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A regional adaptive and assimilative 3D ionospheric model

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ROMA TRE
UNIVERSITÀ DEGLI STUDI

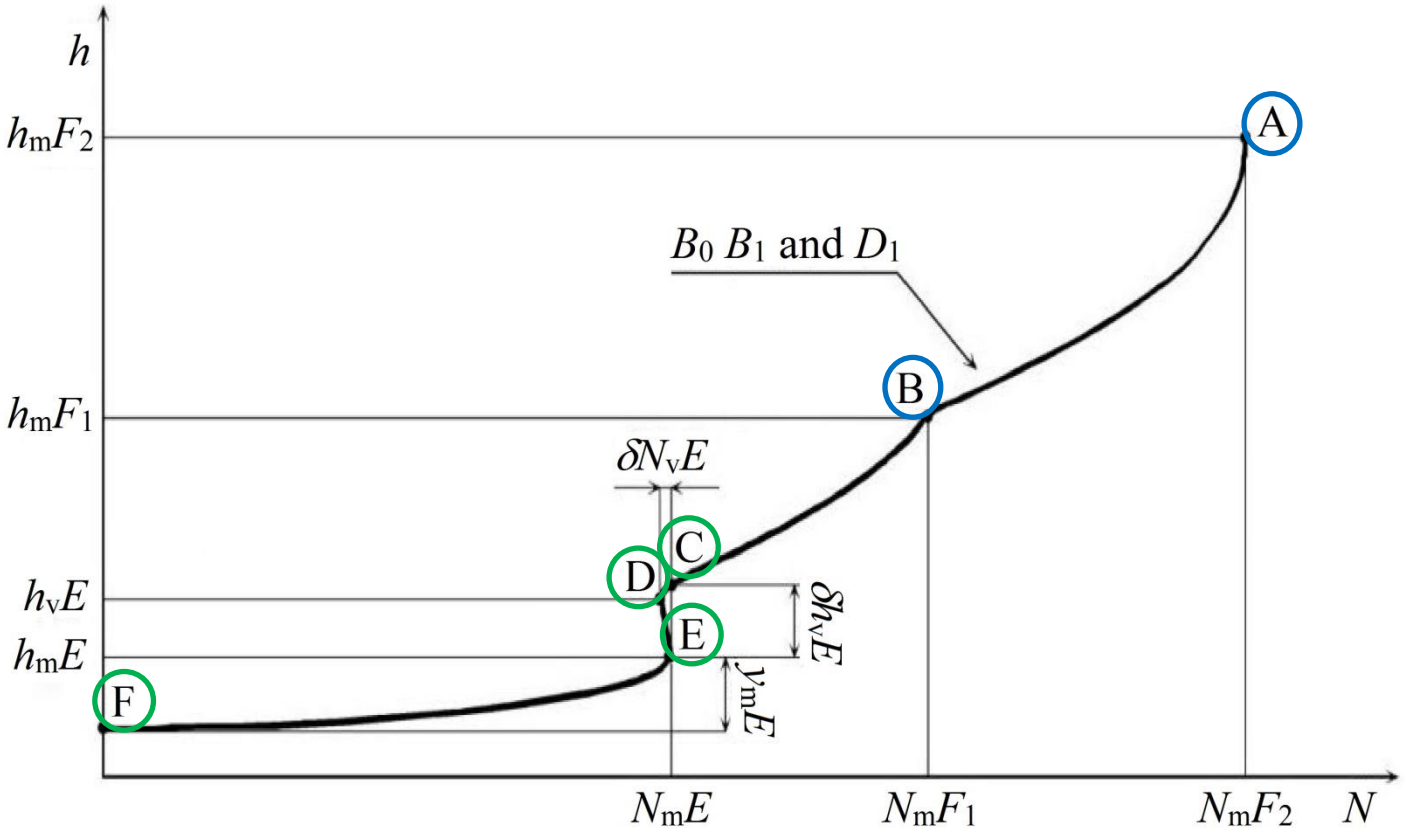
Istituto Nazionale di Geofisica e Vulcanologia

Outline

- ✓ $N(h)$ model with free parameters
- ✓ Climatological 3D model through empirical formulas
- ✓ Real-time 3D model through data ingestion
- ✓ Products
- ✓ Validation

$N(h)$ model with free parameters

- ✓ Adaptive Ionospheric Profiler (AIP) applied by Autoscala
- ✓ 12 free parameters



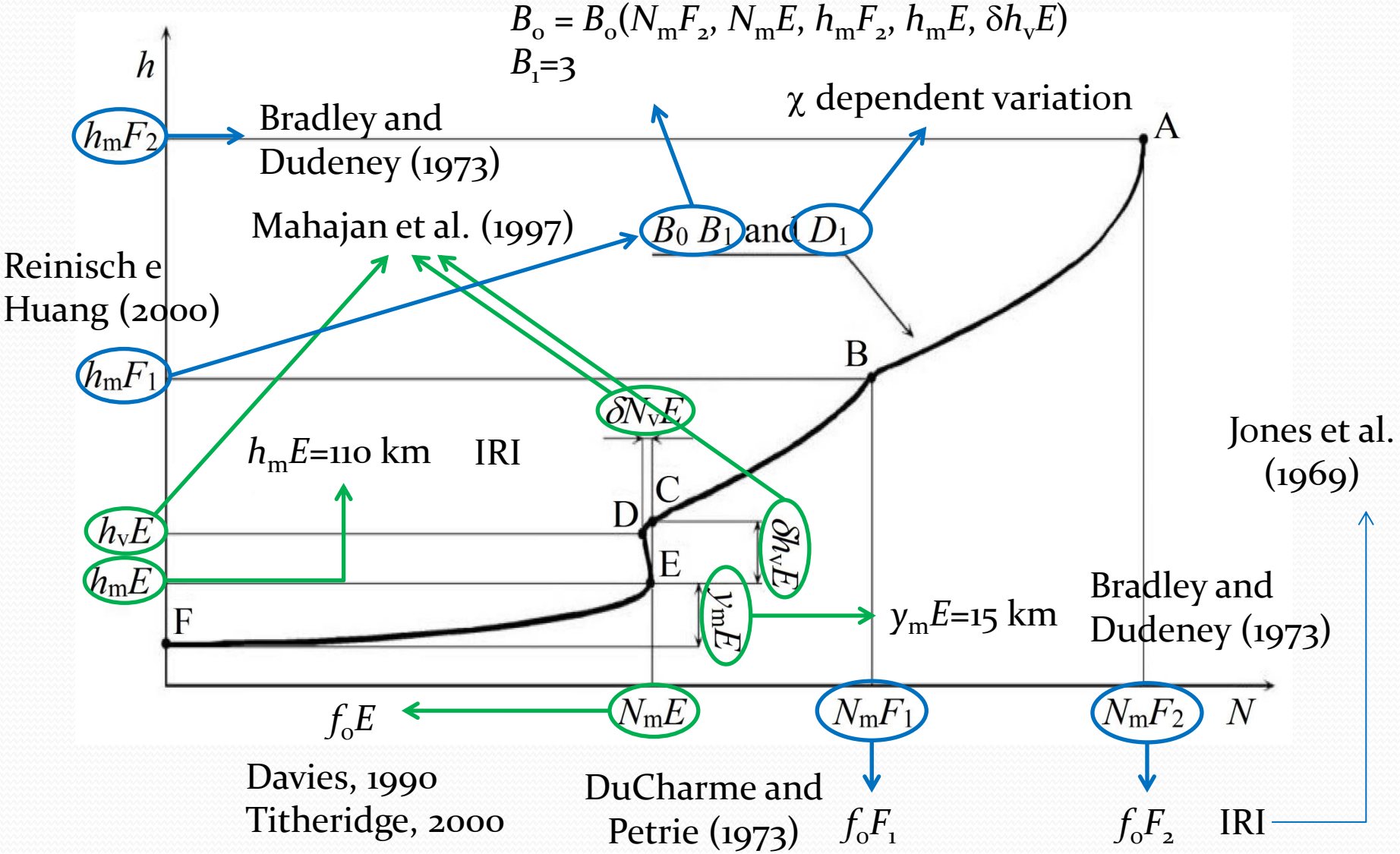
F region

1) N_mF_2
2) h_mF_2
3) N_mF_1
4) B_0
5) B_1
6) D_1

7) N_mE
8) h_mE
9) h_vE
10) δh_vE
11) δN_vE
12) y_mE

E region

Climatological 3D model



Real-time 3D model

✓ Climatological parameter

$P_{i[base]}$ → variation ΔP_i → Actual value $P_i = P_{i[base]} + \Delta P_i$

✓ Parameters varied

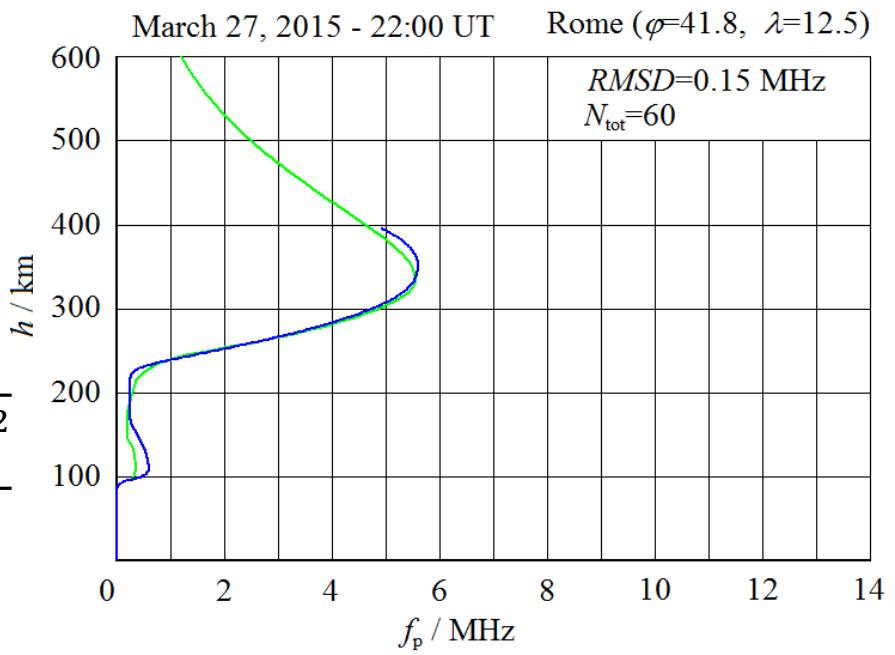
- f_0F_2
- h_mF_2
- δh_vE → different day/night variation ranges
- B_o → variation in a growing around of $B_{o[base]}$

fixed variation ranges

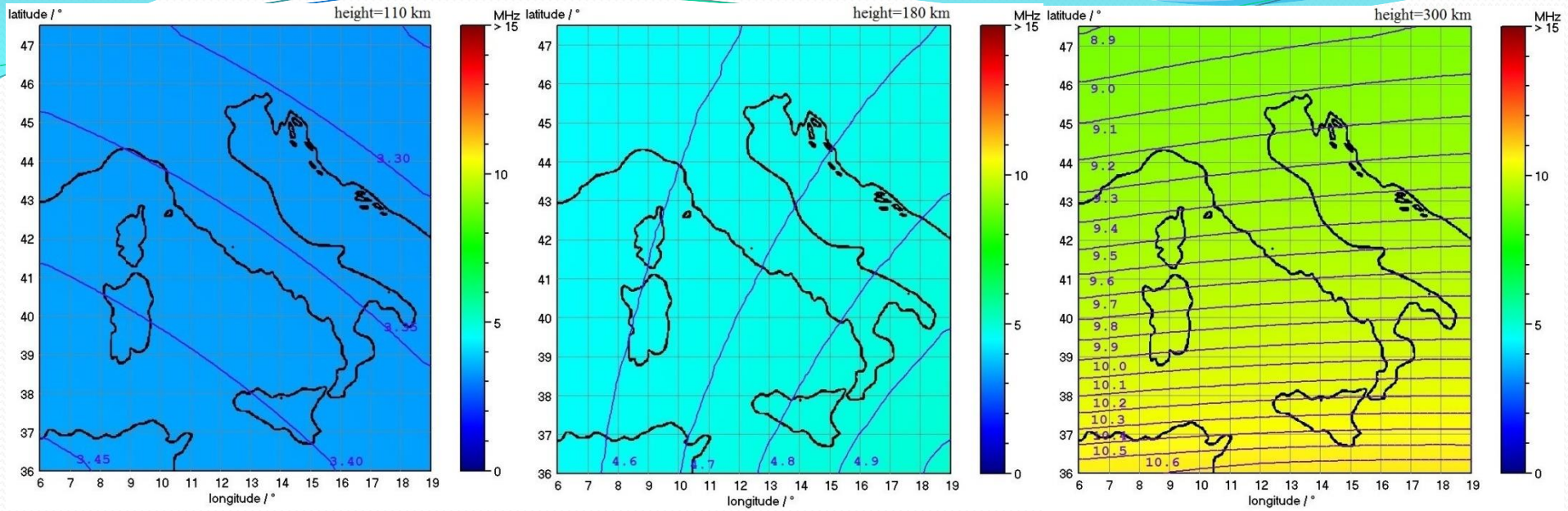
✓ Minimazion of *RMSD* →

- Δf_0F_2
- Δh_mF_2
- $\Delta\delta h_vE$
- ΔB_o

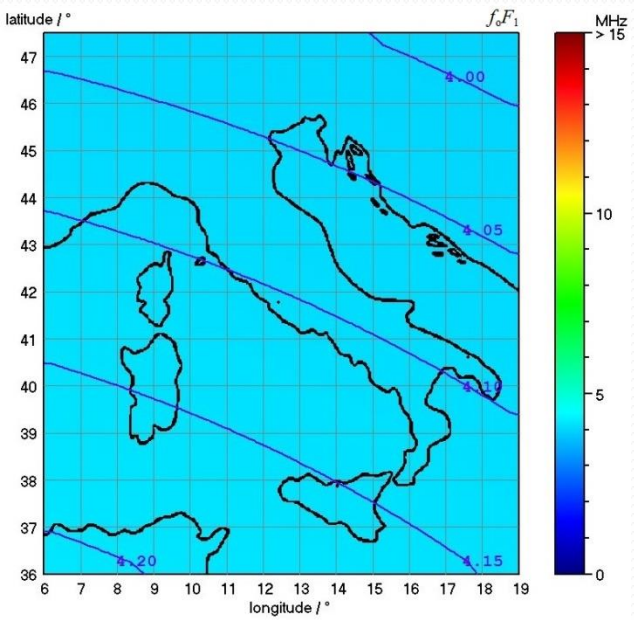
$$RMSD = \sqrt{\frac{\sum_{i=1}^{N_{tot}} \left(f_{p[ionos]}(h^{[i]}) - f_{p[model]}(h^{[i]})\right)^2}{N_{tot}}}$$

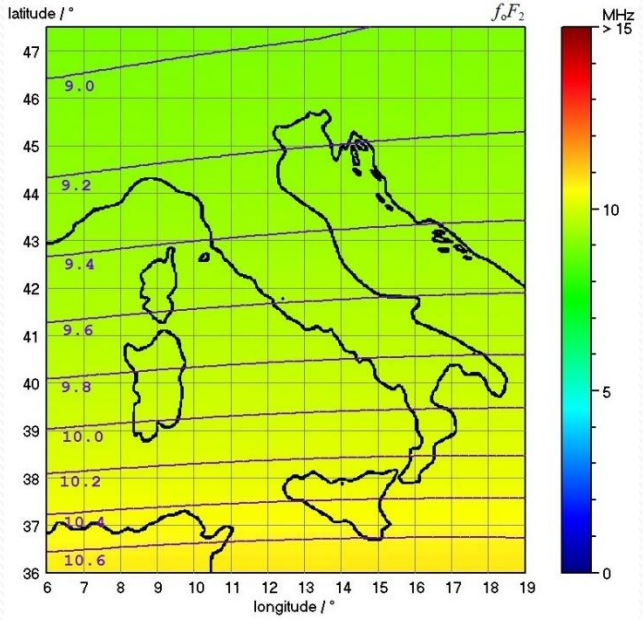


✓ f_p at fixed altitude

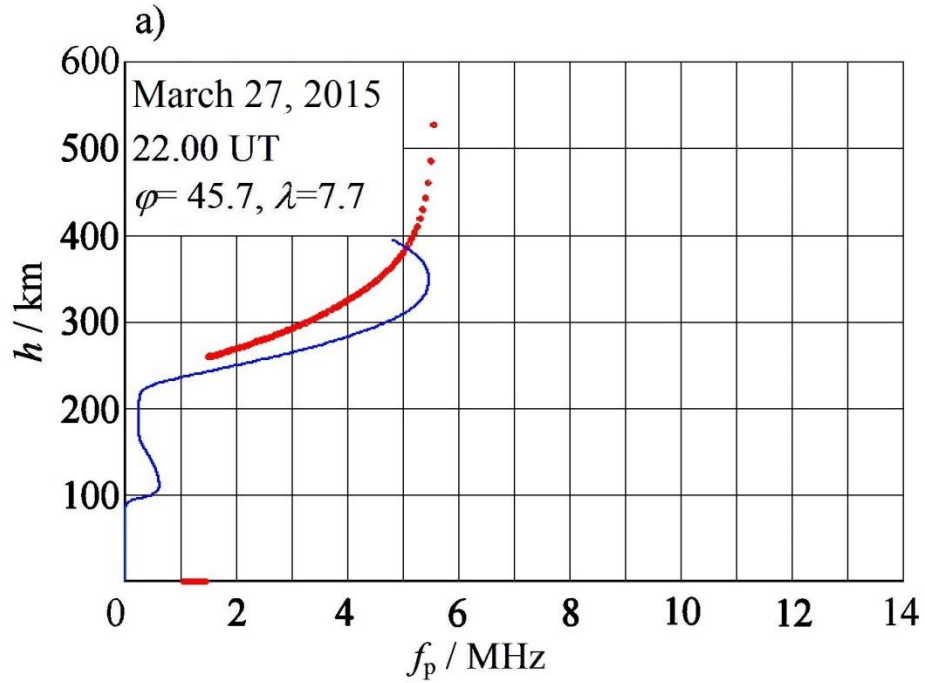


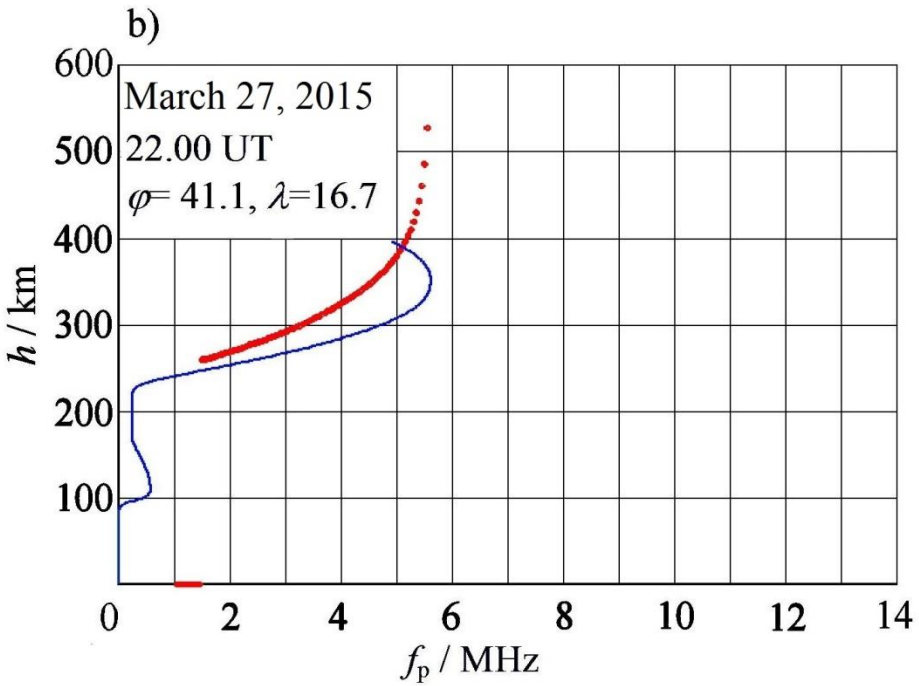
✓ f_0F_1

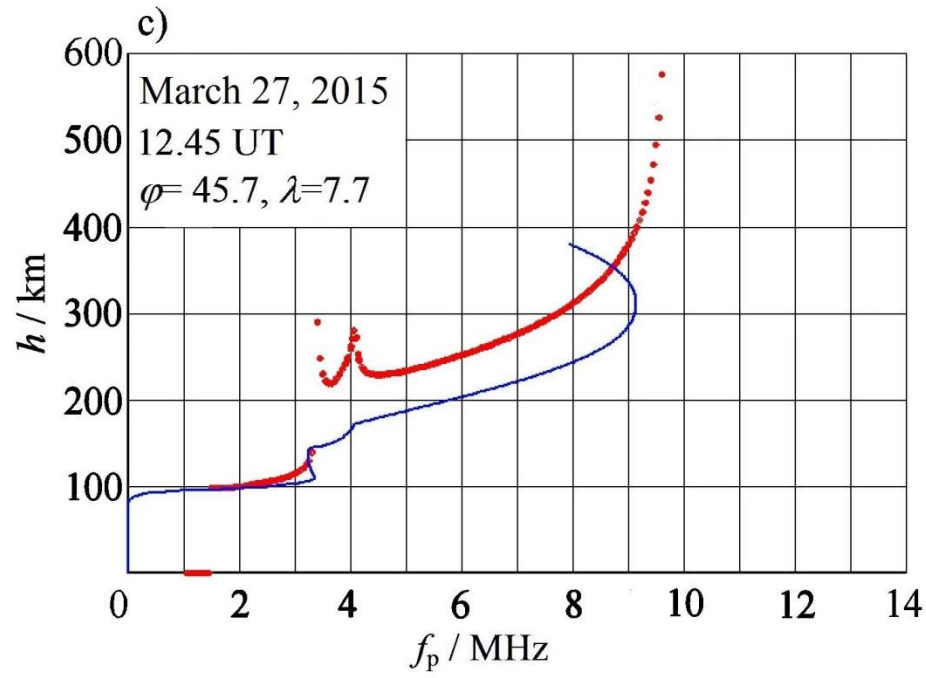


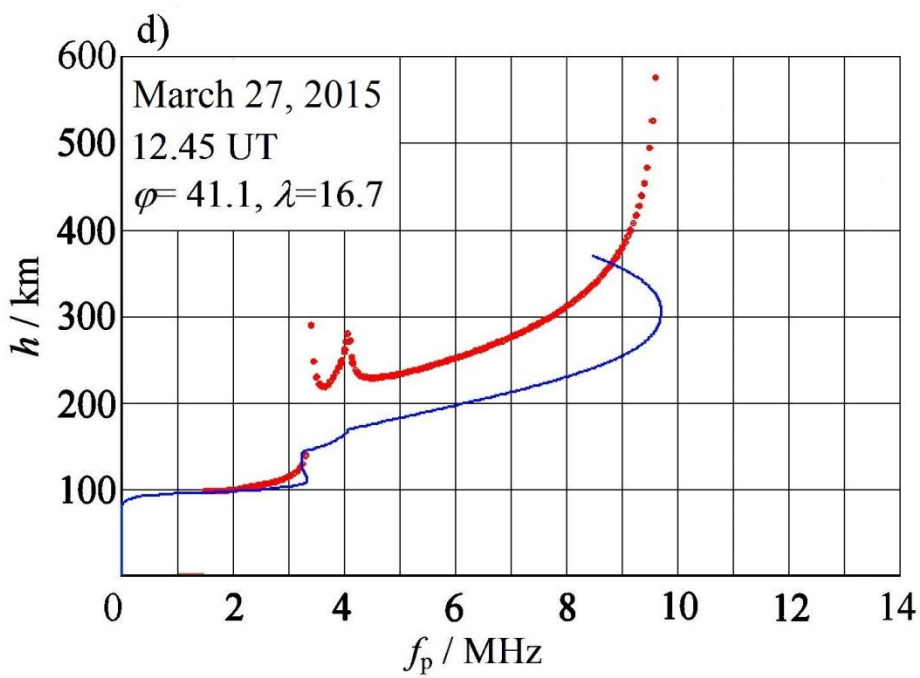


✓ f_0F_2


a)
March 27, 2015
22.00 UT
φ= 45.7, λ=7.7
h / km
600
500
400
300
200
100
0
2
4
6
8
10
12
14
fp / MHz


b)
March 27, 2015
22.00 UT
φ= 41.1, λ=16.7
h / km
600
500
400
300
200
100
0
2
4
6
8
10
12
14
fp / MHz


c)
March 27, 2015
12.45 UT
φ= 45.7, λ=7.7
h / km
600
500
400
300
200
100
0
2
4
6
8
10
12
14
fp / MHz


d)
March 27, 2015
12.45 UT
φ= 41.1, λ=16.7
h / km
600
500
400
300
200
100
0
2
4
6
8
10
12
14
fp / MHz

Model validation

✓ Test:

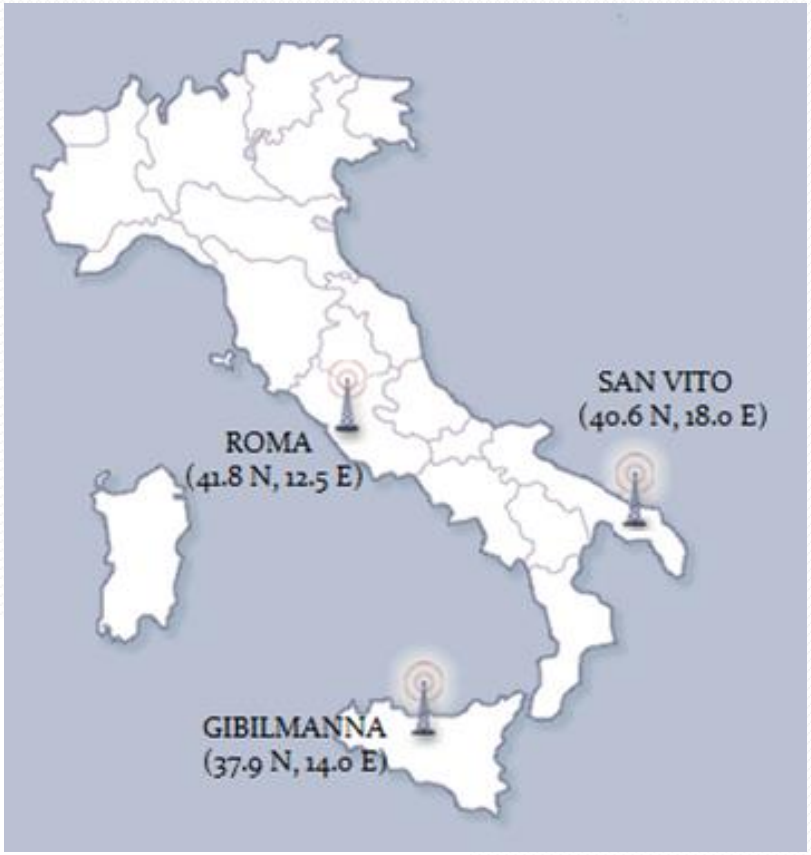
adaptation to data from Rome and Gibilmanna

+

comparison against data from San Vito dei Normanni

- DPS-4 ionosondes
- ARTIST

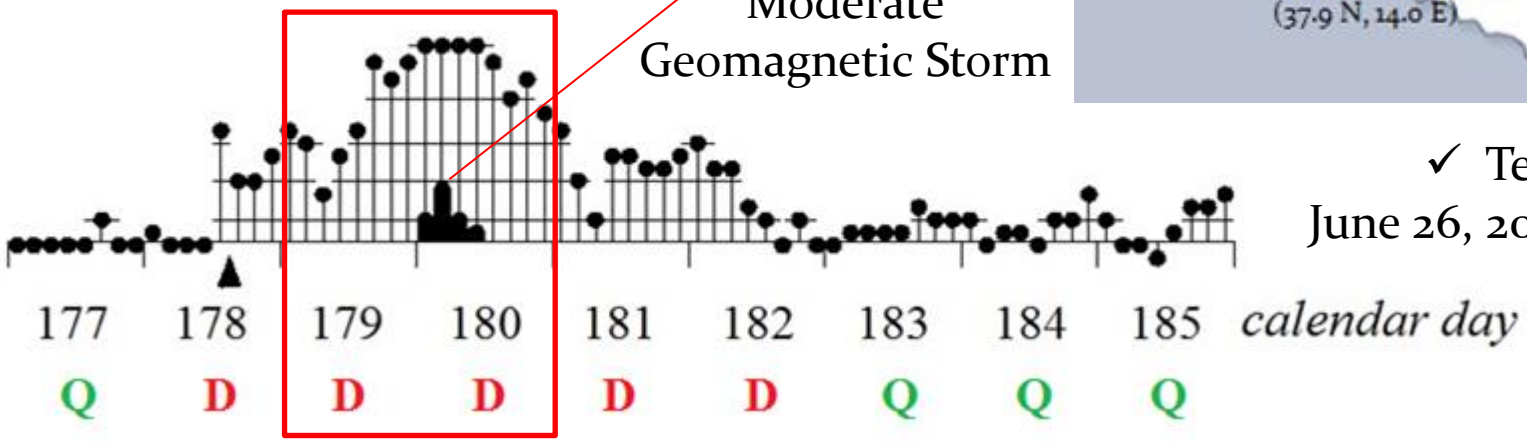
- AIS-INGV ionosonde
- Autoscala



Q = Quiet (K_p<2 throughout day)
D = Disturbed (otherwise)

K_p=6+

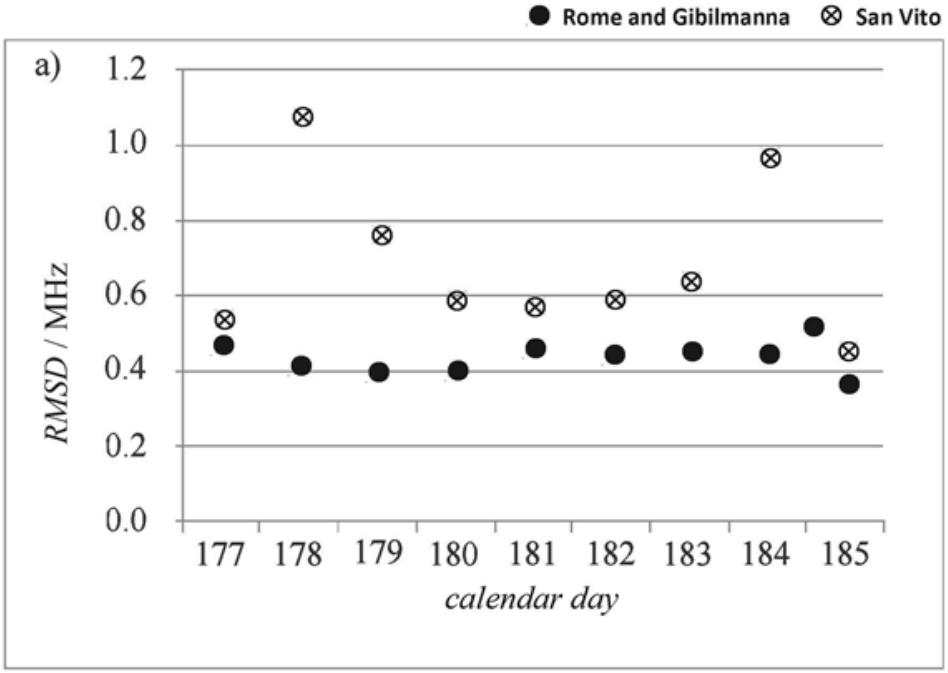
Moderate Geomagnetic Storm



✓ Test period:
June 26, 2013 – July 4, 2013

Results

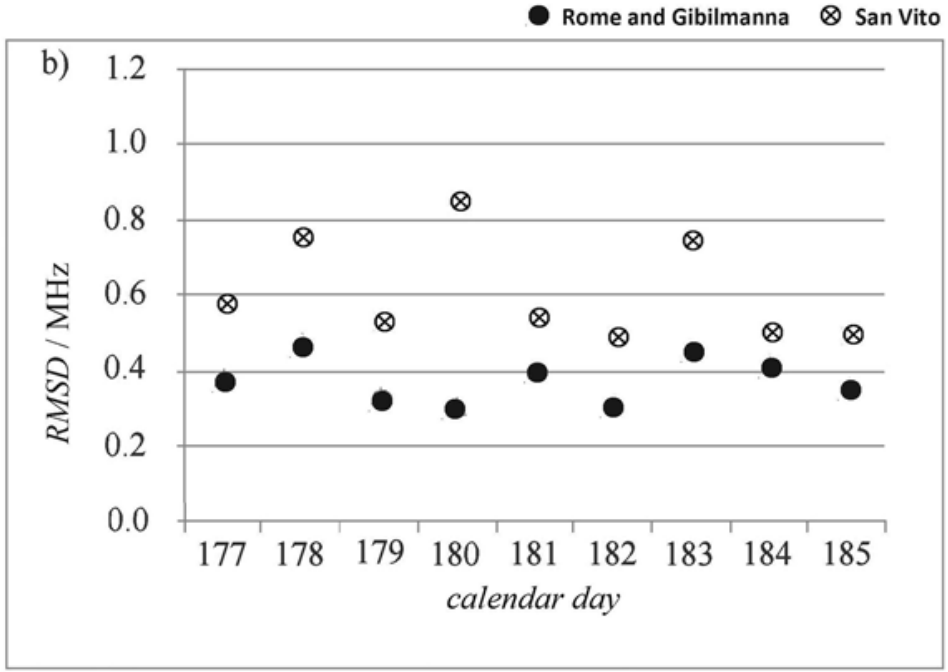
✓ Nighttime averaged values



	% adapted
quiet	95.65
disturbed	88.70
daytime	91.82
nighttime	91.75
all	91.79

✓ using all available $f_p(h)$

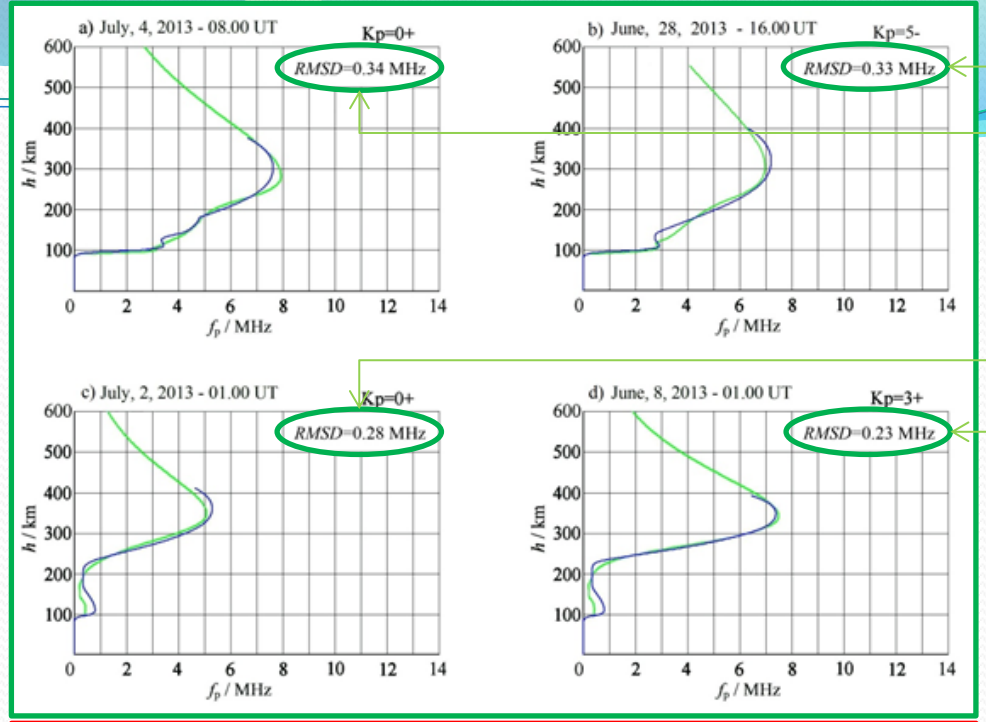
✓ Daytime averaged values



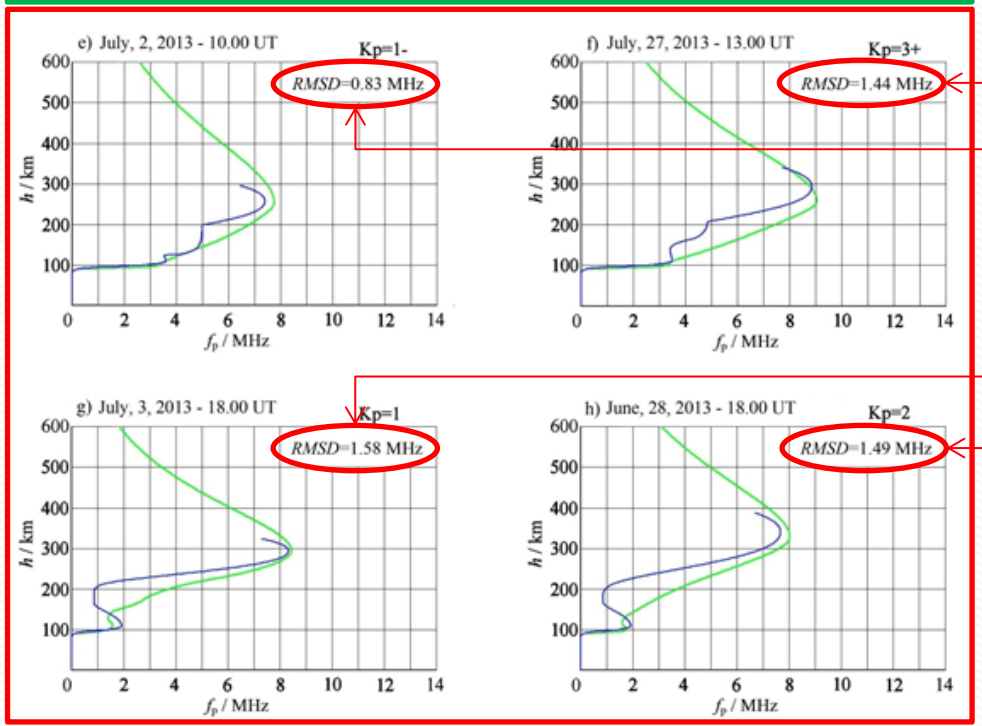
	% adapted
quiet	98.44
disturbed	96.47
daytime	97.18
nighttime	97.44
all	97.32

✓ using only validated $f_p(h)$

✓ $f_p(h)$ profiles at San Vito dei Normanni



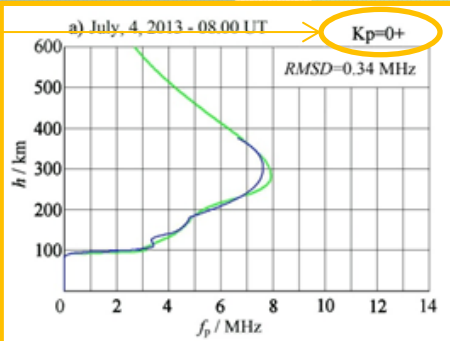
Good accuracy

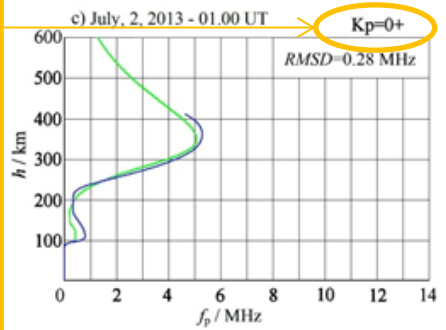


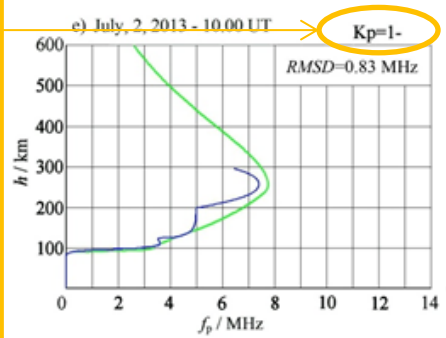
Poor accuracy

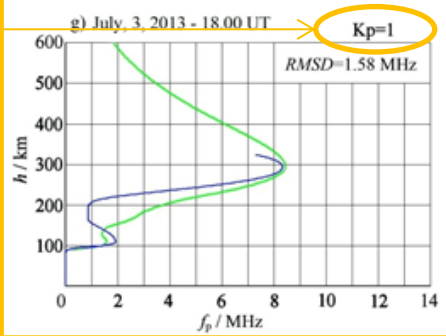
Quiet days

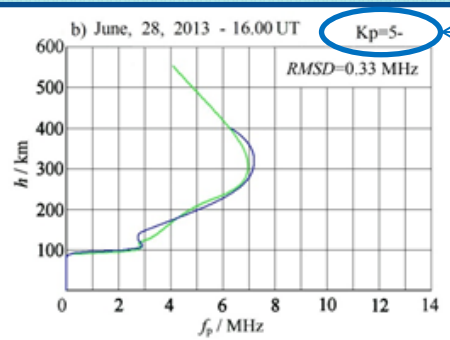
Disturbed days

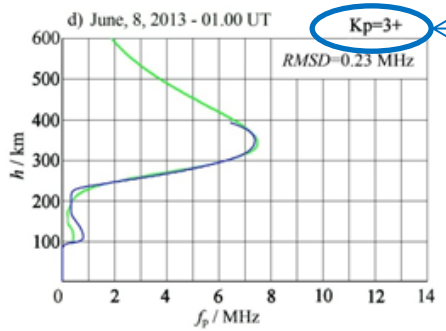


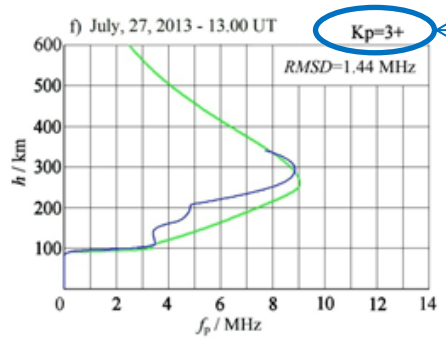


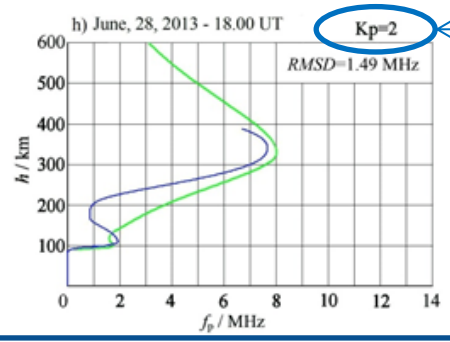


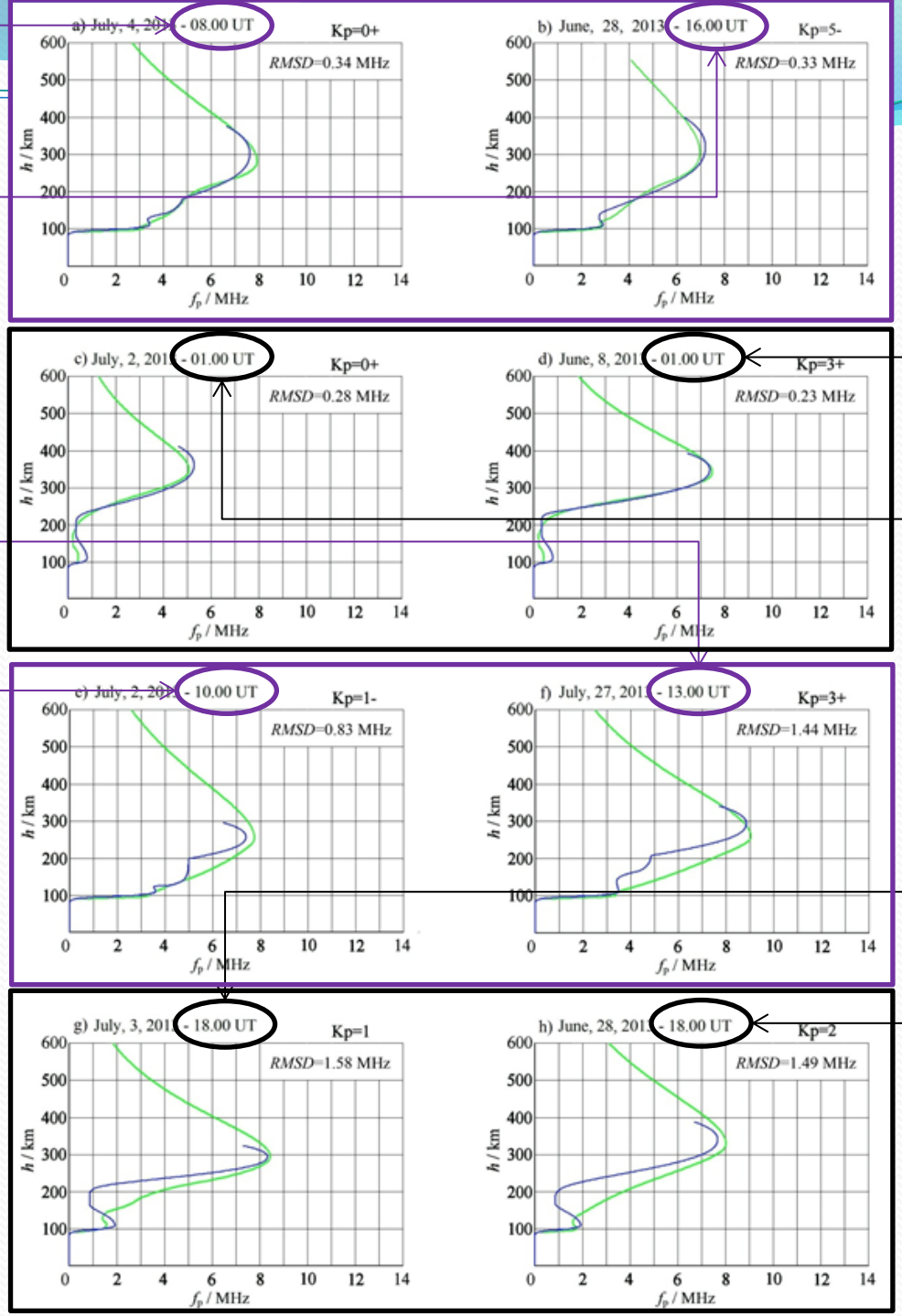












Daytime hours

Nighttime hours

Conclusions

- ✓ **The regional adaptive and assimilative 3D ionospheric model proposed demonstrates an ability to adapt to the ionospheric conditions observed at a given moment**
- ✓ $RMSD_{[\text{Rome and Gibilmanna}]}$ ⇒ adaptability
  - indipendent of geomagnetic conditions
  - slightly better during daytime
- ✓ Quite good degree of adaptability ⟷ 0.1 MHz (URSI standard)
- ✓ The percentages of success of the adjustment procedure for each different data class are higher when we consider only validated profiles

⇒ under all conditions the model is able to fit more frequently correct profiles than incorrect ones ⇒ capability of the model of rejecting the low quality profiles

- ✓ $RMSD_{[\text{San Vito}]}$ ⇒ accuracy for modeling f_p
  - slightly better in geomagnetically quiet conditions
  - somewhat better during daytime

Thank you
for your attention!

	Δf_0F_2 [MHz]	Δh_mF_2 [km]	$\Delta\delta h_vE$ (night) [km]	$\Delta\delta h_vE$ (day) [km]
min	-4.0	-150	10	-7.5
max	4.0	150	105	40.0
step	0.1	15	5	2.5
# values	81	21	20	20
# combinations			34020	34020

$\Delta B_0 = \Delta B_0^{[N]}$

$\Delta B_0^{[n]} = (-1)^{n+1} \cdot n \cdot 0.05\% \cdot B_{0[base]}$ $\quad n = 0, \ldots N$

(until the algorithm is able to adapt the profile)