# ESA Climate Change Initiative Phase-II

# Sea Surface Temperature (SST)

www.esa-sst-cci.org

# Uncertainty validation

**Gary Corlett**

# Introduction

- A key aim of the ESA SST_CCI project is to provide a pixel level standard uncertainty for all products
- A further aim is to validate these product uncertainties using independent measurements
- We hope (expect) users will use the uncertainties in the products and not make their own assessment
- In this presentation we shall look at how we have validated the ESA SST_CCI product uncertainties using match-ups to drifting buoys.
  - Note: The drifting buoys are not totally independent as some match-ups were used in the algorithm selection process. However, the SST_CCI products are not tied to drifting buoys in any way so we use all drifter match-ups as a pseudo-independent dataset.
- The objective of uncertainty validation is to provide confidence that the product uncertainties are realistic with the correct degree of discrimination

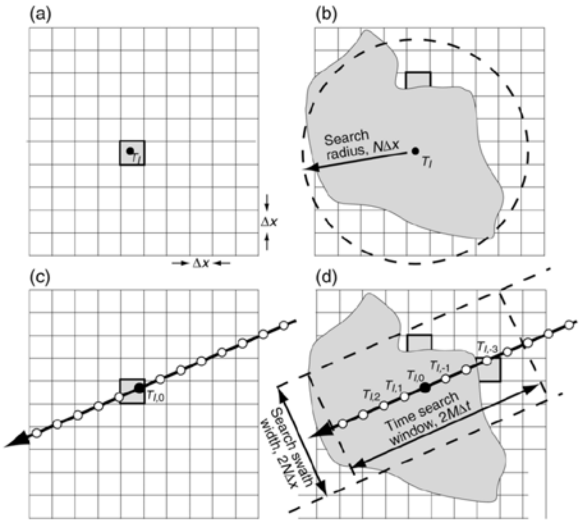
# Some terms

- **Validation**: The process of assessing by independent means the quality of the data products (the results) derived from the system outputs.

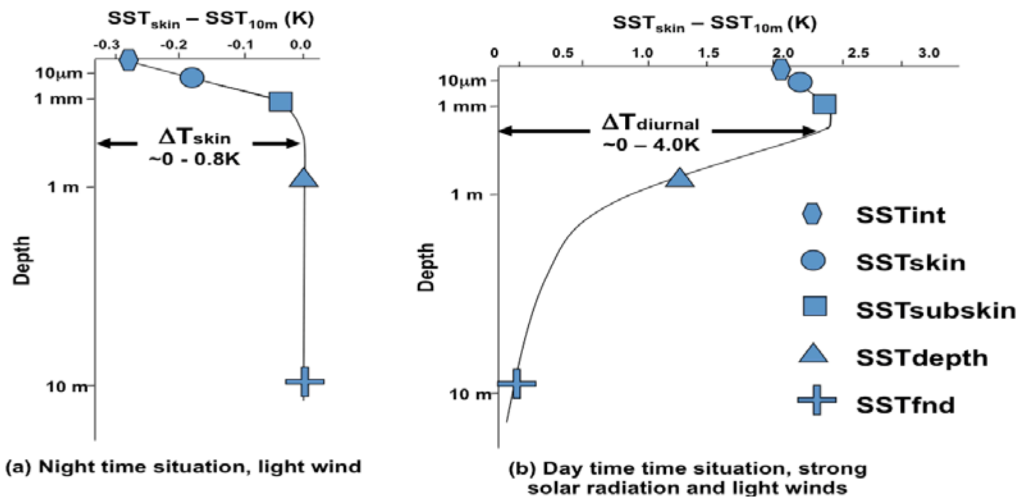
- Classes of validation:
  - Independent reference data: Data not used in algorithm training, test, selection or in product generation
  - Pseudo-independent reference data: Data used in algorithm training, test, selection but not in product generation.

- Types of validation:
  - Type 1 - 'Point': Single pixel comparisons to both class 1 and class 2 reference data
  - Type 2 - 'Grid': e.g. comparisons to HadSST3
  - Type 3 – 'Functional': Knowledge transfer to areas where we have no reference measurements

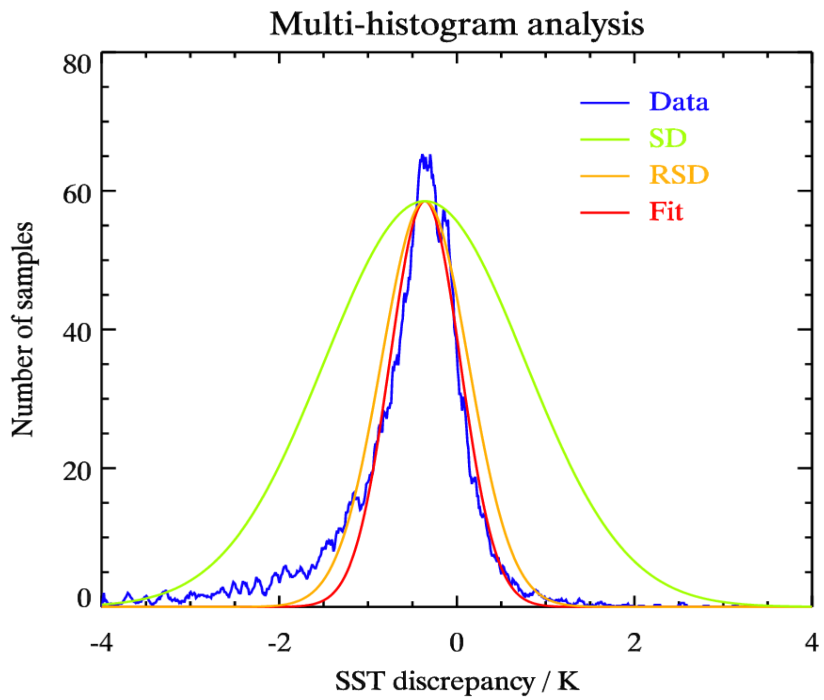
# Understanding the problem (1)








# Understanding the problem (2)




- Assessment of uncertainty of satellite measurements involves comparison to a reference dataset
  - Create 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 simply 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.

# Validation uncertainty budget

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

Satellite ($\sigma_1$)

- Varies pixel by pixel

Reference ($\sigma_2$)

- 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 ($\sigma_3$)

- 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 ($\sigma_4$)

- Systematic for single match-up for different depths; pseudo-random for large dataset at different depths (with diurnal & skin model)

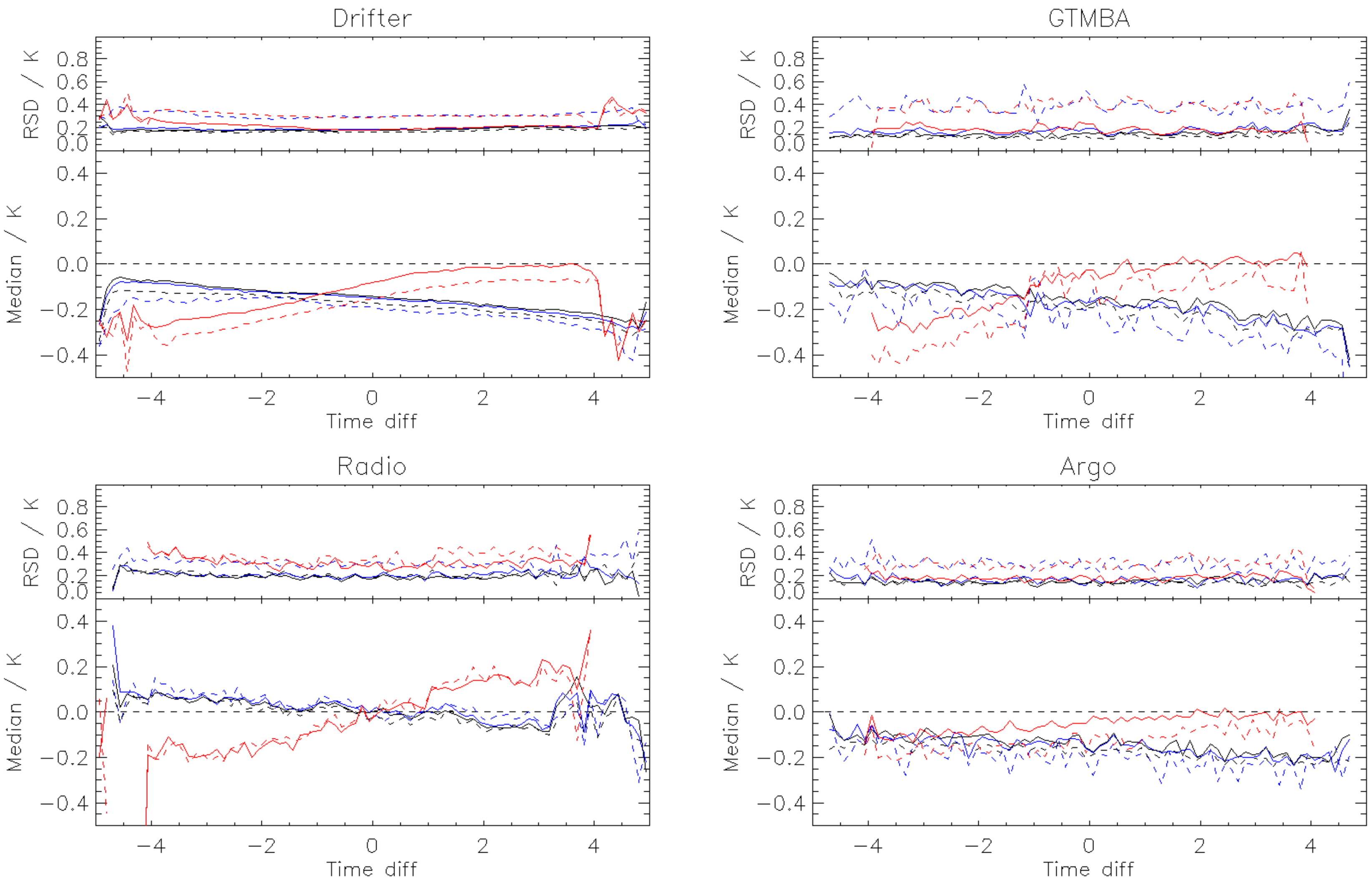
Geophysical: temporal ($\sigma_5$)

- Systematic for single match-up; may be reduced for large dataset (if match-up window small enough)
- Can be reduced with diurnal & skin model

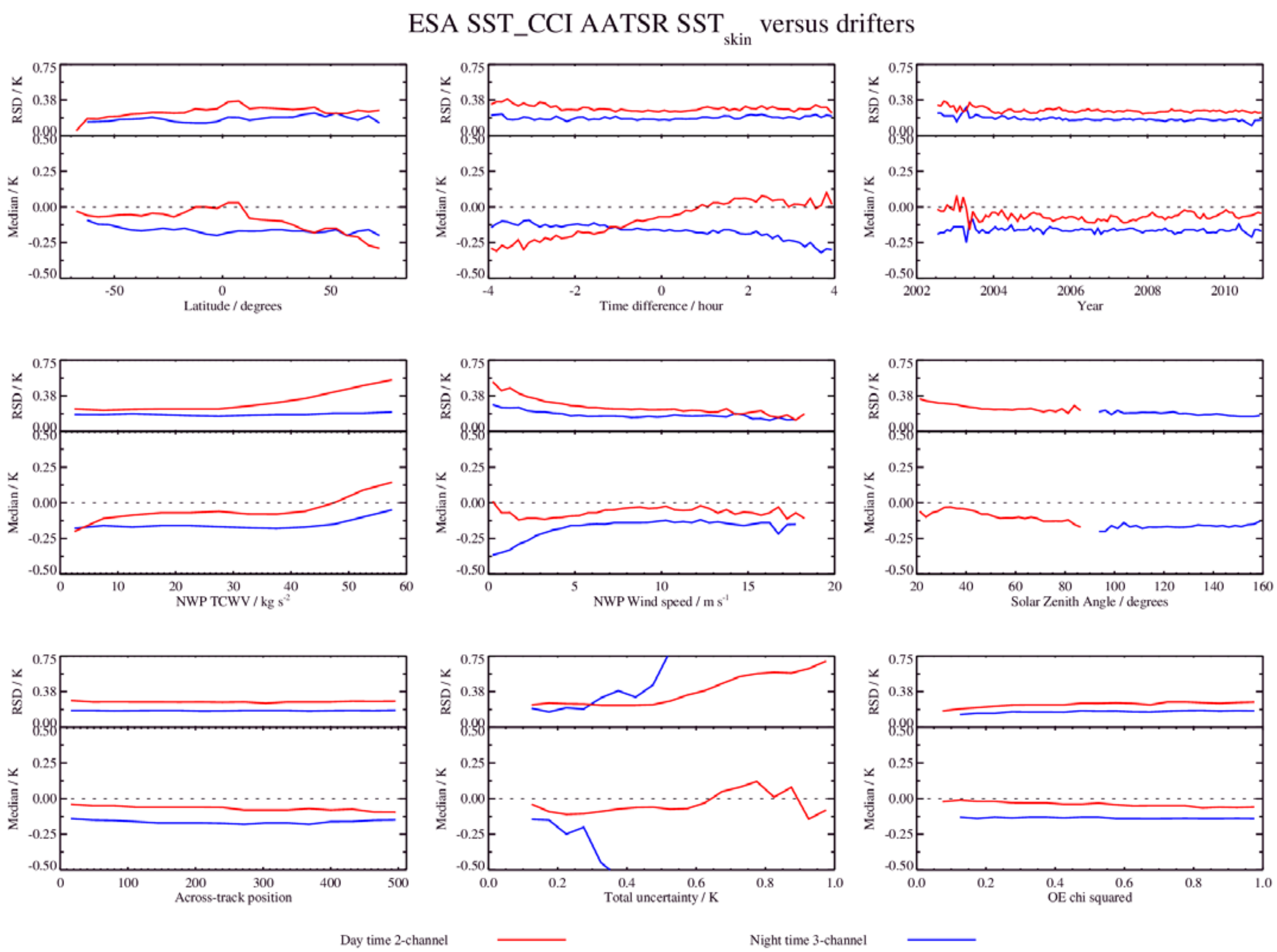
# Reference data for validation (Phase I)

| Data type | Year | Coverage | SST* | Uncertainty |
|---|---|---|---|---|
| Ship-borne IR radiometers | 1998 - | Repeated tracks in the Caribbean Sea, North Atlantic Ocean, North Pacific Ocean, and the Bay of Biscay; episodic deployments elsewhere in the world's oceans. | SSTskin | 0.10 K |
| Argo floats | 2000 - | Global# from ~ 2004 onwards. | SST-5m | 0.05 K |
| GTMBA | 1979 - | Tropical Pacific Ocean array completed in 1998; tropical Atlantic and Indian Ocean arrays installed later. | SST-1m | 0.10 K |
| Drifting buoys | 1991 - | Global# from ~ 2000 onwards. | SST-20cm | 0.20 K |

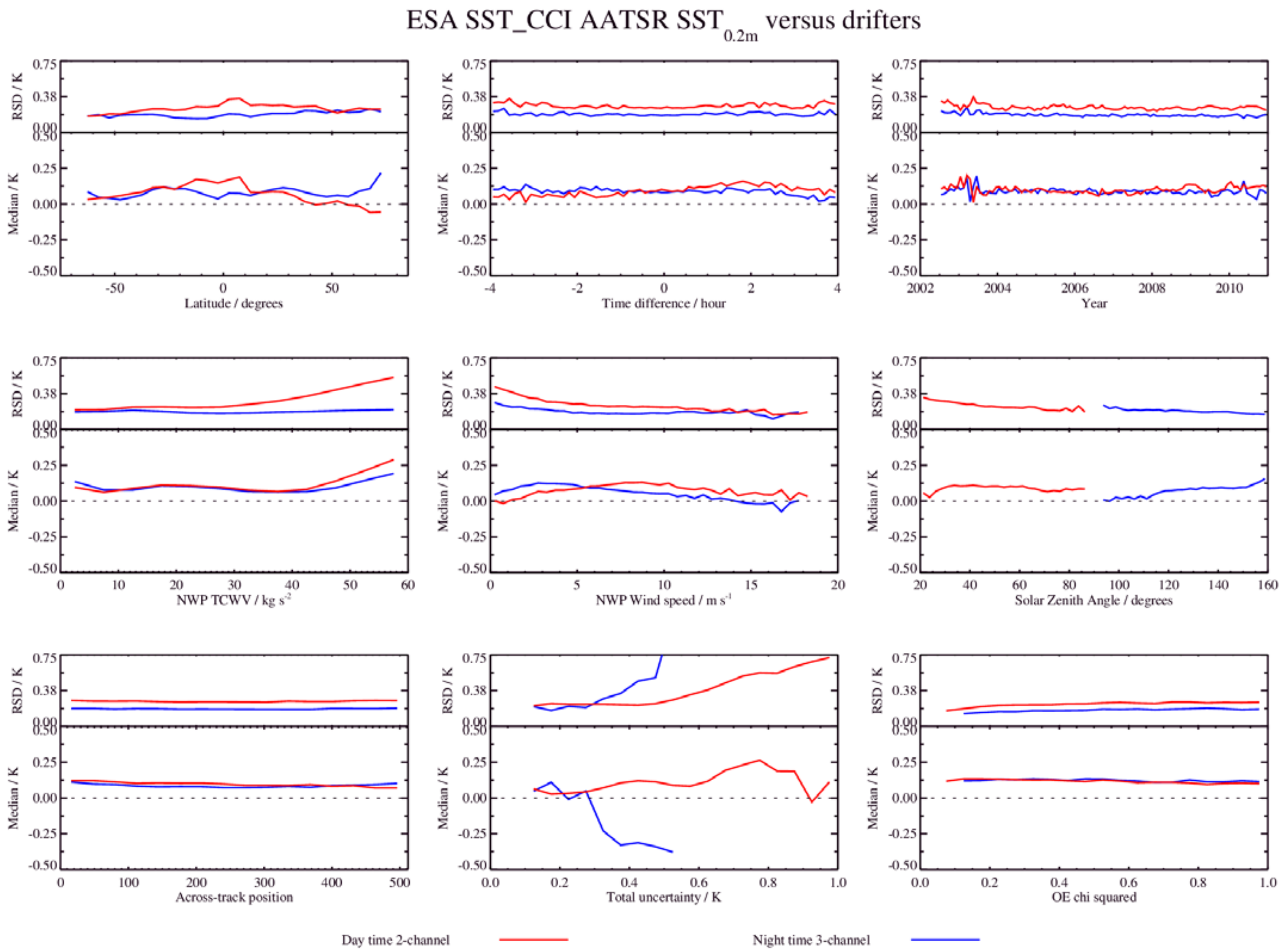
# Adjusting for diurnal variability



# ATSR L3U SST$_{skin}$ validation



# ATSR L3U SST$_{0.2m}$ validation

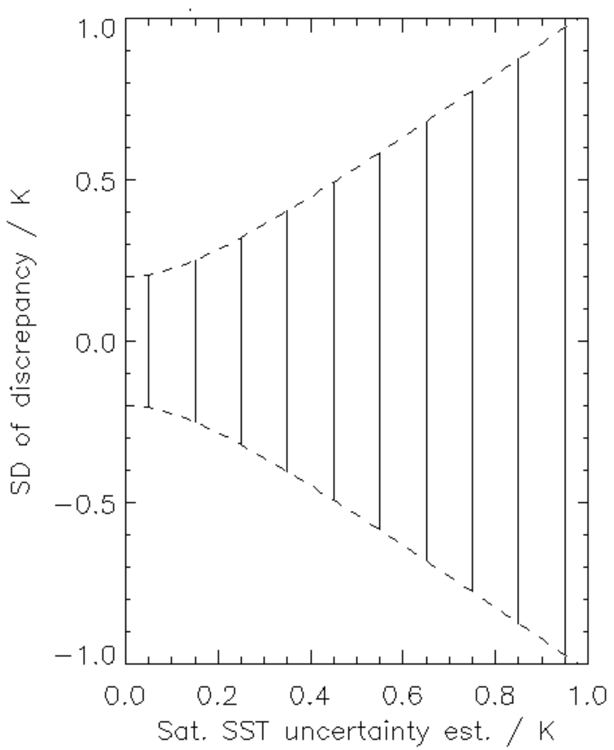


# How to validate uncertainty?

- Example using drifters
- Use mean uncertainty of 0.2 K for $\sigma_2$
- Use large number of match-ups, area averaging and diurnal & skin model to randomise $\sigma_3$ and $\sigma_4$
- Use diurnal & skin model to reduce $\sigma_5$
- Uncertainty budget reduces to:

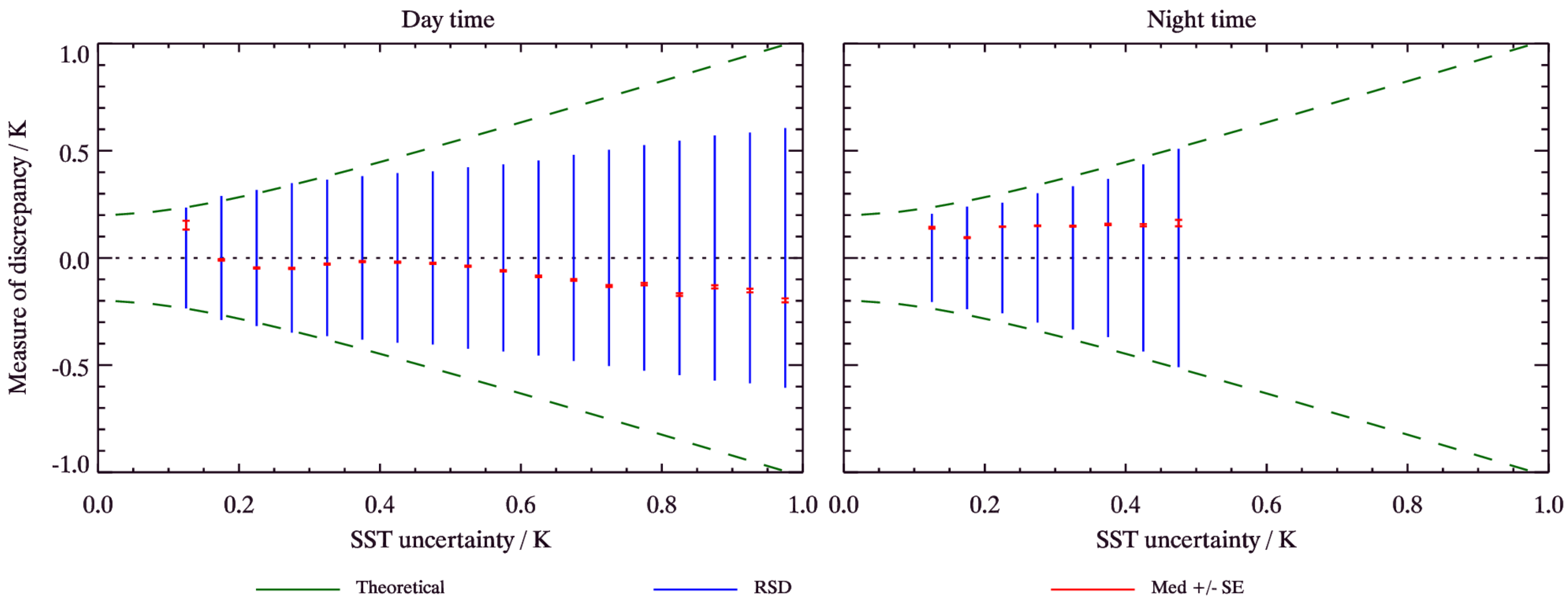
$$\sigma_{sat-ref} = \sqrt{\sigma_{sat}^2 + \sigma_{ref}^2}$$

- Theoretical distribution:

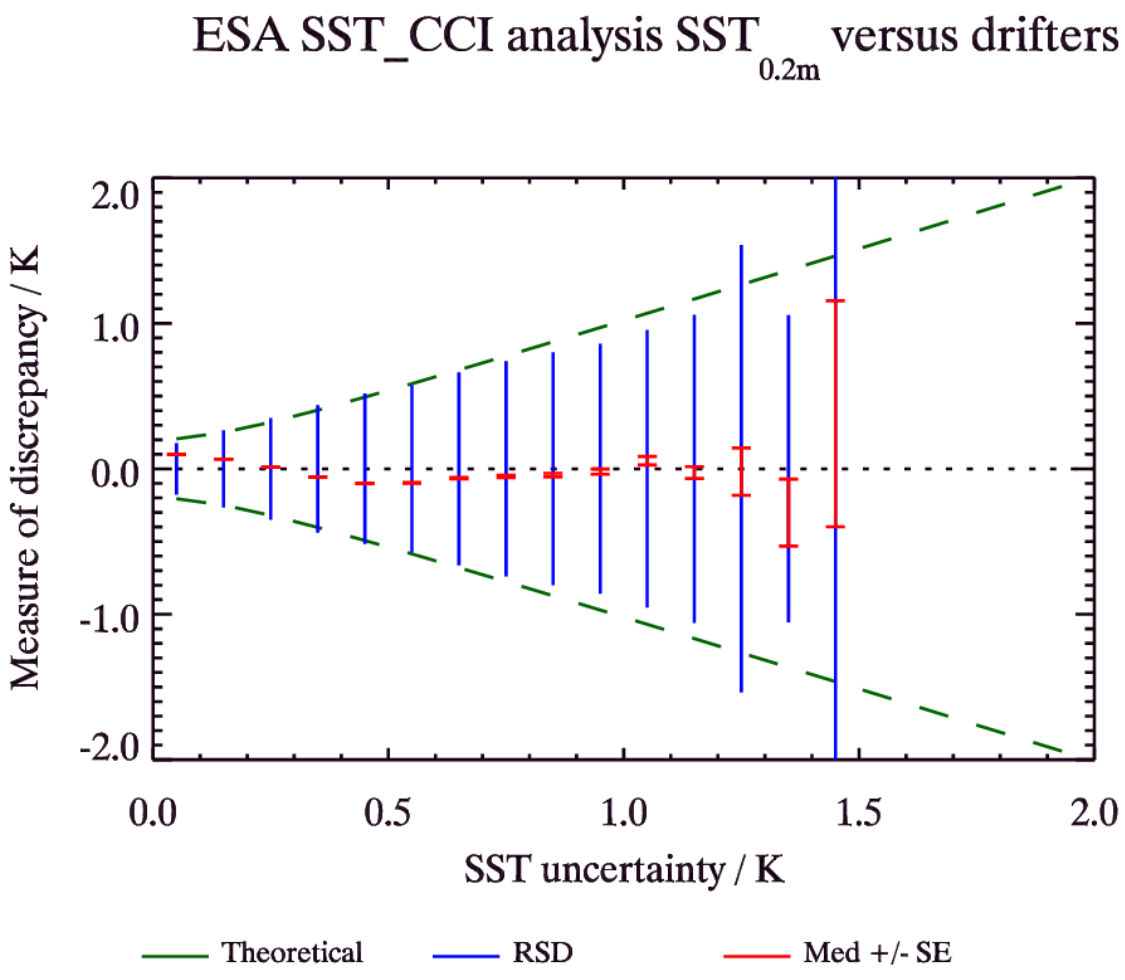


# Results: AVHRR L2P

ESA SST_CCI AVHRR NOAA-18 L2P $SST_{0.2m}$ versus drifters



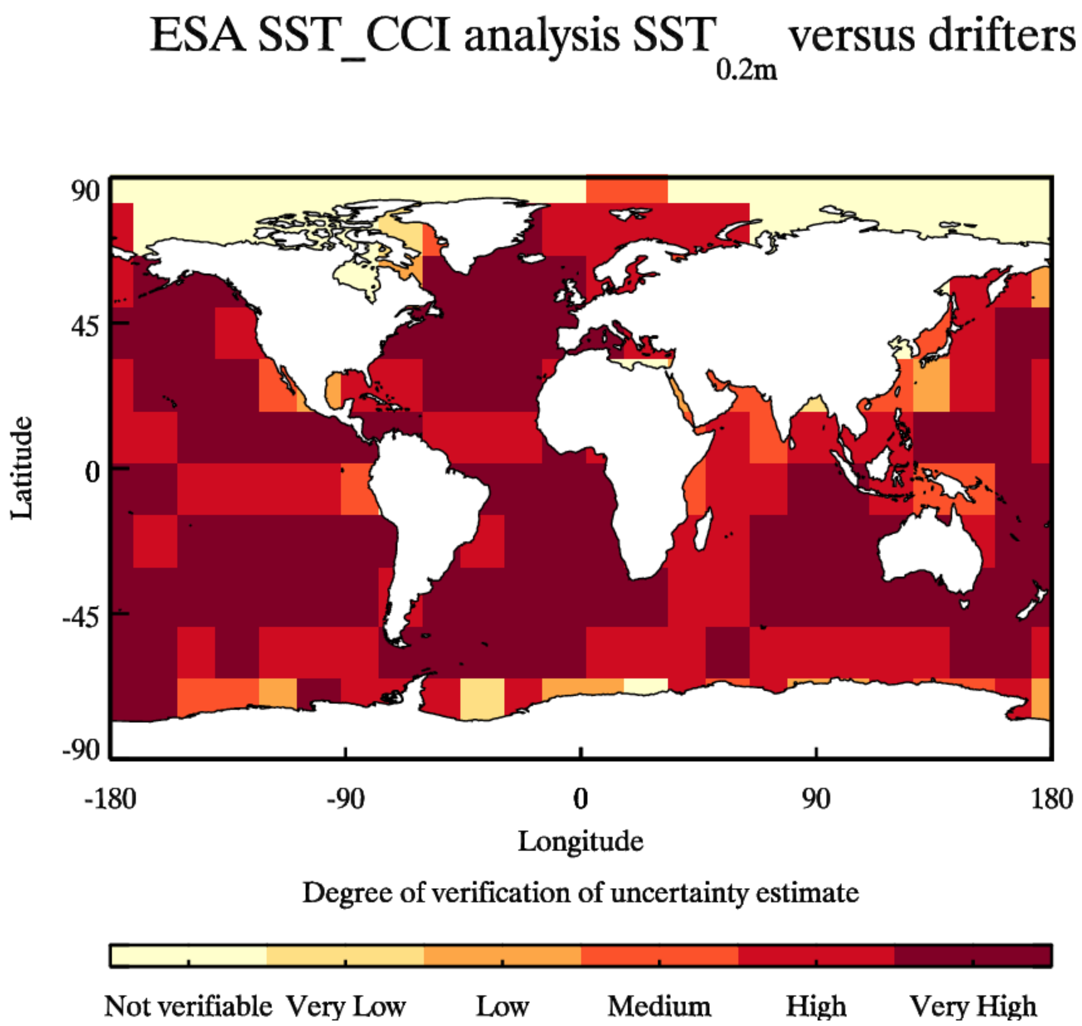
# Results: Analysis L4



# Uncertainty verification

- Important to provide uncertainties for every pixel across entire record
  - Hence use uncertainty model to derive in first place
- However, we cannot validate everywhere owing to limitations in reference data
- But we need to provide some estimate of confidence in product uncertainties at all locations in time
- Try uncertainty verification
  - Very high – uncertainties are confirmed to be within 20% of their quoted values
  - High – uncertainties are confirmed to be within 20% - 40% of their quoted values
  - Medium – uncertainties are confirmed to be within 40% - 60% of their quoted values
  - Low – uncertainties are confirmed to be within 60% - 80% of their quoted values
  - Very low – uncertainties are confirmed to be within 80% - 100% of their quoted values
  - Not verifiable – not possible to independently verify uncertainties
- In Phase II we hope to add 'functional' validation to provide improved confidence in other regions

# Example uncertainty verification: Analysis L4



# Summary

- ESA SST_CCI products contain uncertainties with each SST

- These uncertainties can be validated using *independent* reference data

- Results show uncertainties in V1.0 data are:
  - Good for AVHRR L2P and ATSR L3U night time
    - Less discriminating and over estimated for day time
  - Very realistic and discriminating for analysis L4

- Maps of uncertainty verification
  - To give confidence in product uncertainties everywhere
  - To encourage users to use product uncertainties
  - 'Knowledge transfer' from region to region not yet implemented