THE EUSTACE PROJECT: DELIVERING GLOBAL, DAILY INFORMATION ON SURFACE AIR TEMPERATURE

LIZZIE GOOD

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EUSTACE has received funding from the European Union's Horizon 2020 Programme for Research and Innovation, under Grant Agreement no 640171

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*

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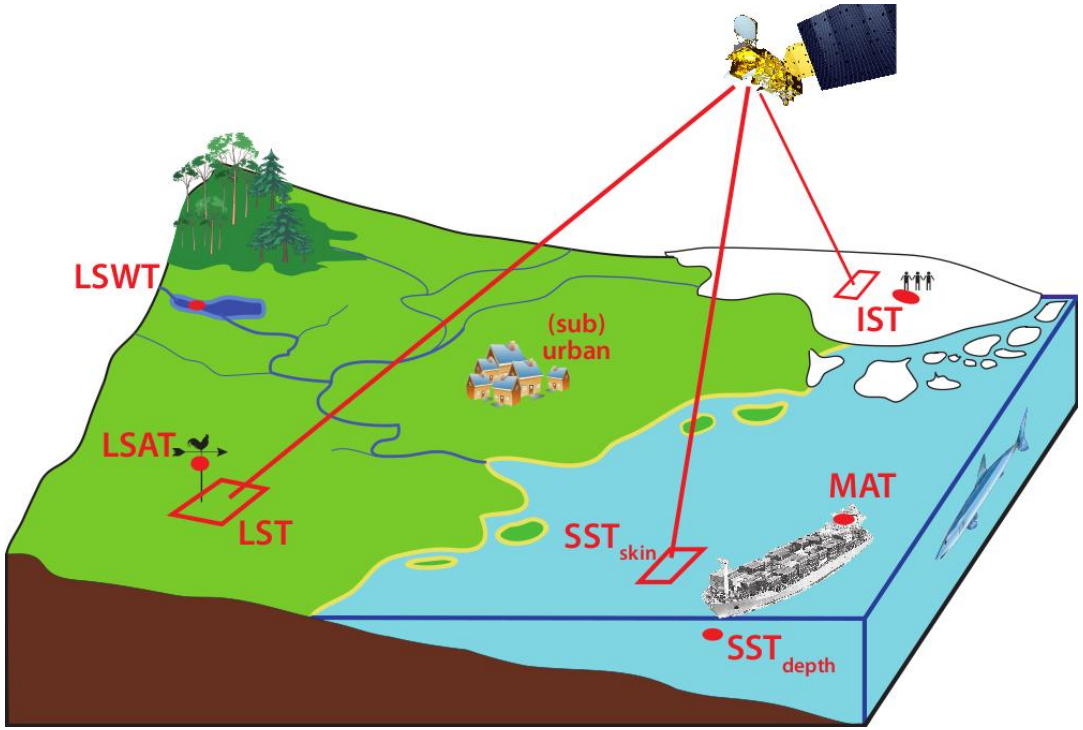
UNDERSTAND RELATIONSHIP BETWEEN AIR AND SKIN TEMPERATURE



From Merchant et al., 2013 community paper and roadmap:
http://www.geosci-instrum-method-data-syst.net/2/305/2013/gi-2-305-2013.html

EarthTemp Network

NERC SCIENCE OF THE ENVIRONMENT

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ESTIMATING AIR TEMPERATURE FROM SKIN TEMPERATURE

Publicly available weather station records

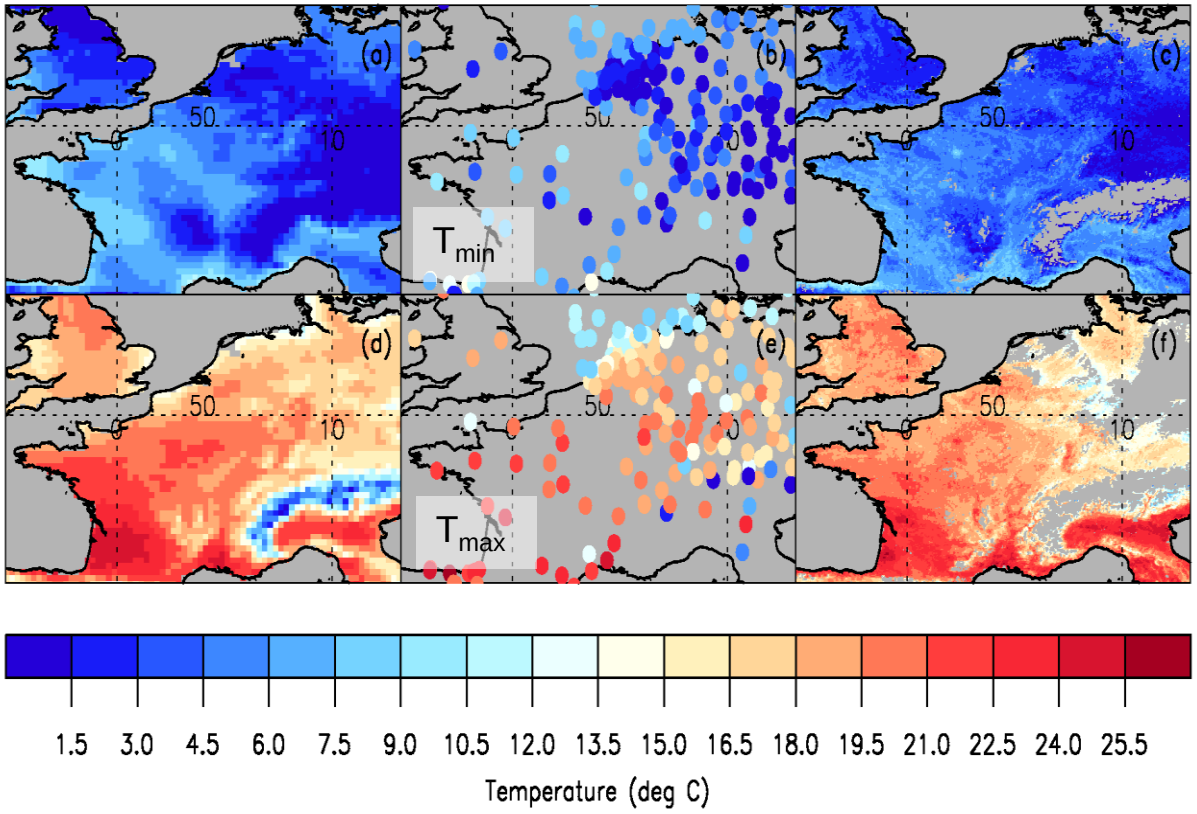
Highest available resolution in-filled air temperature analysis from weather station measurements

EOBS

ECA&D

Satellite LSAT

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



27 March 2012

Met Office Hadley Centre

Good, JGR-Atm, 2015, https://doi.org/10.1002/2014JD022438

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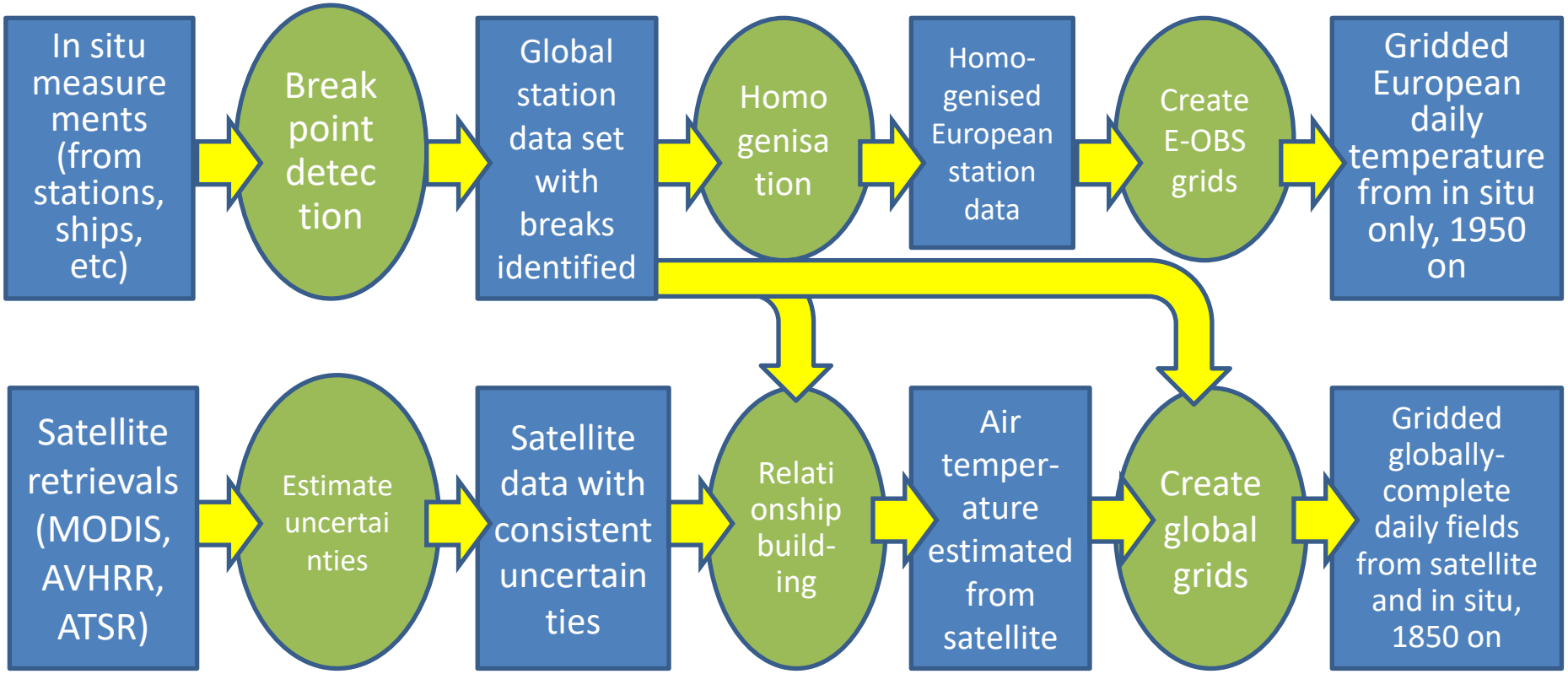
EUSTACE SCHEMATIC



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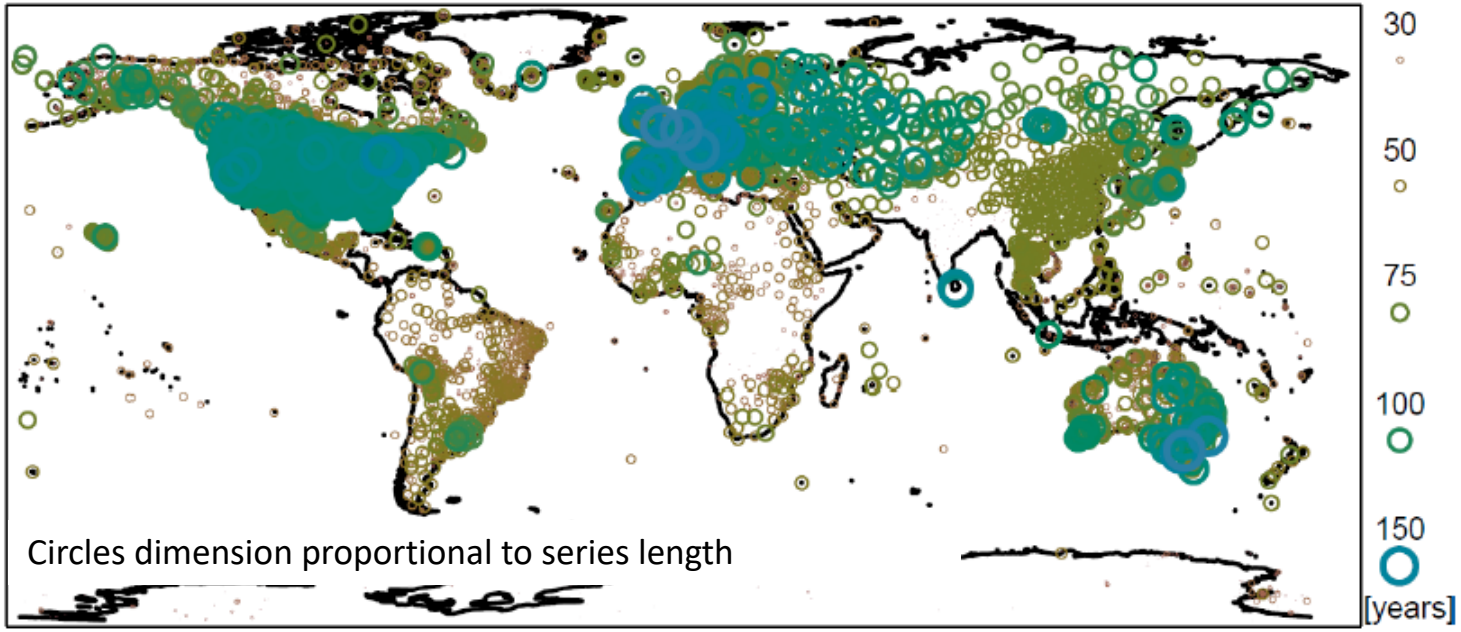
EUSTACE DAILY STATION DATASET



Three different algorithms applied to annual and semi-annual averages of differences between candidate and reference series

+

Absolute test when reference stations not available or insufficient

applied to

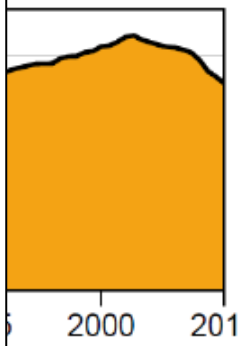
T_{max}

T_{min}

$T_{avg} = (T_{max} + T_{min}) / 2$

$DTR = T_{max} - T_{min}$

Gives a 48-member break point detection ensemble.



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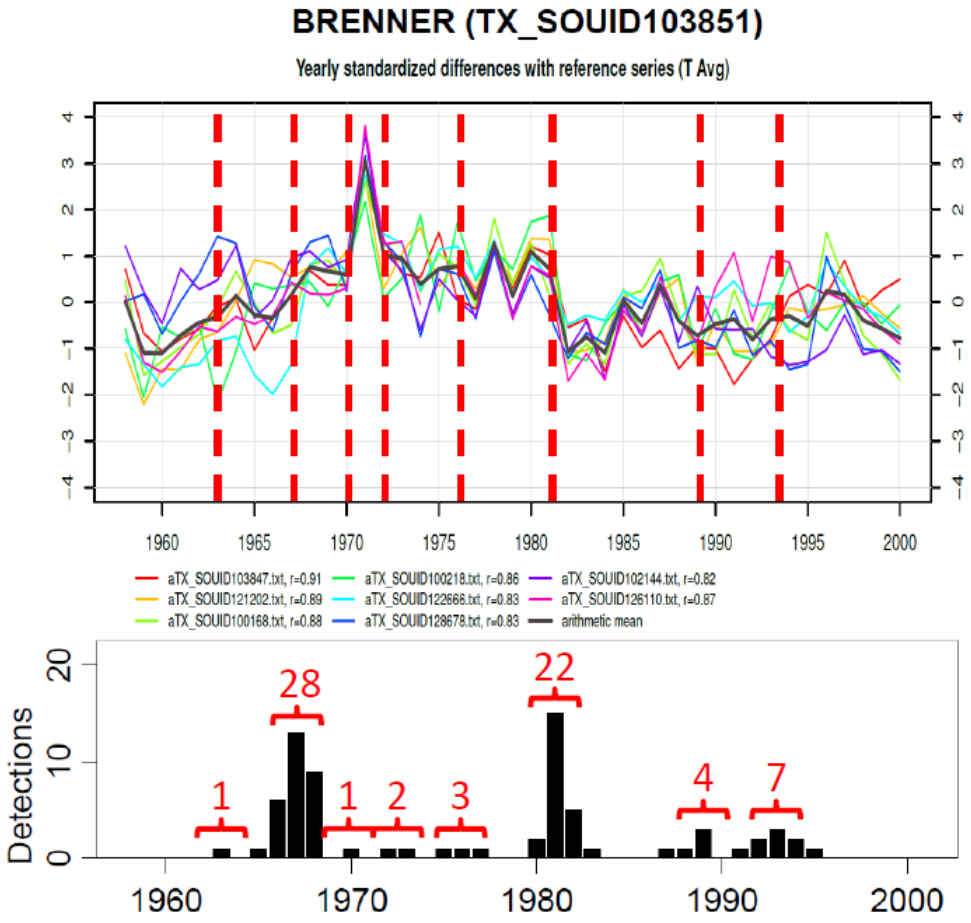
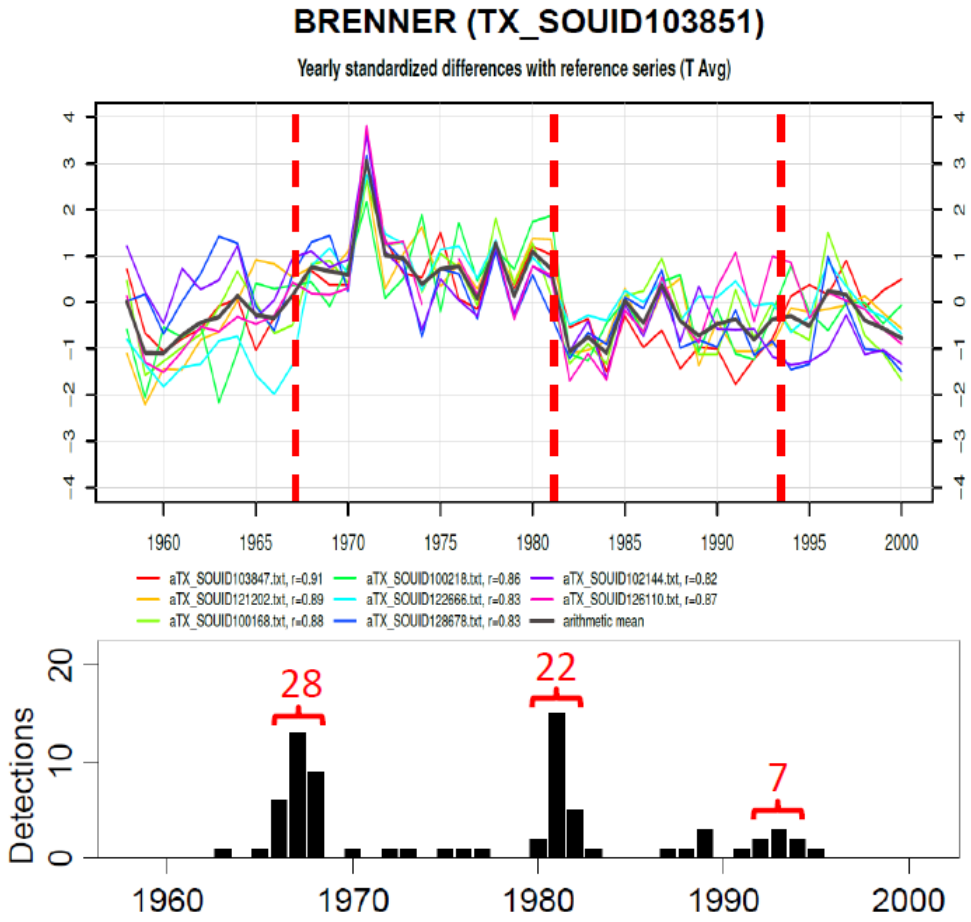
EXAMPLE BREAKPOINT DETECTION



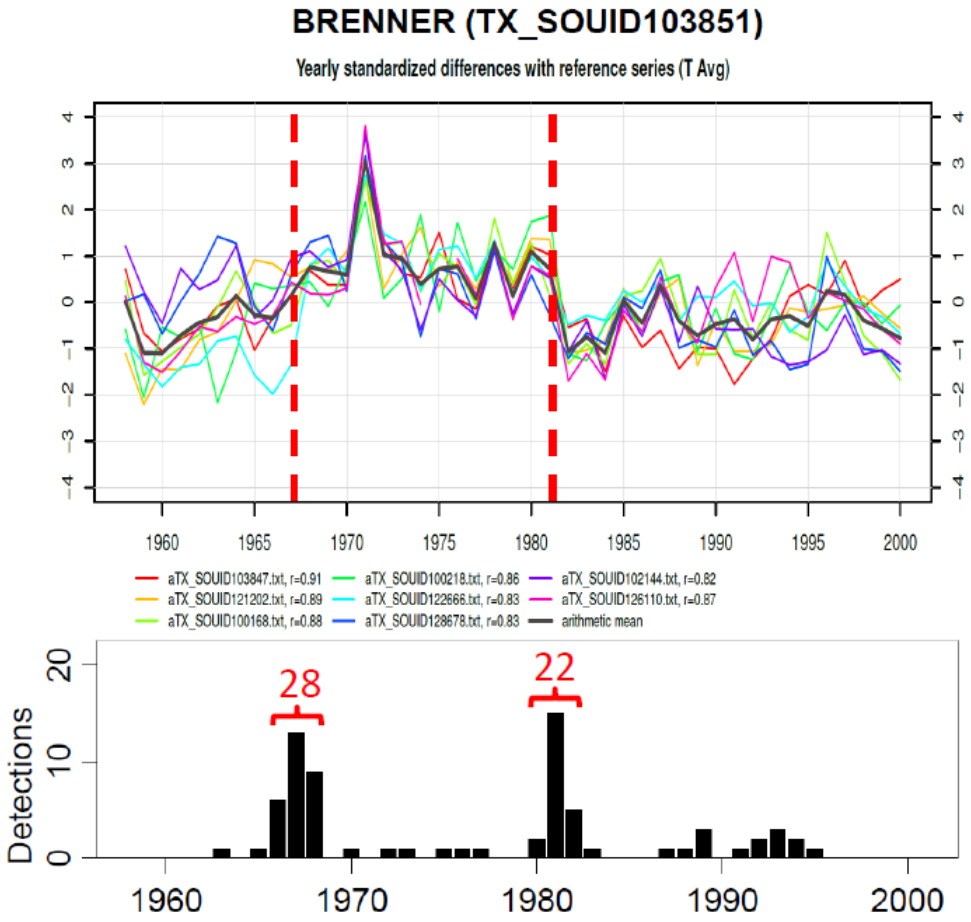
Likelihood index is created from the ensemble for each detected break

EXAMPLE BREAKPOINT DETECTION



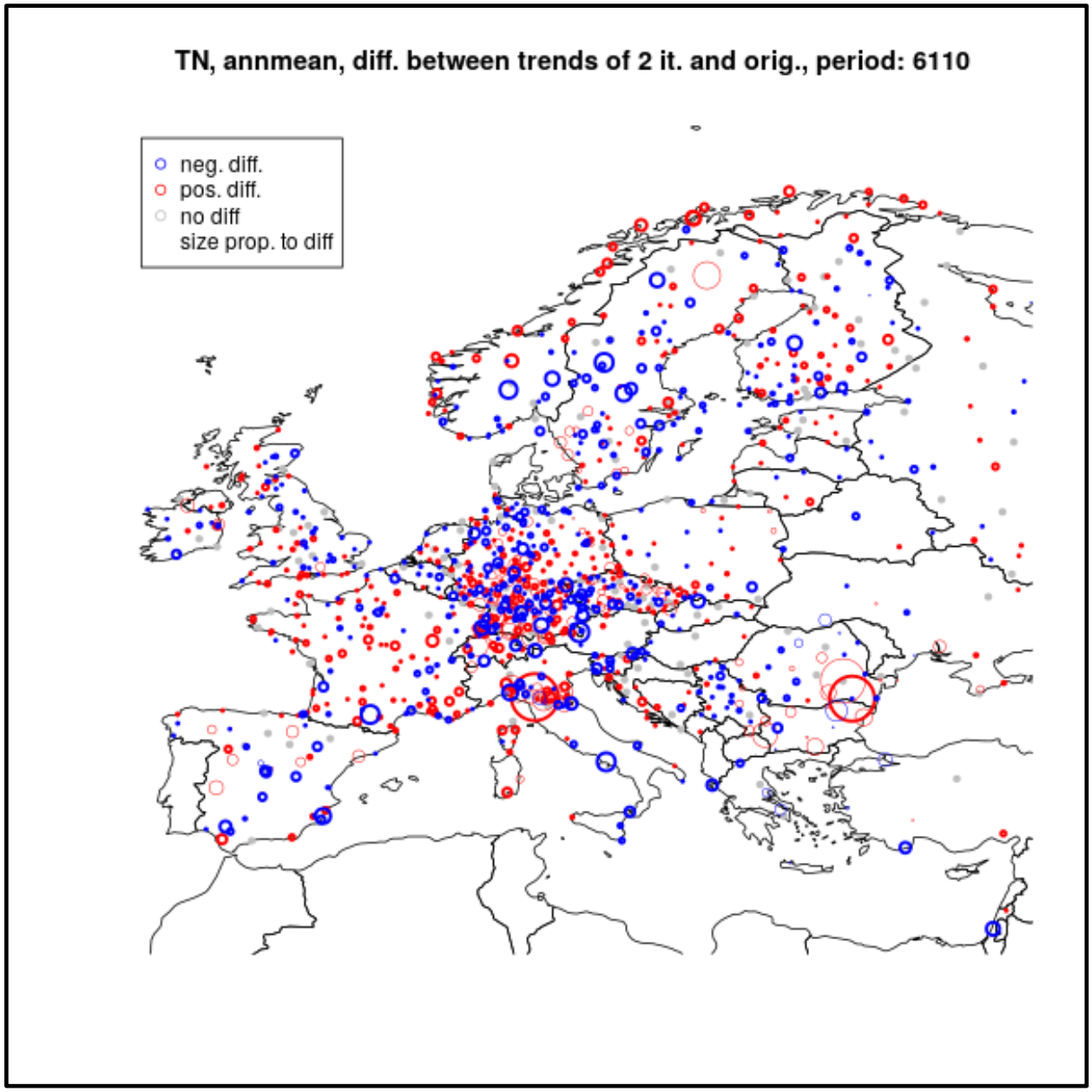
Likelihood threshold ≥ 5

EXAMPLE BREAKPOINT DETECTION



Likelihood threshold ≥ 10

DIFFERENCE IN TRENDS



Difference signs in the adjustments. Adjustments can increase or reduce trends. Stations that showed negative trends now show positive trends in most cases

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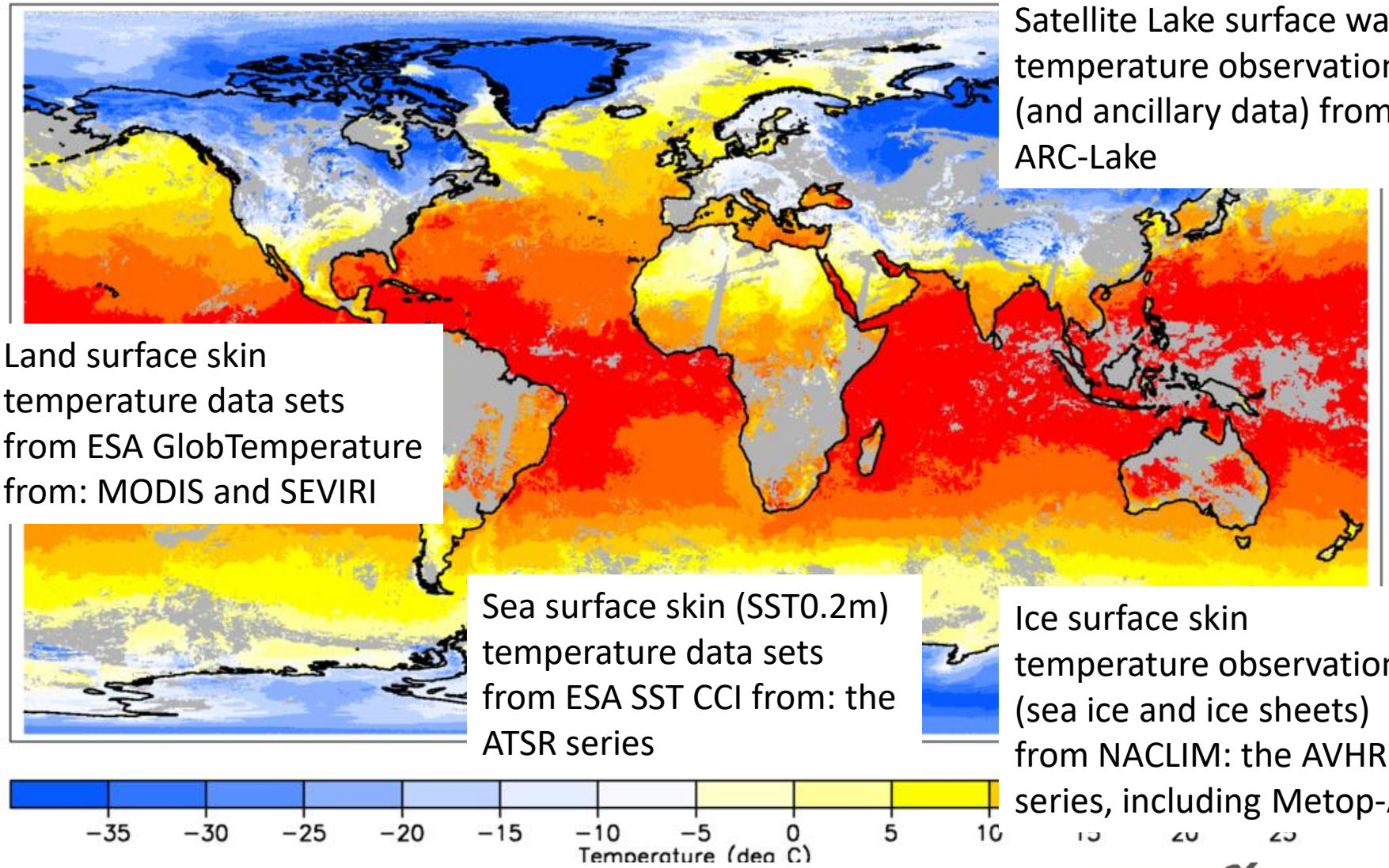
EUSTACE SATELLITE OBSERVATIONS



Satellite Lake surface water temperature observations (and ancillary data) from ARC-Lake

Land surface skin temperature data sets from ESA GlobTemperature from: MODIS and SEVIRI

Sea surface skin (SST0.2m) temperature data sets from ESA SST CCI from: the ATSR series

Ice surface skin temperature observations (sea ice and ice sheets) from NACLIM: the AVHRR series, including Metop-A

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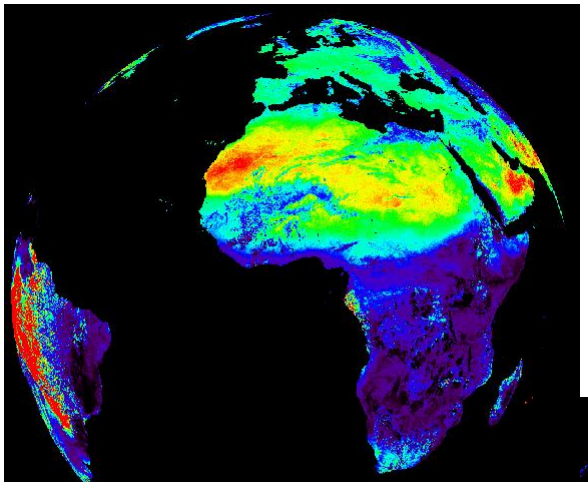
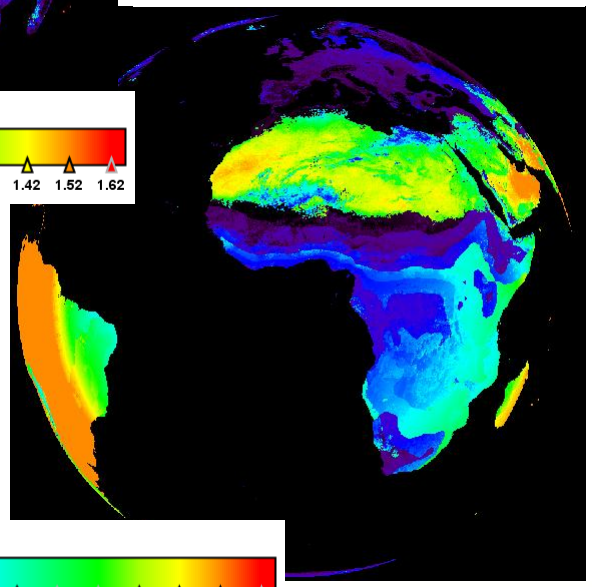
ESTIMATING CONSISTENT UNCERTAINTIES IN SATELLITE RETRIEVALS

- Uncertainties categorised by effects whose errors have distinct correlation properties:
  - ➢ random
  - ➢ locally correlated
  - ➢ (large-scale) correlated

Random



Locally correlated



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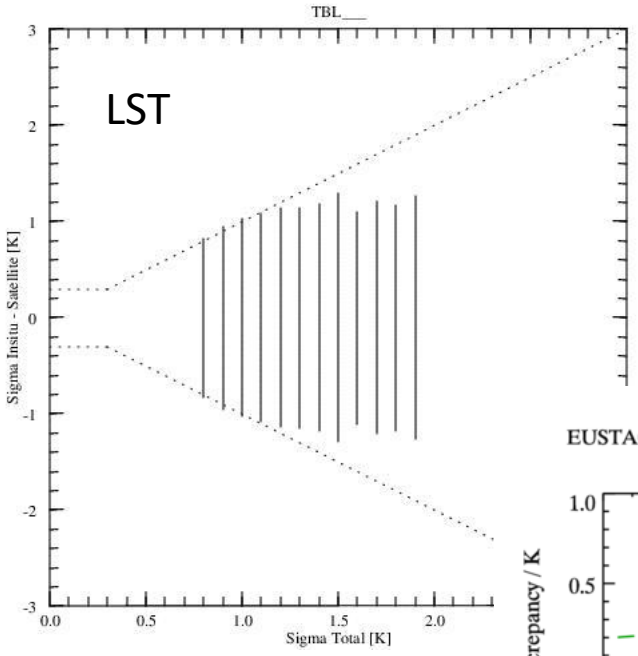
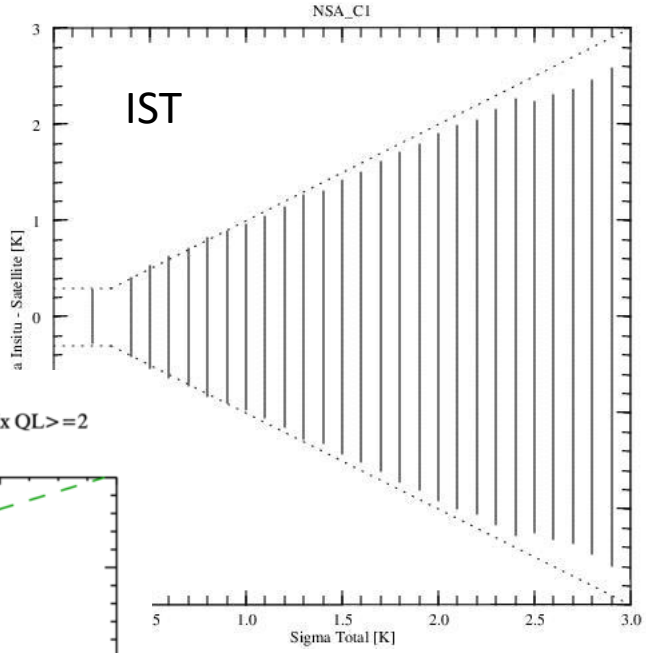
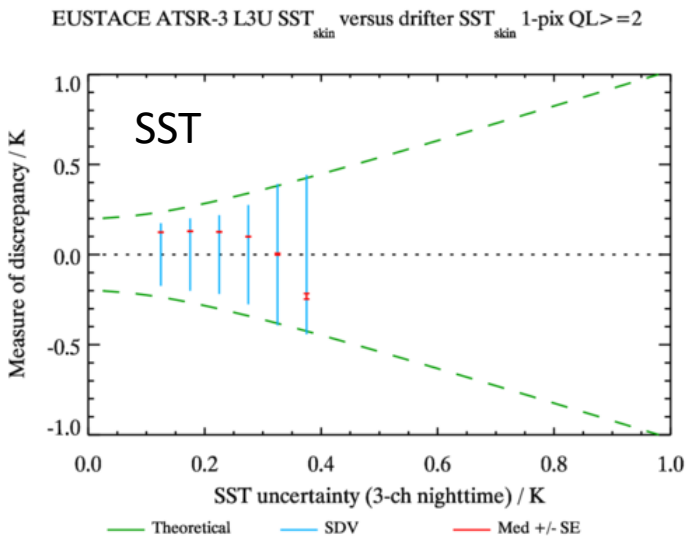
VALIDATION OF LST, IST AND SST UNCERTAINTIES AT REFERENCE STATIONS







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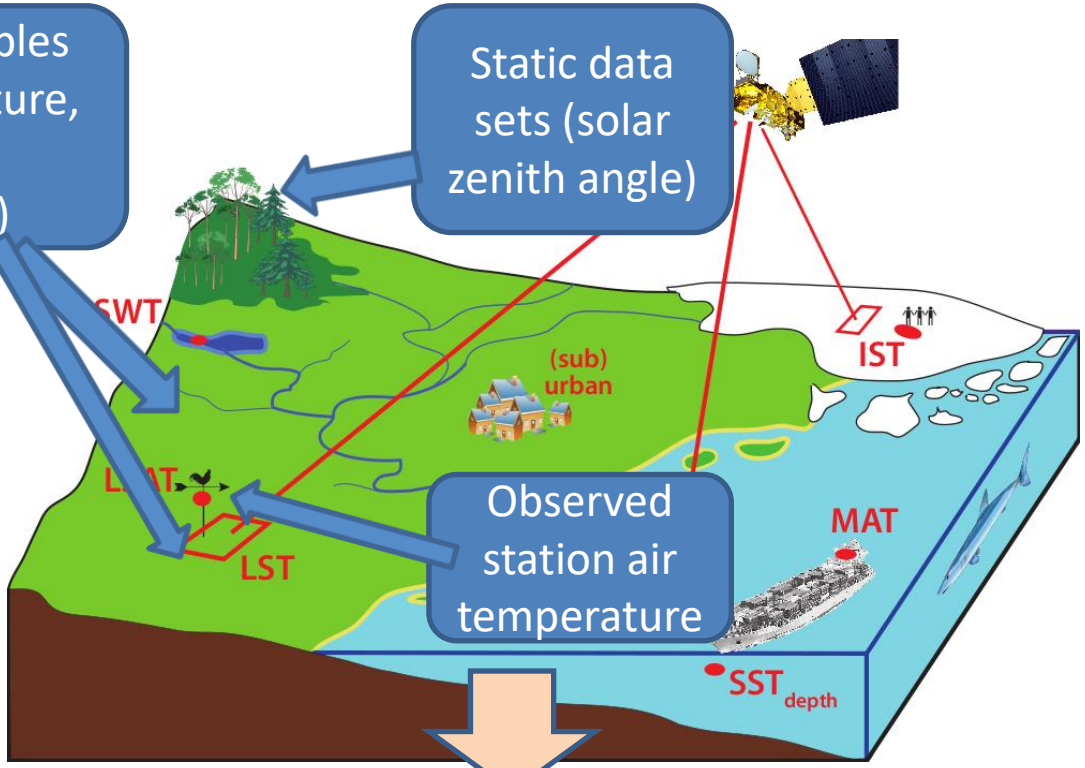
ESTIMATING AIR TEMPERATURE FROM SKIN TEMPERATURE



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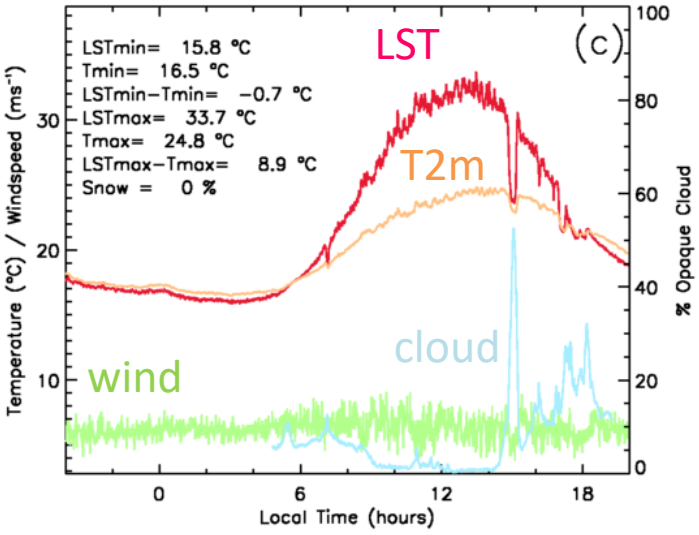
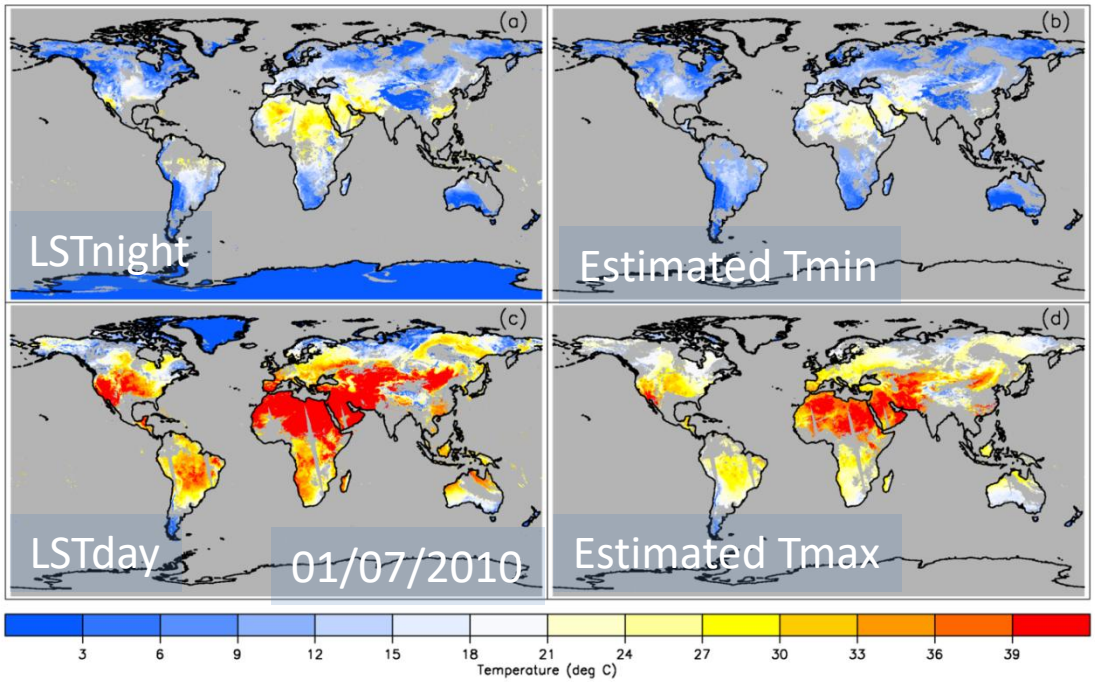
LST/TMAX/TMIN RELATIONSHIPS

Cape Cod, Massachusetts , 21/06/2013

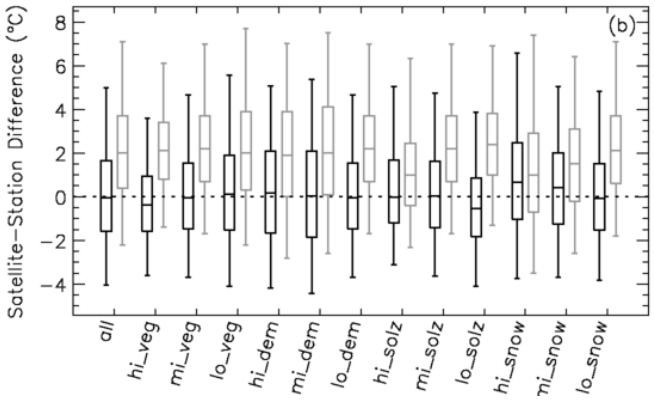


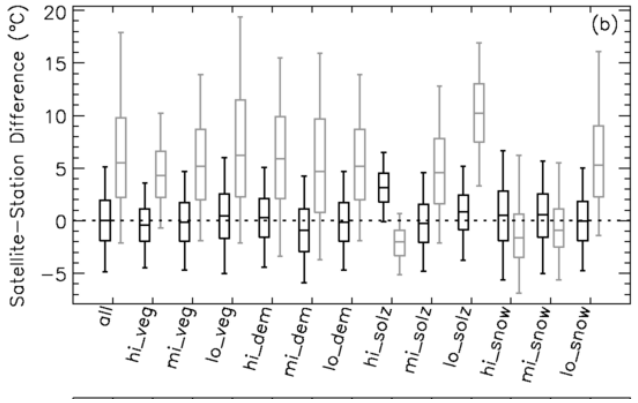


$$T_{max}=\alpha_0+\alpha_1.LST_{day}+\alpha_2.LST_{ngt}+\alpha_3.FVC+\alpha_4.SZA_{noon}+\alpha_5.Snow+\varepsilon_{Tmax}$$

$$T_{min}=\beta_0+\beta_1.LST_{day}+\beta_2.LST_{ngt}+\beta_3.FVC+\beta_4.SZA_{noon}+\beta_5.Snow+\varepsilon_{Tmin}$$

Estimated Tmin vs independent stations





Estimated Tmax vs independent stations

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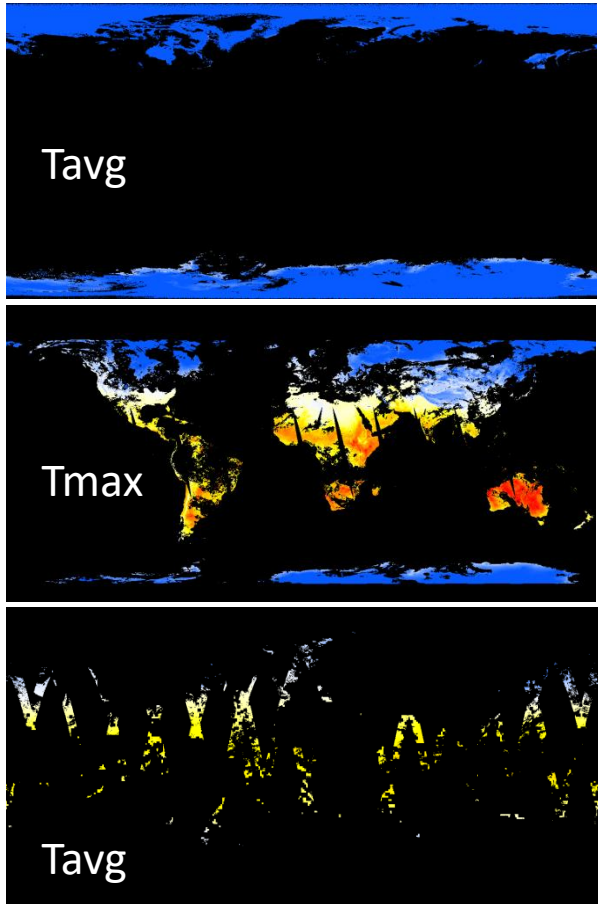
CONSISTENT AIR TEMPERATURE ESTIMATED FROM SATELLITE DATA

- A main surface air temperature file per day per surface type (land, ocean, ice)
- The main files contain total uncertainty budget per grid box and so uncertainty is consistently expressed for all surface types
- There is an ancillary file per day per surface type which contains more detailed uncertainty information. These depend on surface type as uncertainty models differ.
- Link to YouTube video



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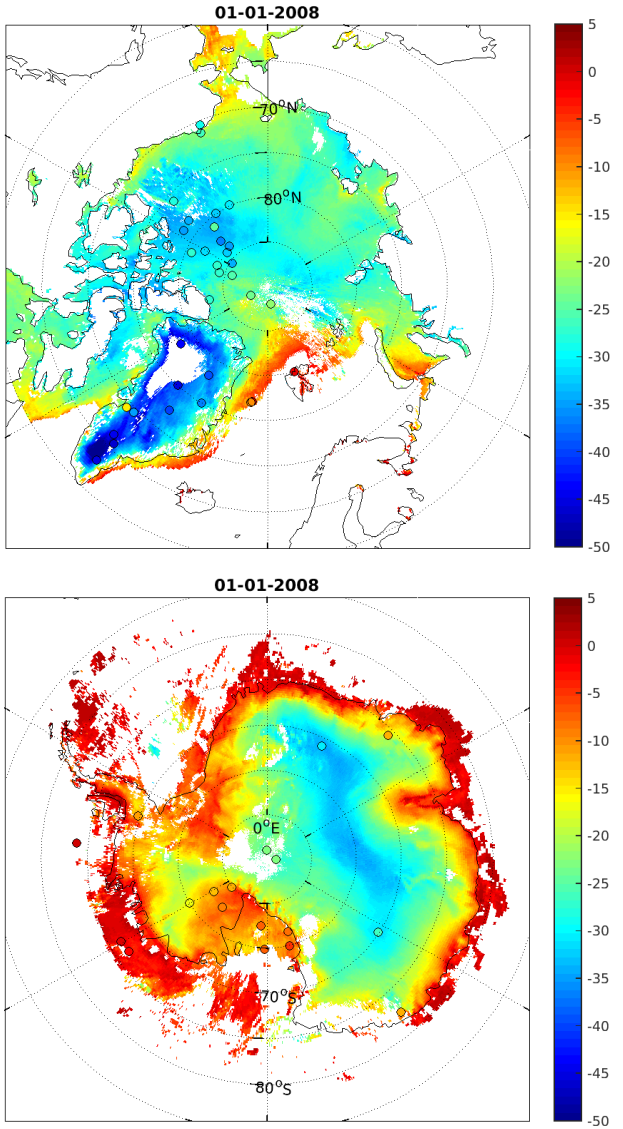
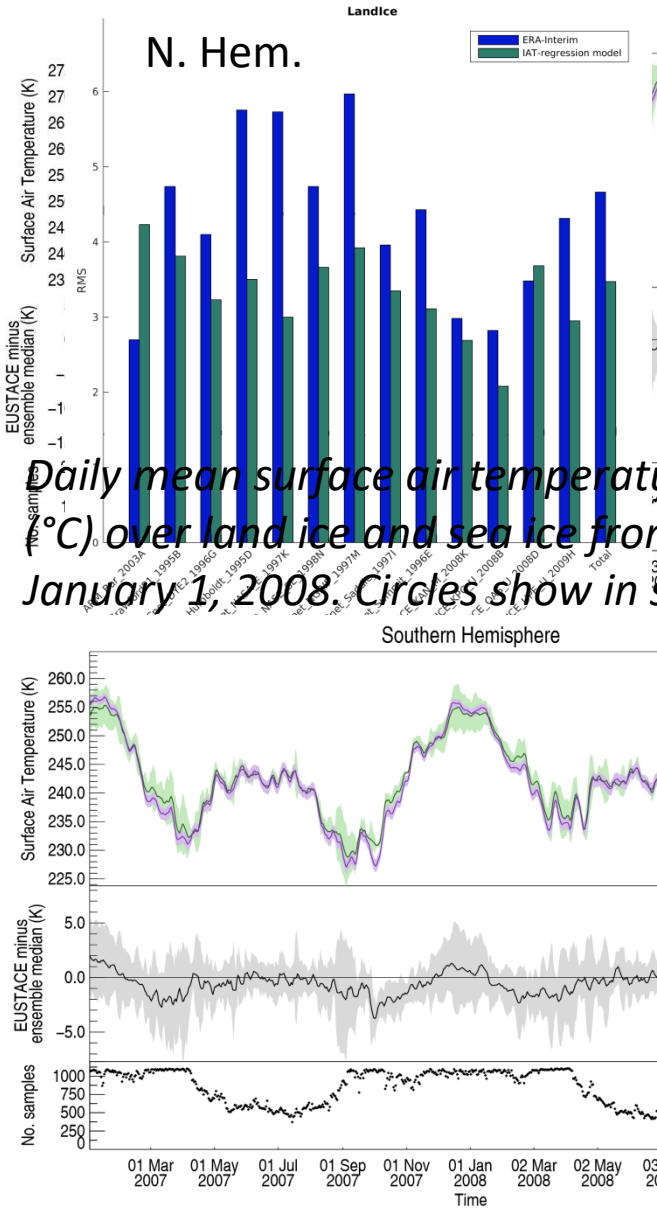
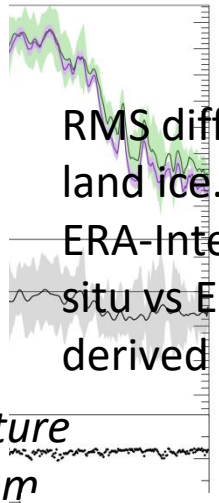
VALIDATION & INTERCOMPARISON



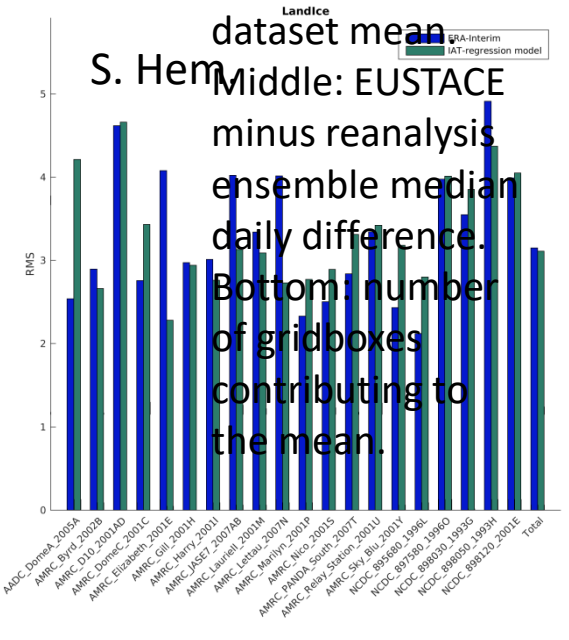
Daily mean surface air temperature (°C) over land ice and sea ice from January 1, 2008. Circles show in s





RMS differences (°C) over land ice. Blue: in situ vs ERA-Interim. Green: in situ vs EUSTACE satellite-derived air temperature.

Mean daily air temperature over Greenland and Antarctica, 2007-2008. Top: ensemble median (green line) and EUSTACE test dataset mean. Middle: EUSTACE minus reanalysis ensemble median daily difference. Bottom: number of gridboxes contributing to the mean.



INFILLED ANALYSIS: AIMS

The desirable properties for analysis depend on the application, and sometimes there is a trade-off between different properties. Some desirable properties we may consider are:

- The mathematical model for the temperature field should be easy to communicate
- The statistical assumptions about the temperature field in the model should be consistent with our knowledge of the physics of the situation
- Data output should be in a form that is easy to use even for those without expertise in spatial statistical methods
- Data output should be in a form that makes it easy to retrieve uncertainty information
- Results for temperature field should have low cross-validation error
- Results for uncertainties should also validate well
- Where uncertainties are difficult to determine, they should overestimate the uncertainty
- Data output formats should work well with commonly available software tools
- It should be possible to see from data output where/when temperature estimates are not well constrained by the model

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HOW WE MODEL TEMPERATURES IN EUSTACE

MEASUREMENT = TEMPERATURE + BIAS + ERROR

TEMPERATURE = CLIMATOLOGY + LARGE SCALE + LOCAL

BIAS = SYSTEMATIC RETRIEVAL ERROR + SEASONAL SKIN-to-AIR OFFSET

ERROR = SENSOR NOISE + WEATHER DEPENDENT EFFECTS

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TWO STRANDS OF DEVELOPMENT OF STATISTICAL INTERPOLATION

AMBITIOUS

- Novel statistical methods created specifically for EUSTACE
- State of the art
- Idea is to use CEMS computing facility to the full
- Challenging for implementation

ADVANCED STANDARD

- Extend current methods to proposed EUSTACE resolution and data volumes
- Low risk
- Designed to be extended to greater complexity
- Sharing techniques with the ambitious method for efficient processing.

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EUSTACE PRODUCTS

Product	Description	Date
Station series and E-OBS update	Global data set of daily weather station air temperature measurements (Tmax and Tmin) with non-climatic breaks identified – Station time series and gridded for Europe	Completed 2017
Satellite skin temperature retrievals	Daily satellite skin temperature estimates for all surfaces of Earth with consistent uncertainty estimates – Gridded or along satellite's track	Release 2018
Skin/air temperature relationships	Understanding of the relationship between surface skin and surface air temperature over all surfaces of Earth and in different seasons – A report on EUSTACE website	Publish 2018
Air temperature estimates from satellites	Gridded daily estimates of surface air temperature from skin temperature retrievals	Complete 2018
Globally complete air temperature fields	Globally-complete daily fields of surface air temperature over all corners of Earth since 1850 – Gridded (0.25° lat/lon) perhaps an ensemble. (Tmax and Tmin over land, Tmean elsewhere.)	Release 2019
Derived products	For example, global means and climatologies	Release 2019

SUMMARY/FURTHER INFO

- EUSTACE is producing global, daily information on surface air temperature by combining measurements made in situ with satellite retrievals
- Non-climatic breaks in global station data have been identified and removed from European station data
- Consistent estimates of uncertainty have been estimated for skin temperature retrievals
- Relationships between skin and air temperature have been used to estimate air temperature from satellite retrievals
- Statistical interpolation methods are being developed
- For further information about EUSTACE, visit https://www.eustaceproject.eu/

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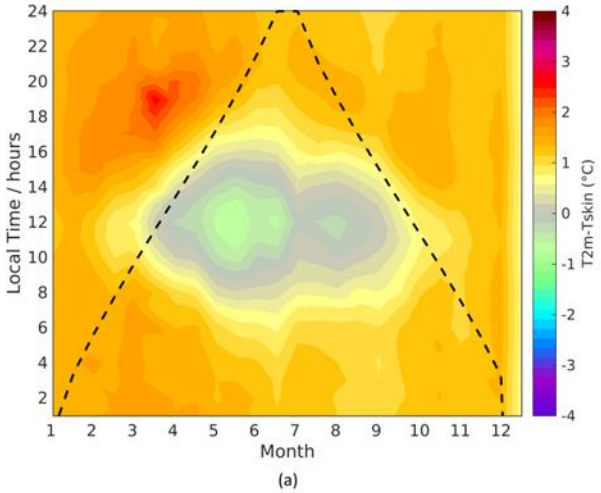
QUESTIONS

EUSTACE has received funding from the European Union's Horizon 2020 Programme for Research and Innovation, under Grant Agreement no 640171

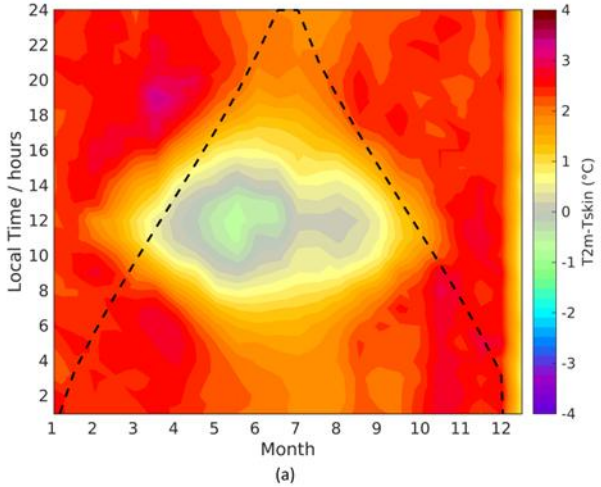
IMPACTS OF CLOUDS

- **Difference between Skin Temperature and T2m**
- **PROMICE - KAN U**
- **Smallest difference during afternoon**
- **Largest differences in clear sky conditions**
- **Seasonal changes**

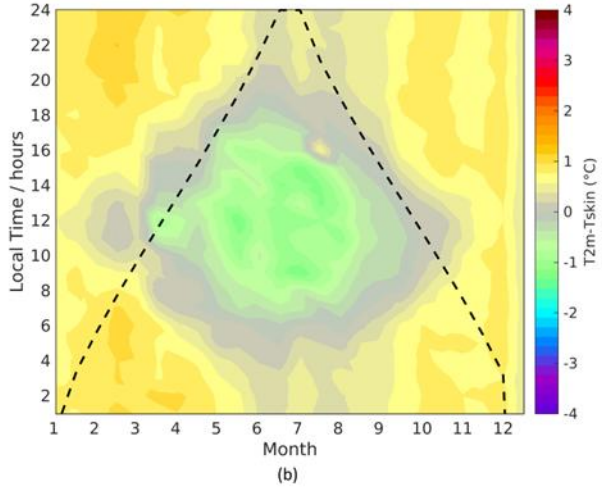
All sky



Clear sky



Overcast



T2m – Tskin (°C)

DMI
Danish Meteorological Institute

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ADVANCED STANDARD

Performing the analysis

WE NEED A STARTING POINT

A

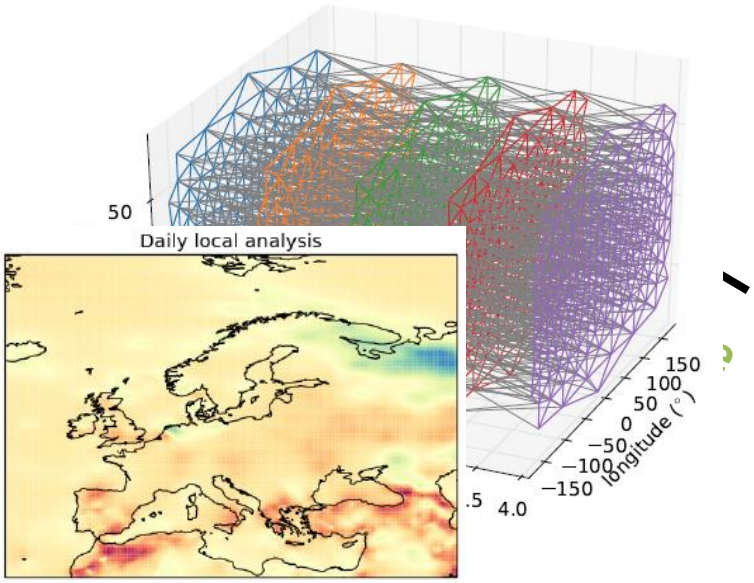
Process observations

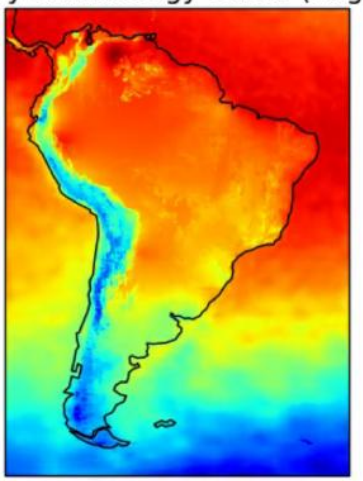
Solve climatology

B

Process observations conditioned on A

Solve large scale





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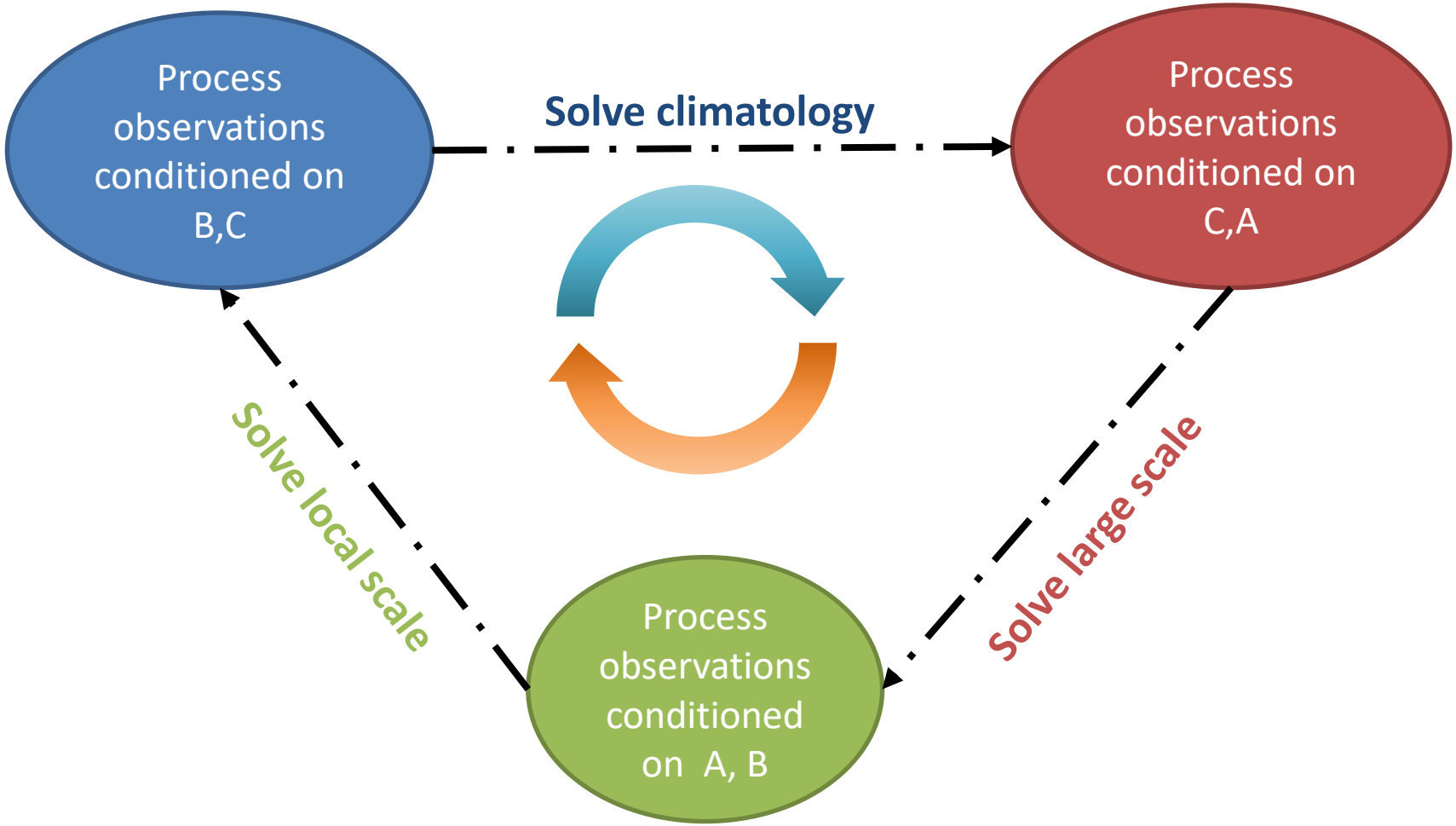
ADVANCED STANDARD

Performing the analysis



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