climate change initiative

→ SEA SURFACE TEMPERATURE

Coastal-zone sea surface temperature at ~100 m resolution

C J Merchant, O Embury, L Carrea, J Mittaz, C Bulgin

sst cci

University of Reading

Met Office

Danish Meteorological Institute

Missions to the coastal zones

- Coastal zones have: spatiotemporal complexity and irregular coastline
- GHRSST products based on ~>1 km sensors don’t capture coastal zones well
- Landsat and ECOSTRESS show potential, and Trishna will be better

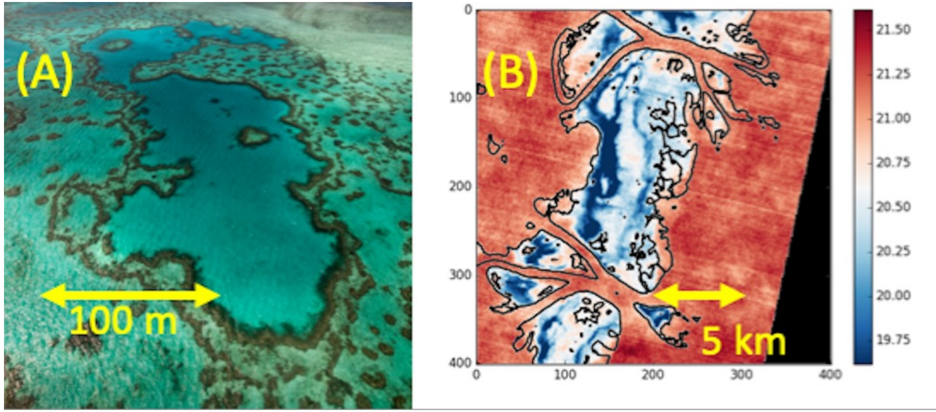
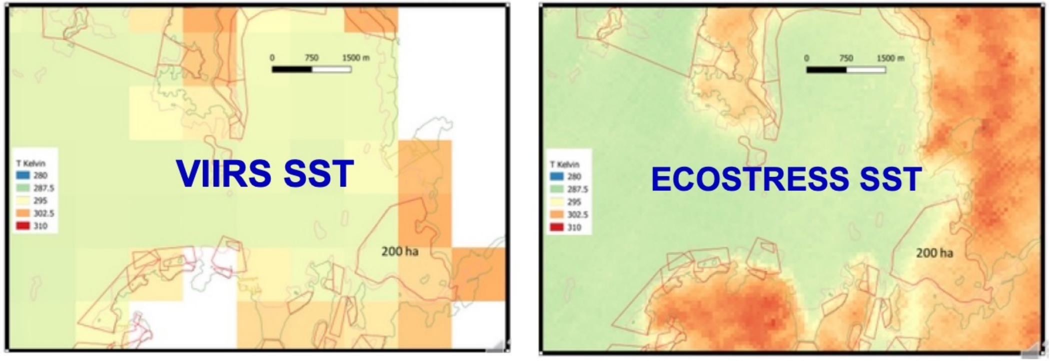


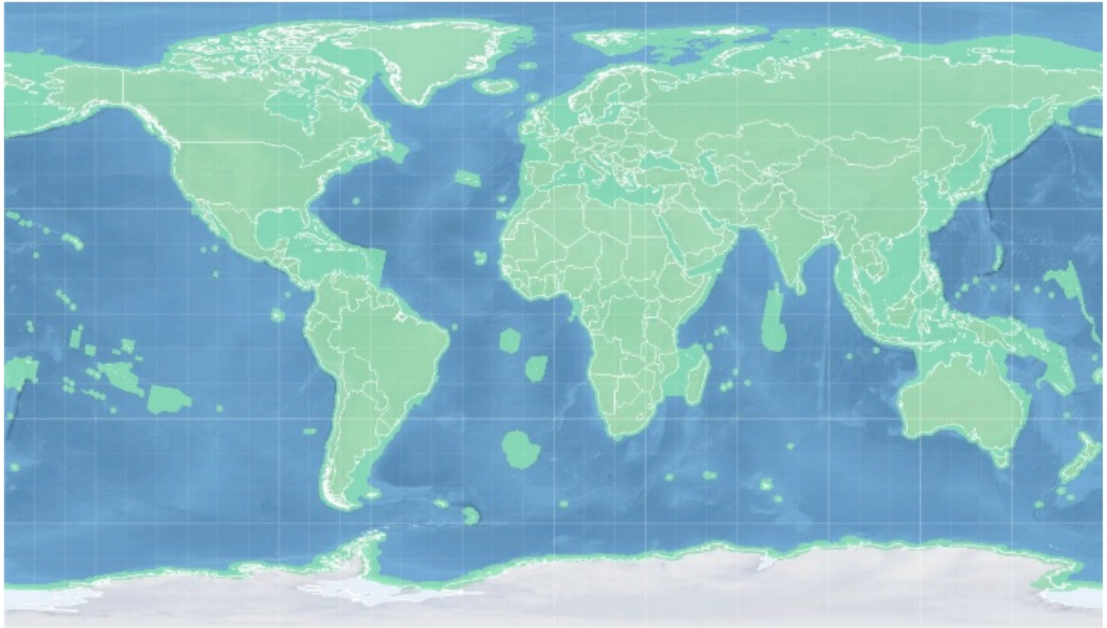
Illustration of spatial detail in Landsat across a coral reef

Intertidal shellfish beds
Galicia, NW Spain



David Wethey presentation from GHRSST 2021

Looking forward to Trishna



Trishna acquisition mask

L1C resampled to 60 m
12.30 am and pm

as presented at ESA workshop 2023 by Philippe Gamet https://thermal2023.esa.int/iframe-agenda/files/presentation-114.pdf

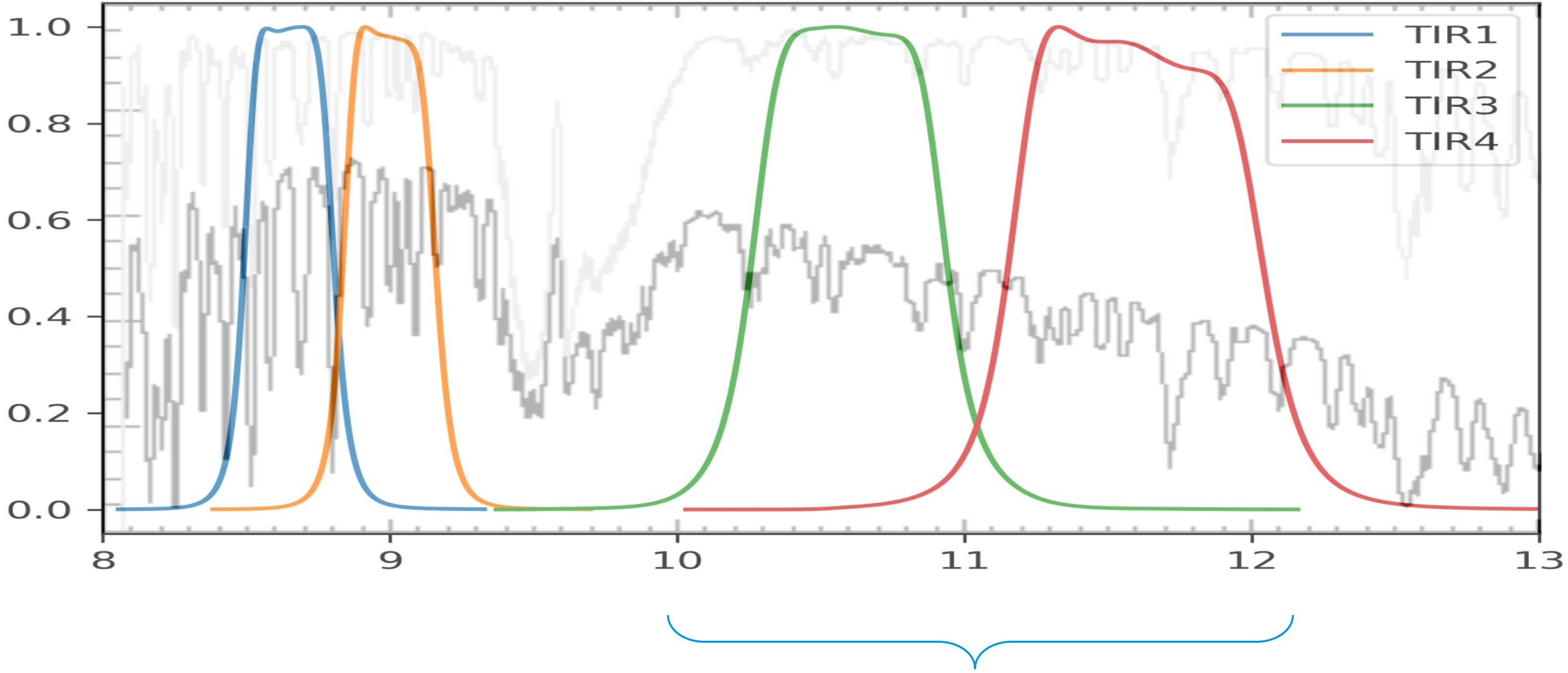
But SST is a challenge cf. LST

Requirements:

Resolve contrasts ~ 1 K

Bias <0.1 K

Spectral response functions



Trad. "split window"

The new channels also provide differential WV sensitivity

Thermal channel specifications

Band	Centre / um	FWHM / nm	NEDT / K	Unc. abs. / K	Unc. inter-band
TIR1	8.65	350	0.25	0.5	0.3
TIR2	9.0	350	0.25	0.5	0.3
TIR3	10.6	700	0.2	0.5	0.3
TIR4	11.6	1000	0.2	0.5	0.3

Buffet, Gamet et al., SPIE, 2021

Corresponding error covariance matrix
(uncorrelated + structured + common errors)

$$\begin{bmatrix} .25^2 & 0 & 0 & 0 \\ 0 & .25^2 & 0 & 0 \\ 0 & 0 & .20^2 & 0 \\ 0 & 0 & 0 & .20^2 \end{bmatrix} + .21^2 \boldsymbol{I_4} + .45^2 \boldsymbol{J_4}$$

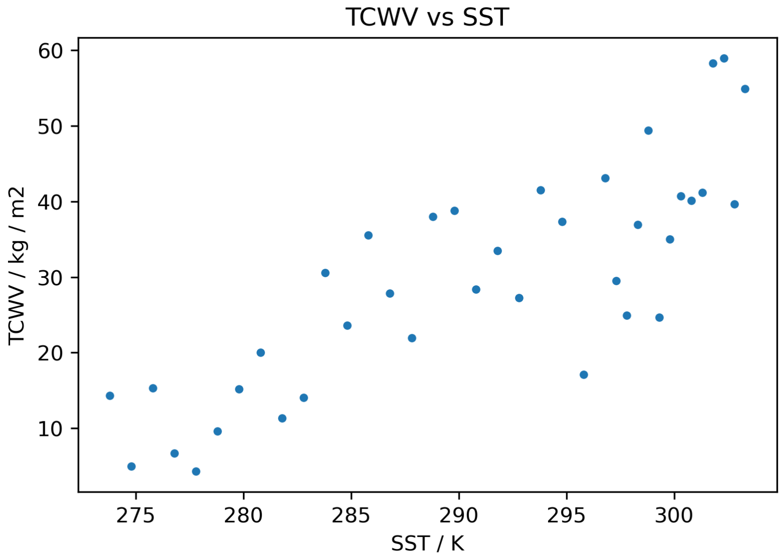
FIDUCEO terminology

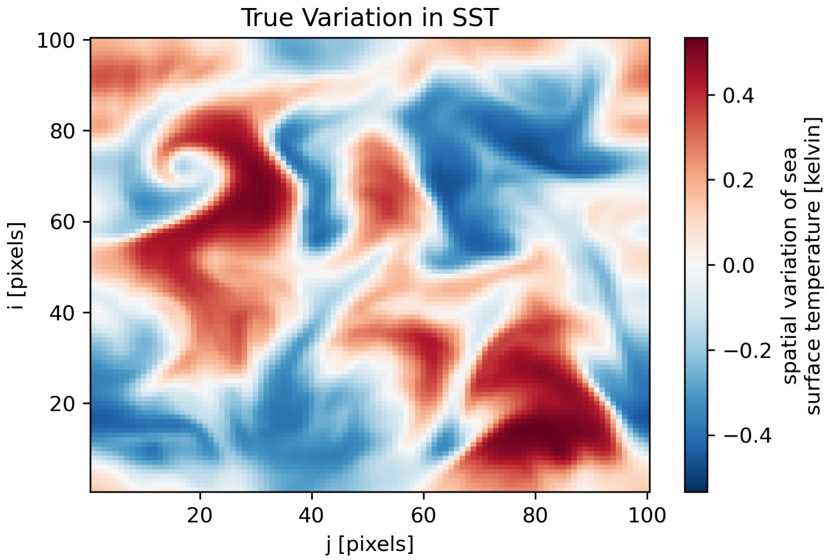
uncorrelated structured common

Mittaz, Merchant, and Woolliams (2019) Applying principles of metrology to historical Earth observations from satellites. *Metrologia*, 56 (3). doi.org/10.1088/1681-7575/ab1705

Simulation study

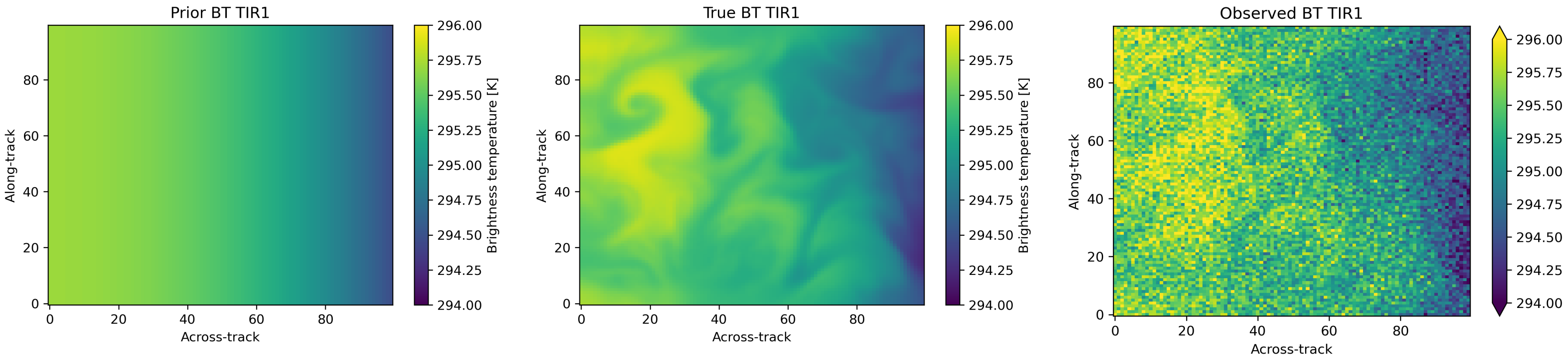
- Range of SST 274 K to 303.5 K, 37 profiles
- TCWV 4.5 to 64 kg m^{-2}
- SST pattern over a 100 x 100 pixel box with +/-1 K
- Full range of Trishna satellite zenith angle imposed across track





Simulated 'prior', 'true' and 'observed' BTs

Example of profile 35, for which SST = 302 K and TCWV = 40 kg/m^2



Constant prior SST, with scene-mean uncertainties of 0.3 K and 10%.

Full range of SZA compressed into 100 pixels for purpose of study.
Pixel 0 is nadir, pixel 99 is 38^o

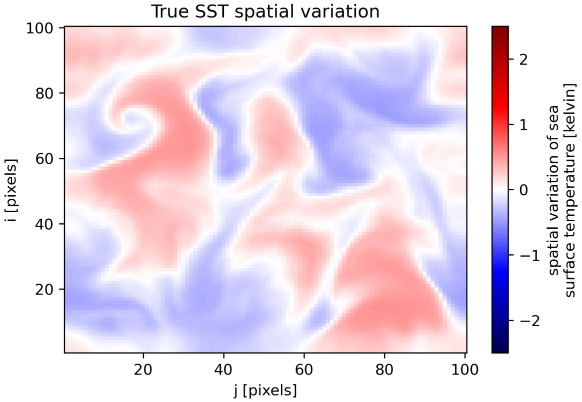
Noise at 0.25 K

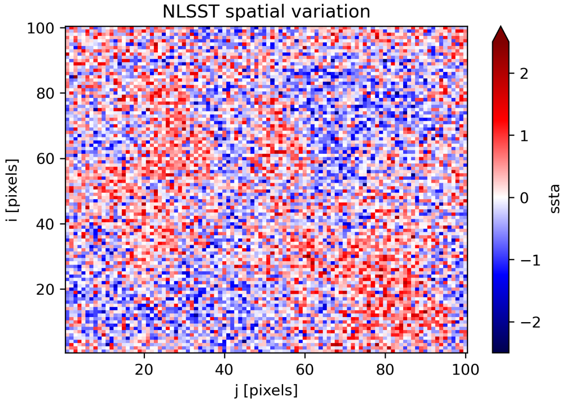
Options for retrieving SST

- Given the Trishna channels
  - Split-window such as NLSST — Unnecessarily noisy
  - Temperature-emissivity separation — A priori emissivity constraint
  - **Physically-based retrieval, optimal estimation**

Illustration of noise using NLSST (per pixel)

NLSST coeffs
of Jang & Park (2019)*
made for Landsat
+ propagating Trishna
noise levels





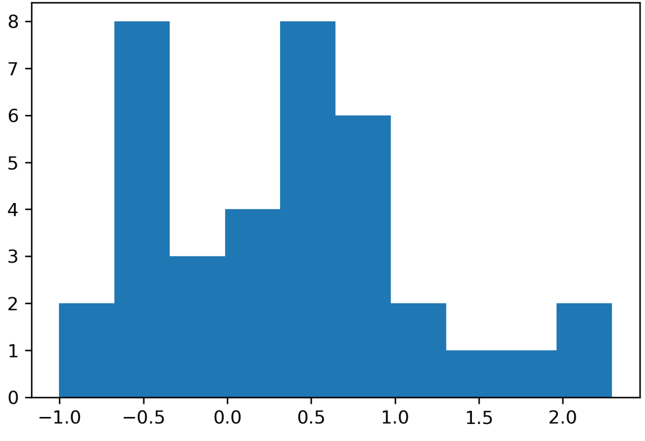
0.62 K noise

*Remote Sens. 2019, 11, 2687; doi:10.3390/rs11222687

SST bias performance: structured and common errors

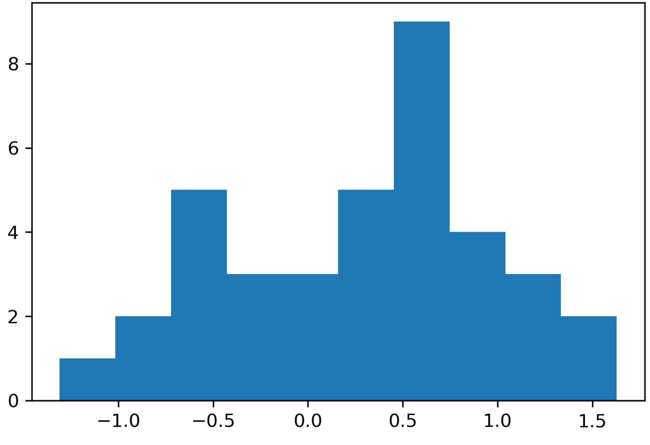
- Scene-average SST retrieval
- Simulated calibration errors consistent with error covariance (specifications)
- Very weak prior SST constraint (7.0 K uncertainty), reveals calibration impact

Split window only
Typical SST bias ~0.9 K



Simulated sample of biases / K

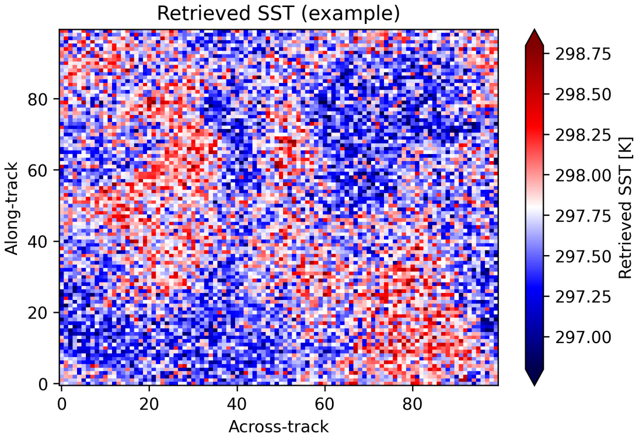
Four channels
Typical SST bias ~0.7 K

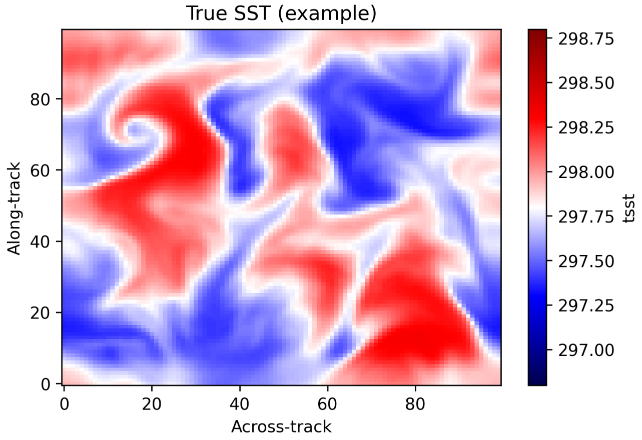


Simulated sample of biases / K

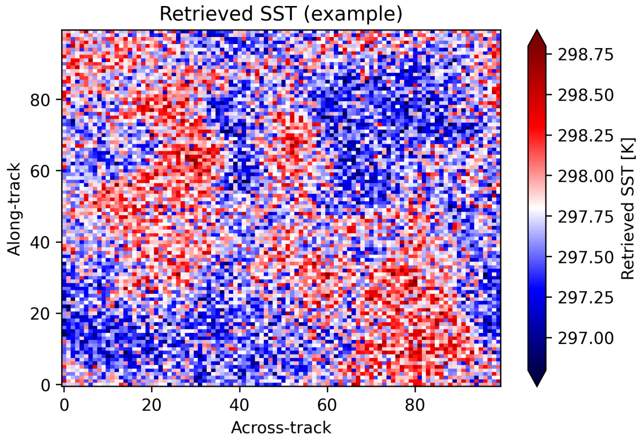
Per-pixel OE (cal. bias free; example location)

2-ch





4-ch

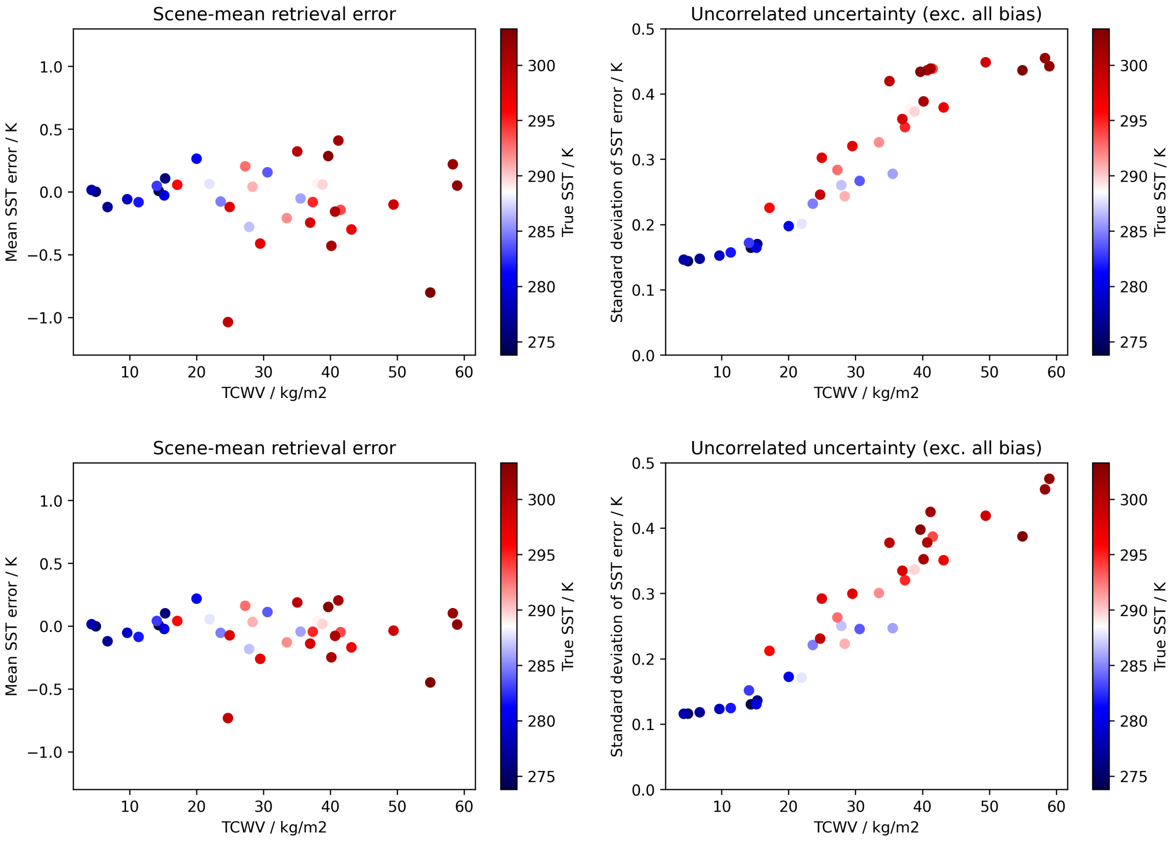


	2-ch	4-ch
Scene bias / K	-0.12	-0.08
Scene noise / K	0.30	0.29
Sensitivity K/K	84%	93%

Per-pixel OE across all locations

2-ch

4-ch



As expected, there is a small benefit from using 4 channels in suppressing some noise and some bias reduction.

Smooth-atmosphere OE (4 channel)

Retrieve the SST for a localized area of clear-sky pixels all together, with one common retrieved water vapour content across many pixels.

This is justified by atmospheric variability being considered small over scales of several hundred metres.

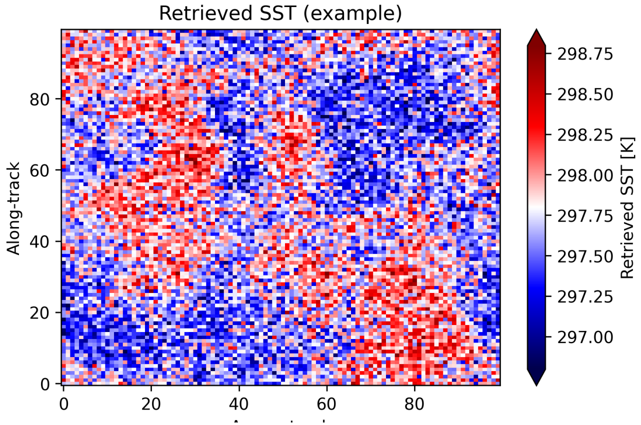
Disambiguates noise from water-vapour-content effects in individual pixels and as a result drives down two forms of error:

- SST noise
- propagated error from the error in prior water vapour

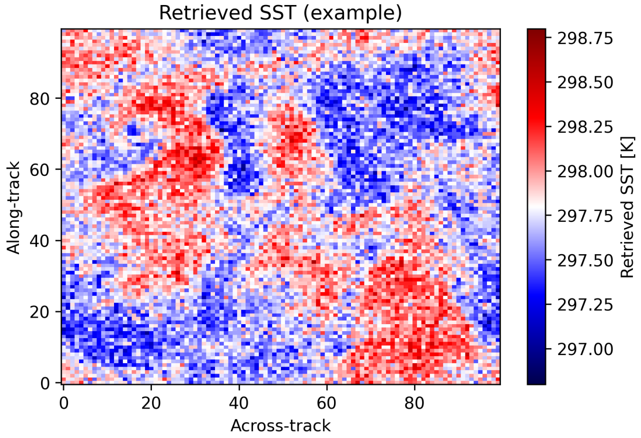
Merchant, C. J., Le Borgne, P., Roquet, H. and Legendre, G. (2013) Extended optimal estimation techniques … Remote Sensing of Environment, 131. pp. 287-297. ISSN 0034-4257 doi: 10.1016/j.rse.2012.12.019

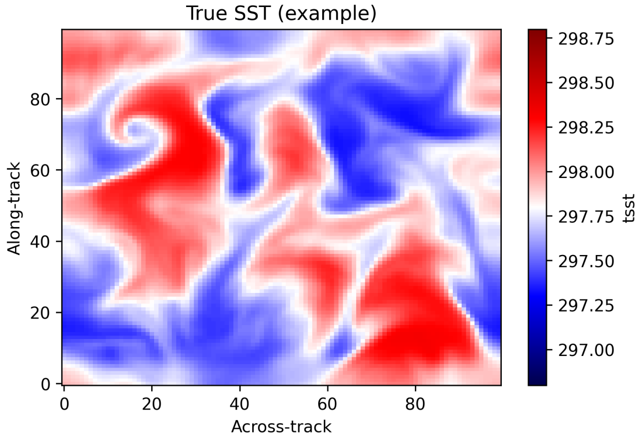
Per-pixel vs. smooth-atmosphere (4 chan)

PerP



Sm.



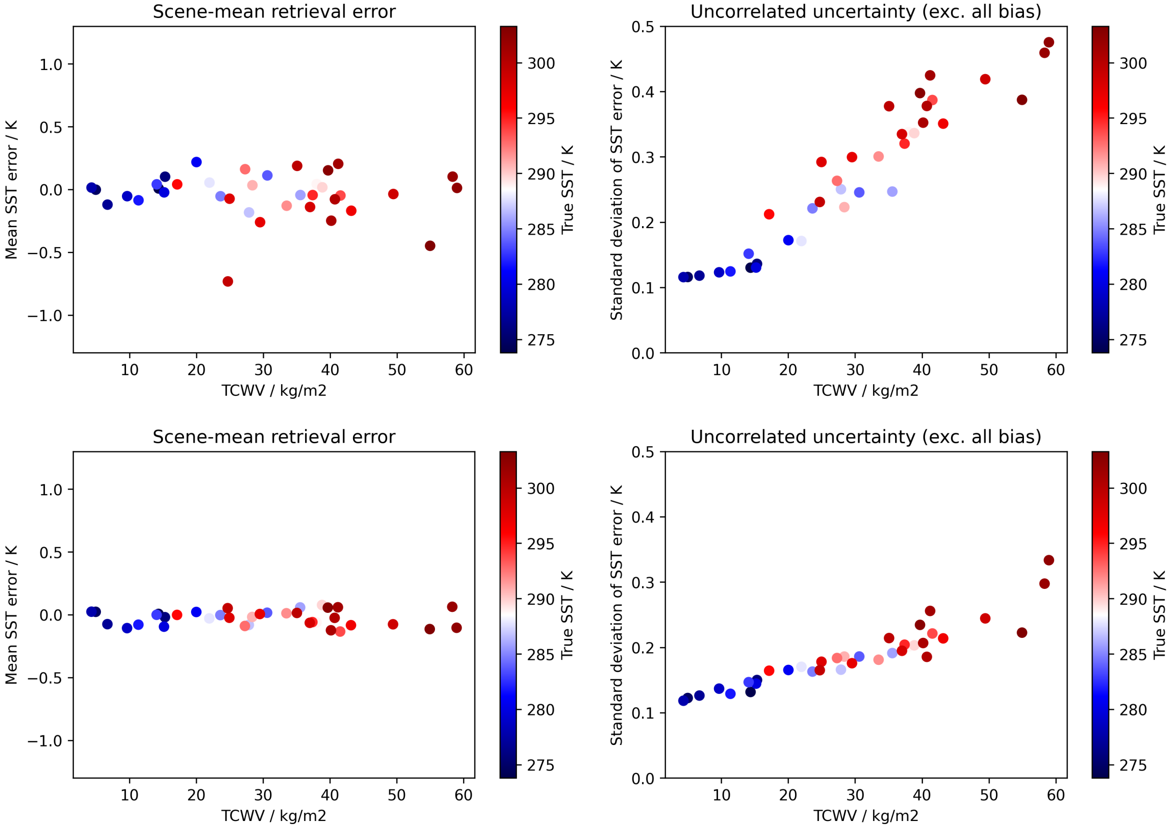


	PerP	Smooth
Scene bias / K	-0.08	-0.02
Scene noise / K	0.29	0.18
Sensitivity K/K	93%	98%

Per-pixel vs. smooth-atmosphere OE (4-chan)

PerP

Sm.

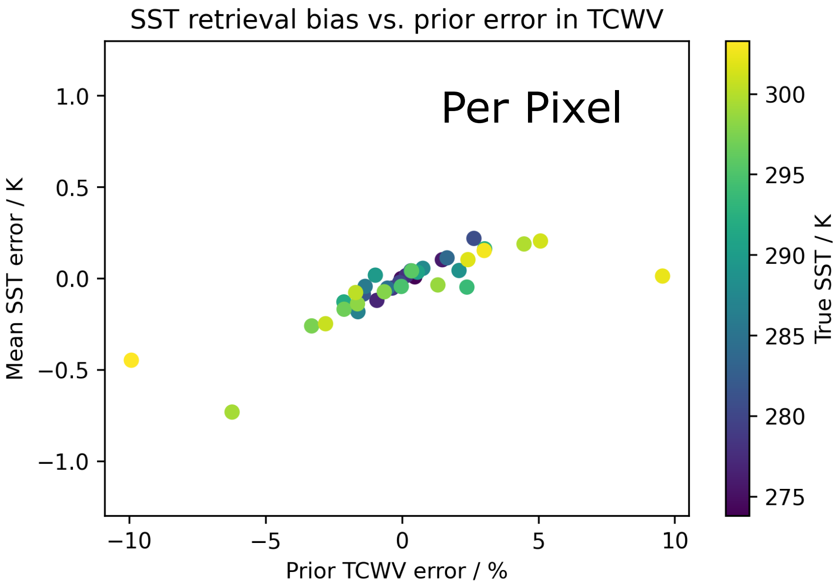


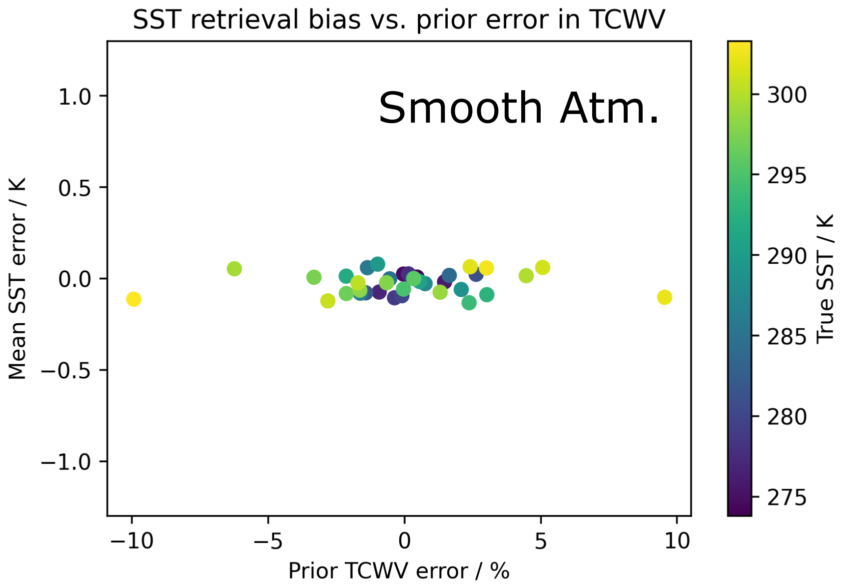
Smooth-atmosph. technique greatly reduces SST noise (right)

Also reduces scene-mean biases (left)

Why smooth OE improves BIAS as well as noise

- Smoothing out retrieved water-vapour fluctuations will obviously help noise.
- It also reduces bias associated with prior WV error.





Scene-mean (no-calibration-error) biases.

(NB. this bias improvement effect does not occur with Harris-96 atmospheric correction smoothing.)

Summary

- **Trishna** will be a great opportunity for coastal zone SST
- Both Noise and Calibration Bias will be larger than SST world is used to
- To reduce biases and SST noise to levels useful for SST **requires**:
  - **bias correction**
  - **low-noise algorithms**
- Simulation study of BIAS-AWARE SMOOTH-ATMOSPHERE OPTIMAL ESTIMATION
- Conclusions:
  - **Use all four channels** to reduce noise
  - **SST noise from 0.1 to 0.3 K** (dry to wet locations)
  - **Smooth-atmosphere OE reduces noise** (known) **and bias** (new insight)