ESA Climate Change Initiative Phase-II

Sea Surface Temperature (SST)

www.esa-sst-cci.org

SST_CCI validation

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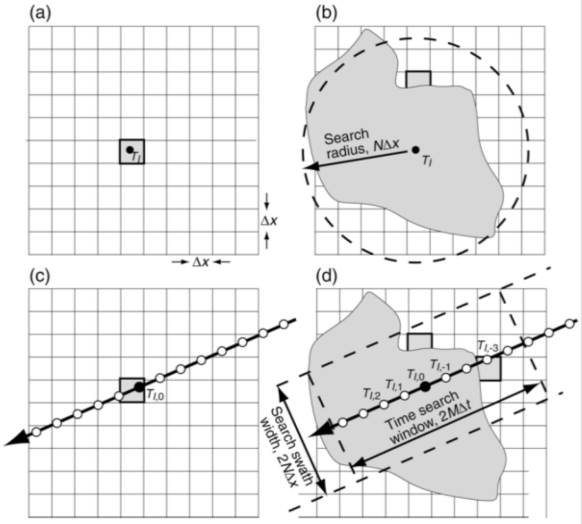
Introduction

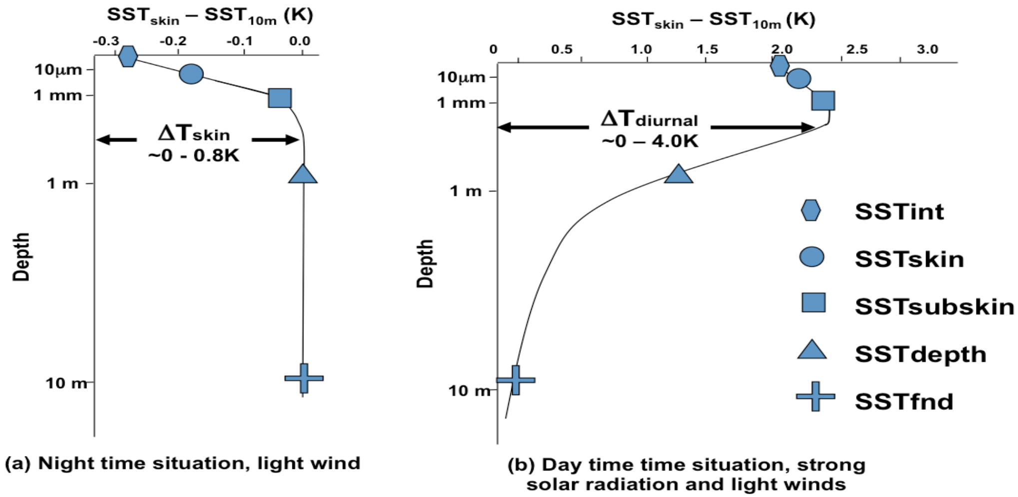
- A key aim of the ESA SST_CCI project is to provide a pixel level standard uncertainty for all products
- A further aim is to validate these product uncertainties using independent measurements
- We hope (expect) users will use the uncertainties in the products and not make their own assessment
- In this presentation we shall look at how we have validated the ESA SST_CCI products and their uncertainties

Some terms

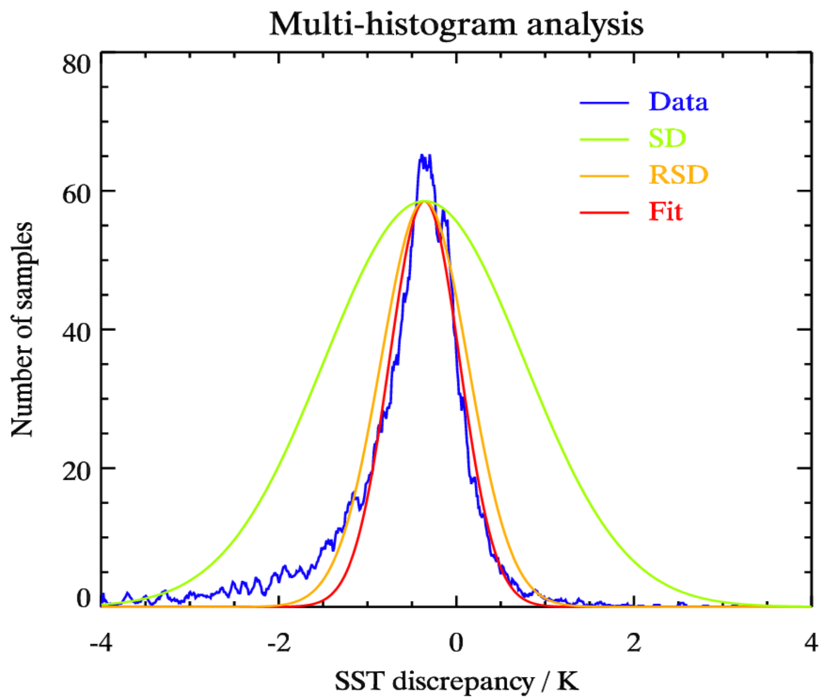
- **Validation**: The process of assessing by independent means the quality of the data products (the results) derived from the system outputs.
- **Classes of validation**:
  - Independent reference data: Data not used in algorithm training, test, selection or in product generation
  - Pseudo-independent reference data: Data used in algorithm training, test, selection but not in product generation.
- **Types of validation**:
  - Type 1 - 'Point': Single pixel comparisons
  - 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

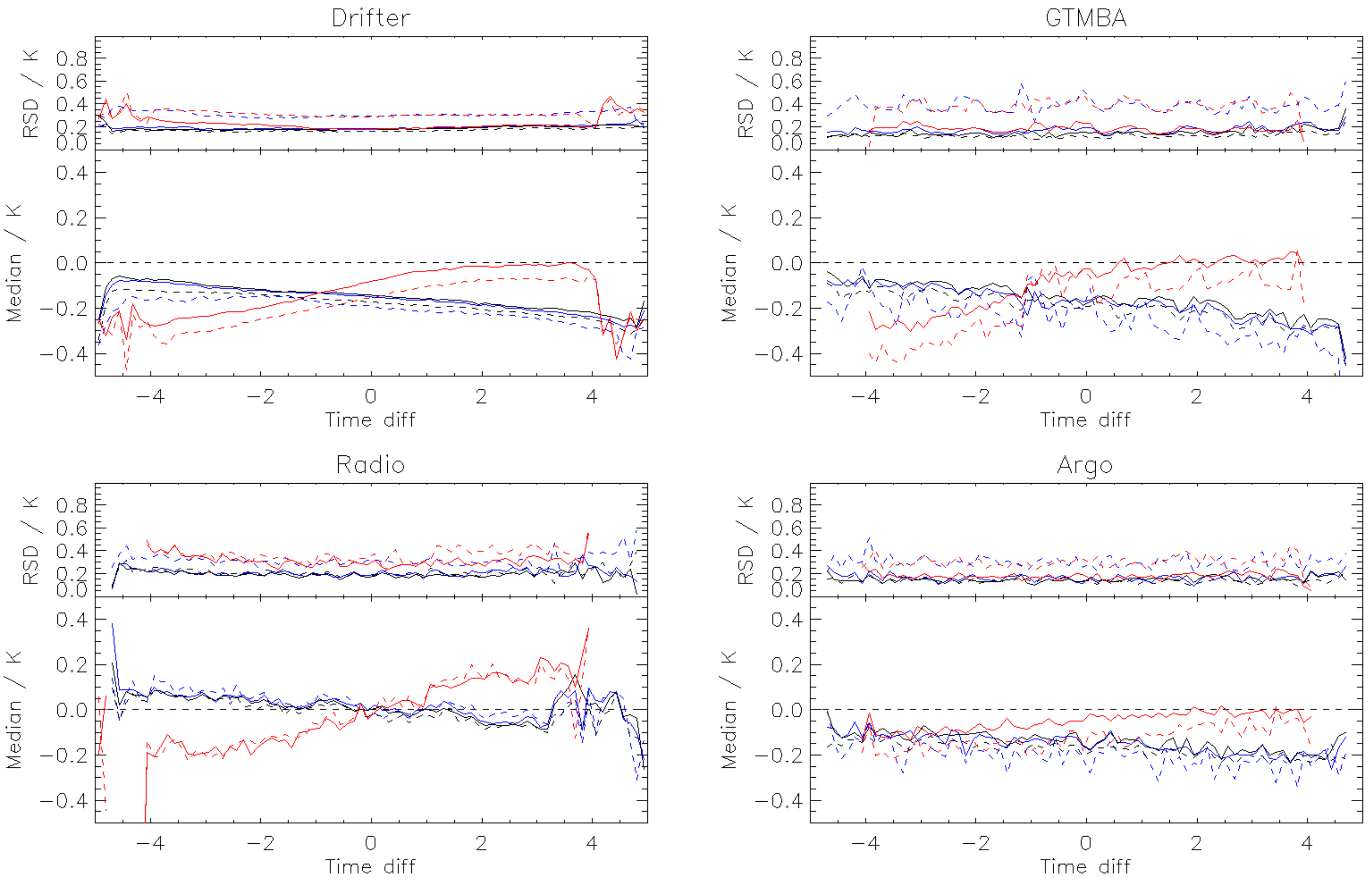
$$\sigma_{Total} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \sigma_4^2 + \sigma_5^2}$$

- Satellite (σ_1)
  - Varies pixel by pixel
- Reference (σ_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 (σ_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 (σ_4)
  - Systematic for single match-up for different depths; pseudo-random for large dataset at different depths (with diurnal & skin model)
- Geophysical: temporal (σ_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

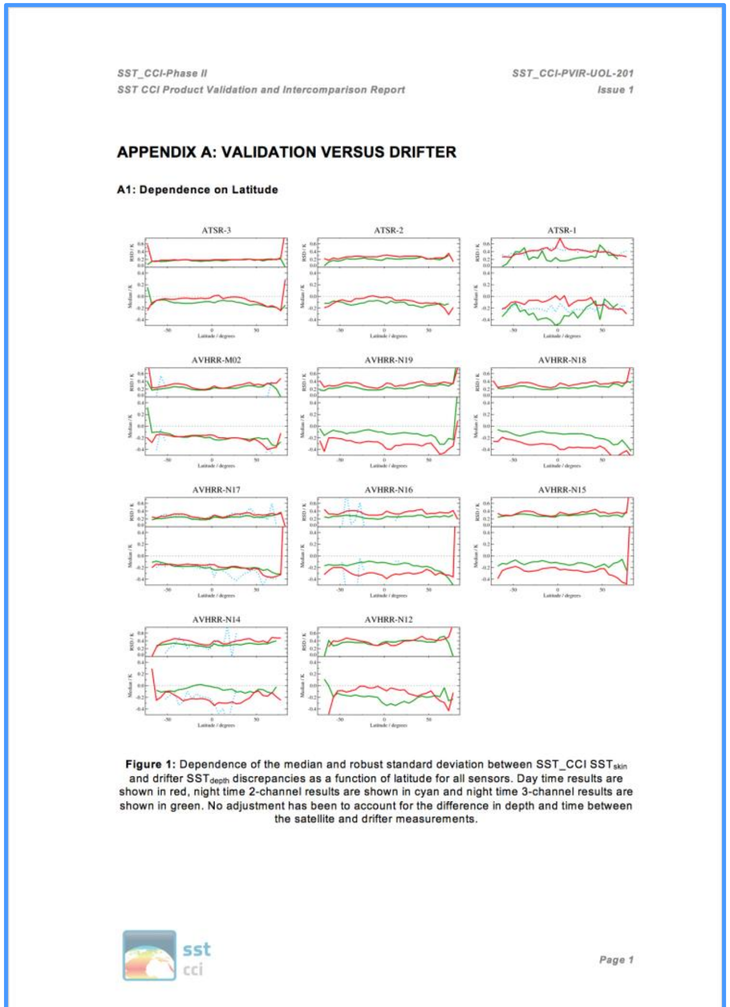


PVIR automation

- Modular validation processing
  - In situ data collation (HadIOD – drifters and Argo; plus GTMBA; plus radiometers)
  - Match-up generation (MMD files)
  - SST_CCI product extraction, or **process directly on MMD files**
  - Base file generation – contains all variables except for satellite data
    - Includes DV adjustments (http://sstcci2.blogspot.com/2014/09/what-differences-to-use-in-validation.html)
  - Combine with satellite data; rapid for direct processing
  - Basic image and statistical analysis

- Automatic document generation using python-docx
  - One for main body of PVIR
  - One for generating an appendix (one per reference data type)

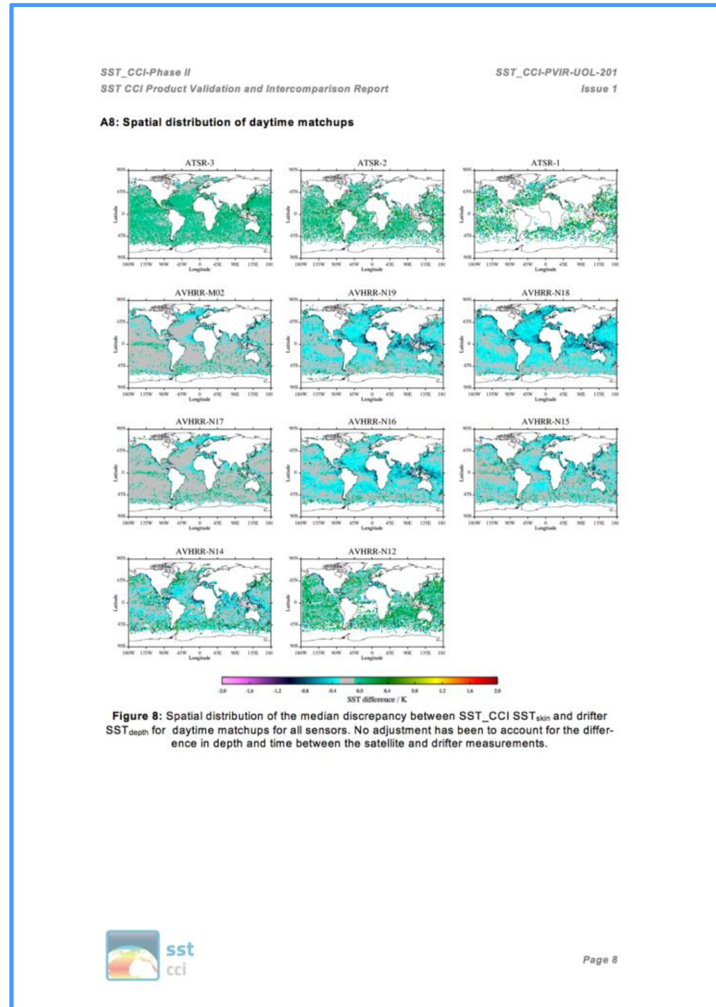
PVIR appendices – examples



APPENDIX A: VALIDATION VERSUS DRIFTER

A1: Dependence on Latitude

Figure 1: Dependence of the median and robust standard deviation between SST_CCI SST_{skin} and drifter SST_{depth} discrepancies as a function of latitude for all sensors. Day time results are shown in red, night time 2-channel results are shown in cyan and night time 3-channel results are shown in green. No adjustment has been to account for the difference in depth and time between the satellite and drifter measurements.



A8: Spatial distribution of daytime matchups

Figure 8: Spatial distribution of the median discrepancy between SST_CCI SST_{skin} and drifter SST_{depth} for daytime matchups for all sensors. No adjustment has been to account for the differ-ence in depth and time between the satellite and drifter measurements.

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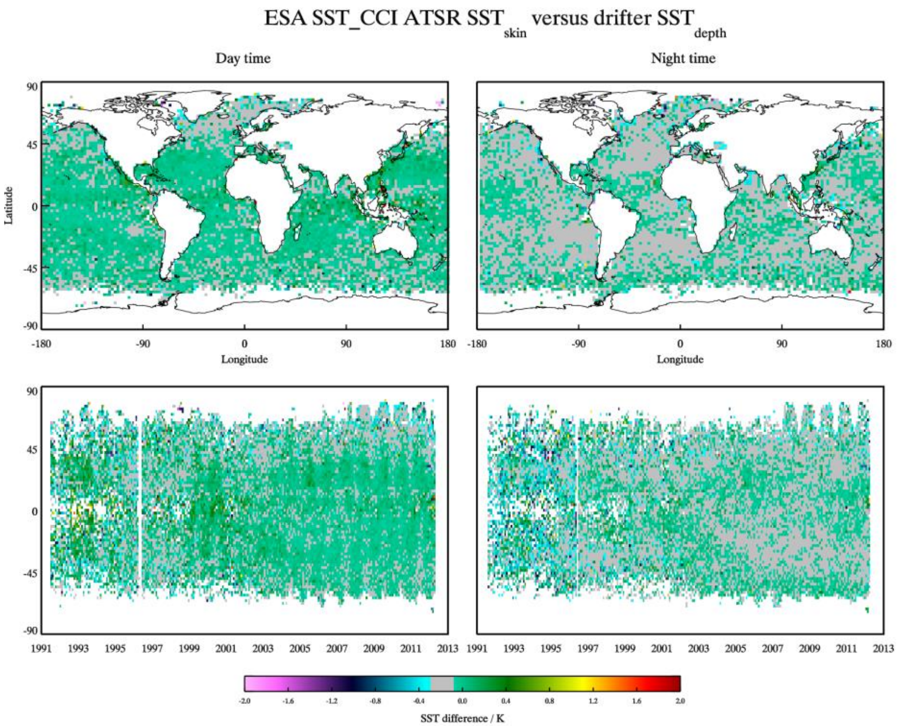
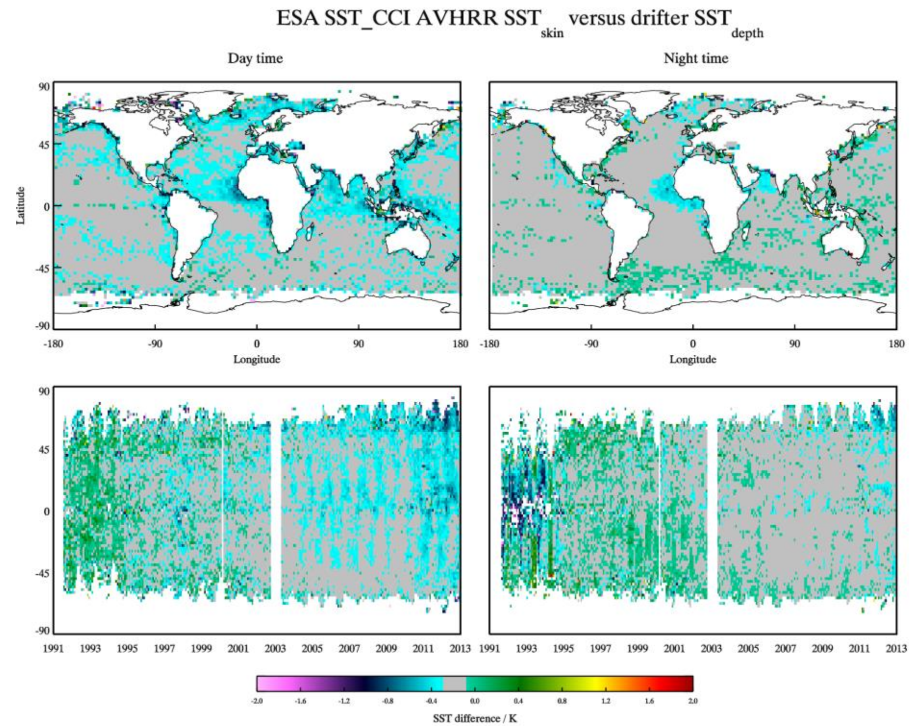
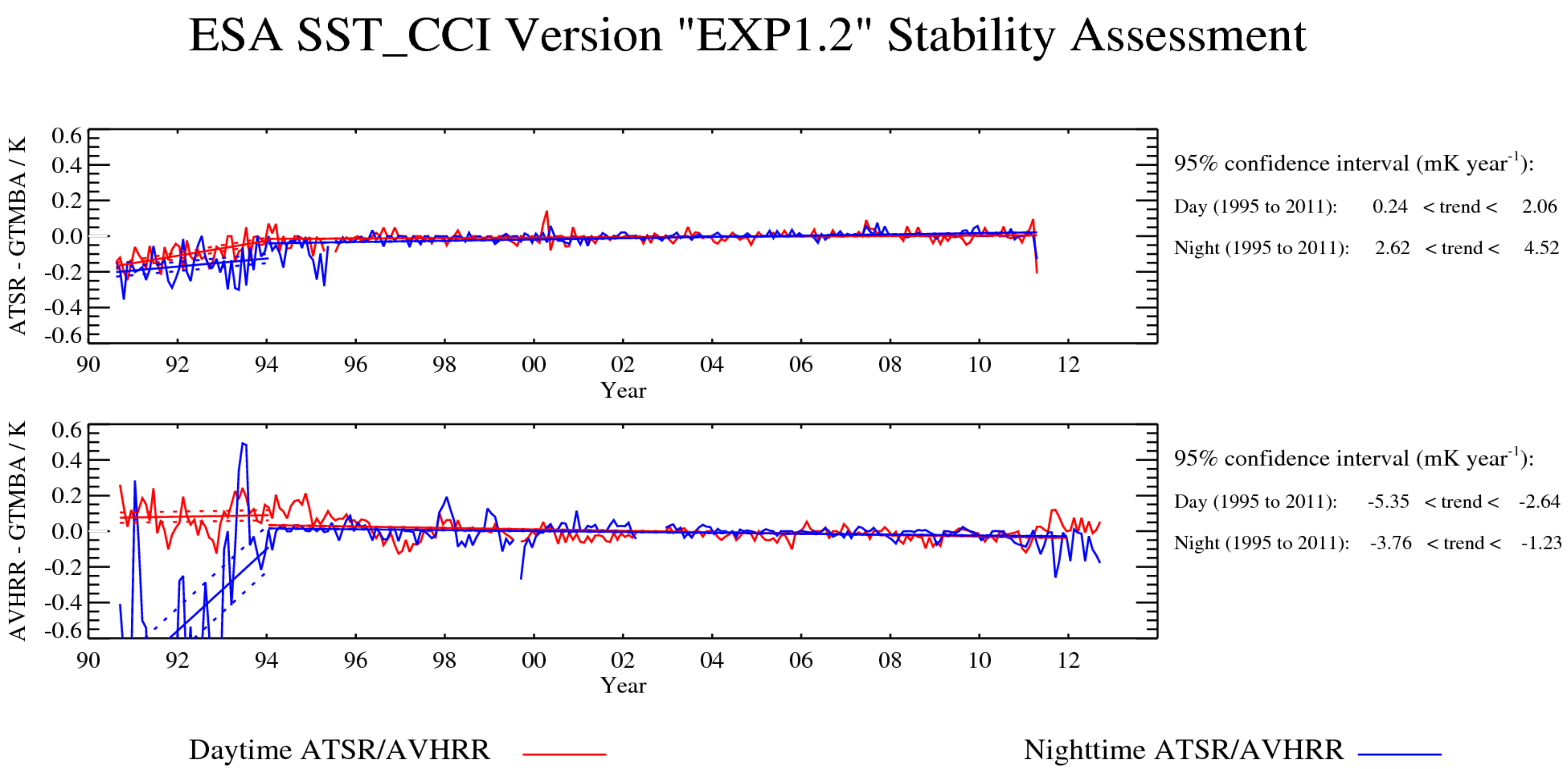
ATSR and AVHRR results “EXP1.2”





Stability



- Calculated using method in GHRSST CDAF
- Only applicable to region of TAO/TRITON tropical moorings

Need to sample the full validation measurement space

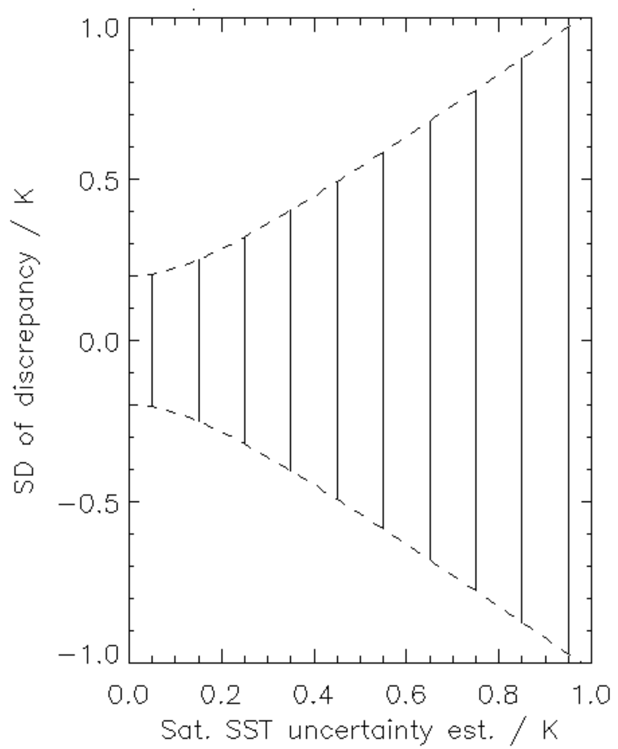
- Satellite SSTs have many sources of error that cannot be easily corrected
- Calculate an uncertainty model to represent these sources of error
  - See Bulgin et al. 2016, http://dx.doi.org/10.1016/j.rse.2016.02.022
- Need to make sure that all possible error sources are validated
  - Dependence
    - Latitude, wind speed, TCWV, SZA, time difference, date, across-track, TCC, Local Solar Time, probability of clear sky, sensitivity, chi^2
  - For all retrieval combinations; both day and night
  - Accounting for DV
  - Spatial and temporal variability
  - Histograms
    - Look for non-Gaussian behaviour
  - Uncertainties
    - Underestimated or overestimated

How to validate uncertainty?

- Example using drifters
- Use mean uncertainty of 0.2 K for σ_2
- Use large number of match-ups, area averaging and diurnal & skin model to randomise σ_3 and σ_4
- Use diurnal & skin model to reduce σ_5
- Uncertainty budget reduces to:

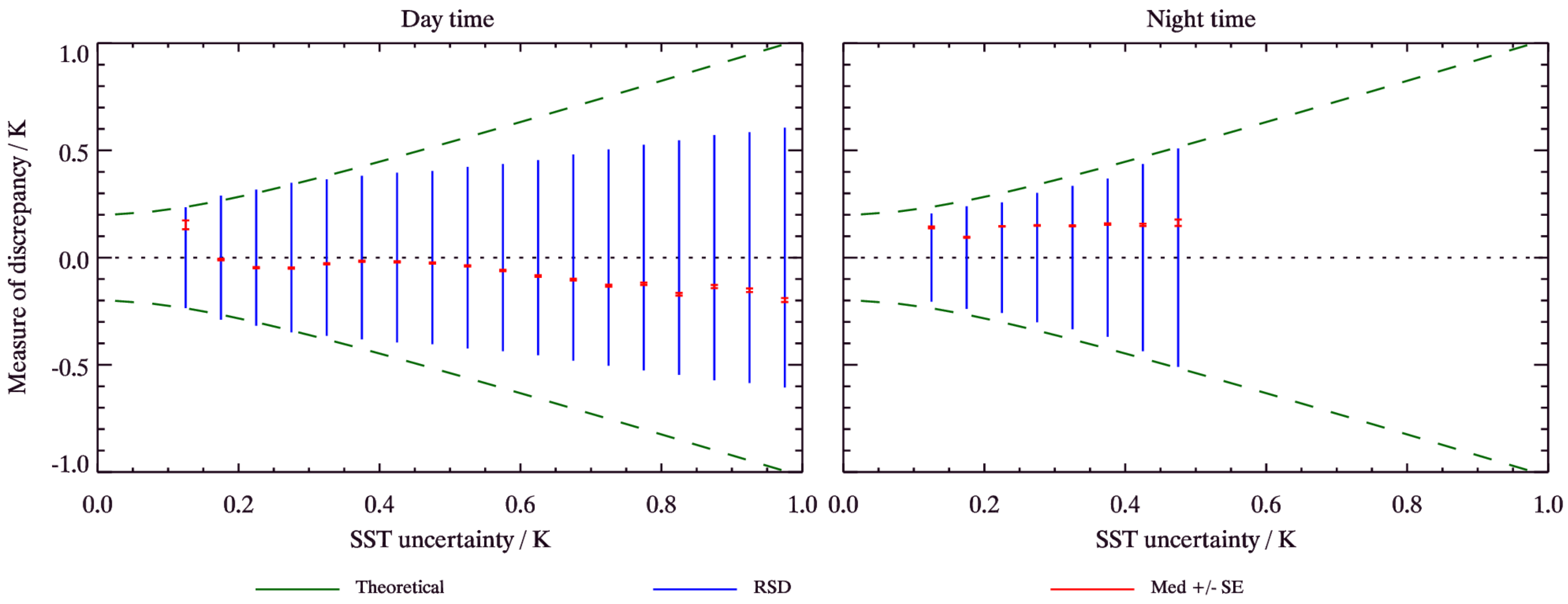
$$s_{sat-ref} = \sqrt{s_{sat}^2 + s_{ref}^2}$$

- Theoretical distribution:

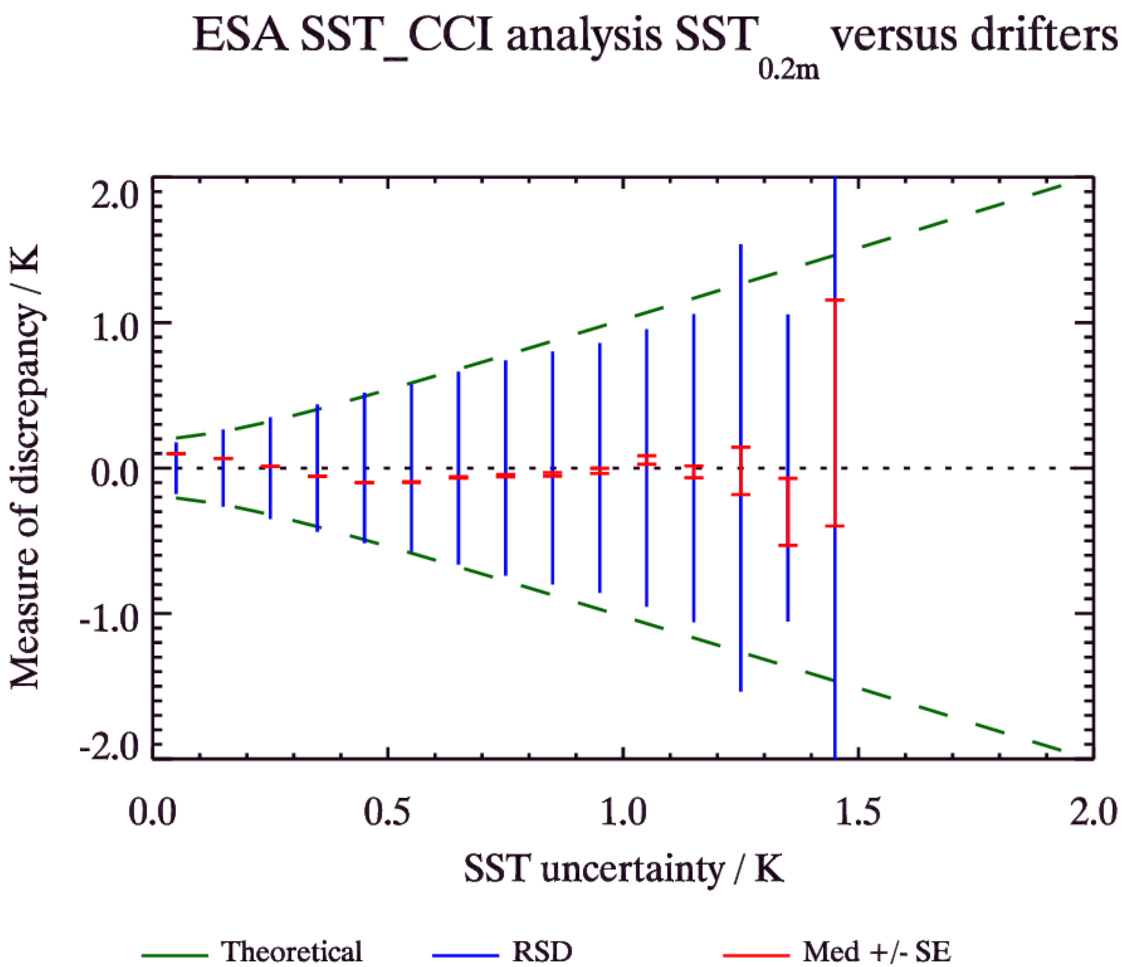


Results: AVHRR L2P

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



Results: Analysis L4



Summary

- ESA SST_CCI products contain uncertainties with each SST

- These SST and their 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