IST products, validation and plans

- OSISAF, DMI, MET and EUMETSAT

DMI – Team:
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Outline

• Satellite IST measurement challenge
  • IST – spatial and temporal variability
• Algorithm and general characteristics of OSISAF AVHRR level 2 IST.
  • uncertainties and quality assessment
• OSI-205 IST (OSISAF, Metop-AVHRR)
  • Level 2
• CMEMS IST (DMI, Metop-AVHRR)
  • level 4
• AASTI IST (DMI+METNO, GAC-AVHRR, CDR)
  • level 2+3
• IASI IST (EUMETSAT, IASI+AMSU+MHS)
  • level 2+3
• Compiling a data base of ice buoy measurements with QC
• Plans
The IST challenge

- skin temperature vs snow and air temperatures

- Large vertical variability
- Large diurnal variability
- Skin T is coldest

DMI-AWS observations from Qaanaaq.

Metop AVHRR IST compared with in situ air and skin temperature measurements: STD and bias from comparing Metop AVHRR IST with 2m, 1m and skin temperature observations – within 10 min. (solid line) and 30 min. (dashed line).
FRM - iSVP buoy intercomparison in Qaanaaq

Deployed January
Deployed April
Measurements from iSVP

**Instrument temporal coverage**

- New Buoy 1
- New Buoy 2
- Old Buoy 1
- Old Buoy 2
- AWS

**iSVP Buoy Time Series**

- Temperature (°C)
- New Buoy 1
- New Buoy 2
- Old Buoy 1
- Old Buoy 2
- Drifting Event

Date range: Apr 09 to Sep 24, 2017
**TIR Satellite IST**

Baseline algorithm for AVHRR

\[
IST = a + bT11 + c(T11 - T12) + d(T11 - T12)\text{steta} \quad (Key \ et \ al. \ 1997);
\]

Where \(\text{steta} = \frac{1}{\cos(\text{satza})} - 1\) and \((T11 - T12)\) is the mean value within 3x3 pixels.

The algorithm is sensor specific, tuned using NWP surface and atmosphere data from ERA-INTERIM and corresponding Top-of-Atmosphere radiances calculated by RTTOV.
IST is tested for clouds, scan and sun angles. A penalty given if a given pixel does NOT comply to the test:
• Not-cloudy: a pixel must be cloud free or ice contaminated.
• Cm-quality high: The cloud mask quality indicator must be of high-quality
• Cloud-box 3x3: all 8 adjacent pixels must be cloud free or “ice contaminated”
• Scan-angle <60: Scan angle (view angle) must be less than 60 degrees
• Sun-zenith angle must be less than 80 degrees

<table>
<thead>
<tr>
<th>IST-test</th>
<th>Cloud mask (cm)</th>
<th>cm-quality</th>
<th>Cloud-box (3x3)</th>
<th>Scan-angle</th>
<th>Sunzen-angle</th>
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</thead>
<tbody>
<tr>
<td>Penalty</td>
<td>Cloud free</td>
<td>High</td>
<td>All cloud free</td>
<td>&lt;60</td>
<td>&lt;80</td>
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</table>

QL 5, best
Comply to all criteria
QL 4, acceptable
Fail 1 minor criterion
QL 3, low
Fail 2 minor criteria
QL 2, worst
Fail 3 or more minor criteria
QL 1, bad
Fail 1 major or more criteria, or flagged, i.e. T outside 150-350K
QL 0, no data
Everything else
Uncertainty algorithm

\[
\text{Pixel Uncertainty} = \sqrt{U_{\text{synoptic}}^2 + U_{\text{Random}}^2 + U_{\text{Global}}^2}
\]

- **Random uncertainty** = \(\sqrt{U_{\text{geo}}^2 + U_{\text{NEdT}}^2}\)
  
  Ugeo, geolocation error *(Temperature difference between ocean and ice, Ice Concentration, spatial resolution coeff.)*
  
  Unedt, sensor noise (sensor specific)

- **Synoptic scales Uncertainty** = \(\sqrt{U_{\text{emis}}^2 + U_{\text{fmt}}^2}\)
  
  Uemis, snow emissivity variations *(satellite zenith angle dependency, snow density and grain size)*
  
  Ufmt, algorithm uncertainty (residual of fit)

- **Large/global scale Uncertainty** = \(U_{\text{glob}}\)
  
  Fixed uncertainties for each quality level *(Expert judgement)*

<table>
<thead>
<tr>
<th>Quality level</th>
<th>Uglob</th>
</tr>
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<tr>
<td>5</td>
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<tr>
<td>4</td>
<td>0.5</td>
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<tr>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
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<tr>
<td>1</td>
<td>Fillvalue</td>
</tr>
<tr>
<td>0</td>
<td>Fillvalue</td>
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</table>
Uncertainty validation

AASTI IST uncertainty validation with respect to ARM in-situ data for 2009. Dashed lines show ideal uncertainty model accounting for uncertainties in the in situ data and geophysical uncertainties arising from spatial and temporal collocation. Solid black lines show one standard deviation of the retrieved minus in situ IST differences for each 0.1 K bin (EUSTACE deliverable D3.1, D Ghent)
EUMETSAT OSISAF level 2 IST OSI-205
OSI-205 characteristics

• Metop-AVHRR / VIIRS
• Integrated IST, SST and MIZT surface temperature product
• Operational since May 2016
• Level 2 – multiple daily coverage
• 1.1/0.7 km at Nadir
• Cover sea ice and waters polewards from 50 North and 50 South. Greenland and Antarctic ice sheets are included.
OSISAF validation
- against raw data from DMI-GTS

<table>
<thead>
<tr>
<th>Month</th>
<th>Number of cases</th>
<th>Bias °C</th>
<th>Bias Req °C</th>
<th>Std Dev °C</th>
<th>Std Dev Req °C</th>
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<tbody>
<tr>
<td>JAN. 2017</td>
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<td>-3.0</td>
<td>5.21</td>
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<tr>
<td>FEB. 2017</td>
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<tr>
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<td>-1.20</td>
<td>-3.0</td>
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<td>4.0</td>
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<tr>
<td>JAN. 2017</td>
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<td>-3.0</td>
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<td>4.0</td>
</tr>
<tr>
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<td>APR. 2017</td>
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<td>JUN. 2017</td>
<td>20</td>
<td>-4.22</td>
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</table>

Quality results for Metop AVHRR IST, for quality levels 4 and 5 (acceptable and best qualities), by night and by day.

Mean IST error and bias with respect to conventional buoys measurements from the DMI GTS. Only data with for quality level 5 are shown.
Validation
- against one selected in situ platform

This one-buoy validation seen in context of the general validation suggest that the algorithm works, but there are serious issues with the cloud mask and/or the in situ temperature data sets need thorough QC.

OSI-205 validation (ql 4+5) against a single WMO buoy. Bias is -2.72 K and STD is 2.07 K.
Satellite IST intercomparison
- Agains DMI-AWS at Qaanaaq field site (FRM4STS case study)

Pairwise statistics between DMI AWS Ice surface temperatures and the 4 different satellite IST products for normal averaging (top), closest pixel (middle) and cloud free average (bottom).
Copernicus, level 4 IST
based on OSI-205

• Metop-AVHRR
• Integrated IST, SST and MIZT surface temperature
• Operational since May 2016
• Level 4, daily
• 0.05 degree x 0.05 degree
• Cover ice and water areas North of 50 North
AASTI CDR, level 2 and 3

- NOAA and Metop AVHRR
- Integrated IST, SST and MIZT surface temperature
- Climate Data Record, based on the CLARA radiance CDR (cmsaf)
- Version 1 by 2015, 2000-2009
  - version 2 in progress, 1982-2015
- Level 2/3, multiple daily/daily
- ~4 km/0.25x0.25 degrees, based Global-Area-Coverage data.
- Cover ice and water areas polewards from 50 North and 50 South
### Validation of AASTI v.1 Level 3 IST against in situ IST and air Temperature (IAT).

<table>
<thead>
<tr>
<th>Station</th>
<th>N</th>
<th>corr</th>
<th>Bias (°C)</th>
<th>std (°C)</th>
<th>RMS (°C)</th>
<th>corr</th>
<th>Bias (°C)</th>
<th>std (°C)</th>
<th>RMS (°C)</th>
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<td>ARM_Atg</td>
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<td>ARM_Bar</td>
<td>1594</td>
<td>94.1</td>
<td>-0.73</td>
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<td>93.2</td>
<td>-3.36</td>
<td>4.12</td>
<td>5.32</td>
</tr>
</tbody>
</table>
EUMETSAT IASI IST

• IASI All-Sky IST algorithm
  – A Piece-Wise Linear Regression algorithm combining IASI, AMSU and MHS radiances. A cloud screening procedure decides whether to use Thermal Intra Red (TIR) algorithm only – or the combined IR and MW algorithm.

• Since 2011 (I think...)
• Level 2
• ~12 km
IASI IST performance on Greenland land ice – against Water Vapour

Seems to perform best at intermediate humid atmospheres…

STD and bias

IASI IST – in situ IST

counts
IASI IST performance on Greenland land ice
– against Sun-Zenith angle; day/night

Performance is best during day light hours.
Performance on sea ice
- against IST quality indicator

STD, Bias and distribution for IASI IST – Buoy air Temperature, as a function of IASI IST quality indicator.
IASI IST vs other Satellite algorithms – level 3
- Latitude dependency

IASI IST is warm biased against TIR IST - increasing polewards

Latitudinal bias (solid) and standard deviation (dashed) of temperature differences, IASI minus other satellite L3 IR products
A new observation db
- OSISAF, EUSTACE, EUMETSAT

• A new uniform sea ice observation db for IST and ice drift validation.
• Data are gathered from all known one-off field campaigns and continuous programs.
• All in situ data are converted to a uniform netCDF format, using CF conventions where possible
• Quality Control – 15 steps
FRM’ing traditional ice buoy measurements with Quality tests

1. Gross Error: The temperature is outside of the interval \((-80, 20)\)
2. Spike Test Short: The absolute temperature difference from the median temperature of a 1 day rolling window is greater than 10 degrees
3. Spike Test Long: The absolute temperature difference from the median temperature of a 3 day rolling window is greater than 20 degrees
4. Buddy Check: The absolute difference from the median of a ’500 km x 500 km x 1 day’ bin, to which the temperature value belongs, is greater than 20 degrees
5. Neighbouring bins check: The rolling variance (using a 1 day time window) is greater than twice the mean variance of measurements from neighboring stations (i.e. those in the same ’500 km x 500 km x 1 day’ bin).
6. Age Check: The data-point is greater than 1 year from start date of file
7. Sea Ice Concentration test: The sea ice concentration is less than 30%
8. Temperature variability check: The series standard deviation in a 1 day window is less than 0.1 C
9. Speed test: The speed is greater than 0.5 m/s
10. Position Sanity: The absolute latitude is greater than 50°, or the longitude is 0° while the latitude is 90°
11. Duplicates: There is another value with the same timestamp
12. Global tests applied: True for whole series if no global quality flags have been checked. Only if the check has been applied and ALL global tests were passed are ALL the 1s set to 0s
13. Has flag 5 been tested: The buddy check has not been applied. The flag is set for all points if not every point has been tested in test 5.
14. Gappiness: The interval between successive points is greater than 2.5 times the median interval
15. Close to land: The location of the measurement is less than 15 km from land
16. Very close to land: The location of the measurement is less than 5 km from land
PLANS for all IST products

- OSISAF OSI-205; Level-2
  - Adaption to METimager
  - Product bias correction using RTM
  - Further geographically stratified algorithm tuning
  - Testing and further development of probability data (of land, sea and ice)
  - Improve QC/QL
- Copernicus; Level-4
  - Improvements based on OSI-205 developments
  - (Southern Hemisphere...)
- AASTI CDR; Level-3
  - Version 2, based on CLARA version2 (climate saf)
  - Level 4 CDR
- Applying the new MUDB for sea ice surface temperatures