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Global Landscape Freeze-Thaw Classification using Spaceborne Microwave Remote Sensing

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Introduction:
The freeze-thaw (F/T) status of the landscape is closely linked to surface energy budget and hydrological activity, the seasonal dynamics of vegetation growing seasons, terrestrial carbon budgets and land-atmosphere trace gas exchange. Satellite microwave radars and radiometers are well suited for global F/T monitoring due to insensitivity to signal degradation by atmospheric contamination and solar illumination effects, are uniquely capable of detecting the distinct change in landscape dielectric properties between predominantly frozen and thawed states, and provide a surrogate measure of a range of biophysical processes associated with the F/T signal, especially at high latitudes.

Data and Methods:

Surface air temperature data for FT_ESDR calibration and verification
(1) NASA DAO (2000-2006) 6-hour reanalysis (1° x 1.25°)
(2) NCEP/NCAR (NNR, 1988-2007) 6-hour reanalysis (1.875° x 2°)
(3) NCDC (1988-2007): daily summary of the day from WMO weather stations

Ancillary data for quality control (QC) assessment

F/T Algorithms: Seasonal Threshold Approach (STA)

Global FT_ESDR domain:
- Defined by a 2-year DAO reanalysis climatology using a “cold temperature constraint index” (CTCI, days yr-1)
- encompasses all vegetated regions where low temperatures are a major constraint to ecosystem processes.

Global FT classification criteria:
- The STA based SSM/I and AMSR-E AM/PM F/T classifications are produced as discrete frozen (0) or non-frozen (1) daily values;
- The combined SSM/I and AMSR-E F/T classifications are determined as frozen (0) or non-frozen (1) where the same F/T classification value occurs for both AM and PM retrievals, as daily output; as transitional (2) where AM frozen and PM non-frozen values occur, and inverse transitional (3) where AM non-frozen and PM frozen results occur;
- The SeaWinds daily F/T classification (frozen or non-frozen) is derived using the BYU daily global sigma-0 browse product from QuikSCAT L1B data.

FT global accuracy assessment using NCDC stations:

Global annual non-frozen period:

20-year QC Map:
FT_ESDR quality (QC:1998-2007) assessment was developed to identify regions of relative high to low quality of F/T classification results in relation to general climate and landscape features; the QC map ranges from low (minimum accuracy = 50%) to high (minimum accuracy >90%) quality categories; areas in white are outside the FT_ESDR domain

20-year SSM/I global non-frozen period variation:

Mean annual non-frozen period

Variation (Std Dev) in mean annual non-frozen period

Mean FT seasonal cycle derived from the combined SSM/I classification results over the FT_ESDR domain and 20-year (1988-2007) satellite record, including frozen (A), non-frozen (B), and transitional (C) categories; interannual variability (D) in the frozen and non-frozen areas is expressed as twice the standard deviation of the areas classification results.

Conclusions:
- The various microwave sensors produce similar FT spatial & temporal patterns, with 72-93% mean annual classification accuracy relative to NCDC stations, while global SSM/I/FT time series and corresponding annual frozen/non-frozen periods were quantified over a 20 year record;
- Approx. 66 million km² of the global land area are constrained by seasonally frozen temperatures; the average (1988-2007) seasonal progression of SSM/I derived frozen area ranges from 0.48 (±0.03) million km² (August) to 34.6 (±0.9) million km² (January);
- Daily FT transitional areas occupy from 3.2 ±0.27 million km² (August) to 13.2 ±0.59 million km² (November);
- These results are being used to construct a consistent, systematic long-term (>20 yr) daily global record of F/T dynamics with well defined accuracy;
- The FT_ESDR will be available online at (http://freezethaw.ntsg.umt.edu/) and archived to the NSIDC DAAC.

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