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:

	Passive		Active
Sensor	SSM/I	AMSR-E	SeaWinds
Platform	DMSP	EOS Aqua	QuikSCAT
Frequency	37GHz	36GHz	13.4GHz (Ku-band)
Polarization	V-pol	V-pol	V-pol/H-pol
Resolution	25x25km	25x25km	15x25km
Overpass	6am/pm	1:30am/pm	Daily average
Periods	1988-2007	2003-2007	2000-2007

Surface air temperature data for FT_ESDR calibration and verification

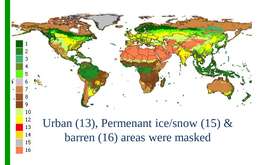
(1) NASA DAO (2000-2006) 6-hour reanalysis (1° x 1.25°)

(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

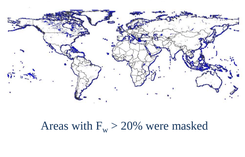
Ancillary data for quality control (QC) assessment

IGBP land cover classification



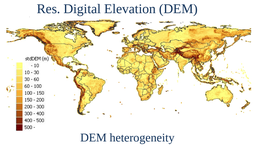
Urban (13), Permenant ice/snow (15) & barren (16) areas were masked

Open water fraction (F_w>20%; Blue)



Areas with F_w > 20% were masked

Variations (Std Dev) in USGS 1km Res. Digital Elevation (DEM)



DEM heterogeneity

F/T Algorithms: [1]Seasonal Threshold Approach (STA)

$$\Delta(\sigma \text{ or } T_b) = \frac{\sigma(t) - \sigma_{fr}}{\sigma_{th} - \sigma_{fr}}$$

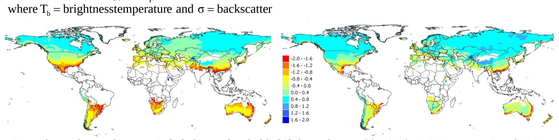
σ_{fr} = frozen reference state (mean T_b or σ in Jan)

σ_{th} = non – frozen reference state (mean T_b or σ in Jul)

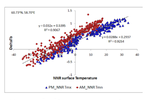
$\Delta(\sigma \text{ or } T_b) > T$ Thawed

$\Delta(\sigma \text{ or } T_b) \le T$ Frozen

where T_b = brightnesstemperature and σ = backscatter



Example pixel-wise dynamic T_b [K] change thresholds [T] derived using SSM/I P37V (PM overpass) and NNR T_{mx} (at left) and SSM/I A37V (AM overpass) and NNR T_{mn} (at right) in 2004



Example linear regression relationships between the spatial and seasonal scale factor, ΔT_b [K] derived from SSM/I 37V AM and PM overpass daily time series, and NNR daily surface air Temperatures, T_{mn} and T_{mx} [°C] in 2004 (above)

Global FT_ESDR domain:

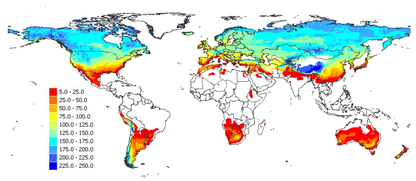
-defined by 7-year DAO reanalysis climatology using a [2]cold temperature constraint index [CCI, days yr^{-1}];

-encompasses all vegetated regions where low temperatures are a major constraint to ecosystem processes.

$$iT_{Min} = \begin{cases} 0, & \text{if } T_{mn} \le T_{Mmin}, \\ \dfrac{T_{mn} - T_{Mmin}}{T_{Mmax} - T_{Mmin}}, & \text{if } T_{Mmax} > T_{mn} > T_{Mmin}, \\ 1, & \text{if } T_{mn} \ge T_{Mmax}, \end{cases}$$

$$CCI = 365 - iT_{Min}$$

T_{Mmax} and T_{Mmin} vary by major land cover class using a global Biome Properties Lookup Table (BPLUT)



Global FT_ESDR domain derived from CCI [days yr^{-1}] using DAO daily minimum air temperature climatology (2000-2006); approximately 52.5 % (66 million km^2) of the global land area.

[1]Source: McDonald and Kimball, *EHS* 2004.

[2]Source: Jolly et al, *Global Change Biol* 2005.

Global F/T classification criteria:

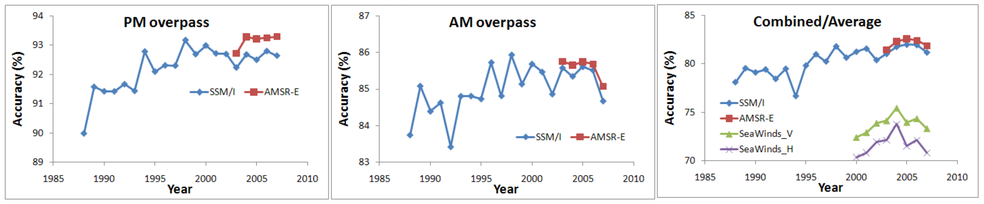
- The STA based SSM/I and AMSR-E AM/PM F/T classifications are produced as discrete frozen (0) or non-frozen (1) daily values;

-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;

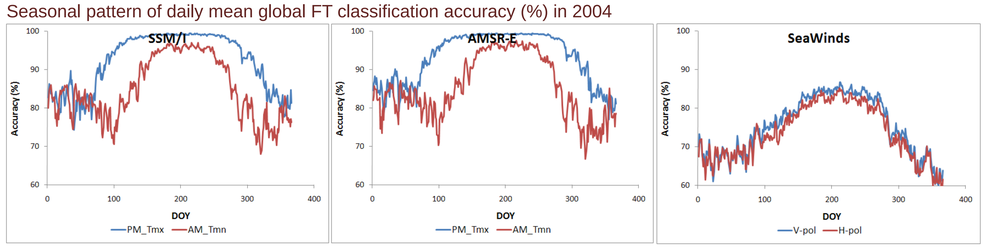
-The SeaWinds daily F/T classification (frozen or non-frozen) is derived using the BYU daily global sigma-0 browse product from QuikSCAT L1B data.

FT global accuracy assessment using NCDC stations:

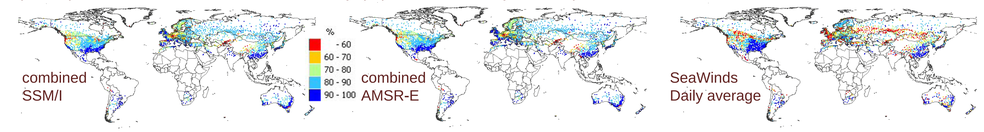
Global mean annual FT classification accuracy (%) between 1988 and 2007



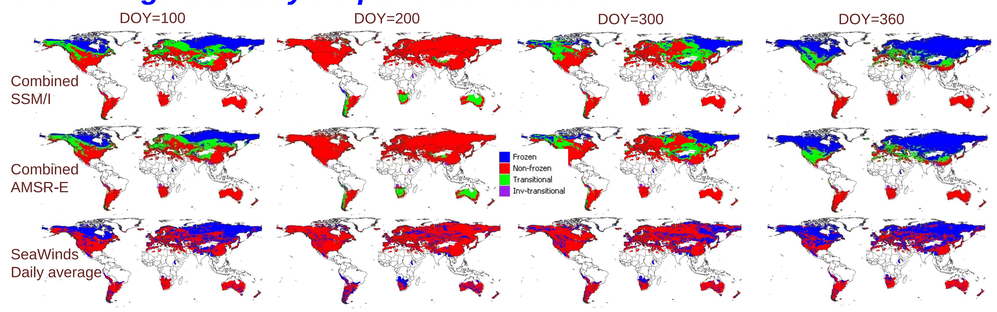
Seasonal pattern of daily mean global FT classification accuracy (%) in 2004



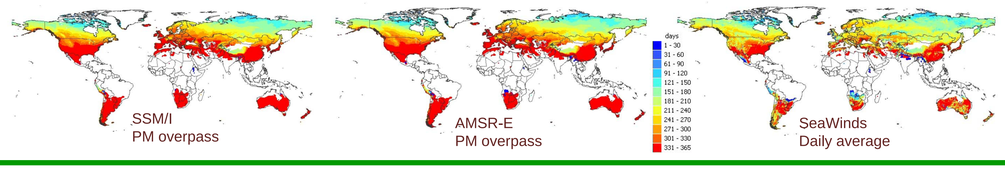
Spatial pattern of mean annual FT accuracy (%) relative to daily air temperatures from 3,701 NCDC stations in 2004



Selected global daily FT patterns for 2004:

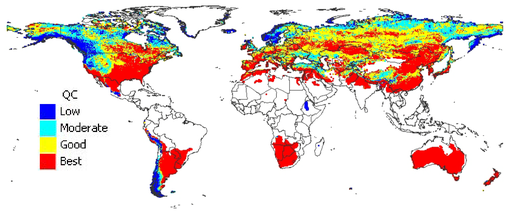


2004 annual non-frozen period:



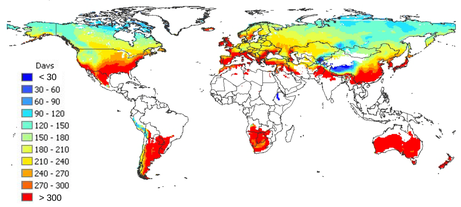
20-year QC Map:

FT_ESDR quality (QC;1988-2007) 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 (estimated accuracy < 70 %) to best (estimated accuracy > 90 %) quality categories; areas in white are outside the FT_ESDR domain

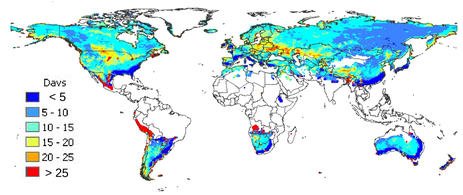


20-year SSM/I global non-frozen period variation:

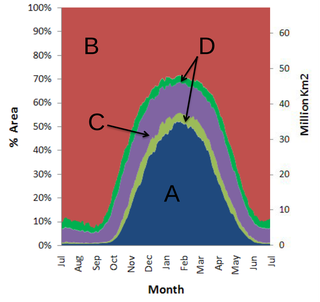
Mean annual non-frozen period



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



Mean FT seasonal cycle



Mean FT seasonal climatology 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 area 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 F/T time series and corresponding annual frozen/non-frozen periods were quantified over a 20 year record;

- Approx. 66 million km^2 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 km^2 (August) to 34.6 (±0.9) million km^2 (January);

-Daily F/T transitional areas occupy from 3.2 ±0.27 million km^2 (August) to 13.2 ±0.59 million km^2 (November);

-These results are being used to construct a consistent, systematic long-term (>20 yr) global daily 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.

Acknowledgements

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