MAIN CONCLUSIONS:

1. Dayside convection throat rotates towards afternoon sector before main phase
2. Then electric potential increases and dayside throat rotates back towards noon
3. Average large-scale morphological changes in the electric field during storms happen on dayside

Average Ionospheric Electric Field Morphologies during Geomagnetic Storm Phases

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Using SuperDARN* & Principal Component Analysis

Motivation

- SuperDARN's addition of mid-latitude radars allows us to study the high-latitude **ionospheric electric field with improved coverage**
- We are building a model of improved ionospheric electric field dynamics, which will include time-variability:

Need to know average storm dynamics to build improved models

Method

- SuperDARN was built to study high latitude ionospheric convection
- Radio signals are backscattered by magnetic field-aligned ionospheric irregularities
- Doppler shift is used to calculate ionospheric convection velocities
- A **large dataset (2 min cadence, 2010-2016) allows us to statistically study average storm dynamics**
- We use the **geomagnetic storm list from Walach & Grocott (2019) which uses Sym-H to automatically identify 54 geomagnetic storms and their storm phases**
- The **median durations** are:
  - **Initial phase: 9.8 hours**
  - **Main phase: 4.5 hours**
  - **Recovery phase: 27.9 hours**
- We **perform a superposed epoch analysis** on the SuperDARN data, **normalised to the median storm phase durations**, to make **average maps of ionospheric convection** (at a 2-minute cadence)
- We perform a **principal component analysis** on the **resulting ionospheric electric field** to **extract and quantify dominant morphologies without bias**

Principal Component Analysis

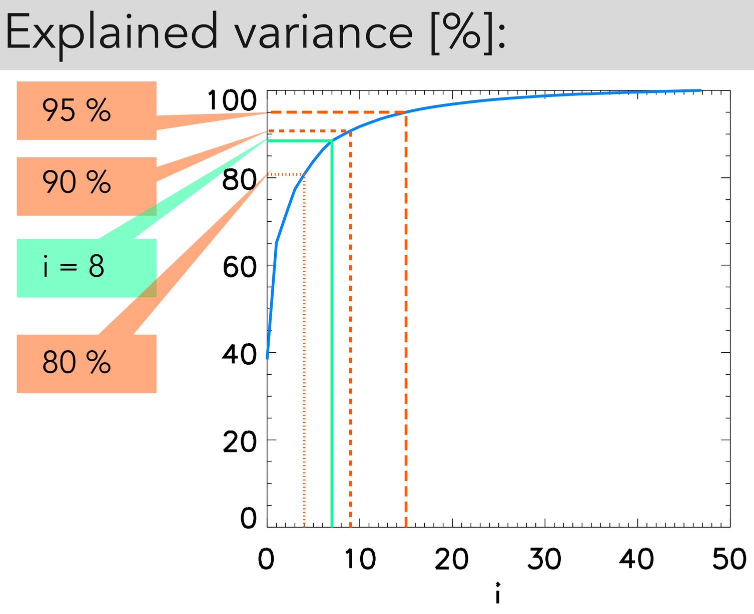
- Each original electric potential map (**ϕ_t**) can be expressed (or reconstructed) in terms of eigenvectors of the covariance matrix of **$\phi(X_i)$** and their eigenvalues (**α_i**), where:

$$\alpha_i = \mathbf{\Phi_t} \cdot \mathbf{X_i} \qquad (1)$$

$$\mathbf{\Phi_t} = \sum_{\mathbf{i=1}}^{\mathbf{m}} \alpha_\mathbf{i} \mathbf{X_i} \qquad (2)$$

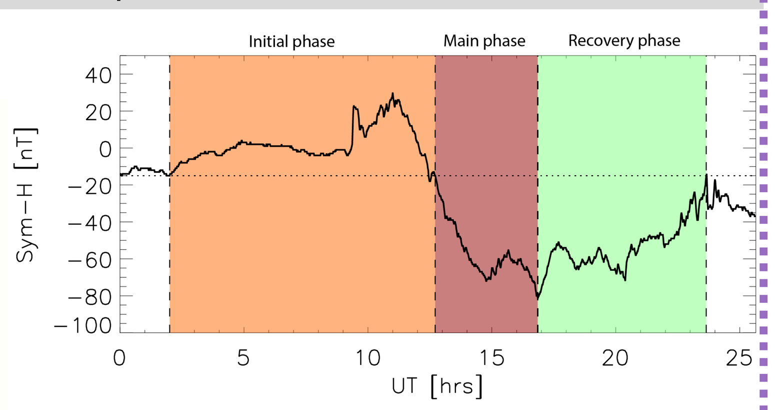
- We use the **Householder method** for **eigen-decomposition** to achieve this (e.g. Press et al. 2007)
- We **scale each average storm map** to **40°** magnetic colatitude and use a **2°×2° resolution** for the **electrostatic potential**
- This gives use **4500 eigenvectors and values**, which describe the storm-time dynamics

Explained variance [%]:



Curve converges fast, which means not many eigenvectors & eigenvalues are needed to explain the majority of morphologies

Example geomagnetic storm:



Geomagnetic storms **event list** is **openly available to download** as part of Supporting Information to **Walach & Grocott, 2019 in JGR: Space Physics**

Super Dual Auroral Radar Network is a collection of radars funded by national scientific funding agencies of Australia, Canada, China, France, Japan, South Africa, United Kingdom, and United States of America, and we thank the international PI team for providing the data.

SuperDARN network:

SuperDARN* coverage, Jan. 2018:

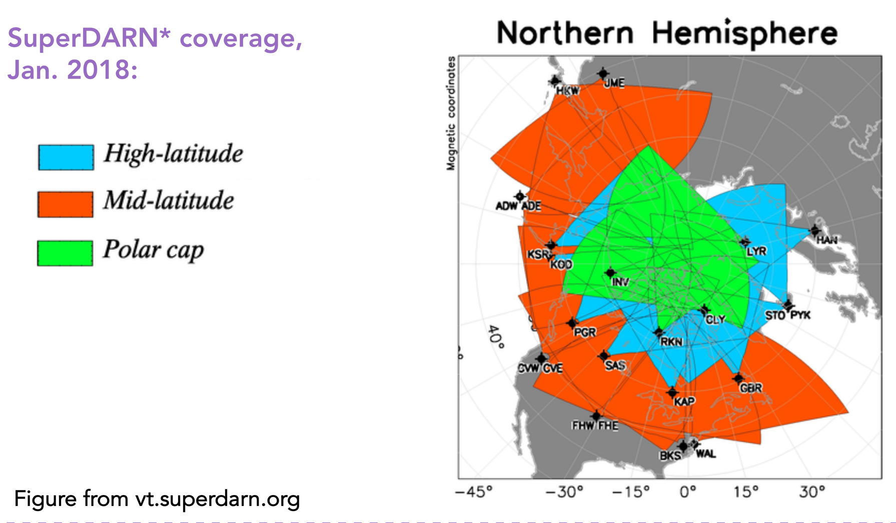
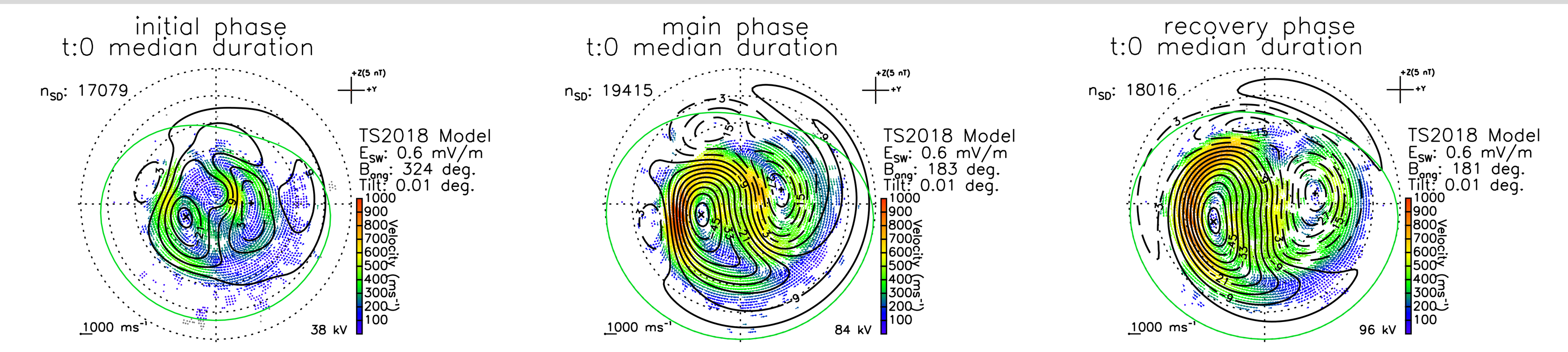
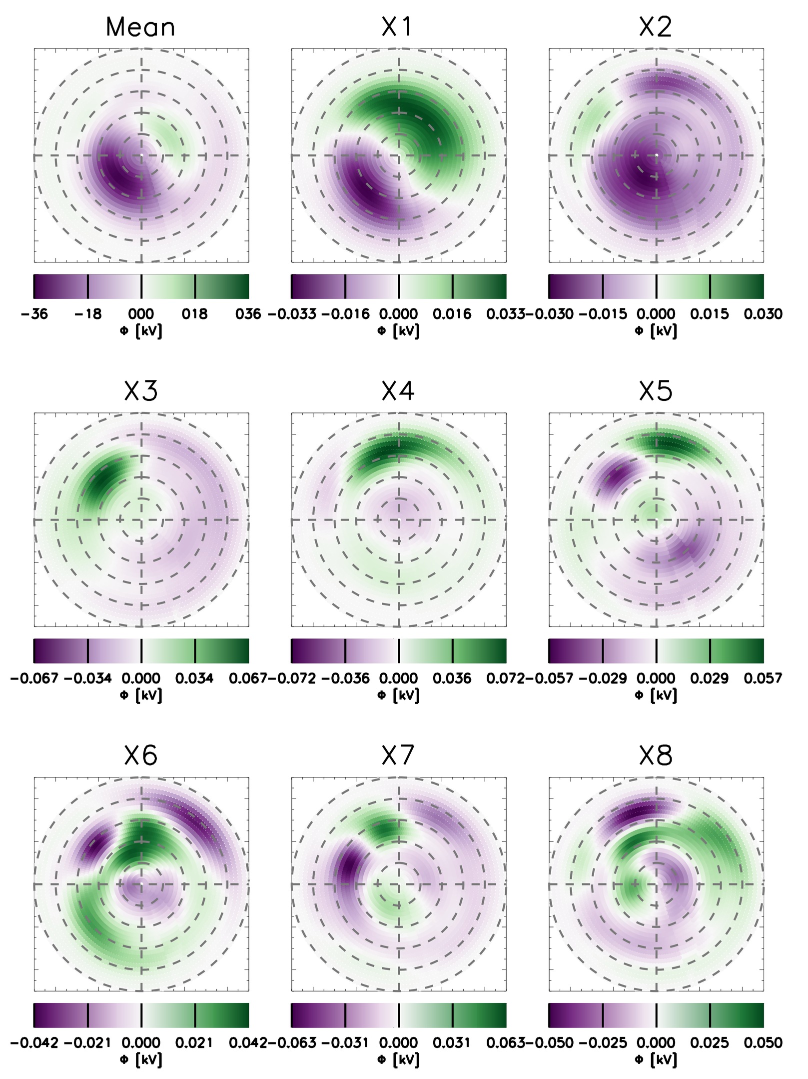


Figure from vt.superdarn.org

Example average SuperDARN maps (normalised by storm phase duration):



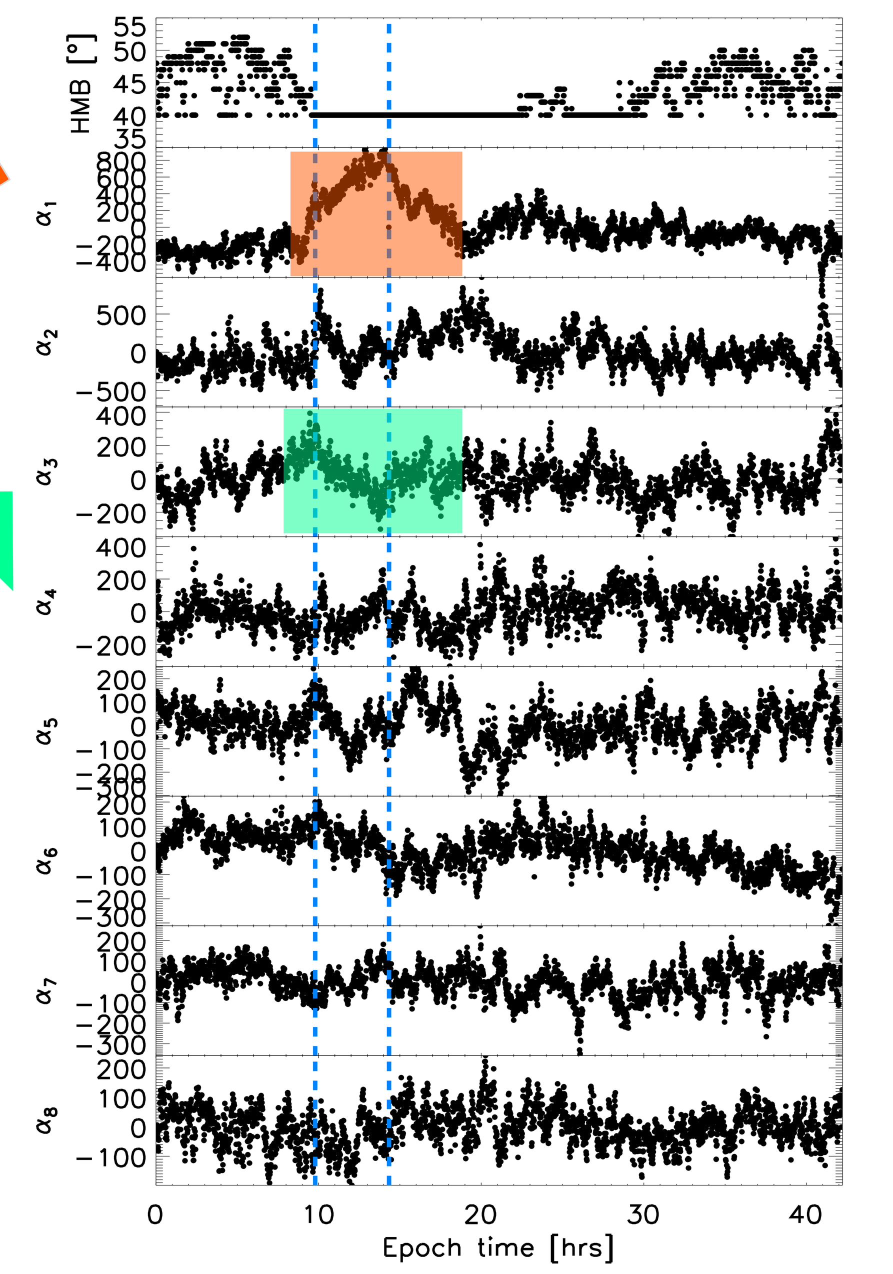
Eigenvectors:



- Two-cell convection pattern is dominant
- X1 provides increase/decrease in two-cell potential
- X2 provides a way to add asymmetry
- X3+ provide rotation of the dayside convection throat & rotation of overall pattern

- Most variability is on the dayside
- Clear increase of α_1 throughout main phase, followed by a decrease: Ionospheric electric potential increases throughout main phase and the decreases as soon as recovery phase starts
- α_3 increases towards start of main phase and then clearly decreases throughout main phase: Dayside convection throat rotates towards afternoon sector before main phase and then as potential increases, dayside throat rotates back towards noon

Eigenvalues:



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