THE NEQUICK MODEL

- Access & Usage -

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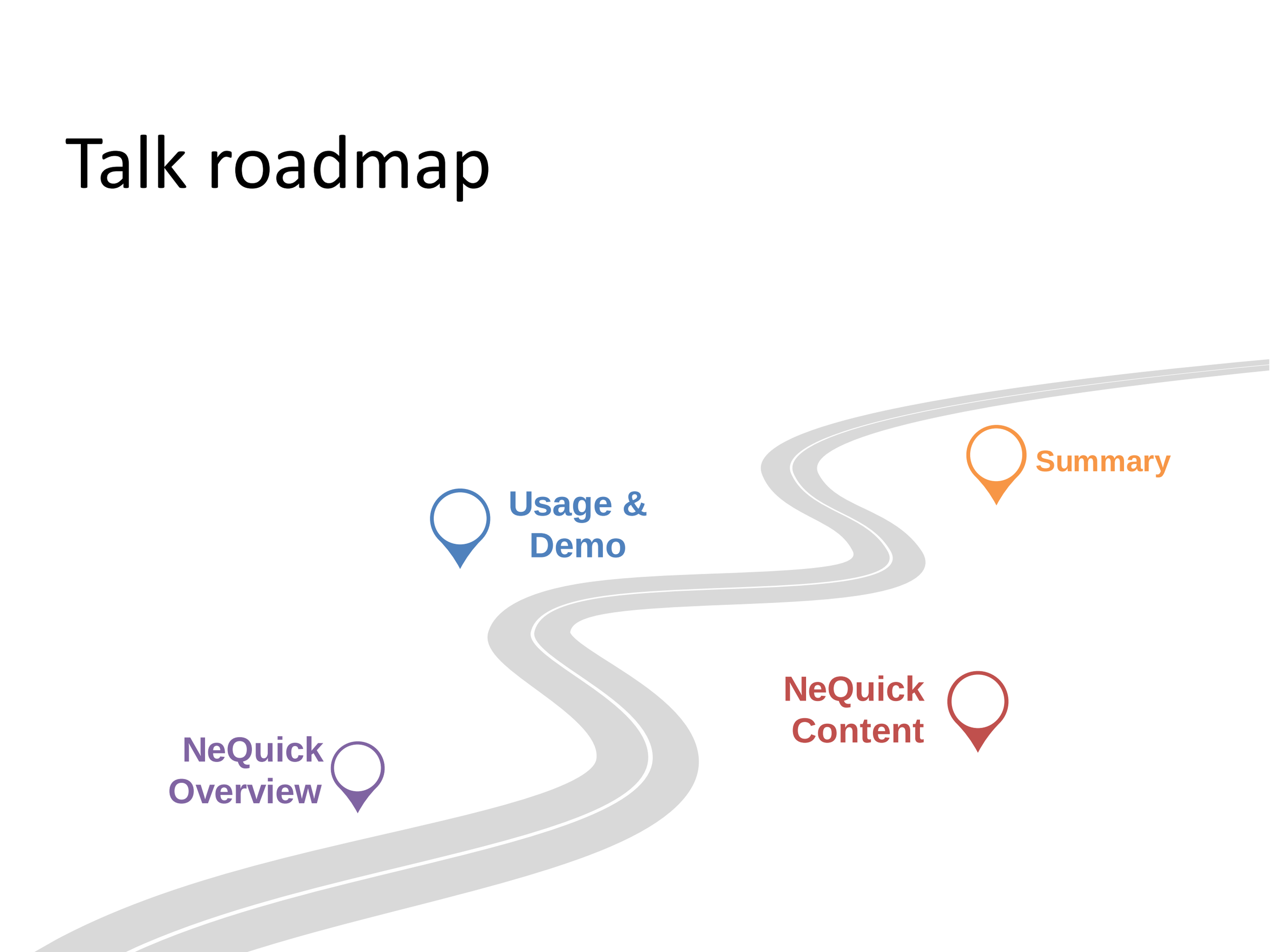
The International Reference Ionosphere and NeQuick – Improving the Representation of the Real-Time Ionosphere
|Trieste, Italy 29 September -10 October, 2025

Talk roadmap



Summary

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& Demo

NeQuick
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NeQuick
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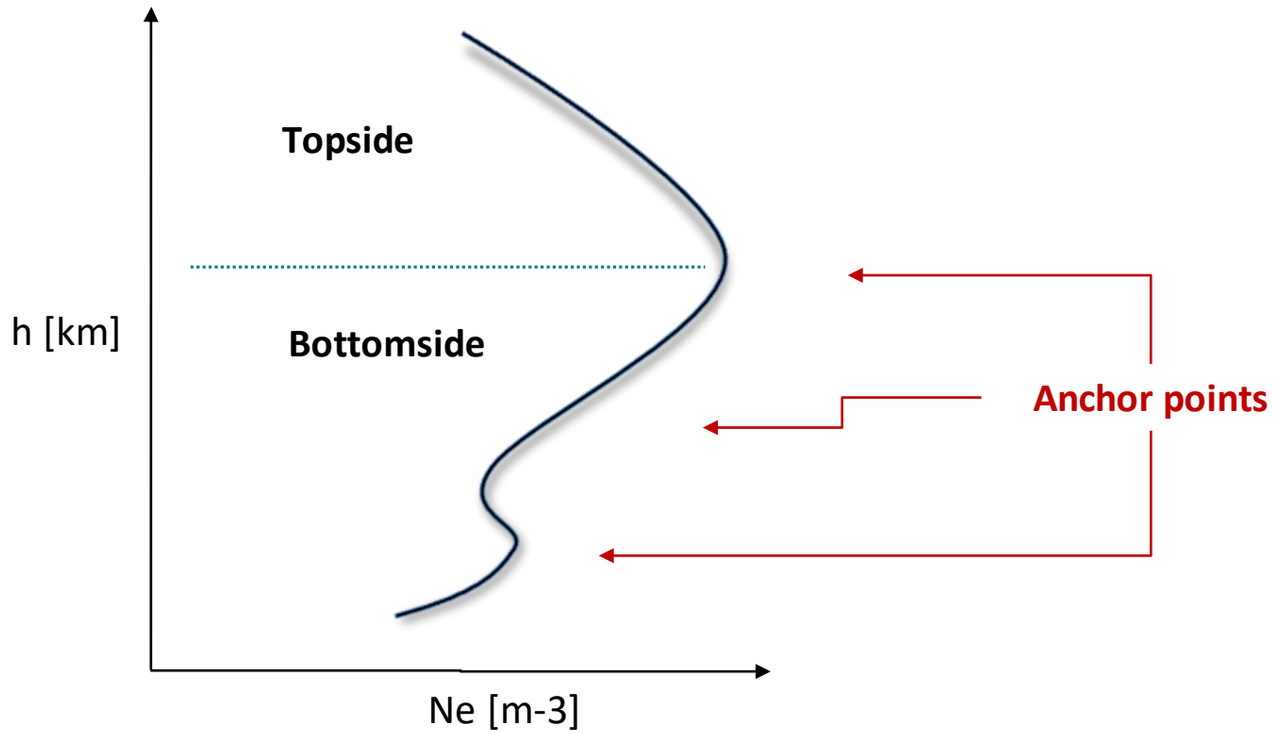
NeQuick Overview

NeQuick's profile includes 6 semi-Epstein layers and makes use of anchor points defined by foE, foF1, foF2 and M(3000)F2 values.



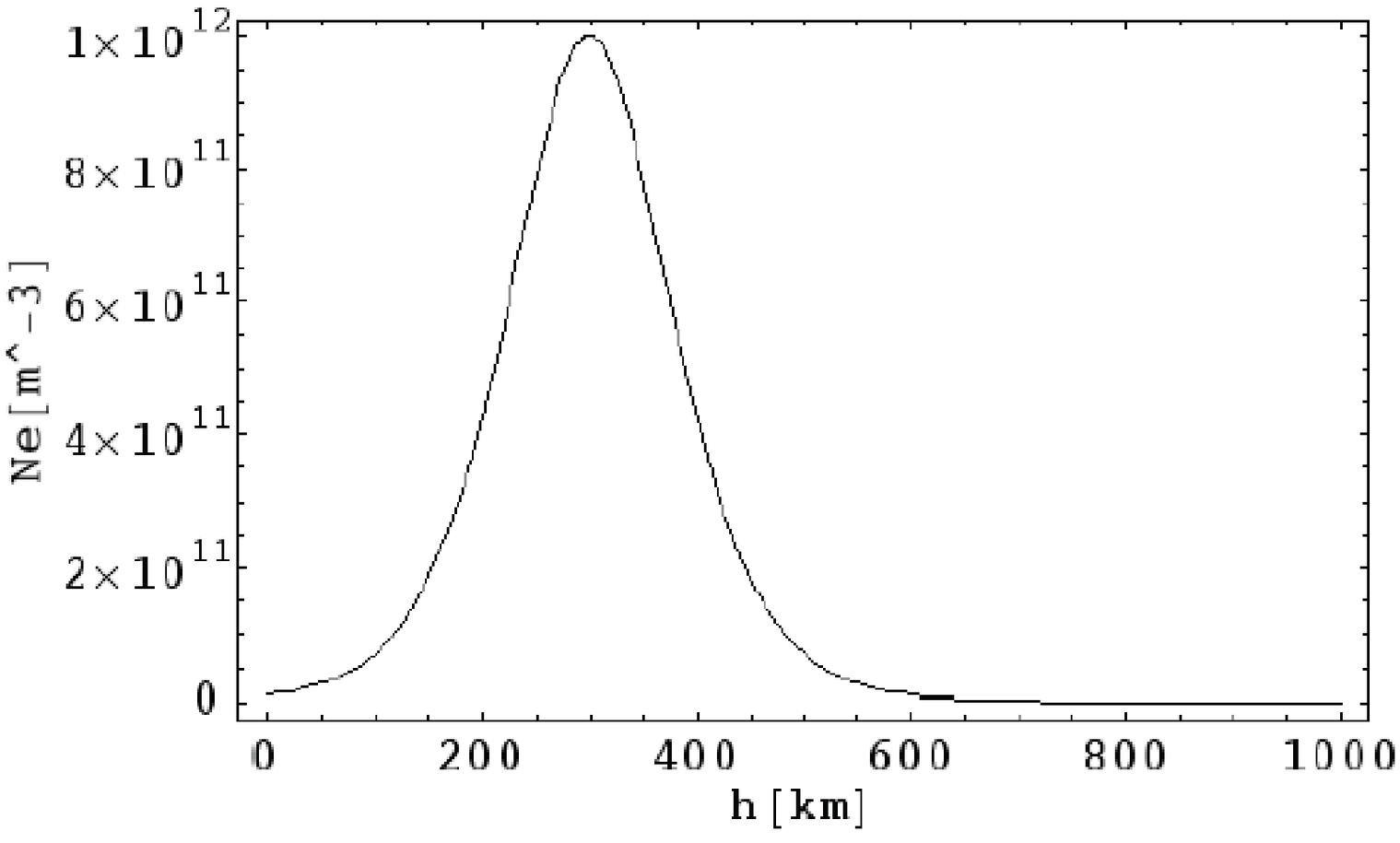
modelled (e.g. ITU-R coefficients for foF2, M(3000)F2) or experimentally derived

Position (degN,degE,km)
Time (mth, UT)
Solar Activity (R12,F10.7)

Ne (φ,λ,t)
TEC

Epstein Layer

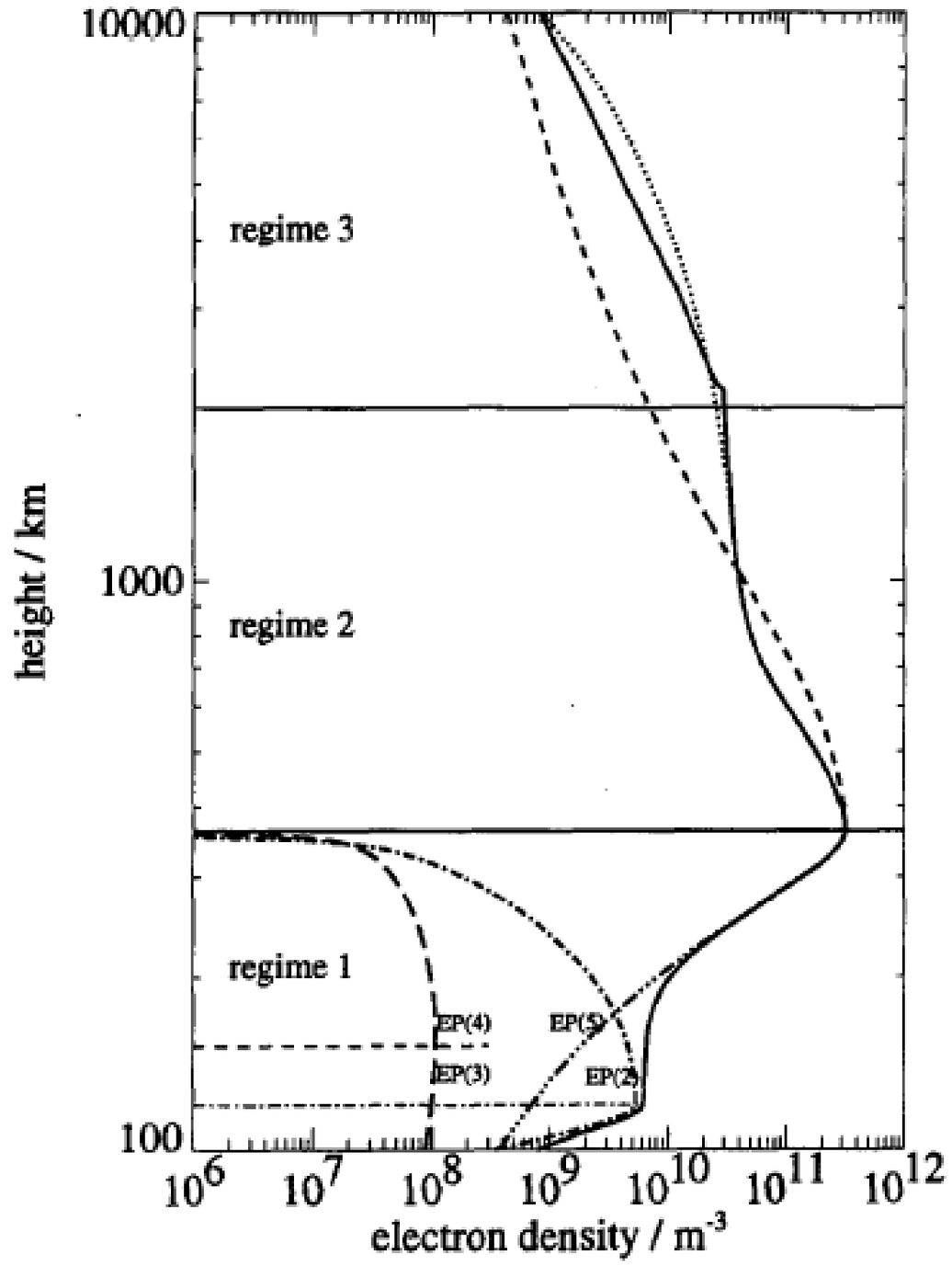
$$N(h,hmax,Nmax,B) = \frac{4Nmax}{(1+\exp(h-hmax/B))^2} \exp\left(\frac{h-hmax}{B}\right)$$



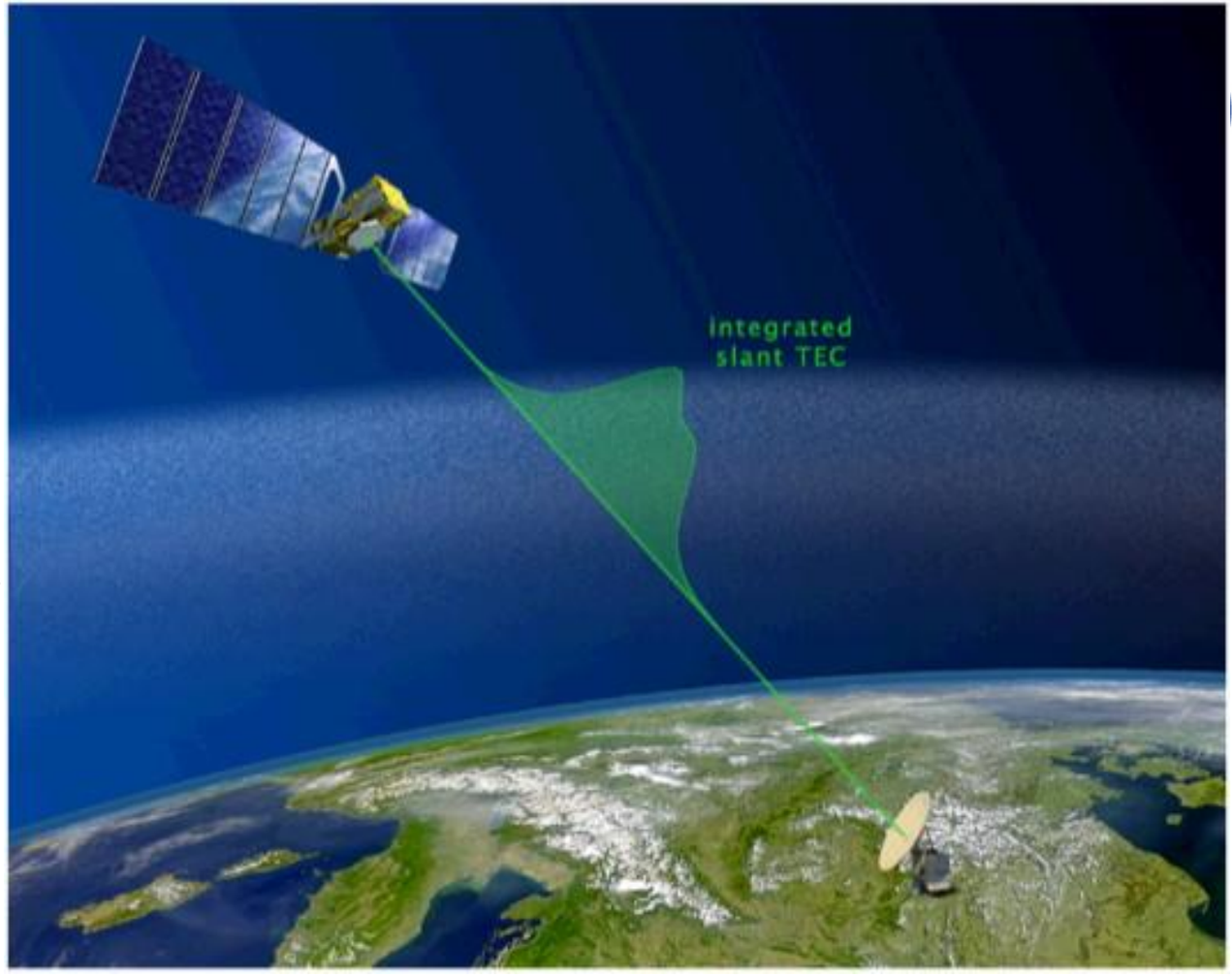
Epstein, (1930) *Rawer, K. (1982),Advances in Space Research*

NeQuick formulation

Hochegger et al, 2000, Phys. Chem. Earth



NeQuick versions



- NeQuick 1: recommended by ITU-R

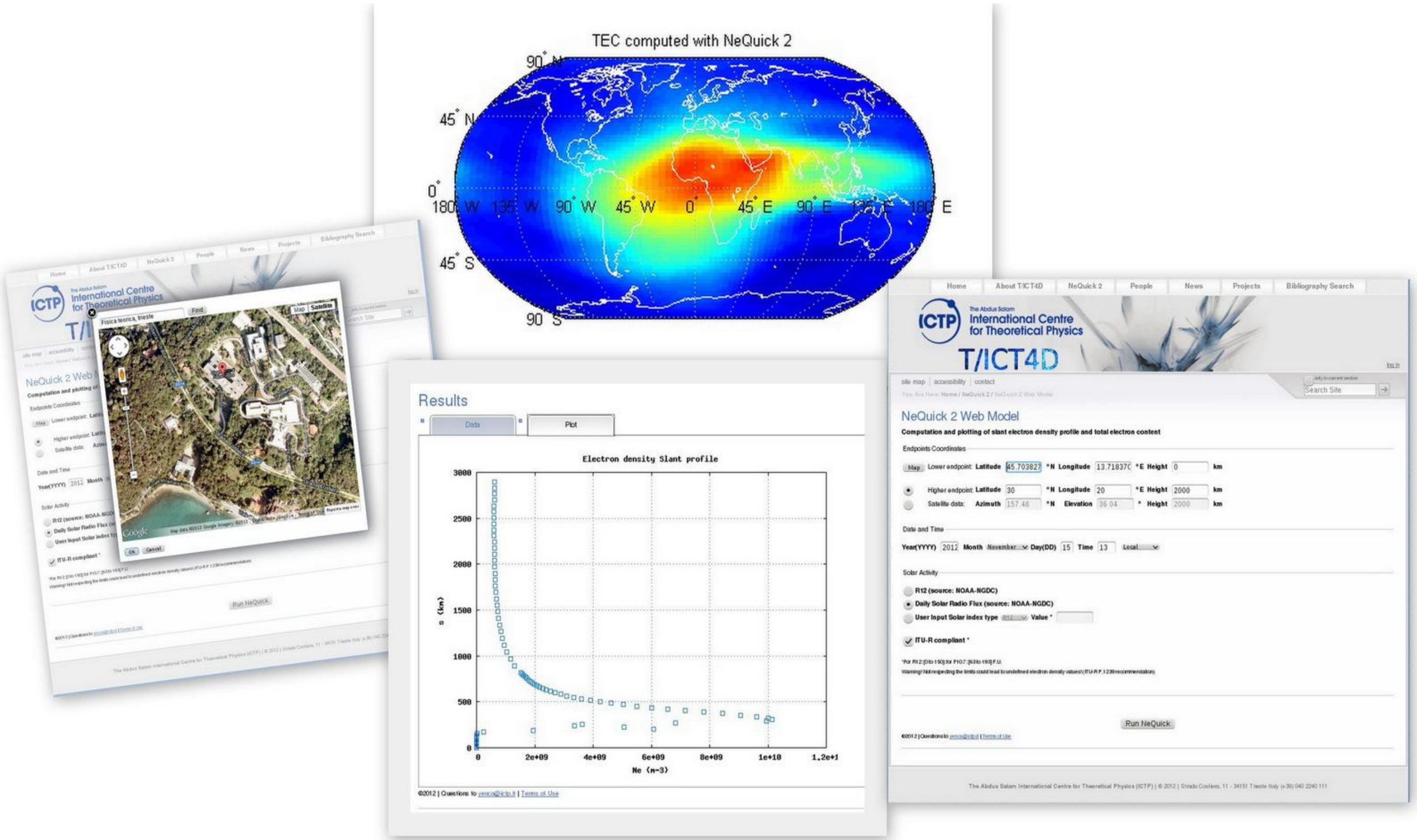
- NeQuick 2: ITU-R source code, https://www.itu.int/

  NeQuick 2 online: http://t-ict4d.ictp.it/nequick2

- NeQuick G (ESA) $Az = a_0 + a_1\mu + a_2\mu^2$

  https://www.gsc-europa.eu/support-to-developers/ionospheric-correction-algorithms/nequick-g-source-code

NeQuick 2 online: http://t-ict4d.ictp.it/nequick2



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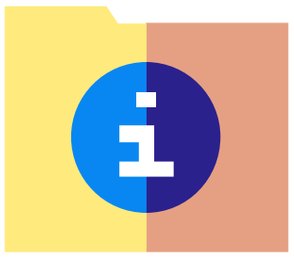
User: ”Help! I cannot find the NeQuick executable!”



Content of NeQuick 2 package

- NeQuick_2_0_2.for
- slQu_2_0_2.for

} FORTRAN 77 source code

- ccir11.asc…ccir22.asc — ITU-R coefficients
- modip.asc — Grid of modip values
- R12.dat — R12 values from 1931 to 2015
- /Test cases
- README.txt

ITU-R (CCIR) files

NeQuick 2 uses the ITU-R coefficients to compute *foF2* and *M(3000)F2* characteristics. These coefficients are stored in the ccirXX.asc files and include the spherical harmonic coefficients representing the development of monthly median *foF2* and *M(3000)F2* all over the world.
The coefficients correspond to low (SSN=0) and high (SSN=100) solar activity conditions and are interpolated (or extrapolated) to obtain the values for the solar activity required.

Note: Since NeQuick 2 is compliant with ITU-R Recommendation P.1239 does not accept (**by default**) F10.7 input values below 63 F.U. (R12=0) and saturates the F10.7 at 193 F.U (R12=150) if solar flux input exceeds 193 F.U (R12=150).

Modip file

NeQuick 2 uses a grid of modip, (μ) contained in the file modip.asc. The values of modip (in degrees) are organized from 90 S to 90N of latitude in steps of 5 degrees and from 180W to 180E of longitude in steps of 10 degrees.

$$\tan\mu = \frac{I}{\sqrt{\cos\phi}}$$ *Rawer [1963]*

Note: The modip map included in the package of NeQuick 2 ITU-R version corresponds to the geomagnetic field for the year 1970.
In the case you want to update or use a different geomagnetic field model you can replace the *modip.asc* file taking into account the grid spacing.

NeQuick Content

Main functions and subroutines

NeQuick2_0_2.for

- All the necessary functions and subroutines to compute Ne.
- Model parameters functions.
- Auxiliary parameters computation.

slQu2_0_2.for

- Main program
- Calculate TEC for arbitrarily chosen rays which do not cut the surface of the Earth between the given endpoints.
- Auxiliary subroutines and functions

Slqu.dat

NeQuick Content

NeQuick_2_0_2.for

```
function NeQuick(h,alat,along,mth,flx,UT) → Ne [m-3]
subroutine prepNeQ(alat,along,mth,UT,flx) → hm,Nm,thickness parameters
```

Ne Computation:

```
function NeNeQ(h,hm,aep,bb)  → Ne [m-3]
function NeMdGR(aep,hm,bb,h) → Ne [m-3], h<=hmF2
function topq(h,No,hmax,Ho)  → Ne [m-3], h>hmF2
subroutine prepmdgr(mth,R12,foF2,efoF1,efoE,M3000)→ hm,Nm,thickness param.
```

NeQuick Content

NeQuick_2_0_2.for *Cont.d*

```
subroutine ef1(alat,mth,flx,chi,foF2) → efoE[MHz],efoF1[MHz]
subroutine cciri(xMODIP,mth,UT,R12,alat,along) → foF2[MHz],M3000
function gamma1(xMODIP,alat,along,hour,iharm,nq,k1,m,mm,m3,sfe)
function peakh(foE,foF2,M3000) → hmF2[km]
subroutine modin(pmodip)
function amodip(pmodip,alat,along) -> modip
```

NeQuick Code

slQu_2_0_2.for

TEC Calculation

ray conventions:
- spherical Earth (RE=6371,2km)
- straight line "rays“
- coordinate s [km] along the ray, origin in ray perigee, point of ray closest to the centre of the Earth.

function gint → numerical integration along a slant ray
function gintv → numerical integration along a vertical ray (if r_p<0.1km)

slQu_2_0_2.for *Cont.d*

```
subroutine rays →  set and check ray endpoints,
                   calculates geometric parameters for ray

subroutine dat_t_sa →  set date and solar activity

subroutine gcirc → calculates great circle path properties

subroutine naut → calculates position of ray perigee, zenith angle of
ray at lower endpoint, and slant to vertical projection factor cos(chi)

subroutine geogra → calculates h, lat and long along the ray from the
perigee of the ray, s

function eld →  gives Ne as a function of the coordinate s
```

NeQuick Content

For compliancy reasons, the NeQuick 2 code does not allow a F10.7 input below 63 F.U. (R12=0) and saturates the F10.7 at 193 F.U (R12=150).

If a value below 63 F.U (R12=0) is input, the subroutine will stop the program. The limits on F10.7 (or R12) input can be removed at the user's own risk by commenting the lines 197 to 208 in the source file NeQuick_2_1.for (prepNeq subroutine) as follows:

NeQuick Content

```
195C     *** flux saturation above 193 FU and blocked below 63 FU to avoid
196C     unrealistic or undefined electron density values! ***
197C     if (flx1 .gt. 193.0D0) then
198C     flx1=193.0D0
199C     write(*,'(2A/A/A)')'***WARNING! Solar flux limit F=193 (R12=150)',
200C    &                    ' exceeded.',
201C    &                    ' NeQuick saturates F to 193 units',
202C    &                    ' (ITU-R P.1239 reccomendation).'
203C     endif
204C     if (flx1 .lt. 63.0D0) then
205C     write(*,'(2A/A)')'***WARNING! Solar flux below 63 FU (R12 <0)',
206C    &                  'program stopped!'
207C     stop
208C     endif
```

WARNING!

After removing the limits on F10.7 (or R12), if values outside the range [63,193] for F10.7 (or [0,150] for R12) are used, unrealistic or undefined electron densities values can be obtained

?

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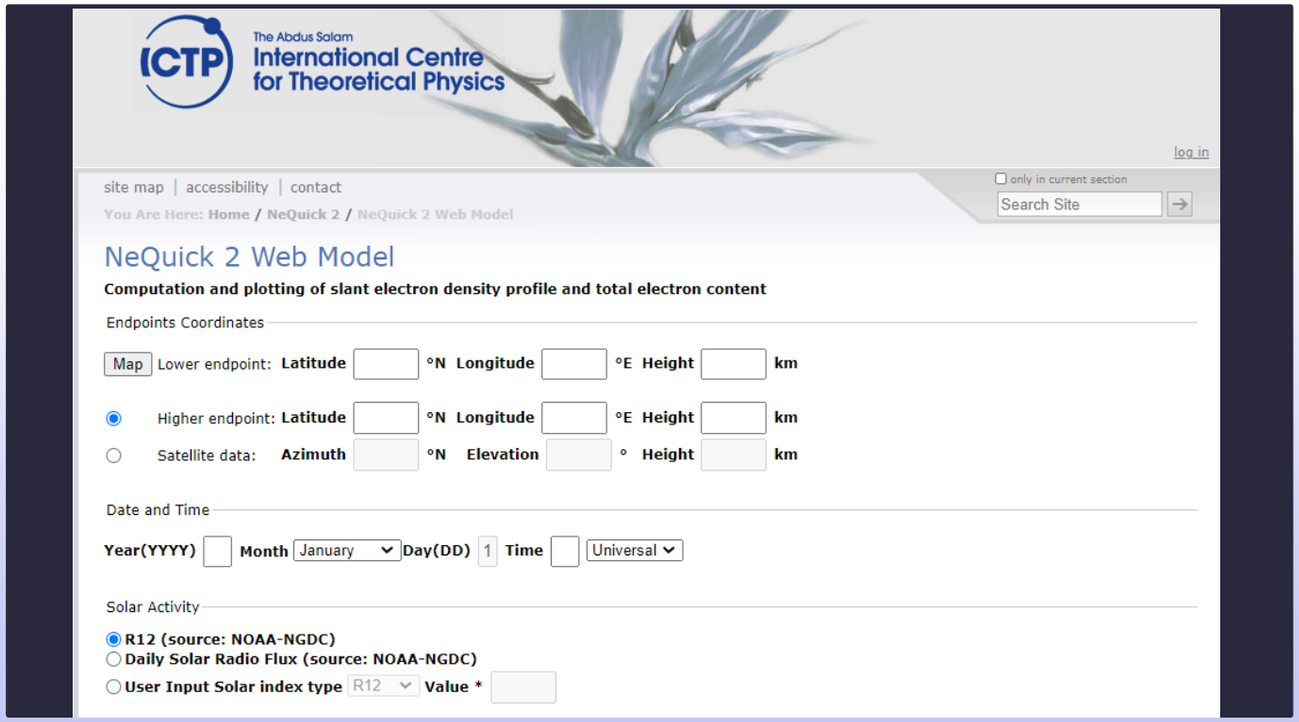
http://t-ict4d.ictp.it/nequick2



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NeQuick 2 Web Model

Computation and plotting of slant electron density profile and total electron content

Endpoints Coordinates

Map Lower endpoint: **Latitude** [ ] °N **Longitude** [ ] °E **Height** [ ] **km**

Higher endpoint: **Latitude** [ ] °N **Longitude** [ ] °E **Height** [ ] **km**

Satellite data: **Azimuth** [ ] °N **Elevation** [ ] ° **Height** [ ] **km**

Date and Time

Year(YYYY) [ ] **Month** January **Day(DD)** 1 **Time** [ ] Universal

Solar Activity

R12 (source: NOAA-NGDC)

Daily Solar Radio Flux (source: NOAA-NGDC)

User Input Solar index type R12 **Value *** [ ]

ITU-R compliant *

*For R12: [0 to 150]; for F10.7: [63 to 193] F.U.

Warning! Not respecting the limits could lead to undefined electron density values! (ITU-R P.1239 recommendation)

Run NeQuick

http://t-ict4d.ictp.it/nequick2

Model usage

Results

Data | Plot

Ray endpoint 1: lat. (deg. N), long. (deg. E), height (km)
28.00 151.00 60.00
Ray endpoint 2: lat. (deg. N), long. (deg. E), height (km)
30.00 151.00 2000.00
zenith angle (deg.) and azimuth (N over E to S, deg.) of ray at endpoint 1
8.59 0.00
Year, S10.7, R12, month, UT: 2021, 75.2, 15.5, 1, 14.0

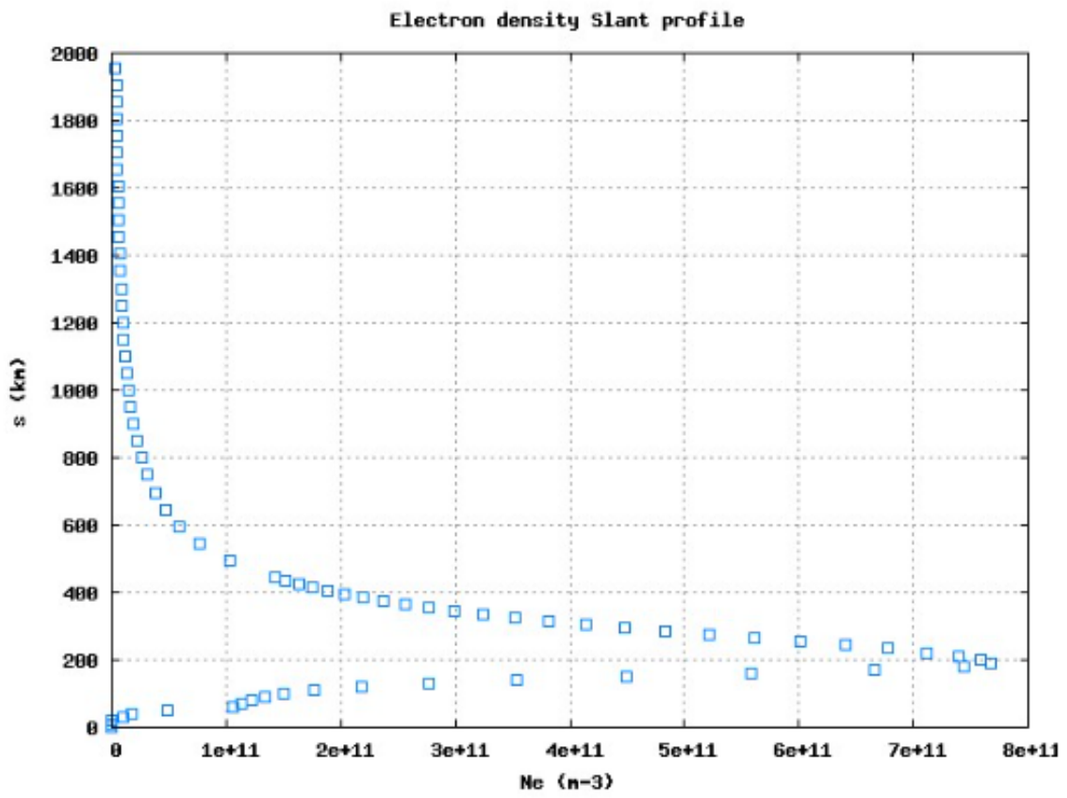
Electron contents along ray.
(h1-h2) means from point in height h1 to point in height h2 (heights in km)
s: coordinate along ray
r: radius (distance from center of Earth)

s km	r km	height km	lat deg N	long deg E	el.density m^-3
0.0	6431.2	60.0	28.00	151.00	0.000000E+00
10.1	6441.2	70.0	28.01	151.00	0.104415E+04
20.2	6451.2	80.0	28.03	151.00	0.481307E+07
30.3	6461.2	90.0	28.04	151.00	0.185524E+11
40.5	6471.2	100.0	28.05	151.00	0.179281E+11
50.6	6481.2	110.0	28.07	151.00	0.486088E+11
60.7	6491.2	120.0	28.08	151.00	0.105461E+12
70.8	6501.2	130.0	28.09	151.00	0.111955E+12
80.9	6511.2	140.0	28.11	151.00	0.123481E+12
91.0	6521.2	150.0	28.12	151.00	0.111534E+12
101.1	6531.2	160.0	28.13	151.00	0.150479E+12
111.2	6541.2	170.0	28.15	151.00	0.177246E+12
121.3	6551.2	180.0	28.16	151.00	0.318085E+12
131.4	6561.2	190.0	28.17	151.00	0.270528E+12
141.6	6571.2	200.0	28.18	151.00	0.352913E+12
151.7	6581.2	210.0	28.20	151.00	0.448688E+12
161.8	6591.2	220.0	28.21	151.00	0.558515E+12
171.9	6601.2	230.0	28.22	151.00	0.666323E+12
183.0	6611.2	240.0	28.24	151.00	0.741588E+12
193.1	6621.2	250.0	28.25	151.00	0.767336E+12
203.2	6631.2	260.0	28.26	151.00	0.758669E+12
213.3	6641.2	270.0	28.27	151.00	0.739318E+12
223.4	6651.2	280.0	28.29	151.00	0.711723E+12
233.5	6661.2	290.0	28.30	151.00	0.678177E+12
243.6	6671.2	300.0	28.31	151.00	0.640837E+12
253.7	6681.2	310.0	28.32	151.00	0.601546E+12
263.8	6691.2	320.0	28.34	151.00	0.522111E+12
273.9	6701.2	330.0	28.35	151.00	0.483974E+12
283.0	6711.2	340.0	28.36	151.00	0.447641E+12
293.1	6721.2	350.0	28.37	151.00	0.413443E+12
303.2	6731.2	360.0	28.39	151.00	0.381529E+12
313.3	6741.2	370.0	28.40	151.00	0.351953E+12
323.5	6751.2	380.0	28.41	151.00	0.324685E+12
333.6	6761.2	390.0	28.42	151.00	0.299643E+12
343.7	6771.2	400.0	28.43	151.00	0.276783E+12
353.8	6781.2	410.0	28.45	151.00	0.255716E+12
363.9	6791.2	420.0	28.46	151.00	0.236595E+12
374.0	6801.2	430.0	28.47	151.00	0.219134E+12
384.1	6811.2	440.0	28.48	151.00	0.203218E+12
394.2	6821.2	450.0	28.49	151.00	0.188687E+12
404.3	6831.2	460.0	28.51	151.00	0.175418E+12
414.4	6841.2	470.0	28.52	151.00	0.163344E+12
424.5	6851.2	480.0	28.53	151.00	0.152396E+12
434.6	6861.2	490.0	28.54	151.00	0.142195E+12
444.7	6871.2	500.0	28.55	151.00	0.133016E+12
495.2	6921.2	550.0	28.61	151.00	0.771258E+11
545.6	6971.2	600.0	28.67	151.00	0.594655E+11
596.1	7021.2	650.0	28.73	151.00	0.476444E+11
646.6	7071.2	700.0	28.78	151.00	0.388589E+11
697.1	7121.2	750.0	28.84	151.00	0.319923E+11
747.5	7171.2	800.0	28.89	151.00	0.263332E+11
798.0	7221.2	850.0	28.95	151.00	0.234161E+11
848.4	7271.2	900.0	29.00	151.00	0.191288E+11
898.8	7321.2	950.0	29.05	151.00	0.168558E+11
949.3	7371.2	1000.0	29.10	151.00	0.148469E+11
999.7	7421.2	1050.0	29.15	151.00	0.131917E+11
1050.1	7471.2	1100.0	29.20	151.00	0.118174E+11
1100.5	7521.2	1150.0	29.25	151.00	0.106596E+11
1150.9	7571.2	1200.0	29.30	151.00	0.967634E+10
1201.4	7621.2	1250.0	29.35	151.00	0.883484E+10
1251.8	7671.2	1300.0	29.40	151.00	0.810676E+10
1302.1	7721.2	1350.0	29.44	151.00	0.747425E+10
1352.5	7771.2	1400.0	29.49	151.00	0.693048E+10
1402.9	7821.2	1450.0	29.53	151.00	0.643268E+10
1453.3	7871.2	1500.0	29.58	151.00	0.600054E+10
1503.7	7921.2	1550.0	29.62	151.00	0.561578E+10
1554.0	7971.2	1600.0	29.67	151.00	0.527133E+10
1604.4	8021.2	1650.0	29.71	151.00	0.496173E+10
1654.8	8071.2	1700.0	29.75	151.00	0.468226E+10
1705.1	8121.2	1750.0	29.80	151.00	0.443097E+10
1755.5	8171.2	1800.0	29.84	151.00	0.419855E+10
1805.8	8221.2	1850.0	29.88	151.00	0.398825E+10
1856.2	8271.2	1900.0	29.92	151.00	0.379566E+10
1906.5	8321.2	1950.0	29.96	151.00	0.361875E+10
1956.8	8371.2	2000.0	30.00	151.00	0.361875E+10

Electron contents (60-1000),(1000-2000),(60-2000)
174.50 7.61 182.10 x10^15 m^-2
TEC= 18.21 TECu (1TECu=1x10^16 m^-2)

Results

Data | Plot



1906.5 8321.2 1950.0 29.96 351.00 0.379566E+10
1956.8 8371.2 2000.0 30.00 351.00 0.361875E+10

Electron contents (60-1000),(1000-2000),(60-2000)
174.50 7.61 182.10 x10^15 m^-2
TEC= 18.21 TECu (1TECu=1x10^16 m^-2)

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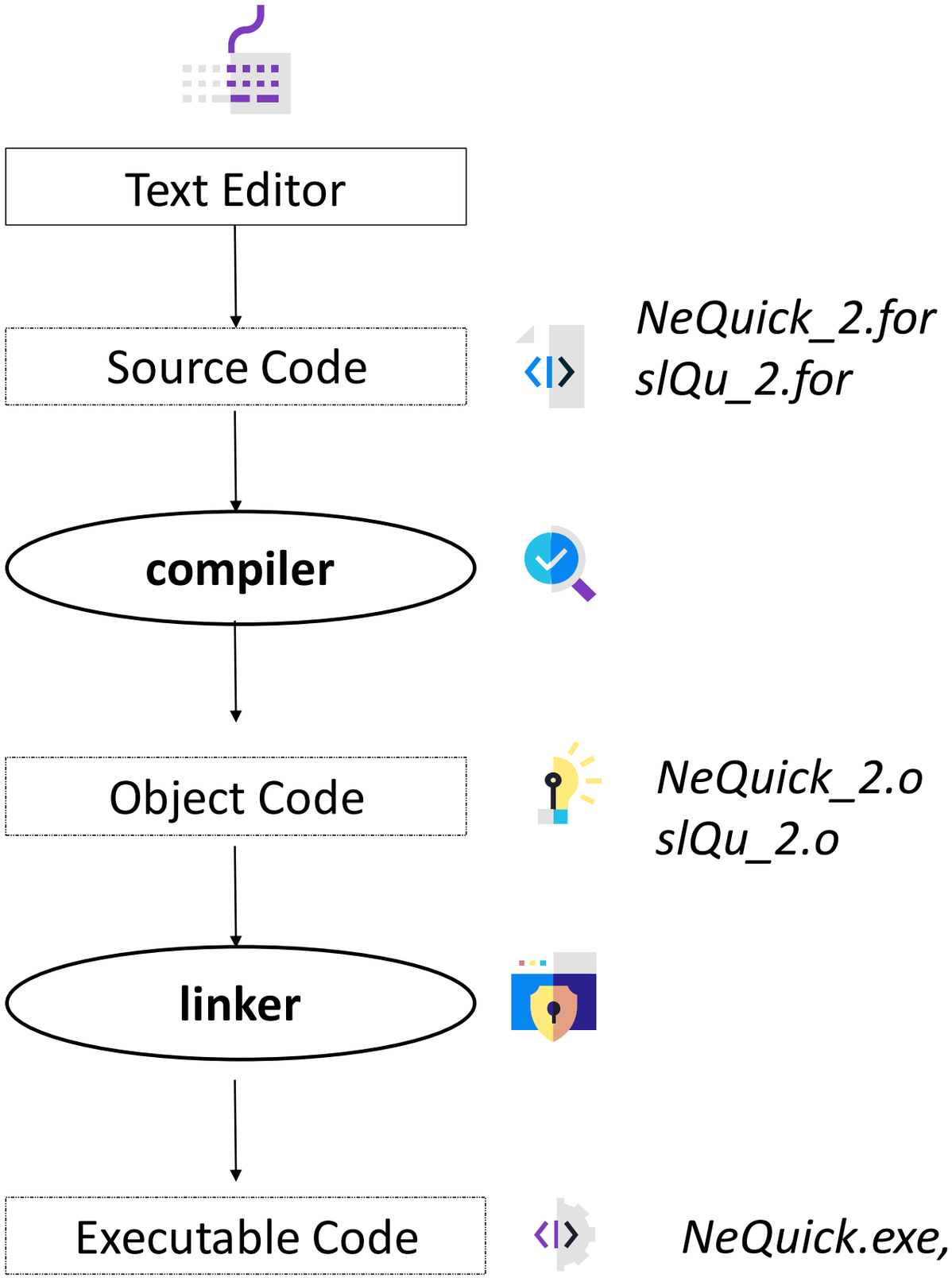
Model usage



Translate

NeQuick_2.for
slQu_2.for

Put together

NeQuick_2.o
slQu_2.o

NeQuick.exe, a.out

Fortran 77 compilers

F77, G77

Intel Fortran Compiler for Linux

Gfortran – the GNU Fortran Compiler

Salford FTN95 Compiler

For Windows Users:

MinGW 's (Gfortran, G77)

Cygwin

Force Project

Model usage

NeQuick Compilation

Compile and Link NeQuick_2.for and **slQu_2.for** with a FORTRAN 77 compiler

Command format:

```
compiler [-o outputfile] NeQuick_2.for slQu_2.for
```

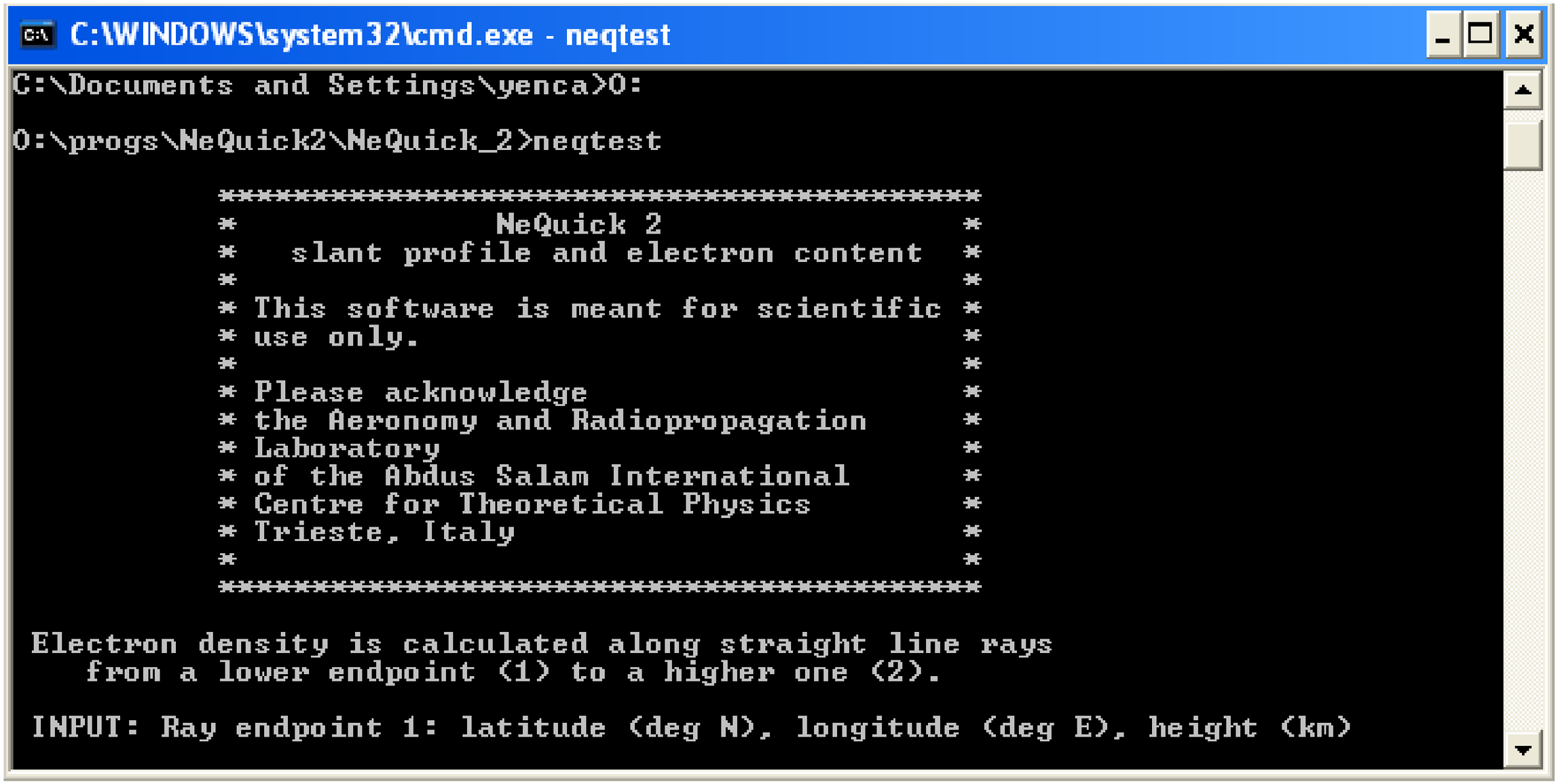
For example:

```
f77 -o neq2 NeQuick_2.for slQu_2.for
```

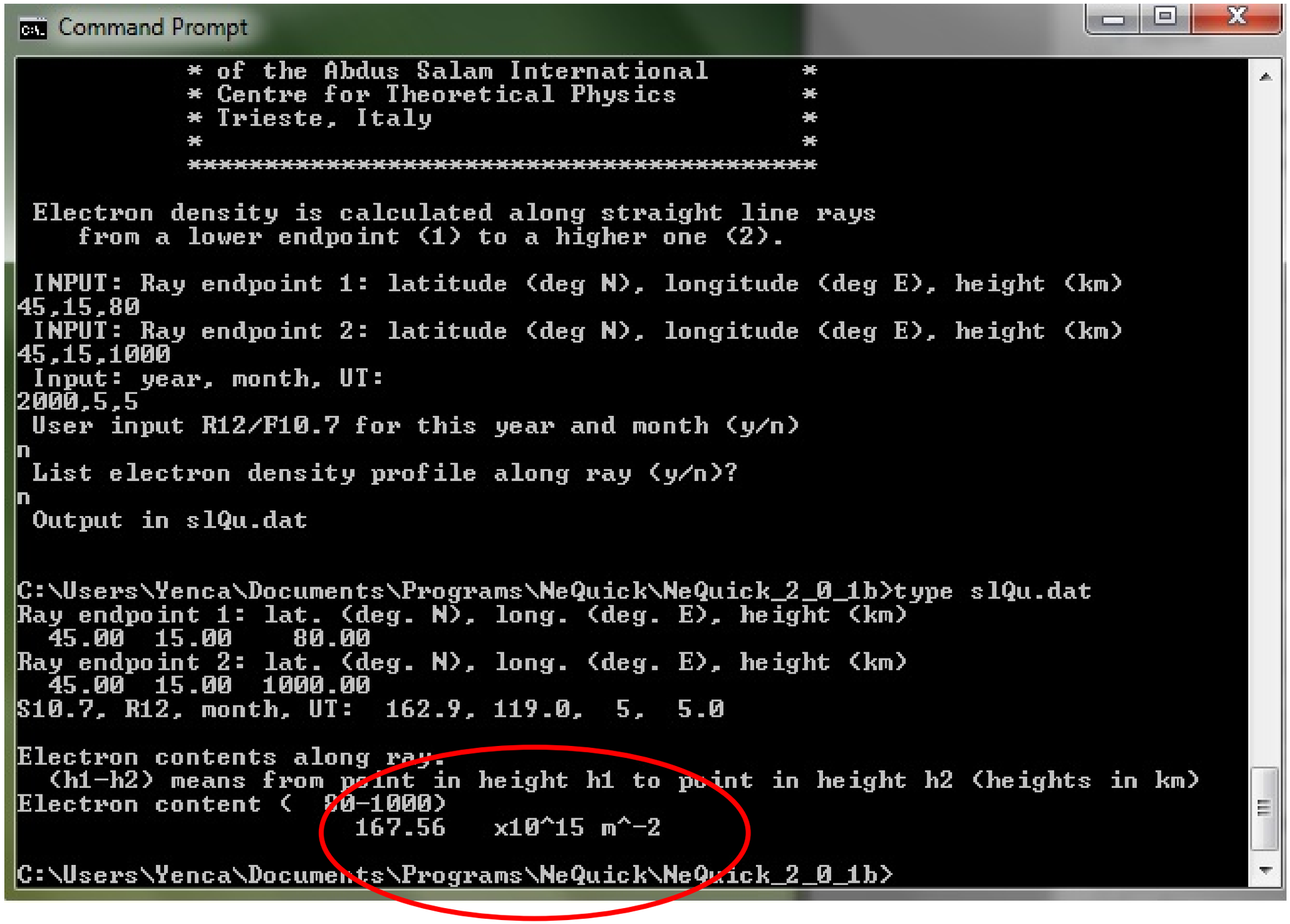
To run:

```
./neq2
./a.out
a.exe
```

Running…


C:\WINDOWS\system32\cmd.exe - neqtest
C:\Documents and Settings\yenca>O:
O:\progs\NeQuick2\NeQuick_2>neqtest
NeQuick 2
slant profile and electron content
This software is meant for scientific use only.
Please acknowledge
the Aeronomy and Radiopropagation Laboratory
of the Abdus Salam International Centre for Theoretical Physics
Trieste, Italy
Electron density is calculated along straight line rays
from a lower endpoint (1) to a higher one (2).
INPUT: Ray endpoint 1: latitude (deg N), longitude (deg E), height (km)

Running…



Not TECU!

Running…

https://users.ictp.it/~yenca/IRI_NEQ/

Exercise

I have VTEC derived from a GNSS station and I want to calculate VTEC with NeQuick for a specific month and year along the day every hour.

Driver Program Example

```
program NeQ_Station
      implicit none
      real*8 ut,stat_lat,stat_lon,h0,h2,flx,tec
      integer mth,year,h

      character*30 filename

C     Invoked function
double precision vtec

h0=0.0
h2=20000.0
year=
mth=
flx=
stat_lat=
stat_lon=

filename='filewithTEC.txt'
    open(16,file=filename)
   do h=0,23
      ut=real(h)
      tec=vtec(h0,h2,stat_lat,stat_lon,mth,ut,flx)
      write(16,'(2F8.2)')ut,tec
   enddo
close(16)
end program NeQ_Station
```

```
real*8 function vtec(h0,h2,alat, along, mth, ut, az)

      implicit real*8 (a-h,o-z)
      dimension hm(3),aep(3),bb(6)
      real*8 gintv

      common /nepar/hm,aep,bb

      h1a=1000.0D0
      h1b=2000.0D0

          call prepNeQ(alat,along,mth,ut,az,hm,aep,bb)
     tec1=gintv(h0, h1a,1.0D-3)
     tec2=gintv(h1a,h1b,1.0D-2)
      tec3=gintv(h1b,h2, 1.0D-2)
      tec4=tec1+tec2+tec3
      vtec=tec4/1.0D13
return
end
```

```
real*8 function gintv (g1,g2,eps)
C     integrates NeNeQ for vertical profile

      implicit real*8 (a-h,o-z)
      real*8 NeNeQ
      dimension hm(3),aep(3),bb(6)
      common /nepar/hm,aep,bb
         gint1 = 0.0D0
         n = 8
    1    h  =  (g2-g1) / dfloat(n)
        hh = 0.5D0*h
         g  = h*0.5773502691896D0
         y  = g1 + (h-g)*0.5D0
         gint2  =  NeNeQ(y,hm,aep,bb)+
+              NeNeQ(y+g,hm,aep,bb)
      do m = 1,n-1
         gint2 = gint2 + NeNeQ(y+h+g,hm,aep,bb)+
+                        NeNeQ(y+h,hm,aep,bb)
         y = y + h
      enddo
      gint2 = gint2*hh
      if (n.eq.8.or.abs(gint1-gint2).gt.eps*abs(gint1)) then
         n = n*2
         gint1 = gint2
         if (n.lt.1024) goto 1
      endif
      gintv = gint2+(gint2-gint1)/15.0D0
 return
 end
```

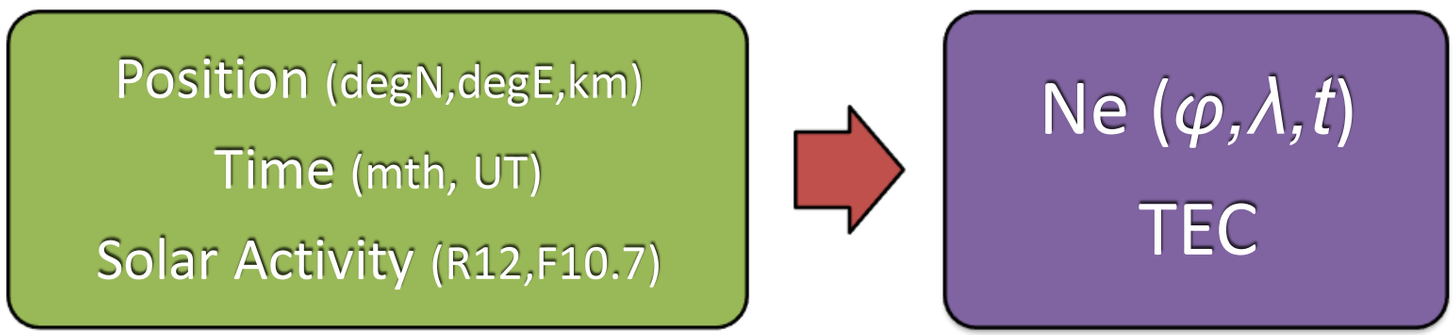
Command format:

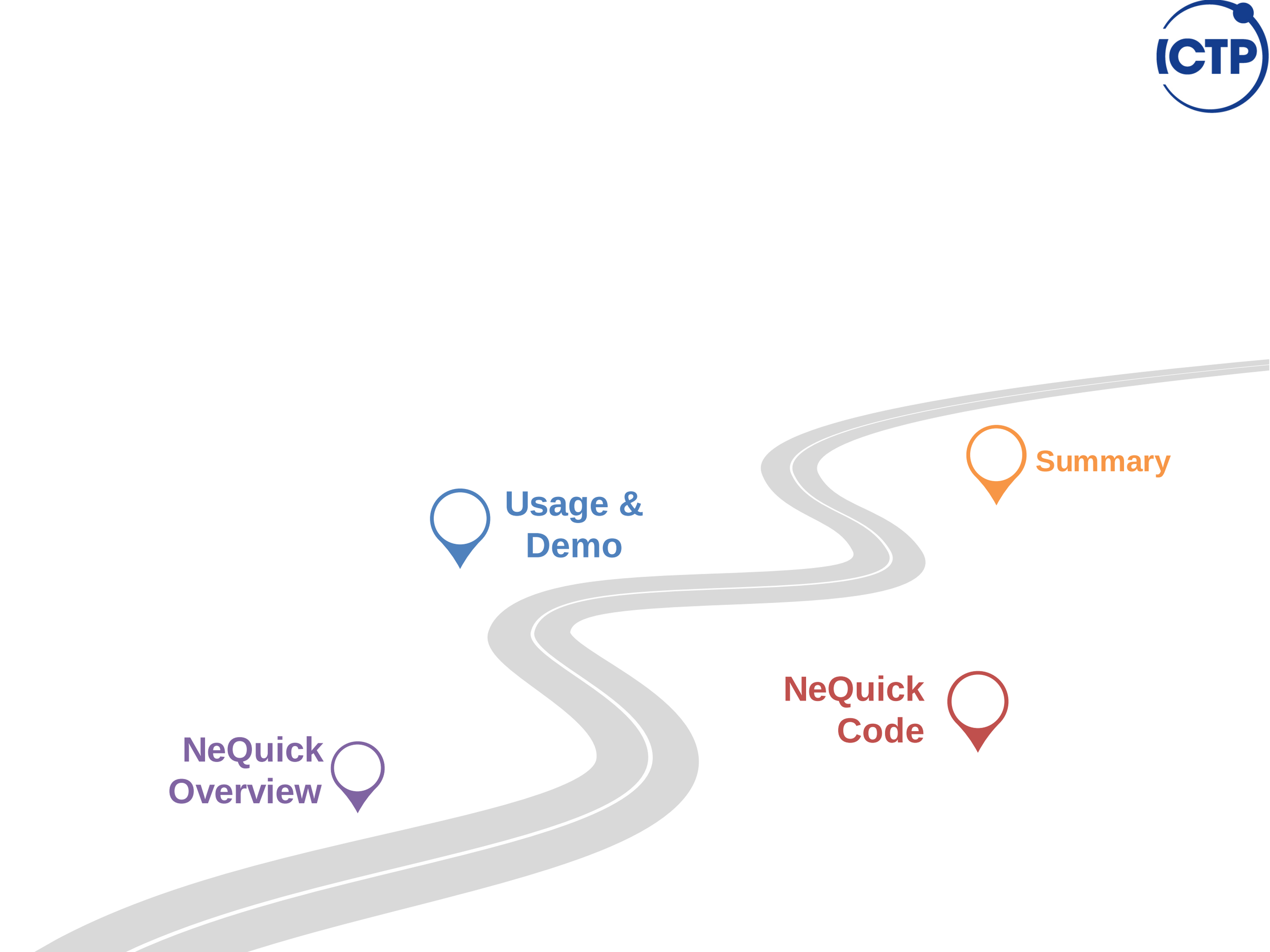
gfortran [-o outputfile] NeQuick_2_0_2.for NeQ_Station.f gintv.f vtec.f

Model usage

May I use NeQuick 2 to assess its performance during geomagnetic storms?

NeQuick is an empirical climatological model that represents monthly median states of the ionosphere




Summary
Usage &
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NeQuick
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NeQuick
Overview

Summary

- NeQuick is a three-dimensional and time dependent empirical ionospheric electron density model to represent the climatology of the ionosphere.

- Predecessors, versions and usage of the model have been presented, together with the main functions and subroutines.

- We have briefly demonstrated how to prepare the executable, run and use the NeQuick model (and how you should not ☺).

Thank you!

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