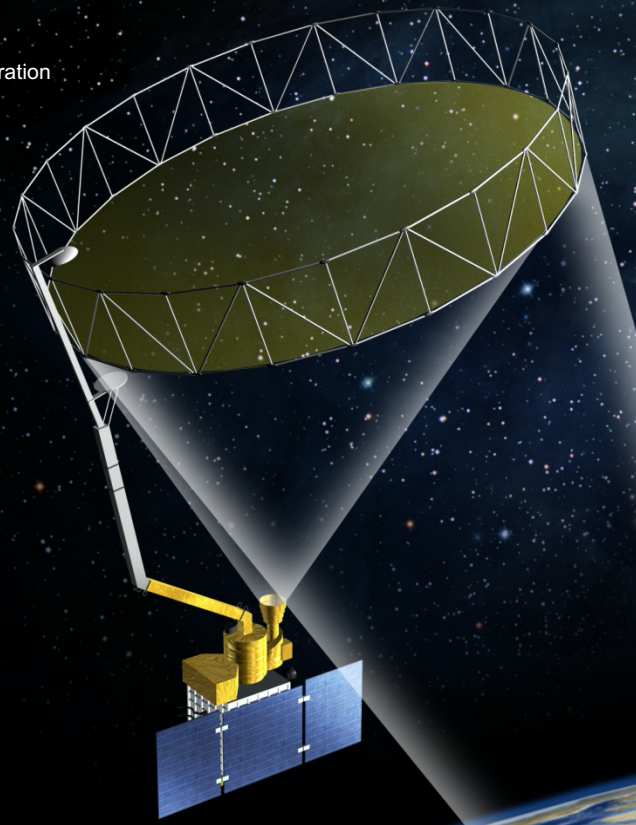
National Aeronautics and Space Administration

Soil Moisture Active Passive Mission

SMAP



Landscape Freeze/Thaw Standard and Enhanced Products from SMAP Radiometer Data

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[3] Numerical Terradynamic Simulation Group, University of Montana, Missoula, MT, USA

2018 IGARSS International Geoscience and Remote Sensing Symposium

Milestones for Freeze/Thaw algorithm

- 2013-2015 Reference generated from Aquarius
- Jan. 2015 L3-FT-A trace the F/T trend
- Feb. 2016 L3-FT-P kicked in to continue F/T retrieval (NPR)

- Apr. 2016 L3-FT-A beta release (Hybrid reference)

- Oct. 2016 L3-FT-P beta release
- Dec. 2016 L3-FT-P-E beta release

- 2017-current L3-FT-P[E] (include Global Grid)

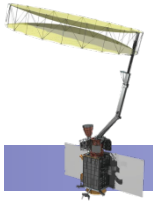
Overview

1. Baseline Algorithm Refinement (Flow Chart)

   Global Grid is included in the new release (in progress)

2. Combined algorithm review
   - Primary Algorithm: NPR (Reference difference > 0.1)
   - Supplementary Algorithm: FT-SCV (High correlation between physical temperature and TB)
   - False flag mitigation
3. Retrieval quality flag
4. Preliminary Results for water corrected TB
5. Cal/Val is in progress
   a. Polar Grid : validation based on Core Sites with both soil temperature and air temperature
   b. Global Grid (lower latitude): primarily on air temperature (WMO stations)

Combined F/T Algorithm Flowchart



L1C_TB:
- Global
- North Polar

F/T Classifier (NPR + FTSCV)

L3_FT_P
- North Polar
- Global

- NPR: F/T-Ref, Threshold
- FTSCV: TBv Threshold, Correlation
- Algorithm selection (0. Invalid, 1. NPR, 2. FTSCV)
- AMSRE-weekly mask

L1C_TB:
- Global

F/T Classifier (NPR + FTSCV)

Binary States To L2/3_SM_P

L3_FT_P new release

L3_FT_P product:
Groups:
/Ancillary_Data
/Freeze_Thaw_Retrieval_Data
/Radiometer_Data

L3_FT_P product:
Groups:
/Freeze_Thaw_Retrieval_Data_Polar
/Freeze_Thaw_Retrieval_Data_Global

Primary Algorithm: Normalized Polarization Ratio

- **Primary** algorithm for L3_FT_P(_E) using L1C_TB(_E) inputs:

$$FFrel = \frac{FF(t) - FF_{fr}}{FF_{th} - FF_{fr}} \qquad FF_{NPR} = \frac{TB_V - TB_H}{TB_V + TB_H} * 100$$

$$FFrel(t) > T(=0.5), thaw$$

$$FFrel(t) < T(=0.5), freeze$$

- Thaw reference: Average 2 months SMAP NPR value from Jul./Aug over 3 years (2015,2016,2017)
- Freeze reference: Average lowest 20 SMAP NPR value from Jan/Feb over 3 years (2016,2017,2018)
- Thresholds: fixed at 0.5

L1C input: water corrected TB or RAW TB ??

Supplementary Algorithm: FT-SCV

Freeze/Thaw -Single Channel Algorithm :
Heritage from high frequency FT algorithm (AMSR)

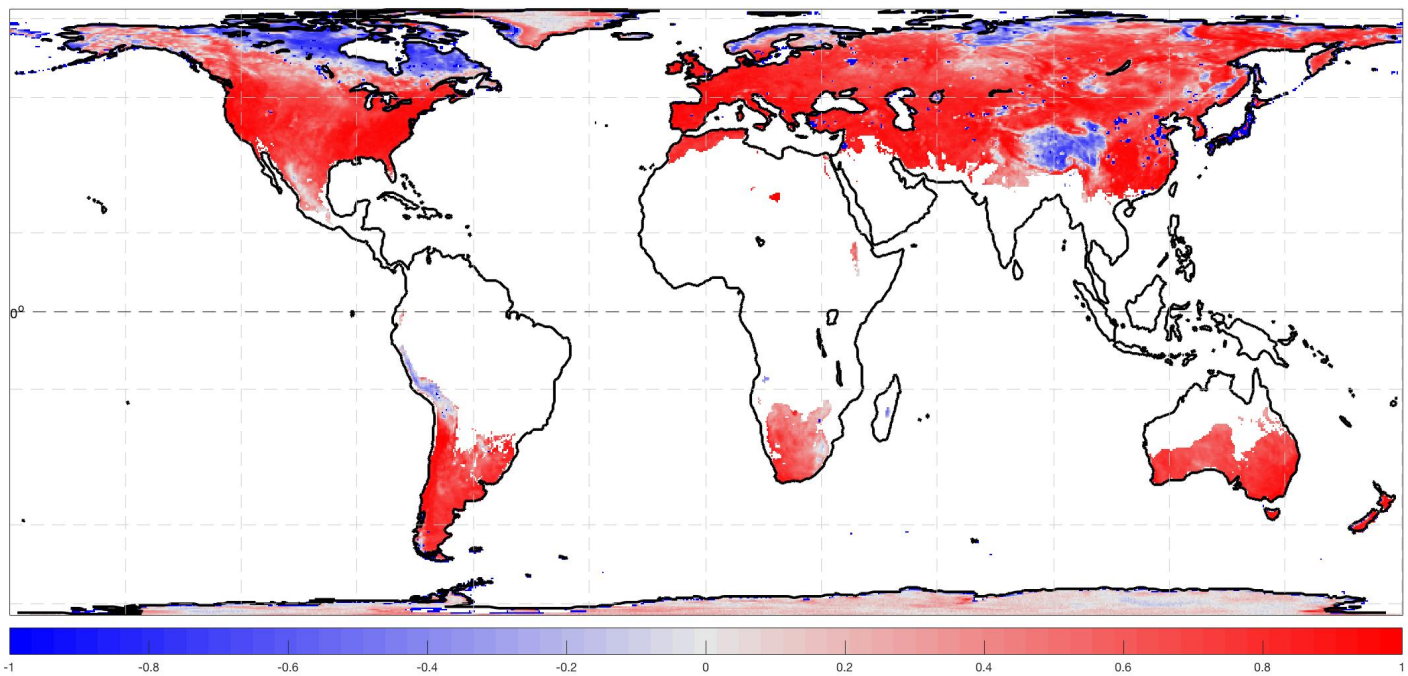
$R>0$

$$FT = \begin{cases} Thaw\ , if\ Tbv > threshold \\ Freeze, if\ Tbv < threshold \end{cases}$$

$R<0$

$$FT = \begin{cases} Thaw\ , if\ Tbv < threshold \\ Freeze, if\ Tbv > threshold \end{cases}$$

Correlation (R) between GMAO & Tbv



False Flag Mitigation

- Tbv or Tbh >273 = THAW
- Daily AMSR-E masks: Over a 31 day window, identify pixels that were never classified as frozen/thawed over 2002~2016 period (AMSRE/AMSR2):

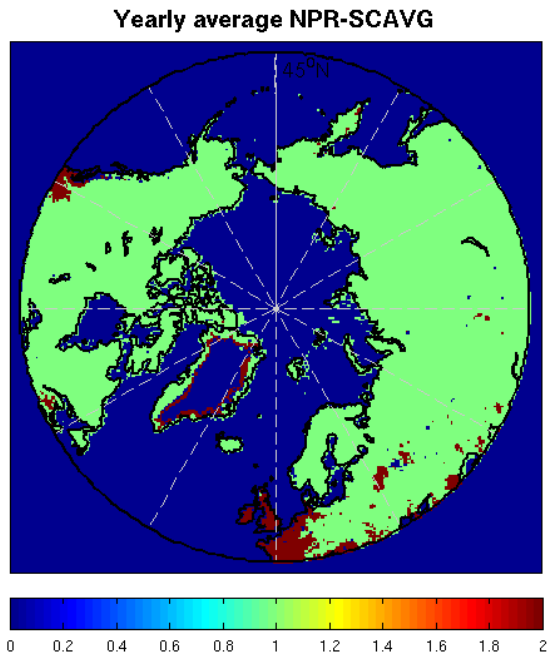
$$NF(doy) = \sum_{i=doy-15}^{doy+15} Freeze_AMSR_flag(i)$$

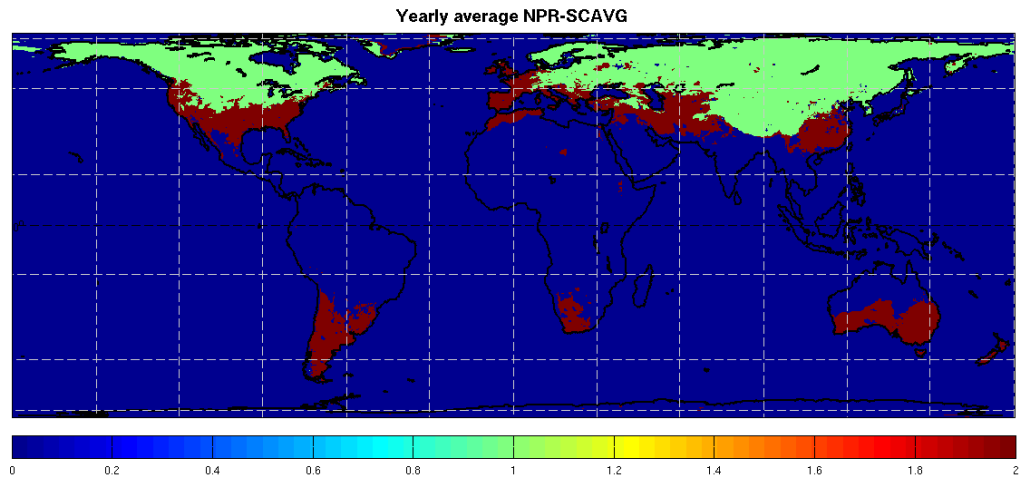
$$NF_mask = (NF == 0)$$

$$NT(doy) = \sum_{i=doy-15}^{doy+15} Thaw_AMSR_flag(i)$$

$$NT_mask = (NT == 0)$$

Combined Algorithm





0. IGBP == Urban, Water fraction > 50%, no FT retrieval
1. Reference difference > 0.1, using NPR
2. Single channel algorithm

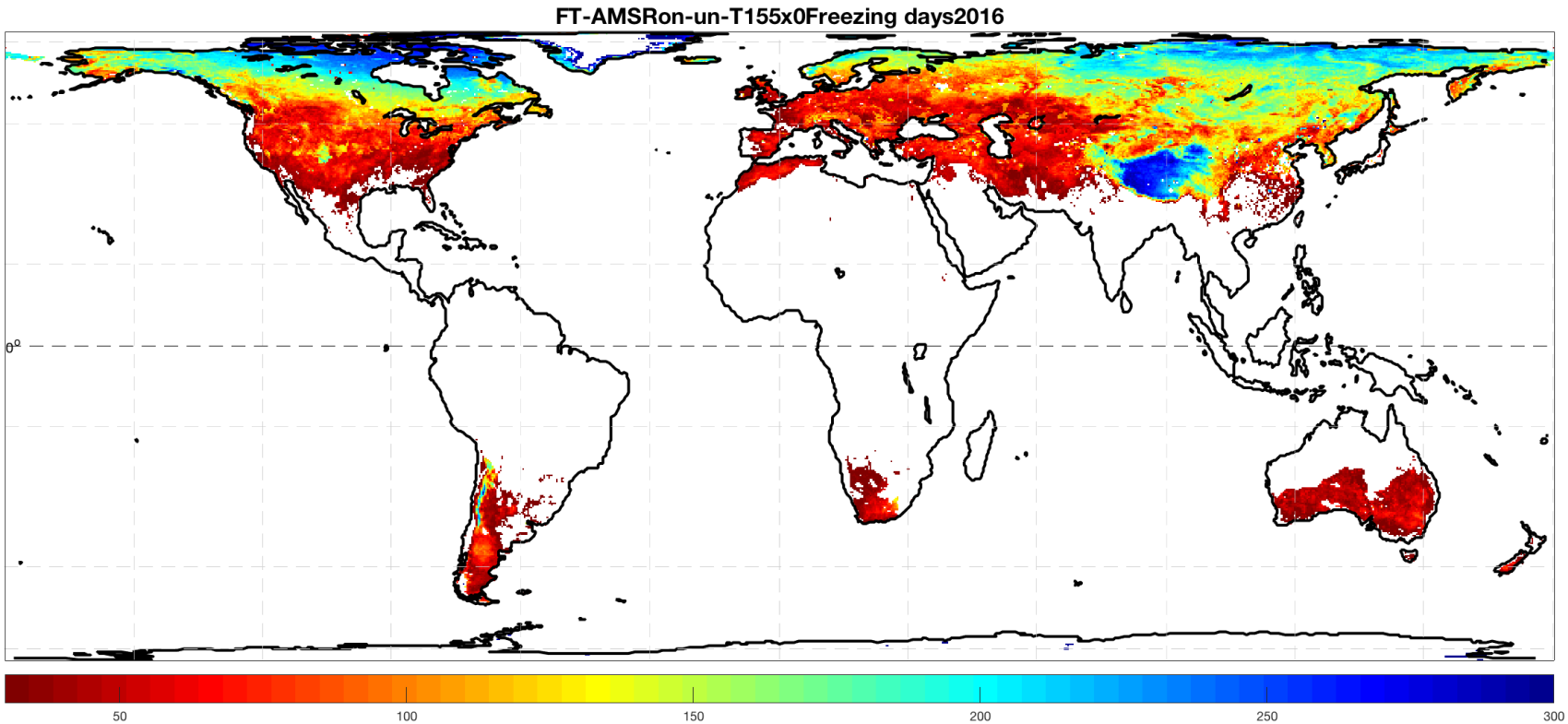
Parameter files (Look-up Table)

Parameters	Current version	Improvement
Freeze reference	Lowest 20 from Jan/Feb	Lowest 20 from Nov to Mar, check temperature, only valid if T < 0C
Thaw reference	Highest 20 from Jul/Aug	Average 2 summer months (Jul to Aug) check temperature, only valid if T > 0C
Threshold	0.5 everywhere	0.5 only in valid area (a) ref-difference >0.1 (b) valid Freeze/Thaw reference
Single channel Threshold	N/A	for lower latitude when NPR is not valid
Single channel Correlation	N/A (default set to 1)	run algorithm (adding quality flag)
AMSR-mask	yearly	weekly (mainly removed summer false flag)
Algorithm Selection	N/A	0: algorithm is run 1: NPR 2: FT-SCV

Retrieval Quality Flag (Bit Flags)

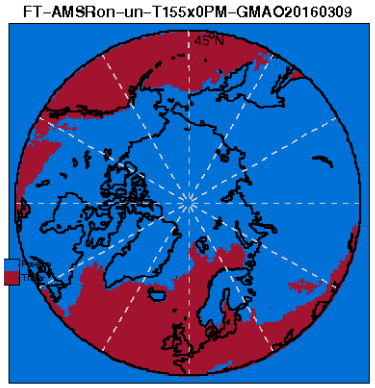
Name	Bit Position	Value	Interpretation
FT retrieval attempted flag	0	0	F/T is retrieved for the pixel
(Algorithm selection)		1	F/T is not retrieved (IGBP: Urban or water fraction > 50% or no valid TB)
High Water Fraction flag	1	0	Water fraction less than 20%
		1	Water fraction between (20%-50%)
Permanent Ice Flag	2	0	IGBP: non-permanent snow/ice
		1	IGBP: permanent snow/ice
Low Correlation Flag	3	0	SCV is used and correlation > 0.5
		1	SCV is used and correlation < 0.5

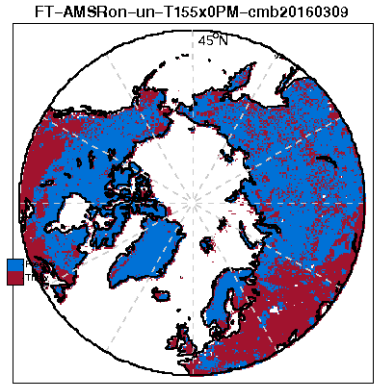
Total Freezing Days 2016



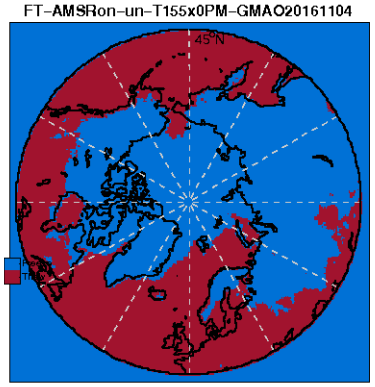
Snapshot Polar Grid (2016)

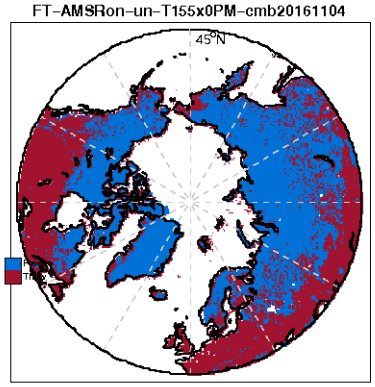
Thawing process (Spring)

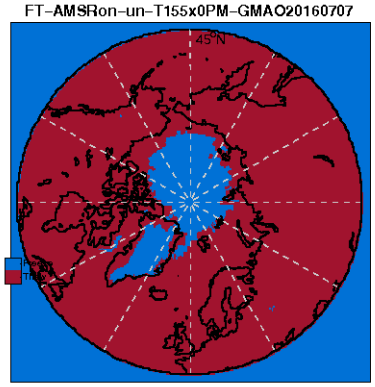


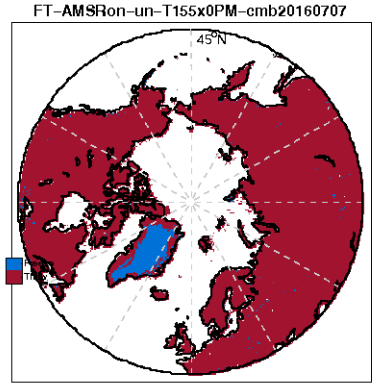


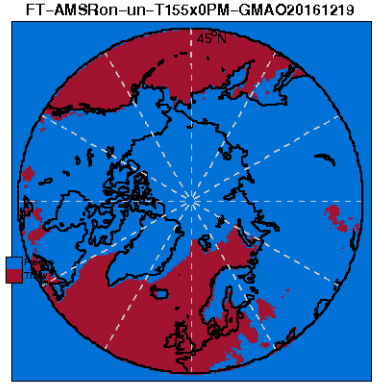
Freezing process (Spring)

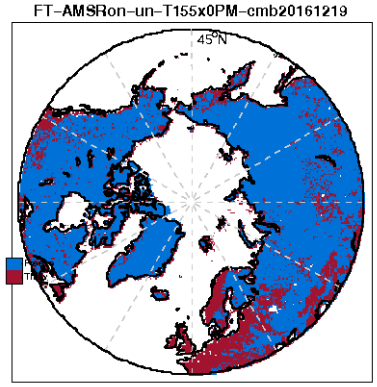




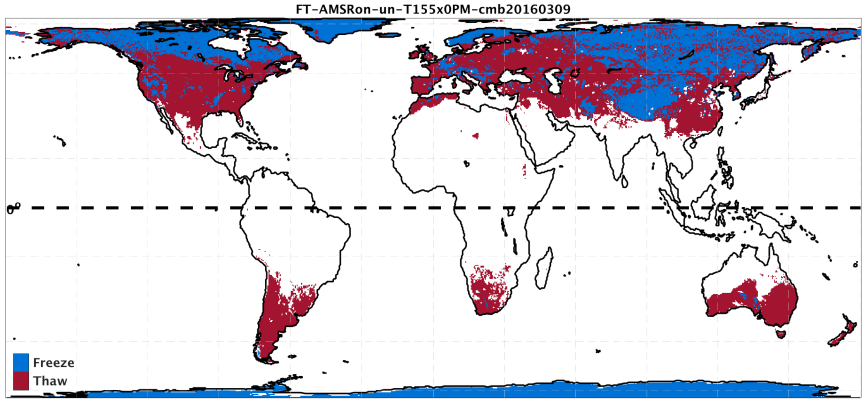




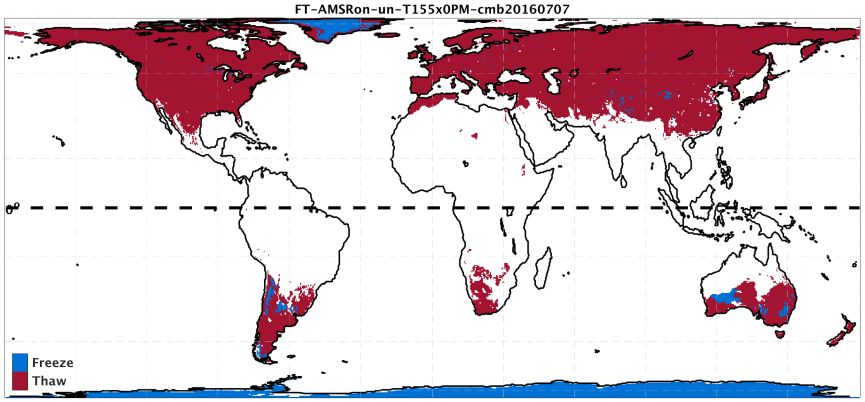




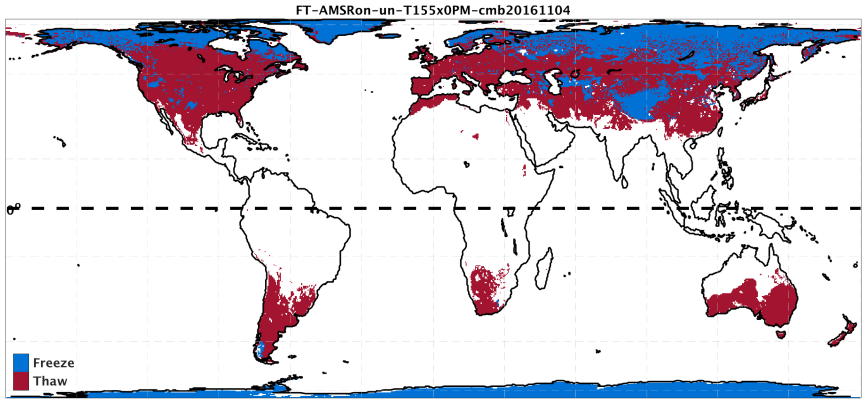
Snapshot 2016: Combined Algorithm



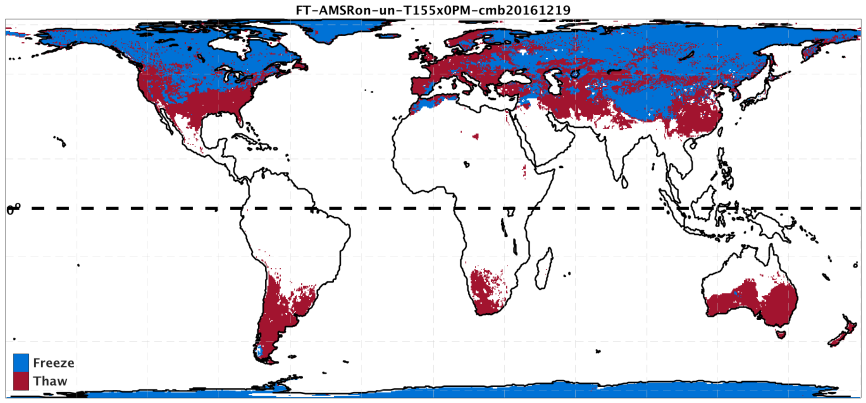
Mar 9, 2016



Jul 7, 2016

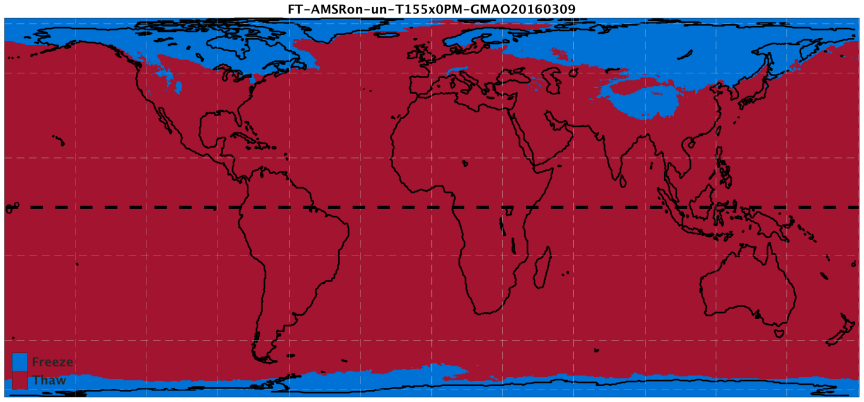


Nov 4, 2016

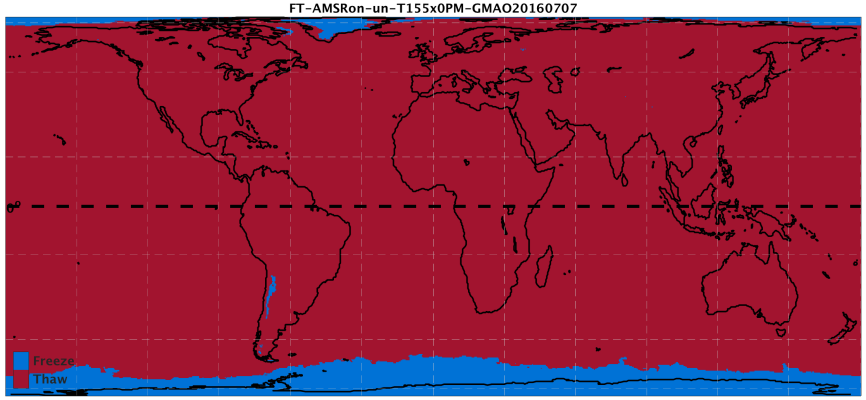


Dec 19, 2016

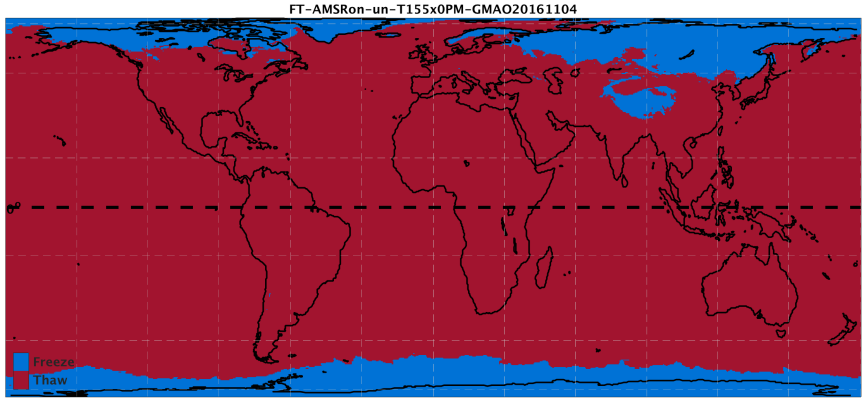
Snapshot: 2016 GMAO



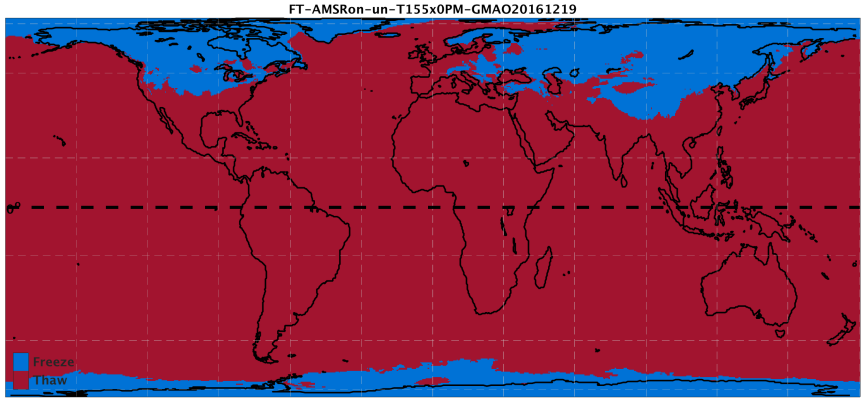
Mar 9, 2016



Jul 7, 2016



Nov 4, 2016



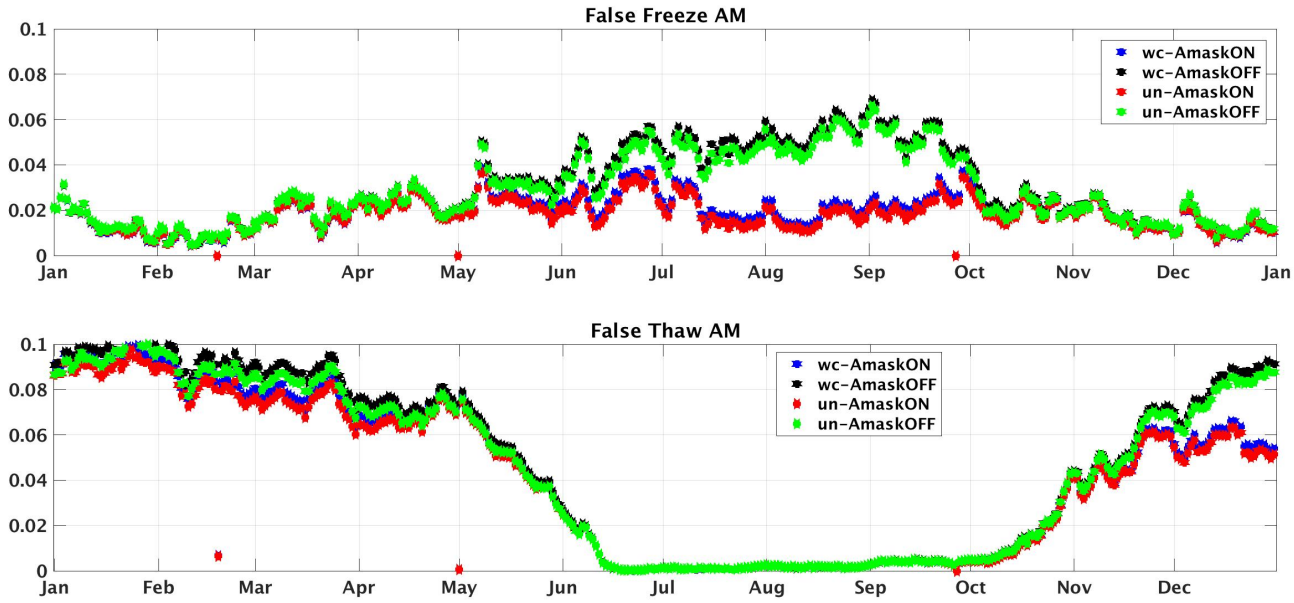
Dec 19, 2016

Error analysis using GMAO

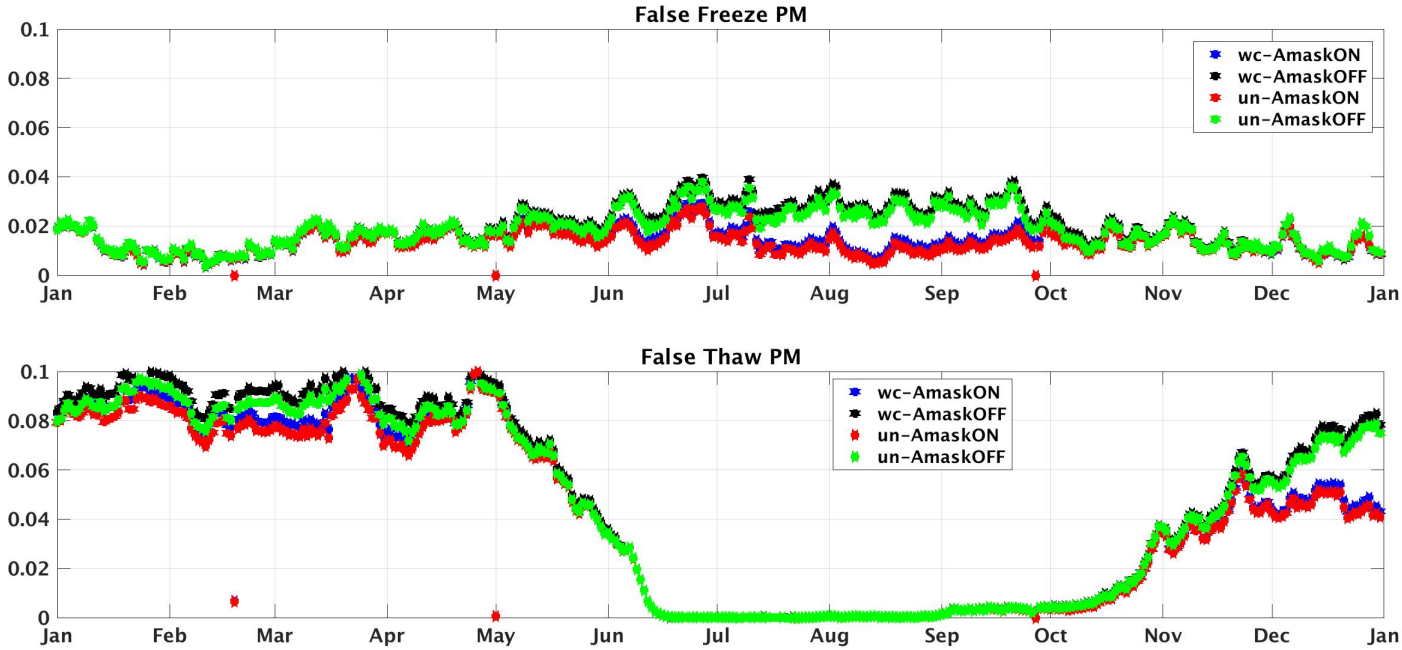
Four cases are compared

a) Water-corrected TB with AMSRE weekly mask ON
b) Water-corrected TB with AMSRE weekly mask OFF
c) raw TB with AMSRE weekly mask ON
d) raw TB with AMSRE weekly mask OFF

False Thaw (FT/T-error): NPR algorithm is thaw, GMAO Temperature < -5
False Freeze(FF/F-error):NPR algorithm is freeze, GMAO Temperature > 5

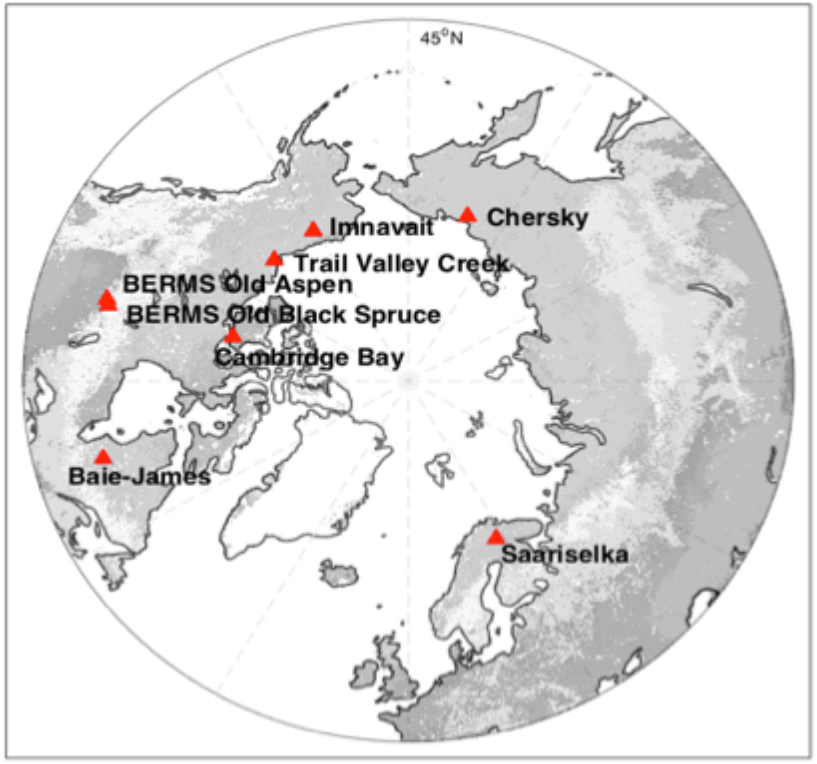


Error analysis using GMAO



1. FT derived from uncorrected TB with AMSR weekly mask shows the lowest error throughout a year
2. AM has higher error than PM (consistent with our previous analysis)

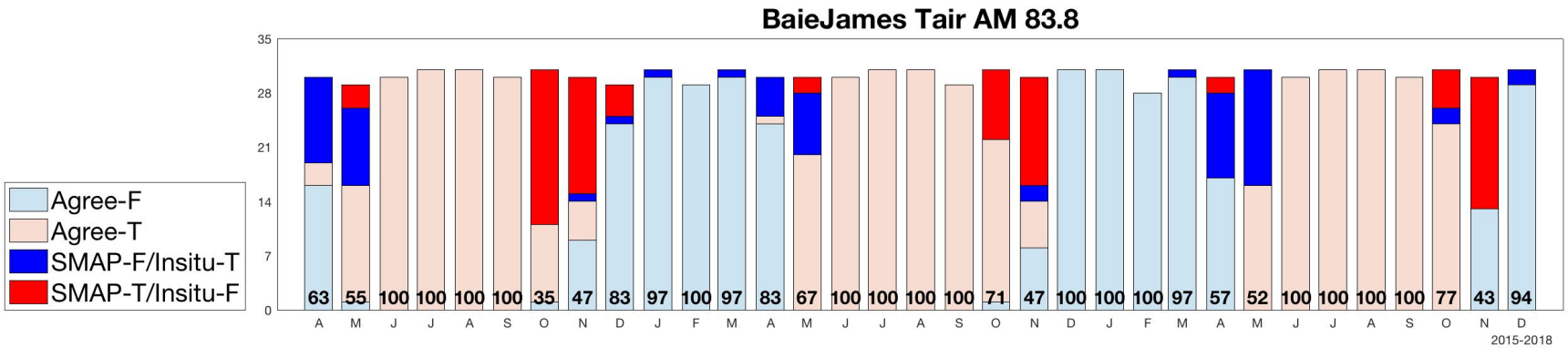
L3_FT Cal/Val Summary: Core Sites (T15160)

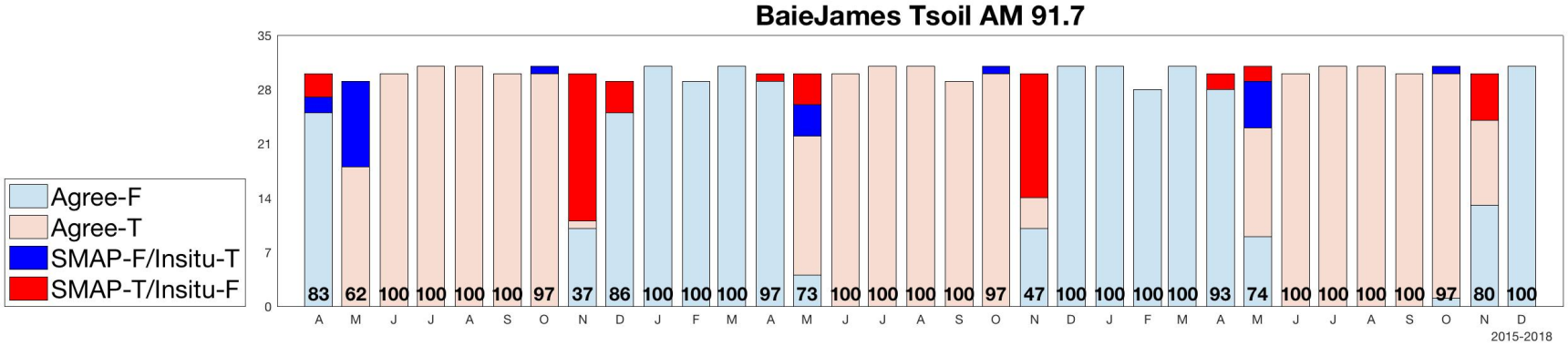


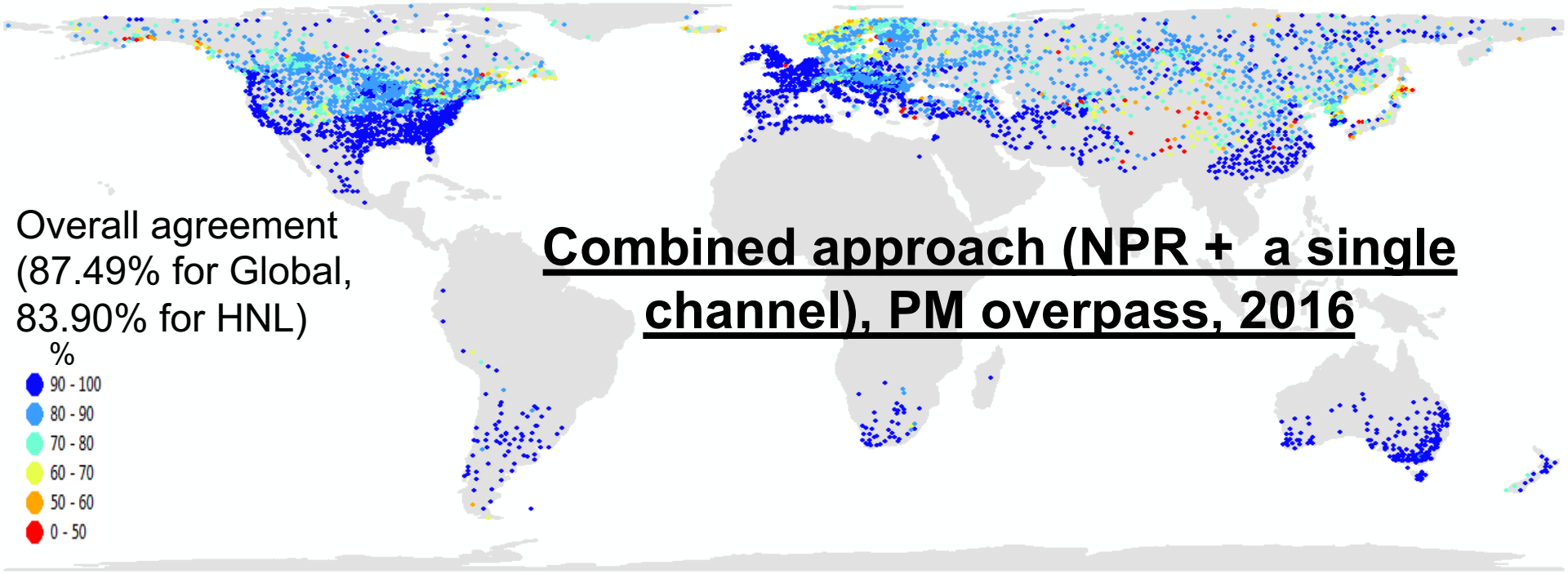
ID	Site Name	Tair AM	Tsoil AM	Tair PM	Tsoil PM
5502	Cambridge-Bay	92.8	90.4	92.4	91.2
6801	Chersky				
3501	Imnavait	71.4	65.8	77.5	73.6
5501	Baie-James	83.8	91.7	84.5	89
2701	Kenaston	80.8	80.8	78.2	78.2
3401	BERMS-OAS	84.7	85.4	85.7	86.1
3402	BERMS-OBS	87.6	85.9	82.8	84.9
1701	Sodankyla	84.8	79.3	85.2	81.7
1702	Saariselka	73.8	73.8	73.7	73.7

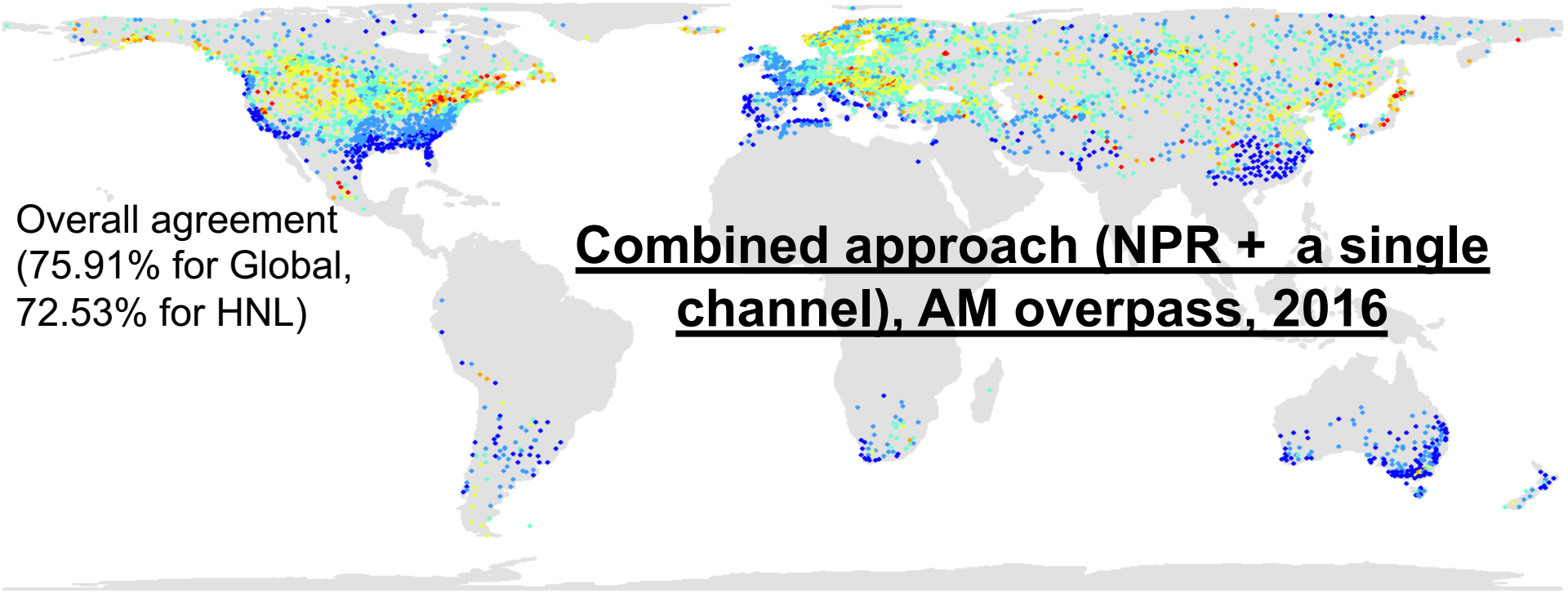
Evaluation of SMAP measurements and FT retrievals from 1 April 2015 to 1 January 2018 indicates the baseline classification accuracy (80%) is met for most metrics and evaluation datasets, and the minimum mission requirement of 70% is met if using air temperature.

Baie-James station

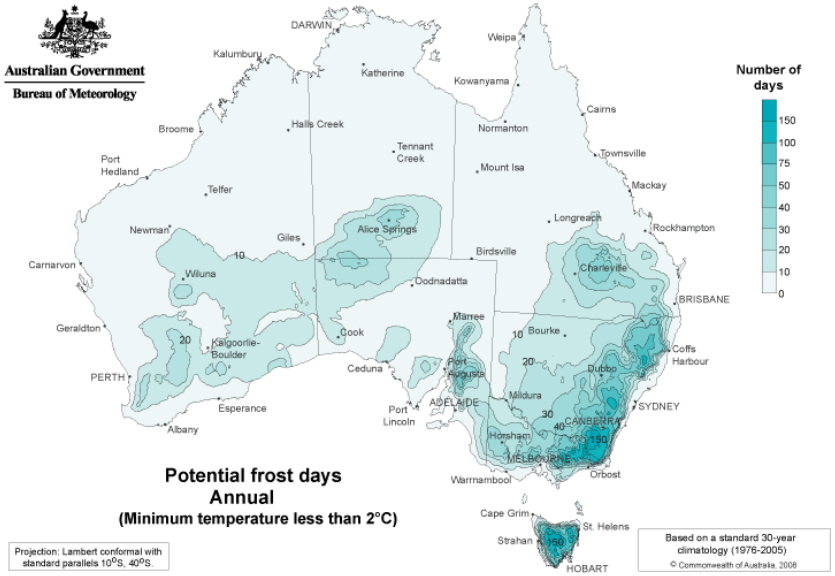





Overall agreement
(87.49% for Global,
83.90% for HNL)
%
90 - 100
80 - 90
70 - 80
60 - 70
50 - 60
0 - 50
Combined approach (NPR + a single channel), PM overpass, 2016

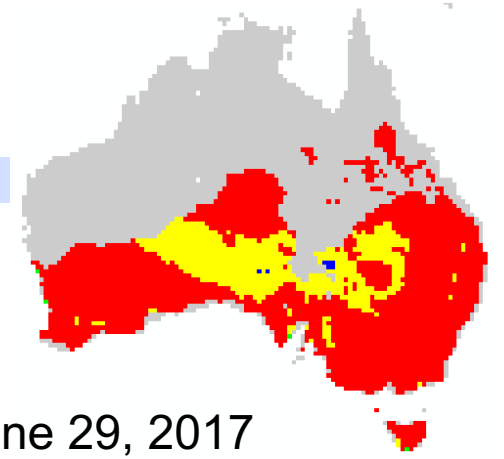

Overall agreement
(75.91% for Global,
72.53% for HNL)
Combined approach (NPR + a single channel), AM overpass, 2016

Severe frost over Australia

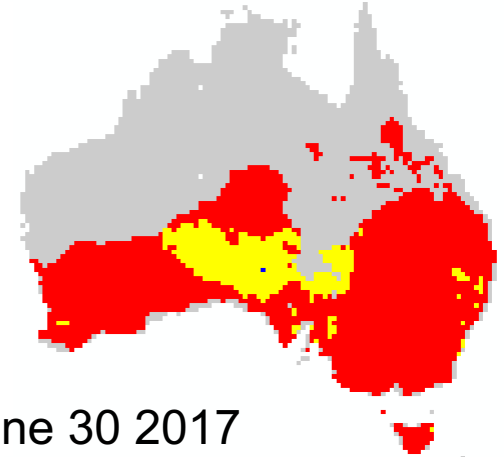


A single channel FT data

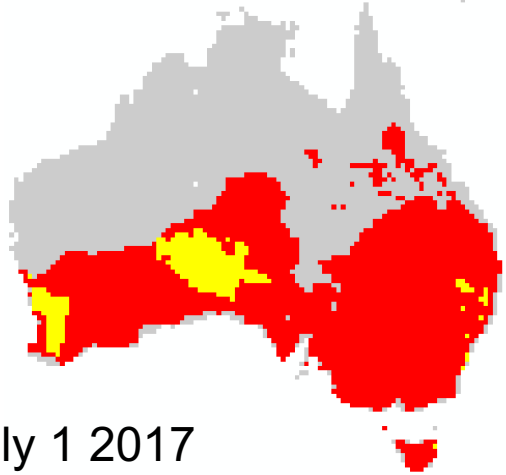
- Thaw
- Frozen
- Transitional
- Inv-Transitional



June 29, 2017



June 30 2017



July 1 2017

2017 Australia Frost Events

http://www.news.com.au/technology/environment/snow-plummeting-temperatures-hail-and-unbelievably-severe-frost-on-the-way/news-story/1d43311c2e8c4c5f47d1ddf3205b6b32

Summary

1. Baseline Algorithm Refinement : Combined algorithm

   (L3-FT-P-Enhance product is still processing)

   Documentation updates: ATBD,

   - Primary Algorithm: NPR (Reference difference > 0.1)
   - Supplementary Algorithm: FT-SCV (High correlation between physical temperature and TB)
   - False flag mitigation

2. Raw TB (not water corrected TB) is recommend

3. Cal/Val need to be updated

   a. Polar Grid : validation based on Core Sites with both soil temperature and air temperature

   b. Global Grid (lower latitude): primarily on air temperature (WMO stations)