NOAA's Preparations for the Next Generation of Geostationary Satellites: GOES-R

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EUMeTrain Event Week, 7 Nov. 2016

Outline

- GOES-R and Himawari Introduction
- Baseline Products
- GOES-R Risk Reduction and Proving Ground
- Improvements in spatial, temporal, and spectral resolution
- Development of True Color Imagery

GOES-R and Himawari

- GOES-R and Himawari-8 are Geostationary satellites that carry state-of-the-art instruments, allowing for weather imagery never before seen

- Himawari-8 was launched by the Japanese Meteorological Agency in October 2014, and its Advanced Himawari Imager (AHI) has been providing amazing imagery for over a year

- GOES-R is scheduled for launch in November 2016 – it will carry the Advanced Baseline Imager (ABI) and a Geostationary Lightning Mapper (GLM), in addition to 4 space weather instruments

- As will be shown in a few slides, the FCI aboard MTG is quite similar to the ABI and the AHI

The Advanced Baseline Imager being installed on the GOES-R spacecraft

GOES-R Baseline Products

ADVANCED BASELINE IMAGER (ABI)

Aerosol Detection (Including Smoke and Dust)
Aerosol Optical Depth (AOD)
Clear Sky Masks
Cloud and Moisture Imagery
Cloud Optical Depth
Cloud Particle Size Distribution
Cloud Top Height
Cloud Top Phase
Cloud Top Pressure
Cloud Top Temperature
Derived Motion Winds
Derived Stability Indices
Downward Shortwave Radiation: Surface
Fire/Hot Spot Characterization
Hurricane Intensity Estimation
Land Surface Temperature (Skin)
Legacy Vertical Moisture Profile
Legacy Vertical Temperature Profile
Radiances
Rainfall Rate / QPE
Reflected Shortwave Radiation: TOA
Sea Surface Temperature (Skin)
Snow Cover
Total Precipitable Water
Volcanic Ash: Detection and Height

GEOSTATIONARY LIGHTNING MAPPER (GLM)

Lightning Detection: Events, Groups & Flashes

SPACE ENVIRONMENT IN-SITU SUITE (SEISS)

Energetic Heavy Ions
Magnetospheric Electrons & Protons: Low Energy
Magnetospheric Electrons & Protons: Med & High Energy
Solar & Galactic Protons

MAGNETOMETER (MAG)

Geomagnetic Field

EXTREME ULTRAVIOLET AND X-RAY IRRADIANCE SUITE (EXIS)

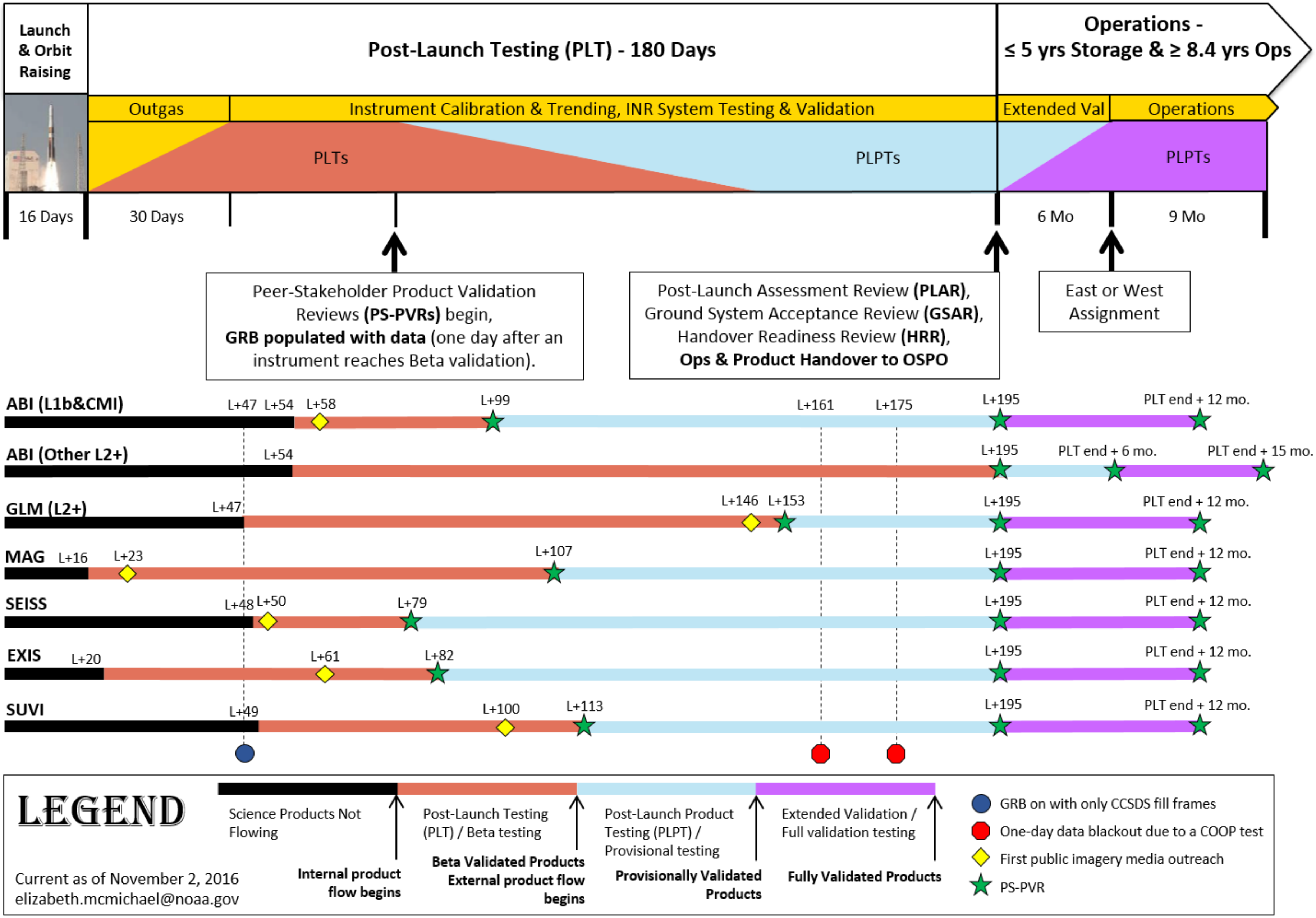
Solar Flux: EUV
Solar Flux: X-ray Irradiance

SOLAR ULTRAVIOLET IMAGER (SUVI)

Solar EUV Imagery

http://www.goes-r.gov/products/baseline.html

GOES-R Post-Launch Science Product Validation Schedule



Note: All dates are coordinated with Flight/MOST PLT SOE group and are subject to change.

GOES-R Risk Reduction and Proving Ground

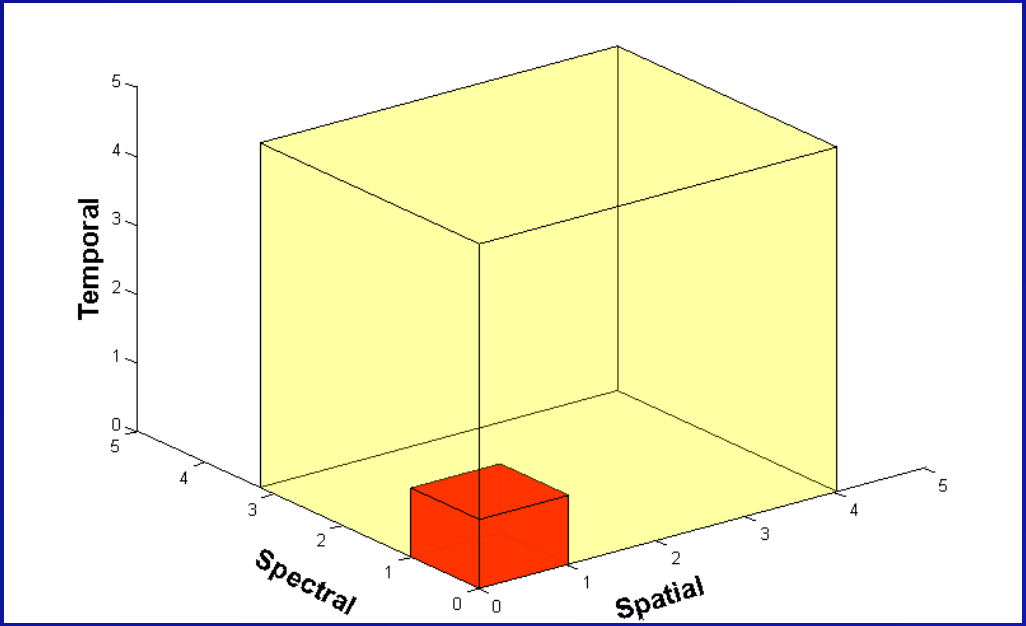
Risk Reduction

- A research program meant to promote applied research based on the use of GOES-R data
- Encourages development of products making use of data from multiple platforms/sources, i.e., satellite, radar, numerical weather prediction, surface observations, etc.). Also known as "Fused-data" products
- Risk Reduction seeks to address possible new products not part of the baseline product set established 15 years ago

Proving Ground

- A collaborative effort among the GOES-R program, NOAA Cooperative Institutes, NASA, the National Weather Service, and other NOAA testbeds
- The goal of the Proving Ground is to test GOES-R products (using proxy data, typically) in an operational setting (e.g., at National Weather Service forecast offices) before the launch of the satellite, so that when the real data begins to flow, there are no problems
- It is also used to gain feedback from forecasters on new experimental products

Advanced Baseline Imager



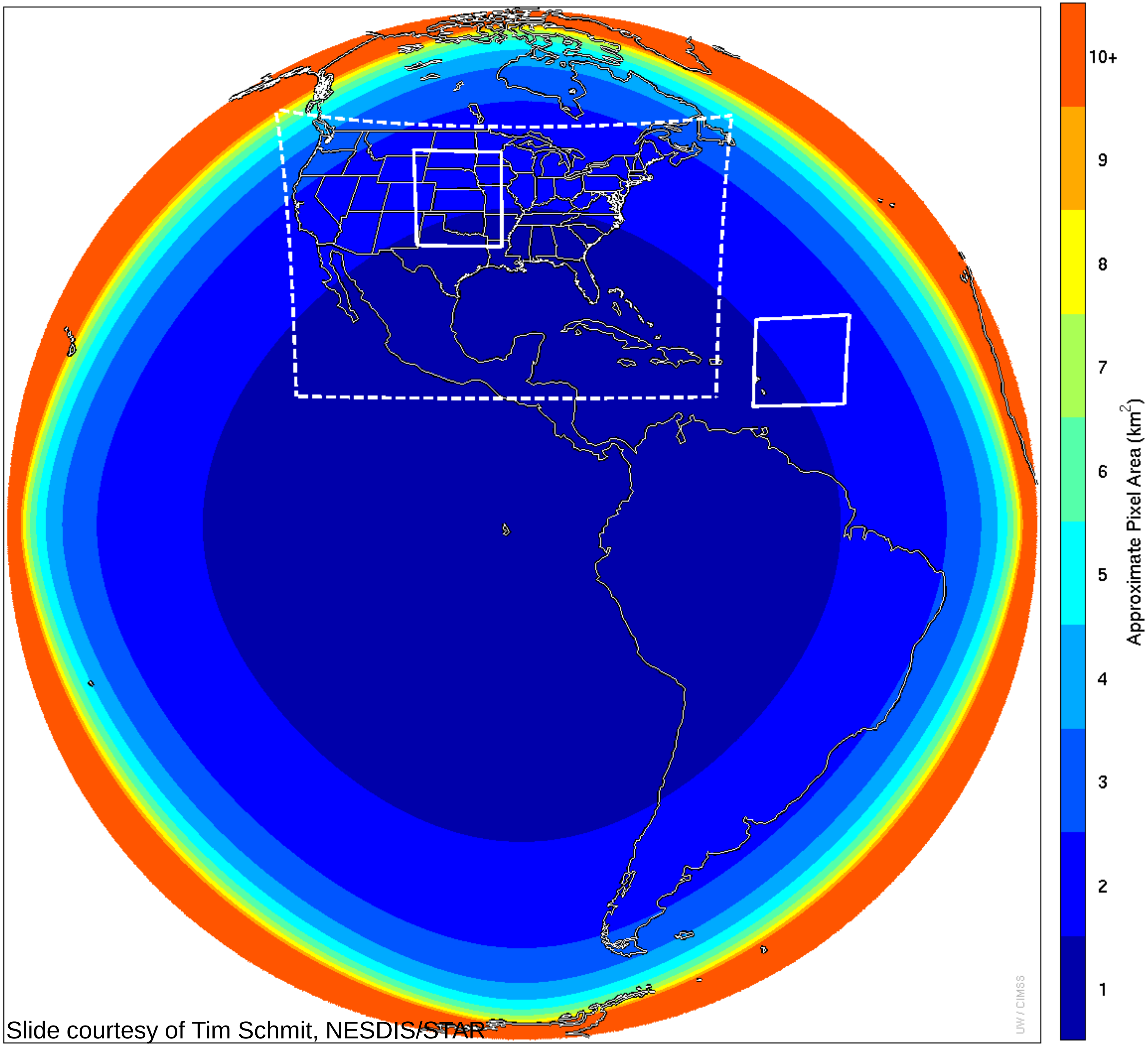
5x Faster coverage (5-minute full disk vs. 25-minute)

4x Improved spatial resolution (2 km IR vs. 4 km)

3x More spectral bands (16 on ABI vs. 5 on the current imager)

Slide courtesy of Tim Schmit, NESDIS/STAR

Approximate Pixel Area (Nominally 1km at Nadir) from -89.5 West



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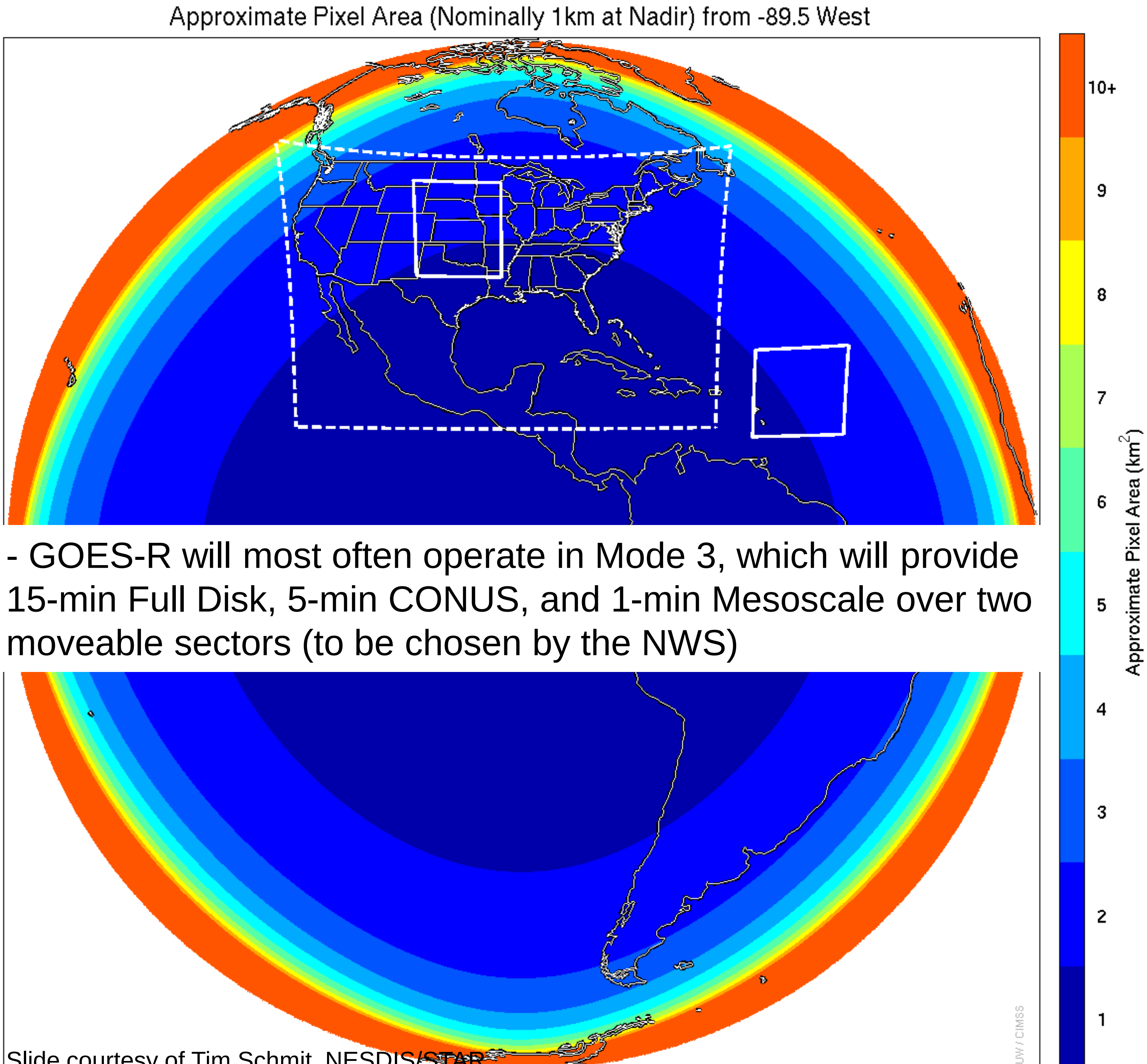

- GOES-R will most often operate in Mode 3, which will provide 15-min Full Disk, 5-min CONUS, and 1-min Mesoscale over two moveable sectors (to be chosen by the NWS)

Slide courtesy of Tim Schmit, NESDIS/STAR

Comparison of Spectral Bands

Approx. Central Wavelength (µm)	Band Explanation	GOES-R ABI	Himawari AHI	GK-2 AMI	MTG FCI	FY-4 AGRI
		Central Wavelength (µm) [Band Number]				
0.47	Visible/reflective	0.47 [1]	0.47 [1]	0.46 [1]	0.44 [1]	0.47 [1]
0.51		None	0.51 [2]	0.51 [2]	0.51 [2]	None
0.64		0.64 [2]	0.64 [3]	0.64 [3]	0.64 [3]	0.65 [2]
0.865	Reflective	0.865 [3]	0.86 [4]	0.86 [4]	0.865 [4]	0.825 [3]
0.91		None	None	None	0.914 [5]	None
1.378	Cirrus	1.378 [4]	None	1.38 [5]	1.38 [6]	1.375 [4]
1.61	Snow/Ice	1.61 [5]	1.61 [5]	1.61 [6]	1.61 [7]	1.61 [5]
2.25	Particle size	2.25 [6]	2.25 [6]	None	2.25 [8]	2.25 [6]
3.90	Shortwave IR	3.90 [7]	3.9 [7]	3.85 [7]	3.8 [9]	3.75[2] [7,8]
6.19	Water vapor	6.19 [8]	6.2 [8]	6.24 [8]	6.3 [10]	6.25 [9]
6.95		6.95 [9]	6.9 [9]	6.95 [9]	None	7.1 [10]
7.34		7.34 [10]	7.3 [10]	7.35 [10]	7.35 [11]	None
8.5	Water vapor, SO_2	8.5 [11]	8.6 [11]	8.6 [11]	8.7 [12]	8.5 [11]
9.61	Ozone	9.61 [12]	9.6 [12]	9.63 [12]	9.66 [13]	None
10.35	Longwave IR	10.4 [13]	10.4 [13]	10.43 [13]	10.5 [14]	10.7 [12]
11.2		11.2 [14]	11.2 [14]	11.2 [14]	None	None
12.3		12.3 [15]	12.3 [15]	12.3 [15]	12.3 [15]	12.0 [13]
13.3		13.3 [16]	13.3 [16]	13.3 [16]	13.3 [16]	13.5 [14]

True-color component bands are highlighted in red, green, and blue.

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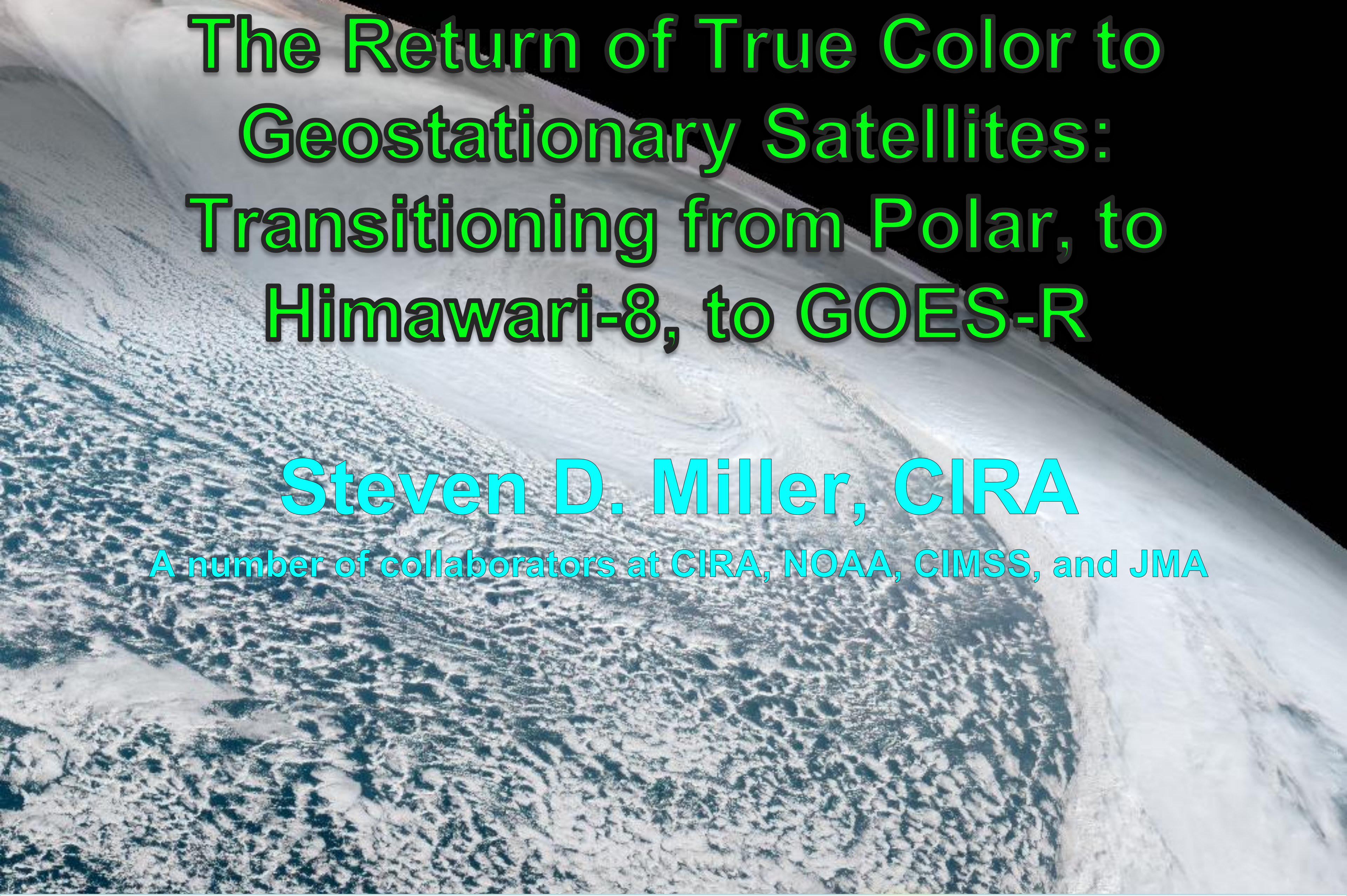
The Return of True Color to Geostationary Satellites: Transitioning from Polar, to Himawari-8, to GOES-R



Steven D. Miller, CIRA

A number of collaborators at CIRA, NOAA, CIMSS, and JMA

CIRA Connecting Models and Observations

NOAA U.S. Department of Commerce National Oceanic and Atmospheric Administration

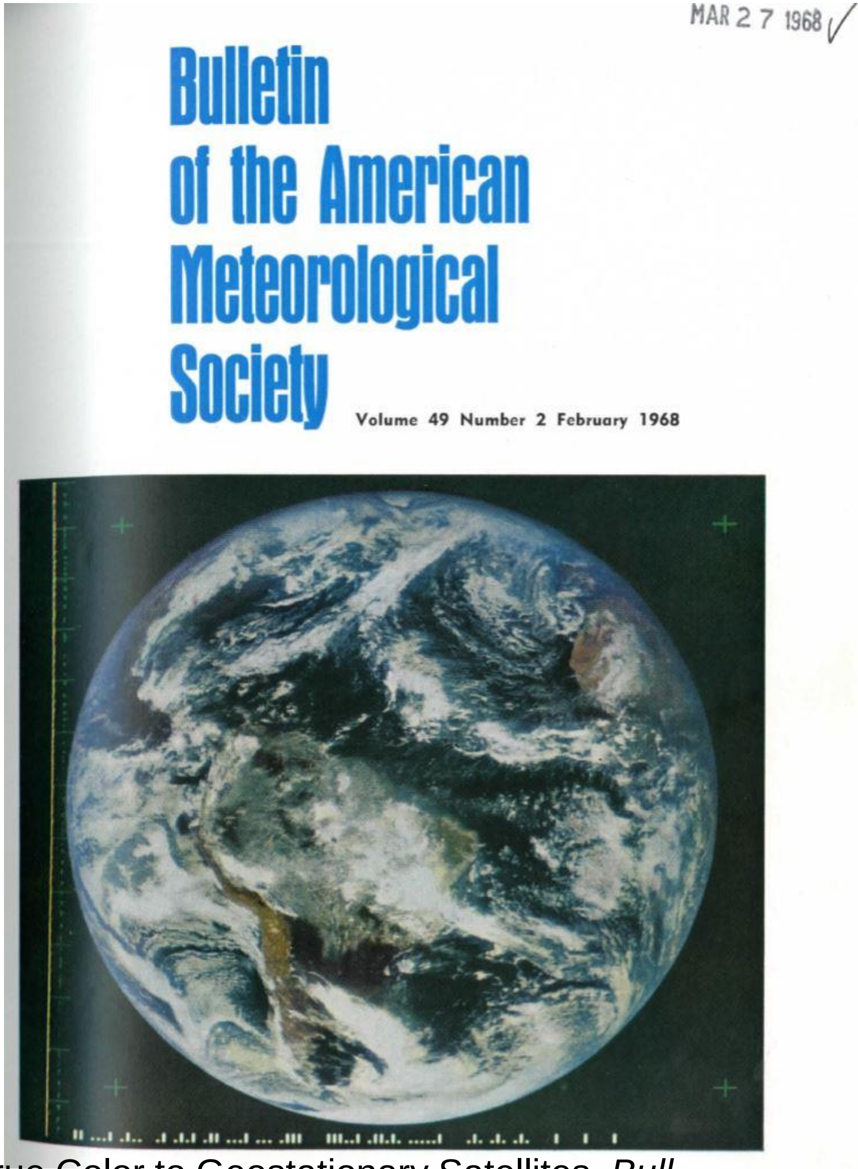
NOAA NESDIS STAR Center for Satellite Applications and Research

CIMSS

JMA

True Color from Geostationary Orbit

NASA ATS-3 (1967)
The last geostationary satellite to offer a true color imaging capability.



Miller, S. D., et al., 2016, A Sight for Sore Eyes: the Return of True Color to Geostationary Satellites. *Bull. Amer. Meteorol. Soc.,* in press. http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-15-00154.1

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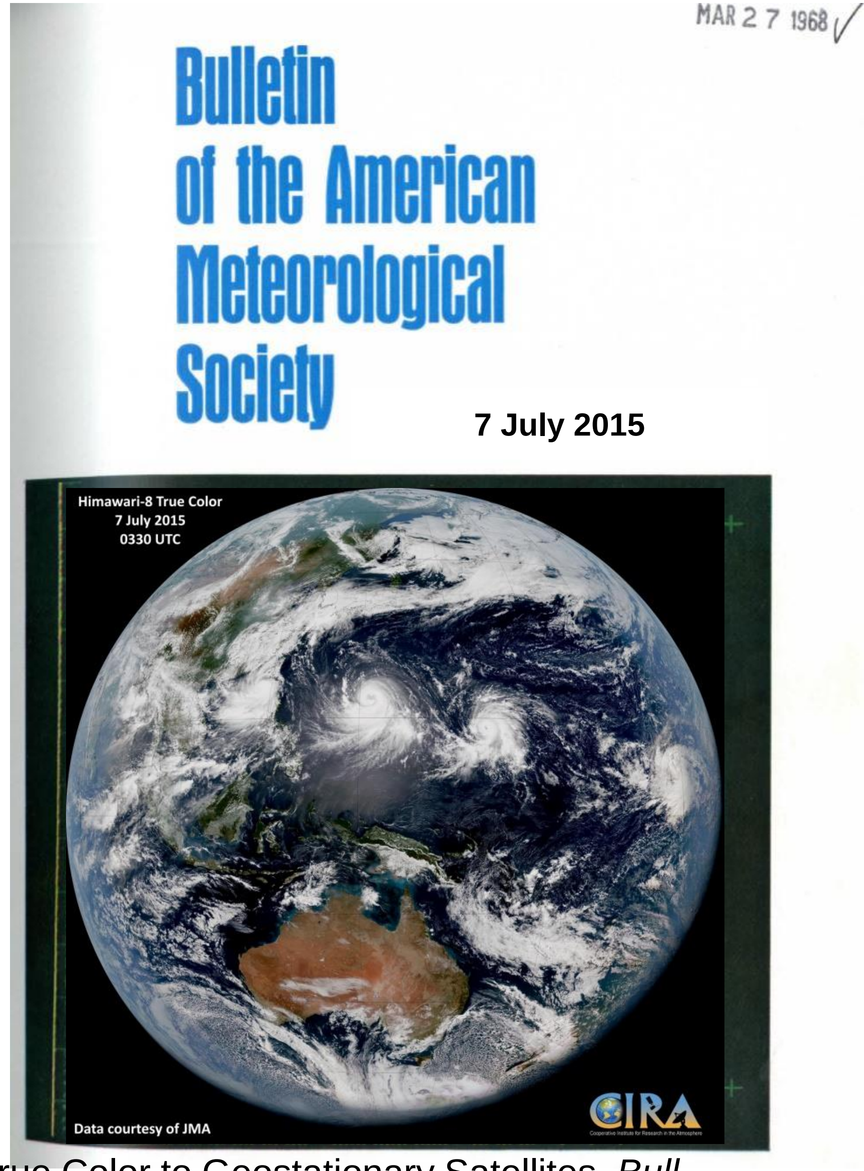

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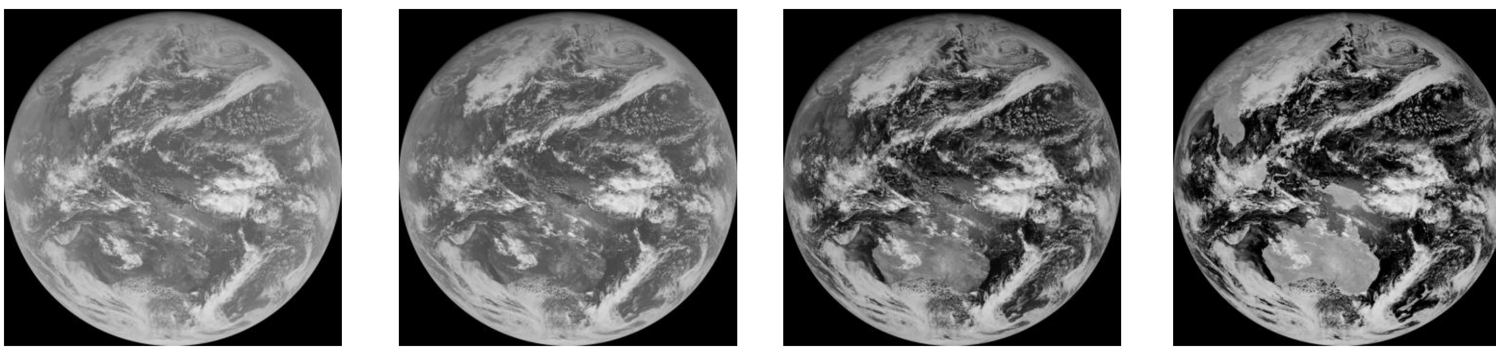
The Fundamental Value of True Color

- True Color is a special case of Red/Green/Blue (R/G/B) composite imagery.
- Visible-band reflectance data from red (0.65 µm), green (0.55 µm), and blue (0.47 µm) are loaded into the respective R/G/B color guns.
- True Color provides a visually intuitive (*<u>Read: minimal training requirements</u>*) form of baseline imagery for scene interpretation.
- Features appear the color that one expects them to appear, e.g., brown dust

Rayleigh Corrections

- Molecular scatter of sunlight by the gaseous atmosphere is significant, particularly in the blue-band
- Adapted atmospheric correction software, applied previously to SeaWiFS/MODIS/VIIRS sensors, to AHI bands
- Corrections are a function of solar & satellite geometry

Blue Green Red NIR



→ *These atmospheric corrections are a critical step in attaining high-quality true color imagery*

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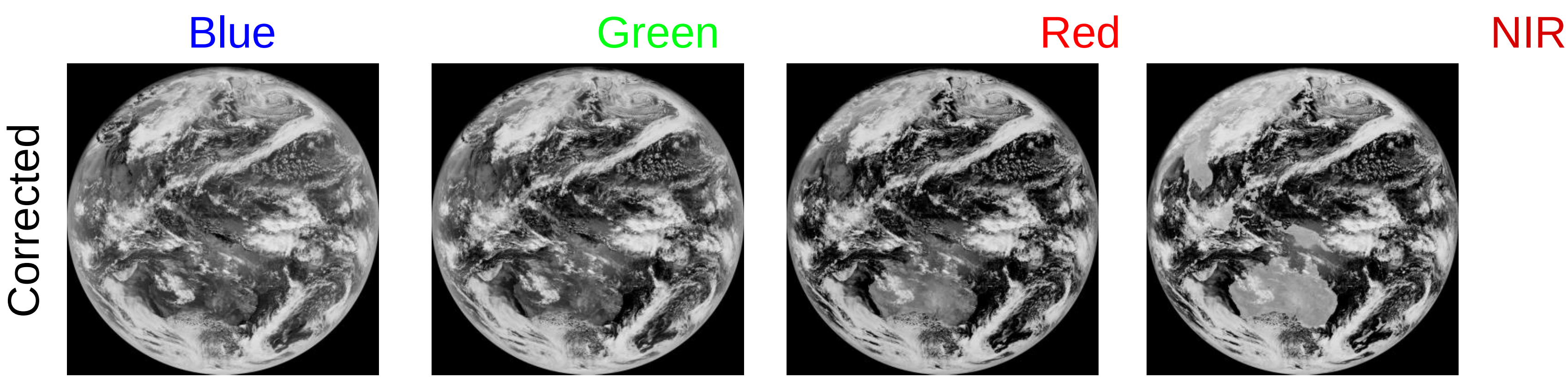

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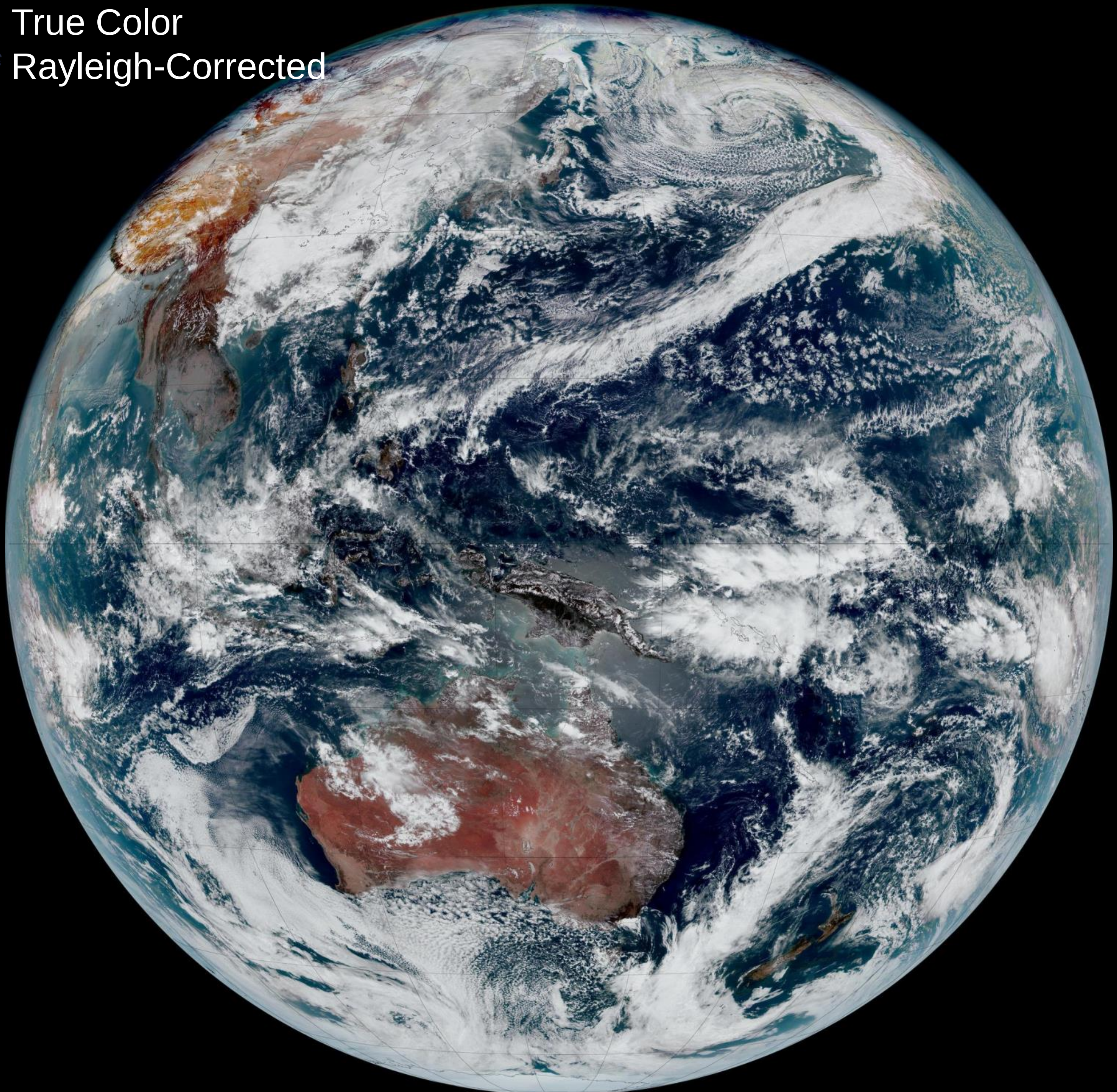
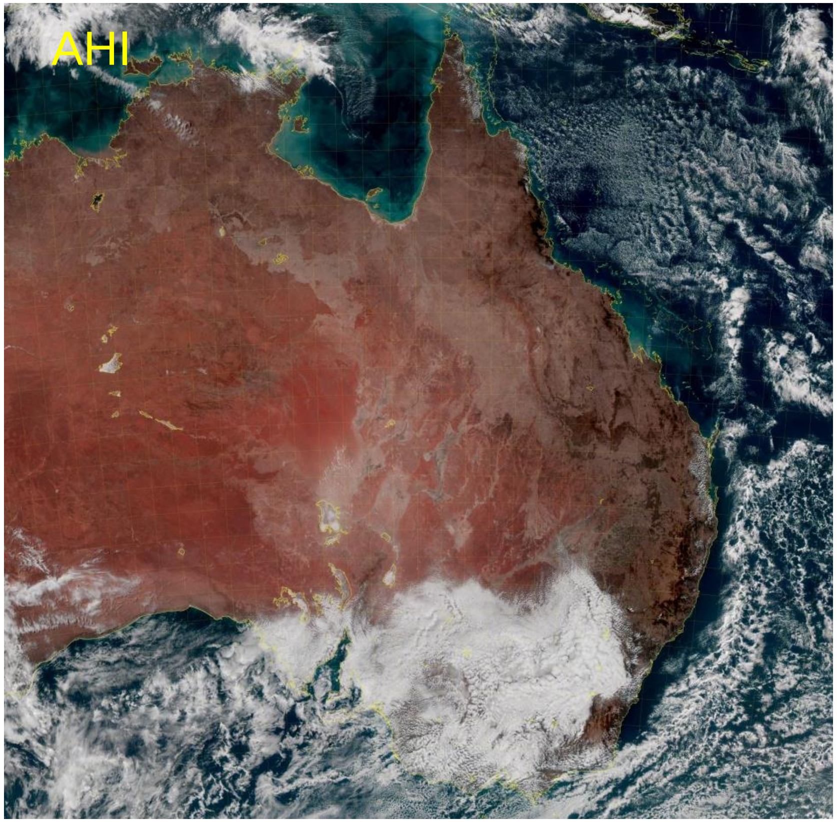
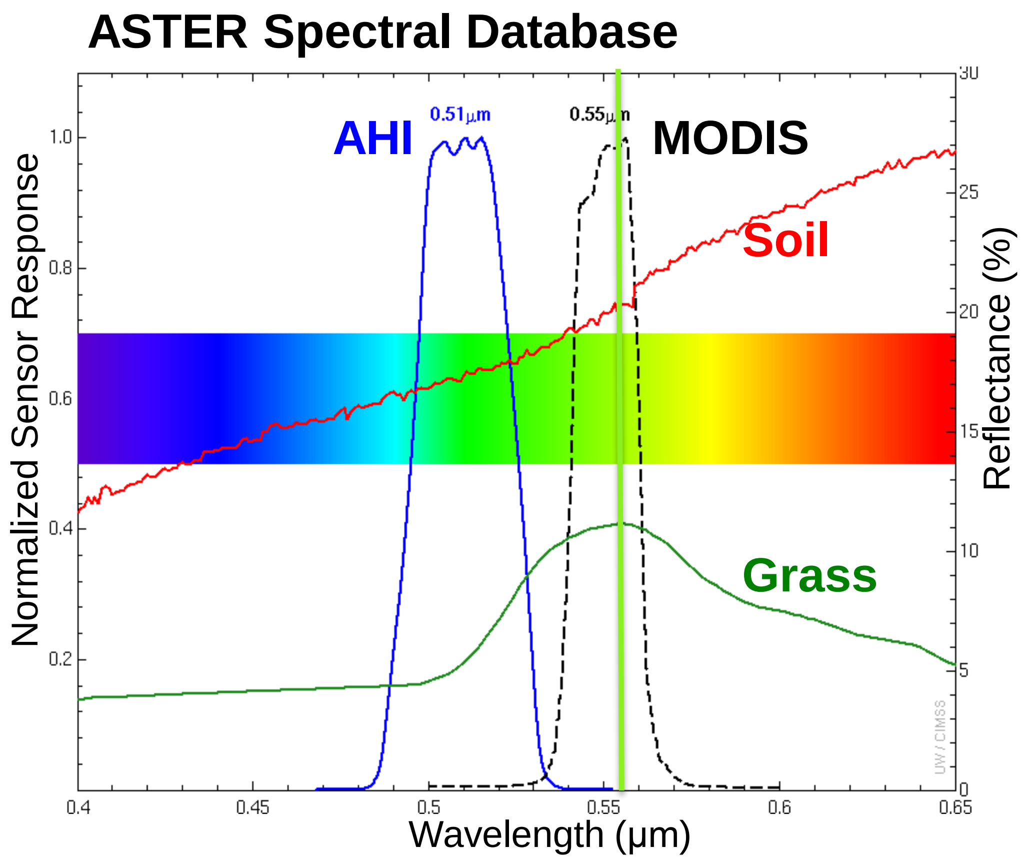
True Color
No Correction


True Color
Rayleigh-Corrected

Inconsistencies with MODIS/VIIRS





- Comparisons of AHI true color imagery to VIIRS & MODIS showed vegetation too brown, deserts too red…
- The 510 nm AHI band misses the 555 nm chlorophyll signal, and mineral soils are more absorbing (MODIS & VIIRS both use 555 nm).

Proposing a '*Hybrid Green*' Band

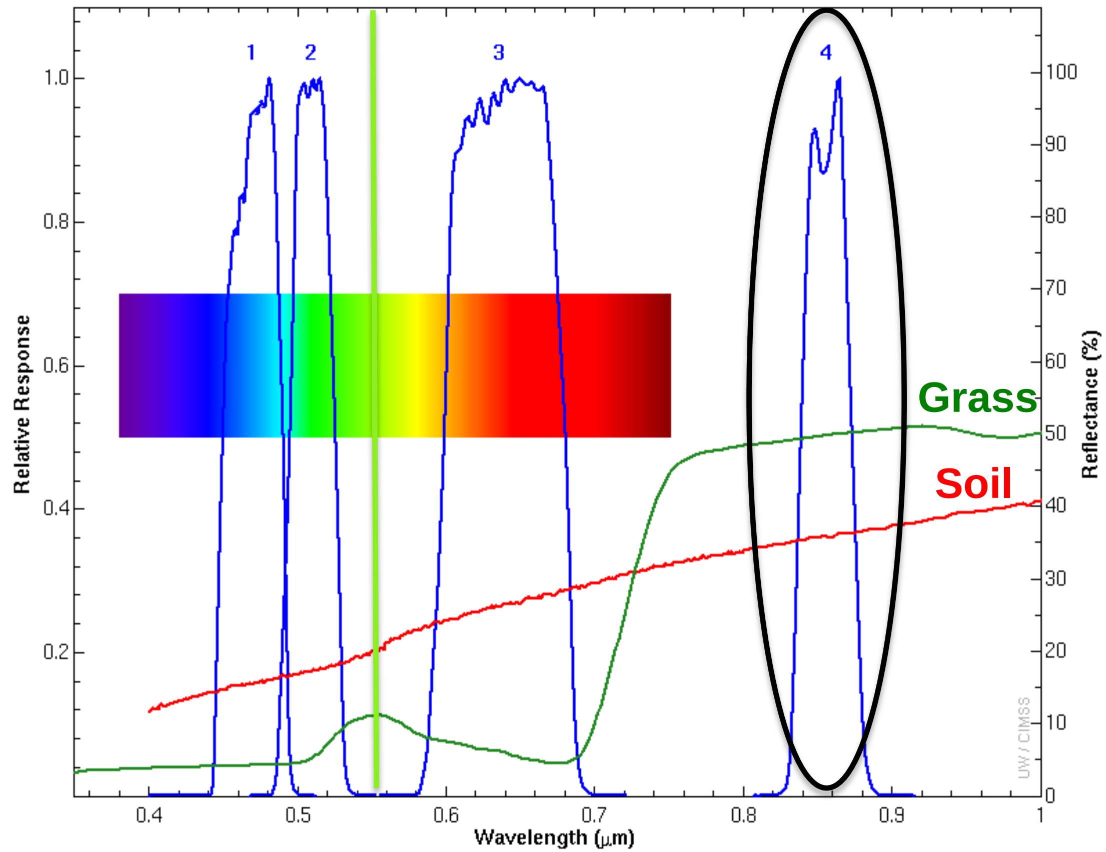
- Blend 510 nm green band with vegetation-sensitive 856 nm band to produce a 'hybrid green' band (G_H):

$$G_H = (1-F) * R\_510 + F * R\_856$$

F ~ 0.07 (experimental)

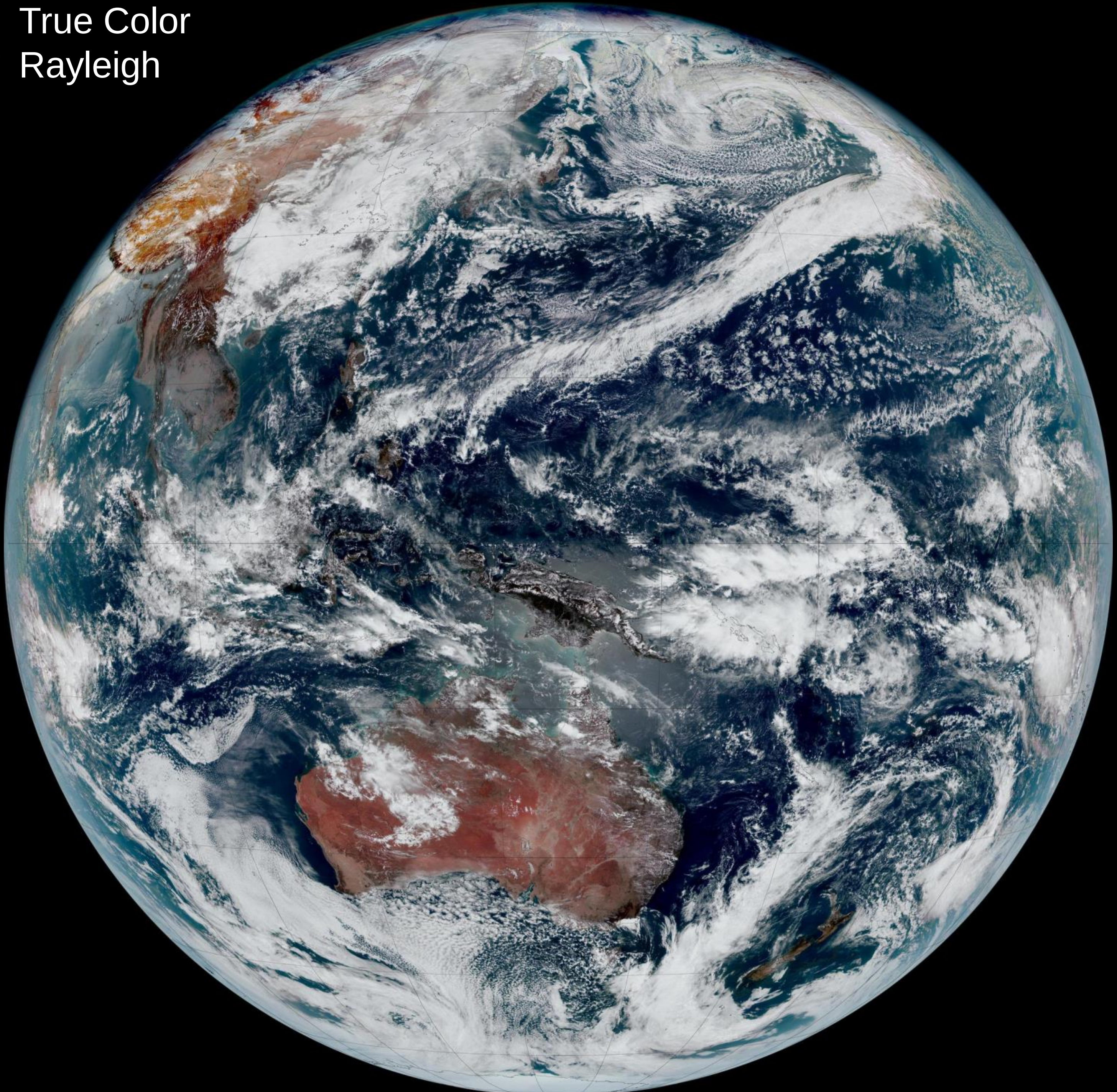
- Provides enhancement to green vegetation and to mineral soils (e.g., deserts).

- Minimal impact to other features of the scene (clouds, ocean, and shallow-water coloration)

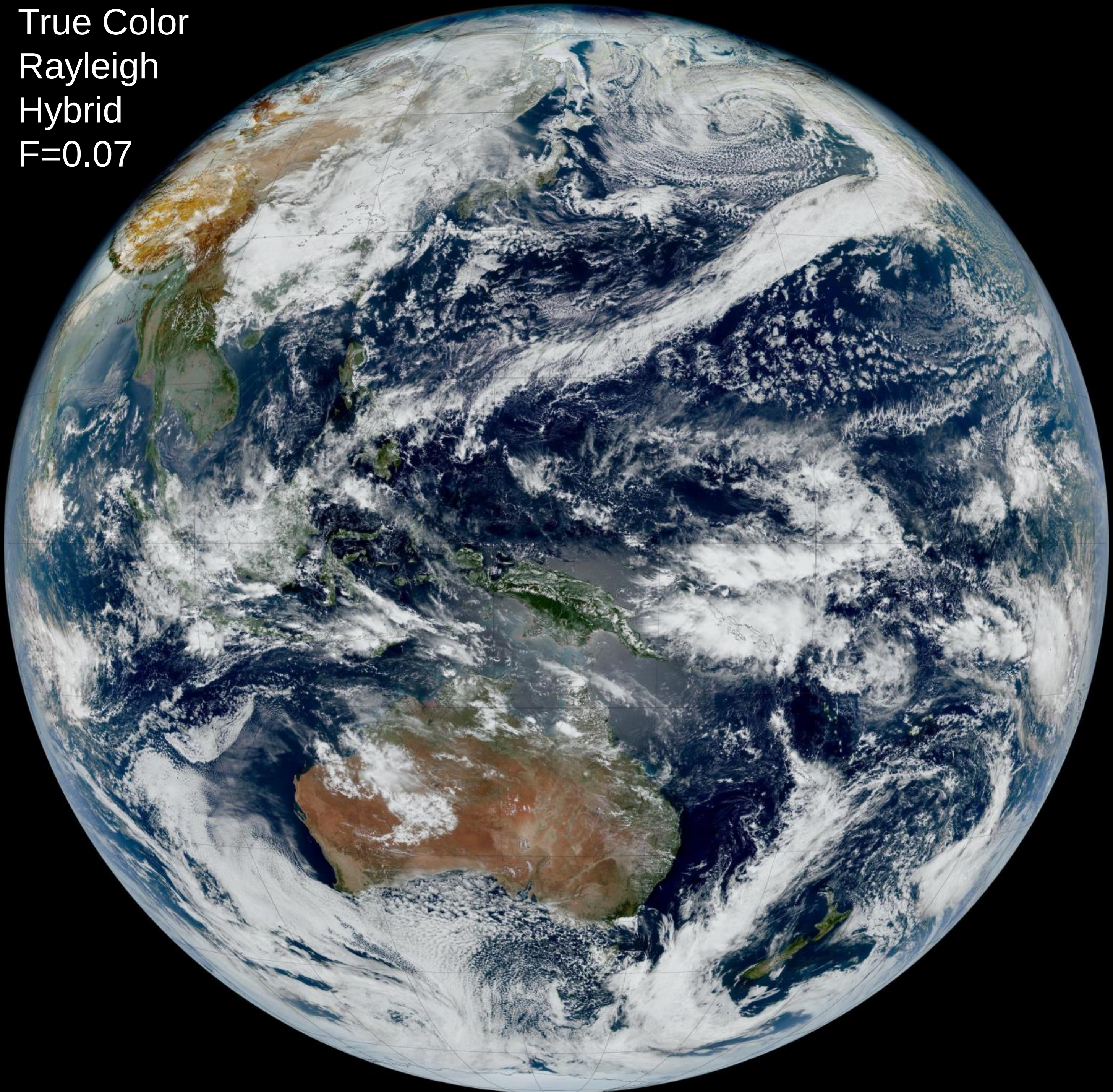


→ **AHI Band 4 (856 nm) provides a 'boost' to the 510 nm vegetation and soil reflectance…**

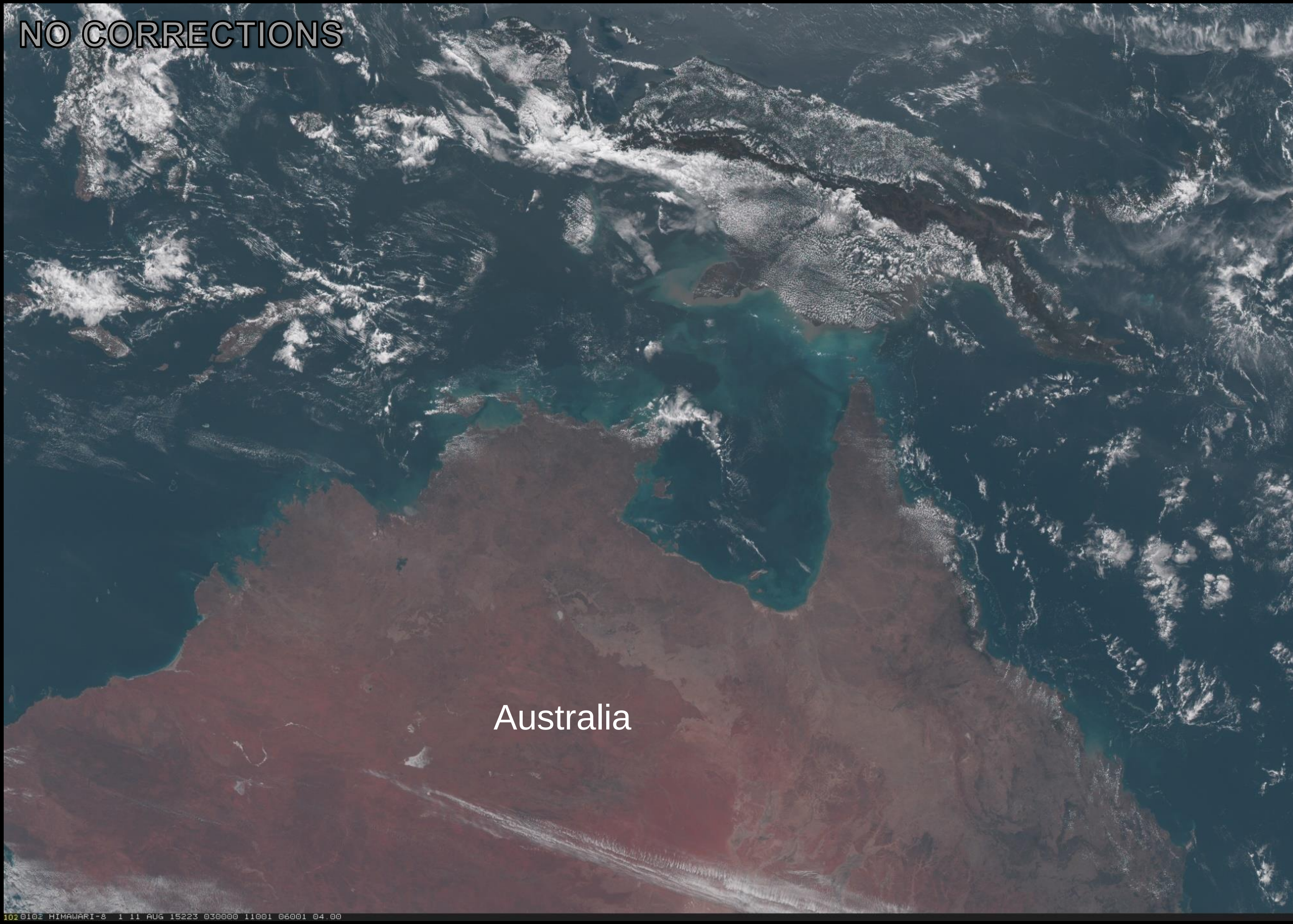
True Color
Rayleigh



True Color
Rayleigh
Hybrid
F=0.07



Connecting Models and Observations



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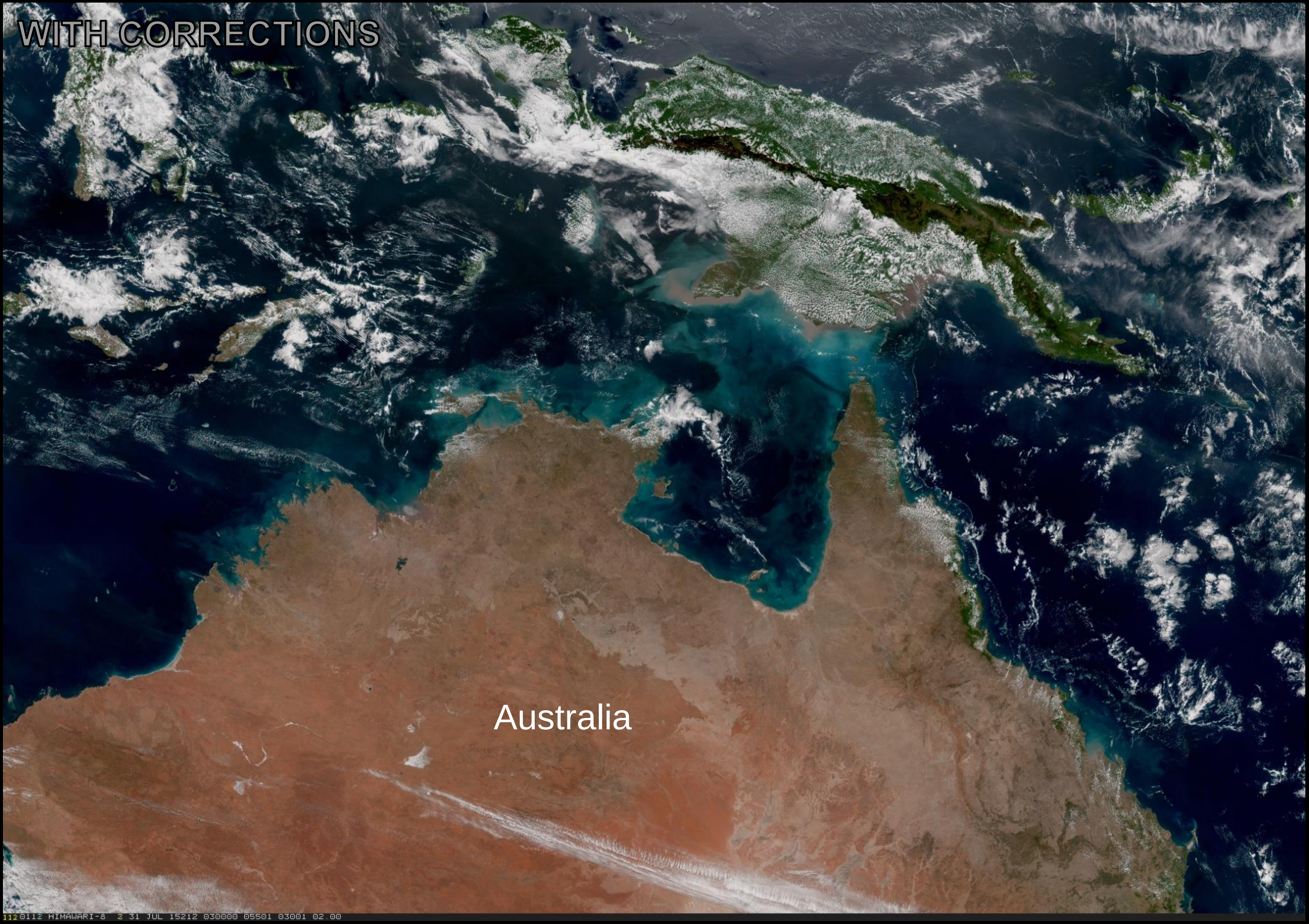
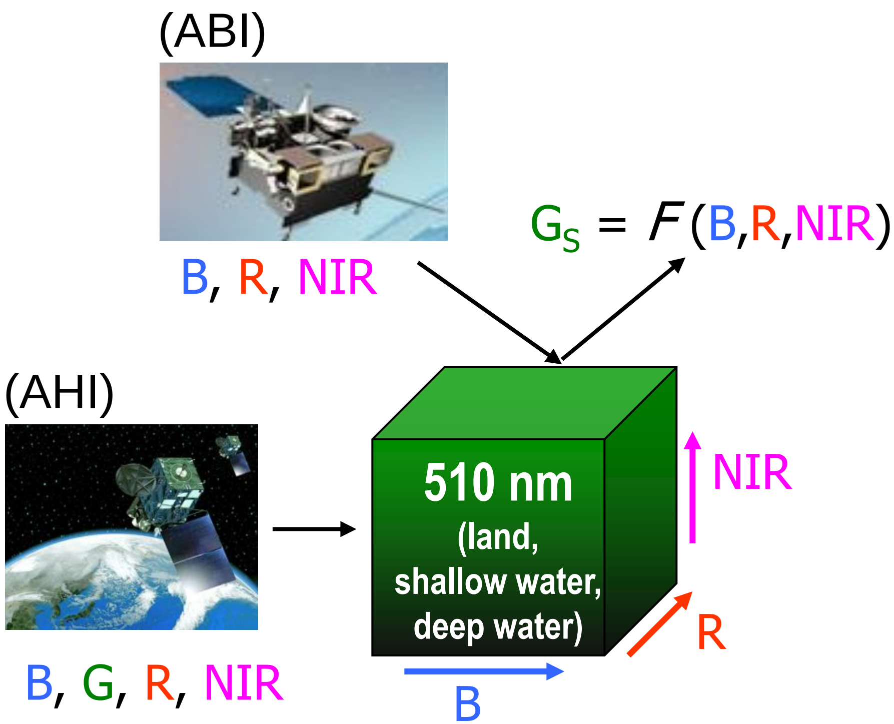


A Synthetic Green Solution for GOES-R

GOES-R ABI has no green band—in order to enable true color imagery, we must approximate it via correlations with other available bands. We are using Himawari-8 AHI to help define this relationship:



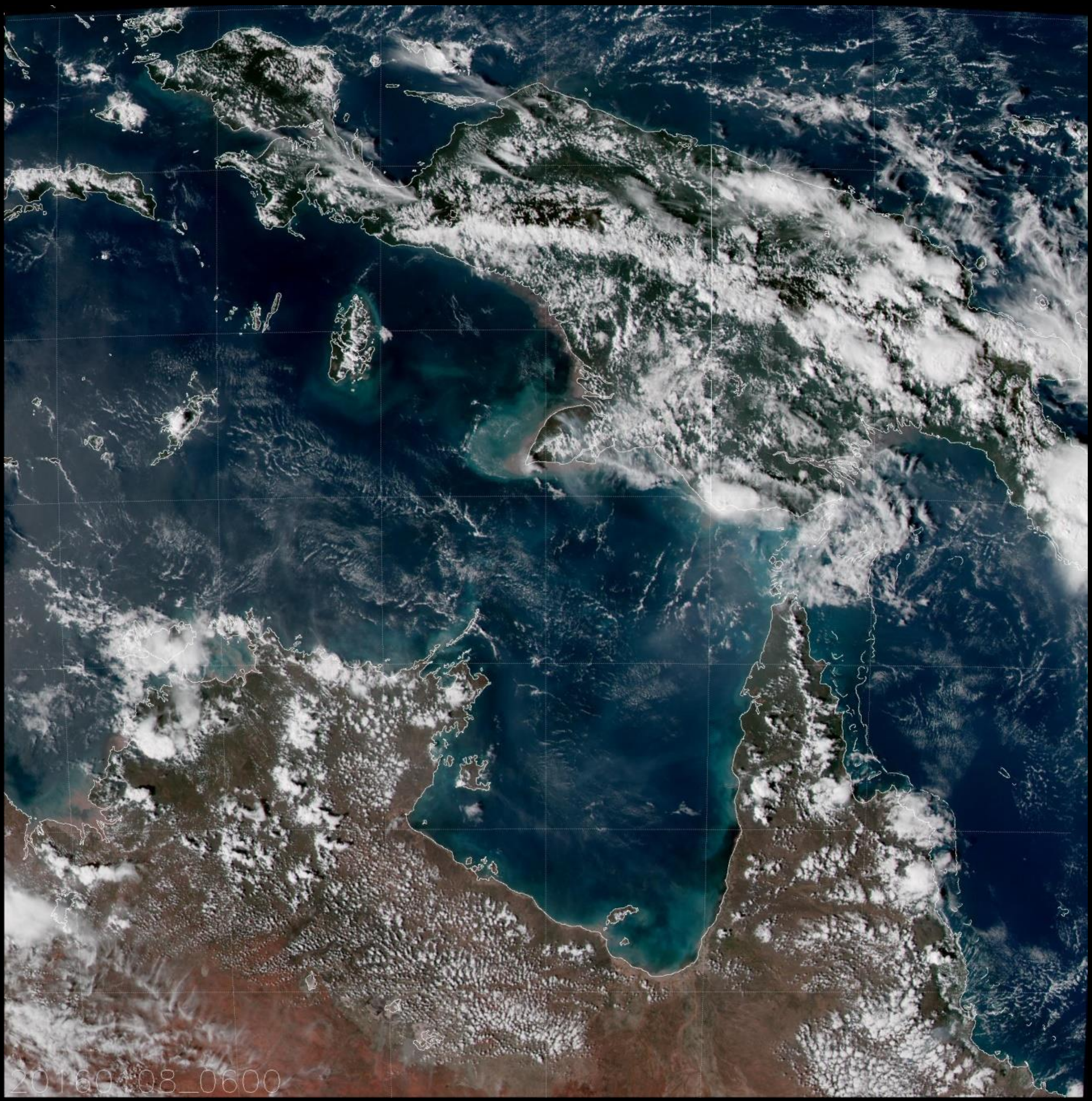
The look-up table (LUT) is built from many representative scenes. Multiple entries to a given index are averaged.

For GOES-R ABI, we will first construct G_S (510 nm), then compute $G_{H,S}$ via:

$$G_{H,S} = (1-F)*G_S + F*R_{856} \quad , F = 0.07$$

Miller, S. D., et al., 2012, *Int. J. Rem. Sens.*, **33**(13), 3999-4028.

Timor Sea



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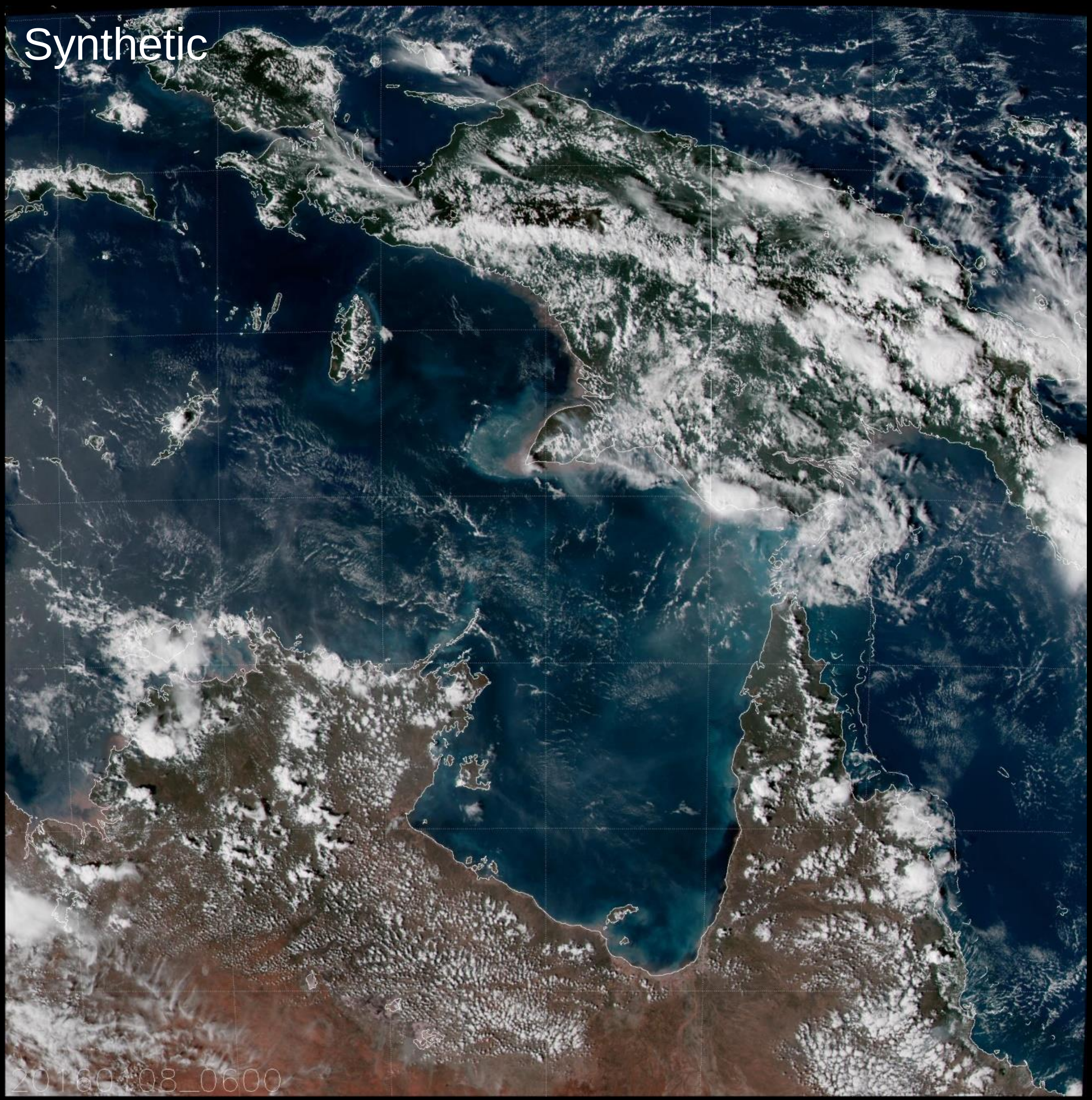

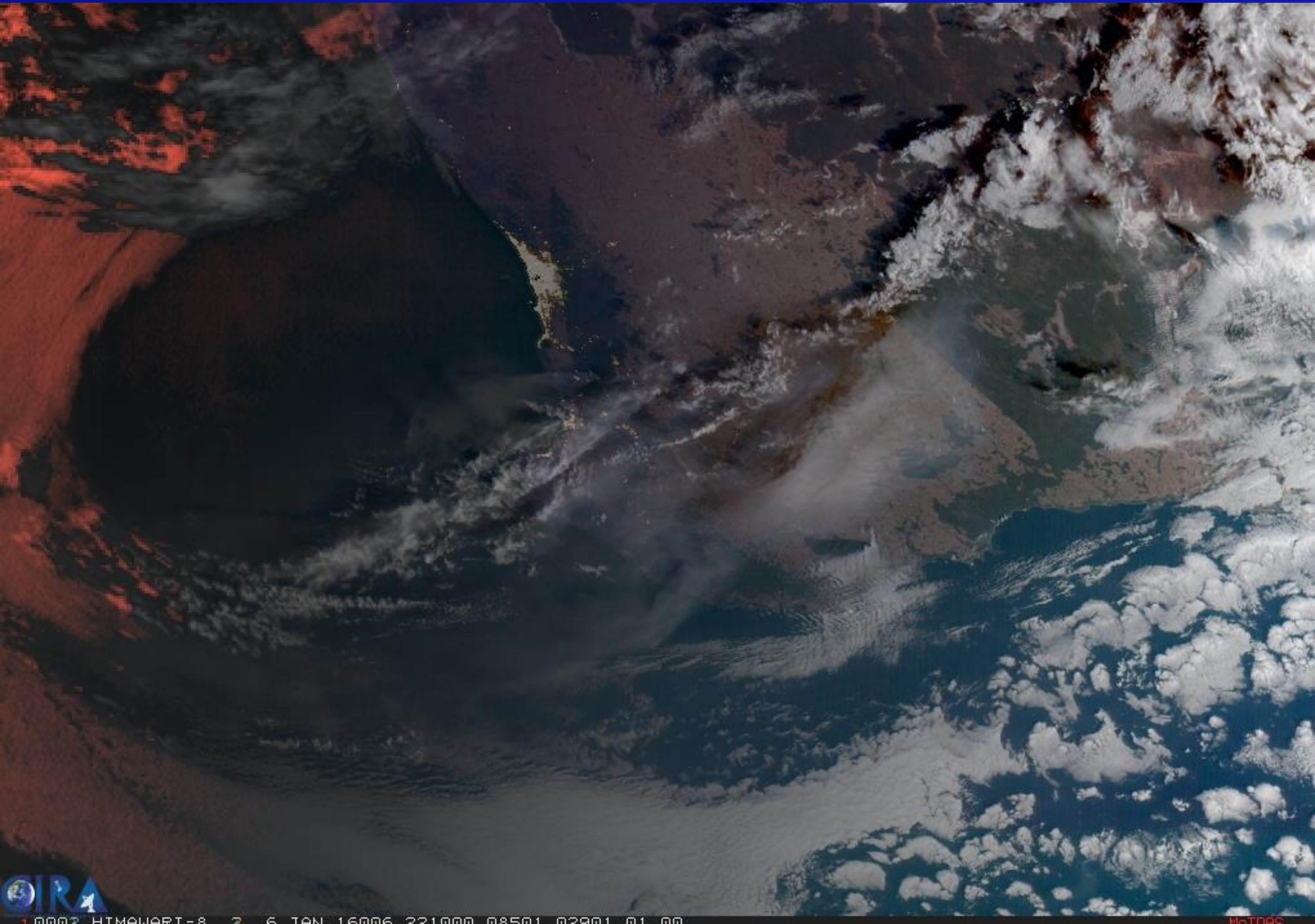
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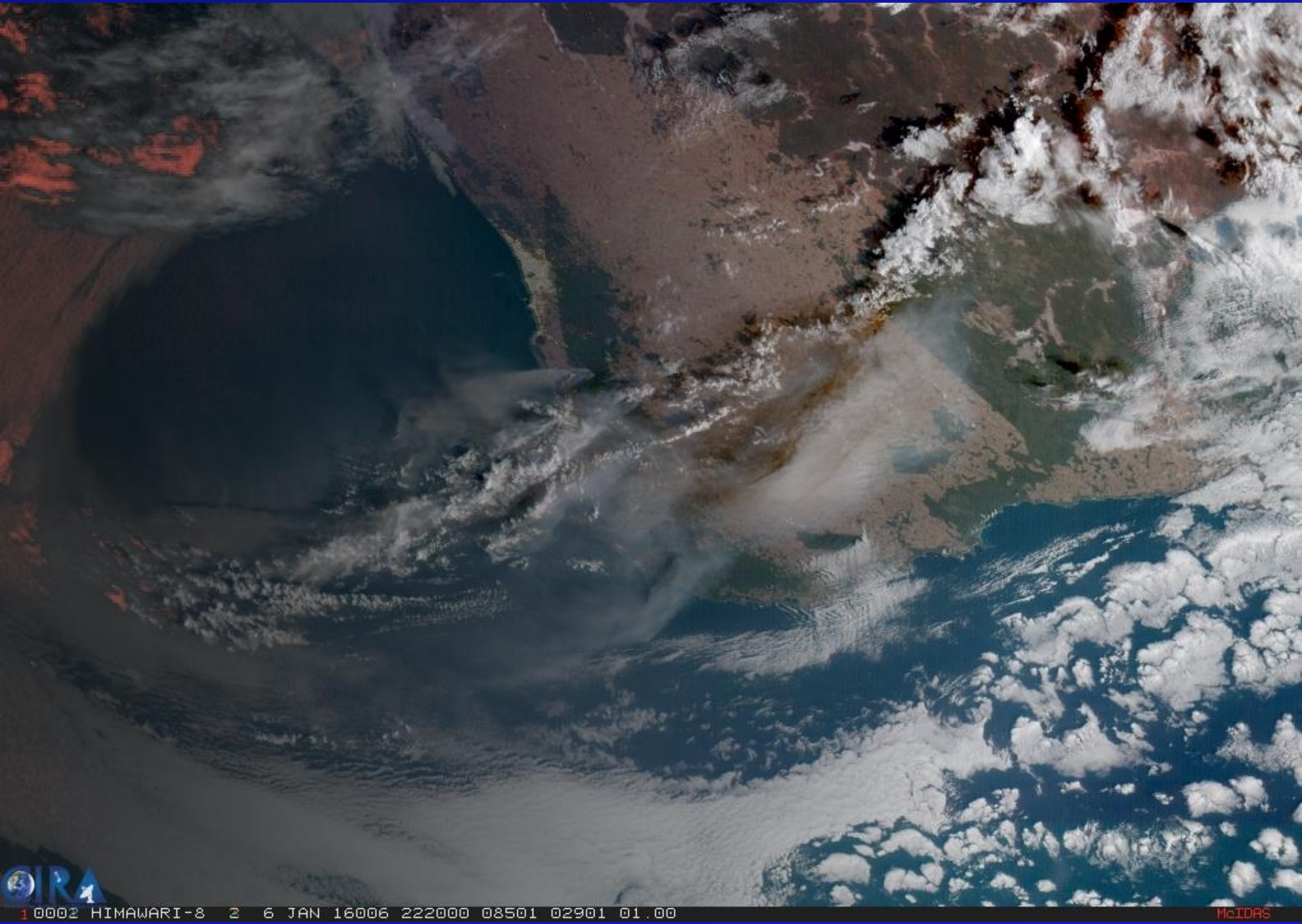
McIDAS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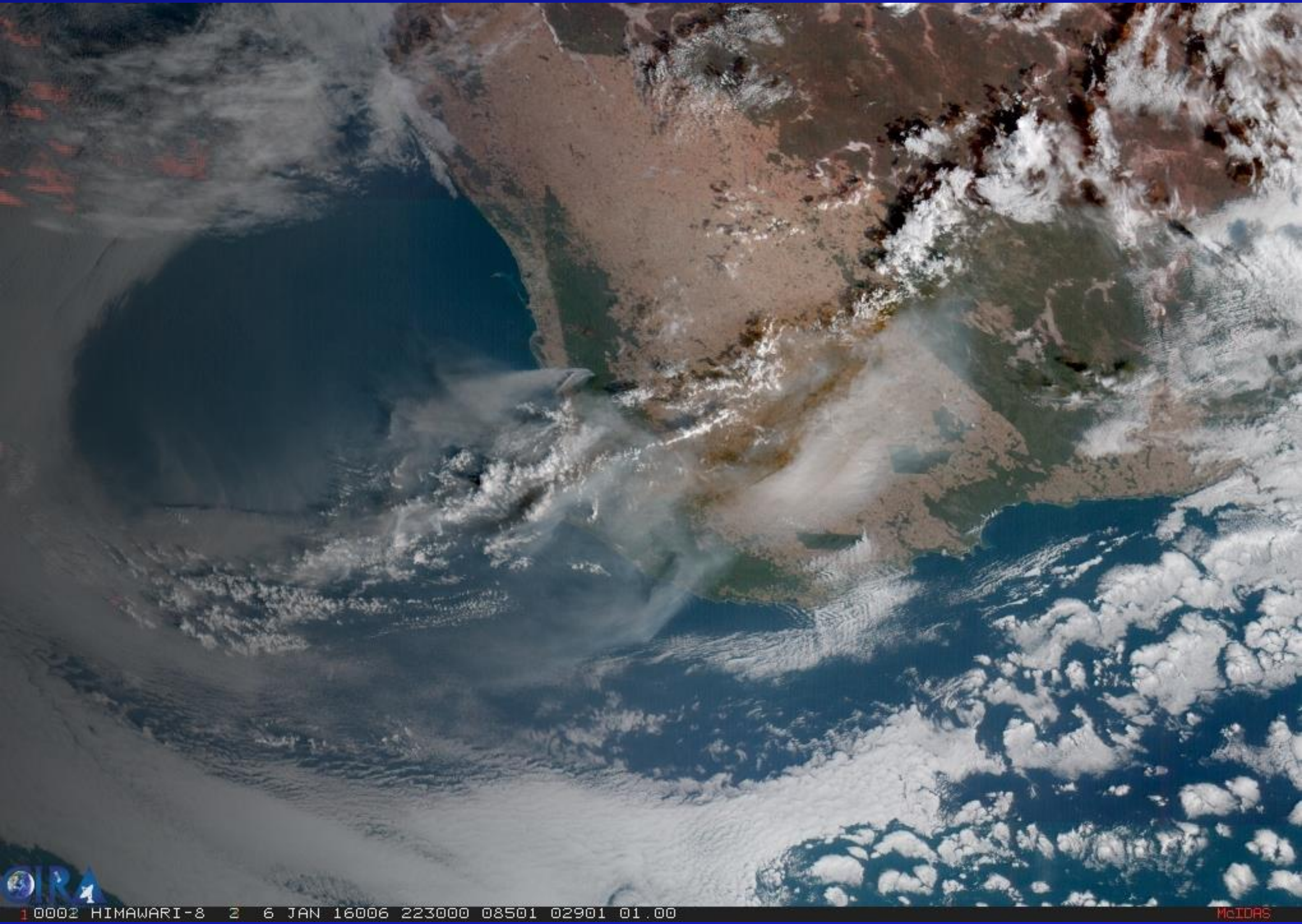
CIRA
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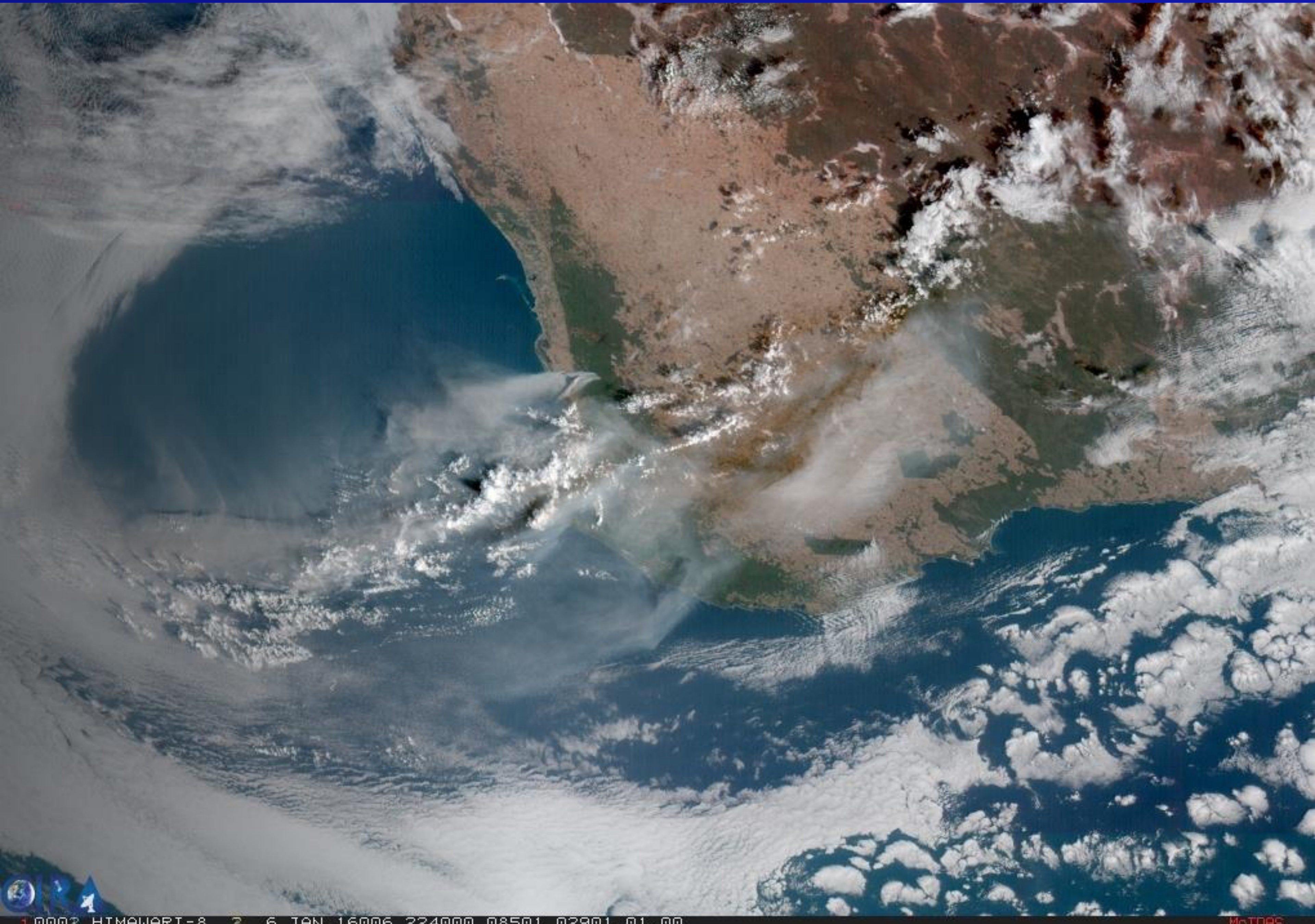
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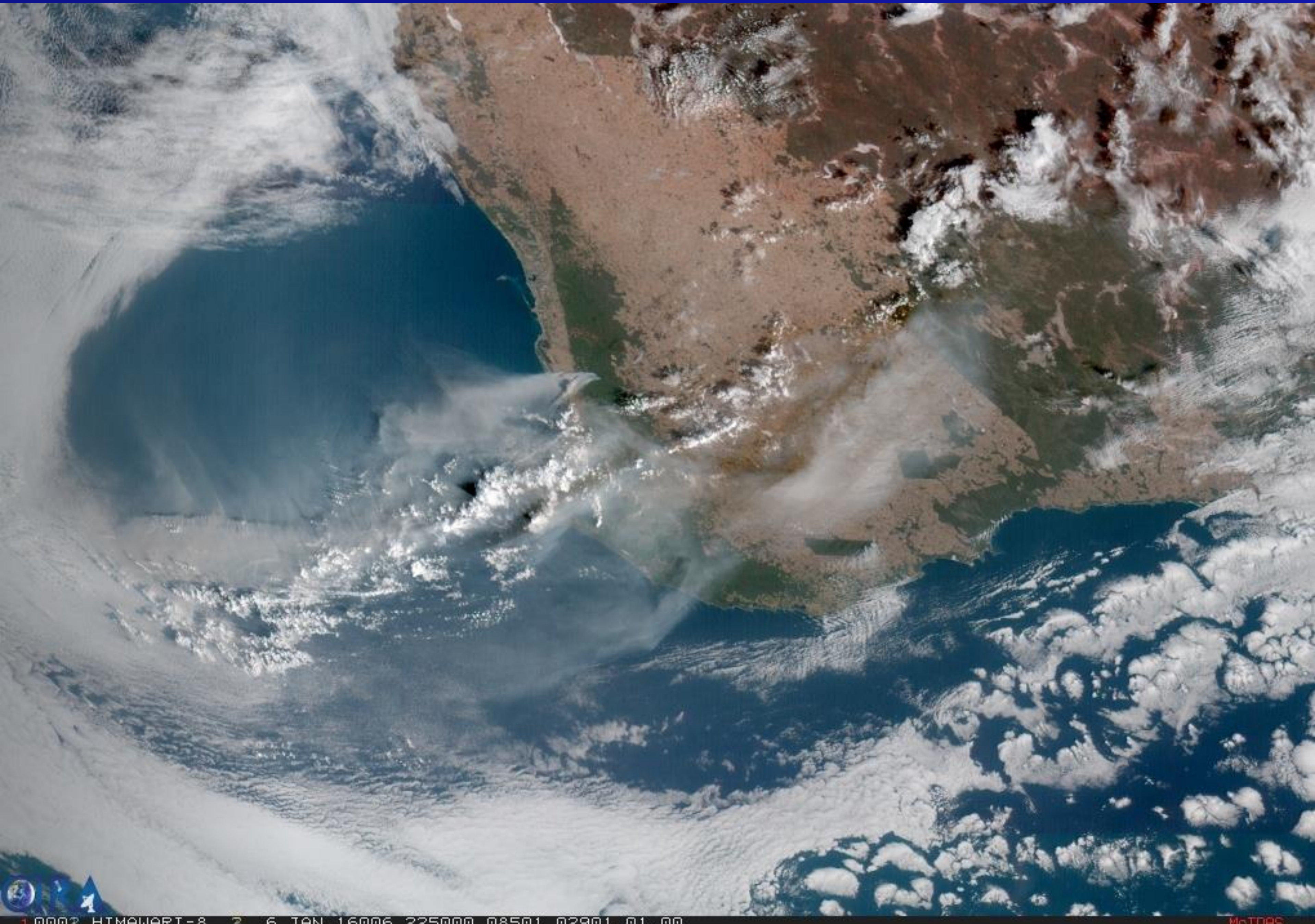
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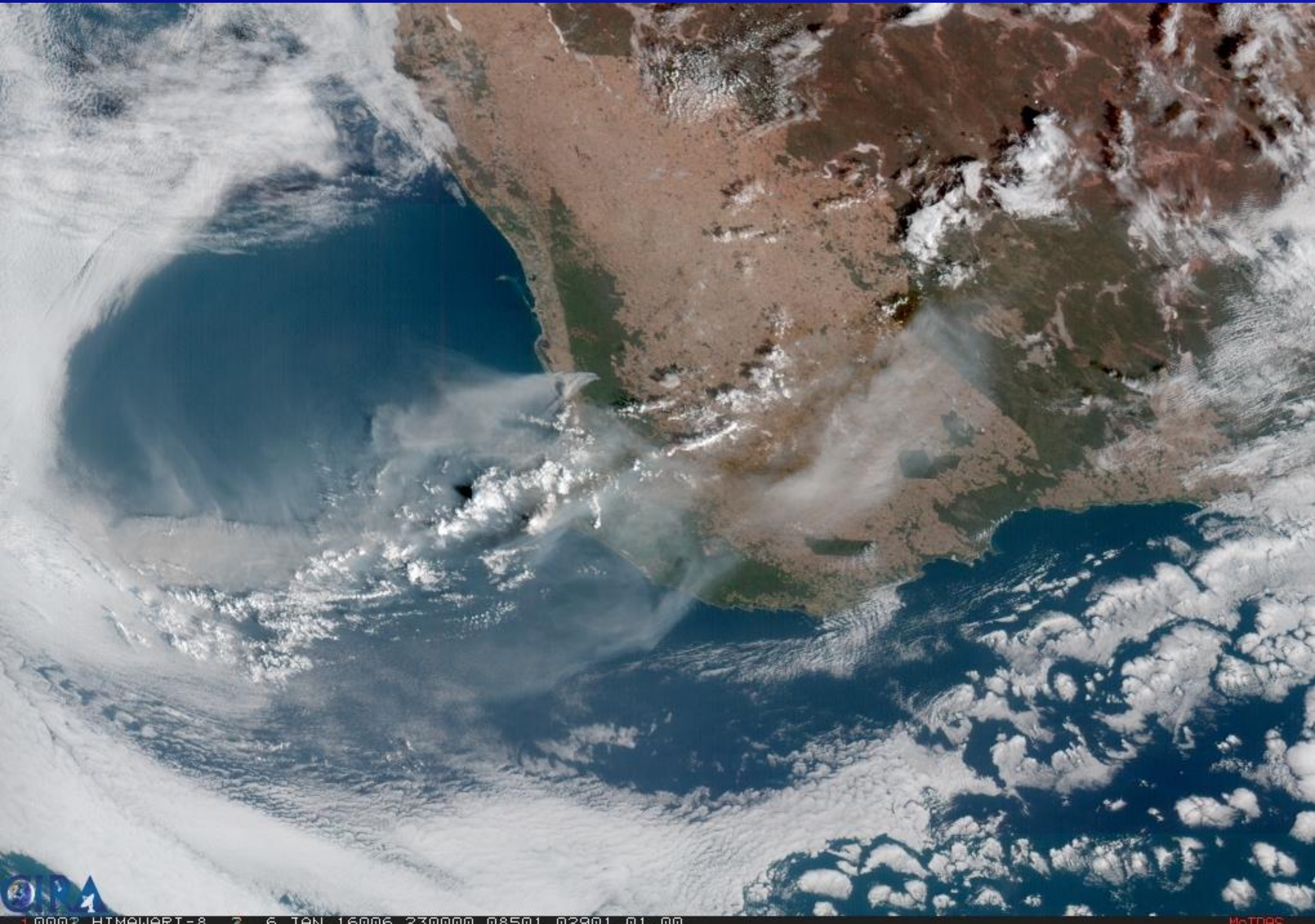
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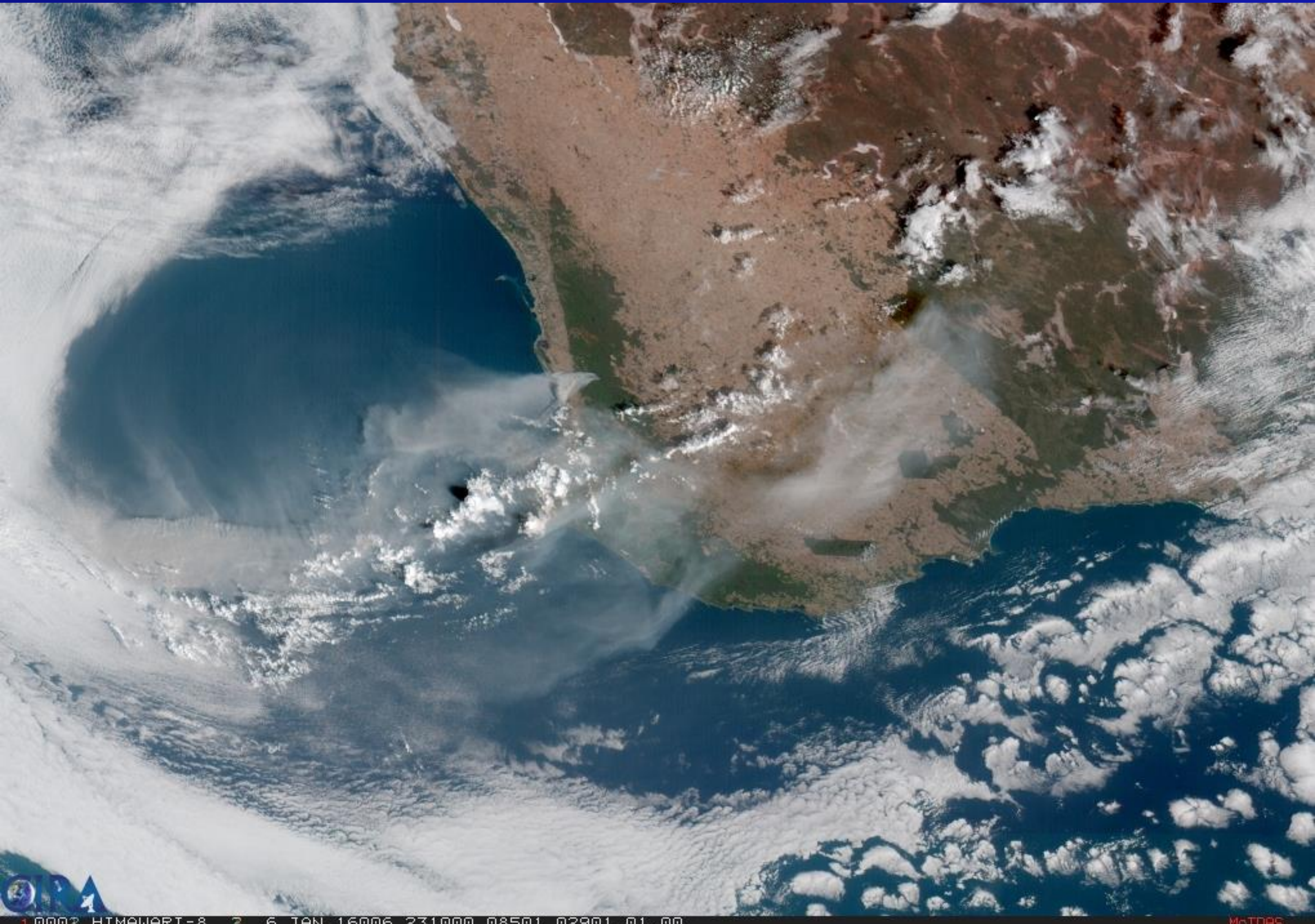
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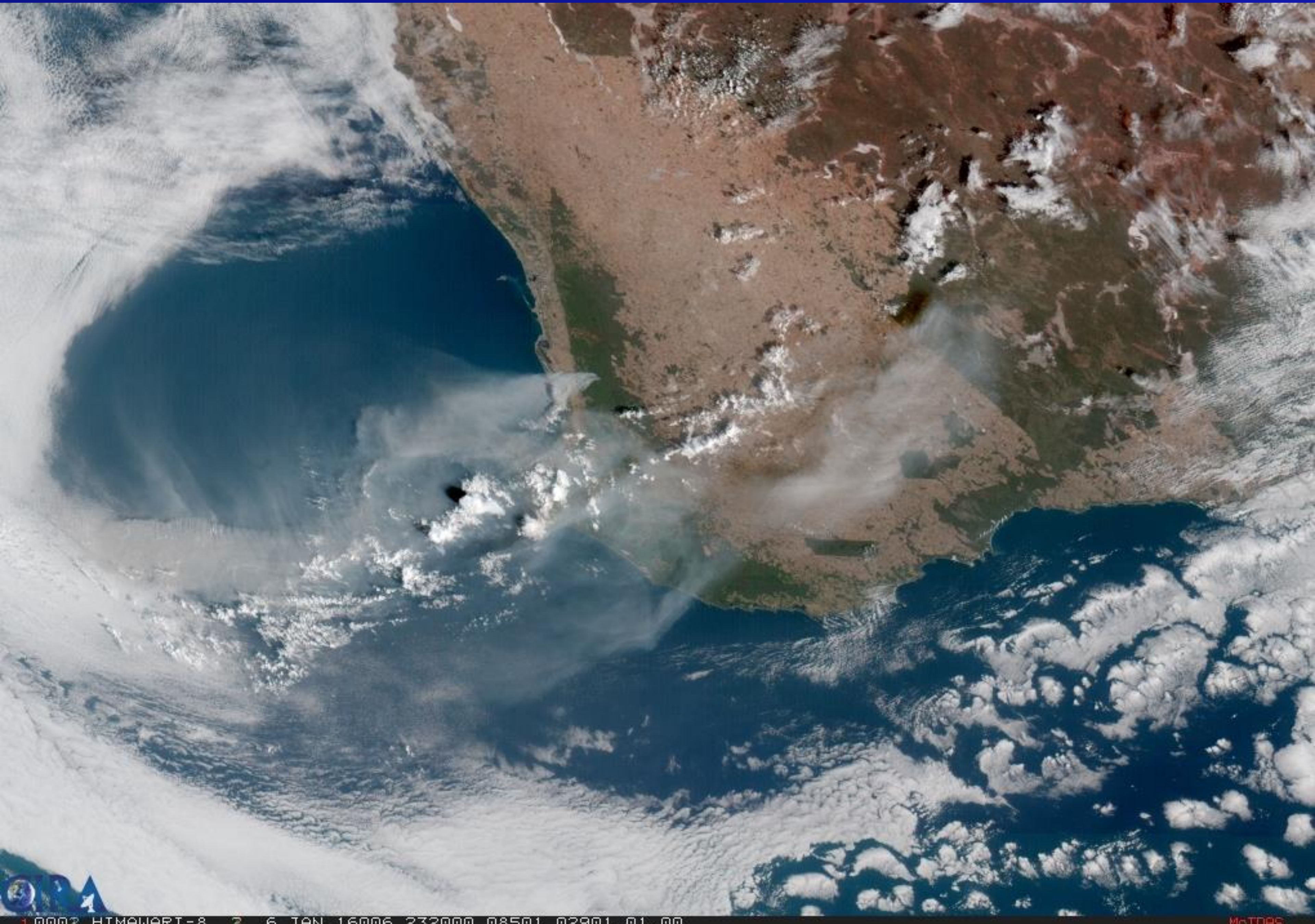
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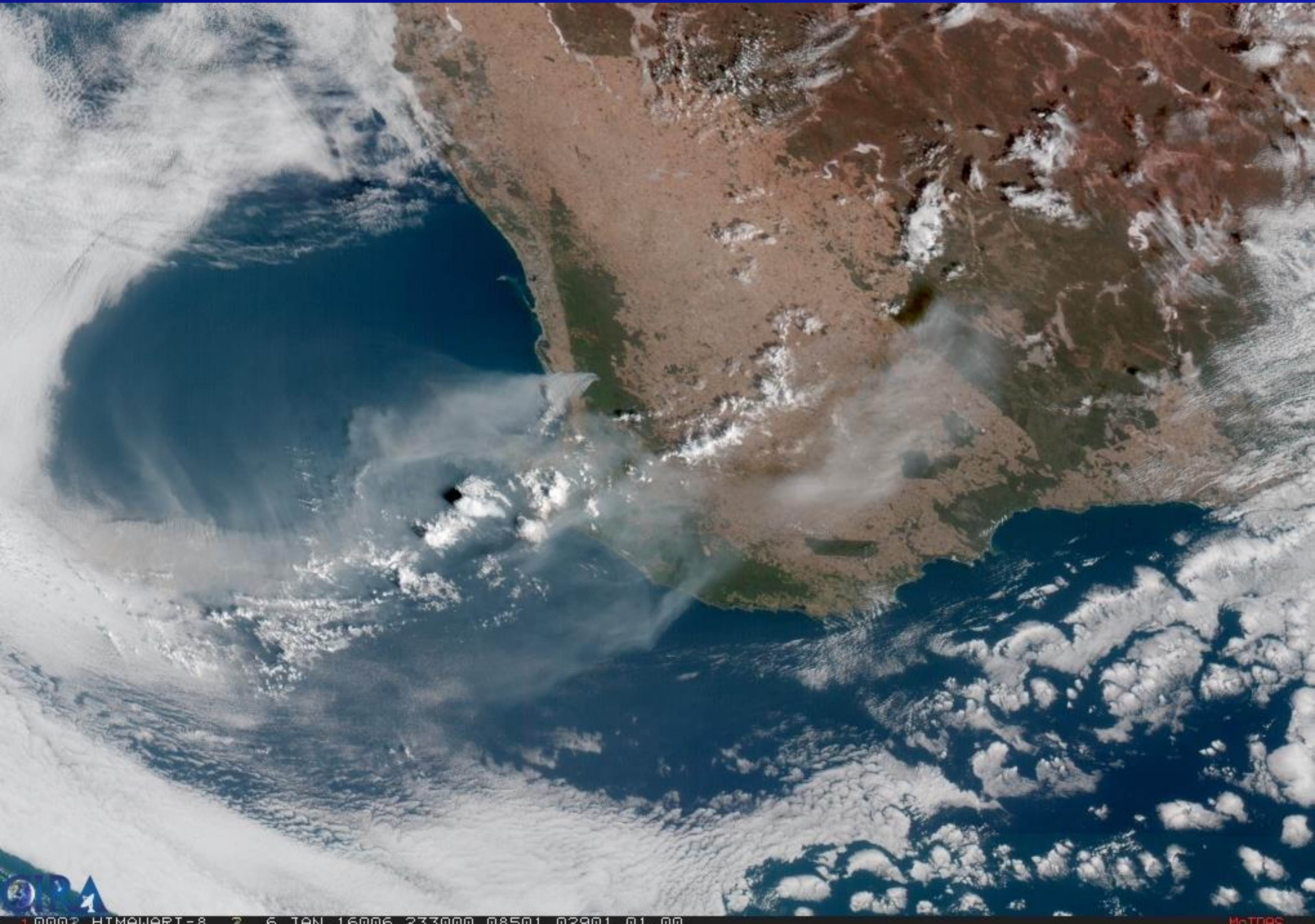
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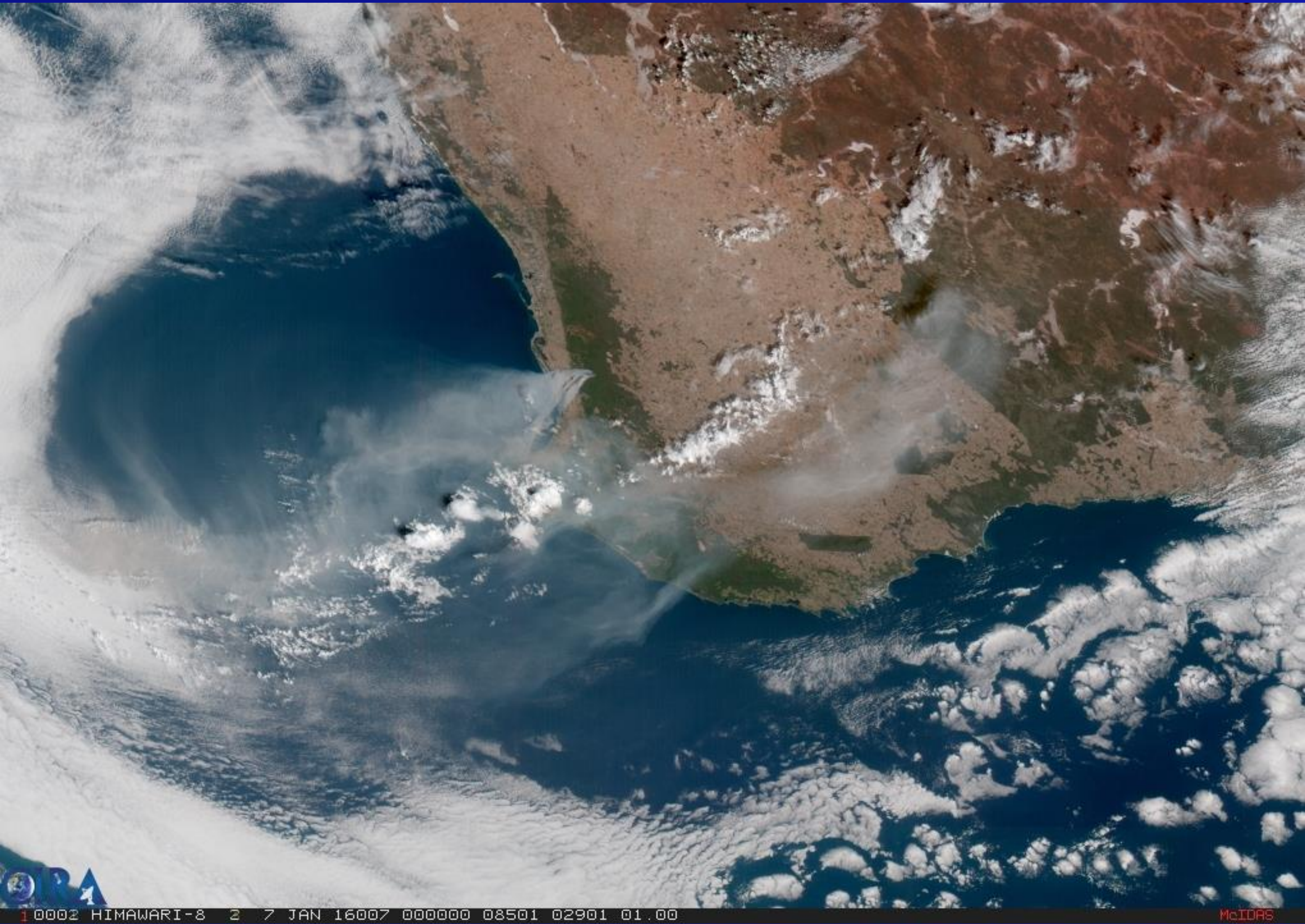
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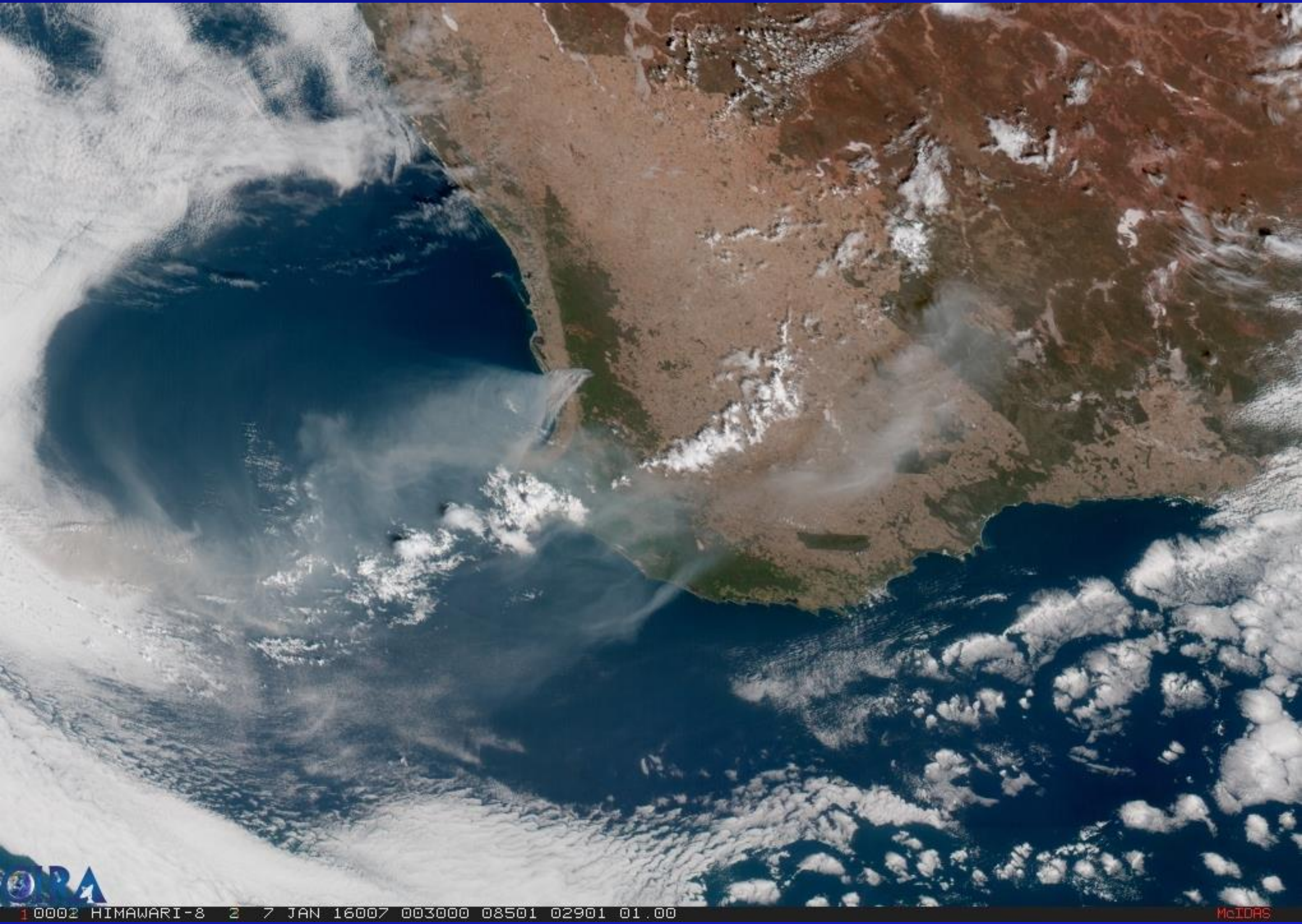
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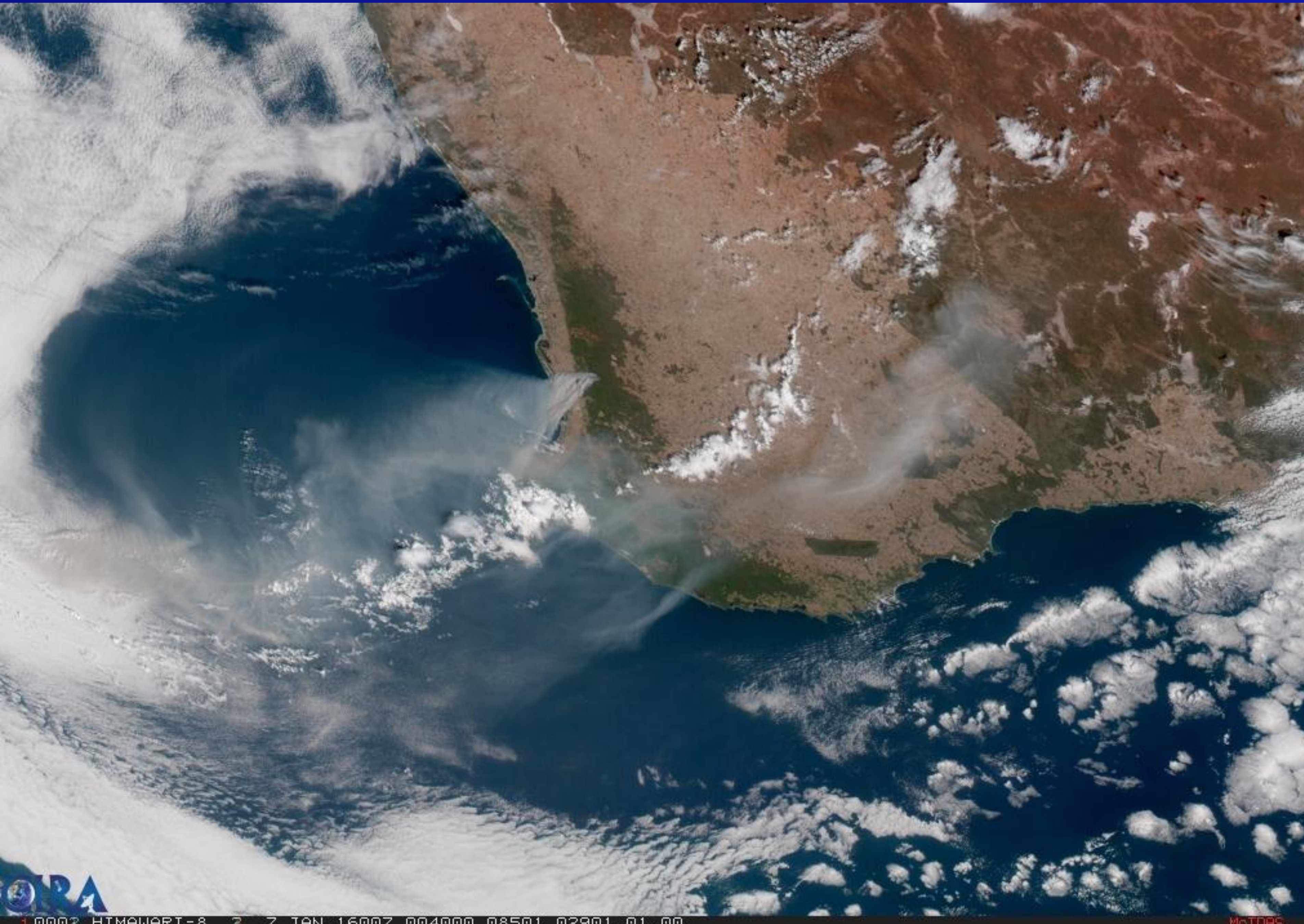
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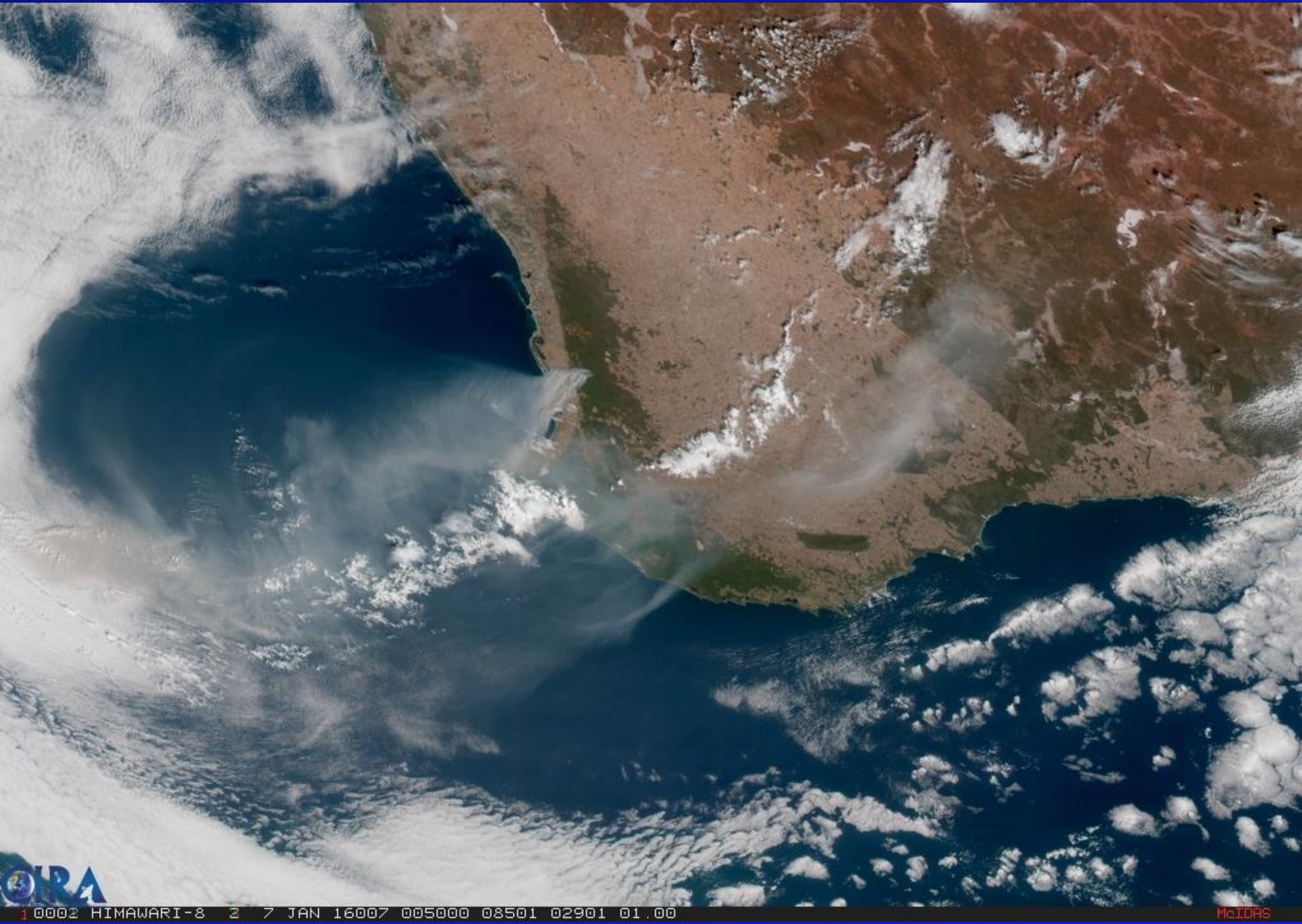
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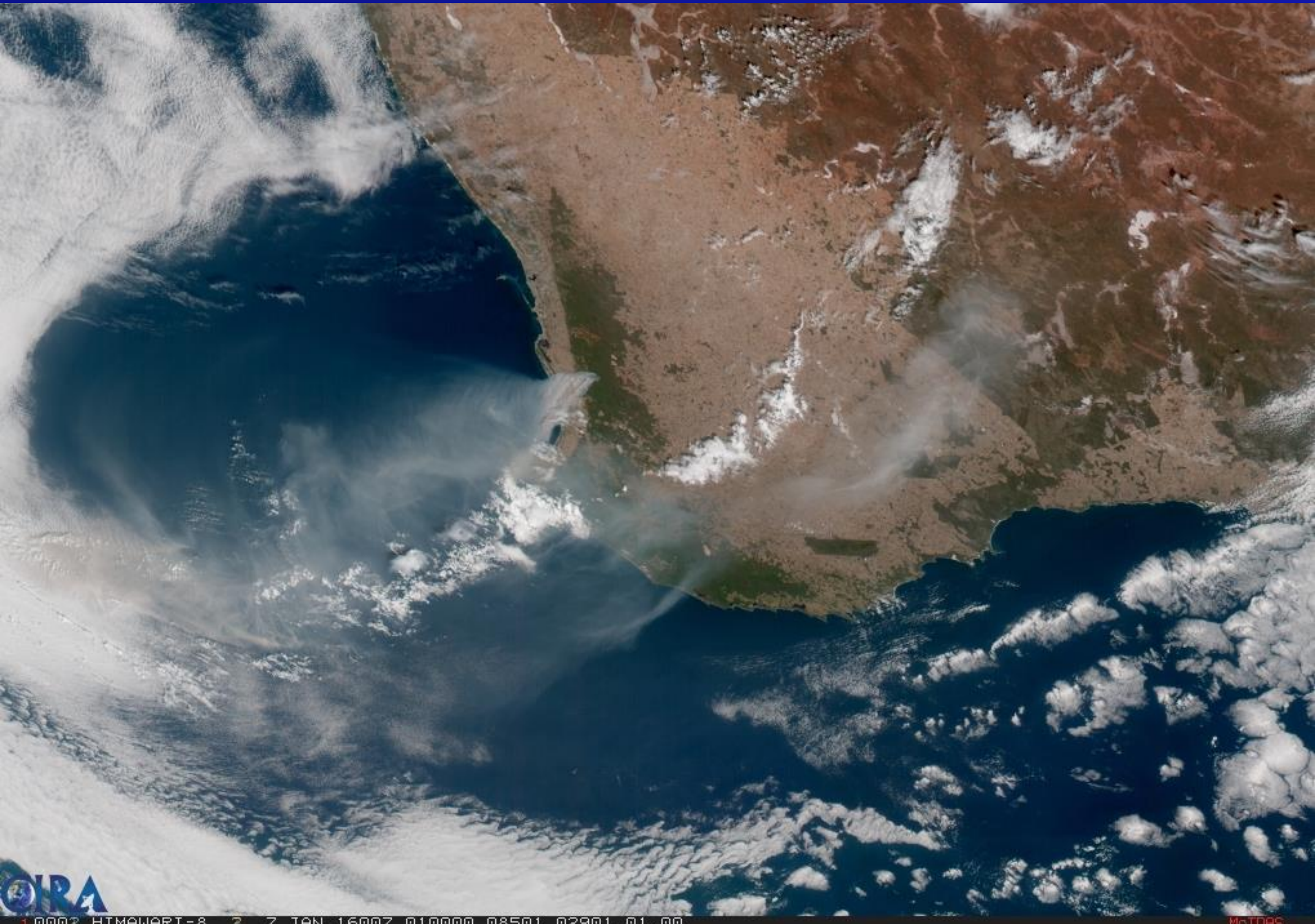
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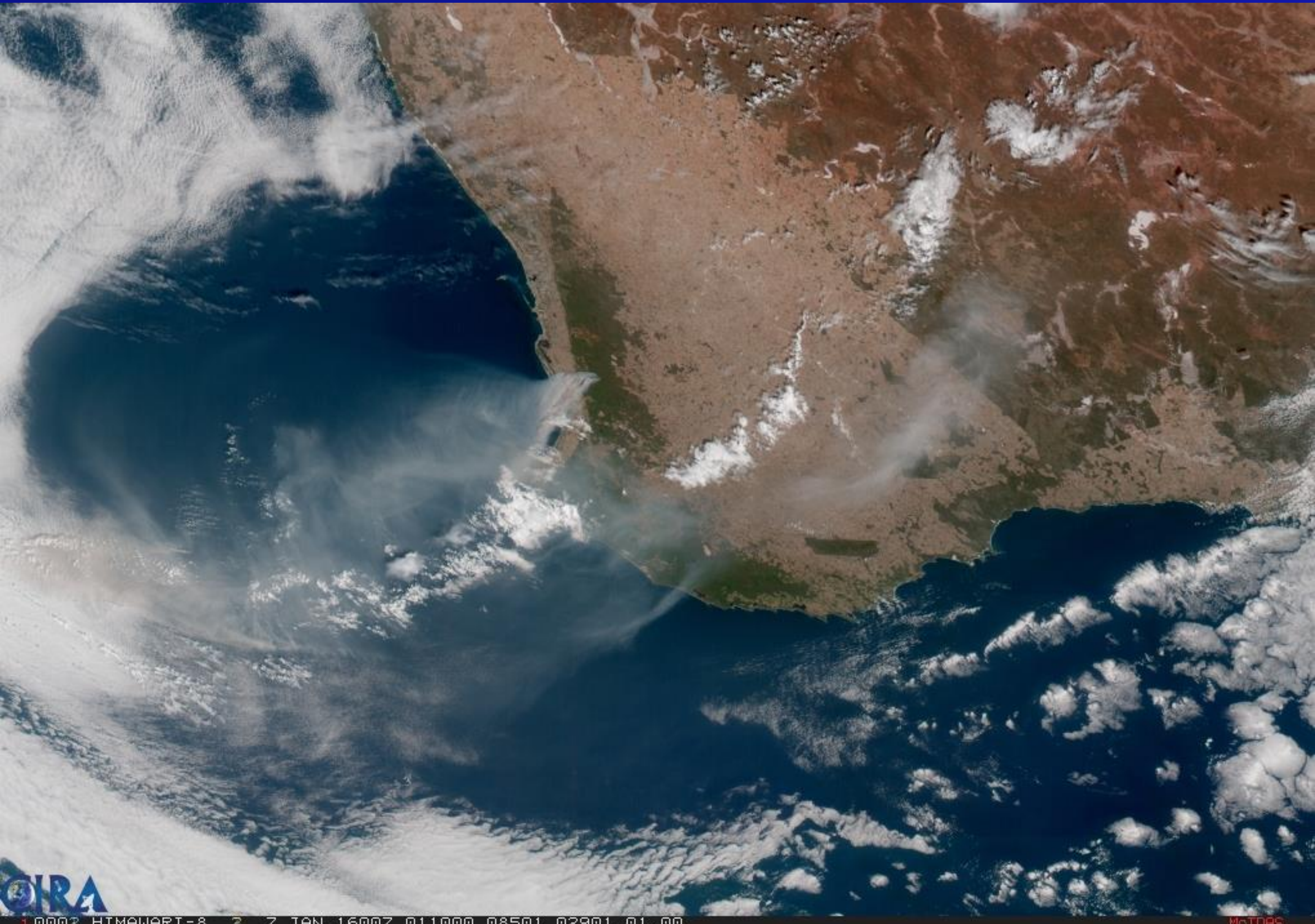
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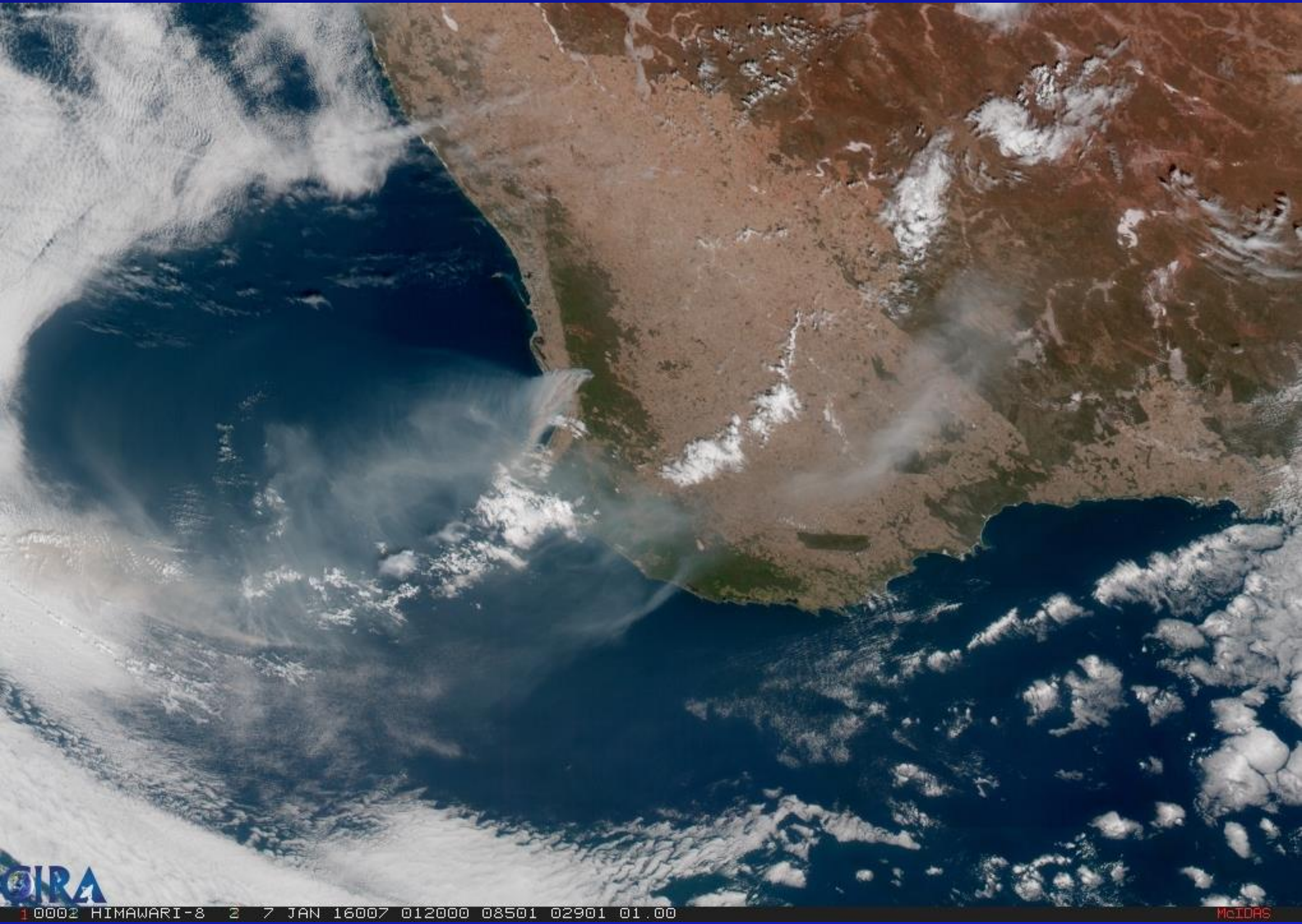
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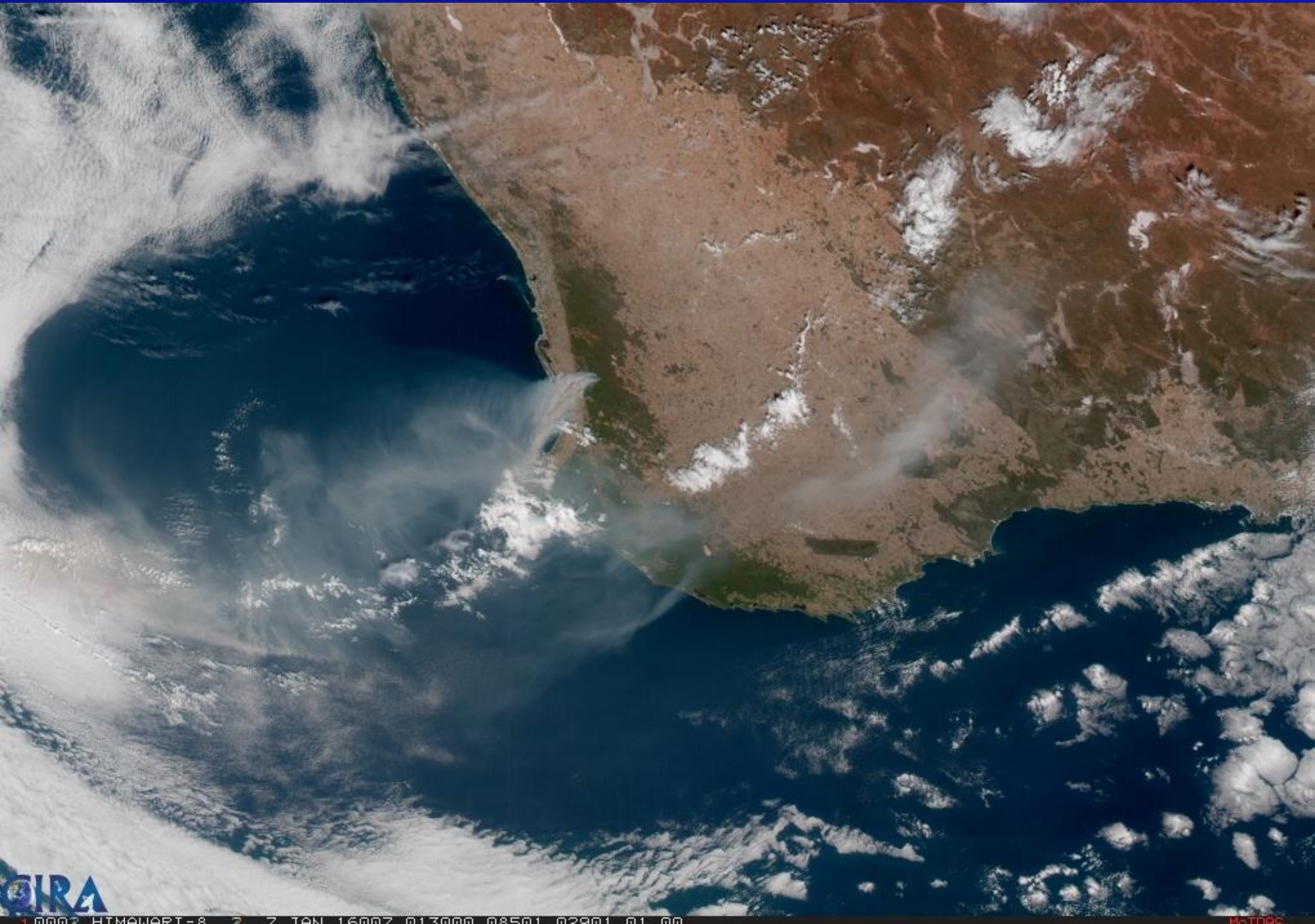
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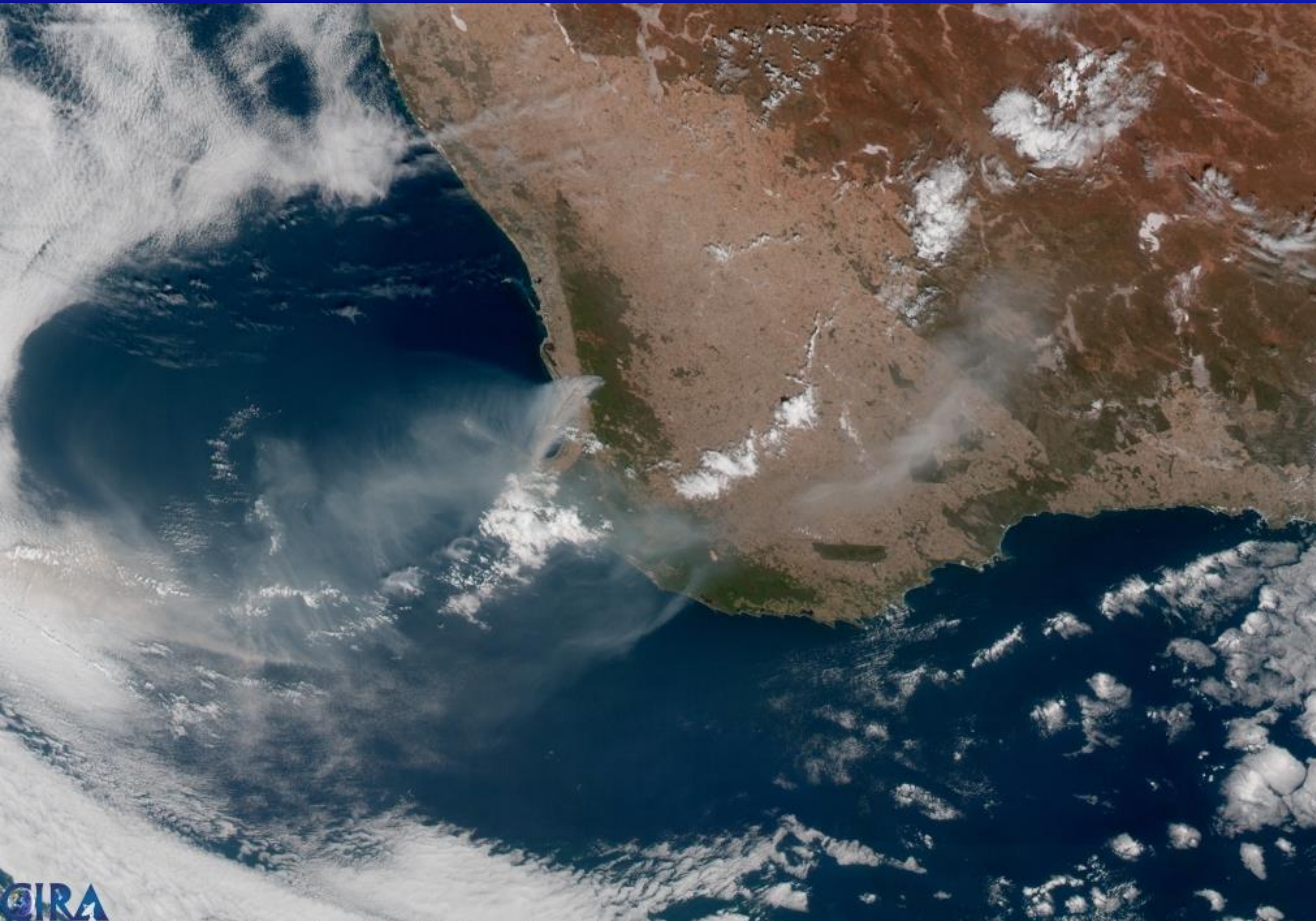
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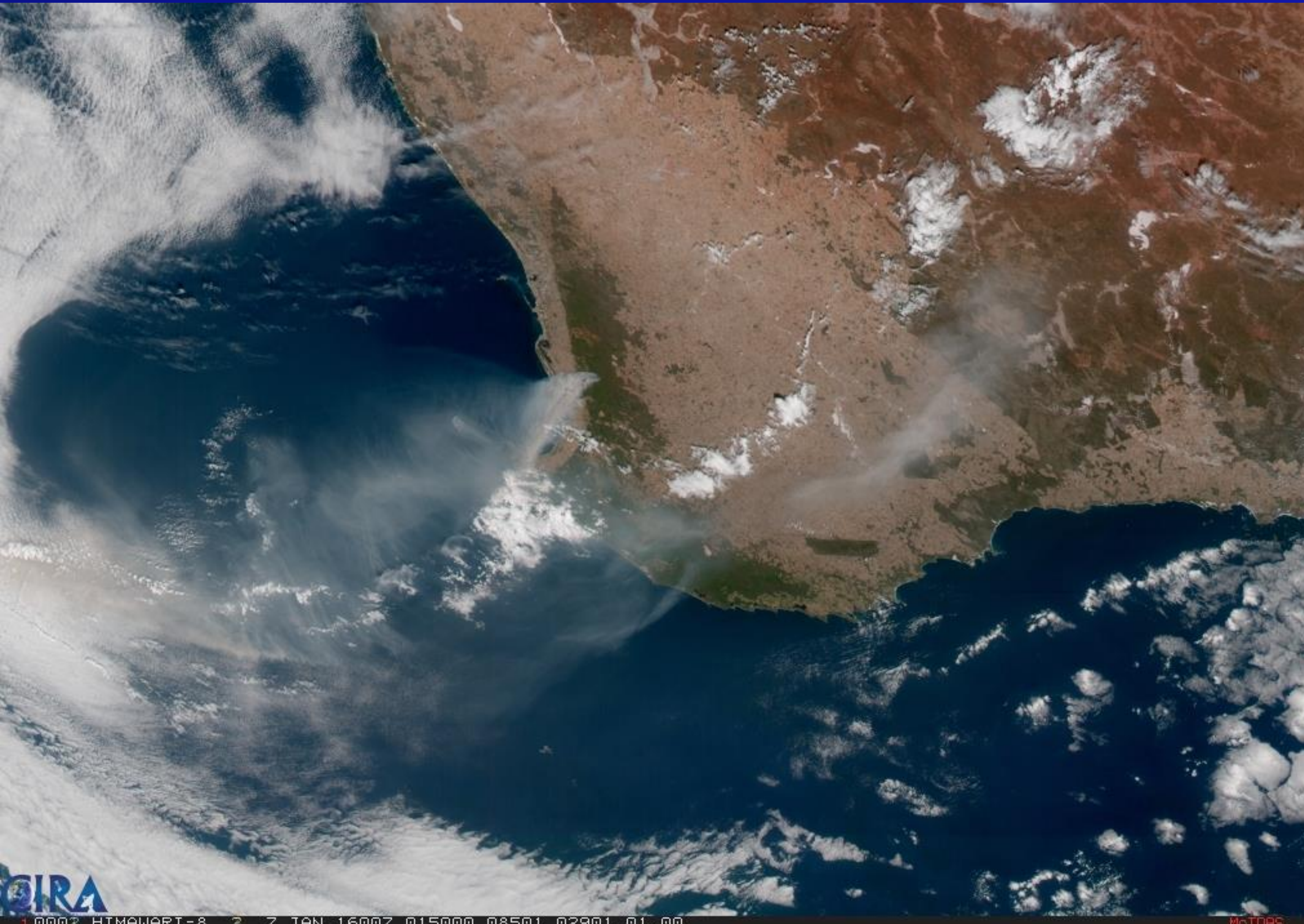
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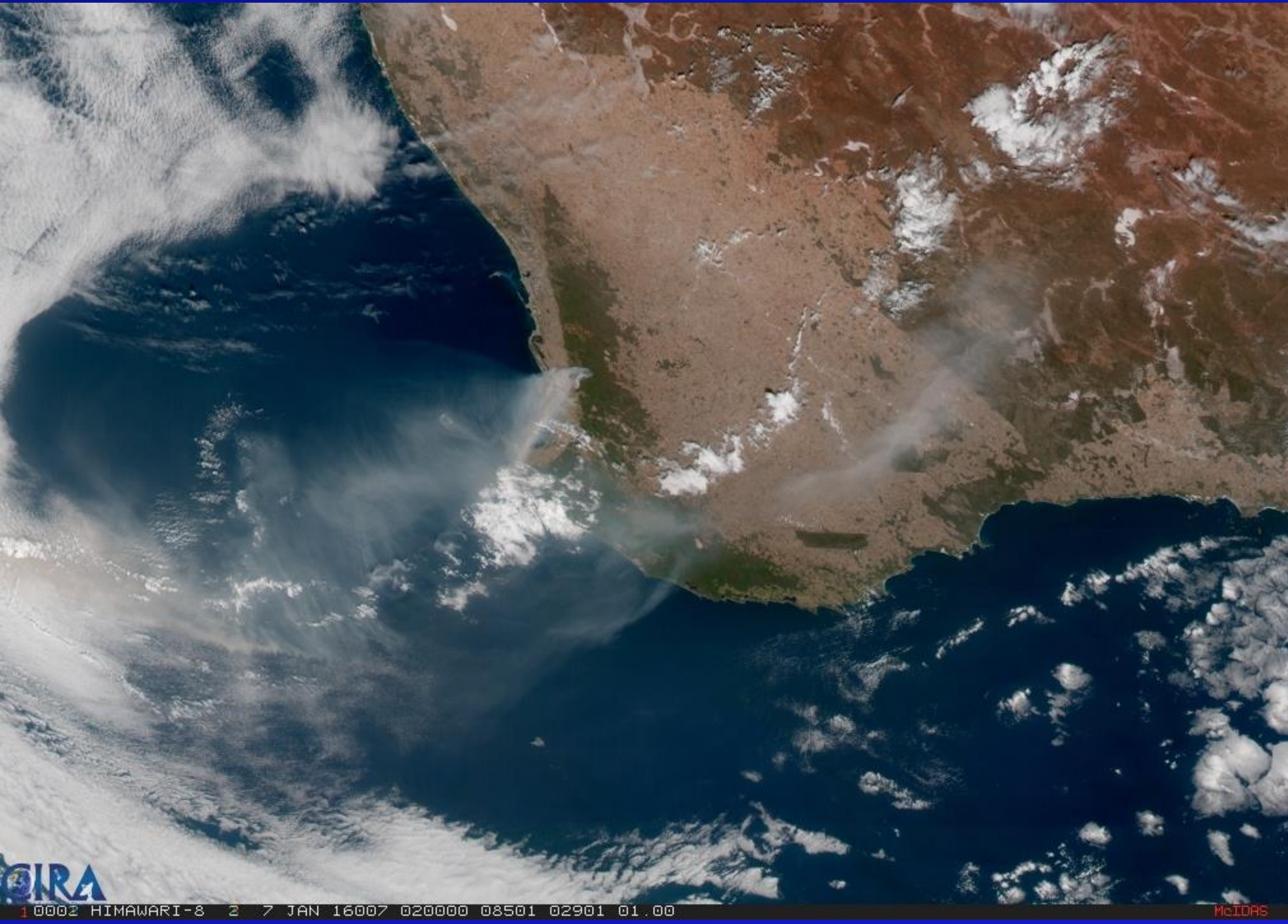
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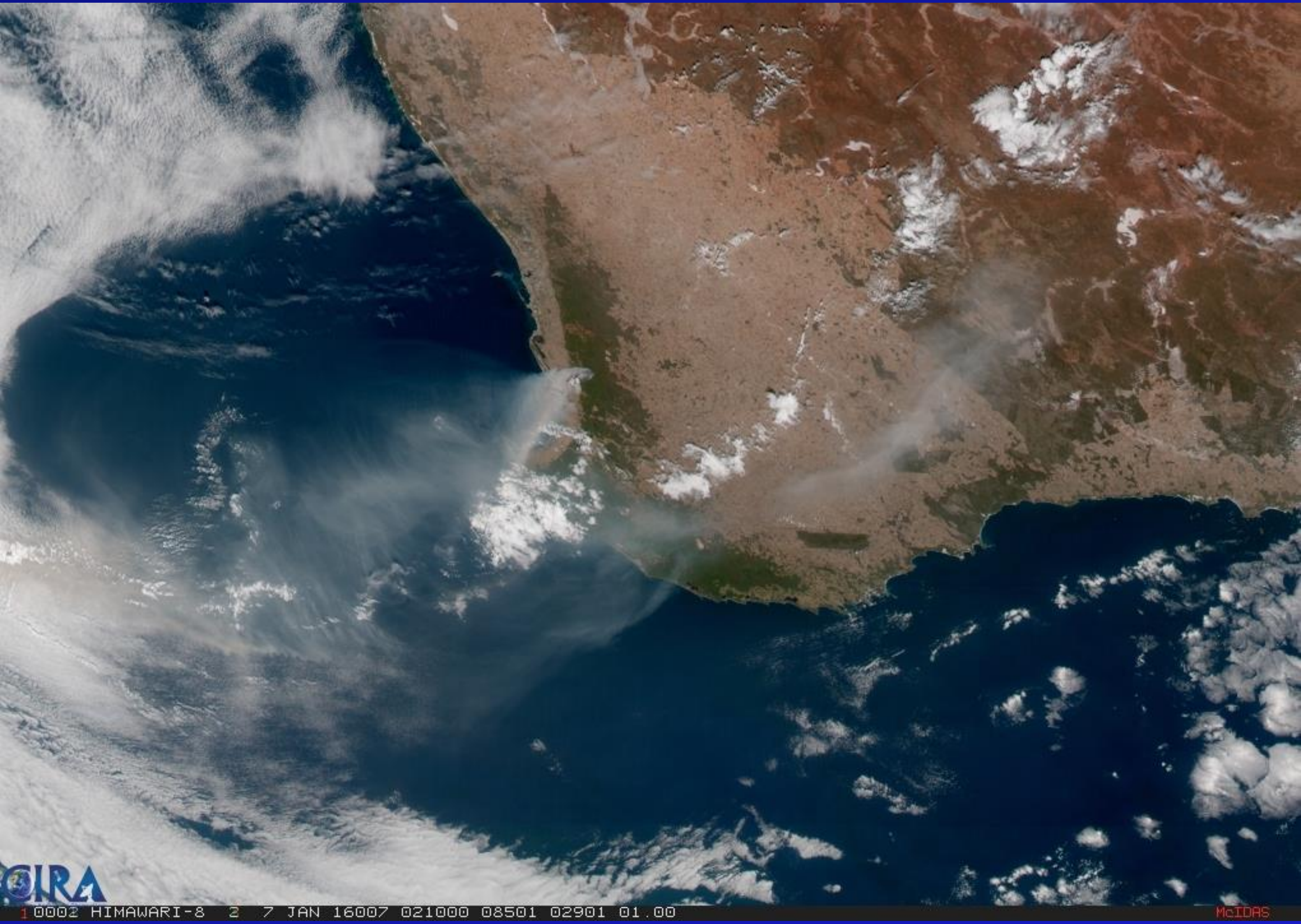
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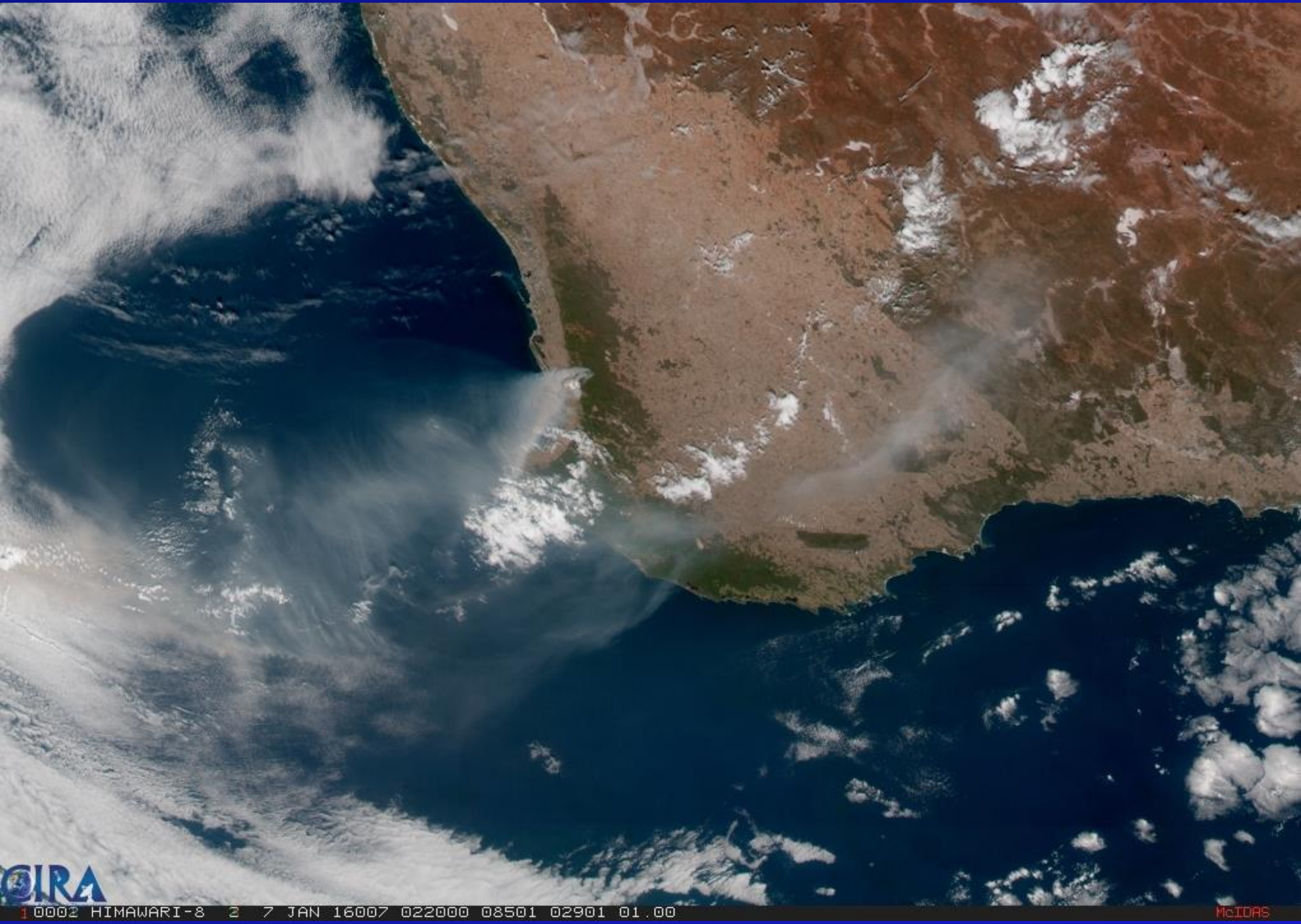
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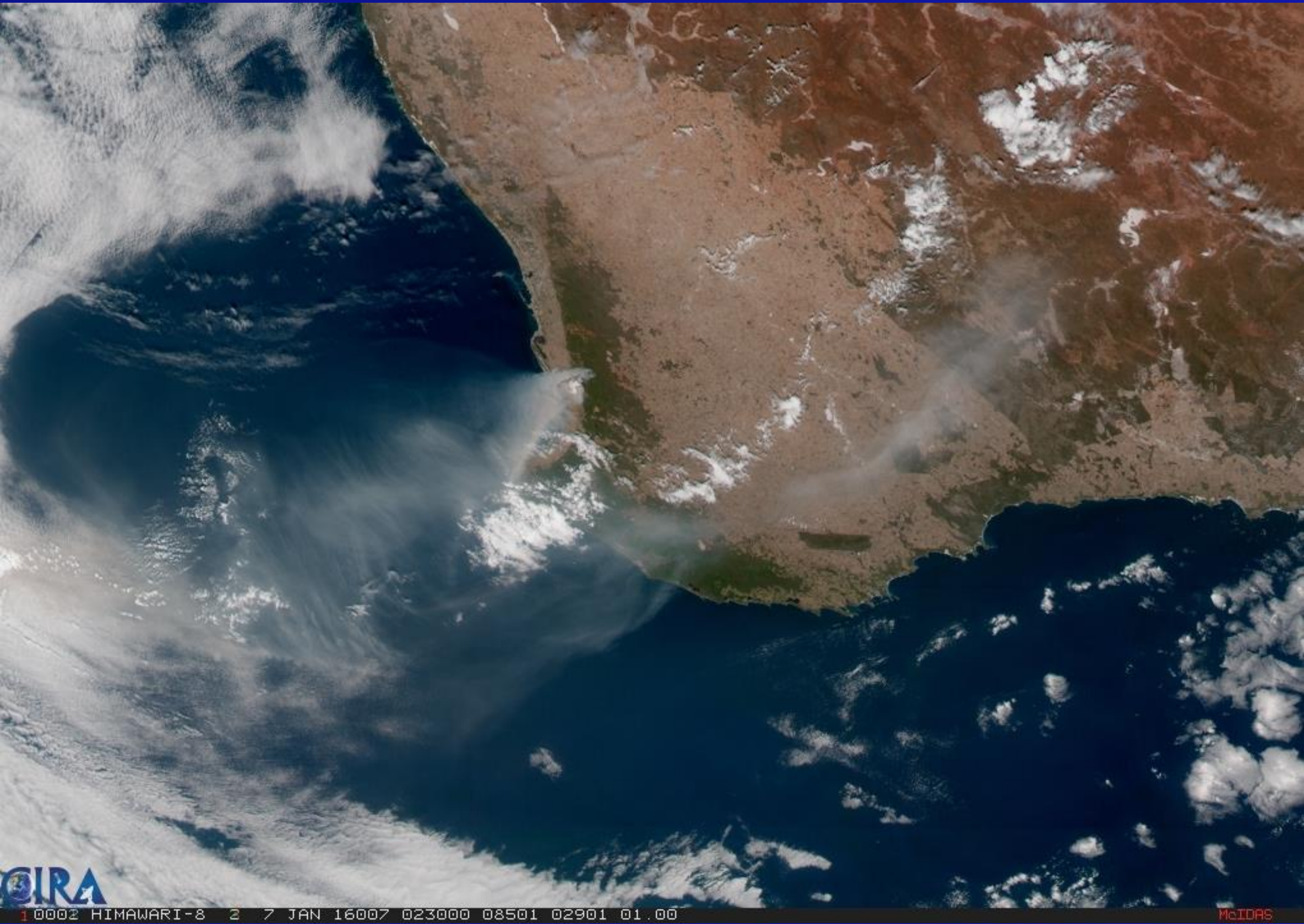
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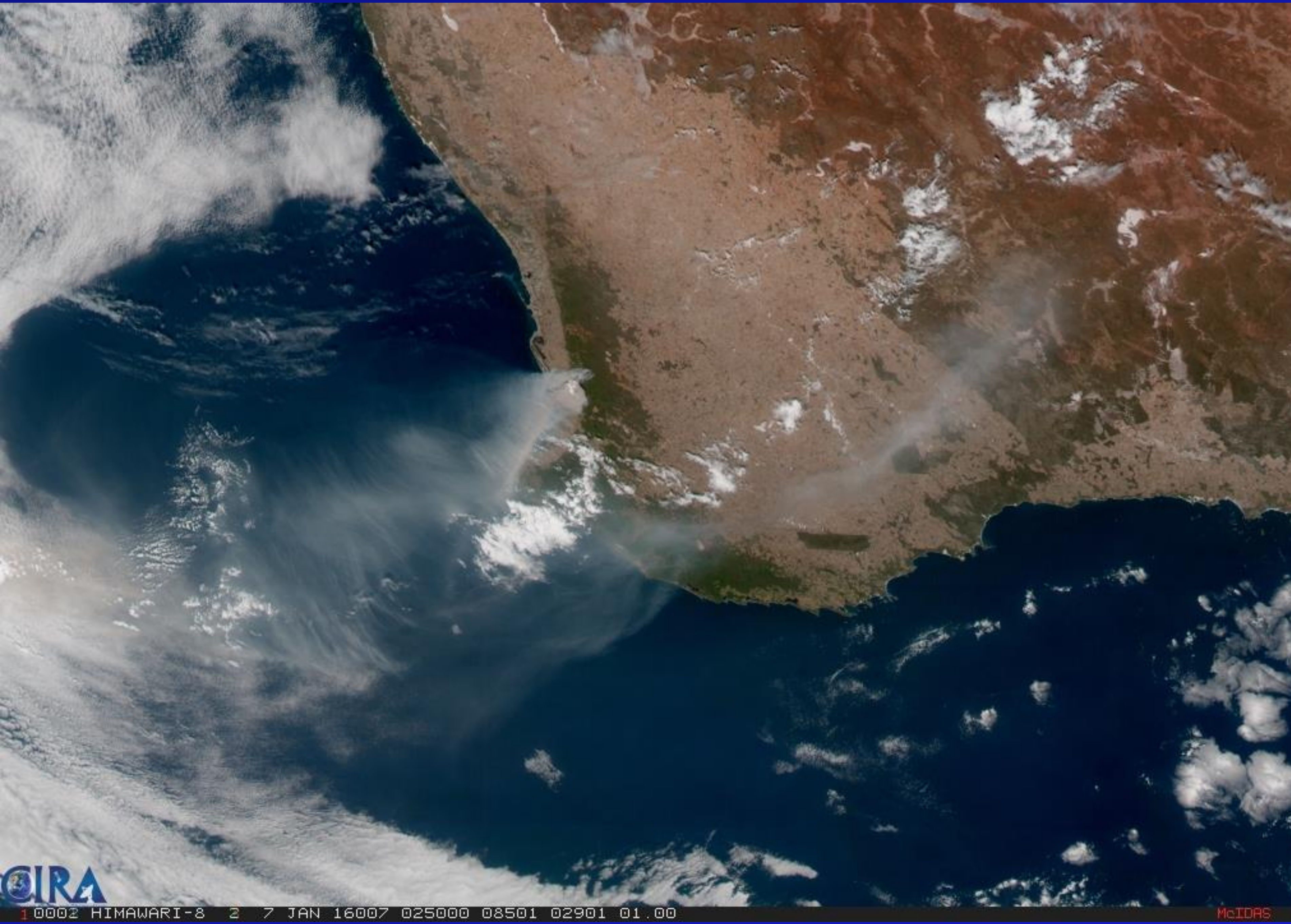
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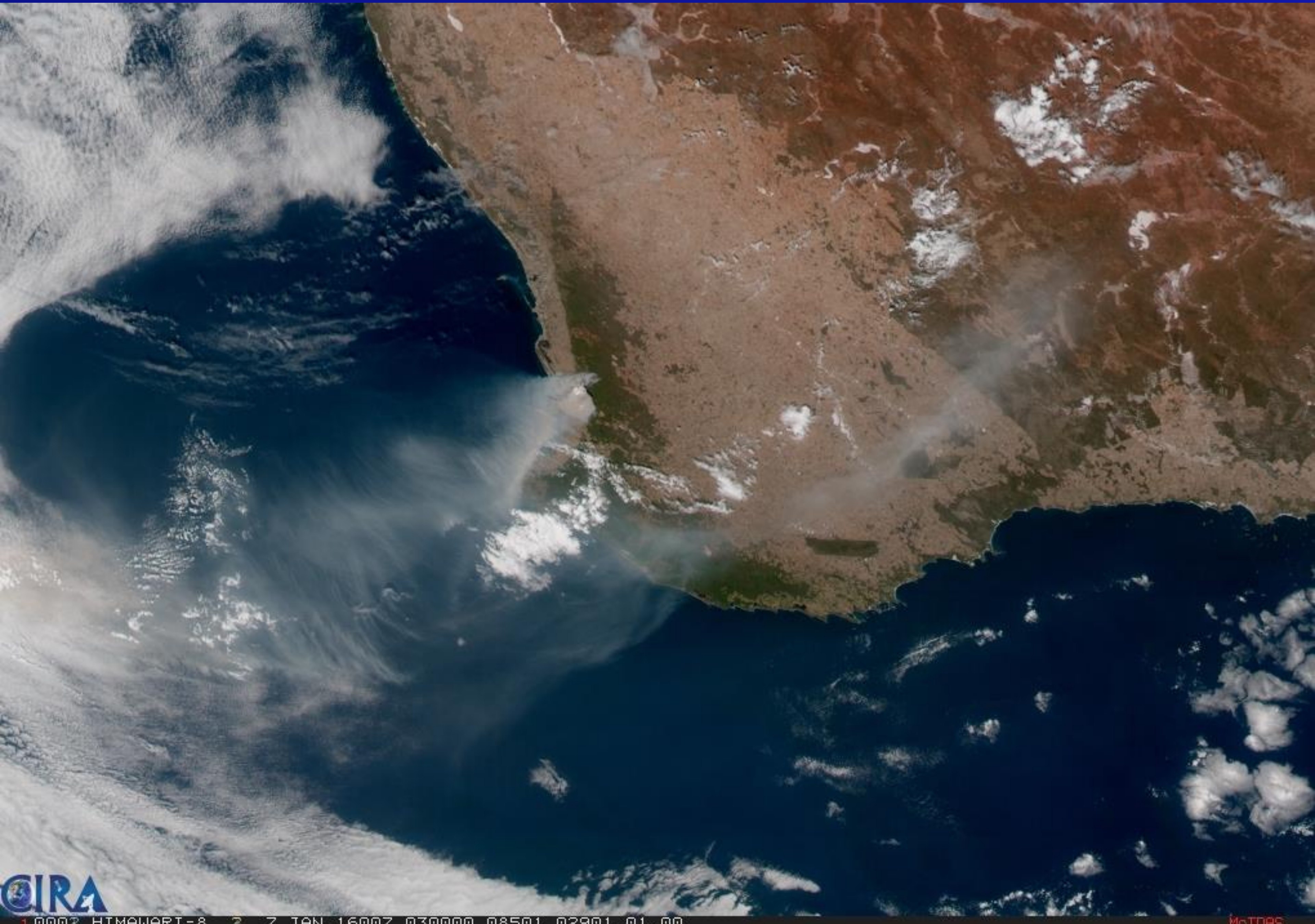
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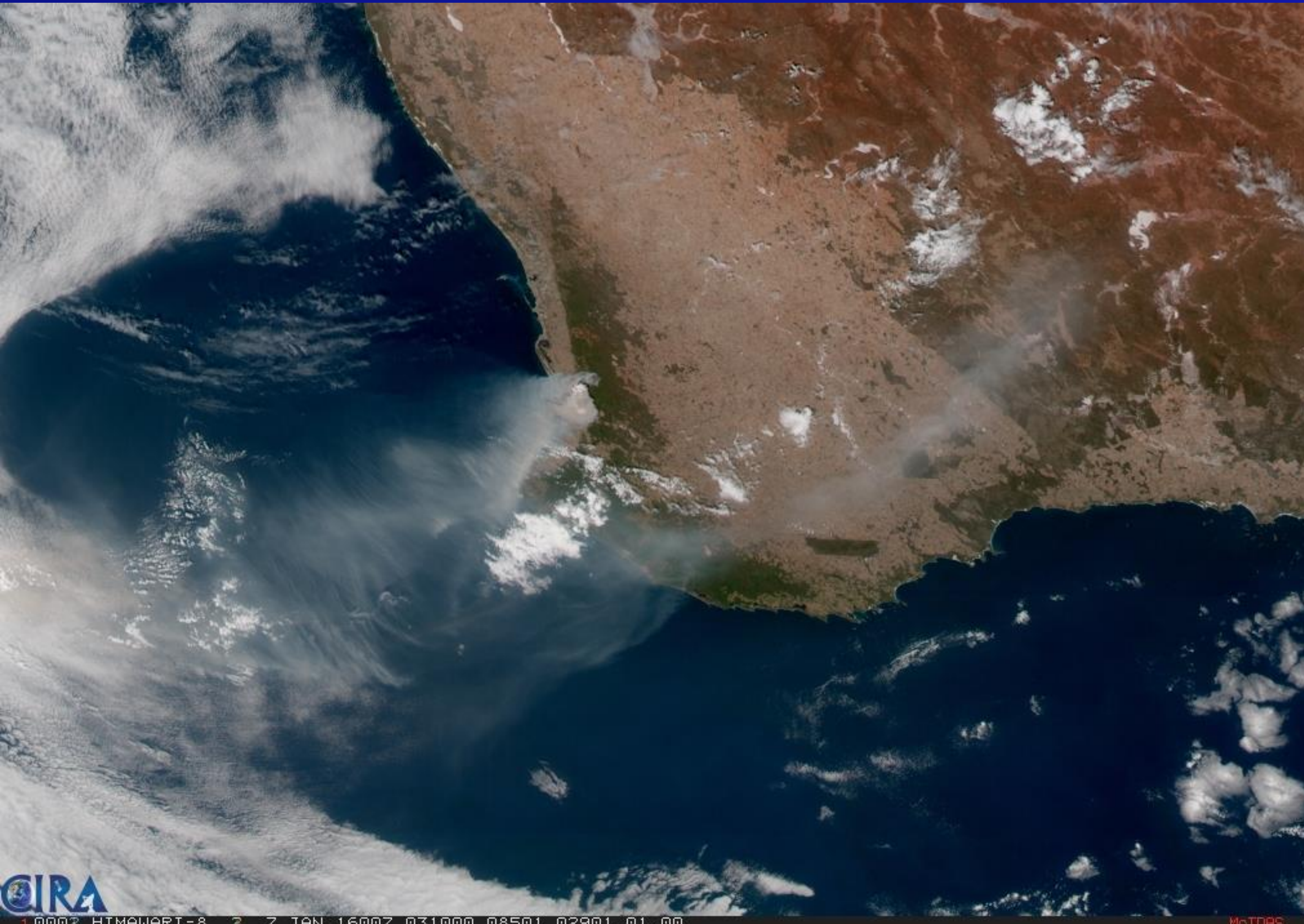
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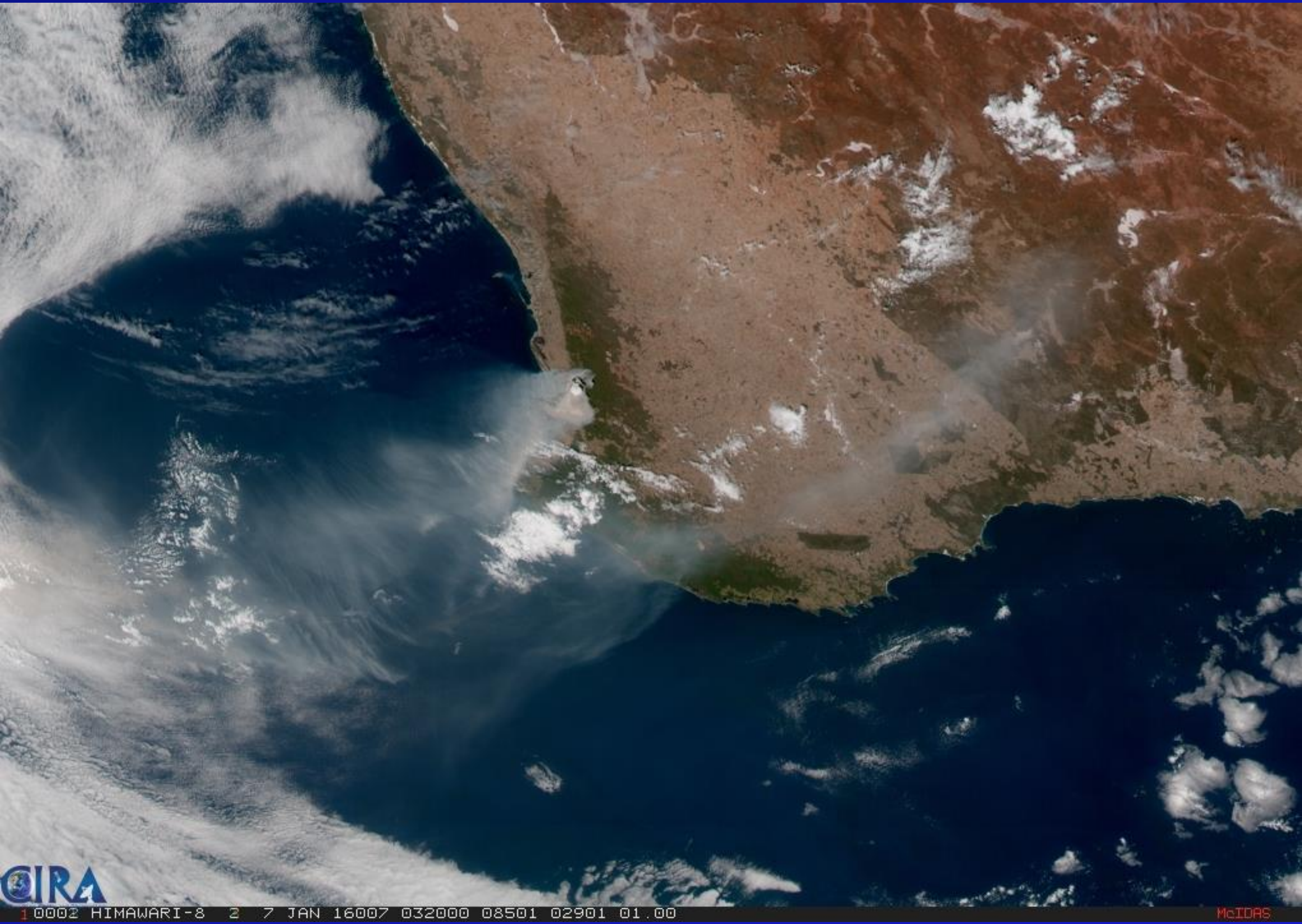
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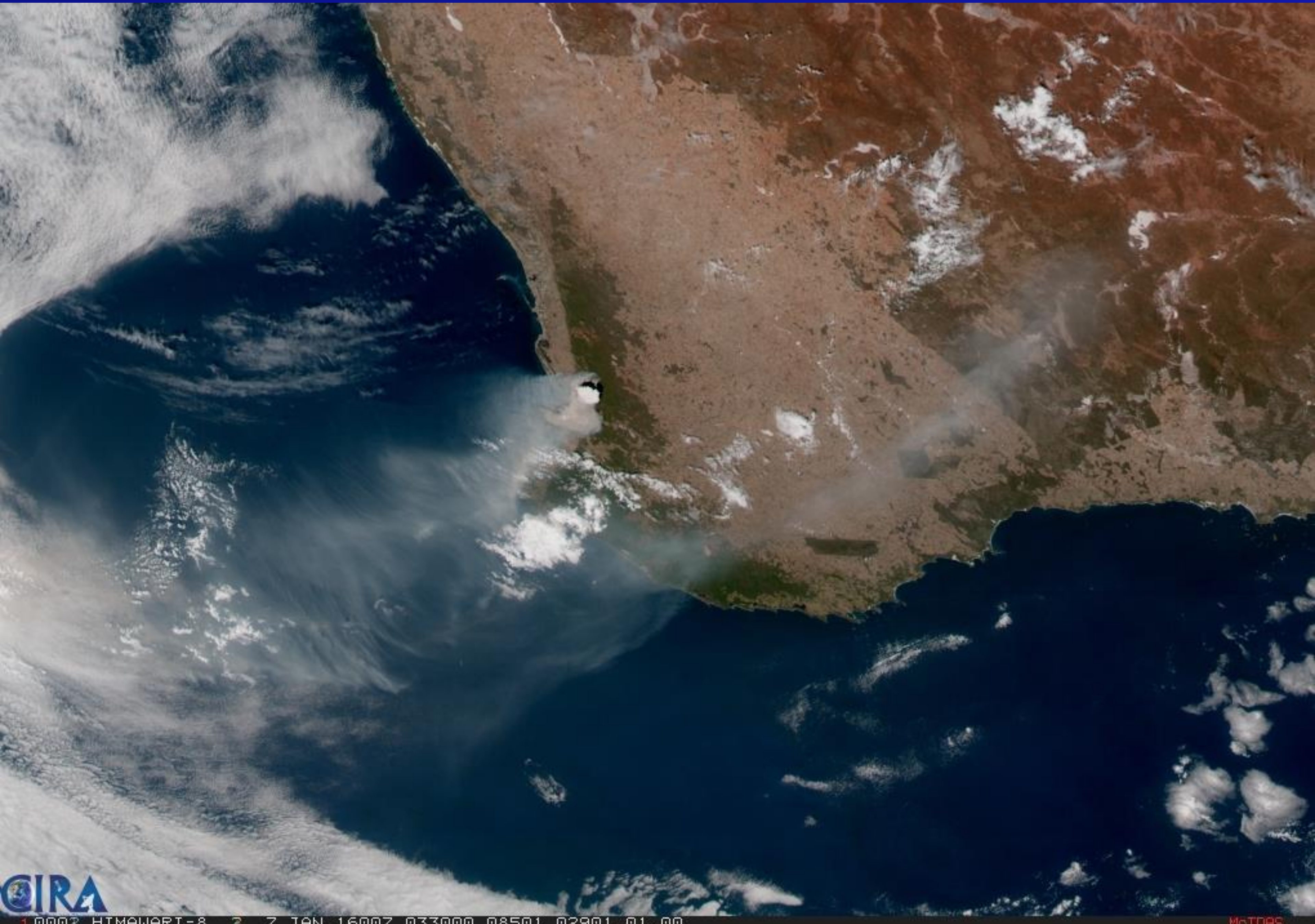
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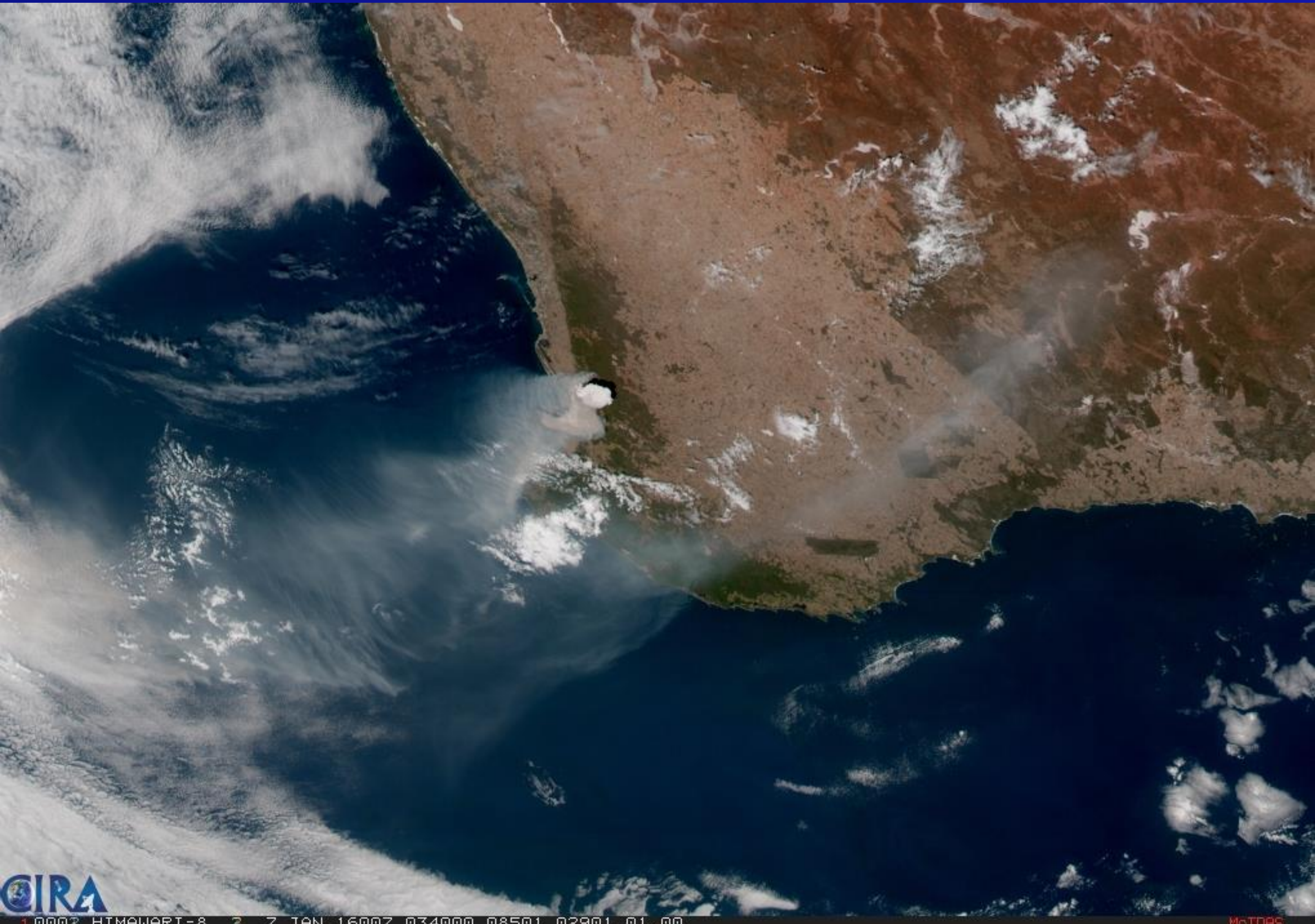
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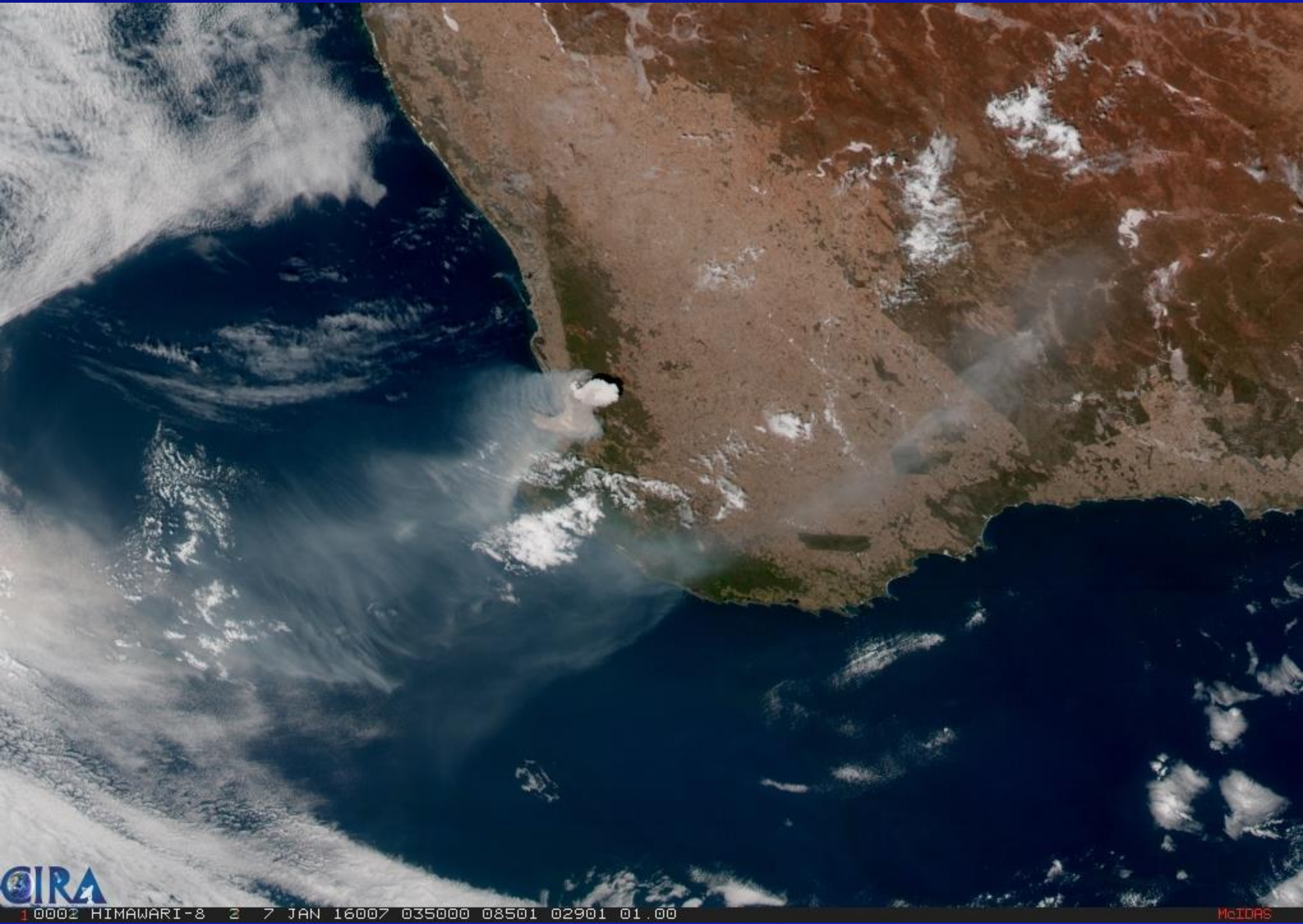
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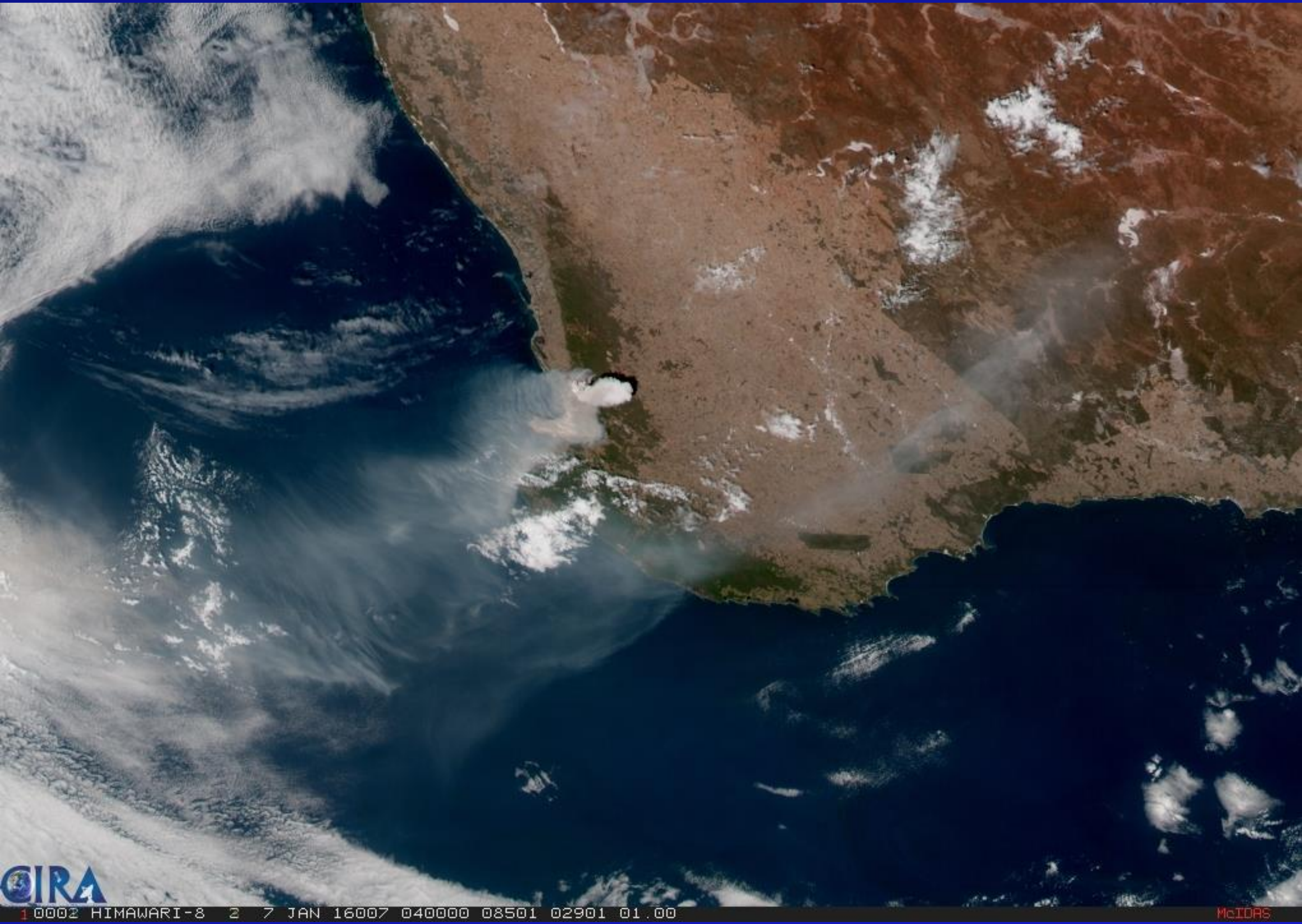
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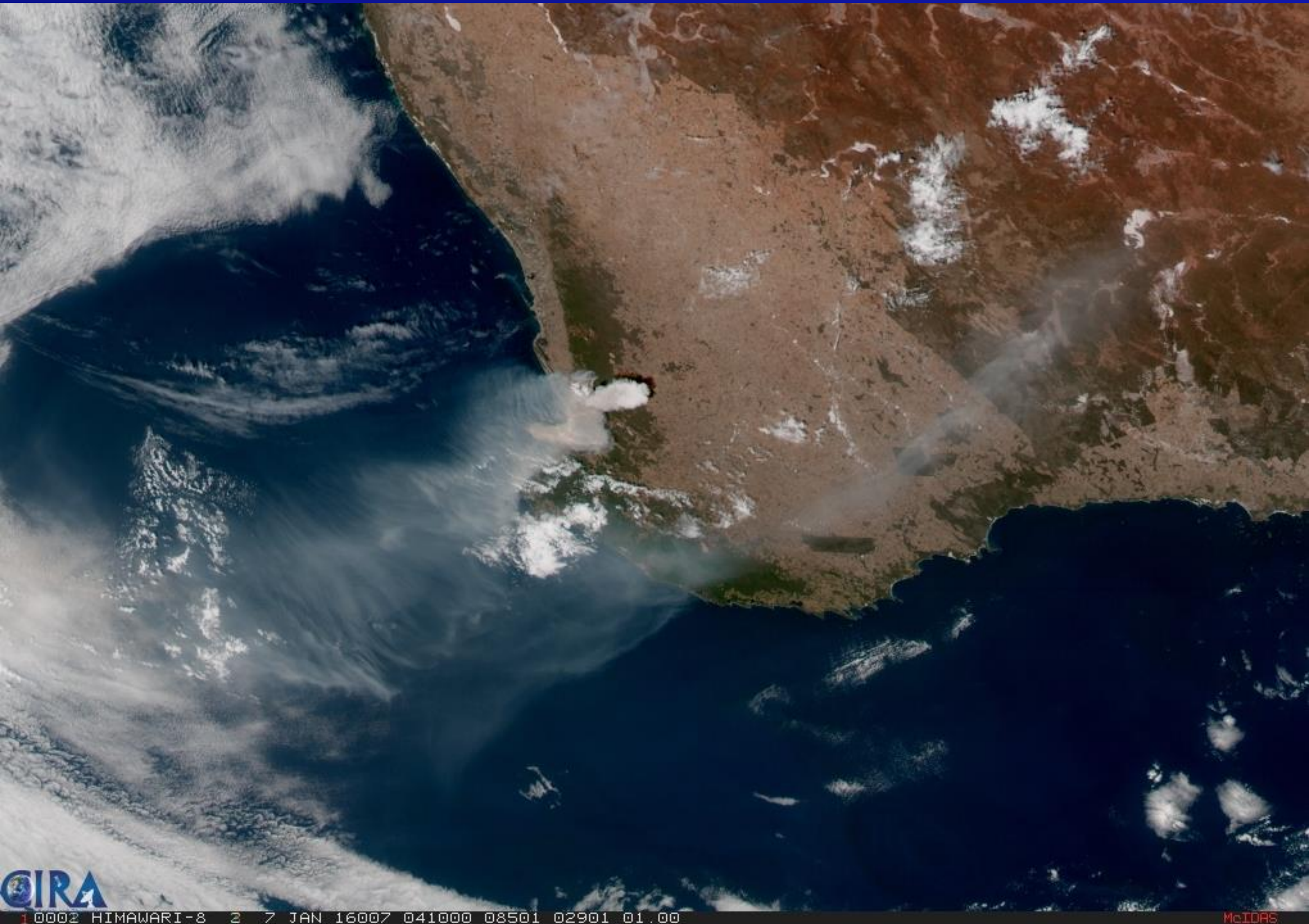
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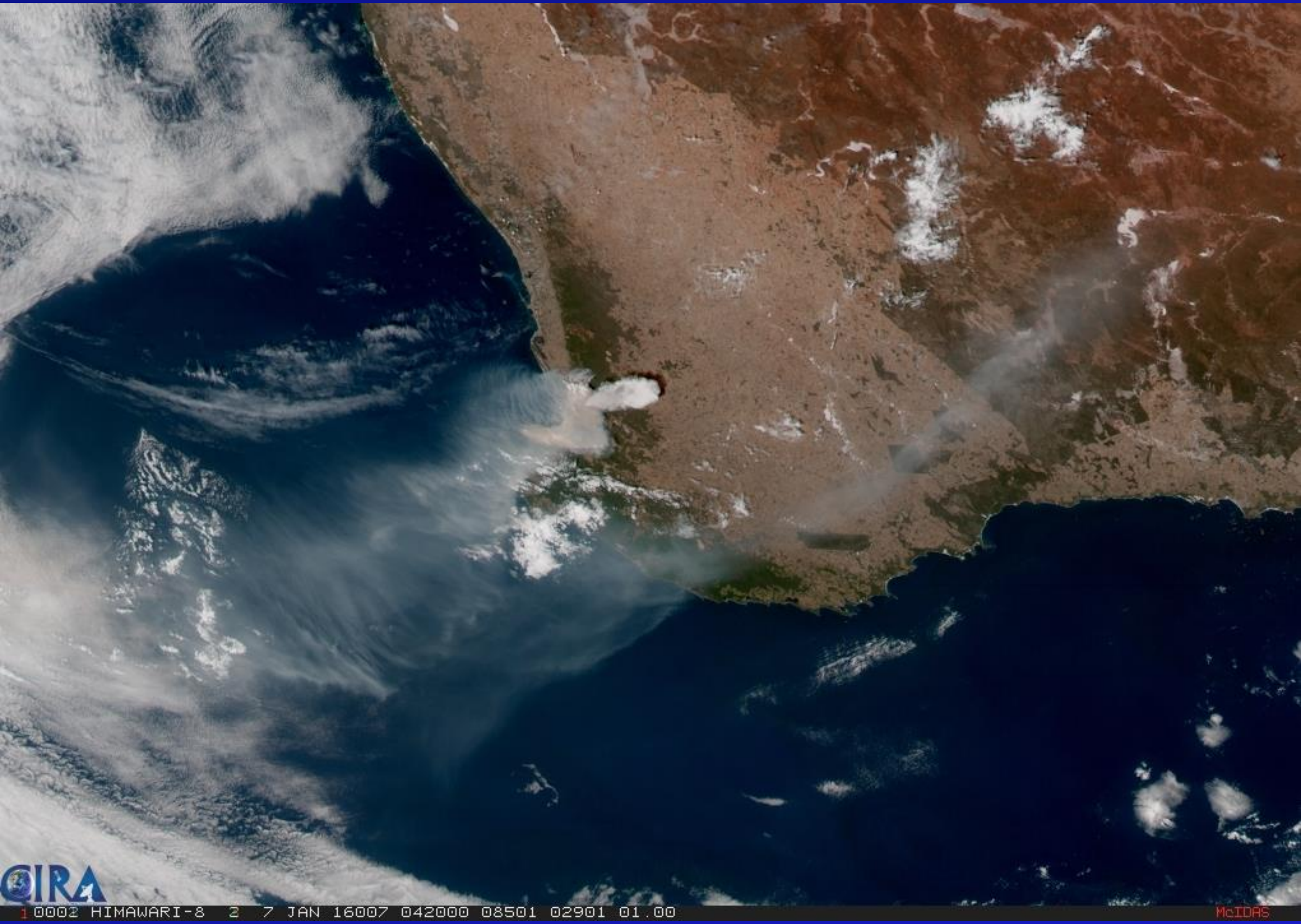
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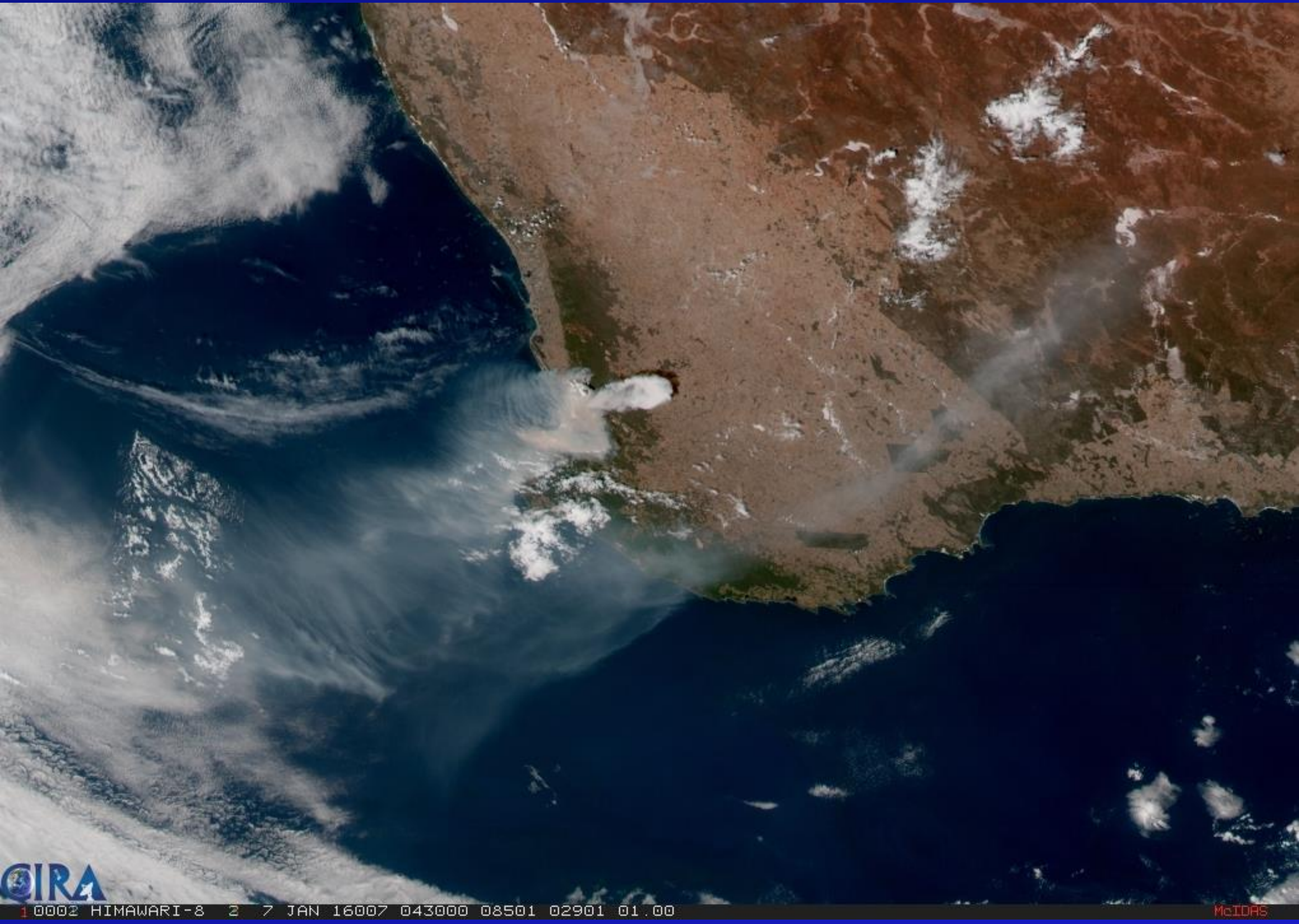
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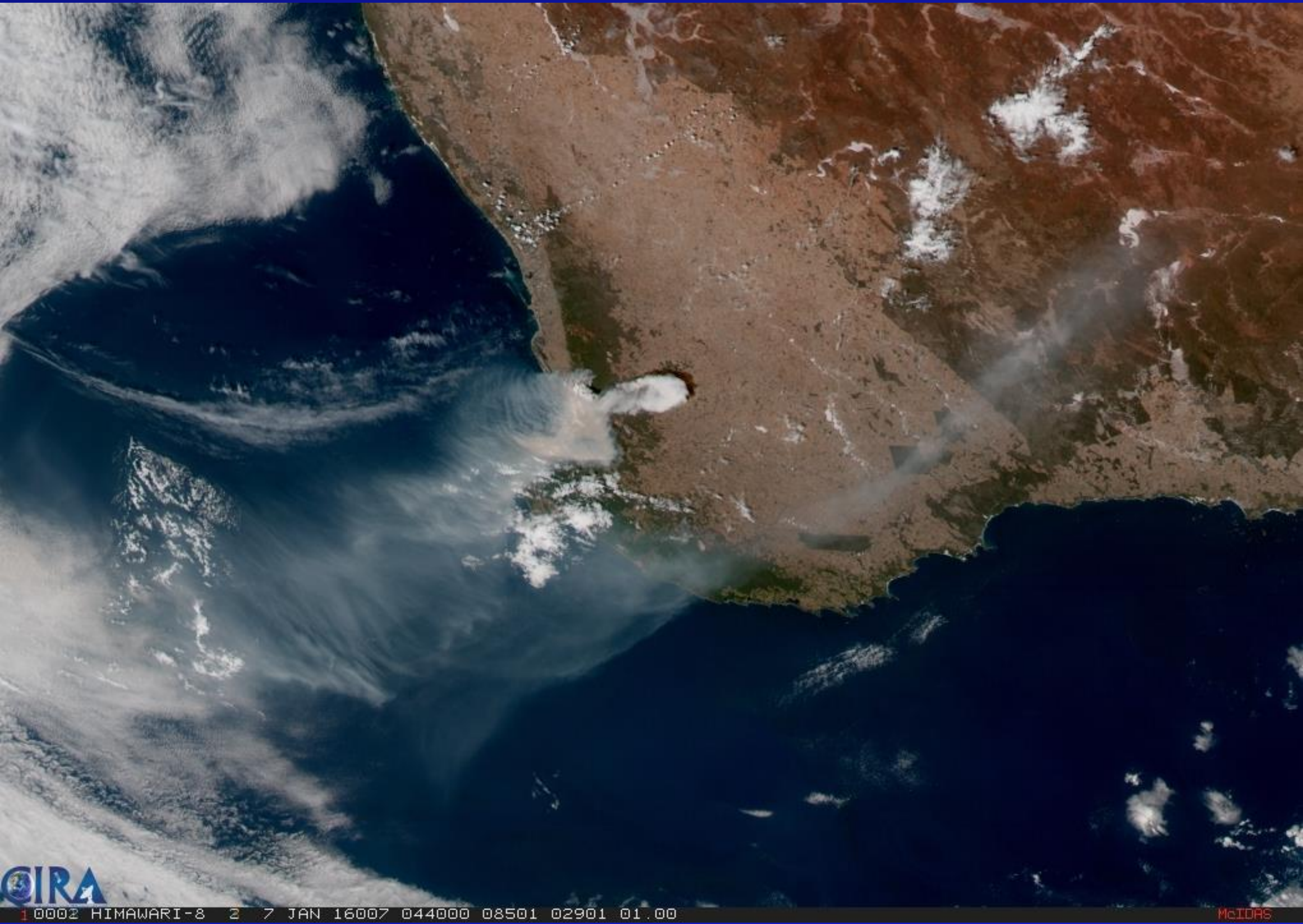

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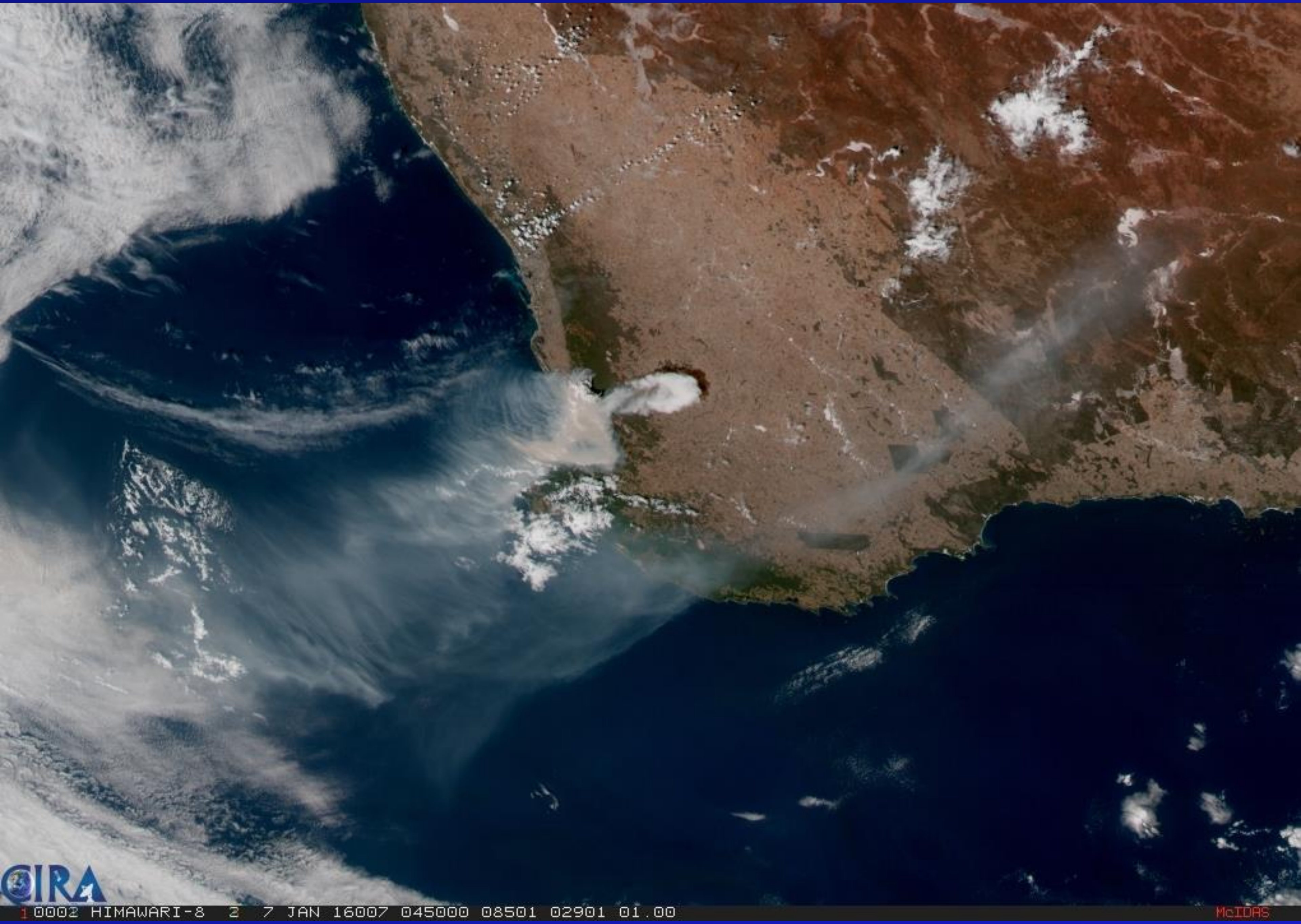
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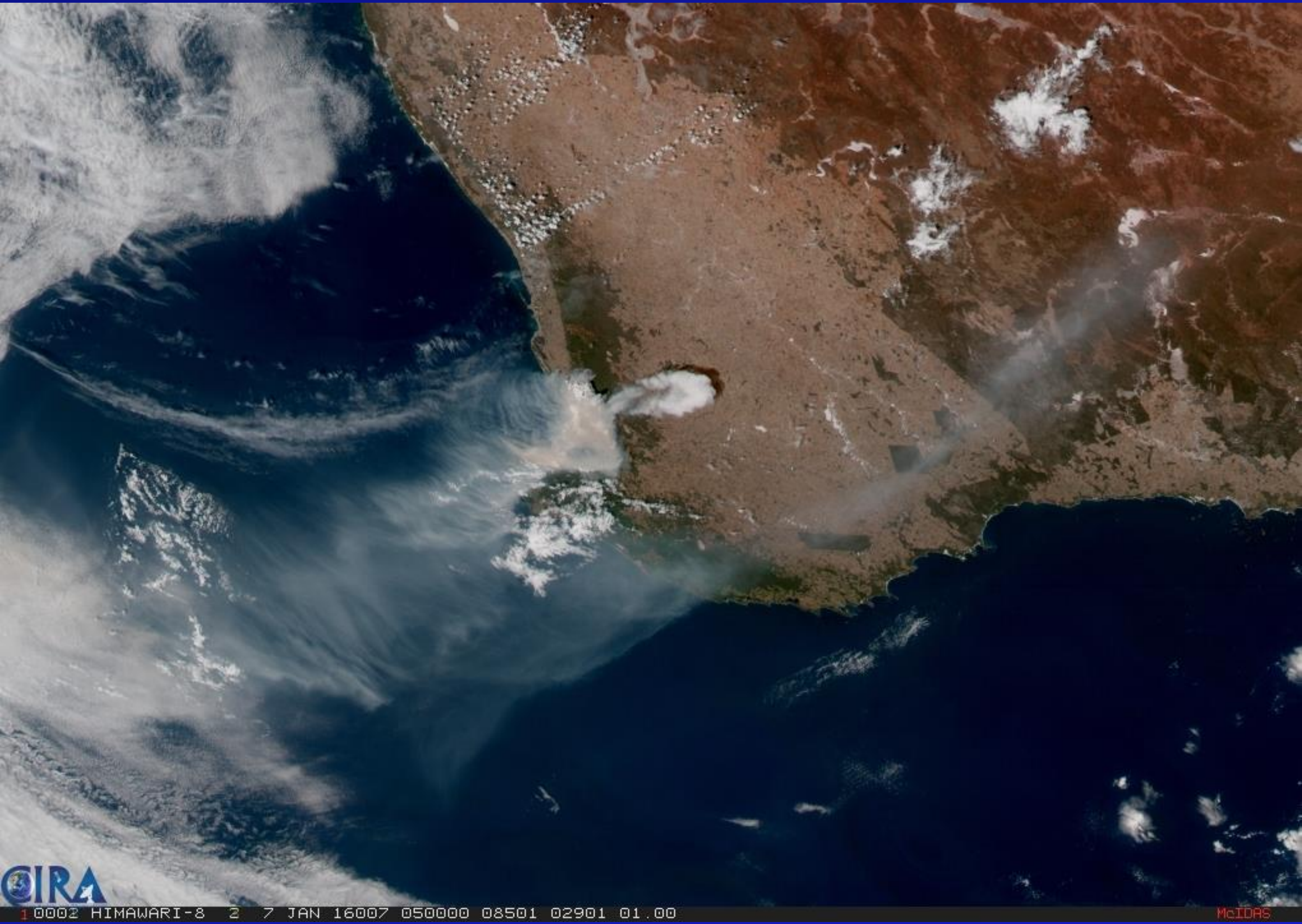
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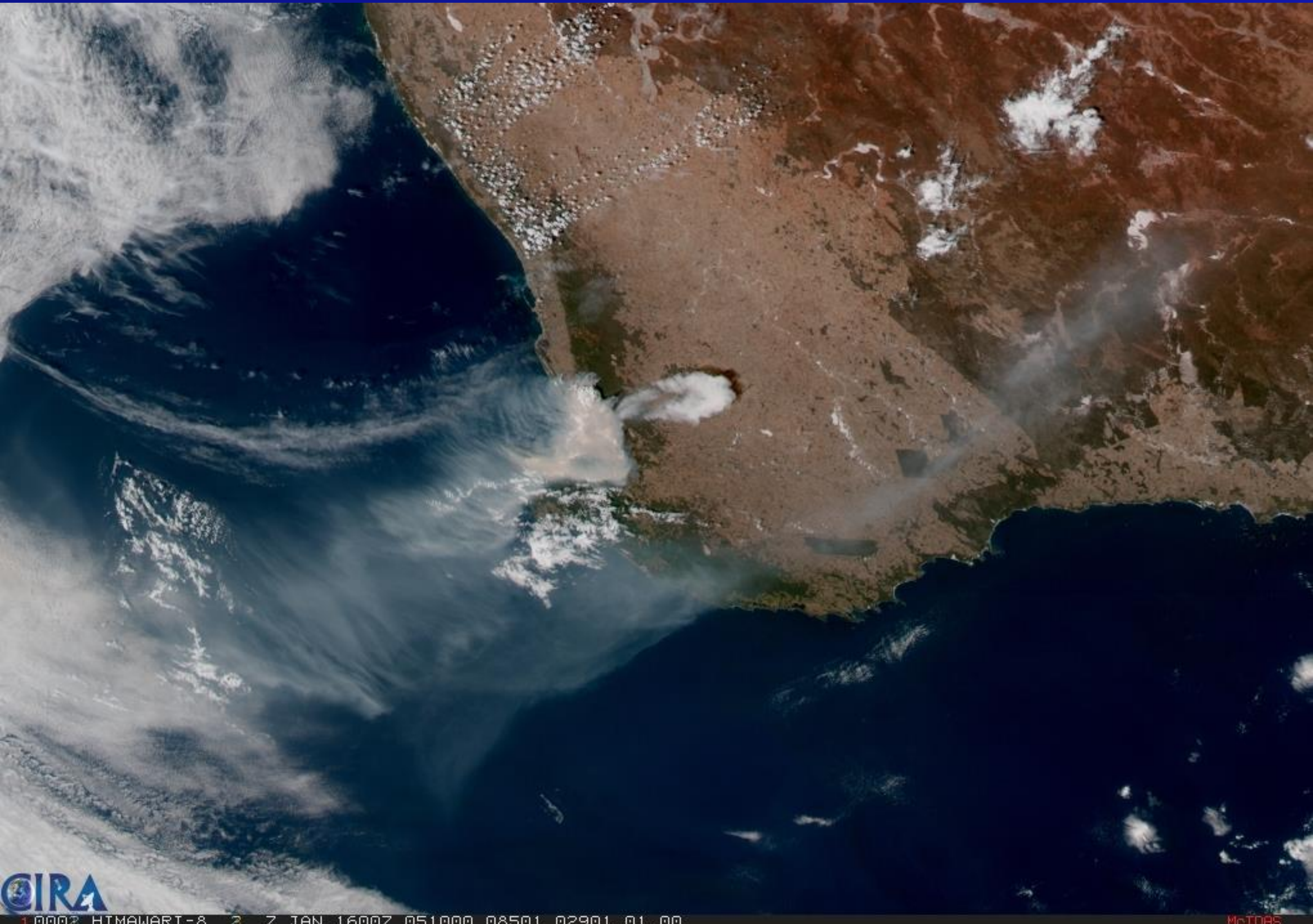
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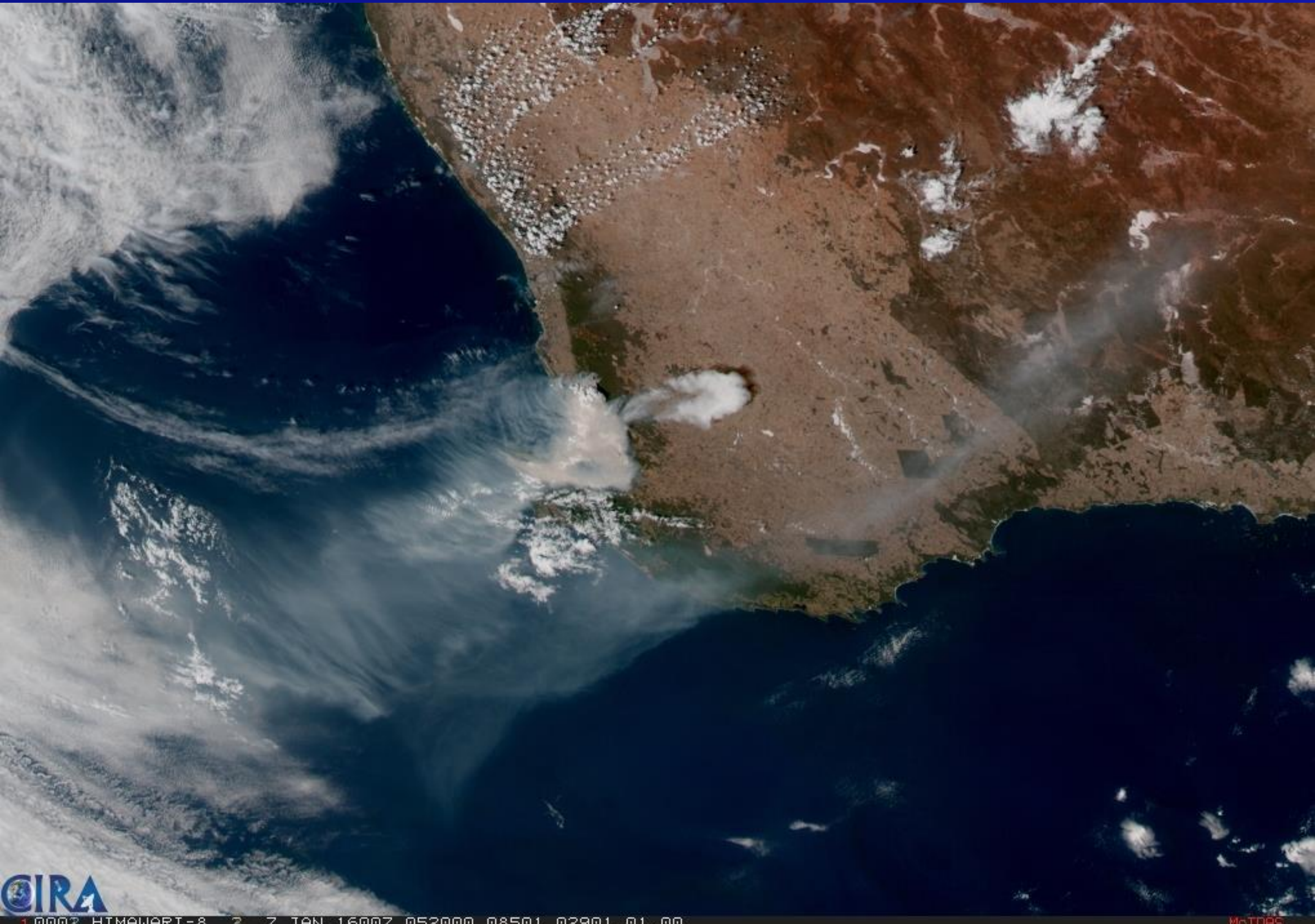
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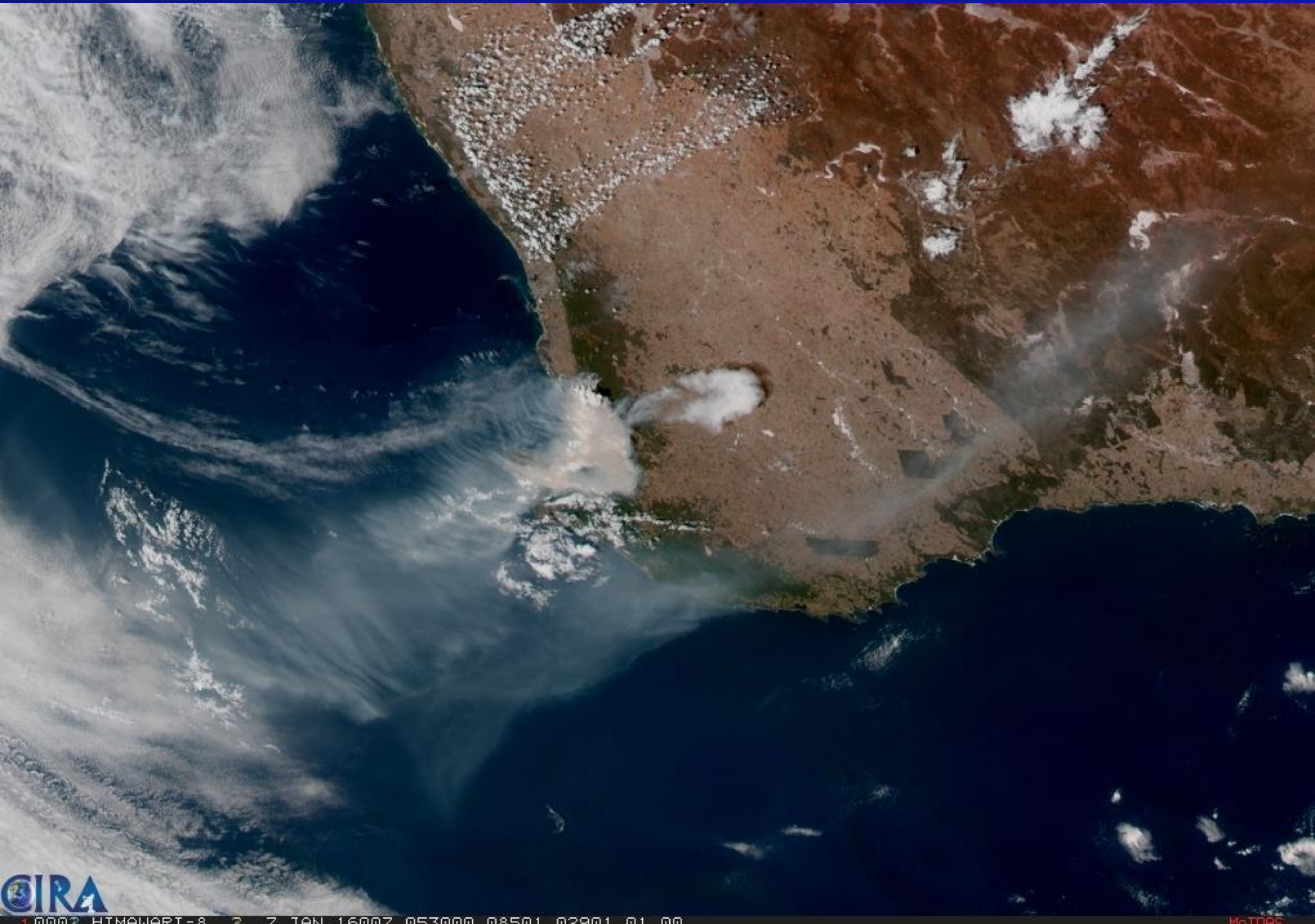
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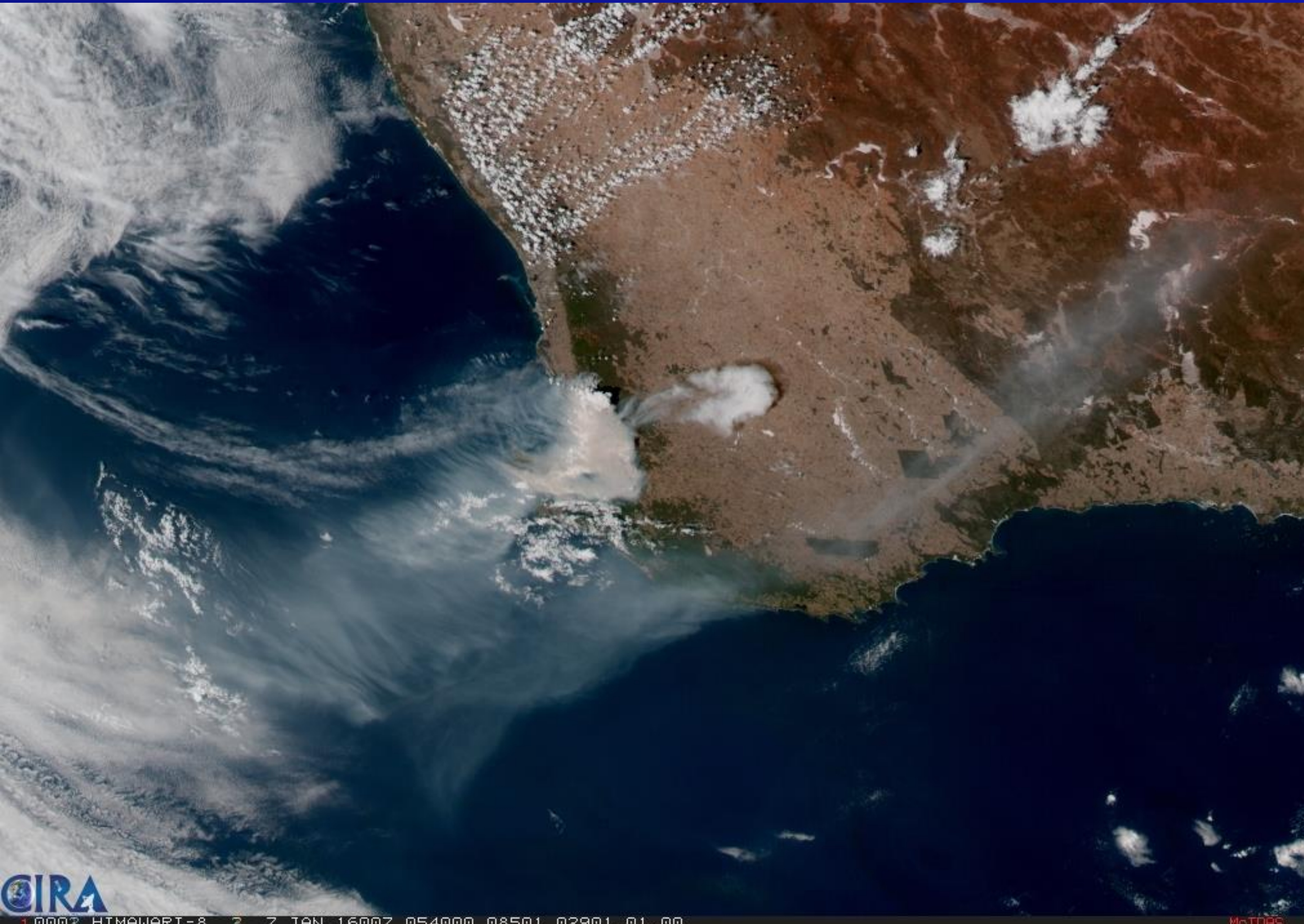
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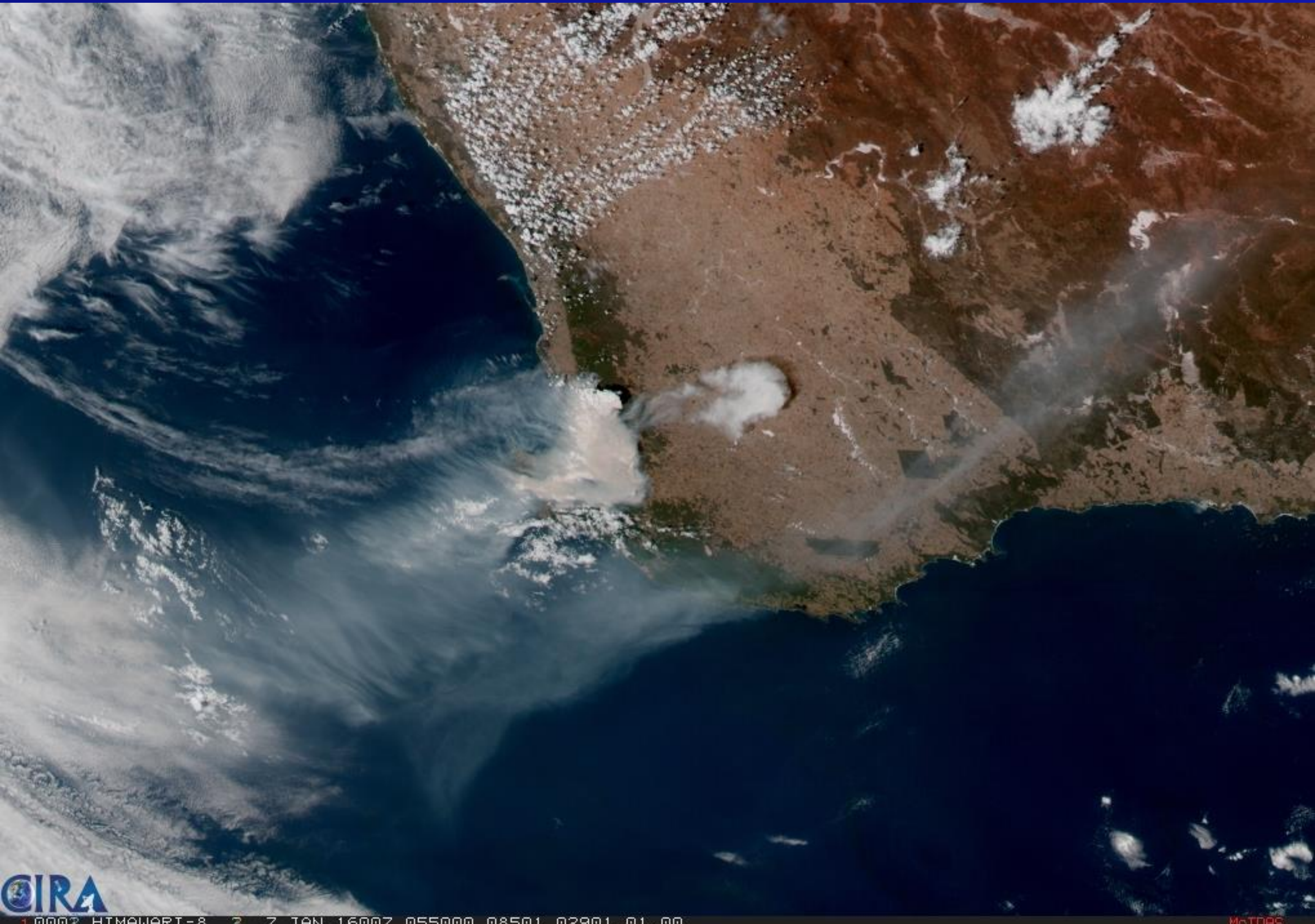
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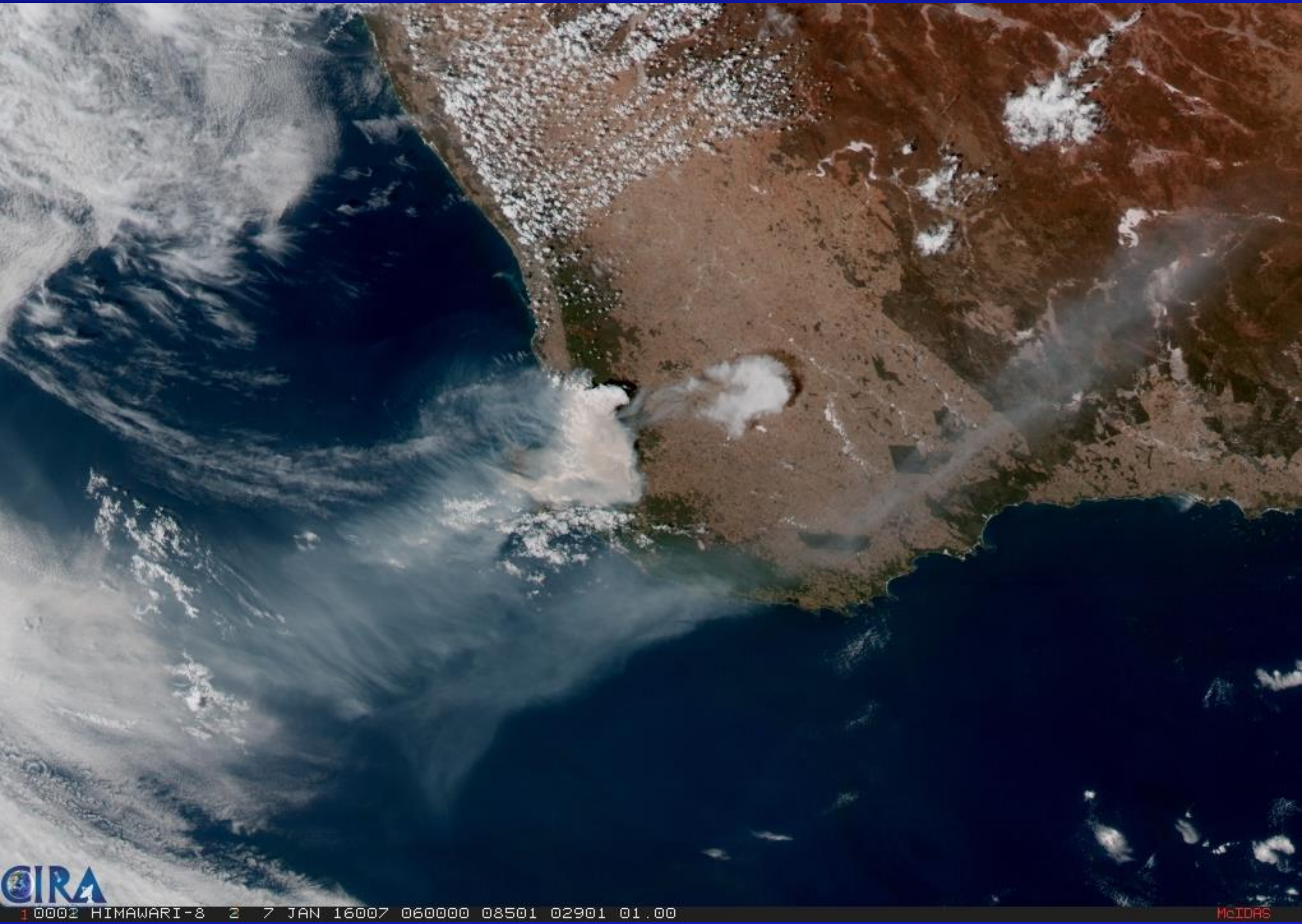
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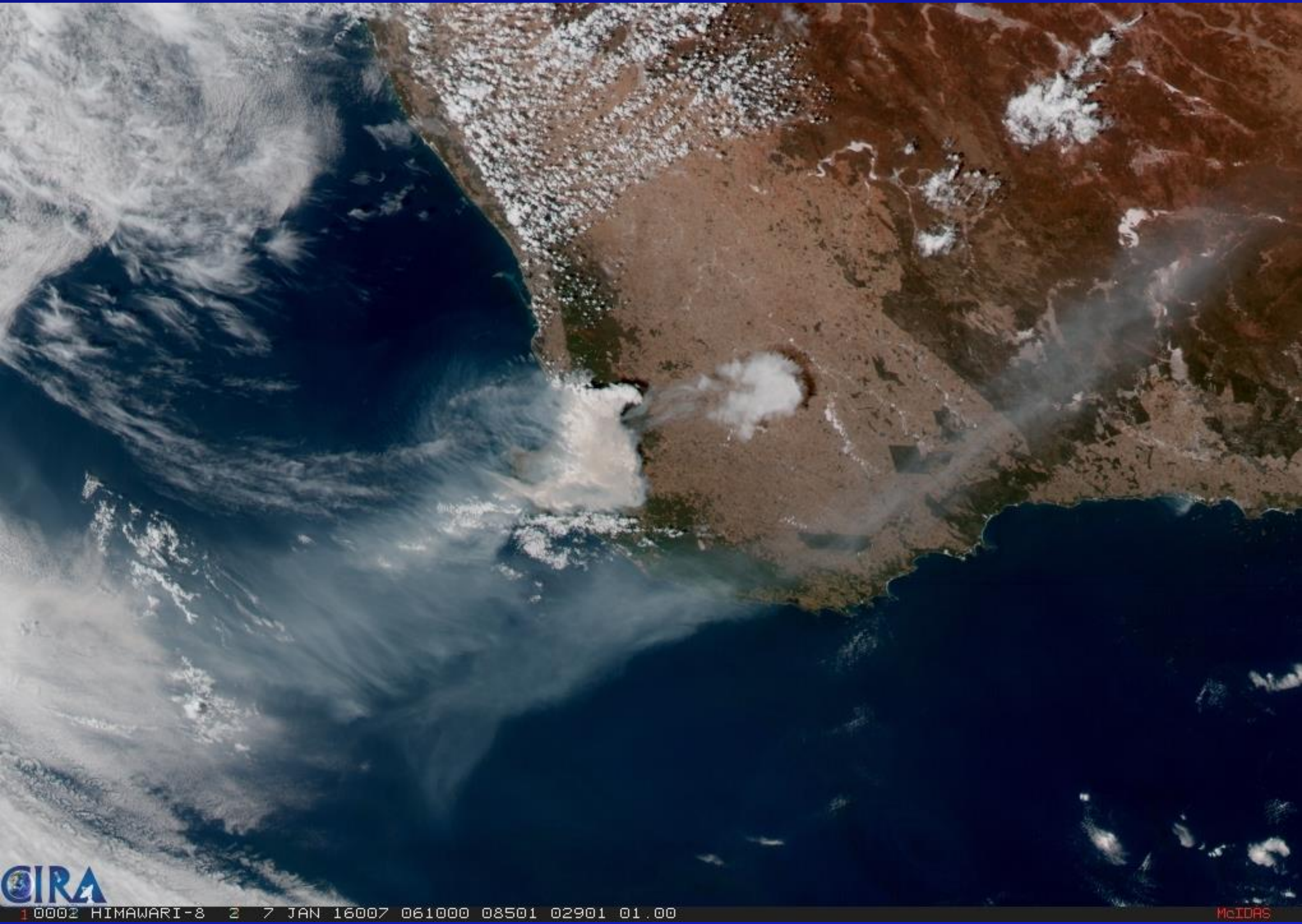
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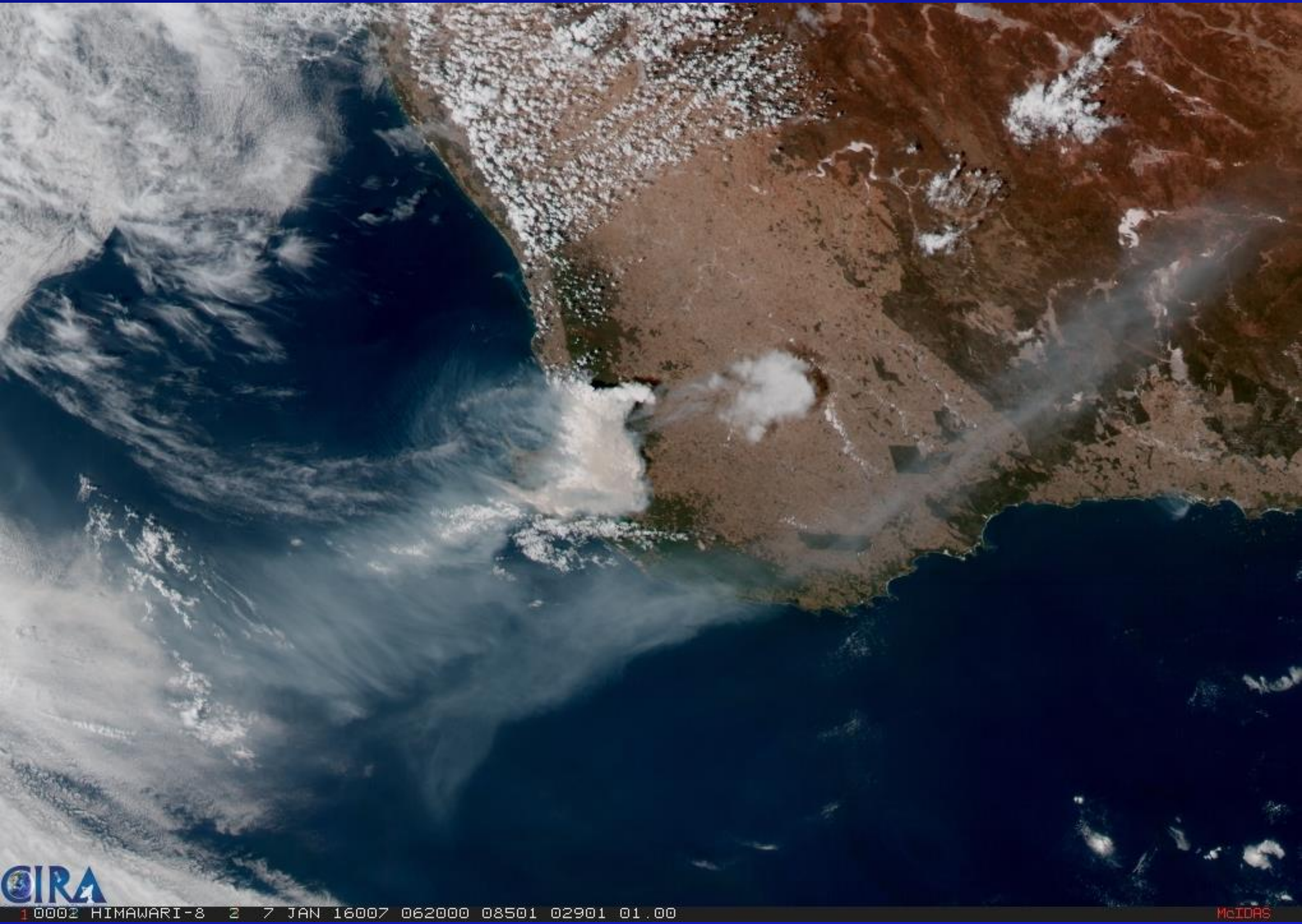
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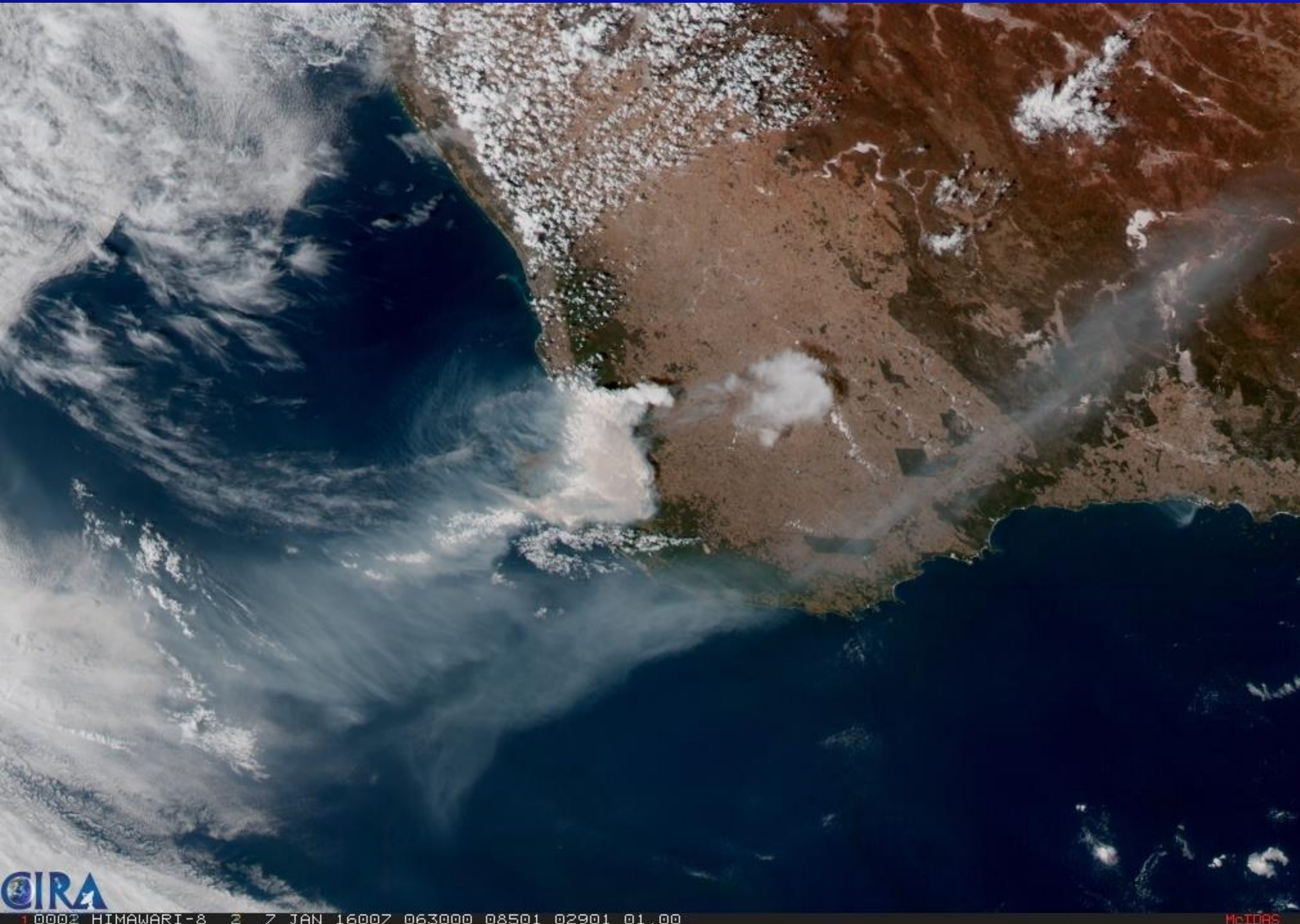
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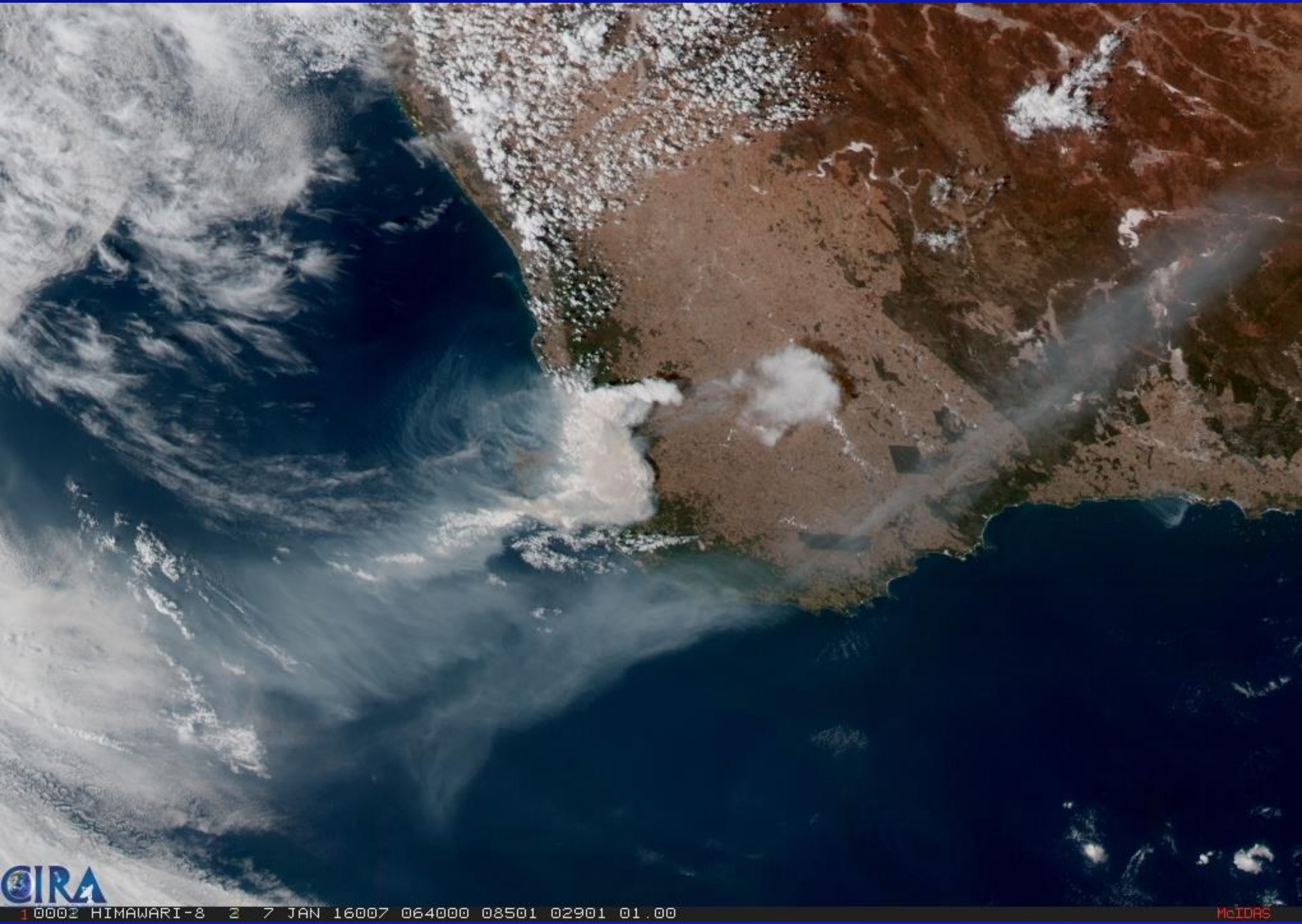
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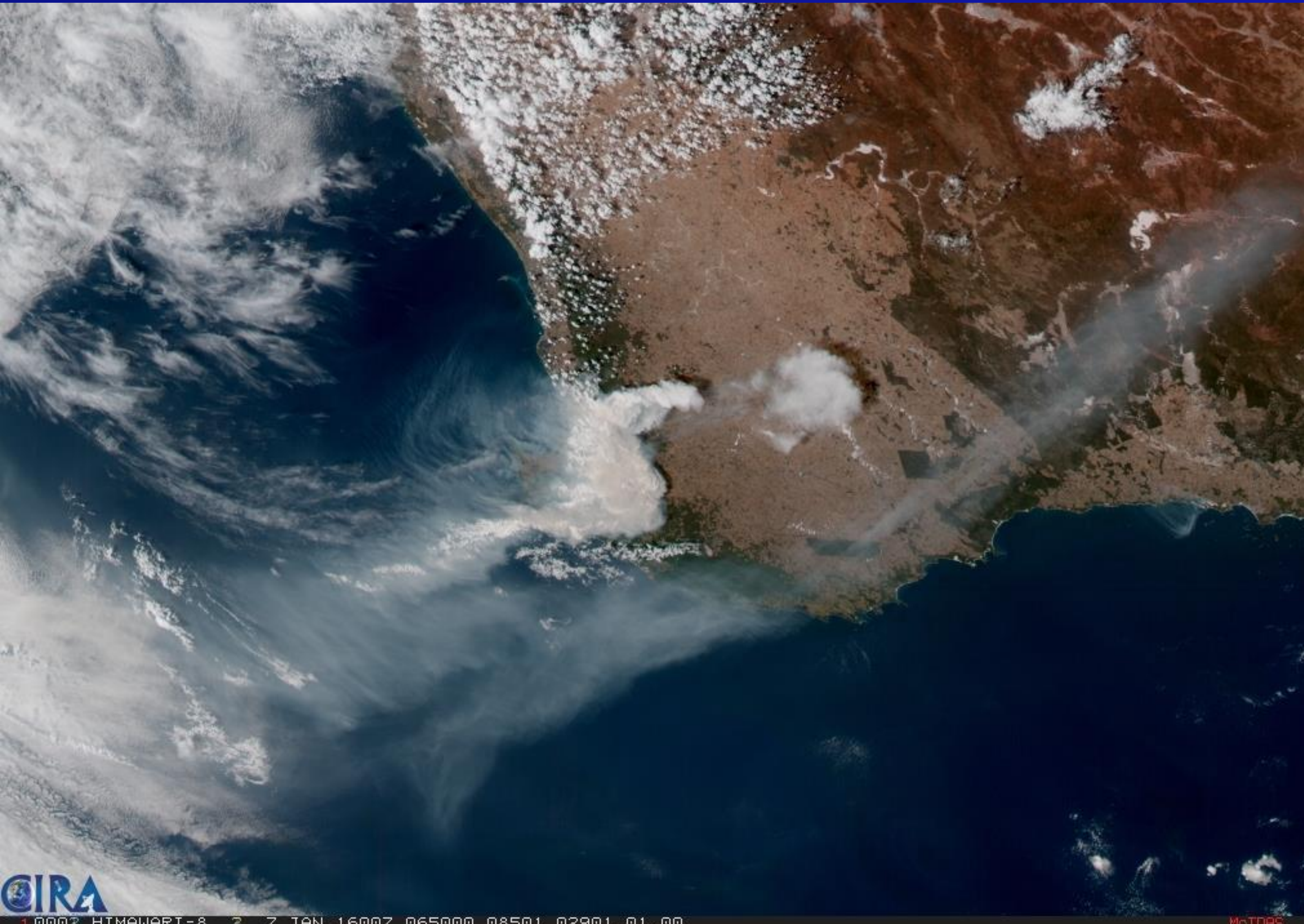
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Final Remarks

- This represents an exciting time in satellite meteorology!
- Himawari-8 has provided NOAA some wonderful proxy data to prepare for the new stream of data from GOES-R
- Some modifications to straight red/green/blue imagery are recommended in order maximize the quality of the imagery for users
- If launch occurs later this month, first light imagery should be available in late January 2017
- GOES-R will be placed at 89.5° W longitude (near Chicago's longitude) for 1 year after launch, then it will be moved either to the –East or the –West position to replace GOES-13 or GOES-15
- NWS should begin receiving data in ~Spring 2017
- We feel that GOES-R Risk Reduction and the GOES-R Proving Ground have been very successful programs to best prepare users for the data from the new instruments