Characteristics of ionospheric disturbances over Japan

an estimation from integrated measurements of
HF Doppler (HFD)
and
Direction Finding (DF)

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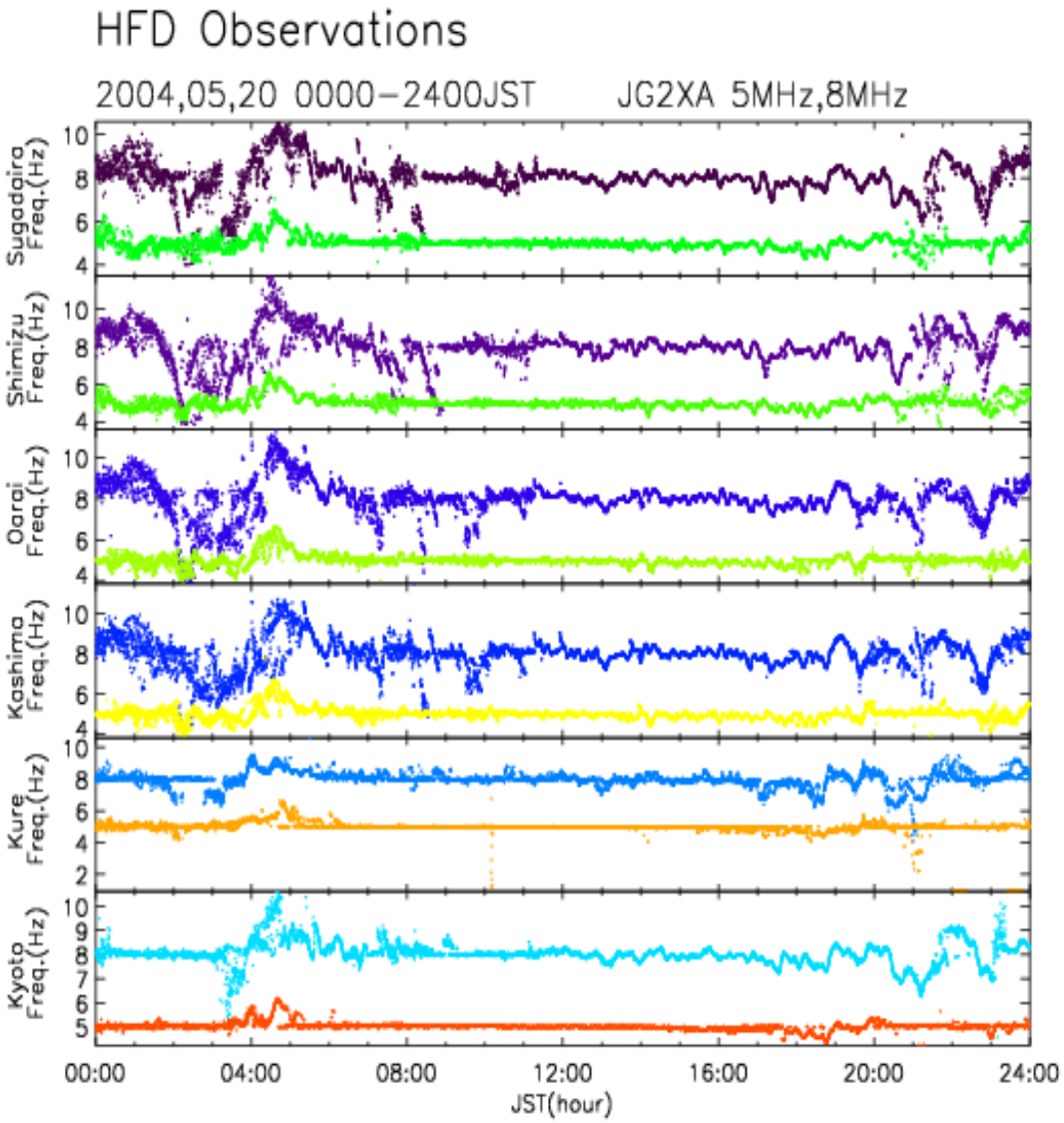
NICT

HFD observations array over Japan (operateve by UEC)

An example HFD observations – May 20th, 2004



Operating frequency

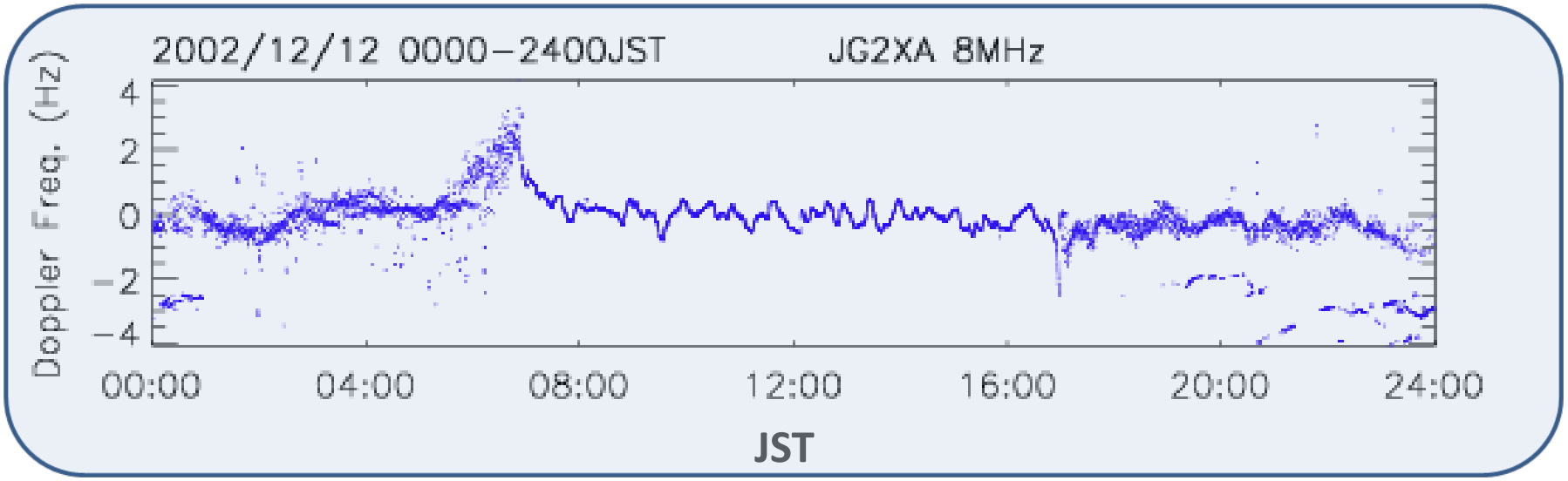
5.006MHz, 8.006MHz

Sampling time interval

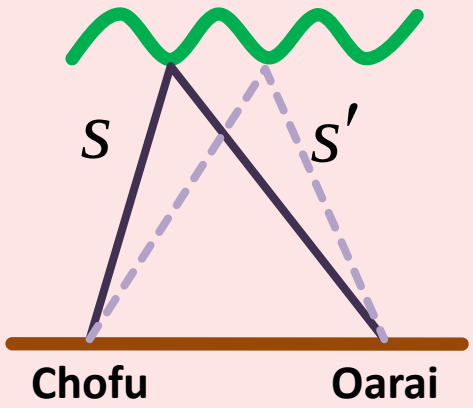
10sec

6 stations

What causes Doppler shifts in HFD observations?（at Oarai）



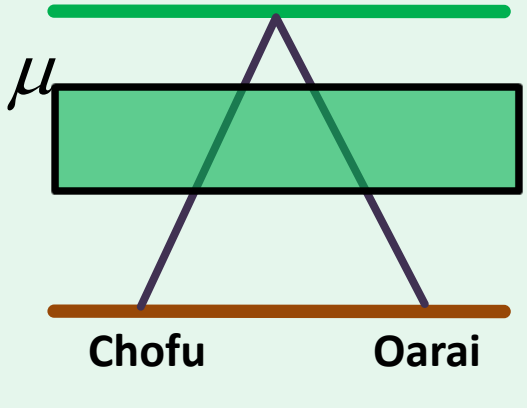
Path length



HFD observation

$$\Delta f = -\frac{f_0}{C}\frac{d}{dt}\left(\int_s \mu\, ds\right)$$

Electron density



Purpose of this study

We can estimate frequency and wavelength of ionospheric wave-like disturbaces from the HFD observations. However, it is impossible to derive amplitude and/or propagation direction only from the HFD observations, which makes it difficult to discuss characteristics of the disturbances in detail.

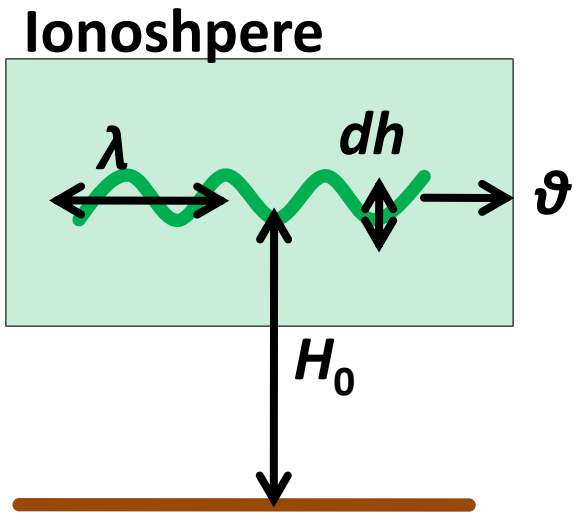
In this study, we try to estimate detailed characteristics of ionospheric wave-like features by combining the HFD measurements and Direction finding observations (DF).

HFD observation

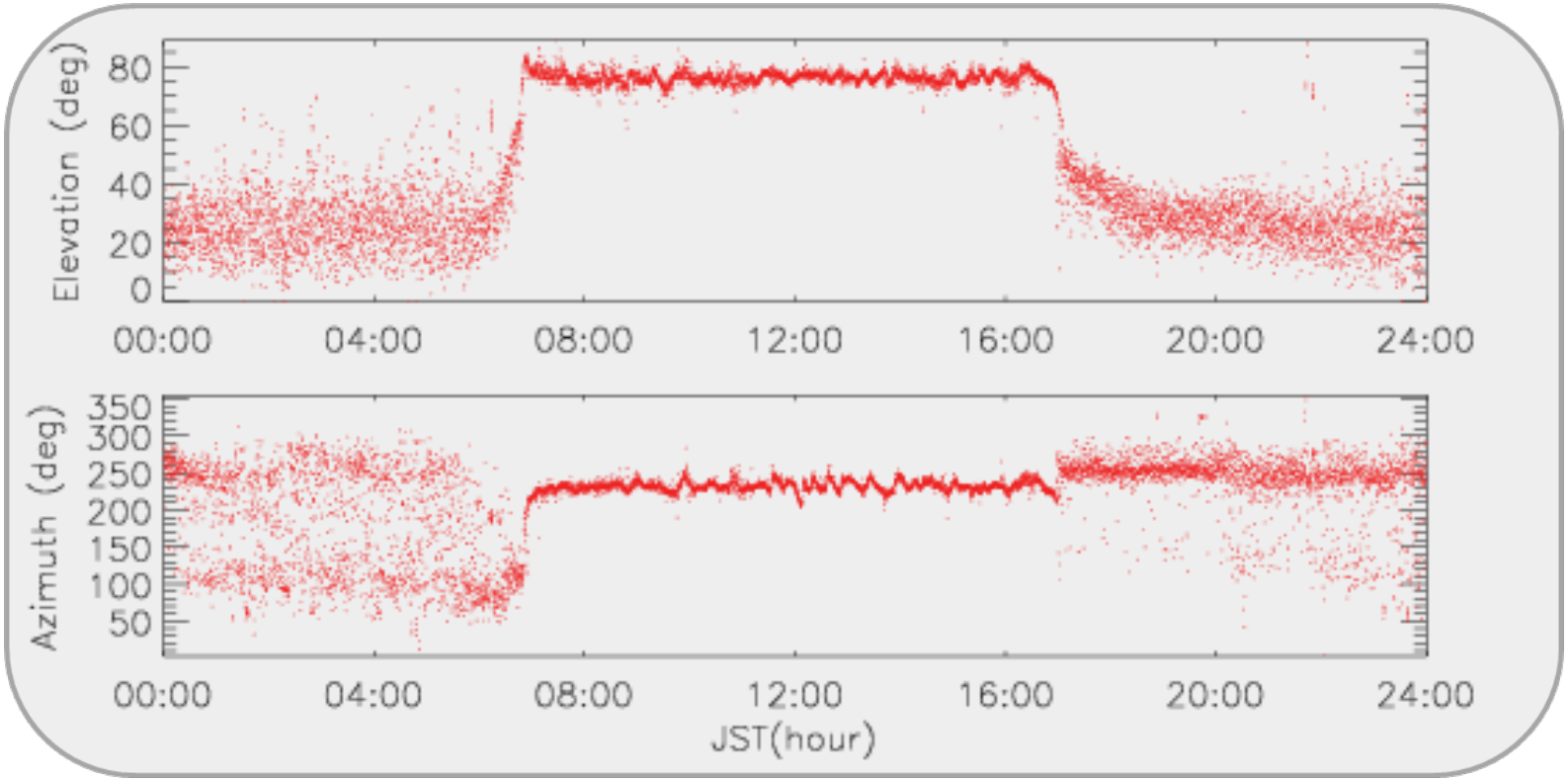
$$\Delta f = -\frac{f_0}{C}\frac{d}{dt}\left(\int_s \mu\, ds\right)$$

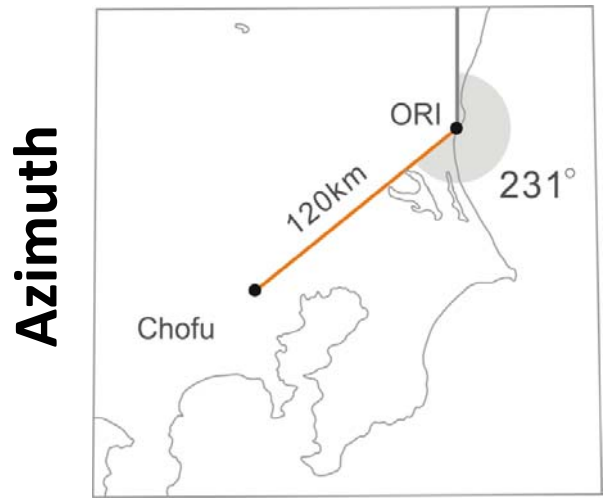
+

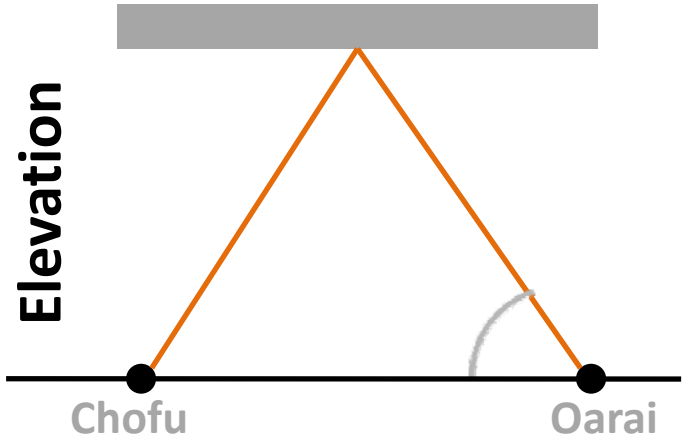
DF observation

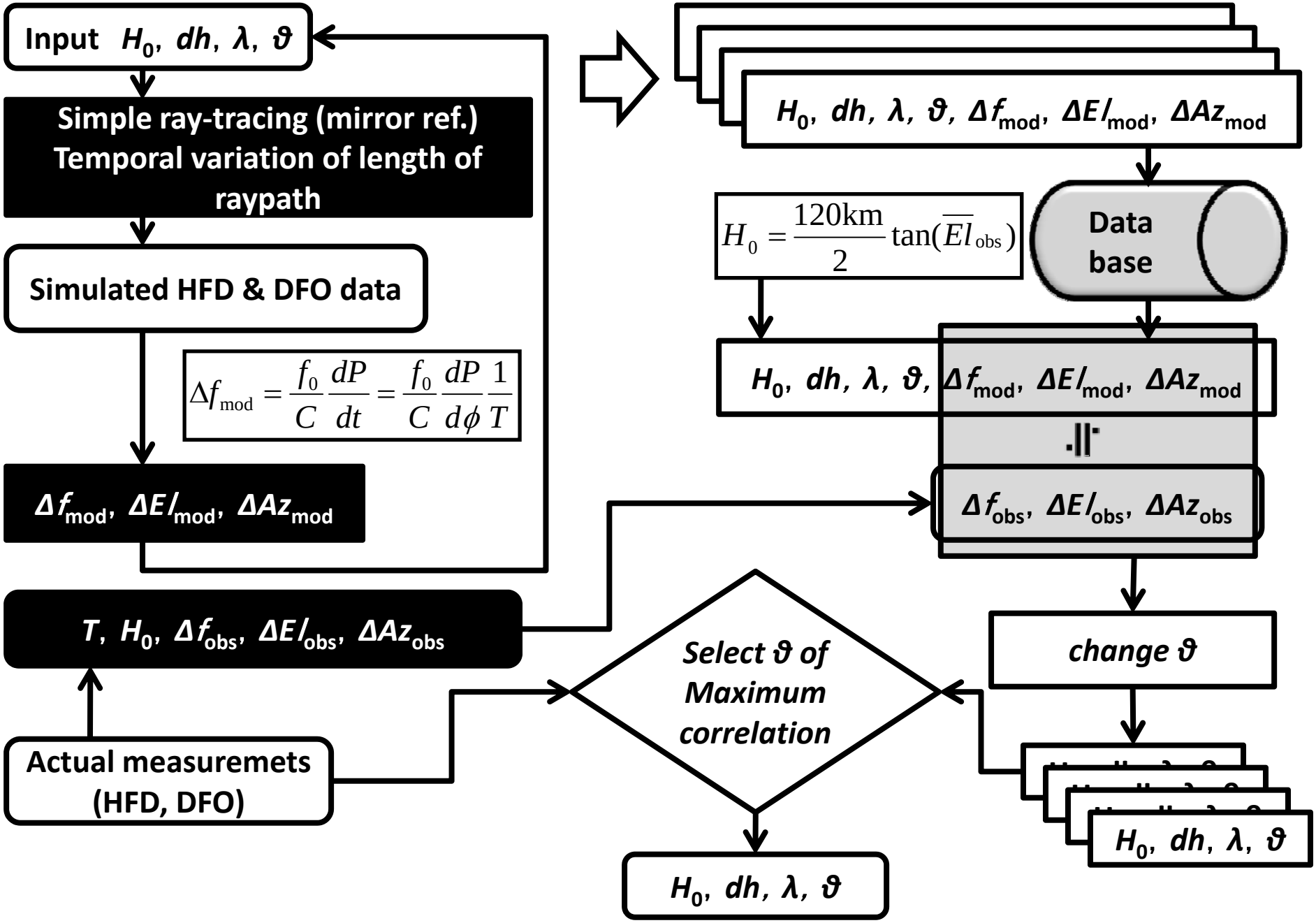


DF observations at Oarai

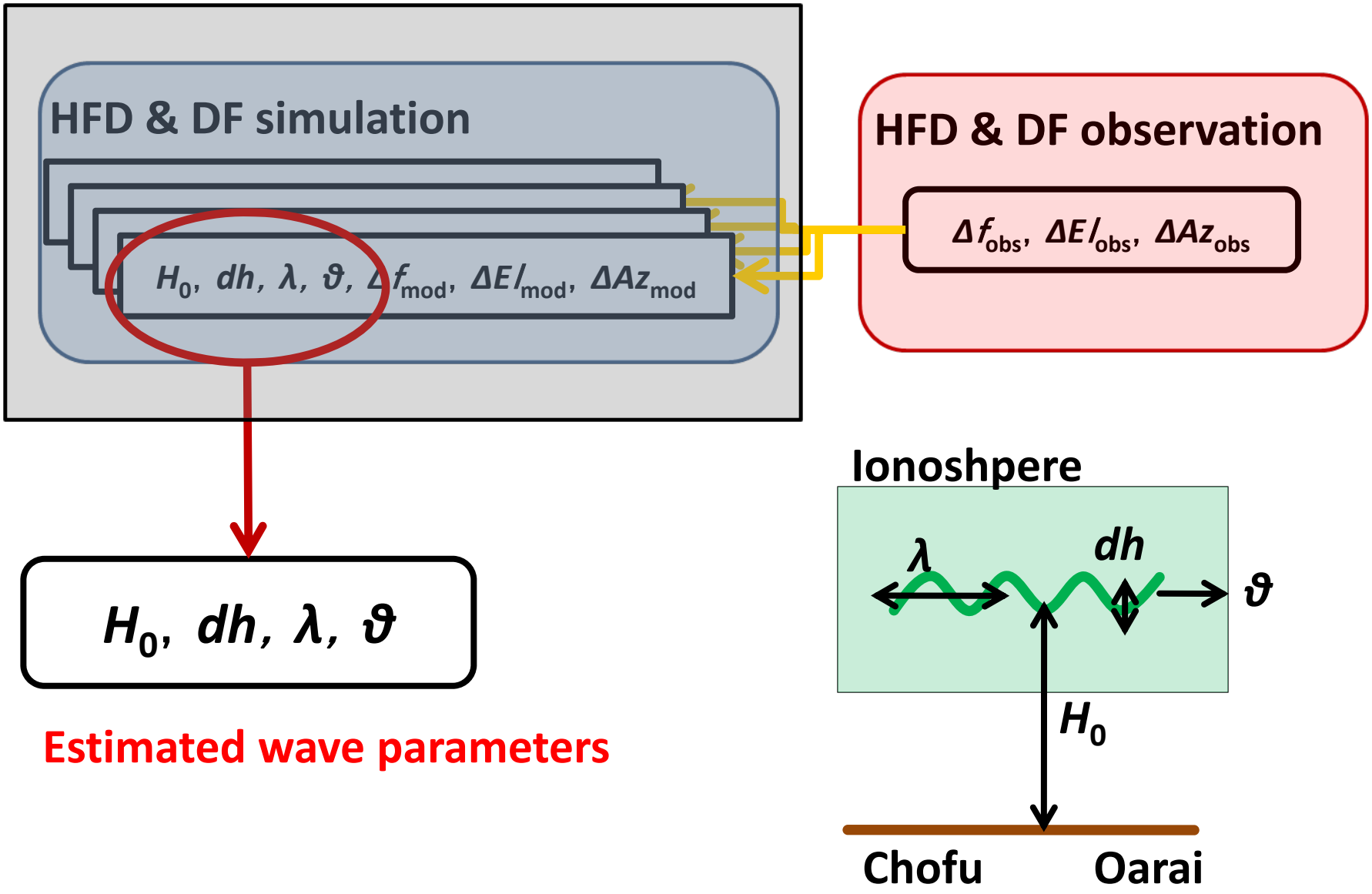




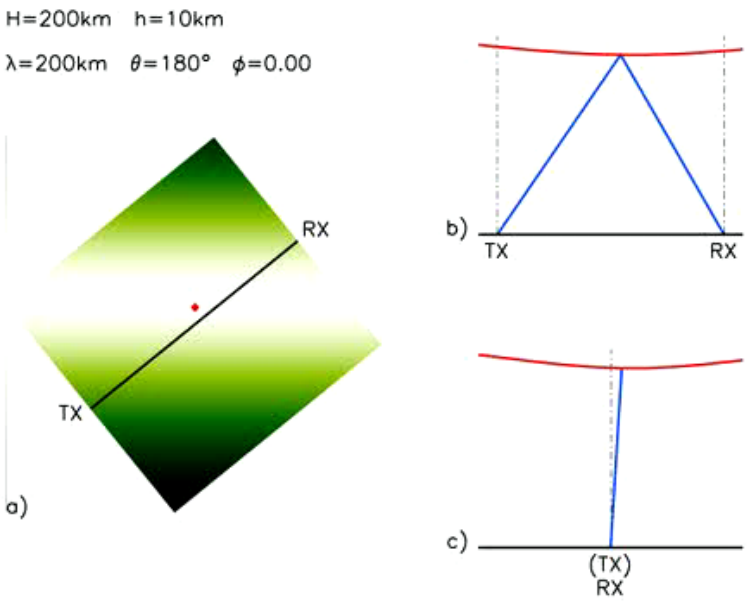



Input H_0, dh, λ, ϑ
Simple ray-tracing (mirror ref.)
Temporal variation of length of raypath
Simulated HFD & DFO data
$\Delta f_{\mathrm{mod}} = \frac{f_0}{C}\frac{dP}{dt} = \frac{f_0}{C}\frac{dP}{d\phi}\frac{1}{T}$
Δf_{mod}, ΔEl_{mod}, ΔAz_{mod}
T, H_0, Δf_{obs}, ΔEl_{obs}, ΔAz_{obs}
Actual measuremets (HFD, DFO)
Select ϑ of Maximum correlation
H_0, dh, λ, ϑ
change ϑ
H_0, dh, λ, ϑ, Δf_{mod}, ΔEl_{mod}, ΔAz_{mod}
$H_0 = \frac{120\mathrm{km}}{2}\tan(\overline{El}_{\mathrm{obs}})$
Data base
H_0, dh, λ, ϑ, Δf_{mod}, ΔEl_{mod}, ΔAz_{mod}
Δf_{obs}, ΔEl_{obs}, ΔAz_{obs}

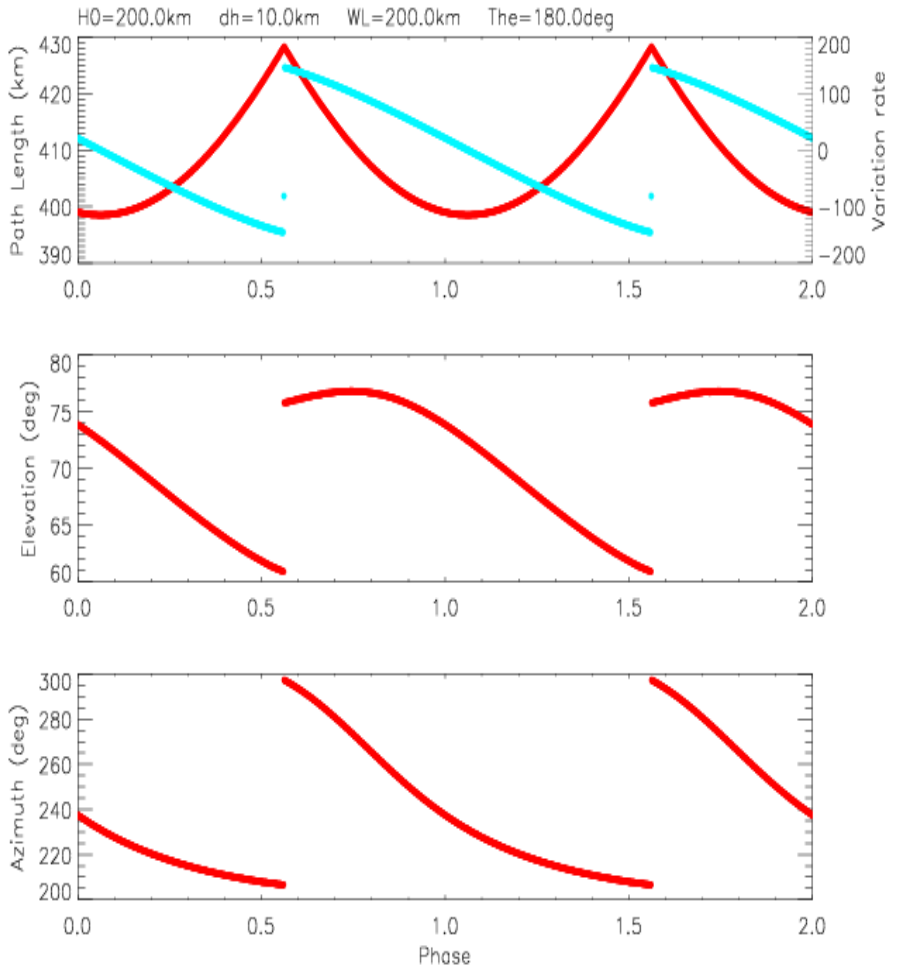
Procedure of estimating wave parameters



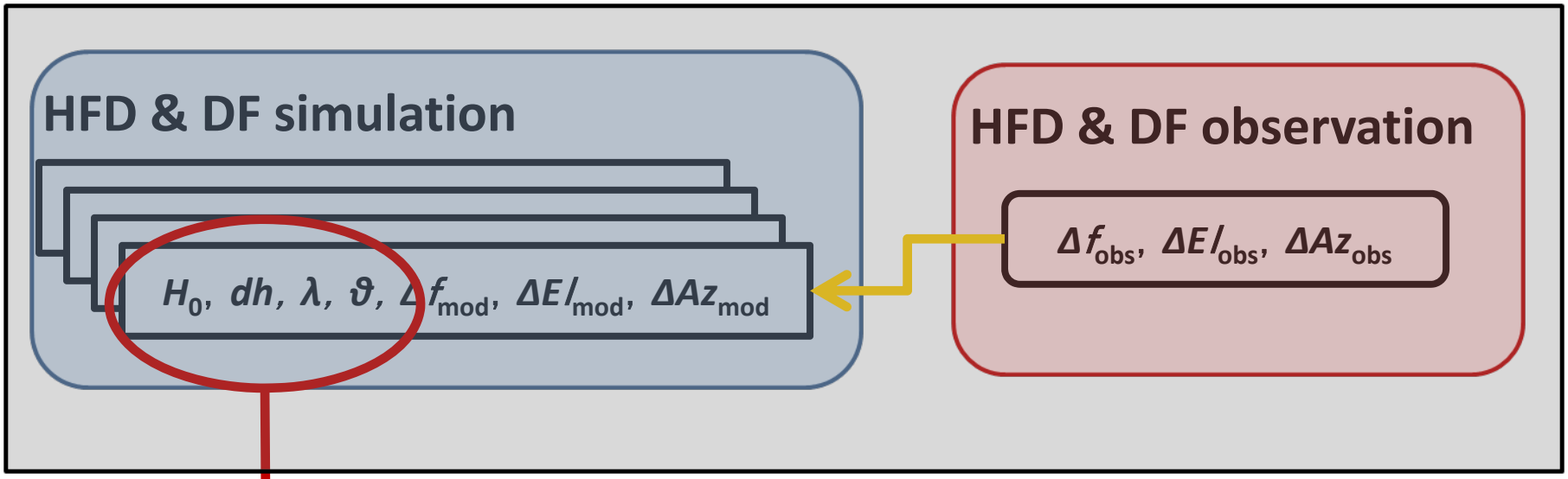
HFD & DF mirror reflection simulation



$$\Delta f_{\mathrm{mod}} = \frac{f_0}{C}\frac{dP}{dt} = \frac{f_0}{C}\frac{dP}{d\phi}\frac{1}{T}$$

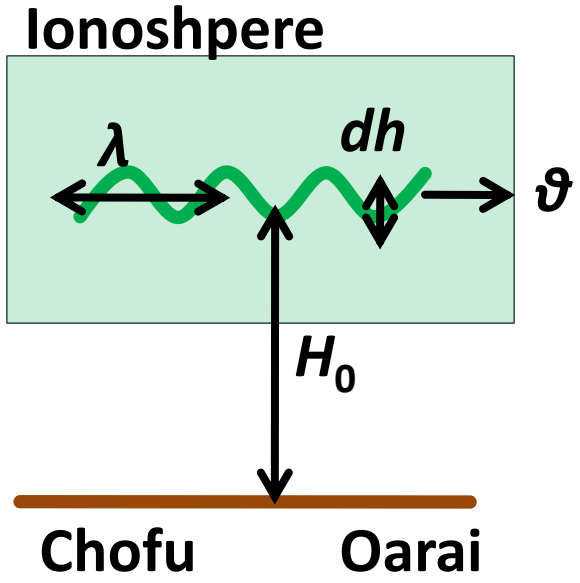


Procedure of estimating wave parameters

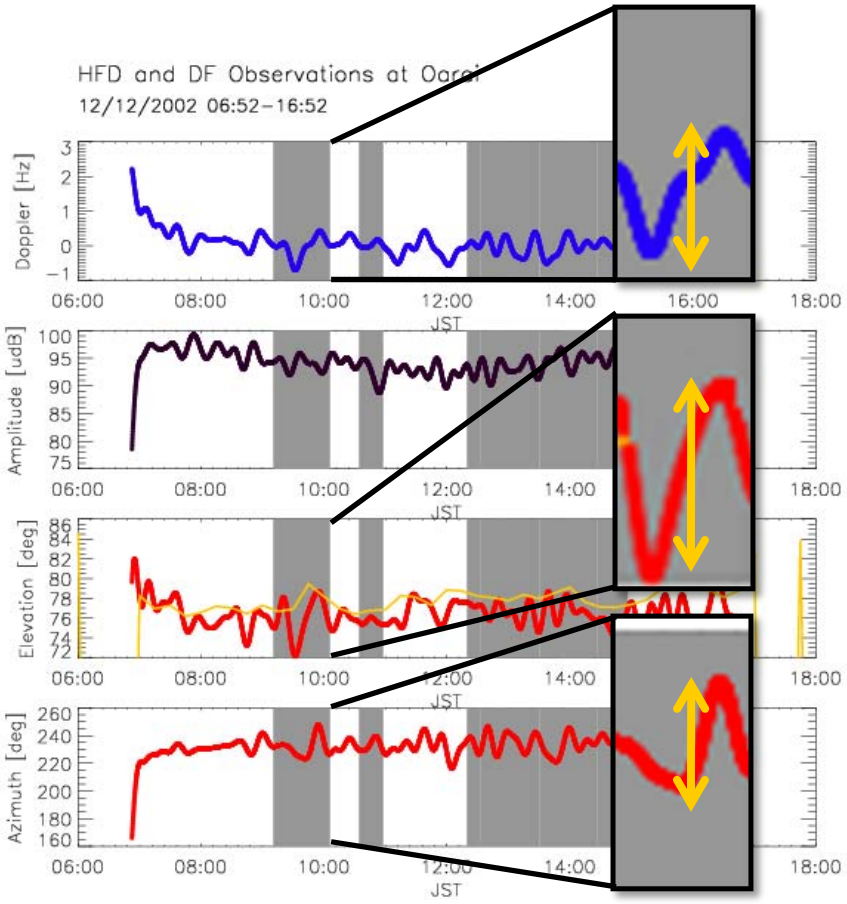


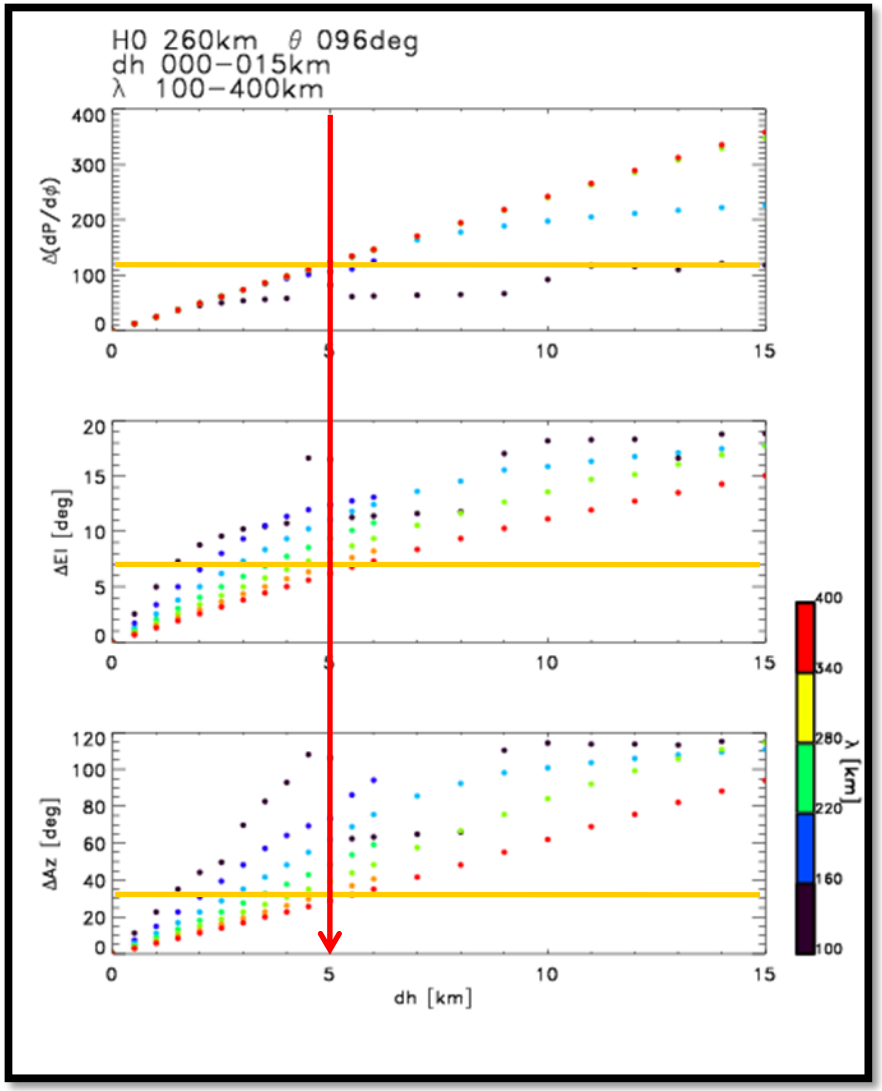
H_0, dh, λ, ϑ

Estimated wave parameters



An example
2002/12/12

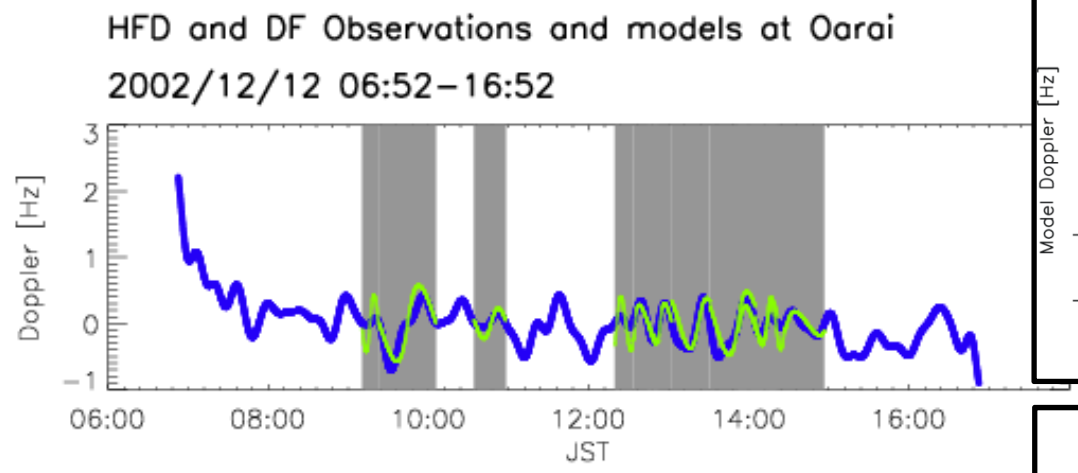


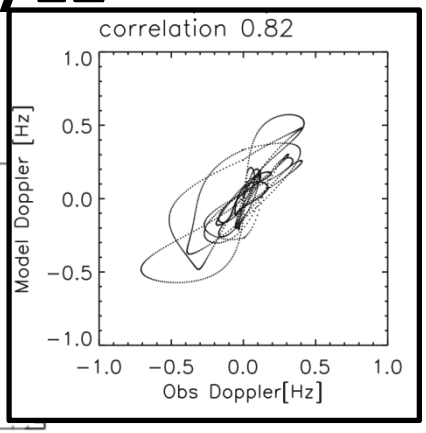


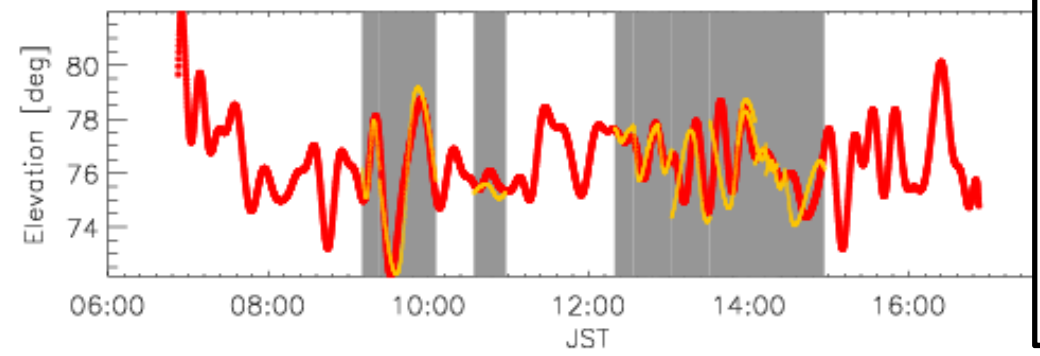
Estimated parameters

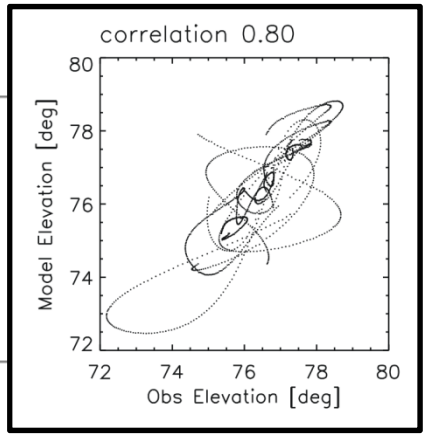
H_0 260km dh 5km λ 400km ϑ 96°

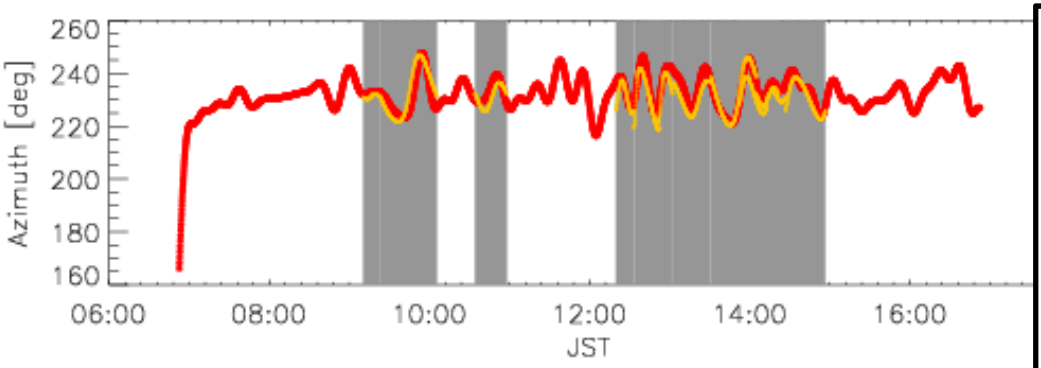
Comparison with simulation 2002/12/12

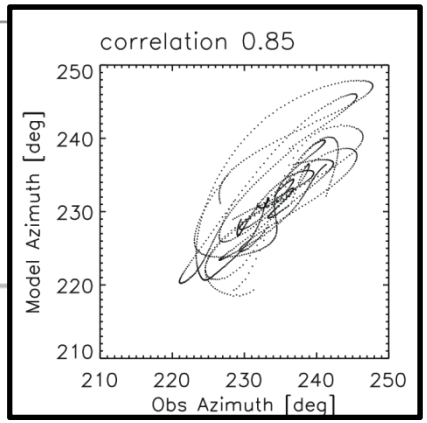




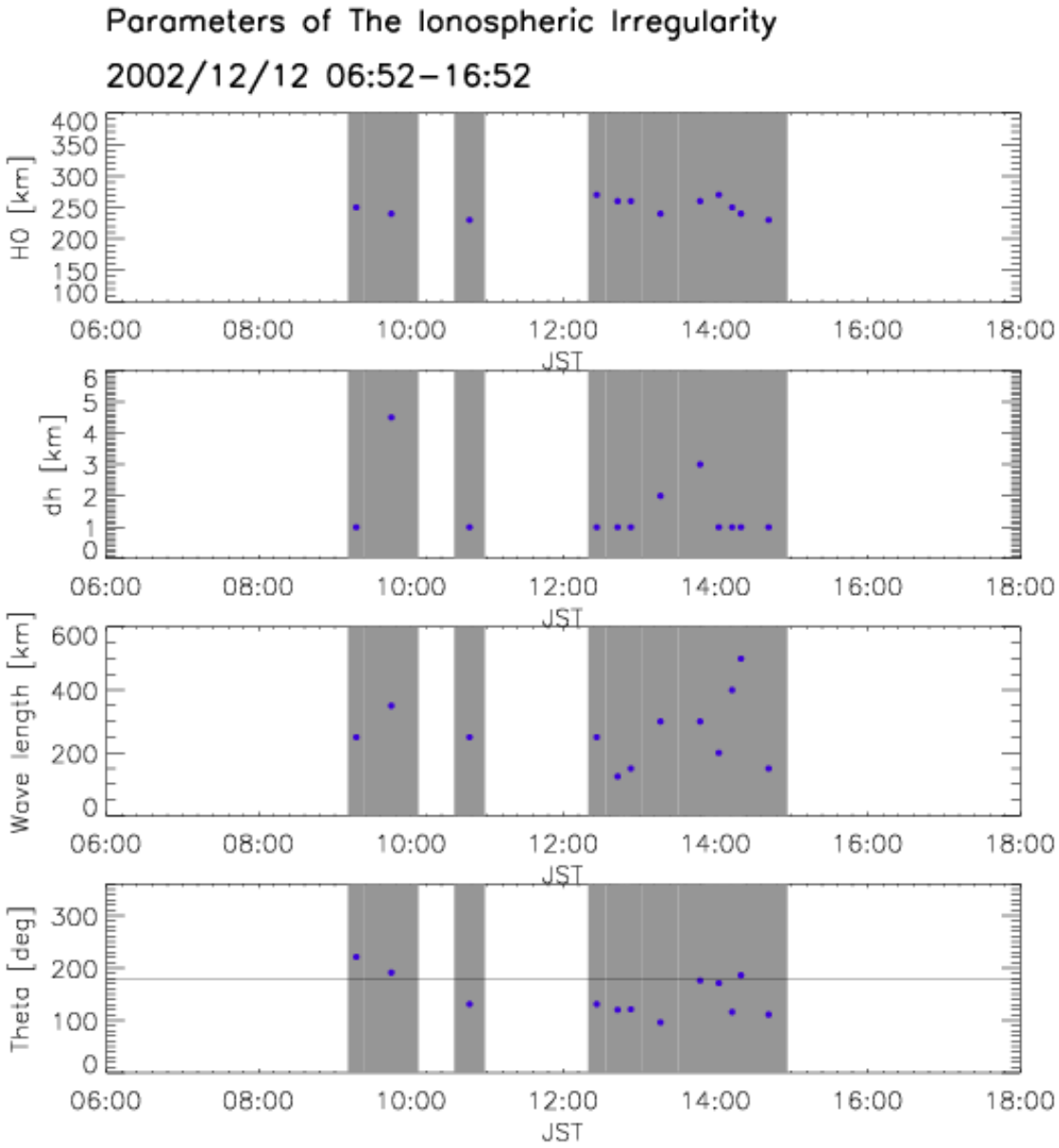


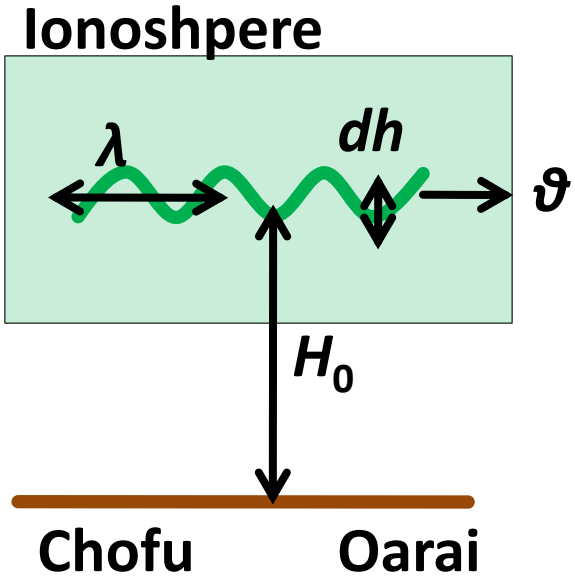




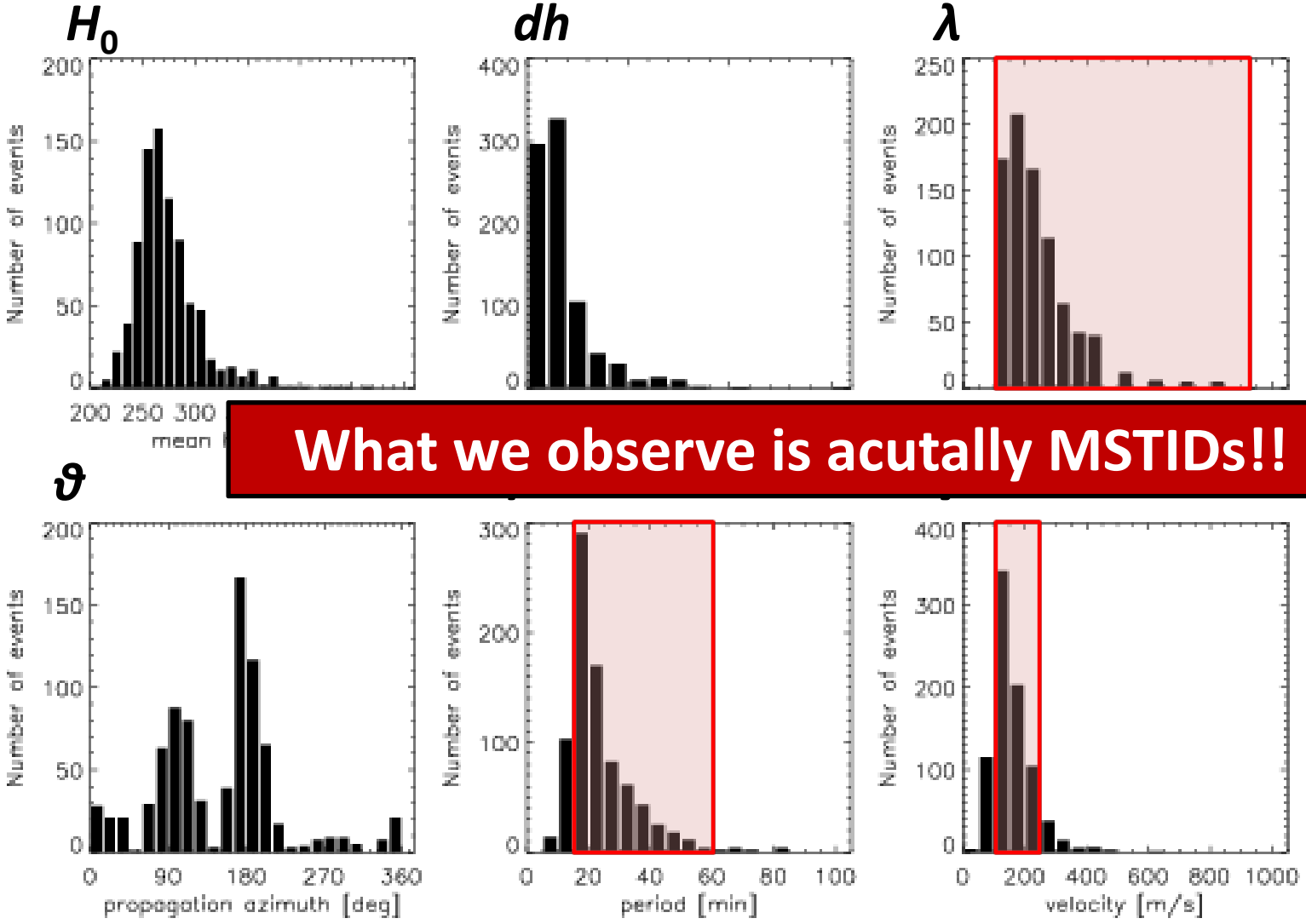


Derived wave parameters 2002/12/12





Statistics of wave parameters total events: 837

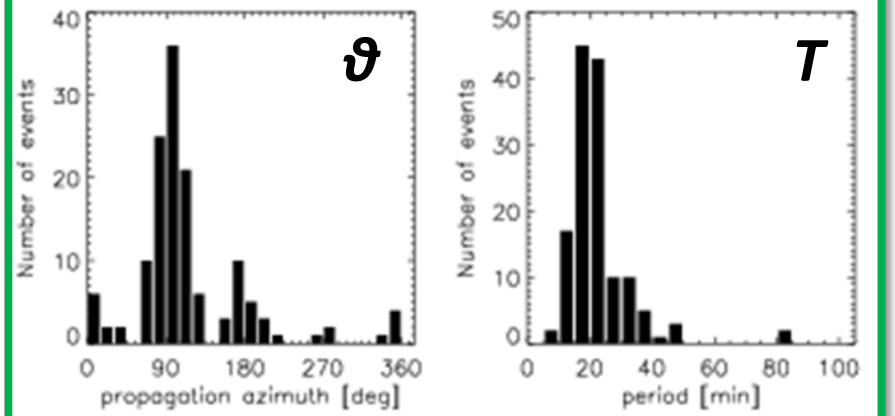


What we observe is acutally MSTIDs!!

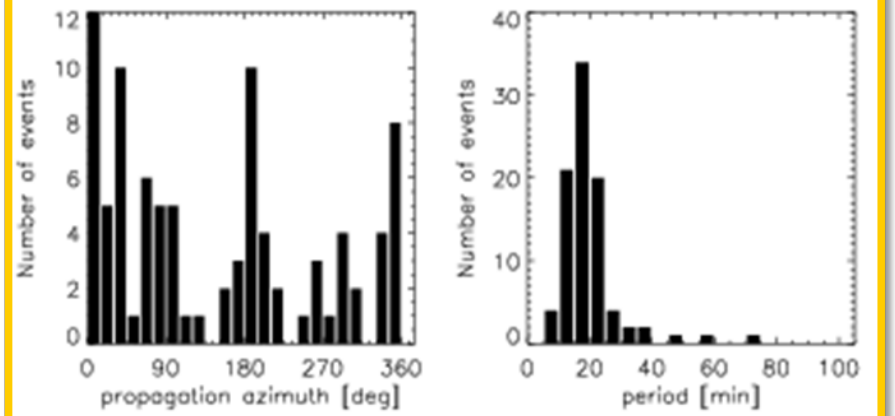
MSTID Horizontal velocity 100-250[m/s] Period 15 min to 1 hour
Wavelength 'several hundred km' (Hunsucker,1982)

Seasonal dependence

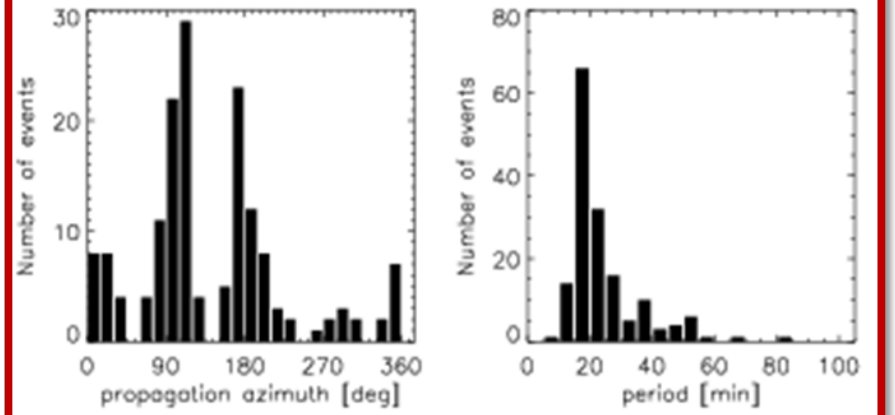
Spring



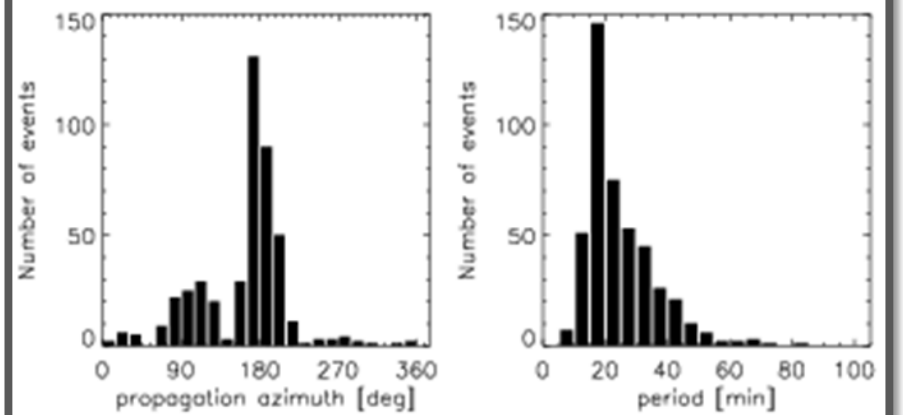
Summer



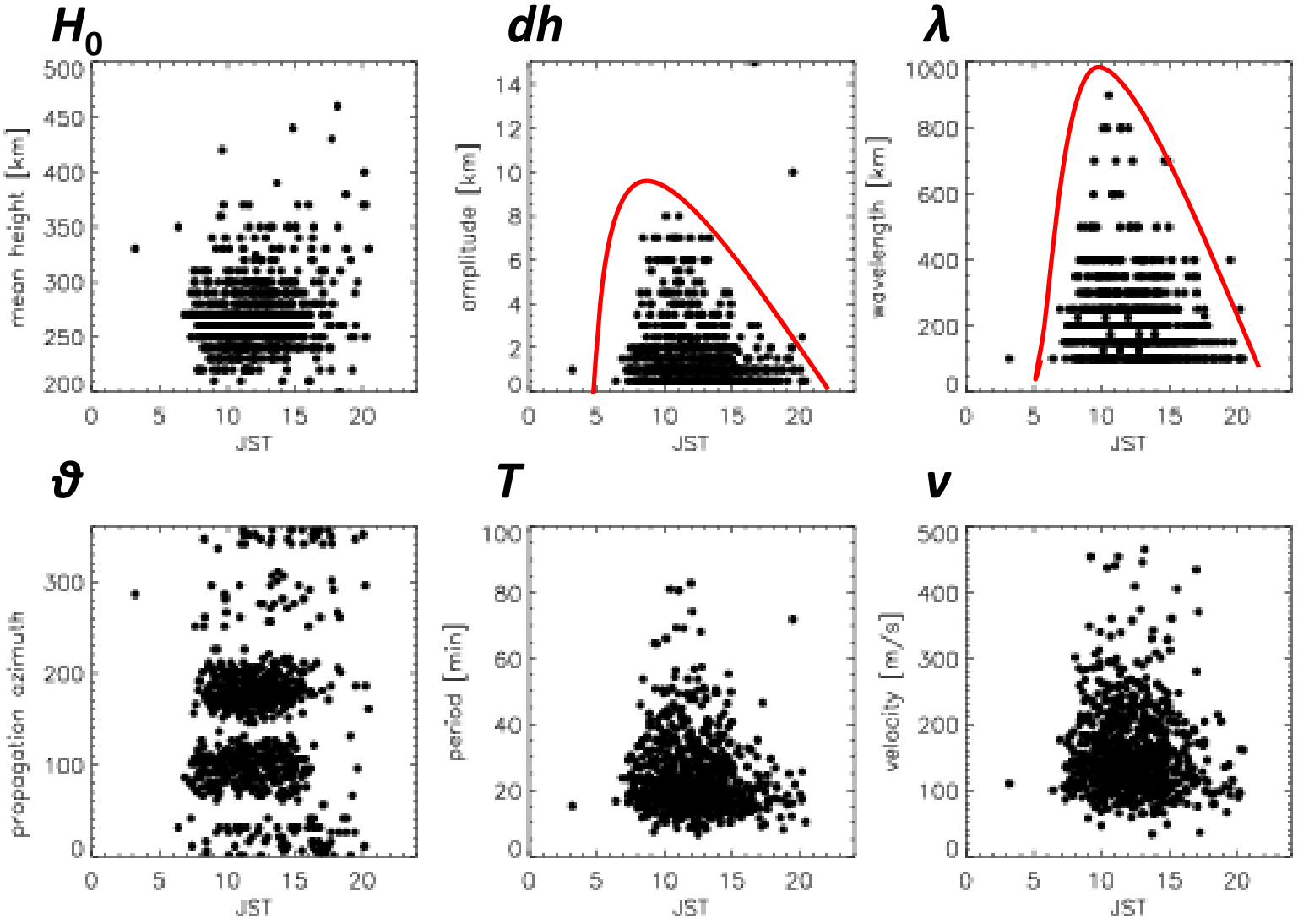
Autumn



Winter



Local time dependence

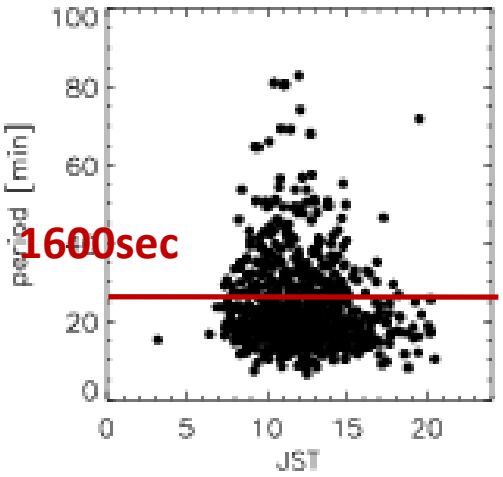


dh and λ (also T?) tend to be relatively larger in pre-noon sector.

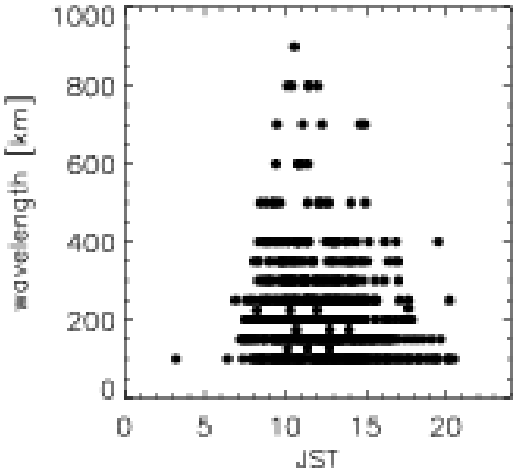
Comparing with other technique (GPS-TEC obs.)

HFD & DF

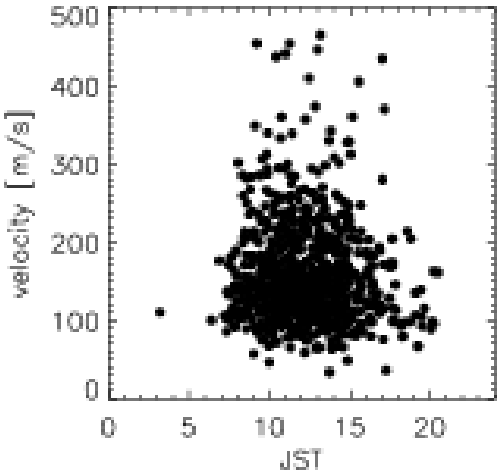
T



λ

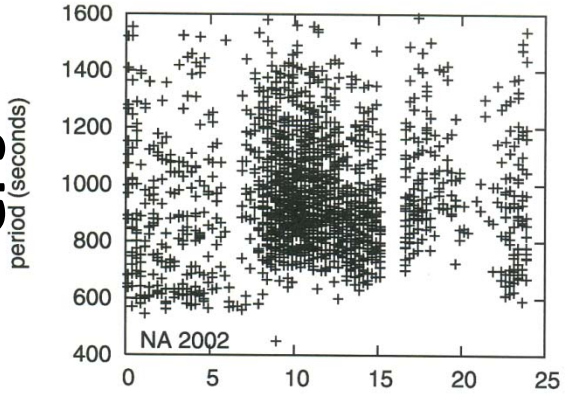


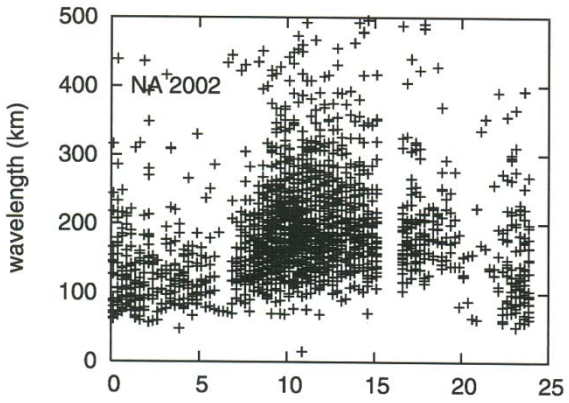
v

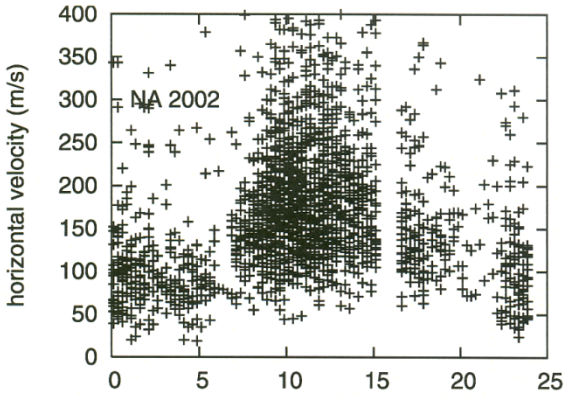


Oarai (Japan) Geo. Long. 139, Geo. Lat. 36

GPS





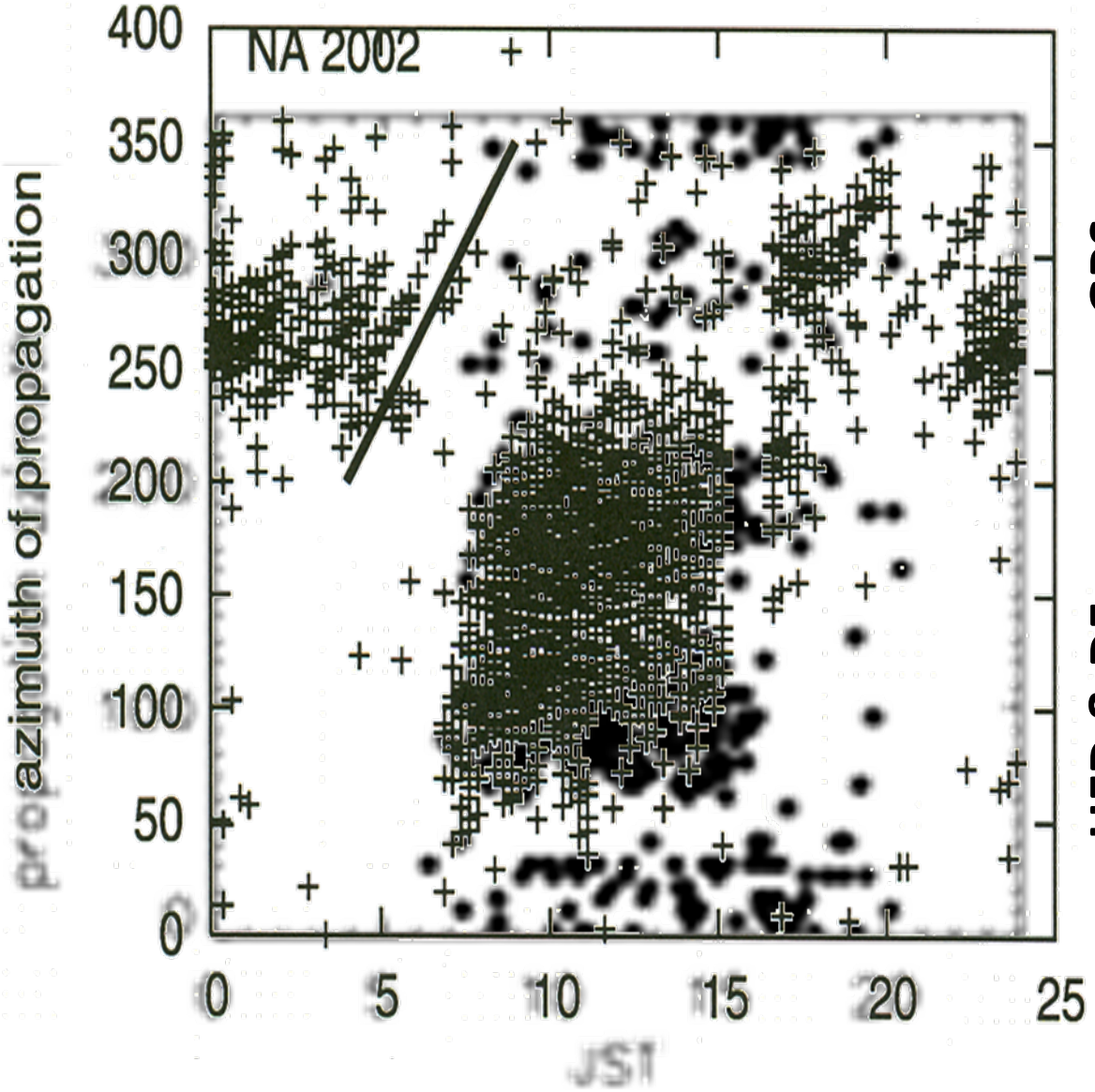


North America Geo. Long. 238, Geo. Lat. 37

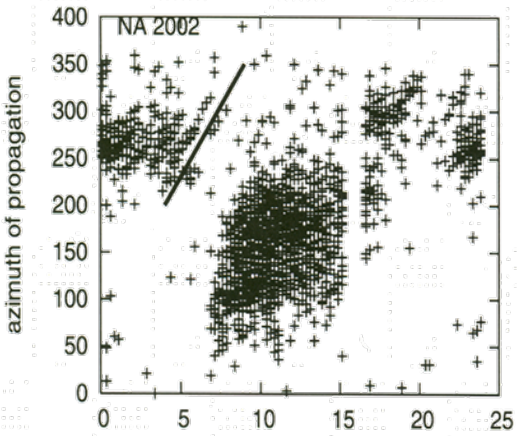
Hernandez-Pajares et al.,2006

If we look into the propagation direction …

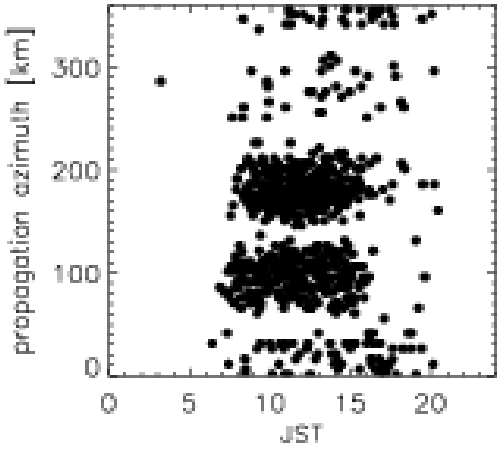
ϑ



GPS

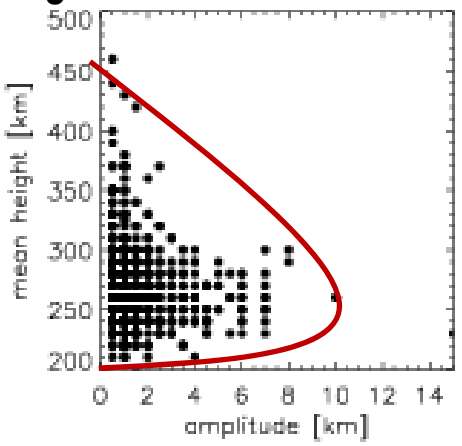


HFD & DF

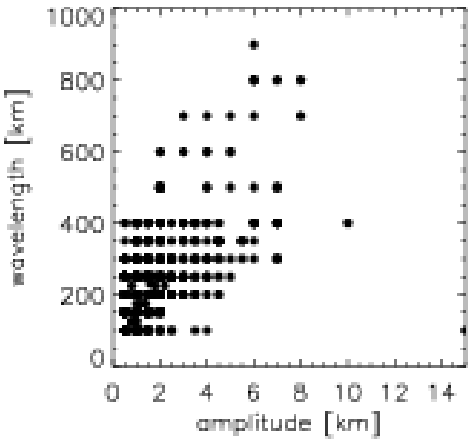


Dependence of wave parameters on wave amplitude

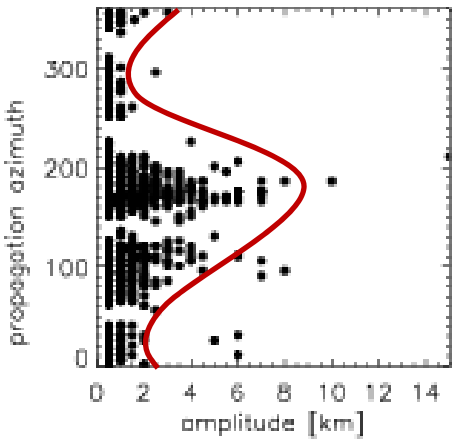
H_0



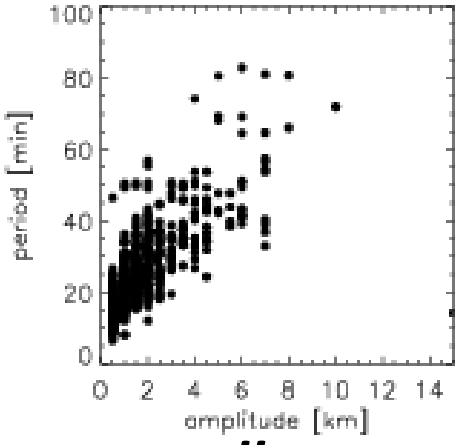
λ



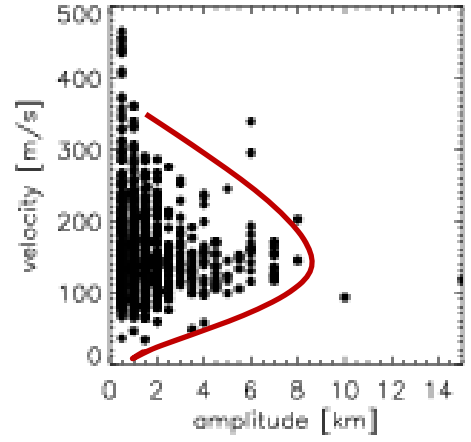
ϑ



T



v



dh

Parameters of wave feature strongly depend on its amplitude.

	H_0	λ	ϑ	T	v
dh ↗	250km	↗	South	↗	100[m/s]

Summary and Conclusion

- **High correlation was obtained between the model calculation and actual measurements, which suggests that our simple ray-tracing simulations well reproduce the actual HFD and DF observations.**
- **What we observe with the HFD and DF can be categorized as traditional MSTIDs.**
- **Clear seasonal variation was found in propagation direction and wave frequency.**
- **Estimated wave parameters such as period, wave length, phase velocity and propagation direction were found to be consistent with past study of MSTIDs with GPS-TEC observations (Hernandez-Pajares et al., 2006).**
- **Parameters of wave feature strongly depend on its amplitude, which indicates that wave amplitude could be a key parameter to define characteristics of MSTIDs.**
- **Our method of combining model calculation and HFD/DF observations can estimate amplitude of MSTIDs, then it could be a powerful tool for visualizing structure of MSTIDs in smaller scale.**

Comparison with observations of MSTIDs by the SuperDARN Hokkaido radar would lead us to comprehensive understanding of MSTIDs in daytime!