

Atmosferski
utjecaj na
parabolički
model
propagacije
radio valova

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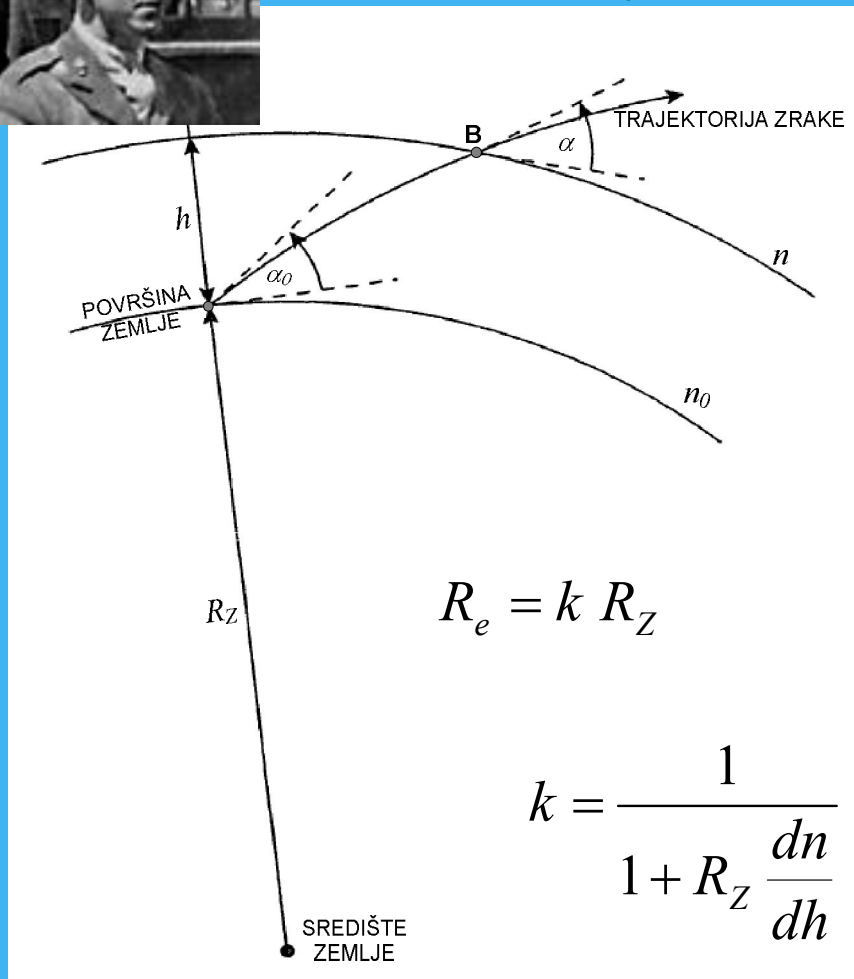
SADRŽAJ

- Klasični model propagacije
- Anomalne refrakcije
- Parabolički model propagacije
- Utjecaj atmosfere na indeks loma za radio valove
- Primjer paraboličkog modela
- Neriješeni problemi
- Značaj propagacijskih modela u bliskoj budućnosti i smjerovi budućih istraživanja

Klasični model refrakcije radio valova u atmosferi



E.V. Appleton (1892-1965)



$$n(R_Z + h) \cos \alpha = n_0 R_Z \cos \alpha_0$$

$$\left(n_0 + \frac{dn}{dh} h \right) (R_Z + h) \cos \alpha = n_0 R_Z \cos \alpha_0$$

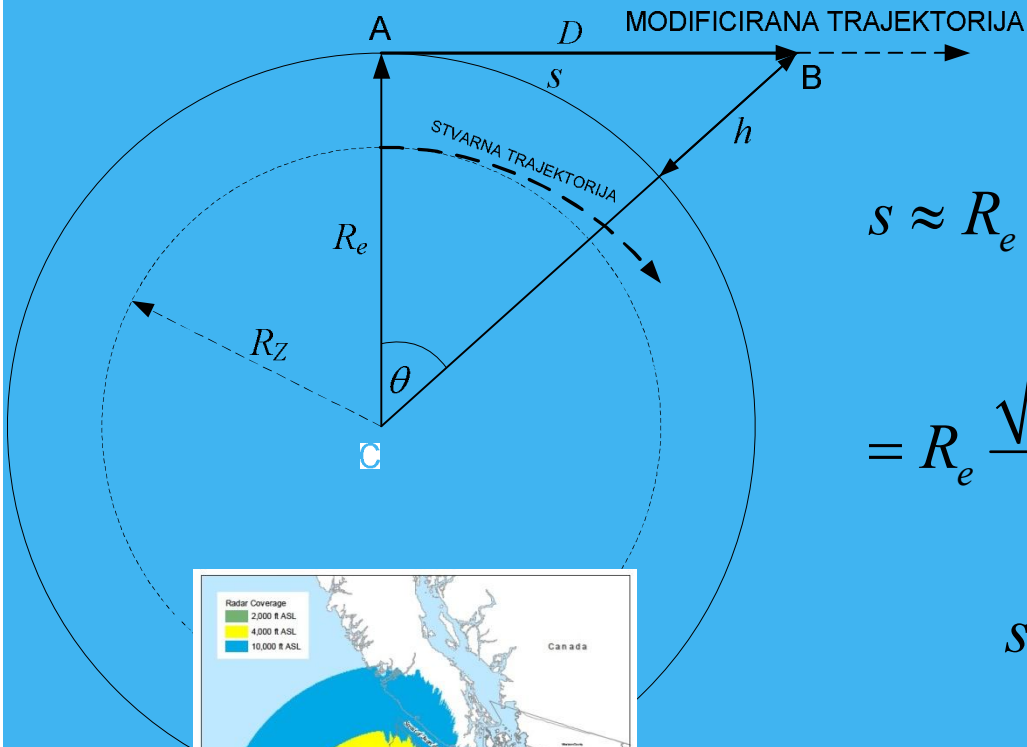
$$\left(1 + \frac{h}{R_Z} + \frac{h}{n_0} \frac{dn}{dh} + \frac{h^2}{n_0 R_Z} \frac{dn}{dh} \right) \cos \alpha = \cos \alpha_0$$

$$R_e = \frac{R_Z}{1 + R_Z \frac{dn}{dh}}$$

$$1.2 < k < 1.9 \Rightarrow k = 4/3$$

$$\left(1 + \frac{h}{R_e} \right) \cos \alpha \approx \cos \alpha_0$$

Klasični model refrakcije radio valova u atmosferi

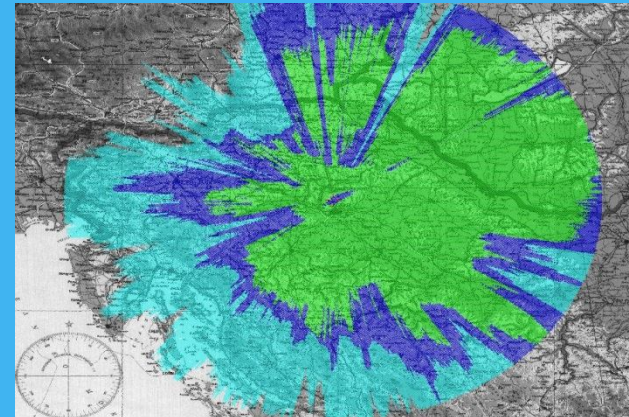
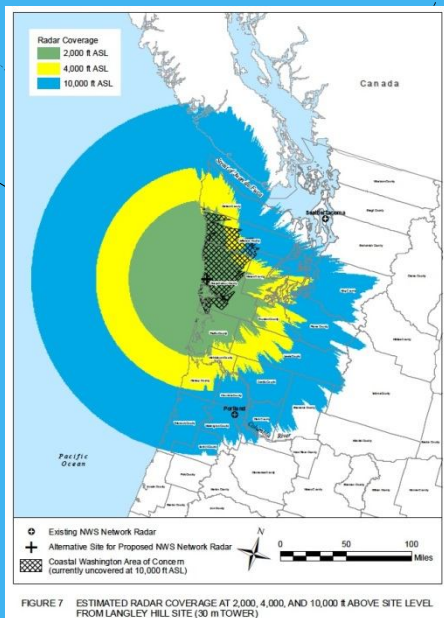


$$s = R_e \cdot \theta$$

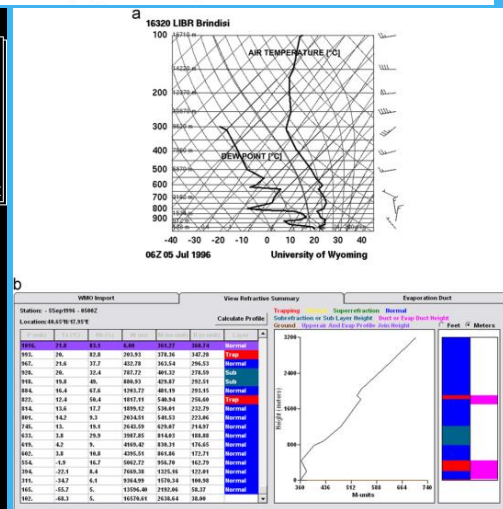
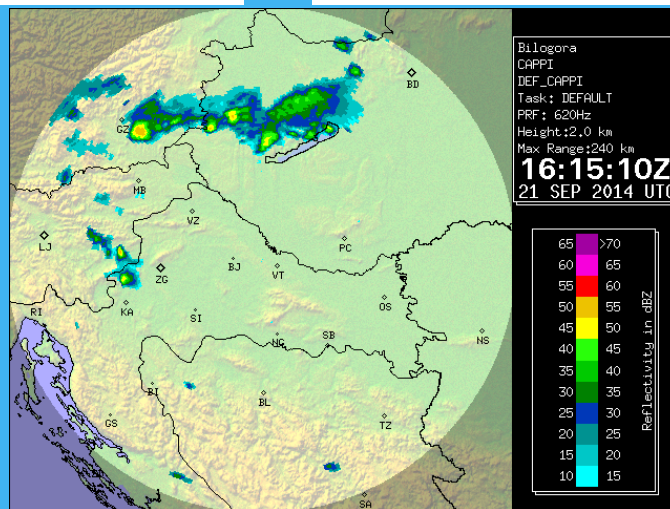
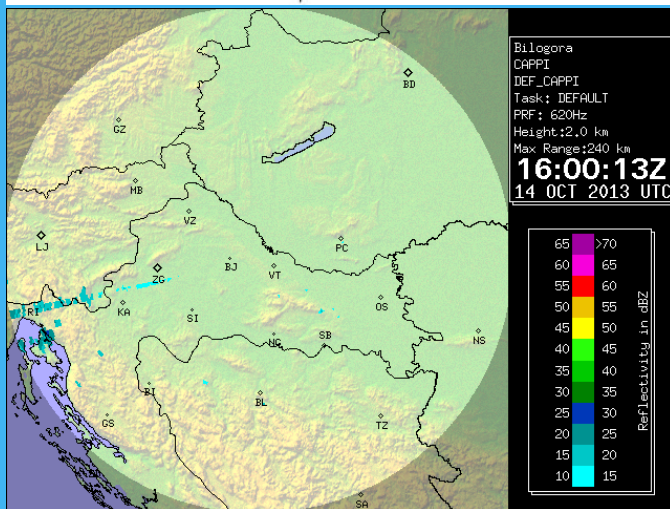
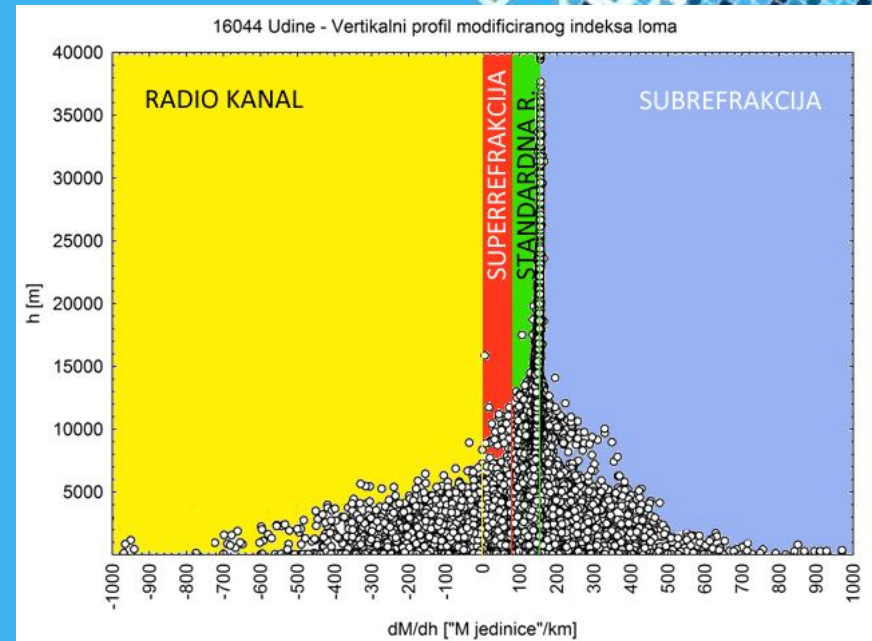
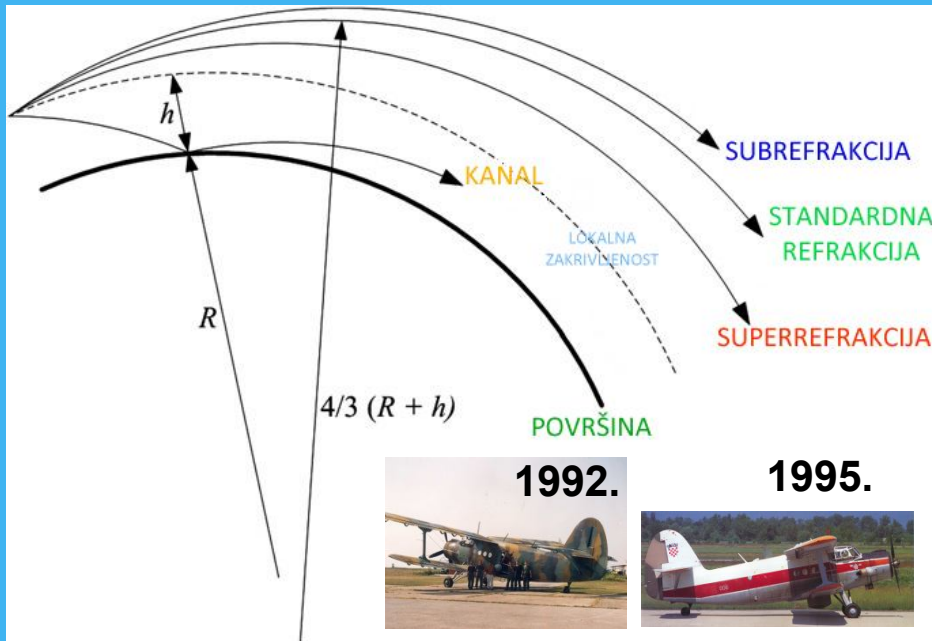
$$s \approx R_e \sin \theta = R_e \frac{D}{R_e + h} =$$

$$= R_e \frac{\sqrt{(R_e + h)^2 - R_e^2}}{R_e + h} = R_e \frac{\sqrt{2R_e h + h^2}}{R_e + h}$$

$$s \approx \sqrt{2R_e h} \Rightarrow h = \frac{1}{2} \frac{s^2}{R_e}$$



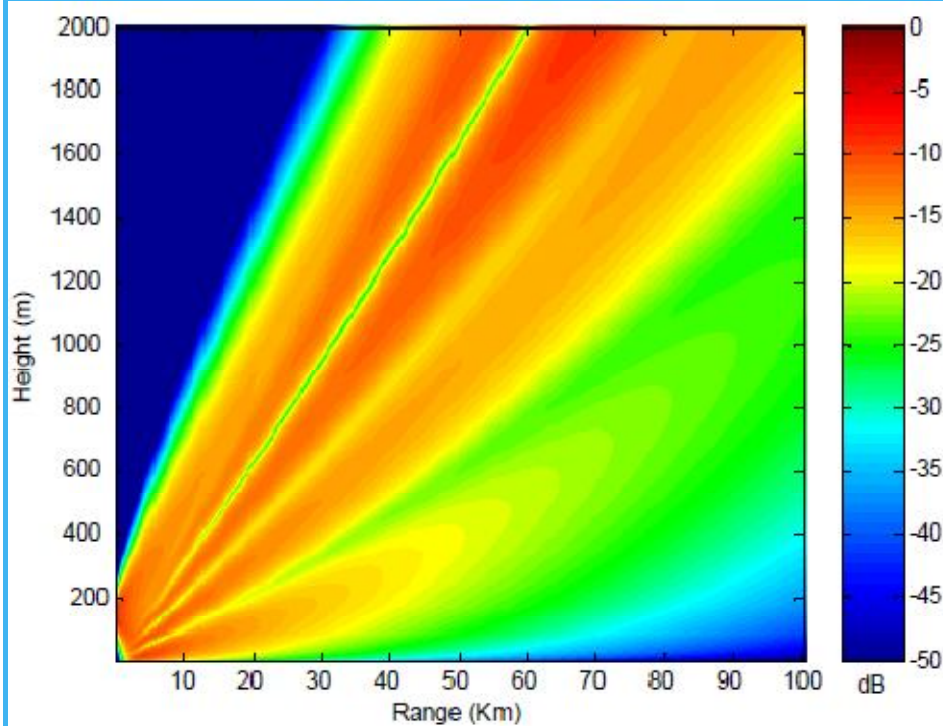
Anomalne refrakcije



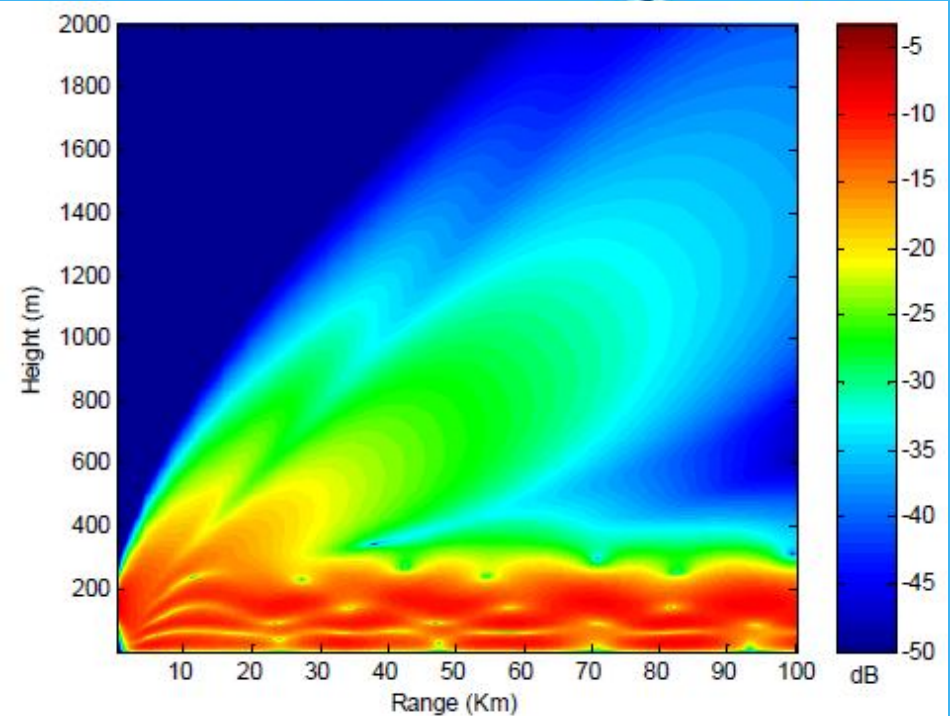
Parabolički model propagacije

$$\frac{\partial^2 E(x, z)}{\partial z^2} + 2jk \frac{\partial E(x, z)}{\partial x} + k^2 \left([n(x, z)]^2 - 1 + \frac{2z}{R} \right) E(x, z) = 0$$

Isaakidis i Xenos, 2004



STANDARDNA REFRAKCIJA



POVRŠINSKI KANAL

Utjecaj atmosfere na indeks loma

IUGG, 1963.

$$N = (n - 1) \cdot 10^6$$

$$N = 77.624 \frac{p_d}{T} + 64.700 \frac{p_w}{T} + 371897 \frac{p_w}{T^2}$$

International Radio Consultative Committee, 1986.

$$N = \frac{77.6 p}{T} - \frac{5.6 e}{T} + \frac{3.75 \cdot 10^5 e}{T^2}$$

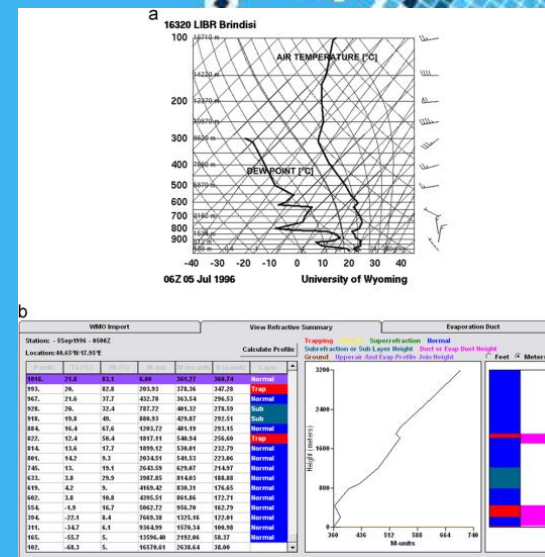
Patterson i dr., 1994; Battan, 1973

$$N = (n - 1) \cdot 10^6 = \frac{77.6 [\text{K} \cdot \text{Pa}^{-1}] \cdot p}{T} + \frac{e'_s \cdot 3.73 \cdot 10^5 [\text{K}^2 \text{Pa}^{-1}]}{T^2}$$

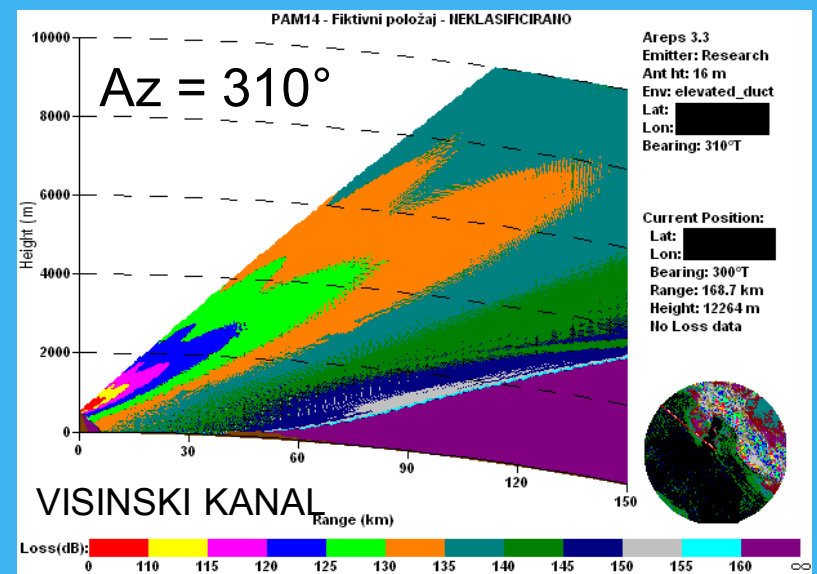
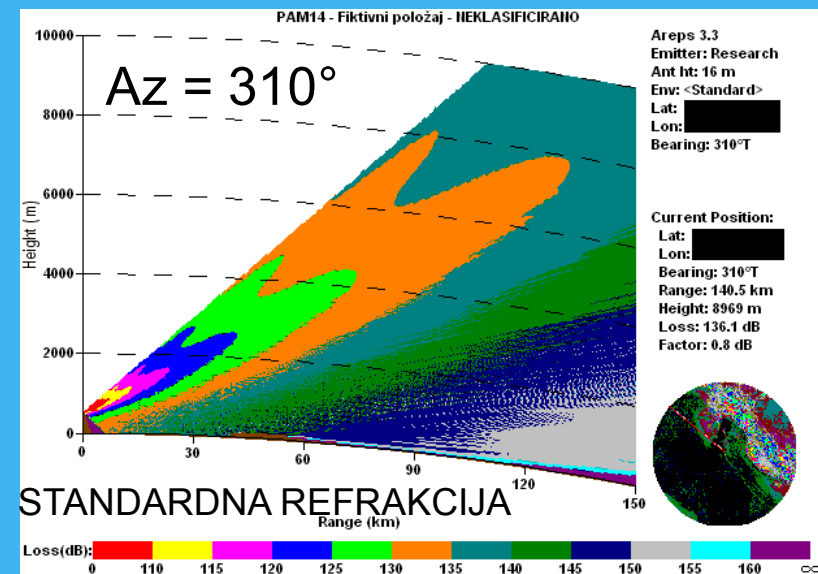
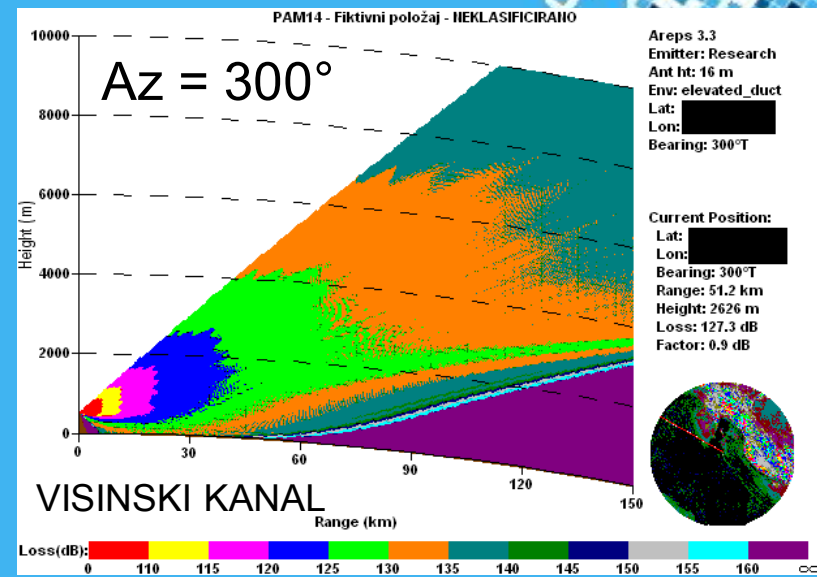
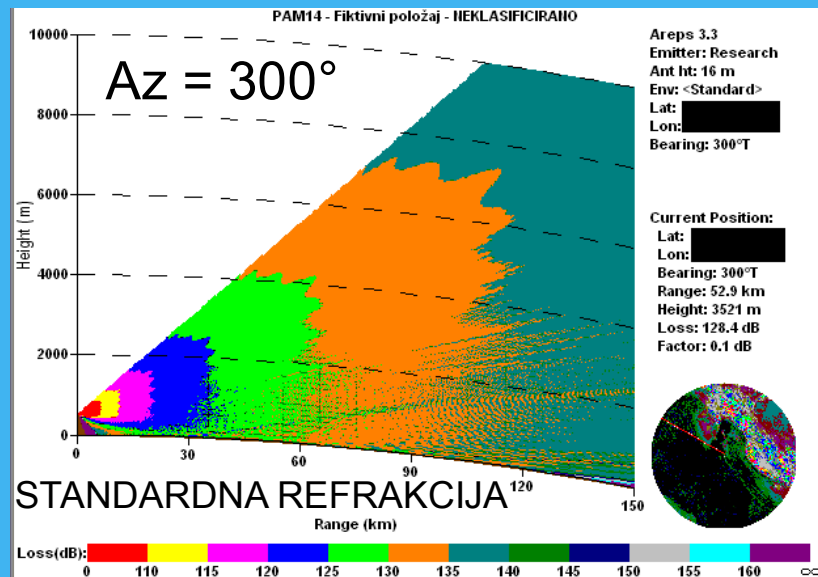
$$e'_s = \frac{rh \cdot 6.105 \cdot \exp(x)}{100} \quad x = 25.22 \frac{T - 273.15 [\text{K}]}{T} - 5.31 \cdot \ln \left(\frac{T}{T_0} \right)$$

ITU-R P.453-9 iz 2003

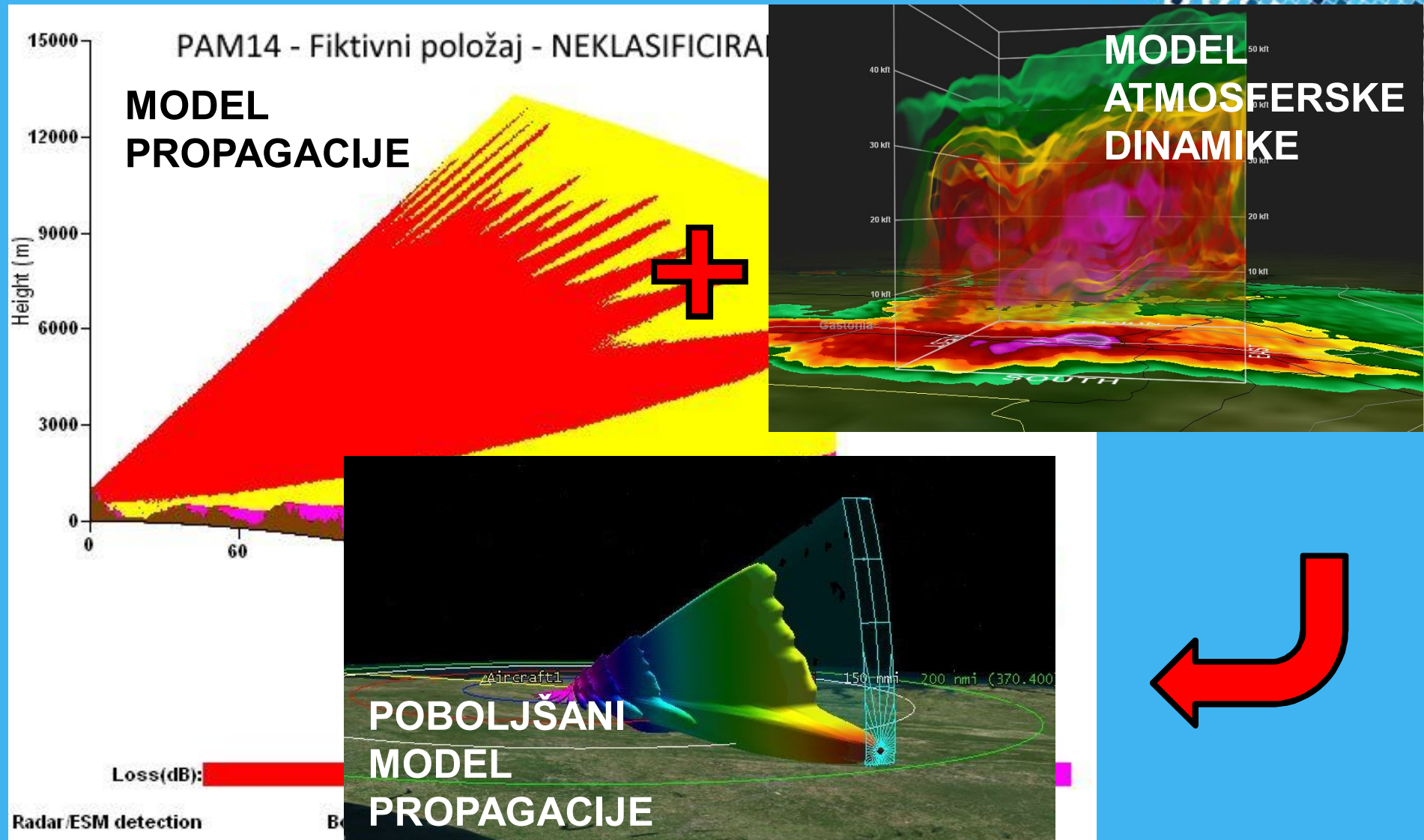
$$N = \frac{77.6}{T} \left(p + 4810 \frac{e}{T} \right)$$



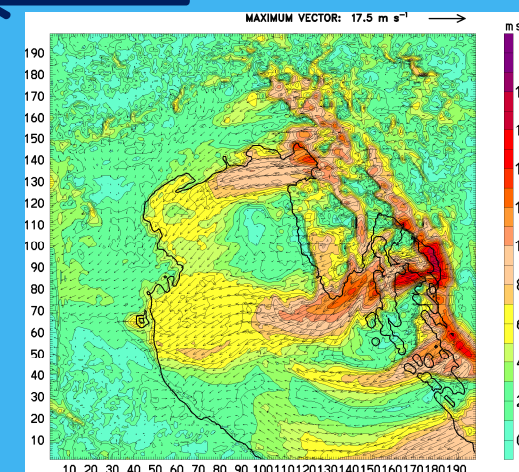
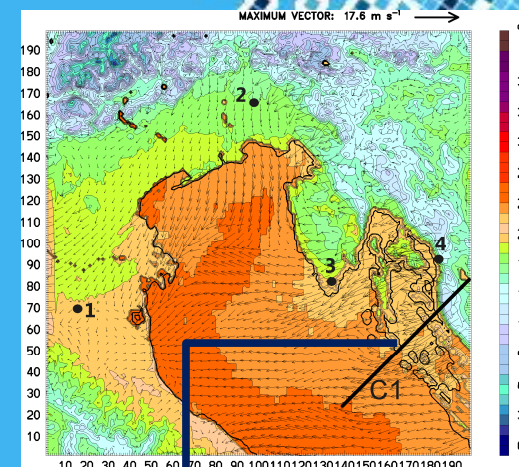
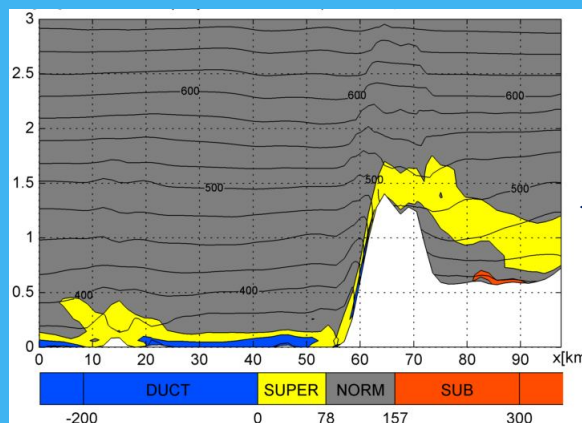
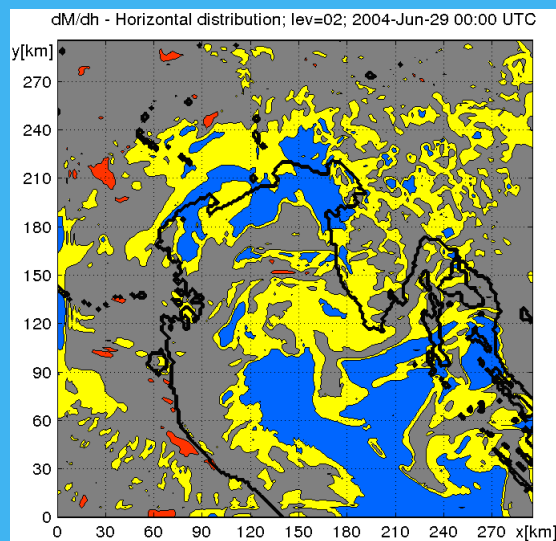
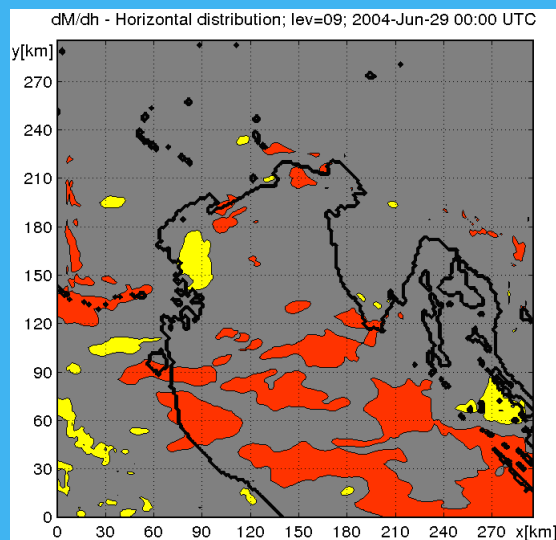
Primjer paraboličnog modela



Neriješeni problemi



WRF model kao ulaz u model propagacije

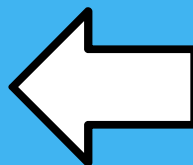


Telišman Prtenjak M.,
Horvat I., Tomažić I.,
Kvakić M., Grisogono B.,
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Smjerovi budućih istraživanja



**PRILIKA ZA SURADNJU
PRIRODNIH I TEHNIČKIH
ZNANOSTI**



Primjena:

- radio i TV difuzija
- telekomunikacije
- radarsko motrenje
- elektroničko djelovanje
- radio navigacija

Problemi:

- sateliti na niskim elevacijama
- ADS-B
- digitalne modulacije
- uži radio kanali
- ciljevi s niskim odrazom
- LPI radari
- VHF radari
- EM polucija
- ...

