1. Motivation and purpose

- Radiance data contributes more in reducing forecast error than conventional data but the radiance data is not effective over land because most low level peaking channels are not used due to the difficulties of specifying the surface properties accurately.
- A new land surface emissivity has developed to make use of the low level peaking channels over land at Met Office and it is necessary to identify which information is improving the forecast accuracy and which is not for further use and tuning of the land radiance data.
- Adjoint-based sensitivity method is a good tool to evaluate satellite impact because it can differentiate its impact every possible combinations (i.e. channels, location, time, ...)

The contribution of IASI data over land with a new surface emissivity is investigated quantitatively based on the adjoint sensitivity tool for a better use of IASI data over land

2. Method

a. Observation Impact Method

Observation impact calculate an aspect of forecast error reduction due to analysis

\[
\sigma_L = \left( \frac{\partial L}{\partial dE} \right) \left( \frac{\partial L}{\partial dE} \right)^T
\]

\[\delta L = \left( \frac{\partial L}{\partial dE} \right) \left( \frac{\partial L}{\partial dE} \right)^T \delta dE
\]

- \( \delta L \) is a decrease of the global dry energy norm error (24 hours) due to analysis and negative value means reduction of forecast error and better performance.
- Adjoint-based sensitivity method produces observational impacts easily aggregated by various subsets such as observation method, time, location, and channels and so on.
- The method is useful to evaluate the impact of satellite radiance which contains lots of channels and depends on the observational condition (i.e. cloud and surface properties).

b. Land Surface Spectral Emissivity (SSE)

Calculate background SSE from Atlas

Training Data Set: UCSB MODIS surface emissivity database

Select 12 leading PCs to represent SSE

\[ A = \sum \left( \lambda_k \right) \left( \lambda_k \right)^T \text{ SSE functional spectra} \]

Get analysis SSE using 1DVar from background SSE

\[ J = \frac{1}{2} \left( \left( x - y \right) B^T \left( x - y \right) + \left( y - H \right) L^T \left( y - H \right) \right) \]

\( SSE \) is included as a background and retrieved with other state variables

(Reference: Zhou et al. (2010) and Ed Pave1)

c. Experimental Design

Experiment Period: 2010.6.1.18UTC ~ 2010.6.7.12UTC(6 hourly)

<table>
<thead>
<tr>
<th>Name</th>
<th>Land Surface Emissivity</th>
<th>Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cod</td>
<td>Fixed SSE(0.05)</td>
<td>No low level peak channels at land</td>
</tr>
<tr>
<td>Exp1</td>
<td>Analysis SSE</td>
<td>With no level peak channels at land</td>
</tr>
<tr>
<td>Exp2</td>
<td>Fixed SSE(0.05)</td>
<td>With low level peak channels at land</td>
</tr>
<tr>
<td>Exp3</td>
<td>Background SSE+Atlas</td>
<td>With no level peak channels at land</td>
</tr>
<tr>
<td>Exp4</td>
<td>Background SSE</td>
<td>With low level peak channels at land</td>
</tr>
<tr>
<td>Exp5</td>
<td>Analysis SSE but with 0 background</td>
<td>With low level peak channels at land</td>
</tr>
</tbody>
</table>

d. The role of surface emissivity on observation impact

Simplified TOA radiance is \( L = (1 - r) F + r \left( F_\text{ emissivity} \right) \) and for window channel(\( v \)) it approaches \( L = w (1 - r) F + w \left( F_\text{ emissivity} \right) \) and background TOA radiance with biased emissivity is simply \( L = (1 - r) F + r \left( F_\text{ emissivity} \right) \), where \( r \) is an error of emissivity.

The observation impact of satellite observation with the emissivity error becomes

\[ \frac{\partial L}{\partial dE} = \frac{1}{2} \left( \frac{\partial L}{\partial dE} \right) \left( \frac{\partial L}{\partial dE} \right)^T \]

\( \text{observation} \), \( \text{innovation} \), analysis sensitivity at observation position and time, and subscript \( i \) means unbiased value.

The observation impact with and without emissivity bias are multiplied to see when the sign of observation impact is changed due to the bias

\[ \delta L = \left( \frac{\partial L}{\partial dE} \right) \left( \frac{\partial L}{\partial dE} \right)^T \delta dE
\]

\( \delta dE \) is a negative when observation innovation is positive

\( \delta dE \) is a negative when innovation is negative

The positive innovation is the region which shows negative value of \( \delta dE \)

3. Results

a. Fractional contribution of IASI impact

- Positive emissivity in Exp1 induces strong observation impact at the negative innovation area where it was compensated by the cold bias of skin temperature of model background.

   - The fixed emissivity which has a large positive bias over land makes the background brightness temperature warm biased and the data with negative innovation degrade the model performance at Exp3
   - The new emissivity improves the bias problem with a better specification of land emissivity and the degrading impact by a negative innovation is disappeared in Exp1
   - It seems like that the calculated brightness temperature get cold bias in Exp1 contrast to Exp3

b. Spectroscopic characteristics of observation impact

- The new emissivity has a good observation impact from 8 to 10um where the emissivity at sand sample is low and it is more significant at night observation.
- But in the high emissivity window region (10-12um), the observation impact is reduced compared to the fixed one (Exp3) and even worse, the assimilation of daytime observation increases forecast error (it is better not to use this data).
- The effect of new emissivity becomes stronger with the 1DVAR analysis of emissivity.

b. Benefit of the new emissivity

- Observation impact during night time for low emissivity region over land (8-10um) becomes observation impact depending on O-B
- The benefit of the new emissivity is shown largely in the spectroscopic region where the fixed emissivity error results in bad observation impact in 10 and < 5um.
- The fixed emissivity has a large positive bias over land makes the background brightness temperature warm biased and the data with negative innovation degrade the model performance at Exp3.
- The new emissivity improves the bias problem with a better specification of land emissivity and the degrading impact by a negative innovation is disappeared in Exp1.
- It seems like the calculated brightness temperature get cold bias in Exp1 contrast to Exp3

4. Summary and plan

- The impact of IASI data over land with a new emissivity is evaluated using an adjoint-based observation impact method.
- The benefit of the land IASI data is shown largely in the spectroscopic region where the fixed emissivity error of sand sample is large (8-10um and < 5um).
- The benefit is more significant for the night time observation and it is considered that the large emissivity bias is compensated by the cold bias of skin temperature of model background.
- The IASI land data with new emissivity shows negative observation impact at the window region (10-13um).
- The better specification of emissivity in 8-10um in Exp1 involves a problem related to the cold bias of the background skin temperature.
- The persistent cold bias induces negative innovation at 10-13um and it opposes positive analysis increment causing negative observation impact.
- The better use of IASI land data with a background temperature bias, it is needed to apply quality control process depending on the innovation for window channels.
- The observation impact and forecast scores will be evaluated with a new quality control for the window channels over land