Temporal Dynamics of the NASA Soil Moisture Product:

Issues and Potential Solution(s) for Improvement

I. E. Mladenova, T. J. Jackson, R. Bindlish, M. Cosh

USDA-ARS, Hydrology and Remote Sensing Lab, Beltsville, MD

E. Njoku, S. Chan

NASA, Jet Propulsion Lab, Pasadena, CA

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Beltsville, Maryland, USA

Introduction:
Project Overview

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Introduction
Algorithms
Approaches
Summary

- … "Evaluate the performance of the AMSR-E standard/baseline algorithm using ground based measurements, and assess its performance against alternative algorithms and soil moisture products.
  Improve the operational NASA approach/product if possible." …

- Algorithm selection criteria
  - Well established
  - Provide global near real time retrieval
  - Able to run using the AMSR-E TB database used by the operational approach
  - Access to the algorithm 'source' code
  - …

Algorithms:
List of Selected Algorithms & Progress

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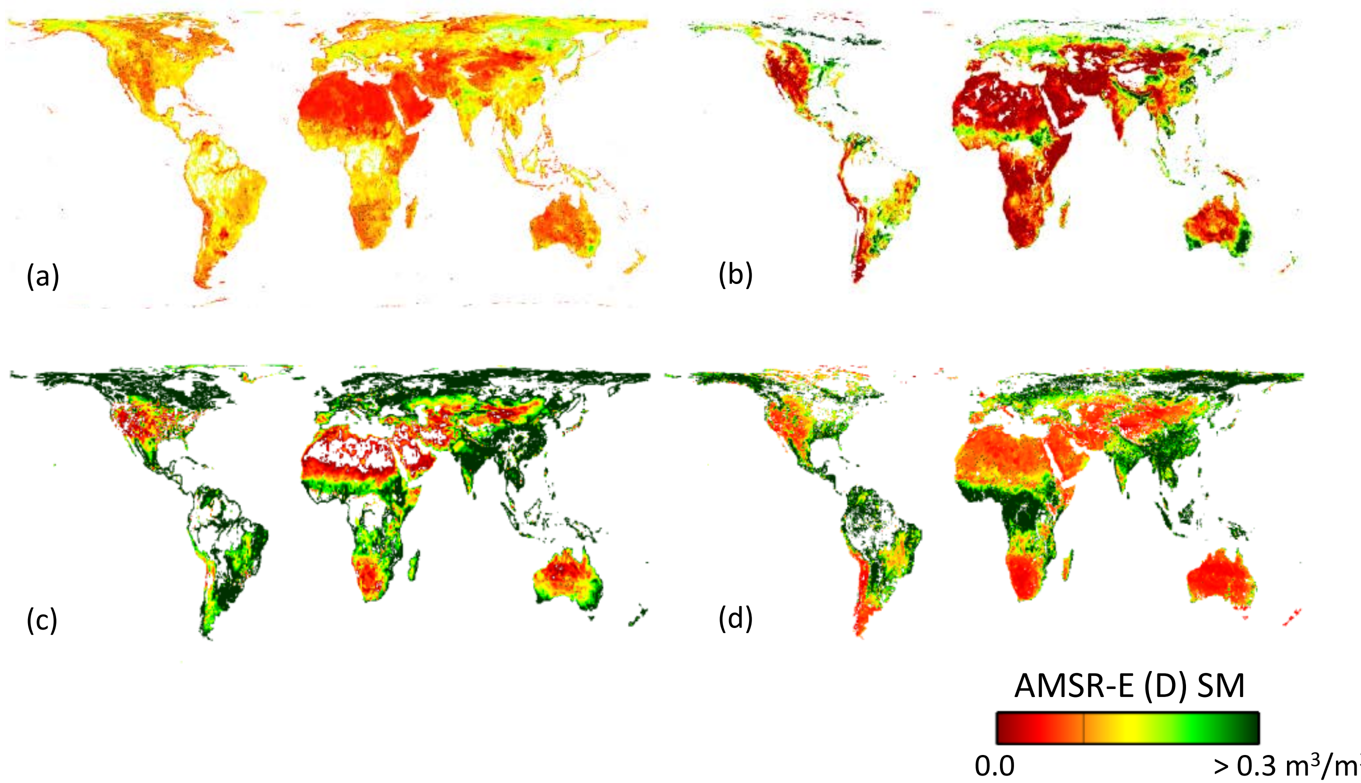
Introduction
Algorithms
Approaches
Summary

- Algorithm update table

[1] *Progress in terms of receiving and implementing the code at HRSL*
[2] *Database at HRSL needs to be updated for recent years*

	Developer	Software specifications	Progress [1] *at HRSL*	AMSR-E input	Output *availability*	*product level*
[1]NASA	National Aeronautics Space Administration (*Njoku & Chan*)	Fortran	ok	NASA T_B swath	available at HRSL	swath
[2]USDA-SCA	U.S. Department of Agriculture-Single Channel Algorithm (*Jackson*)	Fortran	ok	NASA T_B swath	available at HRSL	swath
[3]VU-LPRM	Land Parameter Retrieval Model (*Owe & de Jeu*)	Matlab	ok	NASA T_B swath	available at HRSL	swath
[4]UMo	University of Montana (*Jones & Kimball*)	C	ok	NASA T_B grid	available through NSIDC (2002-2008)	grid
[5]IFAC-Hydroalgo	Istituto di Fisica Applicata (*Paloscia*)	Matlab	ok	Disaggr. C-band T_B data JAXA T_B swath; able to read NASA	*In progress*	high res. grid
[6]JAXA	Japan Aerospace Exploration Agency (*Koike*)	---	*Will not be provided*	---	available at HRSL[2]	swath
[7]UPr	Princeton University (*Gao & Wood*)		*In progress*			
[8]$NRL_{WindSat}$	Naval Research Laboratory (*Li*)	---	*Will not be provided*	---	---	---

Algorithms:
Some of the Current Retrievals…



Current passive microwave retrieval algorithms produce very different soil moisture estimates!

Algorithms:
Difference in Dynamic Range

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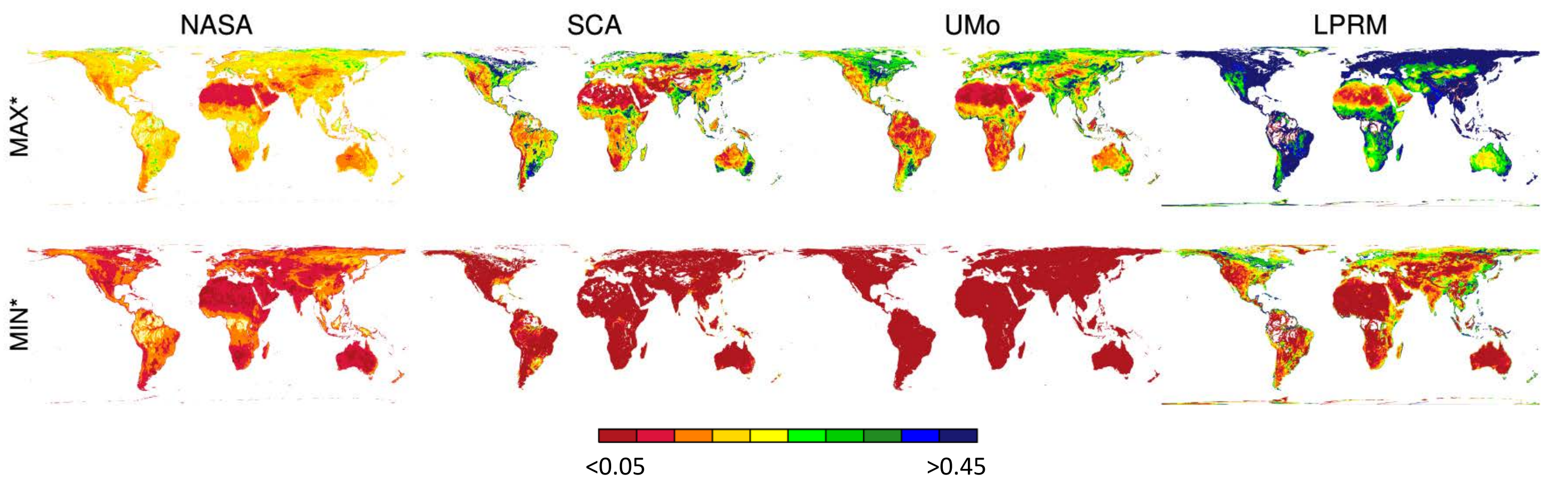
- …" Dampened temporal response,
  Narrow dynamic range &
  Bias."…

- Factors affecting soil moisture dynamic range
  - Environmental: soil hydrologic properties, climate regime, canopy cover, …
  - Technique specific



*AMSR-E, descending overpass; Time period: 2003-2010; * 5/95 percentile*

Possible Approaches

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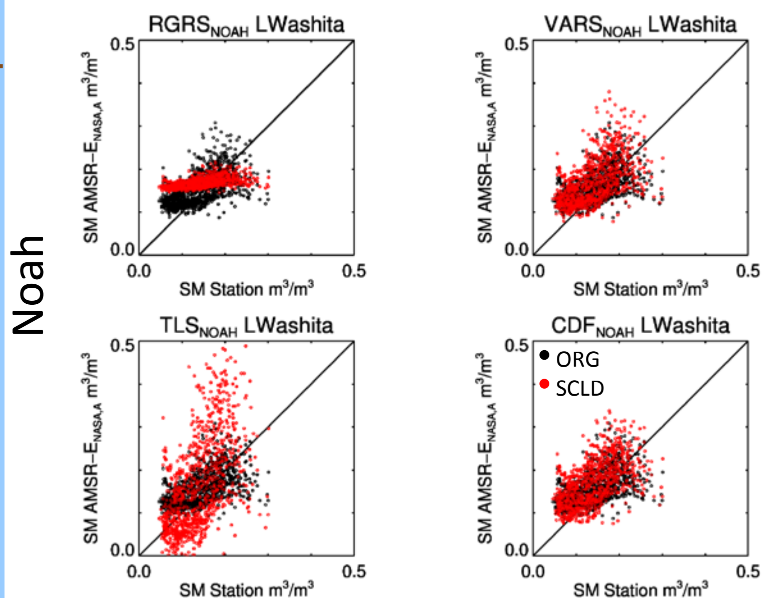
- Approaches
  - Statistical approach, i.e. rescaling.
    - CDF $$cdf_{ref}(SM^{scld}) = cdf_{retr}(SM^{retr})$$
    - Variance $$SM^{scld} = \mu_{ref} + \frac{\sigma_{ref}}{\sigma_{retr}}\left(SM^{retr} - \mu_{ref}\right)$$
    - Regression $$SM^{scld} = \mu_{ref} + \frac{\sigma_{ref}}{\sigma_{retr}}\left(SM^{retr} - \mu_{ref}\right)\rho$$
      - *Ordinary LS*
      - *Total LS*
    - Min/Max $$SM^{scld} = MIN_{ref} + \frac{RNG_{ref}}{RNG_{retr}}\left(SM^{retr} - MIN_{retr}\right)$$
    - TCA
  - Algorithm changes, i.e. theoretical approach.

Possible Approaches:

Rescaling Approach, Station Example

Little Washita; AMSR-E (A)



Overview of rescaling techniques: Rescaling results over the Little Washita using Noah Min and Max and the ascending NASA SM retrievals.

	R	Bias	RMSE
ORG	0.55	-0.02	0.05
RGRS	0.55	-0.03	0.06
VARS	0.55	-0.03	0.06
Mn/Mx	0.55	-0.02	0.05
TLS	0.55	-0.03	0.10
CDF	0.57	-0.03	0.06

Evaluation against station data.

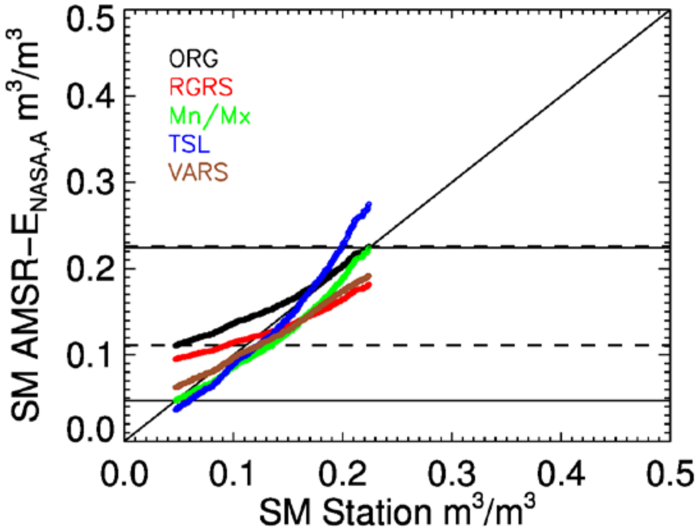
Results depend on the ‘reference’ data set;
Most require ‘sufficiently long’ time series;
Impact on accuracy…
Selection depends on application.

SM – Soil Moisture
ORG – Original
SCLD – Rescaled
RGRS – Regression-based rescaled values using OLS
VARAS – Variance based rescaled values
Mn/Mx – Min/Max-based rescaled values
TLS – Regression-based rescaled values using TLS
CDF – CDF-based rescaled values

Possible Approaches:
Rescaling Approach, Station Example

Little Washita

Station SM



— Original NASA Min/Max
--- Station Min/Max

Slightly different perspective… Rescaling results over the Little Washita using Station Min and Max and the ascending NASA SM retrievals.

Possible Approaches:
Min/Max Rescaling, Station Example

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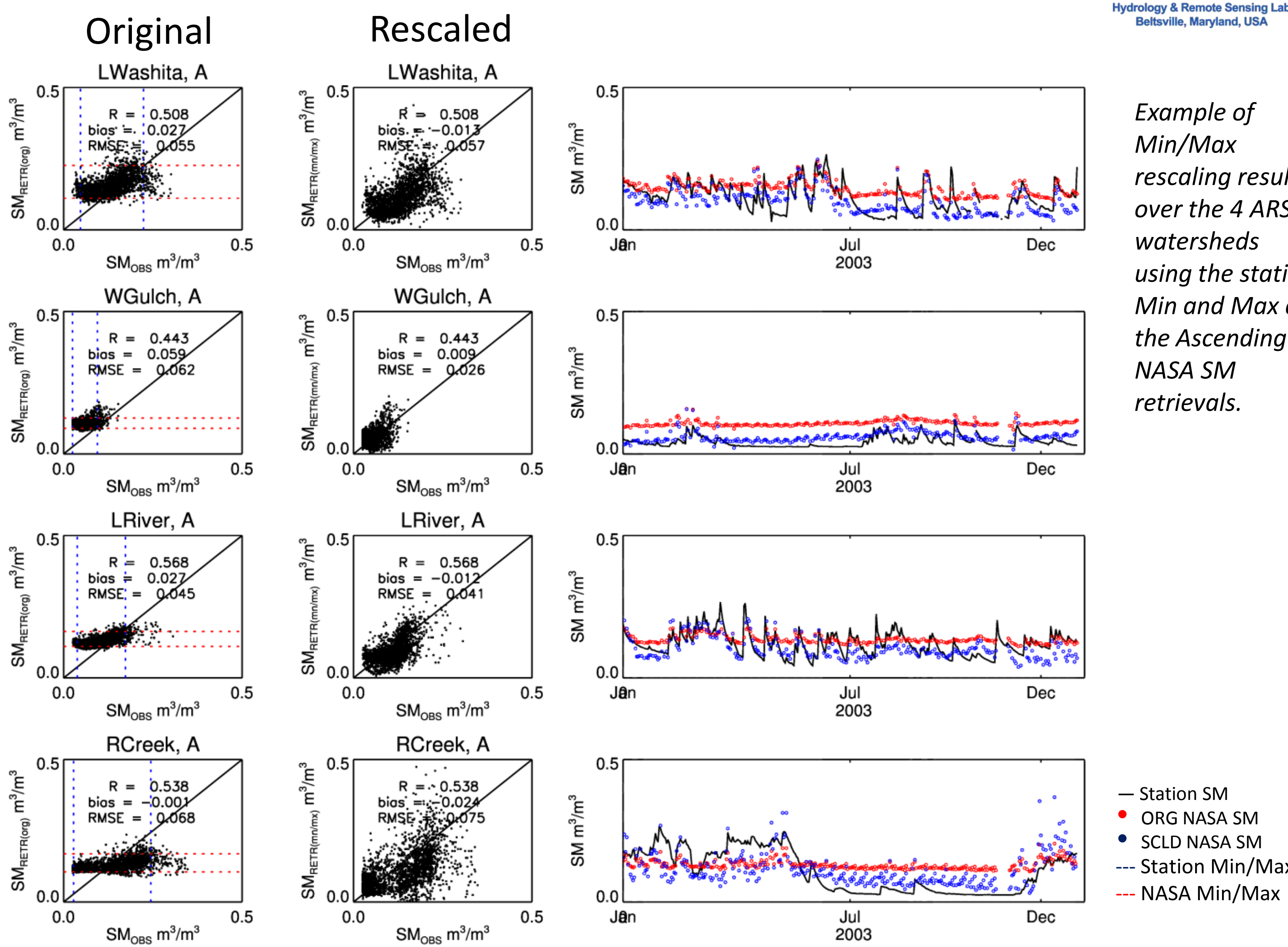

Example of Min/Max rescaling results over the 4 ARS watersheds using the station Min and Max and the Ascending NASA SM retrievals.

Possible Approaches:
Min/Max Rescaling, Global Example

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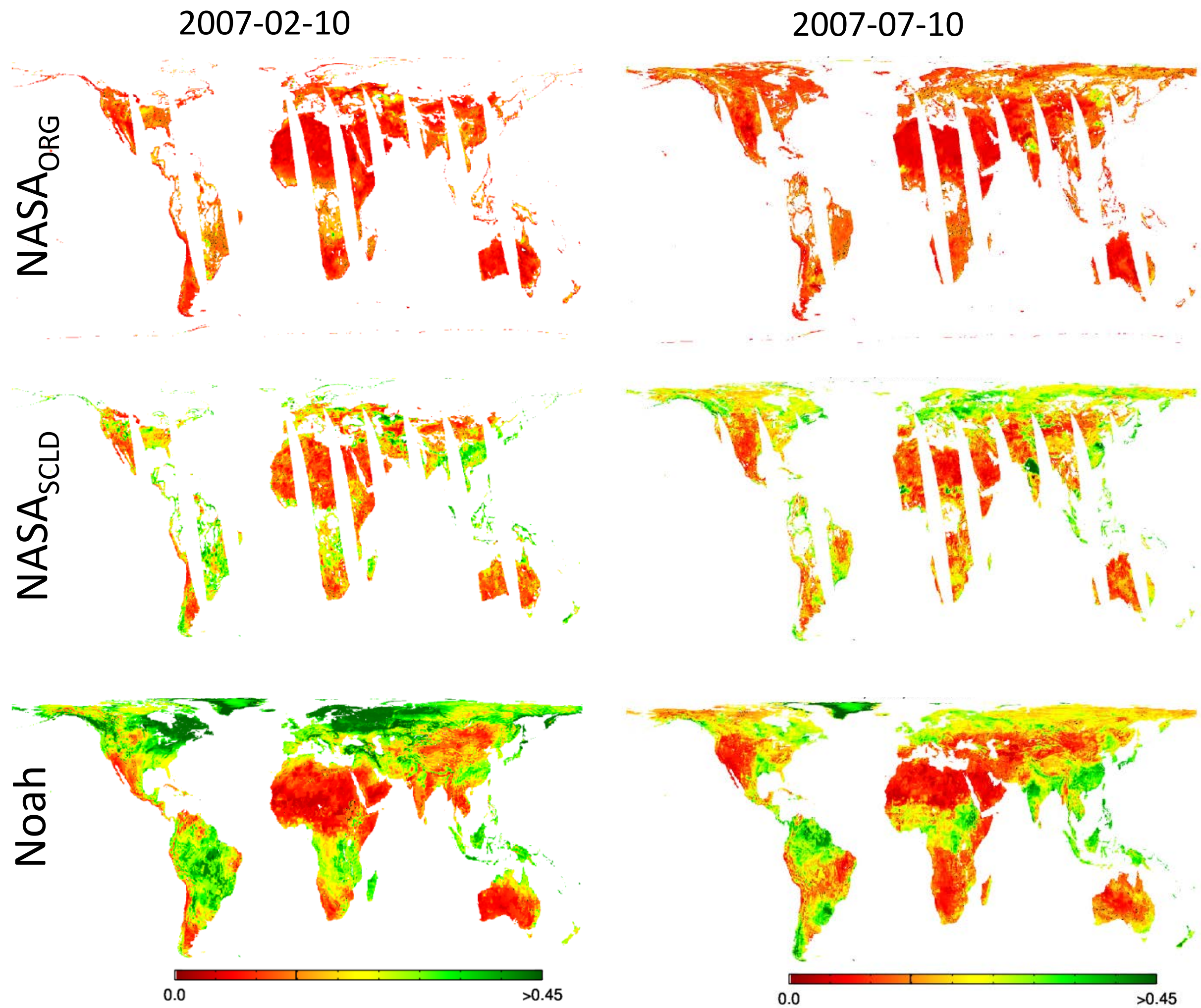
Introduction
Algorithms
Approaches
Rescaling
Theoretical
Summary



Example of Min/Max rescaling results at a global scale using the Noah Min and Max and the Ascending NASA SM retrievals.

Possible Approaches:

Theoretical Approach, Background

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- Retrieval schemes

TB

Atmospheric contribution

Optimization

Retrieval of geophysical parameters not done off line

Canopy attenuation

Roughness effect

Canopy + Soil Physical Temperature

SM

RT

DM

Image courtesy: *https://www.meted.ucar.edu/*

$$T_{B_{\mathrm{TOTAL}}} = T_{A\uparrow} + \mathrm{e}^{-\tau_a}(1-e_r)(T_{A\downarrow} + \mathrm{e}^{-\tau_a} T_{sky})\mathrm{e}^{-2\tau_c} + \mathrm{e}^{-\tau_a} T_{B_{\mathrm{LAND}}}$$

$\tau - \omega$

$$T_{B_{\mathrm{LAND}}} = T_s e_r \mathrm{e}^{-\tau_c} + T_c(1-\omega)(1-\mathrm{e}^{-\tau_c}) + \mathrm{e}^{-\tau_c} T_c (1-\omega)(1-\mathrm{e}^{-\tau_c})(1-e_r)$$

RT – Radiative Transfer modeling
DM – Dielectric Mixing modeling
TB – brightness temperature
SM – Soil Moisture

Possible Approaches:

Theoretical Approach, Background

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- RT + Dielectric mixing modeling
  - Solving approach: forward vs. inverse modeling.
  - Assumptions
    - No/Fixed atmospheric contribution
    - $T^{soil} = T^{canopy}$
    - $\omega = 0$
    - $\omega_H = \omega_V$ & $\tau_H = \tau_V$
    - …

  => Simplifications in the RT equation & Reduced number of unknowns
  - "Correction" modules:
    - Atmosphere: Ignore, Fixed, RT-based estimation
    - Physical temperature: Insensitive, Regression-based modeling
    - Canopy + Roughness effects

      Ancillary database + fixed parameterization

      RT-based modeling + fixed parameterization
  - Dielectric model: Wang and Schmugge vs. Dobson

- Ancillary database & fixed parameters
  - Ancillary data base: source, post processing steps, …

ω – single scattering albedo
τ – optical depth
T – temperature
H/V – Horizontal/Vertical polarization

Possible Approaches:
Theoretical Approach, Ancillary Database

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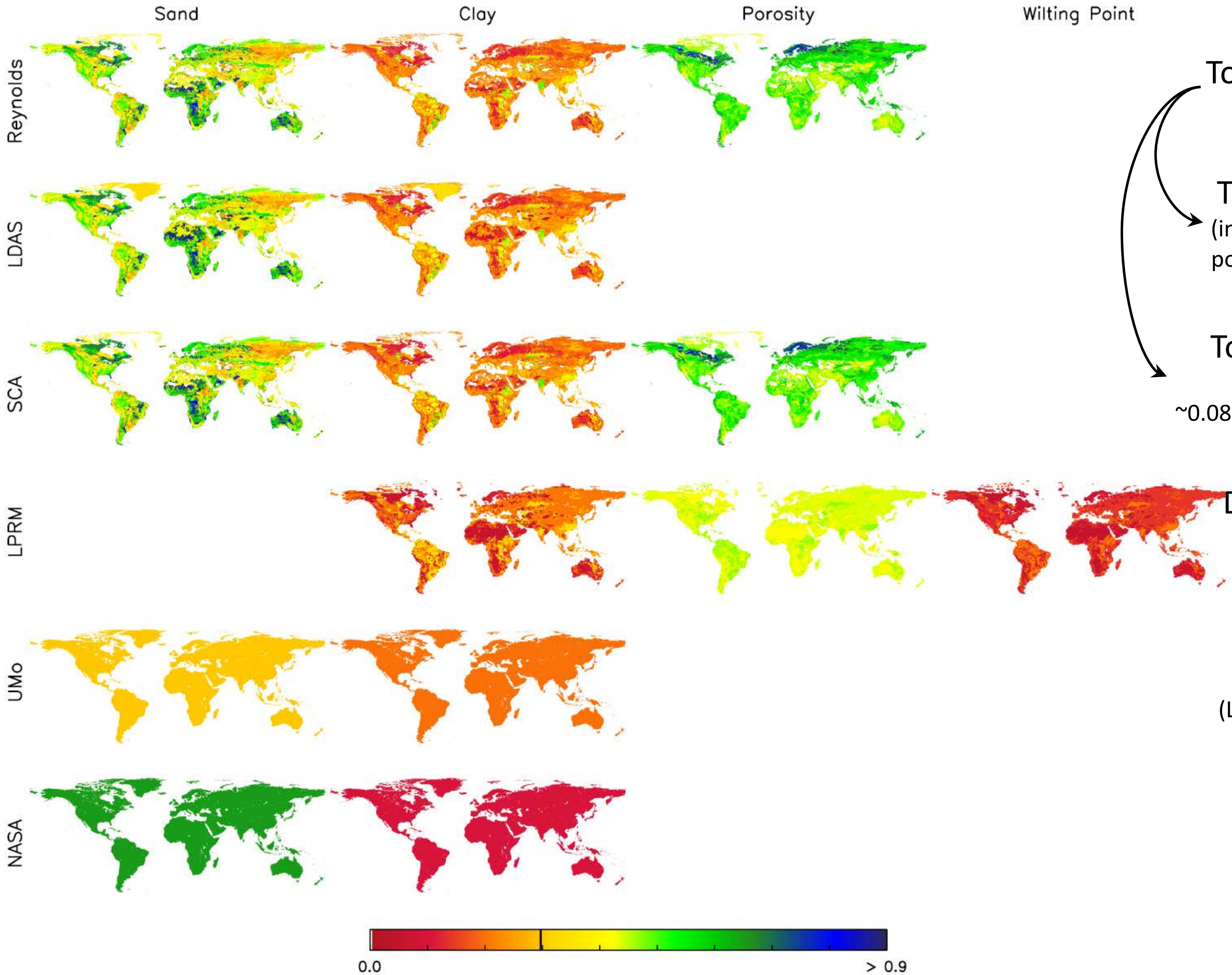

Example of available & algorithm specific soil properties database

Top layer: 0-30 cm
(~ 0.08° grid)

Top layer: 0-2 cm
(interpolated with depth, post-processed to 0.25°)

Top layer: 0-30 cm
(post-processed, ~0.08° grid @ 40 km resolution)

Different soil DBs
(post-processed, 0.25°)

Fixed
(Loamy soils: silty loam)

Fixed
(Sandy loam)

Possible Approaches:

Theoretical Approach

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$$T_{B_{\text{TOTAL}}} = T_{A\uparrow} + e^{-\tau_a}(1-e_r)(T_{A\downarrow} + e^{-\tau_a} T_{sky}) e^{-2\tau_c} + e^{-\tau_a} T_{B_{\text{LAND}}}$$

$\tau - \omega$

$$T_{B_{\text{LAND}}} = T_s e_r e^{-\tau_c} + T_c(1-\omega)(1-e^{-\tau_c}) + e^{-\tau_c} T_c (1-\omega)(1-e^{-\tau_c})(1-e_r)$$

⇒ $\tau - \omega^{\bullet} + \zeta$

$$\zeta = \frac{(T_{Bv} - T_{Bh})}{(T_{Bv} + T_{Bh})}$$

⇒

$$m_v = \tilde{m}_v + \alpha_1(\zeta_{10.7} - \tilde{\zeta}_{10.7}) e^{[\alpha_2 g']}$$

$$g' = f[\ln(\tilde{\zeta}_{10.7})]$$

$$g = \beta_0 + \beta_1 \ln(\zeta_{10.7}) + \beta_2 \ln(\zeta_{18.7})$$

m_v	Soil moisture
$\tilde{m}_v$	Baseline* soil moisture
ζ	Microwave polarization ratio
$\tilde{\zeta}$	Baseline* polarization ratio
α, β	Empirically calibrated coefficients
g	Vegetation + roughness parameter

*bare, dry soil

• simplified $\tau - \omega$

- Is it possible to benefit from the alternative approaches?
  - Direct ‘embedding’ of modules from the alternative retrieval approaches might be a very challenging task and hard to implement.

Summary

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- Improvement of the operational retrieval approach and product can be approached in two ways:
  - [1] Through performing direct statistically based adjustment, or

    A few rescaling approaches…

    Min/Max – independent of long time reference data set
  - [2] Through implementing theoretical modifications

    g is an independent product; good spatial variability, high resemblance with similar geophysical parameters derived from the alternative approaches and ancillary based vegetation products.

    Yet to be done…

    Explore the sensitivity of the individual model parameters;

    Possible recalibration of some of the SM related parameters;

    Benefit from the alternative approaches.