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Comparison (of shipborne radiometers) with other in situ measurements

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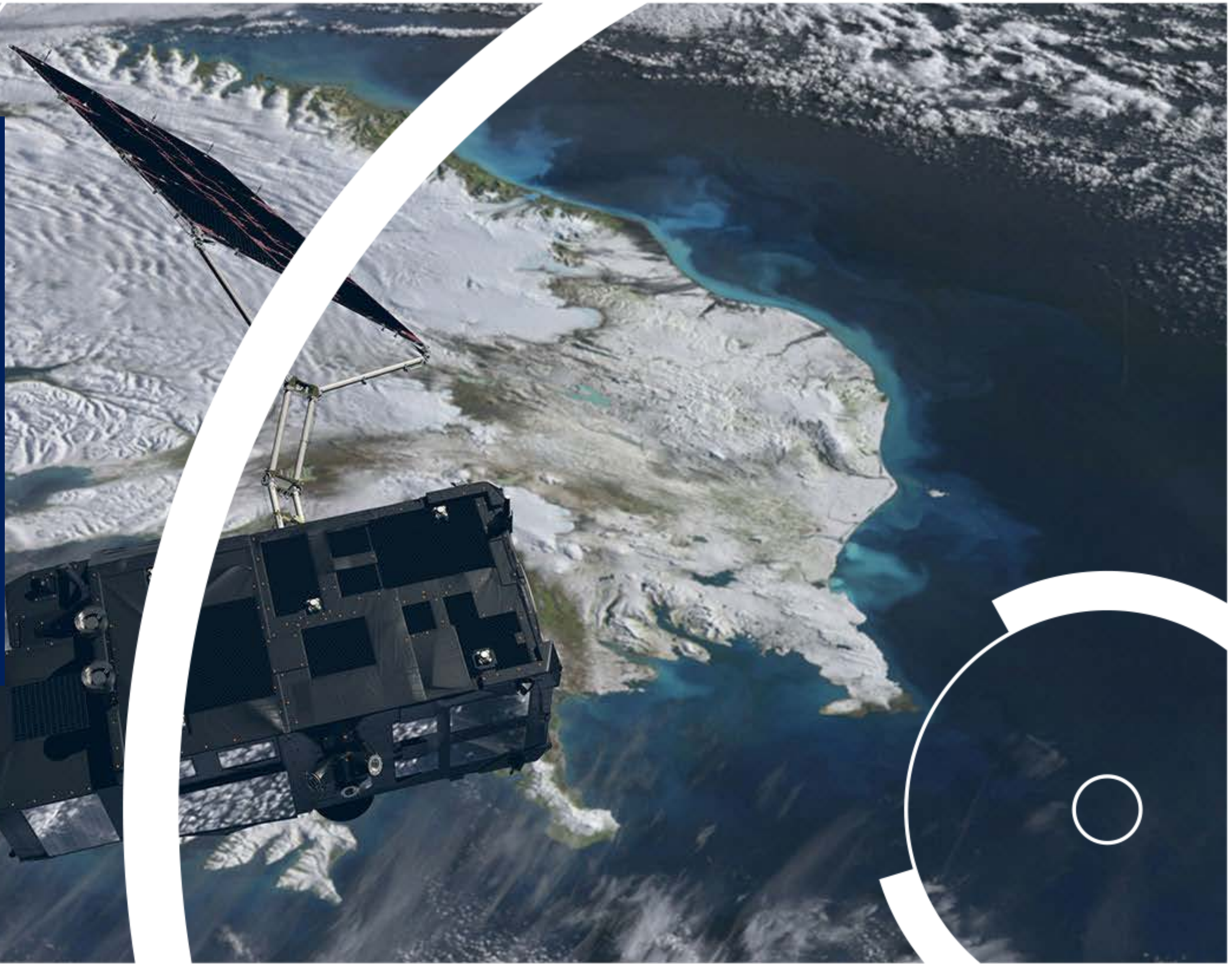
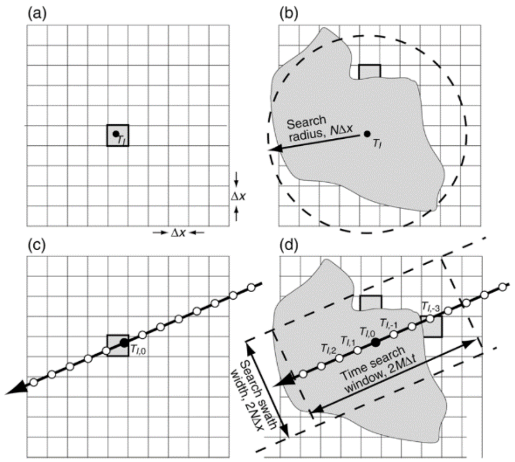


Understanding the problem (1)



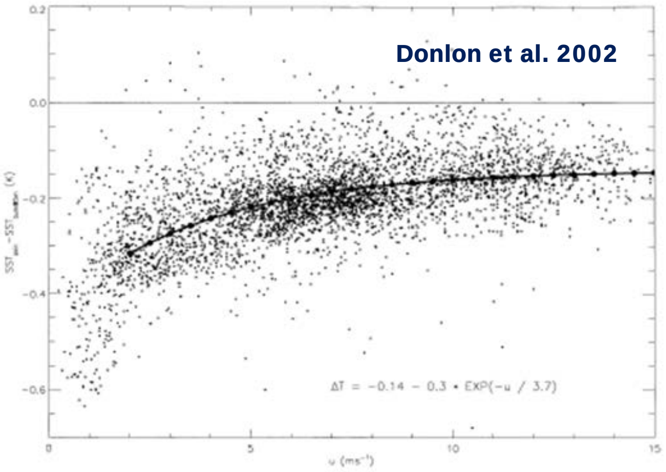
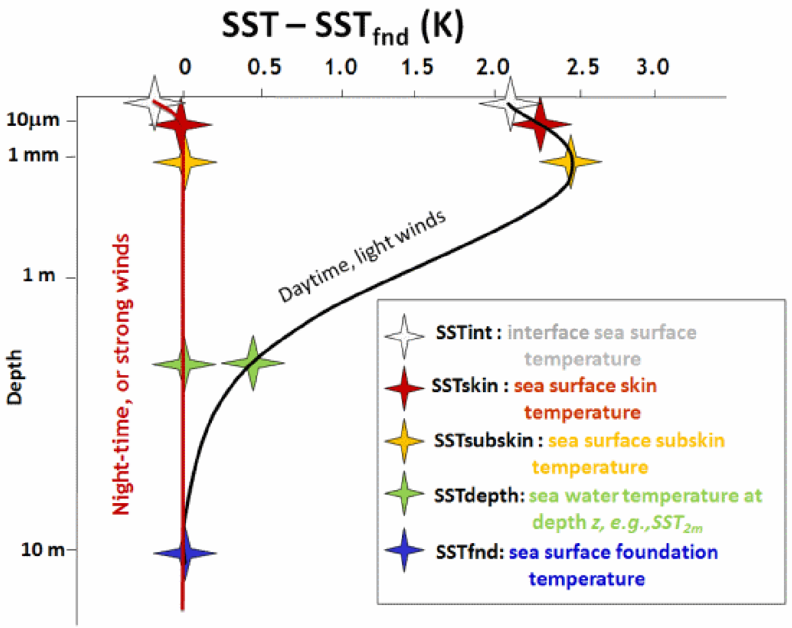
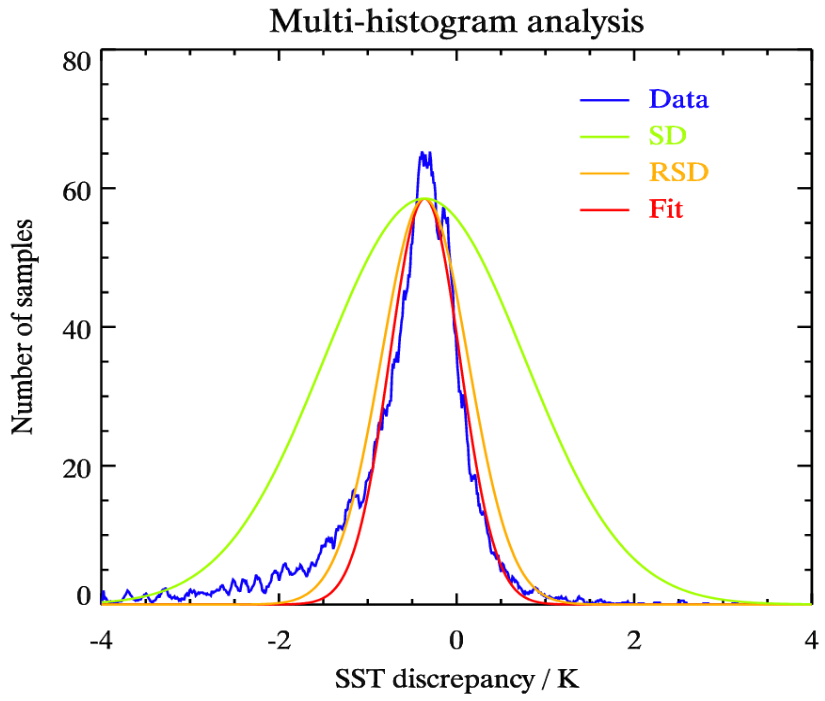


FIG. 5. All nighttime only $\Delta T_{depth\ 5\ m}$ data (as shown in Fig. 4) plotted as a function of wind speed.



Understanding the problem (2)



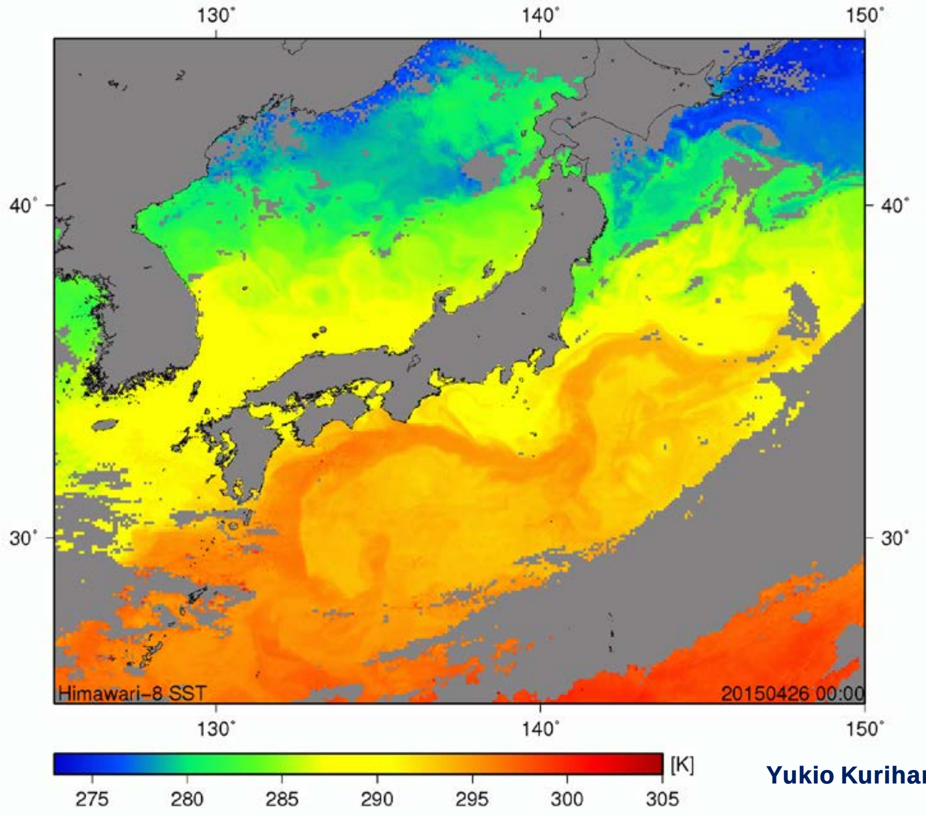
- Assessment of uncertainty of satellite measurements involves comparison to a reference dataset
  - Create a dataset of match-up coincidences within predefined spatial and temporal limits
- The bias and standard deviation calculated from such a comparison do not provide the uncertainty of each dataset individually, but are the mean bias and combined uncertainty of a two dataset comparison.
- Consequently, the resulting statistics are often dominated by real changes in the SST that can occur within the predefined spatial and temporal limits.
  - And outliers!
- Defines an upper limit for the uncertainty budget

See also Merchant and Harris (1999)

Validation uncertainty budget

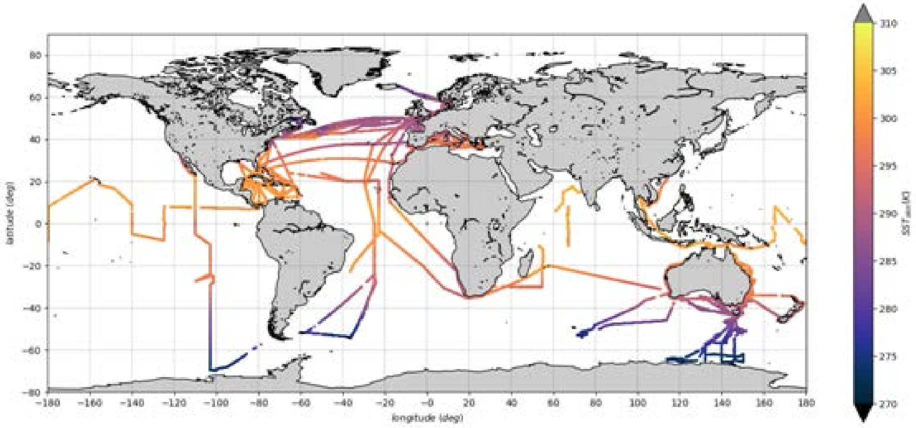
$$\sigma_{Total} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \sigma_4^2 + \sigma_5^2}$$

- Satellite (σ1)
  - Varies pixel by pixel
- Reference (σ2)
  - Generally unknown; Estimate of O(0.1 K) for GTMBA moorings and radiometers; O(0.2 K) for drifters; negligible for Argo
- Geophysical: spatial – surface (σ3)
  - Systematic for single match-up; pseudo-random for large dataset
  - Can be reduced through pixel averaging (e.g. sample 11 by 11 instead of 1 by 1)
  - Includes uncertainty in geolocation (may be systematic even for large numbers)
- Geophysical: spatial – depth (σ4)
  - Systematic for single match-up for different depths; pseudo-random for large dataset at different depths (with diurnal & skin model)
- Geophysical: temporal (σ5)
  - Systematic for single match-up; may be reduced for large dataset (if match-up window small enough)
  - Can be reduced with diurnal & skin model

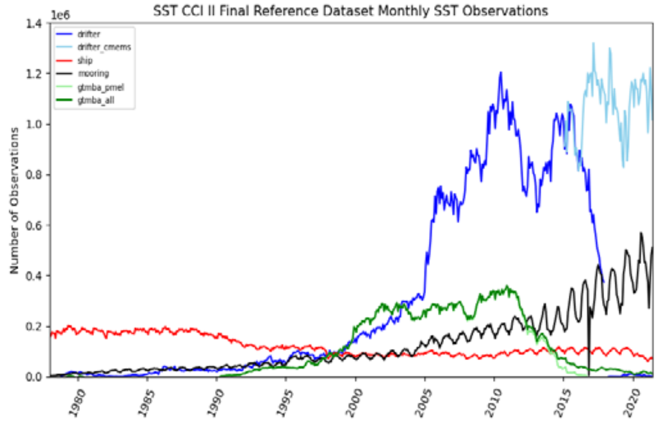


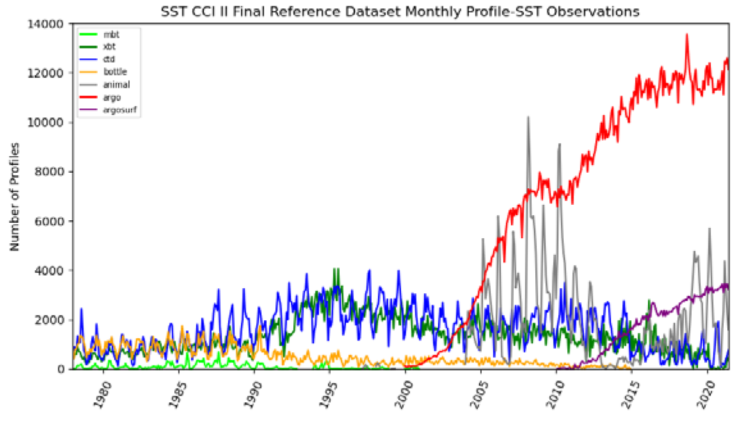
Yukio Kurihara (JAXA)

- Ship-borne radiometers (FRM)
  - Traceable to SI; SST-skin; very-high accuracy; very-poor coverage
  - ISFRN – International Sea Surface Temperature (SST) Fiducial Reference Measurement (FRM) Radiometer Network
- Drifting buoys
  - Variable calibration; global data; SST-depth; good coverage in recent decade(s)
  - GHRSST/DBCP HRSST initiative
  - Copernicus TRUSTED buoys (towards FRM)
- Argo near-surface (FRM-ish)
  - Global; acceptable sampling; very-low uncertainty (calibration method to be analysed)
- GTMBA
  - Better calibration; SST-1m; acceptable coverage (influenced by data collection);
- Everything else...



https://ships4sst.org/

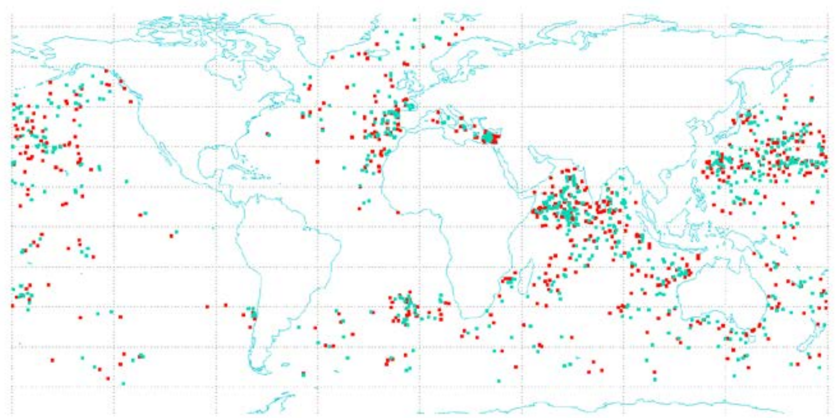




https://www.metoffice.gov.uk/hadobs/hadiod/sirds.html

See also Minnett and Corlett (2012)

The geophysical limit



- Argo 4 m depth SST
- Matched with AATSR
- Only matches with wind speed > 6 ms-1 used

- Nearest (in time and space) match with drifting buoy also found
  - Argo vs. AATSR: σ = 0.15 K
  - DB vs. AATSR: σ = 0.25 K

AATSR N3 (D3) uncertainty = 0.15 (0.27) K
DB uncertainty = 0.2 K
Argo uncertainty = 0.005 K
Geophysical uncertainty = 0.1 K (1-km; +/- 2 hours)

- Geophysical (point to pixel) variability is 0.1 K (upper limit)

- Implied DB uncertainty excluding geophysical effects is 0.20 K (lower limit)

Accounting for geophysical inter-relationships

- To use drifting buoys to validate satellite SSTs we need to estimate drifter SST-skin at time of satellite overpass
  - Take raw drifter measurement at depth (currently assume 20 cm)
    - *"Skin-raw"*
  - Adjust SST-depth to SST-skin at drifter measurement time using model of skin effect and diurnal stratification
  - Adjust to SST-skin at satellite measurement time using same model of skin effect and diurnal stratification
    - *"Skin-skin"*
- So we not only need to validate SSTs, but also skin-to-depth models
- Current model used is combination of Fairall et al. (1996) for skin effect, and Kantha and Clayson (1994) for diurnal stratification (referred to as FKC)

Copernicus Sentinel 3 SST

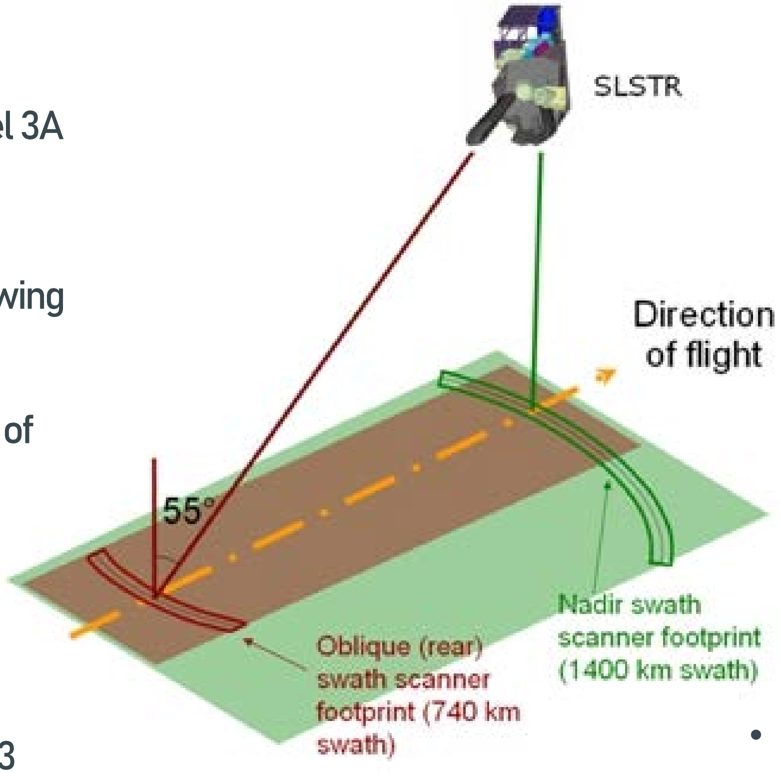
- The first Sea and Land Surface Temperature Radiometer (SLSTR) was launched on Sentinel 3A on 16th February 2016.
  - Sentinel 3B launched on 26 the April 2018
- Dual-view self-calibrating IR radiometer following the ATSR class of sensors
- SST Retrievals by radiative transfer modelling of the form:

$$a_0 + \sum_{1}^{n} a_n BT_n$$

where n is the number of channels

- For SLSTR we use 2 channels during day and 3 during night
  - 3.7 µm not used during day owing to solar contamination
  - We have two views, so we have four SST retrievals in total

SLSTR provides SST_{skin}



SLSTR-A
Operational since 05/07/2017

SLSTR-B
Harmonized to SLSTR-A using SSES
Operational since 12/03/2019

Nominal Channel Centre	Primary Application
S7: 3.7 µm	SST Retrieval
S8: 11 µm	SST/LST Retrieval
S9: 12 µm	SST/LST Retrieval

Four Possible Retrievals:

Nadir 2-channel N2
Nadir 3-channel N3
Dual 2-channel D2
Dual 3-channel D3

- WCT
  - This product provides sea surface temperature for all offered retrieval algorithms.
- **WST**
  - **This product provides the best SST at each SLSTR location in GHRSST L2P format.**

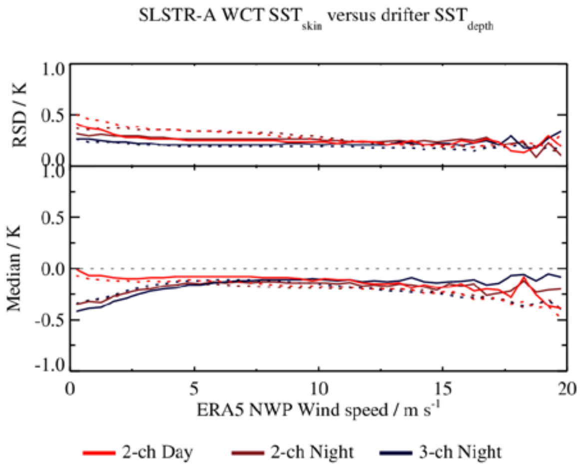
http://slstr.eumetsat.int

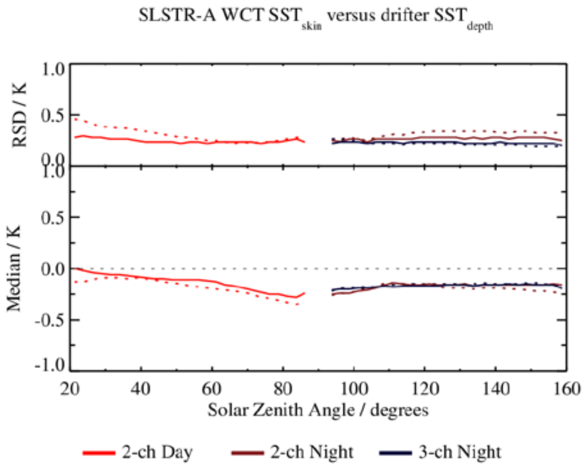
SLSTR MDBs

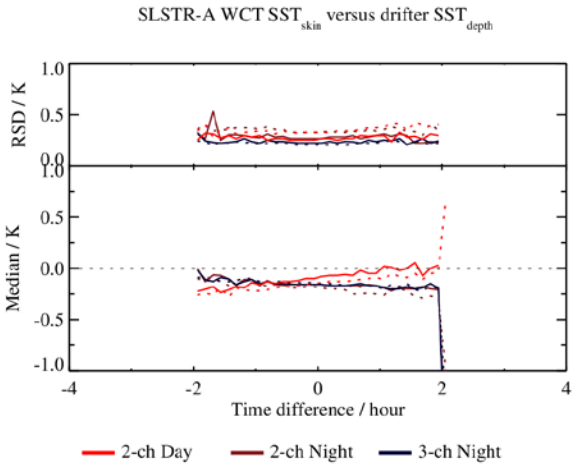
- Main component in SLSTR SST validation
  - Matchups between satellite and in situ data (felyx)
  - Satellite: SLSTR-A/B, AVHRR-B, IASI-B, VIIRS-NPP
  - In situ: drifters, Argo, moored, trusted, **radiometers**
- MDB access: sftp://s3calval.eumetsat.int
  - Available to Sentinel-3 Validation Team (S3VT)
    - To become S3VT member please submit proposal (s3vt.org) and request access to SLSTR MDB
- Revised radiometer dataset (ship4sstr1i1)
  - Repro MDB: 2016/04-2018/04 (full)
  - NRT MDB: 2018/04 – 2018/12 (S3A)
  - Completed 2019 (core) + 1st half 2019 (aux: WCT/MET) (full aux until Oct 2022)
  - 2020: in progress – for Q1 2023 (waiting for new SLSTR MDB version + data access)

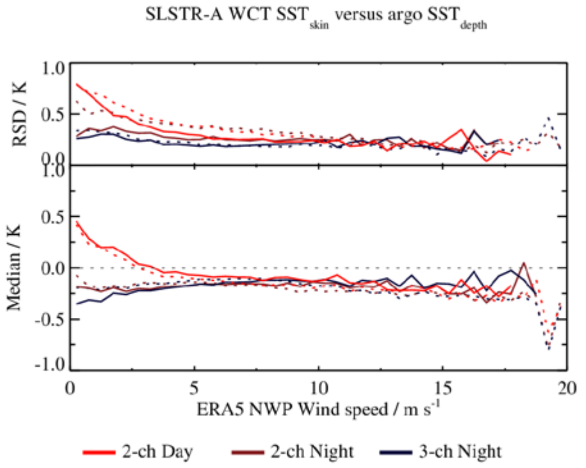
Validation results – “raw” drifter and Argo

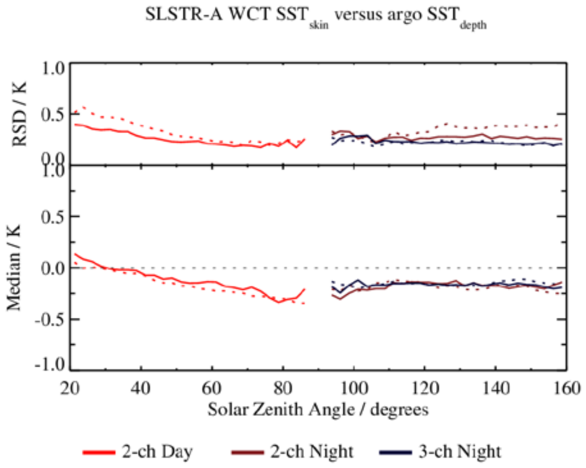
Drifter match-ups (top row) and Argo matchups (bottom row)

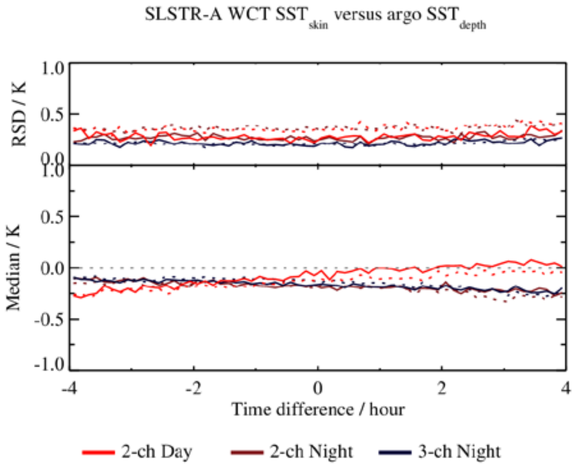








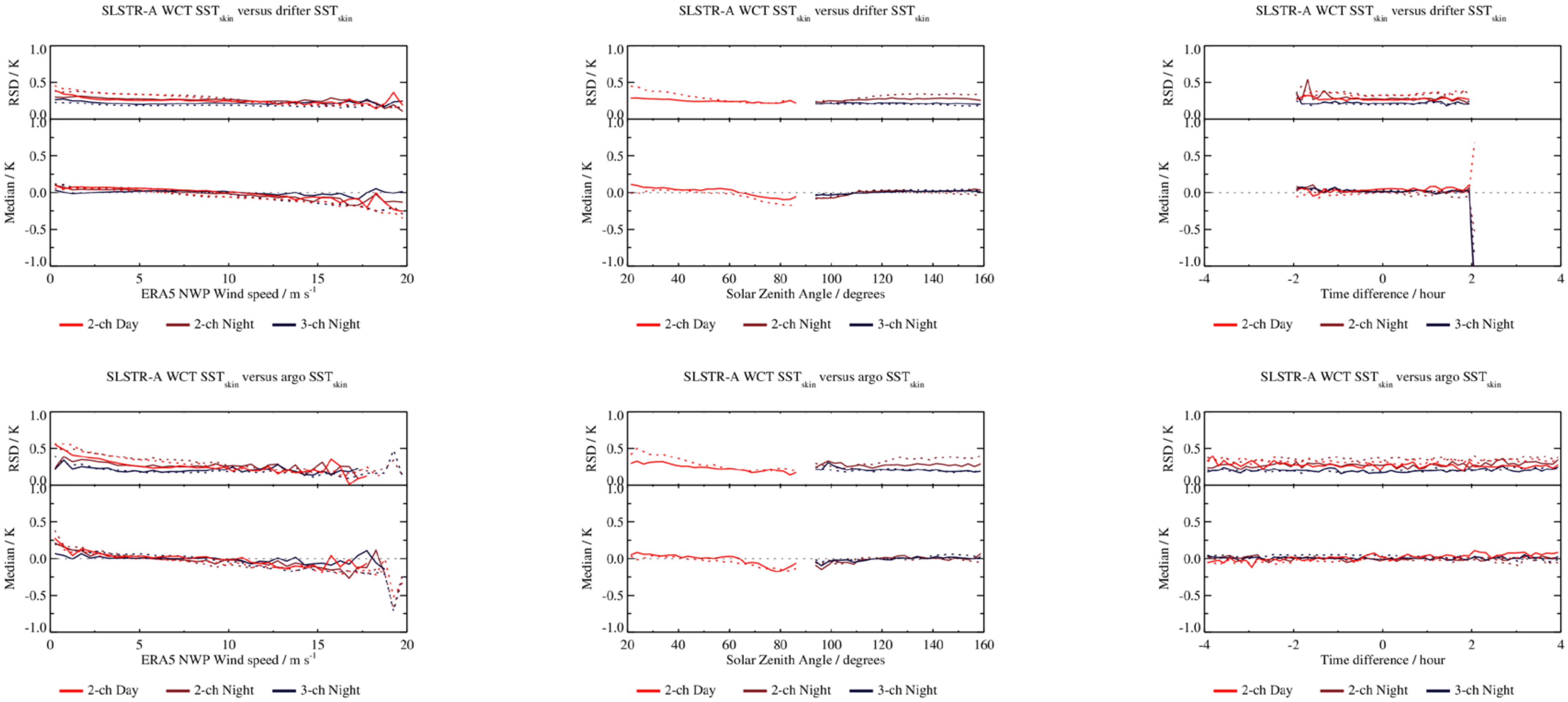




Colours show number of channels; solid lines indicate dual-view; dashed lines indicate nadir-only.

Validation results – drifter and Argo with FKC adjustments

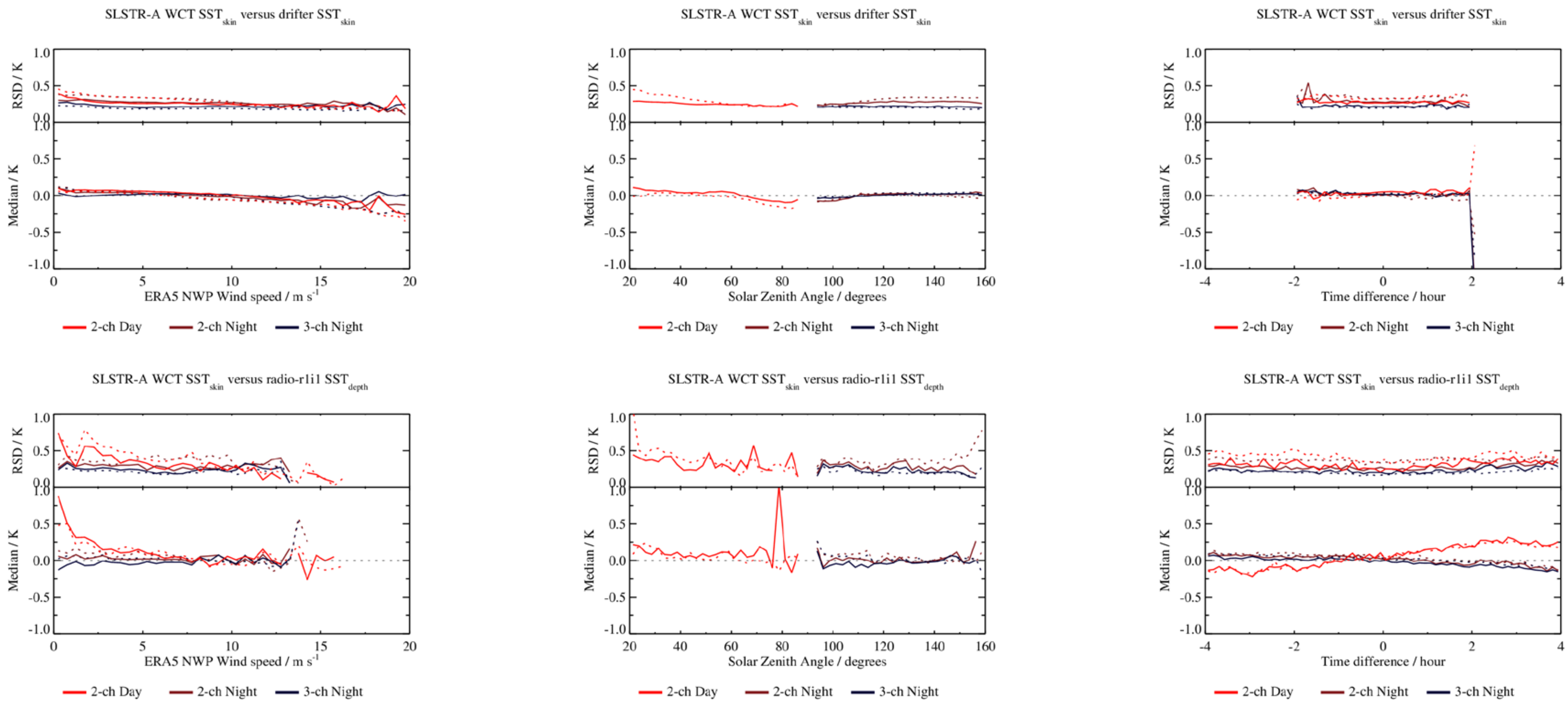
Drifter / FKC match-ups (top row) and Argo / FKC matchups (bottom row)



Colours show number of channels; solid lines indicate dual-view; dashed lines indicate nadir-only.

Validation results – Compare drifter/FKC and radiometer

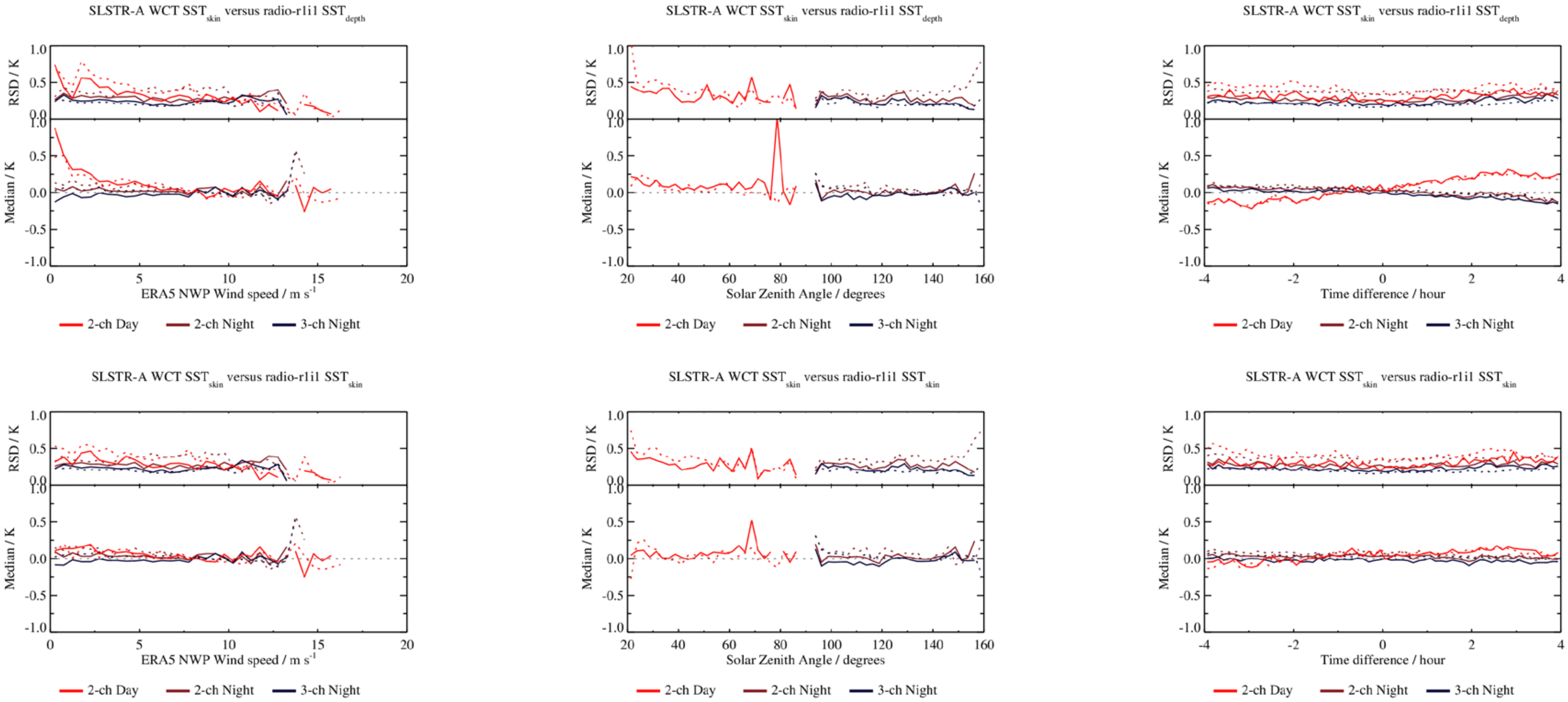
Drifter / FKC match-ups (top row) and radiometer matchups (bottom row)



Colours show number of channels; solid lines indicate dual-view; dashed lines indicate nadir-only.

Validation results – Compare radiometer/FKC and radiometer

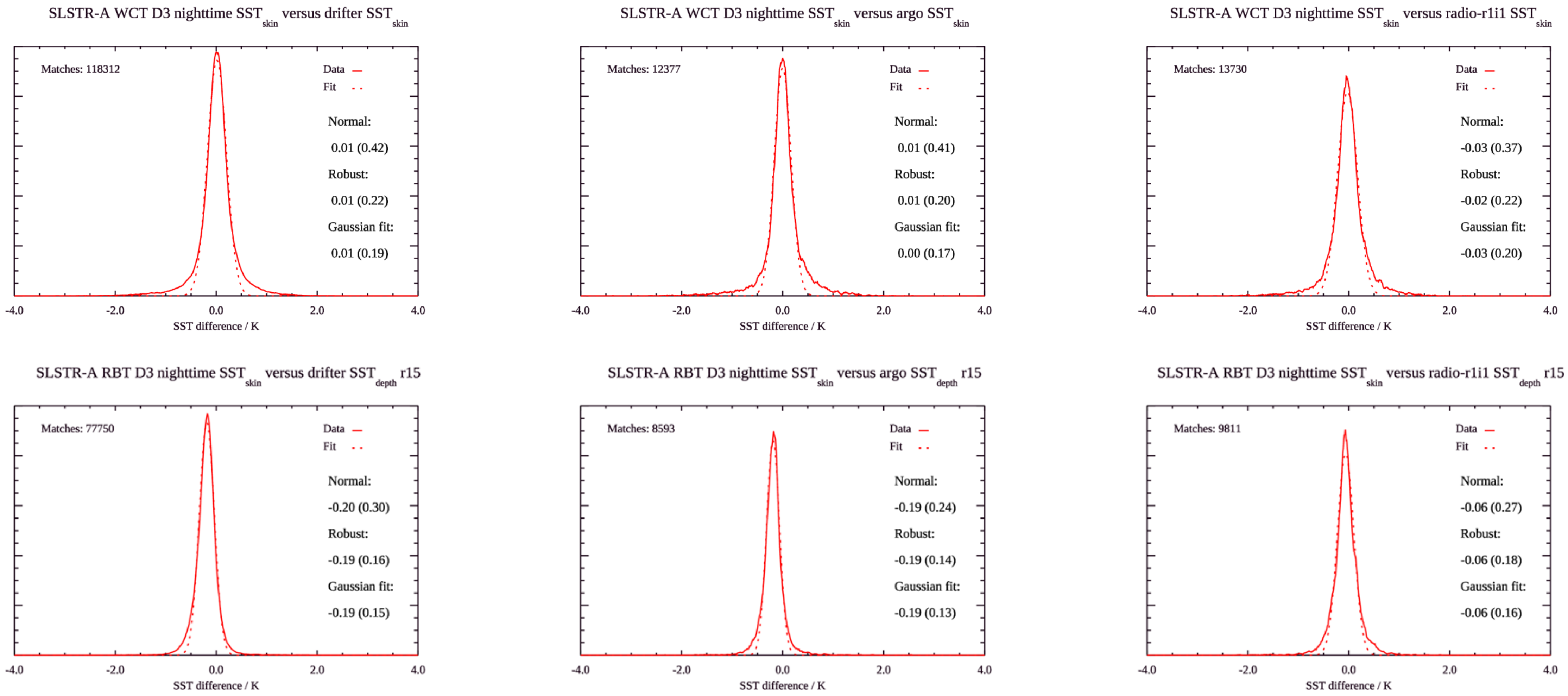
Radiometer match-ups (top row) and radiometer / FKC matchups (bottom row)



Colours show number of channels; solid lines indicate dual-view; dashed lines indicate nadir-only.

Validation results – histograms

Single pixel match-ups (top row) and spatially averaged (5 x 5) match-ups (bottom row)



Colours show number of channels; solid lines indicate dual-view; dashed lines indicate nadir-only.

Summary

- Satellite radiometers such as SLSTR can provide SSTskin to an accuracy better than 0.1 K
- SLSTR does provide a measure of SSTskin
  - Confirmed through independent validation using data from multiple in situ sources / depths
- SLSTR continues to provide high-quality dual-view SSTs as a reference sensor
  - New SST coefficients being evaluated for implementation this autumn
- Demonstrating this requires a thorough understanding of the physics of the atmosphere and the upper ocean
  - Multiple measurement sources, models and methods are needed
- New generation in situ (FRM) are required to support SSTskin validation
  - To identify geophysical effects from retrieval effects
- Continuity of SSTskin FRM is essential to maintain long-term SST records
  - As is continuity of drifter, Argo and mooring records as well – we need an integrated observing system

Acknowledgments:

Chris Merchant, Owen Embury, Chris Atkinson, Jean-Francois Piolle, Yukio Kuirihara, and of course all the radiometer PIs!

Thank you!

Questions are welcome.