GOES FUNDAMENTAL CLIMATE DATA RECORD: HISTORICAL GOES 8-15

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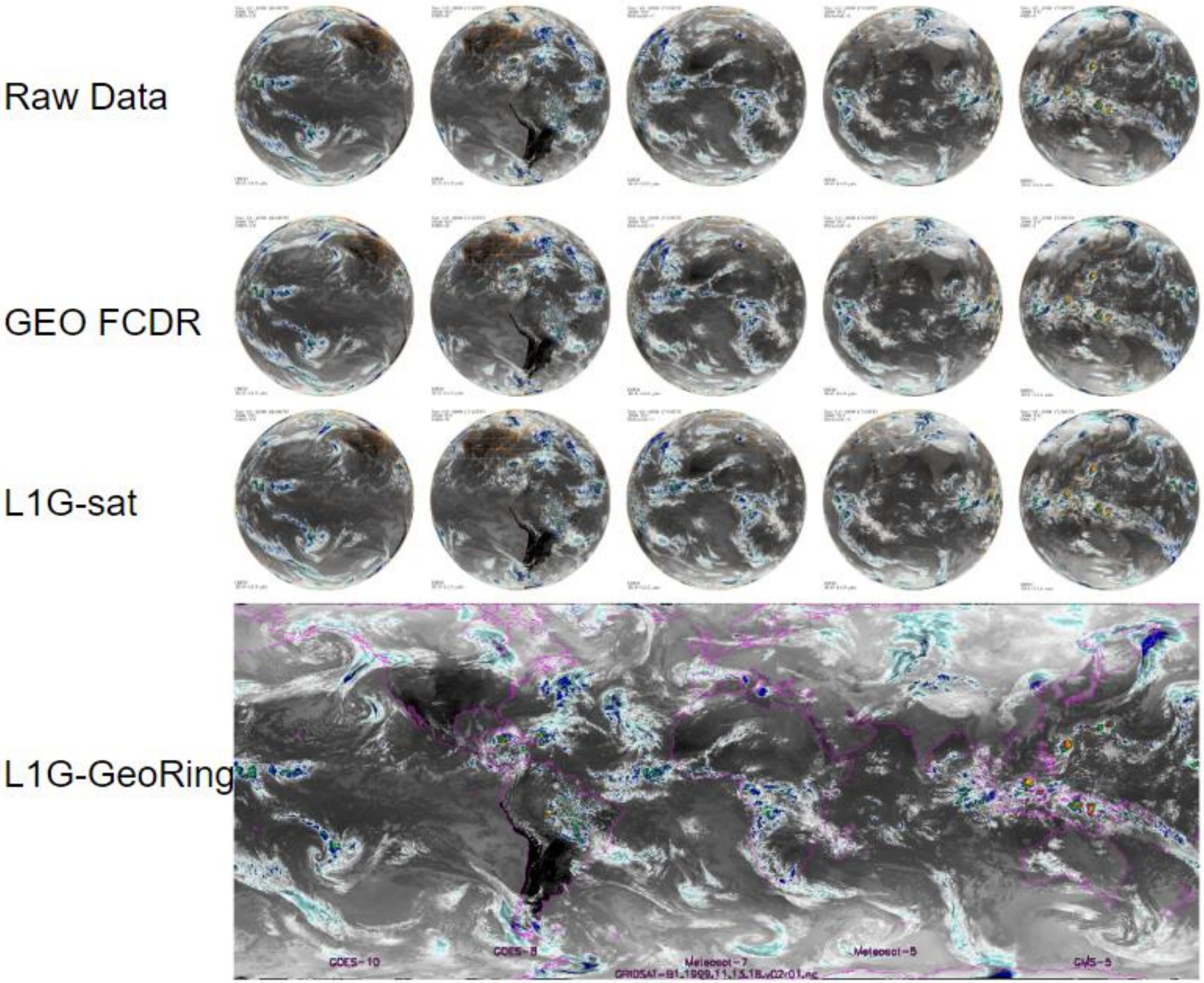
MOTIVATION

The current approach to archive and access of historic GOES Imager data is not user-friendly:

- archived data formats are **difficult to use,**
- there are **known gaps** in the time series,
- historical imagery has **duplicates** with no **metadata** explanation,
- **calibration** is not included, and
- the download process is **arduous**.



EUMETSAT-NOAA GEO-RING FCDR

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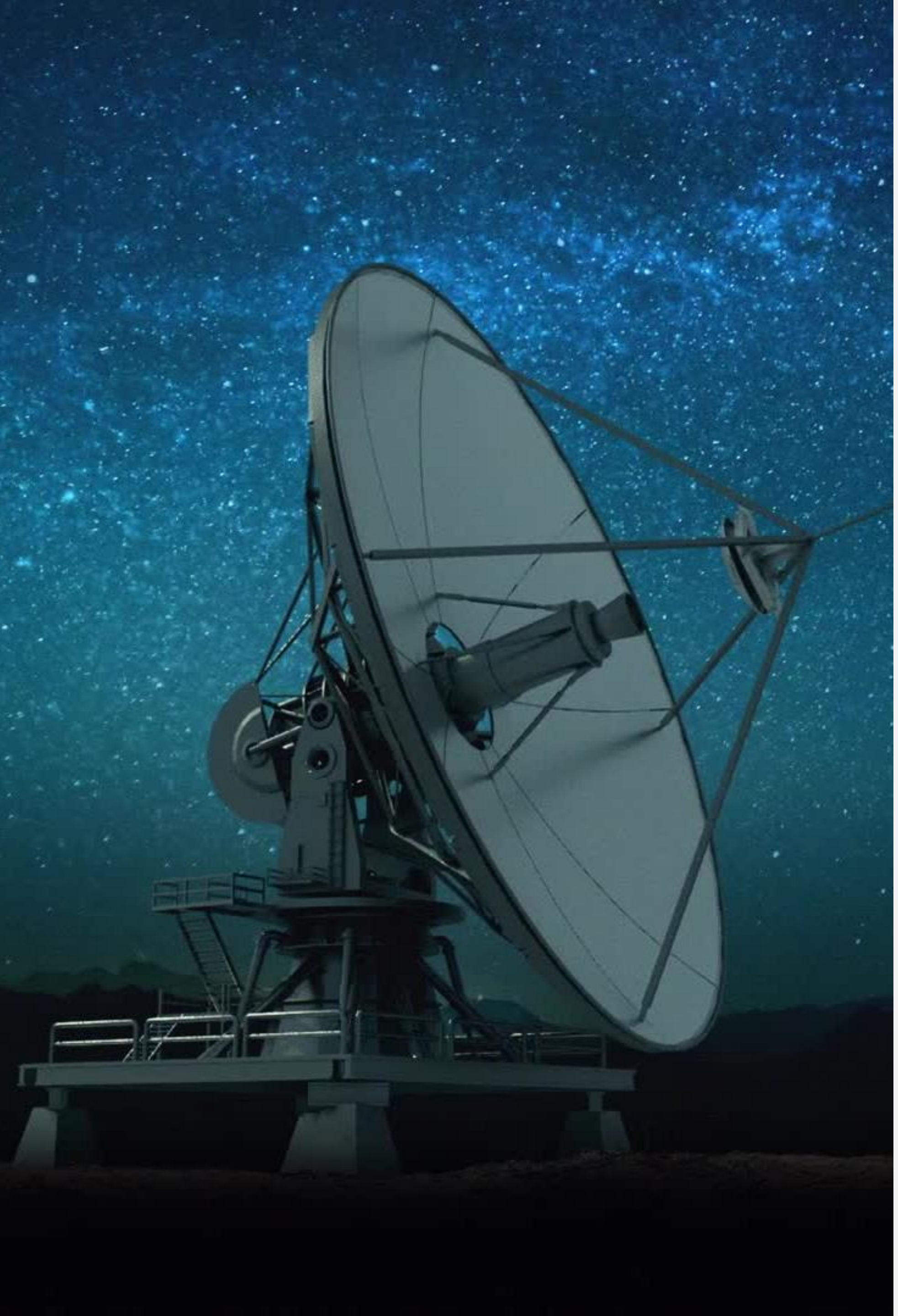

OVERVIEW

This multi-year project will create a GOES Imager Fundamental Climate Data Record (FCDR) for all satellites from SMS-1 through GOES-15 (1974-2018). This static FCDR will be available operationally, while the original raw data will be moved to NCEI's deep archive. The GOES FCDR will provide data with:

- ❑ **uniform** format
- ❑ **uniform** data quality assessment
- ❑ **uniform** calibration
- ❑ **uniform** navigation

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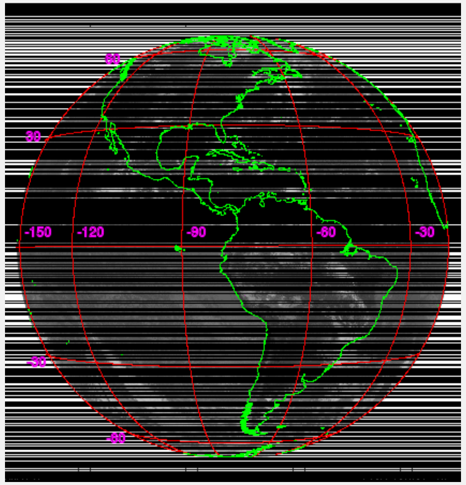
SMS/GOES DATA RESCUE (1978-1996)

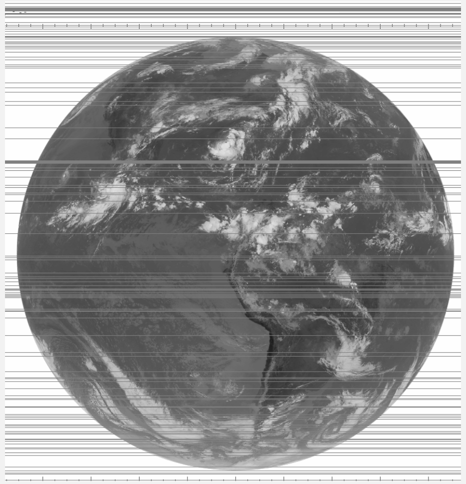
Stewardship of SMS 1-2 and GOES 1-7 data (UW/SSEC): The process for reading data from the tapes was not stable and resulted in incomplete files, multiple files, and corrupted files.

Developed 'smart' decoders that detected errors in sync patterns (the binary data used to signal start of each scan from the satellite to the ground station). This results in restoring missing data to complete full disk images.

Reconciliation of SSEC and NOAA/CLASS archive holdings



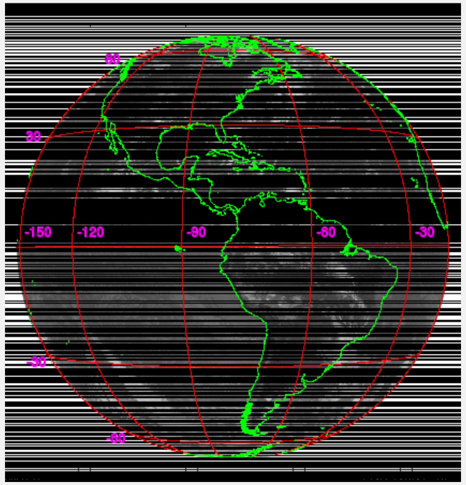
NOAA CLASS
GOES-5 IR
1981-08-17 15:30 UTC



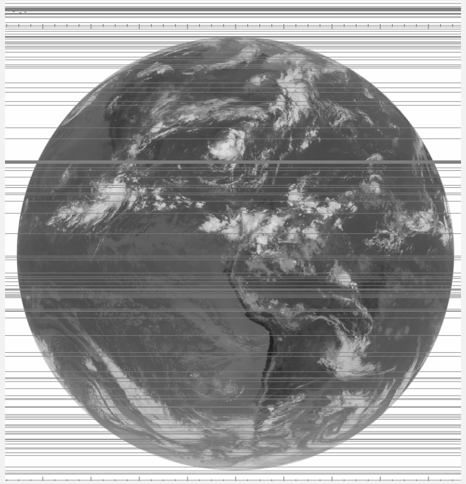
SSEC reprocessed
GOES-5 IR
1981-08-17 15:30 UTC

SMS/GOES DATA RESCUE (1978-1996)

•<u>Lines deleted/added</u>: Caused by multiple/bad sync or ground station send errors, sometimes resulted in multiple images in one index.
•<u>Bit slip</u>: Bits inserted between sync and type blocks and/or data, probably from when U-matic was first recorded, or may have happened during playback.
•<u>Fixed type</u>: IR (0) or VIS (1-8) incorrect, sometimes due to bit slip or multiple/bad sync.
•<u>Fixed line number</u>: Line number was changed, caused by bit error.
<u>Framing Error</u>: IR data block size was incorrect.



NOAA CLASS
GOES-5 IR
1981-08-17 15:30 UTC



SSEC reprocessed
GOES-5 IR
1981-08-17 15:30 UTC

PROJECT SCOPE

- Review and assess existing calibration approaches of historical GOES visible and infrared channels.
- Define GOES FCDR format for consistency and compatibility.
- Prepare for and perform data processing (in the cloud).

PLAN HOW TO INCORPORATE CALIBRATION INFORMATION INTO THE FINAL CDR.

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HISTORICAL GOES 8-15 CALIBRATION

NESDIS Operational: Operational calibration coefficients.

CERES: Geostationary Visible Imager Calibration for the CERES SYN1deg Edition 4 Product (Doelling et al, 2018)

Desert-based: Pseudo-invariant desert sites (Uprety and Cao, 2010)

Inamdar-Knapp: Compared ISCCP B1 data with PATMOS x AVHRR reflectances (Inamdar and Knapp, 2015)

ISCCP: Normalization and calibration of geostationary satellite radiances for ISCCP (Desormeaux et al, 1993)

Lunar: Evaluation of ISCCP multisatellite radiance calibration for geostationary imager visible channels using the moon (Stone et al, 2013)

Full Disk Reflectance: Using GOES-R ABI Full-Disk Reflectance as a calibration source for the GOES Imager channels (Heidinger et al, 2022)

DCC: Deep convective clouds as invariant targets (Doelling et al., 2016)

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Method	Equation	Variables	Paper
CERES Full Disk Reflectance NESDIS	$S = \frac{S_0\,(100 + Ax + Bx^2)}{100}$	x : time in years since start of calibration S_0 : calibration slope	Doelling et al, 2018 Heidinger et al, 2022 Stone et al, 2013
Lunar	$C = C_0\,(A_0 + A_1(t - t_0) + A_2(t - t_0)^2)$	t_0 : operational dates $t - t_0$: elapsed times in days	Stone et al, 2013
Deep Convective Clouds	$G = G_0 + G_1 dsl + G_2 dsl^2$	dsl : days since launch	Doelling et al., 2016
Desert-Based	$G = G_0\,(1 + G_1 Y + G_2 Y^2)$	Y : years since launched	Inamdar and Knapp, 2015
ISCCP	$G = G_0\,(1 + G_1 Y + G_2 Y^2)$	Y : years since launched	Desormeaux et al, 1993
Inamdar-Knapp	$G = G_0\,(1 + G_1 Y + G_2 Y^2)$	Y : years since launched	Inamdar and Knapp, 2015

$$G = g_0(1 + g_1 Y + g_2 Y^2)$$

$$[W\ m^{-2}\ ster^{-1}\ count^{-1}]$$

Calibration Coefficients: g_0, g_1, g_2

Time since launch: Y

AGGREGATION OF THE METHODS

- Mean of G

$$\mathbb{E}[\![G]\!] = \mathbb{E}[\![g_0\,(1\;+g_1Y+g_2Y^2)]\!]$$

- Compute G using Mean Coefficients

$$\overline{g_o} = \;\mathbb{E}[\![g_o]\!],\;\; \overline{g_1} = \;\mathbb{E}[\![g_1]\!],\;\; \overline{g_2} = \;\mathbb{E}[\![g_2]\!]$$

$$\Longrightarrow\; G' = \;G_0\,(1\;+G_1Y+G_2Y^2)$$

AGGREGATION OF THE METHODS

- Mean of G

$$\mathbb{E}[\![G]\!] = \mathbb{E}[\![g_0\,(1 + g_1 Y + g_2 Y^2)]\!]$$

Assumes linear relationship

Accounts for interaction between Y and G

Because g_0, g_1, g_2 are constants…..

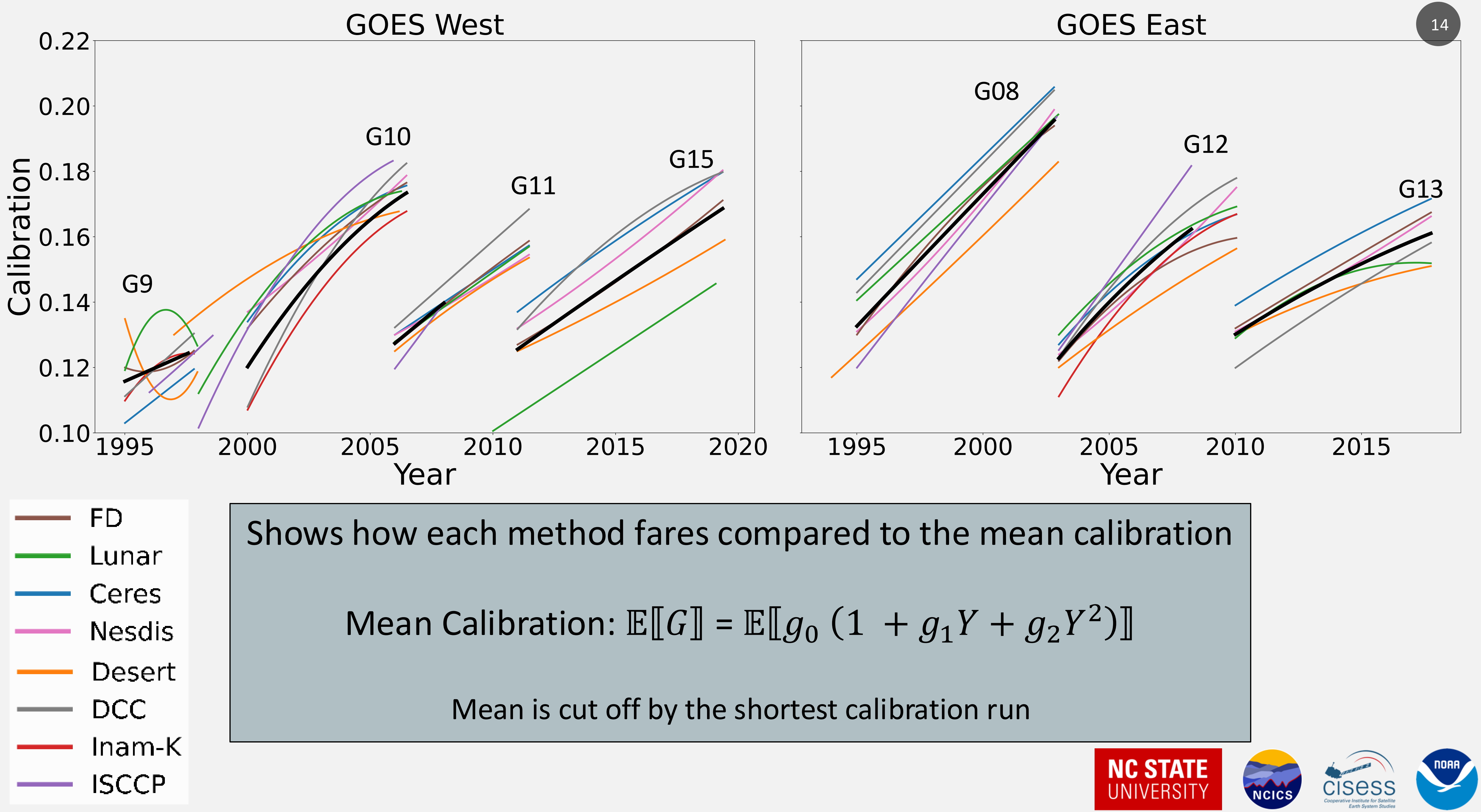
- Compute G using Mean Coefficients

THEN $\mathbb{E}[\![G]\!]$ and G' are the same

$$G_0 = \mathbb{E}[\![g_0]\!],\quad G_1 = \mathbb{E}[\![g_1]\!],\quad G_2 = \mathbb{E}[\![g_2]\!]$$

$$\Longrightarrow \quad G' = G_0\,(1 + G_1 Y + G_2 Y^2)$$

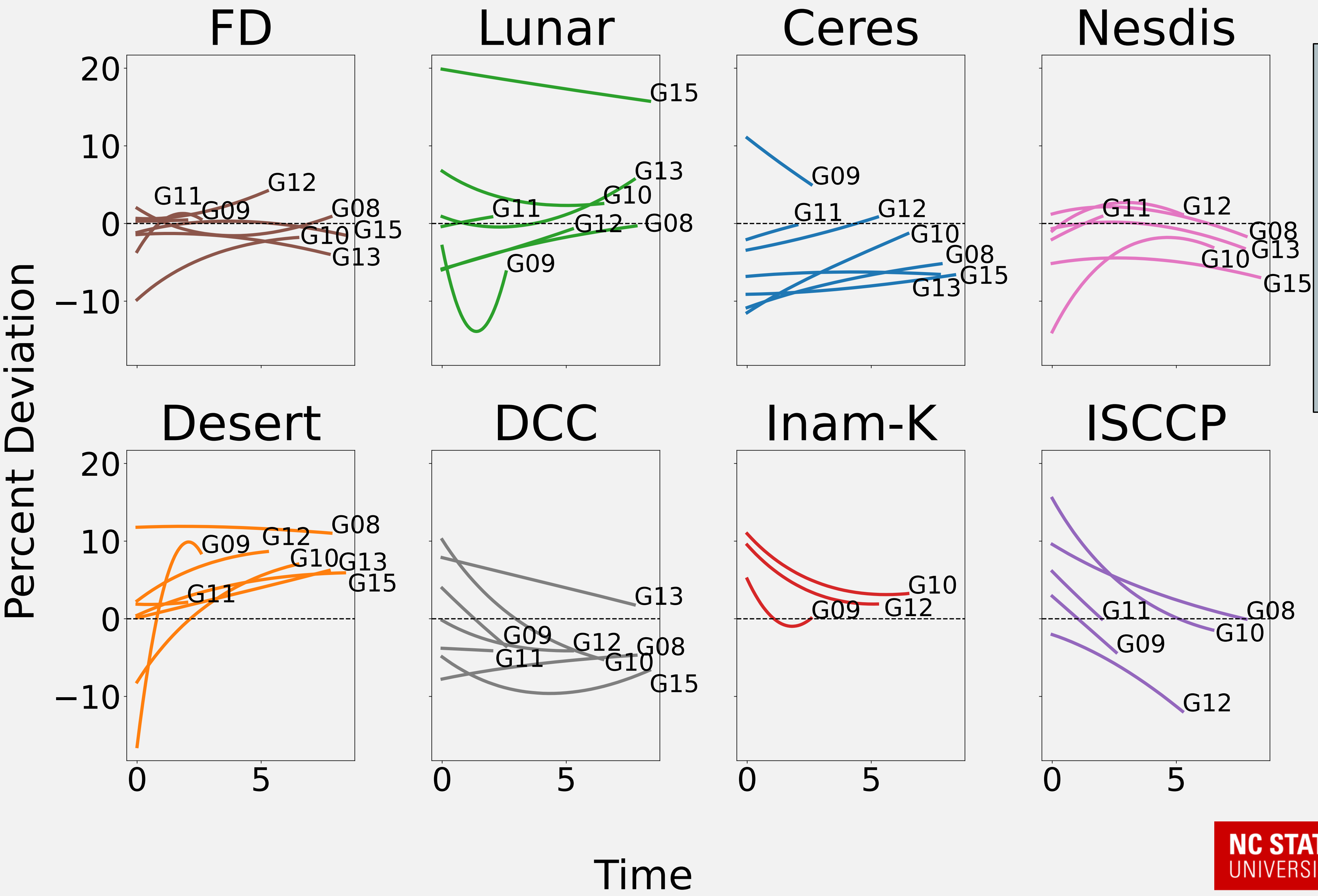
Assumes coefficients do not interact with Y



Shows how each method fares compared to the mean calibration

Mean Calibration: $\mathbb{E}[\![G]\!] = \mathbb{E}[\![g_0\,(1 + g_1 Y + g_2 Y^2)]\!]$

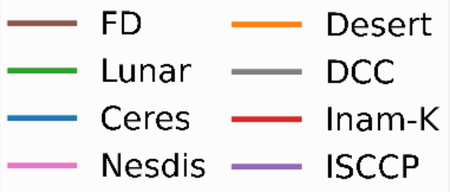
Mean is cut off by the shortest calibration run

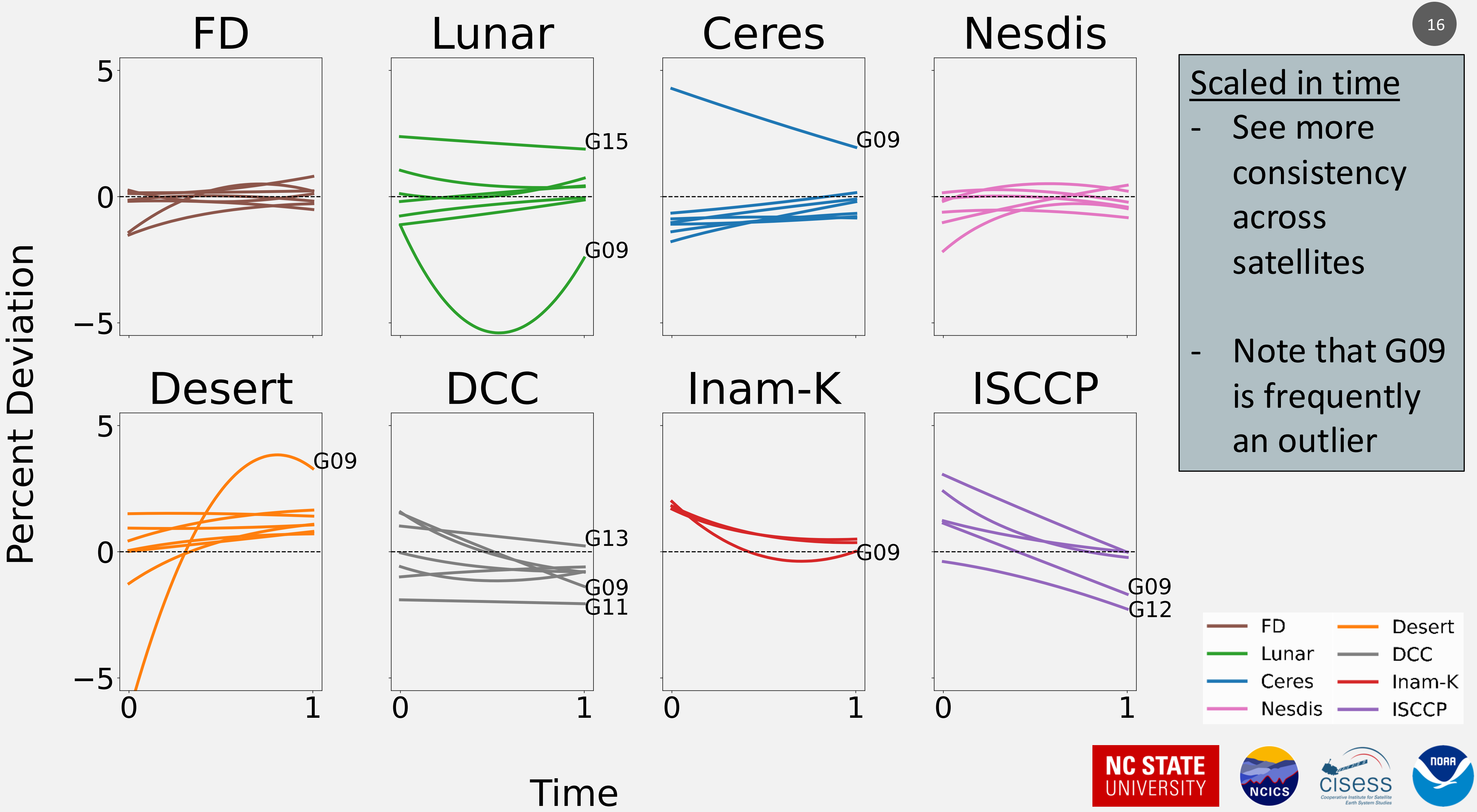


$$\Delta G = \frac{\mathbb{E}[\![G]\!] - G}{\mathbb{E}[\![G]\!]}$$

Most are within 10% deviation

A few are close to 0%





Scaled in time

- See more consistency across satellites
- Note that G09 is frequently an outlier

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Review and assess existing calibration approaches of historical GOES visible and infrared channels.

Define GOES FCDR format for consistency and compatibility.

Prepare for and perform data processing (in the cloud).

- NAVIGATION

- QUALITY CONTROL

- GOES R FORMAT (METADATA & VARIABLES) AS TEMPLATE

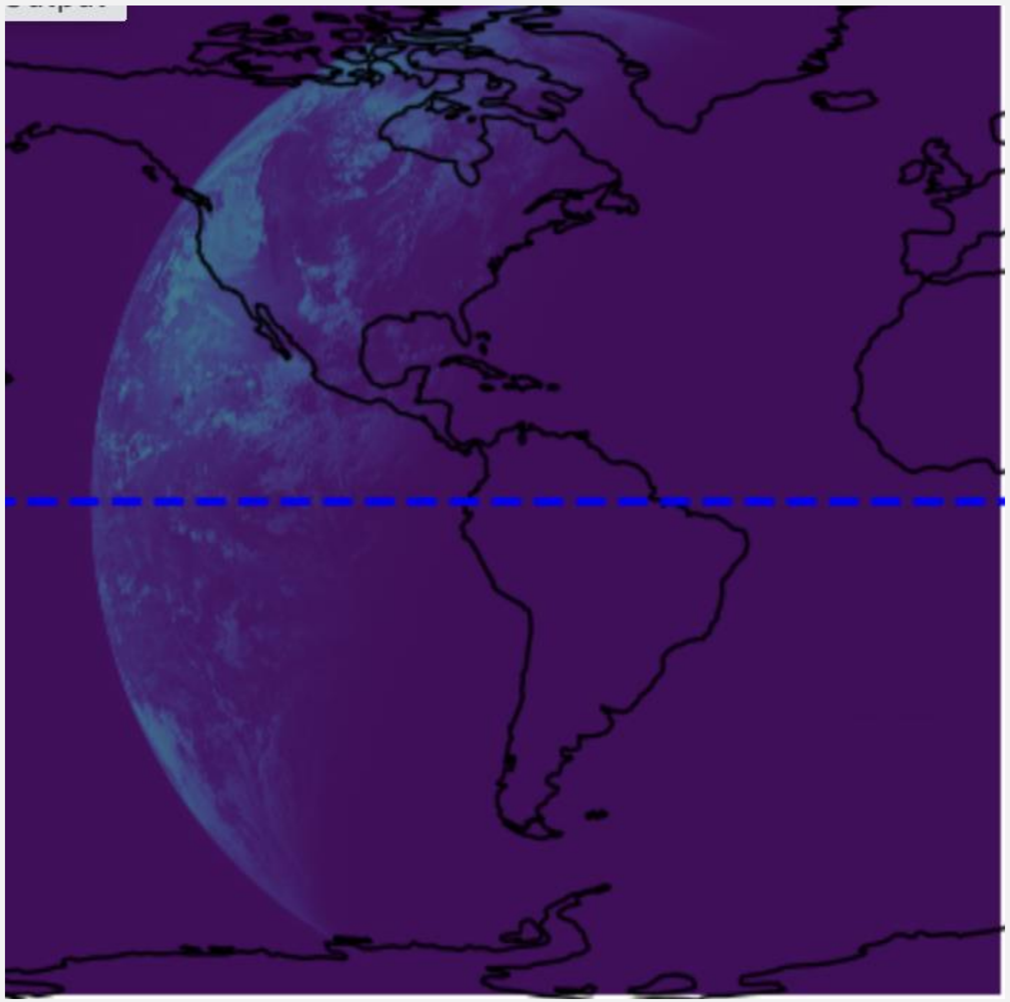
- COMPARE WITH EUMETSAT FCDR FORMATS

NAVIGATION

- CONVERTED IDL AND FORTRAN NAVIGATION INTO PYTHON

- ENSURED STABILITY OF NAVIGATION BY CONVERTING LINE/PIXEL TO LATITUDE/LONGITUDE AND BACK WITH MINIMAL DIFFERENCE

INITIAL IMAGE



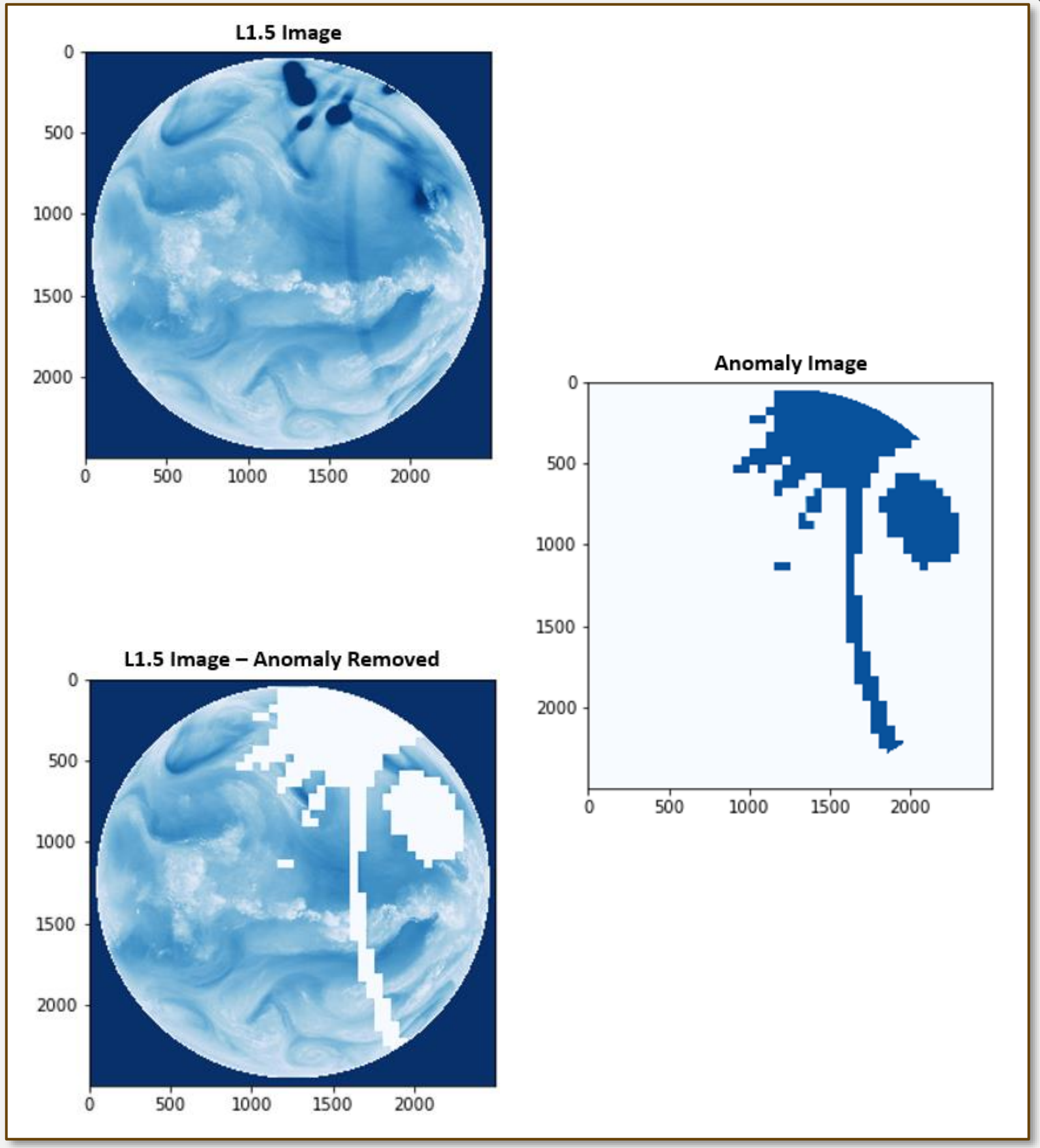
QUALITY CONTROL

EUMETSAT is developing a QC tool

- Uses AI to identify scan articles in the GOES record for global consistency
- Already done for other international geostationary satellites (e.g. Meteosat, GMS)
- Currently working on SMS1 - GOES 7

We will apply QC tool in the FCDR process

- **Binary matrix of good/bad pixels**



NEXT STEPS

Calibration

Determine implementation of the multiple calibration methods into the FCDR

Navigation

Validate and ensure accuracy of the coordinates

Format

Piece the calibration, navigation, and QC to create a NetCDF

WHAT ARE YOUR THOUGHTS FOR WAYS TO INCLUDE CALIBRATION INTO THE FCDR?