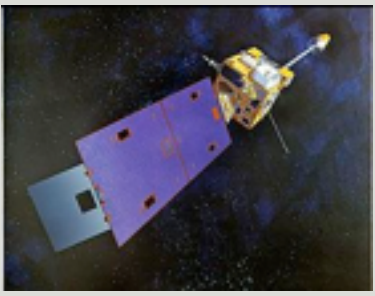




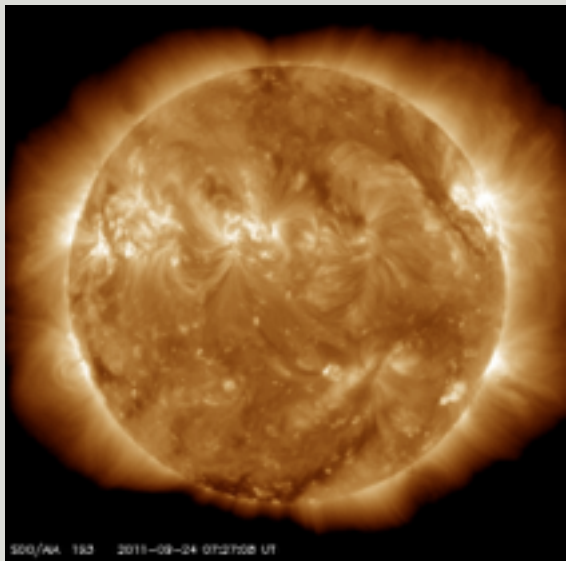
地上・衛星統合解析に基づく 磁気擾乱時の中層大気上部の応答の検証



PANSYレーダー
(地上)



GOES
(静止軌道)

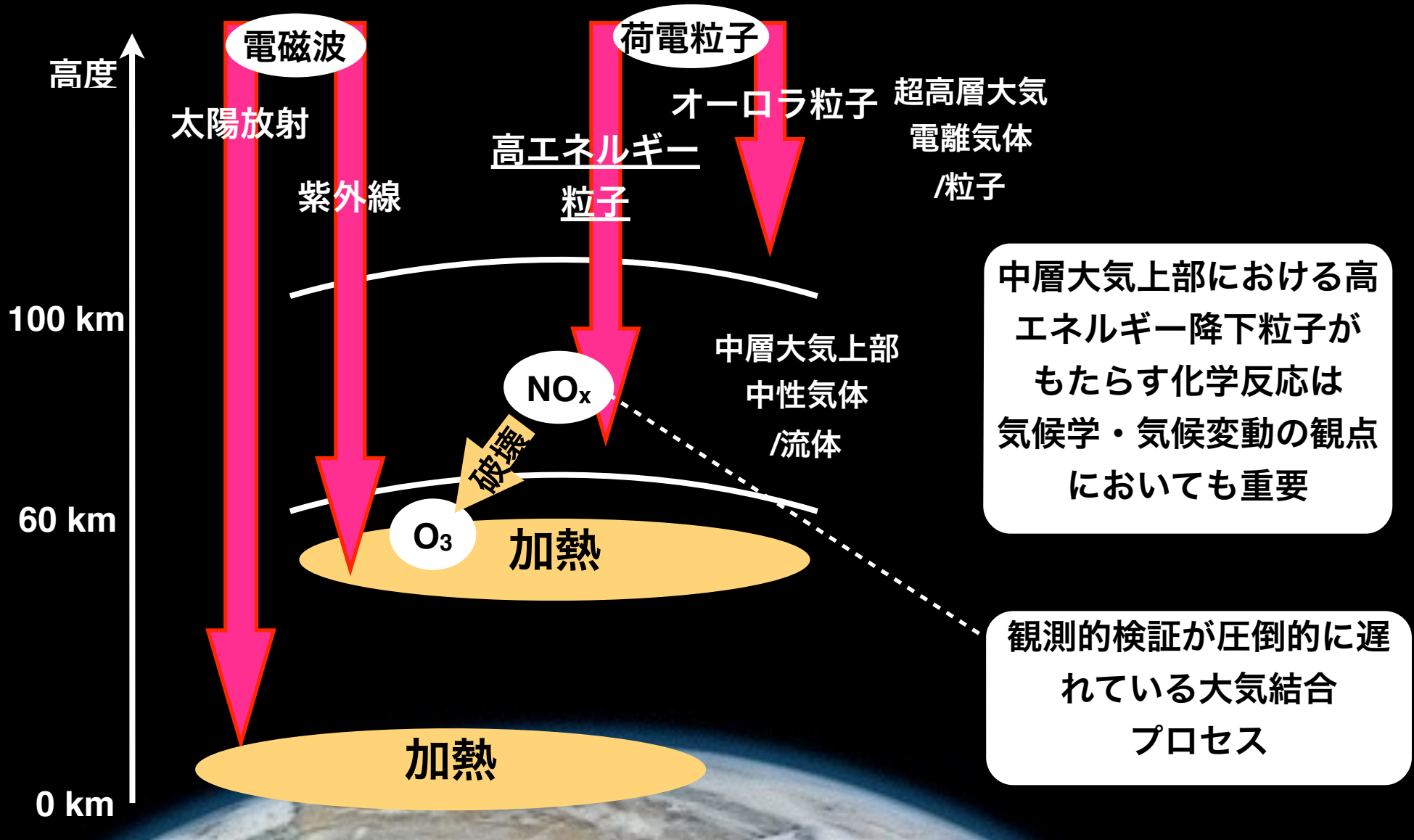


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Solar Energy Input

太陽放射 (UV, 可視光, 赤外) に加えて、**高エネルギー粒子**による**極域大気へのインパクト**が大きい



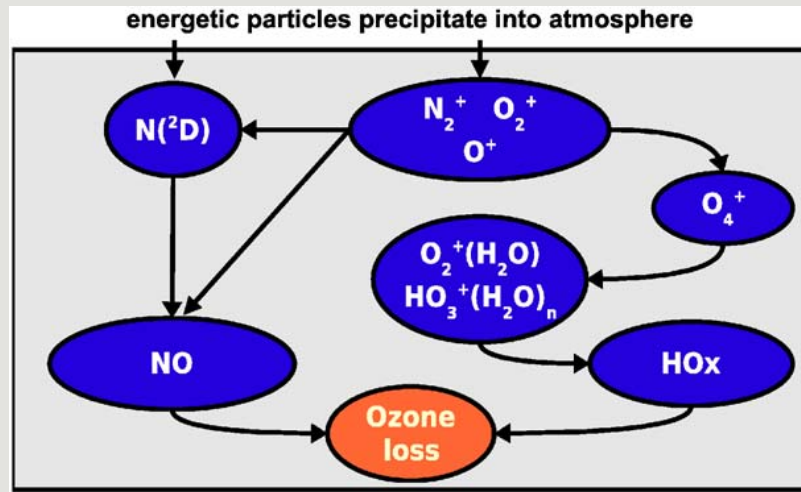


Chemical effect on EPPs (1)

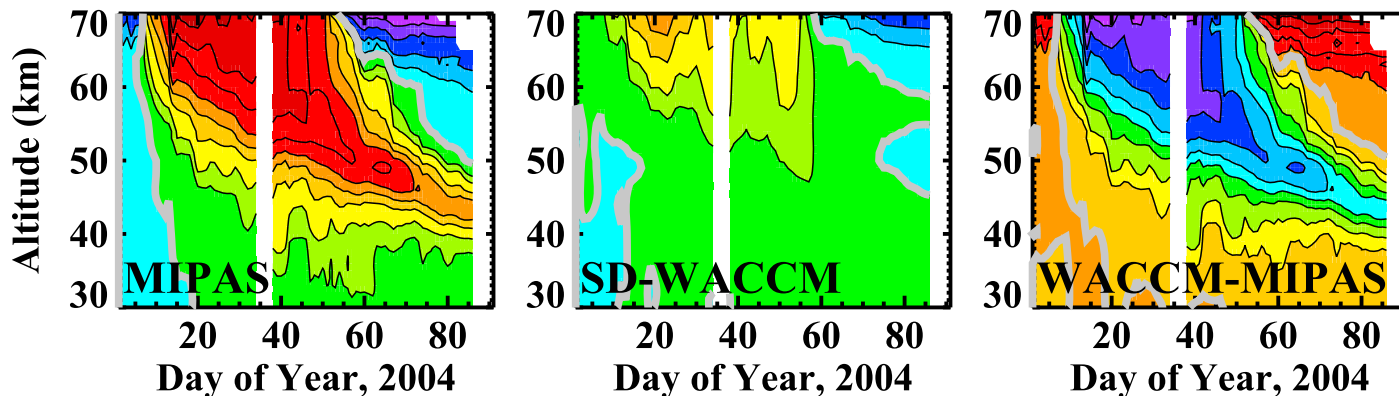
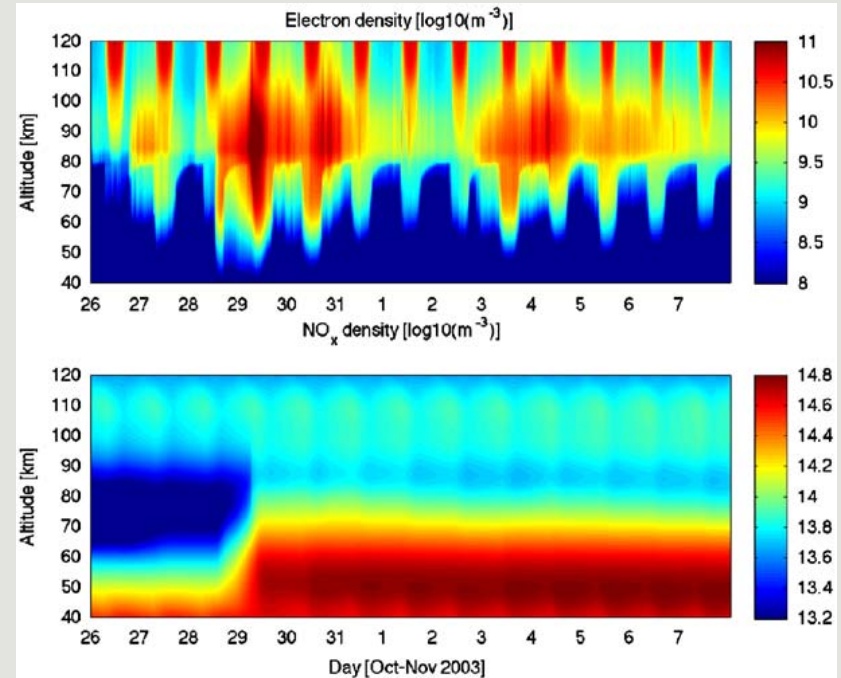
✓ Energetic Particle Precipitations (EPPs) の中間圏への化学応答

– モデル計算 : [Turunen et al., 2009; Randall et al., 2015]

[Turunen et al., 2009]



[Randall et al., 2015]



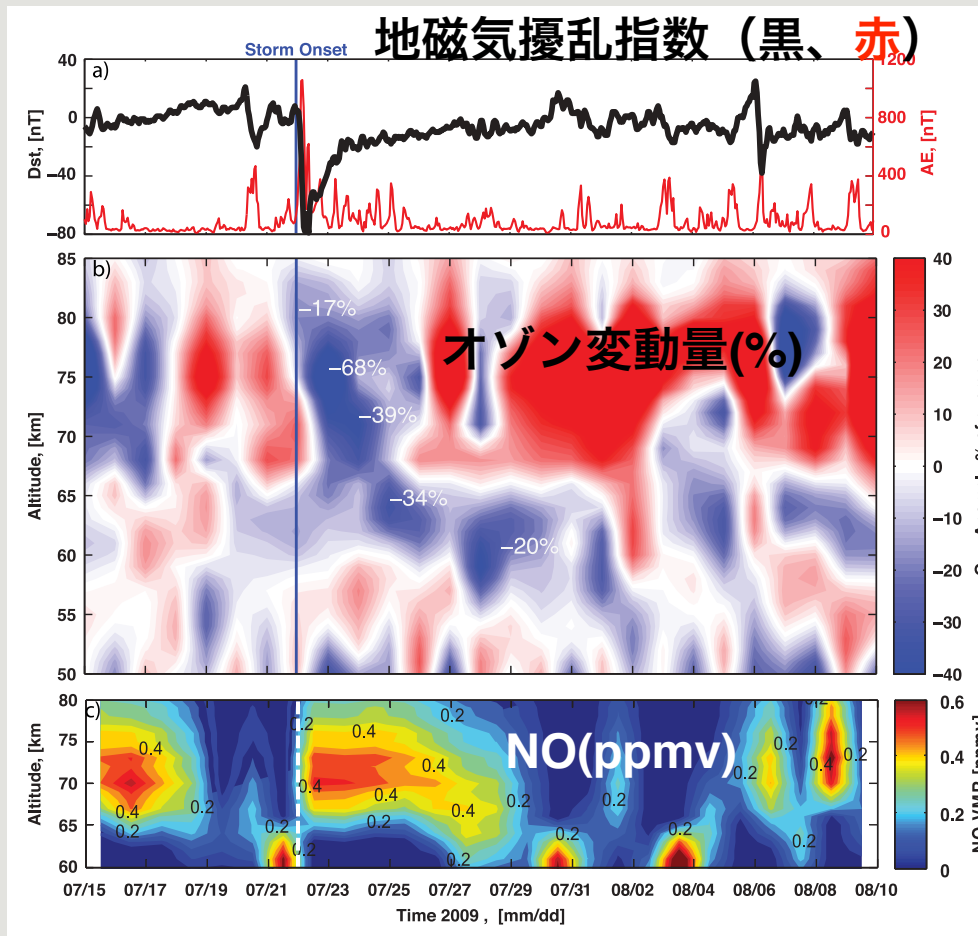
現状では数値モデルと衛星リモートセンシングによる研究が先行



Chemical effect on EPPs (2)

✓ Energetic Particle Precipitations (EPPs) の中間圏への化学応答

– 地上観測：[Daae et al., 2012]



• 地上／衛星観測においては鉛直方向の高度分解能や時間分解能が不十分

⇒ 観測による詳細な物理過程の検証が不可欠

- 1) エネルギー流入量の評価,
- 2) 物質の鉛直輸送,
- 3) 温度/風速場変動

最新の南極大型大気レーダーを活用し、太陽と中層大気との領域間結合の観点から研究する



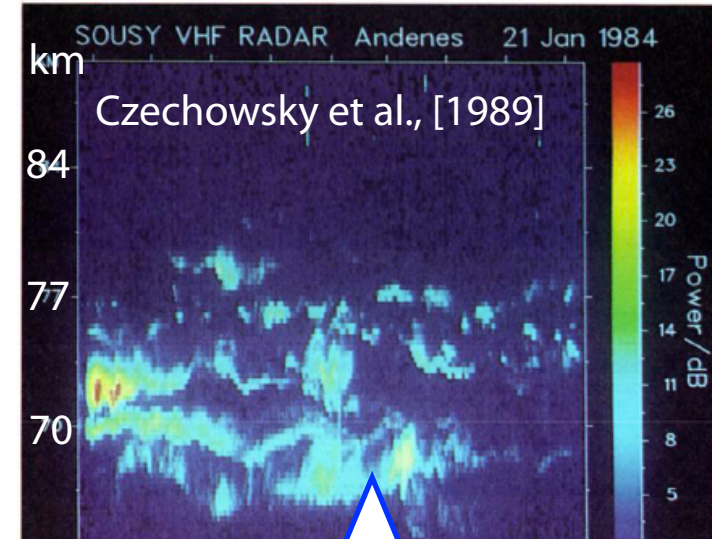
Polar Mesosphere Winter Echo

- ✓ Polar Mesosphere Winter Echo (PMWE)
 - Mesosphere echo in the polar regions during non-summer period [e.g., *Ecklund and Balsley, 1981*]

$$\eta^{coh} = 8\pi^2 \left(\frac{e^2 \overline{N_e}}{2\epsilon_0 m_e c^2} \right)^2 \Phi_{N_e}(\kappa)$$

Volume reflectivity

3-D power spectral density of electron density fluctuation at the Bragg wave number (κ)

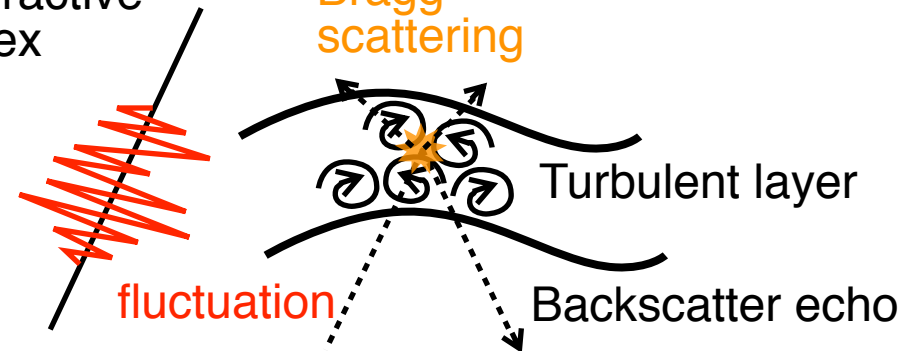


[*Tatarski, 1961; Lübken et al., 2006*]

Contributions of **electron density** to echo power are significant.

Refractive index

Bragg scattering



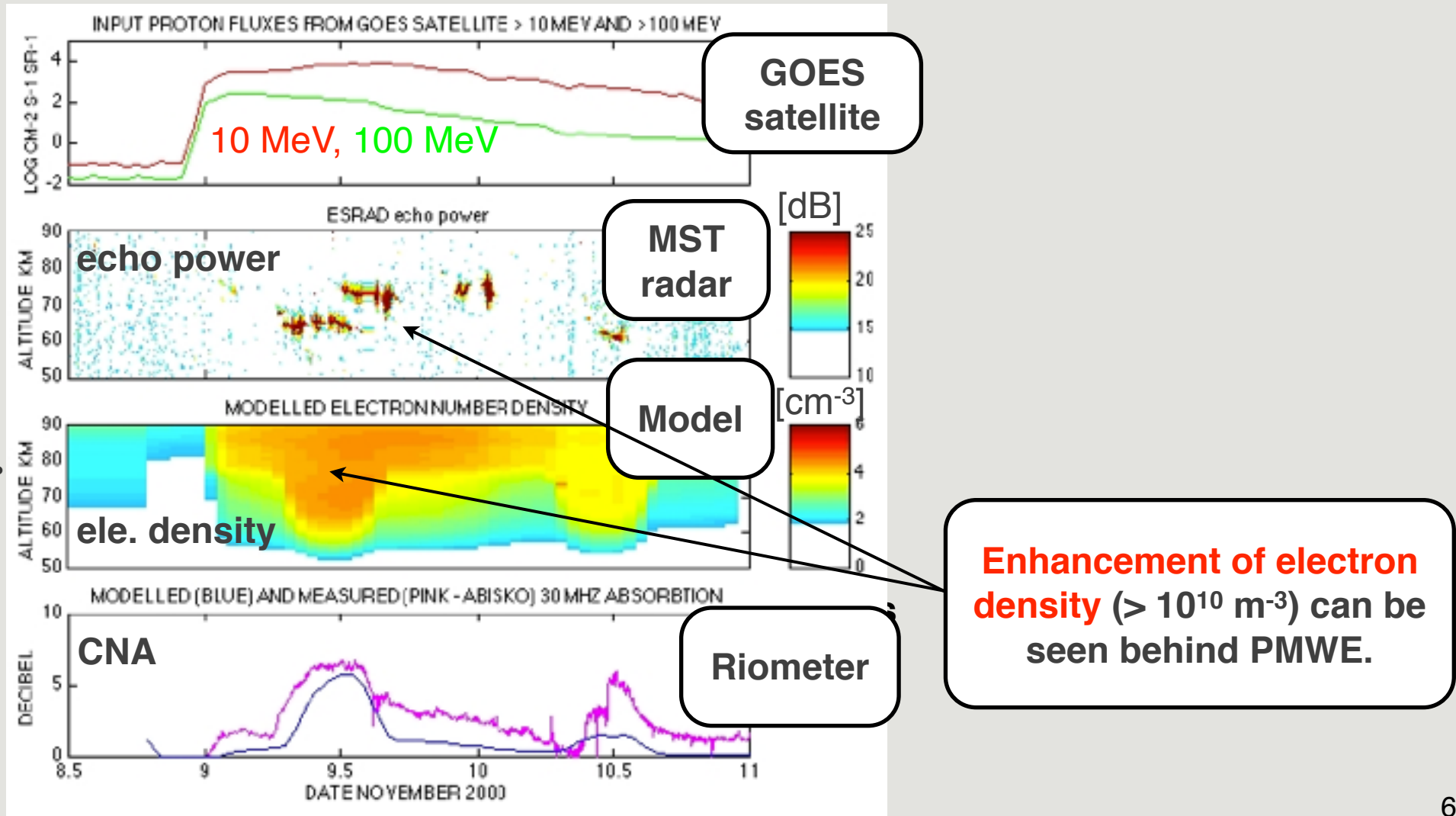
- Mean occurrence rate is only 2.9 % (Total 447.5 h) [*Zeller et al. 2006*]
 - Free electron, as scatterer, is not produced enough around dark mesopause in polar winter.
 - Good correlation to enhancement of electron density in D region due to **Solar Proton Event (SPE)** [*Kirkwood et al., 2002*]



Coincidence: SPE and PMWE

- ✓ First report on PMWE associated with Solar Proton Event
 - Quasi simultaneous detection of **SPE**, **PMWE**, and **CNA** (GOES, MST radar @Esrang, Riometer @Abisko)

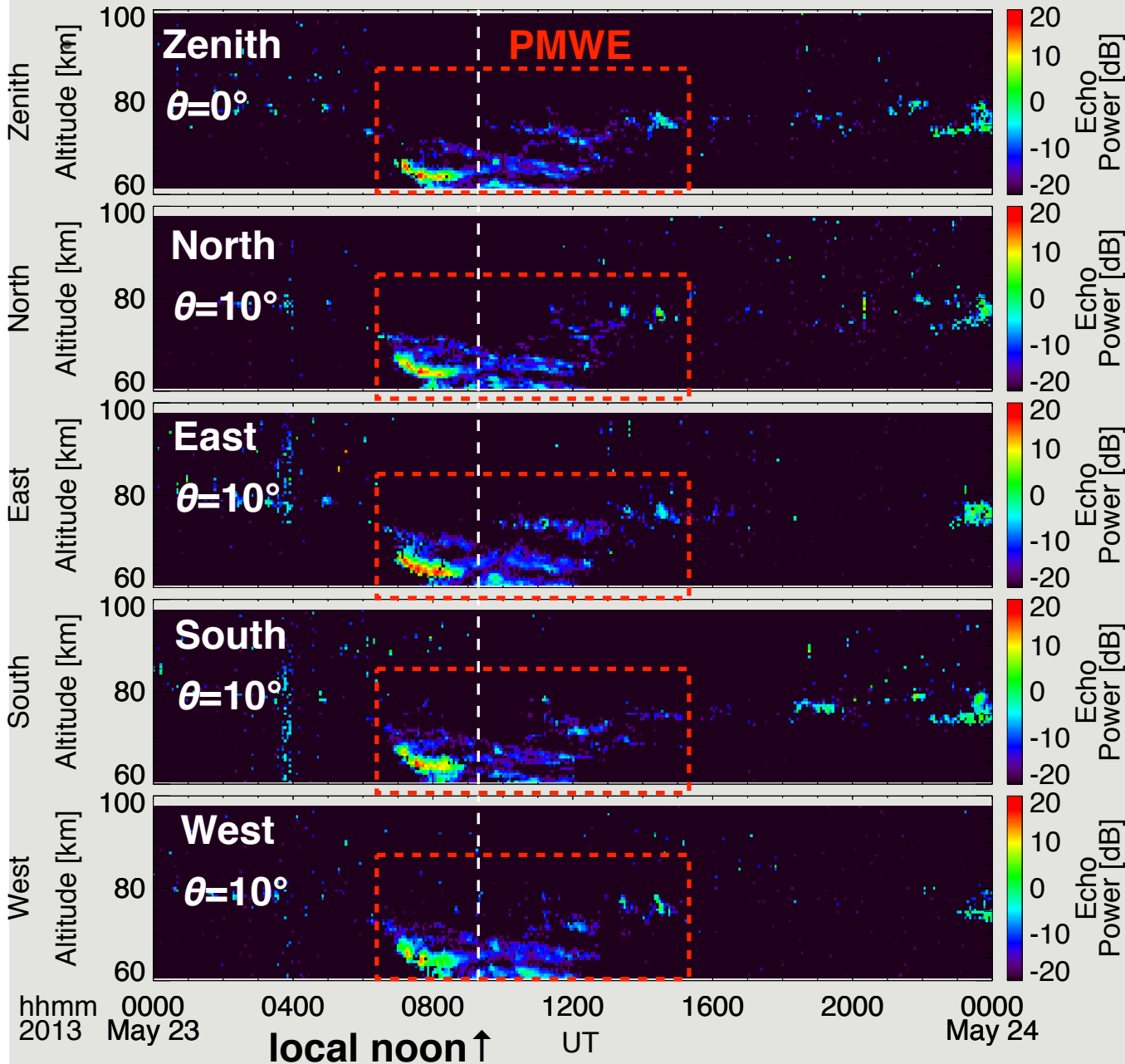
Kirkwood et al., [2002]





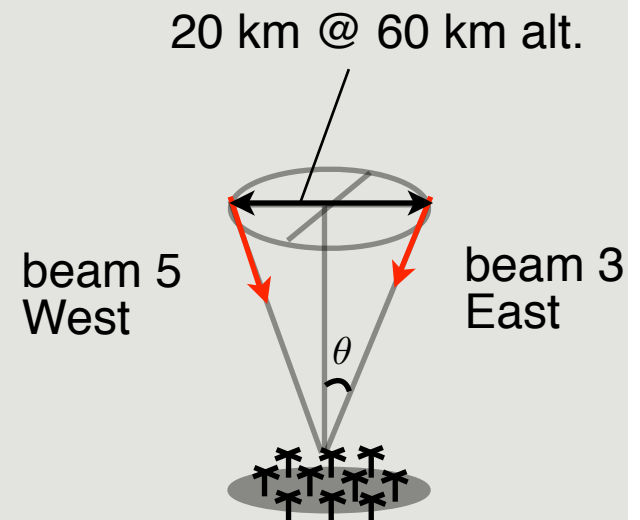
PMWE detected by PANSY

PANSY radar beams #1-5



Range resolution: 600 m
Time resolution: almost 4 min.

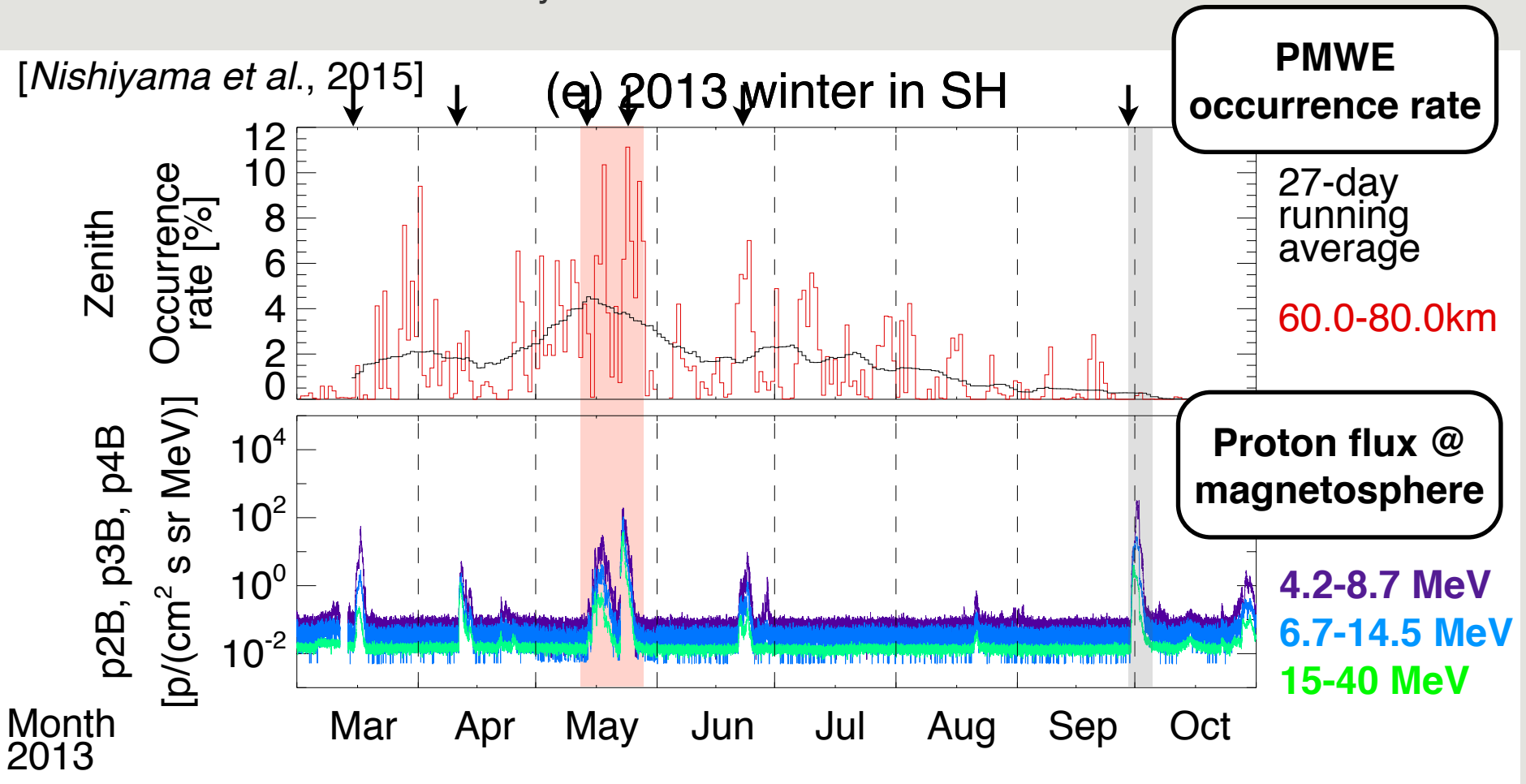
All echoes in five directions show almost the same characteristics in height and time, which suggests **isotropic scattering by atmospheric turbulence.**





Correlations to SPEs

- ✓ Seasonal variations of daily occurrence rate for PMWE



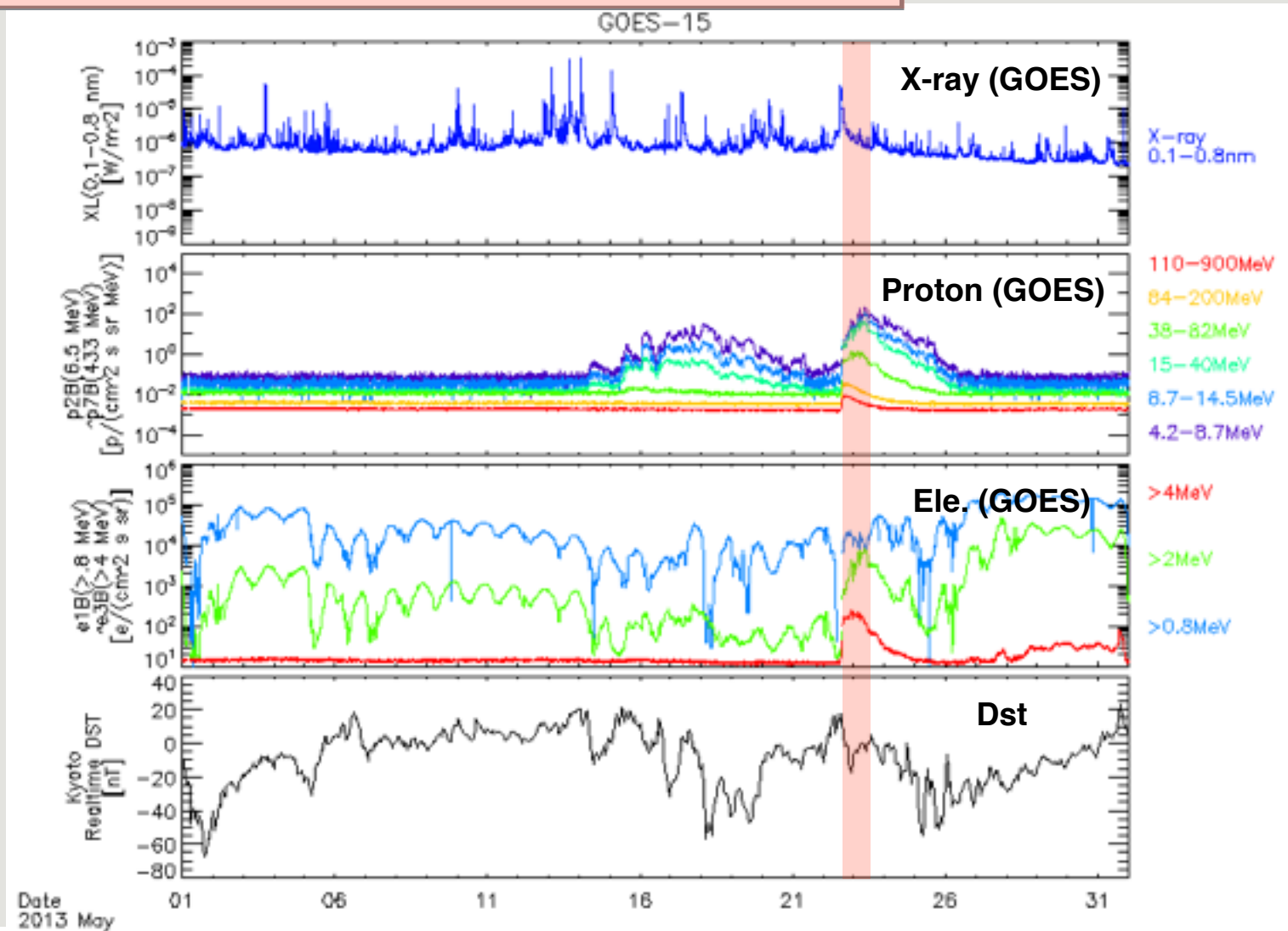
- ✓ Two SPEs occurred in May 2013. (6 SPEs March through October 2013)
 - Good correlation to the most of SPEs or EEPs



Two SPEs in May 2015

- ✓ Summary plot for GOES and geomagnetic activity

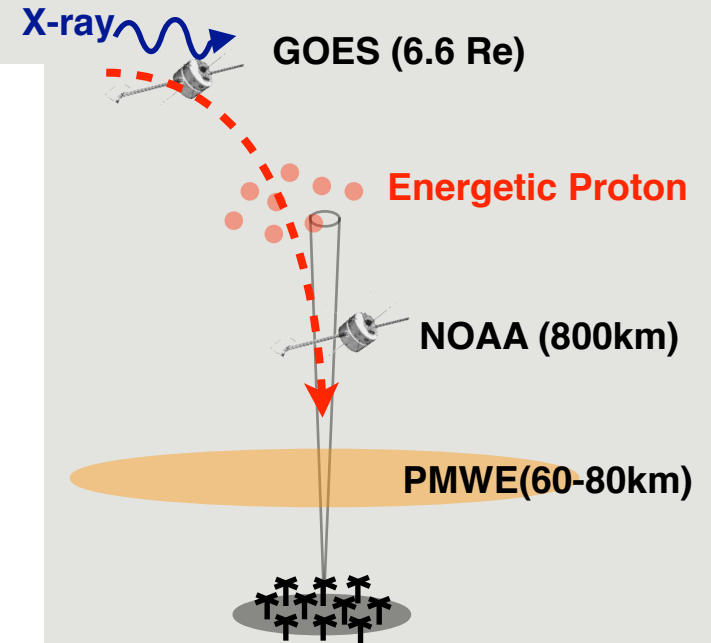
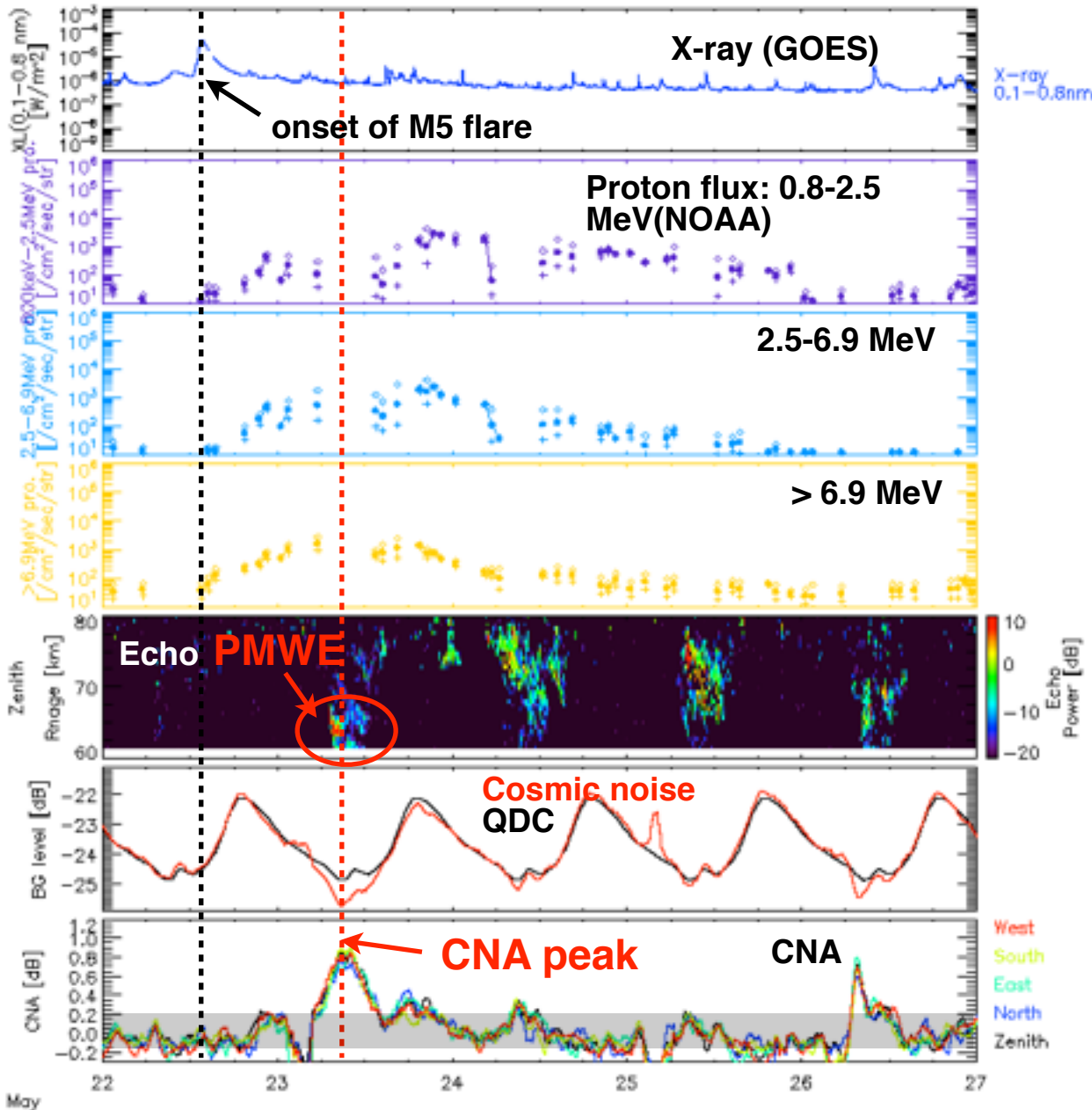
Start	End	PFU (@> 10 MeV)
May 14/1325	May 17/1720	41
May 22/1420	May 23/0650	1660





SPE: PMWE and CNA

✓ A case study during SPE on May 23, 2013



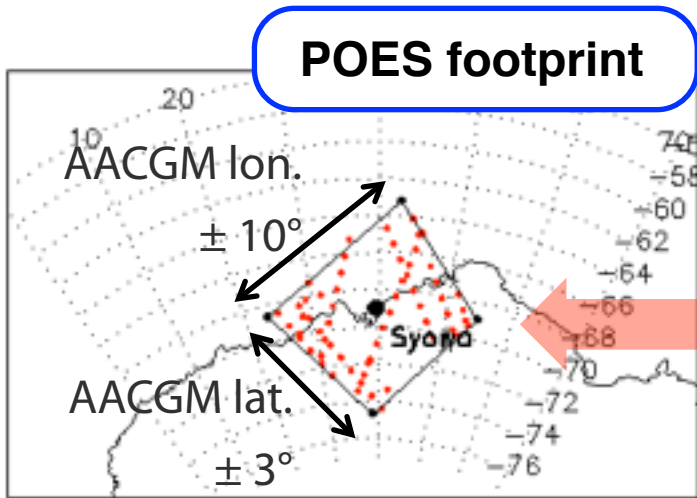
Proton precipitation was observed over Syowa.
⇒ Significant ionization in the lower mesosphere

- 1) Sudden appearance of PMWE around 65 km
- 2) Strong absorption of cosmic noise (~0.8 dB)



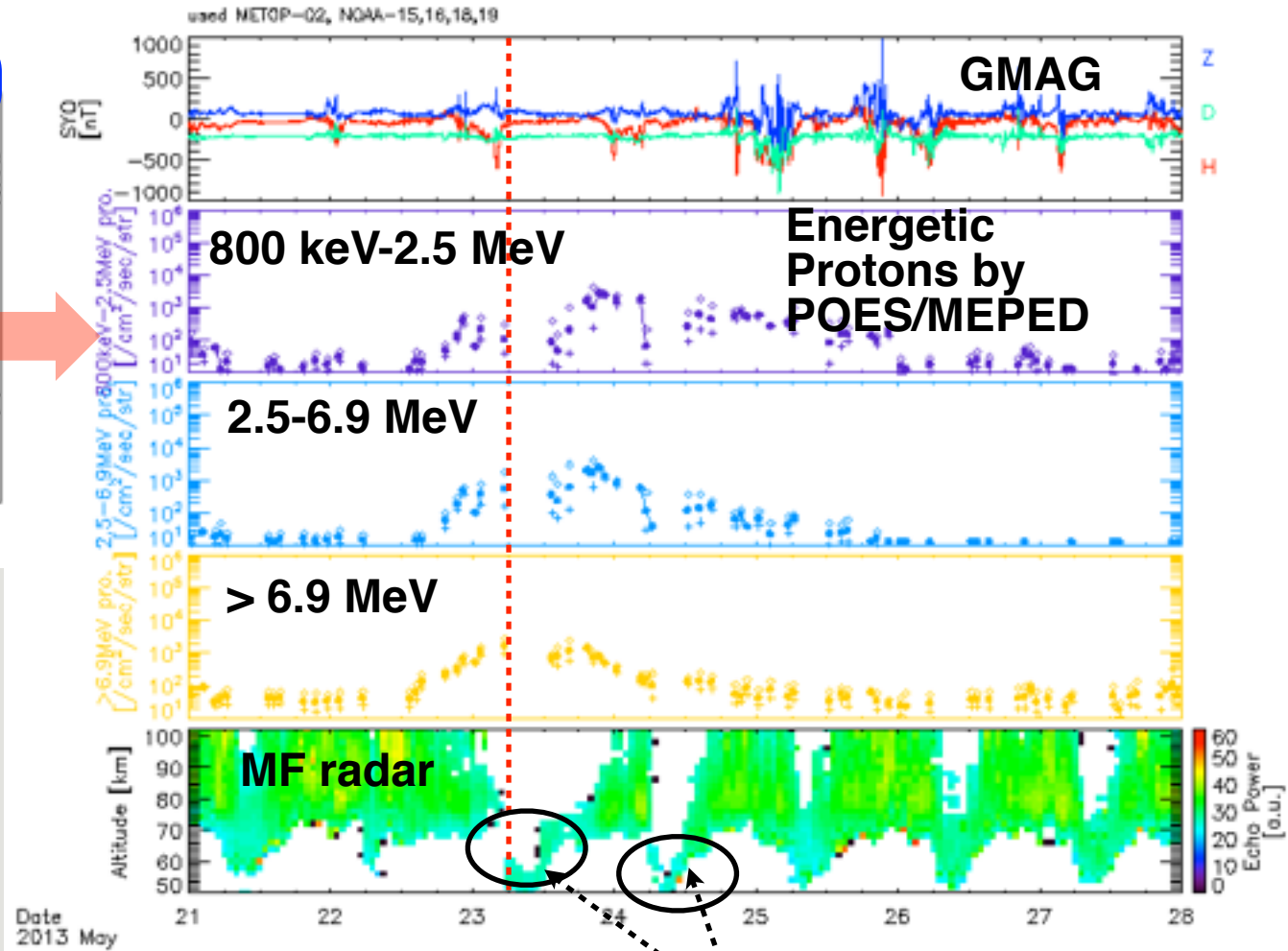
SPE: POES/MEPED and MF radar

2013-05
AACGM coordinate at alt. of 80 km
used METOP-02, NOAA-15,16,18,19



POES footprint

In this event, ILME also detected by MF radar due to reflection in high electron density at altitude 60-100 km.



ILME (Isolated Lower Mesosphere Echo)



Summary

✓ まとめにかえて

- 高エネルギー粒子降下による中層大気上部の応答を検証
 - SPEDASを用いた地上観測や衛星観測の統合データ解析
 - 大型大気レーダーで観測されるPMWE（中間圏エコー）を中層大気上部の電離のプロキシとして注目
- 2013年5月23日のSPEに対応するイベントを紹介
 - POES/MEPEDで高エネルギープロトンのフラックスの上昇が観測
 - 同時に非常に強いPMWE @ 60-70kmとCNA（ ~ 0.8 dB）を検出
 - 降下プロトンによる中層大気上部の異常電離に起因
- St. Patrick Day'sや2015年6月22日の磁気嵐に対応するPMWEのエンハンスも確認
 - 高エネルギー電子（ > 100 keV）による電離の重要性



Future Work

✓ 「より多くのデータを統合させた解析」に発展

- PMWE（中間圏の電離領域）の空間分布や時間発展: **SuperDARN**
- 鉛直方向の輸送過程: **ライダーやレーダー**，**衛星リモートセンシング**

