climate change initiative

→ LAND SURFACE TEMPERATURE

On the use of satellite land surface temperatures to augment near-surface air temperature data in climate science and services

land surface temperature cci

Elizabeth Good (Met Office), Freya Aldred, Darren Ghent, Karen Veal, Carlos Jiménez

Presented by Claire Bulgin (U. Reading)

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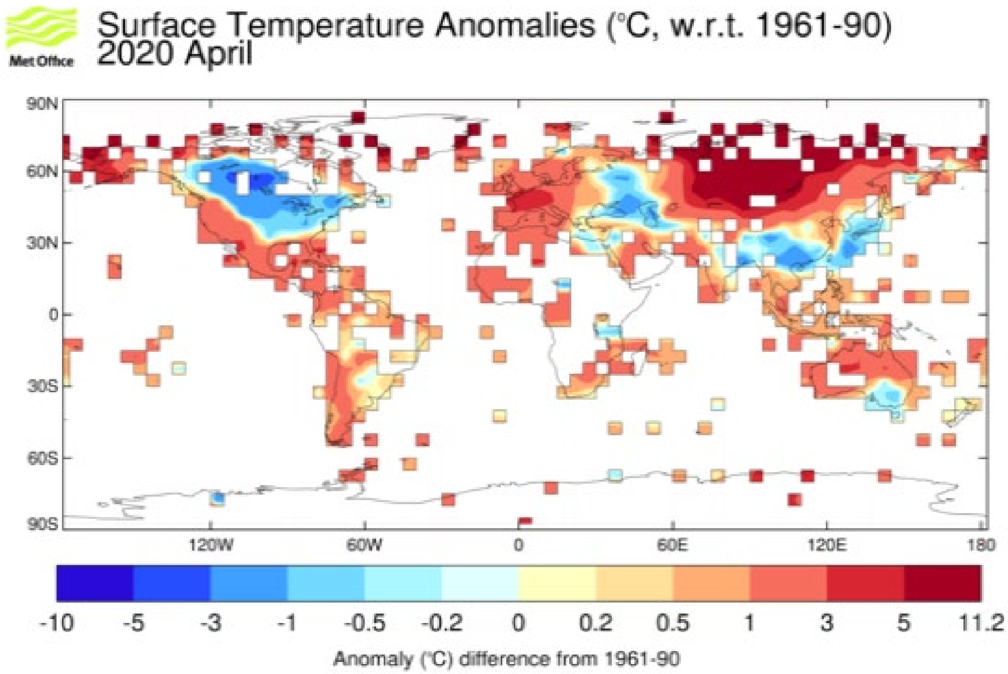
Background and motivation

Can satellite land surface temperature (LST) anomalies be used with or in place of traditional T2m anomalies in climate science and services?

This study: LST vs T2m relationship and trends

Good et al., 'An Analysis of the Stability and Trends in the LST_cci Land Surface Temperature Datasets over Europe', submitted to Earth and Space Science



Gridded station T2m anomalies from CRUTEM

Study data

- Homogenised daily station data (EUSTACE: https://www.eustaceproject.org/)
- Europe only

LST_cci data with length >7 years

Dataset	Years	Observation time	Resolution
ERS-2 ATSR-2	1995–2003	10:30 am/pm	0.05°
Envisat AATSR	2002–2012	10:00 am/pm	0.05°
Terra MODIS	2000–2018	10:30 am/pm	0.05°
Aqua MODIS	2002–2018	1:30 am/pm	0.05°
Multisensor IR	1995–2012	10:00 am/pm	0.05°
Multisensor MW	1995-2020	6:00 am/pm	0.25°

Study outline

Assess agreement between LST_cci anomalies and T2m anomalies

↓

Assess the temporal stability of LST_cci datasets using homogenised T2m

↓

Calculate trends in LST_cci datasets and compare with T2m trends

Key assumption:
EUSTACE T2m station time series are free from non-climatic discontinuities

Method

Compare LST anomalies to ‘conventional T2m anomalies’ -> same type of anomalies used in climate monitoring, IPCC, etc.

- We want to know if/how well the LST anomalies ‘match’ these T2m anomalies

Daily climatologies are calculated separately for LST and T2m using all available data for the common temporal period (e.g. 2002–2012 for analysis of AATSR)

The median climatology is subtracted from the time series data to calculate the daily anomalies:

$$LST_{anom} = LST_{observed} - LST_{climatology}$$

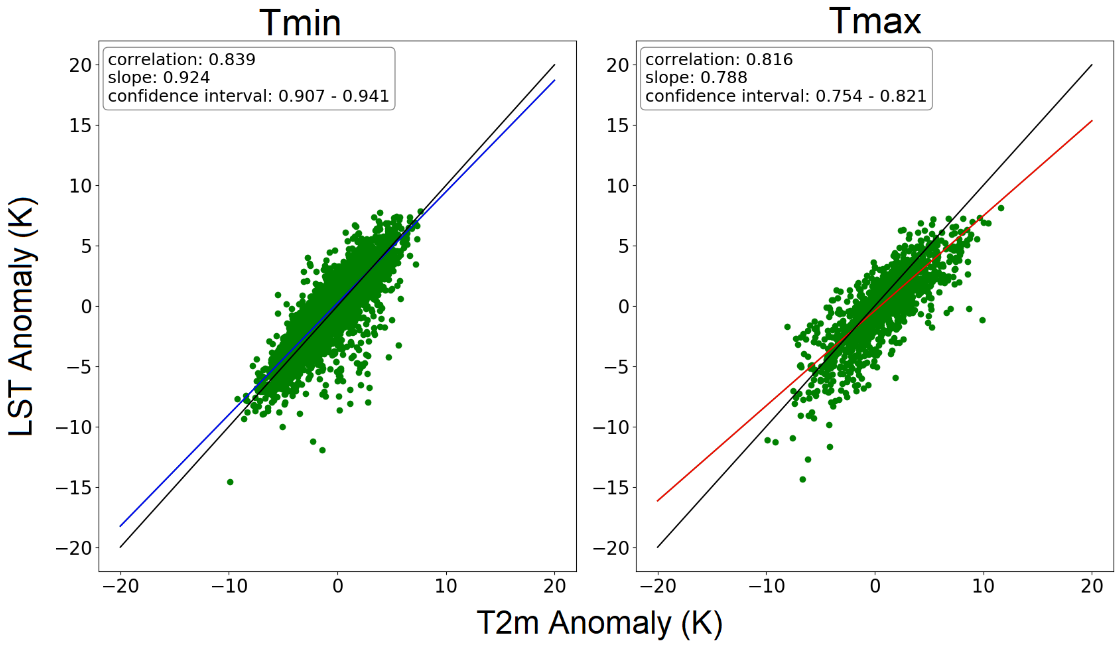
$$T2m_{anom} = T2m_{observed} - T2m_{climatology}$$

Step 1: Assess the relationship between LST and T2m anomalies

Step 2: Assess the temporal stability of LST_cci datasets

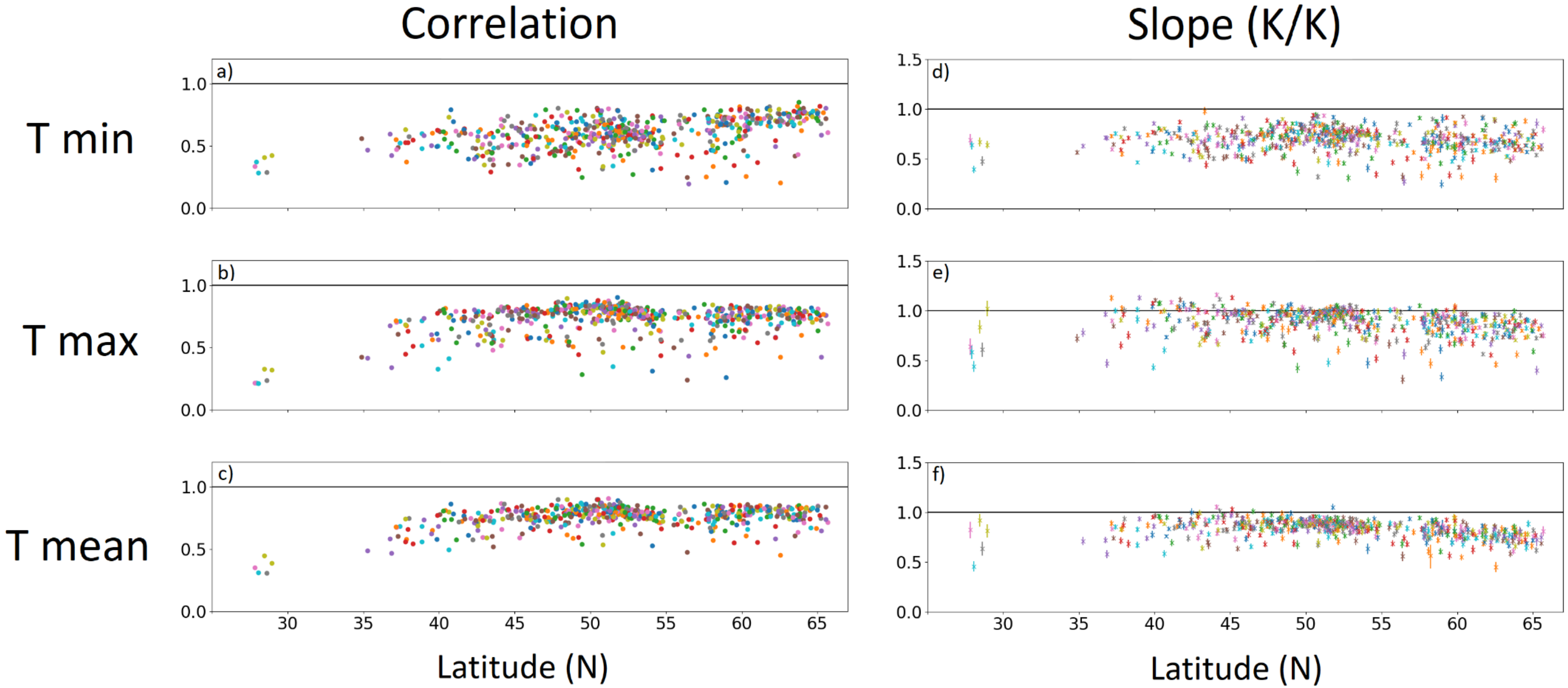
Step 3: Calculate trends in LST and compare with T2m trends

Example relationship between LST_{anom} and $T2m_{anom}$ for MODIS/Aqua

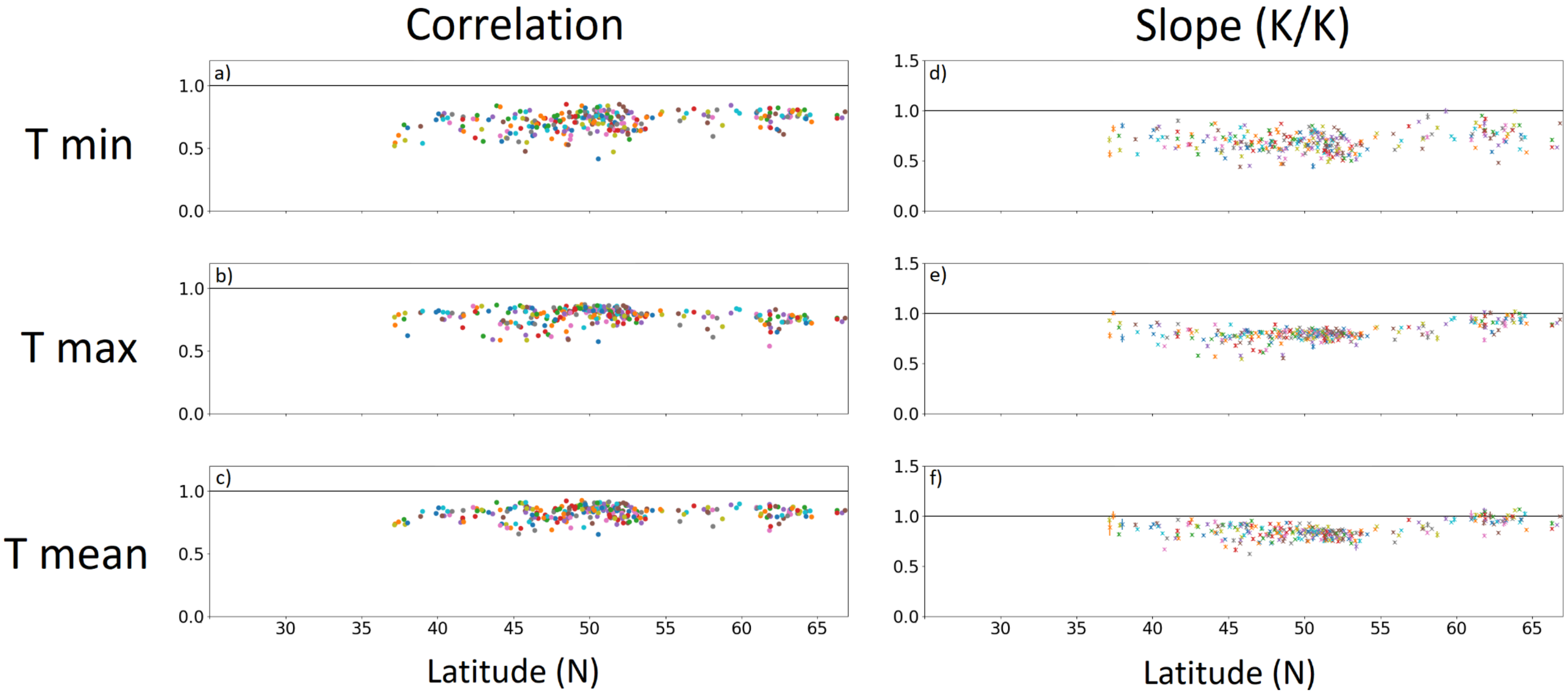


- Correlation '*r*'
- Slope '*m*' of the best fit line (blue and red lines)
- A perfect relationship is *r*=1 and *m*=1
- Analysis performed at each station

Anomaly Relationship: MODIS/Aqua



Anomaly Relationship: Multisensor MW



Agreement between LST and T2m anomalies

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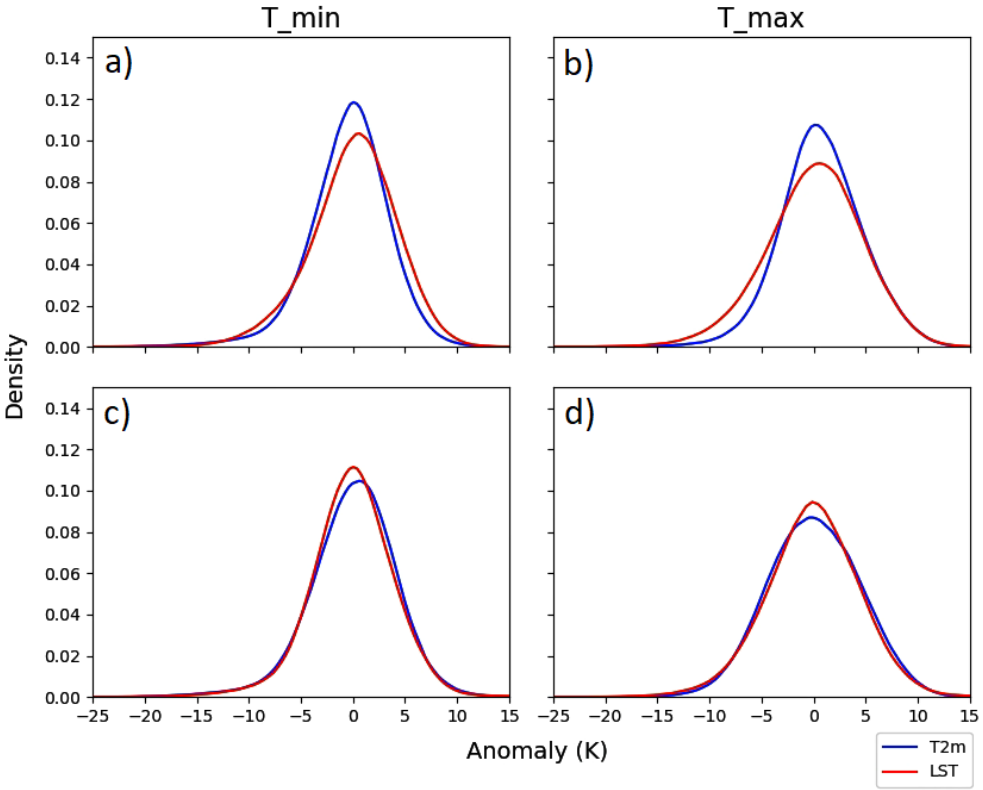
MODIS/Aqua LSTnight

Tmin

MW LST_6am

Tmin



MODIS/Aqua LSTday

Tmax

MW LST_6pm

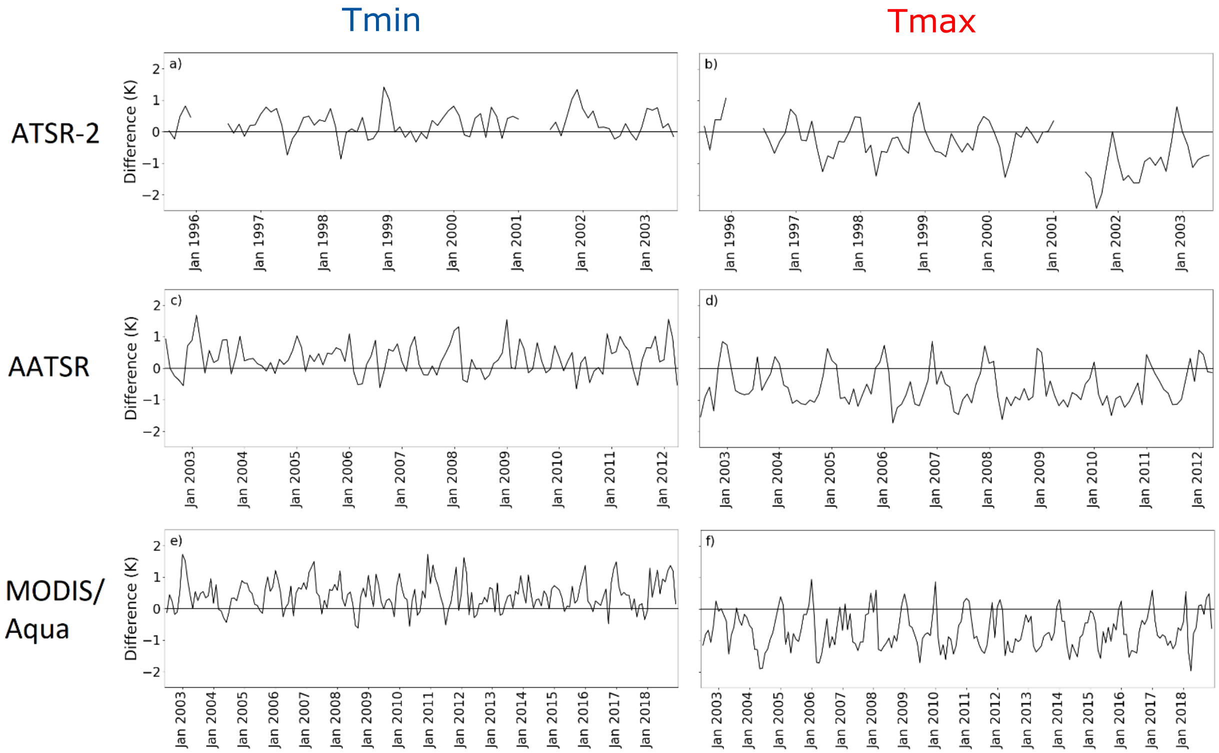
Tmax

Step 1: Assess the relationship between LST and T2m anomalies

Step 2: Assess the temporal stability of LST_cci datasets

Step 3: Calculate trends in LST and compare with T2m trends

Time series of LST minus T2m Anomalies



0.03 K/decade (-0.32 – 0.45)
-1.21 K/decade (-1.8 – -0.55)
=> NOT STABLE

-0.01 K/decade (-0.37 – 0.32)
-0.04 K/decade (-0.38 – 0.32)
=> STABLE

0.03 K/decade (-0.11 – 0.17)
0.00K/decade (-0.19 – 0.19)
=> STABLE

Time series of LST minus T2m Anomalies

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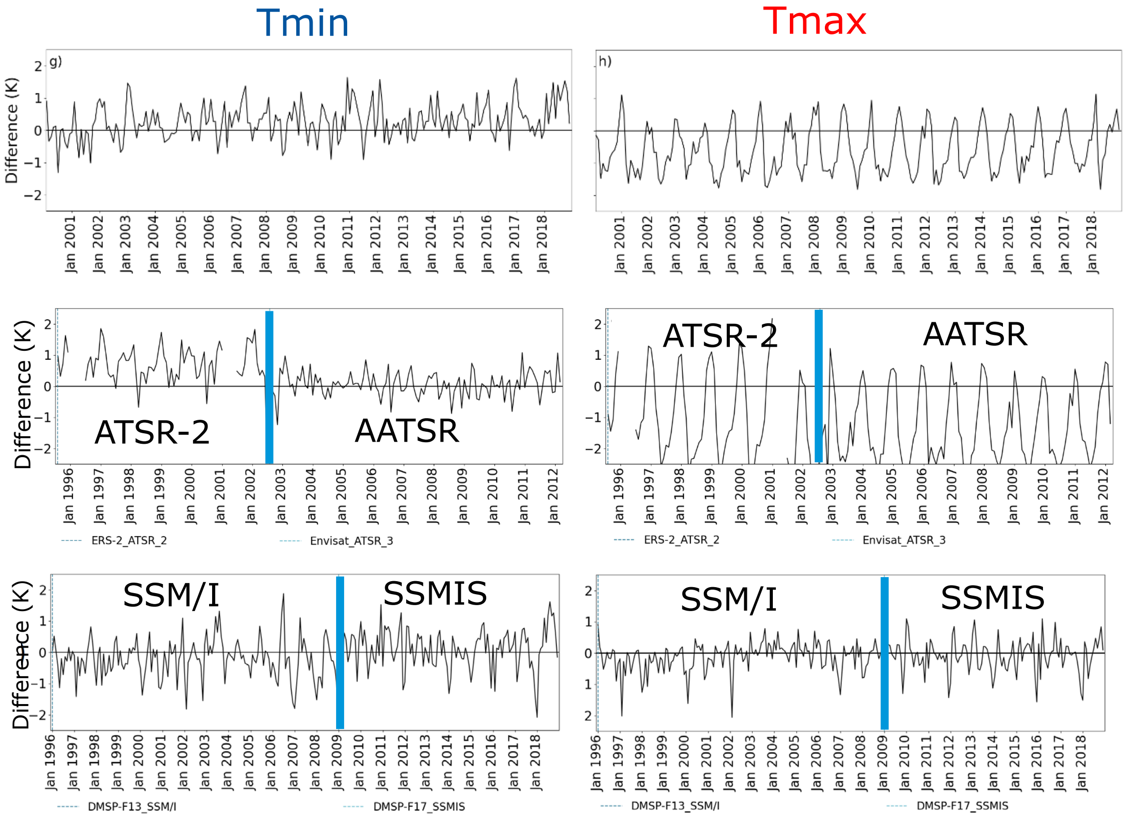
MODIS/ Terra

Multi-sensor IR

Multi-sensor MW



0.23 K/decade (0.11 – 0.35)
0.15 K/decade (-0.02 – 0.32)
=> NOT STABLE

-0.55 K/decade (-0.71 – -0.40)
-0.24 K/decade (-0.60 – 0.13)
=> NOT STABLE
BUT individual sensor time series are stable

0.21 K/decade (0.10 – 0.32)
0.07 K/decade (0.00 – 0.15)
=> NOT STABLE
BUT 3 of 4 individual sensor time series are stable

Step 1: Establish whether there is a relationship between LST and T2m anomalies ✓

Step 2: Assess the temporal stability of LST_cci datasets ✓

MODIS/Aqua & AATSR only

Step 3: Calculate trends in LST and compare with T2m trends

Calculated trends

T2m trends shown are 'conventional', and include both clear and cloudy observations

LST trends shown are for IR data and are therefore clear-sky only

No statistically significant difference between LST & T2m trends

			MODIS/Aqua (2002-2018)	AATSR (2002-2012)
Tmin	*LST*	*t (K/decade)*	*0.64*	0.09
		CI (K/decade)	0.24 – 1.05	-0.69 – 0.88
	T2m	*t (K/decade)*	*0.51*	0.07
		CI (K/decade)	0.16 – 0.83	-0.62 – 0.69
Tmax	*LST*	*t (K/decade)*	*0.66*	0.35
		CI (K/decade)	0.18 – 1.12	-0.65 – 1.39
	T2m	*t (K/decade)*	*0.58*	0.22
		CI (K/decade)	0.18 – 0.98	-0.75 – 1.12
Tmean	*LST*	*t (K/decade)*	*0.66*	-0.14
		CI (K/decade)	0.23 – 1.11	-0.89 – 0.64
	T2m	*t (K/decade)*	*0.53*	0.15
		CI (K/decade)	0.16 – 0.93	-0.65 – 0.93

Summary and Conclusions

- There is a strong relationship between LST and T2m anomalies; consistent with previous studies
  - T2m anomalies appear to agree more closely with MW LST anomalies compared with IR LST anomalies, probably because both T2m and MW are all-sky.
- Only two (AATSR and MODIS/Aqua) of the six LST_cci datasets are stable
  - ATSR-2, MODIS/Terra, multisensor IR and multisensor MW suffer from drift and/or jumps due to changes in sensor
- There are no statistically significant differences between the trends in LST and T2m for the two stable datasets
  - MODIS/Aqua (2002-2018): LST ~0.65 K/decade, T2m ~0.54 K/decade
  - AATSR (2002 – 2012) = no detectable trend in either LST or T2m
- Study suggests LST can be used to complement and augment T2m (e.g. fill data gaps)

QUESTIONS?

Please contact:

Lizzie Good - elizabeth.good@metoffice.gov.uk

Freya Aldred – freya.aldred@metoffice.gov.uk

Annual cycle in IR differenced time series

Climatologies are created using all data available for each dataset

To perform the comparisons, anomaly data are spatially and temporally matched

Only data available for both datasets are used

This means we are now only looking at clear-sky data for T2m for IR comparisons

We do not want to use anomalies with respect to a clear-sky T2m climatology because we want to test the LST anomalies against the 'conventional' T2m data we use routinely for climate monitoring

Annual cycle in IR differenced time series

- Anomaly data from 5 stations from the MODIS/Terra comparison for T_{max} before and after temporal matching
- Removing cloudy T2m (as determined from satellite observations) creates an annual cycle in the T2m time series
- This results in an annual cycle in the differenced time series

All data

Temporally matched