## GlobTemperature UCM3 Uncertainty Breakout Session

The aim of this session is to give you an opportunity to look at the uncertainties provided with GlobTemperature LST products and think about how you can make use of this information in your application. We have extracted a 5x5 pixel region over which to identify different components of the uncertainty budget and consider how these uncertainties propagate from a per pixel level to a gridded product. Figure 1 shows the location of our extracted data, over northern Africa. For this exercise we have chosen a cloud-free region.

Figure 1: LST and cloudmask data for an AATSR orbit on 1st April 2004. A 5x5 pixel extract has been taken from cloud-free data over northern Africa.

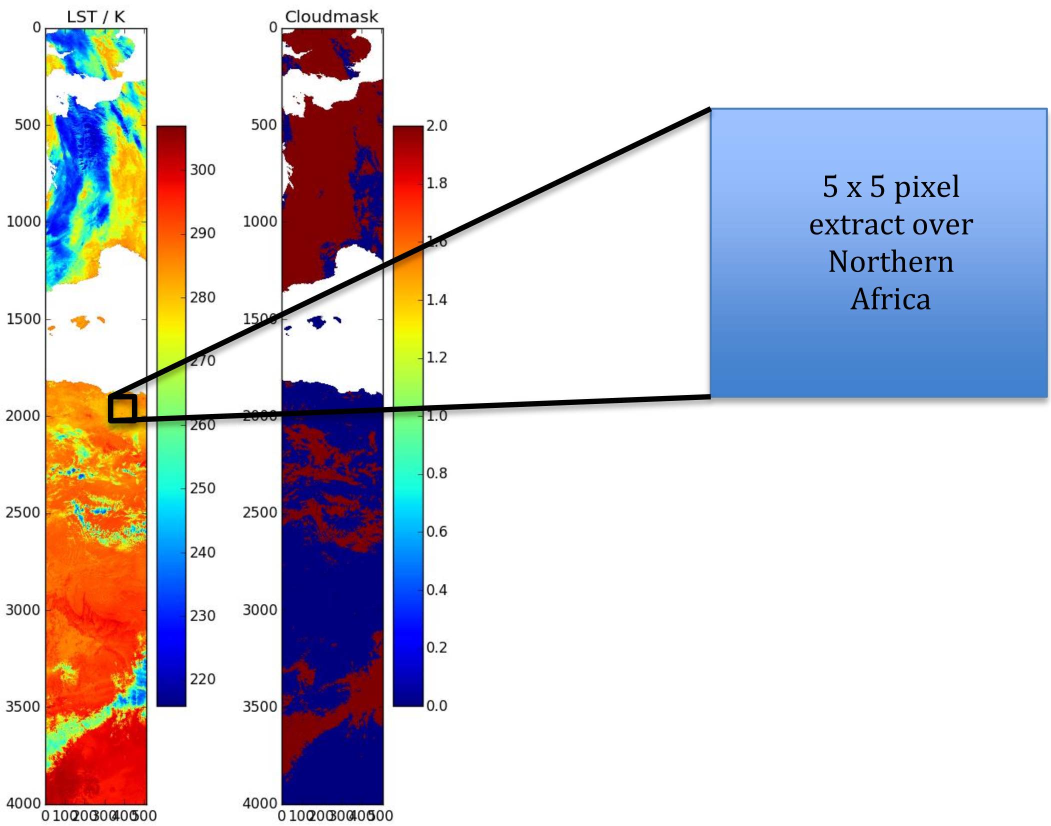
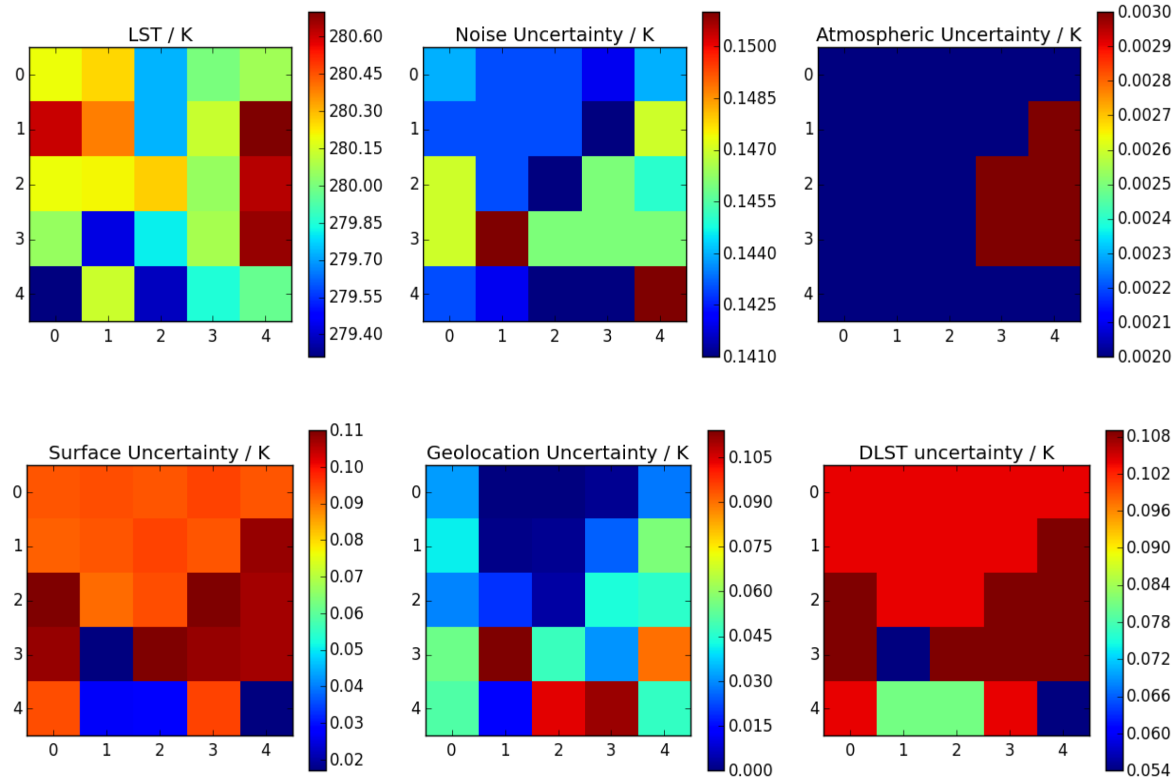



Figure 2 shows the L2 LST and associated uncertainty fields provided with GlobTemperature LST products (at a per pixel level). These include:

- Instrument noise.
- Uncertainties from parameterization of atmospheric fields.
- Uncertainties from surface parameters (eg. surface emissivity).
- Geolocation uncertainty.
- Model fitting uncertainty.

Figure 2: Per-pixel LST and associated uncertainties in L2 AATSR GlobTemperature products.




With L2 data, uncertainties are added in quadrature using the following formula:

$$u = \sqrt{u_{noise}^2 + u_{atm}^2 + u_{surface}^2 + u_{geo}^2 + u_{DLST}^2}$$

Given that these are the per-pixel values of the different uncertainty components for the first five pixels in the extracted cell, calculate the total uncertainty in each pixel?

| **Pixel** | **Noise ($u_{noise}$)** | **Atm ($u_{atm}$)** | **Surface ($u_{surf}$)** | **Geo ($u_{geo}$)** | **DLST ($u_{dlst}$)** | **Total (u)** |
|---|---|---|---|---|---|---|
| 1 | 0.144 | 0.002 | 0.093 | 0.032 | 0.104 | 0.203 |
| 2 | 0.143 | 0.002 | 0.092 | 0.041 | 0.104 | 0.204 |
| 3 | 0.147 | 0.002 | 0.11 | 0.029 | 0.109 | 0.215 |
| 4 | 0.147 | 0.002 | 0.108 | 0.055 | 0.109 | 0.22 |
| 5 | 0.143 | 0.002 | 0.094 | 0.051 | 0.104 | 0.207 |

What do you notice about the values that you have calculated? Are these the same for all pixels? Do different sources of uncertainty vary on different scales?

Many users will make use of L3 gridded products rather than L2 per-pixel products. Uncertainties from L2 products need to be correctly propagated into L3 products and the method for doing this depends on the type of uncertainty.

For sources of uncertainty that are uncorrelated between pixels (for example instrument noise) the total uncertainty in a gridded product scales by the product of $1/\sqrt{n}$. To calculate uncertainties due to noise, the following formula is used:

$$u_{noise} = \sqrt{\frac{1}{N_{Clear}}\left(\frac{\sum_{Clear} S_{noise}^2}{N_{clear}}\right)}$$

For the 25 values in the 5x5 pixel extract give below calculate the noise in the grid cell. Is this significantly less than the per-pixel noise uncertainty?

| **Noise Uncertainty ($S_{noise}$)** | | | | | **Cell Uncertainty** |
|---|---|---|---|---|---|
| 0.144 | 0.143 | 0.147 | 0.147 | 0.143 | 0.076 |
| 0.143 | 0.143 | 0.143 | 0.151 | 0.142 | |
| 0.143 | 0.143 | 0.141 | 0.146 | 0.141 | |
| 0.142 | 0.141 | 0.146 | 0.146 | 0.141 | |
| 0.144 | 0.147 | 0.145 | 0.146 | 0.151 | |

Uncertainties that arise from systematic effects, such as the atmospheric, surface geolocation and model fit components are not propagated in the same way, as the uncertainties are correlated over the grid cell domain. These are calculated using the following formula:

$$u_{sys} = \sqrt{\frac{\sum_{Clear} S_{systematic\ component}^2}{N_{Clear}}}$$

For each of the systematic components below, calculate the grid cell uncertainty using the formula above.

| **Atmospheric Uncertainty ($S_{atm}$)** | | | | | **Cell Uncertainty** |
|---|---|---|---|---|---|
| 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | |
| 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | |
| 0.002 | 0.002 | 0.003 | 0.003 | 0.002 | |
| 0.002 | 0.003 | 0.003 | 0.003 | 0.002 | |

| **Surface Uncertainty ($S_{surf}$)** | | | | | **Cell Uncertainty** |
|---|---|---|---|---|---|
| 0.093 | 0.092 | 0.11 | 0.108 | 0.094 | |
| 0.094 | 0.093 | 0.091 | 0.017 | 0.027 | |

| | | | | | |
|---|---|---|---|---|---|
| 0.093 | 0.095 | 0.094 | 0.11 | 0.028 | 0.0916 |
| 0.095 | 0.093 | 0.11 | 0.108 | 0.095 | |
| 0.093 | 0.108 | 0.107 | 0.107 | 0.017 | |

| **Geolocation Uncertainty ($S_{geo}$)** | | | | | **Cell Uncertainty** |
|---|---|---|---|---|---|
| 0.032 | 0.041 | 0.029 | 0.055 | 0.051 | 0.0522 |
| 0.0 | 0.001 | 0.02 | 0.114 | 0.014 | |
| 0.0 | 0.002 | 0.004 | 0.048 | 0.104 | |
| 0.002 | 0.025 | 0.044 | 0.031 | 0.111 | |
| 0.028 | 0.057 | 0.046 | 0.09 | 0.047 | |

| **DLST Uncertainty ($S_{dlst}$)** | | | | | **Cell Uncertainty** |
|---|---|---|---|---|---|
| 0.104 | 0.104 | 0.109 | 0.109 | 0.104 | 0.101 |
| 0.104 | 0.104 | 0.104 | 0.054 | 0.081 | |
| 0.104 | 0.104 | 0.104 | 0.109 | 0.081 | |
| 0.104 | 0.104 | 0.109 | 0.109 | 0.104 | |
| 0.104 | 0.109 | 0.109 | 0.109 | 0.054 | |

When we grid products at L3 we also introduce another source of uncertainty that comes from LST in some pixels being unavailable due to the presence of cloud. The equation for calculating the spatial sampling uncertainty in a given grid cell is:

$$u_{samp} = \frac{N_{cloud} Var_{LST}}{N_{clear} + N_{cloud} - 1}$$

The crosses in the table below represent the observations that are cloudy in our given grid cell, with the LST values in the clear sky pixels shown. From this table calculate the sampling uncertainty using the equation above.

| **Pixels** | **LST for Clear Pixels (X denotes cloud)** | | | | | **Sampling Uncertainty** |
|---|---|---|---|---|---|---|
| 1-5 | X | X | X | 280.05 | X | 0.029 |
| 6-10 | X | X | 280.21 | 279.43 | 280.14 | |
| 11-15 | 279.73 | 279.73 | 280.27 | 279.81 | 279.39 | |
| 16-20 | 280.0 | 280.13 | X | 280.08 | 279.85 | |
| 21-25 | 280.07 | X | X | X | 279.97 | |

Finally, all of these components can be added in quadrature (as with L2 data) to give the total uncertainty in the grid cell.

What is the total uncertainty? **0.167 K**