EU SURFACE TEMPERATURE FOR ALL CORNERS OF EARTH (EUSTACE)

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Data Requirements to Address the WCRP Grand Challenge on Weather and Climate Extremes
Sydney, Australia, 25-27 February 2015

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

CONTENTS

- Identified needs
- Aims of EUSTACE
- Homogenisation of daily/sub-daily station data
- Estimation of uncertainties for satellite data
- Estimating air temperature from skin temperature retrievals
- Creating complete, gridded fields

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WCRP GC EXTREMES OBSERVATIONAL NEEDS

"The current suite of climate extremes data sets is inadequate to properly assess climate variability and change and to provide the required underpinning for detection and attribution studies and model evaluation."

Amongst other things we need to:

- Estimate uncertainties in variable estimates from satellite retrievals

- Identify regions and time periods where we can fill in gaps and assess uncertainties

- Instigate efforts to undertake new and novel QC/homogenisation algorithms and benchmark their performance at daily and sub-daily time scales

- Address the mismatch in spatial scales between simulated and observed data to enable a like-for-like comparison

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EUSTACE AIMS

EUSTACE will create validated daily information on surface air temperature and its uncertainties since 1850 over all surfaces of Earth, for use in diverse applications, by combining information from direct measurements with estimates derived from satellite skin retrievals using novel statistical techniques.

To do this, we need to:

- Homogenise/identify inhomogeneities in daily station data
- Produce consistent uncertainty estimates for skin temperature retrievals over all surfaces (land, ocean, ice and lakes)
- Understand how surface temperature measured *in situ* and by satellites relates
- Estimate values in areas where we have no *in situ* or satellite data

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HOMOGENISATION OF DAILY DATA

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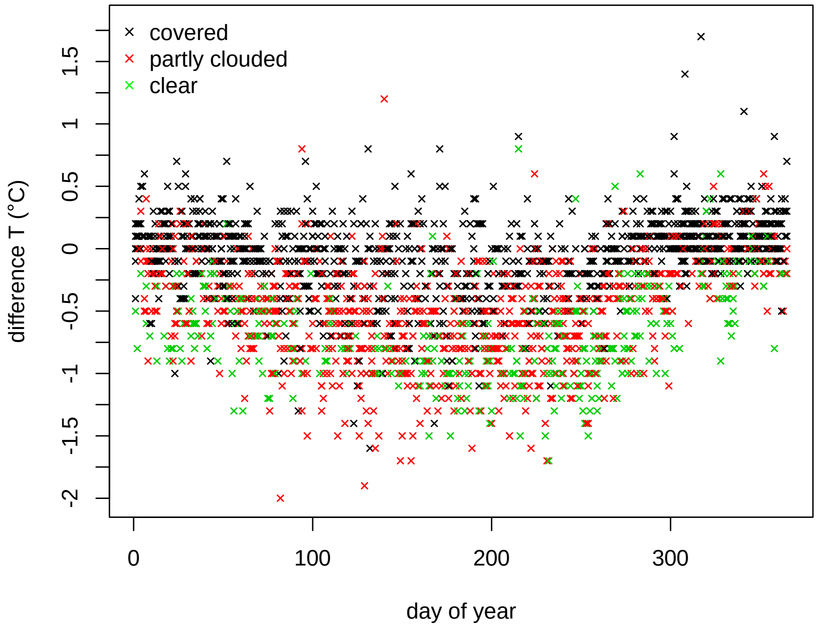
HOMOGENISATION OF DAILY DATA

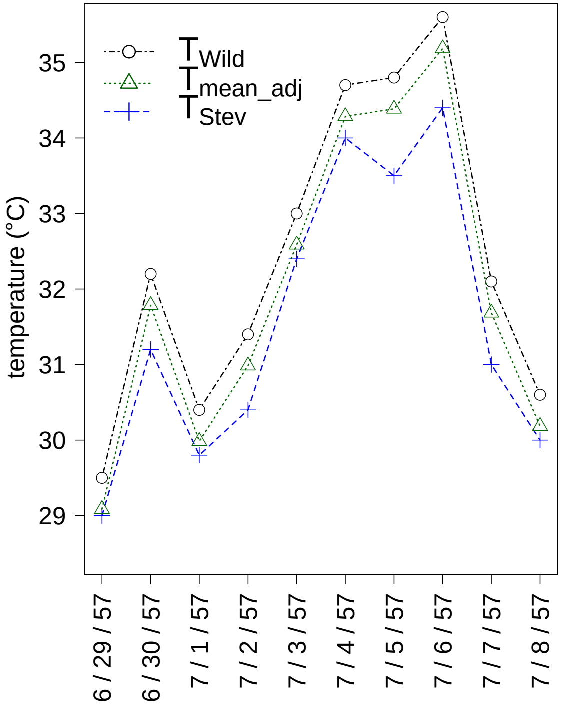
Issues – why it's harder than monthly:

- signal-to-noise ratio small (for detection)
- adjustments depend on nonlinear atmospheric processes

Parallel measurements Stevenson – Wild screens



Inadequacy of adjustments to the mean



Courtesy Renate Auchmann, Uni Bern

HOMOGENISATION OF DAILY DATA

EUSTACE plan:

- Application of selected break detection methods to global GHCN-Daily data
- Assessment of results (for which regions does it work?)
- Evaluation of existing correction methods using benchmark and comparison for few locations with more advanced techniques

Courtesy Renate Auchmann, Uni Bern

HOMOGENISATION OF DAILY DATA

Break detection

- various methods, no method finds all breakpoints/correct breakpoints
  - combination of methods was proven to be more effective (in terms of matching metadata, tested for Swiss Network; Kuglitsch, et al., 2012)
  - suitable test region due to complex orography
- combination especially helpful when no metadata available/ metadata difficult to use (e.g., global dataset)
- EUSTACE will apply this combined approach to try to identify breaks in the global dataset then pass this information to the statistical infilling methods

Courtesy Renate Auchmann, Uni Bern

HOMOGENISATION OF DAILY DATA

Break detection

- 3 methods (applied to seasonal/annual scale):
  - CAUME (Caussinus & Mestre, 2004)
  - Wang (Wang et al., 2007)
  - TORETI (Toreti et al., 2012)
- (known) issues: (too) low station density in some regions, short time series, approach never tested for tropical/polar climates,…

Break correction/Assessment

- EUSTACE applies 2 daily correction methods:
  - daily corrections from monthly corrections (spline)
  - more sophisticated correction of statistical distribution
- validation of homogenisation (detection + correction) using benchmark dataset
- for selected stations comparison with adjustments from physics-based model

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Royal Netherlands Meteorological Institute
Ministry of Infrastructure and the Environment

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Ministry of Infrastructure and the Environment

Science & Technology Facilities Council

University of Leicester

Met Office Hadley Centre

University of Reading

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DMI

PRODUCE CONSISTENT UNCERTAINTY ESTIMATES FOR SKIN TEMPERATURE RETRIEVALS OVER ALL SURFACES

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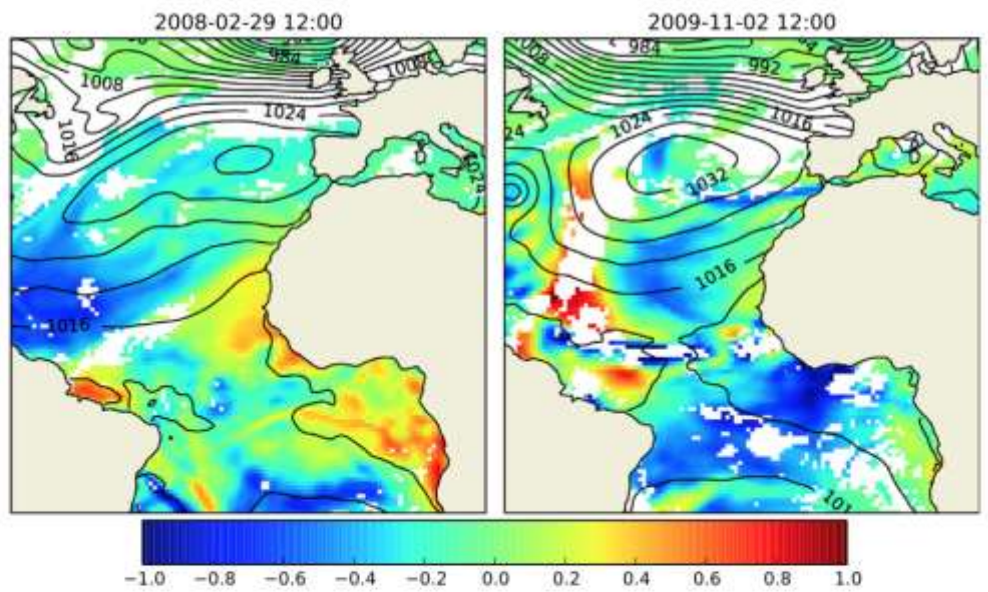
NEED TO UNDERSTAND LST/IST/SST/LSWT UNCERTAINTY

Obvious forms of uncertainty in satellite surface temperatures:

- Random uncertainty from noise in satellite radiances. Estimate by noise propagation.
- Systematic uncertainty from uncertainty in calibration etc. Estimate from radiance accuracy.



Simulation of intrinsic SST retrieval error on two different days. Although errors arise because of atmospheric variability, there is no simple relationship or correction.

Merchant, C. J. and **Embury, O.** (2014) ***Simulation and inversion of satellite thermal measurements.*** In: Zibordi, G., Donlon, C. J. and Parr, A. C. (eds.) Optical radiometry for ocean climate measurements. Experimental methods in the physical sciences, 47 (47). Academic Press, pp. 489-526. ISBN 9780124170117 doi: **10.1016/B978-0-12-417011-7.00015-5**

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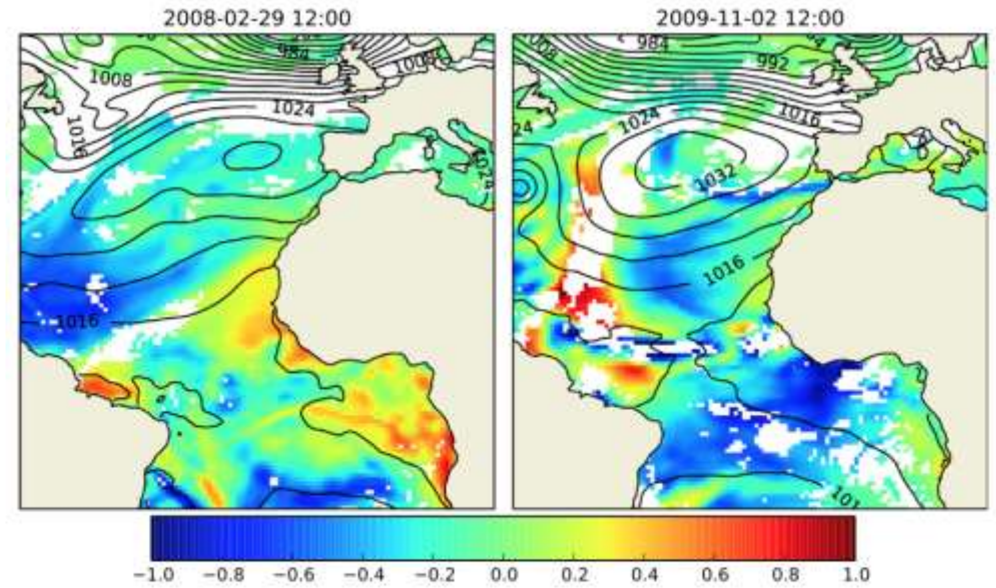
NEED TO UNDERSTAND LST/IST/SST/LSWT UNCERTAINTY

Less obvious is that locally systematic errors are usual (e.g. figure). These arise from effects intrinsic to satellite retrieval.

- Estimate by simulation methods.
- Account for uncertainty from locally correlated effects in ST analyses



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UNDERSTAND HOW SURFACE TEMPERATURE MEASURED *IN SITU* AND BY SATELLITES RELATES

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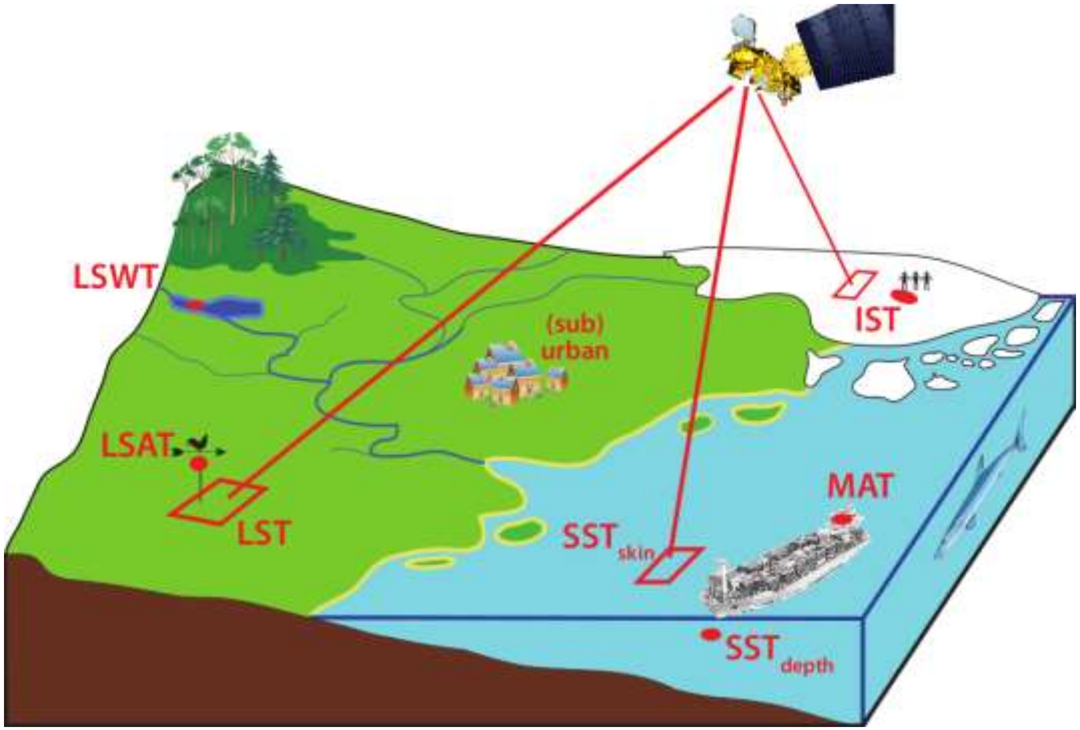
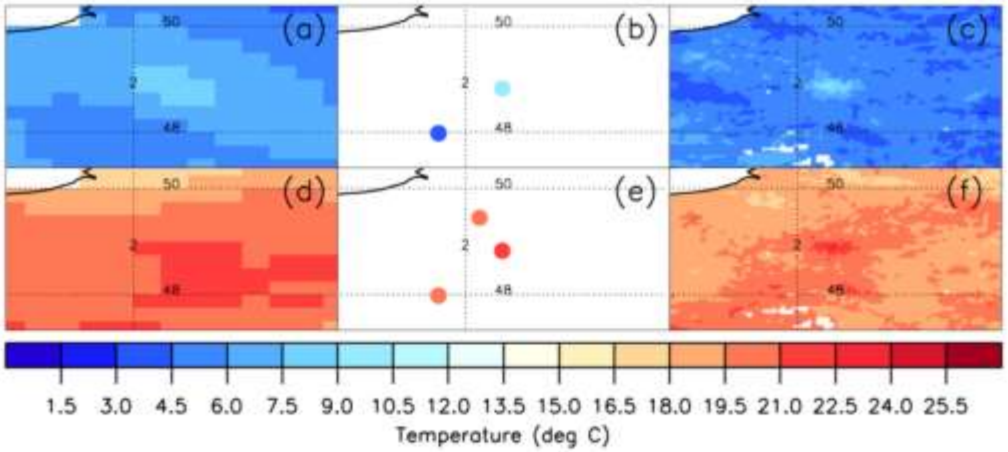
RELATIONSHIP BETWEEN SAT AND LST/IST/SST/LSWT



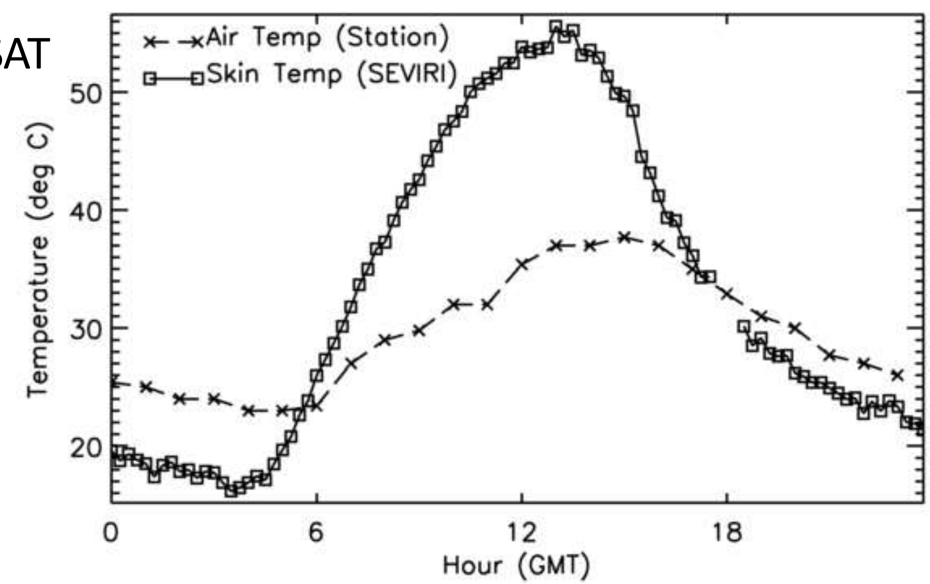
From Merchant et al., 2013 community paper and roadmap:
http://www.geosci-instrum-method-data-syst.net/2/305/2013/gi-2-305-2013.html

LAND: LSAT/LST



EOBS ECA&D Satellite LSAT

Tmin (top row) and Tmax (bottom row) over Paris on 27 March 2012. Satellite LSAT estimated from empirical statistical model.



Diurnal cycle on 2 July 2011 for LST and LSAT at station 607350 (Kairouan, Tunisia)

Met Office Hadley Centre

Courtesy Lizzie Good, Met Office

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ESTIMATION OF TMAX/TMIN

• Anticipating calculating daily Tmin/Tmax over land from the satellite data and using this to estimate Tmean.

• Likely to have an intermediate EUSTACE Tmin/Tmax product from the satellite data for the recent past. This will not be all-sky.

• For polar-orbiting satellites, difficult to relate the 'snapshot' overpass time consistently to Tmean given the overpass times (e.g. 10am) and the natural variability of the LST diurnal cycle shape (NB impact of cloud here).

• For geostationary, full diurnal cycle will not be observed because of cloud in most locations. May fit a diurnal model to estimate Tmean.

• Satellite Tmax estimates from geostationary data will be better than Tmin: less likely to be affected by residual cloud contamination (cloud causes cold-biased LST retrievals so max LST is the most likely to be cloud-free).

USE MAT RATHER THAN SST

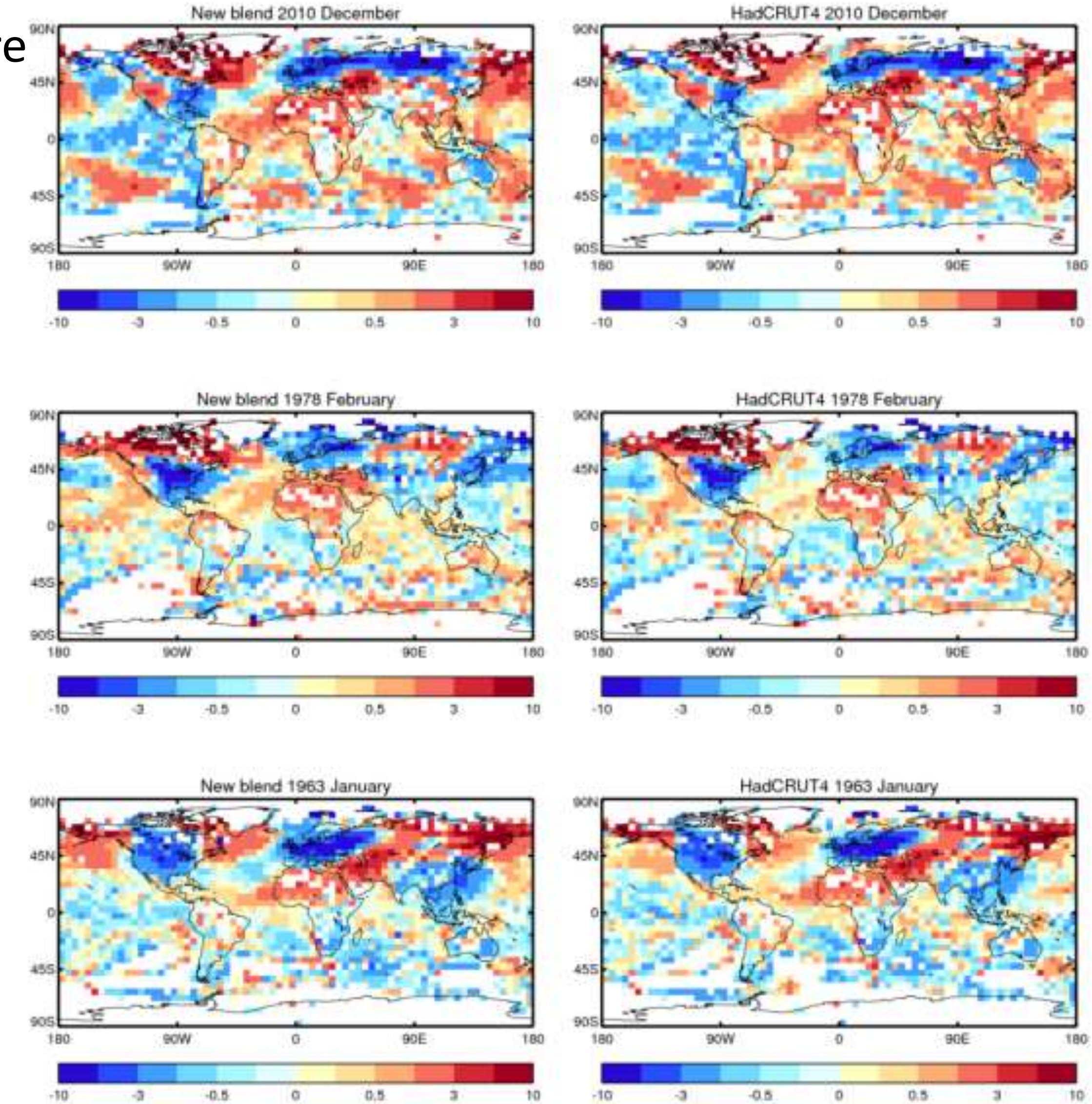
Blend of land and marine air temperature

HadCRUT4

Dec 2010

Feb 1978

Jan 1963



Courtesy John Kennedy, Met Office

ESTIMATE VALUES IN AREAS WHERE WE HAVE NO *IN SITU* OR SATELLITE DATA ON A PARTICULAR DAY

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STATISTICAL ANALYSIS METHODS

Global temperature data sets have either been based on simple aggregation of data in grid boxes or on statistical techniques developed in geosciences in the 1980s and 1990s.

The state-of-the-art in the spatial statistics research community is far ahead of the methods generally used in the Earth sciences.

Two approaches will be investigated in EUSTACE:

1. An "advanced standard" method based upon the more advanced methods currently used in surface temperature data set construction.

2. State-of-the-art novel spatial statistics.

Met Office Hadley Centre Courtesy Colin Morice, Met Office

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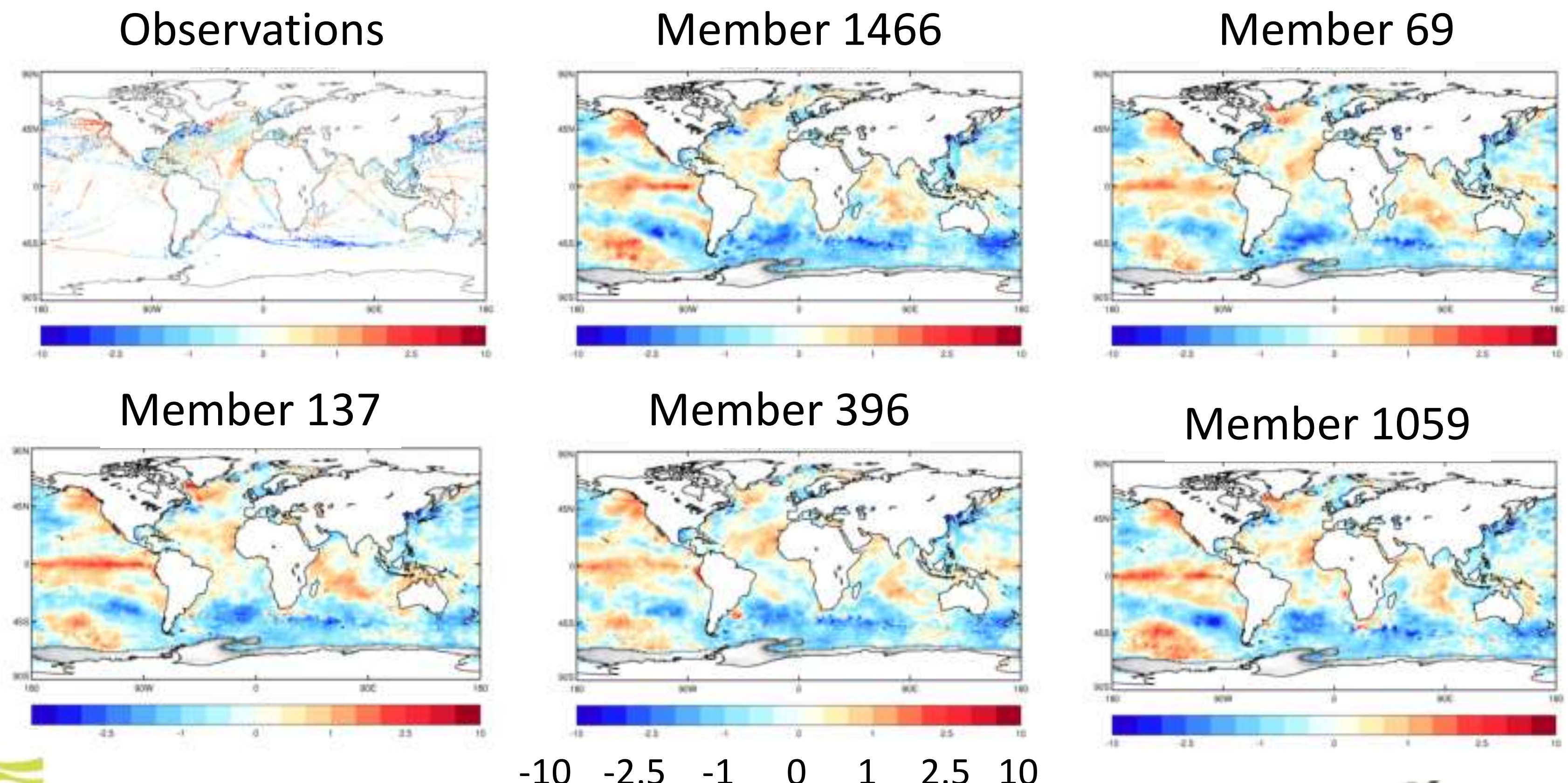
ENSEMBLES TO CONVEY UNCERTAINTIES

Use spatial relationships learned from both dense modern observations and historical data to reconstruct temperature fields from sparse historical *in situ* network



HadISST2 example: SST anomaly ensemble, January 1926

Courtesy Colin Morice, Met Office

DEVELOPMENT OF STATE-OF-THE-ART ANALYSIS METHODS

The main principle is to build a fine-scale stochastic temperature model, where the different sources of calibrated observations enter in a hierarchical fashion, using the uncertainty quantified in the calibration stage as a basis for the data likelihoods in the model.

The posterior distribution of the stochastic temperature field conditionally on all the data is the basis for the statistical output product.

The regions in space and time that only have sparse data will be stochastically linked to regions that have more data, by the conditional distributions defined by the model. By building the model as a combination of random processes on different temporal and spatial scales, the spatio-temporal interpolation is directed towards estimating aspects of the temperature process about which the data are informative, and giving reasonable uncertainty estimates about other aspects

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Courtesy Finn Lindgren, Univ. Bath

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DEVELOPMENT OF STATE-OF-THE-ART ANALYSIS METHODS

The daily minimum and maximum temperatures can not be adequately modelled by Gaussian distributions, but a preliminary analysis indicates that transformed Gaussian processes may be able to capture the distributional tail behaviour relevant to extremes

Courtesy Finn Lindgren, Univ. Bath

State-of-the-art statistical methods to meet product needs

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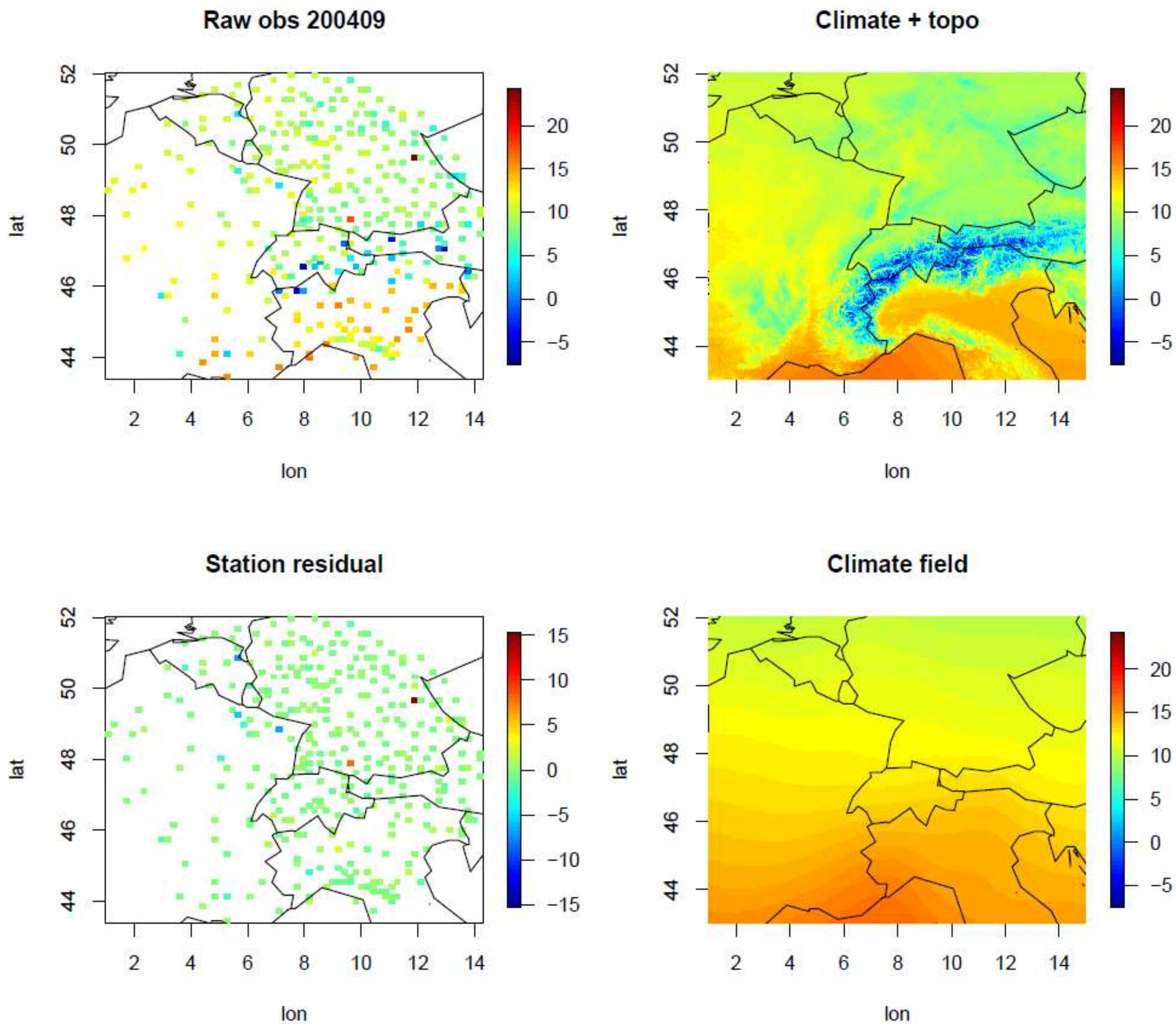
Courtesy Finn Lindgren, Univ Bath

- Estimation is methodologically challenging on the resolution intended
- Need state-of-the-art computationally efficient spatial statistics and numerical methods
- Proof-of-concept spatio-temporal statistical model developed in the ISTI/SAMSI/IMAGe workshop July 2014
- Highly ambitious effort is expected to advance spatial statistics in general.



SUMMARY

EUSTACE is likely to be able to contribute usefully to the provision of some of the data needs for the GC on Extremes and may produce methods that are useful for other variables later. For example:

Methods for detection of breaks in daily station surface air temperature time series will be applied globally. Homogenisation corrections will be applied to European data and information on global breaks will be accounted for in the infilled analysis

Methods for estimation of uncertainties in surface temperature retrievals from satellite-measurements will be adapted for use over all surfaces in order to produce consistent uncertainty estimates

Daily analyses with uncertainty estimates (possibly an ensemble) will be produced to provide clear information on when and where interpolated values can be used with confidence

Daily gridded fields will be produced which can be used to directly compare to model simulations

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MANY THANKS FOR LISTENING

TIME FOR QUESTIONS

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EXTRA SLIDES

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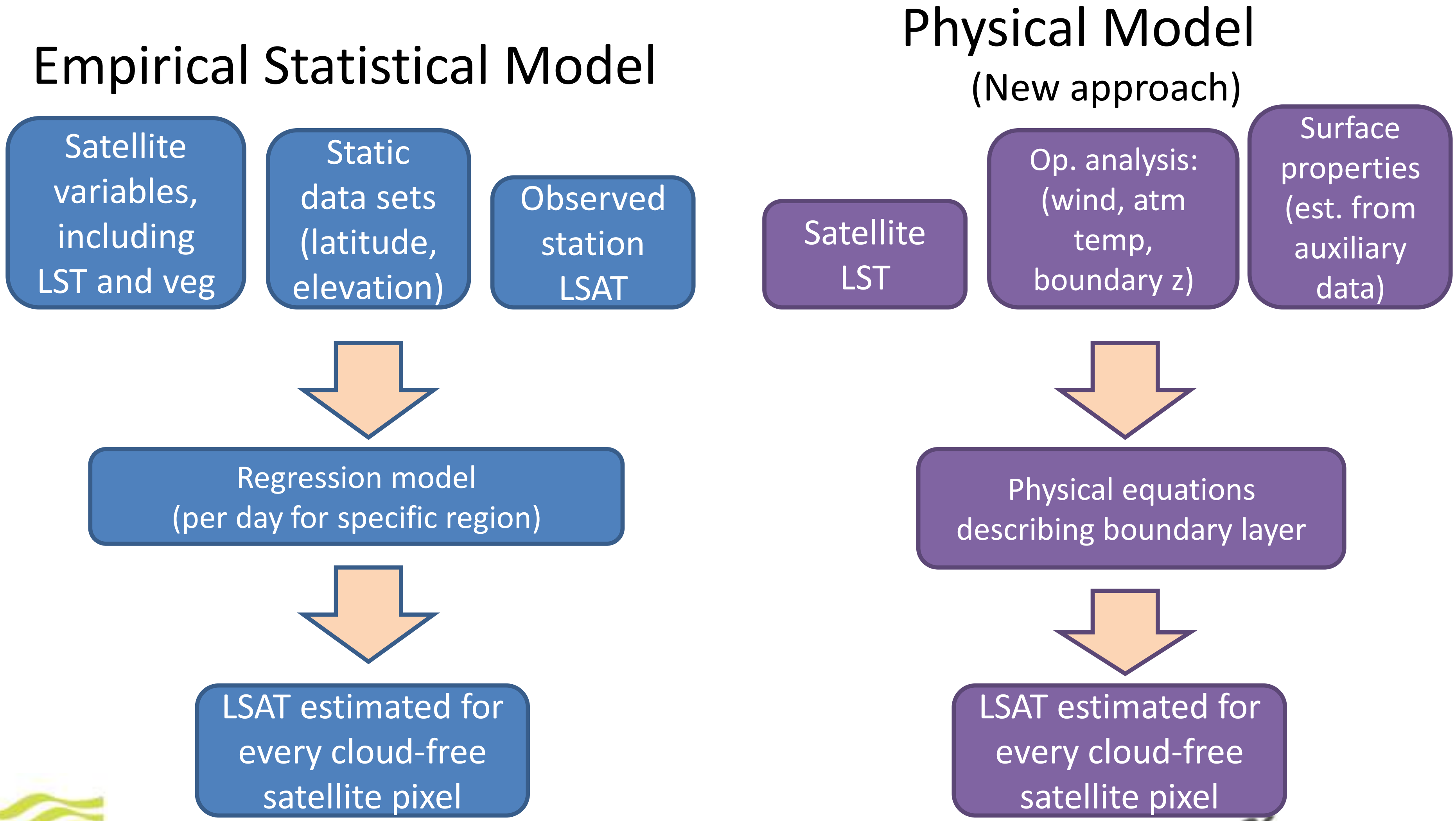
ESTIMATION OF AIR TEMPERATURE FROM LST



Courtesy Lizzie Good, Met Office

DEVELOPMENT OF STATE-OF-THE-ART ANALYSIS METHODS

Using a high resolution basis expansion EUSTACE will produce:

- Conditional simulations; a random sample consistent with the input data
- Predictive distributions, providing best estimates as well as uncertainty

Simple point estimates of spatial averages are necessarily smoother than the true temperature process values, and are therefore unsuited to investigating spatial and temporal extremes when the data coverage is sparse or uneven

When aggregating onto coarse grid cells, the within-cell variation can be tracked, so that some of the information about extreme temperatures is retained

This can also involve keeping track of grid-cell minima and maxima in addition to grid-cell averages and variances, as well as tracking the uncertainty about all these quantities

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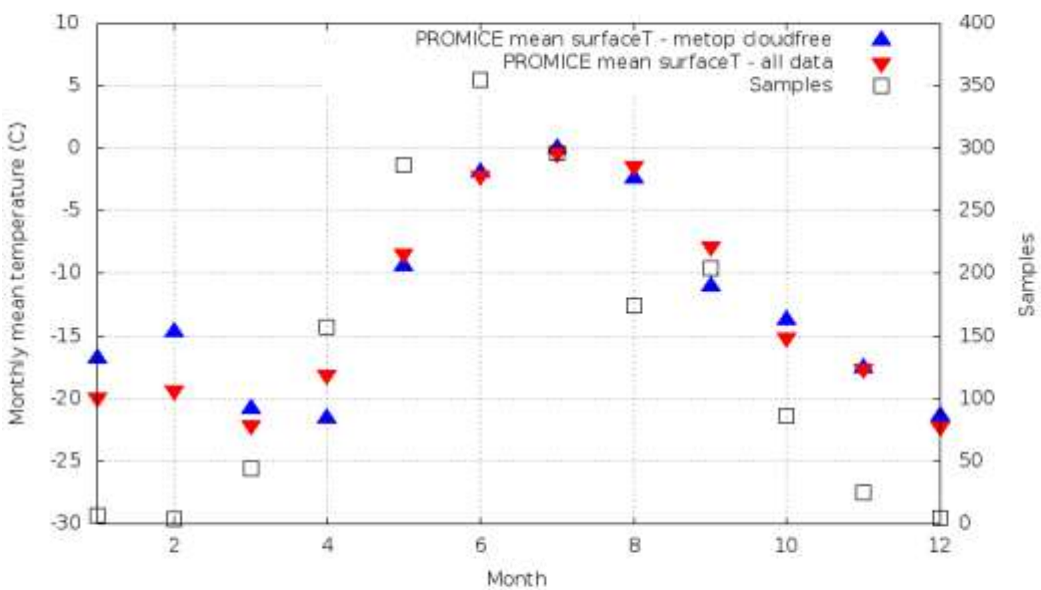
AIR TEMPERATURE OVER ICE

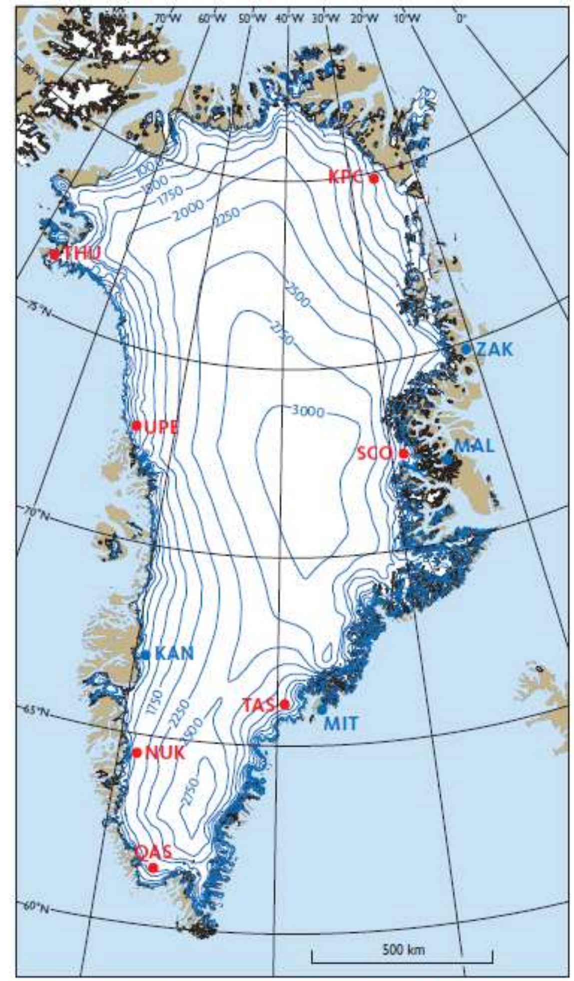
Clear sky bias from satellite?

Promice monthly mean surface temperature

- All observations (red triangles)
- Subsampled to Metop_A clear sky (blue triangles)

ISAR Radiometer IST, Qaanaq, April, 2013





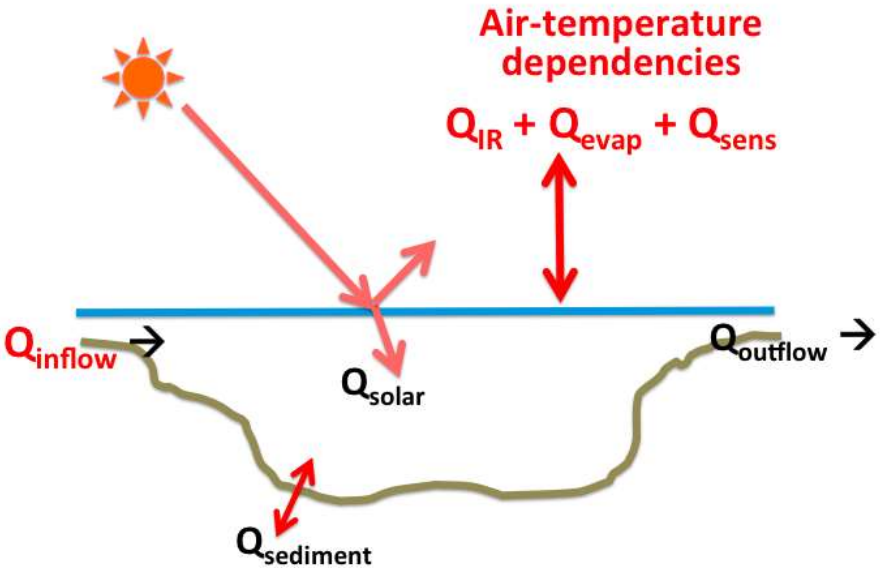
De otte områder på Indlandsisen, hvor der står målestationer, som drives af PROMICE. I hvert område står der to eller tre stationer på isen i forskellige højder. I Sydgrønland på station QAS står der tre stationer. Station QAS_L står i 310 meters højde på isen.

Courtesy Jacob Hoyer, DMI

Using lake temperature anomalies

Courtesy Chris Merchant, Univ Reading

- Task: derive constraints on surface air temperature anomalies by inverting lake surface water temperature (LSWT)and ice-on/off information



Lake thermal balance affected by T_{air} via inflow and non-solar surface fluxes

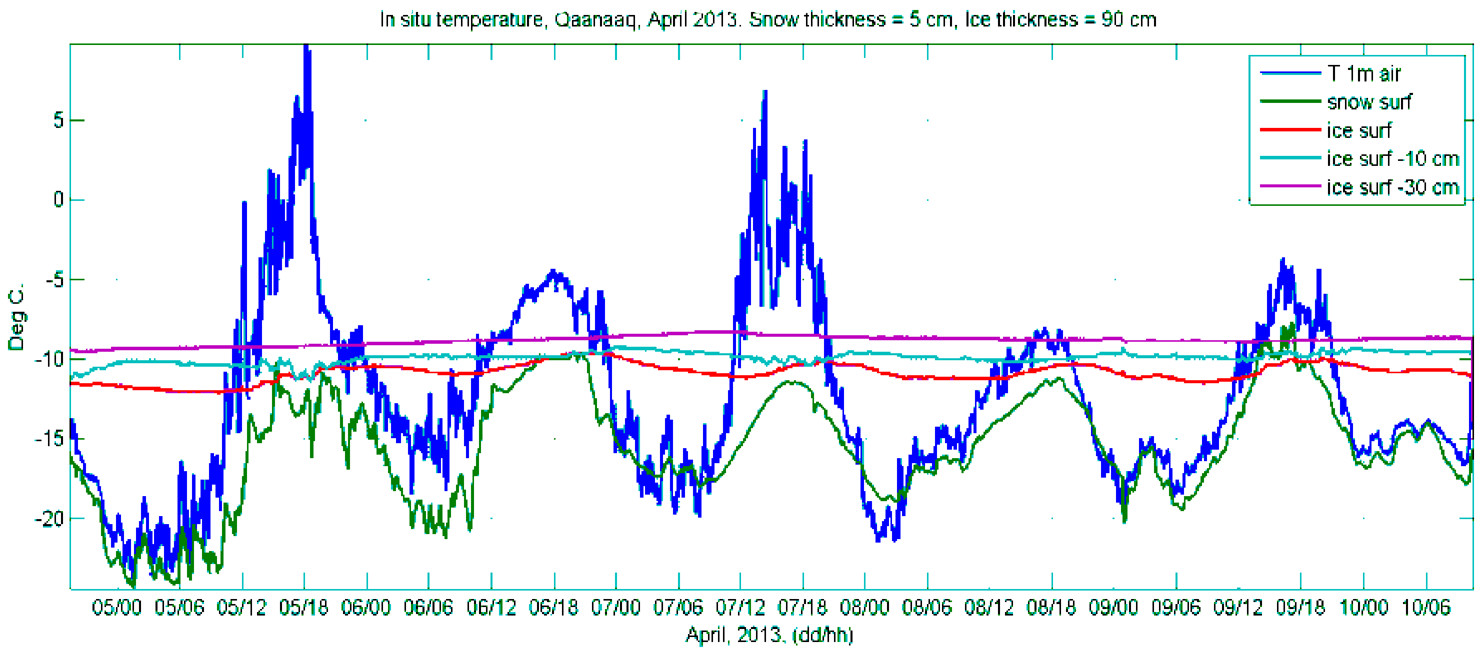
Data:
Satellite-derived LSWT (ARC-Lake and GloboLakes)
Hunt and collect *in situ* historical records

EUSTACE ARC Lake esa GloboLakes NERC SCIENCE OF THE ENVIRONMENT

Courtesy Jacob Hoyer, DMI

Vertical temperature variability over sea ice

- Large gradients within snow and sea ice
- Snow very effective insulator



Courtesy Darren Ghent, Univ Leicester

How will we know if it's any good?

Validation and intercomparison

- Adhere to standardised protocols for each surface type, with the aim to fit the profile of Quality Assurance for Essential Climate Variables Data (QA4ECV)
- Existing principles from SST and LST will be extended to matching up collocated surface air temperature against *in situ* measurements across all surfaces:
- Withhold sufficient fully-SI-traceable measurements for the highest quality validation, ensuring full independence from project output datasets
- Validation of the uncertainty information to increase confidence in the quality of the data products
- Intercomparison on common spatial and temporal grids of the output surface temperature datasets with other surface air temperature datasets and reanalysis data

User engagement with EUSTACE

- EUSTACE products will be made for wide range of users: researchers, policy makers, health, agriculture, …. etc.
- User engagement needed **from the start** to assure usability/salience

- Activities in which users can be engaged and/or informed:
  - User workshops (first in month 4 – April 2015, splinter session at EGU, then in month 5 for non-climate scientist users): users' requirements
  - As trail blazers
  - Dissemination on the progress and products through web site
  - Guidance on use of products

- EUSTACE will have been successful when the products are used.
- If you are interested, please contact bessembi@knmi.nl

Courtesy Janette Bessembinder, KNMI