IROWG-2

Estes Park, CO, USA

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Ionospheric correction of RO signals by direct modelling of ionosphere

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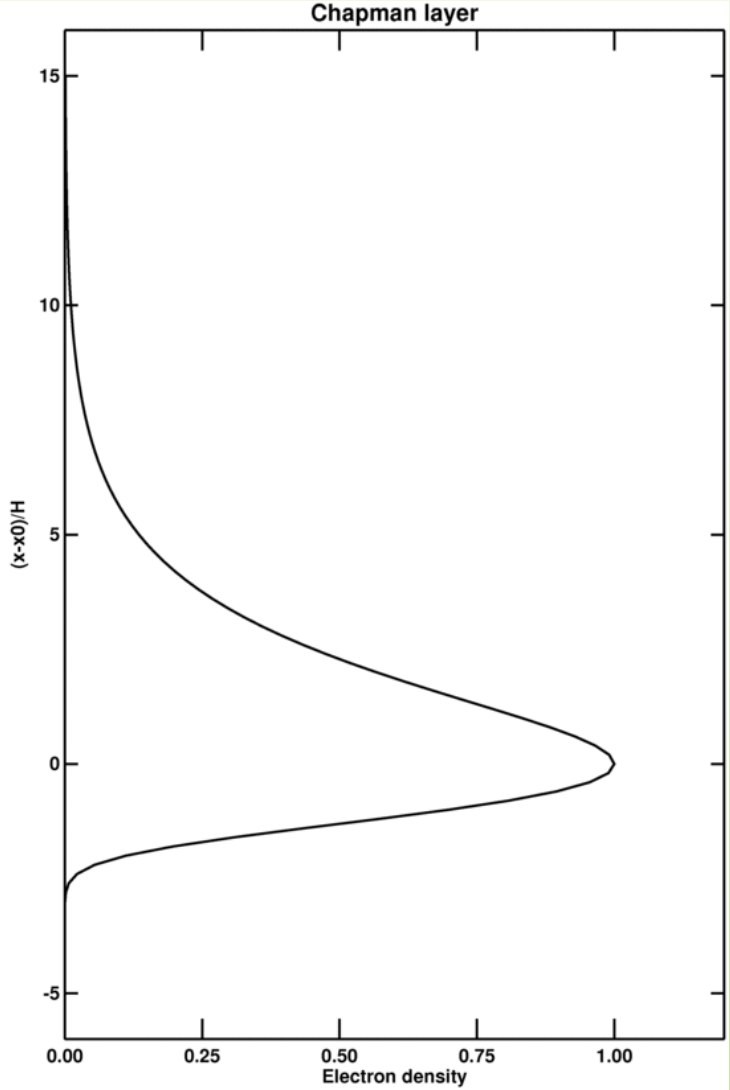
Motivation

Ultimate aim: direct assimilation of L1 and L2 signals in NWP

- How to do ionospheric correction when L2 signal drops out?
- Different (better?) tropospheric retrievals if L1 and L2 both used?
- Some information on ionospheric parameters?

Model ionosphere: electron density



Single Chapman Layer (Chapman 1931)

$n_e(r) = TEC/\sqrt{(2\pi e H^2)} \cdot \exp(\frac{1}{2}(1 - u - e^{-u}))$,

where $u = (r - r_0) / H$.

3 parameters:

$TEC = \int n_e \, dr$

r_0 = peak height

H = *ionospheric* scale height

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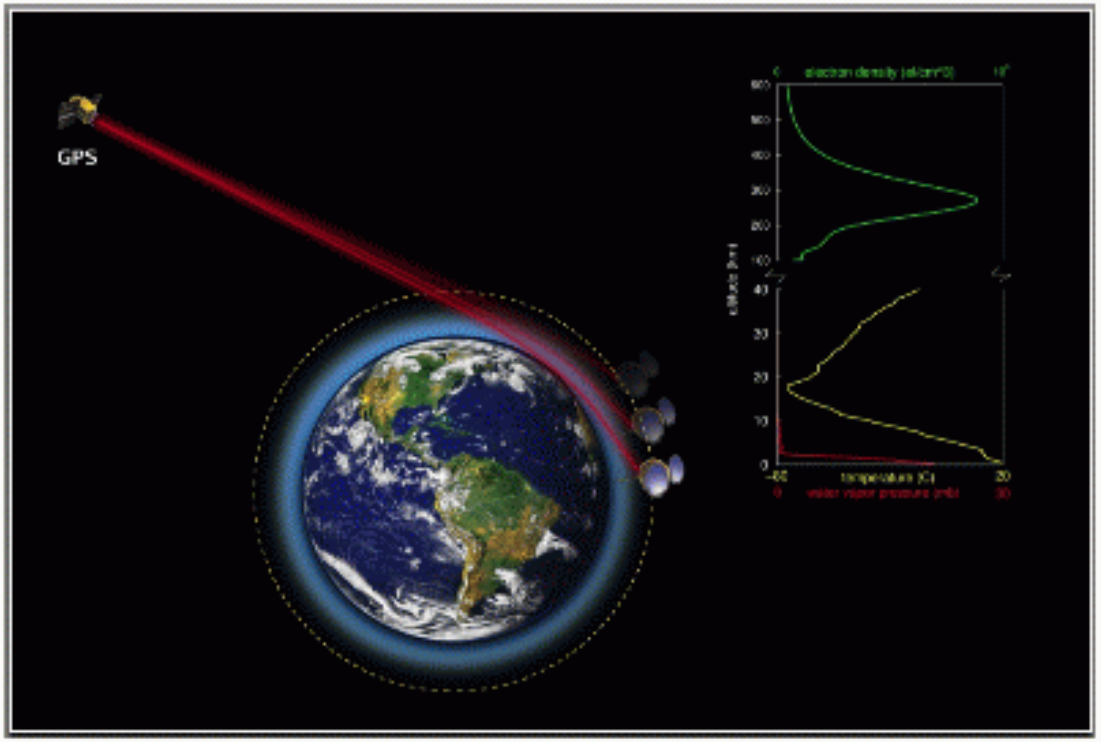
Model ionosphere: electron density

IROWG

International Radio Occultation Working Group



The International Radio Occultation Gro
permanent Working Group of the Coordi
Satellites (CGMS) at the 37th meeting or
South Korea). The IROWG is co-sponso
Meteorological Organization (WMO). The
operational and research users of radio
Working Groups of CGMS can be found
GROUPS).

The CGMS secretariat is run by EUMETS
http://www.eumetsat.int

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Model ionosphere: bending angle

$$\alpha_{Li}(a) = -\,2a \int_a^{\infty} d\log n/dx\, dx \,/\, \sqrt{(x^2 - a^2)}, \qquad x = nr$$

$$\approx (k_4 / f_{Li}^2)\, 2a \int_a^{\infty} dn_e/dx\, dx \,/\, \sqrt{(x^2 - a^2)},\ k_4 = 40.3\ m^3 s^{-2}$$

$$\approx (k_4 / f_{Li}^2)\, 2a \,/\, \sqrt{(r_0 + a)} \int_a^{\infty} dn_e/dr\, dr \,/\, \sqrt{(r - a)}$$

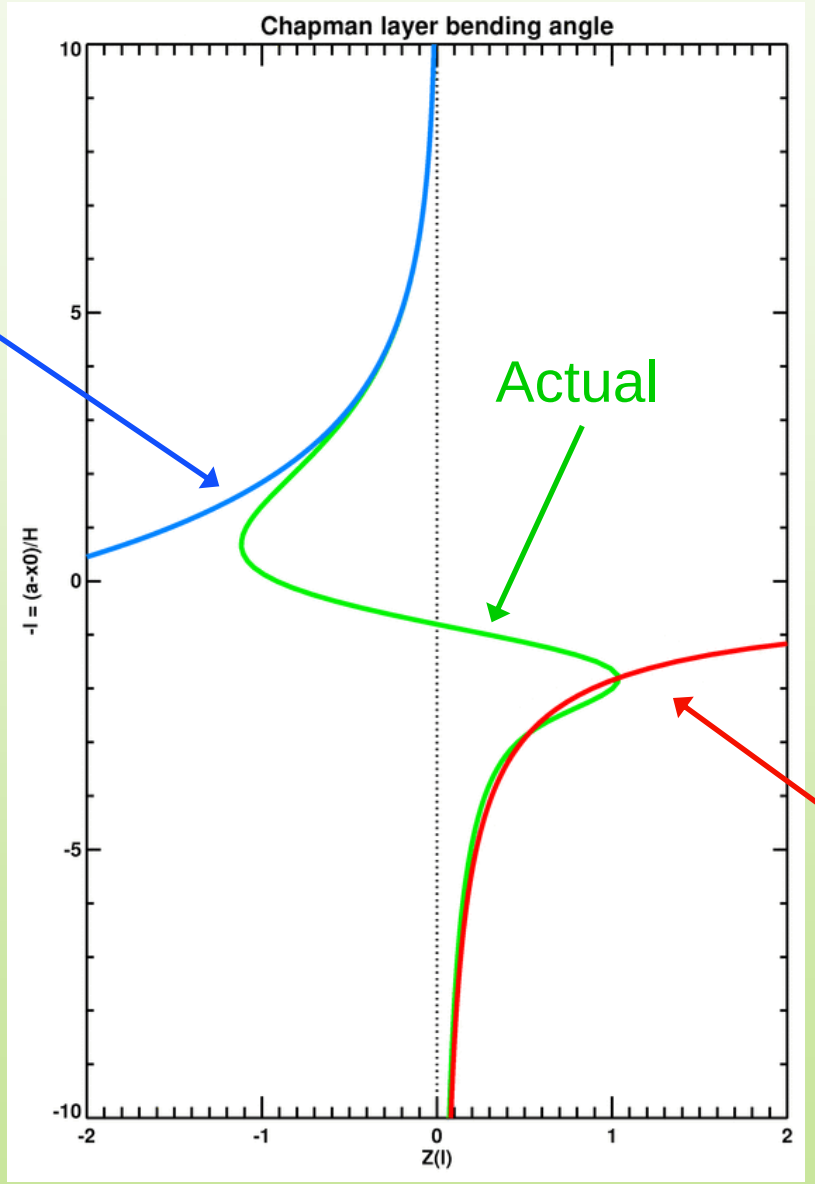
$$= (k_4 / f_{Li}^2)\, [a\, TEC \,/ \sqrt{(2\pi (r_0 + a) H^3)}] \cdot Z(l)$$

where

$$\mathbf{Z(l) = \int_{-l}^{\infty} (e^{-u} - 1) \exp(\tfrac{1}{2}(1 - u - e^{-u})) \,/\, \sqrt{(u + l)}\ du}$$

is just a function of $\mathbf{l = (r_0 - a) / H}$

Model ionosphere: bending angle Z(l)



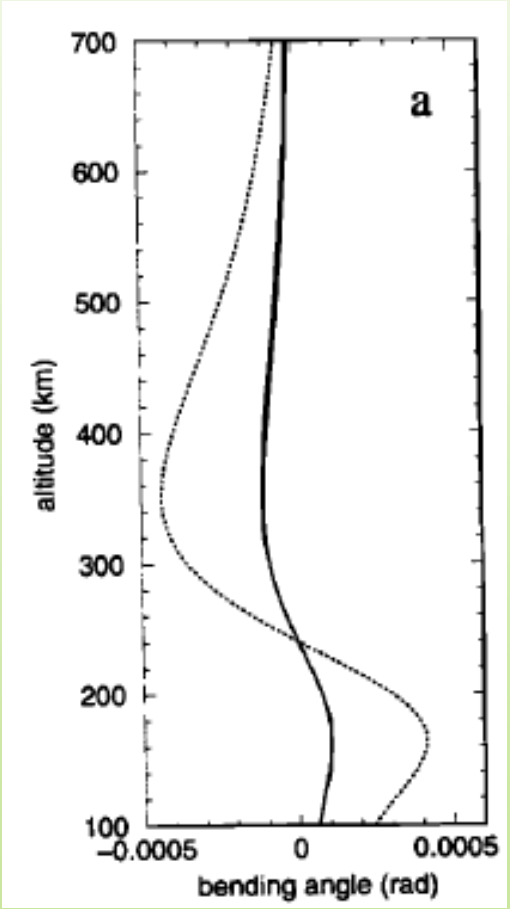
$-\sqrt{(2\pi)}\ e^{l/2}$

Actual

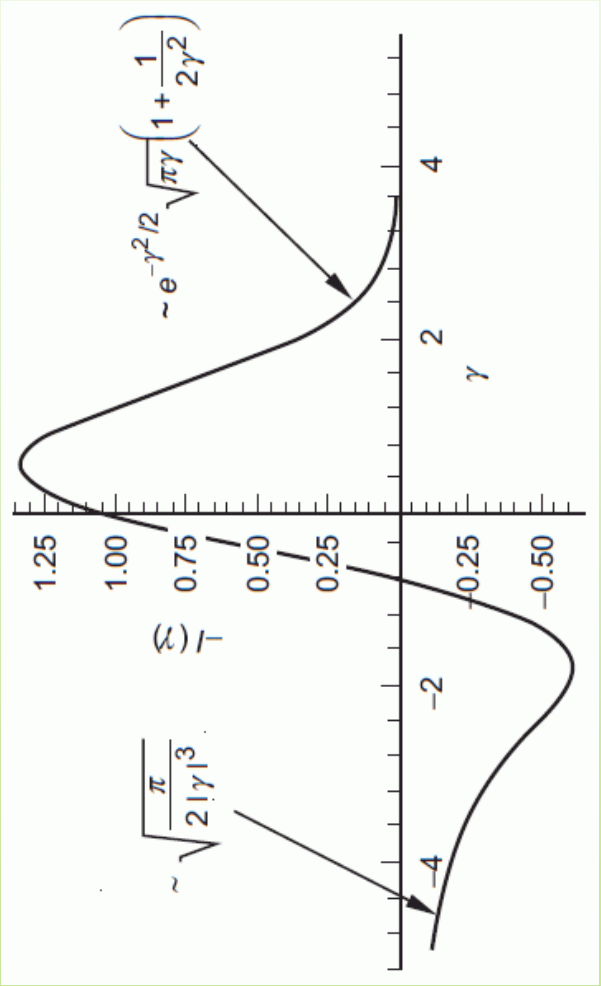
$\sqrt{(2\pi/l^3)}$

Model ionosphere: bending angle Z(l)

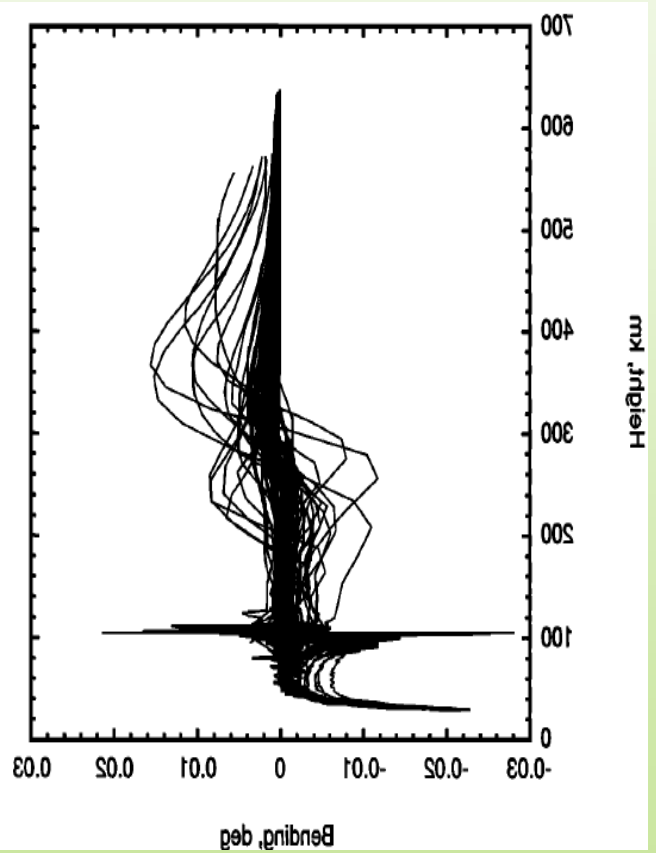
Schreiner et al, 1999, Chapman layer



Melbourne, 2004, Gaussian n_e



Hajj & Romans, 1998, GPS/MET



1. Extrapolation of L2 signal

$$\alpha_{L1} = \alpha_n + k_4 f_{L1}^{-2} a\,TEC / \sqrt{(2\pi(r_0+a)H^3)}\, Z((r_0-a)/H)$$

➔

$$\alpha_n = \alpha_{L1} + (f_{L2}^2/(f_{L1}^2 - f_{L2}^2))\,(\alpha_{L1} - \alpha_{L2})$$

Replace

$(\alpha_{L1} - \alpha_{L2})$ ~ const or linear in impact parameter a

with

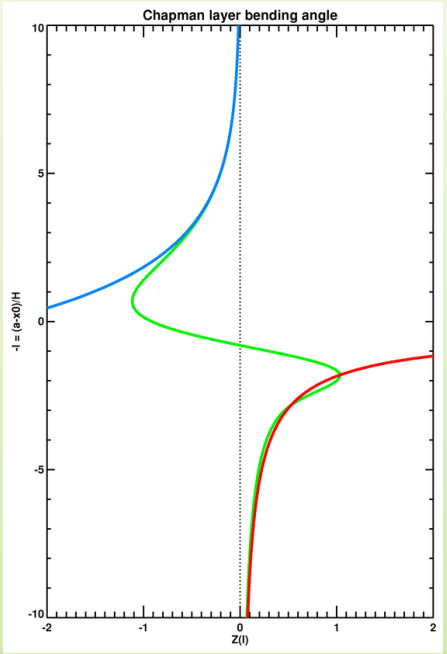
Fitting parameter

$(\alpha_{L1} - \alpha_{L2}) = \gamma\, a\, r_0\, (r_0^2 - a^2)^{-3/2}$ (delta function ionosphere)

Fitting parameter (sometimes)

1. Extrapolation of L2 signal

- EUMETSAT find some weak benefit at low altitudes, but detrimental at high (stratosphere).



- Not too surprising?

- Suggests replacing

$(\alpha_{L1} - \alpha_{L2}) \sim$ const or linear in impact parameter a

with

Fitting parameter

$(\alpha_{L1} - \alpha_{L2}) = \gamma\, a/\sqrt{(2\pi(r_0+a)H^3)}\, Z((r_0 - a)/H)$ (general Zorro function)

Fitting parameter (sometimes)

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2. Retrievals based on L1 and L2

- Forward modelling of *model* ionosphere directly allows use of L1 and L2 separately. Is it worth it?

- Very simple test in a toy **0-D** model:

$$\alpha_{L1,2}(a) = k_1 \, (p^*/T) \, \sqrt{(2\pi g a/RT)} \, \exp(-g(a - R_E)/RT)$$

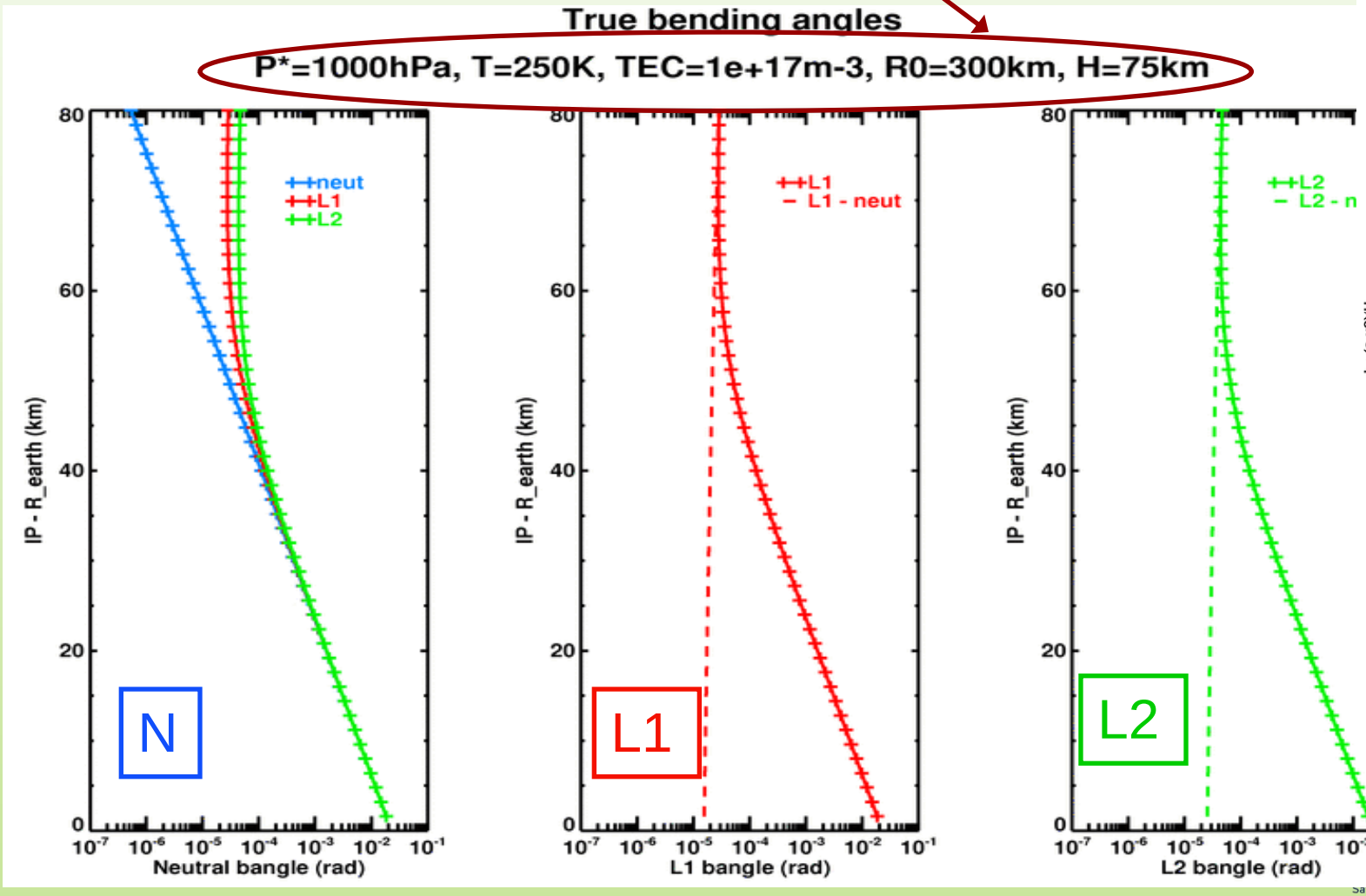
$$+ \, k_4 \, f_{L1,2}^{-2} \, a \, TEC \, / \sqrt{(2\pi(r_0+a)H^3)} \, Z((r_0 - a)/H)$$

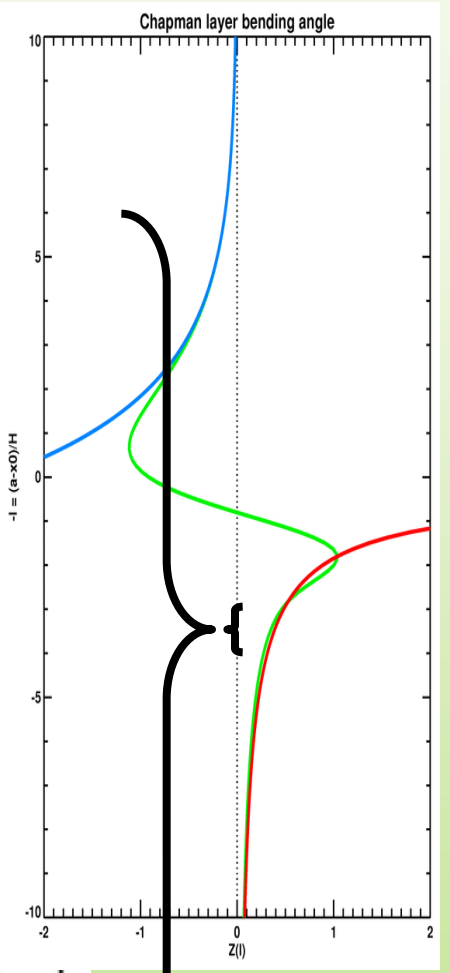
- 5 element state vector: {T, p*, TEC, r_0, H}

- Generate bending angles, add noise, perturb true state → background, pass through minimiser, compare to “truth”.

2. Retrievals based on L1 and L2

- Example 1: “standard ionosphere”





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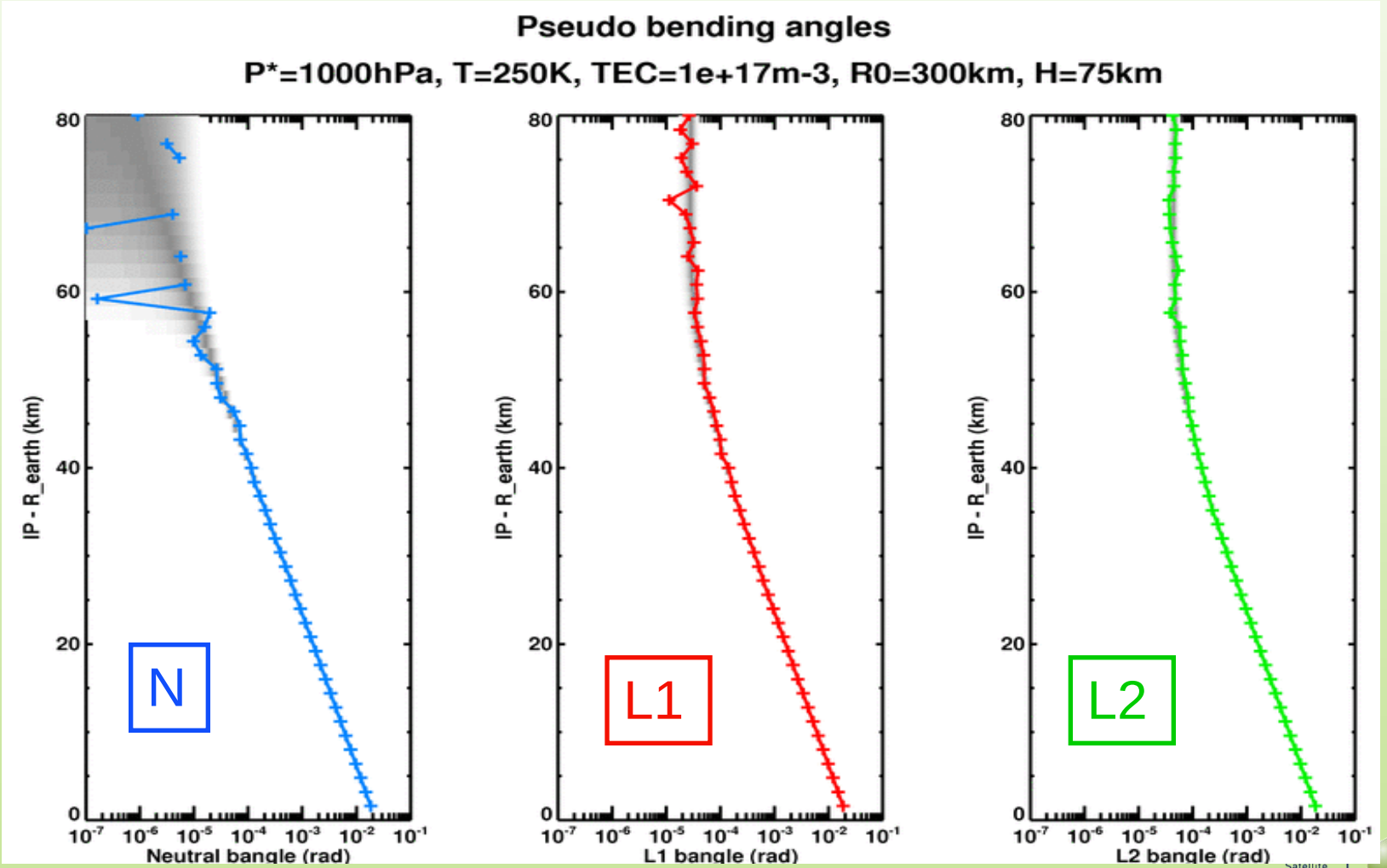
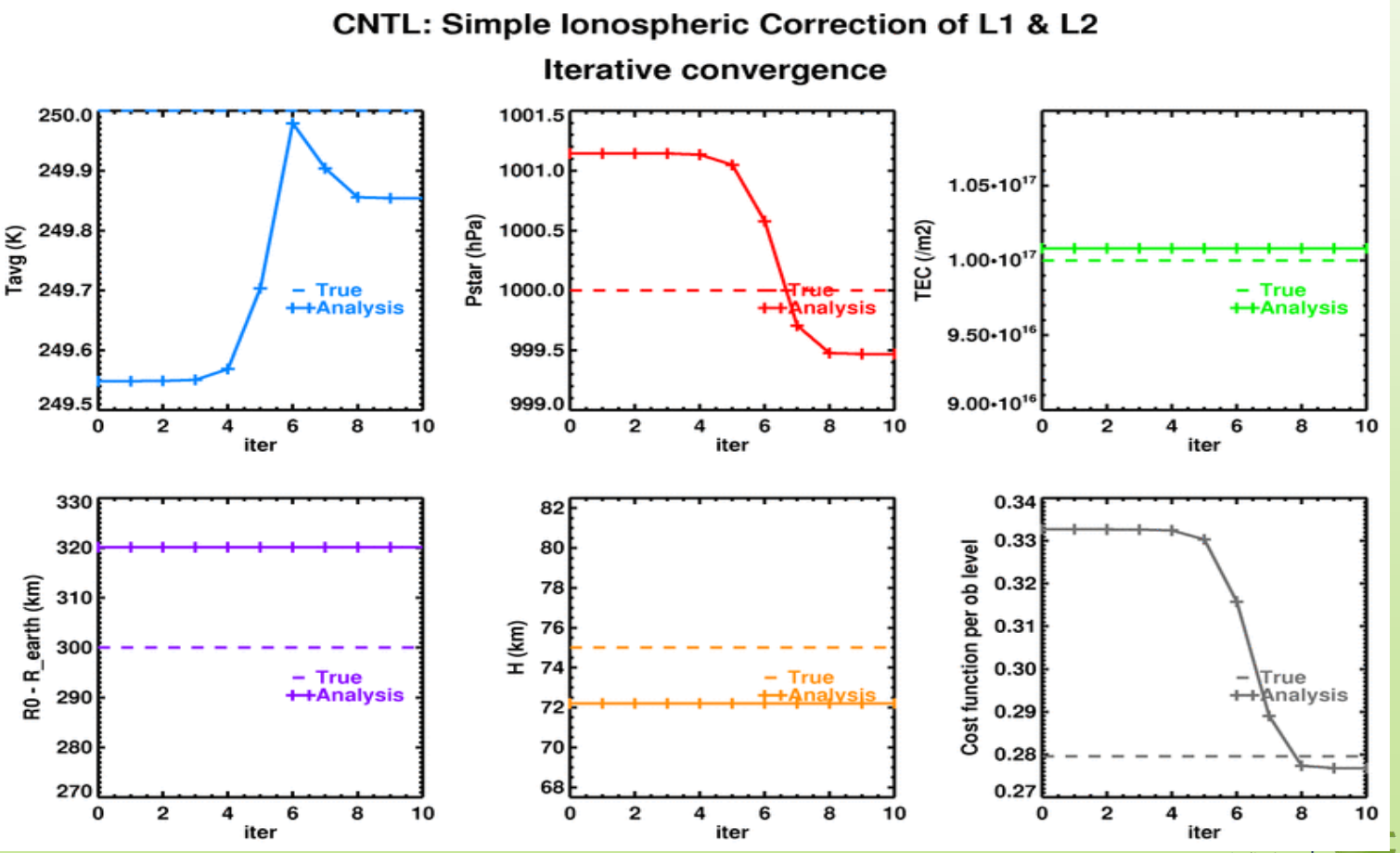
2. Retrievals based on L1 and L2

- Example 1: “standard ionosphere”



2. Retrievals based on L1 and L2

- Example 1: “standard ionosphere”.
- CNTL: 1dvar retrieval of {T, p*} based on $\alpha_N = ()\alpha_{L1} - ()\alpha_{L2} / () - ()$



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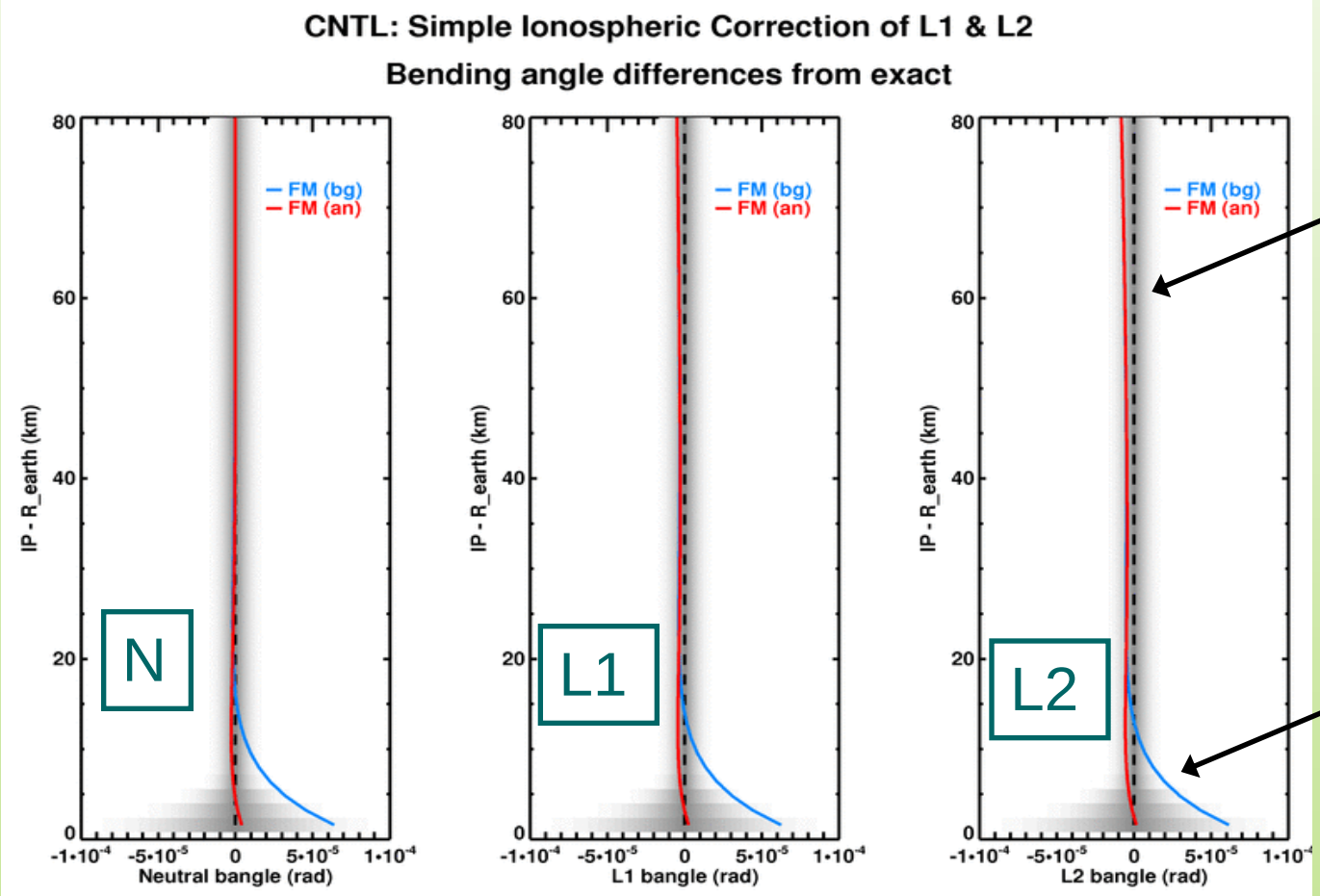

No better

Better

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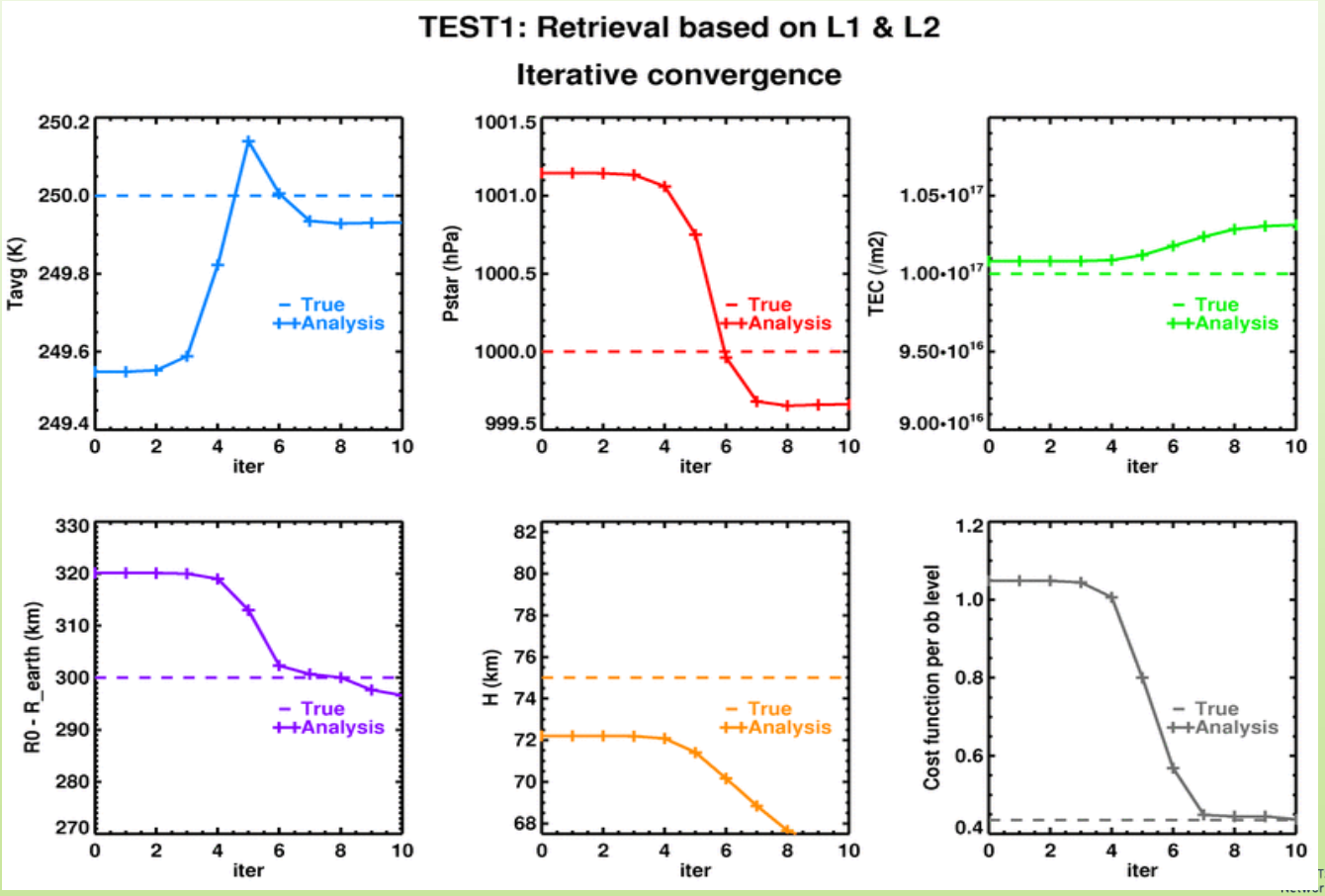
2. Retrievals based on L1 and L2

- Example 1: “standard ionosphere”.
- TEST1: 1dvar retrieval of {T, p*, TEC, R_0, H} based on {α_{L1}, α_{L2}}



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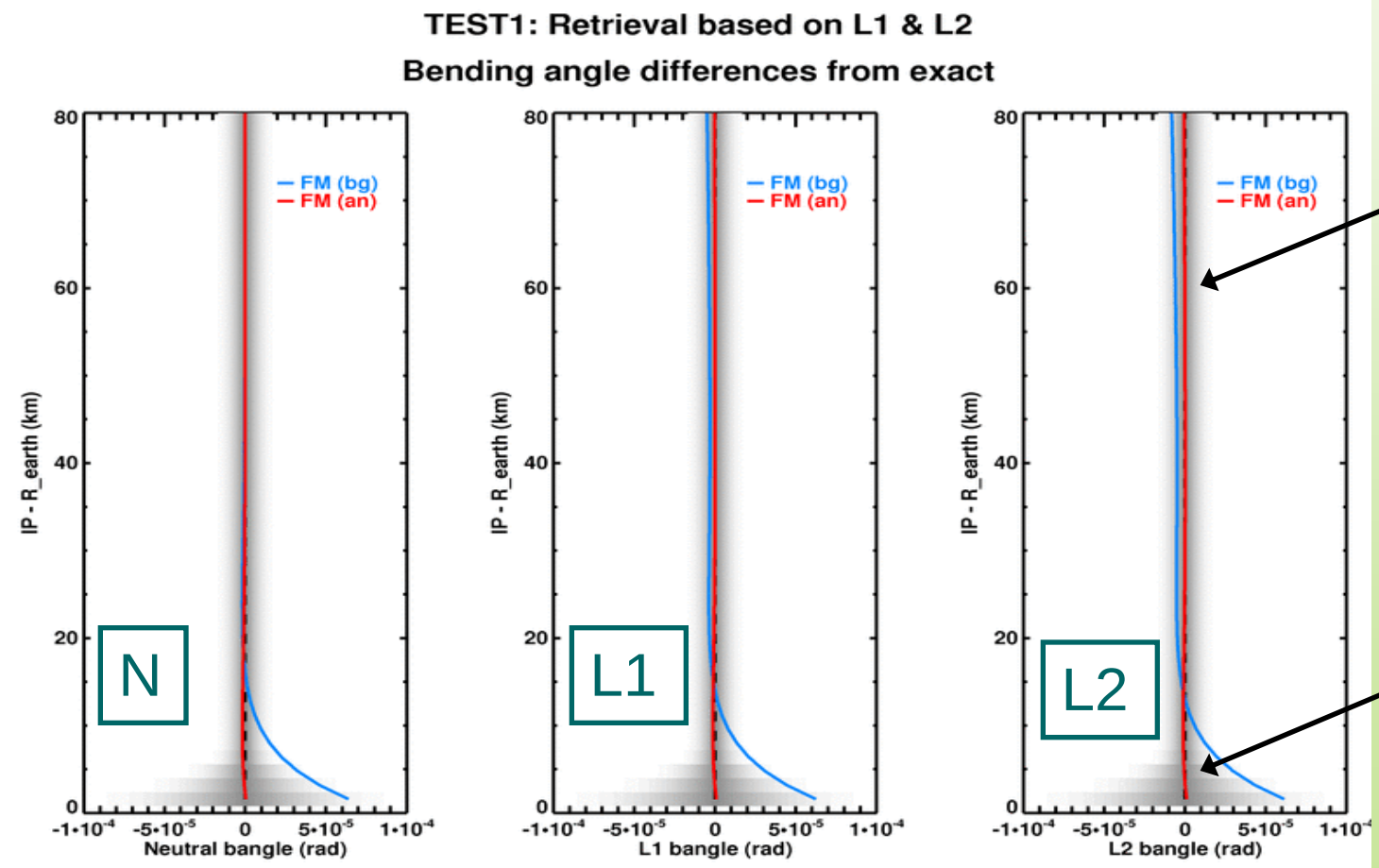
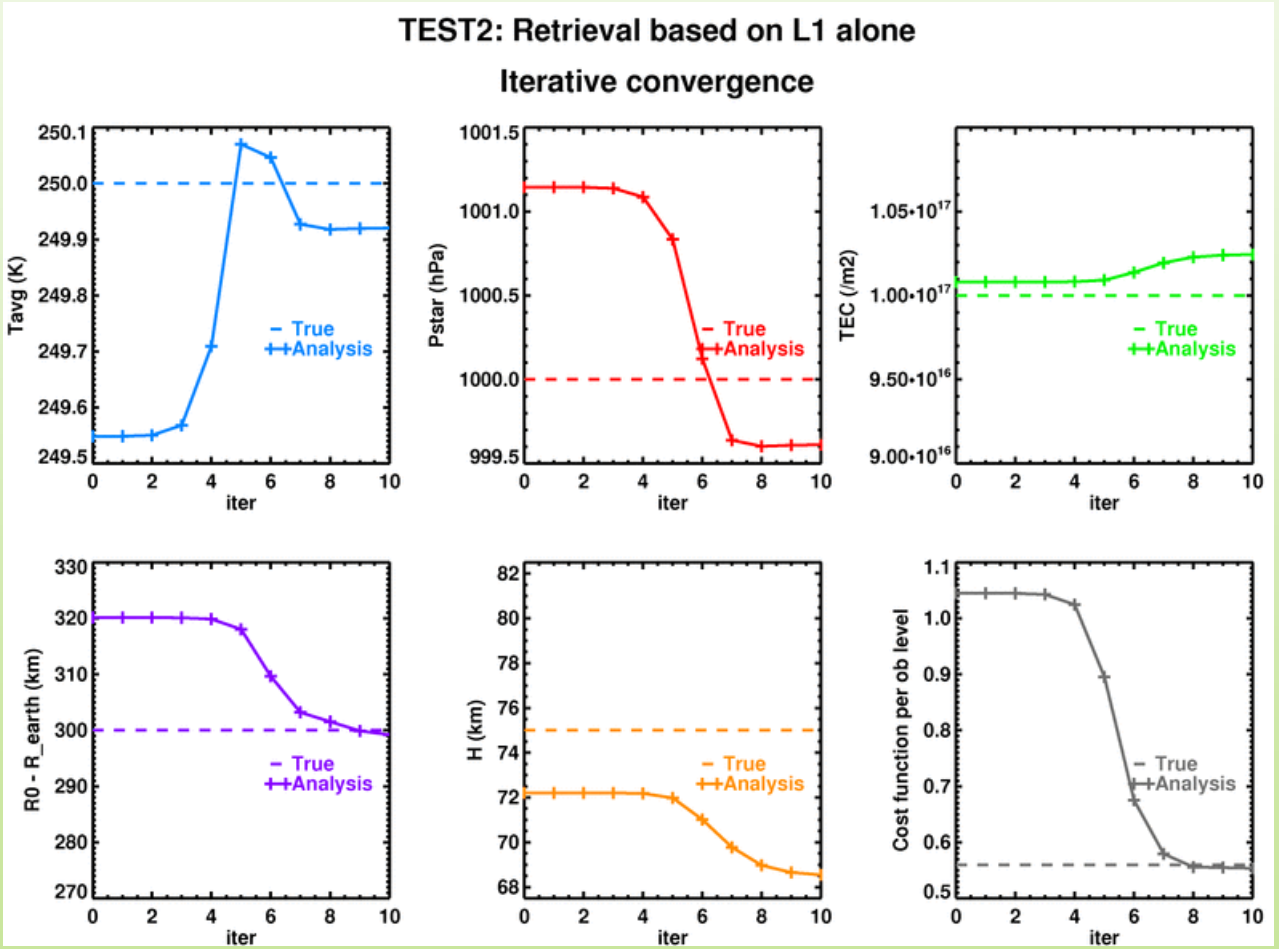


2. Retrievals based on L1 and L2

- Example 1: “standard ionosphere”.
- TEST2: 1dvar retrieval of {T, p*, TEC, R_0, H} based on {α_{L1}} alone



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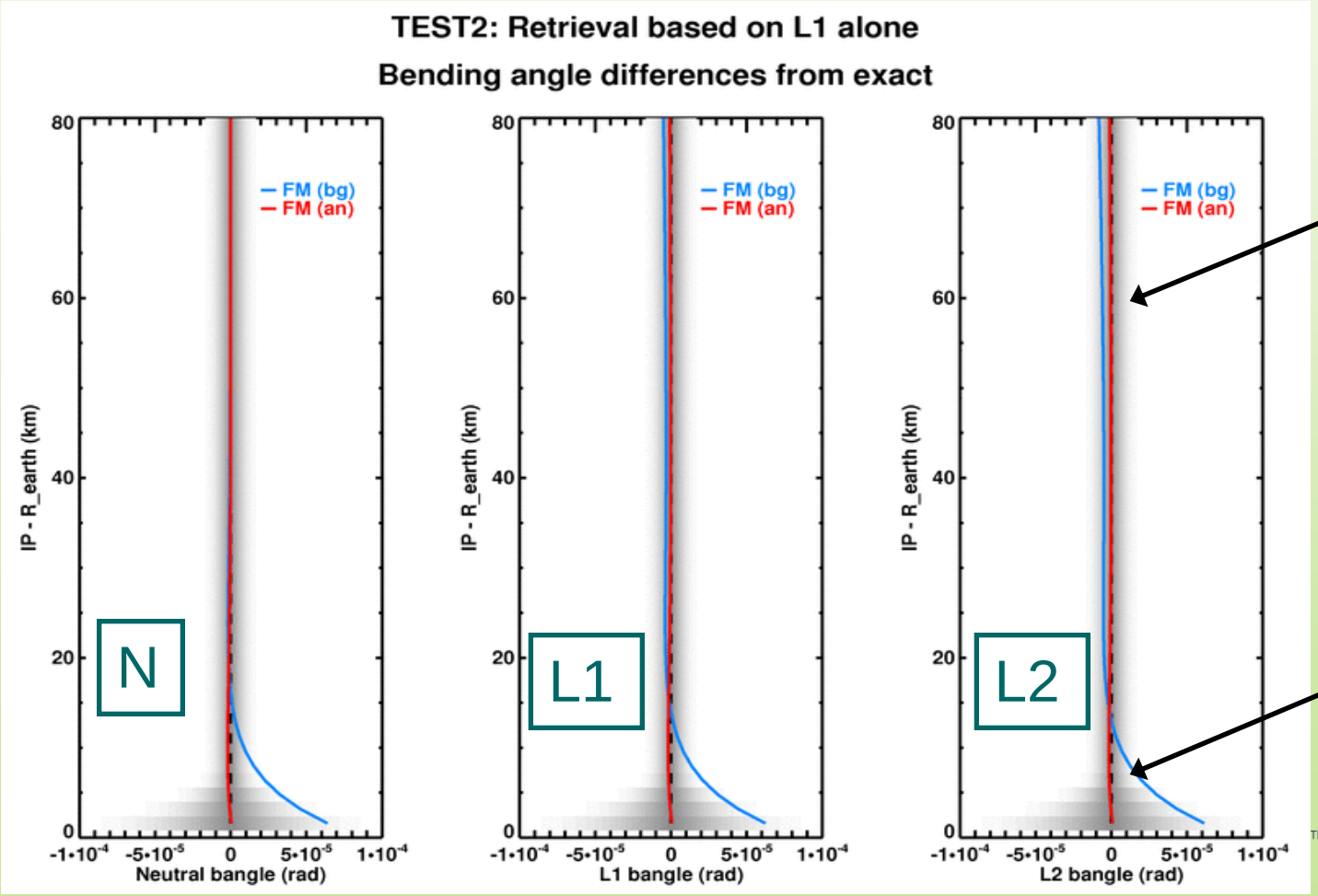
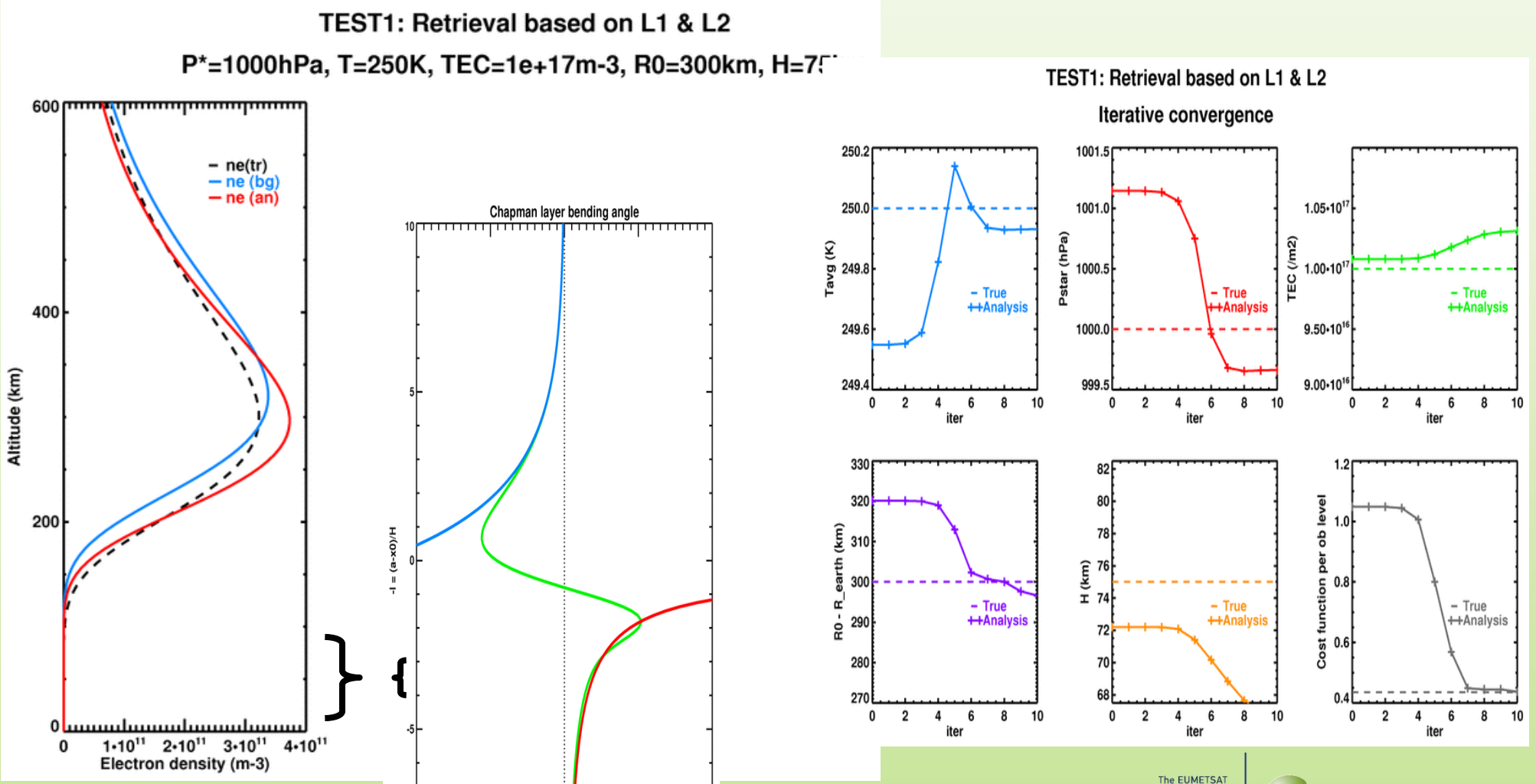


3. Retrievals of ionospheric parameters?

- Example 1: “standard ionosphere”



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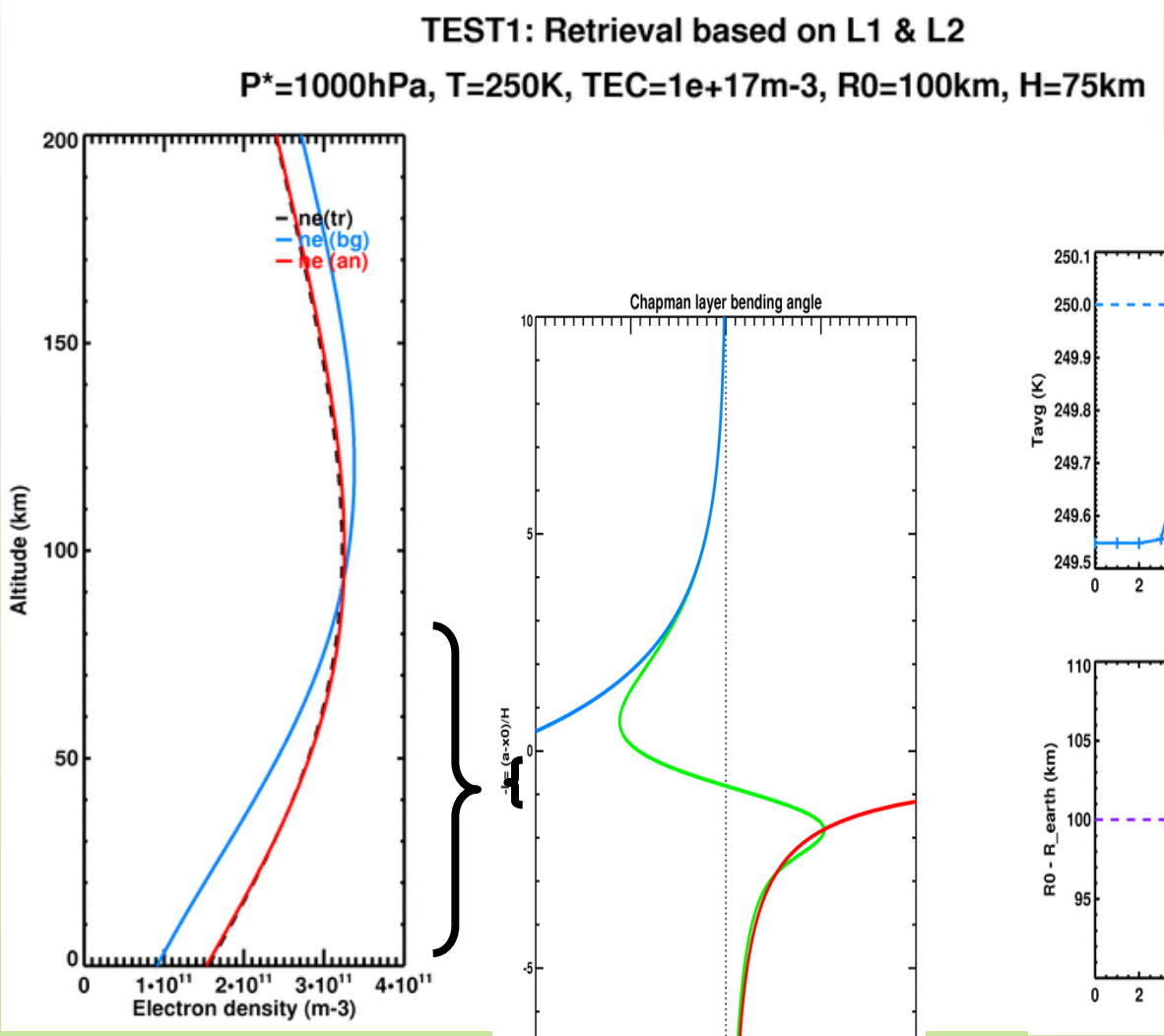
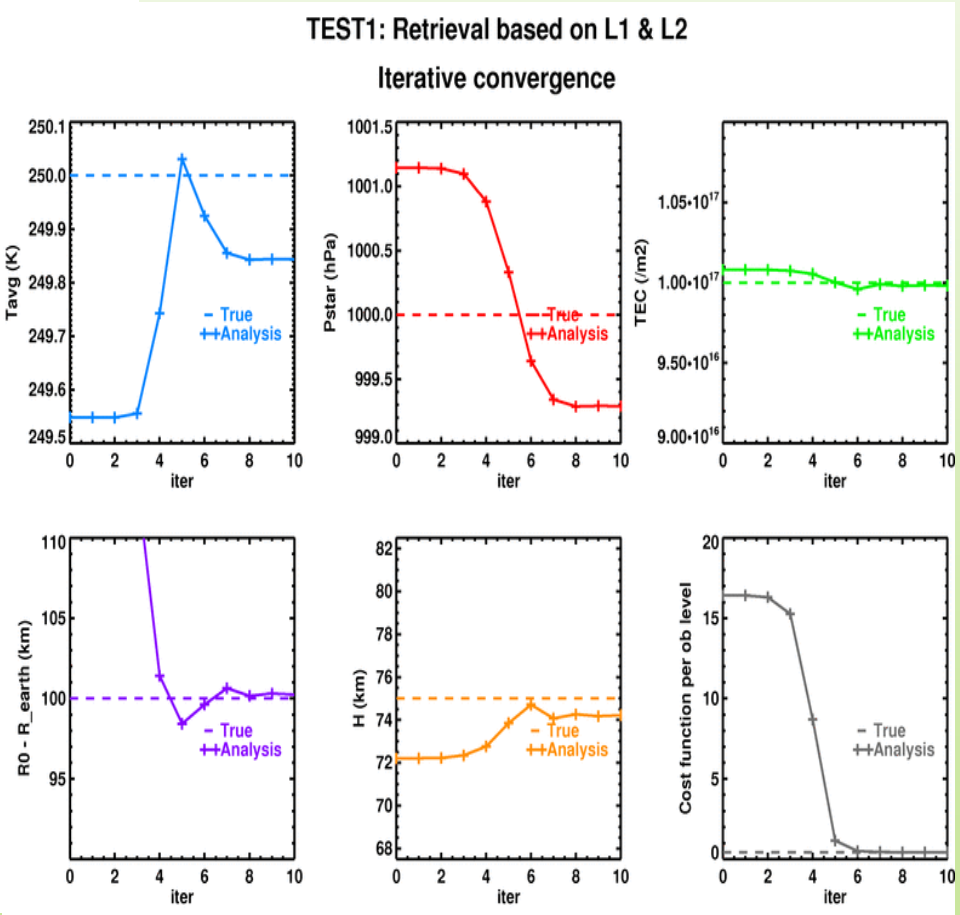
3. Retrievals of ionospheric parameters?

- Example 2: “low ionosphere”





Conclusions

- Bending angles produced by a *model* Chapman layer ionosphere have been described
- Theory offers some hope for improved L2 extrapolation
- Might allow retrievals based on L1 and L2 signals directly (toy model)
- Probably won't allow inferences of ionospheric params to be made.