University of New Brunswick – Nav Canada

Atmospheric Investigations for WAAS

Troposphere

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Presented at U.N.B., Fredericton, New Brunswick.

April 6th – 7th 1998

Current Developments

- Obtained radiosonde data for North America.
- Investigated other data sources, e.g. British Atmospheric Data Centre (BADC) has radiosonde data for Europe on-line.
- Obtained and written software for data processing.
- Investigated suitable statistical methods for investigating extremes.

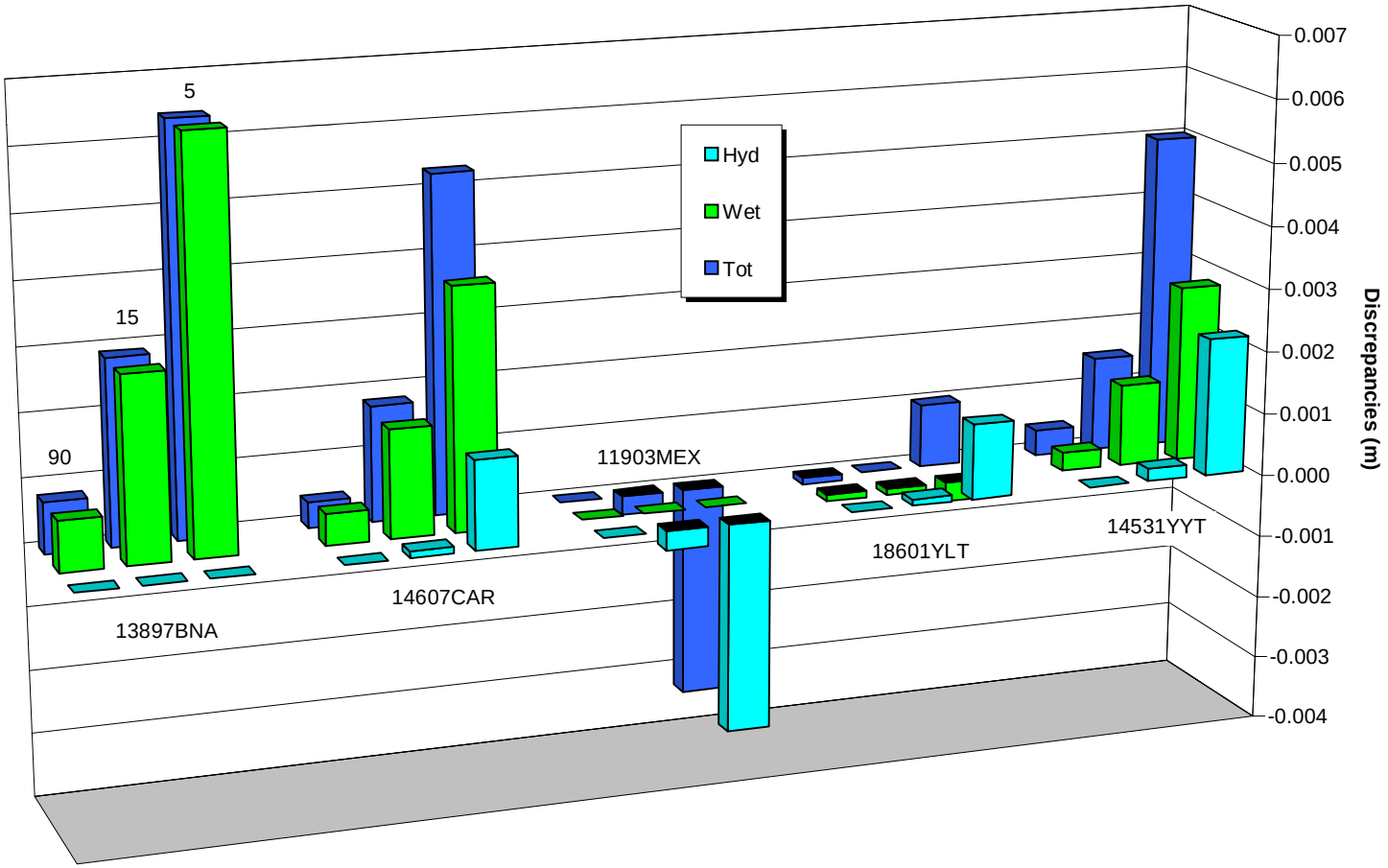
- Three stages:
  - (1) Scan raw radiosonde soundings for anomalous measurements; provide upper atmosphere profile; format for ray-trace software (1/2 hr. per year of data).
  - (2) Ray-trace atmospheric profiles to obtain "truth" source of GPS range delays (1 hr/year @ zenith, 3-4 hr/year @ 5°).
  - (3) Process range delays with UNB3(B&E) model, compute statistics of average and extreme performance (< 5 min/year/e-angle/model).

  – Tends to be an iterative process ...

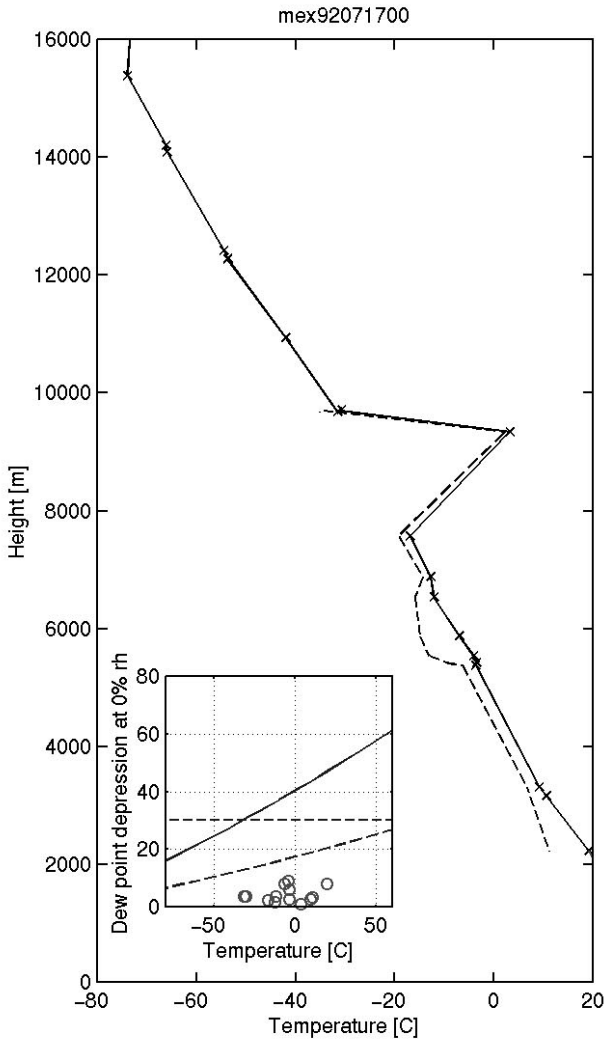
- Stage 1: RAOBSCAN
  - Radiosonde data only provided upto 100 mbar.
    - (95% of water vapour below 500 mbar).
    - requires upper atmospheric temperature profile for hydrostatic delay.
    - missing water vapour extrapolated upto 100 mbar using parameters computed from the data.
  - Radiosonde data notoriously poor quality.
    - numerous temperature and dew-point temperature ‘spikes’.
    - errors tend to cause ‘extremes’ e.g.:
      - a few profiles were saturated 100%.
      - anomalous surface measurements.

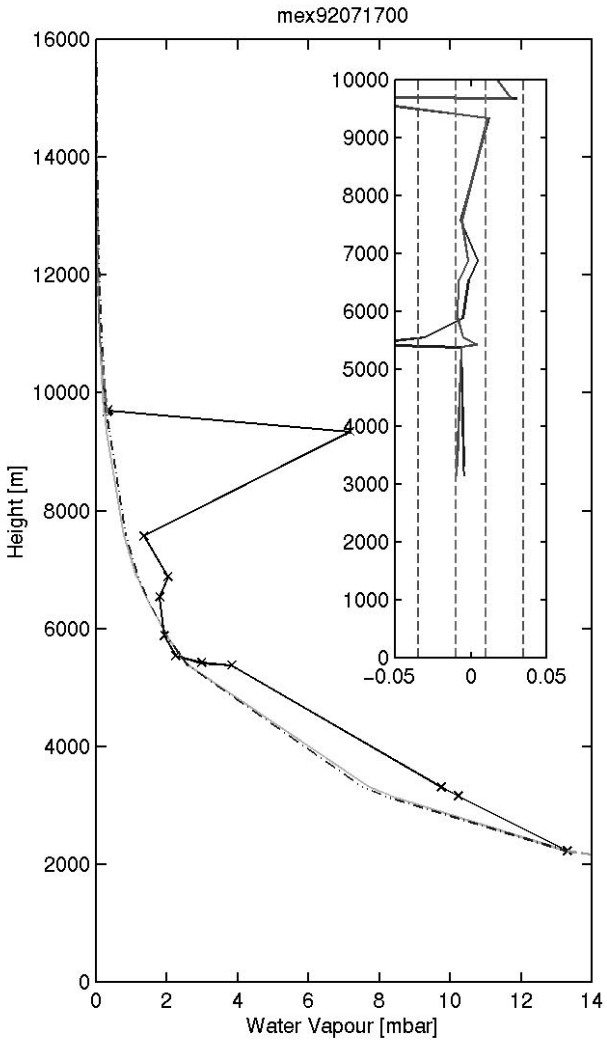
Delay errors due extrapolated profiles above 100mbar

Histogram bars represent hydrostatic, wet and total delay differences for elevation angles of 90, 15 and 5 degrees respectively, left-to-right.

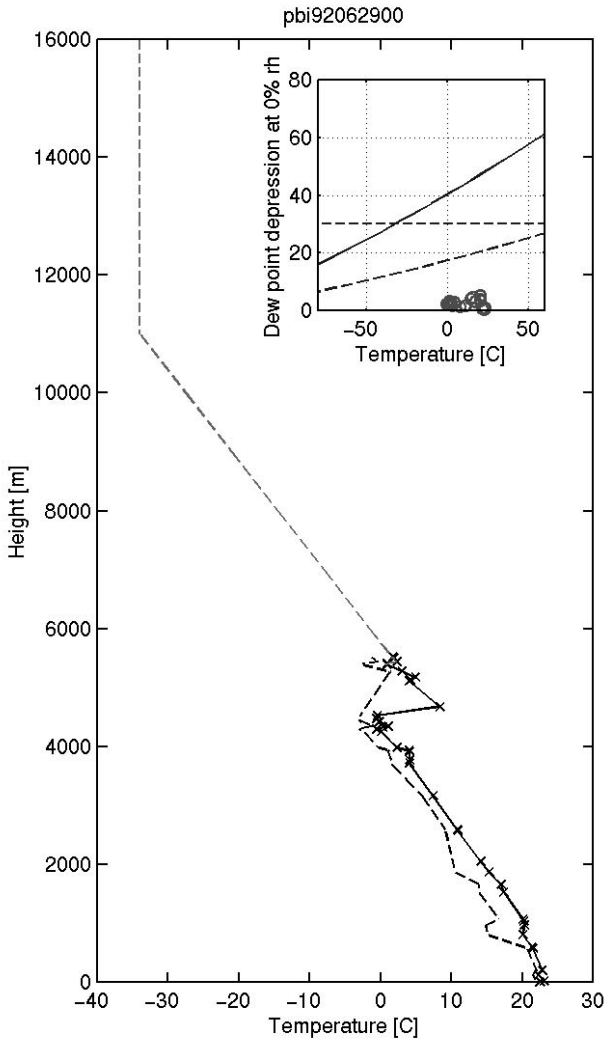


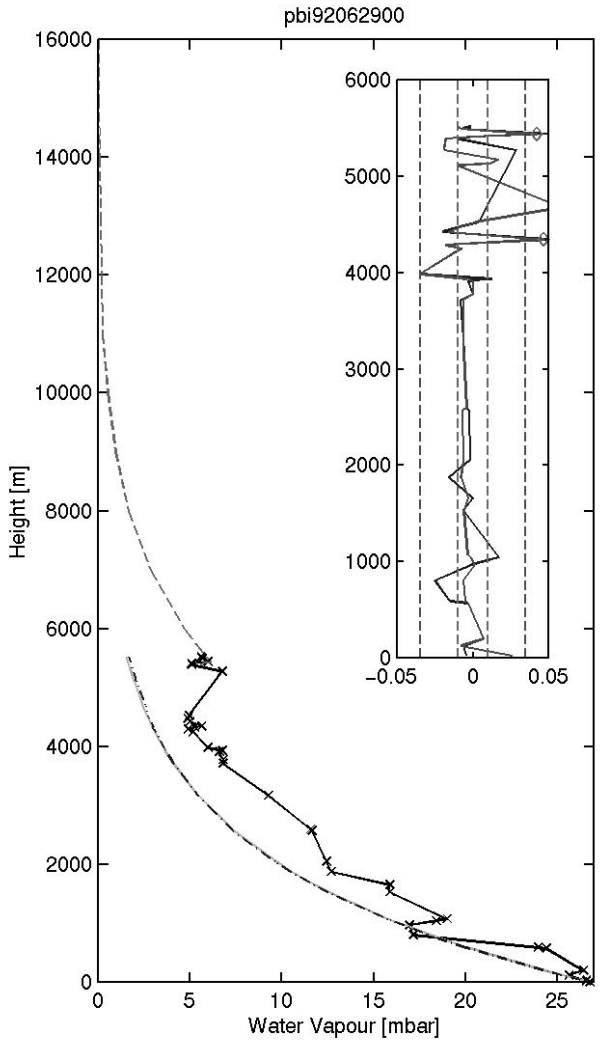
Sample Sounding (1)



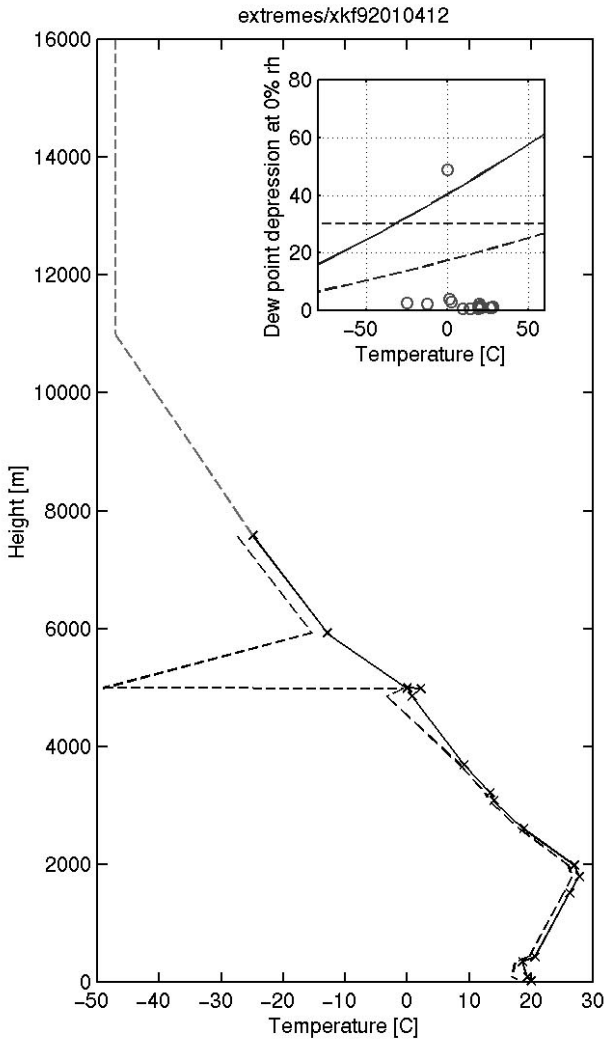


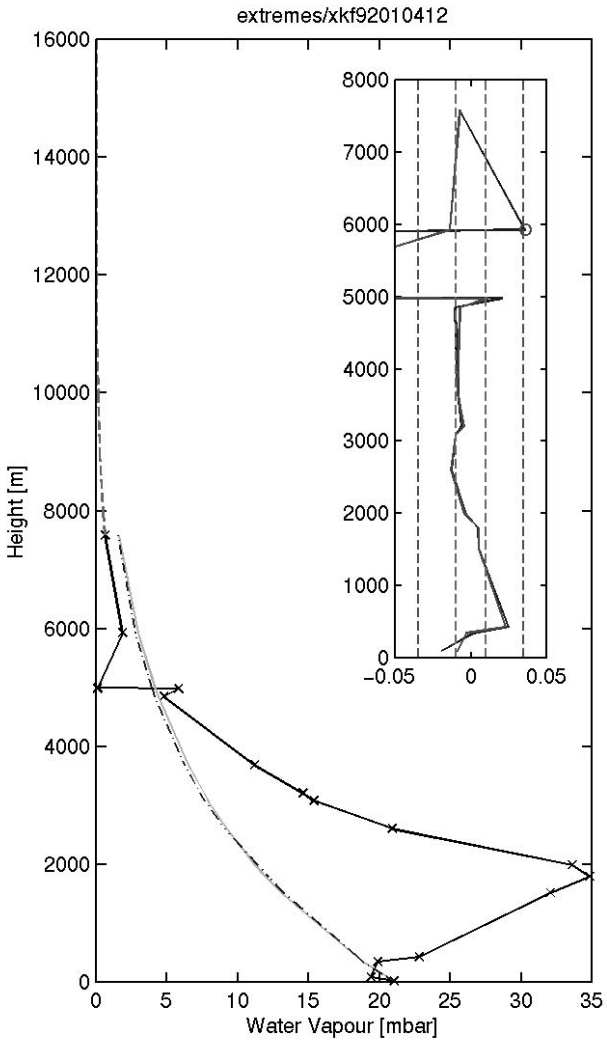
Sample Sounding (2)





Sample Sounding (3)





- Stage 2: RAOBTRACE
  - Obtained from Virgilio Mendes; written at M.I.T. by J.L Davis, T. Herring, A.E. Niell.
  - A few improvements, viz.: efficiency, new file formats, etc.
  - Speed of computation dependent on integration step size:

Step size (metres)	Time taken @ 90° (~ 500 profiles)	Delay difference (max, mm)
5	1 min : 28 sec	–
10	48 sec	0.1
20	26 sec	0.2
50	14 sec	0.8
100	10 sec	1.8

  - Step size of 50 m used in processing.

- Stage 3: RAOBSTAT
  - Compares model range delays to "truth" computed by ray-tracing.
  - Summarise by station / latitude band / all data.
  - Picks out extreme errors (size specified by user).

UNB3(B&E) 1990 Zenith Delay Error (m)

Latitude Band	mean error	standard deviation	rms (max)	range -max	range +max	#Stn's	#profiles
[00-15)	+0.01	+0.05	+0.07	-0.13	+0.15	7	3043
[15-30)	+0.00	+0.05	+0.10	-0.19	+0.24	32	14742
[30-45)	-0.02	+0.05	+0.12	-0.19	+0.24	67	46441
[45-60)	-0.03	+0.04	+0.06	-0.17	+0.16	37	24314
[60-75)	-0.03	+0.04	+0.06	-0.15	+0.14	18	12548
[75-90]	-0.04	+0.03	+0.05	-0.12	+0.04	3	2157
[00-90]	**-0.02**	**+0.05**	**+0.12**	**-0.19**	**+0.24**	**164**	**103245**

No extremes less than -0.20m recorded

3 positive extremes recorded:
13840DAY, 166.00 0.24m
21001999, 167.50 0.24m
93214VBG, 212.50 0.22m

UNB3(B&E) 1991 Zenith Delay Error (m)

Latitude Band	mean error	standard deviation	rms (max)	range -max	range +max	#Stn's	#profiles
[00-15)	+0.01	+0.05	+0.07	-0.12	+0.14	6	2652
[15-30)	+0.00	+0.05	+0.12	-0.19	+0.15	33	13499
[30-45)	-0.01	+0.05	+0.12	-0.20	+0.19	68	44639
[45-60)	-0.02	+0.04	+0.06	-0.18	+0.18	38	23548
[60-75)	-0.03	+0.03	+0.06	-0.13	+0.13	17	11955
[75-90]	-0.03	+0.03	+0.05	-0.13	+0.05	3	2129
[00-90]	**-0.02**	**+0.05**	**+0.12**	**-0.20**	**+0.19**	**165**	**98422**

1 negative extreme recorded:
93223VBG, 200.50 -0.20m

No extremes greater than 0.20m recorded

UNB3(B&E) 1992 Zenith Delay Error (m)

Latitude Band	mean error	standard deviation	rms (max)	range -max	range +max	#Stn's	#profiles
[00-15)	+0.02	+0.05	+0.06	-0.11	+0.14	6	1998
[15-30)	+0.00	+0.05	+0.12	-0.21	+0.19	32	13089
[30-45)	-0.02	+0.05	+0.15	-0.20	+0.36	71	45654
[45-60)	-0.03	+0.04	+0.06	-0.17	+0.14	37	23504
[60-75)	-0.03	+0.03	+0.06	-0.14	+0.09	17	11816
[75-90]	-0.03	+0.03	+0.05	-0.12	+0.06	3	2052
[00-90]	**-0.02**	**+0.05**	**+0.15**	**-0.21**	**+0.36**	**166**	**98113**

9 negative extremes recorded:
031251Y7, 167.50 -0.20m, 169.50 -0.20m, 170.50 -0.20m, 171.50 -0.20m, 183.50 -0.20m
22103LAP, 115.46 -0.20m, 166.50 -0.21m, 167.50 -0.21m, 278.00 -0.21m

2 positive extremes recorded:
13601XKF, 4.50 0.31m, 31.50 0.36m

UNB3(B&E) 1993 Zenith Delay Error (m)

Latitude Band	mean error	standard deviation	rms (max)	range -max	range +max	#Stn's	#profiles
[00-15)	+0.02	+0.05	+0.07	-0.15	+0.27	7	2009
[15-30)	+0.00	+0.06	+0.11	-0.22	+0.18	35	12403
[30-45)	-0.02	+0.05	+0.12	-0.21	+0.19	79	46061
[45-60)	-0.02	+0.04	+0.06	-0.14	+0.20	38	23539
[60-75)	-0.03	+0.04	+0.06	-0.14	+0.12	18	12194
[75-90]	-0.03	+0.03	+0.05	-0.11	+0.07	3	1872
[00-90]	**-0.02**	**+0.05**	**+0.12**	**-0.22**	**+0.27**	**180**	**98078**

9 negative extremes recorded:
031251Y7, 165.50 -0.21m, 168.50 -0.20m, 173.50 -0.21m, 225.50 -0.21m
22103LAP, 120.46 -0.21m, 125.46 -0.20m, 144.46 -0.20m, 162.46 -0.22m
93116NSI, 181.04 -0.20m
2 positive extremes recorded:
10701BLB, 57.00 0.27m
14685YCX, 188.29 0.20m

UNB3(B&E) 1994 Zenith Delay Error (m)

Latitude Band	mean error	standard deviation	rms (max)	range -max	range +max	#Stn's	#profiles
[00-15)	+0.01	+0.05	+0.06	-0.14	+0.14	8	2289
[15-30)	+0.00	+0.05	+0.13	-0.21	+0.19	37	14419
[30-45)	-0.02	+0.05	+0.12	-0.21	+0.22	87	44921
[45-60)	-0.03	+0.04	+0.08	-0.17	+0.19	44	24570
[60-75)	-0.03	+0.04	+0.06	-0.15	+0.14	18	12766
[75-90]	-0.03	+0.03	+0.05	-0.13	+0.06	3	2118
[00-90]	**-0.02**	**+0.05**	**+0.13**	**-0.21**	**+0.22**	**197**	**101083**

8 negative extremes recorded:
031251Y7, 188.50 -0.21m, 189.50 -0.21m, 193.50 -0.20m, 194.50 -0.20m
21001999, 114.00 -0.20m
21101SIC, 97.46 -0.21m
22104GYM, 134.96 -0.21m, 188.96 -0.20m
2 positive extremes recorded:
13601XKF, 154.00 0.22m, 154.96 0.22m

Summary

- Future work:
  - Process at least ten years of radiosonde data.
  - Confirm extreme profiles from other sources.
  - Perform position error simulations using extreme delay errors and GPS constellation for particular times and places.