The contribution of extratropical cyclones to precipitation formation in the Russian Federation

Akperov M.[1], Gnatiuk N.[2], Radchenko I.[2], Semenov V.[1]

[1]A.M. Obukhov Institute of Atmospheric Physics, RAS, Moscow, Russia
[2]Nansen Center, Saint Petersburg, Russia

*aseid@ifaran.ru

Using ERA5 reanalysis data for the period 1998–2024, we quantified the seasonal and regional patterns and changes in cyclone activity in the Northern Hemisphere atmosphere, and determined the contribution of extratropical cyclones to the formation of corresponding patterns and precipitation changes. We found that extratropical cyclones contribute over 60% to the total amount of precipitation; in regions with a high cyclone frequency, this figure rises to 75% in winter and 65% in summer. Intense cyclones contribute the most, accounting for 60% of winter precipitation and 35% of summer precipitation.
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Keywords: ERA5, cyclones, precipitation, Russia

Weather Regimes in Northern Eurasia: Statistics, Predictability and Associated Weather Anomalies

Babanov B.A.[1] , Semenov V.A.[1,2]

[1.]A.M. Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences, 119017 Moscow, Russia
[2] Institute of Geography, Russian Academy of Sciences, 119017 Moscow, Russia

babanov@ifaran.ru

This study applies a weather regimes approach to analyze large-scale circulation patterns over North Eurasia (0–180° E, 40–80° N) for the 1940–2022 period using the ERA5 reanalysis data. Four weather regimes (WRs) were identified for both boreal winter and summer via k-means clustering of daily 500-hPa geopotential height fields. Winter WRs show no significant long-term trends in occurrence, while three summer WRs exhibit statistically significant linear trends, including a +2.4 days per decade increase for the Summer Ural High regime linked to anticyclonic activity over the Ural Mountains. Both seasons feature loops of significant WRs transitions, indicating non-random evolution along preferred paths. WRs occurrences vary with El Niño phases and Northern Hemisphere sea-ice anomalies in prior seasons: autumn El Niño increases Winter Scandinavian Blocking occurrence but reduces Winter North Eastern High; negative autumn sea-ice anomalies increase Winter Ural High while decreasing Winter Scandinavian Low. NE WRs are associated with substantial (up to several-fold) shifts in the probability of regional temperature and precipitation extremes.

Climate risks in Russian regions

Chernokulsky A.V.[1,2,3]
[1] A.M. Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences, Moscow, Russia
[2] Institute of Geography, Russian Academy of Sciences, Moscow, Russia
[3] HSE University, Moscow, Russia

a.chernokulsky@ifaran.ru

A simplified heuristic approach that uses the hazard-exposure-vulnerability framework to assess climate risks in Russia is proposed [1]. In particular, 27 climate and socio-economic indicators are proposed to calculate five key risk: heatwaves affecting urban population, water stress impacting agriculture, wildfires threatening forestry and ecosystems, extreme precipitation endangering population and infrastructure, and permafrost degradation affecting population, housing and utilities. Russian regions are ranked for key climate risks under different climate scenarios. Contribution of each component to the overall risk level is estimated. Regions with high levels of multiple risks highlighted as most in need of adaptation. The results demonstrate the uneven allocation of climate risks across Russian territory. Russia's southwest faces primarily risks related to heatwaves and water stress, the northeast deals with the risks associated with permafrost and forest fires, while the southeast faces mainly with flood-related risks. Regions having multiple overlapping risks are identified, emphasising the importance of integrated adaptation strategies to address the potential nonlinear impacts of these risks.

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Climate Change Projections over High Latitudes Northern Asia Using a Regional Climate Model

Gao X.[a], Tang X.[a], Han Z.[b]

[a] *CCRC, IAP, Chinese Academy of Sciences, Beijing, China*
[b] *National Climate Center, China Meteorological Administration, Beijing, China*

A regional climate model, the Abdus Salam International Centre for Theoretical Physics (ICTP) Regional Climate Model version 5, RegCM5, is used to investigate future climate changes over high latitudes Northern Asia, a region very sensitive to the global warming but relatively less studied. Tests have been firstly conducted to customize the model configuration for the better performances over the region. In the climate change simulations, RegCM5 is driven by three CMIP6 global climate models of MPI-ESM1-2-HR, EC-Earth3-Veg, and NorESM2-MM, respectively, for the periods of 1995-2014 (the present day) and 2080-2099 (the end of the 21st century) under SSP2-4.5 pathway. Validation of the present day simulations show good model performances in reproducing the spatial distribution and too a less extent, the amount for both temperature and precipitation. The model shows large warm biases during DJF but cold biases during JJA in northeastern part of the region. A general overestimation for precipitation in both seasons is found. Biases of RegCM5 show agreements to the GCMs, but to a larger magnitude. General warming is projected by both GCM and RegCM5. For precipitation changes, in DJF, while large increase is projected by the GCMs, slight change to decrease is projected by RegCM5. A drier condition is also projected by RegCM5 during JJA, leading to the overall decrease for the annual mean. Further analysis is underway to investigate the underlying mechanism behind.

Key words Regional climate model, Climate change simulations, Mid-high latitudes Northern Asia

Source, transport, deposition and direct radiative effect of mineral dust over western China in summertime

Han Z., Liang L., Chen W., Li J., Liang M., Shen S.

State Key Laboratory of Earth System Numerical Modeling and Application (NLESM)
Institute of Atmospheric Physics, Chinese Academy of Sciences (IAP, CAS)

A Regional Air Quality Model System (RAQMS) driven by WRF was applied to explore the emission, transport, deposition, and direct radiative effect of mineral dust over western China in July 2022, with the focus on Tibetan Plateau (TP). A dust event originated from the Taklimakan Desert (TKD) influenced eastern and central TP by the clockwise circulation during 3–7 July 2022, resulting in the maximum hourly PM_{10} concentration exceeding 50 μg m^{-3} in Lhasa. Shortwave radiation was reduced considerably by dust aerosols over eastern TP, with the maximum decrease in daily mean shortwave radiation reaching 30 W m^{-2} around Nyingzhi on 5 July. Anthropogenic aerosols dominated PM_{10} mass in the capital cities of western China (54~67%), while dust aerosols were dominant in the cities near the deserts. On 5-7 July, dust aerosols from TKD and Qaidam Desert (QDD) significantly influenced eastern TP, with dust contributions to PM_{10} mass of 52%, 76% and 69%, respectively, in Chamdo, Lhasa and Nyingchi. The total dust emission in western China was about 10.6 Tg in July 2022, with the largest contribution from TKD (63.5%), followed by Gobi Desert (GB) (26%). The total deposition of dust was estimated to be 6.2 Tg, in which TKD and GB contributed 66% and 22%, respectively. During the study period, about 418 Gg dust aerosols were deposited on TP, 49% of which was from TKD and 25% from QDD. Foreign dust sources contributed approximately 9% to total deposition on TP. Over southern TP, the source contribution to dust deposition was estimated to be 42%, 24% and 21% from TKD, foreign sources and QDD, respectively, suggesting important impact of long-range transboundary dust transport on deposition, surface albedo and climate over TP.

Aeroelectric structures in the dust aerosol emission

Malinovskaya E.A., Chkhetiani O.G.
A.M. Obukhov Institute of Atmospheric Physics RAS, Moscow, Russia

Along with the known mechanisms of space charge redistribution in the surface layer (electrode effect, aerosol electrification by ion adsorption, thunderstorm activity [Pawar, 2010]), electrification events are observed caused by the passage of a dust storm (snow storm) or dust vortex [Stow, 1969], dust emissions during volcanic eruptions [Aizawa, 2010]. There are surges in the electric field strength, with the opposite direction of the planetary electric field strength [Lacks, 2011] (and more complex local changes [Williams, 2009; Zhang, 2020]), which is associated with a change in charge and redistribution of large and small particles with opposite charges by height. At moderate wind velocity, saltations (bouncing) of particles near the impact surface facilitate electron transfer via tunneling [Kok & Lacks, 2009]. Large particles on the surface acquire a positive charge [Esposito et al., 2016; Schmidt et al, 1998; Stow, 1969], and dust particles shaken off them carry away a negative charge [Kok & Renno, 2008; Bo et al., 2013; Stow, 1969].

This paper presents an analysis of the data of temperature and wind velocity (1000 Hz), electric field strength (100 Hz), and dust aerosol concentration (10 Hz) measurements in arid conditions (2022-2024). Its allow us to reveal the coherent structures that permanently emerge here [Malinovskaya, 2024]. Synchronisation of fluctuations in aerosol concentration, temperature and electric intensity are observed. Correlations for their averaged values are also persistently observed.

For the spectra of temperature, velocity, concentration, and electric field strength, in addition to the known slope -5/3, other slopes -1, -3, and -1/3 associated with convective processes and structures are observed.

The following characteristic scales were determined at the bending points of the spectra taking into account the values of wind velocities at the height of measurements: for velocity pulsations it is 0.2 m (time scale 0.03 s), for dust aerosol concentration it is 0.7 m (time scale 0.1 s), for temperature it is 2.7 m (time scale 0.46 s), for electric field strength it is 5.3 m (time scale 0.9 s).

As a result, the study of the dynamics of changes on different time scales allows the detection of aeroelectric structures.

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. Study of mesoscale atmospheric circulation in marine cold-air outbreaks in the Arctic using observations from the v/s "Akademik Nikolay Strakhov" 2021

[1] Marchuk E., [1] Chechin D., [1,2] Repina I.,[1,2] Artamonov A. [1]

[1] *Obukhov Institute of Atmospheric Physics, Moscow, Russia*
[2] *Lomonosov Moscow State University Research Computing Center, Moscow, Russia*

murchuk-ekaterin@mail.ru

Key words: Cold air outbreaks, satellite and in site measurements.

Cold air outbreaks, characterized by the advection of cold Arctic or continental air masses over ice-free ocean surfaces, are significant meteorological phenomena during the cold season. These events induce substantial energy exchange between the atmosphere and the ocean due to pronounced air-sea temperature differences (Myslenkov et al. 2021). During such cold invasions, various mesoscale circulations, ranging in genesis and scale from convective cells and instability lines to ice breezes and mesocyclones, are observed to form over the ocean. These mesoscale circulations critically influence the spatio-temporal heterogeneity of surface wind speed, heat fluxes, and momentum transfer [Chechin, Pichugin, 2015]; however, their intrinsic characteristics and genesis mechanisms remain incompletely understood.

This study investigates the characteristics of convective cells, including their associated amplitudes and horizontal scales of variability in wind speed, air temperature, and turbulent momentum and heat fluxes. The estimations are derived from data collected during the R/V Akademik Strakhov voyage along the Arkhangelsk-Kaliningrad route in November 2021, supplemented by Sentinel-1 satellite Synthetic Aperture Radar imagery. Specifically, wind speed fields obtained from satellite imagery are analyzed to quantify the scale and amplitude of wind variability associated with convective cells formed during cold air outbreaks. These satellite-derived estimates are subsequently validated against concurrent in-situ measurements acquired aboard the research vessel. This work was supported by the Russian Science Foundation under grant 25-17-00060.

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Factors contributing to extreme surface temperature over the European part of Russia during the 2010 heatwave

Morgunova A.A.[1,2] *, Semenov V.A.*[1,2]

[1.] A.M. Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences, 119017 Moscow, Russia
[2] Institute of Geography, Russian Academy of Sciences, 119017 Moscow, Russia

The 2010 mega-heatwave was the most intense event ever recorded over the European part of Russia, with temperature records set across many regions that remain unbroken to this day. However, the mechanisms responsible for the development of such extreme surface air temperatures are not yet fully understood. This study investigates the key drivers of temperature extremes by analyzing surface heat flux balances, as well as the components of the temperature tendency equation throughout the atmospheric column, and discusses the role of different processes in shaping exceptionally high temperatures. The results show that in 2010 the record-breaking temperatures were made possible by the combined effect of diabatic heating and the advection of warm air masses from regions located to the southeast.

Modeling of atmospheric air pollution in a mountain area near Kislovodsk using the Chimere chemical transport model

Nakhaev M.

IAP, Russian Academy of Sciences, Moscow, Russia

In this study, high-resolution data in both time and space were utilized to obtain a more accurate and detailed picture of the atmospheric air quality in the Kislovodsk region. Instrumental measurements of two key pollutants - CO and O3 - were collected at the automated air quality monitoring station located at the Kislovodsk. These data feature a high temporal resolution, allowing for the analysis of short-term fluctuations and the identification of patterns in pollution dynamics. Additionally, vertical profiles of air temperature in the lower 1000 meters of the atmosphere were measured. This enabled the detection of key features of temperature stratification, such as ground-level and elevated inversions, as well as isothermal conditions, which significantly influence dispersion and transport processes of pollutants. The research employed the Chimere chemical transport model, integrating meteorological input data from the WRF-ARW model. The calculations were performed in an online mode without considering feedback effects, simulating air quality for each day over the period from January 1 to March 31, 2025. The study confirmed that the Chimere model is a reliable tool for atmospheric quality monitoring, and when fine-tuned to account for pollution sources, seasonal and diurnal variations, it can provide a more detailed picture of the spatial distribution of pollutants. As a result, quantitative assessments of pollution levels were obtained, revealing key features of air pollution in the region. For most of the modeling area, the contribution of orographic factors ranged from 25 to 50%. Additionally, the influence of the "aerodynamic chimney" effect was discovered, which promotes a reduction in pollution levels in the Podkumok River valley and the western parts of Kislovodsk.

Key words: Chemical transport model, Atmospheric pollution, Air quality

Cloud-radiative effect in the Arctic: a comparison of CMIP6 models and CERES satellite data

Narizhnaya A.I. [1], Latonin M.M. [1,2], Timazhev A.[1], Chernokulsky A.V.[1,3]

[1] A.M. Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences, Moscow
[2] Nansen International Environmental and Remote Sensing Centre, Saint Petersburg
[3] Institute of Geography, Russian Academy of Sciences, Moscow

alex.narihnaya@ifaran.ru

The Arctic climate is changing dramatically in recent decades. Arctic clouds are both changing themselves and influencing on changes in other variables. Despite their importance, cloud properties are still imperfectly simulated by climate models, which should be validated against observations.

This paper presents a comparative analysis of cloud properties based on model and satellite observations over the high Arctic waters (north of 65°N). We estimated properties such as cloud total fraction (CLT, %), longwave and shortwave radiative fluxes at the surface, W m^{-2} (LWR and SWR, respectively) and cloud-radiative effect, W m^{-2} (CRE), which characterises the effect of clouds on the radiative fluxes in the atmosphere and is defined as the difference between the radiative fluxes in the presence of clouds and in a cloudless atmosphere. We used model data from the Coupled Model Intercomparison Project (CMIP6) and satellite data from NASA's Clouds and the Earth's Radiant Energy System (CERES) project. The analysis was performed for cold (January to March) and warm (July to September) seasons. Cloud variables were calculated for different sea ice conditions, depending on sea ice concentration (SIC), namely, for open water (SIC<5%), transient sea ice concentration (5%≤SIC≤95%) and solid ice (SIC>95%).

We found that models show much stronger interannual variability (both in winter and in summer, both for SWR and for LWR fluxes, and both over ice and over water) than observations. The largest biases in both CLT and CRE are found over the solid sea ice concentration during the winter season. The better agreement between models and observations was found for longwave CRE over open water during the summer season, with a spread of ~20 W m^{-2} in general. The models were found to contribute to a cooling of the Arctic lower atmosphere in the summer and a warming in the winter. The spatial correlation between modelled and observed data for both CLT and CRE is higher (more consistent) in summer, with some models showing negative correlation values for the winter season). The 'best' models have been highlighted that aligned with CERES in assessing the spatial distribution of long-term mean cloud characteristics and assessing the interannual variability of the Arctic mean cloud characteristics.

A performance evaluation of various cloud and radiation schemes, based on the consistency between model and observational data, revealed that models utilizing the Rapid Radiative Transfer Model for GCMs (RRTM-G) and Community Atmosphere Model (CAM) family models are the most successful in representing the spatial pattern and interannual variability of mean CRE and cloud-related parameters (CLT) over the Arctic.

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The influence of the underlying surface structure in the Arctic on exchange processes in the atmospheric surface layer

Repina I.A.[1,2], Zhou L.[3], Chechin D.G.[1]

[1]A.M. Obukhov Institute of Atmospheric Physics, Russian Academy of Science, Moscow, Russia
[2]Lomonosov Moscow State University, Research Computing Center, Moscow, Russia
[3]Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China

Based on measurements of the turbulent structure of the atmospheric surface layer above various surfaces typical of the Arctic, the influence of the underlying surface on exchange processes is investigated. The surfaces of glaciers and two types of tundra are considered. Exchange coefficients and the roughness parameter are determined for each type. In the case of tundra, the influence of surface humidity is investigated.
The measurements carried out showed the significant role of the relief in the formation of wind and temperature conditions in the coastal regions of Svalbard and the significant contribution of glaciers to the formation of the heat balance in summer.

Strong negative summer sea ice area anomalies in the Arctic in observations and CMIP6 models during the modern period

Romanenko V.A[1]., Semenov V.A.[1,2]

[1.] A.M. Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences, 119017 Moscow, Russia
[2] Institute of Geography, Russian Academy of Sciences, 119017 Moscow, Russia

Changes in the area of Arctic sea ice were studied according to the CMIP6 project climate models and ERA5 reanalysis data. Most models reproduce a rather drastic reduction in the area of the ice sheet by 2020. Some models show that by the end of the period under review, a significant part of the Arctic will become ice-free. The zone of the most accelerated melting is observed in the East Siberian and North American waters of the Arctic. The average area of sea ice reproduces a close to linear negative trend over the period 1980-2020 and does not demonstrate accelerated melting at the beginning of the 20th century. At this paper the record minima of sea ice area in September 2012, along with similar minima in climate models for the same period was analysed. It was found that both the observed and modeled sea ice minima are associated with a certain atmospheric circulation in the previous August – a pressure dipole with a cyclone over the Arctic Ocean and an anticyclone over the North Pacific Ocean. Such circulation contributed to the accelerated melting of sea ice both dynamically and thermodynamically. In this paper, the influence of the contribution of anomalies of various meteorological fields on the magnitude of the ice area anomaly in the Arctic in certain years is analyzed. According to earlier studies, the sharp reduction in ice area in 2012 could also be influenced by the increased advection of warmer waters into the Arctic through the straits. The distribution of the periods of minimum ice area in the Arctic by year according to CMIP6 models for 1980 – 2024 shows that most models reproduce the minimum ice area after 2020. Since the 2030s, most models have demonstrated accelerated melting of the ice sheet.

Arctic sea ice changes: anthropogenic versus natural variations

Semenov V.A., Aldonina T.A.

A.M. Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences, Pyzhevsky 3, 119017 Moscow, Russia

Institute of Geography, Russian Academy of Sciences, Staromonetny 29, 119017 Moscow, Russia

The shrinking Arctic sea ice area (SIA) in recent decades is a striking manifestation of the ongoing climate change. The sea ice area has been declining by about 13% per decade in summer for the last four decades, suggesting a seasonally ice free Arctic in some 15-20 years from the present. Climate models forced by anthropogenic GHG emissions in general reproduce the observed decline, also showing a perspective of an ice free Arctic in the close future.

However, there are some puzzling evidence from the historical past and from the recent sea ice variations that point to some gaps in our understanding Arctic sea ice variability mechanisms and a relative role of anthropogenic versus natural contribution to the recent sea ice decline.

Here, we discuss these features consisting of the record minimum of the September Arctic sea ice in 2012 that has not yet been beaten until present and the large sea ice decline during the middle of the 20th century, which was comparable to the present decline and was presumably caused by a natural variation.

Methane in the western part of Eurasian Arctic in late autumn 2023: AMK-93 observations and model simulation

Shtabkin Yu.A. [1], Moiseenko K.B. [1], Vasileva A.V. [1], Belikov I.B. [1], Belousov V.A. [1], Kravchishina M.D. [2], Pestunov D.A. [3]

[1]*A.M. Obukhov Institute of Atmospheric Physics of Russian Academy of Sciences*
[2]*P.P. Shirshov Institute of Oceanology of Russian Academy of Sciences*
[3]*V.E. Zuev Institute of Atmospheric Optics Russian Academy of Sciences, Siberian Branch*

Methane (CH4) is the second most important greenhouse gas in atmosphere after carbon dioxide (CO2). Since 2005, according to measurements, there has been a noticeable increase in near-surface methane concentration. This phenomenon is especially strong in Arctic. Unfortunately, data of surface methane concentrations are extremely limited for this region, it makes it difficult to quantify the impact of emissions from the most important regional anthropogenic and biogenic sources. This gap is partially filled by long-term observations at Arctic and subarctic monitoring stations, as well as by measuring companies during expeditions on research vessels.
This paper presents the results of continuous measurements of methane and carbon dioxide concentration, and isotope δ13CCH4 in atmospheric bottom layer over the waters of Kara and Barents Seas during the 93rd expedition of RV Akademik Mstislav Keldysh (AMK-93), November 08 – December 07, 2023. In addition, data obtained were compared with regional chemical climate model WRF-Chem calculations and model fields of surface methane content for certain regions of the Russian Arctic were shown. Model estimates of methane fluxes from sea surface have been made for Baydaratskaya Bay area and compared with observations conducted during the expedition.

Flux tower measurements in Russian and Chinese cities in the context of urban parameterization for weather and climate models

Varentsov M.I. [1,2], Repina I.A. [2,1], Tarasova M.A. [1,2], Artamonov A.Yu. [2], Drozd I.D.[2], Stepanenko V.M. [1], Telminov A.E. [3], Kobzev A.A. [3], Zhou L. [4]

[1]Lomonosov Moscow State University, Research Computing Center, Moscow, Russia
[2]A.M. Obukhov Institute of Atmospheric Physics, Russian Academy of Science, Moscow, Russia
[3]Institute of Monitoring of Climatic and Ecological Systems, Siberian Branch of the Russian Academy of Sciences, Tomsk, Russia
[4]Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China

To take into account the influence of cities on atmospheric processes, so-called urban parameterizations are used in weather and climate forecast models. To date, a large number of such parameterizations of varying complexity have been developed, many of which have been implemented in atmospheric models. Large international projects on mutual comparison and verification of urban parameterizations are being carried out.

For verification and calibration of urban parameterizations, the most valuable are observations of the characteristics of the energy exchange of the atmosphere with the surface - heat, moisture and momentum flows - quantities that parameterizations must calculate and transfer to the atmospheric model. Such observations are carried out on masts above the roof level, and are extremely rare. Thus, in the latest international project on comparing urban parameterizations, Urban Plumber, it was possible to collect a data set only for 20 urban masts, which does not represent the continental part of Northern Eurasia, including the territories of Russia and China.

The report presents the first results of the work on collecting, systematizing and analyzing the few observations of turbulent energy exchange of urban landscapes with the atmosphere in Northern Eurasia. The data from the micrometeorological mast at the Lomonosov Moscow State University meteorological observatory in Moscow, the Tomskfluxnet pulsation measurement network in Tomsk and its suburbs, and the meteorological masts of the IFA PRC in Beijing and its suburb of Xianghe were used. The uniqueness of the data for Tomsk and Beijing lies in the possibility of comparing the characteristics of the interaction of the atmosphere with the surface for urban and background conditions. Significant (tens of percent) differences in heat and momentum fluxes between urban and background points are shown. The first experience of comparing observational data and modeling results is obtained, promising areas for further research are determined.

A technique for simulating the propagation of acoustic waves and detecting infrasound

Zakirov M.N.[1], Kulichkov S.N.[1], Chulichkov A.I.[1], Chunchuzov I.P.[1], Popov O.E.[1], Bush G.A.[1], Tsybulskaya N.D.[1], Golikova E.V.[1]

[1] A.M. Obukhov Institute of Atmospheric Physics of the Russian Academy of Sciences, 119017, Moscow, Pyzhevsky lane 3

The report presents a new method for calculating the trajectory of acoustic rays in the atmosphere using meteorological weather data (temperature and wind directions) based on the GFS model and taking into account the relief of the underlying Earth's surface. The method makes it possible to quantify the time of sound propagation between two arbitrary points of the Earth, and determine the shape of the wavefront. As an example, the paper shows the result of modeling the propagation of infrasound during the eruption of the Honga-Tonga volcano in the Pacific Ocean to the IS43 infrasound international monitoring station (Ryazan). The calculation method is based on sequentially calculating the average sound speed and wind direction at each point of the trajectory, finding the geometric set of points that the signal manages to reach in a small-time step, and repeating this procedure for the found points, and iteratively updating the wavefront with the removal of internal points to optimize calculations. In this way, a graph is constructed, the vertices of which determine the position of the trajectory point and information about the time the signal traveled to it, and the edges determine the connections between them. The results of comparing calculations by the proposed method with methods known in the literature based on calculating the "effective" speed of sound (projection of wind speed onto the direction of the wave vector) along the arc of a large circle are presented. The results show that due to the anisotropy of signal propagation, the wavefront differs from the circle, and the trajectory of the beam arriving at the receiver in the shortest time, although it passes close to the arc of a large circle, significantly depends on temperature and wind speed. The paper also presents a technique for identifying acoustic signals from pulsed sources (such as volcanoes) using morphological analysis of wavelet spectra in the infrasound range. The presented method provides a more accurate simulation of acoustic propagation in real atmospheric conditions compared to simplified approaches, which is important for monitoring natural and anthropogenic events.

The work was carried out with the financial support of the Russian Science Foundation grant No. 25-17-00060.

Keywords: infrasound, acoustic wave propagation, ray tracing, GFS, Hunga-Tonga eruption, wavefront modeling, atmospheric anisotropy, wavelet analysis

Analyzing trends and causes of double-high pollution of $PM_{2.5}$ and ozone in China from 2015–2023

Zhang M.

Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China

The spatiotemporal variation characteristics of double−high pollution (DHP) from surface fine particulate matter ($PM_{2.5}$) and ozone (O_3) were explored on the basis of ground observations from 2015–2023 across China. Statistics show that the frequency and intensity of DHP days (DHPDs) are highest in North China, followed by South China. Seasonally, DHPDs occur more frequently in spring and autumn across China, accounting for 43% and 27% over nine years, respectively, and the frequency of DHPDs in summer shows a decreasing trend. The number of DHPDs across national sites first tends to decrease (by 48.63% from 2015–2021) but then tends to increase (by 49.37% from 2021–2023). To explore the causes of these variations, gridded $PM_{2.5}$ component concentrations from the TAP dataset (http://tapdata.org.cn) were used to analyze the chemical characteristics of DHPDs. Despite sharp reductions in anthropogenic emissions, the proportion of secondary inorganic components in $PM_{2.5}$ increased by 4.51%, 3.6%, and 5.41% in BTH, FWP, and YRD on DHPDs, respectively, from 2015–2021. Concurrently, the sulfur oxidation ratio increased by 27.04% across China, potentially because of the increasing O_3 concentration. The positive correlations between the detrended $PM_{2.5}$ and O_3 concentrations further support this viewpoint. Moreover, meteorological analysis via the objective weather classification method reveals that DHPDs are most likely to occur under cyclonic low-pressure systems with high temperatures in northern China (BTH and FWP) and anticyclonic high-pressure systems with high temperatures and low humidity in southern China (YRD and SCB). These conditions promote secondary pollutant formation and hinder pollutant dispersion. Overall, increased attention to the atmospheric oxidizing capacity, particularly under adverse meteorological conditions, is necessary. Future work will use air quality models to quantify the contribution of ozone to $PM_{2.5}$ and the impact of aerosol feedback on DHPDs.

Extreme wind over the Arctic passage and its possible influential factors

Zhou L.[1,2,3]**, Zhu J.*[1]**, Ma S.*[1]*, Li F.*[1]*, Li P.*[1]*, Zhang Z.*[1,4]

[1] Department of Lower Atmospheric Observation and Research, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China
[2] State Key Laboratory of Atmospheric Boundary Layer Physics and Atmospheric Chemistry, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China
[3] Key Laboratory of Atmospheric Environment and Extreme Meteorology (Chinese Academy of Sciences), Beijing, China
[4] College of Earth and Planetary Science, University of Chinese Academy of Sciences, Beijing, China

Extreme winds over the Arctic passage are essential for not only the navigation efficiency and safety, but also offshore activities in the Arctic and its implications for national security. In this study, the long-term variation in extreme winds over the Svalbard region is firstly analyzed on the basis of high-resolution in situ observational data at Ny-Ålesund from 1991–2023. The results revealed that extreme Arctic winds are dominated by southeasterly and easterly winds, with the strongest intensity (15.5±1.2 m/s) and the highest occurrence frequency (4.2±3.7%) in winter. From 1991 to 2023, the extreme winds and their occurrence frequency over the Svalbard region decreased, with larger decreasing trends in the winter and spring. A typical extreme wind event is selected from an intensified experiment, and a polar Weather Research and Forecasting (WRF) model simulation is conducted to reveal the possible factors affecting extreme Arctic wind variation. During the extreme wind event, the extreme wind intensity was largely strengthened by the Icelandic low through momentum transfer downward from the lower troposphere. In addition, the local katabatic flow from the glacier surface could have also contributed more than 10% of the extreme wind intensity. Our studies indicate that extreme wind variation can be strongly affected by both synoptic situations and local thermal forcings, not only over the Svalbard region but also over some other regions along the Arctic passage, which needs to be further studied in the future.

Keywords: extreme wind, Arctic passage, affected factor, katabatic flow

Anthropogenic amplification of precipitation variability over the past century

Zhou T., Zhang W.

Institute of Atmospheric Physics, Chinese Academy of Sciences

As the climate warms, the consequent moistening of the atmosphere increases extreme precipitation. Precipitation variability should also increase, producing larger wet-dry swings, but that is yet to be confirmed observationally. Here we show that precipitation variability has already grown globally (over 75% of land area) over the past century, as a result of accumulated anthropogenic warming. The increased variability is seen across daily to intraseasonal timescales, with daily variability increased by 1.2% per 10 years globally, and is particularly prominent over Europe, Australia, and eastern North America. Increased precipitation variability is driven mainly by thermodynamics linked to atmospheric moistening, modulated at decadal timescales by circulation changes. Amplified precipitation variability poses new challenges for weather and climate predictions, as well as for resilience and adaptation by societies and ecosystems.

Key Words: precipitation variability, anthropogenic forcing, detection and attribution

Reference:

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