The 2nd NOAA AVHRR GAC SST Reanalysis (1981-2021)

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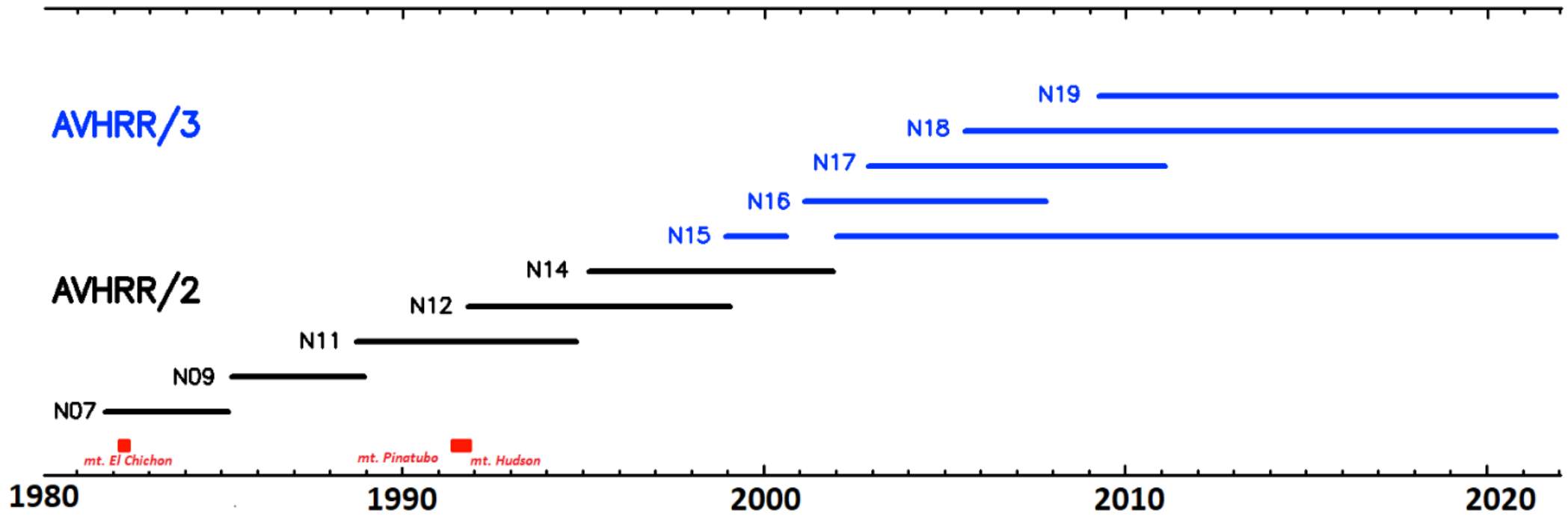
NOAA AVHRR GAC RAN2

- The AVHRR GAC Reanalysis v2 (RAN2) covers the period from 1 September 1981 - present with SSTs retrieved from 4 km AVHRR GAC data of 10 NOAA satellites with the Advanced Clear-Sky Processor for Ocean (ACSPO) enterprise system
- The goal of RAN2 was to create SST record, maximally consistent with *in situ* data, in an optimal retrieval domain
- The RAN2 data are available at https://coastwatch.noaa.gov/pub/socd2/coastwatch/sst/ran/avhrr_gac/ in the following formats:
  - ✓ L2P : 4km/nadir Swath, 144 10-min files/satellite/24hr
  - ✓ 0.02° L3U : Gridded Uncollated, 144 10-min files/satellite/24hr
  - ✓ 0.02° L3C : Gridded Collated (L3C), 2 files/satellite/24hr (day and night)

The presentation describes the major characteristics of the NOAA RAN2 SST and evaluates its performance

RAN2 SST temporal coverage



- As of today, the RAN2 record covers from 1 Sep 1981 – 31 Dec 2021
- 3 AVHRR/3s remain functional: on N15, N18, and N19
- L1b data are processed in RAN2 with ~6 months latency

The NOAA AVHRR GAC L1B data were reprocessed as completely as possible

RAN2 products

- Two SST products reported in the full AVHRR swath (VZA~±68°, ~3000 km):

"Subskin" SST:	"Depth" SST ("Subskin" minus SSES Bias):
- Global regression	- Piecewise Regression
- De-biased wrt *in situ* SST	- More precise & accurate wrt *in situ* SST
- Sensitivity: ~0.98 (night), ~0.90 (day)	- Sensitivity: ~0.6 (day and night)

- AVHRR bands used for SST:
  Night (SZA>90°): 3.7, 10.8 and 12 µm; Day (SZA>90°): 10.8 and 12 µm

- Using *in situ* data for training:
  - N07 and N09 SSTs: Ships (SH) + Drifters (D)+ Tropical Moorings (TM)
  - N11/N12/N14/N15/N16/N17/N18/N19 SSTs: D + TM

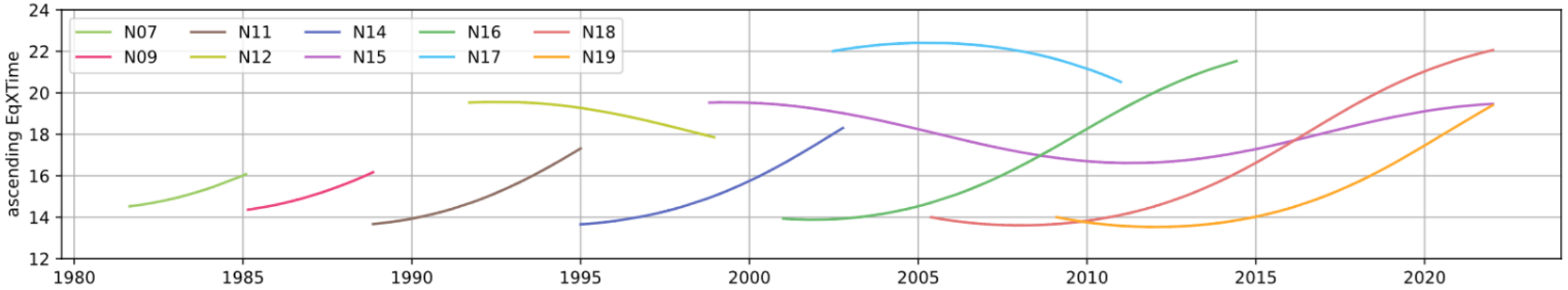
- First guess SST:
  - N07/09/11 (before 1 Sep 1991): ESA Climate Change Initiative (CCI) v.2.1 L4 SST
  - N11/12/14/15/16/17/18/19 Since 1 Sep 1991: Canadian Meteorology Center (CMC) L4 SST

- SSTs of quality level 5 (=all clear-sky) are recommended for use

Equator Crossing Times of the NOAA Satellites

(from https://www.star.nesdis.noaa.gov/socd/sst/3s/)

Ascending Half-Orbits



Types of orbits at the beginnings of the missions:

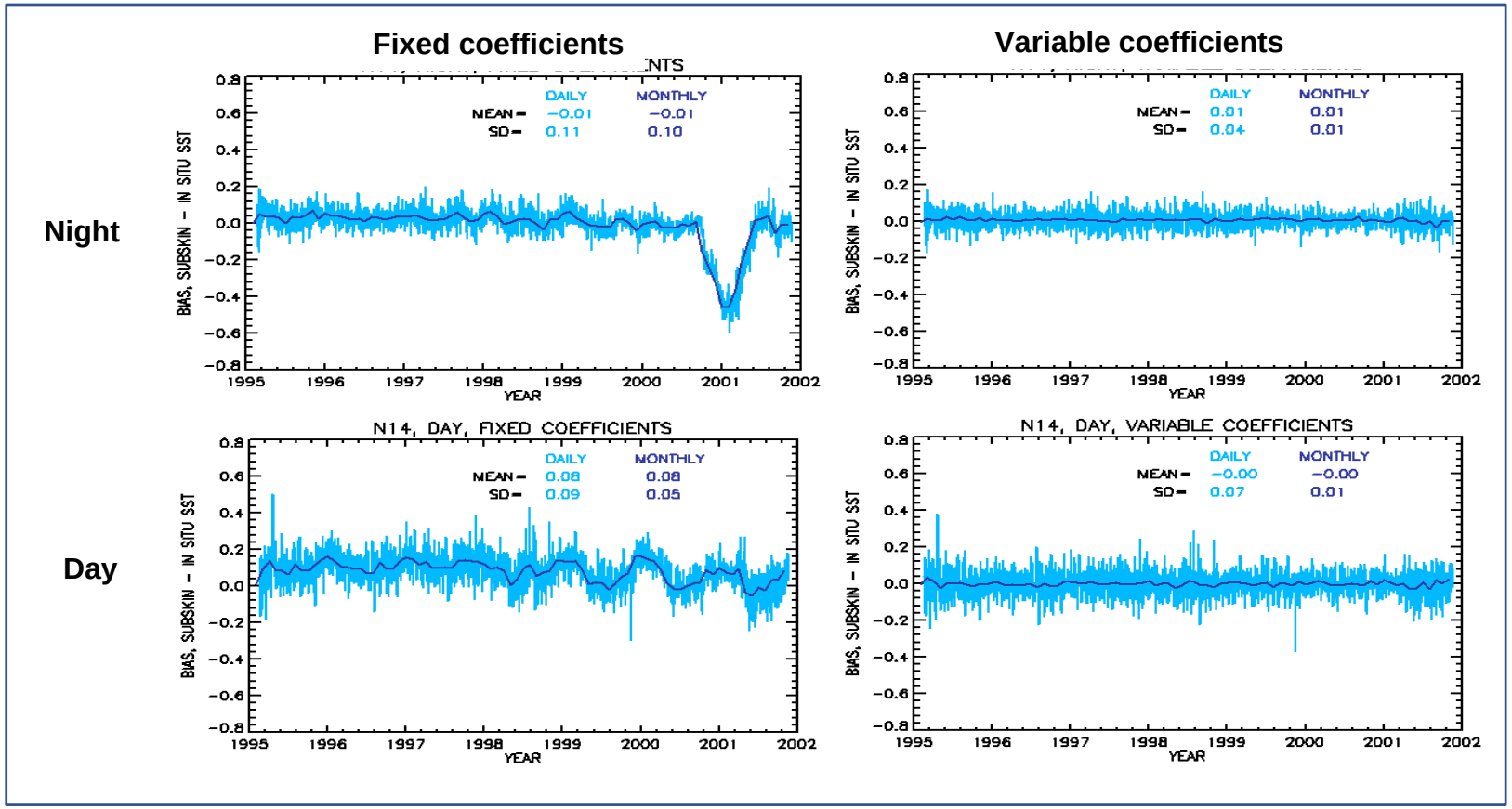
- Afternoon: N07, N09, N11, N14, N16, N18 and N19; Early-morning: N12 and N15; Mid-morning: N17

- Equator crossing times (EXT) changed during the missions; the relationships between satellite and *in situ* data changed accordingly
- The AVHRRs were exposed to sunlight in the twilight zones; satellites on the early-morning orbits suffered the most

Compensation for long-term orbital and sensors' trends

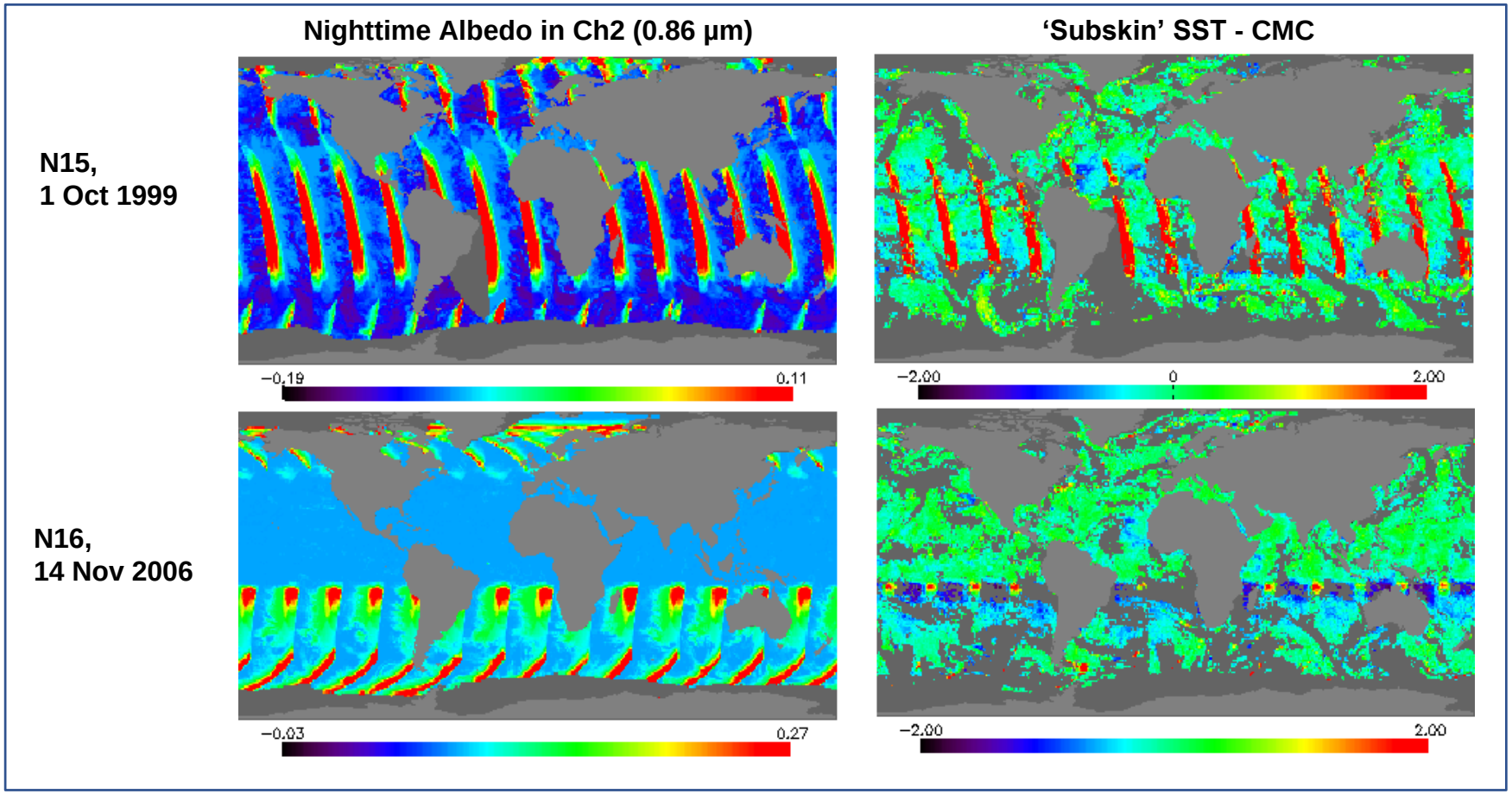
- Variable regression coefficients retrained daily against matchups within moving windows:
  - 91 day for "Subskin SST"
  - 361 day for "Depth" SSTs
  - 31 day for offsets adjustment
- The plots show time series of **daily** and **monthly** biases in N14 'Subskin' – in situ SST, produced with fixed and variable coefficients

SST biases wrt *in situ* SST are minimized and stabilized on a monthly basis



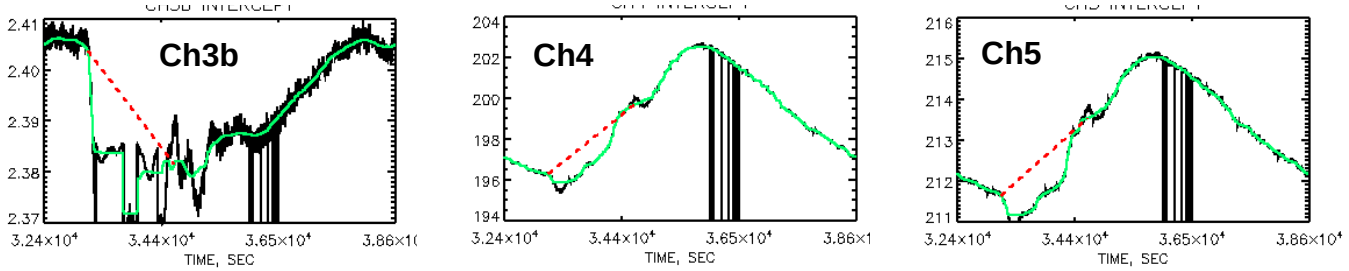
Mitigation of nighttime Sun impingements on the AVHRR: 1 of 4

- The AVHRRs are periodically exposed to sunlight when the satellites fly near terminator over the dark side of the Earth
- Stray light in the Earth view causes warm outliers in BT and SST
- Sun impingements on the AVHRR black body corrupt L1B calibration coefficients. The affected scans are filled with cold BT and SST outliers



Mitigation of nighttime Sun impingements on the AVHRR: 2 of 4

Correction of L1B calibration coefficients (N15, 1 Oct 1999)



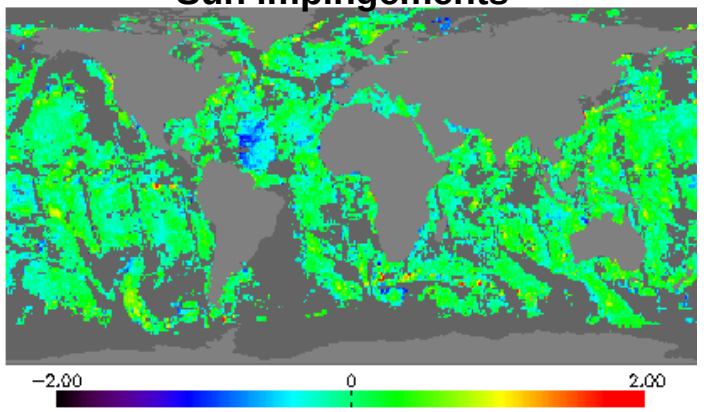
Black: Original, Green: Median filtered, Red: Interpolated coefficients

L1B calibration coefficients are median-filtered and interpolated over the affected scans

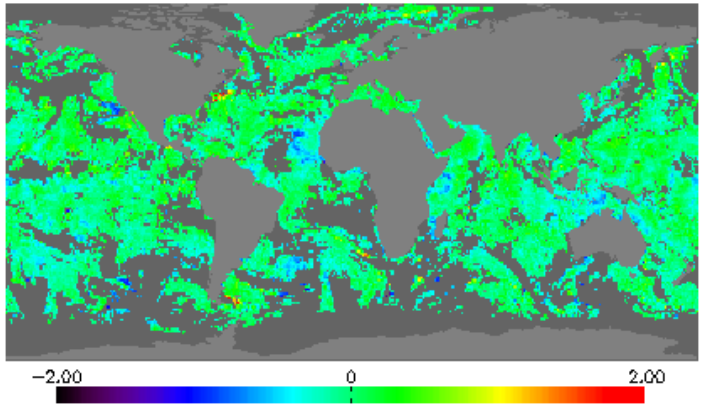
- Correction of L1B calibration coefficients restores abnormally cold SSTs in the affected scans
- Stray light in the Earth view is detected and filtered out using AVHRR band 2 (0.86 µm)
- The maps on the right hand side show results of mitigation of Sun impingements (cf. slide 7)

'Subskin' SST – CMC, after mitigation of Sun impingements

N15, 1 Oct 1999



N16, 14 Nov 2006

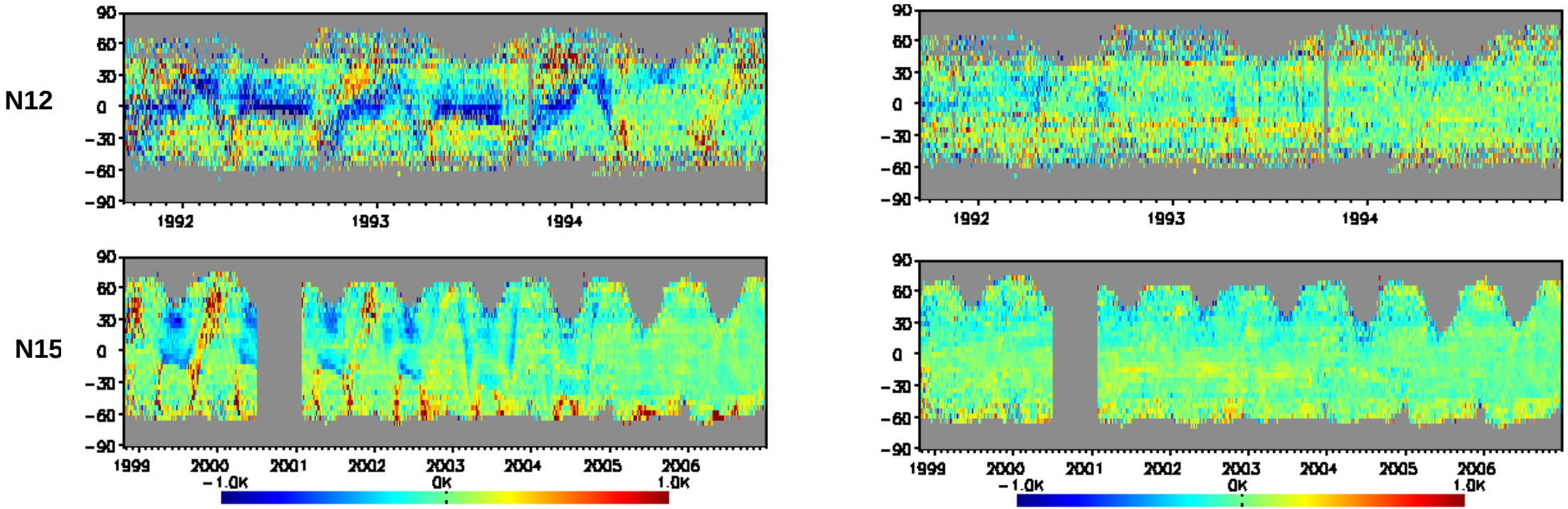


Mitigation of nighttime Sun impingements on the AVHRR: 3 of 4

Early-morning N12 and N15: Latitudinal Hovmöller diagrams of nighttime 'Subskin' – *in situ* SST

No mitigation of Sun impingements

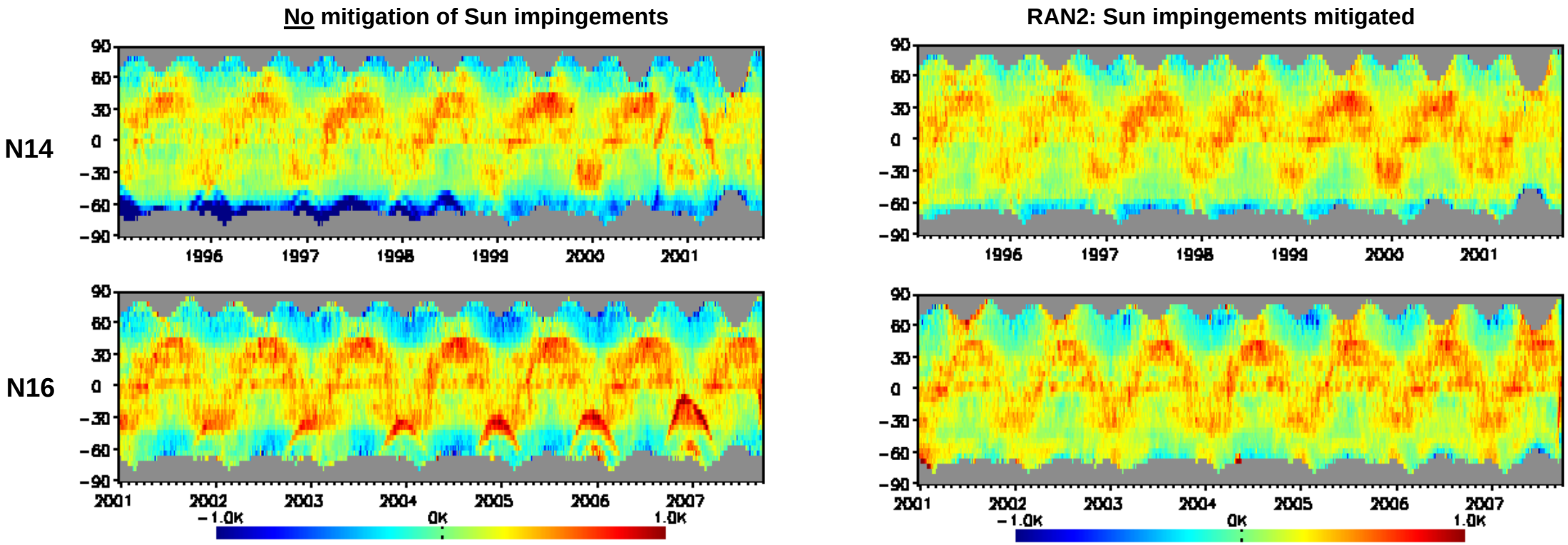
RAN2: Sun impingements mitigated



Mitigation of Sun impingements improves the consistency with *in situ* SST

Mitigation of nighttime Sun impingements on the AVHRR 4 of 4

Afternoon N14 and N16: Latitudinal diagrams of Day-Night Double Differences (DD)



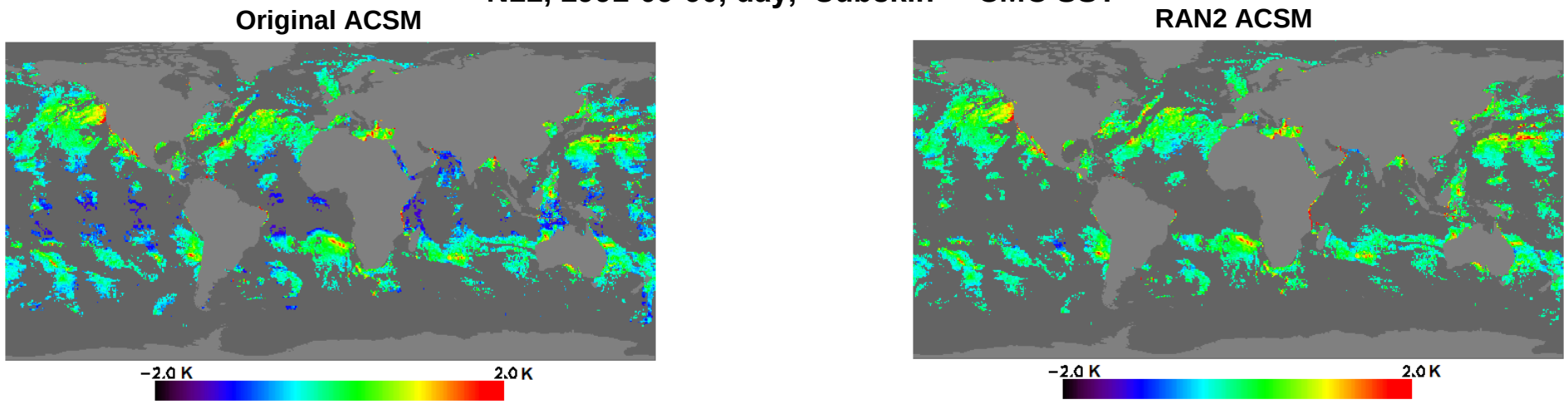
Day-Night DD=<Subskin – CMC SST>$_{DAY}$ - <Subskin-CMC SST>$_{NIGHT}$

Mitigation of Sun impingements on AVHRR improves cross-satellite consistency of diurnal patterns

Filtering cold SST outliers after major volcanic eruptions

- Major volcanic eruptions affected SST retrievals from NOAA-07 (Mt. El Chichon, April 1982); NOAA-11 and NOAA-12 (Mt. Pinatubo, June 1991; Mt. Hudson, August-October 1991)
- The attenuation by volcanic aerosol cooled down AVHRR SSTs within specific latitudinal bands

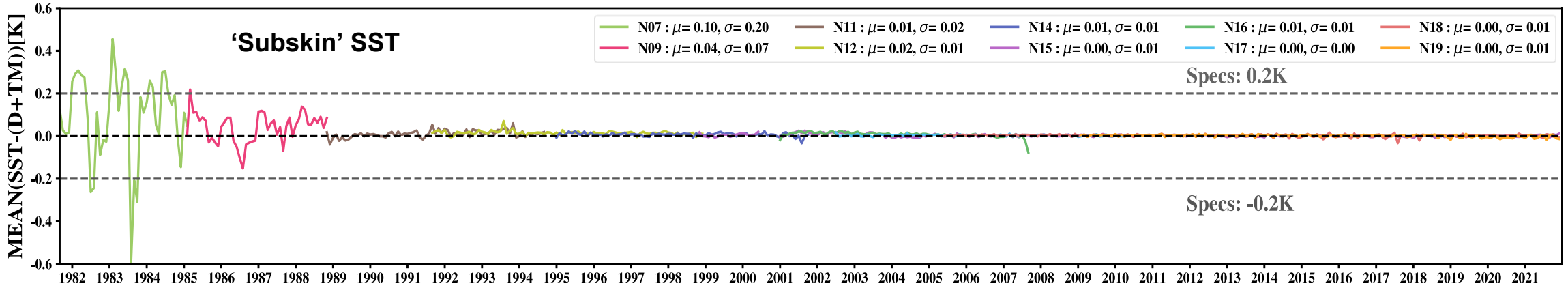
N11, 1991-09-30, day, 'Subskin' – CMC SST

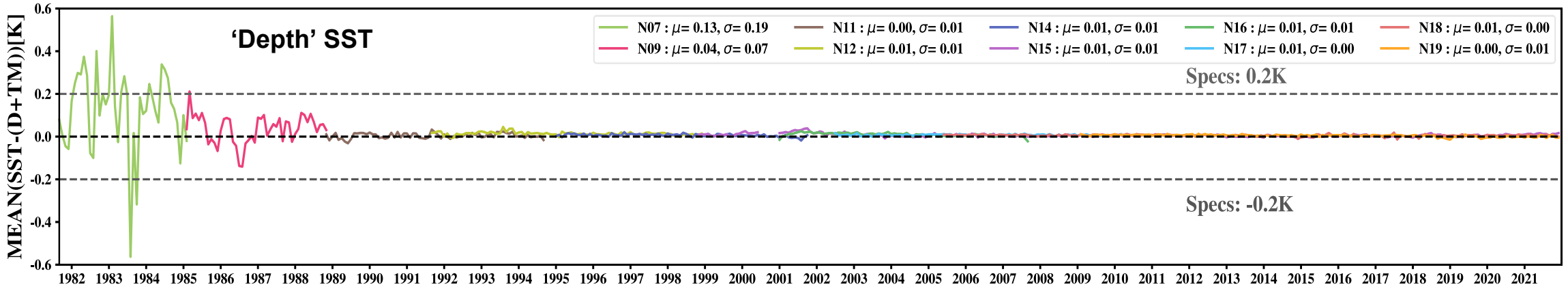


- **In RAN2, the ACSPO Clear-Sky mask (ACSM) becomes more conservative in the latitudinal bands with higher numbers of cold outliers. This improves mitigation of volcanic effects**

Global Monthly Nighttime Biases wrt (D+TM)

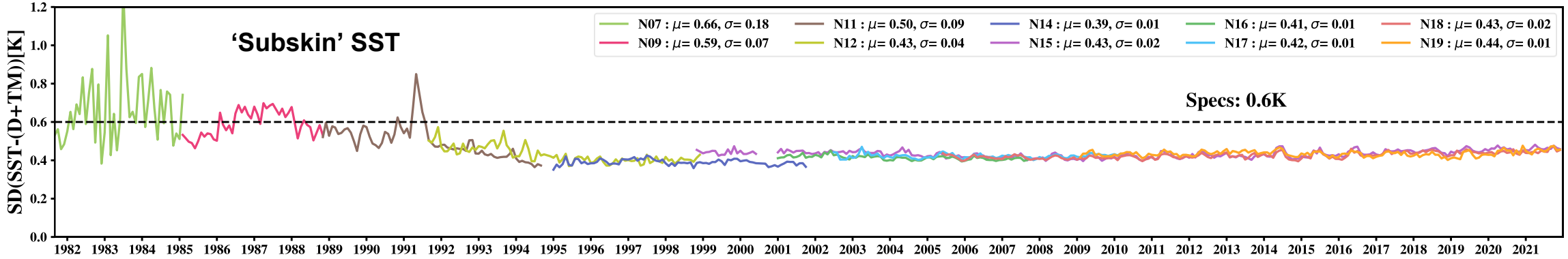
Daytime statistics are available at www.star.nesdis.noaa.gov/socd/sst/squam/index.php

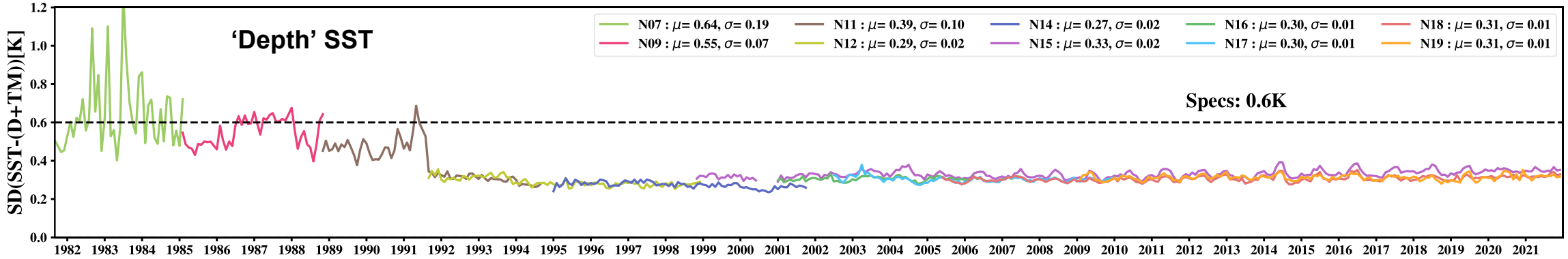




- Monthly N07 and N09 SST biases minimized against (SH+D+TM), but variable wrt (D+TM)
- Monthly SSTs biases from other satellites minimized against (D+TM)
- Time series of 'Subskin' and 'Depth' biases are similar

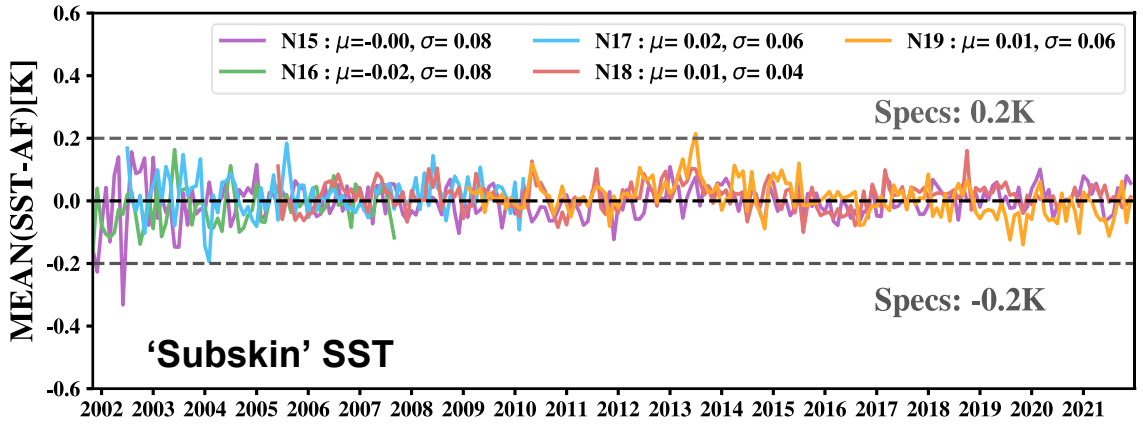
Global Monthly Nighttime SDs wrt (D+TM)

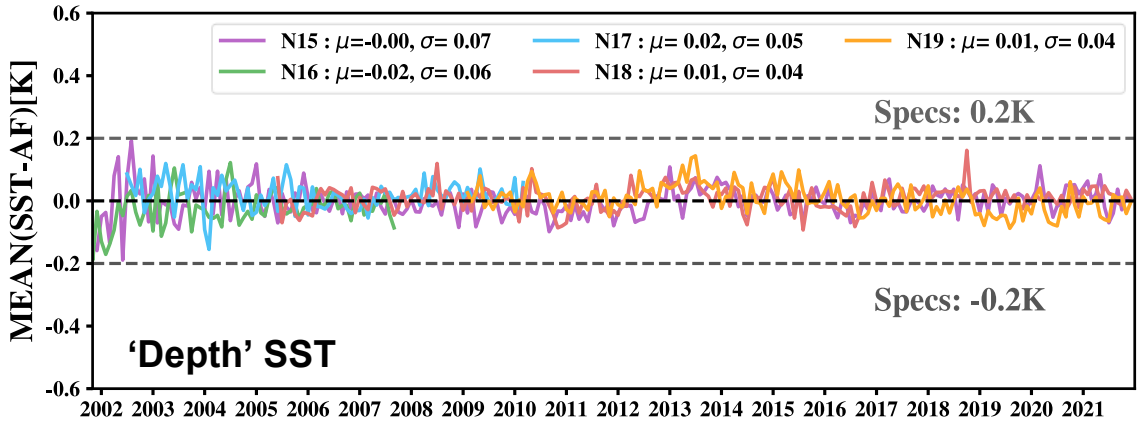




- N07 and N09 SSTs trained against (SH+D+TM); monthly SDs wrt (D+TM) are significant and unstable
- For other satellites, monthly SDs reduce to ~0.4 K ('Subskin') and ~0.3 K ('Depth') after switching the first guess to CMC on 1 September 1991
- SDs for 'Depth' SST are lower by ~0.02-0.04 K for N07 and N09 and 0.10-0.14 K for all other satellites

Global monthly nighttime biases wrt Argo floats (N15-N19)

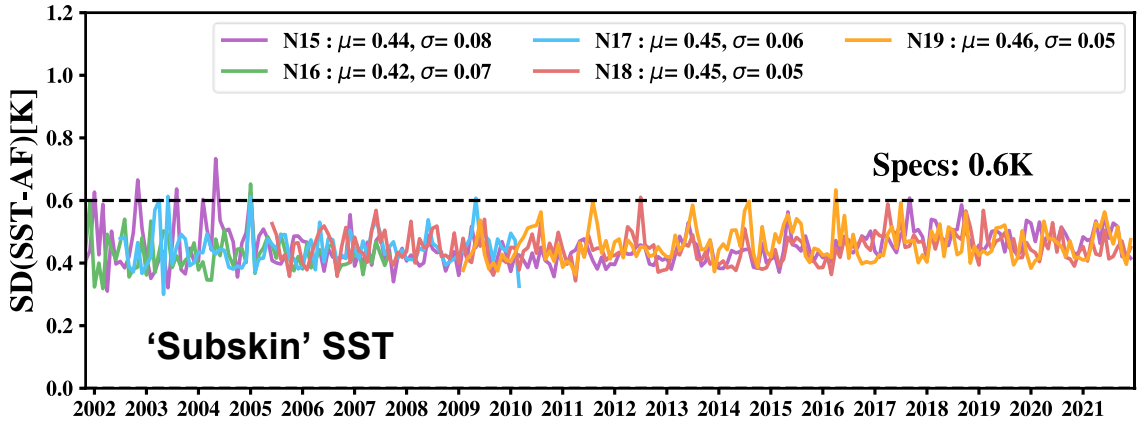


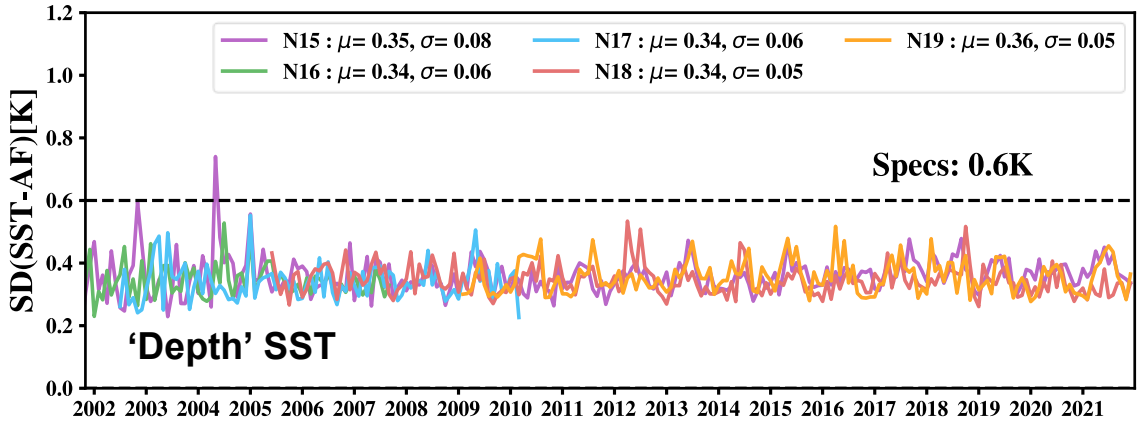


- Matchups for N07-N14 AVHRR/2s were not separated into 'training' and 'validation' data sets, to avoid degradation of retrieved SST
- SSTs from N15 – N19 AVHRR/3 were validated independently against Argo floats (AF)

Nighttime biases wrt AF are well within the spec of ±0.2 K, with mission averages being within ±0.02 K, stable in time and consistent with biases wrt (D+TM)

Global monthly nighttime SDs wrt Argo floats (N15-N19)

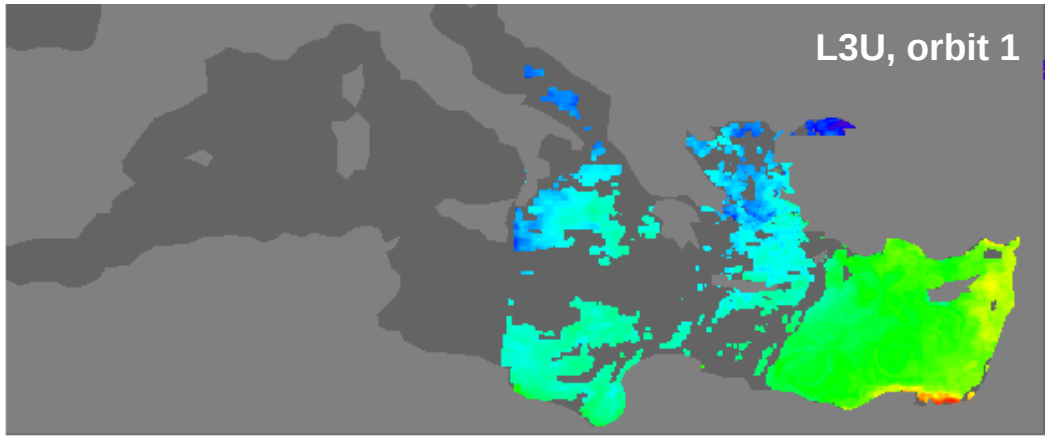


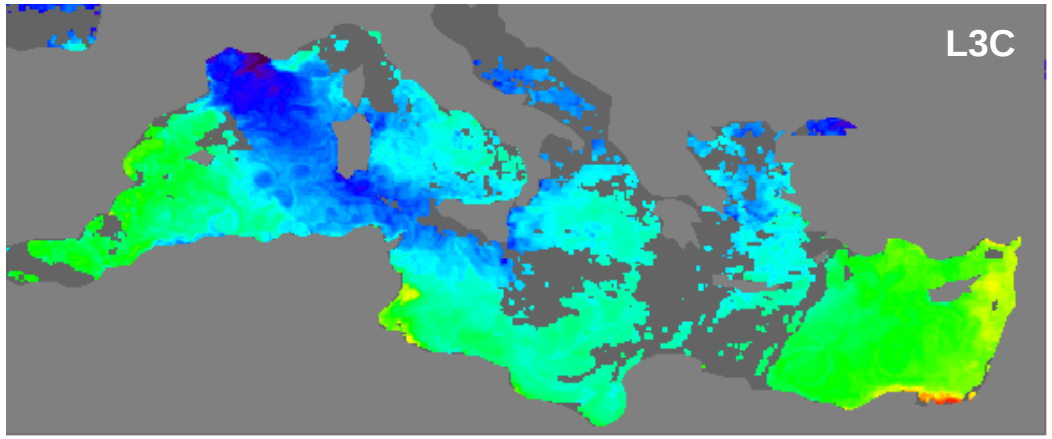


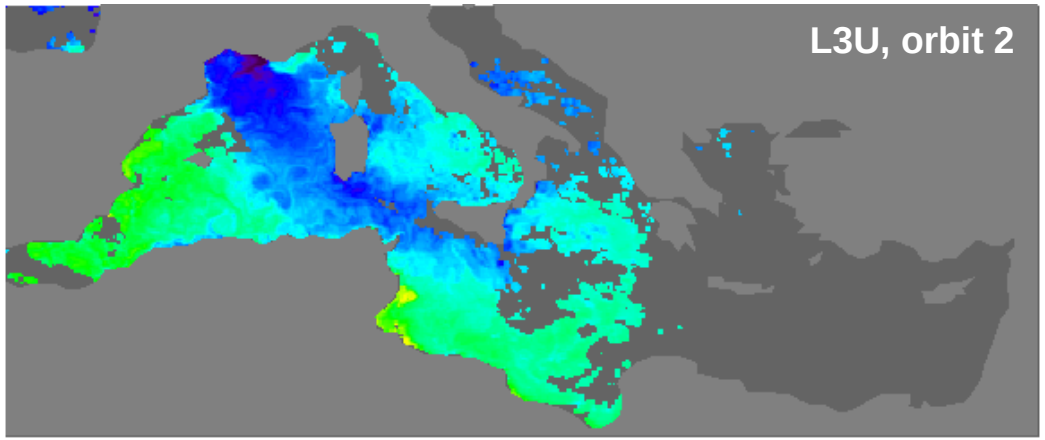
The nighttime SDs wrt AF are:

- **Well below the spec of 0.6 K;**
- **Stable in time and consistent across platforms**
- **Slightly larger than SDs wrt (D+TM) by 0.01-0.04 K ('Skin') and 0.02-0.05 K ('Depth')**

RAN2 Imagery: L3U vs. L3C







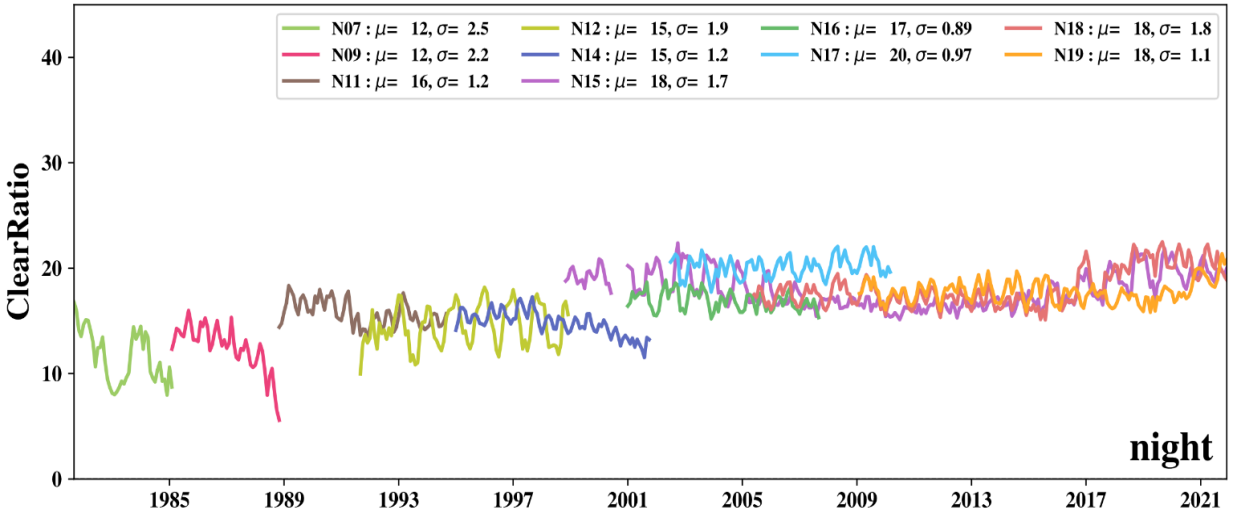
N16 'Subskin' – CMC SST, Mediterranean sea, 2004-06-06, night

- **144 10 min. L3U files are produced daily from L2P SST**
- **2 L3C files (Day and Night) are produced daily from L3U**
- **Both L3U and L3C SSTs have 0.02° resolution.**
- **The collation improves coverage in the overlapped zones**

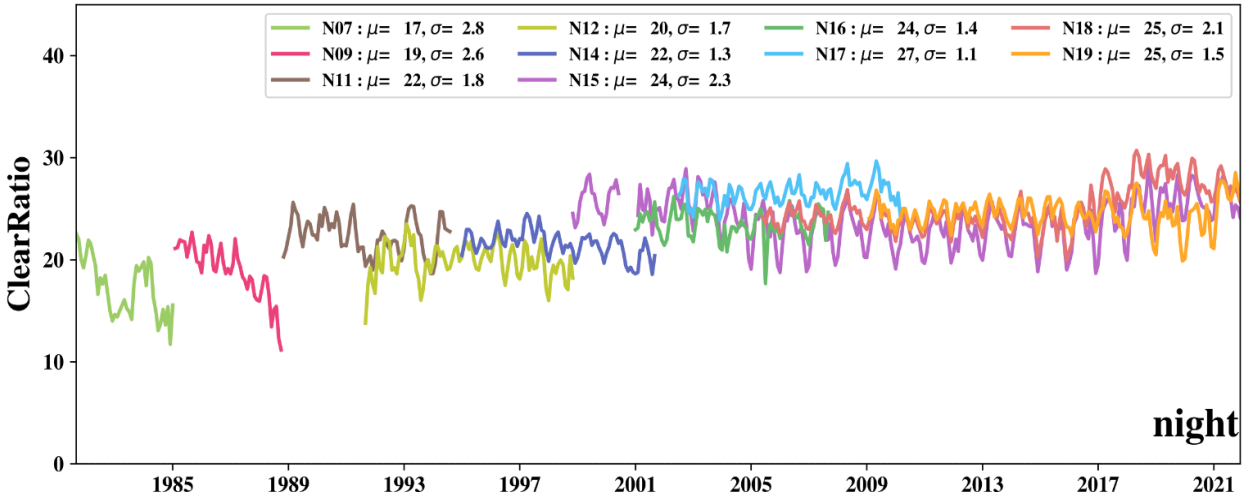
Coverage of Global Ocean with RAN2 data

Clear-Sky Ratio (CSR) = Number of clear-sky observations/Number of ocean pixels

Monthly CSR in RAN2 L2P SST



Monthly CSR in RAN2 L3C SST



Mean monthly CSRs: 12% to 20% in L2P, 17% to 27% in L3C

Collation increases the coverage by 30 - 60 %

Summary

1. The AVHRR GAC RAN2 SST data set covers the period from Sep 1981 – Dec 2021 with SST retrieved from 5 AVHRR/2s (N07/09/11/12/14) and 5 AVHRR/3s (N15/16/17/18/19)
2. The data were reprocessed as completely as possible with the NOAA ACSPO enterprise system
3. The main features of the RAN2 SST are:
   - The data set includes two SST products, retrieved in full AVHRR swath
     - ‘Subskin’ SST is highly sensitive to true skin SST, de-biased wrt *in situ* SST
     - ‘Depth’ SST is more precise wrt *in situ* SST
   - SST biases are minimized on a monthly basis wrt SH+D+TM for N07/N09 and D+TM for all other satellites.
   - Sun impingements on the AVHRR Black Body are mitigated by correction of L1B calibration coefficients
   - Stray light in Earth view pixels is filtered out based on the AVHRR Ch2
   - The retrieval domain: 12% to 18% of all ocean pixels in the L2P format, increases by 30-60% in L3C format.

Future Work: RAN2 Updates & Towards 3rd Reanalysis (RAN3)

- Keep extending the RAN2 dataset w/N15/N18/N19 data beyond 2022, with ~6 month latency
- Explore further improvements to the nighttime calibration, particularly for the earliest N07/09/11
- Explore improvements to the daytime calibration
- Explore correction of navigation problems
- Adjust/Improve the SST and cloud masking algorithms, particularly, in terms of minimization of regional biases
- Explore iterative creation of the L4 analysis from the RAN2 SST and using it in RAN3 as the first guess