SA’s first ocean color sensor in geostationary orbit: ckground, Capabilities and Calibration Strategy

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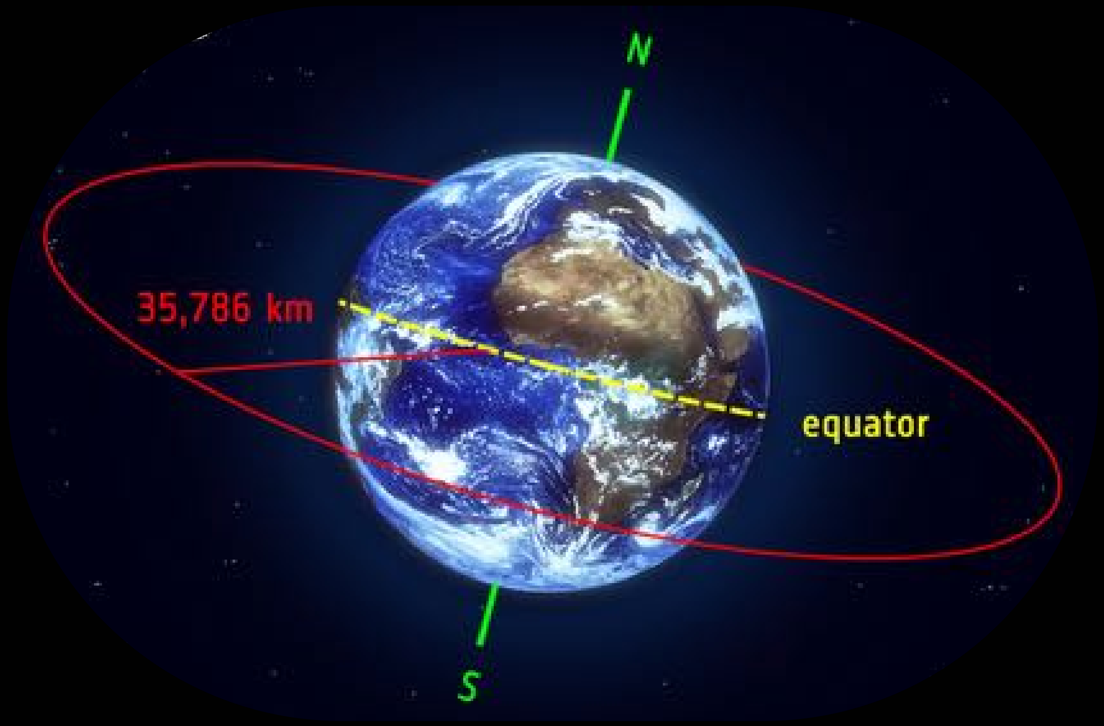
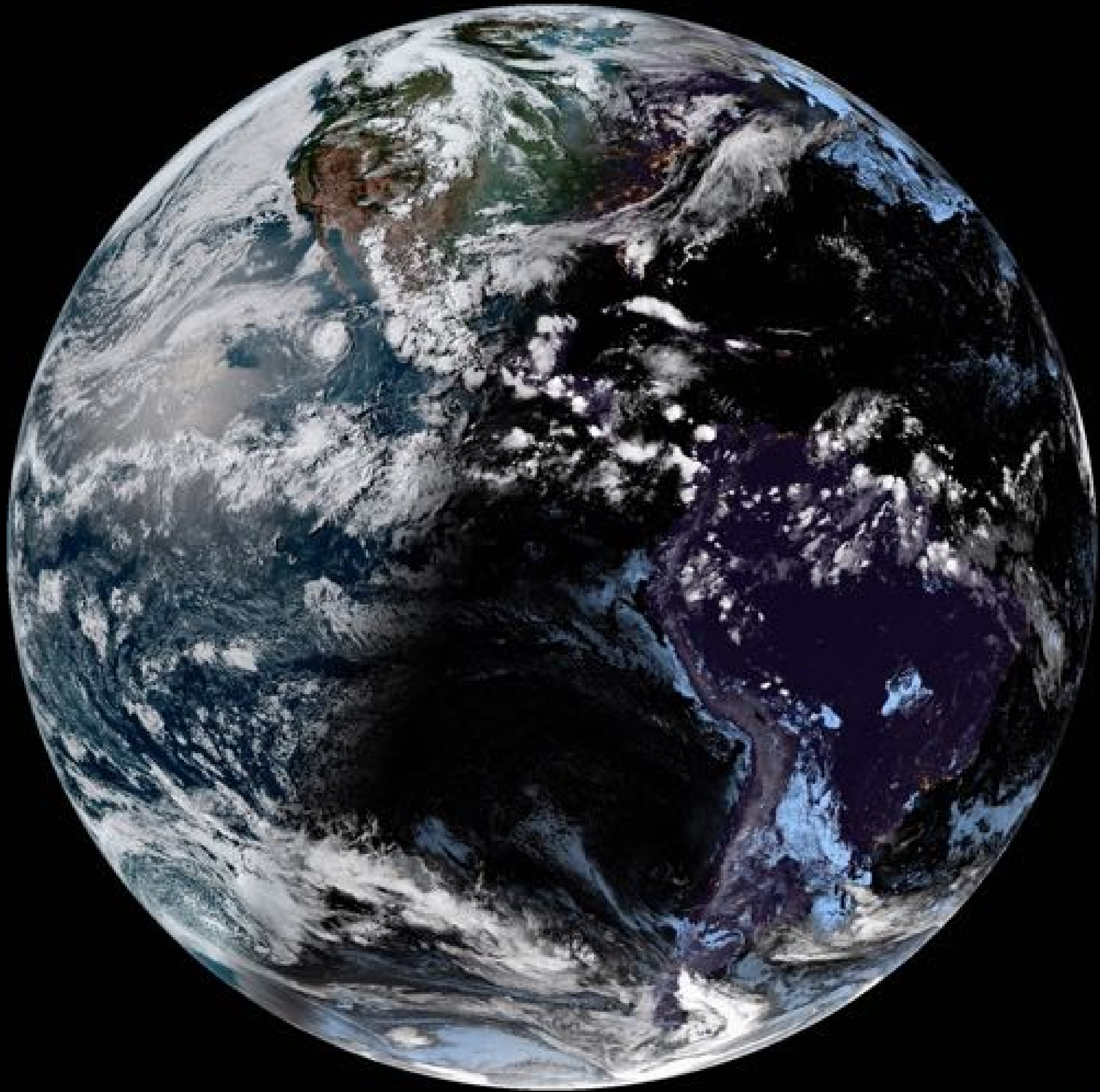
GLIMR

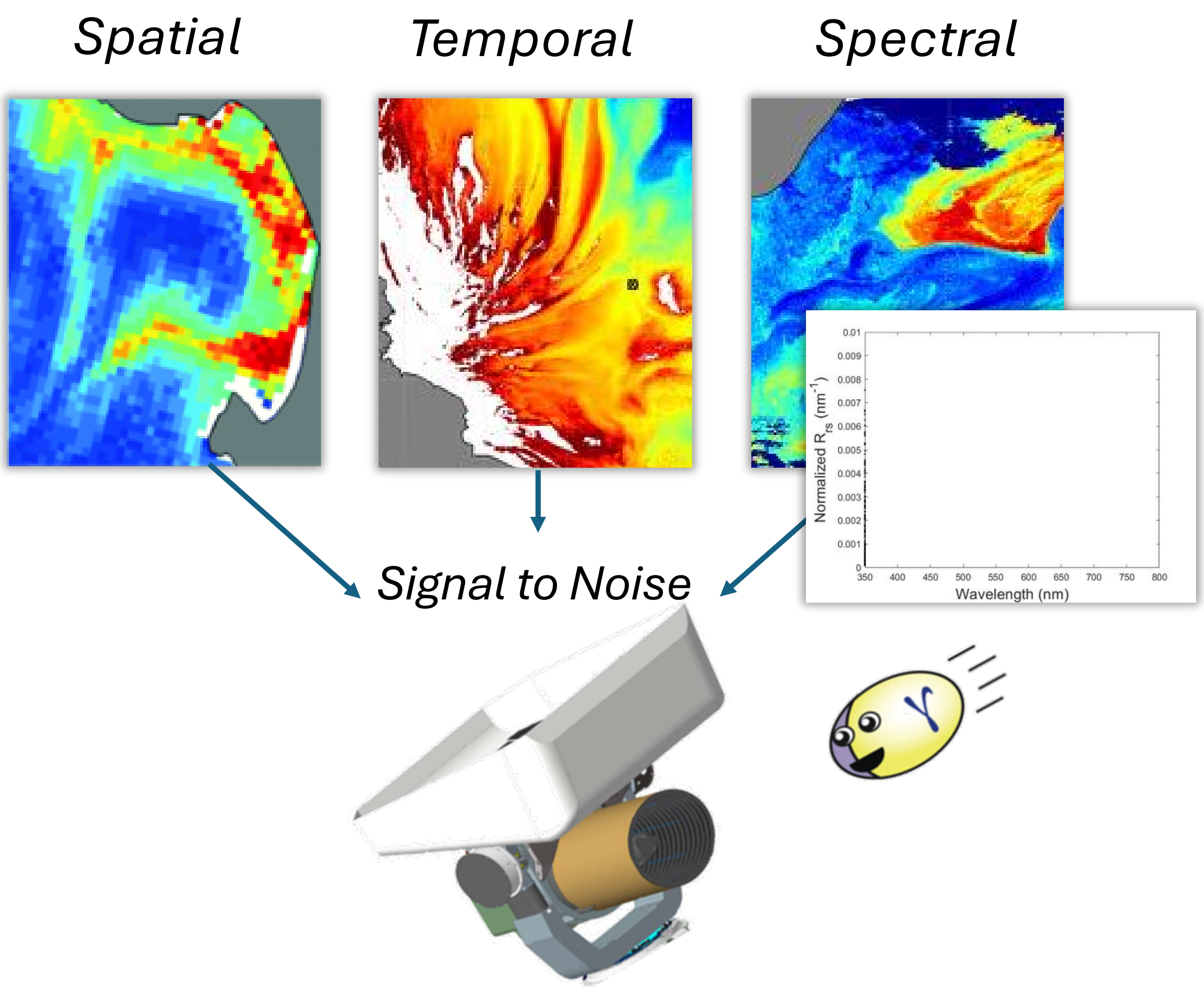
NASA
University of New Hampshire
GODDARD EARTH SCIENCES
Raytheon Intelligence & Space
SwRI

Geostationary Earth Orbit





A glimpse into GLIMR



Telescope mounted on a 2-axis gimbal that actively scans an imaging spectrometer across the region of interest.

Hyperspectral

- 340-1040 nm
- <2 to <7 nm spectral resolution across UV-Vis
- <1 to <4 nm sampling UV-Vis

High Temporal

- ~hourly scans of Gulf of Mexico (6x/day)
- 2x to 3x/day other regions
- 3x/day HAB target sites

High Spatial

- 300 m GSD nadir
- ~328 m Gulf of Mexico
- <500 m over coastal CONUS

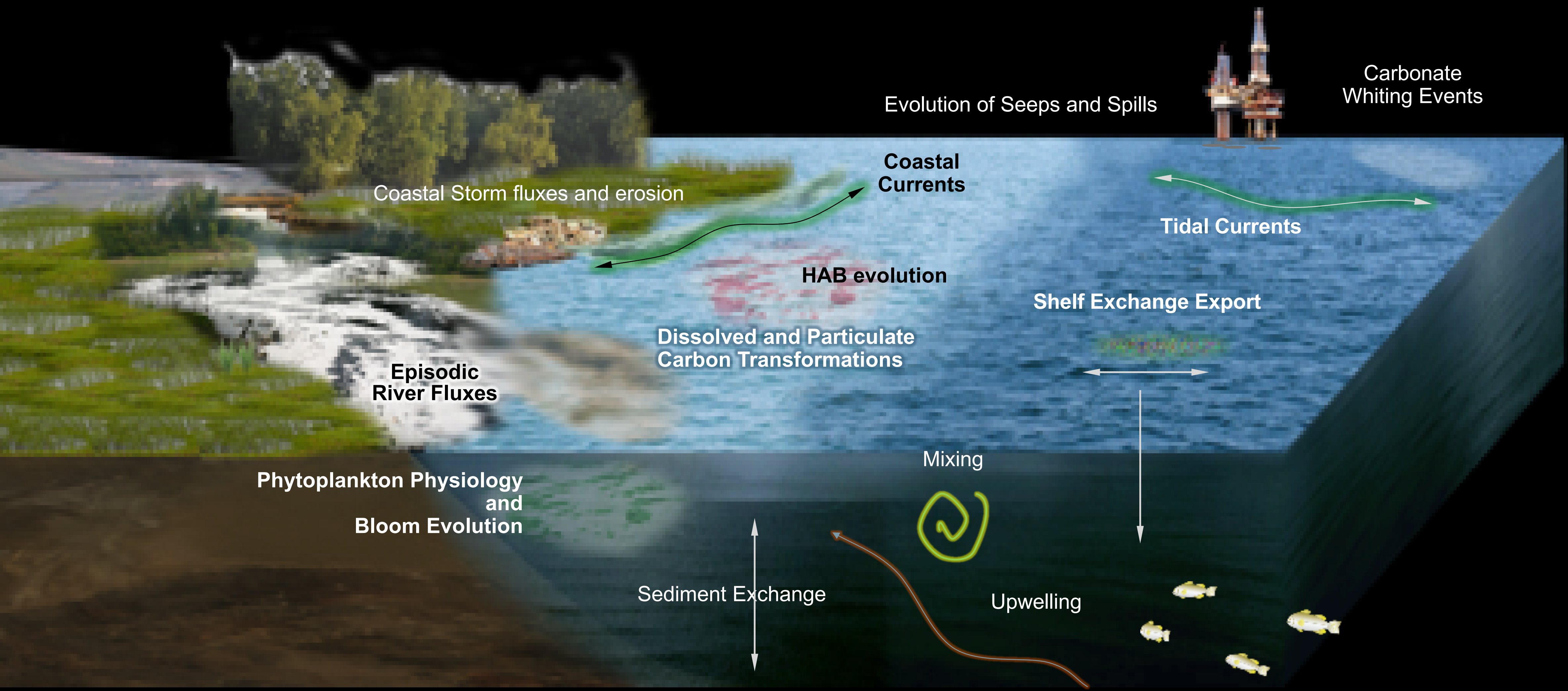
High SNR *(requ's at Ltyp)*

- 360-380 nm: >420
- 380-415 nm: > 650
- 415-580 nm: > 1000
- 580-650 nm: > 750
- 650-880 nm: > 580

Adaptive Scheduling & Targeting

- Flexibility to target episodic events & hazards

GLIMR can image frequently (sub hourly if required) paving the way for new scientific understanding

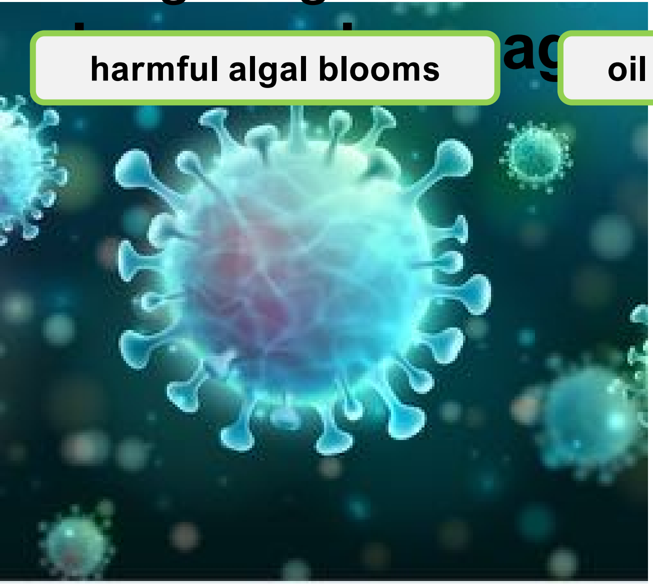


Processes where advancements in understanding require resolution at sub daily timescales

Applied Science Foci Areas

Targeting the **formation, magnitude, and trajectory** of HABs & oil spills, for

harmful algal blooms | oil spills | fisheries | water quality | pathogens | surface currents | navigation



floating algae | food security | coastal management | conservation | tourism | recreation | forecasting

Radiometric Calibration Introduction

- GLIMR's approach to radiometric calibration and accounting for instrument uncertainties and other contributing errors closely follows that developed for the Ocean Color Instrument (OCI) on the NASA Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) Mission (Patt 2018), which in turn was based on lessons learned from NASA ocean color relevant instruments including SeaWiFS, MODIS and VIIRS (Meister et al. 2011).

- Patt, F. (2018), Derivation of PACE OCI Systematic Error Approach, in PACE Technical Report Series, Volume 6: Data Product Requirements and Error Budgets (NASA/TM-2018 – 2018-219027/ Vol. 6), edited by I. Cetinić, C. R. McClain and P. J. Werdell, NASA Goddard Space Flight Space Center. https://pace.oceansciences.org/documents_more.htm?id=1757
- Meister, G., C.R. McClain, Z. Ahmad, et al. (2011), Requirements for an Advanced Ocean Radiometer (NASA/TM-2011 – 215883), NASA Goddard Space Flight Space Center Greenbelt, MD. https://pace.oceansciences.org/docs/01_NASATM20110023620.pdf

On-Orbit Radiometric Calibration Background

Radiometric calibration equation (following PACE OCI approach; Patt 2018; Meister et al. 2011)

$$L_{TOA} = g*K1 * K2(t) * (1 - K3 * (T- T_{ref})) * K5(dn, T) * dn$$

- There are multiple terms in the on-orbit radiometric calibration
  - K1 absolute TOA radiance calibration
  - K1 vicarious gain (g)
  - K2 long-term stability trend of TOA radiances
- Cross-calibration with PACE OCI accomplishes calibration for all three terms
- The GLIMR team has developed a list of alternative on-orbit calibration options in the case that PACE OCI may not be available.

- K1, K2 and g: as described above
- K3: gain for temperature sensitivity
- K5: gain for radiometric response curve (linearity)
- dn = DN – DN_0 (dark offset subtracted from sensor response as digital number)

Radiometric Calibration Plan

Pre-Launch

K1 Absolute Gain
- Absolute gain requirement relaxed for pre-launch calibration

K2 Degradation Trending (=1)

K3 Temperature Sensitivity

K5 Instrument Response Curve
- Pre-launch response curve calibration and correction

Spectral Calibration
- Spectral calibration via lab source

Offset Calibration
- Dark Data Collect

BoL → EoL

Initial PACE OCI Cross-Calibration[1,2]

Daily PACE OCI Cross-Calibration[1,2]

PACE OCI Cross-Calibration[1,2]

Weekly Earth View Fraunhofer/Abs Lines

Monthly PACE Spectral Cross-Calibration[2]

Dark Space Target Calibration

K1 Absolute Gain
- Absolute gain uncertainty improved over time during early mission period
- Vicarious gain (g)

K2 Gain Degradation Trending
- PACE OCI solar/lunar used for temporal gain trending and correction
- GLIMR lunar calibration - TBD

K5 Instrument Response Curve
- Pre-launch calibration monitored & updated as necessary

Spectral Calibration
- PACE OCI solar cross-calibration
- Fraunhofer lines from cloud/surface reflectance and atmospheric absorption lines

Offset Calibration
- Dark Data Collect

$$L_{TOA} = g*K1 * K2(t) * (1 - K3 * (T - T_{ref})) * K5(dn, T) * dn$$

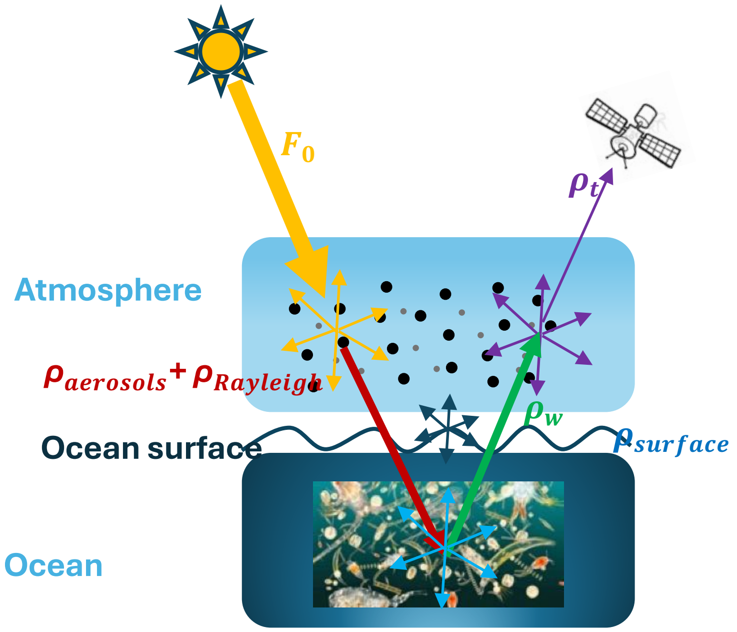
[1] PACE OCI conducts daily solar calibration through Bright Target Solar diffuser and monthly calibration through "Pristine" Bright Target and Dim Target Solar diffusers

[2] PACE OCI conducts monthly spectral calibration through Bright Target Solar Calibration (Solar Fraunhofer Lines)

Cross-(Vicarious) Calibration with OCI

Following methods for polarization sensitive instrument*

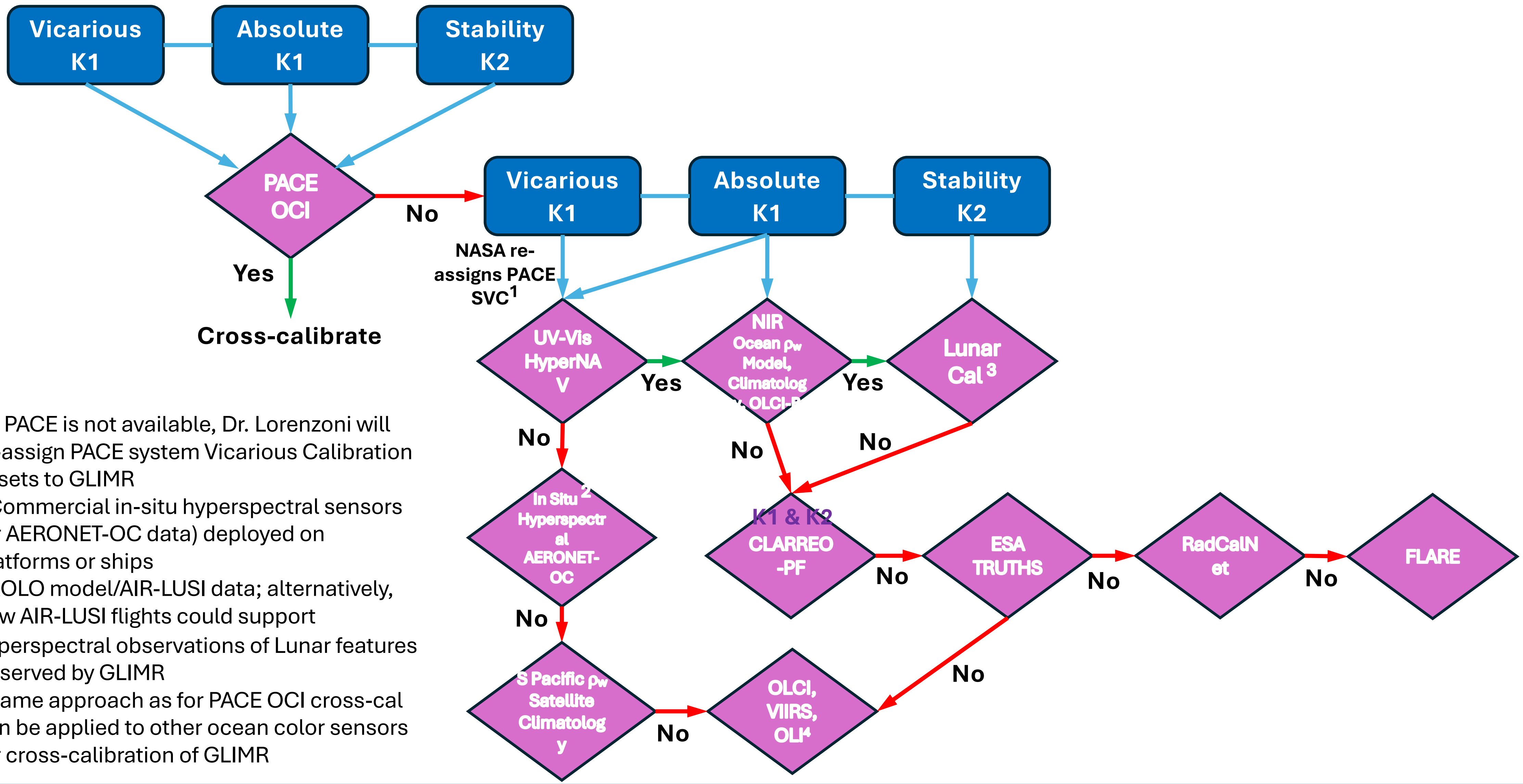
- ➢ Daily matching of GLIMR pixels with OCI normalized water-leaving radiance (nL_w)
  - e.g., 3x3 OCI pixel bins (~3.6x3.6 km)
  - Case 1 waters with depths greater than 1000 m; low AOT and Chl-*a*; homogeneous AOT and Chl-*a*
- ➢ Inverse processing of GLIMR (L2 to L1B) to bring OCI nL_w to the TOA and output modeled pixel Stokes vectors, $[L_t, Q_t, U_t, 0]^T$, at GLIMR wavelengths and GLIMR solar and viewing geometries.
  - Band radiances adjusted to match GLIMR bands
  - BRDF effects are accounted for in the propagation of the radiances from OCI to GLIMR viewing and path geometries
- ➢ Screen TOA pixels (following quality criteria) and generate datasets of radiance pairs $[L_t, Q_t, U_t, 0]^T$; L_m^G) and ancillary information, detector element and time, geographic coordinates, solar and viewing geometries, and glint reflectance.
- ➢ Derive M_{11}, M_{12}, and M_{13} per band and detector element.
- ➢ Compute ratio L_t / L_m^G to derive the cross-/vicarious gain coefficients (g) per band



*Kwiatkowska, Franz, Meister, McClain, & Xiong (2008). Cross calibration of ocean-color bands from Moderate Resolution Imaging Spectroradiometer on Terra platform," Appl. Opt. 47, 6796-6810.

L_m^G = actual GLIMR TOA radiances

On-orbit radiometric calibration decision tree



[1] If PACE is not available, Dr. Lorenzoni will re-assign PACE system Vicarious Calibration assets to GLIMR

[2] Commercial in-situ hyperspectral sensors (or AERONET-OC data) deployed on platforms or ships

[3] ROLO model/AIR-LUSI data; alternatively, new AIR-LUSI flights could support hyperspectral observations of Lunar features observed by GLIMR

[4] Same approach as for PACE OCI cross-cal can be applied to other ocean color sensors for cross-calibration of GLIMR

On-Orbit Radiometric Calibration with PACE OCI

OCI Expected Performance

- Pre-launch: GLAMR provided absolute calibration, better than 0.5% accuracy
- Initial OCI on-orbit calibration:
  - solar diffuser provides absolute calibration (K1) with 2% uncertainty for TOA radiances
  - single day relative gain uncertainty (K2) of 0.12%
- Long-term stability (K2):
  - OCI lunar gain trending will provide radiometric stability (K2) to within 0.102%*
- Vicarious calibration will provide OCI absolute calibration of TOA radiances (K1) for most bands with 0.1% uncertainty (0.2% in UV) after sufficient number of matchups acquired
  - Enables GLIMR to meet PLRA water-leaving ocean reflectance (ρ_w) requirements
- Spectral knowledge and calibration:
  - band center uncertainty <0.1 nm (340-895 nm)
  - weekly calibration using solar Fraunhofer lines and atmospheric absorption bands
    - relative spectral responses of the bands are adjusted as needed to account for changes in the dispersion of the grating
  - Spectral drift <0.04 nm as of 14 November 2025

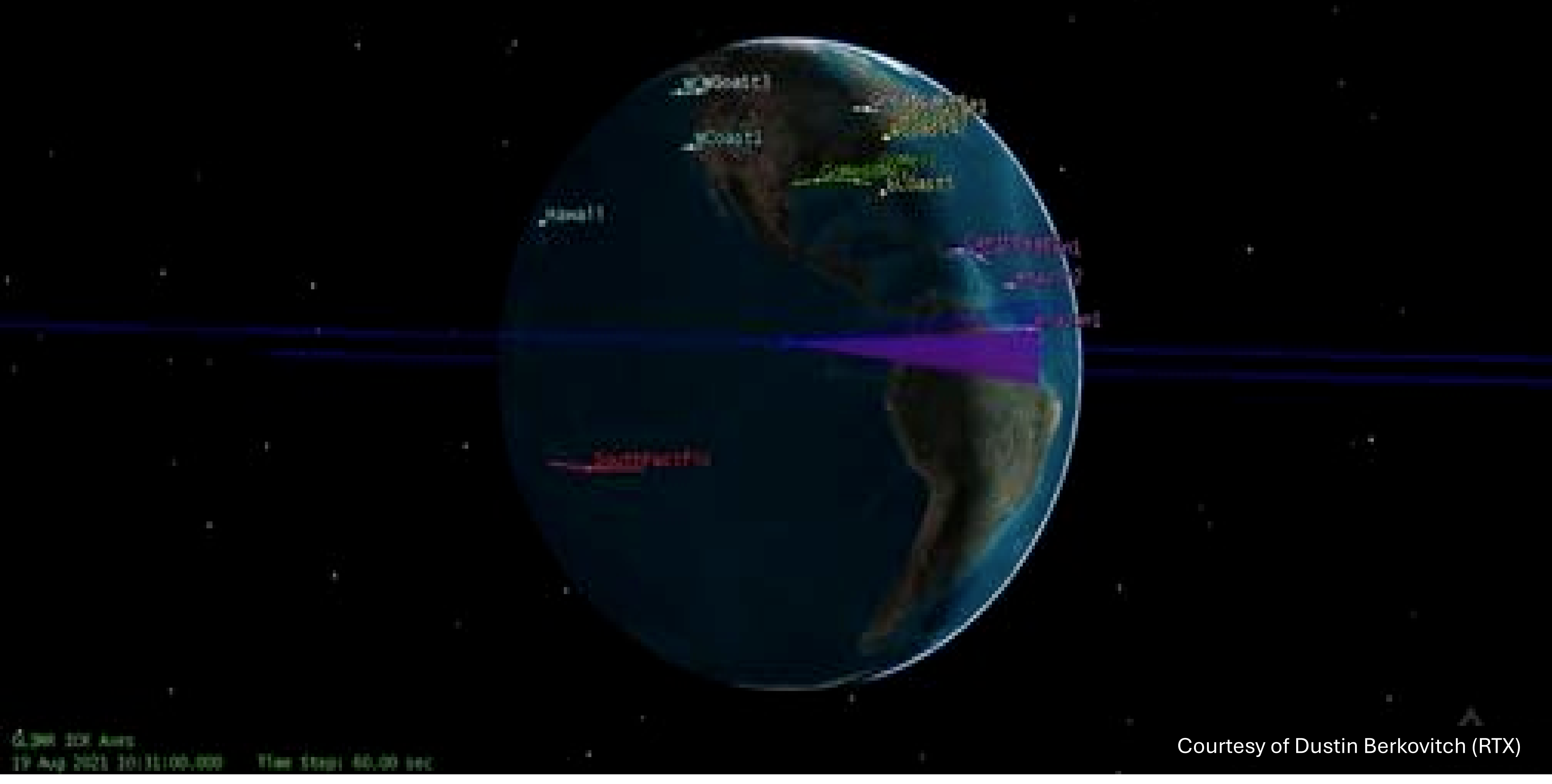
** Patt & Eplee (2018), Strategy and Requirements for the PACE OCI Lunar Calibration, in PACE Technical Report Series, Volume 7: Ocean Color Instrument (OCI) Concept Design Studies (NASA/TM-2018 - 2018-219027/ Vol. 7), NASA GSFC.*

Thank you.

GLIMR Calibration

IOCS slides

A day in the life of GLIMR from 95W



Courtesy of Dustin Berkovitch (RTX)