Dr. Gulab Singh has significantly contributed to the advancement of airborne and spaceborne PolSAR remote sensing by introducing new Generalized 4-component Scattering Power Decomposition (G4U) [*IEEE TGRS*, 2013], 6-component Scattering power Decomposition (6SD [*IEEE TGRS*, 2018] and 7-component Scattering power Decomposition (7SD) [*IEEE TGRS*, 2019] methods in the inversion techniques for retrieving cryo-/bio-physical parameters for monitoring the environmental state of Earth [RSE, 2019, 2020]. These decomposition methods offer a promising straightforward interpretation of the real world [*IEEE TGRS*, 2020]. His polarimetric method is now known as the *"Singh Decomposition Model"* within the radar remote sensing community worldwide. His all decomposition methods [G4U, 6SD, and 7SD] are included in PolSAR Pro. v.5 or higher version software by European Space Agency (ESA). These methods are being used for the creation of full- color 3D image reconstruction for research and education purposes. The first-hand implementation of the 6SD algorithm has been employed in Japan Aerospace Industrial Science and Technology (AIST), Japan, to promote polarimetric SAR data utilization. (https://grst.airc.aist.go/jp/landbrowser/index.html)

His teaching and research contributions also attempt to bridge the intellectual gap between traditional radar polarimetry theories/methods and monitoring the geo-/cryo-/bio-environmental parameters. He has developed novel polarimetric radar remote sensing inversion algorithms and methodologies for retrieving snowpack parameters (snow wetness, density, depth, and snow water equivalent) in the Himalayas [*IEEE TGRS*, 2017, 2021; *RSL*, 2020]. He discovered anomalous glacier dynamics and disintegrating behaviour of glaciers [*RSE*, 2020] using DInSAR. A new climate warming feedback mechanism due to meltwater influx of retreating tributary glaciers is introduced. These contributions fill significant gaps in knowledge about radar remote sensing of glacier dynamics and heterogeneous ice loss. Furthermore, Dr. Singh has made an excellent effort in removing the degrading effects of ionospheric amplitude scintillations in low-frequency PolSAR measurements

Abstracts:

Radar Remote Sensing of the Earth's Cryosphere

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The cryosphere comprises all the solid water in the form of snow and ice, which is distributed across the globe in form of snowpack, glacier, ice cap, ice sheets, permafrost, lake ice, river ice, sea ice. The cryosphere components are sensitive to the changing climate and an indicator of global warming. It is projected that if all the glaciers, ice caps, and ice sheets melt, the global sea level would rise approximately by 70 meters, thereby flooding every coastal city across the globe. In addition, snow and glacier are also the vital resource of fresh water in high-latitude regions and for many densely populated areas in mid and lower latitudes, coinciding with high altitudes. If the climate continues to warm, reduced snow/ice storage will affect freshwater inflows into the river systems, resulting in serious consequences for human health, regional food security, and biodiversity. These will affect the environment as well as the occurrence of floods and droughts, irrigation for agriculture, civilian water supply, groundwater recharge, and hydropower industries, as well as soil moisture for spring planting.

Cryosphere parameters data collections by conventional and ground-based methods are cumbersome, both in terms of cost-effective considerations and sporadic occurrences. Even when made available by manual recovery, cryosphere data represent only point measurements which may or may not be representative of a large area or region. Due to the strong spatial and time-dependent dynamics of the cryosphere parameters, frequent continual observations are necessary.

Satellite remote sensing promises great potential in the study of dynamics of snowpack and glacier parameters due to its repetitive monitoring capability and synoptic coverage.

The most distinct advantage of radar remote sensing is collecting data regardless of weather and during both day and night. The radar remote sensing datasets with a higher temporal resolution facilitate even the slightest change detections on the ground. Spaceborne SAR, radar altimeter, and scatterometer datasets are widely used to map cryosphere in polar and non-polar (alpine and Himalaya) regions and also to develop algorithms to infer physical parameters for the qualitative and quantitative estimation of cryosphere parameters which are essential for climatological and hydrological applications. Multi-temporal SAR data have great potential in mapping ice dynamics and mass balance estimation.

The tutorial lectures will discuss the fundamental and advanced concepts of radar remote sensing applications to the cryosphere. The lecture will also cover the latest polarimetric SAR remote sensing methods to monitor snow extent, snow wetness, snow density, snow depth, snow water equivalent, glacier retreat, firn /snow line, glacier facies, glacier features, ice shelf, icebergs, sea ice classification, lake ice, permafrost, snow/ice avalanches, and glacier lakes and collapses events. The last portion of the tutorial lecture will be on SAR interferometry methods for ice dynamics and geodetic glacier mass balance.

The goal of this tutorial is to provide a comprehensive introduction to the radar remote sensing of the Earth's cryosphere to scientists and students who want to improve their theoretical and a practical knowledge in this research field.

Radar Polarimetry Methods for Diagnosis of Geo-/Bio-Environmental Health

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In the current century, the human race may face a crisis such as global warming, geo-/bio-environmental degradations, and resource depletion caused by natural hazards and man-made impact, and these crises will become great threats to future generations. Therefore, the potential for retrieving the geo-/bio-physical parameters with a high spatial and temporal resolution will represent the functional prospects for studying abrupt as well as slow (mid to long term) environmental changes; thus generating input functions for developing more reliable management and monitoring procedures of natural resources (e.g., forest, snow, ice, etc.) and the disasters reduction, and for developing highly improved hydrological and climate models, which have a great socio-economic impact. Although many scientists throughout the world are monitoring the geo-/bio-physical parameters but these parameter collections by conventional and ground-based methods are highly time-consuming and manpower extensive, which causes delays in assessment responses to governmental and other agencies. Even when made available by manual recovery, geo-/bio-physical data represent only point measurements, which may or may not be representative of a large geo-/bio-environmental destructed area or region.

Satellite remote sensing has great potential in the study of dynamically changing geo-/bio-environments due to its repetitive monitoring capability and synoptic coverage. On average, about 70% of the Earth's surface is covered by clouds, for which optical remote sensing techniques from space fail. Microwave radar sensors are ideally suited for space imaging because they are almost weather independent, and microwaves propagate through the atmosphere with little deteriorating effects due to clouds, storms, rain, fog, aerosol saturation, and haze. However, globally humidity, haze, and cloudiness are increasing at a rather rapid pace for irreversible reasons due to expansive aerosol build-up especially within the tropical/subtropical belts. Thus, optical remote sensing from space especially in the tropical and sub-tropical regions will become ever more ineffective, and microwave remote sensing with polarimetric radar technology must now be advanced strongly and most rapidly for geo-/bio-environmental disaster mitigation assistance.

Polarimetric radar remote sensing provides a very dynamic field driven by advances in space technique and polarization radar design, increasing demand for improved fully polarimetric SAR (POLSAR) processing techniques, scattering mechanisms, and data utilization in earth observations in understanding the geo-/bio-environmental parameters and monitoring rapid changes whether they are naturally occurring changes or due to natural disaster and man-induced crisis.

This tutorial lecture will provide first the basic formulations of POLSAR measurements and then of a theory of radar polarimetry with emphasis on recent advanced concepts and methods in polarimetric radar remote sensing of geo-/bio-environment discipline including latest model decomposition theories for improved scattering parameter recovery backed up by pertinent applications with a few examples fully polarimetric POLSAR images.

Participants will be benefited from the tutorial lecture in learning the latest concept and technology in polarimetric radar remote sensing and its applications. The tutorial lecture will help to bridge the intellectual gap at the radar polarimetry method terminus, where radar polarimetry theories/methods developments traditionally end, --- and the Earth surface parameters monitoring traditionally begins.