Design Considerations for a Geospace Observing System

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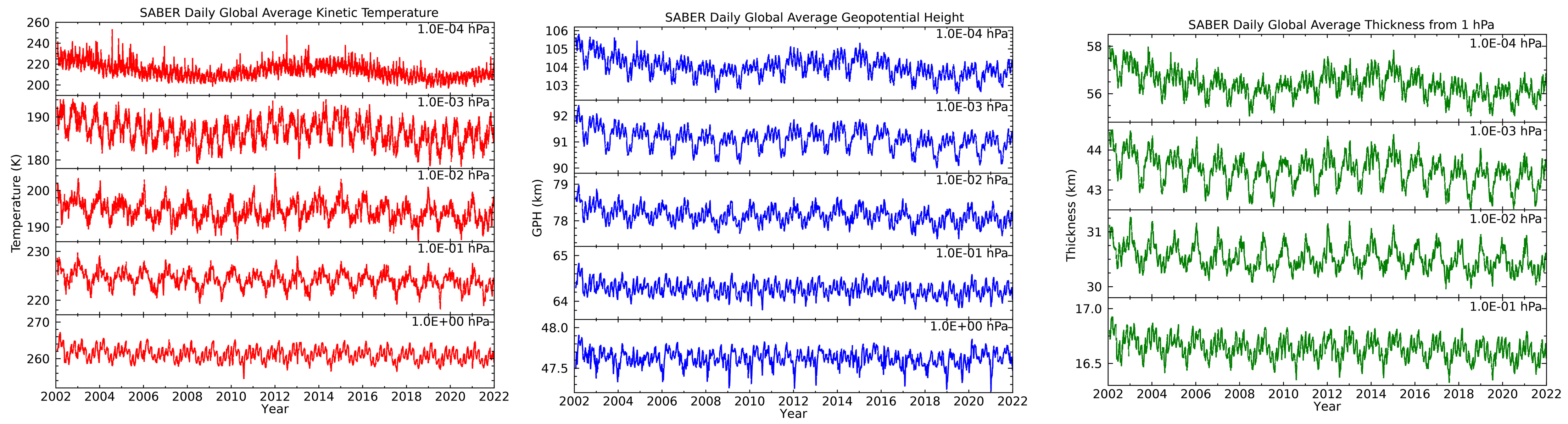
Concept of Geospace Data Record

- A Geospace Data Record (GDR) is analogous to the well-known Climate Data Record (CDR) of tropospheric climate science
- A CDR defined as a *"time series of sufficient length, consistency, and continuity to determine climate variability and change"*
- *Geospace* is defined as the region of the atmosphere from the mesosphere to the exobase (60 km to 600 km)
- A Geospace Data Record (GDR) is a time series of sufficient length, consistency, and continuity to determine *geospace variability and change*
- Geospace is changing due to increasing CO_2
- Solar variability complicates interpretation of long-term change
- Knowledge of Geospace change is critical for future space law, space policy, and the space insurance industry (Mlynczak et al., 2001)

The 21-Year Geospace Data Record from SABER on TIMED

Daily Global Average Temperature, Geopotential Height, and Thickness

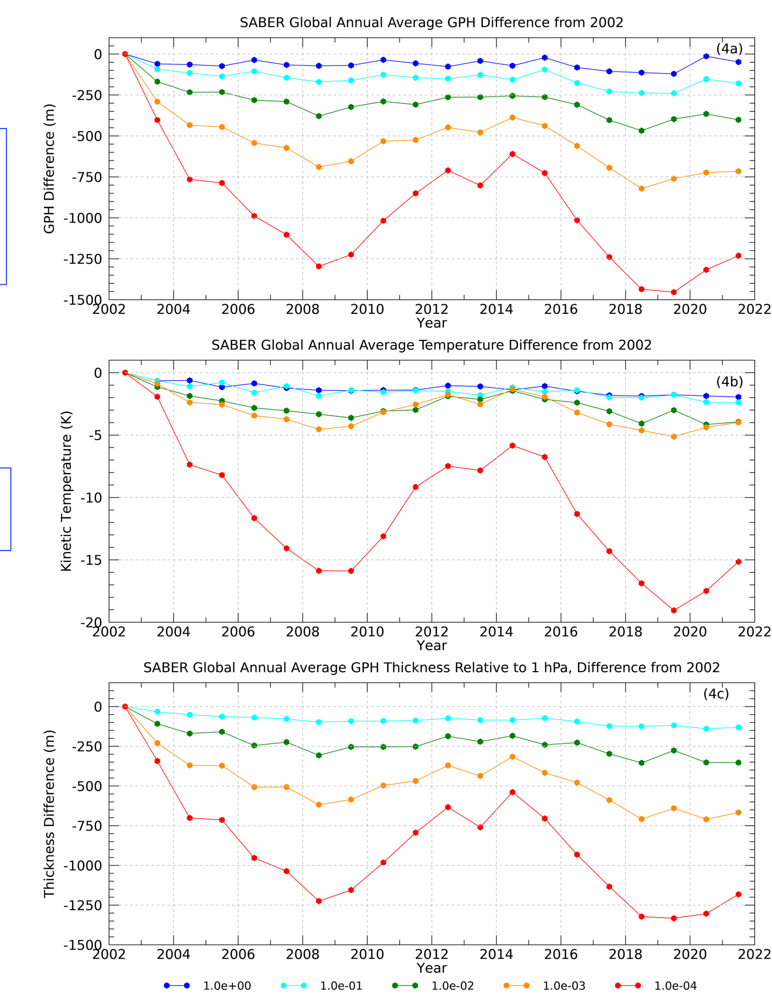


Global Annual Means

Geopotential Height

Temperature

Thickness



Temperature, GPH, and Thickness Trends

Change attributed to increasing CO_2 and declining solar activity

Table 1

Observed Changes From 2002 to 2019 in Global Annual Mean Temperature, Geopotential Height (GPH), and Thickness (Relative to 1 hPa) (Obs. Change); the Trend in Each Quantity Due To Increasing CO_2 (Derived Trend); the Estimated Magnitude of the Change in Each Quantity Due To Increasing CO_2 (Δ CO_2); and the Estimated Magnitude of the Change in Each Quantity Due To Declining Solar Activity (Δ Solar)

Quantity	P (hPa)	Obs. Change	Derived trend	Δ CO_2	Δ Solar
Temperature	1	−1.77 K	−0.55 ± 0.07 K/dec	−0.99 K	−0.78 K
	10^{-1}	−2.05 K	−0.63 ± 0.11 K/dec	−1.13 K	−0.92 K
	10^{-2}	−3.01 K	−0.53 ± 0.17 K/dec	−0.95 K	−2.06 K
	10^{-3}	−5.12 K	−0.51 ± 0.17 K/dec	−0.92 K	−4.20 K
	10^{-4}	−19.05 K	−2.60 ± 0.67 K/dec	−4.68 K	−14.37 K
GPH	1	−121 m	−8 ± 12.3 m/dec	−14.4 m	−106.6 m
	10^{-1}	−240 m	−47 ± 12.9 m/dec	−84.6 m	−155.4 m
	10^{-2}	−397 m	−84 ± 14.9 m/dec	−151.2 m	−245.8 m
	10^{-3}	−761 m	−127 ± 20.0 m/dec	−228.6 m	−532.4 m
	10^{-4}	−1,454 m	−197 ± 33.6 m/dec	−354.6 m	−1,099.4 m
Thickness	10^{-1}	−118 m	−40 ± 3.7 m/dec	−72 m	−46 m
	10^{-2}	−276 m	−77 ± 13.4 m/dec	−138.6 m	−137.4 m
	10^{-3}	−640 m	−119 ± 18.5 m/dec	−214.2 m	−425.8 m
	10^{-4}	−1,333 m	−190 ± 31.6 m/dec	−342 m	−991 m

Note. One-sigma trend uncertainties are also listed in the derived trend column.

- Mesosphere and Lower Thermosphere (MLT) cooled substantially from 2002 to 2022
- MLT also contracted by over 1400 meters
- Cause is determined to be increasing CO_2 and declining solar activity over the time period

Challenges to creating GDRs from satellite observations

Generating a consistent dataset with changes that are solely due to the variability and change in the atmosphere

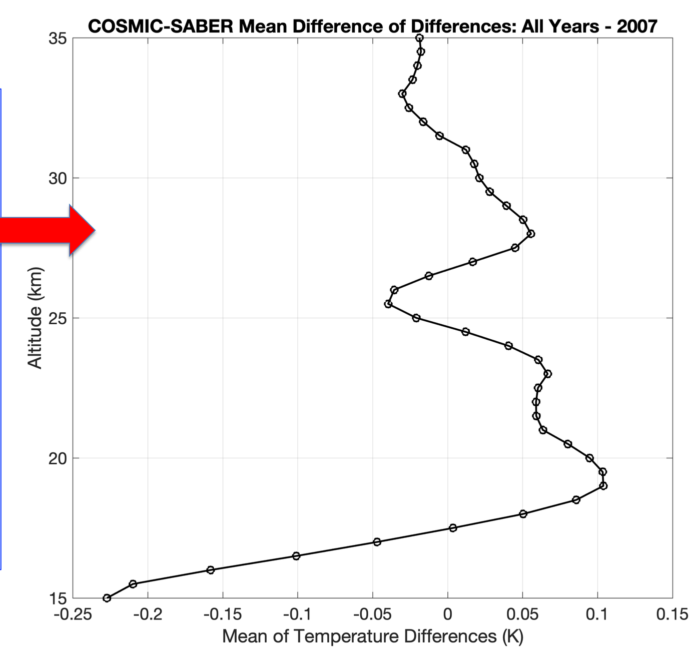
Several factors can contribute to 'instability' of a data record that are instrument or algorithm induced:

- Changing satellite orbit
- Changes to algorithm parameters/inputs over time
- Changing calibration (despite on-board verification)

SABER has been shown to have a remarkably stable calibration, with changes in temperature of ~ 0.1 K/decade

SABER Temp. stability determined by comparison with COSMIC GPS Temps

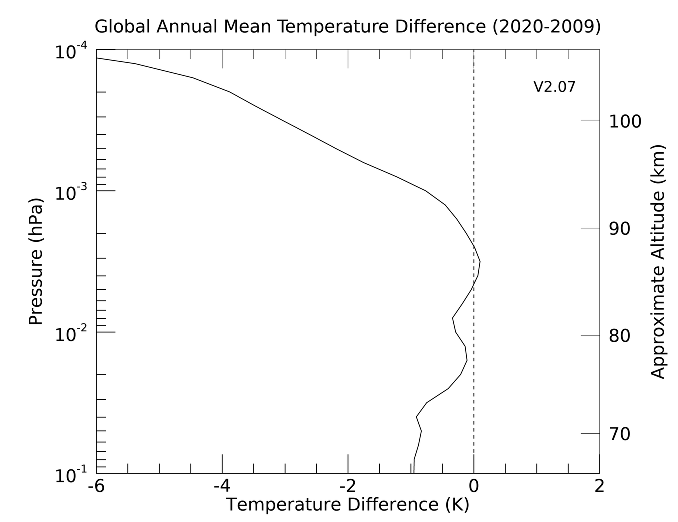
GPS Temps are inherently stable due to their traceability to the SI definition of the second



Example of Algorithm Instability in SABER

SABER Temp (2020 – 2009)

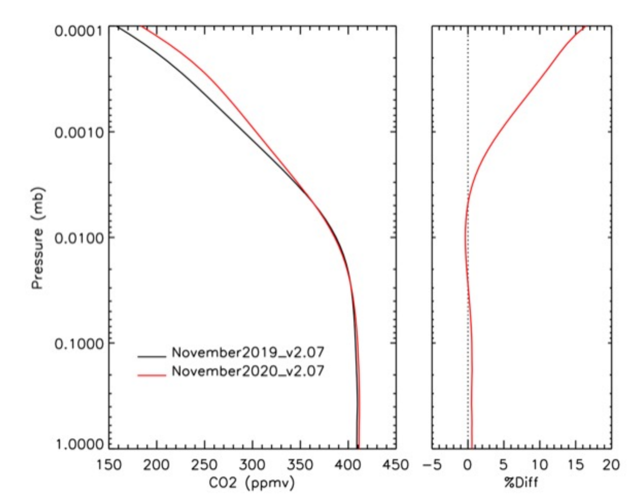
Large, unanticipated difference above 85 km



SABER Temp retrieval uses CO_2 concentrations from WACCM model

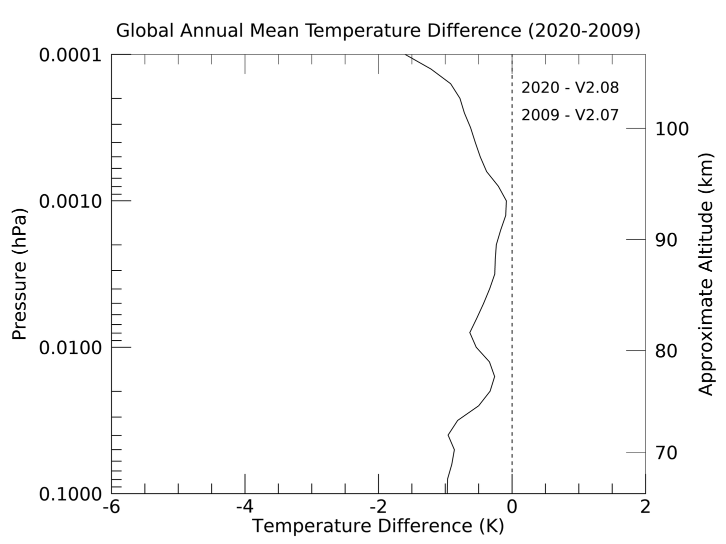
WACCM version changed inadvertently in Dec. 2019

Larger WACCM CO_2 (red curve) led to lower Temps



SABER reverted to original WACCM version

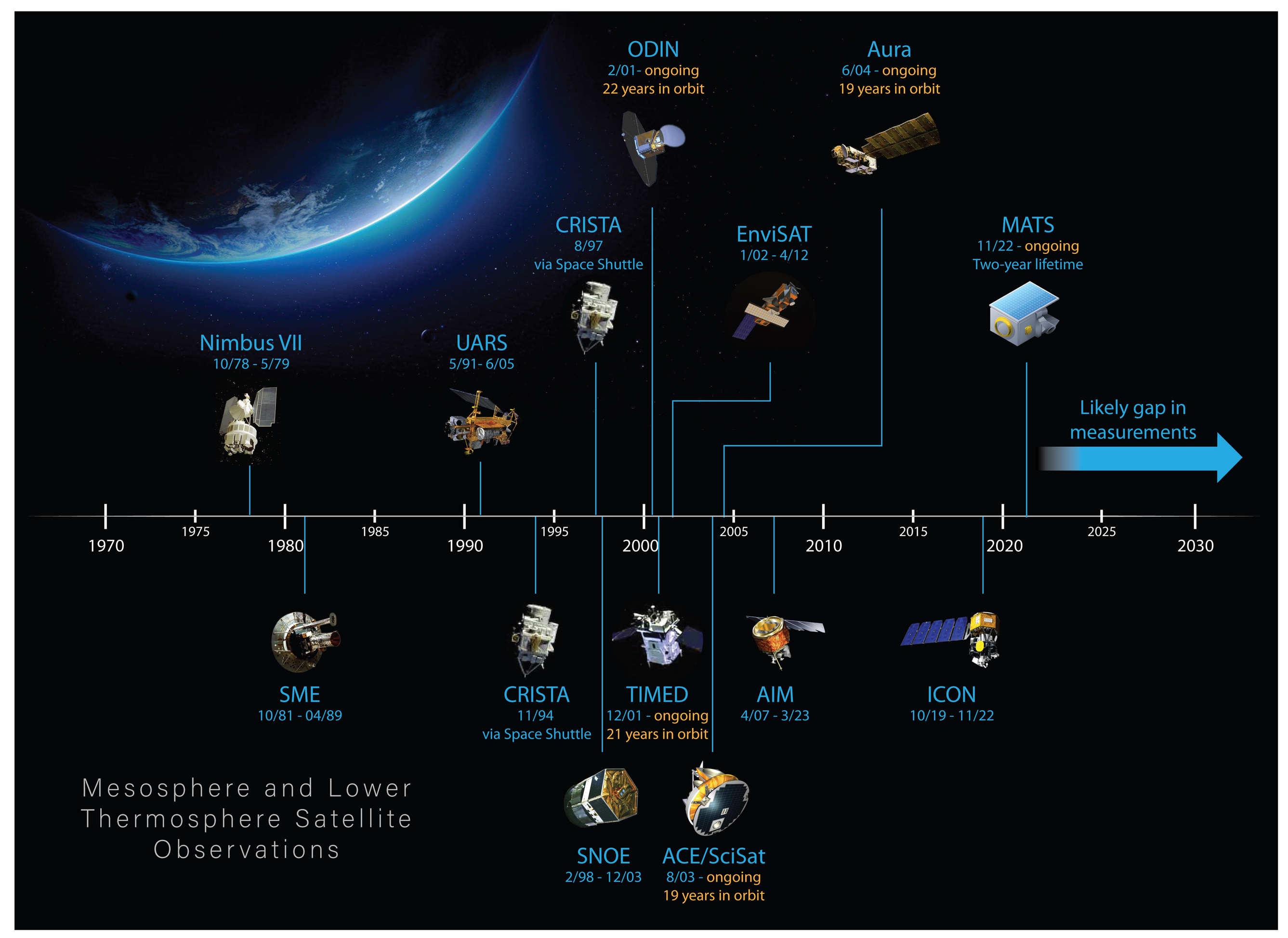
Temps now consistent with CO_2 increase and natural variability



Establishing a Geospace Observing System

- New observing systems must be designed to provide Geospace Data Records
- Designing a *system to measure long-term change*:
  - Accuracy and Precision of individual measurements
  - Orbit stability requirements (local time drift)
  - Algorithm stability
  - Accurately removing natural variability (solar cycle)
- The coming gap in observations must also be addressed

Mind The Gap!



Mind The Gap!