

Contents

- Introduction – why LST is important
- General requirements:
 - Length of record
 - Coverage
 - Homogeneity/stability
 - Communication of uncertainties

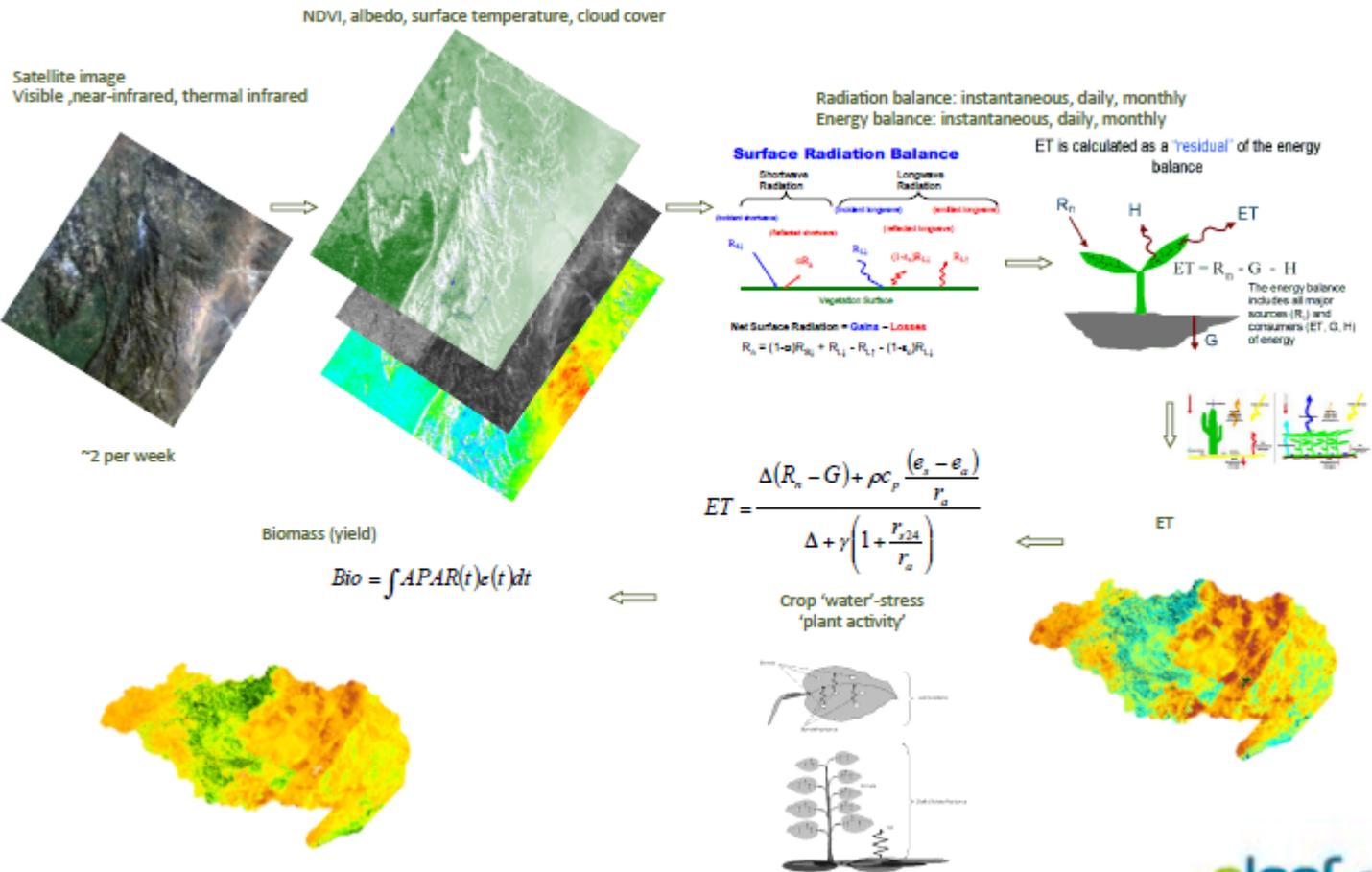
Importance of LST for climate applications

- Land surface temperature (or LST) provides a valuable set of observations for characterising land surface states and land-atmosphere exchange.
- Increasingly recognised as an essential parameter for diagnosing Earth System behaviour and evaluating Earth System Models:
 - provides a globally consistent record from satellite of clear-sky, radiative temperatures of the Earth's surface
 - provides a crucial constraint on surface energy balances, particularly in moisture-limited states.
 - provides a metric of surface state when combined with vegetation parameters and soil moisture, and is related to the driving of vegetation phenology.

Modelling of evapotranspiration



SEBAL model

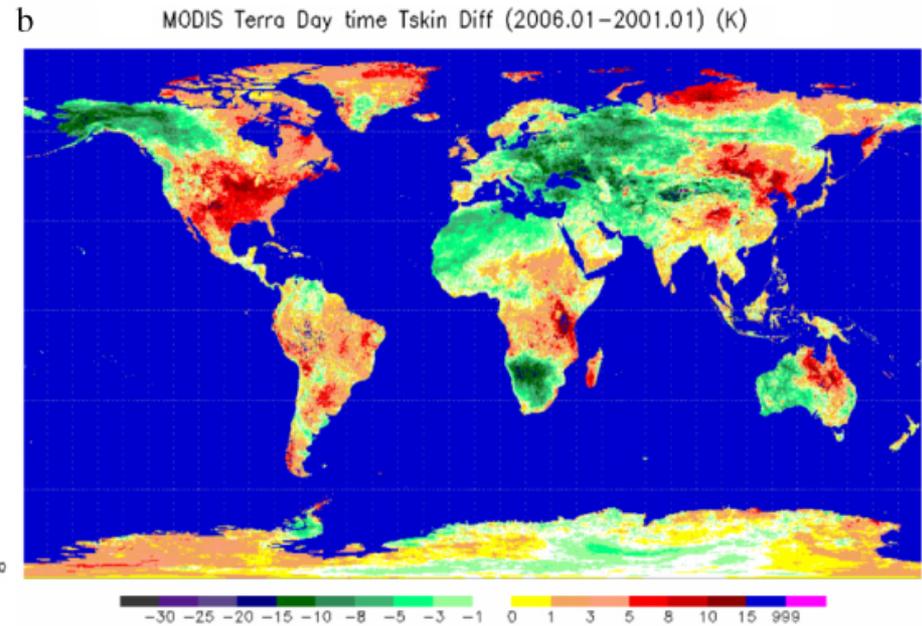
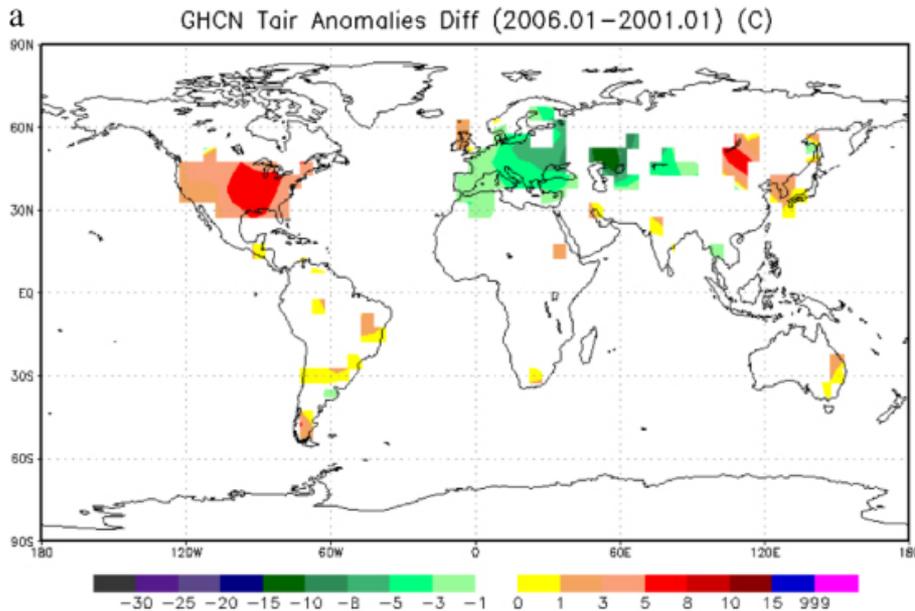


Importance of LST for climate applications

- Land surface temperature (or LST) provides a valuable set of observations for characterising land surface states and land-atmosphere exchange.
- Increasingly recognised as an essential parameter for diagnosing Earth System behaviour and evaluating Earth System Models:
 - an important source of information for deriving surface air temperature in regions with sparse measurement stations, such as parts of Africa and the Arctic

Inter-annual variability for surface air temperature and surface skin temperature

Skin temperature is from MODIS daytime observation at 0.05° latitude/longitude, and air temperature is monthly mean from GHCN (from Jin & Dickinson, 2010)



ESTIMATING AIR TEMPERATURE FROM SKIN TEMPERATURE

Publicly available weather station records

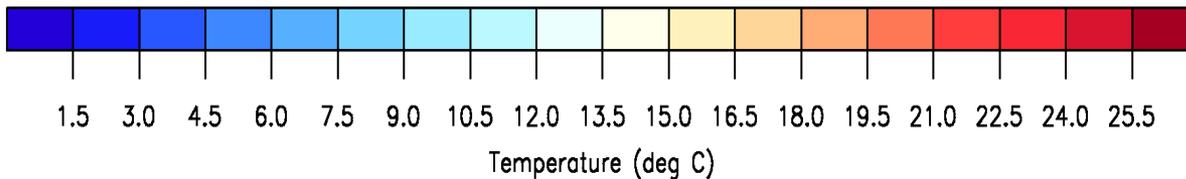
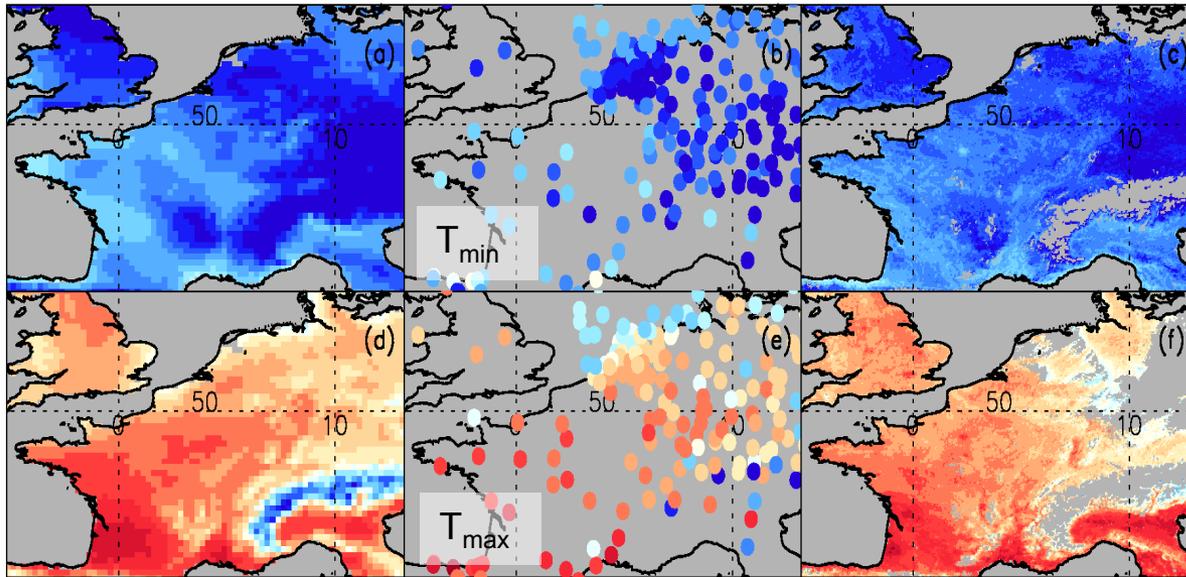
EOBS

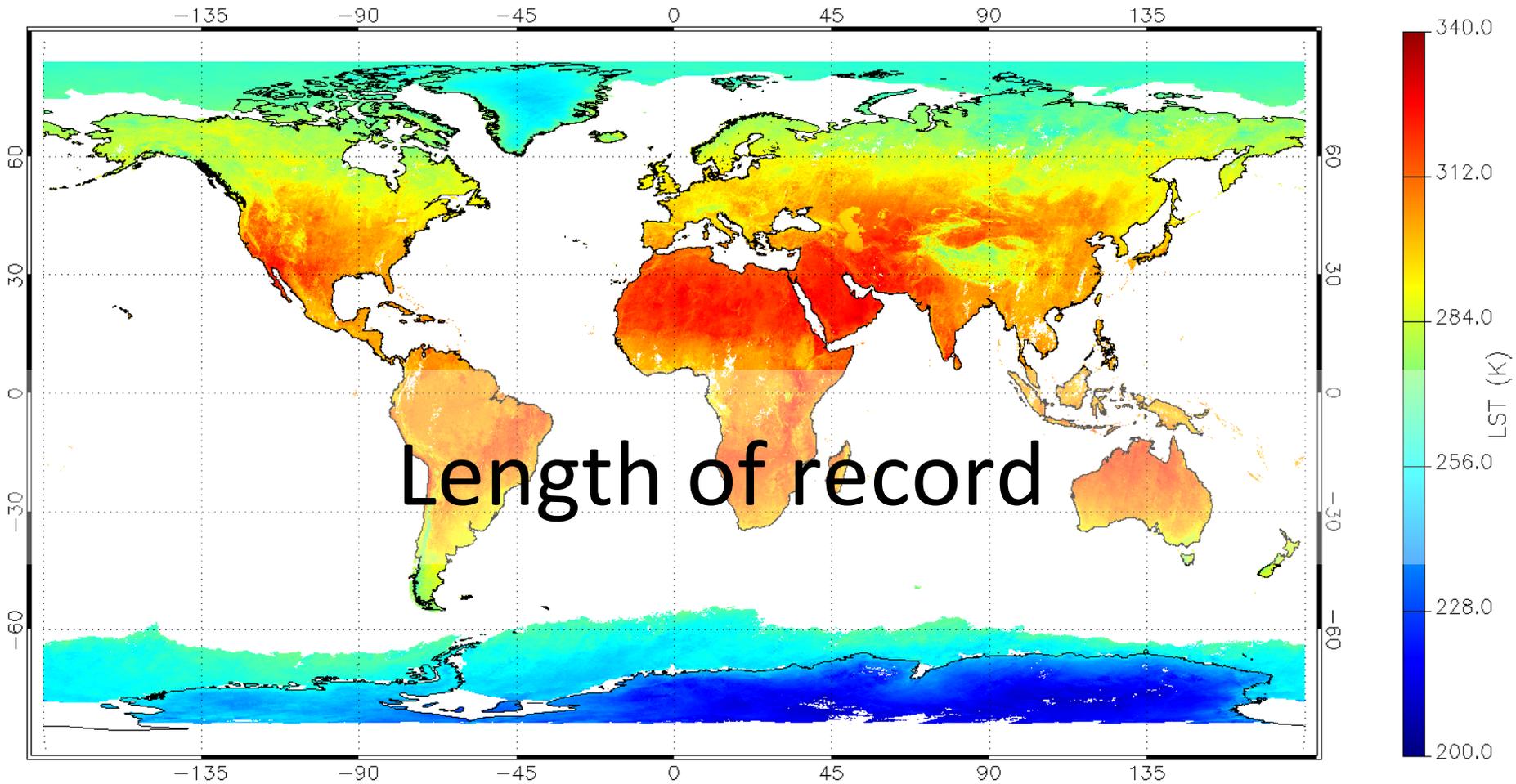
ECA&D

Satellite LSAT

Highest available resolution in-filled air temperature analysis from weather station measurements

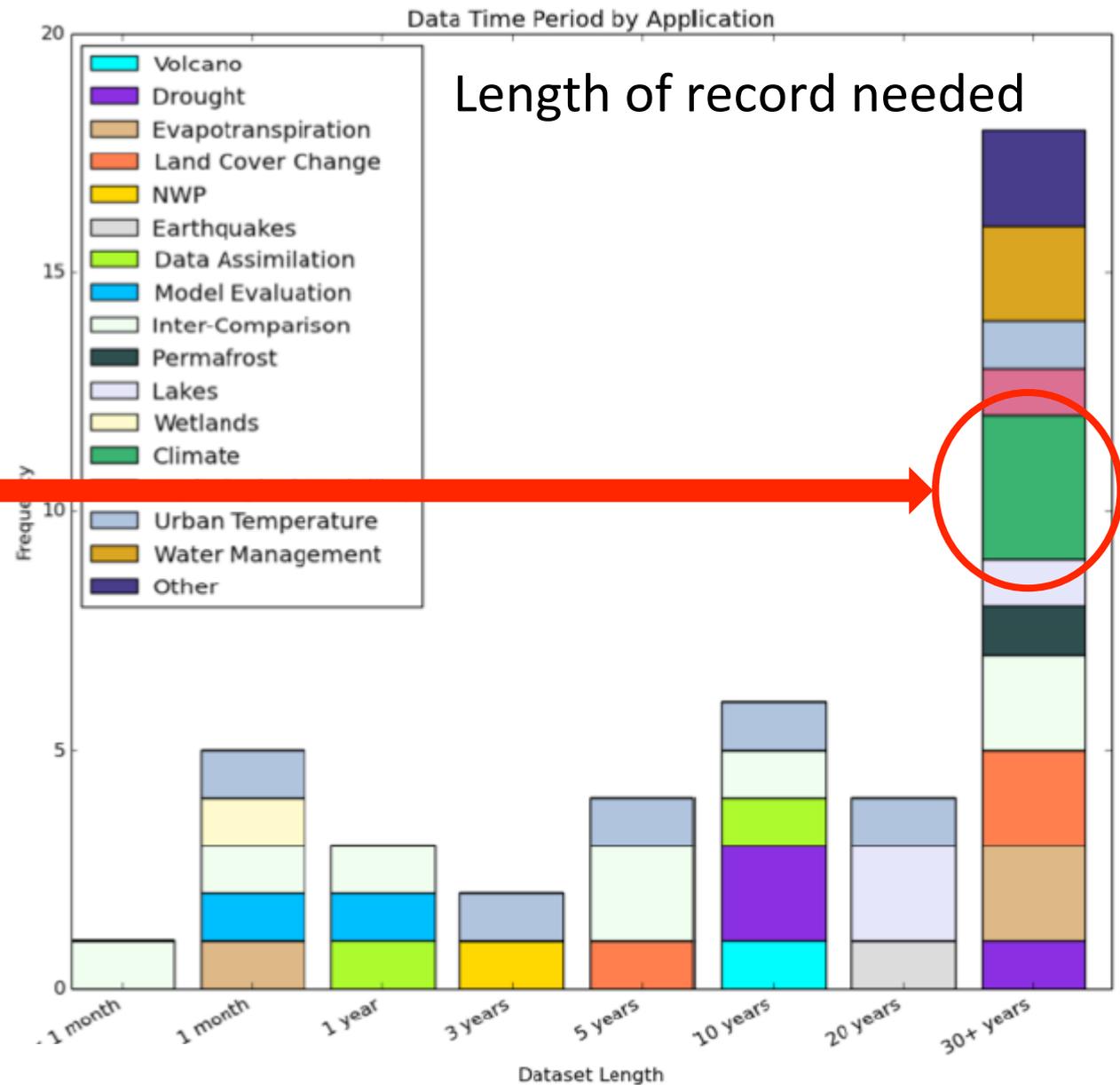
Higher resolution information on air temperature estimated using surface (skin) temperature from satellites





Need as long a record as possible – at least 30 years for “Climate”, e.g.:

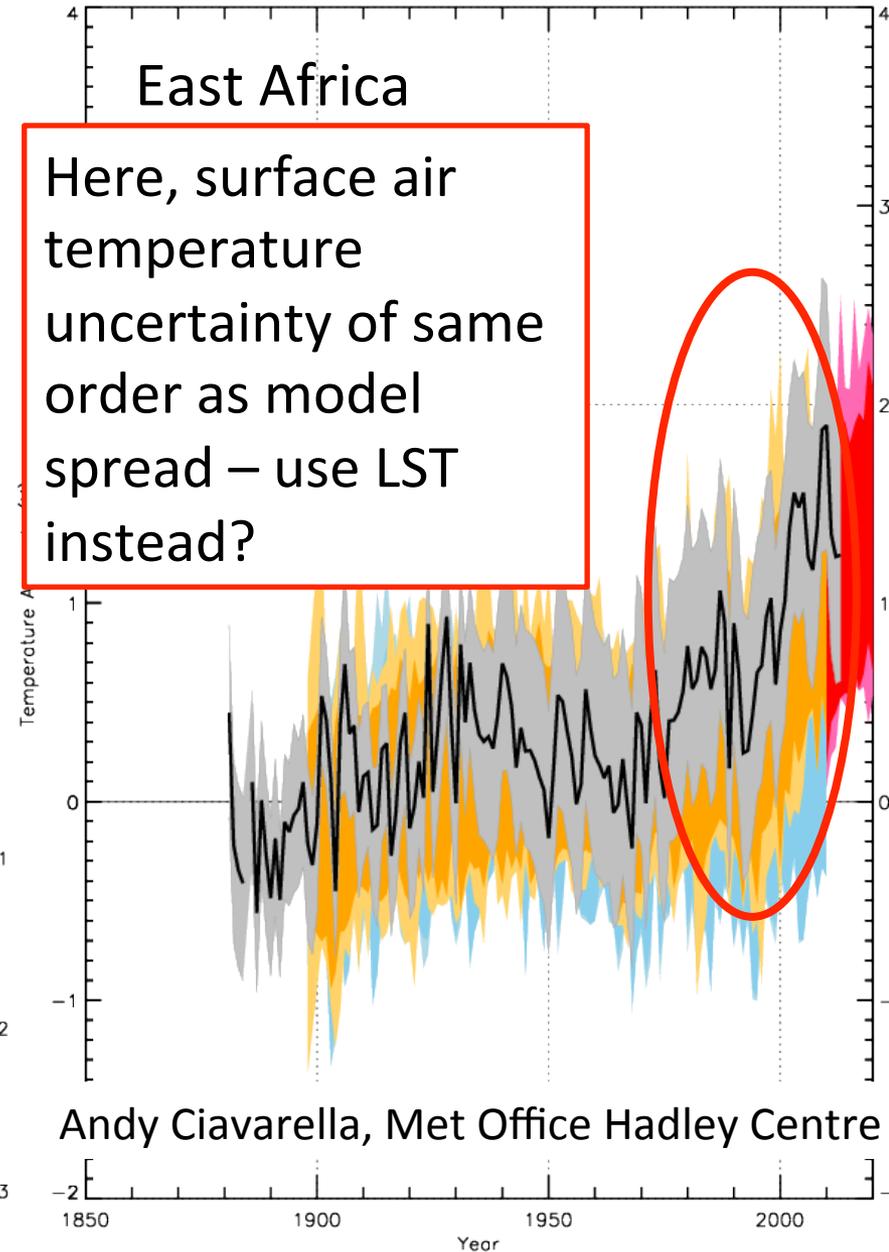
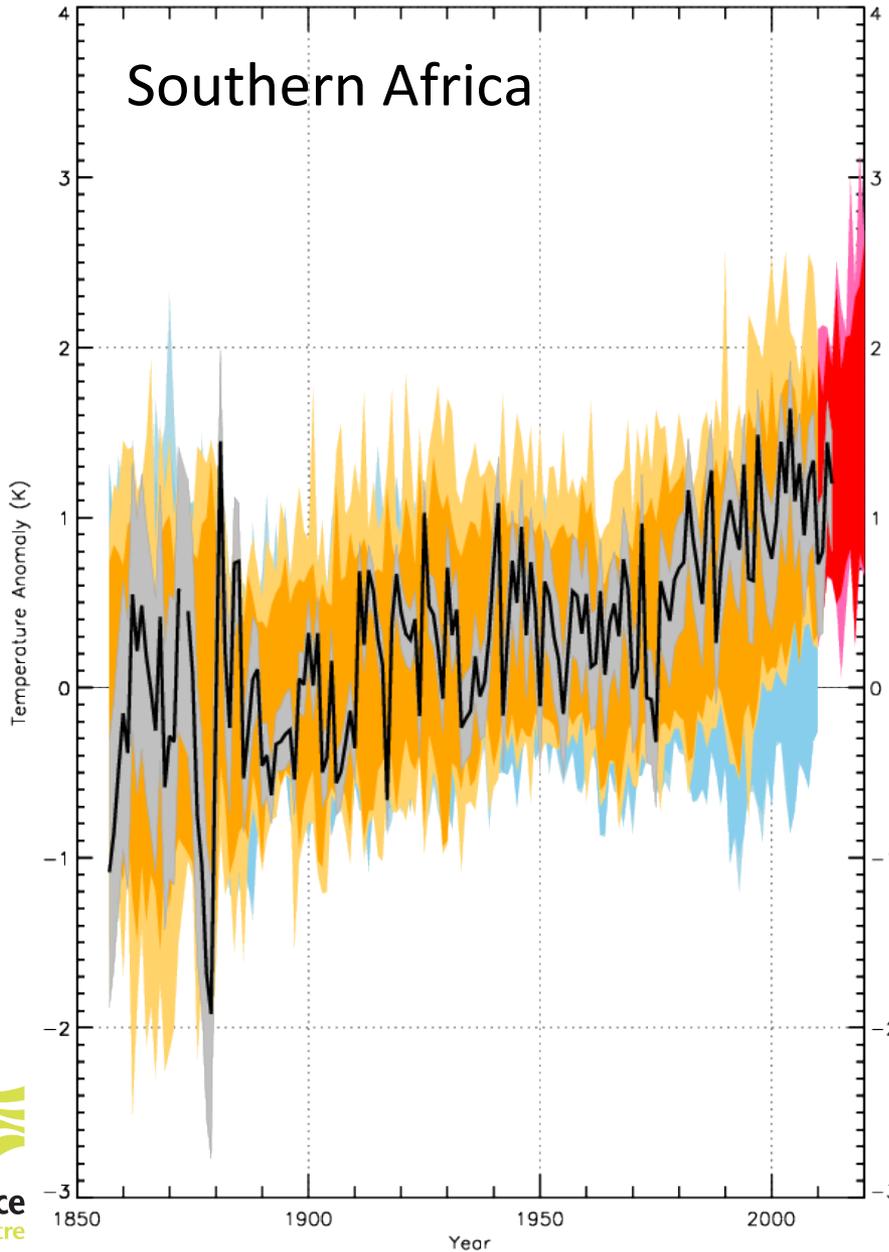
- Model evaluation
- Attribution of changes over Africa (lack of *in situ* here)
- Reconstructing past air temperature



Model evaluation/change attribution

17: S. Africa DJF

16: E. Africa ann

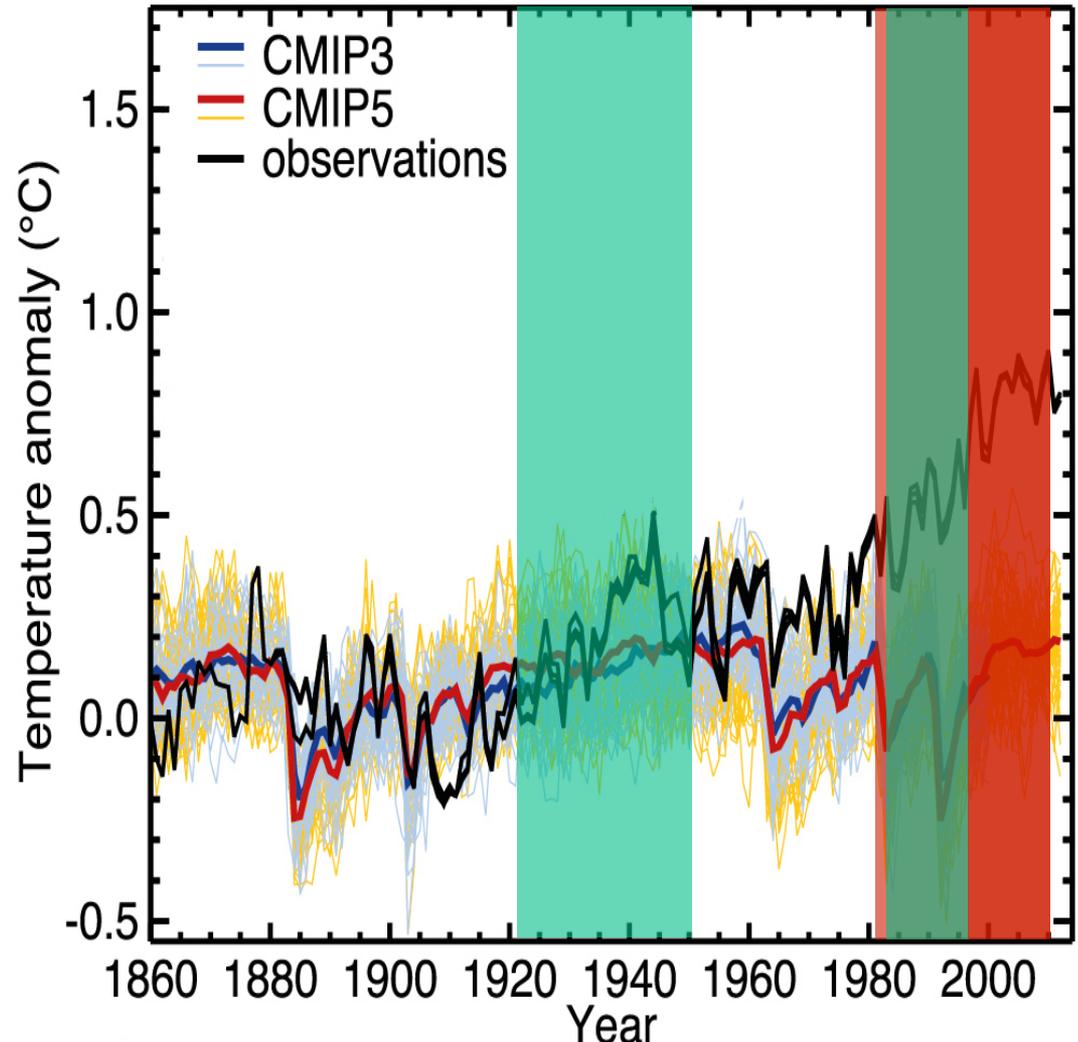


Here, surface air temperature uncertainty of same order as model spread – use LST instead?

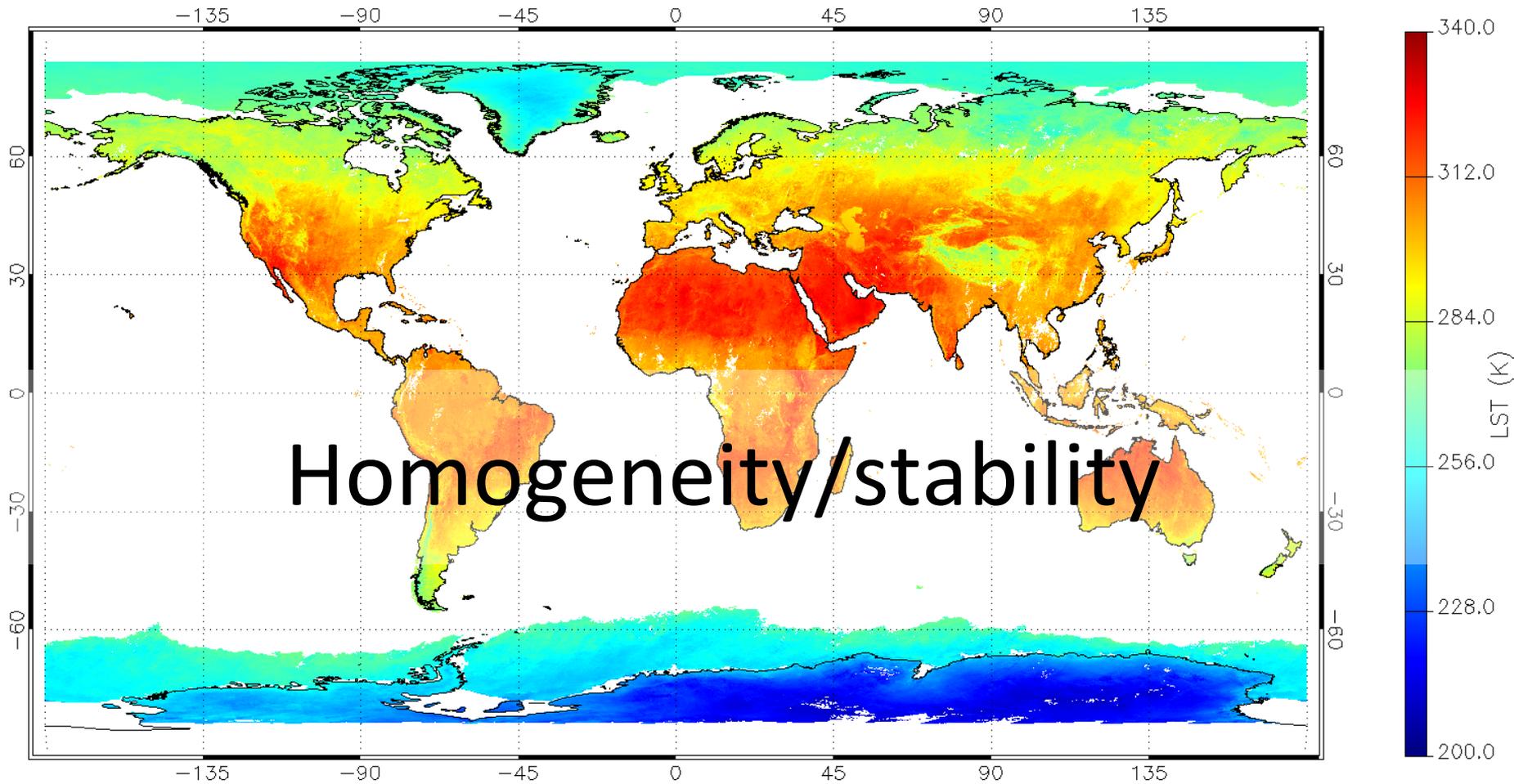
Andy Ciavarella, Met Office Hadley Centre

Need for multi-decadal record: calculating changes relative to a baseline

- To assess changes, a baseline must be established
- Best station data starts 1920s, but satellite data are only from 1980s – some of this record needs to be used to create the baseline



Homogeneity/stability



Homogeneity/stability

- Requirement for stability:
 - 0.1K/decade at breakthrough (GlobTemperature User Requ)
- Need consistent:
 - sensor calibration

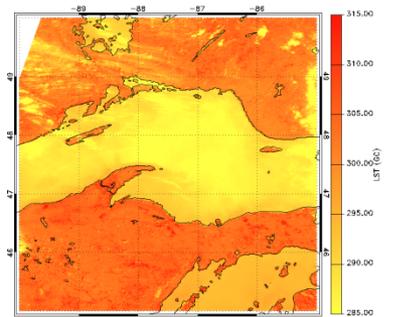
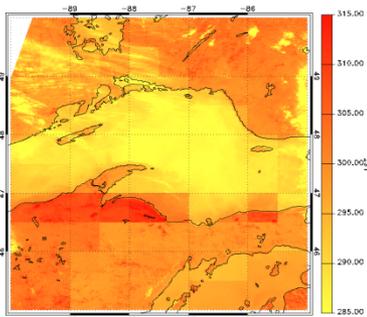
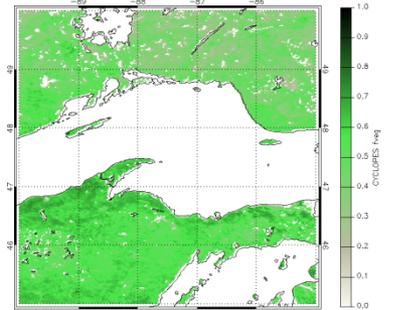
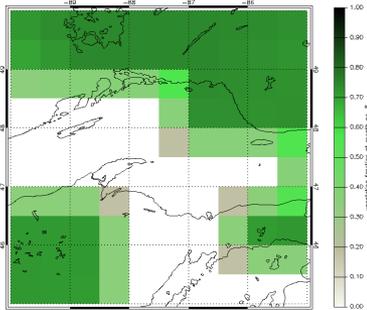
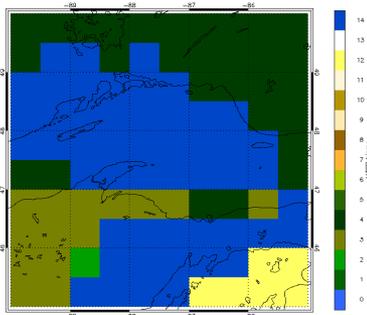
FIDUCEO FCDRs

DATASET	NATURE	POSSIBLE USES
AVHRR FCDR	Harmonised infra-red radiances and best available reflectance radiances, 1982 - 2016	SST, LSWT, aerosol, LST, phenology, cloud properties, surface reflectance ...

Homogeneity/stability

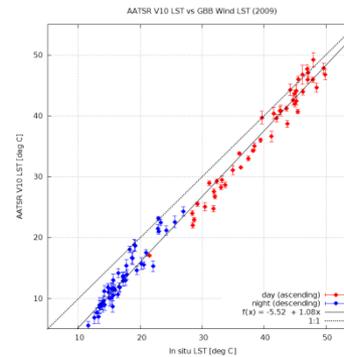
- Requirement for stability:
 - 0.1K/decade at breakthrough (GlobTemperature User Requ)
- Need consistent:
 - sensor calibration and algorithms
 - auxiliary data (early ATSR auxiliary data had inconsistencies leading to large uncertainties)

- Early ATSR auxiliary data (land cover information, emissivity information, atmospheric profiles) had inconsistencies leading to large uncertainties
- GlobTemperature has resolved these issues with use of high spatial and temporal resolution auxiliary data

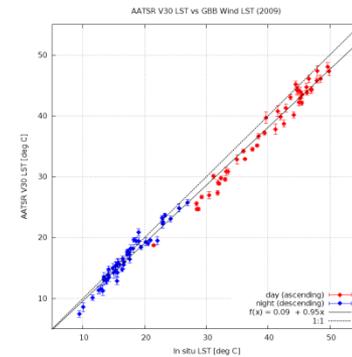


Existing operational

GlobTemp



Existing operational



GlobTemp

Homogeneity/stability

- Requirement for stability:
 - 0.1K/decade at breakthrough (GlobTemperature User Requ)
- Need consistent:
 - sensor calibration and algorithms
 - auxiliary data
 - cloud clearing (changing clear sky biases, etc; GlobTemperature doing this for ATSR only)

Impact on LST retrievals of different automatic cloud clearing algorithms

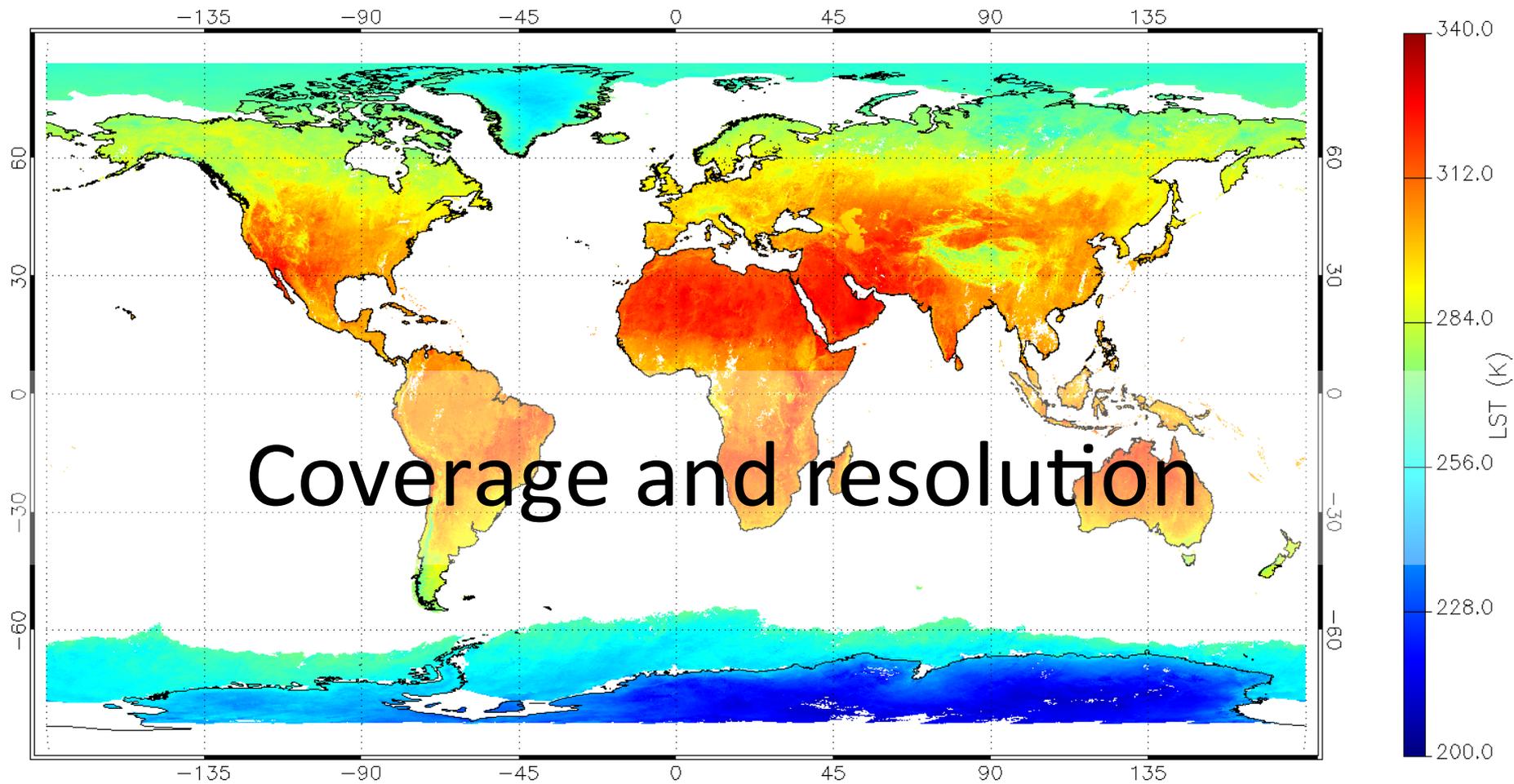
Table 5. LST impacts with reference to the manual mask segregated according to aerosol optical depth.

All	2 K Tolerance	Large uncertainties	Over-flag	Under-flag
SADIST	85.69	0.71	10.86	2.74
UOL_2	91.01	0.36	5.48	3.15
UOL_3	92.02	0.39	4.37	3.22
Bayes Thermal	87.02	0.32	10.49	2.18
Bayes Vis	90.79	0.49	4.90	3.82
Bayes Joint	90.60	0.31	6.98	2.11

Homogeneity/stability

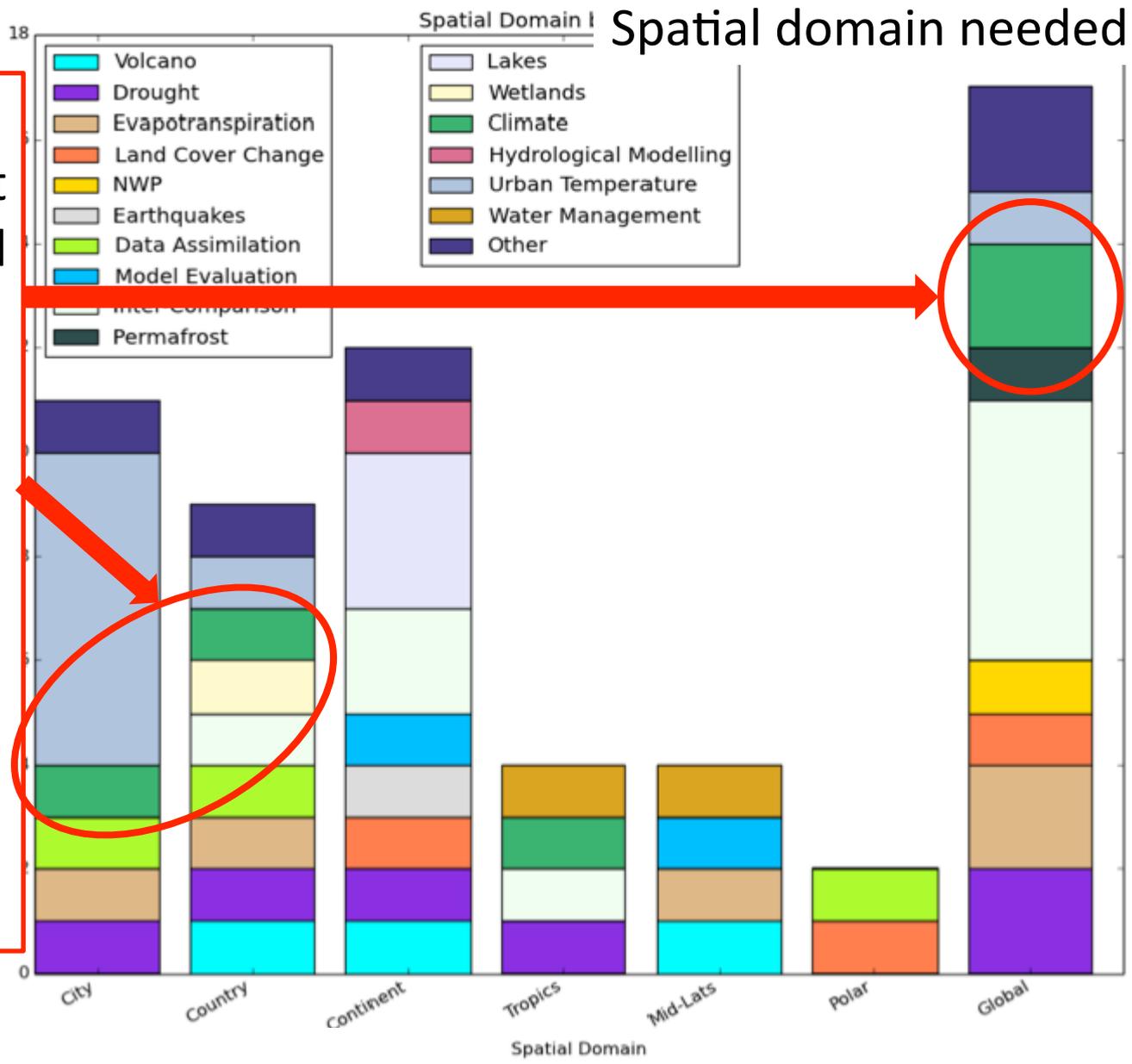
- Requirement for stability:
 - 0.1K/decade at breakthrough (GlobTemperature User Requ)
- Need consistent:
 - sensor calibration and algorithms
 - auxiliary data
 - cloud clearing (changing clear sky biases, etc.; GlobTemperature doing this for ATSR only)
- Changing uncertainties due to inconsistencies leads to unstable system





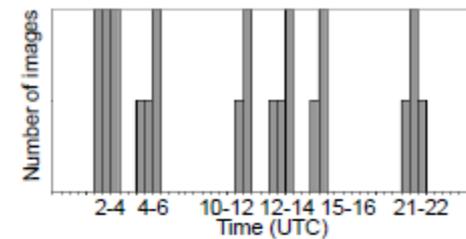
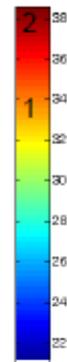
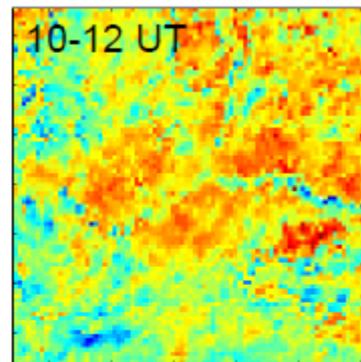
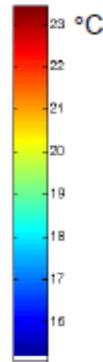
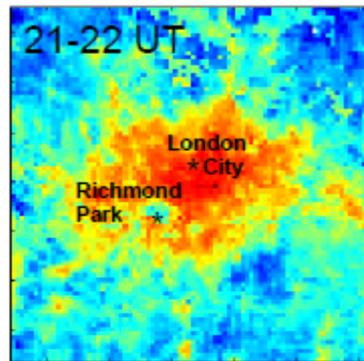
Note the need for global products, but also for country and city-scale products:

- Needed, for example, for policy-related work and urban climate change studies, including assessments of e.g. heat stress

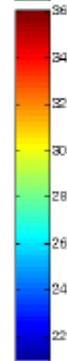
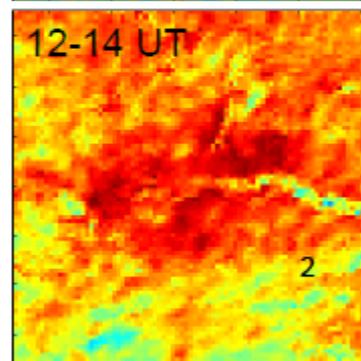
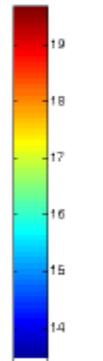
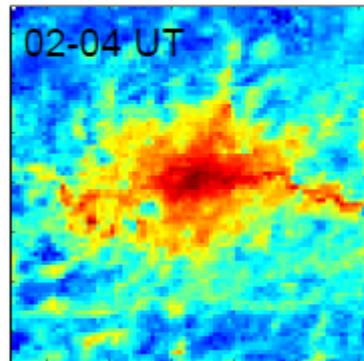


Heat stress in urban environments

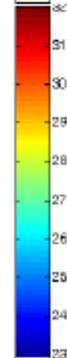
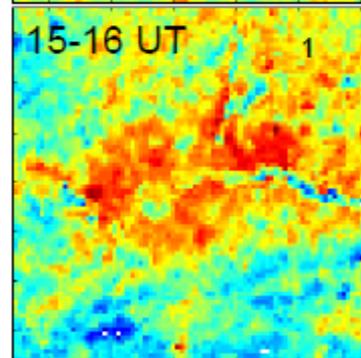
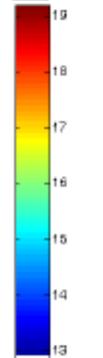
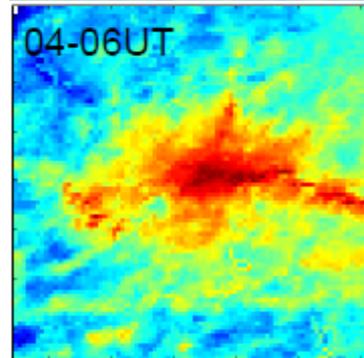
LST variability of London, Aug. 4-13 2003



Distribution of 24 NOAA-AVHRR images Ch.4

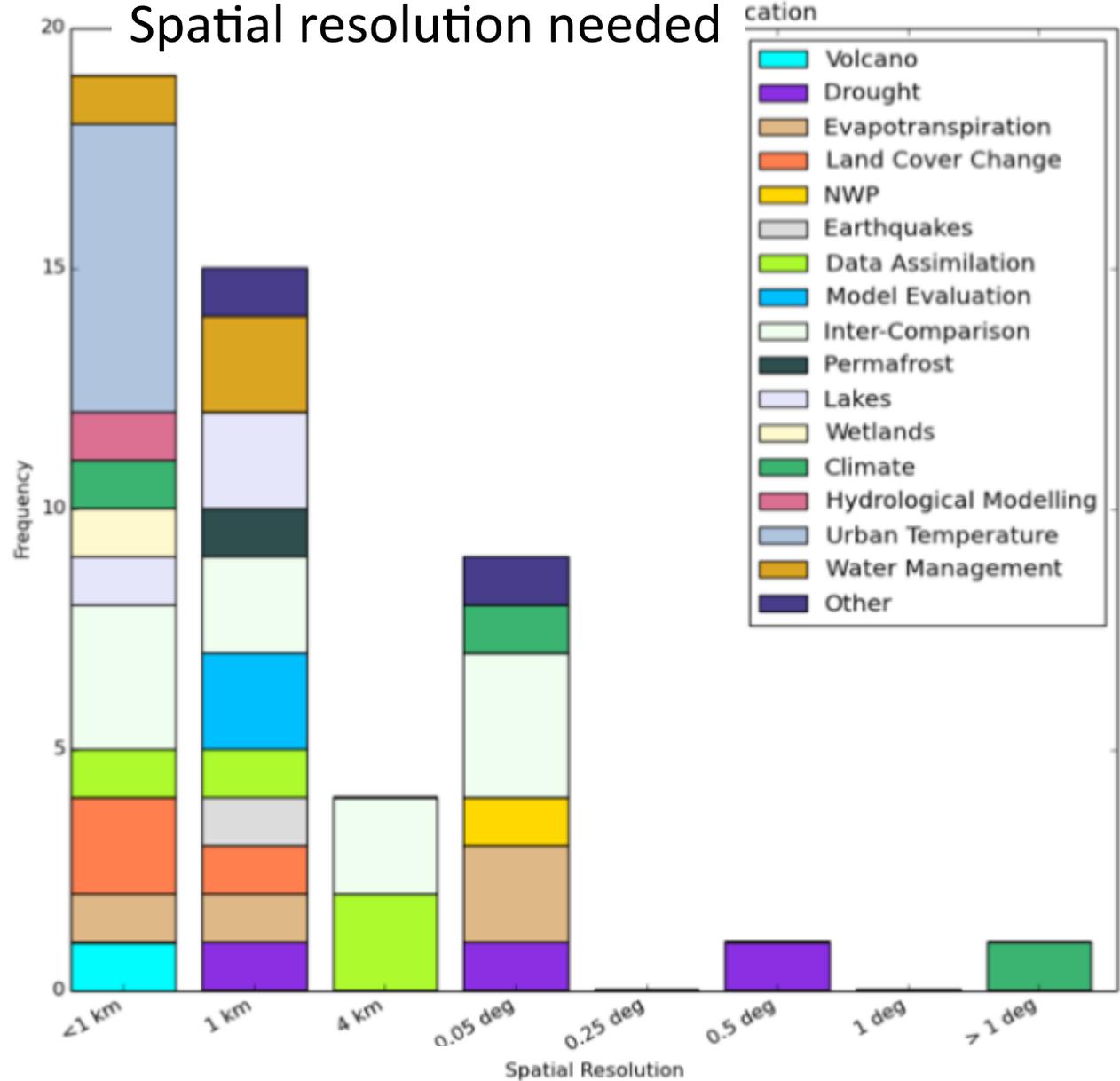


Composite images of the temperature diurnal cycle in London, Aug.4-13 2003



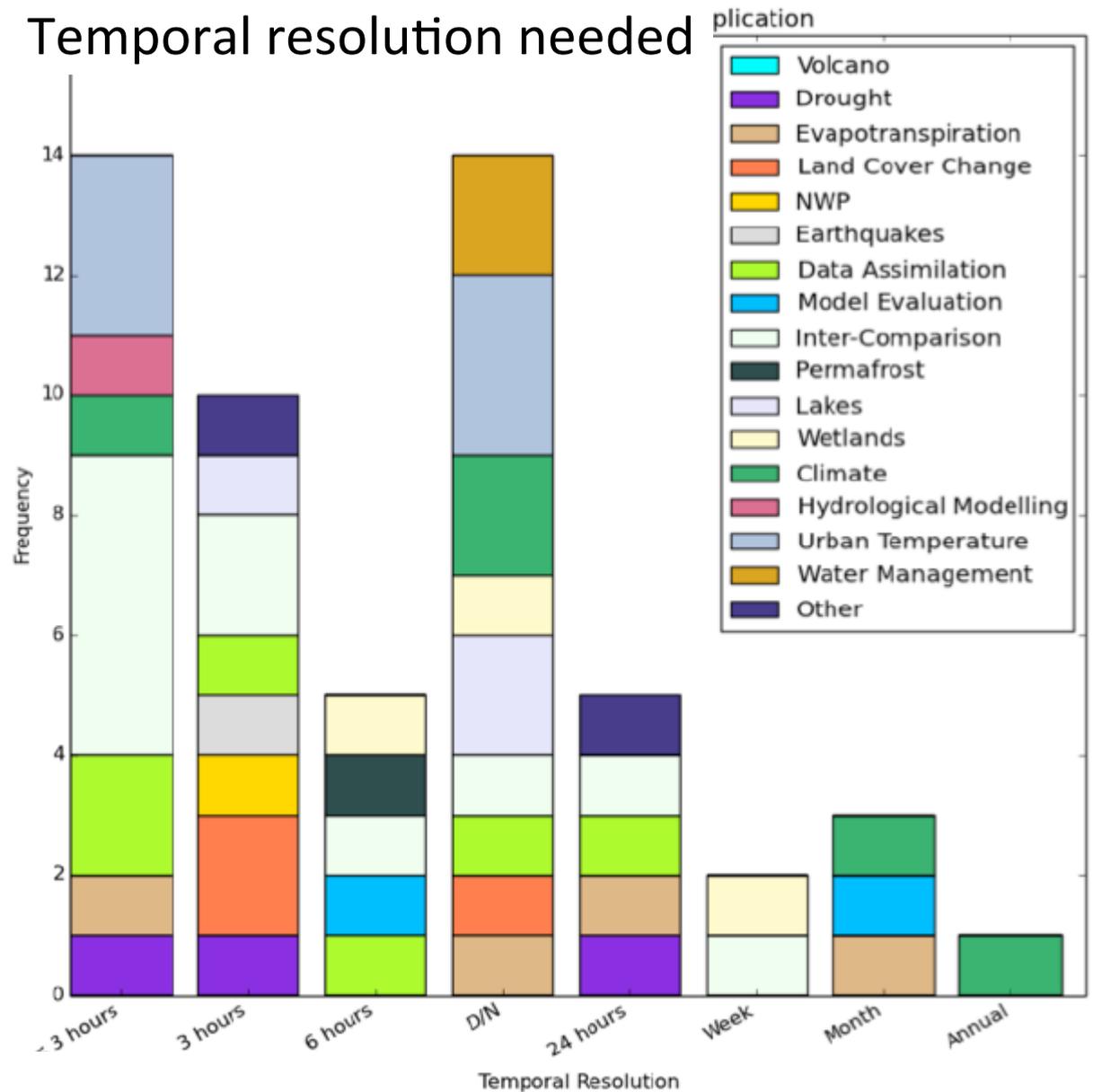
Benedicte Dousset

Spatial resolution needed

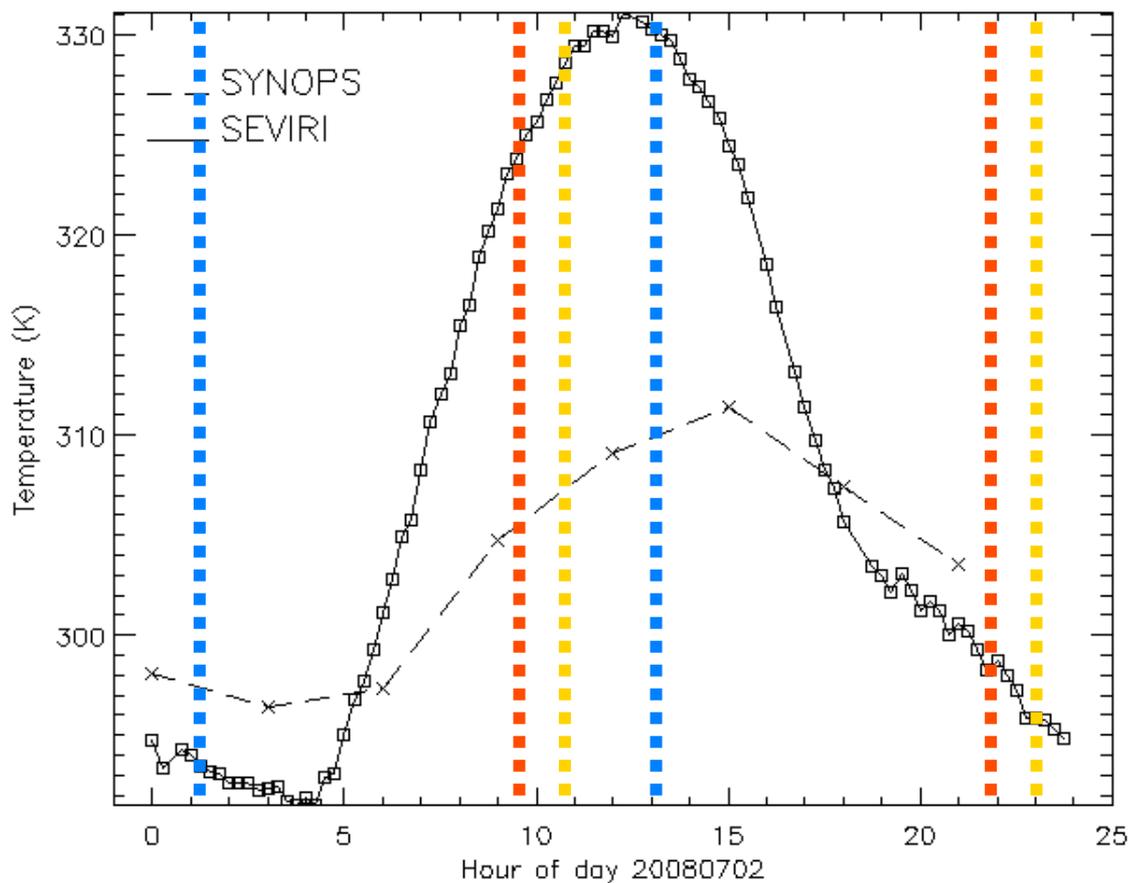


EUSTACE user requirements analysis also indicates a need for information on daily Tmax and Tmin. This is important, e.g. for the analysis of extremes, and climate-related event attribution.

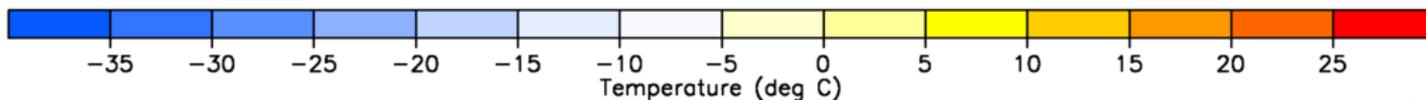
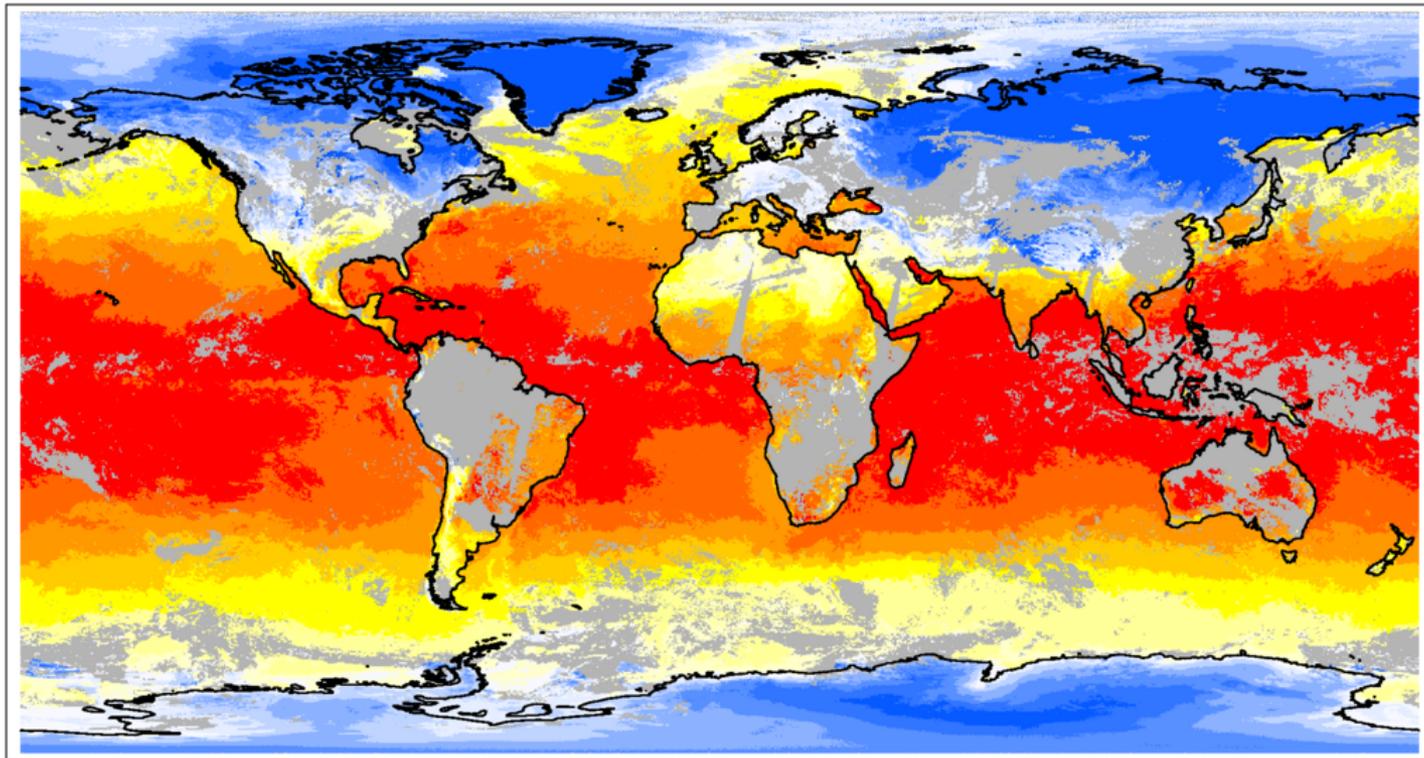
Temporal resolution needed



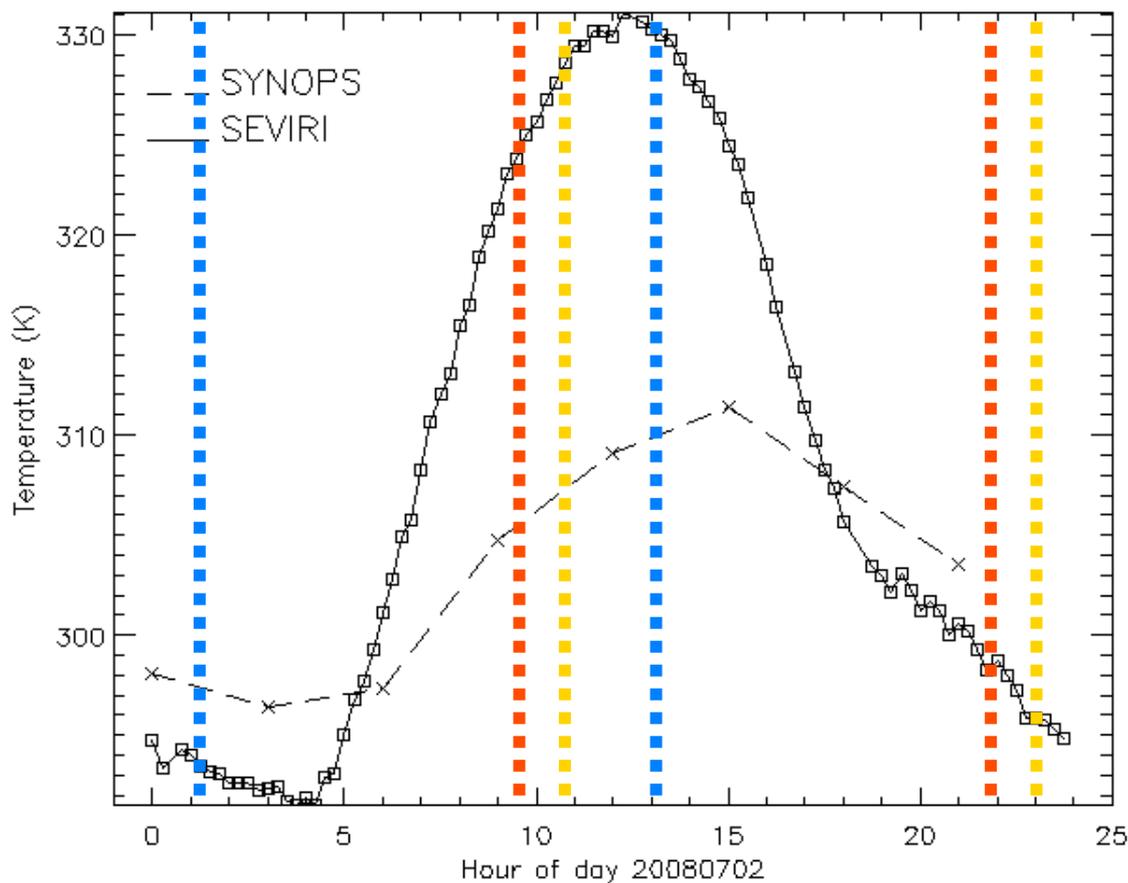
Diurnal cycle observed by SEVIRI and in situ station 60735 (35 40N, 10 06E – Tunisia) with approximate satellite overpass times (Blue = MODIS/Aqua, Yellow = MODIS/Terra, Red=ATSR). Squares indicate 15-minute SEVIRI observations.



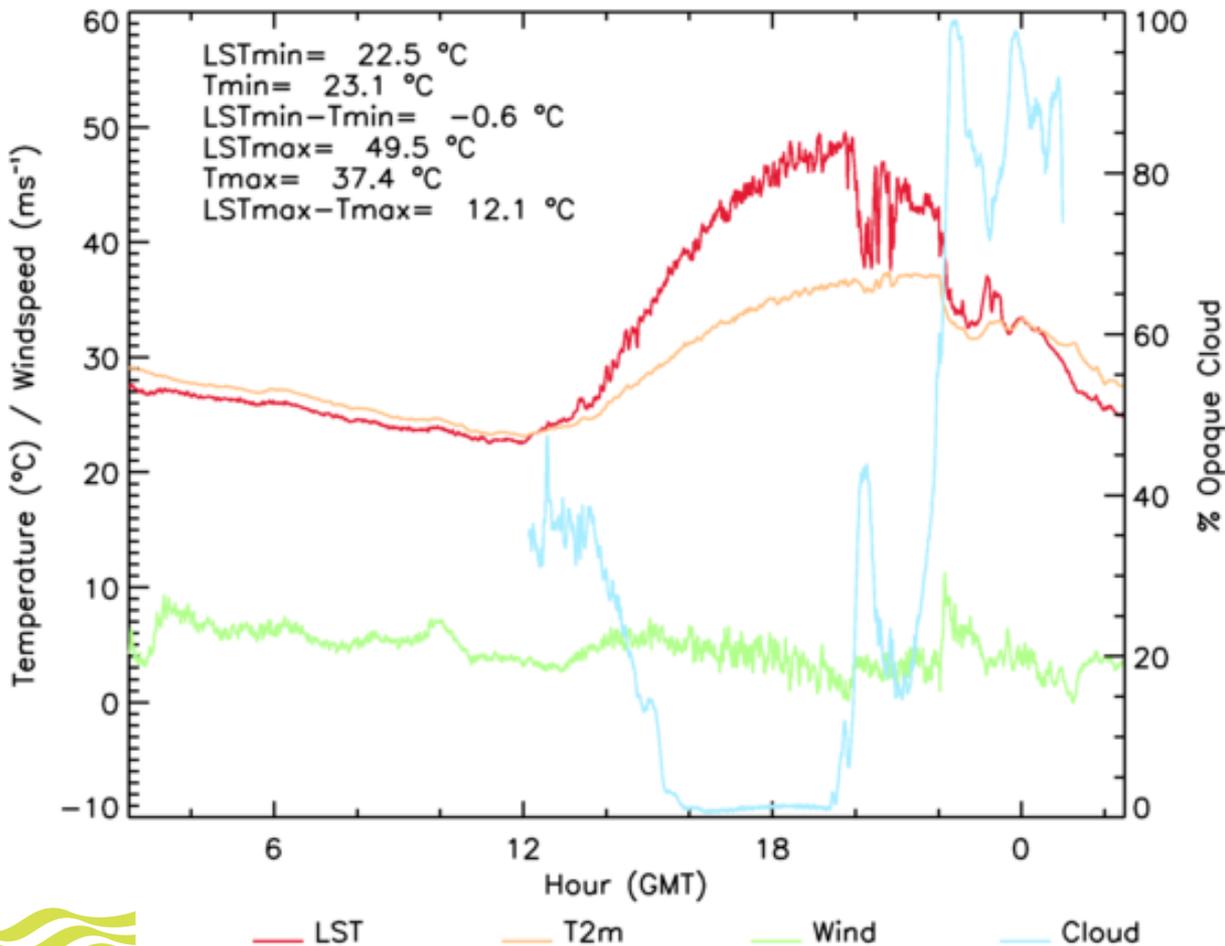
Near-global coverage (over land) from MODIS in one day



Diurnal cycle observed by SEVIRI and in situ station 60735 (35 40N, 10 06E – Tunisia) with approximate satellite overpass times (Blue = MODIS/Aqua, Yellow = MODIS/Terra, Red=ATSR). Squares indicate 15-minute SEVIRI observations.



Temperature observations from the ARM Oklahoma site on 16 August 2014. Cloud has strong influence on temperature evolution, particularly on LST.

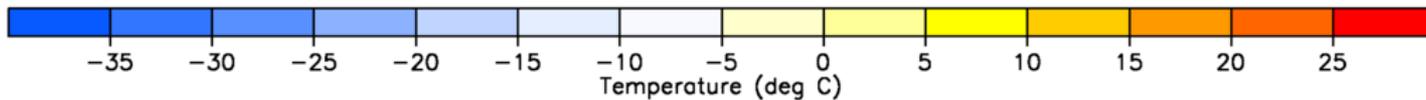
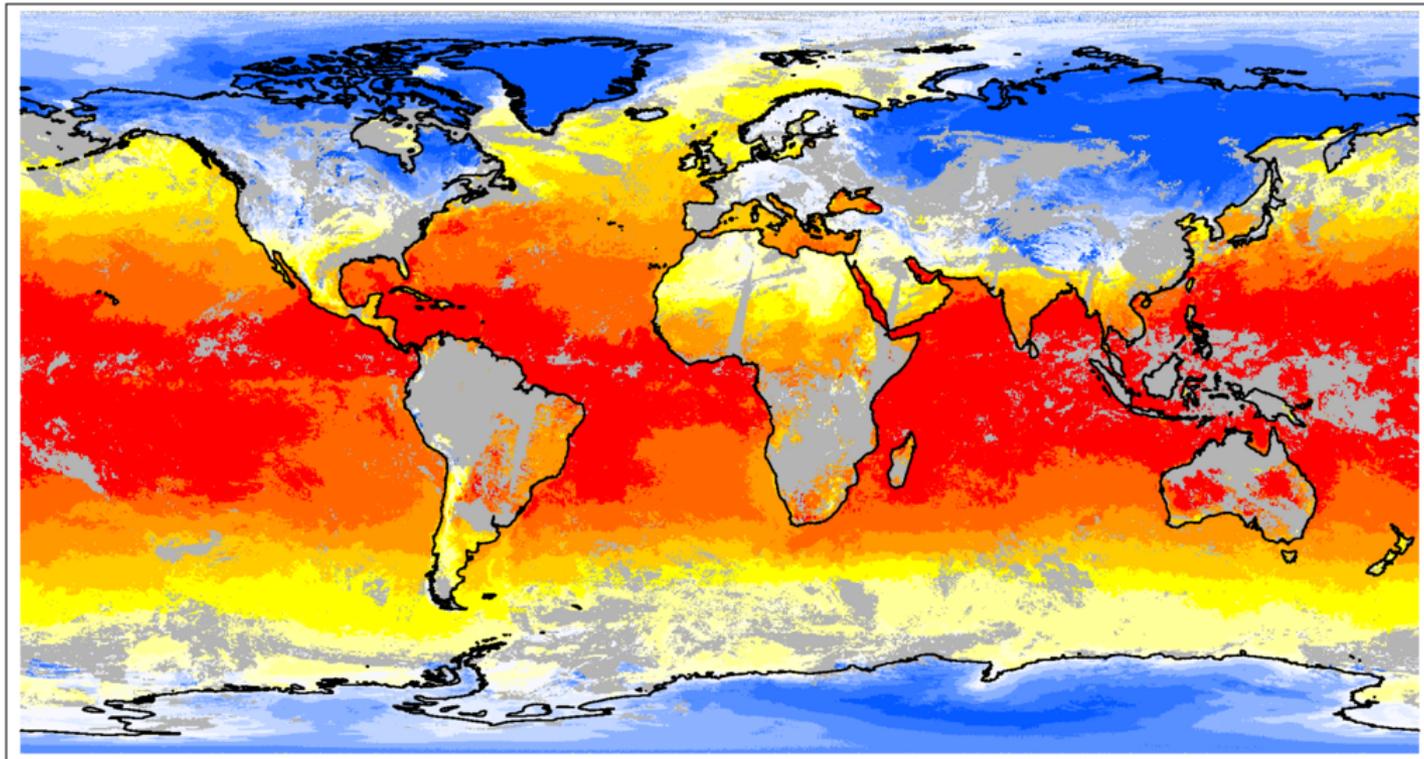


During the day, LST is much warmer than air temperature in clear skies (16:00-20:00 GMT), but the two are much closer under cloud (from 22:00 GMT)

Coverage and resolution

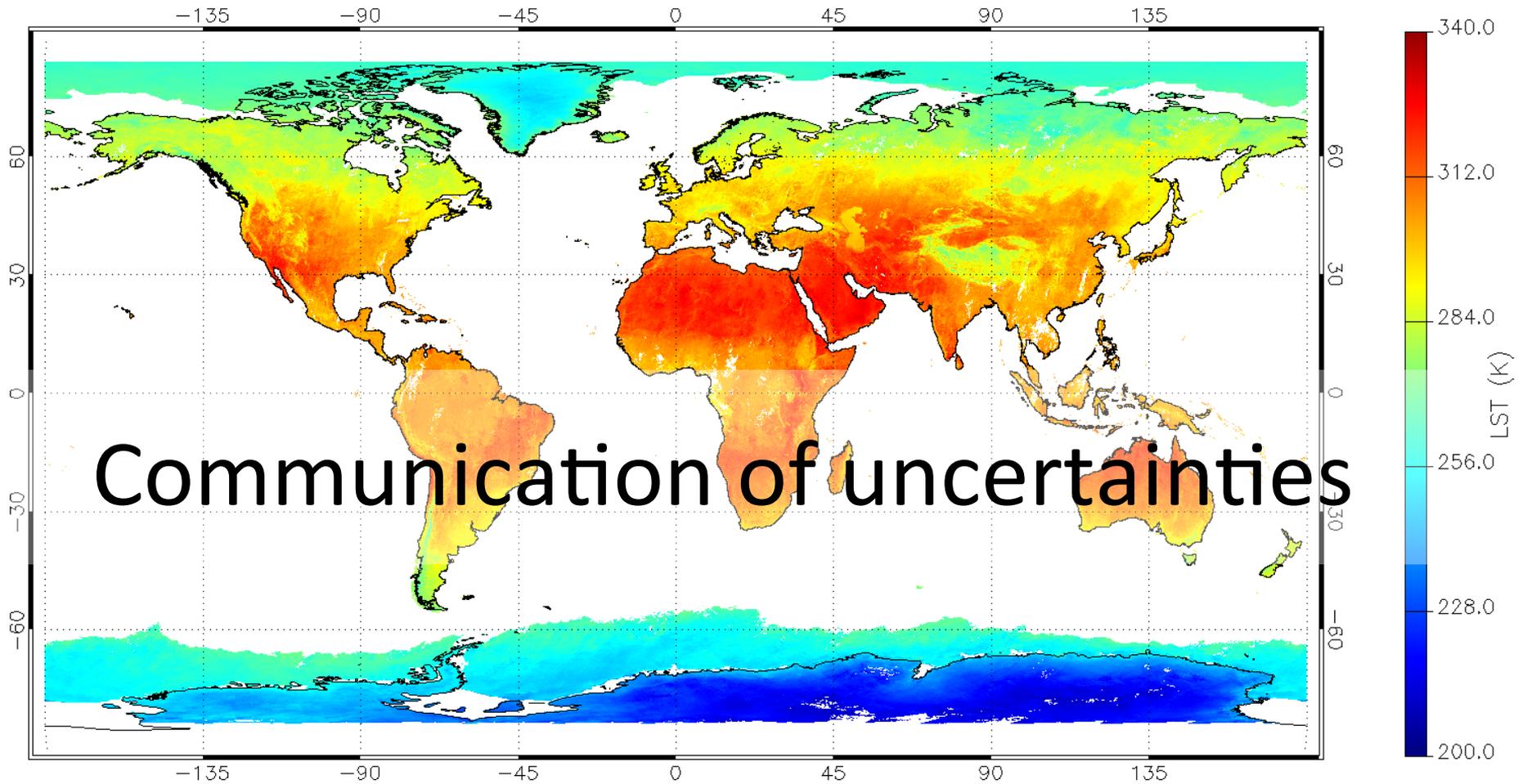
- General LST requirements: 1km or finer to 0.05°, at least day/night (GlobTemperature user requs.)
- EUSTACE user requirements: daily Tmax and Tmin; consistency with other surfaces

Consistency with other surfaces needed



Coverage and resolution

- General LST requirements: 1km or finer to 0.05°, at least day/night (GlobTemperature user requs.)
- EUSTACE user requirements: daily Tmax and Tmin; consistency with other surfaces
- Globtemperature looking at estimating clear sky bias from microwave, but won't cover merging
- Combination of sensors (AVHRR, ATSR, MODIS, VIIRS, geostationaries, microwave) needed to achieve what users need



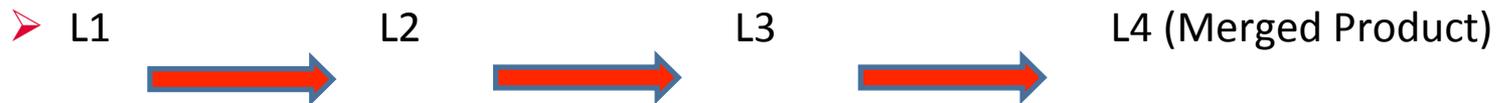
EUSTACE MODIS L2 UNCERTAINTIES

EUSTACE / GlobTemperature MODIS L2 Product

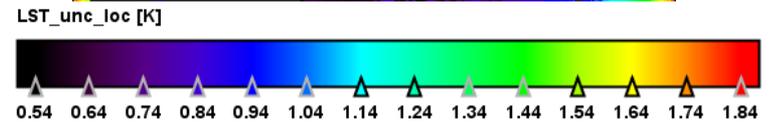
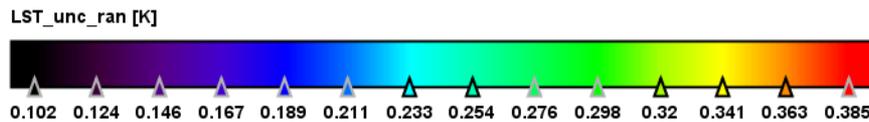
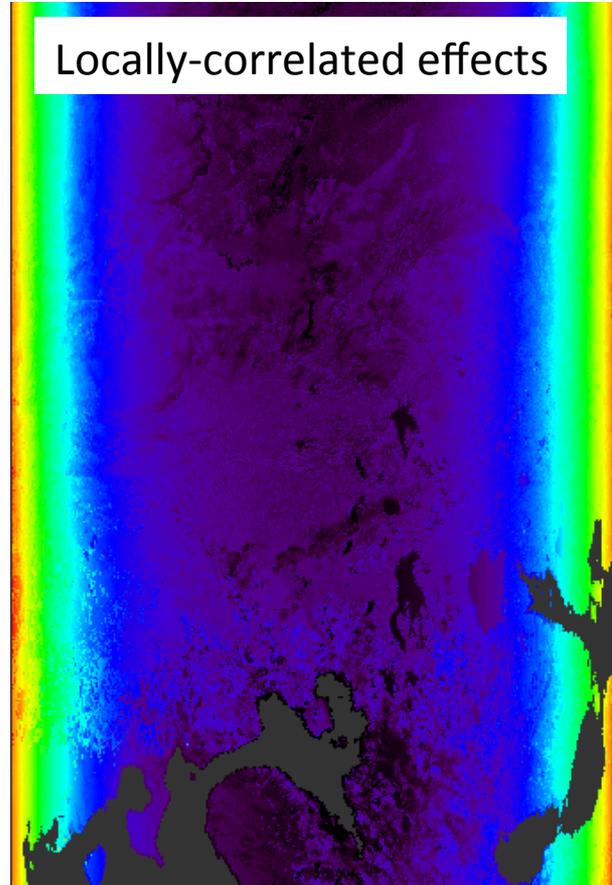
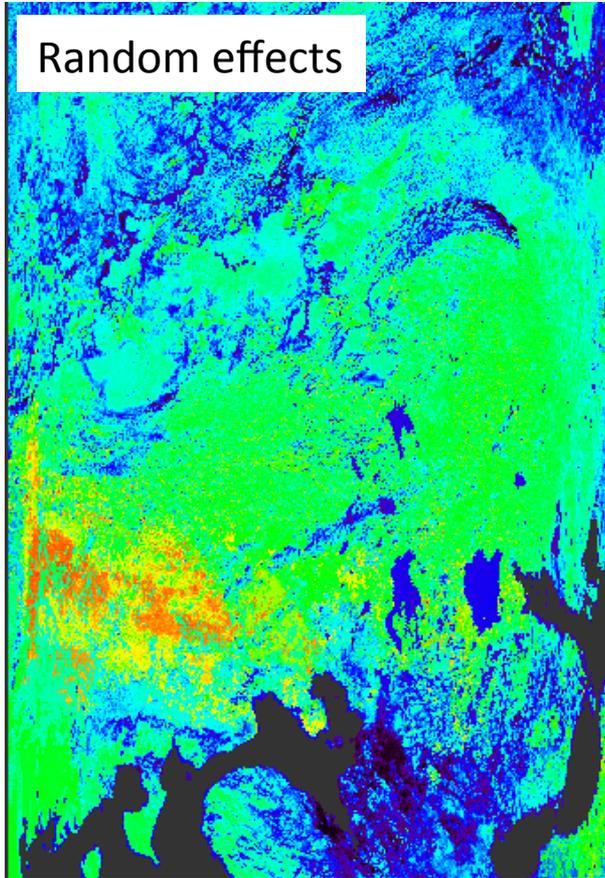
- Traceable globally-robust coefficients
- Uncertainty analysis from first principles

Uncertainties

- **Uncertainties categorised by effects whose errors have distinct correlation properties:**
 - Random, e.g. sensor noise, emissivity specification
 - Locally systematic, e.g. atmospheric state specification, other emissivity issues
 - (large-scale) Systematic, e.g. calibration corrections
- **This three-component model can be applied to all processing levels and LST products**
- **Propagation of uncertainties:**



EUSTACE MODIS L2 UNCERTAINTIES OVER WESTERN RUSSIA

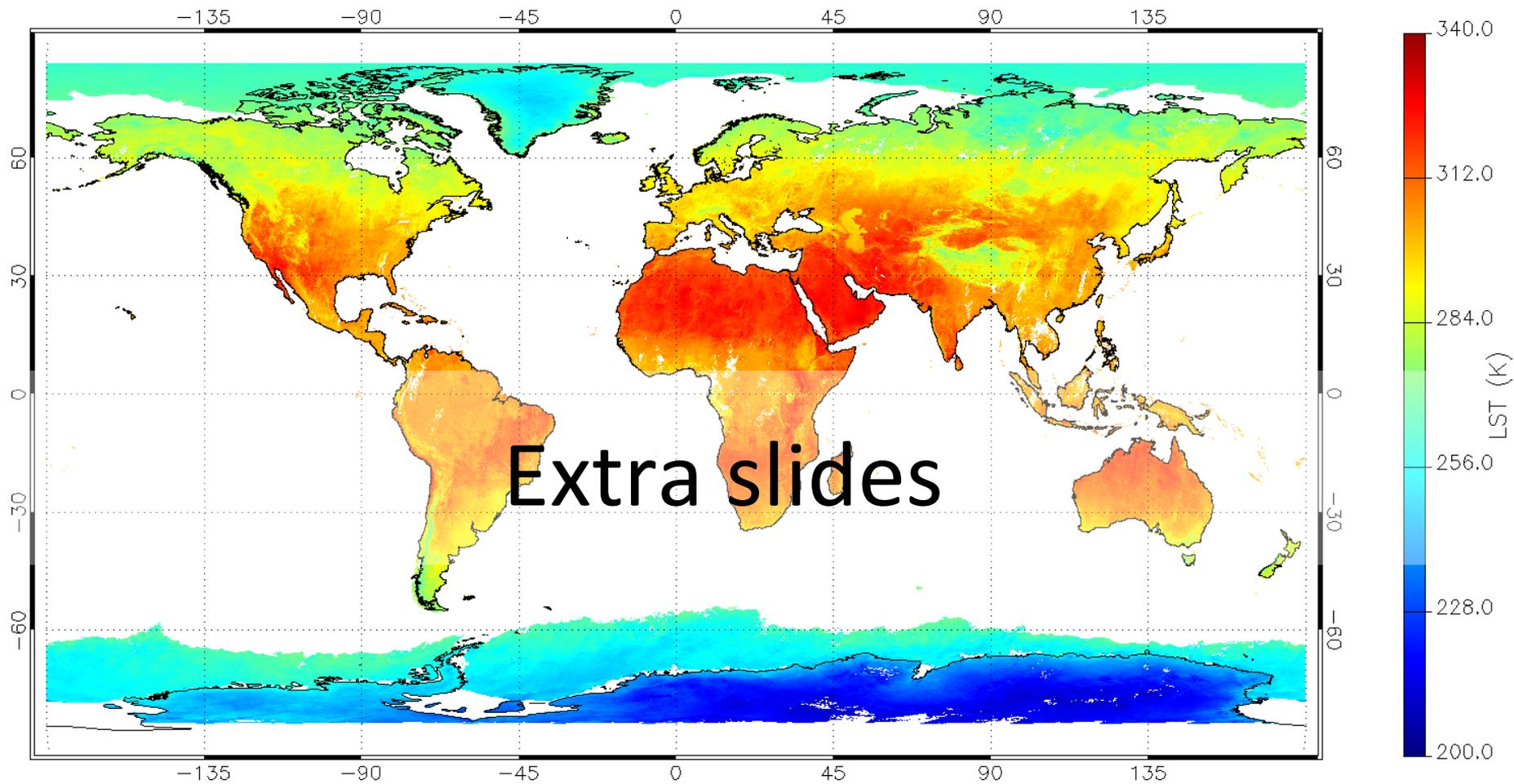


Other communication needs

- Guidance for users to enable them to use the data in their context, e.g. can you substitute LST anomaly for surface air temperature anomaly?
- Guidance on uncertainties
- Relationship to model skin temperatures

Summary

- LST is an important variable for many aspects of climate research and services on global and local scales
- In order to meet climate users' needs for long, homogeneous, sub-daily, $<0.05^\circ$ resolution information with split uncertainty components, a combination of all available sensor types is needed



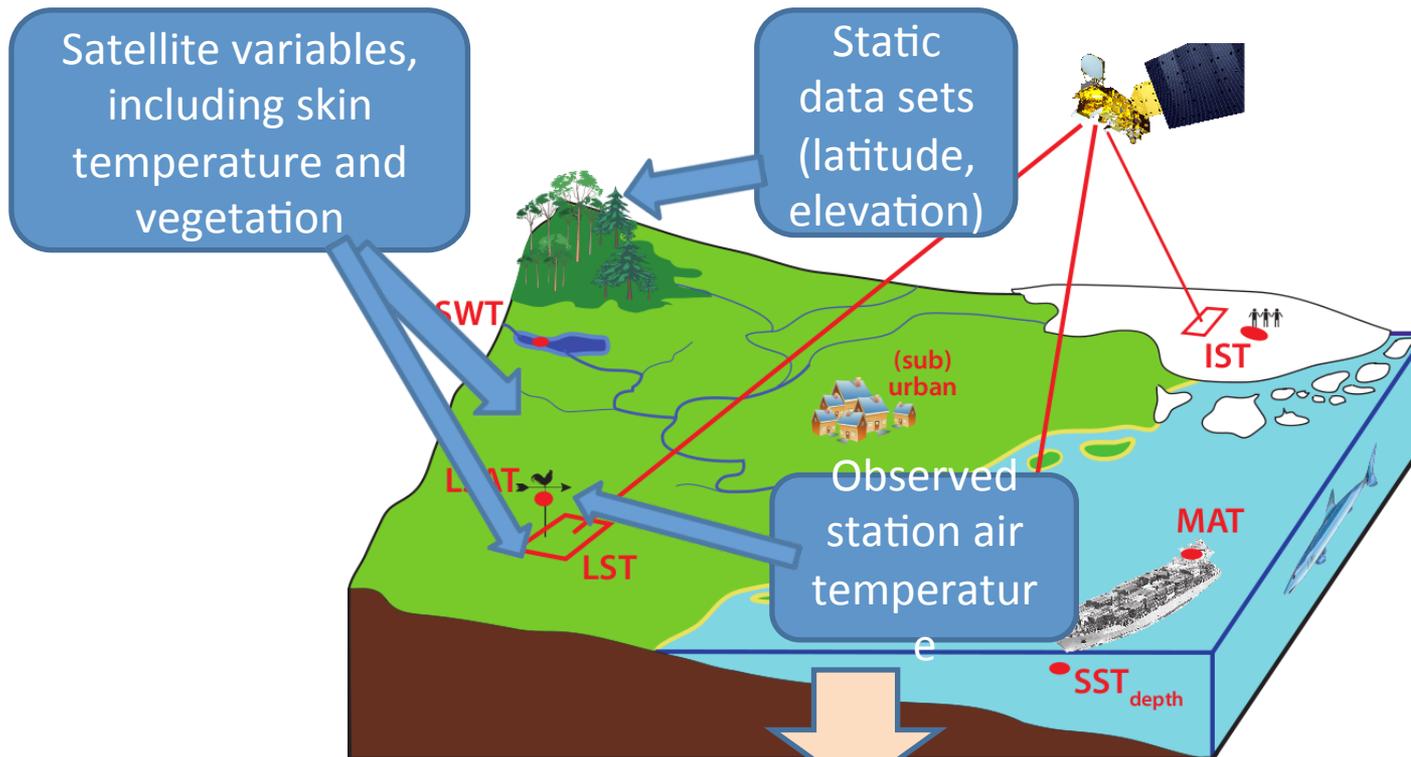
EUSTACE AIMS

EUSTACE will give publicly available daily estimates of surface air temperature since 1850 across the globe for the first time by combining surface and satellite data using novel statistical techniques. To do this, we need to:

- Identify non-climatic discontinuities in daily weather station data, *so users can trust the changes our records show*
- Produce consistent uncertainty estimates for satellite skin temperature retrievals over all surfaces (land, ocean, ice and lakes), *so we know how far to trust the estimates everywhere*
- Understand how surface temperature measured *in situ* and by satellite relates, *to estimate air from skin temperature*
- Estimate values in areas where we have no *in situ* or satellite data, *so users can have daily information here*



ESTIMATING AIR TEMPERATURE FROM SKIN TEMPERATURE



Regression model (per day for specific region)

Air temperature estimated for every cloud-free satellite pixel