ESTIMATING SURFACE AIR TEMPERATURE FROM SATELLITE DATA FOR THE EUSTACE GLOBAL TEMPERATURE ANALYSIS

LIZZIE GOOD
JOHN KENNEDY, JACOB HØYER,
PIA NIELSEN-ENGLYST AND KRISTINE MADSEN

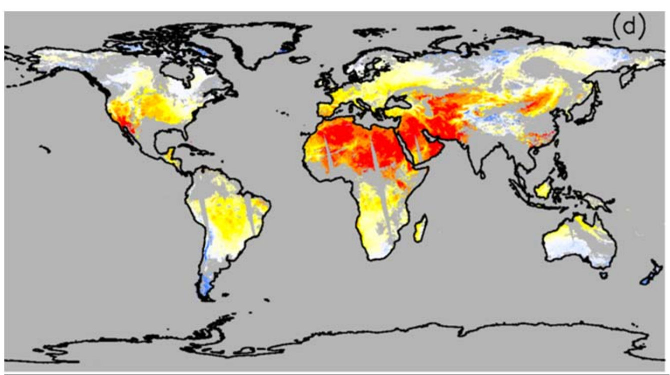
EUSTACE has received funding from the European Union's Horizon 2020 Programme for Research and Innovation, under Grant Agreement no 640171

THE APPROACH

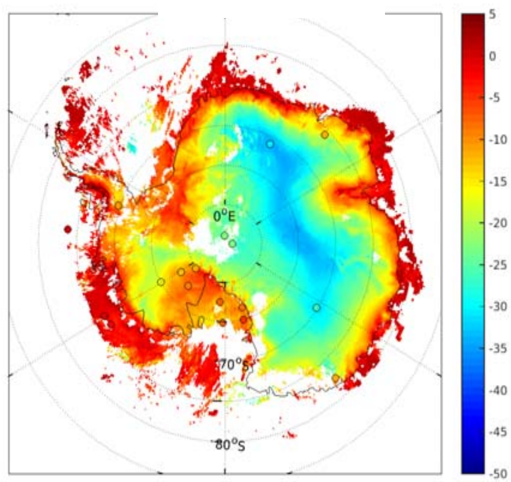
- There are **no global multi-year satellite Tmean/Tmax/Tmin data** in the public domain
  - AIRS (Atmospheric Infrared Sounder) atmospheric temperature profiles include 12-hourly instantaneous estimate of the near-surface air temperature at 50-km spatial resolution (~twice that of the EUSTACE target spatial resolution)
- Established methods in the literature: **empirical multiple linear regression models, physical models, neural networks, physical retrieval** => predict T2m from satellites

Objective:
Develop an approach (based on established methods) that can produce global, multi-year satellite-based T2m estimates for EUSTACE at 0.25° lat/long or better.

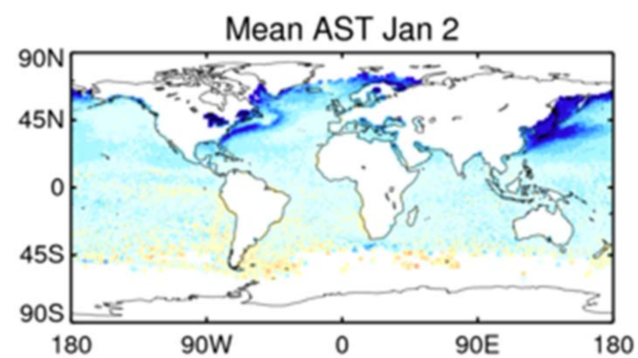
Land



Ice



Ocean



THIS TALK

Very brief overview of the satellite LSAT, IAT and MAT estimates:

- Method of T2m estimation
- Characteristics
- ‘Internal’ evaluation

More this session:

- Evaluation of EUSTACE products and uncertainties *Karen Veal 14:45-14:00*
- Statistical analysis/infilling in EUSTACE *Nick Rayner 14:15-14:30*
- Uncertainties in EUSTACE *Chris Merchant 14:30-14:45*
- Data file structure and User guides *Alison Waterfall 14:45-15:00*

EUSTACE

Lizzie Good

LAND SURFACE AIR TEMPERATURES (LSAT)

Met Office
Hadley Centre

EUSTACE

AN EMPIRICAL STATISTICAL MODEL

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

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

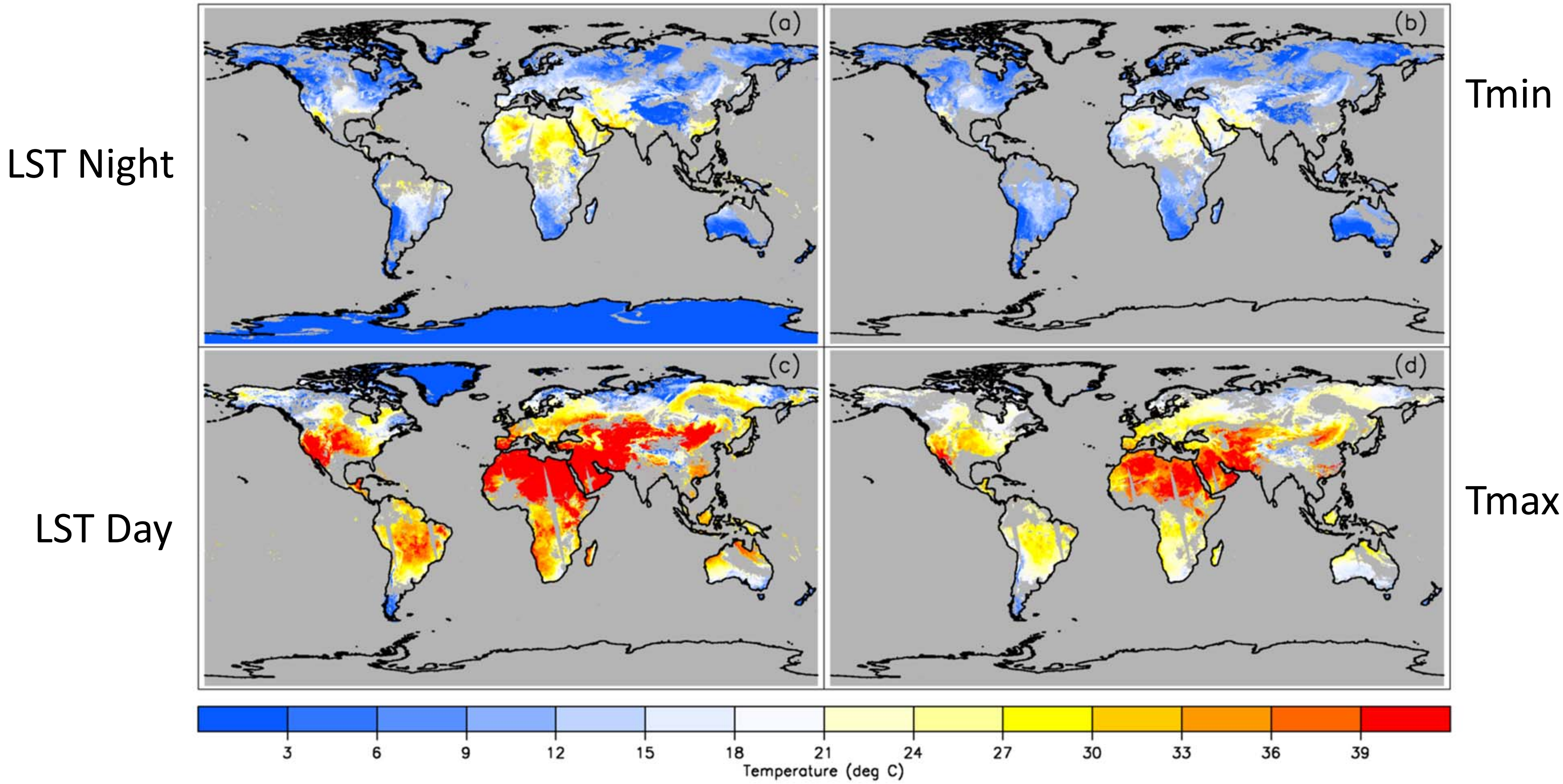
Vegetation fraction

Solar Zenith angle at noon

Error

- Regression coefficients trained on collocated satellite and in situ station observations
- Three model variants for each of Tmax and Tmin:
    - LSTday & LSTngt (primary model)
    - LSTday only
    - LSTngt only
- Not all predictors used in each model – selection based on analysis of residuals, impact of predictors, stability of derived coefficients, etc.
- Uncertainties propagated: L2 -> L3 and then through regression model to give random, atmospheric, surface and global systematic uncertainties per pixel.

EXAMPLE LST AND T2M (1 JULY 2010)



- Relationships are derived at 0.05 degrees and applied to 0.25 degree data (station-satellite relationships peaks at ~0.05 deg and degrades with decreasing spatial resolution)
- Ice and ocean are masked out in product

SUMMARY RESULTS (0.05° LAT/LONG)

Summary evaluation results for each model using ~6800 stations not used in model training.

Model	Correlation	Median (°C) (Sat-Stn)	RSMD (°C)	Slope
Tmin1	0.93	-0.05	2.80	1.03
Tmin2	0.93	-0.03	2.80	1.03
Tmin3	0.76	0.11	4.87	1.08
Tmax1	0.93	0.00	3.08	1.00
Tmax2	0.89	-0.07	3.76	1.01
Tmax3	0.88	0.06	3.89	0.99

- Little difference between Tmin1 and Tmin2 (but using LSTday better for cloud).
- Tmax Model with both LSTday and LSTngt performs best.

Worst model: Tmin predicted with LSTday

Additional efforts undertaken to remove cloud.

Good correlation coefficients

Satellite LST accuracy may be 1-3 °C. Point vs areal average matchup uncertainty up to 2 °C.

Satellite T2m vs station T2m scatter plot. **Slope** is linear regression line. We are looking for a slope close to unity.

Jacob Høyer, Pia Nielsen-Englyst and Kristine Madsen

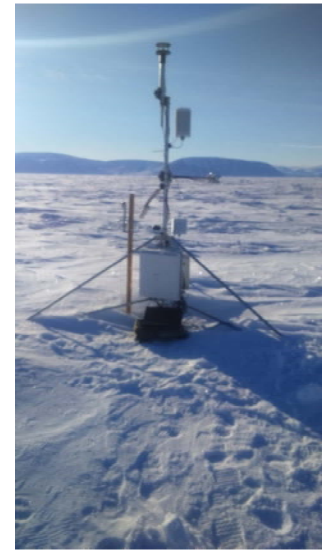
ICE AIR TEMPERATURES (IAT)

DMI
Danish Meteorological Institute

EUSTACE

HOW DO WE ESTIMATE T2M OVER ICE?

– Collect and quality control In situ observations from scientific campaigns
– Analyse the variability and T_{skin} vs. T_{2m} of in-situ and satellite observations
– Construct T_{2m} over ice from satellite data set, using a multi variate regression estimate
  - T2m predicted from daily satellite IST and a seasonal variation assumed to have shape of cosine function
  - Regression model developed using in situ data, separately for NH/SH & land/sea ice.
– Perform uncertainty modelling from L1 -> L2 IST -> L3 IST-> T_{2m}
– Validate and compare against observations and reanalysis products



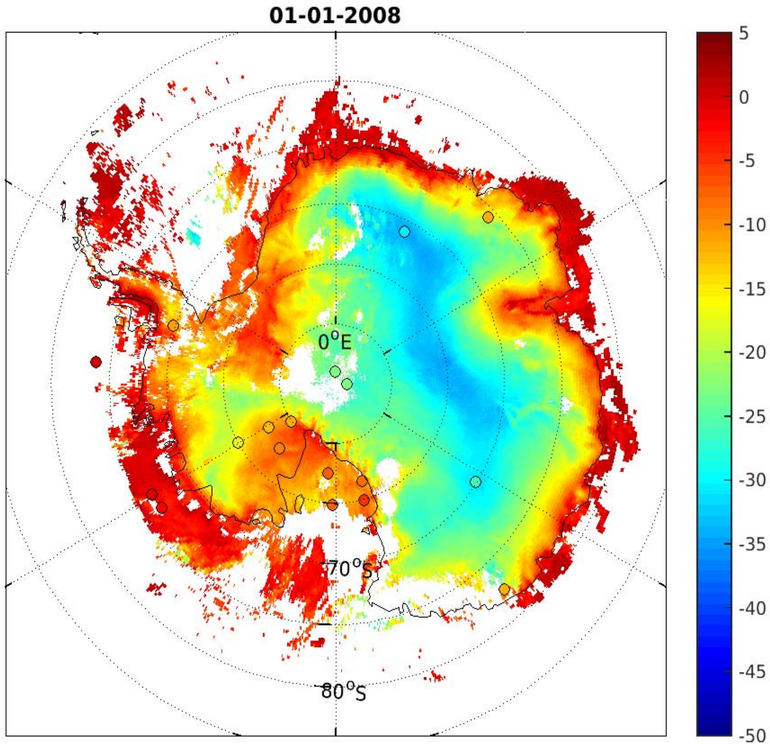
Jacob Høyer's talk: 11:40-12:00 Tues

DMI
Danish Meteorological Institute

EUSTACE

FINAL T2M FROM SATELLITE

- Daily fields in 0.25° by 0.25°, Arctic and Antarctic
- From 2000-2009
- Near surface air temperature: Average, Min and Max
- Uncertainties :
    - Random uncertainties
    - Synoptic scale correlated
    - Globally correlated w/wo cloud component
    - Total uncertainty, w/wo cloud component
- Sea ice concentration
- T2m (ERA Interim)
- Wind speed (ERA Interim)
- Tskin: TAvg, Tmin, Tmax
- Surface type mask



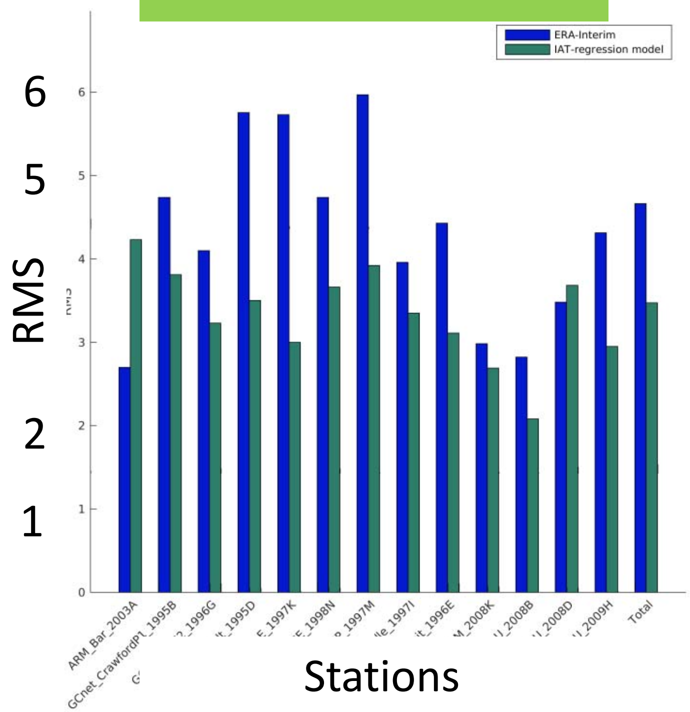
Daily mean air surface temperature (°C) over land ice and sea ice (Antarctica) from 1 January 2008. Circles show in situ measurements.

DMI
Danish Meteorological Institute

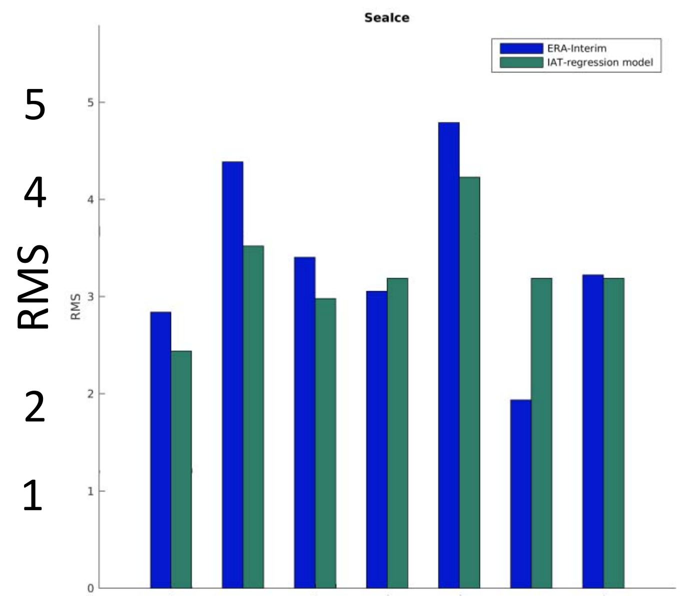
EUSTACE

VALIDATION:
SAT T2M BETTER THAN ERA-INTERIM T2M

Greenland Ice sheet+



Arctic Sea Ice



ERA-Interim

Satellite T2m

	Number of observations	Correlation	Bias (sat – in situ)	Std dev (°C)
Land ice NH	20872	95.5	0.30	3.45
Sea ice NH	16092	96.5	0.35	3.18
Land ice SH	21327	97.3	0.12	3.11
Sea ice SH	620	91.9	0.20	3.55

DMI
Danish Meteorological Institute

EUSTACE

John Kennedy

MARINE AIR TEMPERATURES (MAT)

Met Office
Hadley Centre

EUSTACE

SIMPLE AIR-SEA TEMPERATURE DIFFERENCE MODEL

THE THING DESIRED

Climatological Offset – Fourier series

$$MAT = SST + \delta + \varepsilon$$

Measured by ships only

Measured by satellite/ship

Temporally and spatially correlated variability

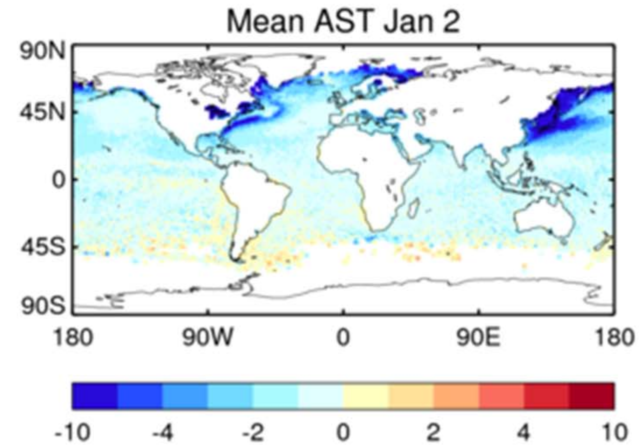
Data from ICOADS 2.5

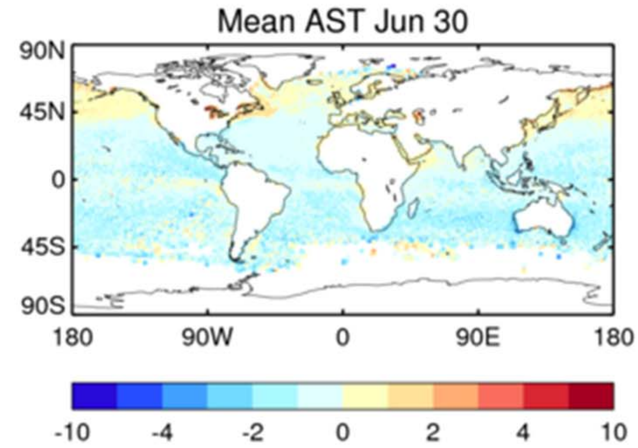
1963-2000

Met Office Hadley Centre

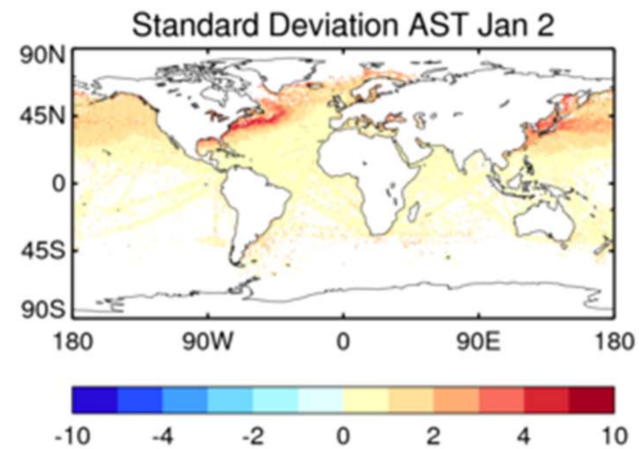
EUSTACE

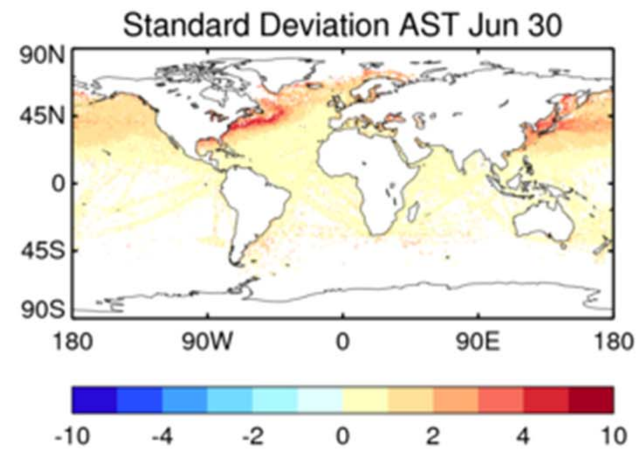
δ – defined as seasonally varying offset

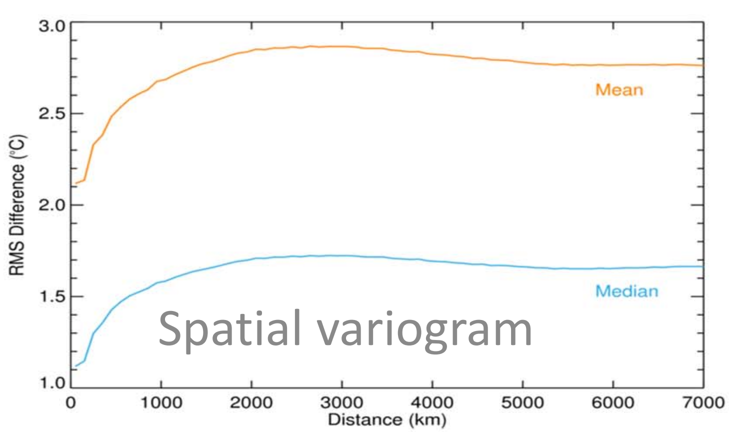


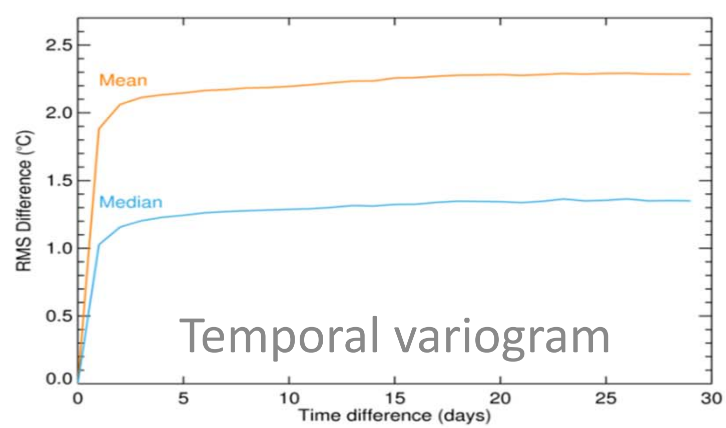


ε – defined by seasonally varying standard deviation and fixed time and length scales





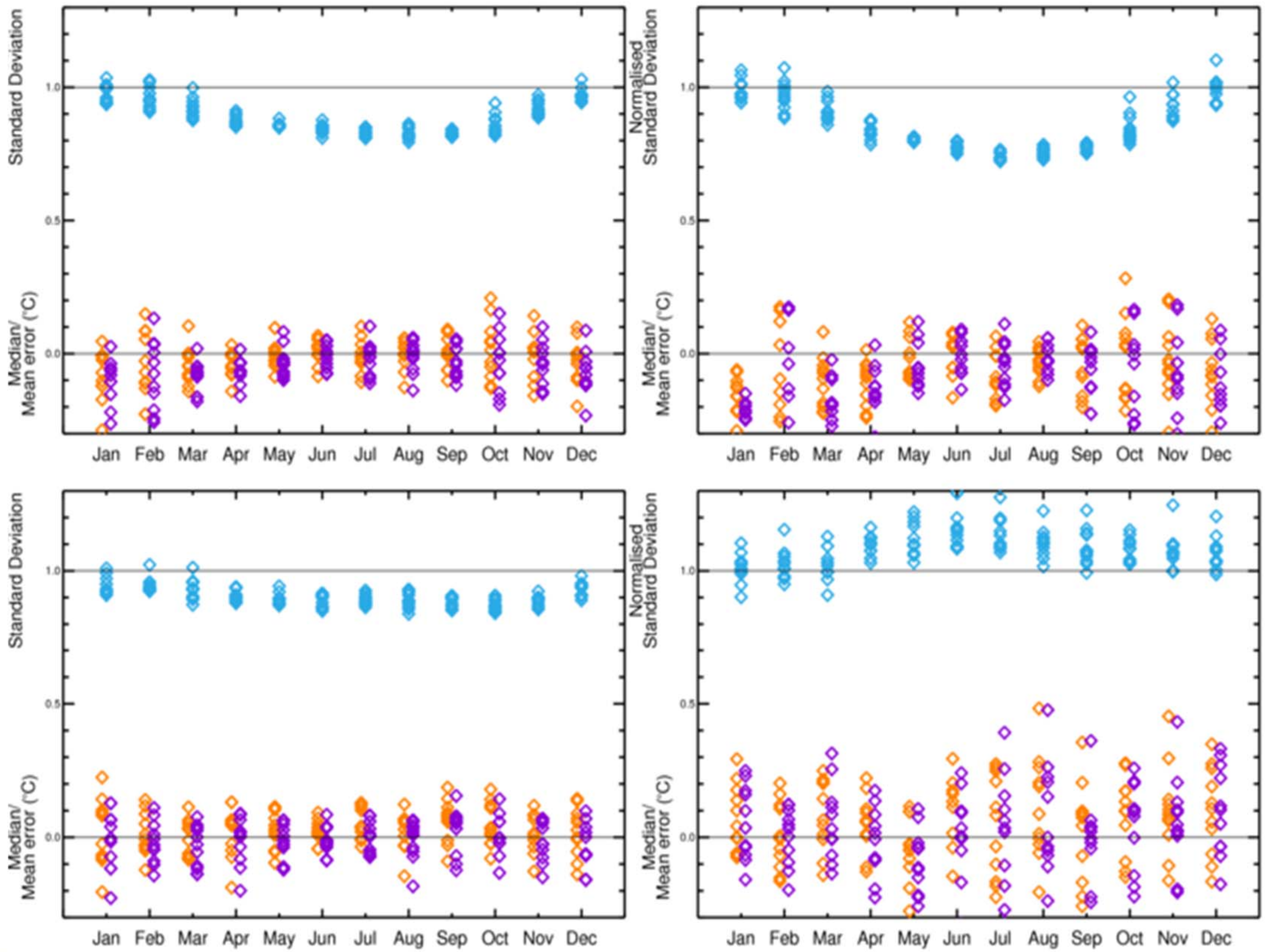




Met Office
Hadley Centre

Globe

N. Extratropics N of 30°N



Tropics 30°N-30°S

S. Extratropics S of 30°S

SUMMARY

- Separate daily T2m estimates for land, ocean and ice at 0.25 deg regular lat/long are produced
  - Land: Tmin/Tmax
  - Ice: Tmin/Tmax/Tmean
  - Ocean: Tmean
- Estimates have uncertainties per cell partitioned by correlation properties, e.g.:
  - Random (e.g. instrument noise)
  - Locally correlated (e.g. uncertainties related to the atmosphere)
  - Globally correlated/systematic
  - To get the total uncertainty: add all elements in quadrature

Chris Merchant's talk: 14:15-14:30 Monday

Made available to users as stand alone products – 'SATSTACE'
Used in full EUSTACE analysis, blended with in situ data – 'FULLSTACE'

EUSTACE

QUESTIONS

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