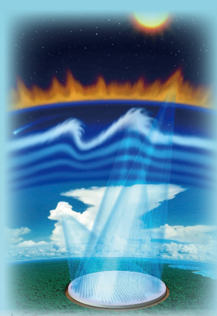
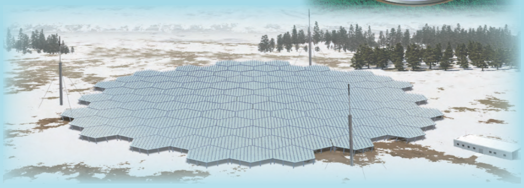
Earth, Planets and Space

Recent Advances in MST and EISCAT/Ionospheric Studies
– Special Issue of the Joint MST15 and EISCAT18 Meetings, May 2017

MST15/iMST2 EISCAT18





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PREFACE **Open Access**

Special issue "Recent Advances in MST and EISCAT/Ionospheric Studies – Special Issue of the Joint MST15 and EISCAT18 Meetings, May 2017"

Mamoru Yamamoto[1*], Wayne K. Hocking[2], Satonori Nozawa[3], Juha Vierinen[4], Huixin Liu[5] and Nozomu Nishitani[3]

Introduction

The Fifteenth Workshop on Technical and Scientific Aspects of MST Radar (MST15) and the Eighteenth EISCAT Symposium (EISCAT18) were jointly held in Tokyo, Japan, at the National Institute of Polar Research (NIPR) during May 26–31, 2017. The MST workshops have a long history of being the primary international meetings on the applications and development of mesosphere–stratosphere–troposphere (MST) radars. The MST workshop has been historically focusing on the atmospheric dynamics but is now including topics related to ionospheric applications of radars. The EISCAT Symposium, on the other hand, is the biennial conference for EISCAT-related radar research and science which is hosted by member institutions of the EISCAT Scientific Association.

This joint MST15/EISCAT18 meeting was a timely opportunity for close and extensive interactions of the middle-atmosphere and ionospheric radar scientists in our era of rapid technological changes and computational advances. The joint meeting was successfully attended by 182 participants from 19 countries/areas and hosted 233 presentations. These numbers were the maximum level ever for either conferences.

This special issue gathered 15 papers from this joint meeting, consisting of ten full papers, three frontier/express letters and two technical reports. The flexible publication style of *Earth, Planets and Space* benefitted us to cover easily both scientific and technical aspects of the research field. In the following, we categorize the articles into several groups and review them briefly.

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Contents of the special issue

Study of atmospheric turbulence

One of important topics of the MST radars is atmospheric turbulence. In this special issue, there are three papers from the same research group who conducted joint experiment of the atmospheric turbulence by remote sensing with the MU radar and by direct measurement with an unmanned aerial vehicle (UAV) that flew nearby to the radar. Luce et al. (2018a) showed a case study of Kelvin–Helmholtz instability (KHI) at the bottom of clouds. The KHI billow structures were successfully observed by the MU radar while a fish-eye lens camera on the ground captured the same event. The authors suggested that this is the first simultaneous detection of KHI from ground-based camera and a radar. Luce et al. (2018b) is the study of concurrent measurement of atmospheric turbulence by the MU radar and a UAV. The UAV measured turbulence kinetic energy (TKE) dissipation rate (ε_U) by a low-noise Pitot tube, and the MU radar showed turbulence intensity by the spectral width (σ). The paper first confirmed same-volume observation by both techniques, and statistically studied empirical relationship between ε_U and σ. The result is $\varepsilon_U \propto \sigma^3$ that is different from previously expected $\varepsilon_U \propto \sigma^2$ relationship. Kantha et al. (2018) conducted further study of this ε_U and σ relationship based on the same database as Luce et al. (2018b). They discussed the validity of the previous theoretical expression of the ε_U and σ relationship. After pointing out missing considerations in the past theories, they proposed a new numerical model described as a MATLAB code for later practical use by the radar community.

Study of polar mesospheric echoes

There are three papers on the study of polar mesospheric echoes. Rauf et al. (2018) conducted a statistical study of influence of particle precipitation on the polar mesospheric summer echoes (PMSE) with the EISCAT VHF radar. They showed that particle precipitation is not a necessary condition for PMSE to exist. However, particle precipitation still affects PMSE when they both occur simultaneously. Reid et al. (2018a) used PMSE echo data for the measurement of momentum flux and found reasonable results compared to previous studies with meteor radars and medium frequency (MF) radars. Belova et al. (2018) conducted a case study of polar mesospheric winter echoes (PMWE) using the tristatic EISCAT radar. Echo duration of the measured PMWE was only 6 min. Then, they found that the presence of patchy negatively charged small-sized dust might explain the observations.

Introduction of new radar facilities

Development of new radar facilities is important for the research field. There are three papers in this category. Ding et al. (2018) showed a newly developed incoherent scatter (IS) radar in Qujing, China (25.6°N, 103.8°E). This is the first IS radar in China that operates at 500 MHz with 2 MW peak envelope power (PEP). The antenna system is 29-m steerable parabolic dish. System description and some preliminary results are reported. Dolman et al. (2018), on the other hand, reported installation of wind profiling radar network over Australian continent. Australian Government Bureau of Meteorology added five more radars. Then, the network now consists of 19 radars (14 operational radars and 5 radars for research). Wind data are included in major models and contribute to more accurate weather forecast. Another paper by Garbanzo-Salas and Hocking (2019) reported a study on 1-year data from the first VHF wind profiler radar in Costa Rica. The radar frequency is 46.6 MHz, and measures wind profiles in the height range of 1–6 km with height resolution of 100 m. They successfully showed behavior of the planetary boundary layer in the low-latitude region.

Study of radar measurement techniques

The accuracy in wind estimation is a very important technical topic for the radar. There are three papers related to this. Hocking (2018) studied possible error from multistatic meteor radar observations. The network of several meteor radars benefits us to diagnose horizontal wind field over the network. This paper points out possible error from such simultaneous measurement of winds from different locations and proposes software to show the error estimation. Reid et al. (2018b) carried out wind comparisons between meteor radars and MF radars at middle- and high-latitude regions in the southern hemisphere. They showed that the winds from MF radars are underestimated and the problem is enhanced above 80 km. They suggested correction factors to mitigate the problem. Renkwitz et al. (2018) carried out wind comparison study between different wind estimation techniques. The study is based on the Saura MF radar (69.1°N, 16.0°E) that is an MF radar but can conduct the Doppler beam swinging (DBS) wind estimation with narrow beams. They showed that the wind estimation suffers from underestimation and suggested optimum combination of methods for better estimation of winds.

New observations and survey for new experiment

It is important to explore new observation methods in any research fields. There are three papers (one frontier letter and two technical reports) in this category. Sato et al. (2018) reported measurement of horizontal structures of the ionosphere from Synthetic Aperture Radar (SAR) measurement aboard the Advanced Land Observation Satellite 2 (ALOS2). This is a very interesting method as the information of azimuth shifts of the SAR image is used for the measurement of horizontal gradient of ionospheric plasma density. They used the EISCAT radar as a reference of observations. There are two more technical reports by Tsuda et al. (2018a, b). They surveyed conditions for artificial aurora experiment with ionospheric heating facility and the IS radar at EISCAT Tromsø site. One report (Tsuda et al. 2018a) suggests the case where they use 4 MHz radio wave for ionospheric heating. However, the chances of possible observations are not high and mostly hopeless during the solar minimum period. In the following report (Tsuda et al. 2018b), they surveyed the possibility of artificial aurora experiment if they can use 2.7 MHz radio wave for heating. They suggested that, by decreasing the frequency of the heating radio wave from 4 to 2.7 MHz, the chance of experiment is much larger and becomes possible even during the solar minimum period.

Acknowledgements

We thank all participants of the Joint MST15/EISCAT18 Meeting in May 2017 and give special acknowledgement to all authors in our special issue. We highly appreciate all referees who served in evaluating the papers and giving the authors helpful comments and suggestions.

Authors' contributions
All authors of this article worked as guest editors for this special issue. Four of them (MY, WKH, SN, and JV) were the conveners of the Joint MST15/EISCAT18 Meeting as well. This preface was prepared by MY and agreed upon by all authors. All authors read and approved the final manuscript.

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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Publisher's Note

FRONTIER LETTER **Open Access**

Imaging high-latitude plasma density irregularities resulting from particle precipitation: spaceborne L-band SAR and EISCAT observations

Hiroatsu Sato*, Jun Su Kim, Norbert Jakowski and Ingemar Häggström

Earth, Planets and Space 2018, **70**, 163 DOI: 10.1186/s40623-018-0934-1
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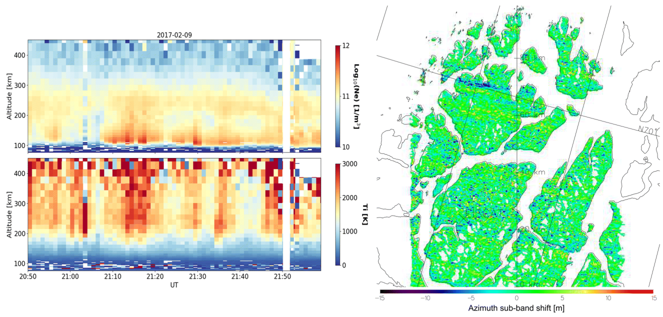
Abstract

High-latitude, small-scale plasma density irregularities are observed by the Advanced Land Observation Satellite 2, Phase Array type L-band Synthetic Aperture Radar-2 and the European Incoherent Scatter radar in Tromsø, Norway. Under high levels of ionization of up to approximately 300 km in height triggered by nighttime particle precipitation, high-resolution SAR images detect horizontal distributions of azimuth shifts resulting from the spatial gradients of electron density. The irregular electron density is characterized by tens of kilometers of band-like structures aligned in the east–west direction with small patch-like structures. We present a method for estimating the local change of TEC gradient and the height of ionospheric irregularities by using single-image SAR sub-band data. The results suggest that these observed structures are likely to be associated with density irregularities caused by precipitating electrons that may have been cascaded into smaller scales by plasma instability processes at F region altitudes. This study presents the first coordinated observations of high-latitude ionosphere features by using SAR satellites and incoherent scatter radar.



Graphical abstract

Keywords: Ionosphere, High latitudes, TEC, SAR, EISCAT

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FRONTIER LETTER **Open Access**

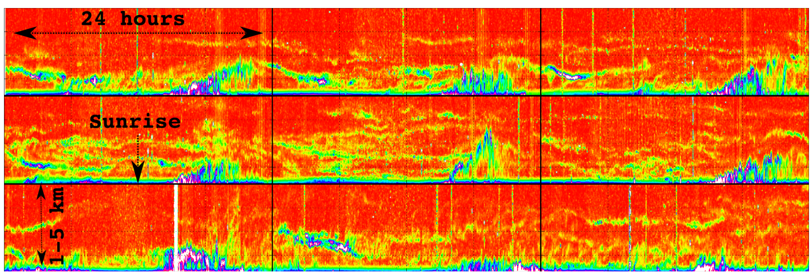
Characterization of atmospheric structures observed by a VHF MST-type radar in the troposphere over Santa Cruz, Costa Rica

Marcial Garbanzo-Salas* and Wayne Hocking

Earth, Planets and Space 2019, **71**, 6 DOI: 10.1186/s40623-019-0985-y
Received: 28 February 2018, Accepted: 4 January 2019, Published: 15 January 2019

Abstract

Results from the first VHF profiler research radar in Costa Rica, operating at a central radar frequency of 46.6 MHz, are presented. Emphasis has been on studies of scattering layers detected in the altitude range 1–6 km, with the main goal being to identify regions with radar echoes and observe the temporal evolution of the echoes. Data were obtained over the course of a full year using a vertical resolution of better than 100 m. Layers of strong scatter were observed regularly, often with simultaneous broad spectra, which may indicate enhanced turbulence. Similar layers have been observed over equatorial Indonesia, and these have been associated with the planetary boundary layer. The presence of echo layers was more common during the dry-season months (December–April); in fact during March, two layers were observed in the lower troposphere for more than 35% of the time. Stable pattern structures often occurred for extended periods, but at times the layers could also vary drastically in behavior from 1 day to the next. After sunset, strong echo layers could persist for several hours. Some examples of regularly observed layer behavior are given.



Graphical abstract

Keywords: MST type radar, Planetary boundary layer, Layers of turbulence

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FULL PAPER **Open Access**

Mesospheric radar wind comparisons at high and middle southern latitudes

Iain M. Reid*, Daniel L. McIntosh, Damian J. Murphy and Robert A. Vincent

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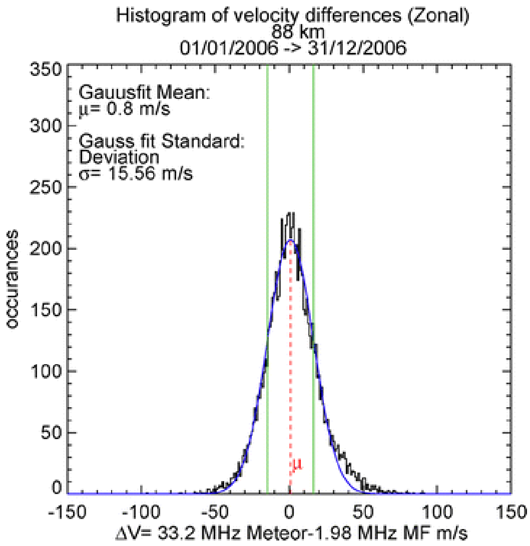
Abstract
We compare hourly averaged neutral winds derived from two meteor radars operating at 33.2 and 55 MHz to estimate the errors in these measurements. We then compare the meteor radar winds with those from a medium-frequency partial reflection radar operating at 1.94 MHz. These three radars are located at Davis Station, Antarctica. We then consider a middle-latitude 55 MHz meteor radar wind comparison with a 1.98 MHz medium-frequency partial reflection radar to determine how representative the Davis results are. At both sites, the medium-frequency radar winds are clearly underestimated, and the underestimation increases from 80 km to the maximum height of 98 km. Correction factors are suggested for these results.

Keywords: Medium-frequency partial reflection radar, Meteor radar, Davis station, Winds



Graphical abstract

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FULL PAPER **Open Access**

The Qujing incoherent scatter radar: system description and preliminary measurements

ZongHua Ding*, Jian Wu, ZhengWen Xu, Bin Xu and LianDong Dai

Earth, Planets and Space 2018, **70**, 87 DOI: 10.1186/s40623-018-0859-8
Received: 28 September 2017, Accepted: 15 May 2018, Published: 25 May 2018

Abstract
The Qujing incoherent scatter radar (QJISR), the first one in China with the geographic location (25.6°N, 103.8°E), was brought into operation since the spring of 2014. The QJISR was a mono-static pulsed radar working in the operating frequency 500 MHz, the peak power 2 Megawatt, and a 29-m steerable parabolic dish. This paper mainly presents the basic configuration and implementation of QJISR, including the antenna, transmitter, receiver, signal processing, and data analysis. Some preliminary observation results are also reported including the raw echo, power spectra, and its ionospheric parameters: electron density, electron temperature, ion temperature, and drift velocity.

Keywords: Incoherent scatter radar, Ionosphere, Echo profile, Power spectra, Electron density, Electron temperature, Ion temperature


Fig. 2

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FULL PAPER **Open Access**

Statistical study about the influence of particle precipitation on mesosphere summer echoes in polar latitudes during July 2013

Abdur Rauf, Hailong Li*, Safi Ullah, Lin Meng, Bin Wang and Maoyan Wang

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Received: 20 February 2018, Accepted: 26 June 2018, Published: 3 July 2018

Abstract

Based on experimental observations with EISCAT VHF radar during the summer period, July 8–12, 2013, the observations of polar mesosphere summer echoes (PMSE) in the absence of particle precipitation indicate that particle precipitation is not a necessary condition for PMSE to exist. But, particle precipitation still affects PMSE when they both occur simultaneously. So in this paper, the relationship between PMSE and particle precipitation both represented by average electron density, occurring simultaneously for time interval of various lengths ($t \geq 2.56$ min), is statistically analyzed using the Spearman rank and Pearson linear correlation coefficients. The new method by comparing the average electron density at altitude of 90 km (proxy of particle precipitation) and PMSE region at altitude of 80–90 km (proxy of PMSE) may compare the two phenomena directly and give some relationship between them. The percentage of events having positive values is dominant, which shows that the electron density variations due to the ionization produced by energetic particle precipitations might have some relationship with PMSE intensity. Moreover, the small percentage of negative correlation coefficient observed might be caused by the very strong precipitation at that time.

Keywords: Ionosphere (particles precipitation), Meteorology and atmospheric dynamics (precipitation), PMSE, EISCAT VHF radar

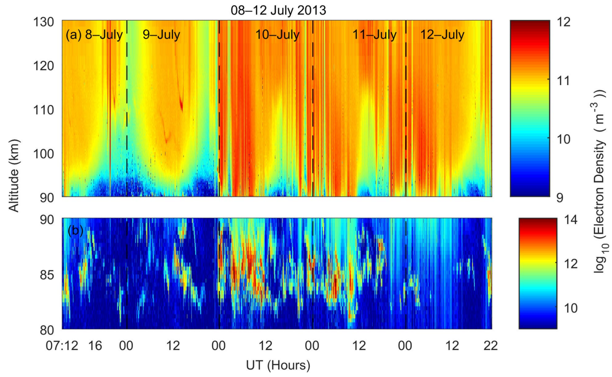

Fig. 1

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FULL PAPER **Open Access**

Tristatic observation of polar mesosphere winter echoes with the EISCAT VHF radar on 8 January 2014: a case study

Evgenia Belova*, Maria Kawnine, Ingemar Häggström, Tima Sergienko, Sheila Kirkwood and Anders Tjulin

Earth, Planets and Space 2018, **70**, 110 DOI: 10.1186/s40623-018-0878-5
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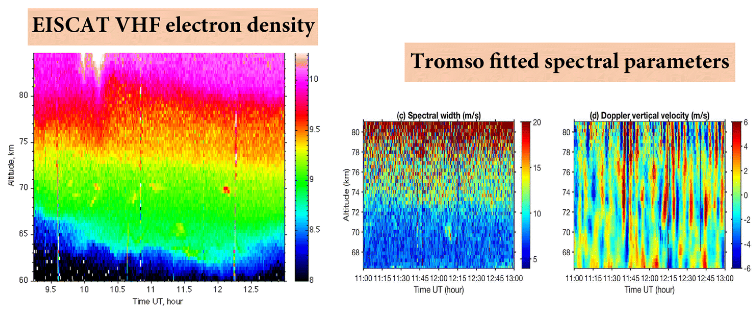
Abstract

Polar mesosphere winter echoes (PMWE) were observed at 70 km over Tromsø, Norway, on 8 January 2014 using the tristatic configuration of the European incoherent scatter VHF radar. For the interval 11:00–13:00 UT where the strongest patch of PMWE of about 6-min duration was detected, the spectra of the received signal were analysed for the Tromsø site and altitude profiles of spectral parameters were derived. For the remote sites Kiruna and Sodankylä, the Doppler velocities and their vertical shear were determined by using the measured autocorrelation functions. Ducted gravity waves with periods of 5–10 min were found in the vertical wind velocity between 66 and 81 km altitudes. The duct might be formed around 70 and 77 km altitude where horizontal wind maxima were observed with the Kiruna receiver. However, we did not find any close relation between wind shear at 70 km altitude and PMWE at the same height: the wind shear was present for 2 h, but PMWE for only 6 min. Enhanced spectral width in the vertical Tromsø beam was observed for the PMWE patch. We discussed these experimental findings in relation to the winter echo generation mechanism. Our conclusion is that the presence of patchy negatively charged small-sized dust might explain the observations although a gravity wave breaking mechanism cannot be completely rejected.

Keywords: PMWE, EISCAT, Tristatic radar measurements, Mesospheric winds and wind shear, Ducted gravity waves



Graphical abstract

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FULL PAPER Open Access

VHF radar measurements of momentum flux using summer polar mesopause echoes

Iain M. Reid*, Rüdiger Rüster, Peter Czechowsky and Andrew J. Spargo

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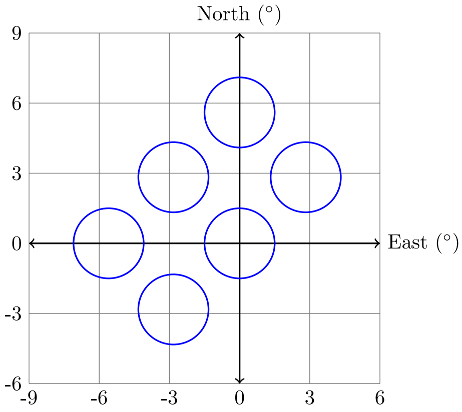
Abstract

We revisit previously unpublished analysis of observations of the dynamics of the mesopause region over the Norwegian Island of Andøya (69°N, 16°E) made during a 1-week period in summer 1987 during the Middle Atmosphere Cooperation-Summer in Northern Europe (MAC-SINE) campaign using the mobile SOUSY VHF (53.5 MHz) Doppler radar operating in a six-beam mode. We do this in the light of: (1) more recent developments in the measurement of the components of the density-normalized Reynolds stress tensor using meteor radars, and with medium-frequency partial reflection radars using the hybrid Doppler interferometric technique, and (2) satellite measurements of the absolute upward flux of horizontal momentum. We consider of the density-normalized total upward flux of horizontal momentum ($\overline{u'w'}+\overline{v'w'}$) for the 83–90 km height interval. Values of the component of the density-normalized flux for the 6 min to 12.8 h period range, after the tidal components have been removed, and the effects of the aspect sensitivity on the radar beam look directions have been accounted for vary between 5 m^2 s^{-2} below 86 km and 13 m^2 s^{-2} above 86 km. The major contribution is from the 6 to 12.8 h period range. The results of the analysis have implications for meteor radar estimates of momentum flux and also for Doppler radar measurements of the same term in the presence of aspect-sensitive scattering.

Keywords: Very high-frequency radar, Momentum flux, Polar mesosphere summer echoes



Graphical abstract

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FULL PAPER Open Access

On the role of anisotropic MF/HF scattering in mesospheric wind estimation

Toralf Renkwitz*, Masaki Tsutsumi, Fazlul I. Laskar, Jorge L. Chau and Ralph Latteck

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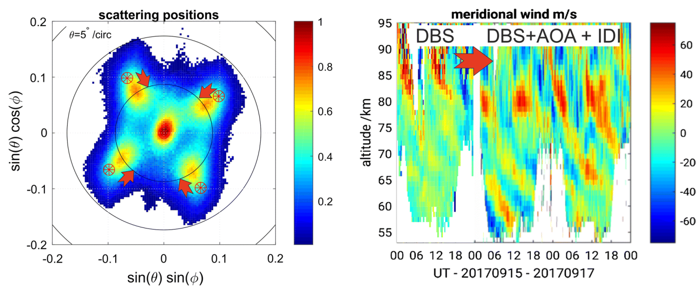
Abstract

The Saura radar is designed and used to measure winds and electron densities at polar latitudes (69°N) within the D region, namely between 50 and 100 km altitude. A relatively narrow radar beam can be generated and steered into distinct pointing directions as a rather large antenna array is used. From the observed radial velocities of the individual pointing directions, the horizontal and vertical wind fields can be obtained using the Doppler beam swinging (DBS) method. With recent upgrades to the radar, the interferometric capabilities are largely improved allowing simultaneous application of different wind estimation techniques now, and also echo localization. In recent studies, Saura DBS winds assuming isotropic scattering were found to be underestimated in comparison with highly reliable winds observed with the MAARSY MST radar in the presence of polar mesospheric summer echoes (PMSE). This underestimation has been investigated by analyzing the scattering positions as well as applying the imaging Doppler interferometry technique. Besides this, Saura winds derived with the classical DBS method seem to be error prone at altitudes above 90 km and even below this altitude for periods of enhanced ionization, e.g., particle precipitations. Various methods taking into account the scattering positions have been used to correct the wind underestimation. These winds are compared to MST radar winds during PMSE, and an optimal combination of these methods for the Saura radar is presented. This combined wind data appears to be reliable; it shows reasonable amplitudes as well as tidal structures for the entire altitude region.

Keywords: Radar, Wind estimation, D region, Interferometry, Scattering



Graphical abstract

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FULL PAPER **Open Access**

Atmospheric Kelvin–Helmholtz billows captured by the MU radar, lidars and a fish-eye camera

Hubert Luce, Lakshmi Kantha, Masanori Yabuki and Hiroyuki Hashiguchi*

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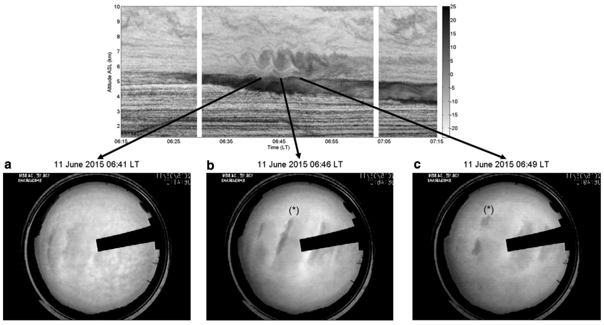
Abstract

On June 11, 2015, a train of large-amplitude Kelvin–Helmholtz (KH) billows was monitored by the Middle and Upper Atmosphere (MU) radar (Shigaraki MU Observatory, Japan) at the altitude of ~ 6.5 km. Four to five KH billows in formation and decay stages were observed for about 20 min at the height of a strong speed shear (> ~ 30 m $s^{-1}km^{-1}$), just a few hundred meters above a mid-level cloud base. The turbulent billows had a spacing of about 3.5–4.0 km (3.71 km in average) and an aspect ratio (depth/spacing) of ~ 0.3. The turbulence kinetic energy dissipation rate estimated was of the order of 10–50 $mWkg^{-1}$, corresponding to moderate turbulence according to ICAO (2010) classification. By chance, an upward-looking fish-eye camera producing pictures once every minute detected smooth protuberances at the cloud base caused by the KH billows so that comparisons of their characteristics could be made for the first time between the radar observations and the pictures. The main characteristics of the KH wave (horizontal wavelength, phase front direction and phase speed) obtained from the analysis of the pictures were fully consistent with those found from radar data. The pictures indicated that the billows were advected by the wind observed at the height of the critical level. They also revealed a very small transverse extent (about twice the horizontal spacing) suggesting that the large-amplitude KH billows were generated by a very localized source. Micro-pulse lidar and Raman–Rayleigh–Mie lidar data also collected during the event permitted us to confirm some of the characteristics of the billows.

Keywords: Kelvin–Helmholtz instability, Turbulence, Kelvin–Helmholtz billows, Wind shear, Kinetic energy dissipation rate, MU radar



Graphical abstract

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FULL PAPER **Open Access**

Stratospheric tropospheric wind profiling radars in the Australian network

Bronwyn K. Dolman*, Iain M. Reid and Chris Tingwell

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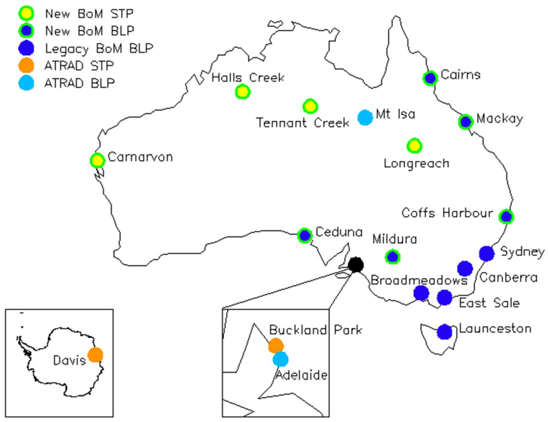
Abstract

The Australian Government Bureau of Meteorology completed the installation of a network of 9 new wind profiling radars across mainland Australia in 2017, which complement an existing network of 5 profilers and 5 research systems. This results in a network of 14 operational, and 19 total, profilers across Australia and Davis Station in Antarctica. Four of the new profilers are higher power stratospheric tropospheric systems, designed to measure winds from near ground level to the tropopause, and maintain the upper air network in Australia where sonde launches are no longer available. Wind measurements in the near field of the radar are demonstrated to be both possible and accurate by comparison with co-located radiosondes. Quality control procedures producing winds of sufficient accuracy for presentation to forecasters and ingestion into global numerical weather prediction models are described. The Australian network data are available on the global telecommunications system and are currently being ingested into all major models. First results from impact studies on forecast error reduction in the Australian Community Climate and Earth Systems Simulator show remote stations have the greatest impact.

Keywords: Stratospheric tropospheric wind profilers, Wind measurements, Forecast error impacts



Graphical abstract

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FULL PAPER **Open Access**

On a numerical model for extracting TKE dissipation rate from very high frequency (VHF) radar spectral width

Lakshmi Kantha, Hubert Luce and Hiroyuki Hashiguchi*

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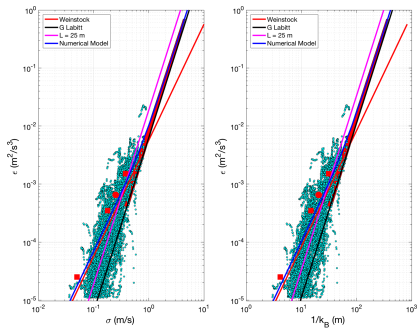
Received: 26 June 2018, Accepted: 13 November 2018, Published: 24 December 2018

Abstract

The standard model (e.g., Hocking in Earth Planets Space 51:525–541, 1999), $\varepsilon = c_0\sigma^2 N$, (where σ is the radar spectral width assumed to be equal to vertical turbulence velocity fluctuation $\sqrt{\overline{w^2}}$, N is the buoyancy frequency, and c_0 is a constant), derived from Weinstock (J Atmos Sci 35:1022–1027, 1978; J Atmos Sci 38:880–883, 1981) formulation, has been used extensively for estimating the turbulence kinetic energy (TKE) dissipation rate ε under stable stratification from VHF radar Doppler spectral width σ. The Weinstock model can be derived by simply integrating the TKE spectrum in the wavenumber space from the buoyancy wavenumber $k_B = \frac{N}{\sigma}$ to ∞. However, it ignores the radar volume dimensions and hence its spatial weighting characteristics. Labitt (Some basic relations concerning the radar measurements of air turbulence, MIT Lincoln Laboratory, ATC Working Paper NO 46WP-5001, 1979) and White et al. (J Atmos Ocean Technol 16:1967–1972, 1999) formulations do take into account the radar spatial weighting characteristics, but assume that the wavenumber range in the integration of TKE spectrum extends from 0 to ∞. The White et al. model accounts for wind speed effects, whereas the other two do not. More importantly, all three formulations make the assumption that $k^{-5/3}$ spectral shape of TKE spectrum extends across the entire wavenumber range of integration. It is traditional to use Weinstock formulation for $k_B^{-1} < 2a, 2b$ (where a and b are radar volume dimensions in the horizontal and vertical directions) and White et al. formulation (without wind advection) for $k_B^{-1} > 2a, 2b$. However, there is no need to invoke these asymptotic limits. We present here a numerical model, which is valid for all values of buoyancy wavenumber k_B and transitions from $\varepsilon \sim \sigma^2$ behavior at lower values of σ in accordance with Weinstock's model, to $\varepsilon \sim \sigma^3$ at higher values of σ, in agreement with Chen (J Atmos Sci 31:2222–2225, 1974) and Bertin et al. (Radio Sci 32:791–804, 1997). It can also account for the effects of wind speed, as well the beam width and altitude. Following Hocking (J Atmos Terr Phys 48:655–670, 1986, Earth Planets Space 51:525–541, 1999), the model also takes into account contributions of velocity fluctuations beyond the inertial subrange. The model has universal applicability and can also be applied to convective turbulence in the atmospheric column. It can also be used to explore the parameter space and hence the influence of various parameters and assumptions on the extracted ε values. In this note, we demonstrate the utility of the numerical model and make available a MATLAB code of the model for potential use by the radar community. The model results are also compared against in situ turbulence measurements using an unmanned aerial vehicle (UAV) flown in the vicinity of the MU radar in Shigaraki, Japan, during the ShUREX 2016 campaign.

Keywords: VHF radar, MU radar, Unmanned aerial vehicles (UAV), Turbulence kinetic energy (TKE), TKE dissipation rate, Radar model, Stably stratified flows, Inertial subrange, Buoyancy subrange, Viscous subrange, Troposphere, Buoyancy scale, Ozmidov scale, Viscous scale, Convective turbulence, Convection, Numerical model



Graphical abstract

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FULL PAPER **Open Access**

Turbulence kinetic energy dissipation rates estimated from concurrent UAV and MU radar measurements

Hubert Luce, Lakshmi Kantha, Hiroyuki Hashiguchi*, Dale Lawrence and Abhiram Doddi

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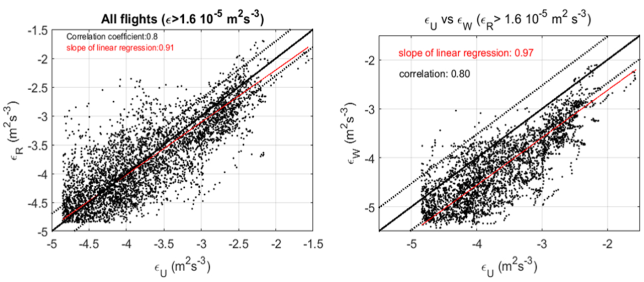
Abstract

We tested models commonly used for estimating turbulence kinetic energy dissipation rates ε from very high frequency stratosphere–troposphere radar data. These models relate the root-mean-square value σ of radial velocity fluctuations assessed from radar Doppler spectra to ε. For this purpose, we used data collected from the middle and upper atmosphere (MU) radar during the Shigaraki unmanned aerial vehicle (UAV)—radar experiment campaigns carried out at the Shigaraki MU Observatory, Japan, in June 2016 and 2017. On these occasions, UAVs equipped with fast-response and low-noise Pitot tube sensors for turbulence measurements were operated in the immediate vicinity of the MU radar. Radar-derived dissipation rates ε estimated from the various models at a range resolution of 150 m from the altitude of 1.345 km up to the altitude of ~ 4.0 km, a (half width half power) beam aperture of 1.32° and a time resolution of 24.6 s, were compared to dissipation rates (ε_U) directly obtained from relative wind speed spectra inferred from UAV measurements. Firstly, statistical analysis results revealed a very close relationship between enhancements of σ and ε_U for $\varepsilon_U \gtrsim 10^{-5} m^2 s^{-3}$, indicating that both instruments detected the same turbulent events with ε_U above this threshold. Secondly, ε_U was found to be statistically proportional to σ^3, whereas a σ^2 dependence is expected when the size of the largest turbulent eddies is smaller than the longitudinal and transverse dimensions of the radar sampling volume. The σ^3 dependence was found even after excluding convectively generated turbulence in the planetary boundary layer and below clouds. The best agreement between ε_U and radar-derived ε was obtained with the simple formulation based on dimensional analysis $\varepsilon = \sigma^3/L_c$ where $L_C \approx$ 50–70 m. This empirical expression constitutes a simple way to estimate dissipation rates in the lower troposphere from MU radar data whatever the sources of turbulence be, in clear air or cloudy conditions, consistent with UAV estimates.

Keywords: VHF radar, Unmanned aerial vehicle, Atmospheric turbulence, Energy dissipation rate, Outer scales of turbulence, Doppler variance



Graphical abstract

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EXPRESS LETTER Open Access

Spatial distribution of errors associated with multistatic meteor radar

W. K. Hocking

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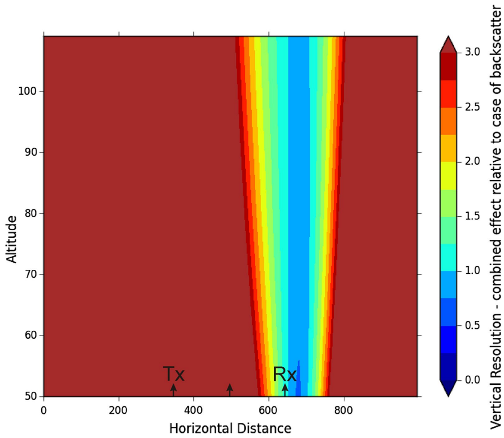
Abstract

With the recent increase in numbers of small and versatile low-power meteor radars, the opportunity exists to benefit from simultaneous application of multiple systems spaced by only a few hundred km and less. Transmissions from one site can be recorded at adjacent receiving sites using various degrees of forward scatter, potentially allowing atmospheric conditions in the mesopause regions between stations to be diagnosed. This can allow a better spatial overview of the atmospheric conditions at any time. Such studies have been carried out using a small version of such so-called multistatic meteor radars, e.g. Chau et al. (Radio Sci 52:811–828, 2017, https://doi.org/10.1002/2016rs006225). These authors were able to also make measurements of vorticity and divergence. However, measurement uncertainties arise which need to be considered in any application of such techniques. Some errors are so severe that they prohibit useful application of the technique in certain locations, particularly for zones at the midpoints of the radars sites. In this paper, software is developed to allow these errors to be determined, and examples of typical errors involved are discussed. The software should be of value to others who wish to optimize their own MMR systems.

Keywords: Radar, Meteor, Errors, Multistatic, Specular, Reflection, Scatter



Graphical abstract

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TECHNICAL REPORT Open Access

Survey of conditions for artificial aurora experiments at EISCAT Tromsø using dynasonde data

T. T. Tsuda*, M. T. Rietveld, M. J. Kosch, S. Oyama, K. Hosokawa, S. Nozawa, T. Kawabata, A. Mizuno and Y. Ogawa

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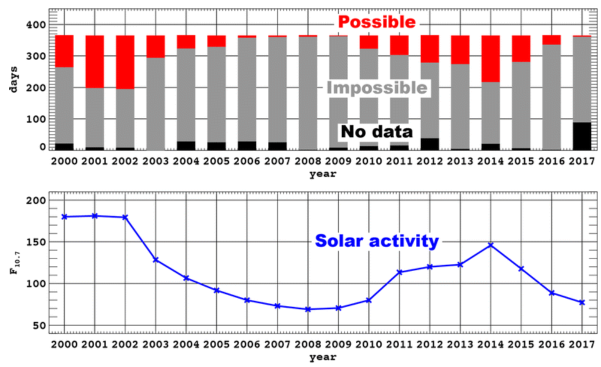
Abstract

We report a brief survey on conditions for artificial aurora optical experiments in *F* region heating with O-mode at the EISCAT Tromsø site using dynasonde data from 2000 to 2017. The results obtained in our survey indicate the following: The possible conditions for conducting artificial aurora experiments are concentrated in twilight hours in both evening and morning, compared with late-night hours; the possible conditions appear in fall, winter, and spring, while there is no chance in summer, and the month-to-month variation among fall, winter, and spring is not clear. The year-to-year variation is well correlated with the solar cycle, and experiments during the solar minimum would be almost hopeless. These findings are useful for planning future artificial aurora optical experiments.

Keywords: Artificial aurora, Ionospheric heating, EISCAT, Tromsø, Dynasonde



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TECHNICAL REPORT Open Access

Survey of conditions for artificial aurora experiments by the second electron gyro-harmonic at EISCAT Tromsø using dynasonde data

T. T. Tsuda*, M. T. Rietveld, M. J. Kosch, S. Oyama, Y. Ogawa, K. Hosokawa, S. Nozawa, T. Kawabata and A. Mizuno

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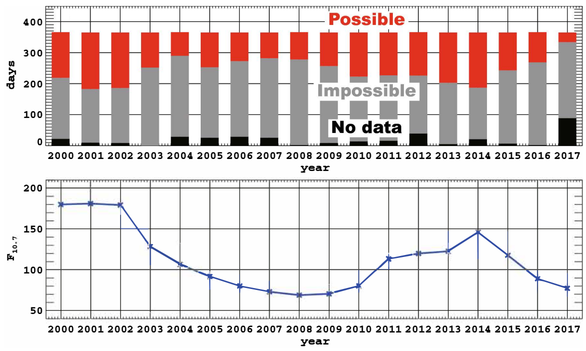
Abstract

We report a brief survey of matching conditions for artificial aurora optical experiments utilizing the second electron gyro-harmonic (2.7-MHz frequency) in *F* region heating with O-mode at the EISCAT Tromsø site using dynasonde data from 2000 to 2017. Our survey indicates the following: The possible conditions for successful artificial aurora experiments are concentrated on twilight hours in both evening and morning, compared with late night hours; the possible conditions appear in fall, winter, and spring, while there is no chance in summer, and the month-to-month variation among fall, winter, and spring is not so clear; the year-to-year variation is well correlated with the solar activity. These characteristics in the case of 2.7-MHz frequency are basically similar to those previously reported in the case of 4-MHz frequency. However, the number of days meeting the possible condition in the case of 2.7-MHz frequency is obviously large, compared with that in the case of 4-MHz frequency. In particular, unlike the 4-MHz frequency operation, the 2.7-MHz frequency operation can provide many chances for successful artificial aurora experiments even during the solar minimum.

Keywords: Artificial aurora, Ionospheric heating, Second electron gyro-harmonic, EISCAT, Tromsø, Dynasonde



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Correspondence

If you have any questions, please contact info@springeropen.com.

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