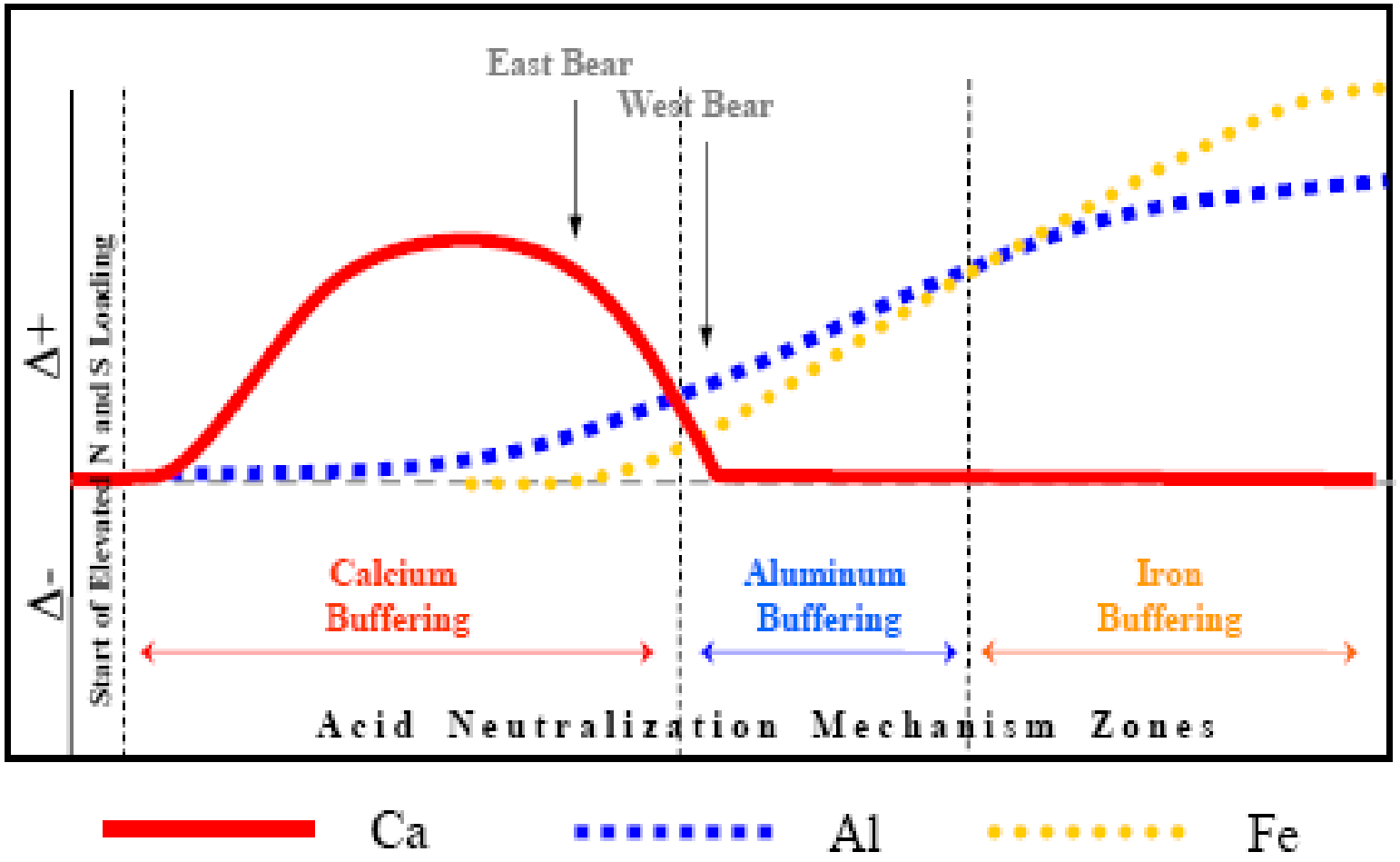


Figure 3 Distribution of P fractions in forest soils at BBWM from a modified Psenner fractionation procedure (SanClements et al. 2010).



West Bear, East Bear


delta Si (WB-EB)
1
0.5
0
-0.5
-1
mg Si/L
1985
1990
1995
2000
2005
2010
calendar year



Conceptual Model of the Progression of Watershed Acid Neutralization Mechanisms

Takk for besøk!

Sporsmåler?