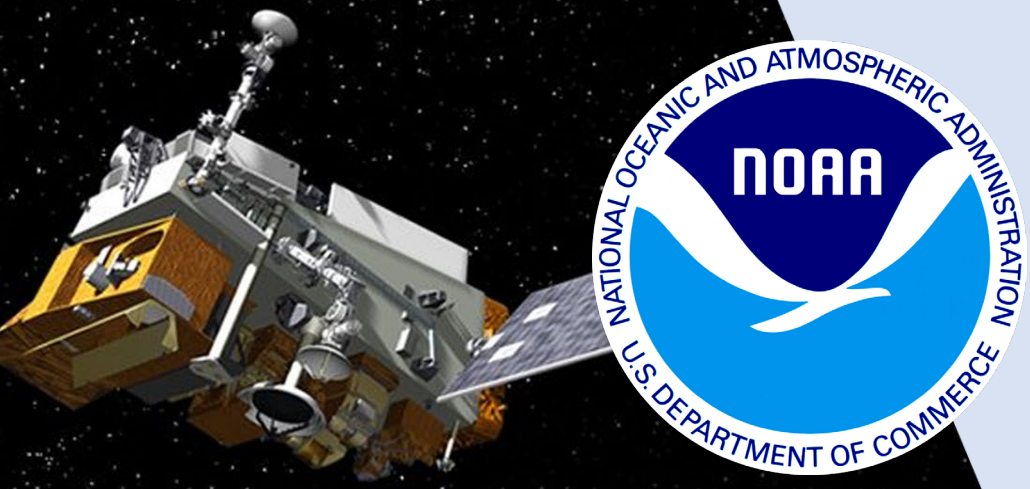


Construction of Temperature Climate Data Records in the Upper Troposphere and Lower Stratosphere Using Multiple RO Missions from September 2006 to July 2023 at NESDIS/STAR

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National Environmental Satellite, Data, and Information Service

Jan 16th, 2025



Motivation and Outline

- NOAA STAR GNSS RO Science and Data Center (SDC) has developed a new dry temperature monthly zonal mean climatology (MMC) in UTLS (8-30 km) from September 2006 to July 2023 based on multi-RO missions processed by NOAA STAR SDC.
- Assessment of the consistency among RO missions shows COSMIC-2 has a positive bias relative to other missions. COSMIC-2 is excluded from the construction of STAR-ROPP MMC.
- COSMIC-2 data has been applied to the study of weather forecasting and climate monitoring. It is essential to understand the causes of its systematic difference.
- Preliminary analysis of the possible causes of COSMIC-2 systematic differences:
  - Effects of solar activity
  - Effects of RO plane direction
- Summary

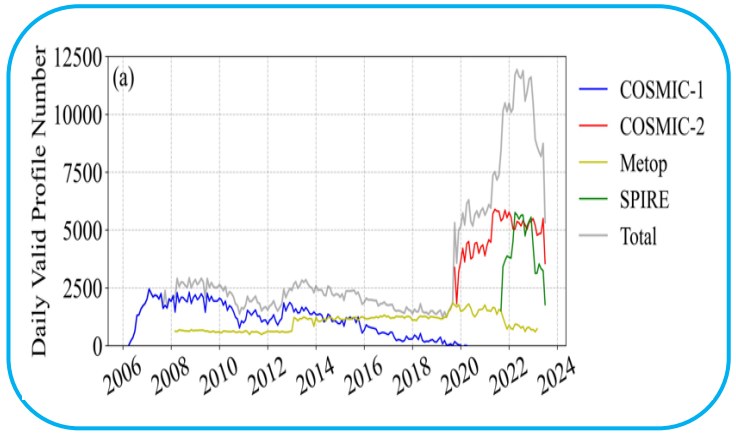
Construction of STAR-ROPP MMC

UCAR Excess phase POD → STAR reconfigured ROPP → Bending angle, refractivity dry temperature profiles → **Validation** → Assess the consistency among RO missions

Reconfigured parameters in ROPP

- Restore high time resolution POD
- Update L1 and L2 frequences for recent RO sensors.
- Add mission-specific pre-processing to manage open-loop and loss-carry flags for recent RO missions.
- Adjust cut-off height to ensure retrieval accuracy and penetration heights.
- Implement a post-process quality control. · · ·

STAR-ROPP version 1.0 ATBD



Chen et al. 2024
Ho et al. 2024a, 2024b

COSMIC-2 positive bias relative to other missions

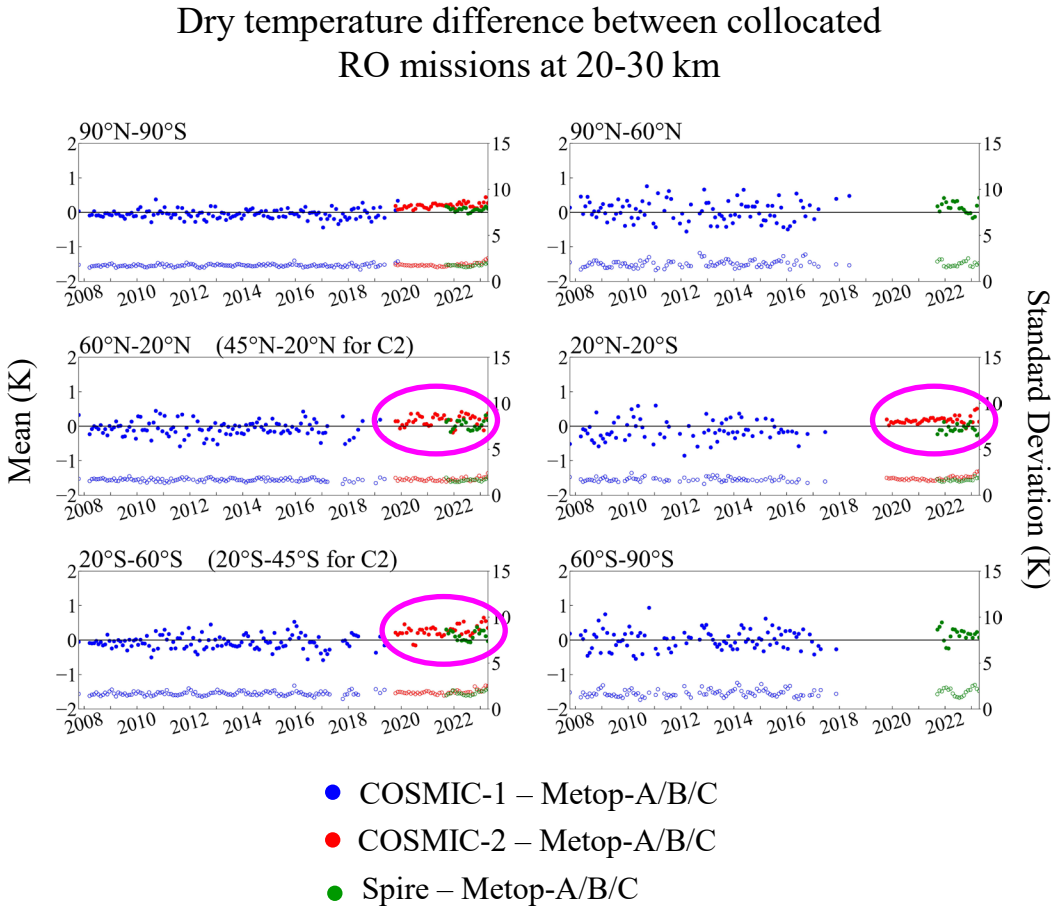
Bin and average on 5° latitude × 0.2 km altitude grids.

Zhou et al. 2024 (under review)

Sampling error correction

STAR-ROPP MMC → **Validation**

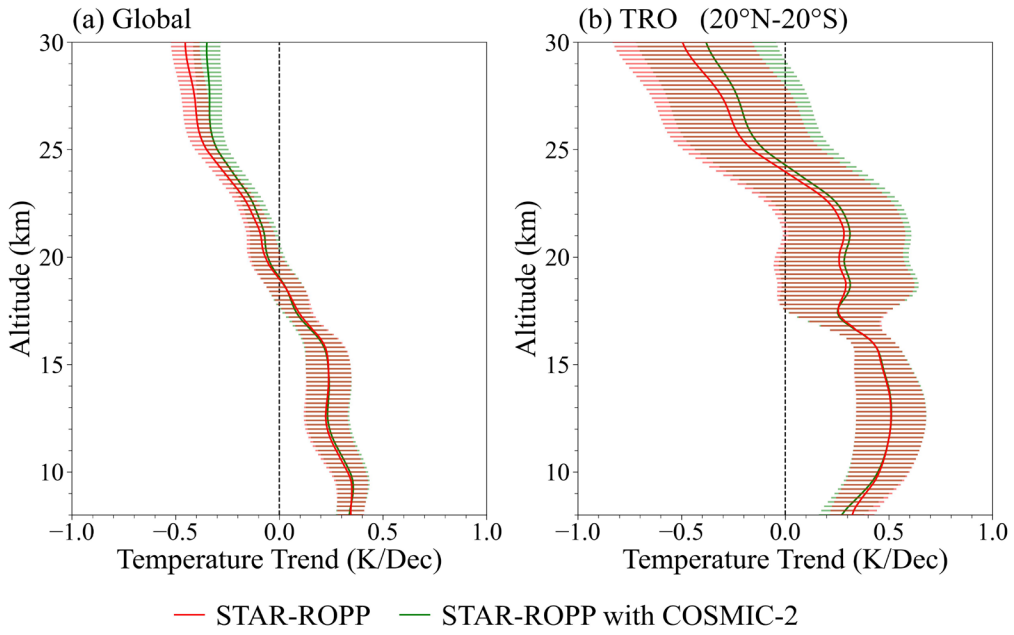
COSMIC-2 Bias against Other Missions



- Use Metop (Metop-A, -B, and -C) as a reference:
  - Cover 2006 to the present
  - Same receiver (GRAS)
  - Stable LEO satellite altitude (~820 km)
- Collocation criteria:
  time difference <30 min
  horizontal distance < 150 km at 19 km of TP
- Above 20 km, COSMIC-2 has positive bias relative to Metop:
  - bias in the Tropics increases with time
  - higher bias (~0.3 K) in mid-latitudes.

Impact of COSMIC-2 Systematic Difference on Temperature Trend Estimation

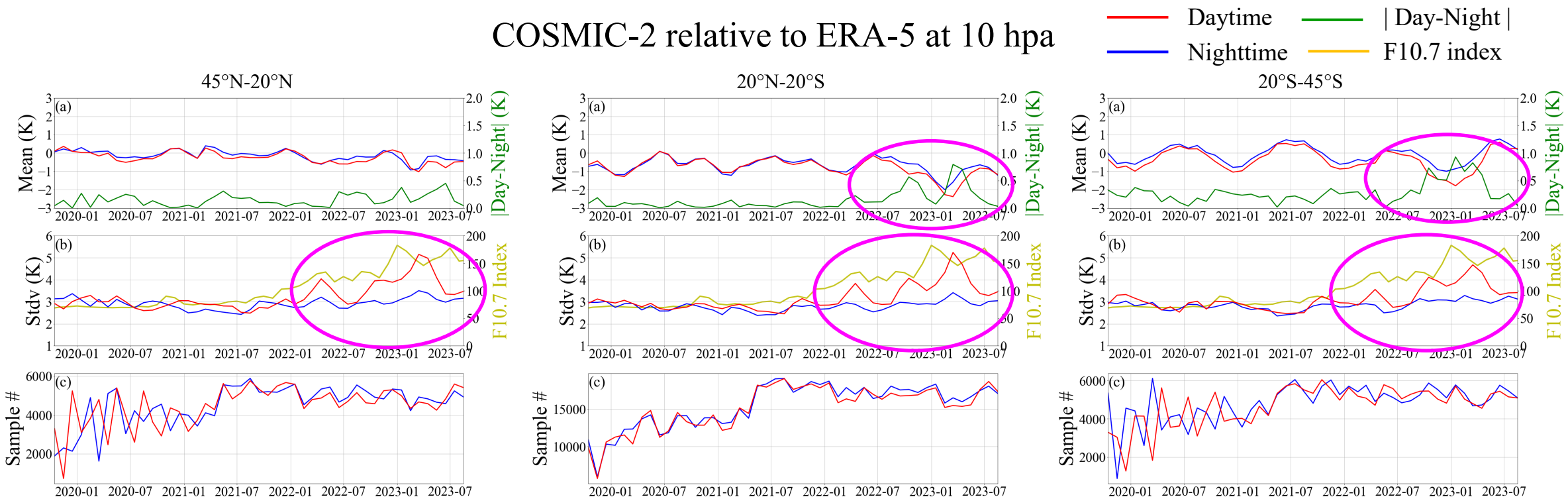
Vertically resolved temperature trends
(September 2006 - July 2023)



- COSMIC-2 positive bias against other missions can increase the temperature trend above 20 km, up to 0.1 K/Decade at 30 km, exceeding GCOS required measurement stability (0.05 K/Decade).
- Removing COSMIC-2 makes the temperature trend cooler in the lower stratosphere.
- COSMIC-2 is excluded from the STAR MMC construction.
- What causes COSMIC-2 systematic difference?
- Why the systematic difference is higher in the mid-latitudes?

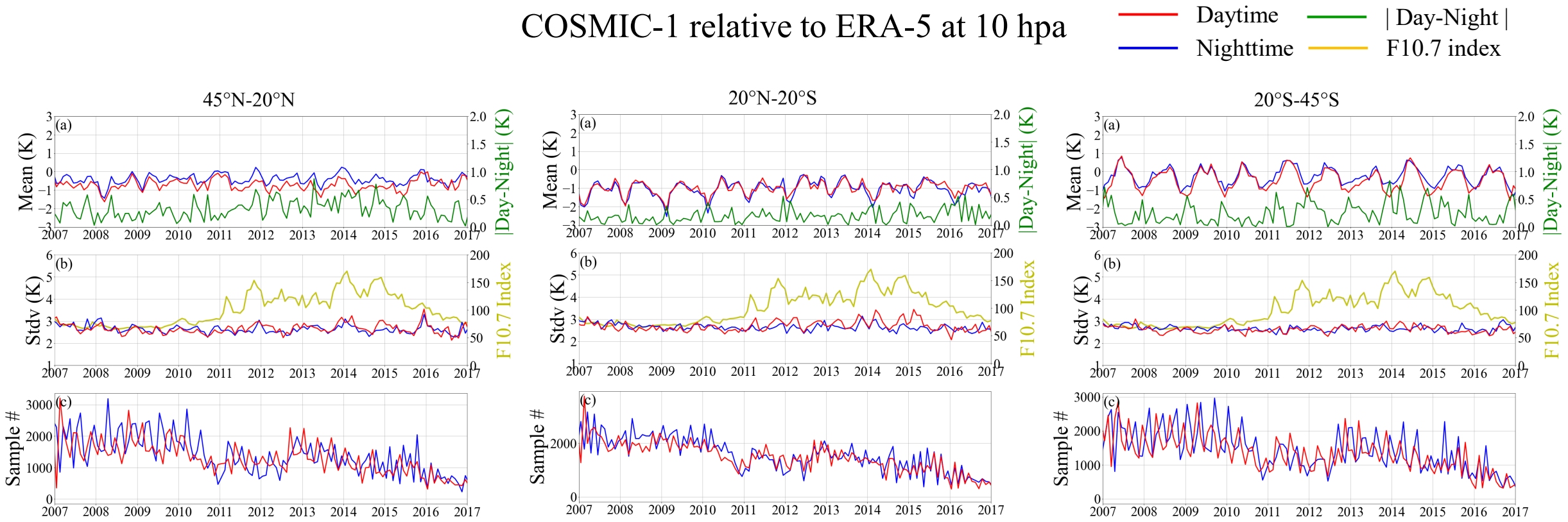
Effects of Solar Activity

Approach: Separate RO minus ERA-5 into daytime and nighttime events, calculate bias and stdv respectively
Daytime: 11:00-15:00 local time
Nighttime: 2:00-6:00 local time (Following separation criteria in Danzer et al., 2013)



- Deviation between daytime and nighttime O-B increases with time and show seasonal variation.
- COSMIC-2 is susceptible to solar activity.

Effects of Solar Activity

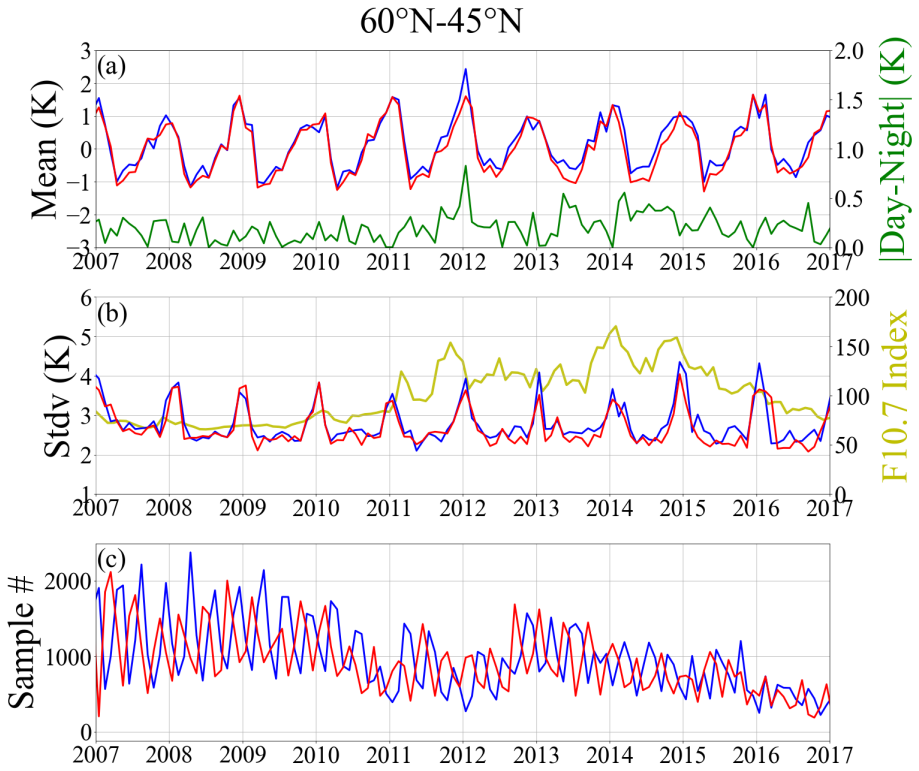


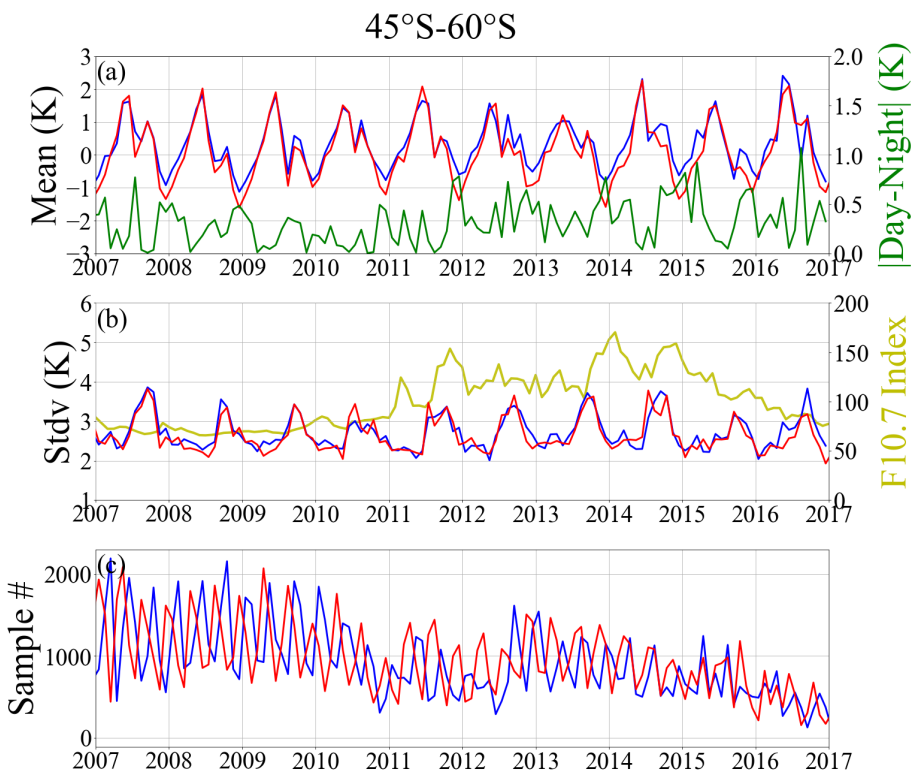
- COSMIC-1 went through the 24th solar cycle.
- No obvious difference is found in the daytime and nighttime bias/standard deviation.

Effects of Solar Activity

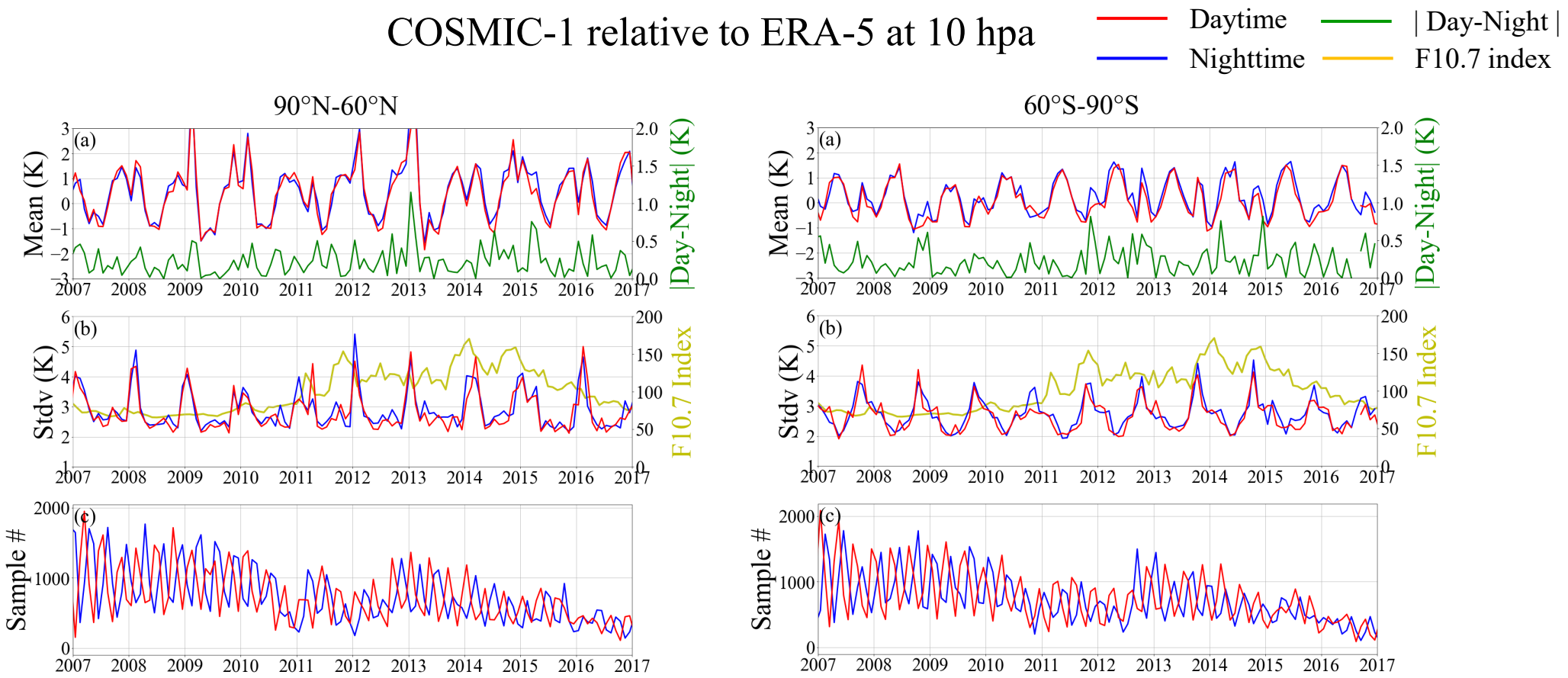
COSMIC-1 relative to ERA-5 at 10 hpa

Daytime | Day-Night |
Nighttime F10.7 index



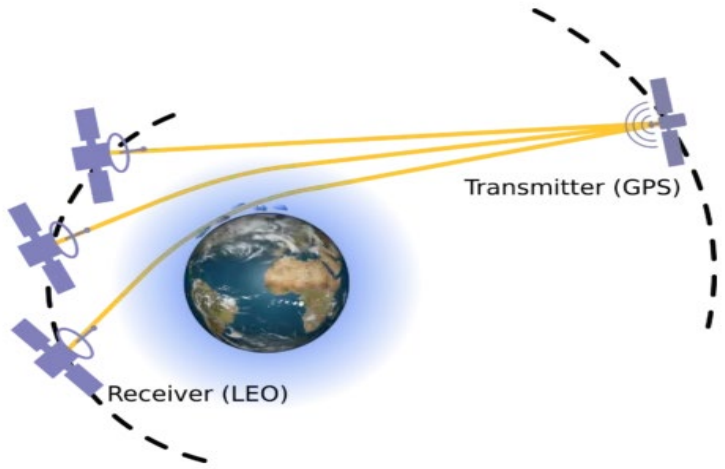


Effects of Solar Activity



- COSMIC-1 is not impacted much by solar activity.

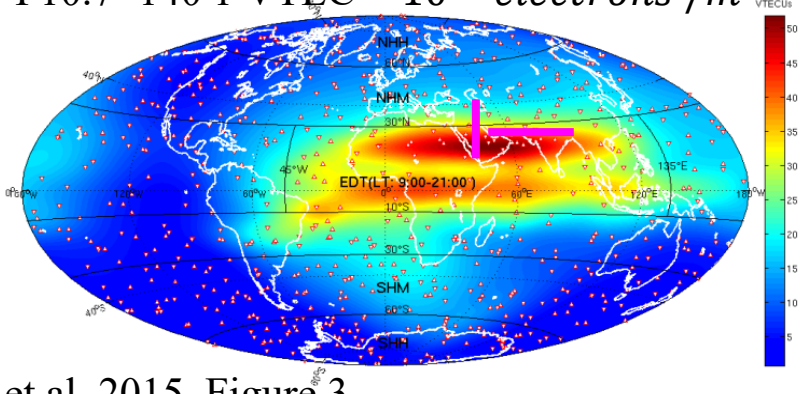
Effects of RO Plane Direction



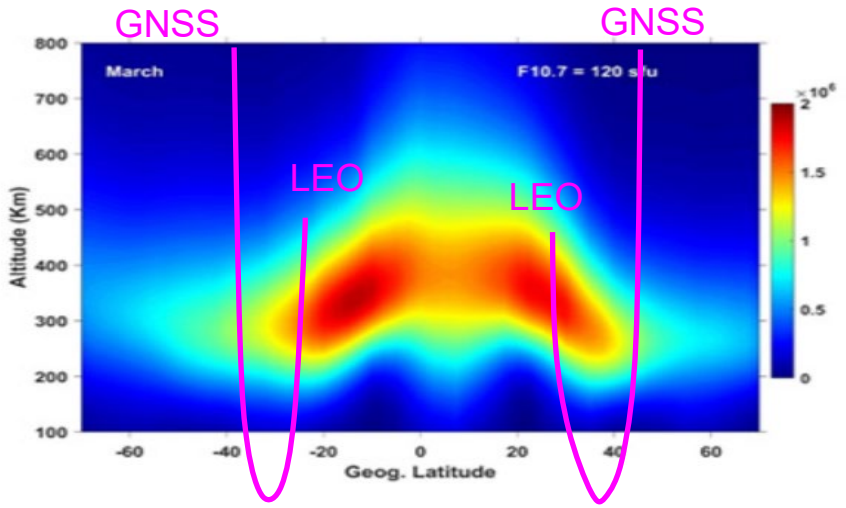
- Previous studies show that the asymmetry in ionospheric electron density along ray path about perigee can:
  - cause larger ray path deviation, and thus higher residual ionospheric error (RIE);
  - violate the assumption of spherical symmetry for Abel inversion.

(Liu et al. 2013, 2015; Coleman et al. 2017)

Global distribution of the vertical total electron content (VTEC) at 12:00 UTC on 15 July 2008 (NeUoG)
F10.7=140 1 VTEC = 10^{16} $electrons\ /m^2$



Liu et al. 2015, Figure 3

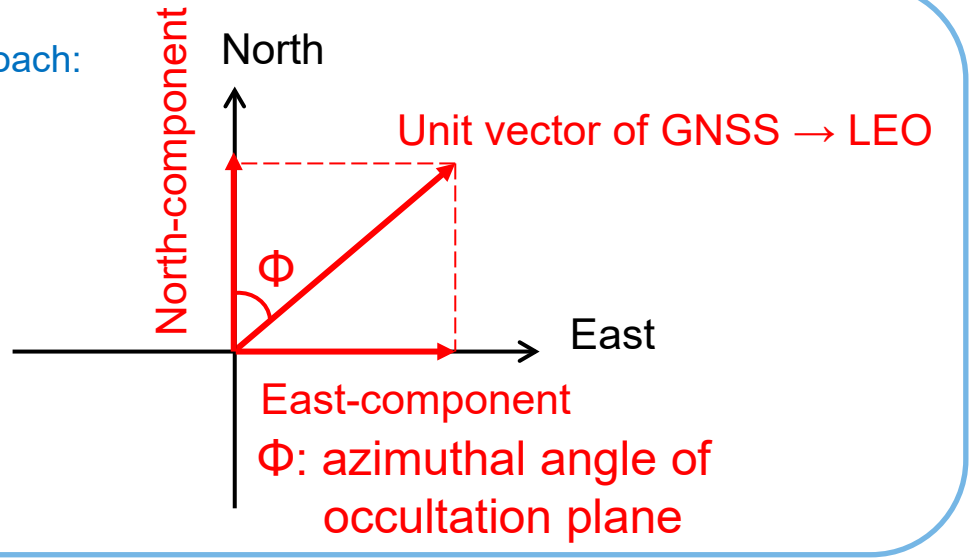


The ionospheric electron density as a function of altitude over Indian longitude during March equinox at 12:00 Hrs. as simulated by ANNIM.

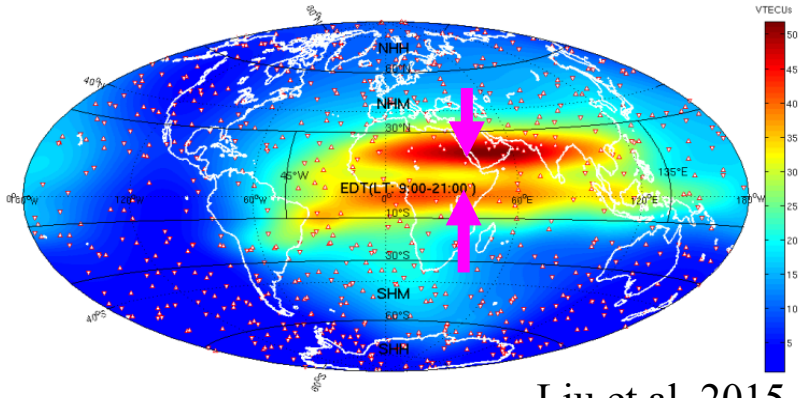
Gowtam et al. 2019

Effects of RO Plane Direction

Approach:

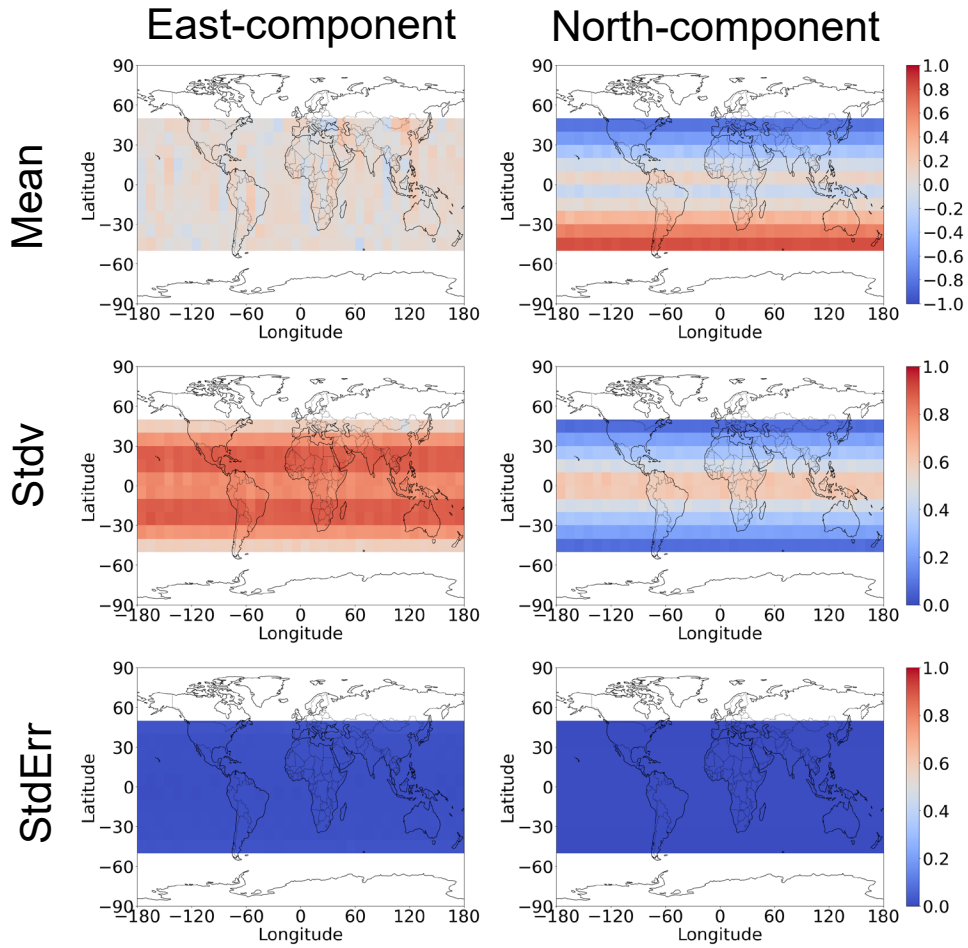


Global distribution of VTEC



Liu et al. 2015, Figure 3

COSMIC-2 RO plane direction (2022)

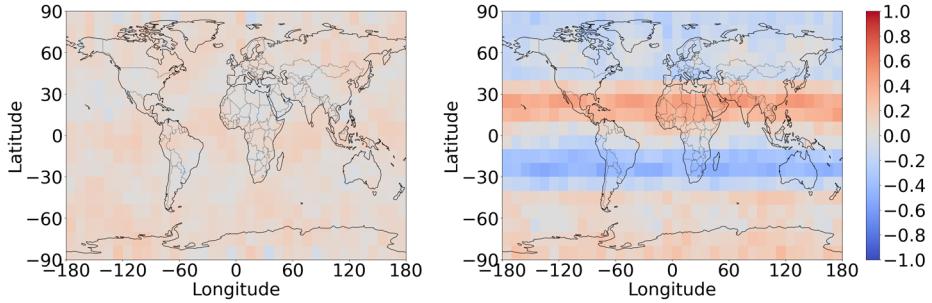


Effects of RO Plane Direction

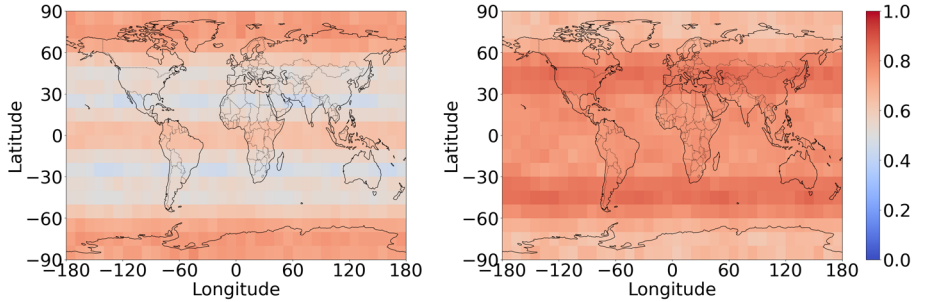
COSMIC-1 RO plane direction (2014)

East-component | North-component

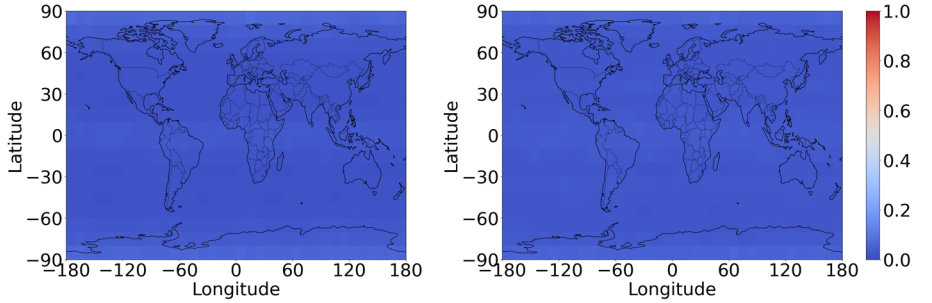
Mean



Standard Deviation



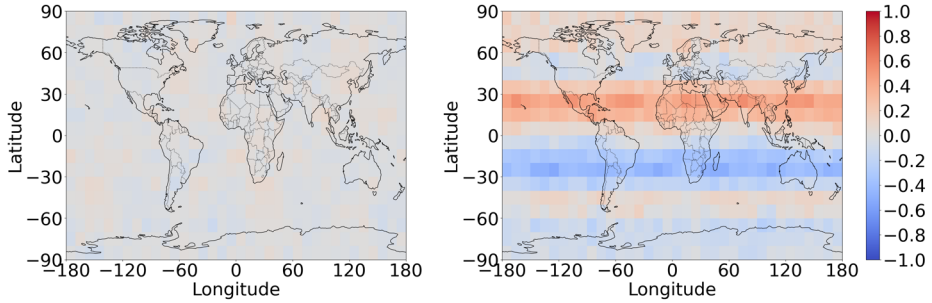
Standard Error



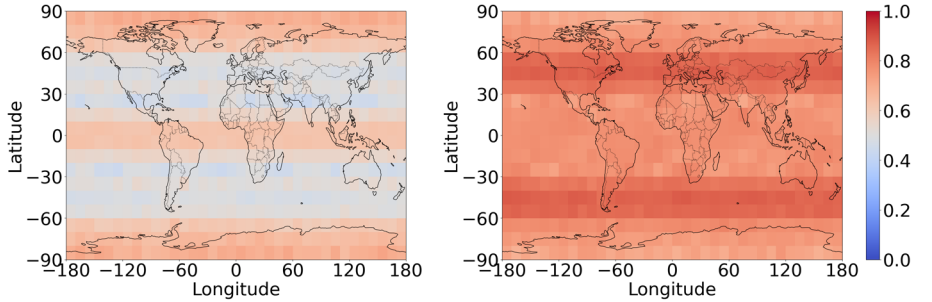
Metop RO plane direction (2014)

East-component | North-component

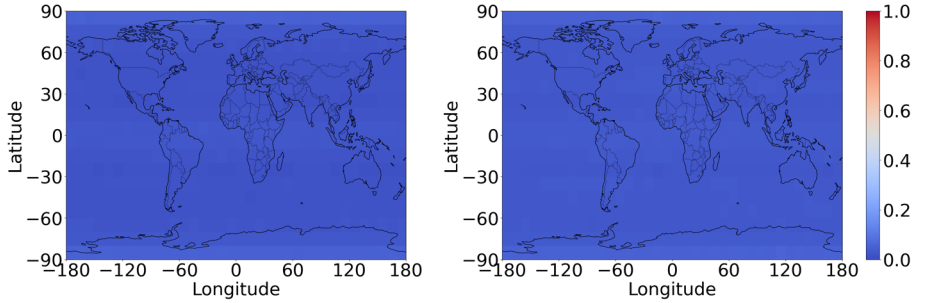
Mean



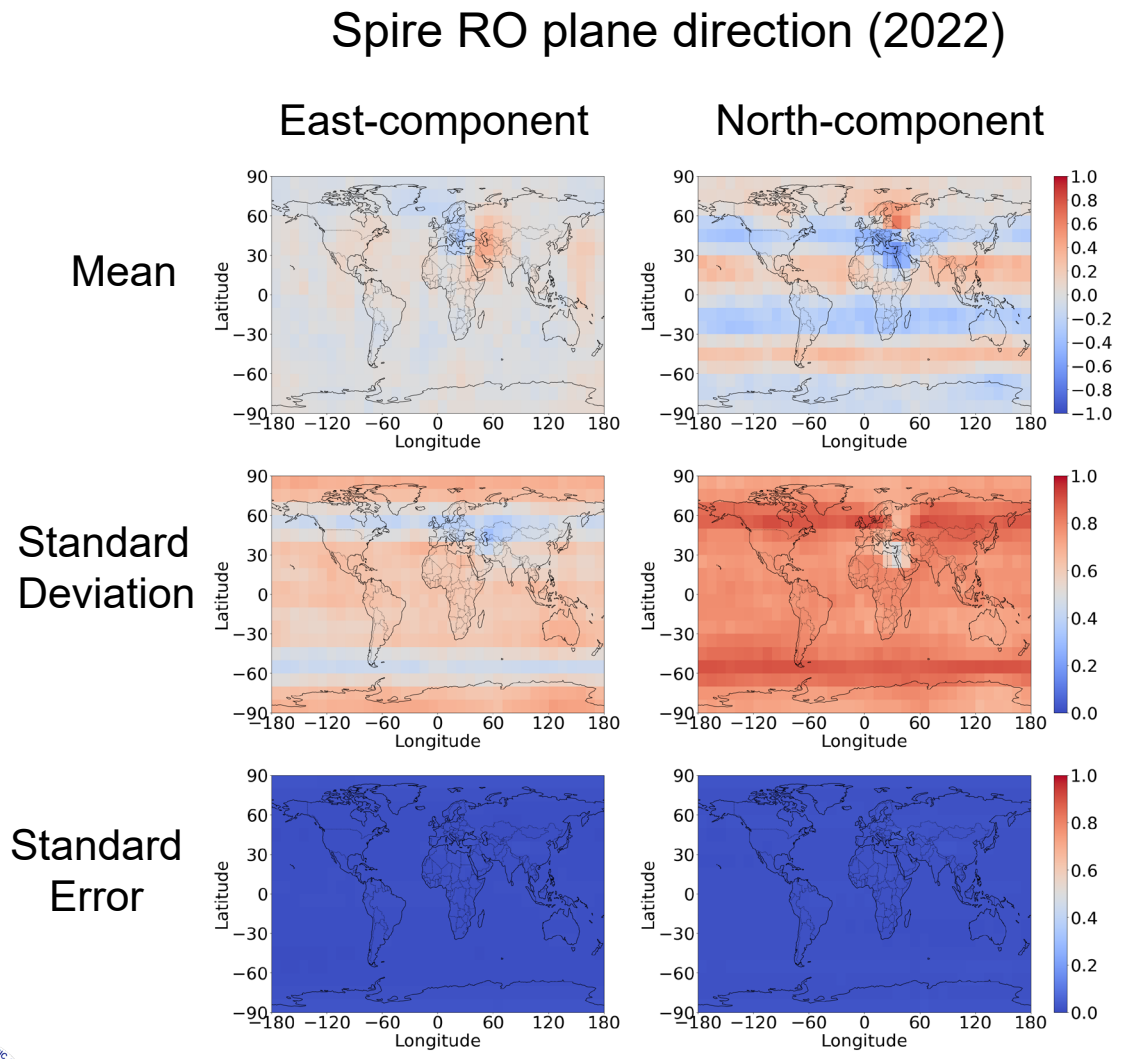
Standard Deviation



Standard Error



Effects of RO Plane Direction



- COSMIC-2 RO planes in mid-latitudes are mostly along latitudinal direction.
- The latitudinal ray paths go through larger electron density gradient due to equatorial anomaly, leading to higher RIE.
- For other missions, the RO plane direction is randomly distributed.
- COSMIC-2 higher positive systematic difference in mid-latitudes may be caused by its special plane direction.



Summary

- NOAA STAR GNSS RO SDC has developed a new monthly zonal mean climatology (MMC) in UTLS from September 2006 to July 2023 based on multi-RO missions.
- COSMIC-2 is excluded from the construction of STAR-ROPP MMC because of its positive bias relative to other missions.
- Preliminary analysis of COSMIC-2 systematic differences shows that:
  - Compared to other missions, COSMIC-2 is more susceptible to solar activity;
  - The higher positive bias in the mid-latitudes may be caused by its special RO plane direction.
- The results need to be further verified and quantified through the end-to-end simulations.
- Other factors in the RO retrieval chain may contribute to COSMIC-2 systematic differences and need to be investigated.



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Questions?

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Backup slides

