ASSESSING DYNAMIC APPROACHES IN SNOW WATER EQUIVALENT/ SNOW DEPTH RETRIEVAL FROM AMSR-E BRIGHTNESS TEMPERATURES

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With the contribution of T. Markus\textsuperscript{2}, R. Reichle\textsuperscript{2} and A. Loew\textsuperscript{5}

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4) University of Waterloo, Canada
5) University of Munich, Germany

MicroRad 2008 – Firenze - Italy
The AMSR-E Snow Water Equivalent

In 2007, after long time a team has been selected from NASA for funding for maintaining and refining the AMSR-E SWE product:

PI – Tedesco M. (lead, CCNY, NASA)
co-PI – Kelly R. (Univ. Waterloo)
co-I’s:
  J. Foster (NASA)
  E. J. Kim (NASA)
  J. Wang (NASA)
Collaborators:
  M. Hallikainen (Finland)
  C. Derksen (Canada)
Support Specialist: J. Miller (RSIS)

\[
SD = FF \cdot \left( A \cdot (18V-36V) \right) + (1-FF) \cdot \left( A \cdot (10V-36V) + B \cdot (10V-18V) \right) \cdot (1-FD*0.6)
\]

Forest
Non-forest
Shallow snow
Non-forest
Deep snow

\( A = f(pol36), B = f(pol18) \)
AMSRSWE
Product Roadmap

Implementation of dynamic physically-based algorithm
Development/leveraging of field experiment data for validation efforts
atmospheric correction

Comparison of Approaches

Coupling of AMSR-E and Quikscat snow products
Coupling of AMSR-E and MODIS snow products

vegetation network model for vegetation correction

Snow energy balance model component
Involvement of EM models

Current algorithm

Simple empirical representation of R/T snow emission (Chang 1987-2003)

Dynamic approaches on grain size growth

• In 2003 Kelly et al. proposed a dynamic approach considering an exponential growth model for grain size combined with an electromagnetic model (DMRT)
• Main hypothesis: snow grains grow along the snow season as an exponential function of the number of days (based on a work by Sturm)
• Results regarding its potential extension to large scale applications are reported here
• Also, results derived when using combined electromagnetic and land surface models driven with meteorological forcing data are reported
• These can support the conceptual development of radiance-based assimilation approaches
- Electromagnetic model → HUT

Inputs to the model are as follows:

a) Snow depth from ground measurements
b) Grain size is derived from the exponential model and it is reduced when snow depth increase to account for the new snow
c) Density and soil temperature are kept fixed
d) Air/snow temperature is derived from ground measurements

Modeled = dots and crosses

AGATA, Russia

Yellowknife, Canada

2002 – 2003

2003 – 2004

2004 – 2005
Comparison between exponential growth modeled (red) and optimum (blue) grain size values.
Grain size is underestimated by the exp. model at the beginning of the season. This leads to an overestimation of snow depth.
SMART
Snow Modelling Algorithm and Retrieval Tool

M. Tedesco, A. Löw, R. Reichle

Providing a tool for the improved retrieval of snow information using remote sensing data

Coupling of different snow process models with remote sensing data using physically based radiative transfer models

Providing a tool for the assimilation of snow information/satellite data into a physically based snow process model

coded in Matlab/Fortran – under testing on 50 wmo stations worldwide

Preliminary questions we are trying to answer: what is the expected behaviour of dynamic coefficients? Can we reproduce this behaviour from information complementary to satellite data? If so, how?
Multi-temporal ingestion of a priori information

- **Surface forcing data**
- **Land Surface Model**
- **Snow parameters**
- **Inputs to the EM model**
- **Electromagnetic model**
- **Simulated Tb**
- **Minimization**
- **SSM/I Tb**
- **Effective grain size**
- **Snow depth**

**Measured/Simulated Snow depth**

**TIME = t_u**

**TIME = t_r**

**EM estimated**

**Fitted exp.**

**Sturm exp.**

**Agata, 2003**

**Agata, 2005**

**Multi-temporal ingestion of a priori information**
Comparison between EM-estimated and physically-based snow model outputs (SNTHERM)

Percentage error (underestimation) between the snow depth values obtained using 1 mm in grain size matching the brightness temperatures obtained considering 0.75 mm.
Ingesting snow depth information: from the snapshot algorithm to a multi-temporal approach

<table>
<thead>
<tr>
<th>RMSE [m]</th>
<th>Chang</th>
<th>Foster</th>
<th>WMO</th>
<th>CLSM</th>
<th>CLSM</th>
<th>WMO</th>
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<td></td>
<td></td>
<td></td>
<td>Dynamic</td>
<td>Mod. Static</td>
<td>Dynamic</td>
<td>Mod. Static</td>
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<tr>
<td>1</td>
<td>0.57</td>
<td>0.52</td>
<td>0.07</td>
<td>0.1</td>
<td>0.17</td>
<td>0.18</td>
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<tr>
<td>2</td>
<td>0.54</td>
<td>0.50</td>
<td>0.05</td>
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<table>
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<th>Percentage error [%]</th>
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<tr>
<td>1</td>
<td>58.6</td>
<td>55.4</td>
<td>5.1</td>
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<td>62</td>
<td>58.9</td>
<td>6</td>
<td>7</td>
<td>49.2</td>
<td>44.3</td>
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<td>3</td>
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<td>55.8</td>
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<td>9.5</td>
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<td>0.45</td>
<td>0.77</td>
<td>0.51</td>
<td>0.73</td>
<td>0.51</td>
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<tr>
<td>2</td>
<td>0.64</td>
<td>0.56</td>
<td>0.82</td>
<td>0.64</td>
<td>0.75</td>
<td>0.64</td>
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<tr>
<td>3</td>
<td>0.84</td>
<td>0.78</td>
<td>0.87</td>
<td>0.84</td>
<td>0.77</td>
<td>0.84</td>
<td>0.58</td>
<td>0.7</td>
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Conclusions

• The current AMSR-E algorithm, delivered on Sept. 2005, makes use of a dynamic approach though still conservative.

• Factors such as vegetation, atmospheric effects and potential improvement deriving from multi-sensor approach have been (are being) evaluated.

• Grain size modeling is a key aspect for development of future dynamic approaches, especially in view of radiance-based assimilation techniques.

• Both simplified and physically-based models cannot consistently reproduce the size of EM effective scatterers, significantly affecting the error on snow depth/SWE retrieval.

• Ingesting a-priori information on snow depth/SWE at given time-steps (e.g. from snow model) considerably improves the retrieval (multi-temporal approach instead of snapshot algorithm).
### Preliminary analysis at large spatial scale

#### Baseline Snow depth error statistics

<table>
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<tr>
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<th>2002 RMSE</th>
<th>2002 Bias</th>
<th>2003 RMSE</th>
<th>2003 Bias</th>
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<td><strong>FF &gt; 50%</strong></td>
<td>16.82</td>
<td>0.15</td>
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<td>-1.10</td>
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#### New method Snow depth error statistics

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<th>2003 Bias</th>
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<td>0.78</td>
<td>24.01</td>
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<tr>
<td><strong>FF = 0%</strong></td>
<td>22.76</td>
<td>-2.49</td>
<td>21.84</td>
<td>-1.25</td>
</tr>
<tr>
<td><strong>FF &gt; 50%</strong></td>
<td>16.45</td>
<td>1.62</td>
<td>17.31</td>
<td>-2.41</td>
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Relationship between optimum grain size and surface temperature evolution

Agata, Russia

Yellowknife, Canada