## Mid-latitude SuperDARN Review Paper

Low latitude aurora behind the SuperDARN HOP East radar (2015.3.18 0110 JST)

Nishitani, N., J.M. Ruohoniemi, M. Lester, J.B.H. Baker, A.V. Koustov, S.G. Shepherd, G. Chisham, T. Hori, E.G. Thomas, R.A. Makarevich, A. Marchaudon, P. Ponomarenko, J.A. Wild, S.E. Milan, W.A. Bristow, J. Devlin, E. Miller, R.A. Greenwald, T. Ogawa, and T. Kikuchi Nishitani et al., SuperDARN 2007 Workshop in Abashiri, Hokkaido

(photo: 2006/11/13)

# Initial observation with the Hokkaido radar

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doi: <u>https://doi.org/10.1186/s40645-019-0270-5</u>

Low latitude aurora behind the SuperDARN HOP East radar (2015.3.18 0110 JST)

## Super Dual Auroral Radar Network (SuperDARN) as of Jun 2004

30 J un 2004

In 2004, all the radars were located at or close to the polar region (FOV > ~60 geomag. lat.) because main interests were related to auroral regions. But the following question arises:

• What is the dynamics of expanded auroral oval?

• What are the dynamics of subauroral phenomena?

• What are the dynamics of mid-latitude phenomena?

Radar frequency: 8-20MHz, spatial res. 15-100 km, temp res. 1s-2min

Number of operating HF radars: 15 (9 in the northern and 6 in the southern hemispheres) as of June 30, 2004: 11 years ago

01:11:00 UT

## Super Dual Auroral Radar Network (SuperDARN)



Number of operating HF radars: 36 (23 in the northern and 13 in the southern hemispheres) as of Jan 1, 2018

## Examples of SuperDARN radars observations



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+



#### **Sub-Auroral Polarization Streams**



# Call for ISEE/CICR International Workshop

 The Institute for Space-Earth Environmental Research (ISEE), Nagoya University, carries out the 6-year program "Study of coupling processes in solarterrestrial system using ground-based observation network" in 2016-2021. In this program, the Center for International Collaborative Research (CICR), ISEE calls for proposals of international workshop. This workshop is to promote extensive one-week discussion on the focused topic on solar-terrestrial system with a limited number (~10) of participants. The results of the workshop should be published in review papers or special issues of international scientific journals and/or books.



ISEE/CICR International Workshop "Review of the accomplishments of the mid-latitude SuperDARN network" (supported by ISEE meeting fund / PWING)

- 10-14 Jan 2017 @ Nagoya Univ.
- 14 participants (11 foreign people)
- The aim of the workshop is to complete a review paper on the mid-latitude SuperDARN for about 10 years
- During this workshop we assigned 5 main scientific fields and decided framework of the paper, team of each field and the overall content / structure of the paper

2nd ISEE/CICR International Workshop on "Review of the accomplishments of the mid-latitude SuperDARN network"

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#### [2017-01-16]

ISEE/CICR International Workshop on "Review of the accomplishments of the mid-latitude SuperDARN network" was held at Room 409 in Research Institute Building II during January 10 to 14, in co-operation with the JSPS Grant Program "Study of dynamical variation of particles and waves in the inner magnetosphere using ground-based network observations (PWING Project)." 15 participants from 5 countries intensively discussed accomplishments and future directions of the mid-latitude SuperDARN network.



2019/06/04

SuperDARN Workshop

# During the 2017 Workshop a serious incident happened.



- The Hokkaido East radar (main computer) stopped working!
- It made me quite upset because it was just 2 months before the continuous operation of the ERG satellite!
- We tentatively solved the problem by replacing main computer with the spare for HKW radar.
- Later, Julian Thornhill found that the faulty main computer was due to the swollen capacitor near the CPU, which was replaced and the machine began working again.



SuperDARN Workshop 2019, Fujiyoshida Review of the Mid-Latitude SuperDARN follow-up workshop (Jan 9-12, 2018) (supported by ISEE meeting fund / PWING)

- 6 participants (Mark, Mike, Jo, Sasha, Nozomu and Tomo) plus 2 online participants (Simon & Evan)
- Follow-up of the international workshop in 2017
- Leader: Nozomu Nishitani
- Dates: Jan 9-12, 2018.
- Place: ISEE, Nagoya University
- Most of the time spent for writing papers
- The paper was submitted to PEPS in August 2018 and was published on March 18, 2019!



## Mid-latitude SuperDARN review paper

- Workshop proposal submitted: April, 2016
- First workshop: Jan 10-14, 2017
- Second Workshop: Jan 9-12, 2018
- First merged draft
- First version submitted to PEPS: August 2, 2018
- Revised version submitted: Dec 10, 2018
- Paper accepted: Feb 01, 2019
- Published: Mar 18, 2019 2019/06/04 SuperDARN Workshop 2019, Fujiyoshida

# Review of the accomplishments of mid-latitude SuperDARN

- 1. Introduction
- 2. Convection
- 3. lonospheric Irregularities
- 4. HF Propagation<sup>®</sup> Analysis
- 5. Ion-Neutral Interactions
- 6. MHD waves
- 7. Future directions



20 authors, 28,000 words (main text only), 37 figures, 235 references (+38 in the supplement): 57(+4) pages (PDF)

# Introduction

## (Nozomu, Mark, Mike, Evan, Sasha)

- Basics of SuperDARN
- Definition of a Mid-latitude Radar
- Meaning of Geomagnetic Coordinates
- Brief History of Mid-latitude SuperDARN
  - Additional file: Historical overview of mid-latitude SuperDARN including the development of Twin-Terminated Folded Dipole (TTFD) antenna array
- Structure of This Paper



# Convection

## (Simon, Jim, Aurélie, Tomoaki, Roman, Evan)

- Storm-Time Convection
- SAPS: Introduction
- Global Characteristics and Control of SAPS
- Longitudinal Extent and Variation of SAPS
- Dependence of SAPS on Solar Wind and Geomagnetic Drivers
- Interhemispheric Comparisons of SAPS
- Temporal Dynamics of SAPS: Introduction
- Lifetime/Longevity and Seasonal Dependence of SAPS
- Evolution and Variability of SAPS
- Occurrence Frequency of SAPS and Their Dependence on Substorm Phase
- Implications for SAPS Formation Scenarios
- Transients
- Convection: Future Directions

## Convection

#### Clausen et al. (2012JGR)

Longitudinal distribution of SAPS using multiple US midlatitude SD radars

### Ebihara et al. (2009JGR)

Identification of the relationship between ring currents and SAPS using numerical simulation

17



## **Ionospheric Irregularities** (**Mike,** Sasha, Roman, Nozomu, Pasha)

- Introduction of Ionospheric Irregularities
- Auroral Irregularities
- SAPS Irregularities
- Sub-auroral Irregularities
- Temperate Mid-latitude Irregularities

# Irregularities

#### Greenwald et al. (2006GRL)

First identification of Subauroral ionospheric scatter (SAIS) echoes possibly associated with temperature gradient instability



### Ogawa et al. (2009JGR)

Identification of the relationship between nighttime MSTIDs and E-region irregularities, suggesting E- and F-region coupling



SuperDARN Workshop 2019, Fujiyoshida

## HF Propagation Analysis (Gareth -> Jo, Mark, Simon, Evan)

- Introduction of HF Propagation Analysis
- Propagation Analysis: Backscatter Classification and Geolocation
- Propagation Analysis: Ionospheric Morphology and Dynamics
- Propagation Analysis: Radar Performance Assessment and Calibration
- Propagation Analysis: Summary and Future Directions

## **HF** propagation

### Ribeiro et al. (2011RS)

### Ponomarenko et al. (2015EPS)

distinguish ionospheric echoes from ground scatter echoes



Development of new algorithm to Development of new algorithm to calibrate interferometer phase displacement for calculating elevation angle -> the efforts led to Tdiff task force



## **Ion-Neutral Interactions** (Sasha, Nozomu, Aurélie, Jo)

- Introduction of Ion-Neutral Interactions
- TIDs: Introduction
- SuperDARN Signatures of LSTIDs
- SuperDARN Signatures of MSTIDs: Introduction
- MSTID Occurrence
- Typical MSTID Parameters
- Daytime MSTIDs: Introduction
- Daytime MSTIDs: Propagation Direction
- Daytime MSTID Generation: Geomagnetic Influences and Polar Vortex Activity
- Nighttime MSTIDs: Introduction
- Nighttime MSTIDs: Propagation Direction
- Nighttime MSTIDs: High-Latitude Geomagnetic Influences
- Nighttime MSTIDs: E Region Signatures and Vertical Coupling
- SuperDARN Detection of Seismically-Activated TIDs
- Ion-Neutral Coupling and Generation of Plasma Irregularities
- Ion-Neutral Interactions: Summary and Future Directions

## (Mid-lat) Daytime / nighttime MSTIDs: they have different characteristics / origins!



Ogawa et al. (2009): nighttime



#### Daytime:

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- caused mainly by the propagation of atmospheric gravity waves seeded by lower atmosphere disturbances Nighttime:
- caused mainly by the growth of ionospheric plasma instability

SuperDARN Workshop 2019,

## Ion-neutral interaction

#### Hayashi et al. (2010JGR)

# First 2-D observation of LSTIDs and comparison with gravity wave simulation

#### 15 Dec 2006 Beam 0 0000 (349) to 0600 (349) Event 1 Event 2 Event 3 /elocity (m/s 4 0 -4 -8 -12 -16 -20 50 Geographic Latitude rec (10<sup>16</sup>el/m<sup>2</sup> 35 30 0100 0000 02<sup>00</sup> 03<sup>00</sup> 0400 05<sup>00</sup> 06<sup>00</sup> UT 2019/06/04

## Frissell et al. (2012JGR)

Identification of the relationship between the daytime MSTIDs and polar vortex index



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## MHD Waves (Mark, Gareth, Pasha, Jim)

- Introduction of MHD Waves
- Pi2 and Pi1 Pulsations
- Pc3-4 and Pc5 Pulsations
- MHD Waves: Future Work

# MHD waves

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#### Frissell et al. (2011JGR)

Study of Pi2 pulsations with dispersions and coherences associated with BBFs



## Greenwald et al. (2008GRL)

Extraction of short-period pulsations using the raw time series data with 0.2 s interval



## Conclusions and future directions (Nozomu, Simon, Mike, Jo, Sasha, Mark, Tomo, Pasha)

- Conclusions and science directions
- Satellite conjunction
- Expansion of SuperDARN coverage
- Interhemispheric conjugacy
- Technical developments (software, hardware and algorithm)
- Cooperation with modeling activities
- National strategy
- Training and public outreach

## Conclusions

- Mid-latitude SuperDARN radars are powerful tools for studying a wide variety of phenomena in the ionosphere and neutral atmosphere in the high- and mid-latitude regions.
- Mid-latitude SuperDARN radars are still expanding (e.g., China, Europe, Russia etc.), which is crucial for understanding global-scale dynamics of the magnetosphere – ionosphere and upper atmosphere system.
- Huge number of scientific accomplishments have been made for the last ~15 years, and a review paper has been recently published in PEPS journal.
- The ISEE/CICR International Workshop played an important role in generating this review paper.
  - Proposals with any subject are very welcome!
- Thanks to all who contributed in any way! <sup>2019/06/04</sup> SuperDARN Workshop 2019, Fulivoshida



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#### Most Cited and Accessed Paper Awards

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The Most Cited Paper Awards 2019

This award is presented to one or more highly cited papers published between 1 January 2016 and 31 December 2017. Only citations in papers which are published during 2018 are counted, and these citations must be acknowledged by Web of Science.

#### Review

Philippine Sea Plate inception, evolution, and consumption with special emphasis on the early stages of Izu-Bonin-Mariana subduction

progearthplanetsci.springeropen.com/articles/10.1186/s40645-016-0085-6 nd



SuperDARN Workshop 2019, Fujiyoshida <u>Call for papers (SPEPS)</u>

Submit manuscript

Aims and scope

SPEPS collections

Highly accessed articles

Most cited and accessed paper awards

Editorial Board



#### 2019/06/04

SuperDARN Workshop 2019, Fujiyoshida

#### Mid-latitude SuperDARN review paper now published online!



Nishitani, N. J.M. Ruohoniemi, M. Lester, J.B.H. Baker, A.V. Koustov, S.G. Shepherd,

G. Chisham, T. Hori, E.G. Thomas, R.A. Makarevich, A. Marchaudon, P. Ponomarenko,

J.A. Wild, S.E. Milan, W.A. Bristow, J. Devlin, E. Miller, R.A. Greenwald, T. Ogawa,

and T. Kikuchi (2019), Prog Earth Planet Sci, 6:27.

## acknowledgements / Funding

Acknowledgements

 This review paper originated from approximately one-week long workshops in January 2017 and January 2018, during which we discussed the content of the paper, its structure and future directions of the mid-latitude SuperDARN network. These workshops were carried out by the joint research program of the Institute for Space-Earth Environmental Research, Nagoya University, and supported by funding agencies described in the 'funding' section. Finally, we would like to thank everyone who contributed to the completion of the review paper.

Funding

 SuperDARN is a collection of radars funded by national scientific funding agencies of Australia, Canada, China, France, Italy, Japan, Norway, South Africa, United Kingdom and the United States of America. Organization of the workshops for writing up the present review paper was supported by Japan Society for the Promotion of Science (JSPS) (Grant-in-Aid for Specially Promoted Research): Study of dynamical variation of particles and waves in the inner magnetosphere using ground-based network observations (PWING), Project Number: 16H06286. Completion of the present review paper was partly supported by JSPS (Grand-in-Aid for Scientific Research), Project Number: 18KK0099. Part of the work of TH was done at the ERG-Science Center operated by ISAS/JAXA and Institute for Space-Earth Environmental Research (ISEE) /Nagoya University.

2019/06/04

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