

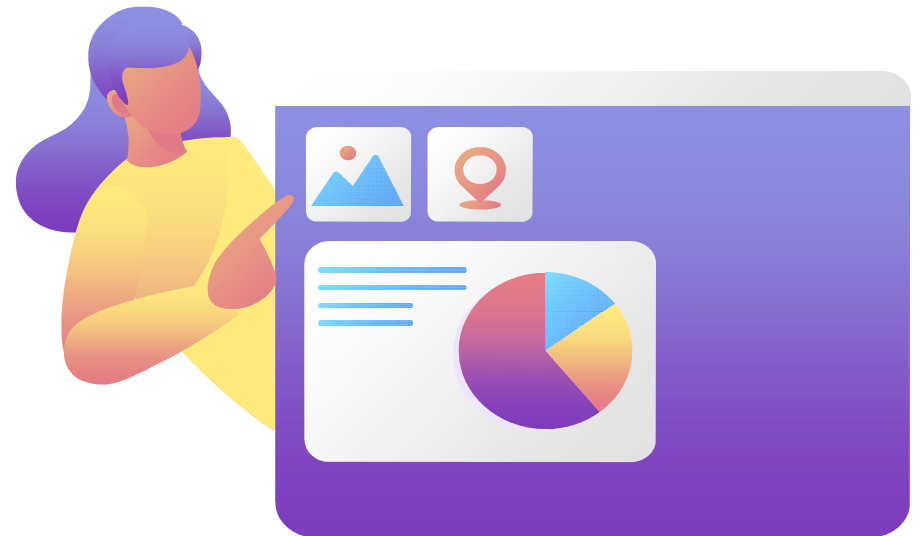


The Abdus Salam  
International Centre  
for Theoretical Physics



# THE NEQUICK MODEL

Yenca Migoya-Orué  
ICTP



# Talk roadmap

NeQuick  
Overview 

NeQuick  
Code 

NeQuick  
formulation 

Model  
usage 

Summary 

Are you ready for...

NeQuiz?

**NeQuick  
Overview**



**NeQuick  
Code**



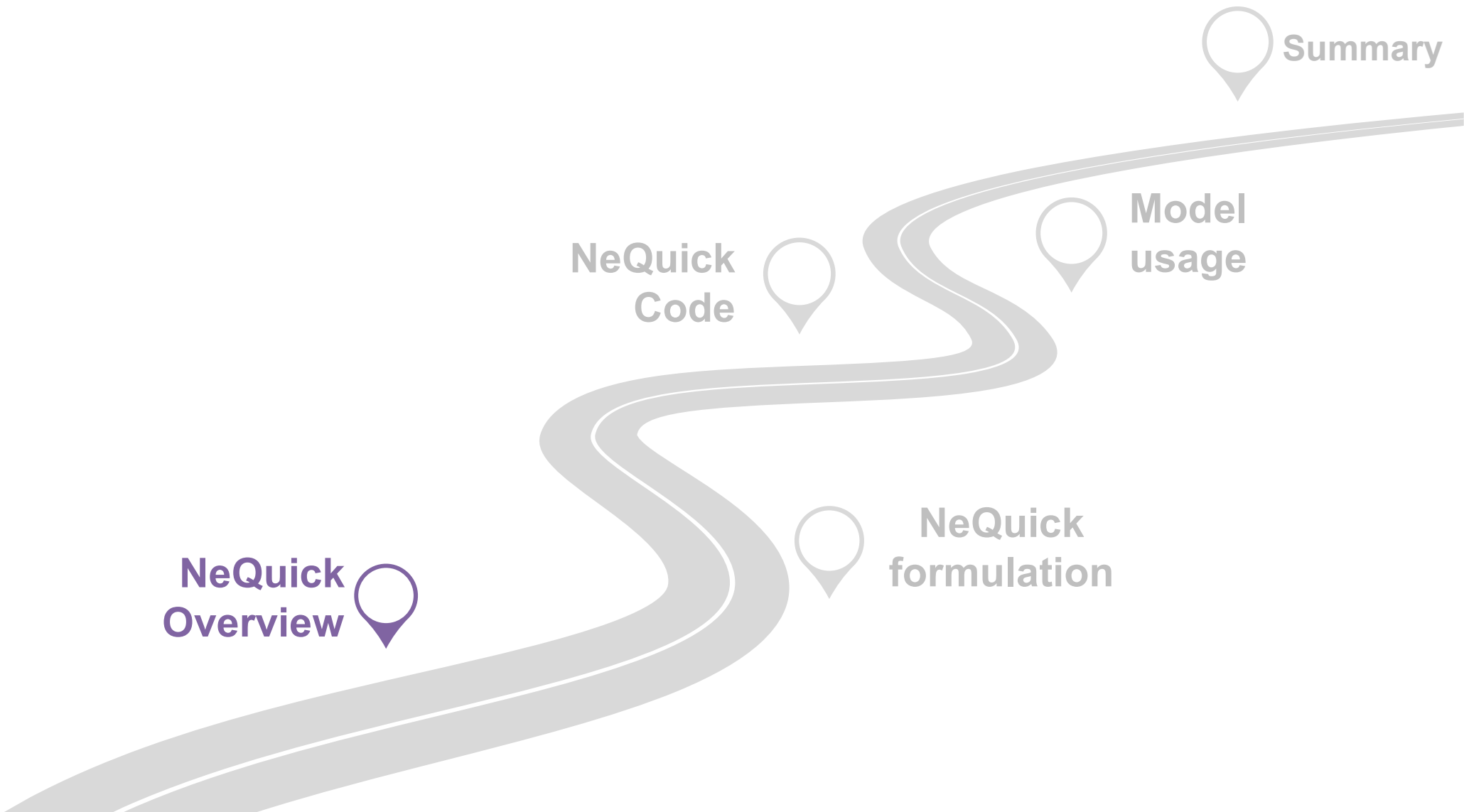
**NeQuick  
formulation**



**Model  
usage**

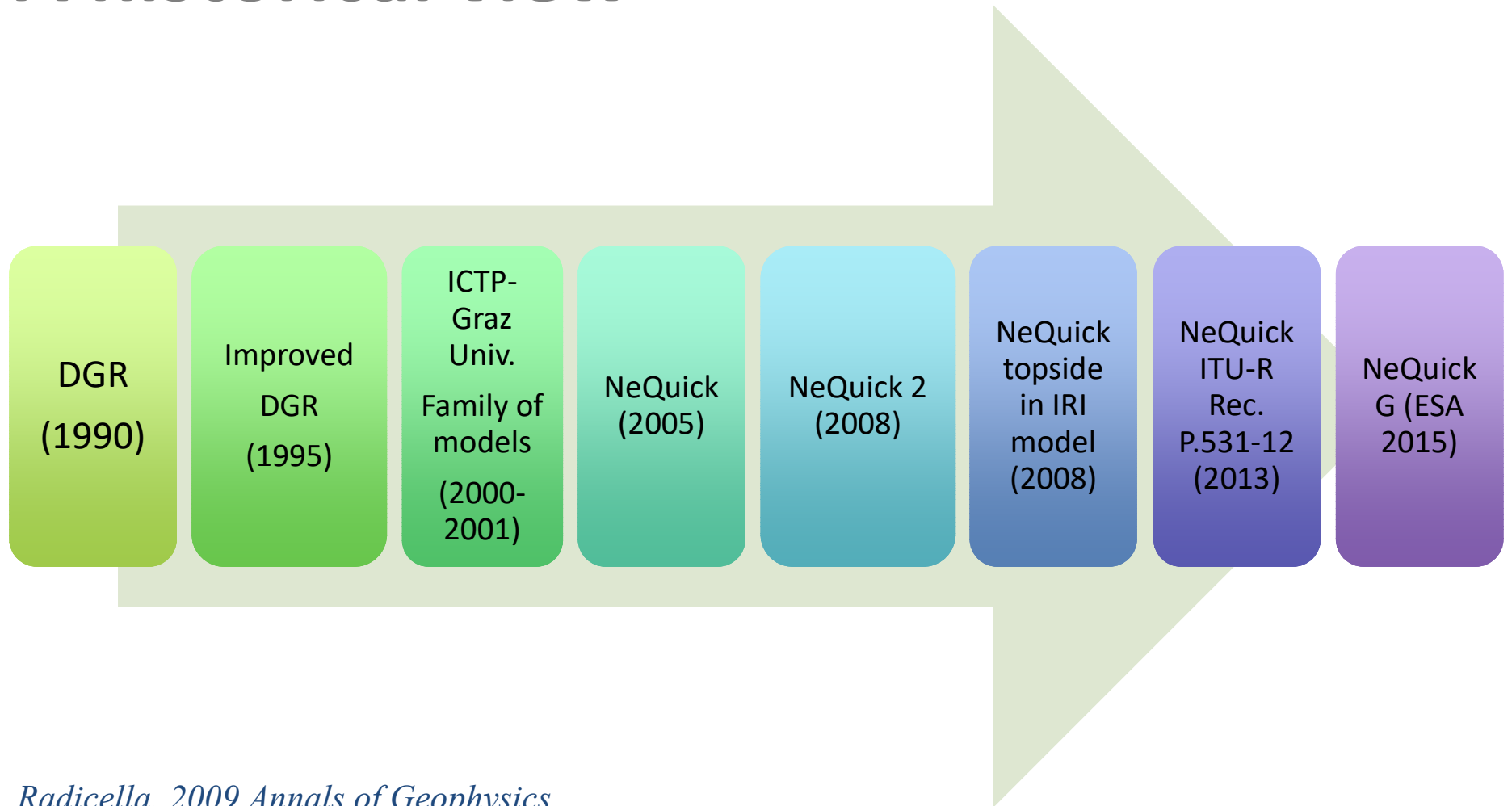


**Summary**



## NeQuick Overview

# A historical view



*Radicella, 2009 Annals of Geophysics*

# Trieste-Graz Family of models

*HOCHEGGER, G., B. NAVA, S.M. RADICELLA, R. LEITINGER (2000) Family of Ionospheric Models for Different Uses, Physics And Chemistry Of The Earth, Part C: Solar, Terrestrial & Planetary Science (25) 4, 307-310*

*RADICELLA, S.M., R. LEITINGER, The Evolution of the DGR Approach to Model Electron Density Profiles, Adv. Space Res., Vol. 27, No. 1, 35-40, 2001*

A family of Ne models, differing in complexity and with different but related application areas based on the DGR «profiler» concept has been developed in collaboration with the University of Graz, Austria.

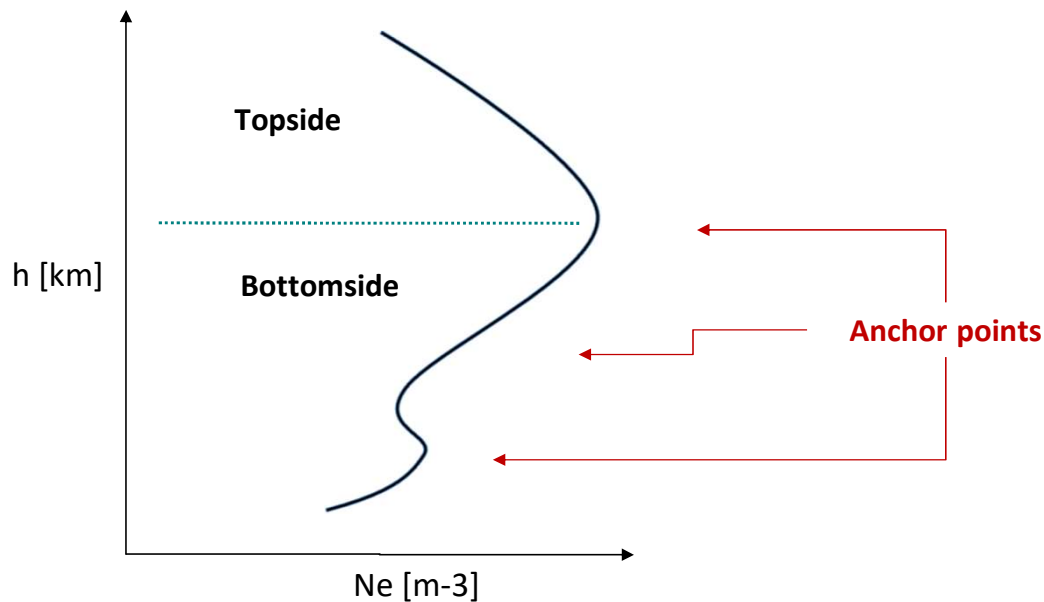
**COSTprof:** For ionospheric and plasmaspheric satellite to ground propagation with particular attention to the changes of gradients in the topside profile of electron density. This model was adopted by the COST 251 action of the European Commission as “profiler” for its final product.

**NeUoG-plas:** For assessment studies involving satellite to satellite propagation paths to take into account an accurate plasmaspheric electron density.

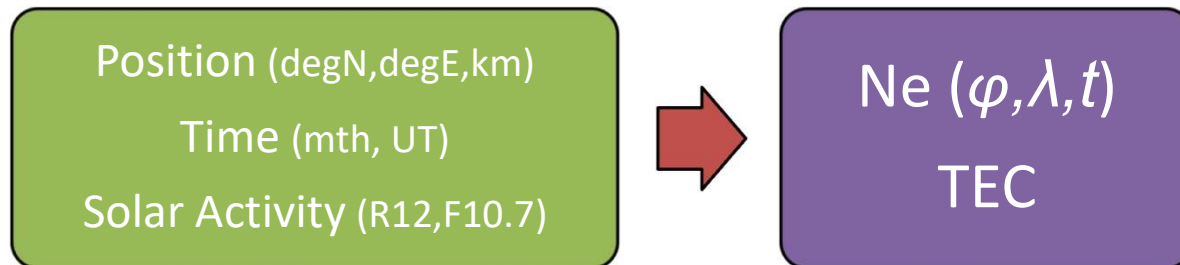
**NeQuick:** A quick-run model for transionospheric applications that allows to calculate both vertical or slant profile of electron density and TEC for any specified path.

## 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.

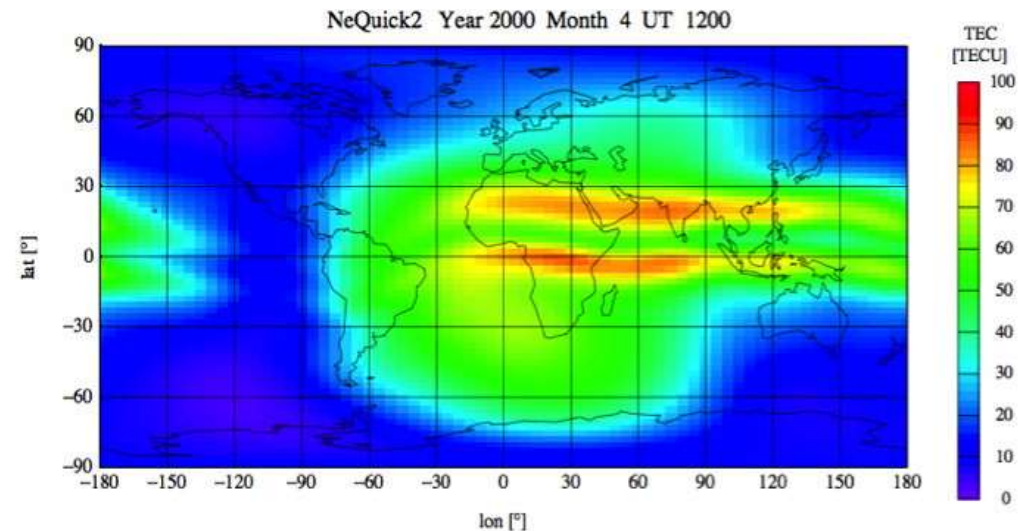


modelled (e.g. ITU-R coefficients for foF2, M(3000)F2) or experimentally derived



# NeQuick 2 Overview

- Revision of the original DGR approach for the F1 and E regions formulation was done.
- Improvement of the topside.
- The computer code of the model was also improved.



COÏSSON, P. AND S.M. RADICELLA, R. LEITINGER AND B. NAVA (2006) Topside electron density in IRI and NeQuick: features and limitations parameters, *Adv. Space Res.*, 37, 937-942

LEITINGER, R., M.L. ZHANG and S. M. RADICELLA (2005), An improved bottomside for the ionospheric electron density model NeQuick, *Annals of Geophysics* 48(3) 525-534

NAVA. B., P. COÏSSON AND S.M. RADICELLA (2008), A new version of the NeQuick ionosphere electron density model; *J.of Atmos.and Solar-Terr. Physics*.



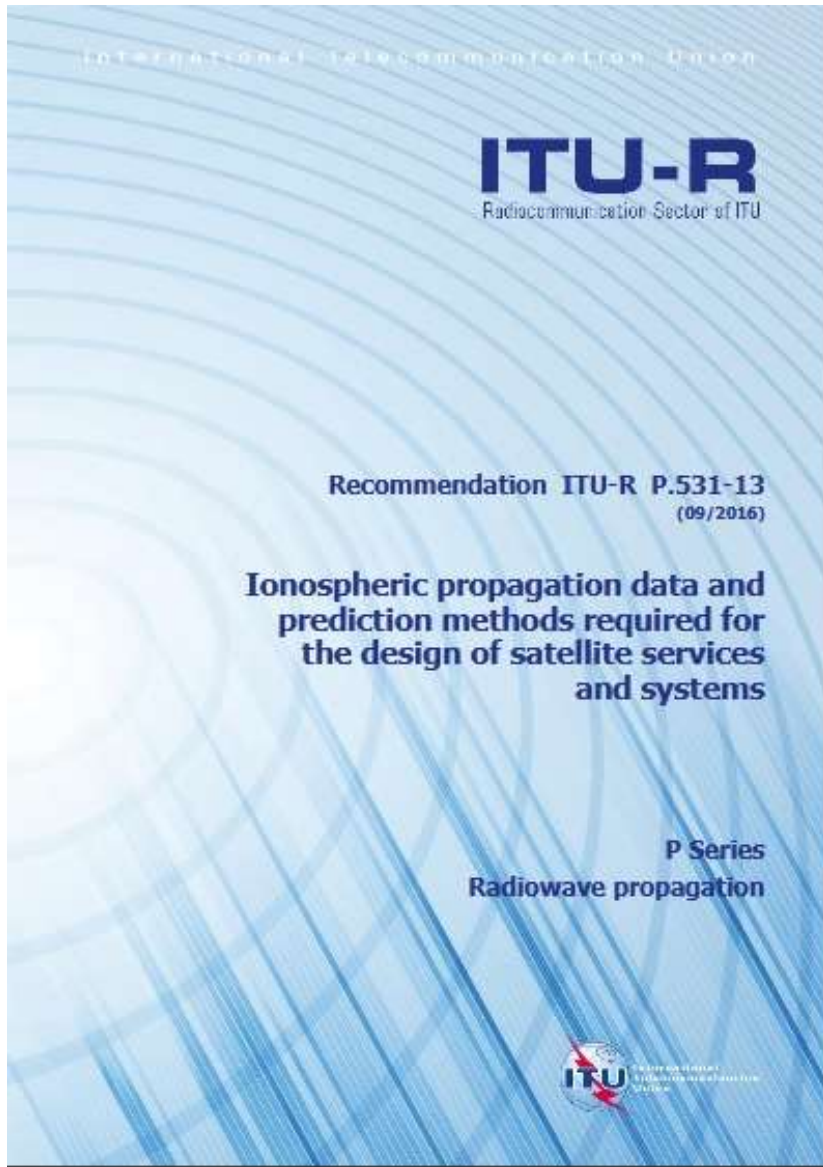
# NeQuick Overview

*Radicella, 2009 Annals of Geophysics*

- NeQuick 2 topside adopted in IRI (since 2007 version) as topside option.
- NeQuick used to produce 'ionospheric scenarios' for EGNOS.
- NeQuick 2 included in the ESA (SPENVIS) Space Environment Information System.
- NeQuick-based version adopted as the model for ionospheric corrections in the single frequency operation of GALILEO.



# NeQuick 2 in ITU-R and NeQuick G



EUROPEAN GNSS (GALILEO) OPEN SERVICE  
**IONOSPHERIC CORRECTION**  
ALGORITHM FOR GALILEO  
SINGLE FREQUENCY USERS



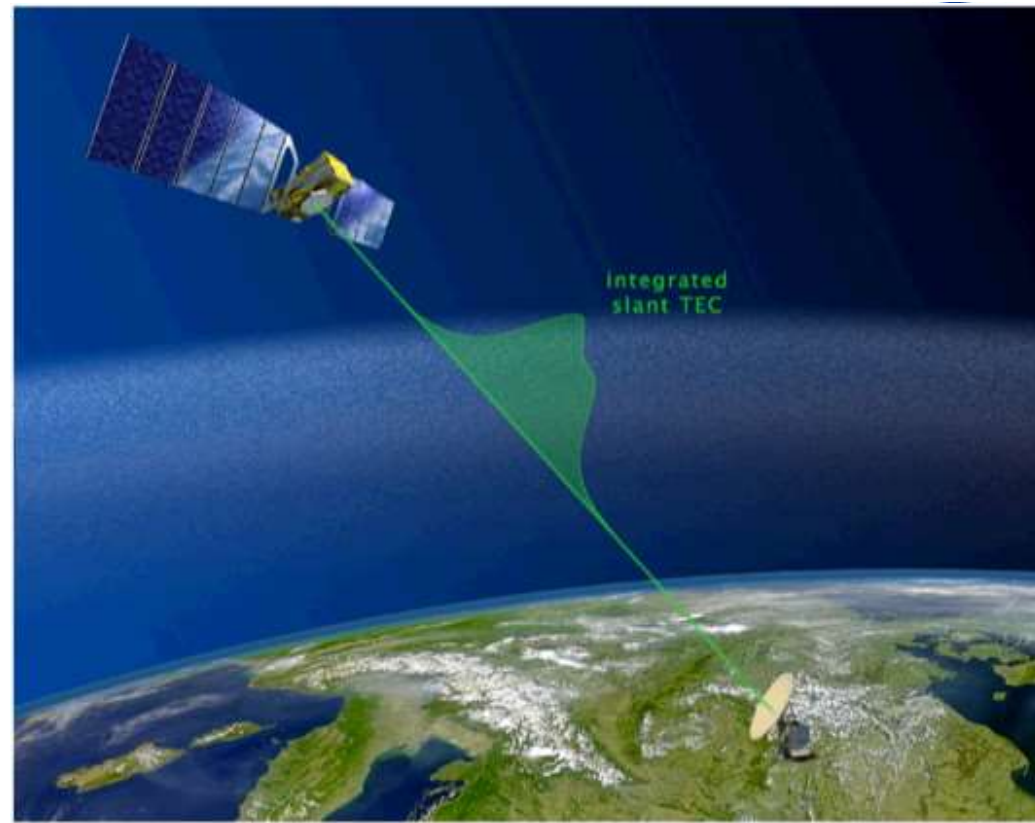
# ICG Working Groups Recommendations

## NeQuick Ionospheric Model

To assess the performance and usability of a NeQuick ionospheric correction algorithm for the single frequency users similar to the one adopted by Galileo in view of its expected good performance compared with other models, i.e. at low latitudes:

[http://www.gsc-europa.eu/system/files/galileo\\_documents/Galileo Ionospheric Model.pdf](http://www.gsc-europa.eu/system/files/galileo_documents/Galileo_Ionospheric_Model.pdf)

# NeQuick versions



- NeQuick 1: available in ITU-R

- NeQuick 2: ITU-R source code,

<https://www.itu.int/rec/R-REC-P.531-14-201908-I/en>

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

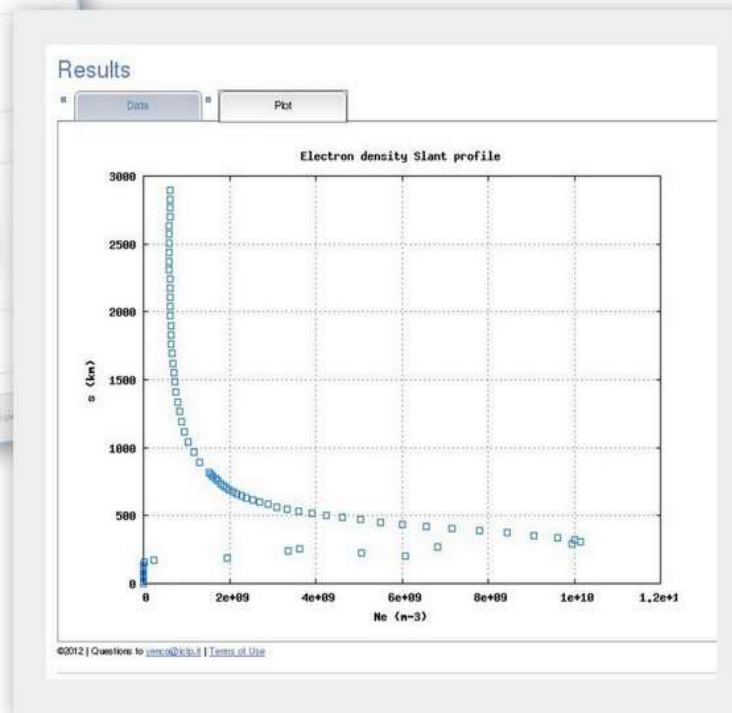
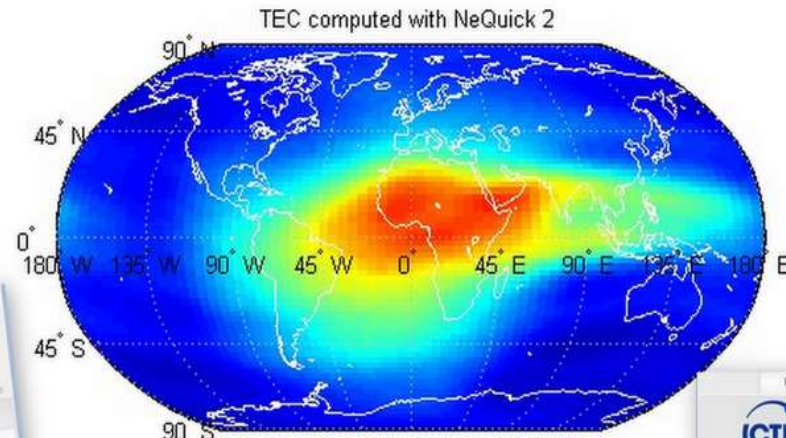
- NeQuick G (ESA)

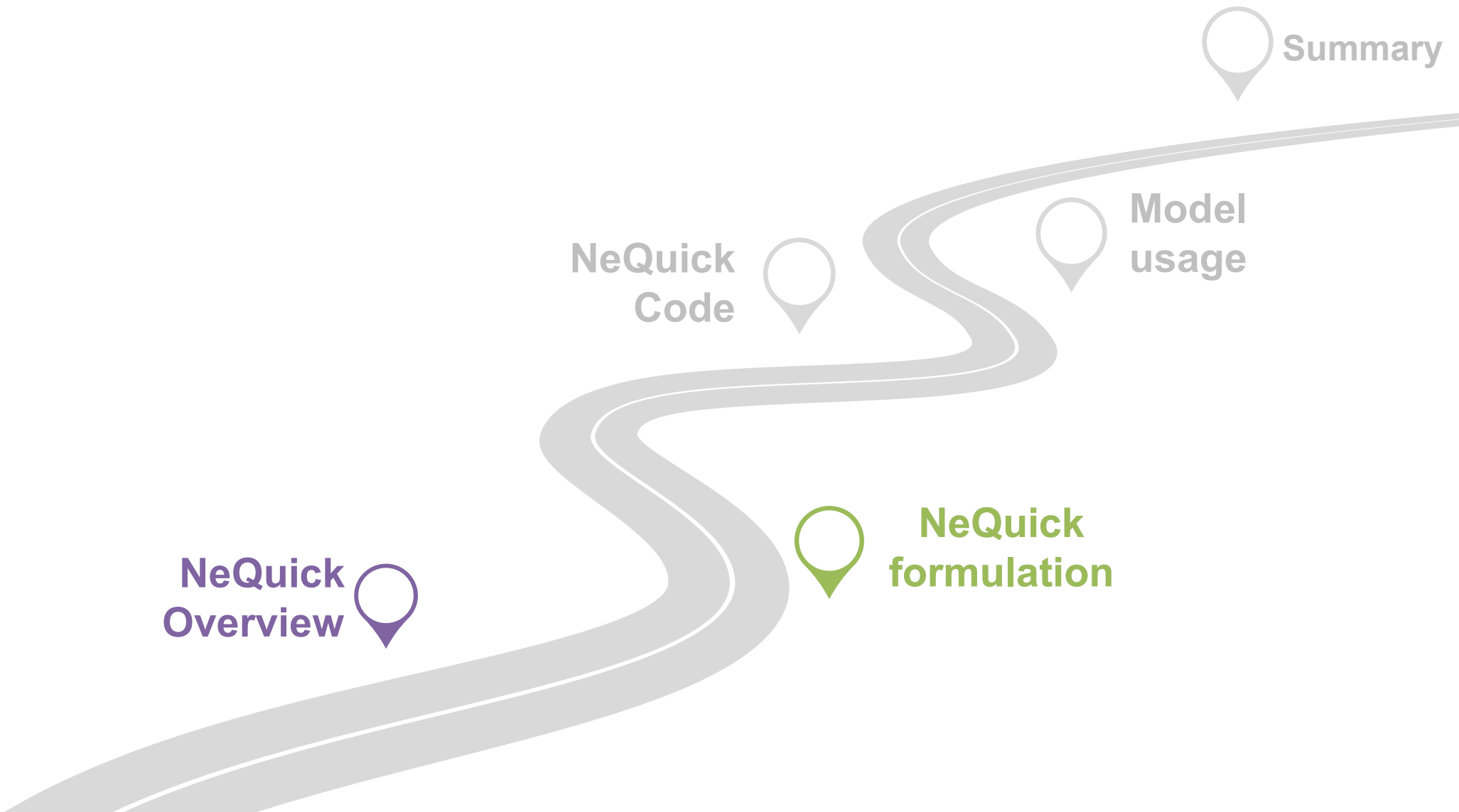
$$Az = a_0 + a_1\mu + a_2\mu^2$$

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



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





NeQuick Overview 

NeQuick Code 

NeQuick formulation 

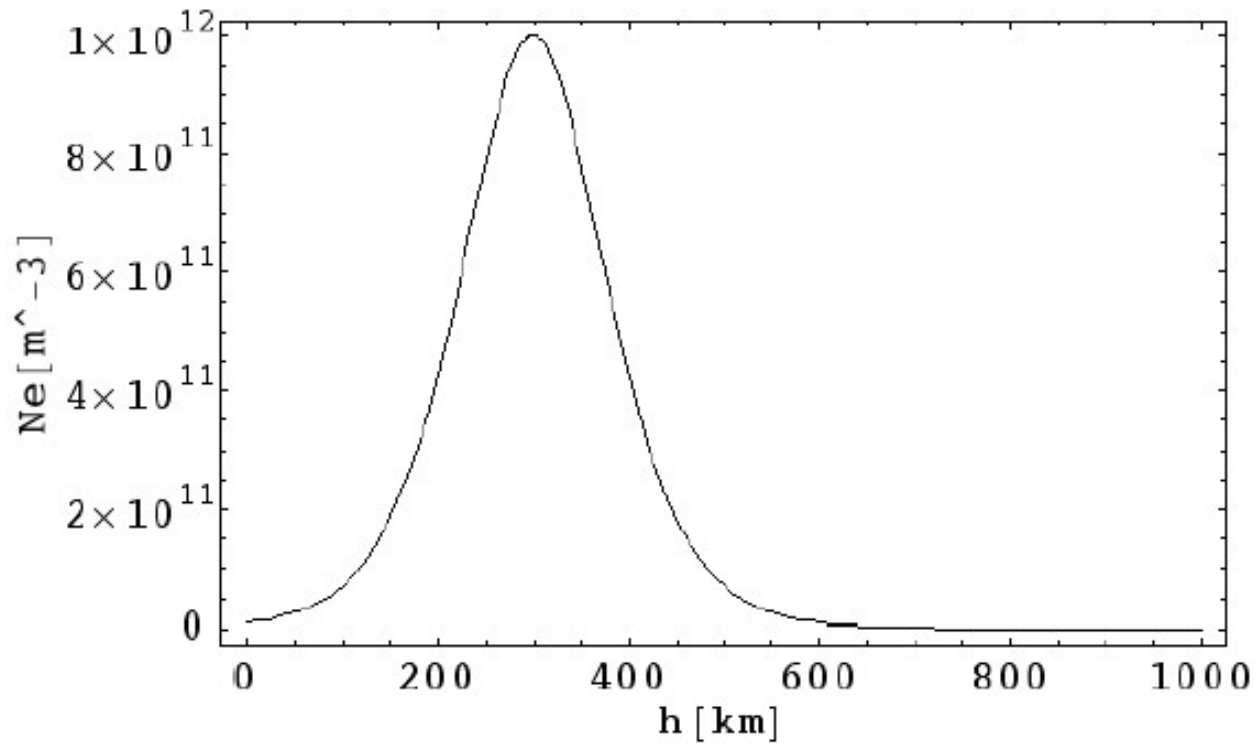
Model usage 

Summary 

# NeQuick formulation

## Epstein Layer

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

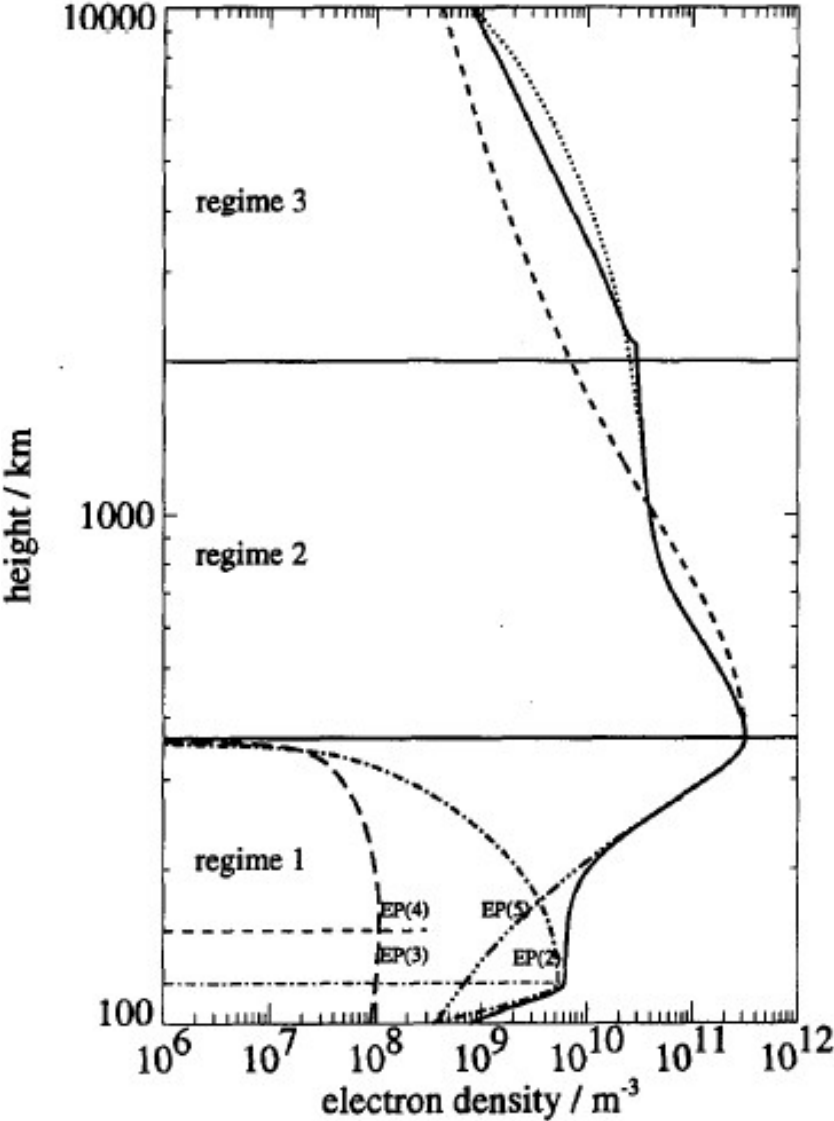


*Epstein, (1930)*

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

# NeQuick formulation

*Hochegger et al, 2000, Phys. Chem. Earth*





## NeQuick formulation

# Bottomside

*Nava et al, 2008, Journal of Atmospheric and Solar-Terrestrial Physics*

$$N_{bot}(h) = N_E(h) + N_{F1}(h) + N_{F2}(h)$$

$$N_E(h) = \frac{4Nm^*E}{\left(1 + \exp\left(\frac{h-hmE}{BE}\xi(h)\right)\right)^2} \exp\left(\frac{h-hmE}{BE}\xi(h)\right)$$

$$N_{F1}(h) = \frac{4Nm^*F1}{\left(1 + \exp\left(\frac{h-hmF1}{B1}\xi(h)\right)\right)^2} \exp\left(\frac{h-hmF1}{B1}\xi(h)\right)$$

$$N_{F2}(h) = \frac{4NmF2}{\left(1 + \exp\left(\frac{h-hmF2}{B2}\right)\right)^2} \exp\left(\frac{h-hmF2}{B2}\right)$$

$$\xi(h) = \exp\left(\frac{10}{1 + 1|h-hmF2|}\right)$$

*to avoid secondary maxima*

### Topside

$$N(h) = \frac{4NmF^2}{(1 + \exp(z))^2} \exp(z)$$

$$z = \frac{h - hmF^2}{H}$$

$$H = H_0 \left[ 1 + \frac{rg(h - hmF^2)}{rH_0 + g(h - hmF^2)} \right]$$

## NeQuick formulation

### Thickness Parameters

$$BE_{bot} = 5$$

$$BE_{top} = \max(0.5(hmF1 - hmE), 7) \quad \textit{Leitinger et al, 2005}$$

$$B1_{bot} = 0.5(hmF1 - hmE)$$

$$B1_{top} = 0.3(hmF2 - hmF1)$$

$$B2_{bot} = \frac{0.385NmF2}{(dN/dh)_{max}}$$

$$H = kB2_{bot} \left[ 1 + \frac{rg(h - hmF2)}{rkB2_{bot} + g(h - hmF2)} \right]$$

## NeQuick formulation

### Thickness Parameters

$$\ln \left( \left( \frac{dN}{dh} \right)_{\max} \right) = -3.467 + 1.714 \ln (foF2) + 2.02 \ln (M(3000)F2)$$

*Mosert de Gonzalez and Radicella, 1990*

$$k = 3.22 - 0.0538 foF2 - 0.00664 hmF2 + 0.113 \frac{hmF2}{B2_{\text{bot}}} + 0.00257 R12$$

$k \geq 1$

*Coisson et al., 2006*

## Peak Heights

$$hmE = 120$$

$$hmF1 = \frac{hmE + hmF2}{2}$$

*Leitinger et al, (2005)*

$$hmF2 = \frac{1490MF}{M + \Delta M} - 176$$

*Radicella and Zhang, (1995)*  
*Dudeney, (1978, 1983)*

$$\Delta M = \begin{cases} 0.253/(foF2/foE \\ -1.215) - 0.012, \\ -0.012 \end{cases} \quad \text{if } foE = 0,$$

$$MF = M \sqrt{\frac{0.0196M^2 + 1}{1.2967M^2 - 1}} \quad M = M(3000)F2.$$

## NeQuick formulation

# Critical Frequencies

$$(foE)^2 = (a_e \sqrt{F107})^2 (\cos \chi_{eff})^{0.6} + 0.49$$

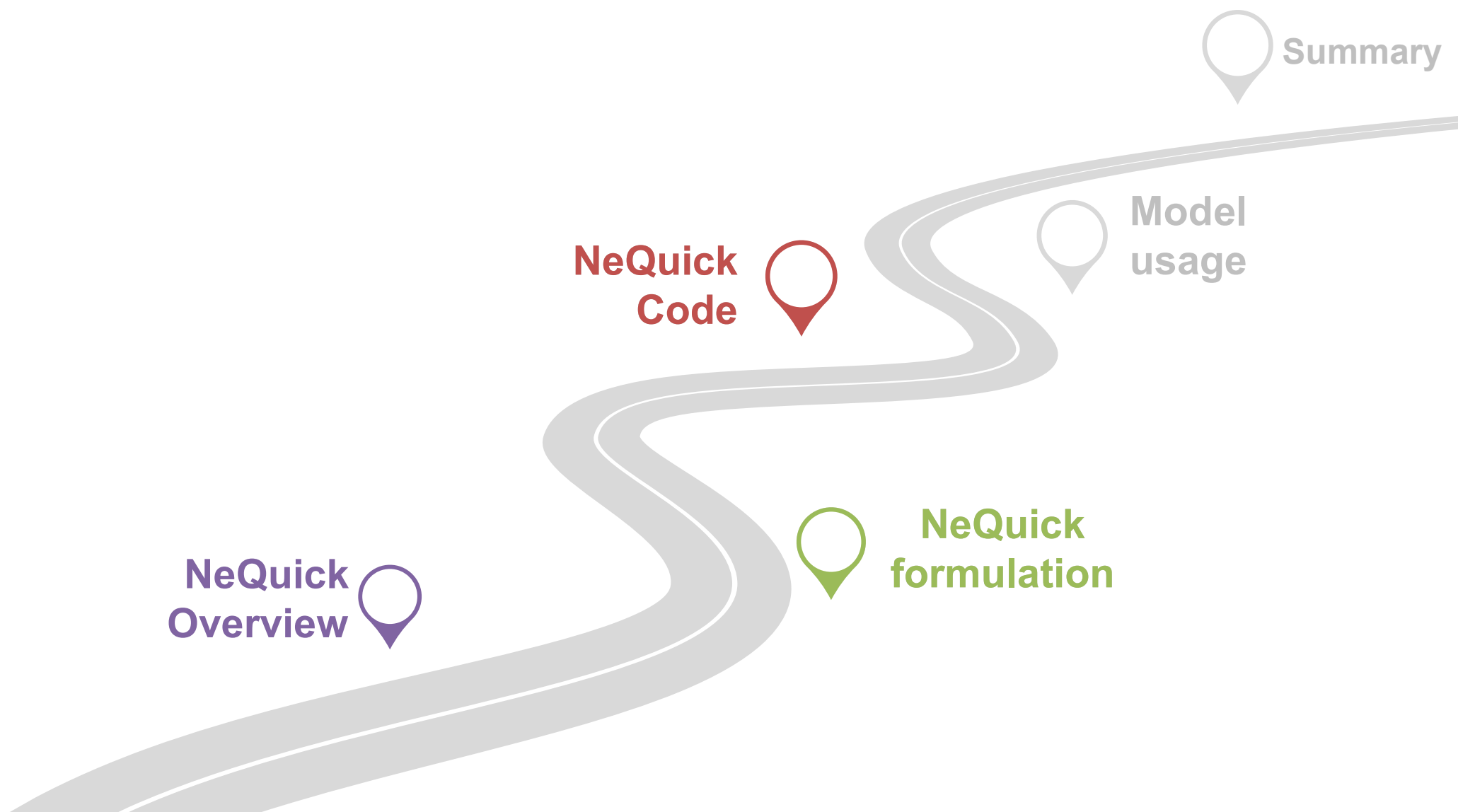
*Titheridge, (1996)*

$$foF1 = \begin{cases} 1.4 foE & \text{if } foE \geq 2 \\ 0 & \text{if } foE < 2 \\ 0.85 \cdot 1.4 foE & \text{if } 1.4 foE > 0.85 foF2 \end{cases}$$

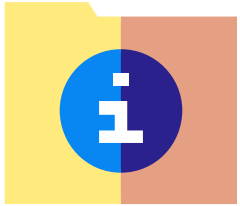
*Leitinger et al.(2005)*

$foF2$  modeled in terms of ITU – R coefficients

$M = M(3000)F2.$  modeled in terms of ITU – R coefficients



# The NeQuick model



## Content of NeQuick 2 package

- NeQuick\_2\_0\_2.for
  - slQu\_2\_0\_2.for
  - ccir11.asc...ccir22.asc
  - modip.asc
  - R12.dat
  - /Test cases
  - README.txt
- } FORTRAN 77 source code
- ITU-R coefficients
- Grid of modip values
- R12 values from 1931 to 2015





### ITU-R (CCIR) files

NeQuick 2 uses the **ITU-R coefficients** to compute  $f_oF2$  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  $f_oF2$  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).

## NeQuick Code



### Modip **file**

NeQuick 2 uses a grid of modip, ( $\mu$ ) 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.

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

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 Code



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 Code

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 prepmogr(mth,R12,foF2,efoF1,efoE,M3000)→ hm,Nm,thickness param.`

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  $r_p < 0.1\text{km}$ )

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  $N_e$  as a function of the coordinate  $s$

## NeQuick Code

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 Code


```
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

**NeQuick  
Overview** 

**NeQuick  
Code** 

**NeQuick  
formulation** 

**Model  
usage** 

**Summary** 



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

The screenshot shows the NeQuick 2 Web Model interface. At the top left is the ICTP logo and the text "The Abdus Salam International Centre for Theoretical Physics". Below this is a navigation bar with links for "site map", "accessibility", and "contact". A "log in" link is located in the top right corner. A search bar with the text "Search Site" and a right-pointing arrow is also present. The main heading is "NeQuick 2 Web Model" followed by the subtitle "Computation and plotting of slant electron density profile and total electron content". Under the heading "Endpoints Coordinates", there are three input options: "Lower endpoint" with fields for Latitude, Longitude, and Height; "Higher endpoint" with similar fields; and "Satellite data" with fields for Azimuth, Elevation, and Height. The "Date and Time" section includes a Year field, a Month dropdown menu (set to January), a Day field (set to 1), and a Time dropdown menu (set to Universal). The "Solar Activity" section has three radio button options: "R12 (source: NOAA-NGDC)" which is selected, "Daily Solar Radio Flux (source: NOAA-NGDC)", and "User Input Solar index type" with a dropdown menu set to "R12" and a "Value \*" input field.





## NeQuick 2 Web Model

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

#### Endpoints Coordinates

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**  **Day(DD)**  **Time**

#### Solar Activity

**R12 (source: NOAA-NGDC)**

**Daily Solar Radio Flux (source: NOAA-NGDC)**

**User Input Solar index type**  **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)

# Model usage

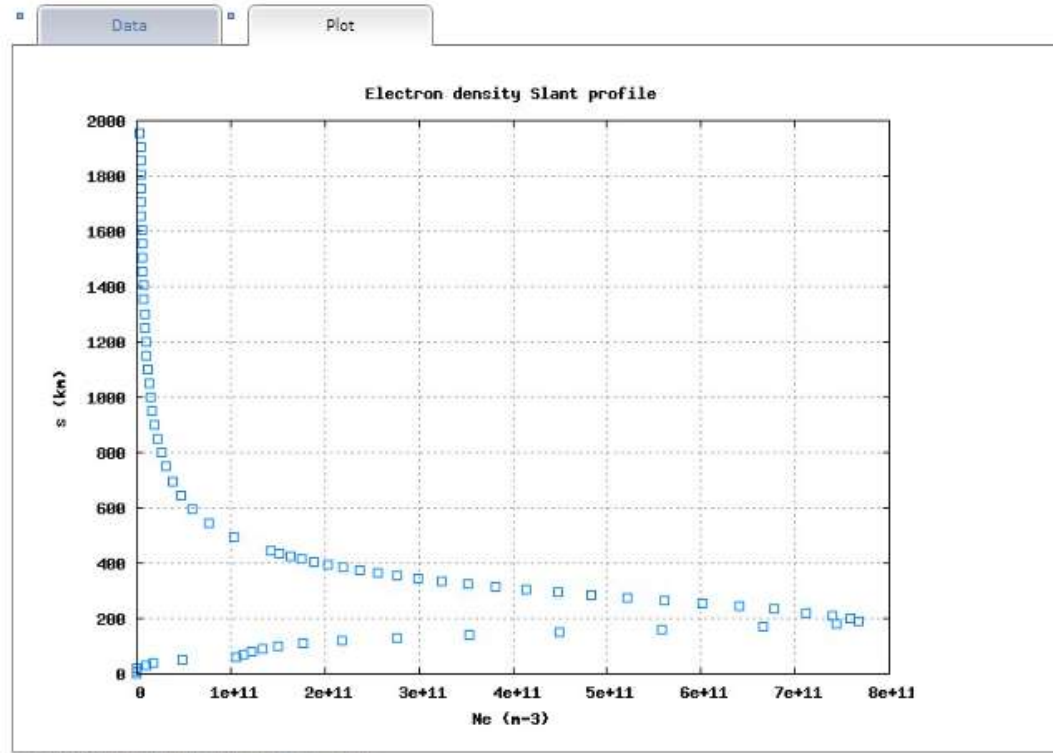
## Results

Ray endpoint 1: lat. (deg. N), long. (deg. E), height (km)  
 28.00 351.00 60.00  
 Ray endpoint 2: lat. (deg. N), long. (deg. E), height (km)  
 30.00 351.00 2000.00  
 zenith angle (deg.) and azimuth (N over E to S, deg.) of ray at endpoint 1  
 8.59 0.00  
 Year, MJD, R12, month, UT: 2021, 75.3, 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	r	height	lat	long	sl.density	n <sup>2</sup> -3
km	km	km	deg N	deg E		
0.0	6431.2	60.0	28.00	351.00	0.000000E+00	
50.1	6451.2	70.0	28.01	351.00	0.104419E+01	
100.2	6451.2	80.0	28.03	351.00	0.481307E+07	
150.3	6461.2	90.0	28.04	351.00	0.180524E+11	
200.4	6471.2	100.0	28.05	351.00	0.179201E+11	
250.5	6481.2	110.0	28.07	351.00	0.480395E+11	
300.6	6491.2	120.0	28.08	351.00	0.105461E+12	
350.7	6501.2	130.0	28.00	351.00	0.113995E+12	
400.8	6501.2	140.0	28.11	351.00	0.122481E+12	
450.9	6511.2	150.0	28.12	351.00	0.135734E+12	
501.0	6521.2	160.0	28.13	351.00	0.150479E+12	
551.1	6531.2	170.0	28.15	351.00	0.177265E+12	
601.2	6541.2	180.0	28.16	351.00	0.218885E+12	
651.3	6551.2	190.0	28.17	351.00	0.276524E+12	
701.4	6561.2	200.0	28.18	351.00	0.352912E+12	
751.5	6571.2	210.0	28.20	351.00	0.448688E+12	
801.6	6581.2	220.0	28.21	351.00	0.568535E+12	
851.7	6591.2	230.0	28.22	351.00	0.665322E+12	
901.8	6601.2	240.0	28.24	351.00	0.749588E+12	
951.9	6611.2	250.0	28.25	351.00	0.767325E+12	
1002.0	6621.2	260.0	28.26	351.00	0.739338E+12	
1052.1	6631.2	270.0	28.27	351.00	0.711731E+12	
1102.2	6641.2	280.0	28.29	351.00	0.678177E+12	
1152.3	6651.2	290.0	28.30	351.00	0.640827E+12	
1202.4	6661.2	300.0	28.31	351.00	0.601668E+12	
1252.5	6671.2	310.0	28.32	351.00	0.561534E+12	
1302.6	6681.2	320.0	28.34	351.00	0.521111E+12	
1352.7	6691.2	330.0	28.35	351.00	0.483974E+12	
1402.8	6701.2	340.0	28.36	351.00	0.448945E+12	
1452.9	6711.2	350.0	28.37	351.00	0.416941E+12	
1503.0	6721.2	360.0	28.39	351.00	0.387526E+12	
1553.1	6731.2	370.0	28.40	351.00	0.360515E+12	
1603.2	6741.2	380.0	28.41	351.00	0.335915E+12	
1653.3	6751.2	390.0	28.42	351.00	0.313685E+12	
1703.4	6761.2	400.0	28.43	351.00	0.293661E+12	
1753.5	6771.2	410.0	28.45	351.00	0.275703E+12	
1803.6	6781.2	420.0	28.46	351.00	0.259695E+12	
1853.7	6791.2	430.0	28.47	351.00	0.245218E+12	
1903.8	6801.2	440.0	28.48	351.00	0.231914E+12	
1953.9	6811.2	450.0	28.49	351.00	0.220218E+12	
2004.0	6821.2	460.0	28.51	351.00	0.208687E+12	
2054.1	6831.2	470.0	28.52	351.00	0.197438E+12	
2104.2	6841.2	480.0	28.53	351.00	0.186364E+12	
2154.3	6851.2	490.0	28.54	351.00	0.175461E+12	
2204.4	6861.2	500.0	28.55	351.00	0.164725E+12	
2254.5	6871.2	510.0	28.61	351.00	0.150104E+12	
2304.6	6881.2	520.0	28.67	351.00	0.132588E+11	
2354.7	6891.2	530.0	28.67	351.00	0.112588E+11	
2404.8	6901.2	540.0	28.73	351.00	0.904655E+10	
2454.9	6911.2	550.0	28.78	351.00	0.678664E+10	
2505.0	6921.2	560.0	28.84	351.00	0.482589E+10	
2555.1	6931.2	570.0	28.89	351.00	0.313923E+10	
2605.2	6941.2	580.0	28.95	351.00	0.205161E+10	
2655.3	6951.2	590.0	29.00	351.00	0.128161E+10	
2705.4	6961.2	600.0	29.05	351.00	0.768558E+09	
2755.5	6971.2	610.0	29.10	351.00	0.568558E+09	
2805.6	6981.2	620.0	29.15	351.00	0.348469E+09	
2855.7	6991.2	630.0	29.20	351.00	0.219377E+09	
2905.8	7001.2	640.0	29.25	351.00	0.118174E+09	
2955.9	7011.2	650.0	29.25	351.00	0.100596E+09	
3006.0	7021.2	660.0	29.30	351.00	0.967634E+08	
3056.1	7031.2	670.0	29.35	351.00	0.967634E+08	
3106.2	7041.2	680.0	29.40	351.00	0.883684E+08	
3156.3	7051.2	690.0	29.44	351.00	0.810675E+08	
3206.4	7061.2	700.0	29.49	351.00	0.749421E+08	
3256.5	7071.2	710.0	29.53	351.00	0.699048E+08	
3306.6	7081.2	720.0	29.58	351.00	0.659208E+08	
3356.7	7091.2	730.0	29.62	351.00	0.629508E+08	
3406.8	7101.2	740.0	29.67	351.00	0.600054E+08	
3456.9	7111.2	750.0	29.71	351.00	0.571131E+08	
3507.0	7121.2	760.0	29.75	351.00	0.542748E+08	
3557.1	7131.2	770.0	29.80	351.00	0.514904E+08	
3607.2	7141.2	780.0	29.84	351.00	0.487604E+08	
3657.3	7151.2	790.0	29.88	351.00	0.460854E+08	
3707.4	7161.2	800.0	29.92	351.00	0.434654E+08	
3757.5	7171.2	810.0	29.96	351.00	0.408994E+08	
3807.6	7181.2	820.0	30.00	351.00	0.383874E+08	
3857.7	7191.2	830.0	30.00	351.00	0.359294E+08	

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

## Results

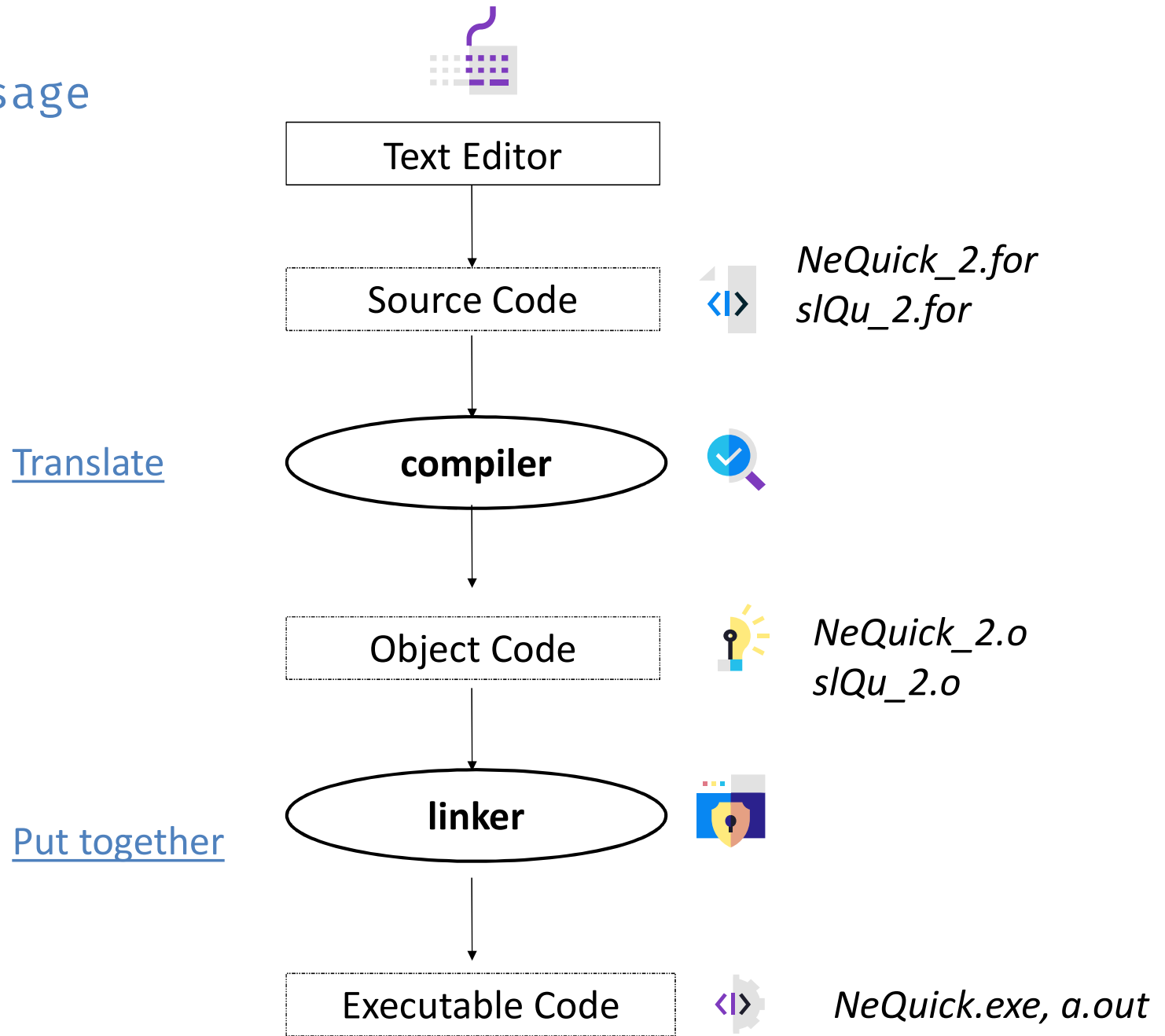


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1030.4 02/1.4 1900.0 29.34 351.00 0.390023E+10  
 1906.5 8321.2 1950.0 29.96 351.00 0.379566E+10  
 1956.8 8371.2 2000.0 30.00 351.00 0.361875E+10  
 Electron contents ( 60-1000),(1000-2000),( 60-2000)  
 174.50 7.61 182.10 x10<sup>15</sup> m<sup>-2</sup>  
 TEC= 18.21 TECu (1TECu=1x10<sup>16</sup> m<sup>-2</sup>)

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# Model usage



## 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



MinGW64



Cygwin



## 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
```

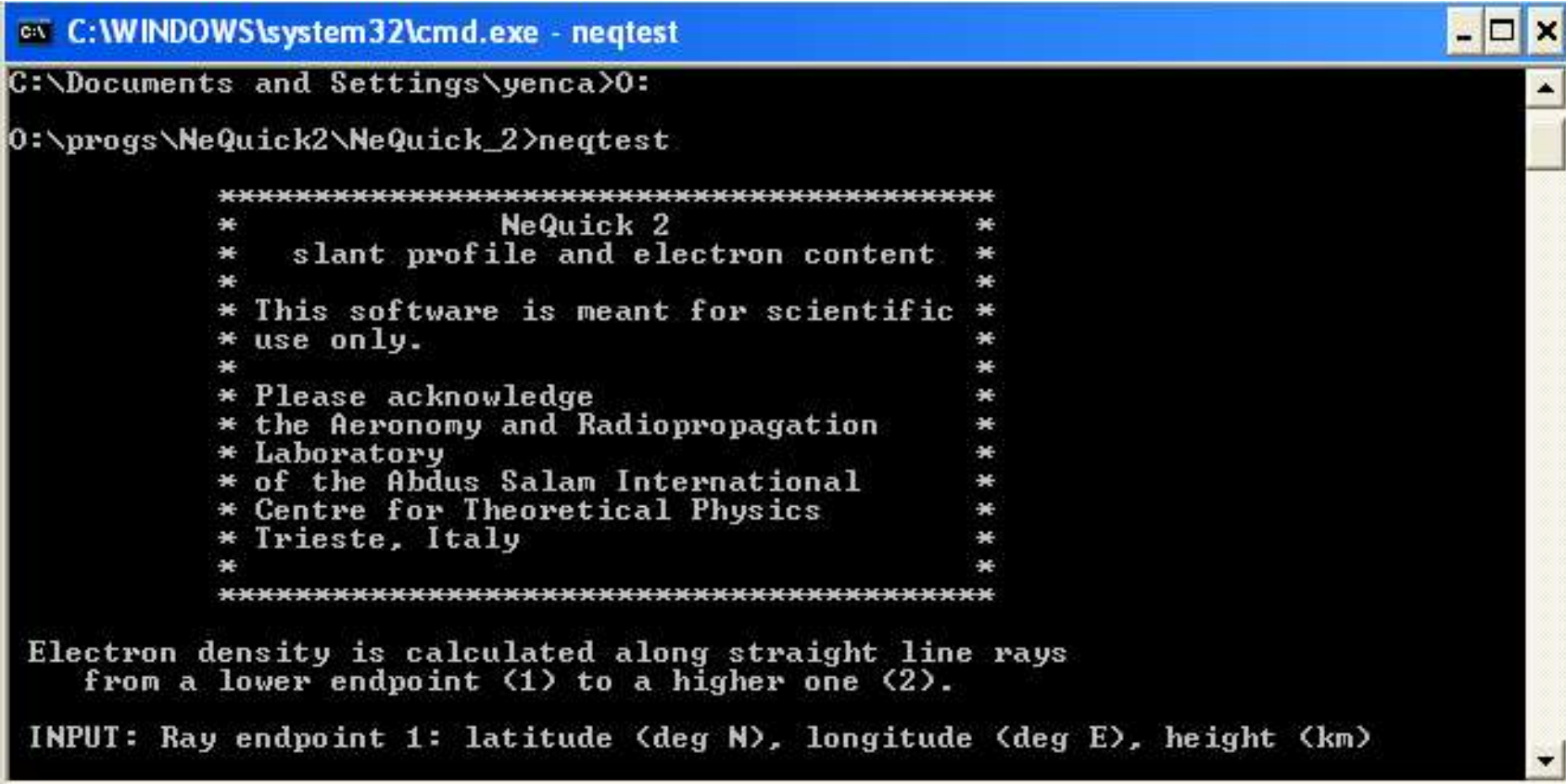
To run:

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



NeQuick 2: Compiling and running

## Running...



```
C:\WINDOWS\system32\cmd.exe - neqtest
C:\Documents and Settings\yenca>0:
0:\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...

```
Command Prompt

* 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)
45,15,80
INPUT: Ray endpoint 2: latitude (deg N), longitude (deg E), height (km)
45,15,1000
Input: year, month, UT:
2000,5,5
User input R12/F10.7 for this year and month (y/n)
n
List electron density profile along ray (y/n)?
n
Output in slQu.dat

C:\Users\Yenca\Documents\Programs\NeQuick\NeQuick_2_0_1h>type slQu.dat
Ray endpoint 1: lat. (deg. N), long. (deg. E), height (km)
45.00 15.00 80.00
Ray endpoint 2: lat. (deg. N), long. (deg. E), height (km)
45.00 15.00 1000.00
S10.7, R12, month, UT: 162.9, 119.0, 5, 5.0

Electron contents along ray:
(h1-h2) means from point in height h1 to point in height h2 (heights in km)
Electron content ( 80-1000)
167.56 x10^15 m^-2

C:\Users\Yenca\Documents\Programs\NeQuick\NeQuick_2_0_1h>
```

**Not TECU!**

NeQuick 2: Compiling and running

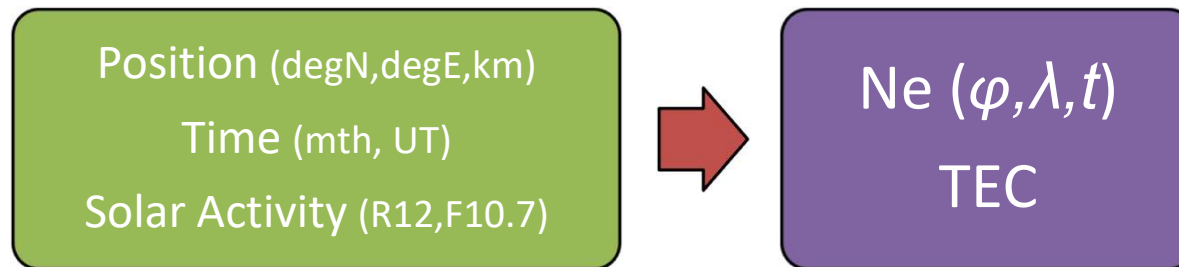
# Running...



## 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



**NeQuick  
Overview** 

**NeQuick  
Code** 

**NeQuick  
formulation** 

**Model  
usage** 

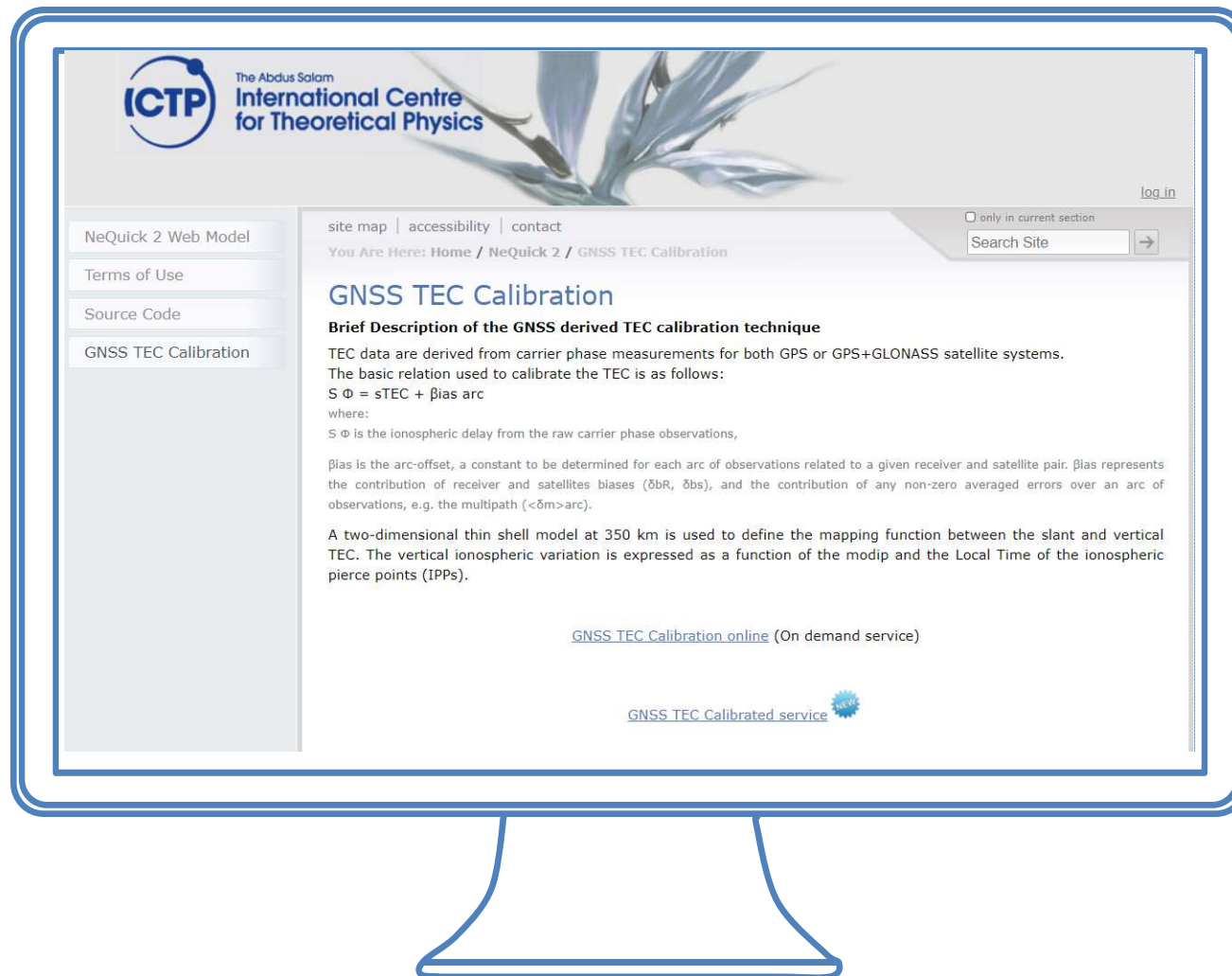
**Summary** 

# Summary

- NeQuick is a three-dimensional and time dependent empirical ionospheric electron density model to represent the climatology of the ionosphere.
- Predecessors, versions and formulation of the model have been presented, together with the main functions and subroutines.
- We have briefly demonstrated how to run and use the model (and how you should not 😊).

# GNSS TEC data

<https://t-ict4d.ictp.it/nequick2/gnss-tec-calibration>



*Thank you!*



*yenca@ictp.it*