Royal Meteorological Institute

STCE

The LIEDR model - recent and future improvements

Tobias Verhulst & Stan Stankov

RMI

Solar-Terrestrial Centre of Excellence

Overview

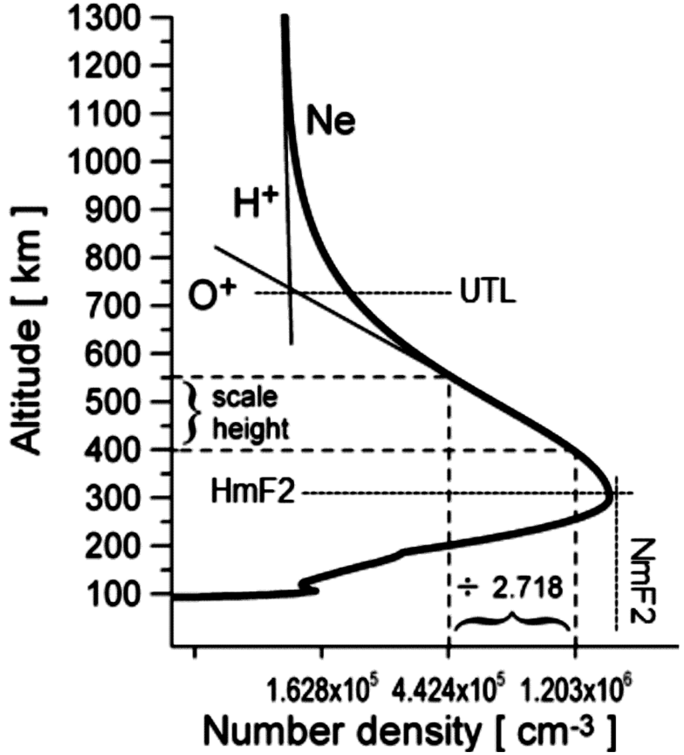
- Introduction
- The topside profiler problem
- The available topside data
- Correlations with physical drivers
- Correlations with measured ionospheric parameters
- Further developments

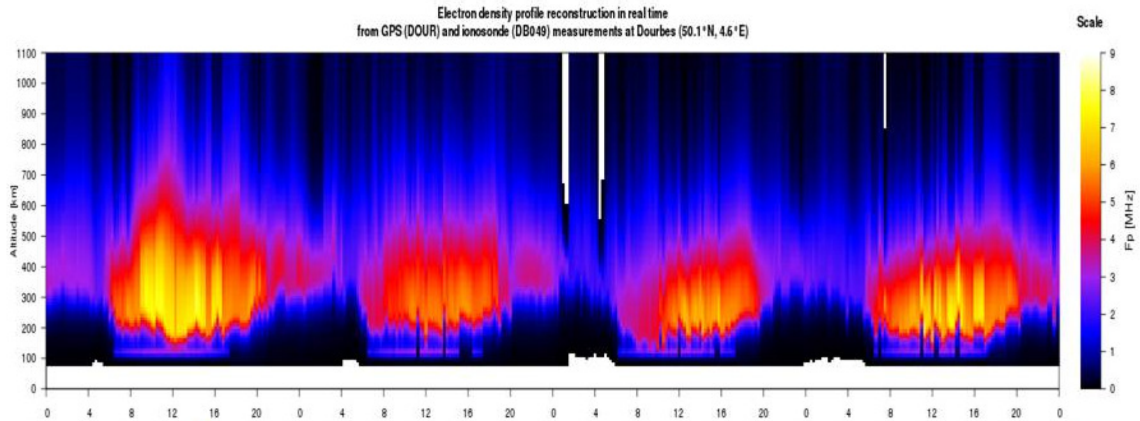
Royal Meteorological Institute

STCE

Introduction

The goal of LIEDR is to reconstruct the electron density profile for the ionosphere:





LIEDR reconstructed electron density profile for four days, showing several failed reconstructions

N_e is reconstructed from 80km up to 1100km.

LIEDR inputs

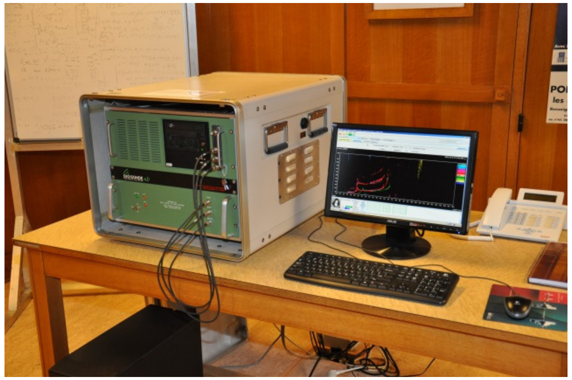
1) Parameters from ground based ionosonde

2) Total (vertical) electron content, obtained from TEC maps (provided by ROB)

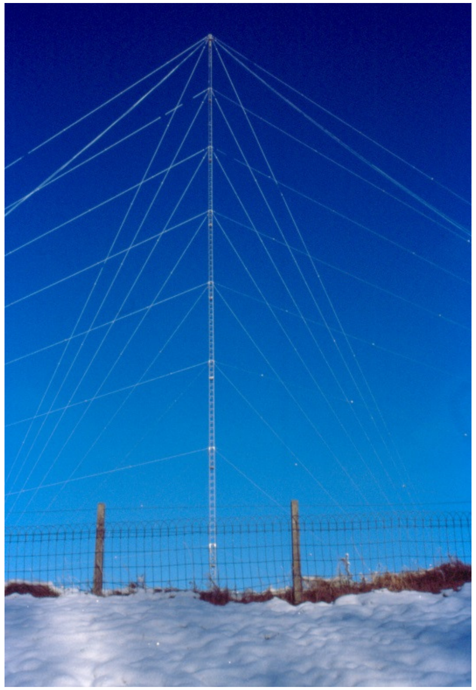
3) Solar activity index (F10.7) and geomagnetic measurements

4) An empirical model for the transition height (UTL)

The ionosonde

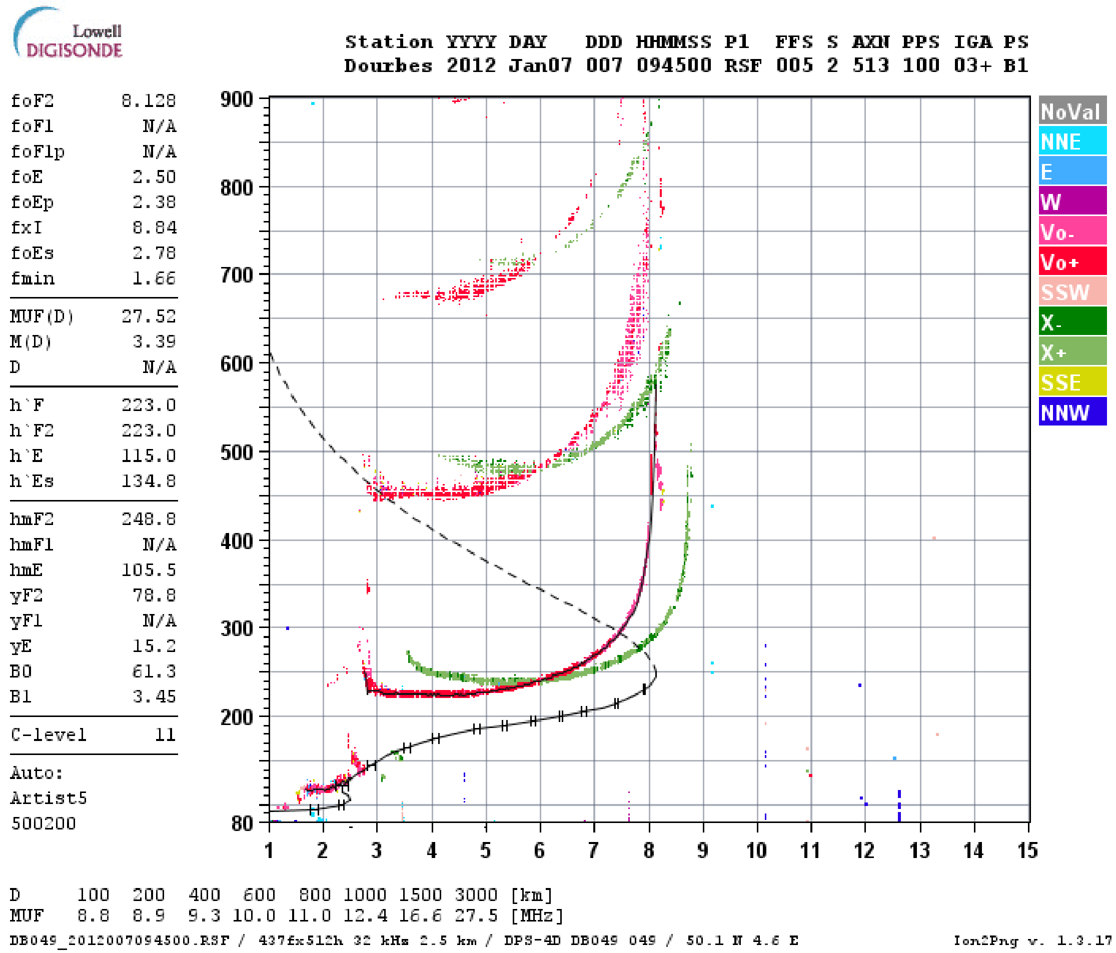


Sounder, transmission antenna and receiver antenna



With the new digisonde, installed in 2011, these measurements are now as good as they can get.

The ionosonde



A typical echo obtained by one frequency sweep of the ionosonde.

Black line is the calculated electron density profile.

Evaluation of the software doing this calculation still needs to be done.

LIEDR inputs (again)

The main problem:

Ground based ionosonde can only measure detailed profiles up to the F_2 peak, for the topside only total electron content can be measured.

Question: *how are these electrons distributed between F_2 height and UTL?*

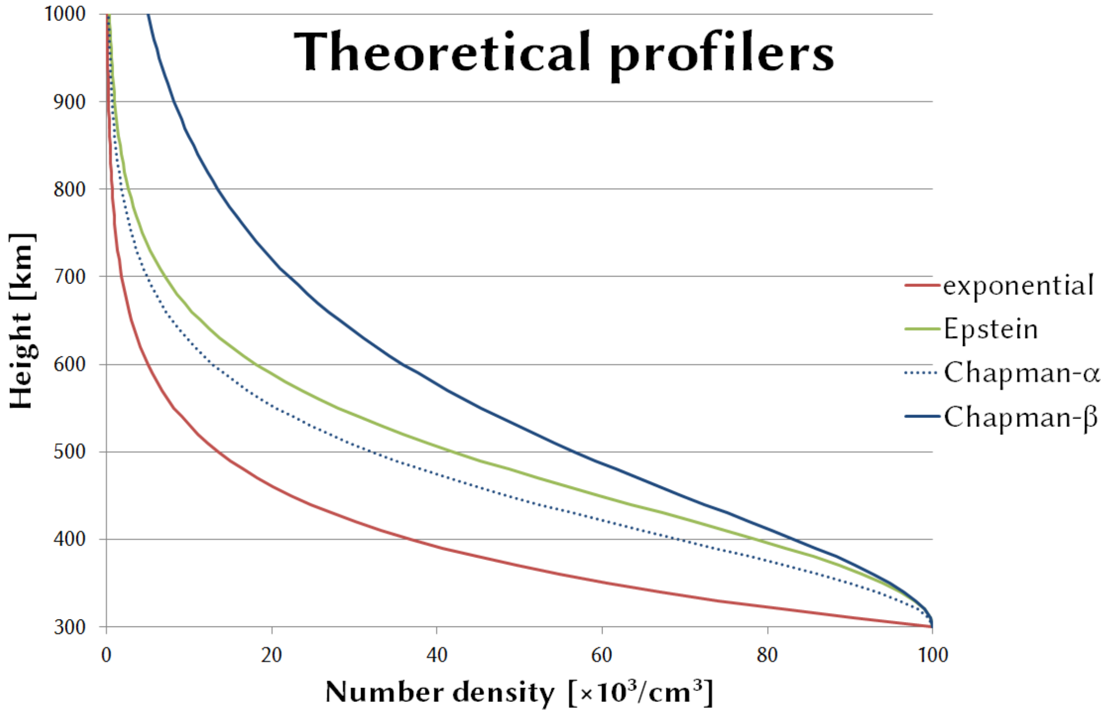
Additional input needed: a model for the topside distribution

Royal Meteorological Institute

STCE

Topside profilers

Different topside profilers are commonly used: exponential, Epstein and Chapman-α and -β.

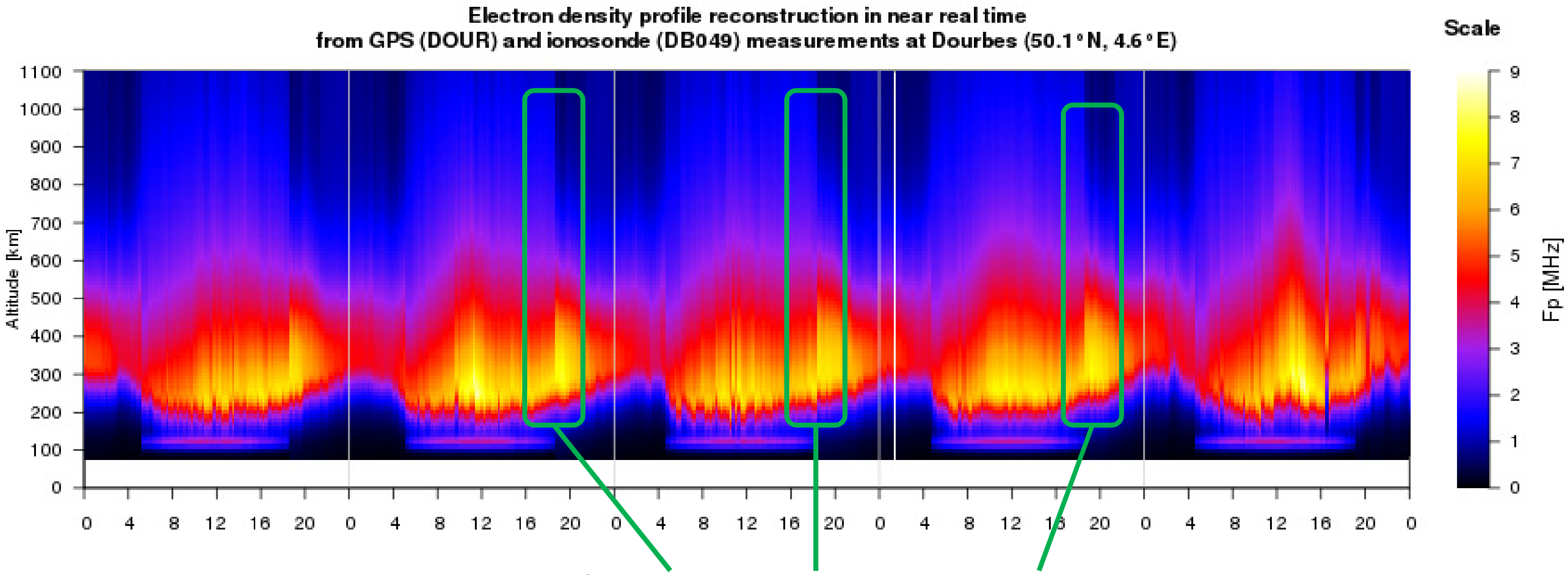


Royal Meteorological Institute

STCE

Day/night selection of profilers

Different profilers are used during day and night, however the transition is problematic.



⇒ Better criteria for profiler selection are important

Royal Meteorological Institute RMI

STCE

Topside ionosonde data

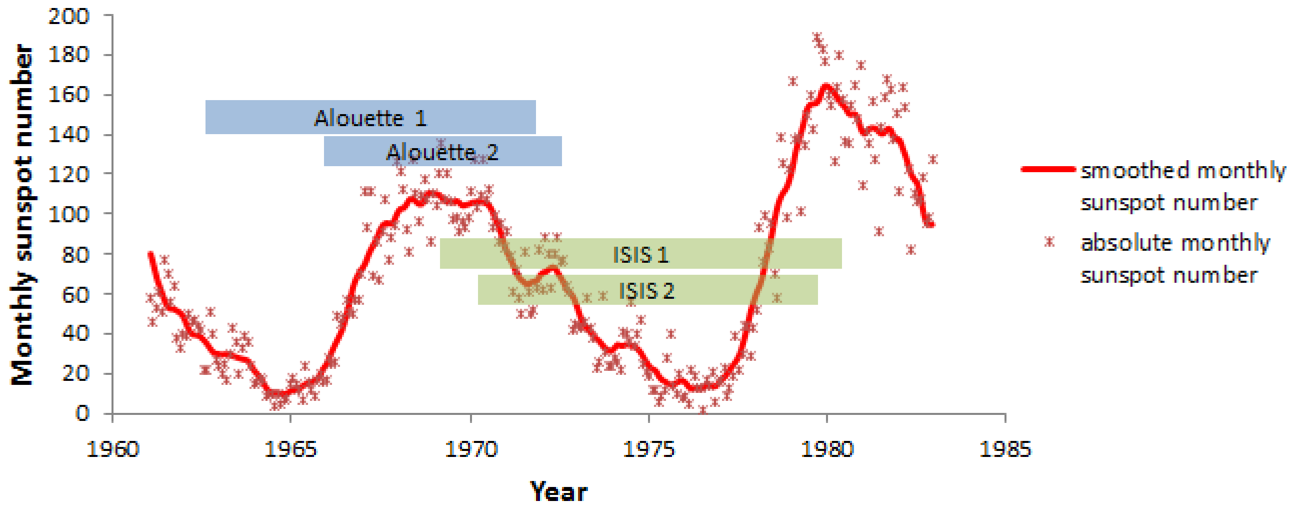
- We need to further investigate which profiler is best suited for use in what conditions.
- Relevant factors include time of day, but also season, solar activity, magnetic activity and magnetic coordinates.
- Data used is historical database, provided by NSSDC, with measurements from four satellites: Alouette 1 & 2 and ISIS 1 & 2.
- 170000+ profiles can each be fitted with the four profilers.

Royal Meteorological Institute

STCE

Data coverage & problems

The data covers all latitudes and longitudes, and spans over more than a complete solar cycle.



Problems:

1) The data is not uniformly distributed in either time or space.
2) There are some profiles that are obviously erroneous and have to be excluded from analyses.

Royal Meteorological Institute

STCE

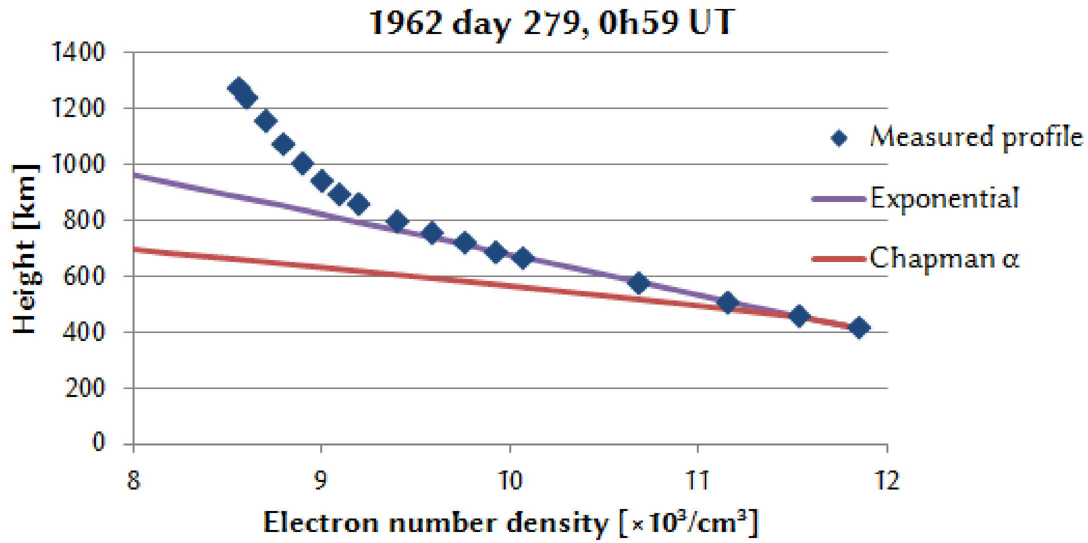
Data coverage & problems

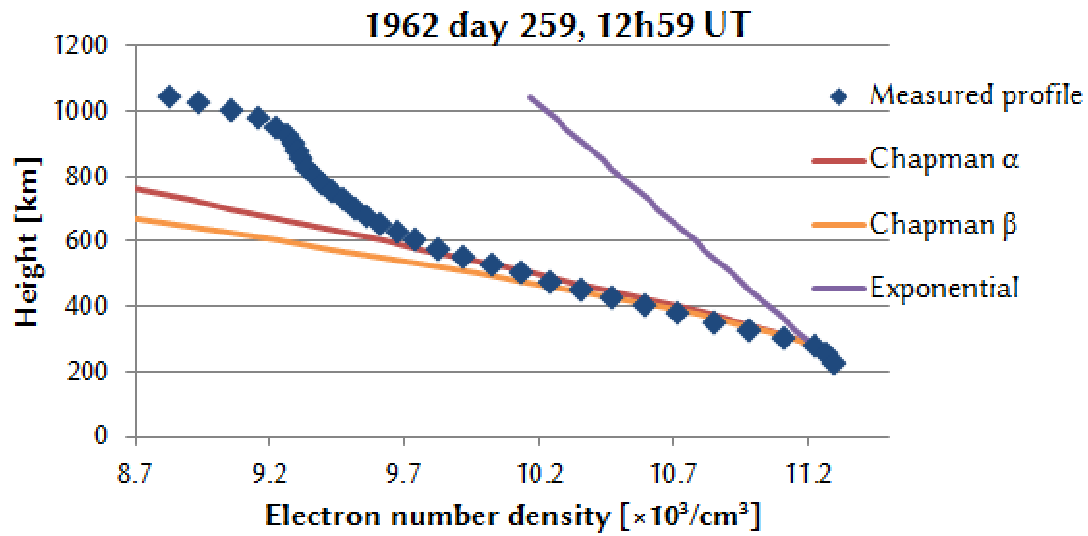
3) To ensure no erroneous data is included, we select profiles based on the proximity of the peak to the IRI prediction. In disturbed conditions, this can exclude correct data, too.

4) We only want profiles that cover the whole topside – from h_mF_2 to UTL. This is the main reason for profiles being excluded from our study.

This last criterion also causes an <u>important bias</u>: profiles with higher UTL are more likely to not go high enough, due to the UTL being above the satellite.

Examples

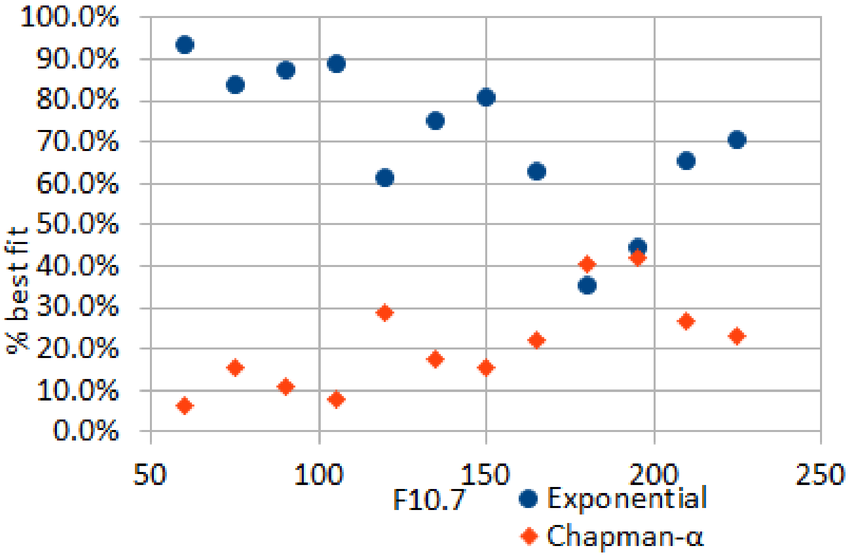




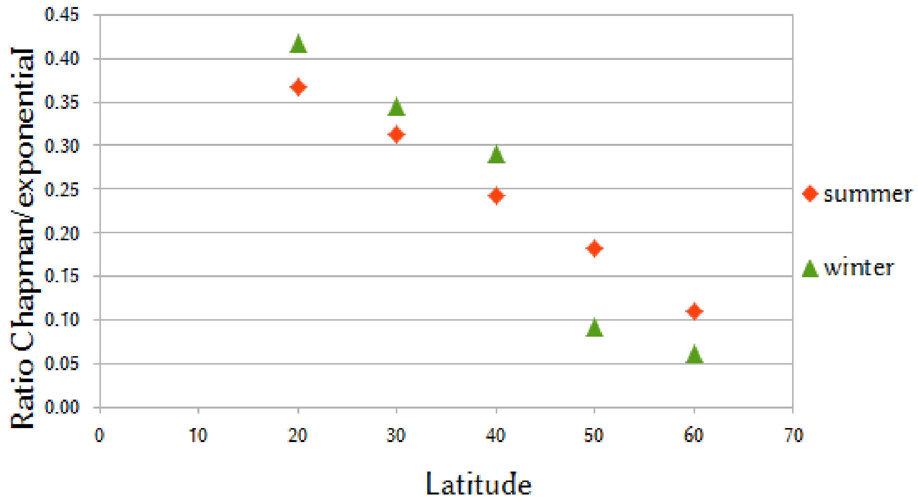
One profile best fitted by an exponential curve (top), the other by a Chapman profile (bottom)

Effects of physical drivers

Effect of F10.7 (daytime)



Effect of latitude (and season)



Effects of physical drivers

Time of day

0—2	2—4	4—6	6—8	8—10	10—12	12—14	14—16	16—18	18—20	20—22	22—24	Latitude
0.13			0.56	0.56	1.38	1.09	5.50	0.24	0.80	0.10	0.00	80°—90°
			0.31	0.21	0.36	0.68	0.23	0.09	0.08		0.20	70°—80°
0.21	0.26		0.43	0.16	0.25	0.37	0.29	0.59	0.61	0.39	0.15	60°—70°
0.16	0.22	0.31	0.24	0.29	0.33	0.28	0.15	0.38	0.50	0.23	0.41	50°—60°
0.17	0.16	0.24	0.32	0.17	0.24	0.20	0.10	0.21	0.22	0.37	0.33	40°—50°
0.11	0.13	0.21	0.33	0.17	0.31	0.28	0.13	0.21	0.27	0.39	0.43	30°—40°
0.29	0.29	0.29	0.35	0.25	0.50	0.43	0.16	0.25	0.28	0.47	0.44	20°—30°
0.53	0.74	0.57	0.48	0.50	0.48	0.45	0.30	1.02	0.76	1.01	0.57	10°—20°
0.87	0.91	0.61	0.94	1.26	1.57	0.98	1.31	1.33	2.05	1.08	0.73	0°—10°

0—2	2—4	4—6	6—8	8—10	10—12	12—14	14—16	16—18	18—20	20—22	22—24	Latitude
0.24	0.38			0.73	1.09	4.00	20.00					80°—90°
0.24	0.54			0.27	0.27	1.40	0.96	1.43				70°—80°
0.33	0.59		0.38		0.50	0.89	0.41					60°—70°
0.36	0.42	0.20	0.51	0.62	0.69	0.62	0.52	0.34	0.55	0.29	0.61	50°—60°
0.41	0.42	0.14	0.45	0.41	0.73	0.56	0.41	0.36	0.53	0.36	0.53	40°—50°
0.33	0.41	0.12	0.31	0.40	0.25	0.51	0.43	0.35	0.42	0.57	0.41	30°—40°
0.29	0.25	0.20	0.28	0.52	0.38	0.80	0.72	0.64	0.41	0.57	0.43	20°—30°
0.52	0.78	0.76	0.77	1.09	0.73	1.05	0.92	0.64	0.48	0.53	1.08	10°—20°
0.94	0.91	1.41	1.59	0.84	1.23	0.93	0.43	0.27	1.00	1.45	1.00	0°—10°

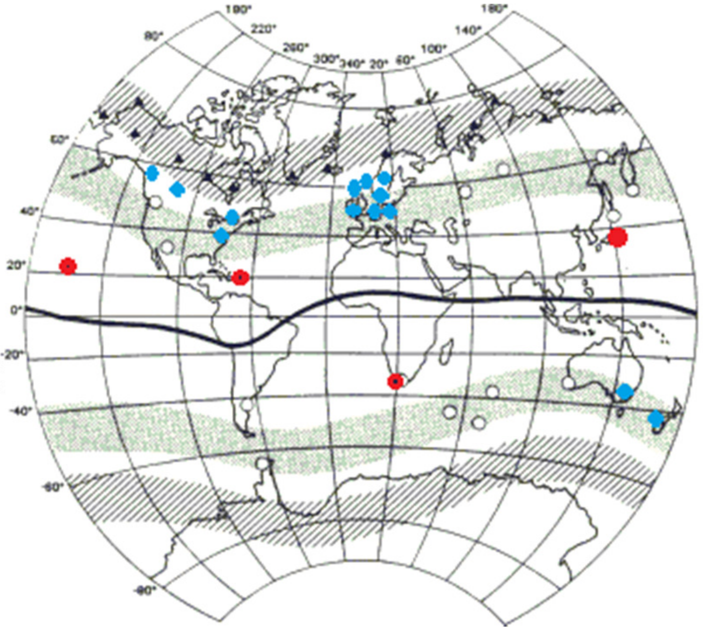
Ratio of non-exponential to exponential profiles, for winter (top) and summer (bottom), by magnetic latitude and local time

Royal Meteorological Institute

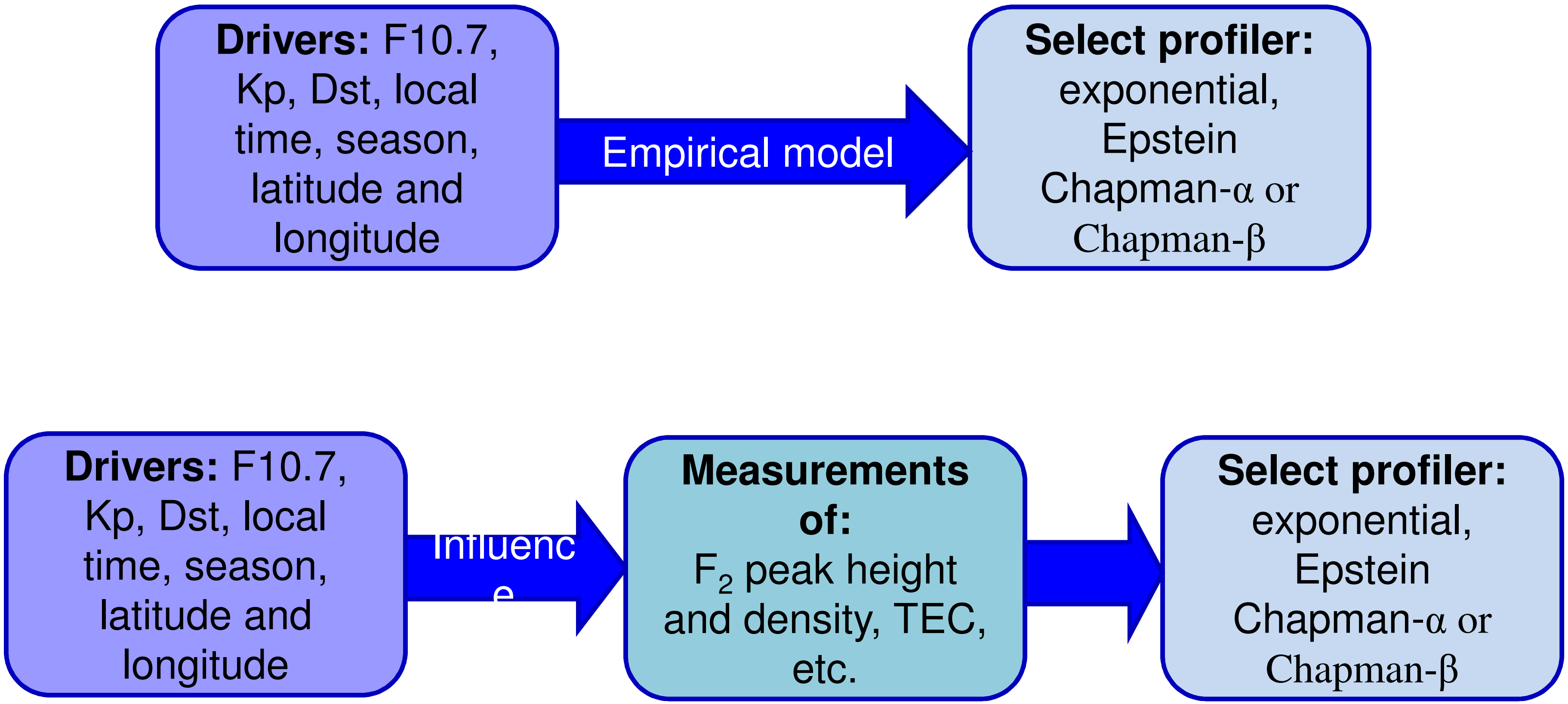
STCE

The problem with empirical models

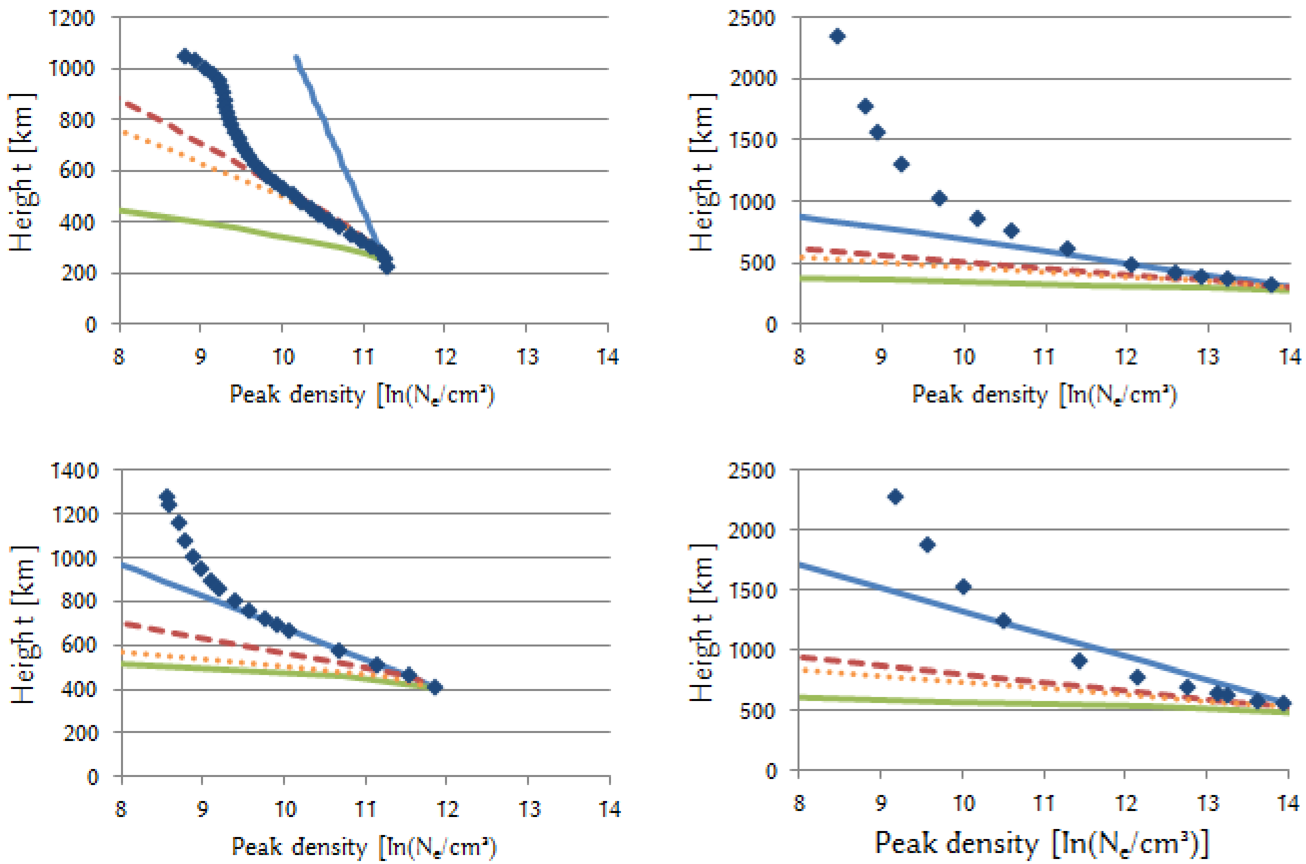
- Effects of the physical drivers are visible, but not usable for the selection of a topside profiler.
- Reasons: correlation between drivers, biases, and intrinsic problems with solar and magnetic indices.
- Better results might be obtained by using measured parameters instead of physical drivers.



The solution: measurement based

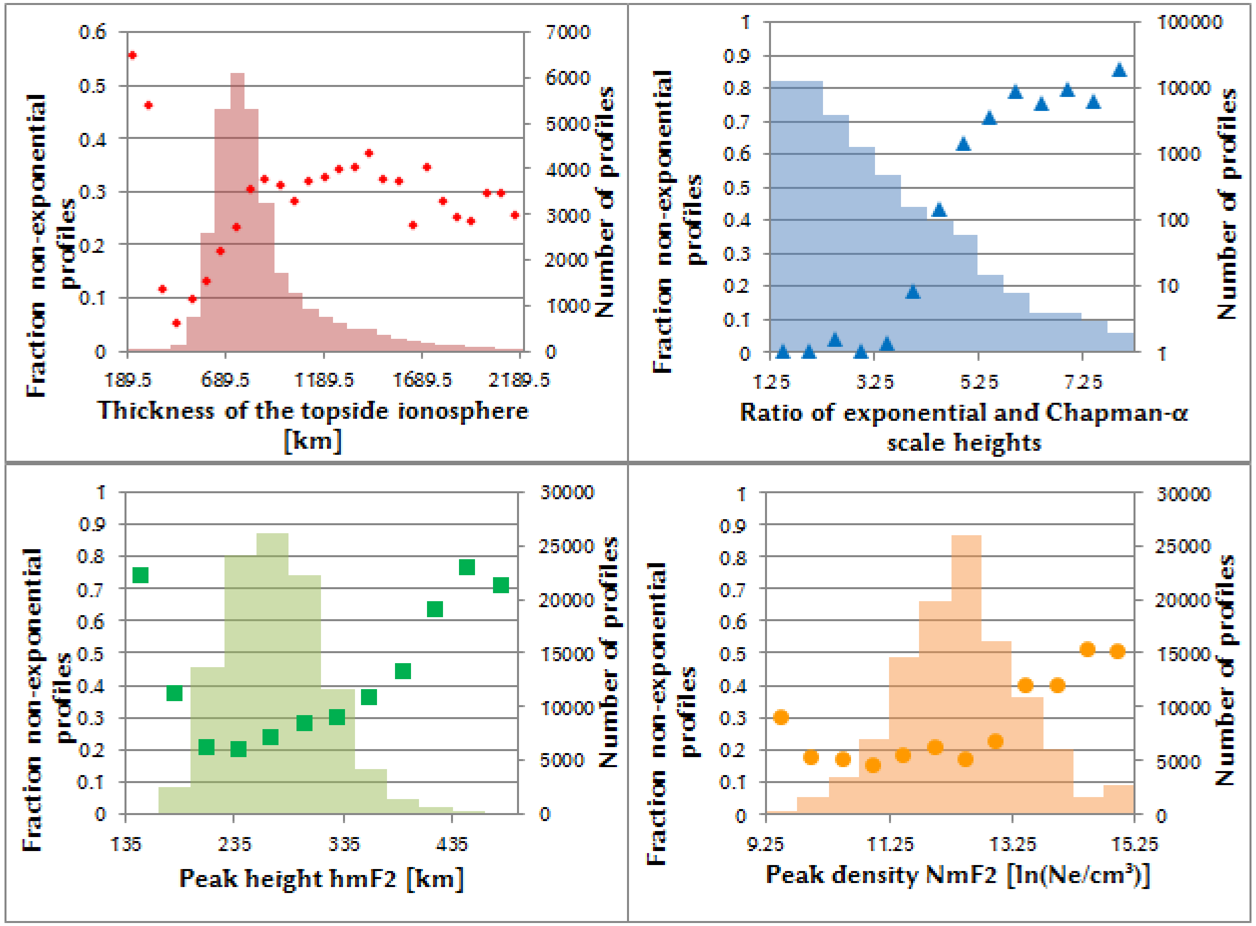


Examples

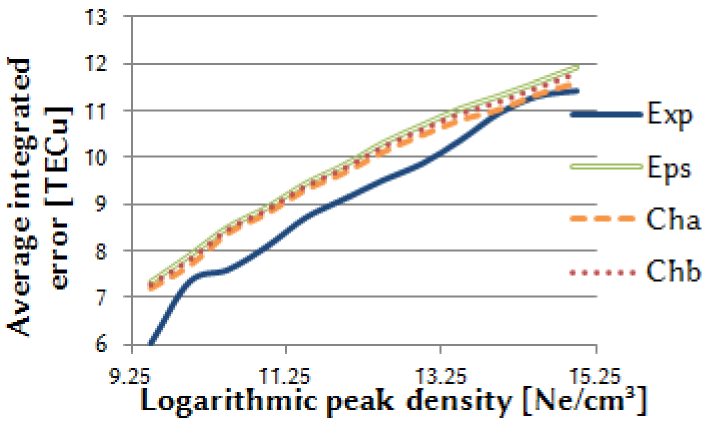


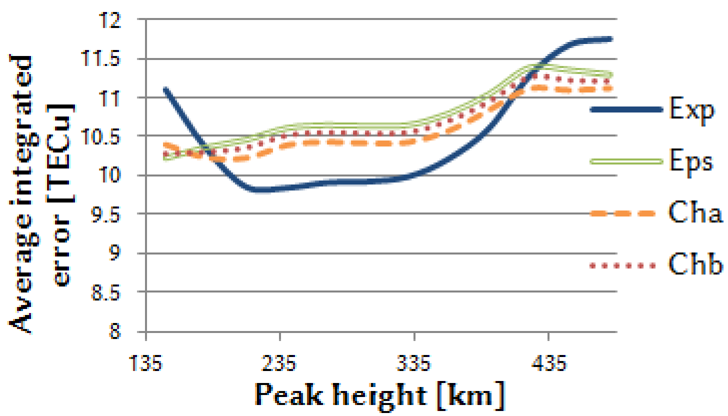
Profiles with extremely large or small values for h_mF_2 and N_mF_2 are fitted best by different profilers

Relation to measured parameters



Average integrated error





It seems that mainly the height of the F_2 peak is useful for the selection of a topside profiler

Future developments

- Implement the selection of topside profiler based of peak characteristics (and possibly TEC)
- If feasible, implement compound profiles or variable scale heights
- Evaluate the new scaling software for the ionosonde data
- Use real time, local GPS data instead of TEC maps
- At a later stage, review the model for the UTL