Accuracy in zenith tropospheric delay from the Canadian regional numerical weather model

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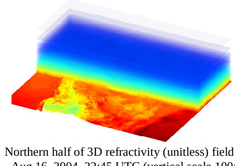
Numerical Weather Models (NWM)

- Common tropospheric delay prediction models:
  (i) Climatological models
  (ii) Surface-measured pressure, temperature, humidity
- NWM: state-of-art
  (i) The daily weather
  (ii) The entire 3-dimensional weather field.



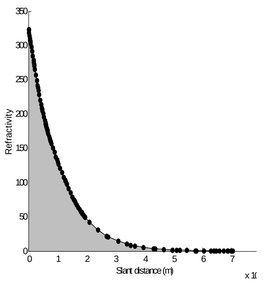
Northern half of 3D refractivity (unitless) field
Aug 16, 2004, 22:45 UTC (vertical scale 100:

Tropospheric delays from NWM

- Proxy variables + delay models:
  – Hydrostatic delay: surface pressure + Saastamoinen & map. func.
  – Non-hydrostatic: IPW + f(T_m) & map. func.
- Ray-tracing:
  – Con: more complicated
  – Pro: development of mapping functions

Ray-tracing

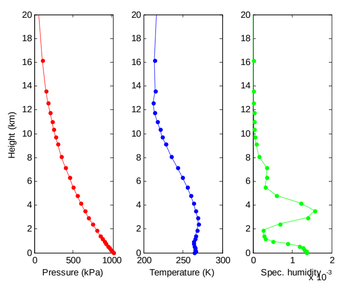
1. $d = 10^{-6}\int_C N(\ell)d\ell$
2. $N = K_1\frac{P_d}{T} + K_2\frac{e}{T} + K_3\frac{e}{T^2}$
3. $p = p_{i-1} + \frac{Z - Z_{i-1}}{Z_i - Z_{i-1}}p_i$,
   $p = T, \ln P, q$
4. $\{\ell\} \mapsto \{x, y, H^G\}$

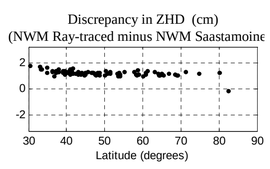


Procedure validation

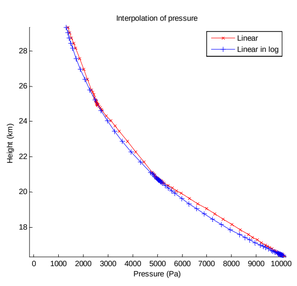
- Vertical interpolation
- Merging of weather and climate models
- Relative geopotential height models
- Near-surface pressure retrieval
- Interpolation in time

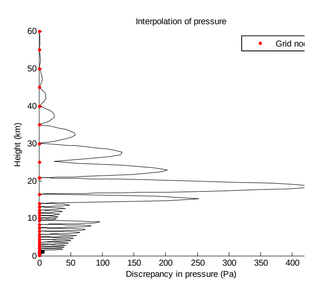
Procedure validation: Vertical interpolation



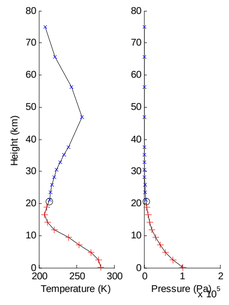


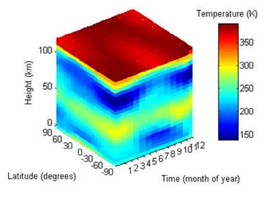
Procedure validation: Vertical interpolation (2)



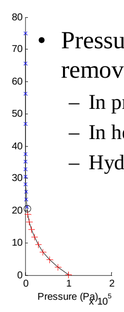


Procedure validation: Merging of weather & climate





Procedure validation: Merging of weather & climate (2)



- Pressure offset removal:
  – In pressure
  – In height
  – Hydrostatic integration

	Discr. ZHD (mm)
none	-1.1
in pressure	3.2
in height	1.3
hydrostatically	-0.6

Procedure validation: Relative geopotential heights

$$d = 10^{-6}\int_C N(\ell)d\ell$$

$$Z(h = N) = 0$$

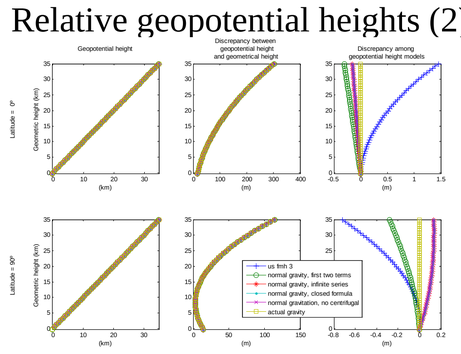
$$Z = Z_{(i)}(h) - Z_{(i)}(h = N)$$

$$Z_{(1)} = H\frac{g}{g_0}\frac{R_e}{R_e + H}$$

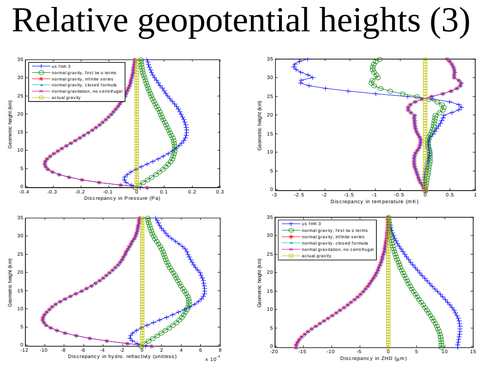
$$Z_{(2)} = -(U - U_0)/g_0$$

$$Z_{(3)} = -(W - W_0)/g_0$$

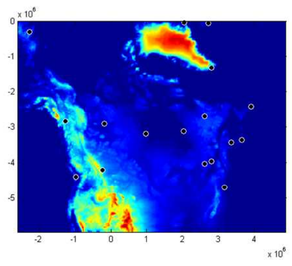
Procedure validation: Relative geopotential heights (2)



Procedure validation: Relative geopotential heights (3)



Procedure validation: Near-surface pressure retrieval



station number	pressure reduction	interp. in height	height above surf.
1	-2.2	-3.3	-30.1
2	-2.4	-1.9	-91.8
3	0.4	0.8	-67.8
4	-1.5	-1.0	28.3
5	-2.8	-3.5	-28.8
6	-3.1	-2.9	-12.1
7	-1.3	-1.3	0.6
8	-0.9	-0.4	23.8
9	-4.9	-4.1	-23.8
10	6.4	6.7	-114.5
11	-6.4	-6.0	-68.4
12	-1.8	-1.5	41.4
13	-1.0	-0.7	112.6
14	-1.0	-1.8	-32.8
15	-4.3	-3.8	16.8
16	-0.7	-0.8	405.6
17	0.5	0.6	0.8
RMS (mm)	**12.8**	**12.6**	

Procedure validation: Interpolation in time

$$\text{if } p\left(\frac{t_1 + t_2}{2}\right) = \frac{p(t_1) + p(t_2)}{2},\ p = P, T, q,$$

$$\text{is it } d\left(\frac{t_1 + t_2}{2}\right) \stackrel{?}{=} \frac{d(t_1) + d(t_2)}{2}$$

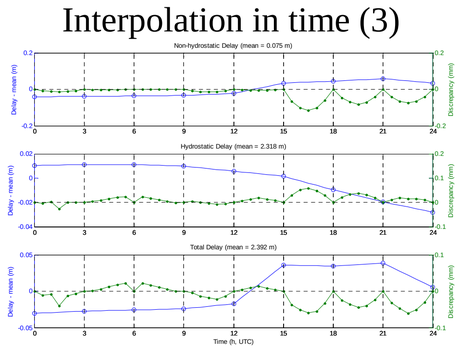
Procedure validation: Interpolation in time (2)

$$N = K_1\frac{P}{T_v} + K_2'\frac{P_w}{T} + K_3\frac{P_w}{T^2}$$

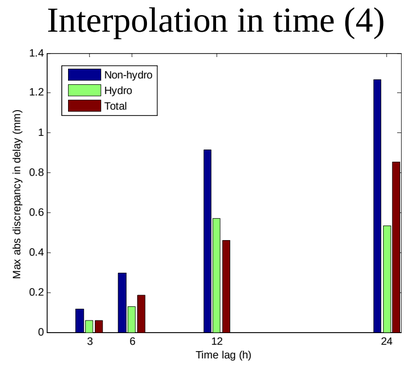
$$N\left(\ell, \frac{t_1 + t_2}{2}\right) \neq \frac{N(\ell, t_1) + N(\ell, t_2)}{2}$$

$$d\left(\frac{t_1 + t_2}{2}\right) \neq \frac{d(t_1) + d(t_2)}{2}$$

Procedure validation: Interpolation in time (3)



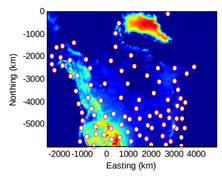
Procedure validation: Interpolation in time (4)



NWM accuracy assessment: Design

- Radiosonde
  – Con: assimilated in GEM NWM; very low temporal resolution.
- GPS with met. package
  – Pro: not assimilated in operational GEM NWM in the past; high temporal resolution.
  – Con: lack of calibration

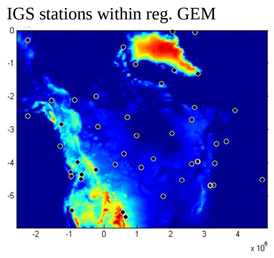
NWM accuracy assessment: Preliminary results (Radiosondes)



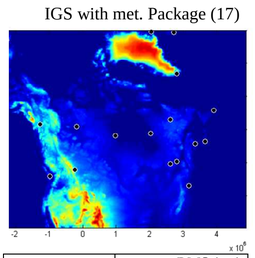
	Bias (cm)	Std (cm)	RMS (cm)
hydro, analysis	-0.11	0.15	0.19
hydro, 12h forecast	-0.10	0.26	0.28
non-hydro, analysis	-0.15	0.68	0.69
non-hydro, 12h forecast	-0.17	1.34	1.35

NWM accuracy assessment: Preliminary results (GPS)

IGS stations within reg. GEM



IGS with met. Package (17)



	RMS (cm)
hydro, analys.	1.26

Conclusions

- Prefer proxy variables to raytracing
  – Definitely for zenith delays.
  – Even for slant delays, unless:
    - developing new mapping functions
    - expecting extraordinary horizontal gradients
    - exploiting observations at very low elevation angles.
  – Simpler, faster, less data.
- Future work: assess accuracy for **longer periods.**

Research carried out under GEOIDE NCE Project **"Next-generation algorithms for navigation, geodesy and earth sciences under modernized Global Navigation Satellite Systems (GNSS)"**

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