HOW IS THE EARTH'S SNOW COVER RESPONDING TO A WARMING CLIMATE?

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ABSTRACT

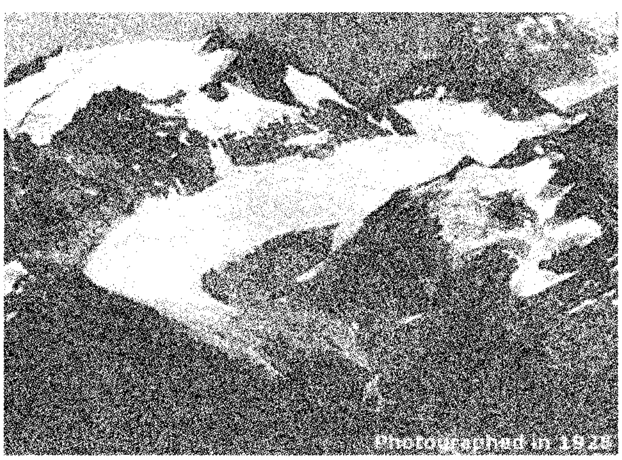
The extent and variability of seasonal snow cover are important parameters in climate and hydrologic systems due to effects on energy and moisture budgets. Northern Hemisphere snow cover extent, comprising about 98 percent of global seasonal snow cover, is the largest single spatial component of the cryosphere, with a mean maximum extent of 47 millions square kilometers (nearly 50 percent of the land surface area). During the past four decades much important information on Northern Hemisphere snow extent has been provided by the NOAS weekly snow extent charts derived from visible-bank polar orbiting and geo-stationary satellite imagery. This product is available from NSIDC as the Northern Hemisphere EASE=Grid Weekly Snow Cover and Sea Ice Extent Version 2. Because of the ability to penetrate clouds, provide data during darkness and the potential to provide an index of snow depth or water equivalent, passive microwave satellite remote sensing offers an additional source for hemispheric scale snow monitoring with the availability of a twenty-three year data record (Scanning Multichannel Microwave Radiometer (SMMR) 1978-1987 and Special Sensor Microwave/Imager (SSM/I) 1987-present). However, trend analysis on the passive microwave record is complicated by the change in sensors from the SMMR to SSM/I and by the short overlap period. We present analysis of land surface "stable" targets as detected by SMMR and SSM/I brightness temperatures during the overlap period to quantify possible discontinuities in sensor observations and derived snow extent and SWE. Finally, we include trend analysis of hemispheric and continental snow extent derived from passive microwave and visible-wavelength satellite data for the period 1987-2005.

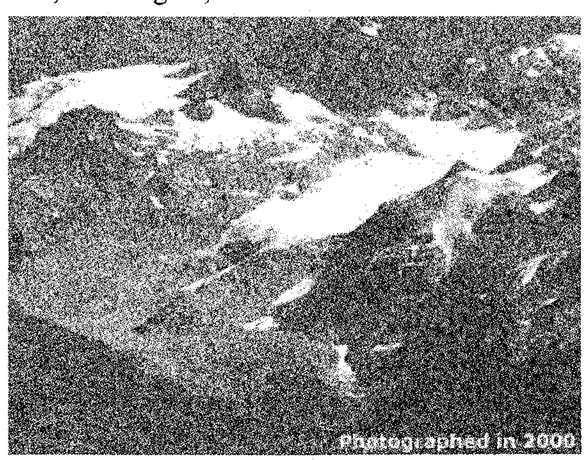
PRESENTATION EXTRACTS

Slide 2: Data at National Snow and Ice Data Center: All elements of the Cryosphere:

- –Snow cover
- –Permafrost & Seasonally Frozen Ground
- –River & Lake Ice
- –Ice Sheets & Ice Shelves
- –Sea Ice
- –Glaciers
- –data catalog - http://nsidc.org

Slide 4: Retreat of South Cascade Glacier, Cascade Mountains, Washington, 1928 – 2000





NSIDC Glacier Photo Collection

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Slide 5: Outline:

- Legacy Data Sets for Hemispheric-Scale Snow Mapping
- Comparison of Optical and Microwave Snow Cover Time Series
- Snow Mapping using Blended Optical and Passive Microwave Data
- SMMR to SSM/I Sensor Transition Complicates Trend Analysis
- Stable Targets Approach to Sensor Cross Calibration
- Trends Derived Using Adjusted Brightness Temperatures

Slide 6: Satellite Remote Sensing of Snow: Hemispheric Scale:

- Optical: GOES, AVHRR, MODIS
    - Higher resolution (~ 0.5 km)
    - Clouds and darkness obscure surface
    - Limited to surface characteristics
    - Magnitude of the reflectance - manual

- Microwave: SMMR, SSM/I, AMSR-E
    - Lower resolution (~ 10-20 km)
    - All weather & day/night
    - Sub-surface characteristics (mass)
    - Unique spectral signature - automated

Slide 7: Source for optical data: NOAA Weekly/Daily Snow Charts since 1966, longest time-series of any parameter derived from satellite remote sensing
NOAA IMS – Interactive Multisensor Snow and Ice Mapping System – http://www.ssd.noaa.gov/PS/SNOW

Slide 8: Source for passive microwave data: SMMR, SSM/I &AMSR-E Brightness Temperatures 1978-2006,

- Equal-Area Scalable Earth Grid, Full Global, North and South Hemispheric Projections, NOAA/NASA Pathfinder Level 3 Gridded Data
- Available from NSIDC: http://nsidc.org

Slide 10: Passive Microwave Remote Sensing of Snow:

- Radiation emitted from the soil is scattered by the snow cover
- Scattering increases in proportion to amount (mass) of snow
- Brightness temperature decrease, negative spectral gradient, polarization difference

Slide 26: Future Trend Analysis Work:

- Run snow extent trend analysis for specific regions of interest, Arctic Basin, Tibet Plateau, sub-regions within USA, etc.
- Produce trend surface maps for snow cover duration and snow water equivalent
- Compare results with surface temperature trends

Slide 27: Definitions for Stable Targets Study:

- Footprint mean = the mean of the brightness temperatures of each grid cell in a footprint.
- Footprint standard deviation =spatial variance at an instant in time or how the grid cells change in brightness temperature over the footprint. Needs to be small to have a homogeneous target.
- Average daily footprint mean = time average of the footprint mean, e.g. over one year.
- Standard deviation of the daily footprint mean = standard deviation of the footprint mean over time. Sites with a low SDDFM when the time period is long are sites that generally have low seasonal brightness temperature variation.
- Average daily footprint standard deviation = the average of each footprint standard deviation over some time series. Sites that are spatially homogeneous or have low brightness temperature gradients across a footprint will have low values of ADFSD. An area with a large ADFSD would not be a suitable calibration target, such as locations near land/water boundaries.

Slide 28: Conical Scan Passive Microwave Sensor Data:

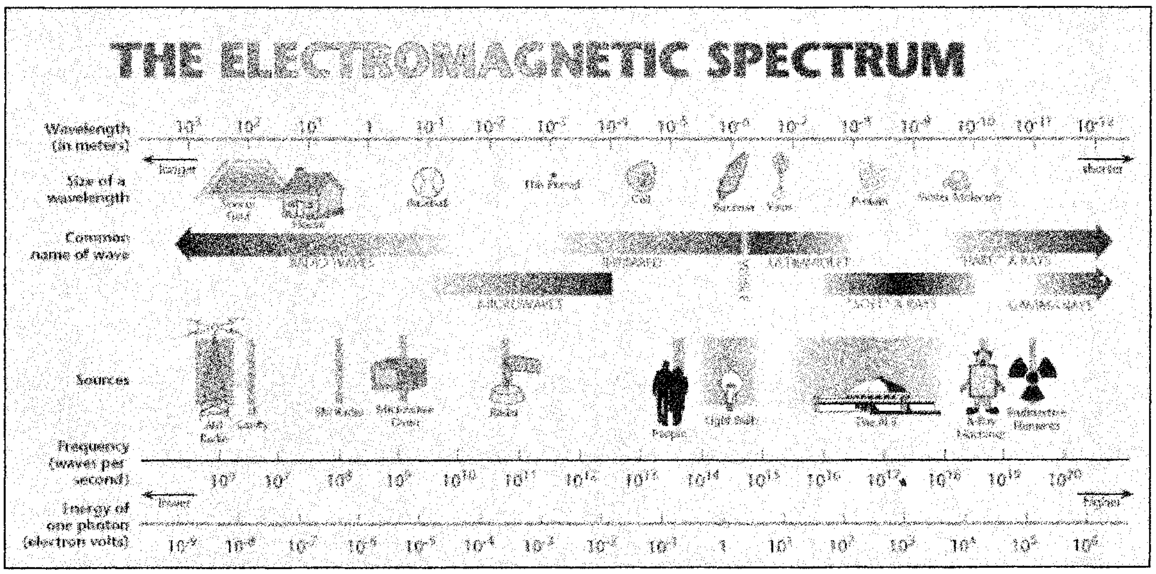
- Data from the SMMR, SSM/I, and AMSR-E are available in common gridded format from NSIDC
- Data cover period from 1978 through the present - though not all channels - and instruments have different frequencies, incidence angles, diurnal sampling, spatial resolution, and revisit intervals, but

care must be taken in combining their data to form consistent long term records of brightness temperatures and derived geophysical parameters

Slide 29: Importance of the Seasonal Snow Cover:

- Role as Climate Change Variable Due to Its Influence on Energy and Moisture Budgets
- Largest single component of the cryosphere - Northern Hemisphere Coverage may Exceed 50 Percent of Land Surface Area.
- Represents the Land Surface Characteristic Responsible for the Largest Annual and Interannual Differences in Albedo.
  - Snow reflects as Much as 80 to 90 percent of Incoming Solar Energy whereas a Snow-Free Surface Such as Soil or Vegetation May Reflect only 10 to 20 Percent
  - Temperature- Albedo Feedback Mechanism
- Represents a Significant Heat Sink During the Melt Period of the Seasonal Cycle Due to a Relatively High Latent Heat of Fusion.
- Realistic Simulation of Snow Cover in Models and Forecast Schemes is Essential for the Correct Representation of the Surface Energy Balance, Winter Water Storage and Year-Round Runoff.

Slide 32: Microwave Radiometry



- Microwaves: 1-300 GHz (frequency), 30 cm – 1 mm (wavelength)