Accounting for STATIC and DYNAMIC OPEN WATER in the modeling of SMAP brightness temperatures over peatlands

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Peatlands: Hotspots of soil organic carbon stocks

- 3% of land surface
- 33% of global soil organic carbon

Increasingly under pressure: drainage / fire / climate change

Global Peatland (Histosol) Distribution; Xu et al., 2018
Peatlands’ global feedback to recent climate change?

Various influencing factors
- peatland type
- peat thickness
- vegetation composition
- climatic setting
- characteristics of climate change
  - …

BUT:
- Lack of spatial information on peatland properties
- Uncalibrated models
- High uncertainty

LOCAL

GLOBAL

Observations (site level)

Modeling

Lack of spatial information on peatland properties
Uncalibrated models
High uncertainty
Global modeling + Satellite Observations

Eg. SMAP, L-band 1.4 GHz
Microwave remote sensing of peatland hydrology

- Sensitivity to **Surface Soil Moisture** and **Water Table Depth** via capillary connection (Kasischke et al. 2009, Kim et al. 2017, Bechtold et al. 2018)

  Thu. 10am, Poster Area R
  Sentinel-1 over peatlands
  #THP1.PR.8 (Asmuß et al.)

Objective

Improve radiative transfer modeling (RTM) of Tb over peatland areas by
• partitioning surface into land and open water fractions, and
• applying surface mixing models

Further outline

• Surface partitioning over peatlands
• RTM inputs
• Surface Mixing Model comparison
• Conclusions
Peatland

Surroundings
Surface partitioning over peatland areas

Surface fraction

Vegetation cover

No vegetation cover (‘exposed open water’)
Surface fractions with vegetation cover

$f_{sm}$

$f_{dow, veg}$
‘Exposed’ open water fractions (=noveg)

\[ f_{\text{SOW,noveg}} \]

\[ f_{\text{DOW,noveg}} \]
Surface partitioning over peatland areas

Surface fraction

<table>
<thead>
<tr>
<th>Vegetation cover</th>
<th>Surface fraction</th>
<th>Tb modeling approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{SM}$</td>
<td>Water level &lt; Soil surface</td>
<td>$\tau - \omega$ model</td>
</tr>
<tr>
<td>$f_{DOW,veg}$</td>
<td>Water level &gt; Soil surface</td>
<td>SMAP algorithm</td>
</tr>
<tr>
<td>$f_{SOW,noveg}$</td>
<td>Static open water</td>
<td>(RTM parameters: De Lannoy and Reichle, 2016, HESS)</td>
</tr>
<tr>
<td>$f_{DOW,noveg}$</td>
<td>Dynamic open water</td>
<td>$\varepsilon_G$ (emissivity of ground)</td>
</tr>
<tr>
<td>No vegetation cover (‘exposed open water’)</td>
<td>Tb of smooth water surface</td>
<td></td>
</tr>
<tr>
<td>$f_{SOW,noveg}$</td>
<td></td>
<td>Dielectric perm. of fresh water (Klein and Swift, 1977)</td>
</tr>
<tr>
<td>$f_{DOW,noveg}$</td>
<td></td>
<td>Fresnel equations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_{water} = T_{soil,5cm}$</td>
</tr>
</tbody>
</table>
CLSM: Catchment Land Surface Model

Koster et al. 2000

→ LSM of NASA’s Goddard Earth Observing System Model (GEOS-5), e.g. used for MERRA-2 reanalysis and SMAP soil moisture products

Main Characteristics:
• Partitioning of land surface into hydrologic catchments
• Water level
• Topographic Wetness Index based model → subgrid soil moisture + water level variability and runoff
• Dynamic partitioning of catchment into hydrologic regimes (saturated, transpiring and wilting areas)
• Peat as soil class (De Lannoy et al. 2014, JAMES)
PEAT-CLSM
Bechtold et al., in prep.

- Revised model structure for peatland hydrological processes
- Modeled dynamic surface fraction with ponding water (to be interpreted mainly as shallow ponding, i.e. vegetation covered surface water \( f_{DOW,veg} \))
PEAT-CLSM: Validation (water table depth data)

Example 1: Bog in NW Germany
Mild winter, high precipitation, $R=0.9$

Example 2: Bog in Belarus
Long freezing period, $R=0.6$

Not calibrated!
Ancillary input (for ‘noveg’ OW fractions)

- SMAP static water / land mask
  → $f_{SOW,\text{noveg}}$
- Daily Global Land Parameters Derived from AMSR-E and AMSR2 (Du et al., 2017)
  → $f_{DOW,\text{noveg}}$

![Graph showing OW against time with SOW and DOW labels](image-url)
Evaluation of mixing models

\[ T_{b_{\text{mod}}} = f_{\text{SM}} T_{b_{\text{SM}}} + (f_{\text{SOW,noveg}} + f_{\text{DOW,noveg}}) T_{b_{\text{OW,noveg}}} + f_{\text{DOW,veg}} T_{b_{\text{OW,veg}}} \]

- SMAP L1C data, H-pol
- Time: snow-free periods 2015 and 2016
- Area: Northern Hemisphere, south of permafrost
  \(~650\ M36\ km\ pixels\)
Incl. static open water reduces bias in Tb forward modeling
Mixing model comparison: $\text{Corr}(\frac{T_{\text{obs}}}{T_{\text{soil}}}, \frac{T_{\text{mod}}}{T_{\text{soil}}})$

- Evaluation for emissivity to increase sensitivity to dynamics of water storage components

![Temporal Pearson R](chart)

Inputs from CLSM:
- Soil moisture + SOW (reference model)
- +DOW from AMSR
- +DOW from CLSM
- +DOW from AMSR and CLSM

Inputs from PEAT-CLSM:
- Soil moisture + SOW
- +DOW from AMSR
- +DOW from PEAT-CLSM
- +DOW from AMSR and PEAT-CLSM

Not calibrated!
$\Delta R$ (best mix. model – reference model

Example time series (PEAT-CLSM model validated by in situ water level data)
Example time series (Western Siberian Lowlands)

<table>
<thead>
<tr>
<th>OW statistics</th>
<th>example site</th>
<th>mean of all M36 pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOW</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>DOW_{\text{AMSR2}} (max-min)</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td>DOW_{\text{PEAT-CLSM}} (max-min)</td>
<td>0.40</td>
<td>0.46</td>
</tr>
</tbody>
</table>

- Dynamics $\rightarrow$ “Best mixing model” with intra- and interannual features also seen in observations
Conclusions

• Current reference model: no dynamic OW + soil moisture from original CLSM
  → low temporal correlation with observed emissivity (mean R = ~0.25)

• Surface mixing models accounting for various open water fractions
  → improved temporal correlation over most peatland areas

• LSM output (peatland version) on ponding water below vegetation cover
  → useful input for RTM mixing models
Acknowledgments

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