# JunoCam Image Processing

Europlanet

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Observatoire de la Côte d'Azur
Nice
2016-05-13

Gerald Eichstädt

# Raw Swath

Example: JNCE_2013282_00C102_V01 (EFB12)

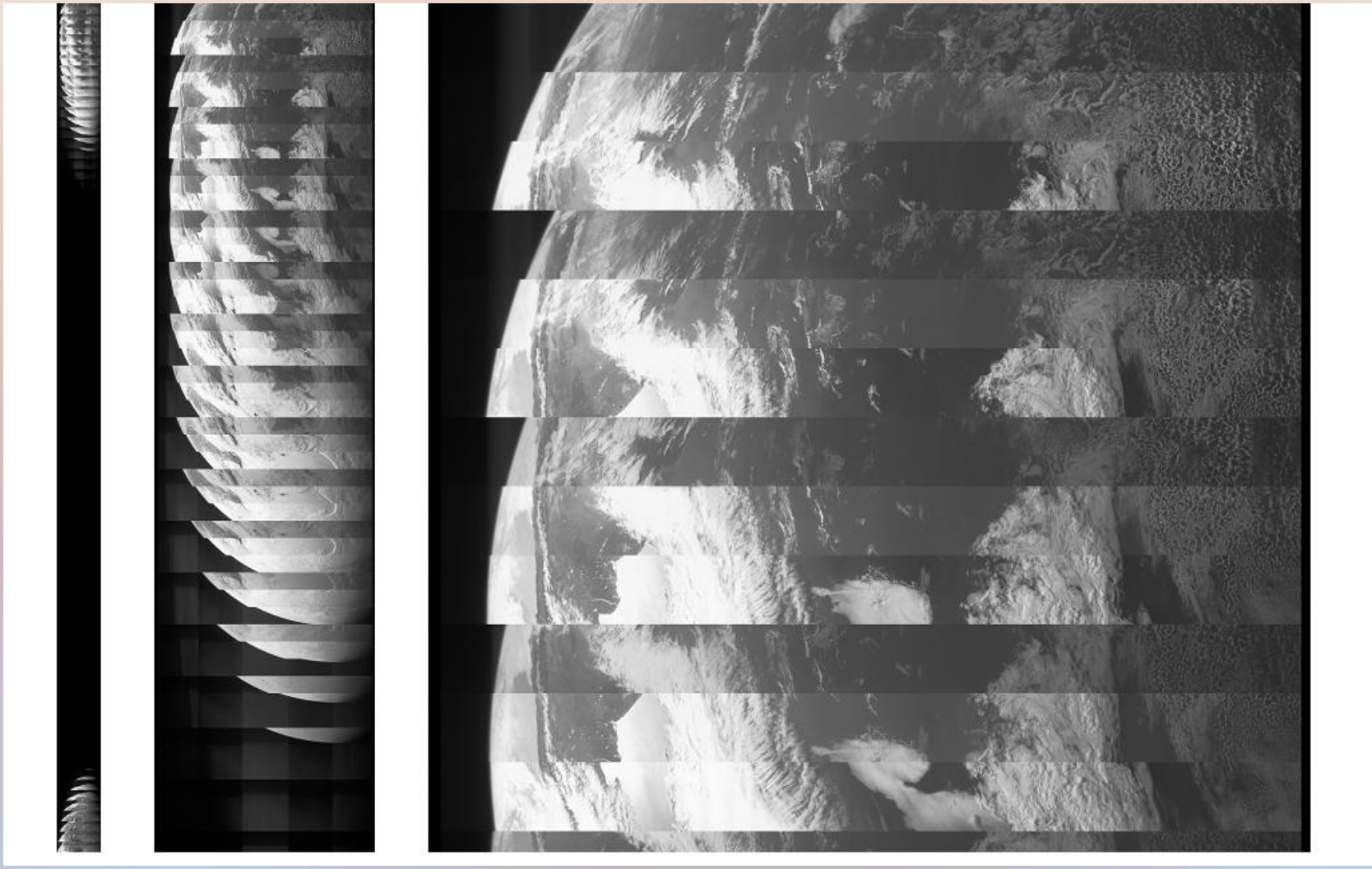

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Structure of a Raw Swath

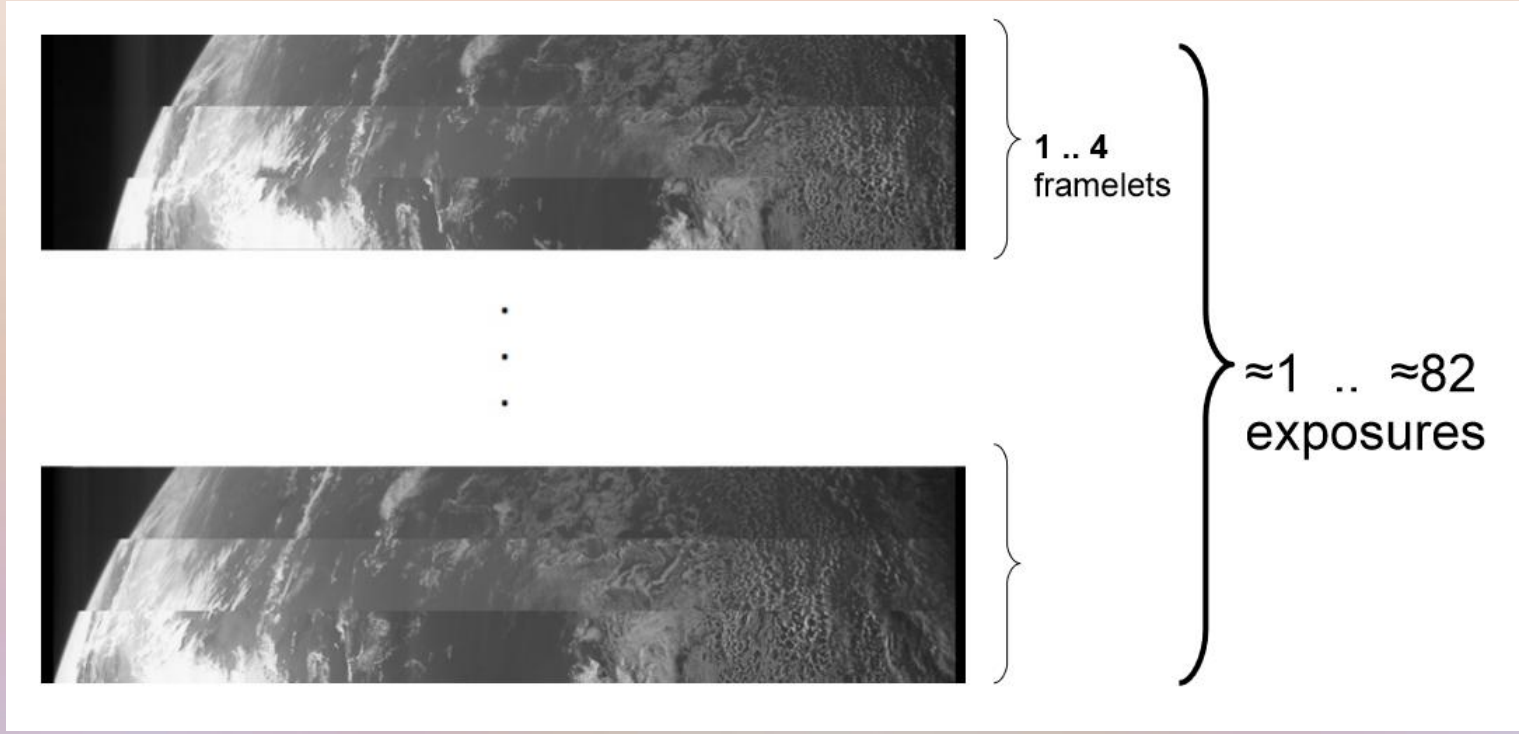


Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

- Within one swath, all exposures consist of the same number of framelets.
- All framelets within one swath are of the same width and height.

# Usual Structure of an Exposure

Alternative 1: Three framelets

Height = **3x128** pixels

Width = **1648** pixels

Alternative 2: One framelet

Height = **128** pixels

Alternative 3: One framelet, 2x2-binned

Height = **64** pixels

Width = **816** pixels

Images: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Example: Exposure of Three Framelets

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Mismatch Between Framelets

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Gap Between Framelets


Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Exposure Readout on the CCD

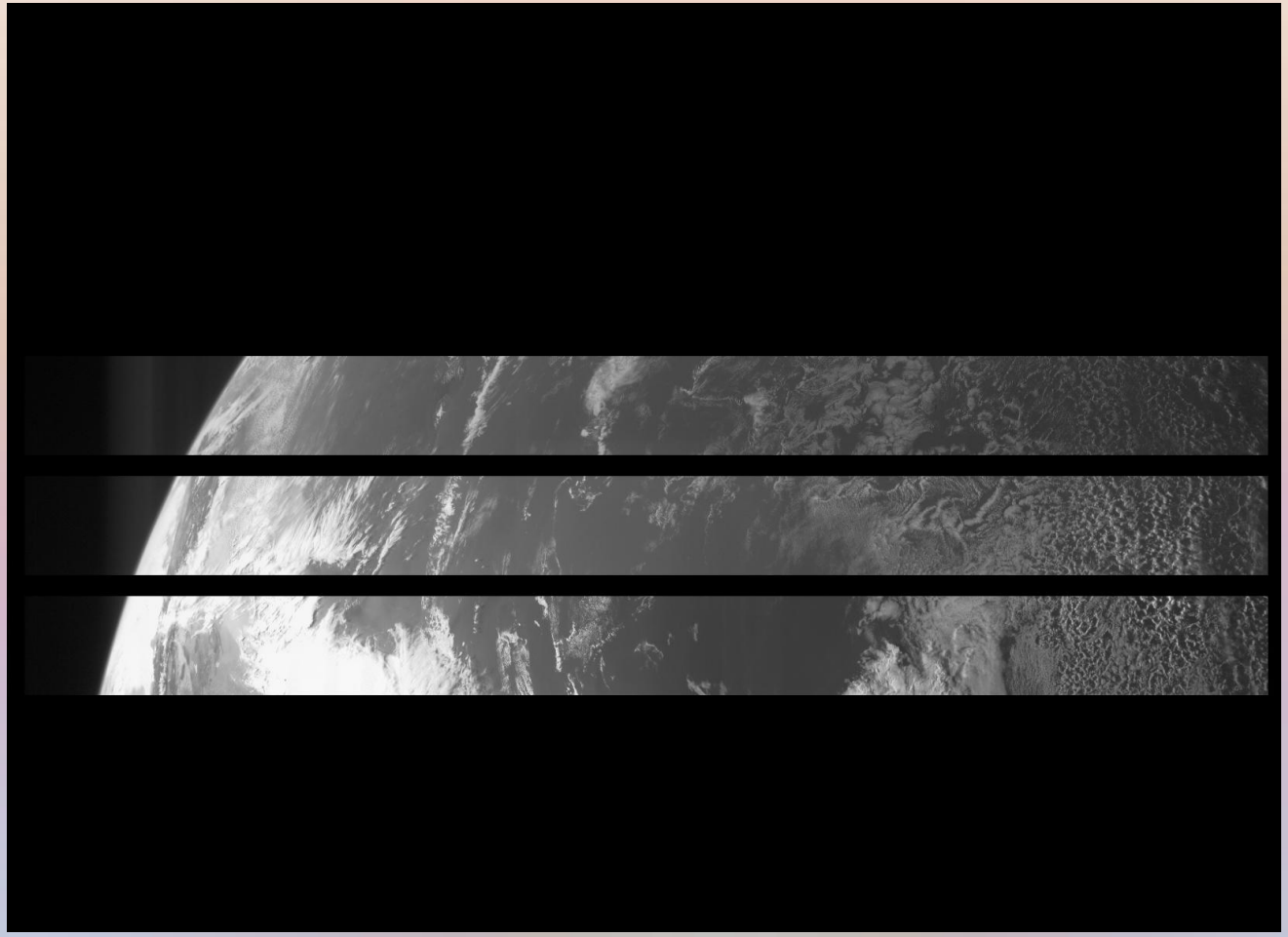

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# All Readout Regions on the CCD

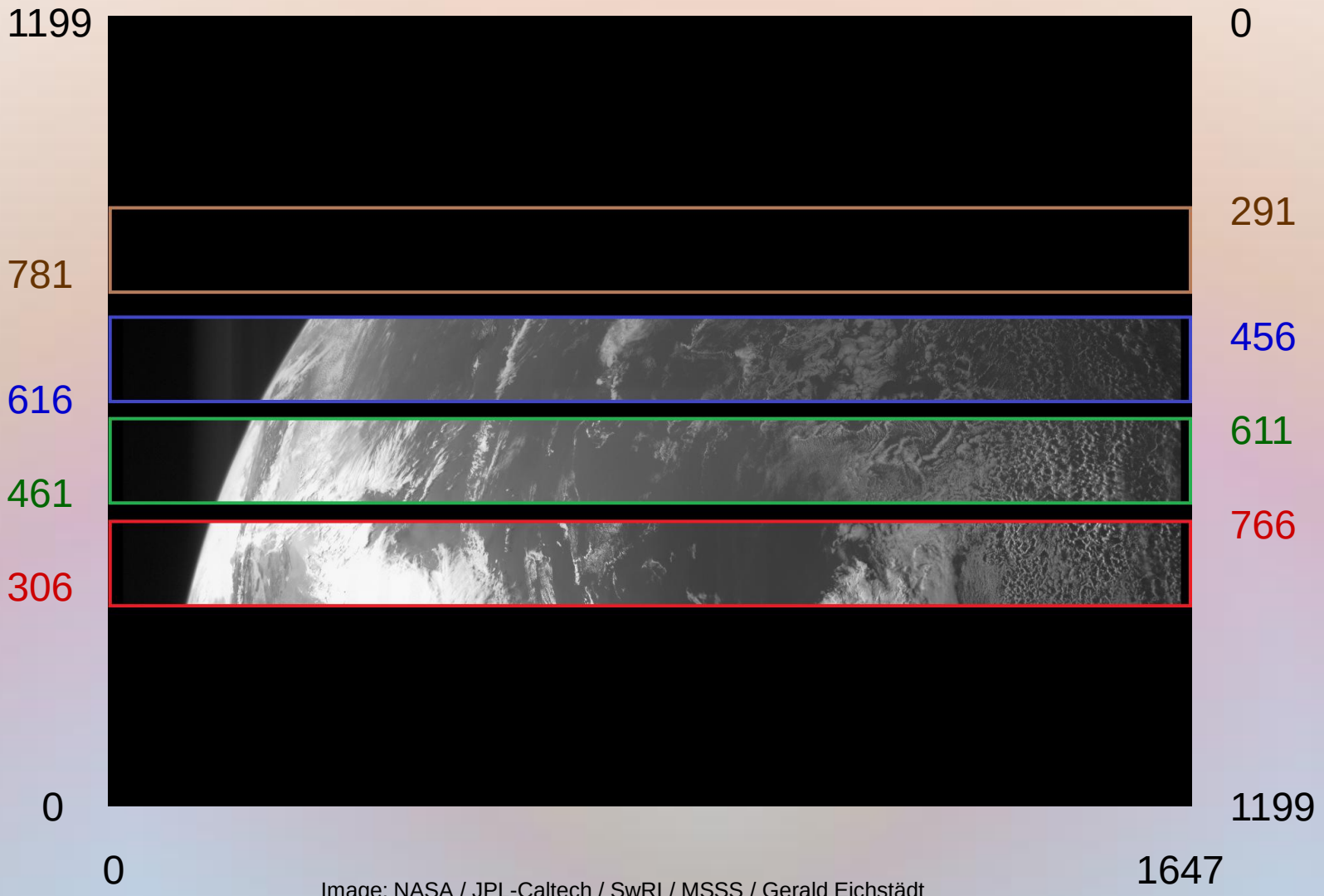


Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

Y-Positions of the readout regions retrieved from a post of M.Caplinger:
http://www.unmannedspaceflight.com/index.php?showtopic=2548&view=findpost&p=203948

# Color Filters

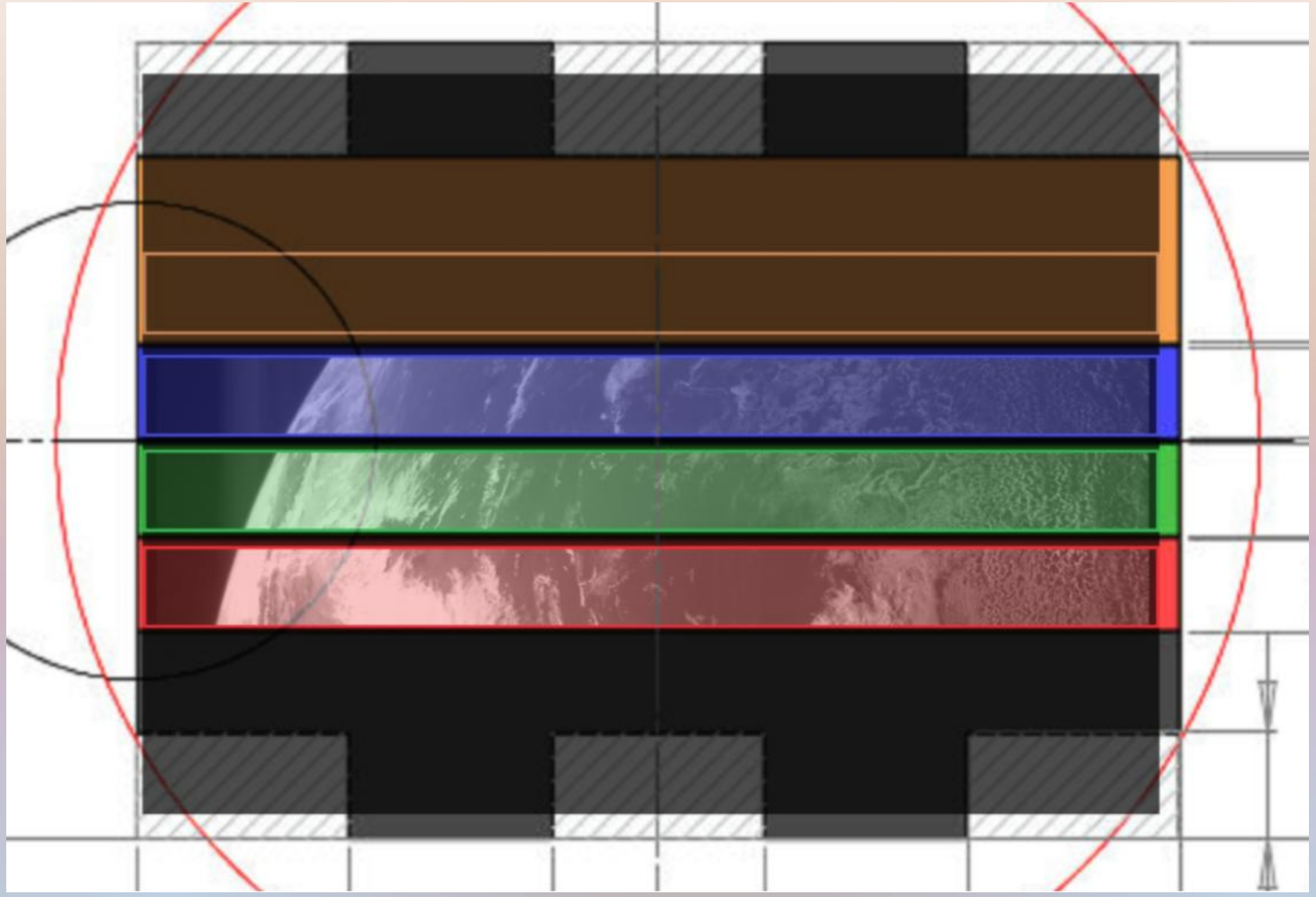

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Result: Colored Exposure

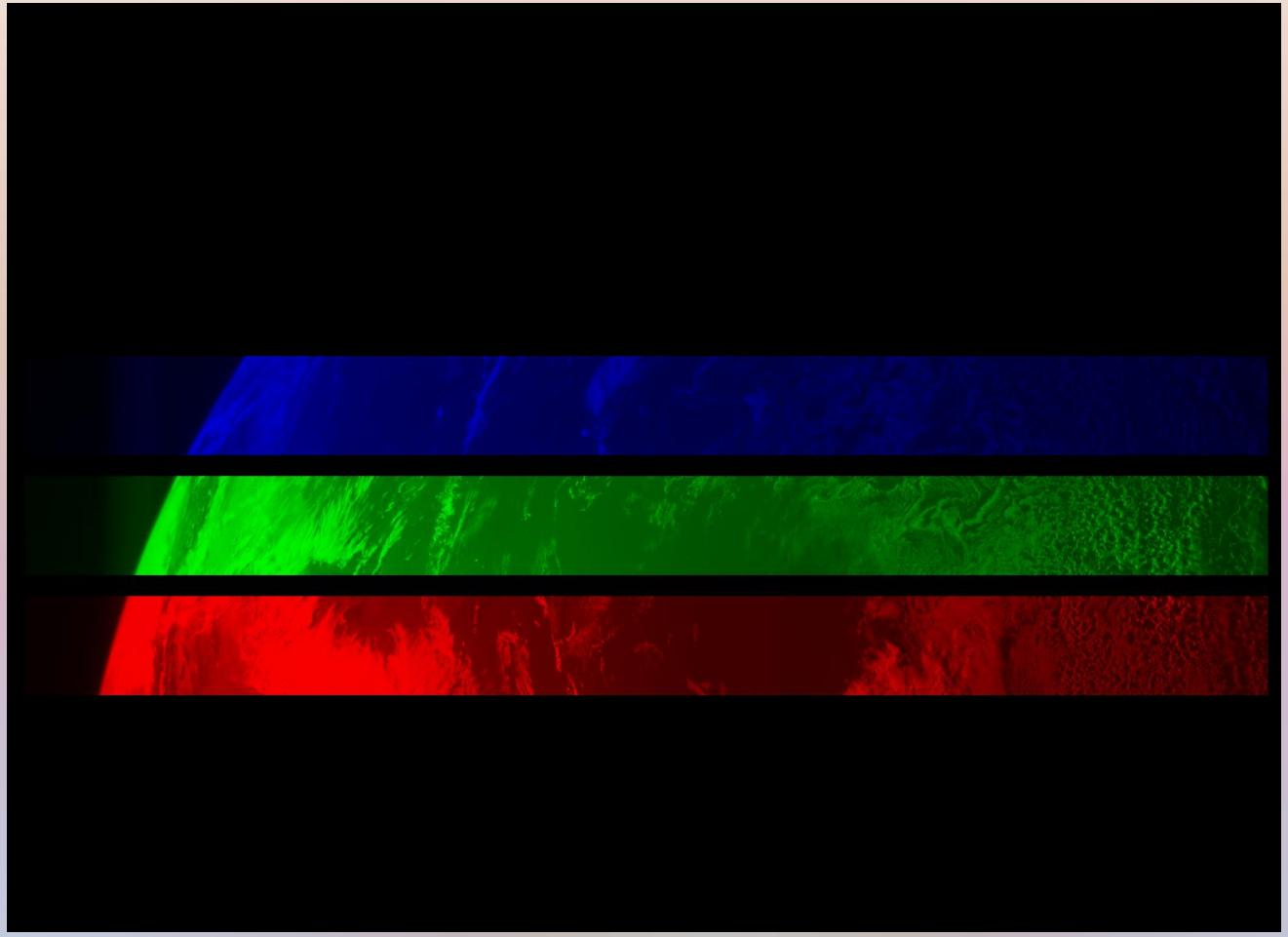

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Next Colored Exposure

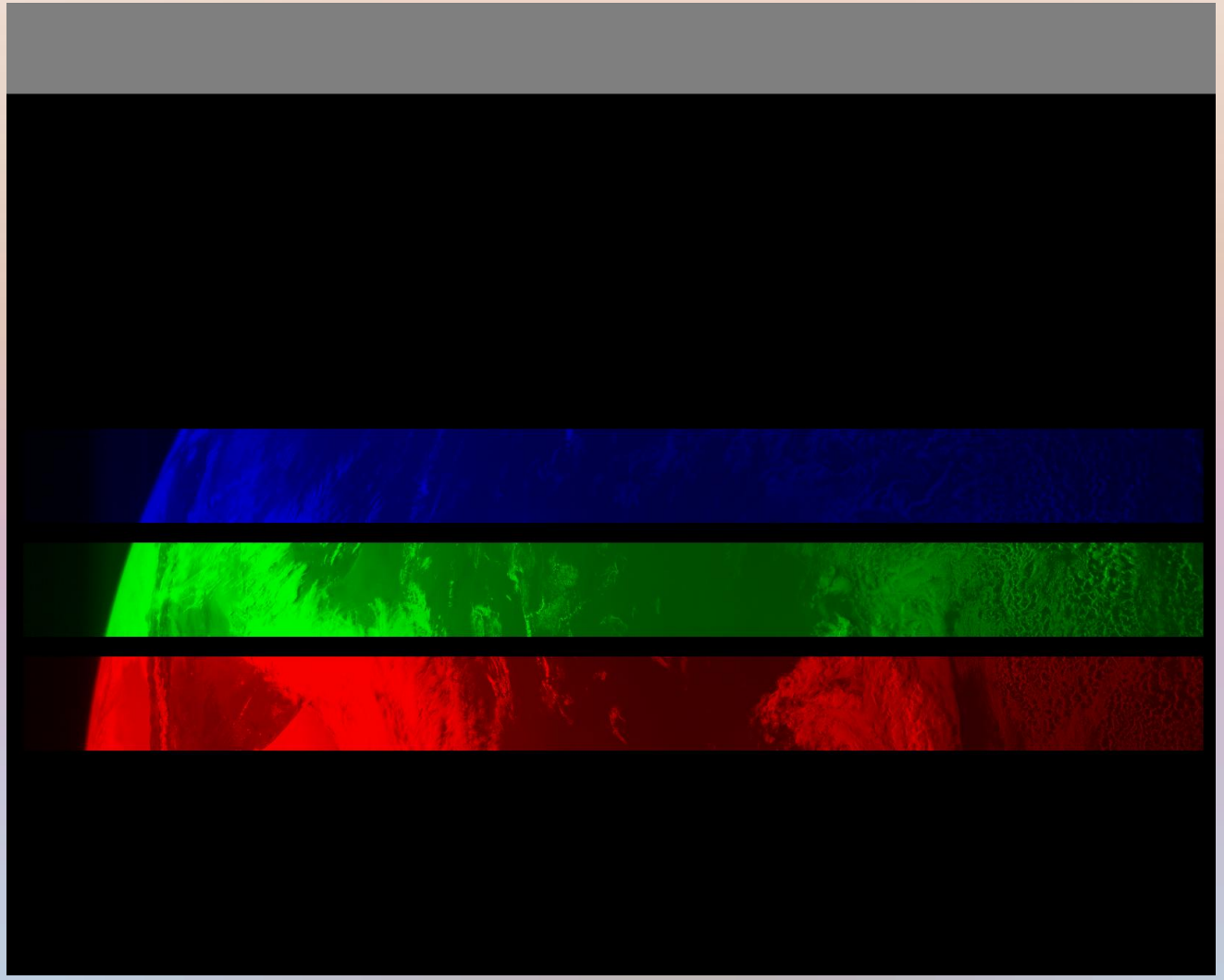

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Combine Channels of ...
# 02 Colored Exposures

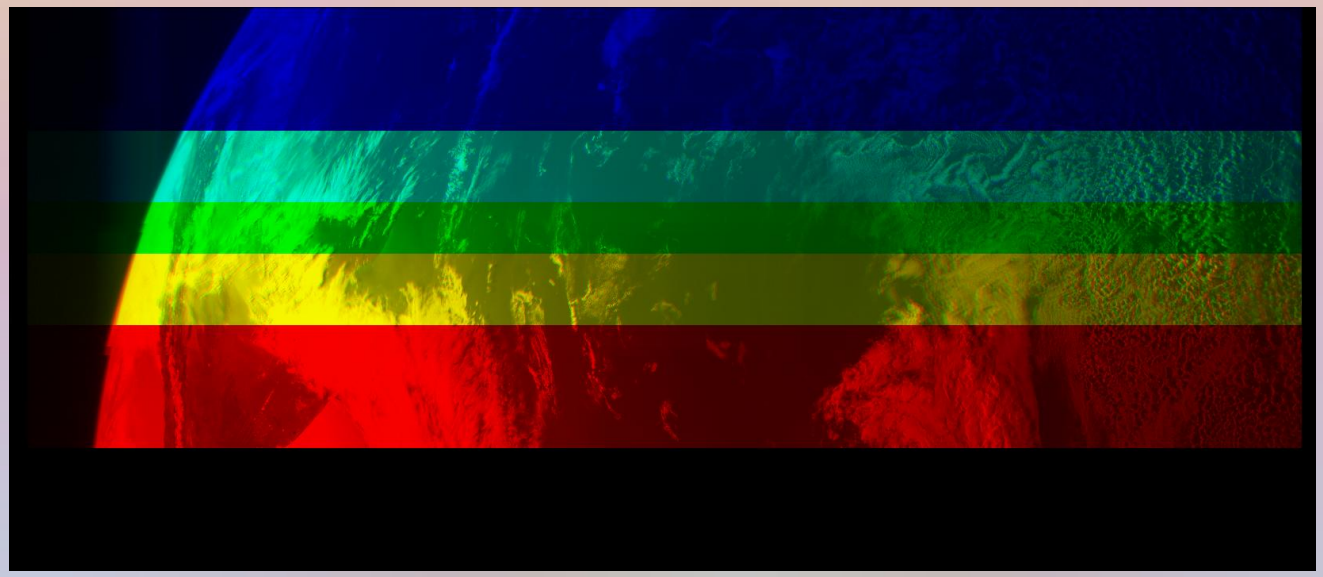

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Combine Channels of ...
# 03 Colored Exposures

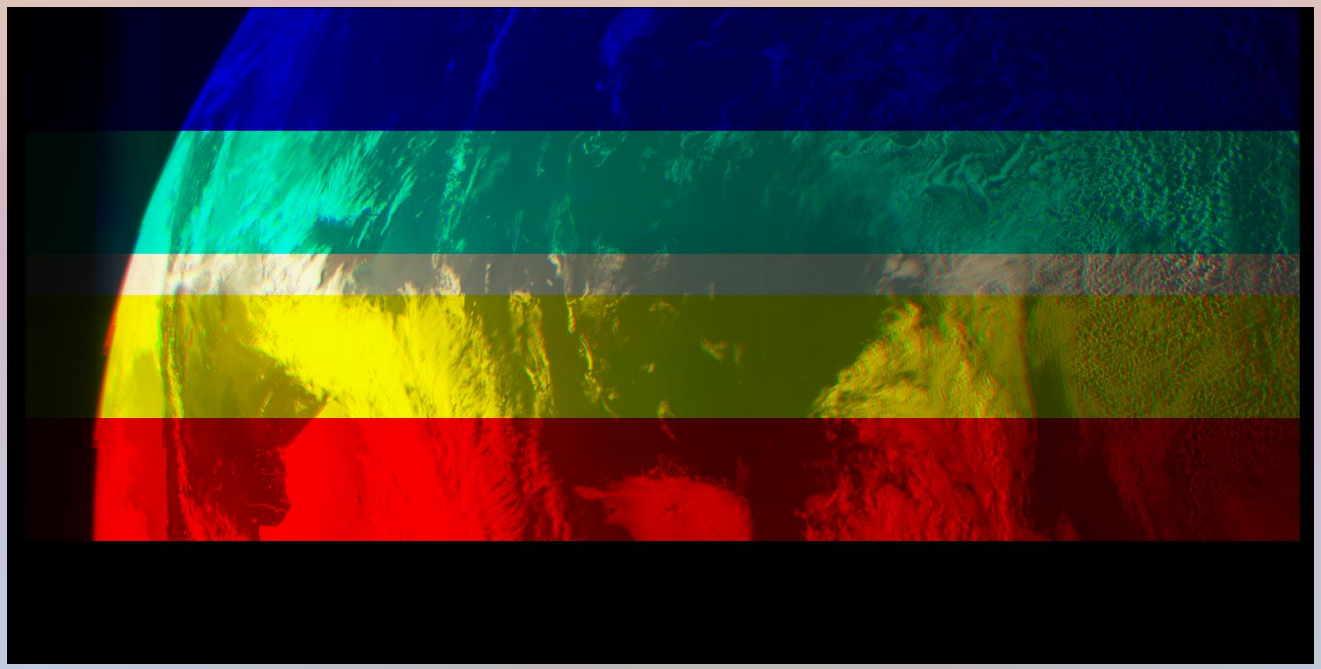

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Combine Channels of ...
# 04 Colored Exposures

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Combine Channels of ...
# 08 Colored Exposures

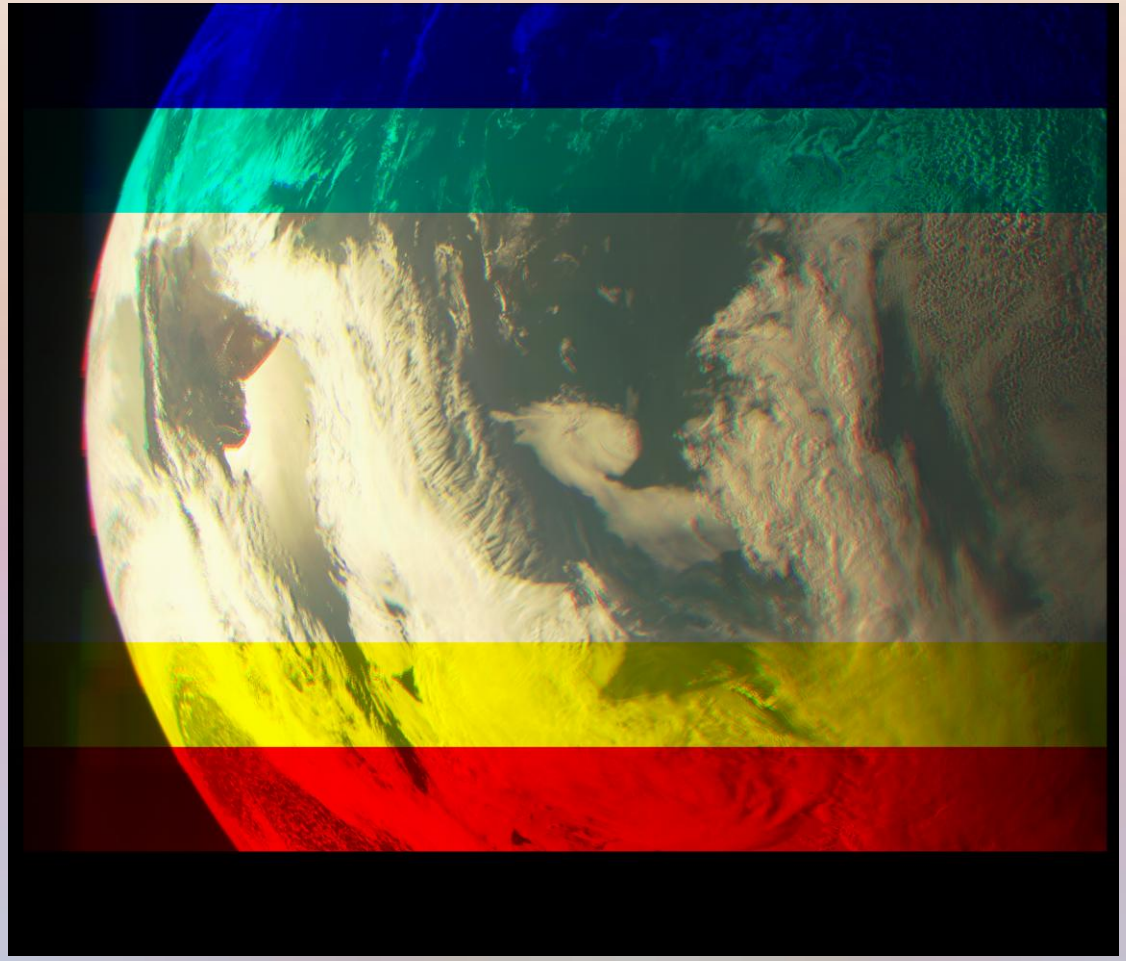

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Combine Channels of ...
# 14 Colored Exposures

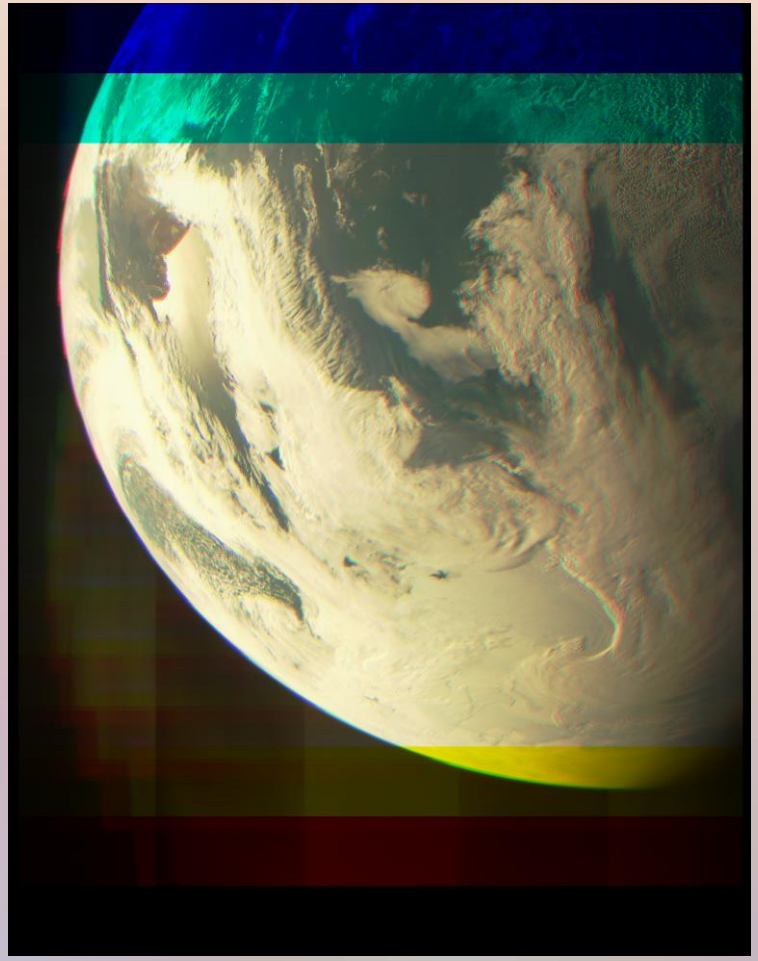

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Select a Region...

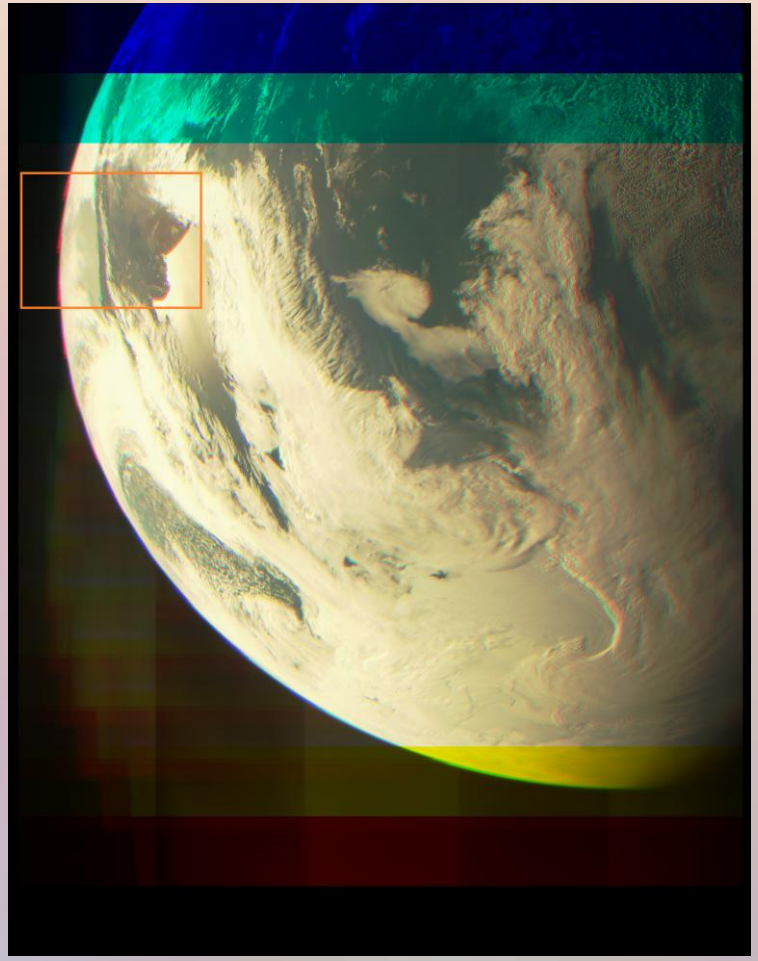

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Zoom-In Reveals Mismatches

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Select Detail...

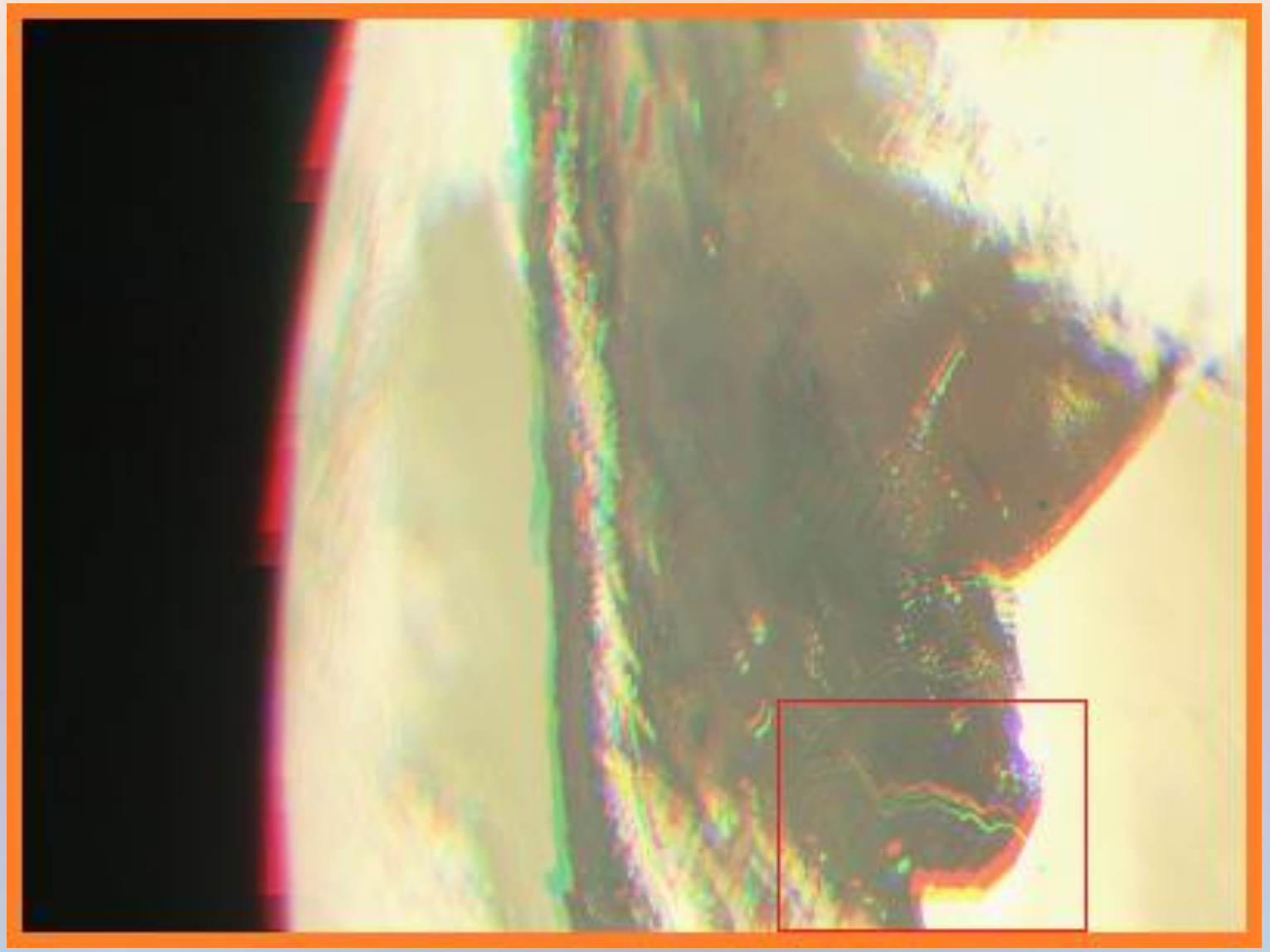

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

# Zoom Into Detail

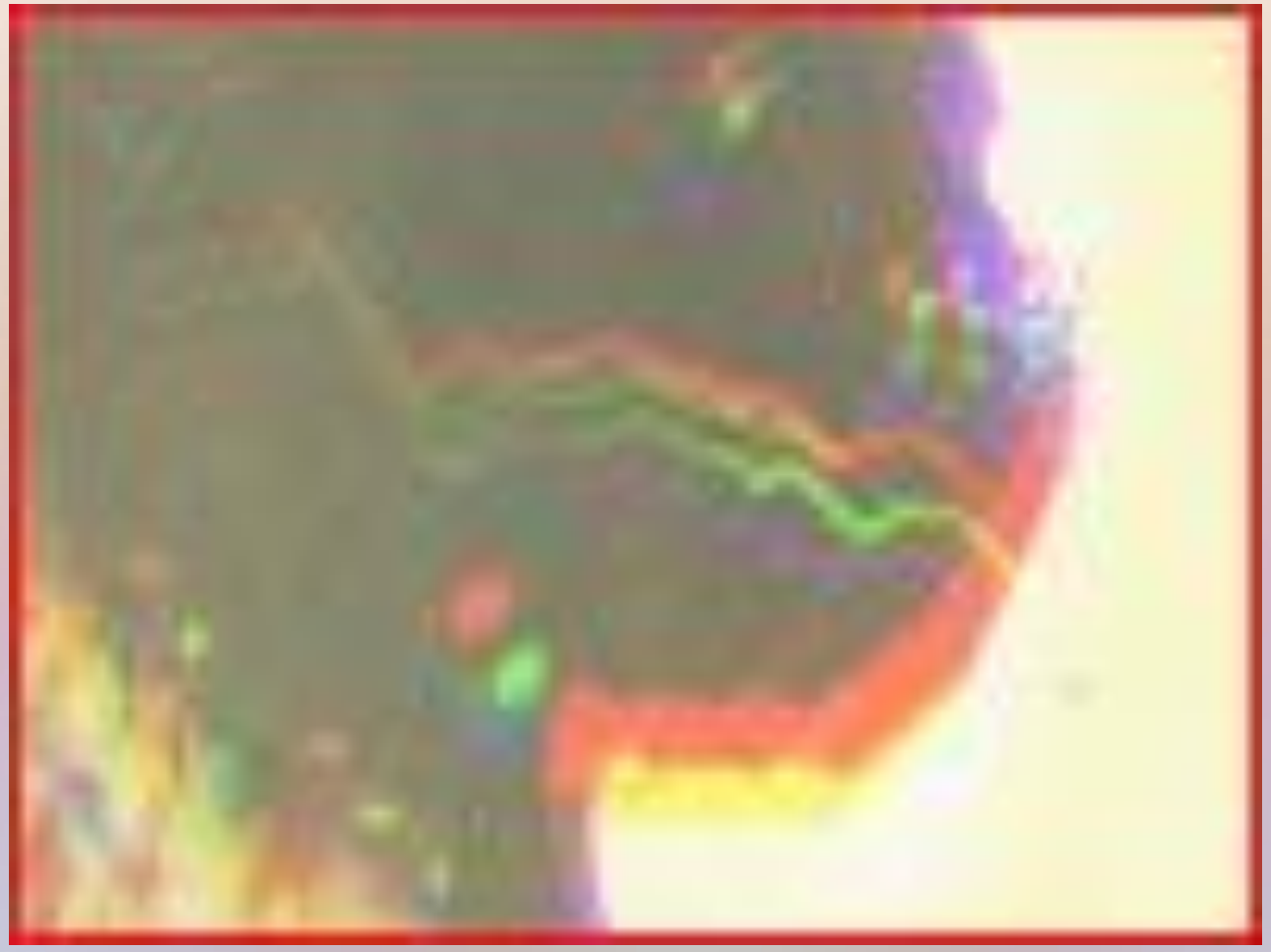

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

One reason for mismatch: Geometry of image depends on rotation of camera.

# Rotation-Invariant Spherical Coordinates

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

Associate camera pixel positions with respective 3-d pointing vectors.
One reason for remaining mismatch: Translational motion of Juno.

# Time-Variant Reprojection

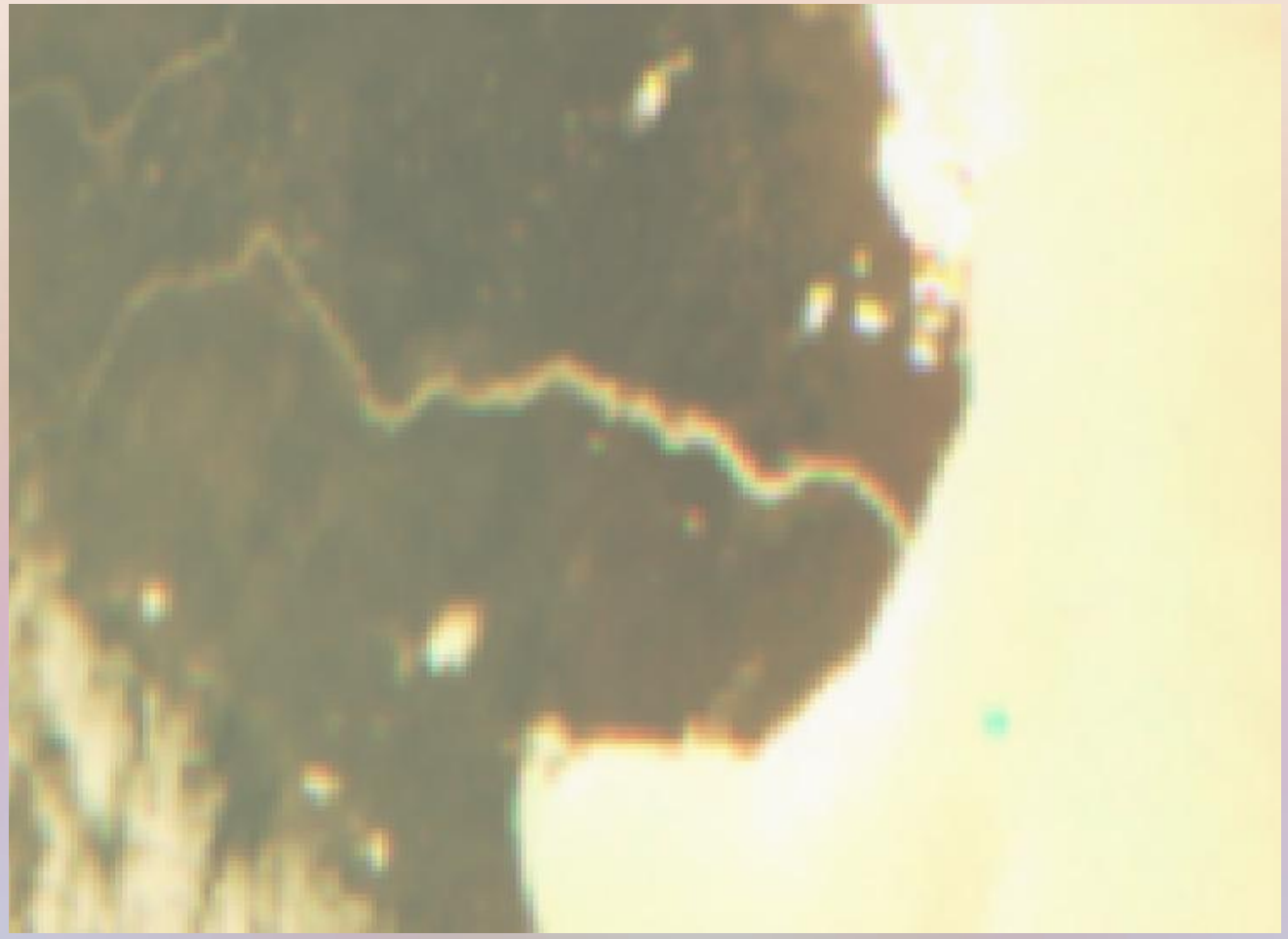

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

“Time-variant“ reprojection varies simulated time with y like raw data; method is ***locally*** resilent w.r.t. small errors in shape model and trajectory. Consider **NAIF** / **SPICE** to estimate shape model and trajectory.

# Some Dark Spots On the CCD

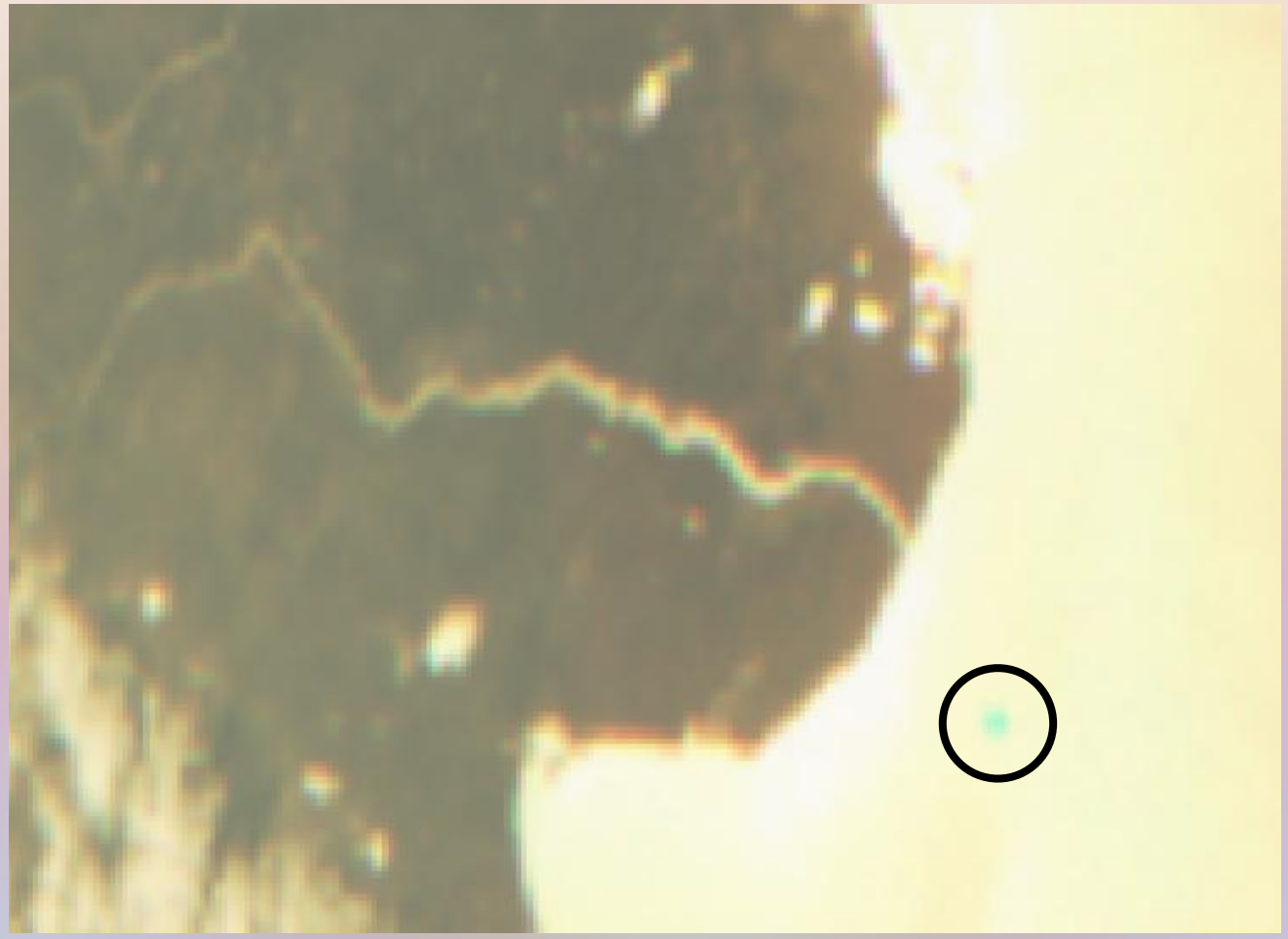

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

The few dark spots are at fixed pixel positions on the CCD.
In swathes they show up as repetitive patterns.

# Zoom-Out Contains Overlap Region

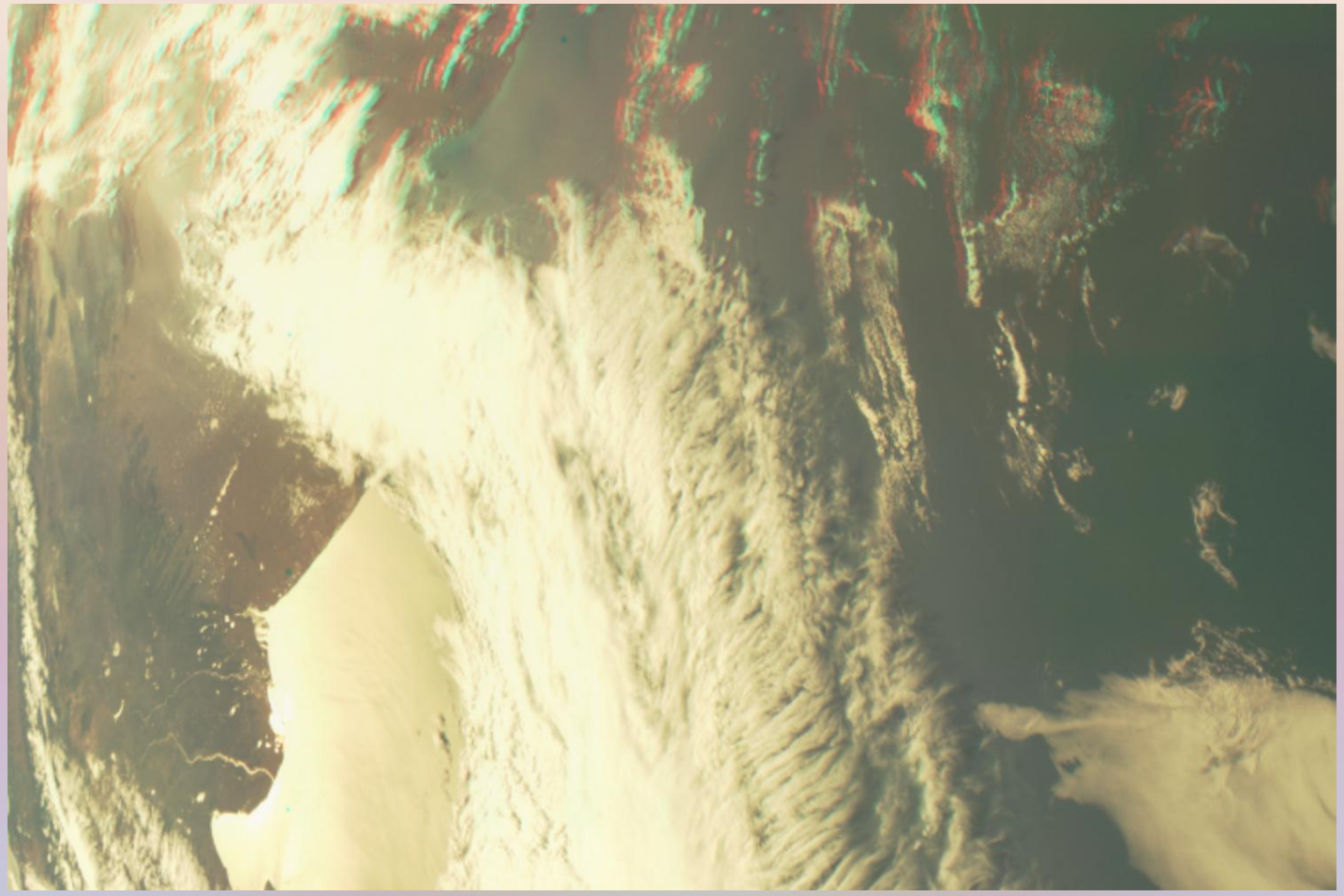

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

Overlap region combines framelets taken at different times.

# Select Detail of Overlap Region...

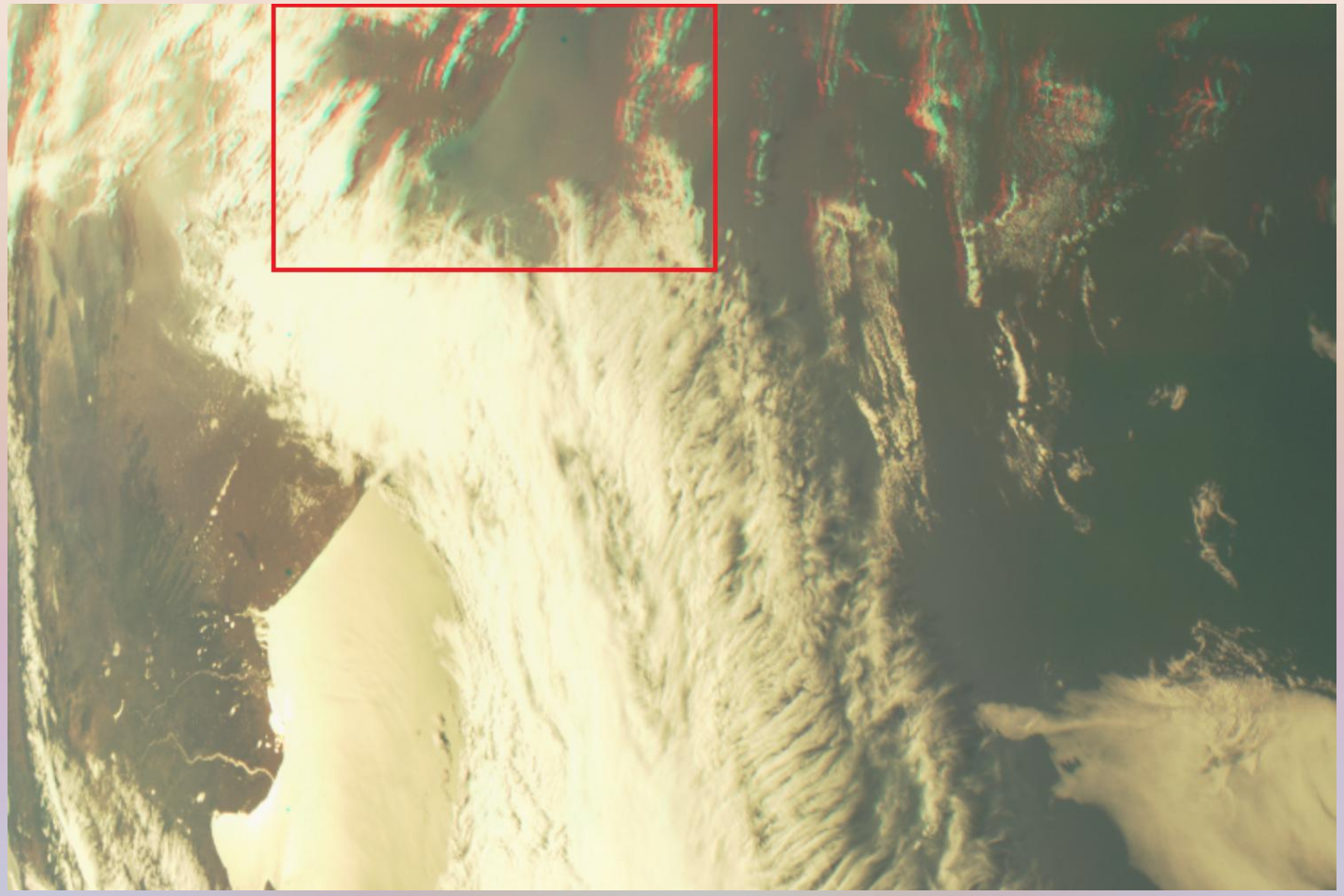

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

Residual ***global*** errors in shape model and trajectory visible.

# Zoom Into Overlap Region

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

One reason for mismatch: Rotation of Planet.
Consider also TDI, small spacecraft nutation and model inaccuracies.

# Include Rotation of Planet

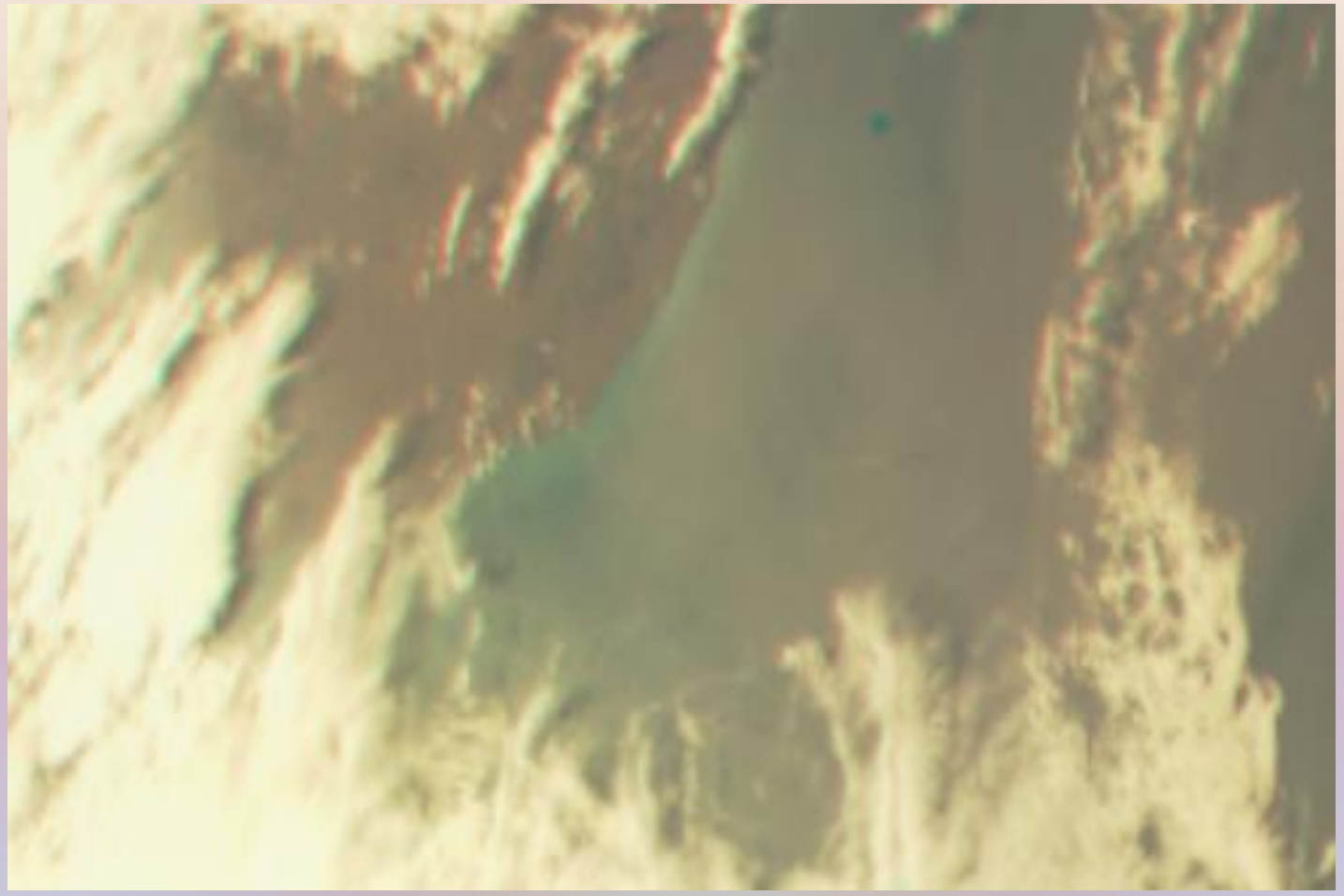

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

Registering looks good. But colors are cast to reddish.

# Moon as Color Calibration Target

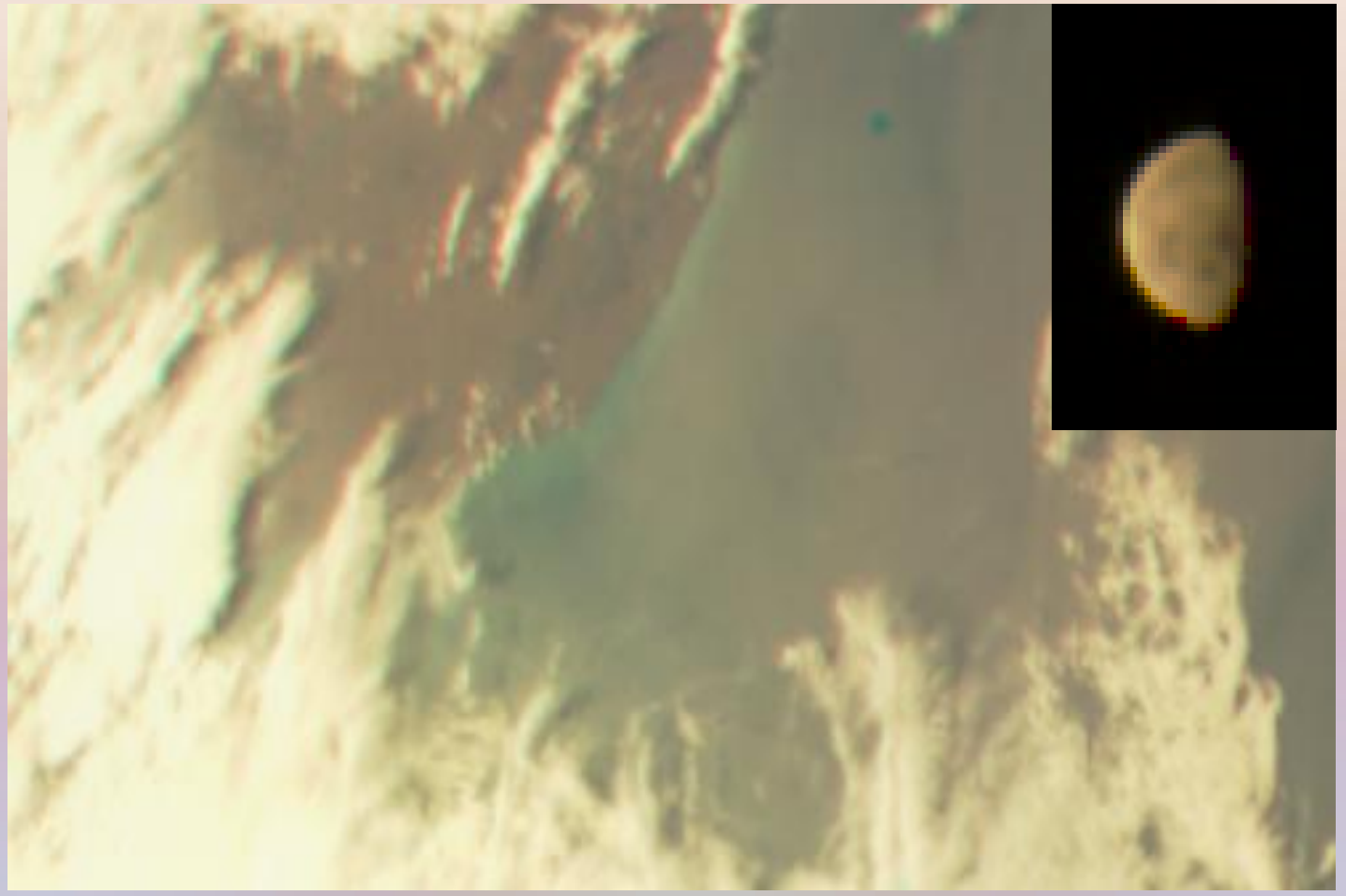

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

Moon is visible in Earth fly-by image EFB01.
Define Earth's moon as grey.

# Calibrate Colors

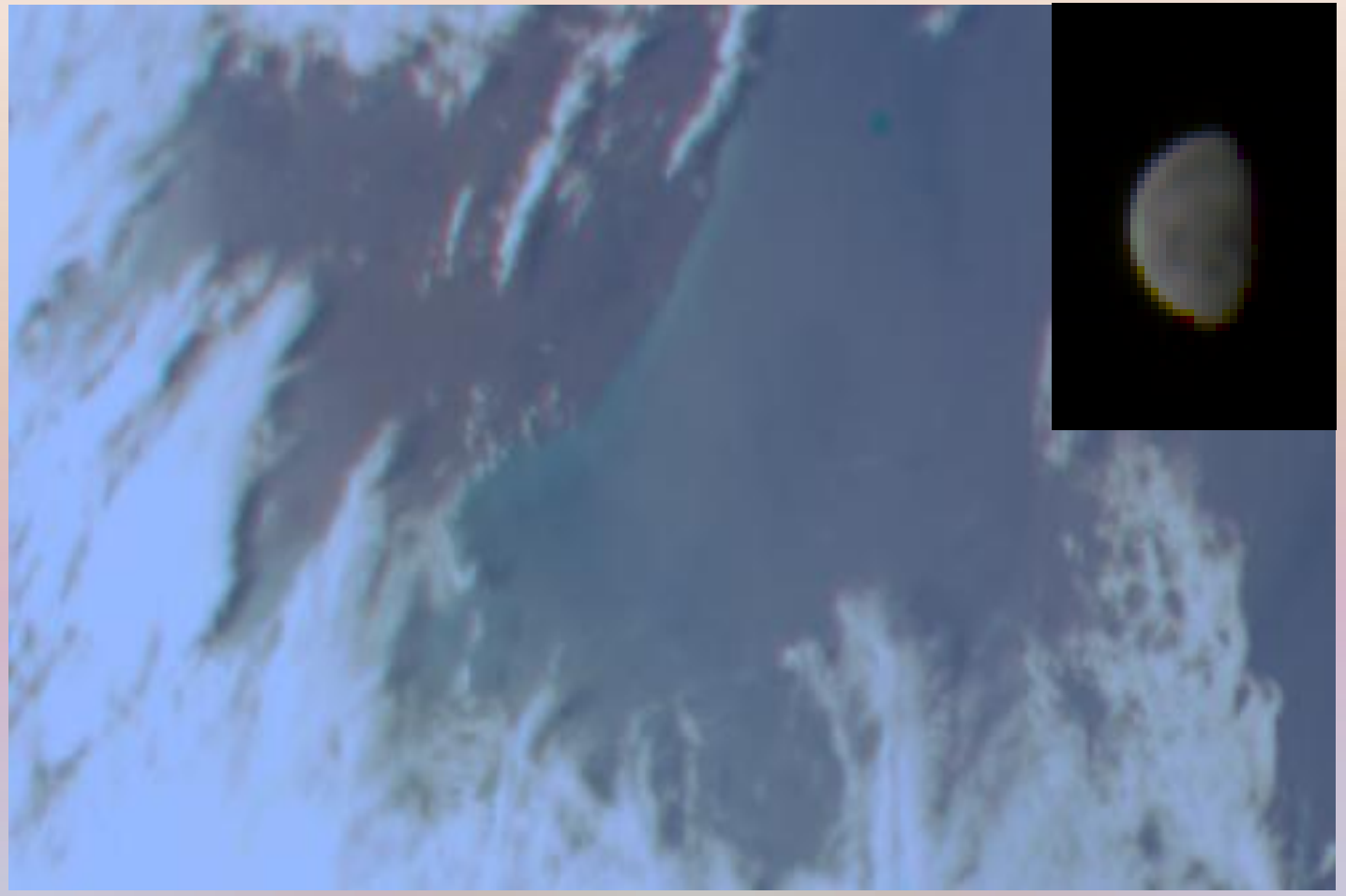

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

Weight factors: red x 0.510, green x 0.630, blue x 1.0
Factors apply to square-root encoded raw images.

# Global View of Time-Variant Reprojection

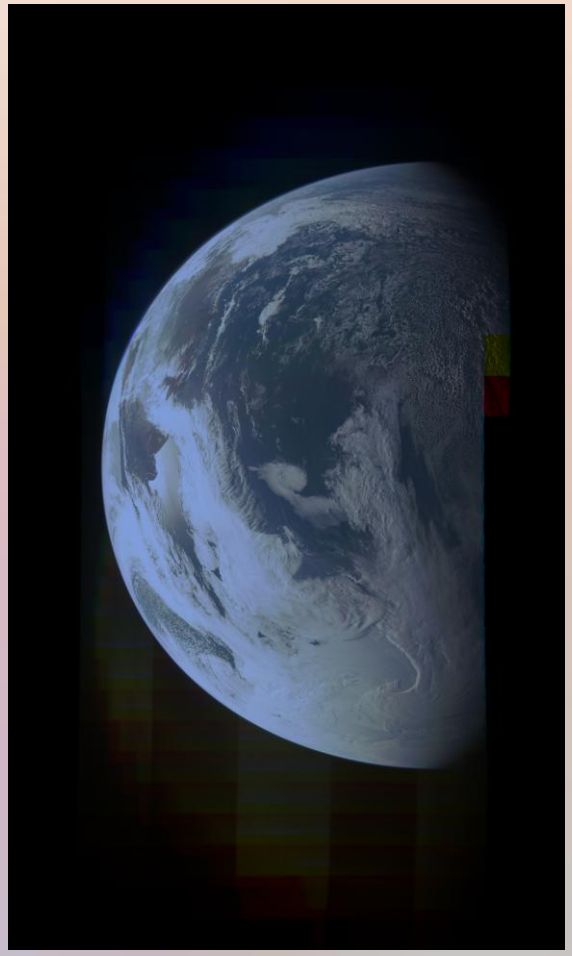

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

- Looks almost photorealistic.
- Slightly distorted, since perspective is continuously changing over y.

# Reprojection for Start-Time

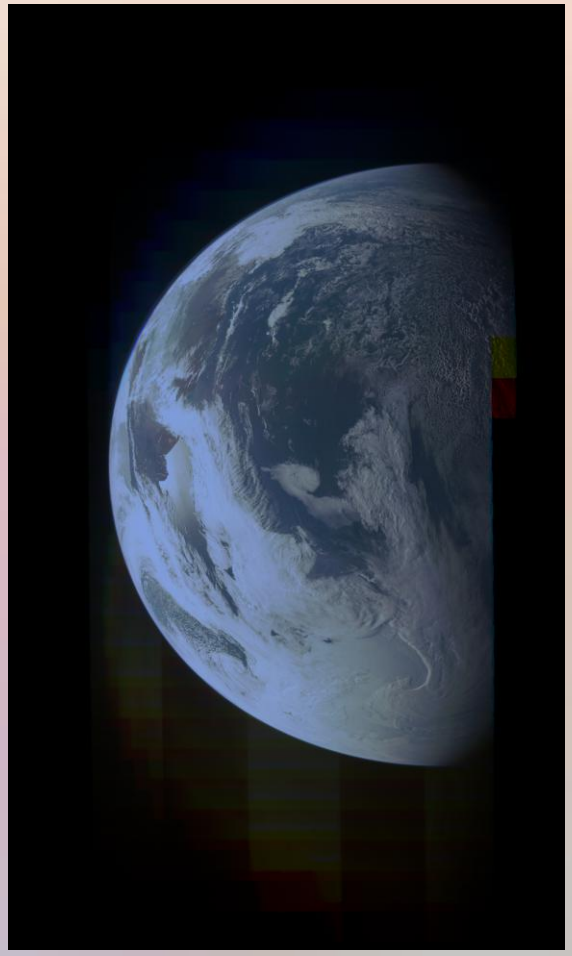

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

Southern hemisphere imaging startet immediately after start-time.
Then the camera pointed to outer space for more than 20 seconds.

# Reprojection for Stop-Time

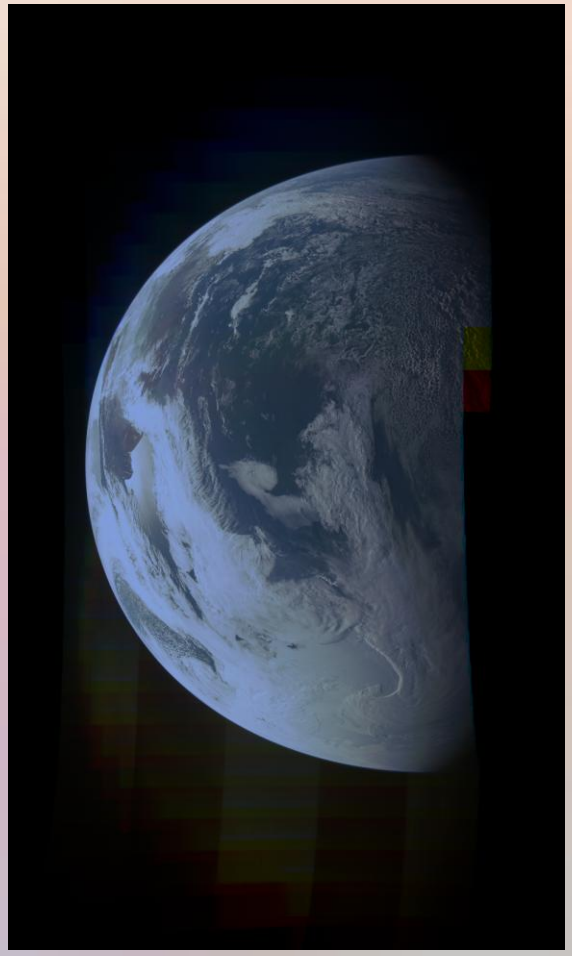

Image: NASA / JPL-Caltech / SwRI / MSSS / Gerald Eichstädt

Northern hemisphere imaging ended immediately before stop-time.
In the meanwhile Juno's vantage point moved.

# Animation Using Two Consecutive Swathes

Image: NASA / JPL-Caltech / SwRI / MSSS / SPICE / ffmpeg / Gerald Eichstädt

Simulation of a flight near Juno's actual trajectory.

# „Methane“ and RGB Image Reprojected

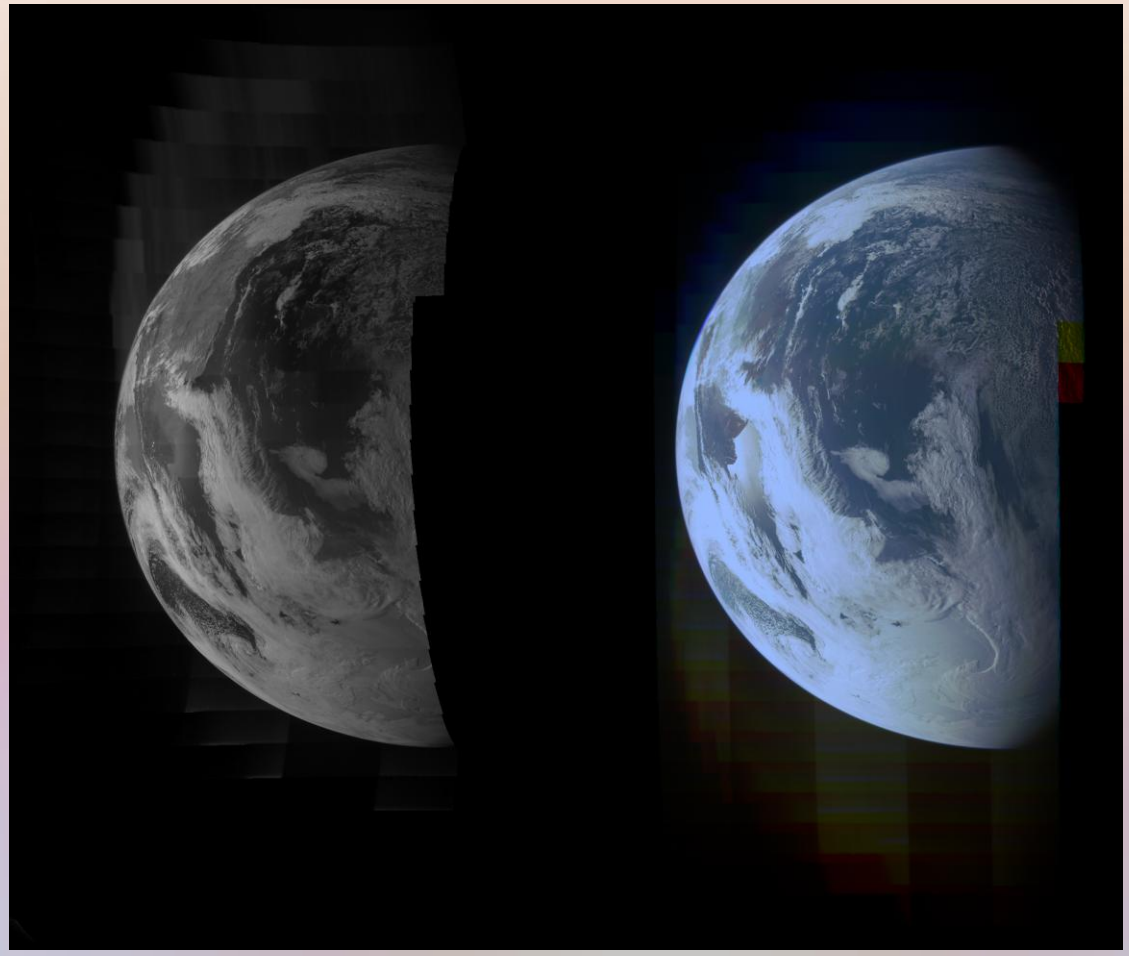

Image: NASA / JPL-Caltech / SwRI / MSSS / SPICE / Gerald Eichstädt

Reprojection of consecutive images to same instant simplifies comparision.

# Combining to a False-Color Image

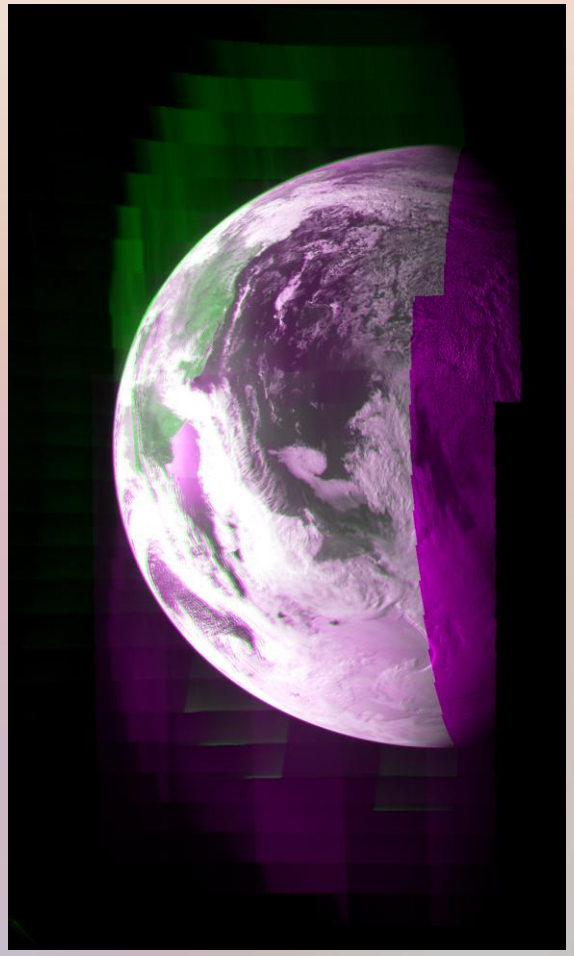

Image: NASA / JPL-Caltech / SwRI / MSSS / SPICE / Gerald Eichstädt

The methane image is used to replace the green channel of the RGB image.
Continents look greenish due to plants reflecting near infra-red.

# Skipped

- Time Delay Integration (TDI)
- Flat field
- Hot pixels
- JPG/DCT compression
- Linearization / Radiometric Factor
- Stray light
- Light leaks
- Energetic particles and camera degradation
- Geometric in-flight calibration
- Methane filter spectral properties

# More High-Level Products

- Stereo images
- Map projections
- Merging several swathes
- Feature tracking
- Cloud-top topography
- Wind fields
- Radiation counting
- Event detection (lightnings, impacts)
- Superresolved products

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# Thank you for your attention!

**Further reading:**

*Junocam: Juno's Outreach Camera*

C.J. Hansen·M.A. Caplinger·A. Ingersoll· M.A. Ravine·E. Jensen·S. Bolton·G. Orton

You may also be interested in following the links and discussions at unmannedspaceflight.com

Questions, Remarks?