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Global Mapping of Landscape Freeze-Thaw Status using Spaceborne Microwave Remote Sensing

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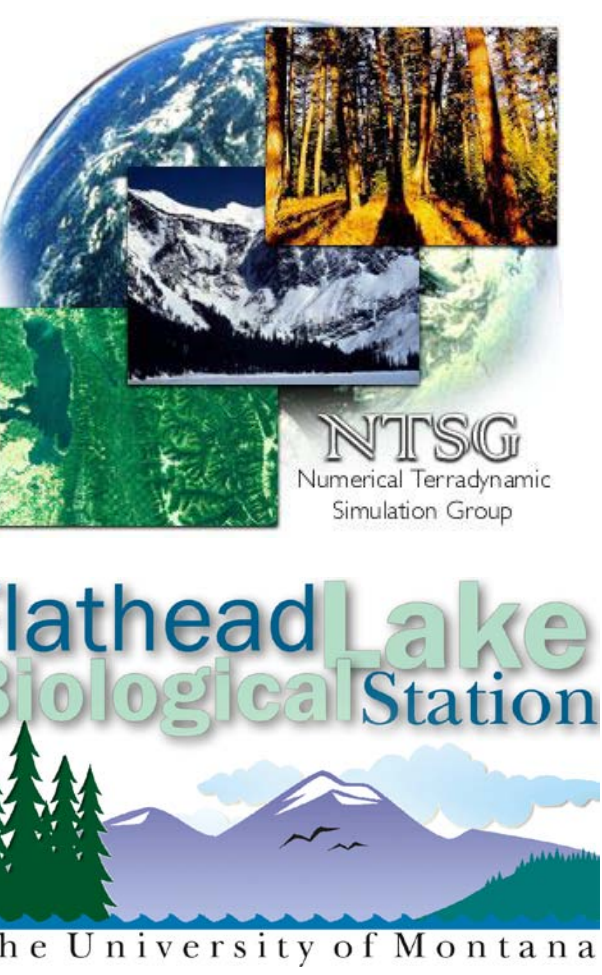
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Kim, Youngwook; Kimball, John S.; McDonald, Kyle C.; and Glassy, Joseph M., "Global Mapping of Landscape Freeze-Thaw Status using Spaceborne Microwave Remote Sensing" (2009). *Numerical Terradynamic Simulation Group Publications*. 367.

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Introduction:

The freeze-thaw (FT) status of the landscape is closely linked to surface energy budget and hydrological activity, vegetation phenology, terrestrial carbon budgets and land-atmosphere trace gas exchange. Spaceborne microwave radars and radiometers are ideally suited for global FT 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.

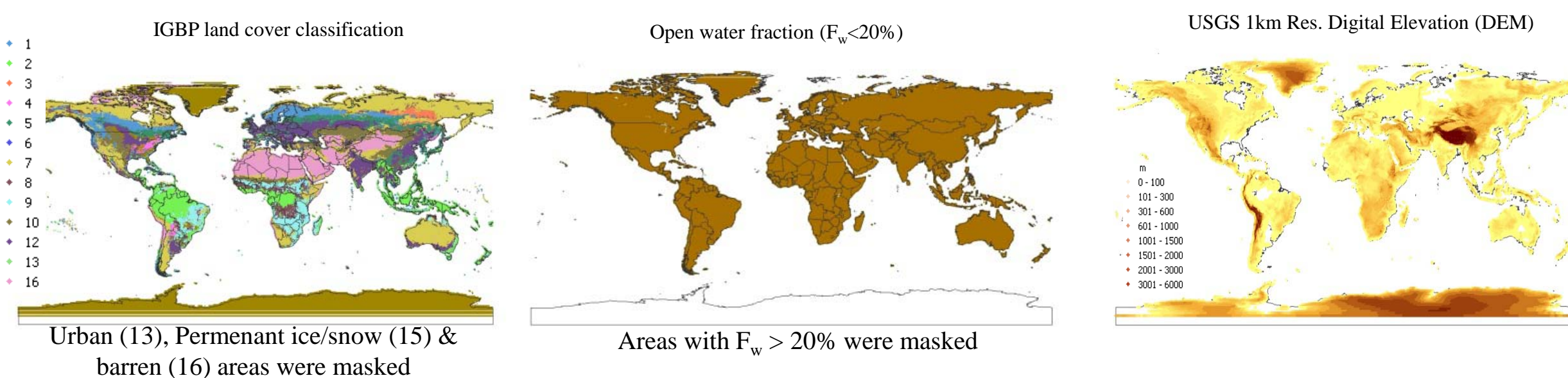
Data and Methods:

	Passive		Active
Sensor	SSM/I	AMSR-E	SeaWinds
Platform	DMSP	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



F/T Algorithms:

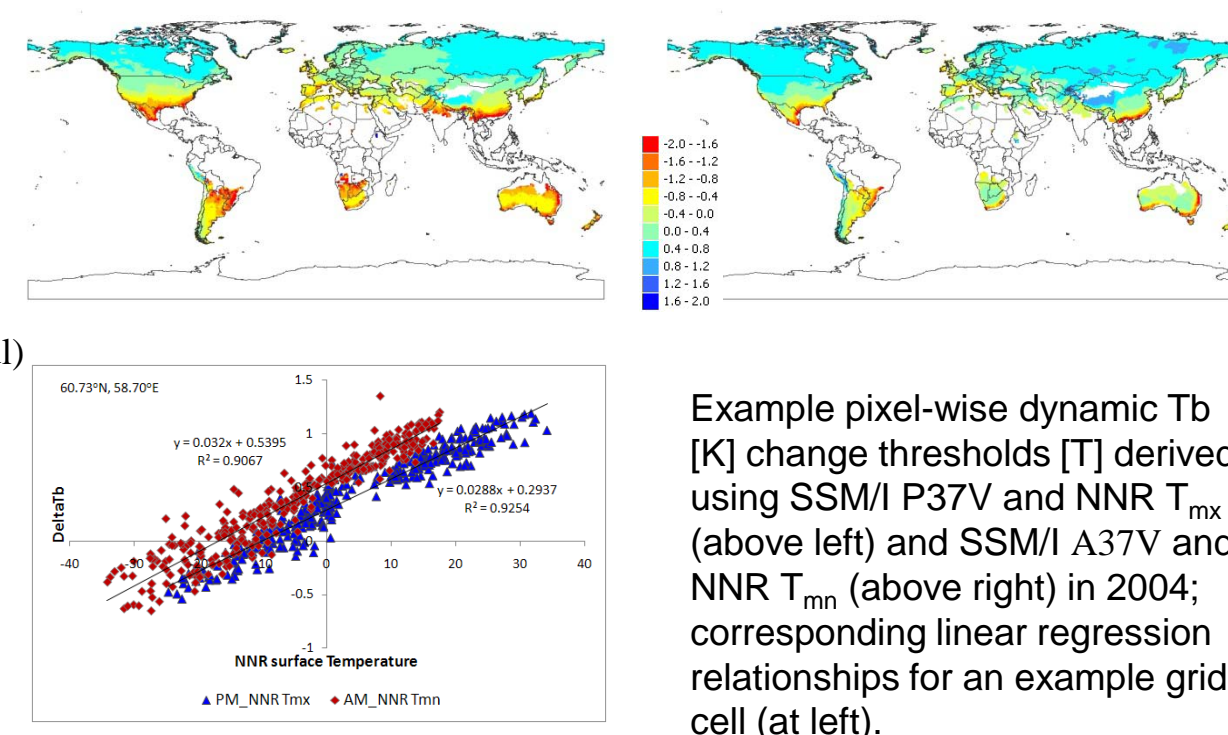
¹Seasonal Threshold Approach (STA)

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

σ_{fr} = frozen reference state (mean SSM/I Tb in Jan)
 σ_{th} = non-frozen reference state (mean SSM/I Tb in Jul)

$$\Delta(t) > T \text{ Thawed}$$

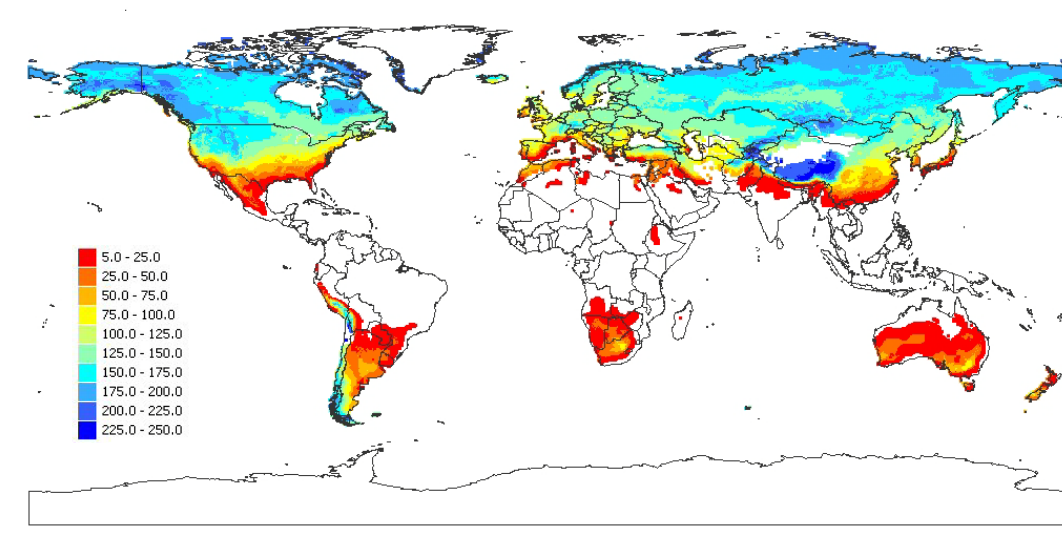
$$\Delta(t) \leq T \text{ Frozen}$$



Global FT_ESDR domain:

-defined by 7-year DAO reanalysis climatology using a ²cold temperature constraint index [CCI, days/yr];
 -encompasses all vegetated regions where low temperatures are a major constraint to ecosystem processes.

$$iT_{Min} = \begin{cases} 0, & \text{if } T_{min} \leq T_{Min} \\ \frac{T_{min} - T_{Min}}{T_{Max} - T_{Min}}, & \text{if } T_{Min} < T_{min} < T_{Max} \\ 1, & \text{if } T_{min} \geq T_{Max} \end{cases} \quad CCI = 365 - iT_{Min}$$



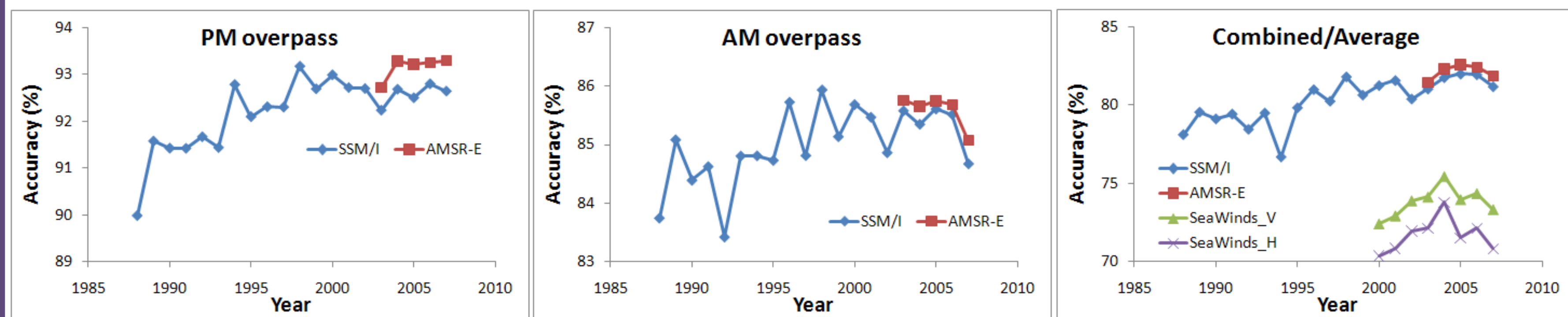
¹T_{Max} and T_{Min} vary by major land cover class using a global Biome Properties Lookup Table (BPLUT)

²Source: McDonald and Kimball, *EHS* 2004.
³Source: Jolly et al, *Global Change Biol* 2005.

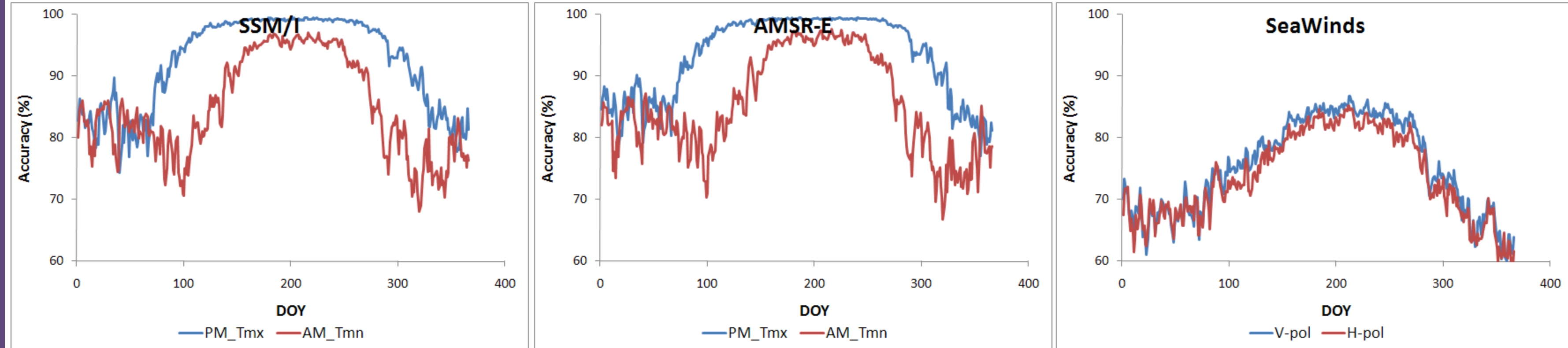
Global F/T classification:

- 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.

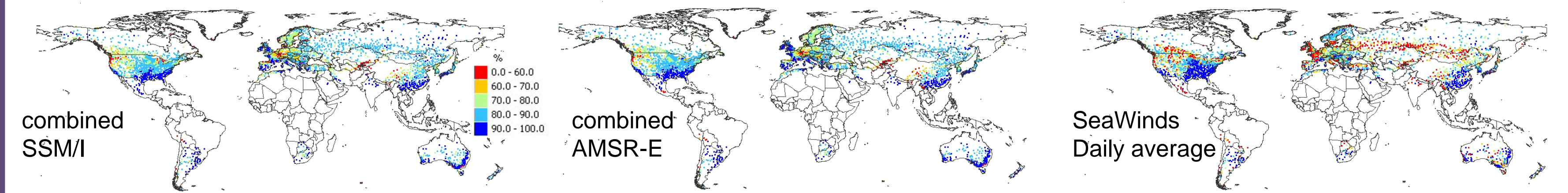
FT global accuracy assessment using NCDC stations:



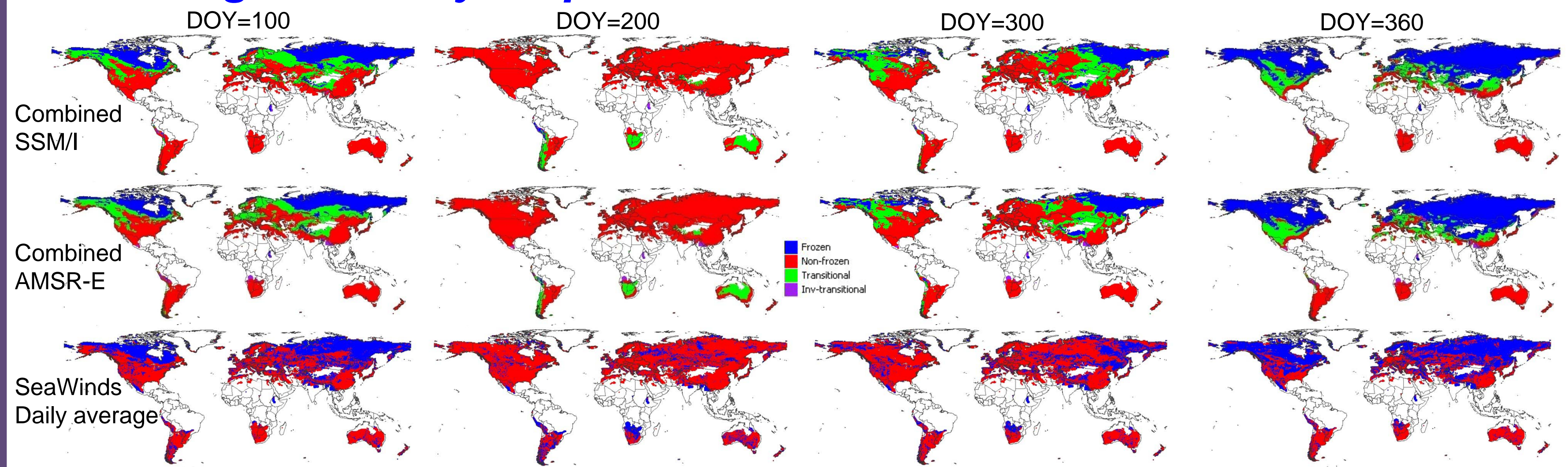
Seasonal pattern of daily mean global FT classification accuracy in 2004



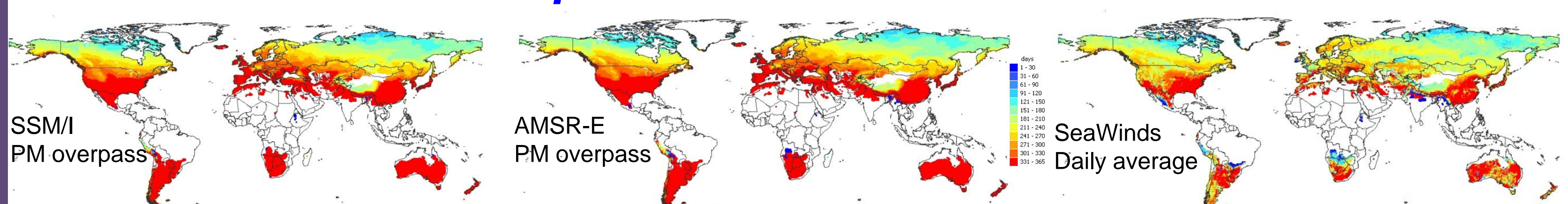
Spatial pattern of mean annual FT accuracy (%) relative to daily air temperatures from 3,701 NCDC stations in 2004



Selected global daily FT patterns for 2004:

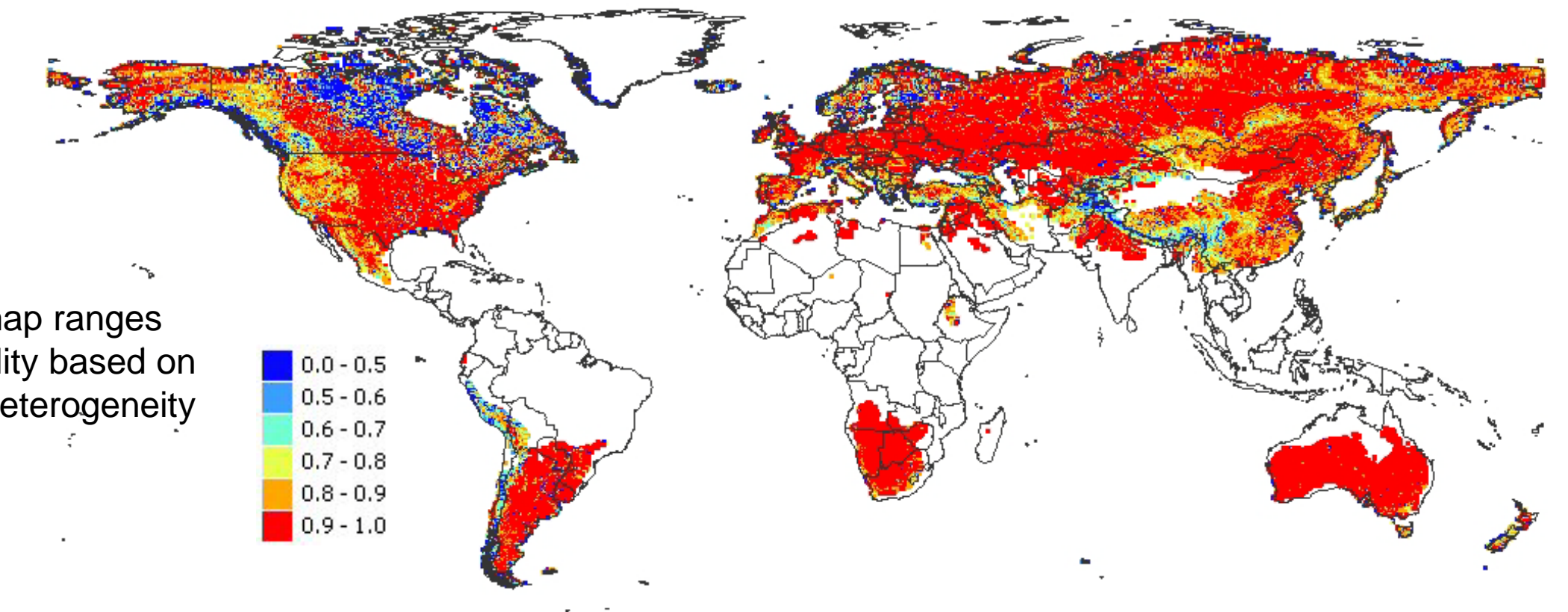


2004 annual non-frozen period

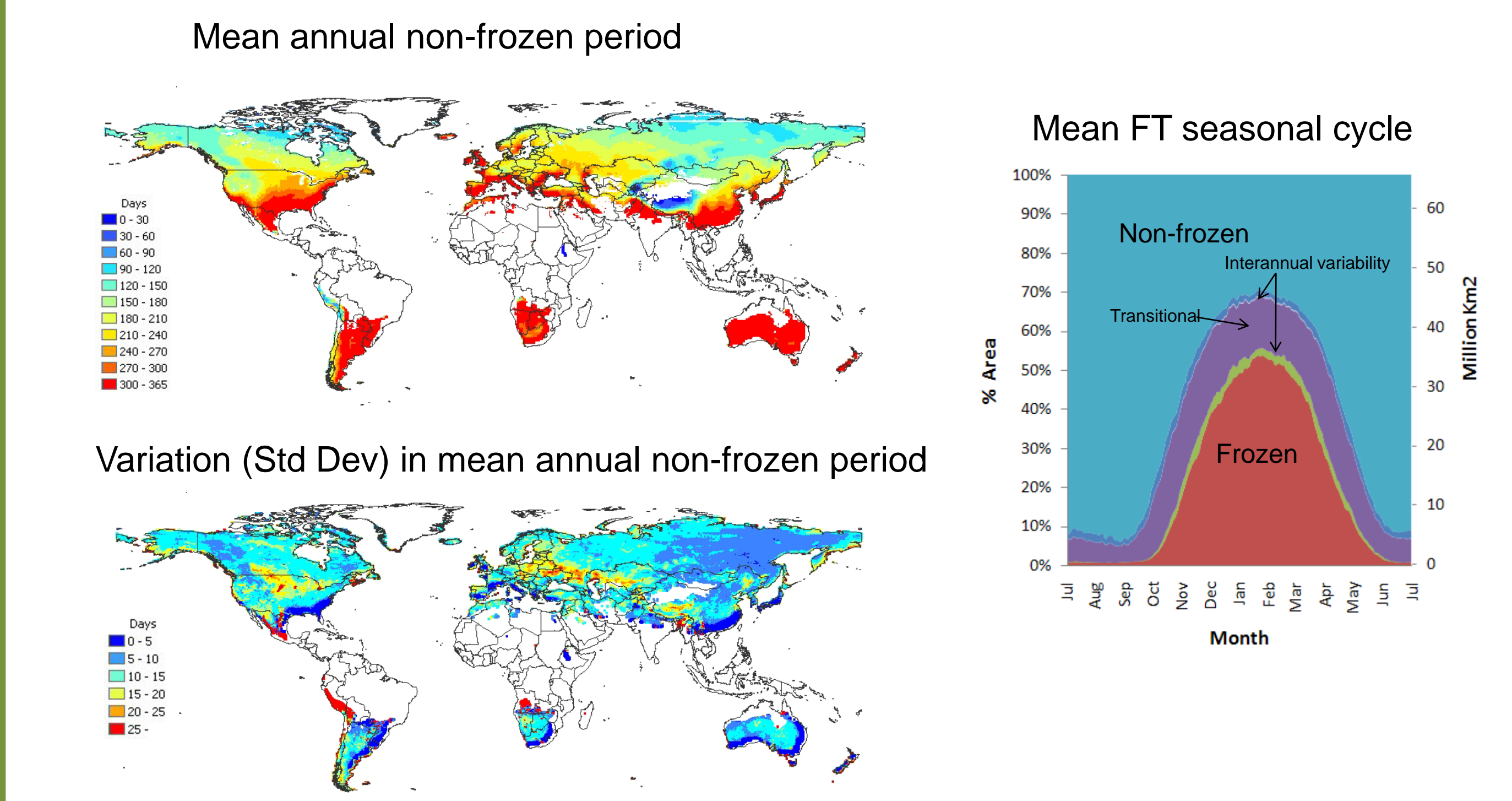


QC Map

The FT_ESDR QC (DIM) map ranges from low (0) to best (1) quality based on sub-grid scale Fw & DEM heterogeneity within each 25km grid cell.



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



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;
- Approximately 66 million km² of the global land area are constrained by seasonally frozen temperatures; the seasonal progression of global frozen area ranges from 0.53 (±0.03) million km² in July to 34.6 (±0.9) Million km² in January.
- The combined FT products show large transitional areas of opposing AM/PM FT states in spring and fall;
- 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 (<http://freezethaw.ntsg.umt.edu/>) and archived to the NSIDC DAAC.

Acknowledgements

This work was performed at the Jet Propulsion Laboratory, California Institute of Technology, and at the University of Montana under contract to NASA (NNH06ZDA001N-MEASURES)