Constraining a Kalman Filter
and
A GPS Relevant Filter

Kai Borre

Copyright © 2011 by Kai Borre

```
%FIXING1    Demonstration of the impact on introducing a constraint
%       with zero variance for the observation

% Written by Kai Borre
% July 1, 1997
% Modified November 2, 2008

A = [-1 0 0 1 0;-1 0 0 0 1;0 0 -1 1 0;0 -1 0 0 1;0 0 0 1 -1];
b = [1.978;0.732;0.988;0.420;1.258];
Cov = eye(5);
x = zeros(5,1);
P = 1.e6*eye(5);
```

Copyright © 2011 by Kai Borre

```
% Regular update
for i = 1:5
   [K,x,P] = k_updateK(x,P,A(i,:),b(i),Cov(i,i))
end

% Update with constraint with variance one
A_aug = [1 1 1 1 1];
b_aug = 100;
Cov_aug = 1;
[K,x,P] = k_updateK(x,P,A_aug,b_aug,Cov_aug);
K, x
Sigma = (norm(b-A*x))^2*P
```

Copyright © 2011 by Kai Borre

```
% Update with constraint with variance zero
Cov_aug = 0;
b_aug = 0;
[K,x,P] = k_updateK(x,P,A_aug,b_aug,Cov_aug);
K, x
Sigma_plus = (norm(b - A*x))^2*P

Cov_aug = 1;
b_aug = 0;
[K,x,P] = k_updateK(x,P,A_aug,b_aug,Cov_aug);
K, x
```

Copyright © 2011 by Kai Borre

```
>> fixing1
K =
        -0.50  % 1st observation
         0
         0
         0.50
         0
x =
        -0.99
         0
         0
         0.99
         0
P =
   500000.25         0         0   499999.75         0
         0   1000000.00         0         0         0
         0         0   1000000.00         0         0
   499999.75         0         0   500000.25         0
         0         0         0         0   1000000.00
```

Copyright © 2011 by Kai Borre

```
K =
        -0.33  % 2nd observation
         0
         0
        -0.33
         0.67
x =
        -0.90
         0
         0
         1.07
        -0.17
P =
    333333.56         0         0    333333.22    333333.22
         0    1000000.00         0         0          0
         0         0    1000000.00         0          0
    333333.22         0         0    333333.89    333332.89
    333333.22         0         0    333332.89    333333.89
```

Copyright © 2011 by Kai Borre

K =

0.25 % 3rd observation

0

−0.75

0.25

0.25

x =

−0.92

0

0.06

1.05

−0.19

P =

250000.37	0	249999.63	249999.88	250000.12
0	1000000.00	0	0	0
249999.63	0	250000.87	250000.12	249999.38
249999.88	0	250000.12	250000.37	249999.63
250000.12	0	249999.38	249999.63	250000.87

Copyright © 2011 by Kai Borre

K =

0.20 % 4th observation

−0.80

0.20

0.20

0.20

x =

−0.80

−0.49

0.19

1.18

−0.07

P =

200000.40	199999.80	199999.80	200000.00	200000.00
199999.80	200001.20	199999.20	199999.40	200000.40
199999.80	199999.20	200001.20	200000.40	199999.40
200000.00	199999.40	200000.40	200000.60	199999.60
200000.00	200000.40	199999.40	199999.60	200000.60

Copyright © 2011 by Kai Borre

K =

−0.00 % 5th observation
−0.33
 0.33
 0.33
−0.33

x =

−0.80
−0.49
 0.19
 1.18
−0.07

P =

200000.40	199999.80	199999.80	200000.00	200000.00
199999.80	200000.87	199999.53	199999.73	200000.07
199999.80	199999.53	200000.87	200000.07	199999.73
200000.00	199999.73	200000.07	200000.27	199999.93
200000.00	200000.07	199999.73	199999.93	200000.27

Copyright © 2011 by Kai Borre

K =

0.20 % Condition: var = 1; A_aug = [1 1 1 1 1]; b_aug = 100;

0.20

0.20

0.20

0.20

x =

19.20

19.51

20.19

21.18

19.93

Sigma =

0.00	−0.00	−0.00	0.00	0.00
−0.00	0.00	−0.00	−0.00	0.00
−0.00	−0.00	0.00	0.00	−0.00
0.00	−0.00	0.00	0.00	−0.00
0.00	0.00	−0.00	−0.00	0.00

Copyright © 2011 by Kai Borre

K =

0.20 % Condition: var = 0;
0.20
0.20
0.20
0.20

x =

−0.80
−0.49
0.19
1.18
−0.07

Sigma_plus =

0.00	−0.00	−0.00	−0.00	−0.00
−0.00	0.00	−0.00	−0.00	0.00
−0.00	−0.00	0.00	0.00	−0.00
−0.00	−0.00	0.00	0.00	−0.00
−0.00	0.00	−0.00	−0.00	0.00

Copyright © 2011 by Kai Borre

K =

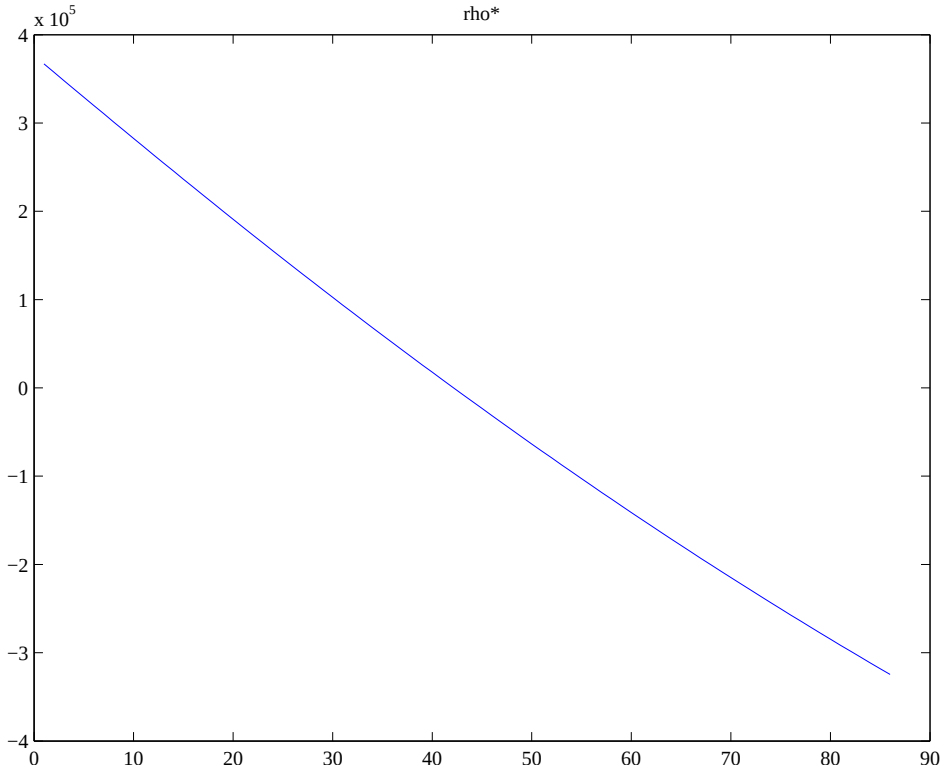
−0.00
−0.00
0
0
0

x =

−0.80
−0.49
0.19
1.18
−0.07

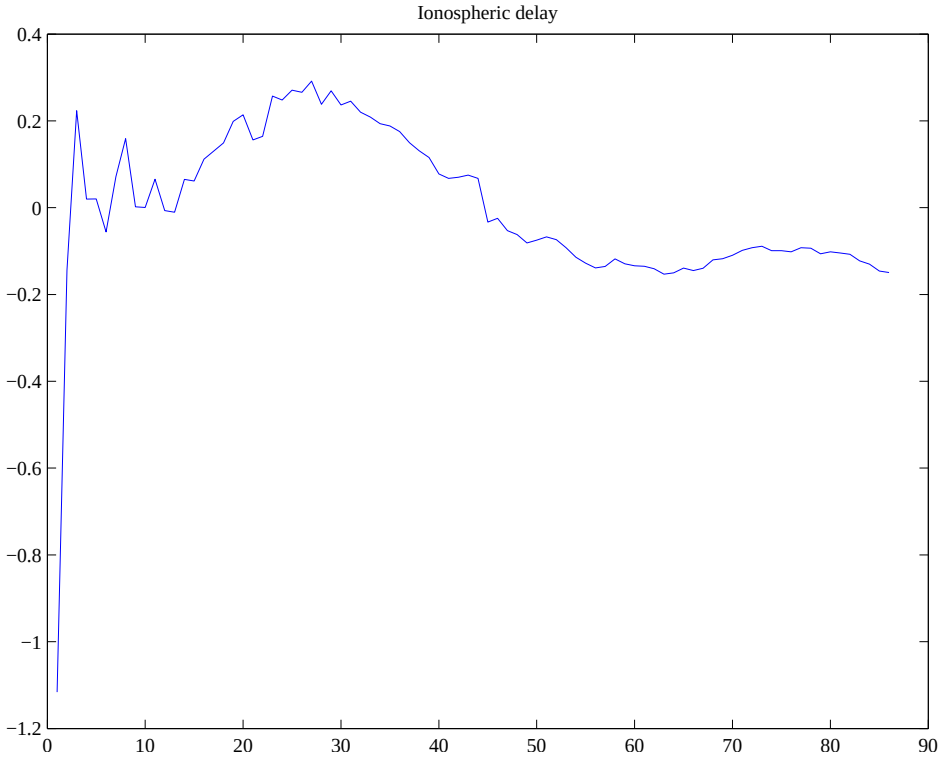
Copyright © 2011 by Kai Borre

Pseudorange ρ^*



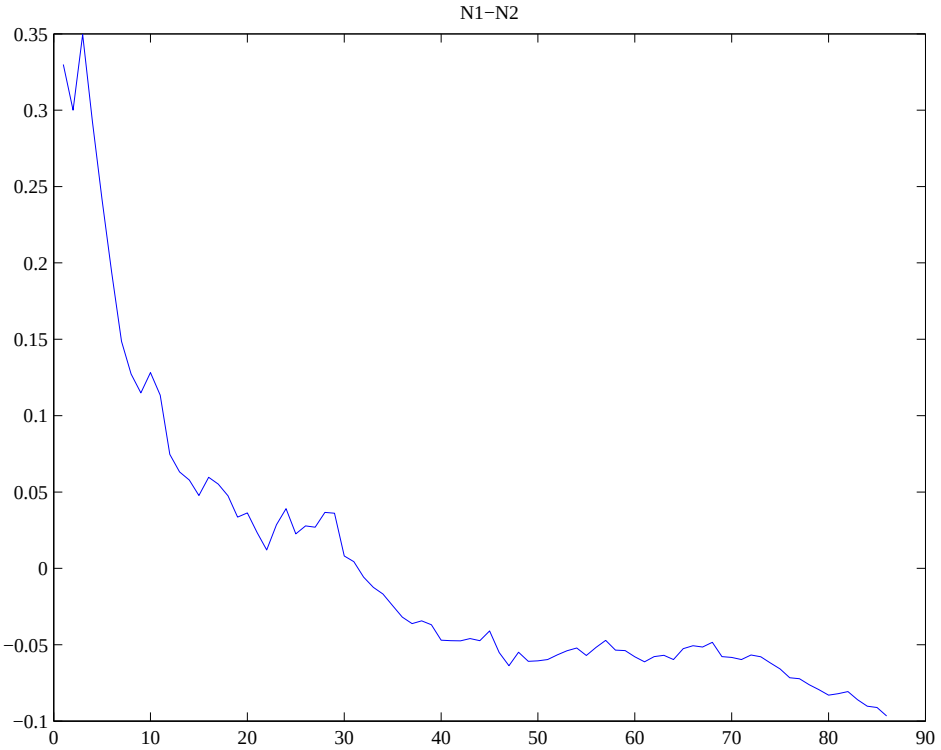
Copyright © 2011 by Kai Borre

Ionospheric delay *I*



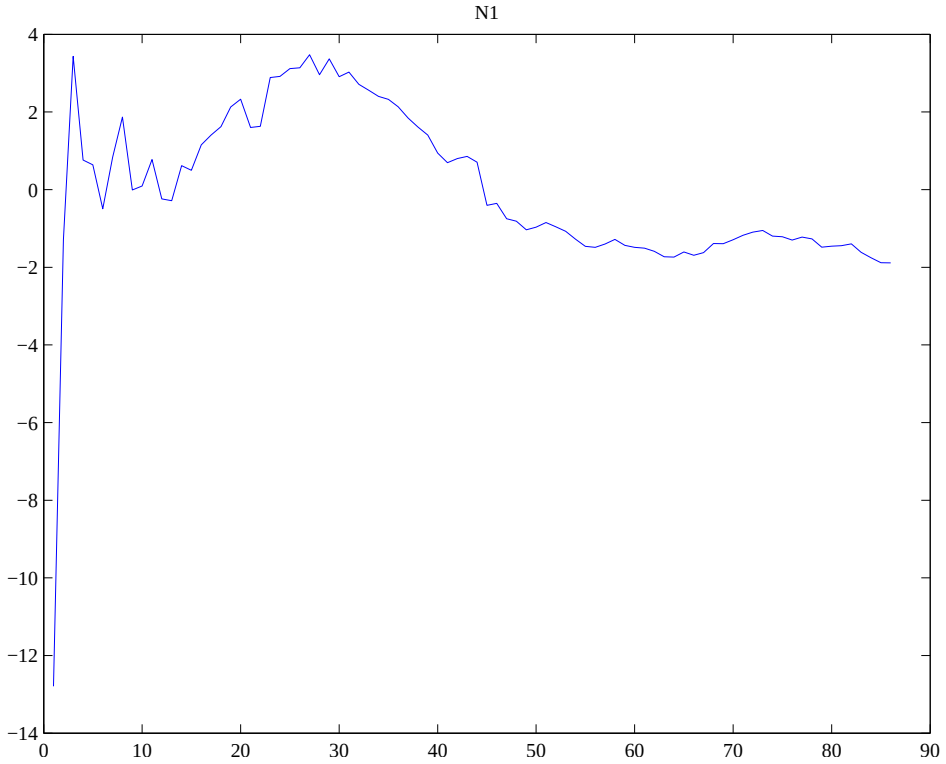
Copyright © 2011 by Kai Borre

Ambiguity $N_1 - N_2$



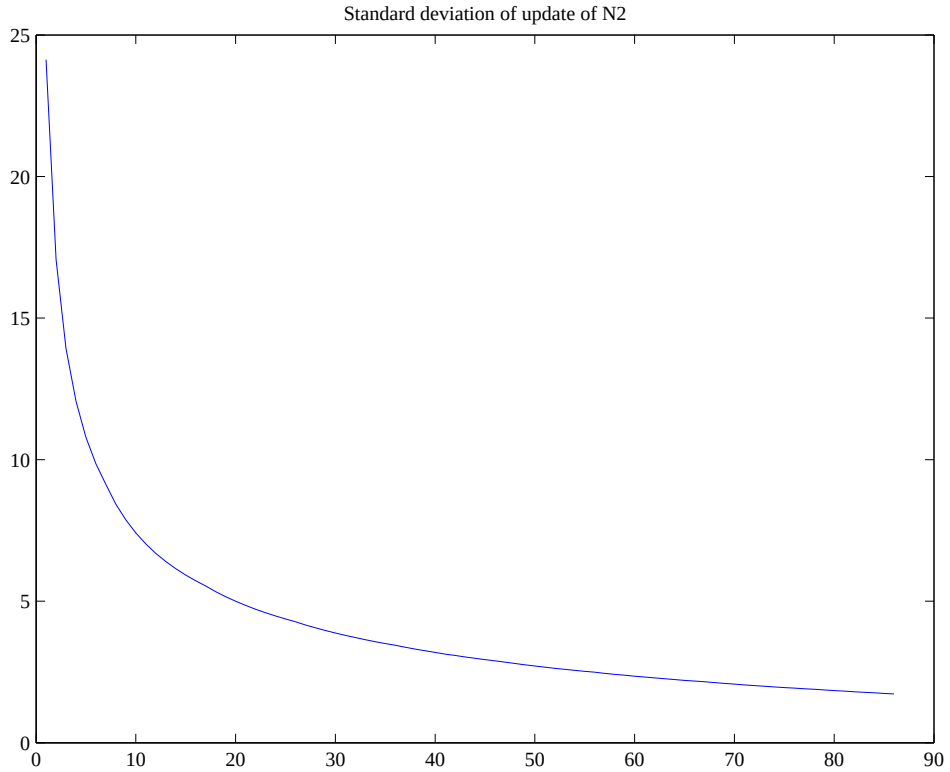
Copyright © 2011 by Kai Borre

Ambiguity N_1



Copyright © 2011 by Kai Borre

Standard deviation of update of N_2



Copyright © 2011 by Kai Borre

Ambiguities as estimated by filtering of one-ways

PRN	Linear Comb.	Master M	Rover R	SD $= M - R$	DD $=$ $\mathrm{SD}_{26} - \mathrm{SD}_i$	Exact DD	Elevation (degrees)
2	$N_1 - N_2$	−27 965 804.3	−24 897 335.6	−3 068 468.7	−104 539.9	−104 540	59–61
	N_1	−126 566 312.1	−112 753 467.5	−13 812 844.6	−458 650.7	−458 650	
9	$N_1 - N_2$	−30 299 948.8	−28 466 967.2	−1 832 981.6	−1 340 027.0	−1 340 027	*14–25*
	N_1	−137 064 692.1	−128 875 084.1	−8 189 608.0	−6 081 887.3	−6 081 889	
16	$N_1 - N_2$	−25 853 811.1	−26 599 158.2	745 347.1	−3 918 355.7	−3 918 356	30–17
	N_1	−117 099 419.5	−120 568 534.1	3 469 114.6	−17 740 609.9	−17 740 609	
23	$N_1 - N_2$	−31 520 321.4	−28 336 205.6	−3 184 115.8	11 107.2	11 107	*17–25*
	N_1	−141 013 589.3	−128 295 732.5	−12 717 856.8	−1 553 638.5	−1 553 637	
26	$N_1 - N_2$	−27 574 563.2	−24 401 554.6	−3 173 008.6			66–75
	N_1	−124 770 191.1	−110 498 695.8	−14 271 495.3			
27	$N_1 - N_2$	−25 222 330.2	−25 755 098.4	532 768.2	−3 705 776.8	−3 705 777	35–23
	N_1	−114 238 281.7	−116 723 571.7	2 485 290.0	−16 756 785.3	−16 756 785	

Copyright © 2011 by Kai Borre