Towards 2nd Reanalysis of NOAA AVHRR GAC Data (RAN2): Methodology

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1. INTRODUCTION

- ☐ Under the **NOAA AVHRR GAC Reanalyses ("RANs")** project, all available **AVHRR GAC data** from 1981-on will be reprocessed with the **Advanced Clear-Sky Processor for Oceans (ACSPO)**.
- ☐ Earlier, the **AVHRR GAC data** for 2002-2015 have been reprocessed under **RAN1** [1]. The ongoing **RAN2** will extend the reanalysis to the whole period of GAC data available from 1981-on.
- ☐ At this time, a "beta" (**RAN2 B01**) SST data set has been created for 1981-2003 from satellites listed in Table 1. The core ACSPO algorithms [2-5] were modified to take advantages of the reanalysis setting (i.e., availability of both the past and the future data) and to mitigate the issues specific to the earlier years.
- ☐ This poster describes the modifications to the ACSPO L2P processing algorithms made during **RAN2 B01**.
- ☐ For detailed validation of the **RAN2 B01 SST** see [6].

Table 1. NOAA AVHRR GAC Sensors Analyzed in RAN2 B01

Satellite	Type of orbit	Type of AVHRR	L1B data available	AVHRR bands used for SST
NOAA-07	Afternoon	AVHRR-2	09.01.1981-02.02.1985	Day and night: Bands 4 and 5 (*)
NOAA-09	Afternoon	AVHRR-2	02.25.1985-11.07.1988	Day (**): Bands 4 and 5 Night(**): Bands 3/3b, 4 and 5
NOAA-11	Afternoon	AVHRR-2	11.08.1988-12.31.1994	
NOAA-12	Morning	AVHRR-2	09.16.1991-12.14.1998	
NOAA-14	Afternoon	AVHRR-2	01.01.1995-10.08.2002	
NOAA-15	Morning	AVHRR-3	11.01-1998-12.31.2018	
NOAA-16	Afternoon	AVHRR-3	01.01.2001-08.22.2009	

(*) For N07, only two AVHRR bands 4 & 5 (10.8 & 12 μm) were used due to early failure of band 3 (3.7 μm).
(**) Day- and nighttime cloud masking, SST and SSES algorithms are switched at solar zenith angle = 90°.

2. *IN SITU* DATA AND L4 ANALYSES

- ☐ Customarily, the ACSPO regression algorithms are trained on *in situ* SST from drifting (D) and tropical moored (TM) buoys. However, in 1981-mid 1990s, both Ds and TMs were too scarce whereas ship SST measurements (S) were much more numerous, although less accurate and precise. In RAN2 B01, we used S+D+TM to train SST regressions for N07/09/11 and customary D+TM for N12/14/15/16.
- ☐ The ACSPO uses L4 SST analyses as the "first guess" in regression NLSST equations and in the Clear-Sky mask. For N07/09/11, we used L4 SST from ESA Climate Change Initiative v.2.1 ("CCI"), available since Sep 1981. For N12/14/15/16, we customarily used L4 SST by Canadian Meteorological Center (CMC), available since Sep 1991.

3. ACSPO SST PRODUCTS AND CLEAR-SKY MASK

- ☐ "Sub-skin" SST [3]:
  - Uses two sets of coefficients (one for day and one for night), trained on global datasets of matchups.
  - Sensitive to "skin" SST, but globally anchored to "depth" SST.
- ☐ "Depth" SST [4]:
  - Uses multiple sets of coefficients, selected by regressors' values. Each set of coefficients is trained on a separate subset of matchups.
  - Less sensitive to "skin" SST but more precise wrt "depth" SST.
- ☐ The ACSPO Clear-Sky Mask (ACSM) uses a set of threshold-based cloud filters [2].

4. TRAINING REGRESSION COEFFICIENTS

- ☐ Compensation for sensor instabilities, orbital and calibration trends:
  - Regression coefficients are recalculated daily, using matchups within running windows of 1±45 days size for "sub-skin" SST and 1±180 days size for "depth" SST.
  - The offsets are adjusted using shorter windows containing at least 100 matchups.
- ☐ The method for training regression coefficients [5]:
  - Preserves mean sensitivity of "Sub-skin" SST to T_{SKIN} at ~ 0.98 for night and ~0.94 for day (which also limits the mean sensitivity to the "first guess" SST at ~0.02 to 0.06).
  - Keeps mean sensitivity of "depth" SST > 0.4.
  - Helps extract maximum information from observations, while keeping the coefficients' estimates stable.

5. FILTERING WARM OUTLIERS

Nighttime SST from earlier AVHRRs is often contaminated with warm outliers caused by direct Sun impingement in sensor aperture (affecting band 3/3b). Locations of such outliers are different for different satellites. In RAN2 B01, such outliers are screened out with the "Warm Outliers filter", specific for each satellite. Figures 1 and 2 show examples of filtering warm outliers in N14 and N15 "sub-skin" SSTs.

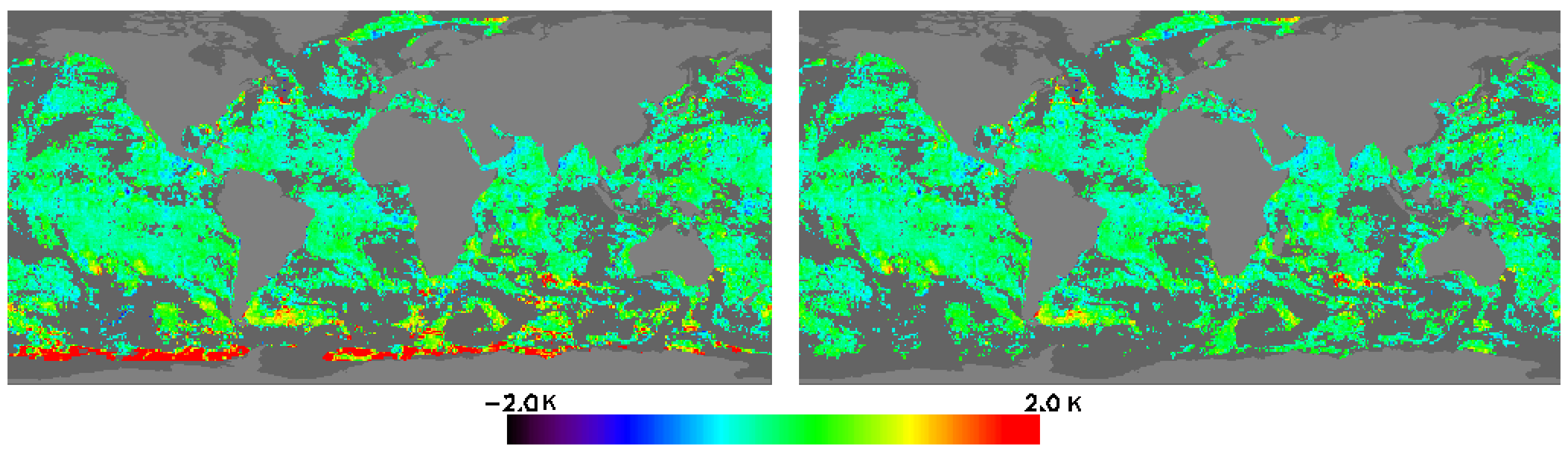

Figure 1. In N14,nighttime warm outliers occasionally appear in the southern high latitudes. Left: Nighttime deviations of "sub-skin" SST from CMC, produced from N14 data for 01.20.1996, before filtering warm outliers . Right: The same deviations after filtering warm outliers.

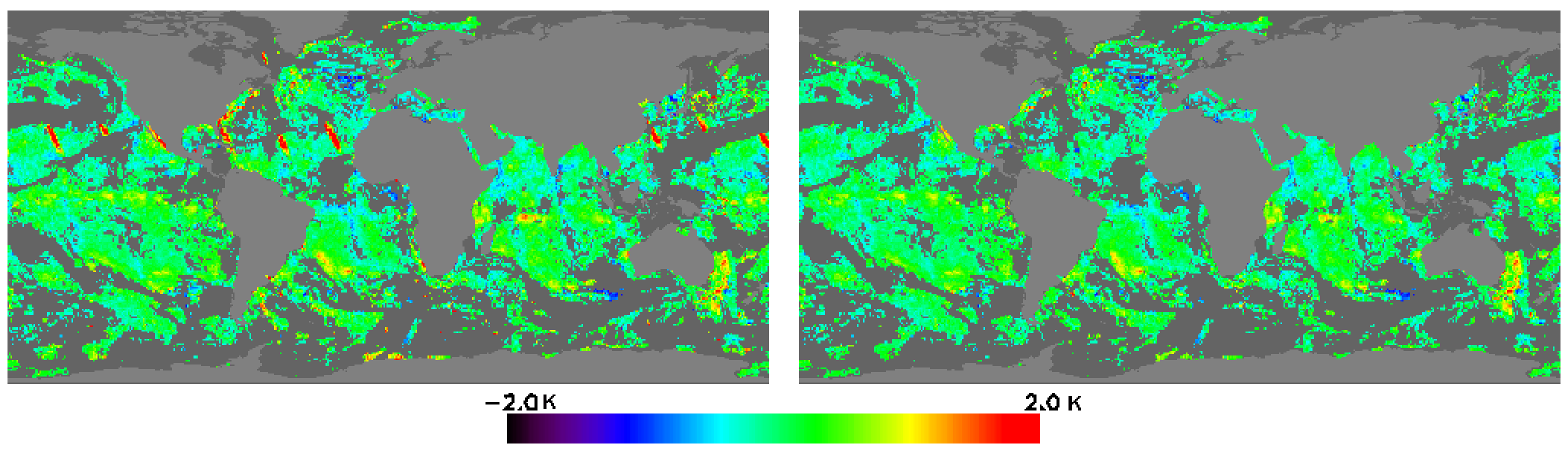

Figure 2. In N15, nighttime warm outliers occur in the northern hemisphere at the western edges of the AVHRR swaths. Left: Nighttime deviations of "N15 "Sub-skin" SST from CMC on15 Feb 1999, before filtering warm outliers. Right: The same deviations after filtering warm outliers.

6. TIME SERIES OF NIGHTTIME BIASES AND STANDARD DEVIATIONS OF N14 SST FROM *IN SITU* SST

Figure 1: (a) With fixed regression coefficients, the biases usually vary within ±0.1 K, but in 2000-2001 they reach -0.4 K for "sub-skin" SST, and -0.2 K for "depth" SST. (b) On average, SDs wrt *in situ* SST are ~0.4 for "sub-skin" SST and ~0.3 K for "depth" SST.

Figure 2: (a) With variable daily coefficients, the biases are practically flat and close to 0 K and (b) SDs of both "sub-skin" and "depth" SST slightly reduce compared with Fig. 1b.

Figure 3: (a, b) The warm SST biases, if not filtered, cause occasional spikes in biases and SDs.

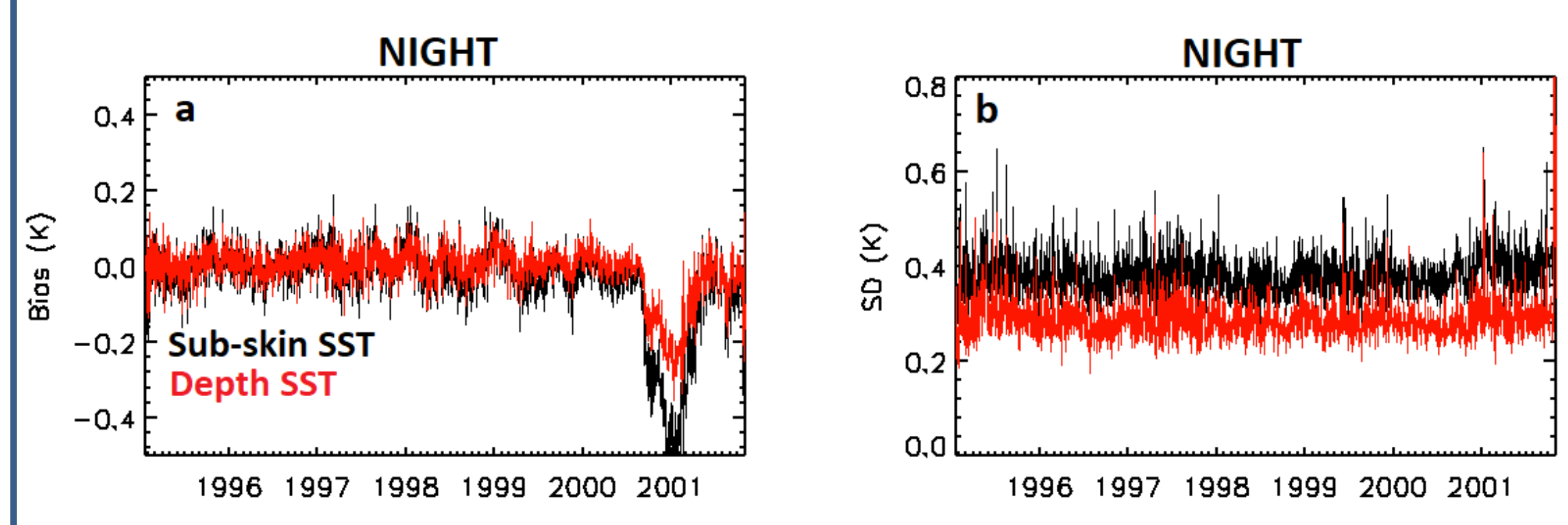

Figure 3. Time series of daily (a) bias and (b) SD of N14 SST wrt in situ SST produced with fixed regression coefficients derived from matchups collected in 1986.

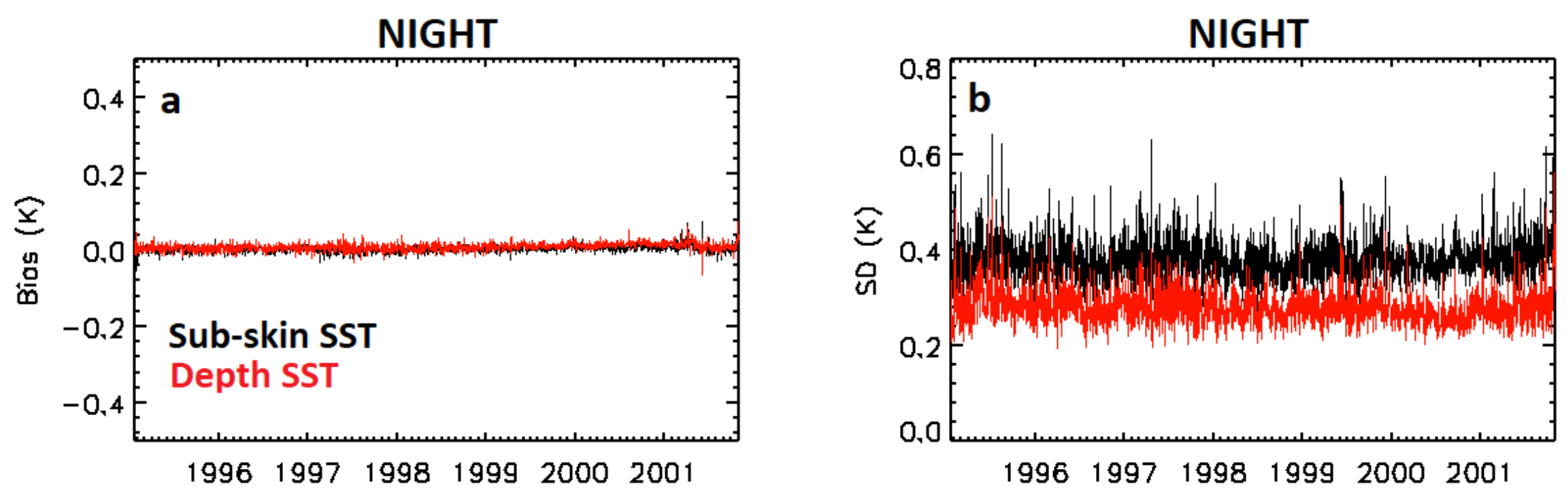

Figure 4. The same time series as in Figure 3 for N14 but produced with variable daily regression coefficients.

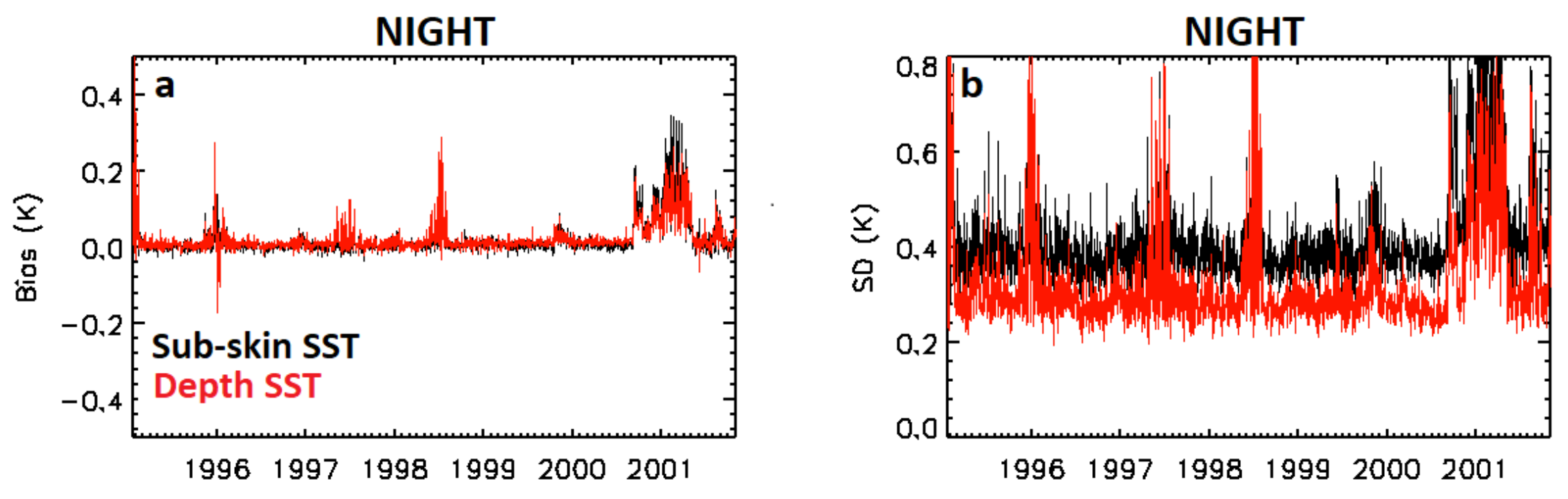

Figure 5. The same time series as in Figure 4 but without filtering warm outliers.

7. SUMMARY AND FUTURE WORK

During creation of the "B01" version of RAN2 AVHRR SST dataset covering 1981-2002, a number of modifications have been made to the ACSPO SST retrieval, training and cloud masking algorithms. This includes a) compensation of the sensor/orbital/calibration trends with variable daily regression coefficients; b) stable estimation of daily regression coefficients for both SST products with predefined sensitivity; c) filtering nighttime warm SST outliers caused by Sun impingement on the band 3/3b sensor.

The future development of RAN2 algorithms will be aimed at mitigation of cold regional biases in retrieved SST (including those caused by contaminations of the atmosphere with volcanic dust) and exploring the potential of correction of AVHRR brightness temperatures based on calibration parameters, available in L1B data.

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Acknowledgement: This work is aimed at creating a long-term SST record consistent across NOAA AVHRR and JPSS VIIRS. The views, opinions, and findings in this report are those of the authors and should not be construed as an official NOAA or U.S. government position or policy.

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