Project Details

ROSES ID: NNH21ZDA001N-LWSTM
Selection Year: 2021
Program Element: Data, Tools, & Methods

Project Title:
Machine learning based automatic detection of upper atmosphere gravity waves from NASA satellite images

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Summary:
Severe weather such as thunderstorms, cold fronts, and hurricanes, excite atmospheric gravity waves (AGWs) that can propagate into the Earth's upper atmosphere. AGWs play key roles in the dynamics and energetics of the mesosphere and thermosphere. They also induce space weather conditions by driving traveling ionosphere disturbances (TIDs) and seeding spread F and plasma bubbles. AGWs imprint their traces in the airglow layers which are several faint emission layers in the mesopause region. AGWs in the upper atmosphere have strong negative correlation with the 11-year solar cycle and the reason is unknown. On the other hand, climate change in the lower atmosphere may change AGW excitations. However, to date, there have been very few satellite observations of global AGWs in the mesopause region. This lack of information about the global AGWs below the E-region ionosphere and lower thermosphere has limited our ability to quantify the impact of AGWs on space weather. Therefore, we propose to undertake a machine learning detection of AGWs in airglow from 10+ years of NASA VIIRS/Day Night Band (DNB) images obtained by two satellites, Suomi NPP and NOAA20 and disseminate the data and algorithm via SPDF. The rich AGW data gained from this work will enable statistical characterization of global AGW morphology in the mesopause region and its solar cycle and long-term variations.
We will build Convolutional Neural Network (CNN) based deep learning models to extract AGW features from DNB images. CNN model is the state-of-the-art technique to classify images and has been widely used in many image detection/classification problems. It typically contains convolutional layer, pooling layer, activation layer such as Rectified Linear Unit (ReLU), fully connected layer, and loss layer in order to capture spatial structure of data in model training. To train CNN models such as 19-layer VGGNet and 50-layer ResNet for AGW detection, we will manually label thousands of images, both with and without AGWs for the training set, and a tenth of the images will be left unused to validate the training model. The training set will be prepared by manually labeling the wave pattern in the wave-containing image. By training the CNN models from the manually labeled images, the models will be able to automatically locate wave patterns and enable us to extract a sub-matrix full of wave patterns from millions of satellite images.

The proposing team combines satellite data processing expertise in both NASA Heliophysics and Earth Sciences, expert in AGW physics, and data science experience in machine learning. The proposed work is listed in the 2021 Heliophysics-LWS Tools announcement: Leverage current technology for the discovery, access, and effective use of NASA's data, as well as enable new technology and analysis techniques for scientific discovery in areas of Heliophysics research covered by LWS objective, quantifies the physics, dynamics, and behavior of the sun-Earth system over the 11-year solar cycle. This work strongly supports the scientific goal emphasized by the 2013-2023 Decadal Survey in Solar and Space Physics, Determine the dynamics and coupling of Earth's magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs." The machine learning algorithm will also be shared with the NASA WAVE mission.

Deliverables to SPDF by July 2023: ~5000 GW images along with corresponding raw VIIRS data; source codes of image classification and localization models; visualization tools.

Publication References:

no references