**Dr. Yelena L. Pichugina**

**Senior Scientist**

***Cooperative Institute for Research in Environmental Sciences (CIRES),***
***University of Colorado, Boulder***

E-mail: yelena.pichugina@noaa.gov Phone: 303-497-6863 Fax: 303-497-5318

## SUMMARY

- Research Scientist III at the Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, affiliated with the Atmospheric Remote Sensing Group (ARS) of the Chemical Sciences Laboratory (CSL), Earth System Research Laboratory (ESRL), National Oceanic and Atmospheric Administration (NOAA) in Boulder, Colorado.
  - ✓ Expertise in atmospheric science, boundary-layer, mesoscale processes, numerical modeling, air quality, and wind-power meteorology.
  - ✓ Participant (PI and co-I) in design, execution and data analysis of inland and offshore field projects involving Doppler Lidar technologies
  - ✓ Extensive experience with preparing and submitting multi-institutional proposals resulted in more than $20M in research funding.
- Leadership: Organized meetings and workshops, chaired conference sessions. Serve on AMS Renewable Energy Sub-Committee, Students Ph.D. Thesis Committee.
- Mentor and advisor to high school and undergraduate students for NOAA scholarship programs.
- Instructor at Ph.D. students summer schools, international students workshops and forums.
- Consultant for Mitsubishi business partners
- Communication: Author of numerous peer-reviewed articles; invited international lecturer.
- Computing Experience: primary, IDL, FORTRAN, C++
- Joined ESRL/NOAA in 1998 from the Central Asia Hydro-Meteorology Research Institute (SANIGMI) in Tashkent Uzbekistan, with 20 years of experience in areas of numerical modeling, remote sensing of snow resources in the Central Asia mountain region, and water flow forecast.

## EDUCATION

***1993*** Ph. D. In Engineering-Technical Sciences. Uzbek Academy of Science, Tashkent, Uzbekistan, title of Ph. D. Thesis: "Monitoring of snow and water resources in the Central Asia mountain region using in-situ, airborne and satellite data".

***1988*** MS in Remote Sensing *(*Satellite data processing), Novosibirsk State University, Novosibirsk, Russia

***1975*** BS in Physics *(*Physical Optics), Tashkent State University, Tashkent, Uzbekistan

## SKILLS AND PROFESSIONAL EXPERIENCE

- Extensive knowledge of boundary-layer meteorology, with respect to mesoscale processes, air quality, and wind energy applications, emphasizing insight gained from new lidar-based observational technologies to evaluate and improve weather prediction models.
- In-depth knowledge of measurements and data analysis to advance understanding of wind systems and atmospheric processes, that are related to air-sea interaction, inland and offshore variability of wind flow, shear-driven turbulence, and Low-Level Jet (LLJ) phenomena.
- Pioneered the use of ship- and ground-based Doppler lidar systems for wind energy applications to quantify dynamic processes such as rapid changes of wind speed and direction or waked wind flow at turbine scales, turbulence events that are likely to present a long- or short-term risk to wind turbine operations.

- Established skills to perform extended analysis of lidar data to characterize wind flows over complex and flat terrain, evaluate the performance of numerical weather prediction (NWP) models, and to estimate the impact of model resolution and improvements in model physics on forecast accuracy from diurnal to seasonal and annual time scales.
- Proven ability to lead national and international projects, participate in proposal writing and execution of multi-institutional experiments, work in the field, develop data processing tools, and prepare project reports.
- Well established publication record with publications in peer-reviewed scientific journals, technical reports, and proceeding of numerous conferences.
- High leadership, communication and coordinating skills to perform teamwork and exchange of scientific ideas, promote remote sensing for boundary layer studies, and inform wind energy business on advances of lidar technology.
- Programming skills to develop software and data visualization tools to analyze and interpret remote-sensing measurements for understanding of physical processes related to terrain effects, weather conditions, and presence of wind farms and to address the optimization of wind turbines layout and the mitigation of natural hazards.
- Supervision, mentoring and a significant educational impact on young scientists and students.

## EMPLOYMENT HISTORY

***Research Scientist III-Senior Scientist*** ***2013 - present***
***Cooperative Institute for Research in Environmental Sciences (CIRES)***
***University of Colorado, Boulder, CO***

**Key roles:**

Lead the strategic development, planning, and research for CSD/Atmospheric Remote Sensing Group for NOAA/ESRL and Department of Energy (DOE) Renewable Energy program. Coordinate efforts with NOAA laboratories and various agencies to demonstrate the impact atmospheric science plays in developing renewable energy as a national energy source leader. Partner with external government agencies, including DOE laboratories, universities, and private business organizations to support weather-dependent renewable energy research and projects to improve numerical weather prediction (NWP) models. Partner with domestic and international community to develop scientific research plans, design deployments of instruments and measurement sequences, maintain project timelines and prepare metrics and reports for agency leadership and project sponsors.

***Project Highlights and Research Goals:***

*2019-2021. Extended analysis of improvements in NWP models.* (DOE and NOAA project).

- Evaluate and improve sub-grid scale parameterizations for the NWP forecast models, including those developed under the WFIP2 by using a rich set of temporally and spatially resolved observations, studies of dynamic processes in boundary layer.
- Update and amend model physics by improving the understanding of important atmospheric features related to winds, turbulence, clouds, and radiation.
- Utilize measurements from network of remote-sensing and in-situ measurements collected during WFIP2 and long-term Atmospheric Radiation Measurements (ARM) at the Southern Great Plains (SGP) facility.

*2015-2020. Second Wind Forecast Improvement Project (WFIP2).* (DOE and NOAA project).

- Participated in the work of WFIP2 team via field trip and kick-off meeting, and conference calls to coordinate scientific efforts of collaborating organizations, finalize the measurement campaign integrated Science Plan, and to advance logistics for instrument deployment, and decision support tools.

- Member of the Verification and Validation (V&V) team to develop the initial concept for testing the performance of models in complex terrain and design validation strategy for each type of instruments involved in the project
- Use measurements from network of unattended scanning Doppler lidars deployed in complex terrain during WFIP2 project to understand physical processes related to terrain effects, weather conditions, and presence of wind farms, evaluate the performance of operational and newly developed NWP models, and to estimate the impact of model resolution and physics on forecast accuracy from diurnal to seasonal and annual time scales.
- Analyze performance of NWP models in complex terrain focusing on model error during atmospheric events observed during WFIP2 such as marine intrusions, cold pools, mountain wakes that are important for wind energy operations. Characterize the response of the wind profiles at multiple sites to the diurnal heating/cooling cycle under diverse large-scale forcing conditions, and characterize the local and large-scale forcing mechanisms and processes that drive the winds.
- Access the ability of the operational models to capture the wind field changes and associated forcing mechanisms, and whether experimental versions improve the skill.
- Evaluate the strengths and weaknesses of models for different local and large-scale forcing mechanisms (land-sea surface heating contrasts, pressure gradient at the west/east sites of Cascades) and processes.

*2016-2019. Indianapolis Flux Experiment (INFLUX)*. (NIST and NOAA project).

- Analyze long-term measurements of wind flow variables from the commercial Halo Photonics Stream-Line XR Doppler lidar.
- Develop technique to estimate turbulence from single Doppler lidar measurements.
- Investigates inter-annual variability of boundary layer height for a variety of atmospheric conditions using long-term lidar measurements and data from other available instrument such as radiosondes or from aircraft.
- Evaluate wind forecast error of High-Resolution Rapid Refresh (HRRRv3) model using lidar measurements.

*2017. Land-Atmosphere Feedback Experiment (LAFE).* (DOE, NOAA, NASA, and University of Hohenheim, Germany project).

- Participate in the analyzes of measurements from several state-of-the-art scanning lidar and remote sensing systems deployed to the ARM Climate Research Facility (SGP) to study feedback processes between the land surface and the atmosphere as well as horizontal and vertical transport processes.
- Analyze temporal, spatial and vertical variability of wind flow focusing on LLJ frequency and LLJ properties at various temporal scales (annual, seasonal, and diurnal), stability classes, and differences due to land cover at 5 lidar sites.
- Examine the physical mechanisms responsible for the jet formation and the climatological relationship between the characteristics of the jet and larger-scale flow patterns.
- Validate the HRRRv3 model's ability to simulate jet properties and associate flow properties, such as spatial heterogeneity.
- Evaluate the climatology of LLJ from long-term (January 2016-December 2019) measurements at the SGP Doppler lidar sites and estimate the representativeness of jet properties during the LAFE period.

*2012-2014. NOAA Study to Inform Meteorological Observation for Offshore Wind: Positioning of Offshore Wind Energy Resources (POWER).* (DOE, NOAA project).

- Use ship-borne lidar measurements in the Gulf of Main to study the temporal and spatial variation of marine winds at the height of modern turbine rotors to benefit research and expedite development of the offshore wind projects.

- Determine if additional lower-tropospheric profilers can improve near-coastal and offshore wind resource assessments.
- Evaluate the skill of operational and developed numerical weather prediction (NWP) models in the offshore area by lidar measurements.
- Participated in the Report to DOE to provide guidance about meteorological observations in support of offshore wind energy and focus future research and requirements for an observation network to support U.S. offshore wind energy and for improving our understanding of the offshore wind resource.

***Notable Results.***

*2019*. Organized and lead weekly Doppler lidar research meetings to plan and coordinate work of 9 highly efficient professionals, including specialists in the instrument development, long-term monitoring, calibration, and data analysis. The group focuses on support of the NOAA/CIRES science objectives and goals for scientific research to examine atmospheric processes in a variety of environments using combined analysis of measurements from traditional in-situ instruments and various types of lidar systems deployed on the ground, ship, or on aircraft. The working atmosphere continues to be highly productive, all members of the group are motivated and creative individuals.

*2018-present*. Represent the Atmospheric Remote Sensing Group (ARS) as a CIRES Lead of the Remote Sensing Studies of the Atmosphere and Oceans project under NOAA theme: "Weather-Ready Nation, Climate Adaptation and Mitigation" to investigate atmospheric composition, dynamics, and transport processes from the surface to the upper troposphere. Prepared annual report to show how these studies have particular relevance to air quality, climate, weather forecasting, aviation, ocean ecosystems, and renewable energy.

*2012-present.* Involved in preparation of Proposal and Statement of Work for DOE and NOAA projects, numerous meetings to discuss the most appropriate and effective roles for Doppler lidars, the most effective combination of ground-based instruments and their locations; measurement needs for improvement of model skills in predicting hub-height winds, ramp events, and BL parameterization. The joint NOAA divisions application was accepted resulting in funds to cover the research study and providing the opportunity of procuring 2 scanning Doppler lidars.

*2010-present*. Participated in the weekly NOAA Wind Energy and Boundary layer Research meetings representing the Chemical Science Division (CSD) to plan new experiments, discuss results and outcomes of performed analyses, and set path for collaborative peer-review publications, conference presentations, and future projects. I co-wrote quarterly and annual scientific Reports to NOAA and DOE leadership participated in bi-annual Briefing of directors of NOAA divisions.

***Research Scientist II*** ***2005-2013***
***Cooperative Institute for Research in Environmental Sciences (CIRES)***
***University of Colorado, Boulder, CO***

***Key roles:***

Designed and lead several scientific research projects. Participated in field experiments; operated remote sensing instruments such as high-resolution Doppler lidar; collected and analyzed observational data for characterization of atmospheric processes. Used measurements from past-year offshore experiments for interpretation of marine wind flows and to provide insight into wind resource assessment. Developed software and visualization tools to process and analyze data from various remote sensing (lidars, wind profilers, sodars) and meteorological in situ instruments, performed data quality analysis and estimated measurement uncertainty. Evaluate the accuracy of the NWP models to forecast wind variability within the lower boundary layer.

Analyzed the vertical and horizontal structure of wind flow features to estimate velocity deficit and wake effects produced by operational wind turbine using scanning ability of Doppler lidar.

The significant velocity deficit and turbulence generated by upstream turbines can reduce the power production and produce harmful vibrations in downstream turbines, which can lead to excessive maintenance costs. The complexity of wake effects depends on many factors relayed to both hardware (turbine size, rotor speed, and blade geometry, etc.) and meteorological conditions (prevalent wind direction at the site, wind velocity, wind gradients, boundary layer stability, turbulence characteristics, etc.).

***Project highlights and Research Goals:***

*2011. Wind turbine wake study by High-Resolution Doppler Lidar. (*Renewable and Sustainable Energy Institute).

- Planned and executed field experiment as a CIRES Principal Investigator (PI) to assess velocity deficit and turbulence associated with operational wind turbines, which is a major issue for wind farm design and optimization of the spacing between turbines.
- Participated in lidar deployment, development of the scanning strategy and field-work to obtain data in real-time and monitor wind and weather conditions.

*2011. Lidar study of turbulence, and coherent vortex structures in the atmospheric boundary layer.* (Civilian Research and Development Foundation seed grant.)

- Proposed and executed the successful Doppler lidar campaigns as a Principal Investigator (PI) of the project, leading the team of US scientists to characterize the relationships between the meteorological inflow and turbine wakes
- Participated in the development of new theoretical approaches and lidar data processing techniques to estimate atmospheric turbulence field structure in the vicinity of wind turbine.
- Coordinated the collaborative Report and supported the idea of purchasing a scanning Doppler lidar by the Russian team, the first such instrument in their country.
- Lead communication and exchange of scientific ideas between 2 international teams leading to publication of results in 6 peer-reviewed journals and 3 conference papers.

*2011-2013 Four-dimensional characterization of inflow to and wakes from a multi-MW turbine: the Turbine Wake and Inflow Characterization Study (TWICS).* (DOE project).

- Acted as a Principal Investigator (PI) from CIRES of this multi-institutional project. The centerpiece instrument of the TWICS campaign was the NOAA High-Resolution Doppler lidar (HRDL), a scanning lidar which captured three-dimensional images of the turbine inflow and turbine-disturbed outflow (wakes).
- Monitored the quality of real-time observations, especially with respect to the meteorological conditions, cloud, and aerosol interference. Lidar observations during a variety of wind speed conditions and atmospheric stability allowed to study wake features and provide 3-dimension results on wake parameters such as length, meandering, intersection with the ground, and temporal extension.
- Developed software for the statistical analysis of data, visualization of lidar and in situ measurements, experiment web-site.

*2009. National Weather Prediction Services (NWS) field experiment*. (NWS project).

- Participated in field experiment to obtain data from Doppler lidar and wind profiling radars
- Monitored weather conditions and provided data archive.
- collaborated with industry colleagues from Vaisala and Honeywell

*2005-2009 Data mining from the 2004 New England Air Quality Study* (NOAA project).

- Used measurements from ship-borne lidar to investigate variability of marine wind flows at turbine height, offshore LLJs, and estimate the error in wind power production by using wind measurements available from buoy network.

***Notable Results.***

The focus of this period was on the development of methods for wind turbine outflow characterization using various scanning types from Doppler lidar measurements of high temporal and spatial resolution.

Lead and co-lead several collaborative field campaigns at the National Wind Technology Center (NREL/NWTC) in south Boulder, CO to characterize the relationships between the meteorological inflow and turbine wakes.

The NOAA/CIRES team activity was an integral part of the successful collaboration with national experts aimed to develop statistical methods for the analysis of wake parameters.

The pioneered work in this area was highlighted in several media reports featuring interviews with Yelena Pichugina and led to several publications by US and international collaborators.

***Research Associate*** ***1998 - 2005***
***Cooperative Institute for Research in the Atmosphere (CIRA), Colorado State University (CSU) affiliated with NOAA, Boulder, CO.***

Participated in Climatological and Historical Analysis of Clouds for Environmental Simulations (CHANCES) project, performed quality analysis, and processing of GOES imagery. Developed FORTRAN and IDL routines to read, display, and re-map surface temperature data. In 1998 involved with NOAA in Flatland-96 and CASES-99 projects to process and analyze the High-Resolution Doppler Lidar data and moved to the CIRA office at the NOAA facility in Boulder, CO.

***Notable Results.***
Participated in the Lamar Low-Level Jet Program in southeast Colorado to test ability of using lidar for wind energy research and quantify lidar measurement uncertainty by comparing to data from sodar and tall tower sonic anemometers, developed software to analyze multi-instrument data, contributed to journal papers and NREL technical reports.

***Research Scientist (1975) to Senior Research Scientist (1994)*** **1975-1996**
***Central Asia Hydro-Meteorology Research Institute (SANIGMI), Tashkent, Uzbekistan***
Developed techniques for monitoring snow resources in the mountains using NOAA AVHRR and METEOR imagery. Processed satellite images to estimate the impact of climate change on snow and water resources in Central Asia mountain region. Designed and implemented statistical models for the river-flow forecast, using surface and airborne measurements, gamma-survey, and satellite information.

***Notable Results.***
As a Secretary of the Hydrology Work Group (during 1994-1996) to provide coordination and cooperation between scientists of Uzbekistan, Russia, and other 13 Former Soviet Union countries.

Participated in several International projects:

- *Variability of snow and glaciers in Central Asia and hydrological modeling*, National Snow and Ice Data Center (NSIDC), CU Boulder project. Worked in close collaboration with Professor Roger Barry and Richard Armstrong
- *Integrated land and water management of the upper watersheds*. Western European Consortium (WARMAP) project.
- *Framework Convention on Climate Change in Uzbekistan*, the Global Ecological Fund project.

Provided publications in domestic and international journals, participated in conferences and workshops.

**AWARDS**

2017 CIRES team Award. "*Technology Transfer for improving forecasts of turbine-height winds and solar irradiance from their HRRR weather model to improve usage of renewable power by industry*"

2012 CIRES Outstanding Performance Award in Science and Engineering, "*Groundbreaking research focusing on dynamic atmospheric processes at the heights of modern wind turbine rotors, work that has helped to characterize the atmospheric phenomena, turbulence, and boundary layer processes important to the wind energy industry*"

**MEDIA COVERAGE**

2015 Interview and video for the National Council for Science and the Environment. The video was shown at the National Conference & Global Forum: Energy and Climate Change, Washington DC **https://vimeo.com/115670693**

2011 **Where the Wind Blows**. *CIRES scientist investigates the unknown: offshore wind at the heights of modern wind turbines.* CIRES Spheres Magazine, Special Edition 07, #20, December 2012. By Katy Human.
**http://cires.colorado.edu/science/spheres/arctic-meltdown/wind.html**

2011 **In the Wake of the Wind Turbine**. *CIRES and NOAA scientists study the wake effect of wind turbines to improve efficiency and reduce damage* CIRES news. April 26, 2011. By Jane Palmer
**http://cires.colorado.edu/news/press/2011/turbines.html**

2011 **Offshore winds: Investigating the unknown at turbine heights**
AGU Fall Meeting Press Conference.
**AGU FM11 - Changing the energy landscape: More efficient wind farms and cleaner biofuels**

**PROFESSIONAL SOCIETIES**

American Meteorological Society (AMS), 2003-present
American Geophysical Union (AGU), 2005-present