



KEY POINTS

- E3D-BRITE is a proposed open-source, Python-based technique** to use EISCAT_3D (and possibly other) measurements to reconstruct a 3D, self-consistent picture of quasi-static IT electrodynamics.
- To begin development, we have created a synthetic EISCAT_3D measurement data set using output from the GEMINI model¹ and the uncertainty estimation technique presented by Lehtinen, Virtanen, and Obispää².
- Synthetic measurements of 3D ion convection vectors, plasma density, and their uncertainties are used to estimate the perpendicular current density $j_{\perp}$.
- Preliminary tests suggest that it is possible to estimate $j_{\parallel}$ via integration of $\nabla \cdot j_{\perp}$.
- Force balance between the $\mathbf{J} \times \mathbf{B}$ force and plasma-neutral collisions indicates that EISCAT_3D measurements only enable estimation of the neutral wind $\mathbf{u}_{\perp}$ over a limited range of altitudes (~95–125 km).

PROCEDURE FOR GENERATING SYNTHETIC EISCAT_3D DATA

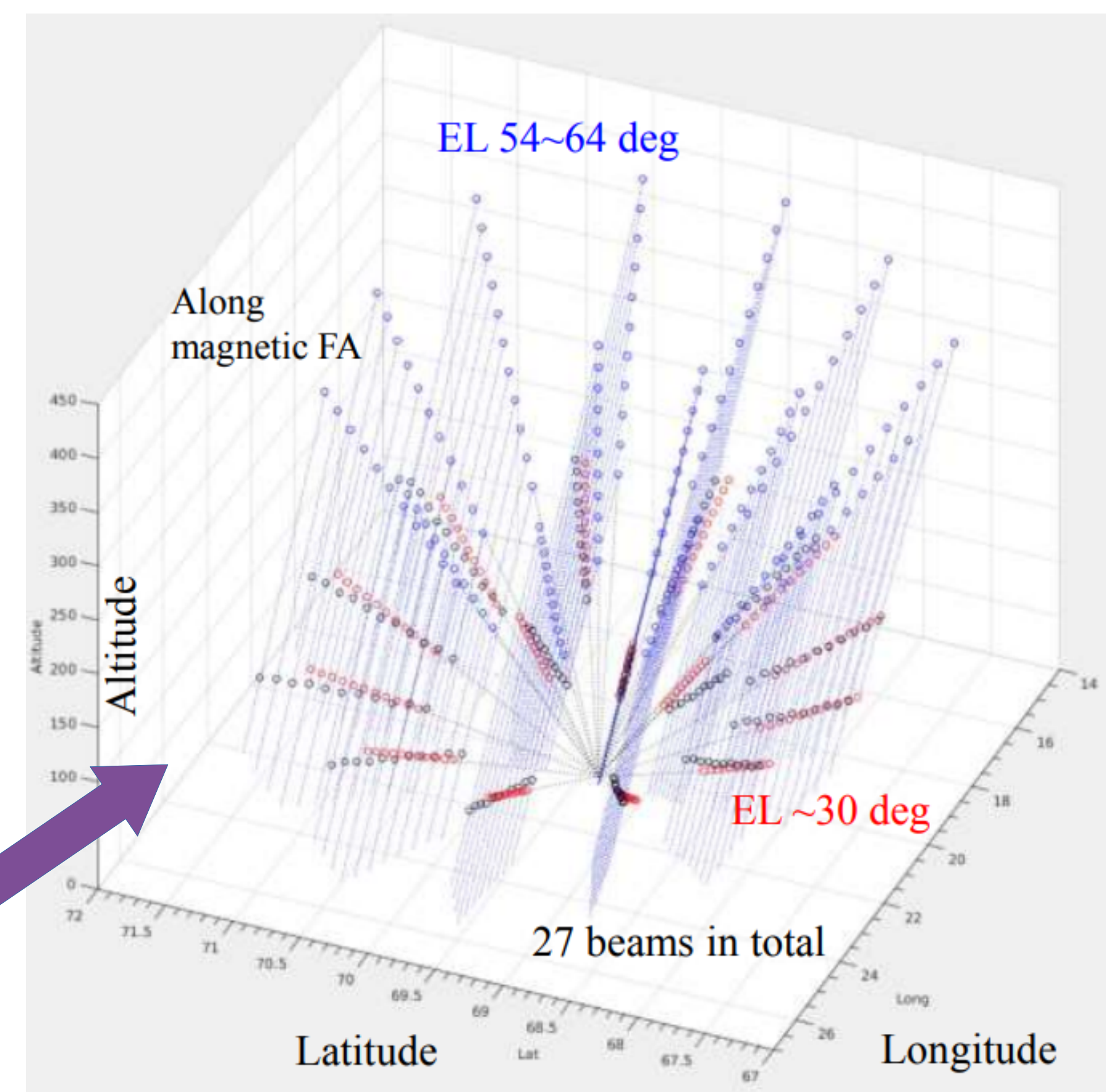
1. Get GEMINI data

- Duration: 2100–2130 UT on 2020/03/26
- Domain: Ionosphere over Skibotn
 - 60–75° glat, 5–50° glon, 80–1200 km alt
 - Cell volume: several km³
 - Grid: Dipolar
- Monoenergetic ($E_0 = 2$ keV) e^- precip
 - Gaussian in lat/lon

2. Sample GEMINI along proposed E3D Common Programme beams³

3. Use ISgeometry (R package⁴) to estimate velocity and isotropic parameter noise.

- Use E3D system parameters + assumptions such as Gaussian range uncertainty and antenna beam shape to estimate, given particular integration time, uncertainty in electron and ion temperatures T_e and T_i , plasma density n_e , and ion convection velocity $\mathbf{v}_i$.

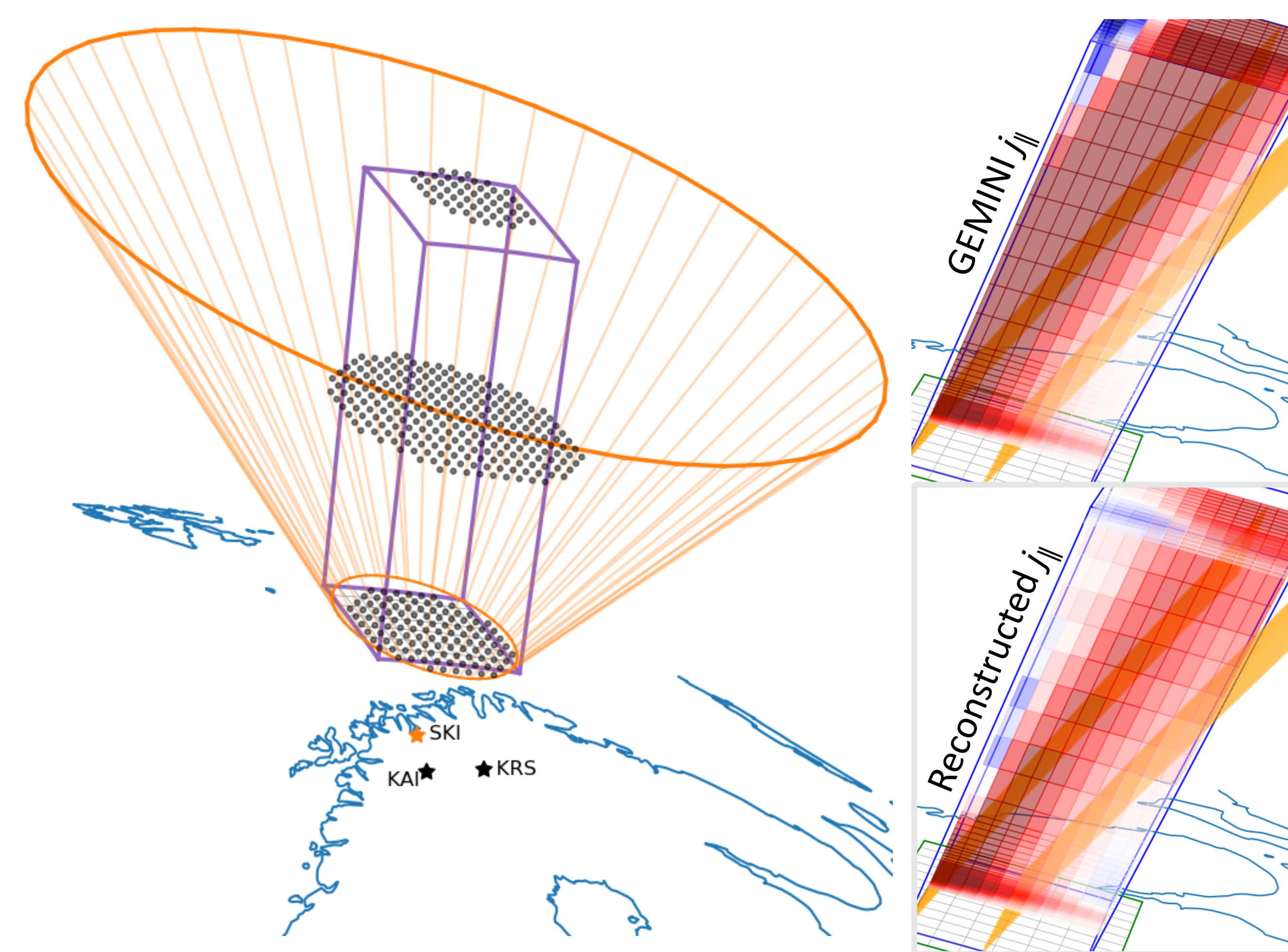


Configuration of beams along which we sample GEMINI to generate synthetic E3D data. (Credit: Y. Ogawa et al)

THE E3D-BRITE TECHNIQUE

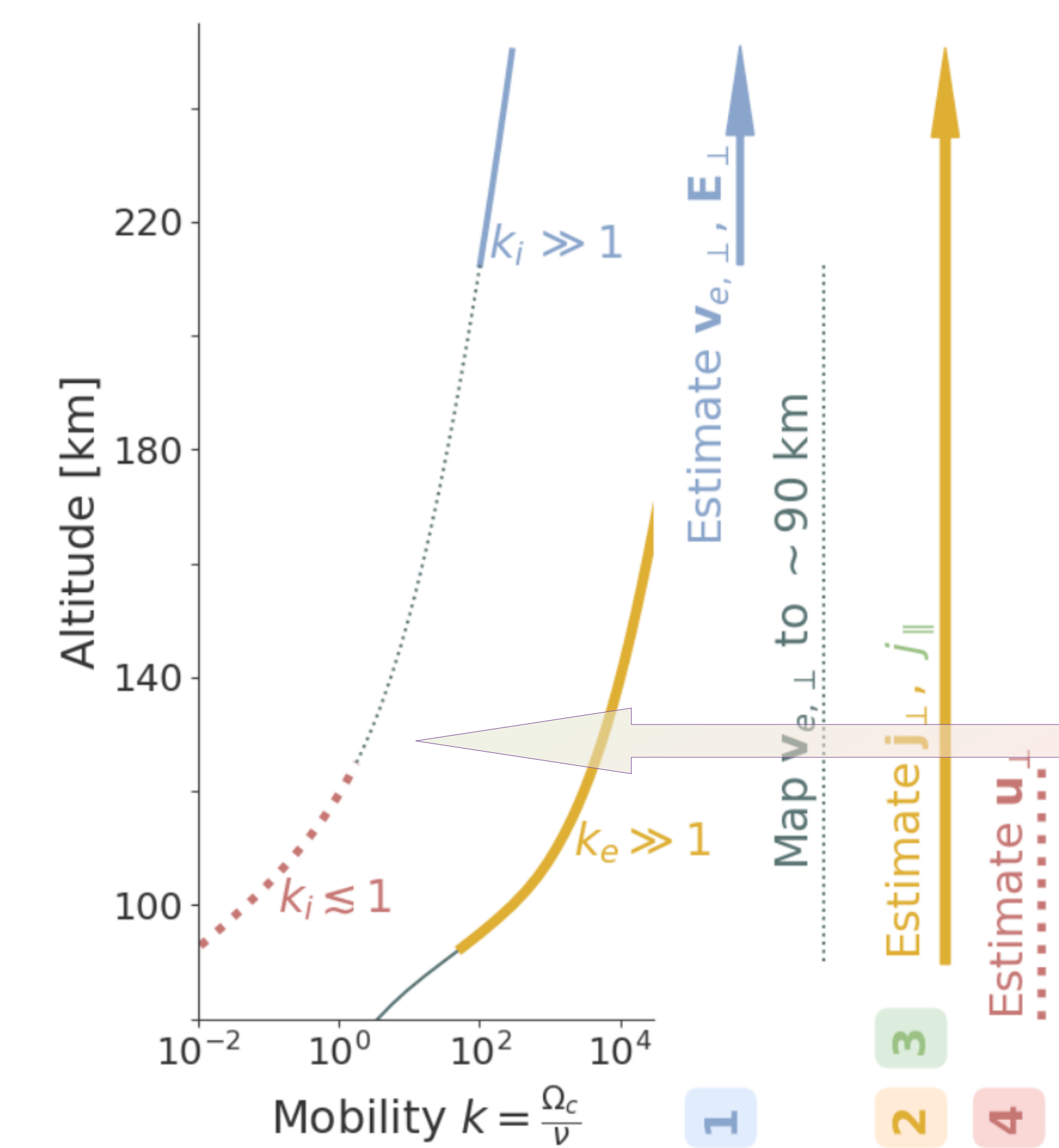
	Input	Assumptions, Equations	Output
1. Estimate $\mathbf{v}_{e\perp}, \mathbf{E}_{\perp}$	$\mathbf{v}_i$	$\mathbf{v}_{e\perp} = \mathbf{v}_{i\perp}$ $\mathbf{E}_{\perp} = -\mathbf{v}_{i\perp} \times \mathbf{B}$	$\mathbf{v}_{e\perp}, \mathbf{E}_{\perp}$
2. Estimate $j_{\perp}$	$n_e, \mathbf{v}_{i\perp}, \mathbf{v}_{e\perp}$	$\mathbf{v}_{e\perp}$ maps to 90 km $j_{\perp} = qn_e(\mathbf{v}_{i\perp} - \mathbf{v}_{e\perp})$	$j_{\perp}$
3. Estimate $j_{\parallel}$	$j_{\perp}$	Current continuity $j_{\parallel} = -\int \nabla_{\perp} \cdot j_{\perp} ds$	$j_{\parallel}$
4. Estimate $\mathbf{u}_{\perp}$	$\mathbf{v}_{i\perp}, \mathbf{v}_{e\perp}$	Force balance	$\mathbf{u}_{\perp}$

Outline of E3D-BRITE reconstruction technique. The approximate altitude ranges at which it is possible to reconstruct each quantity are dictated by the ion and electron mobilities k_i and k_e shown at right.



Orange lines: volume observed by the EISCAT_3D transceiver in Skibotn for 30° elevation. Purple box: approximate volume within which reconstruction of perpendicular ionospheric current system will be possible, assuming 10-minute integration of E3D measurements. The scatter points indicate where the three EISCAT_3D sites can estimate standard ISR quantities with ACF noise of $\leq 5\%$, assuming a duty cycle of 10% at Skibotn and 100% at Karesuvanto and Kaiseniemi.

Example 3D reconstruction of $j_{\parallel}$ based on of Steps 1–3 of the E3D-BRITE technique. Simulated $j_{\parallel}$ (top) and reconstructed $j_{\parallel}$ (bottom).



NEUTRAL WIND ESTIMATES AND FORCE BALANCE

Straightforward computation of the neutral wind $\mathbf{u}$ based on force balance for the two dominant forces in the collisional ionosphere, the $\mathbf{J} \times \mathbf{B}$ force and collisional momentum exchange, produces

$$\mathbf{u} = \left(1 + \frac{k_i}{k_e}\right)^{-1} \left[\mathbf{v}_i + \frac{k_i}{k_e} \mathbf{v}_e - k_i (\mathbf{v}_i - \mathbf{v}_e) \times \hat{\mathbf{b}} \right]$$

Above ~125-km altitude, the three terms in square brackets at right are increasingly dominated by k_i with increasing altitude.

(See plot of k_i vs altitude here)

For example, for $k_i = 100$ and 1 m/s uncertainty in either $\mathbf{v}_i$ or $\mathbf{v}_e$, the uncertainty in $|\mathbf{u}|$ is unacceptably large (100 m/s).

Thus, estimating the neutral wind above ~125-km altitude will apparently not be possible with E3D measurements.

QUESTIONS

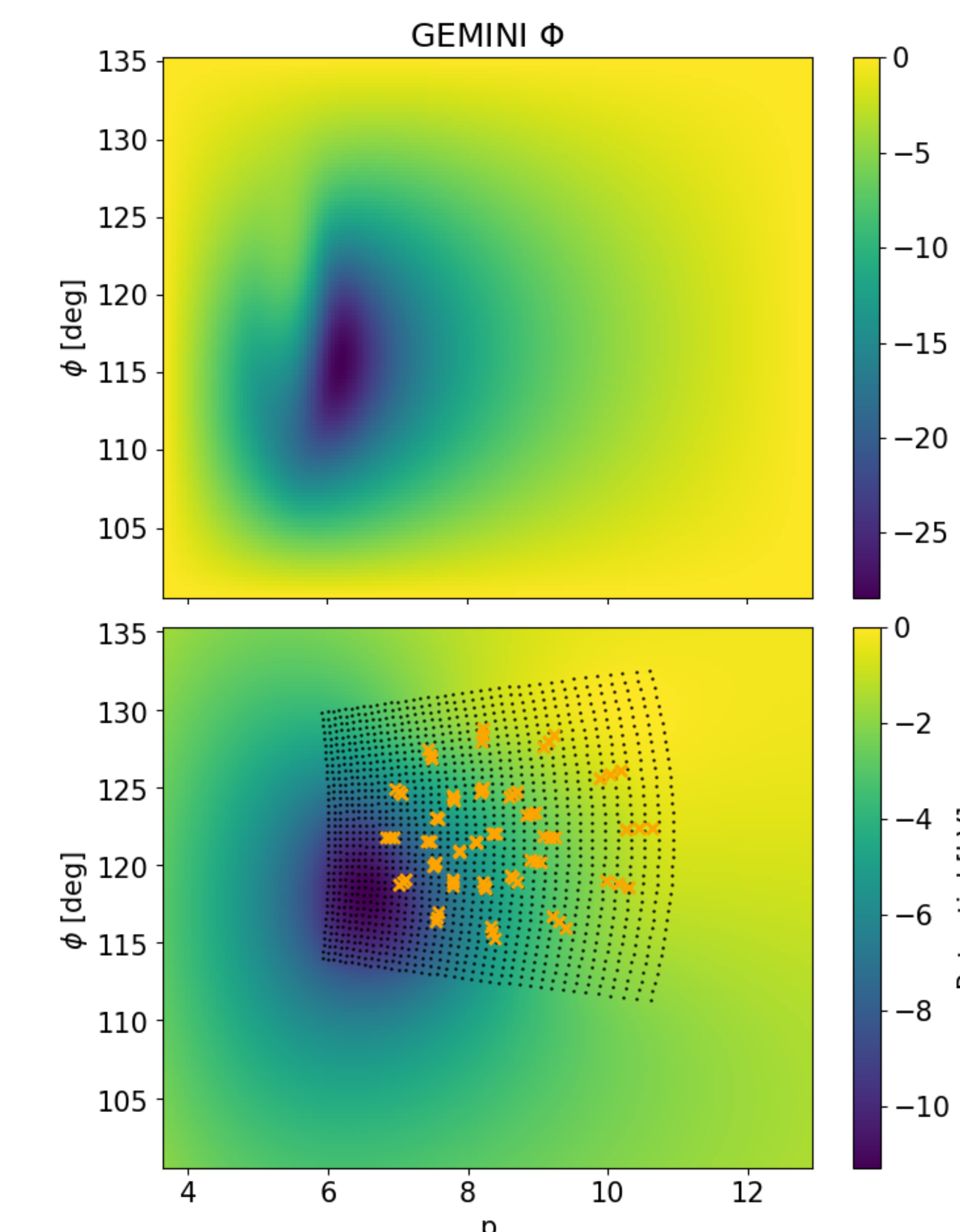
- How to optimize beam selection for reconstruction of 2D quasistatic electric convection potential?
- Why does Lompe technique (so far) seem to always have a hard time reproducing the ionospheric potential in some region (*not shown, but feel free to ask me about this!*)
- When will EISCAT_3D have permission to use all three sites for genuine 3D estimation of ion convection velocity?**

REFERENCES

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GEMINI ionospheric potential (top) and example reconstruction (bottom) based on 486 synthetic measurements (orange crosses). The reconstruction is made by mapping synthetic measurements of the perpendicular ion convection velocity from 350–400 km to 110 km and using the Lompe technique⁵ to reconstruct the ionospheric potential.