Destriping VIIRS brightness temperatures for SST

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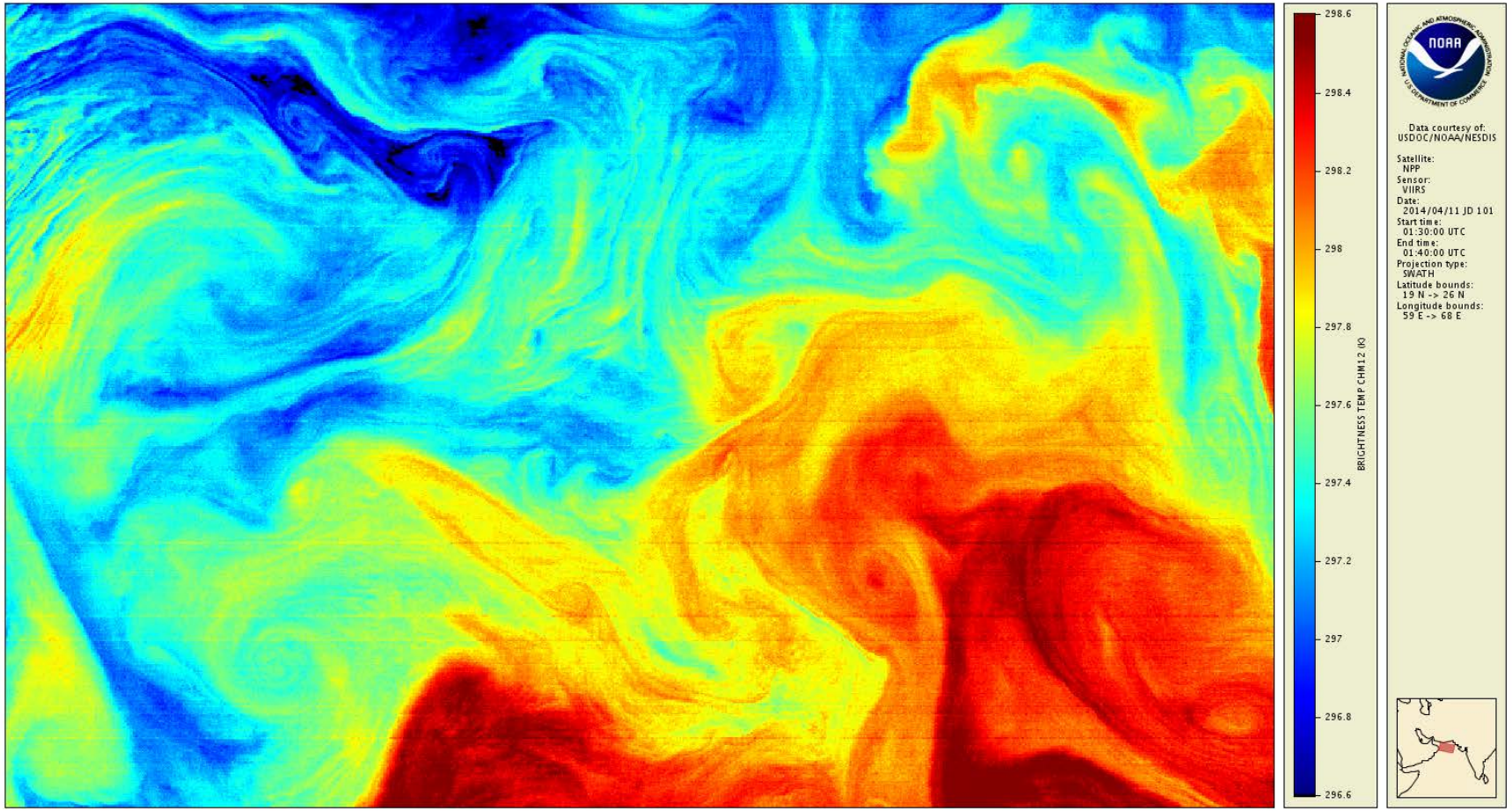
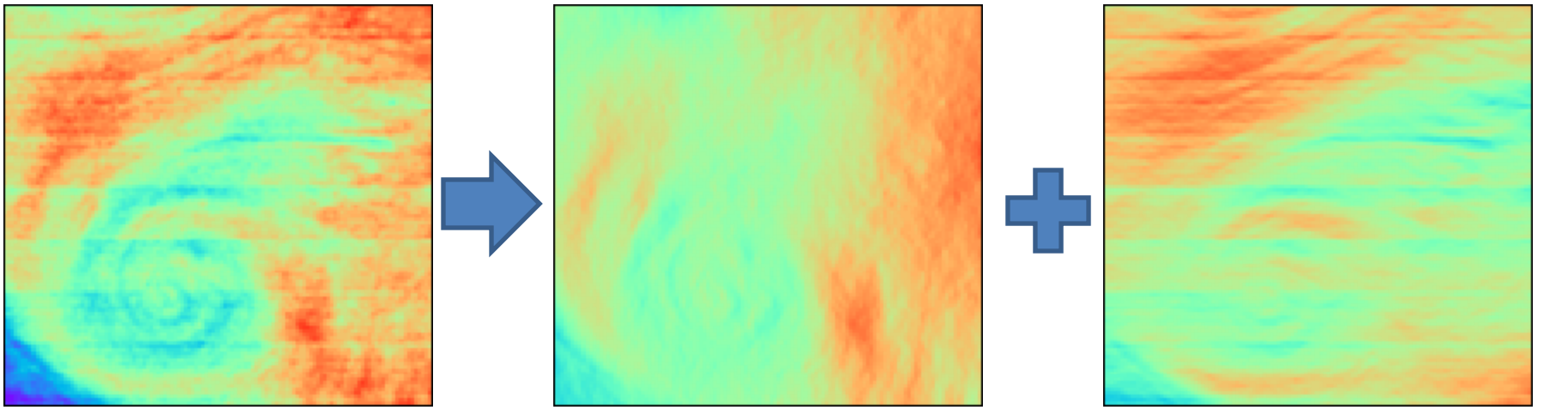
Motivation: Example striping in nighttime VIIRS M12 BT



- Low amplitude
- Unidirectional artifact
- Strongly affects SST gradients

Destriping Method

- Start with striped image
- Calculate gradients
- Discard “y” gradients in striped, but otherwise smooth regions
- Poisson reconstruction (with DCT using FFT) yields approximate destriped image
- Split the original image into destriped and striped components

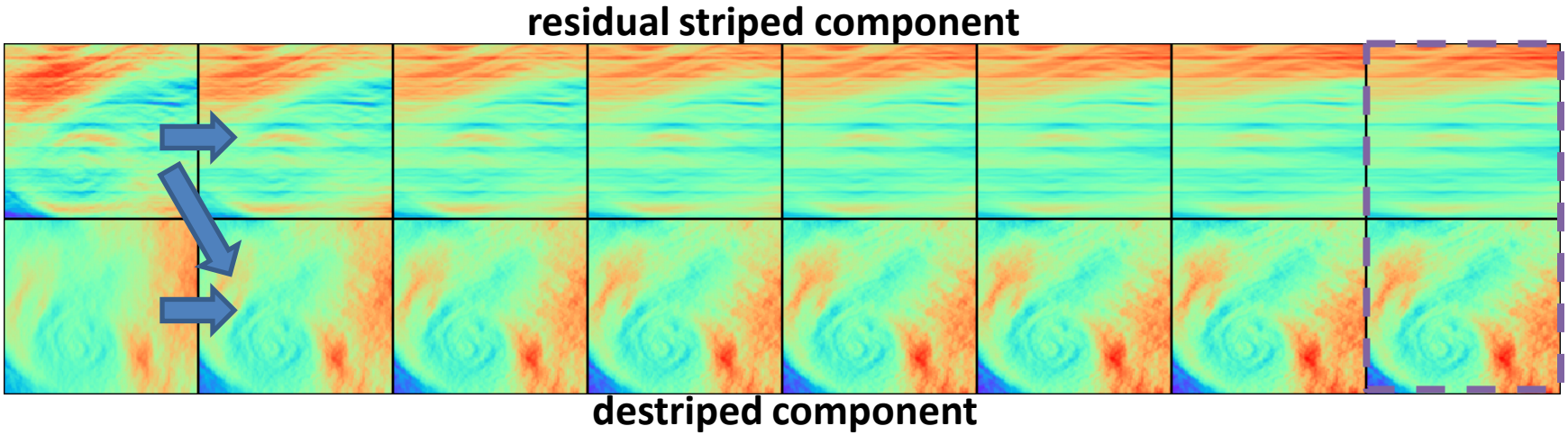


original image **destriped component** **residual striped component**

Algorithm: M. Bouali, A. Ignatov, *J. Atmos. Oceanic Technol.*, **31**, 150-163 (2014).

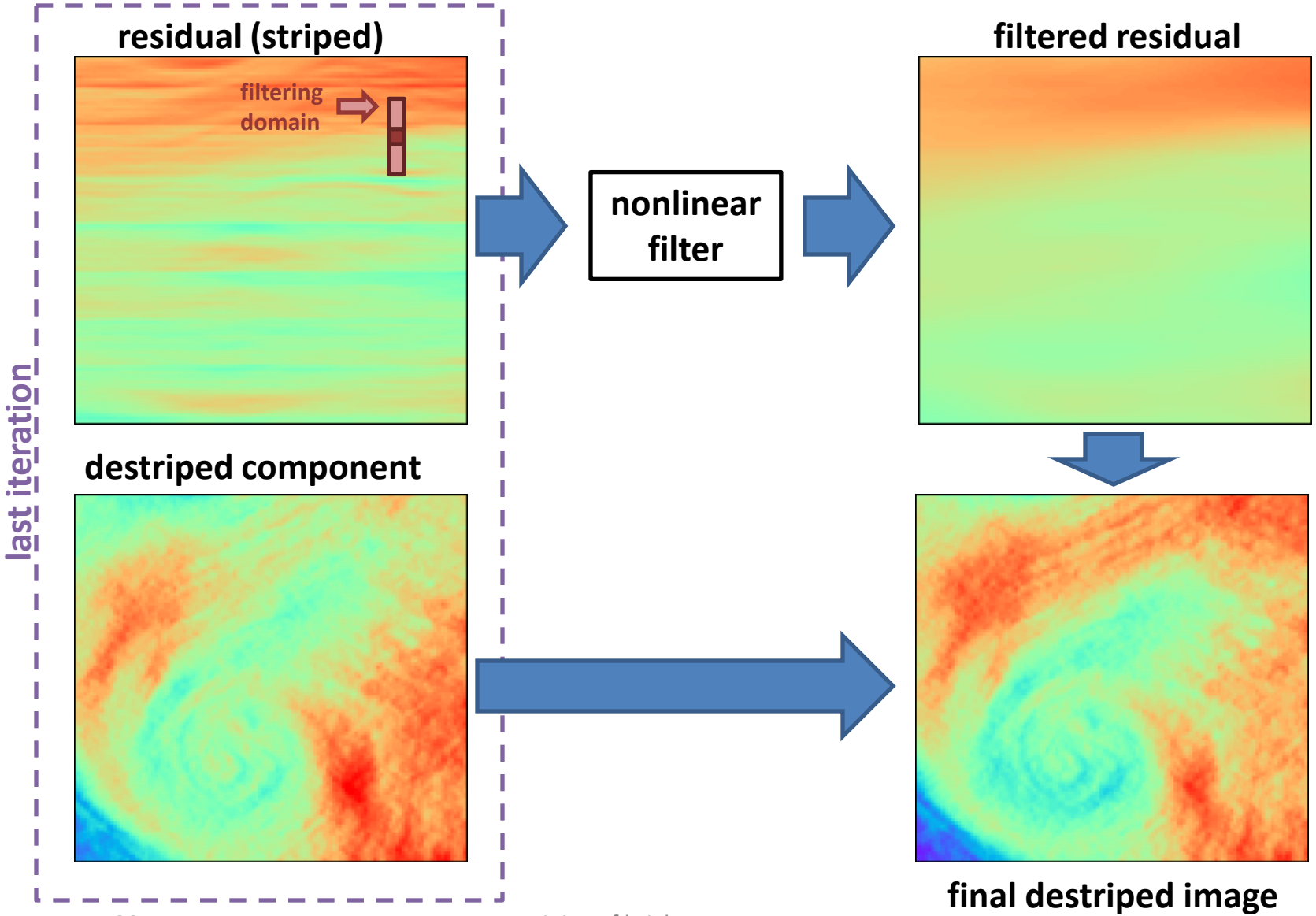
Destriping Method: Iterative refinement

- At each iteration, contribution to destriped image is extracted from residual striped component
- Repeat until destriped component contains (nearly) all useful information and residual is (nearly) reduced to stripes



Algorithm: M. Bouali, A. Ignatov, *J. Atmos. Oceanic Technol.*, **31**, 150-163 (2014).

Destriping Method: Nonlinear filter

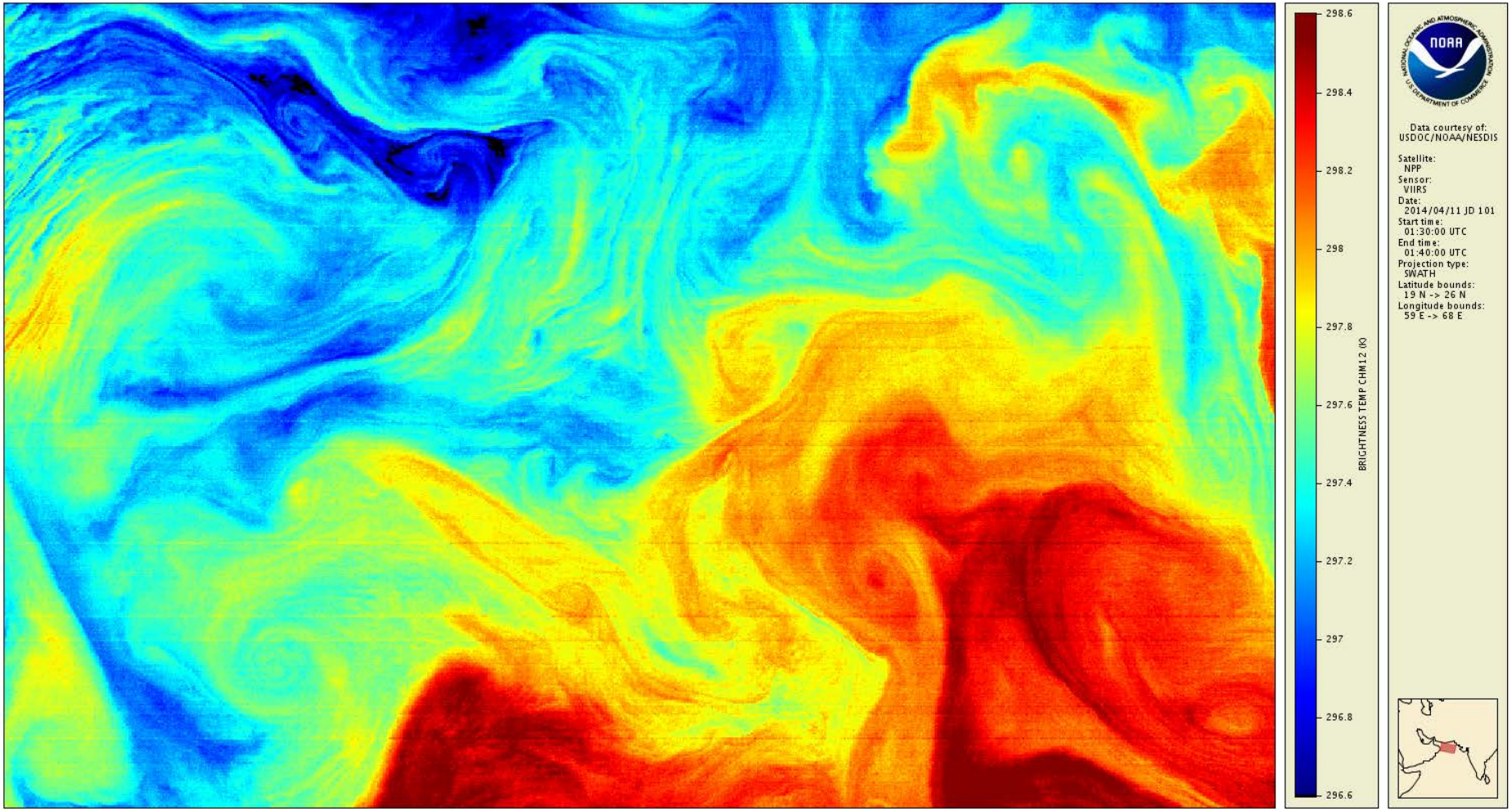


Nighttime

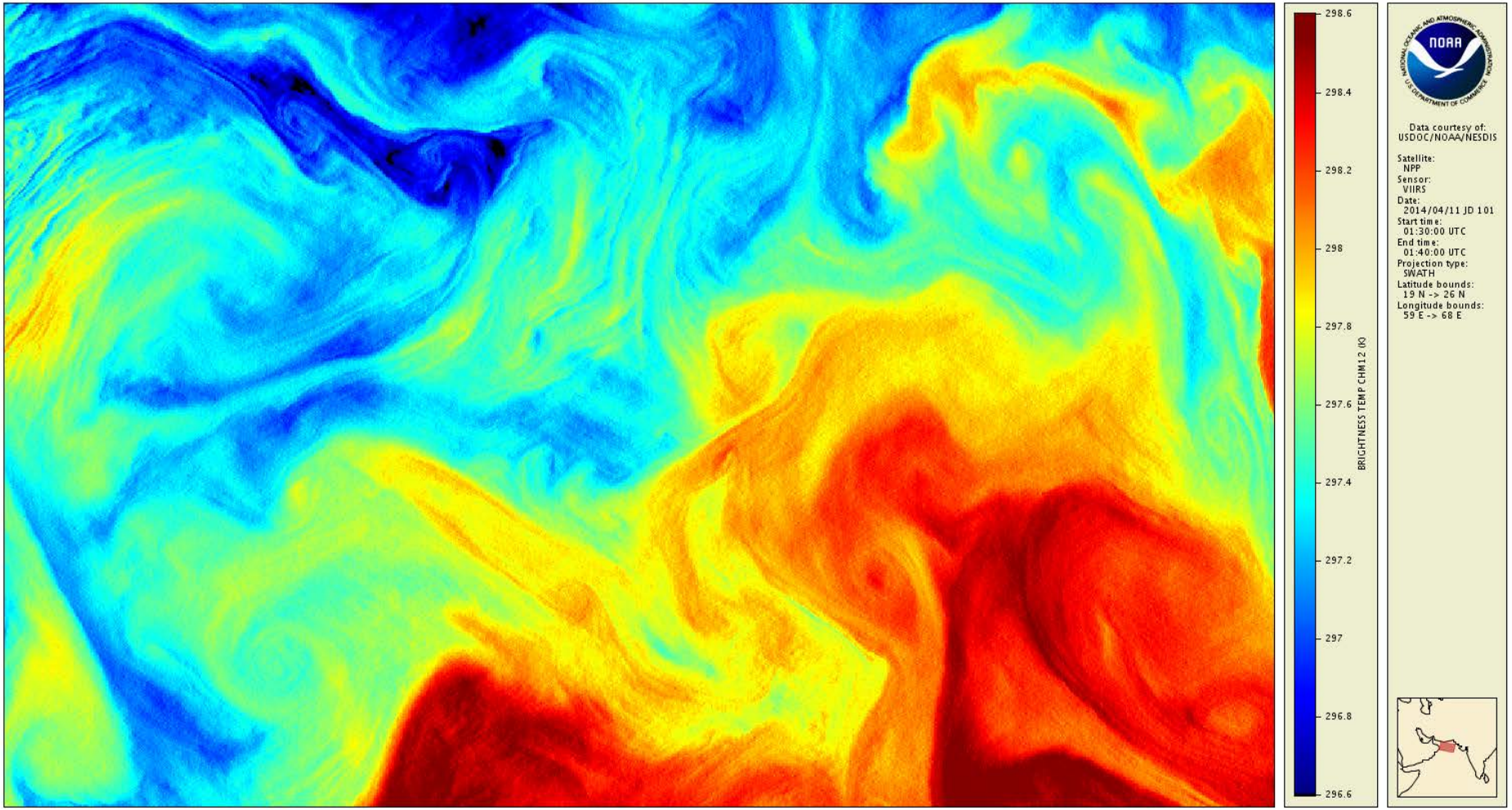
$$T_S = a_0 + (a_1 + a_2 S_\vartheta) T_{3.7} + (a_3 + a_4 S_\vartheta) (T_{11} - T_{12}) + a_5 S_\vartheta$$

$T_{3.7}, T_{11}, T_{12}$	observed BTs in M12, M15, M16
$S_\vartheta = 1/\cos(\vartheta)$	ϑ is view zenith angle
a's	regression coefficients

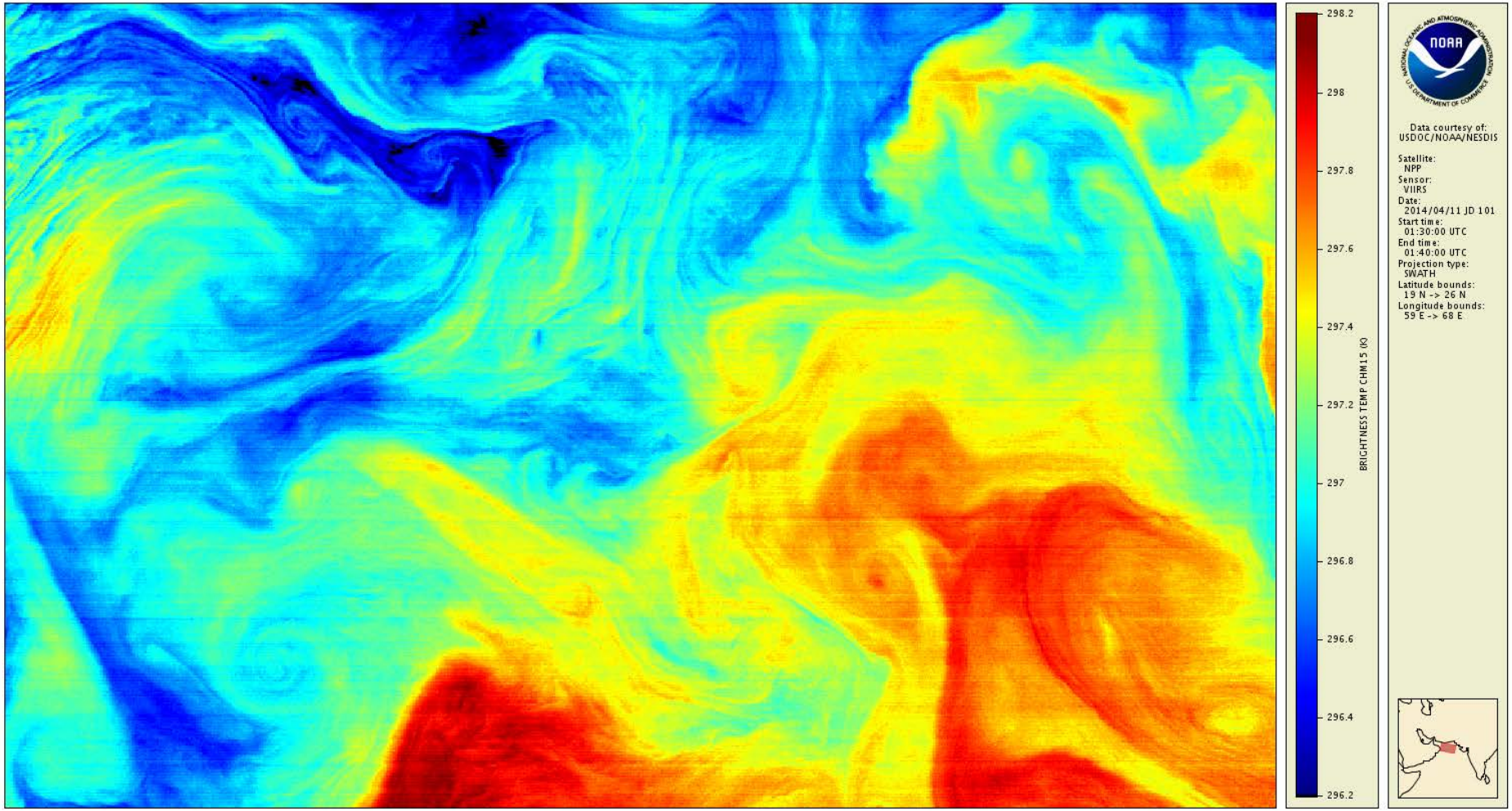
NIGHT – Original BT in VIIRS band M12 (3.7μm)



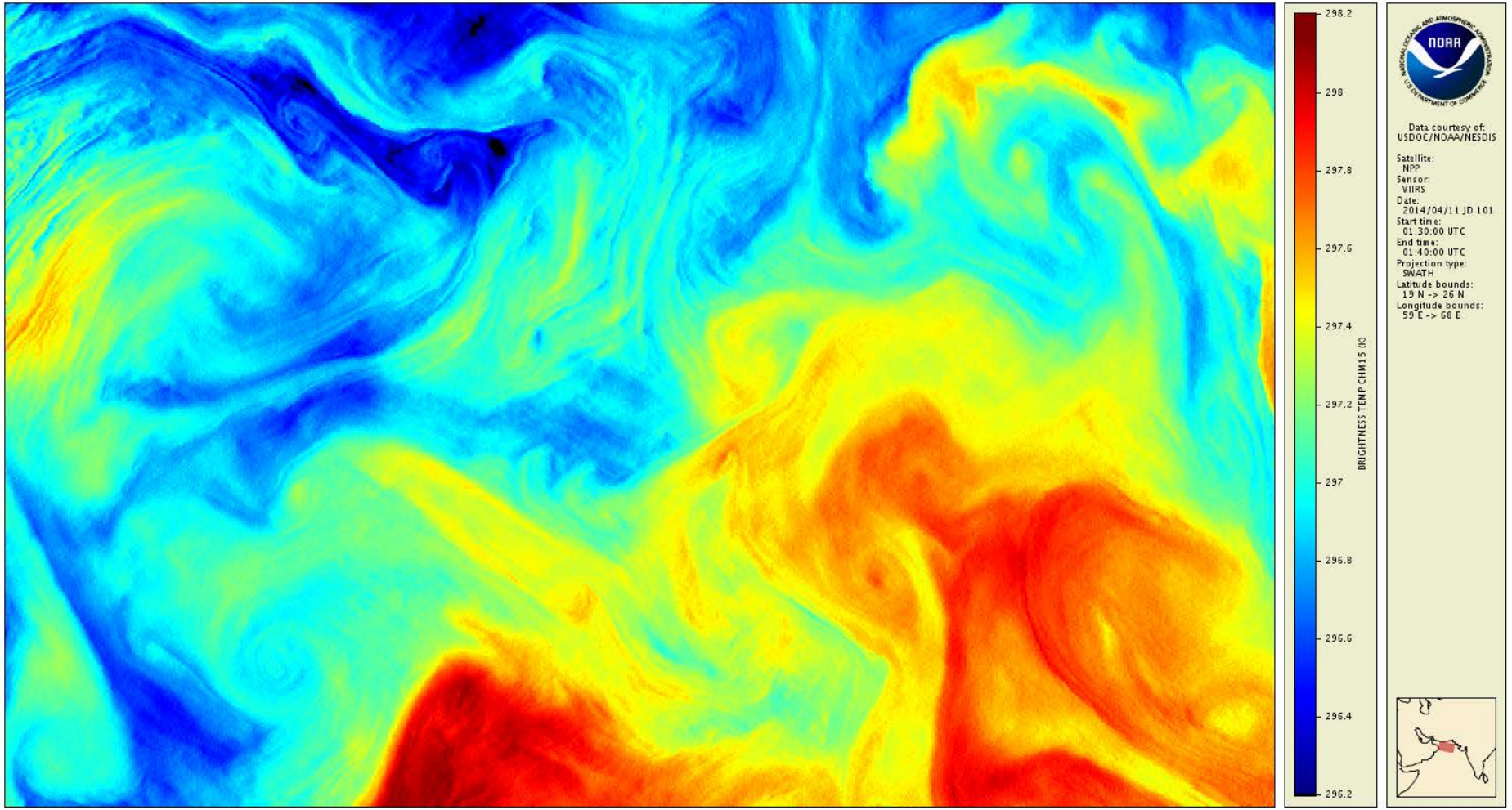
NIGHT – Destriped BT in VIIRS band M12 (3.7μm)



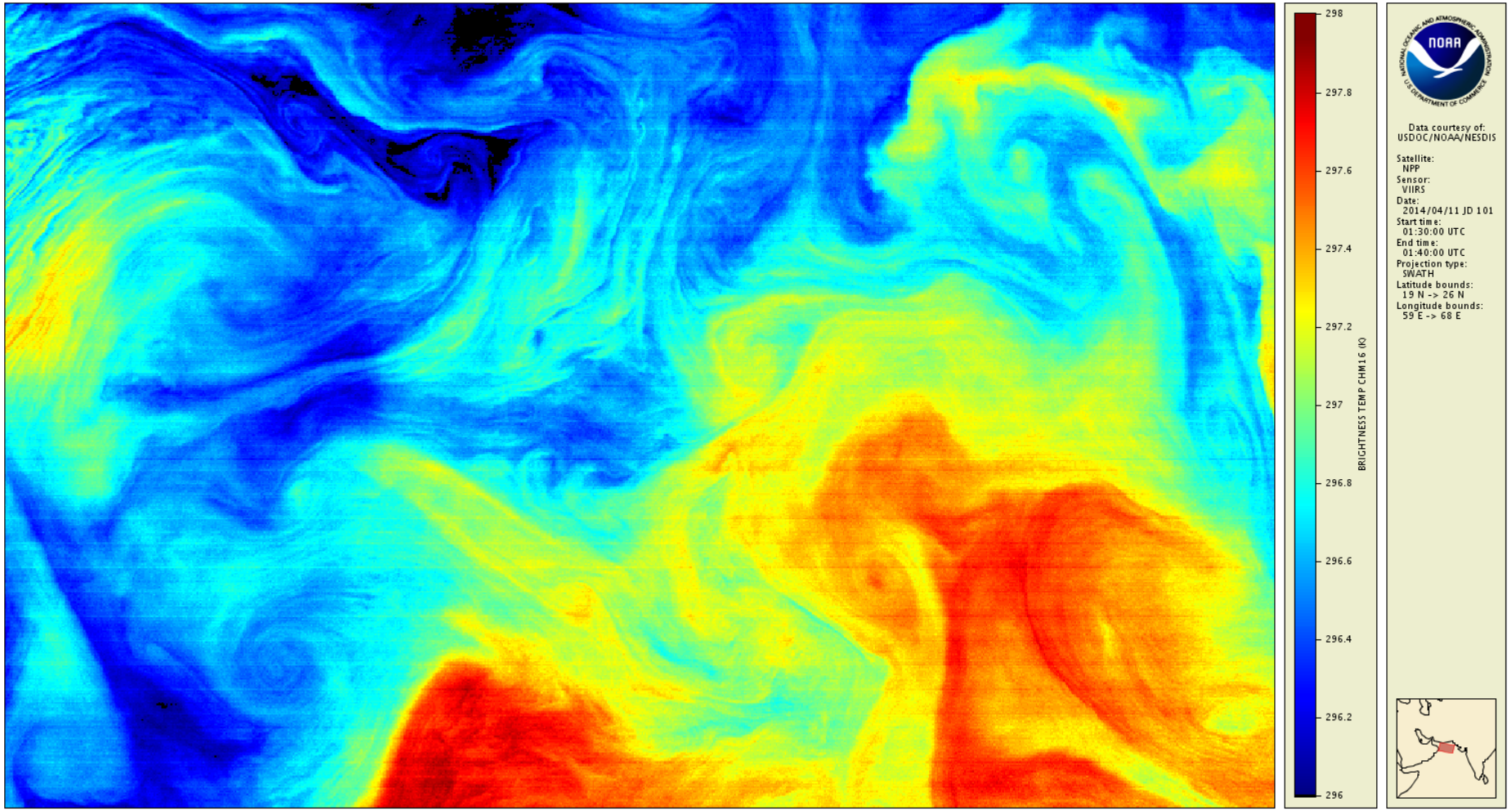
NIGHT – Original BT in VIIRS band M15 (10.8μm)



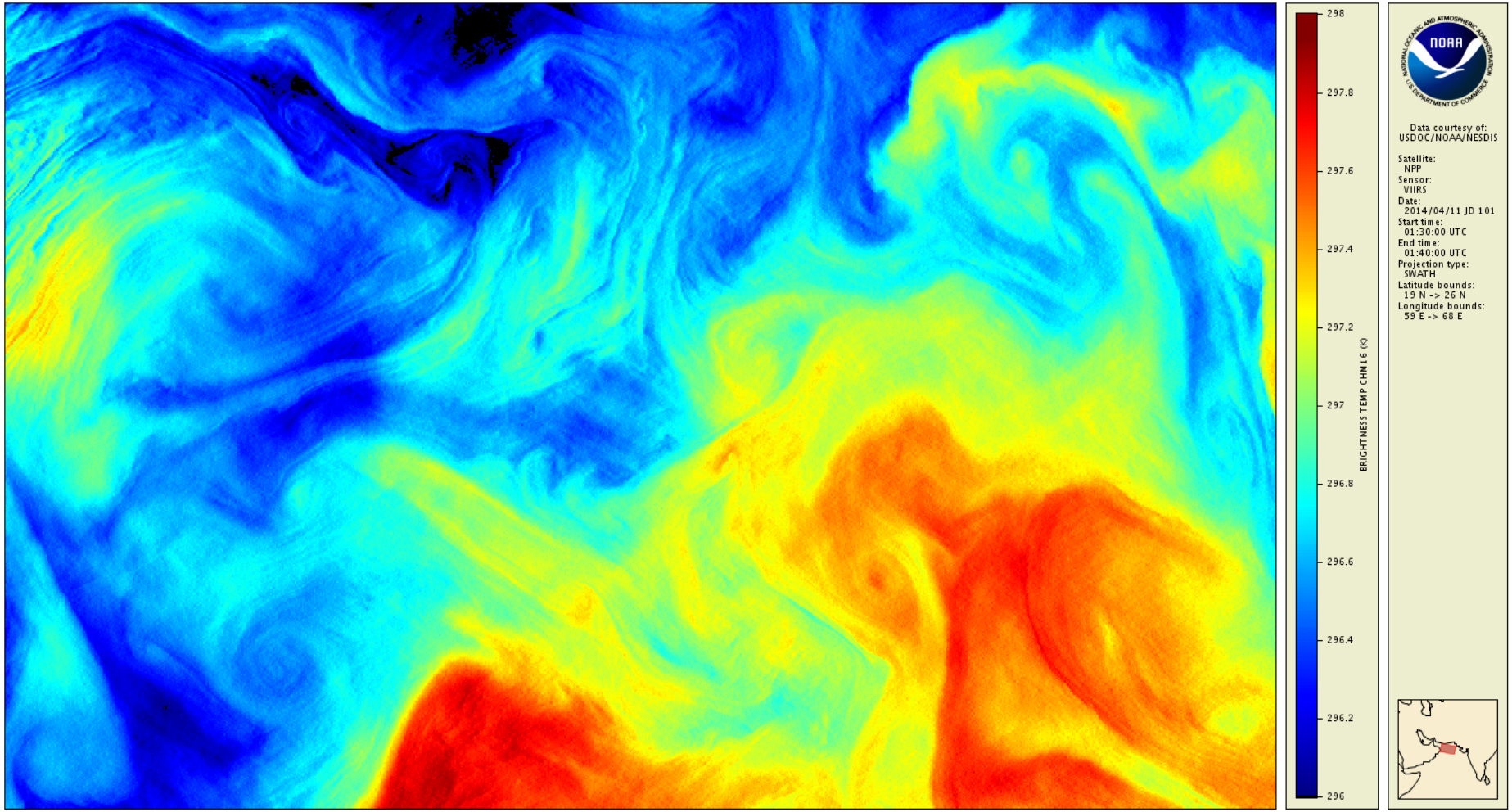
NIGHT – Destriped BT in VIIRS band M15 (10.8μm)



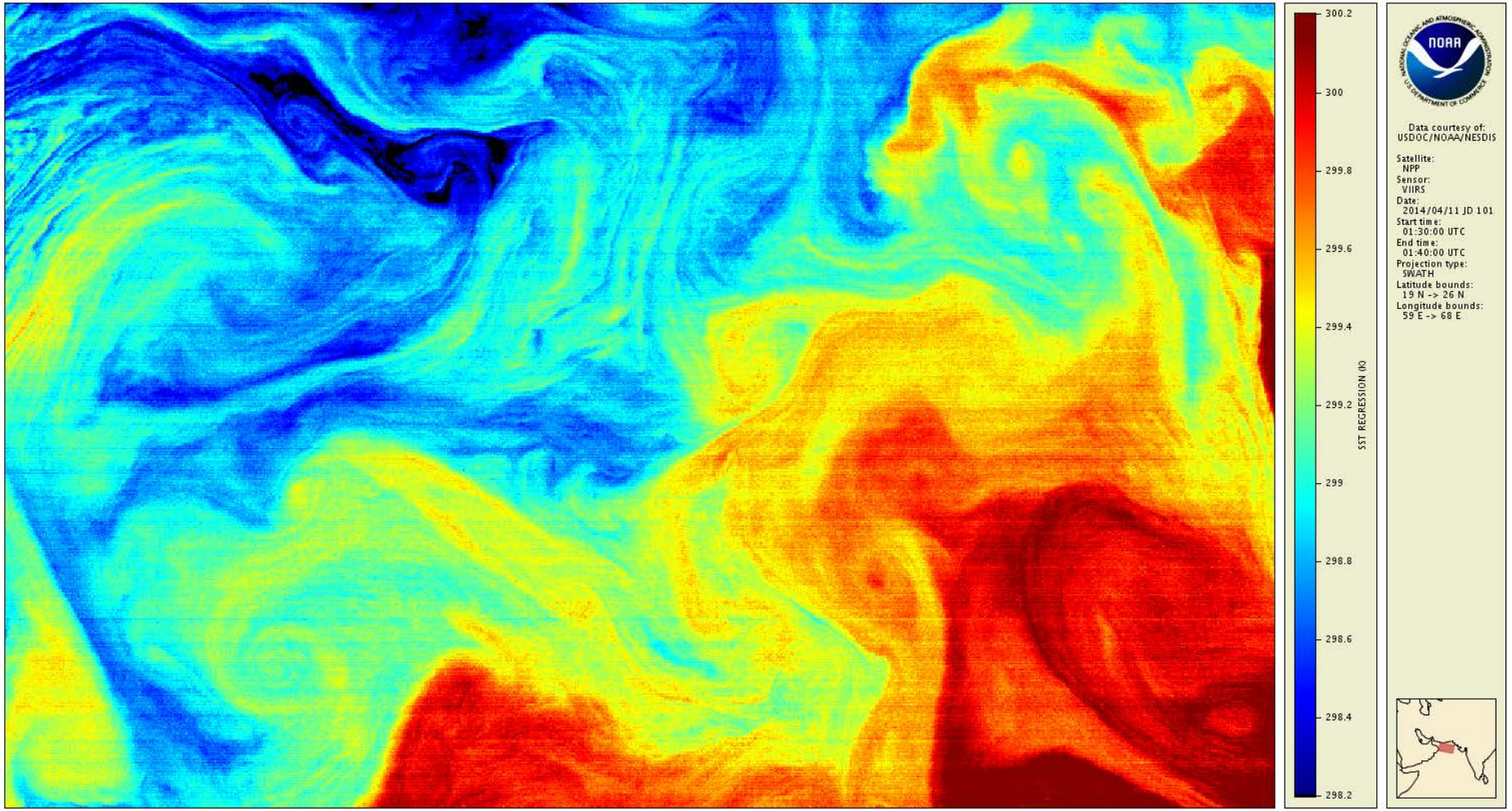
NIGHT – Original BT in VIIRS band M16 (12μm)



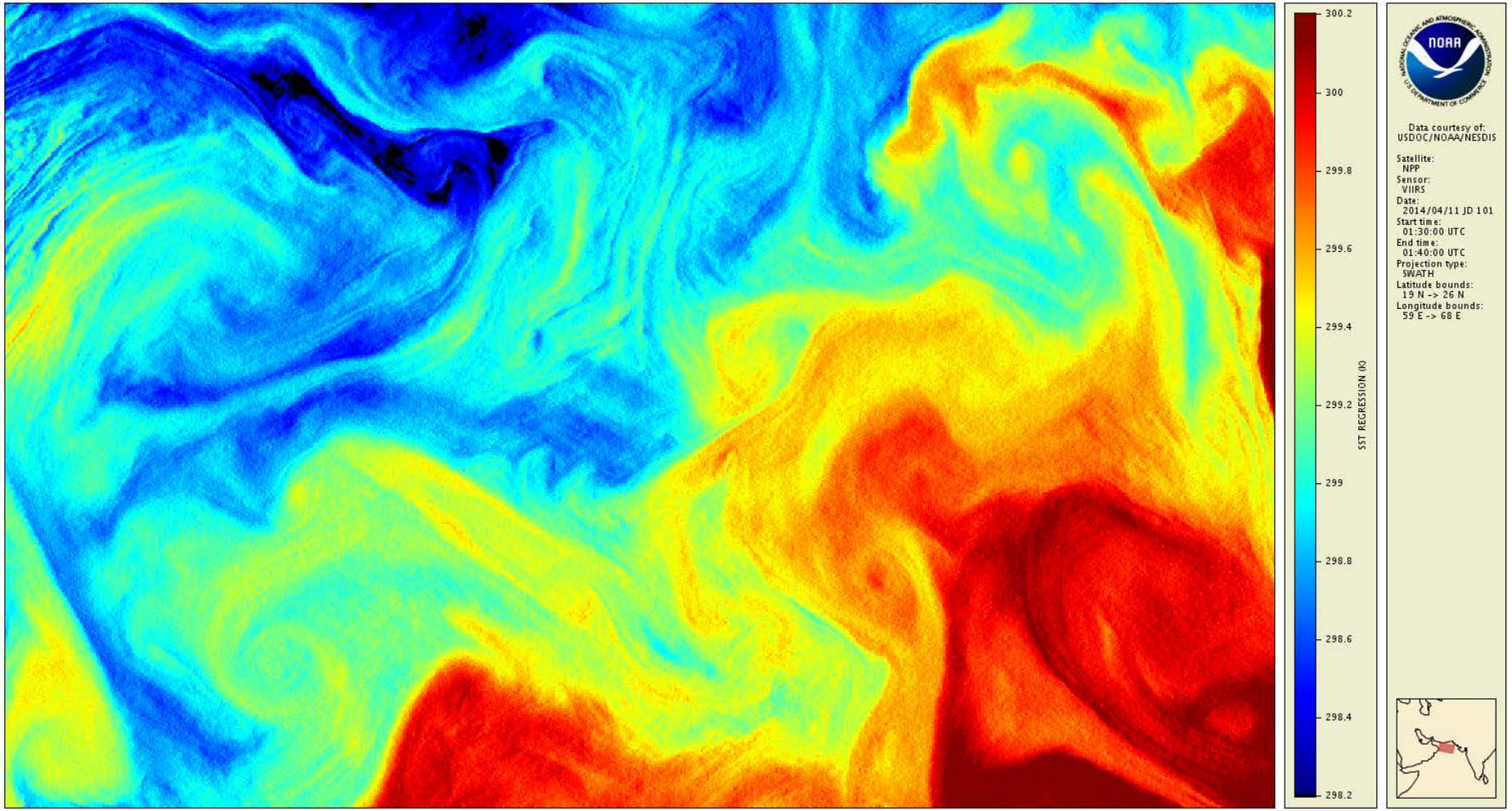
NIGHT – Destriped BT in VIIRS band M16 (12μm)



NIGHT – SST from original BTs in M12, M15, M16



NIGHT – SST from destriped BTs in M12, M15, M16

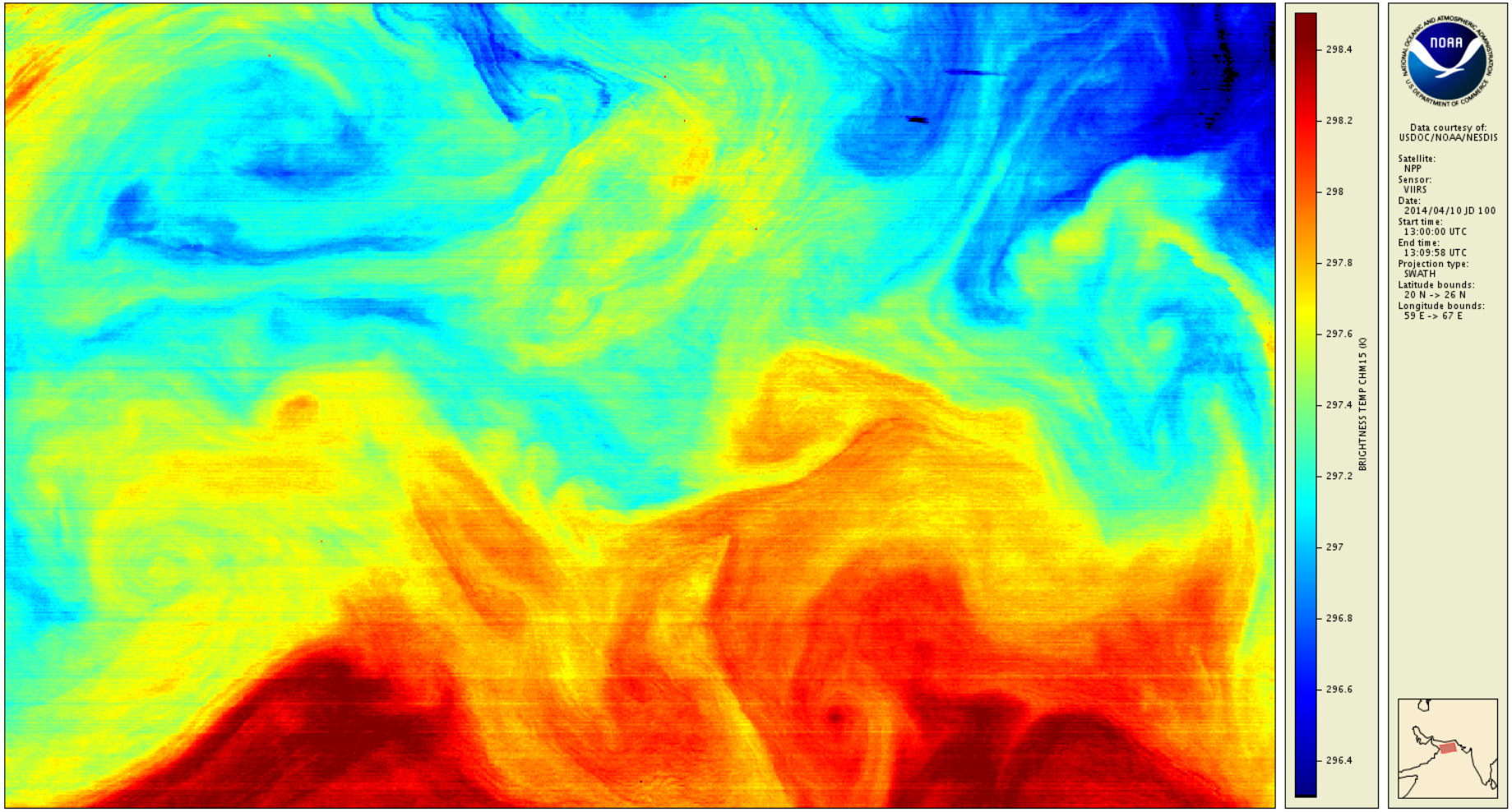


Daytime

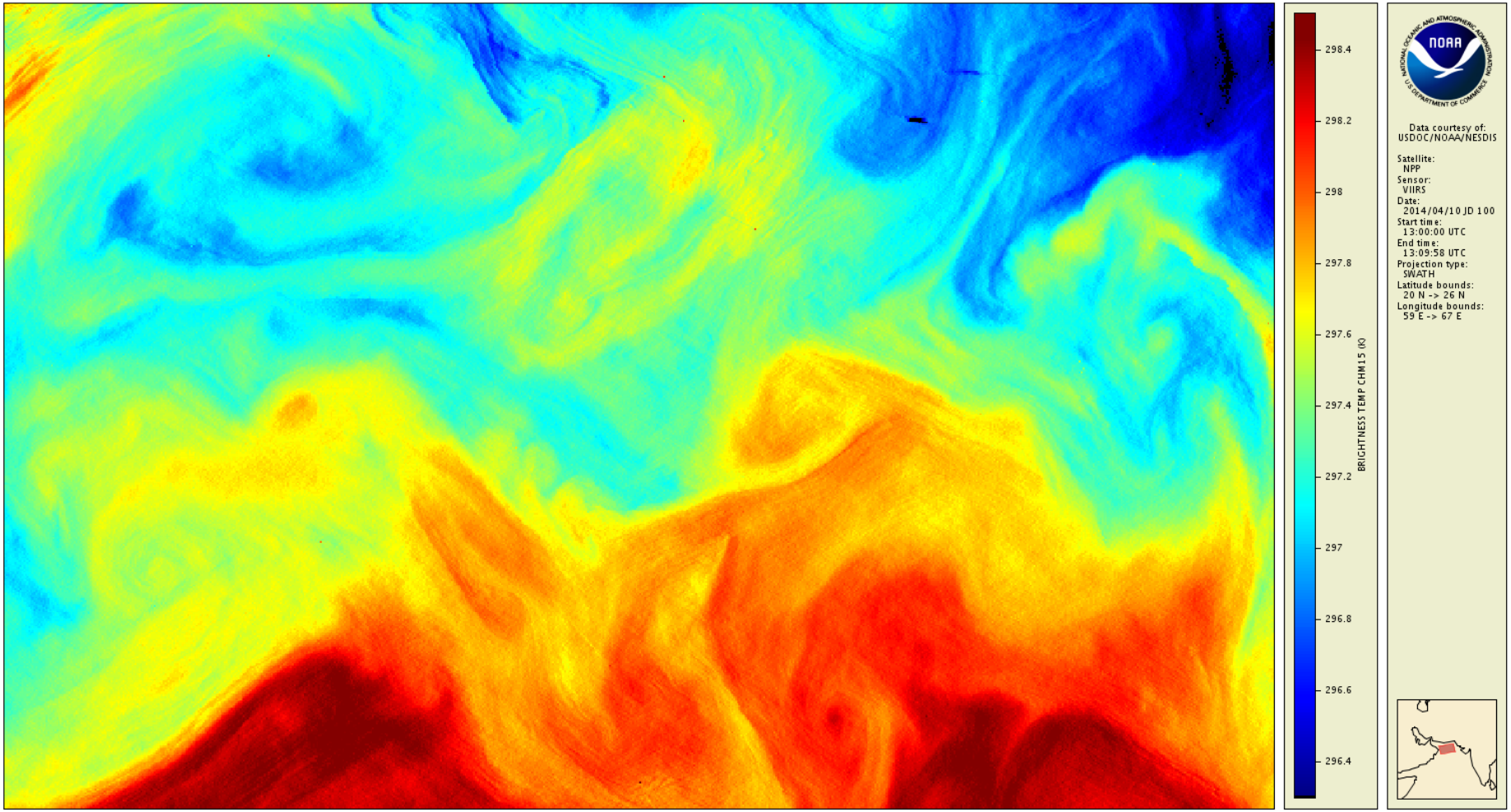
$$T_S = a_0 + (a_1 + a_2 S_\vartheta) T_{11} + [a_3 + a_4 T_S^0 + a_5 S_\vartheta] (T_{11} - T_{12}) + a_6 S_\vartheta$$

T_{11}, T_{12}	observed BTs in M15, M16
$S_\vartheta = 1/\cos(\vartheta)$	ϑ is view zenith angle
T_S^0	first guess SST (in °C)
a's	regression coefficients

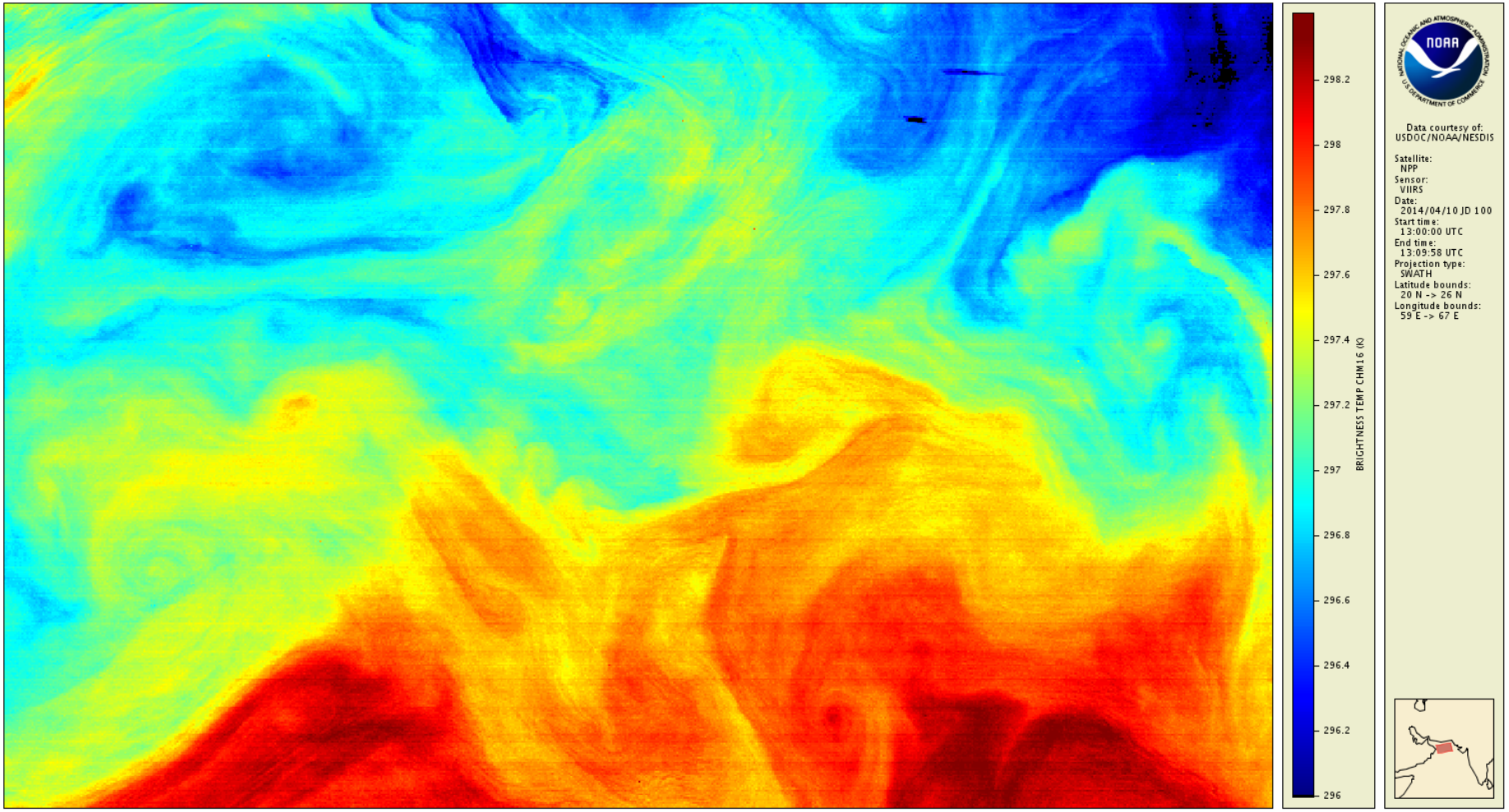
DAY – Original BT in VIIRS band M15 (10.8μm)



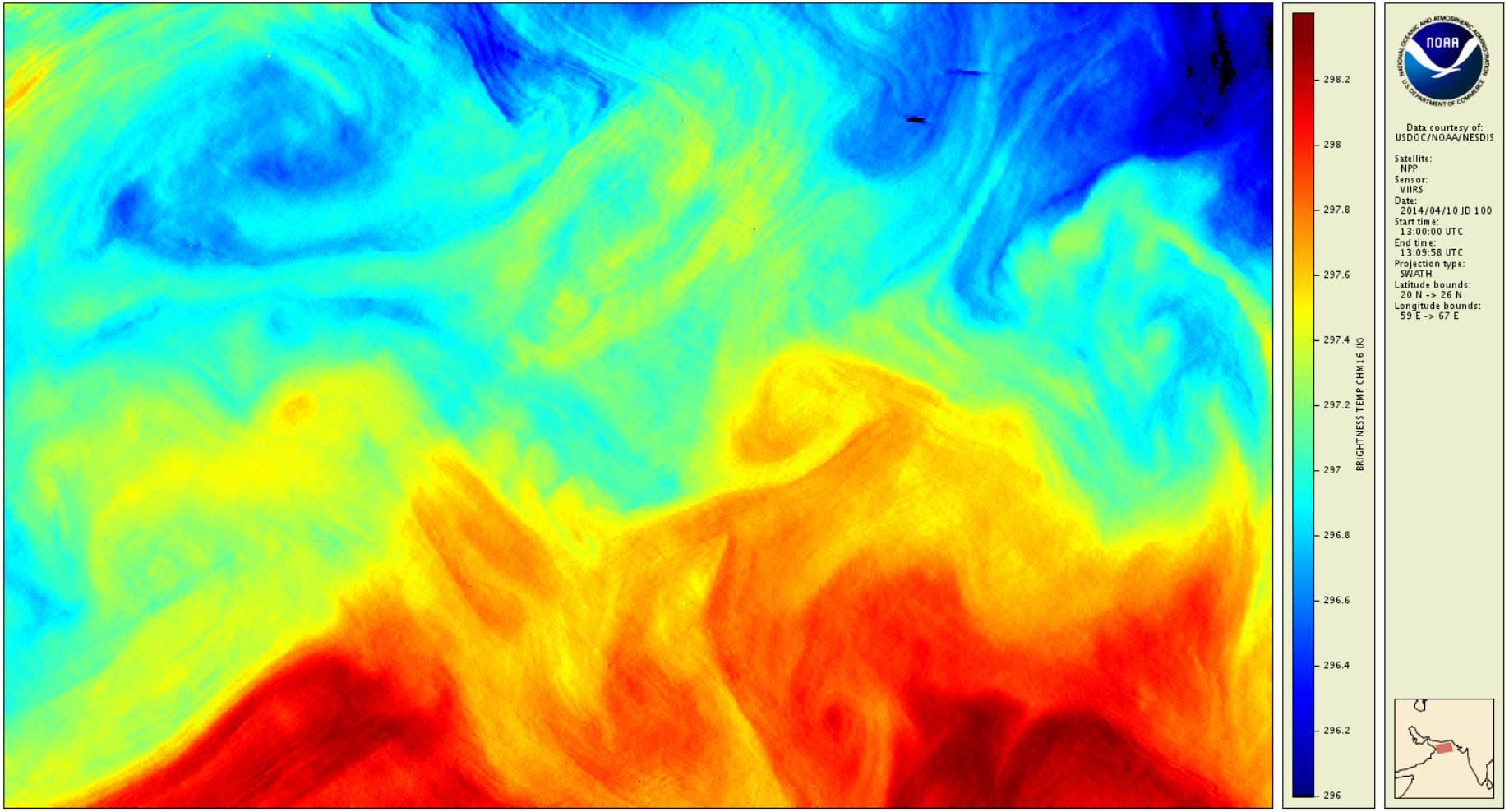
DAY – Destriped BT in VIIRS band M15 (10.8μm)



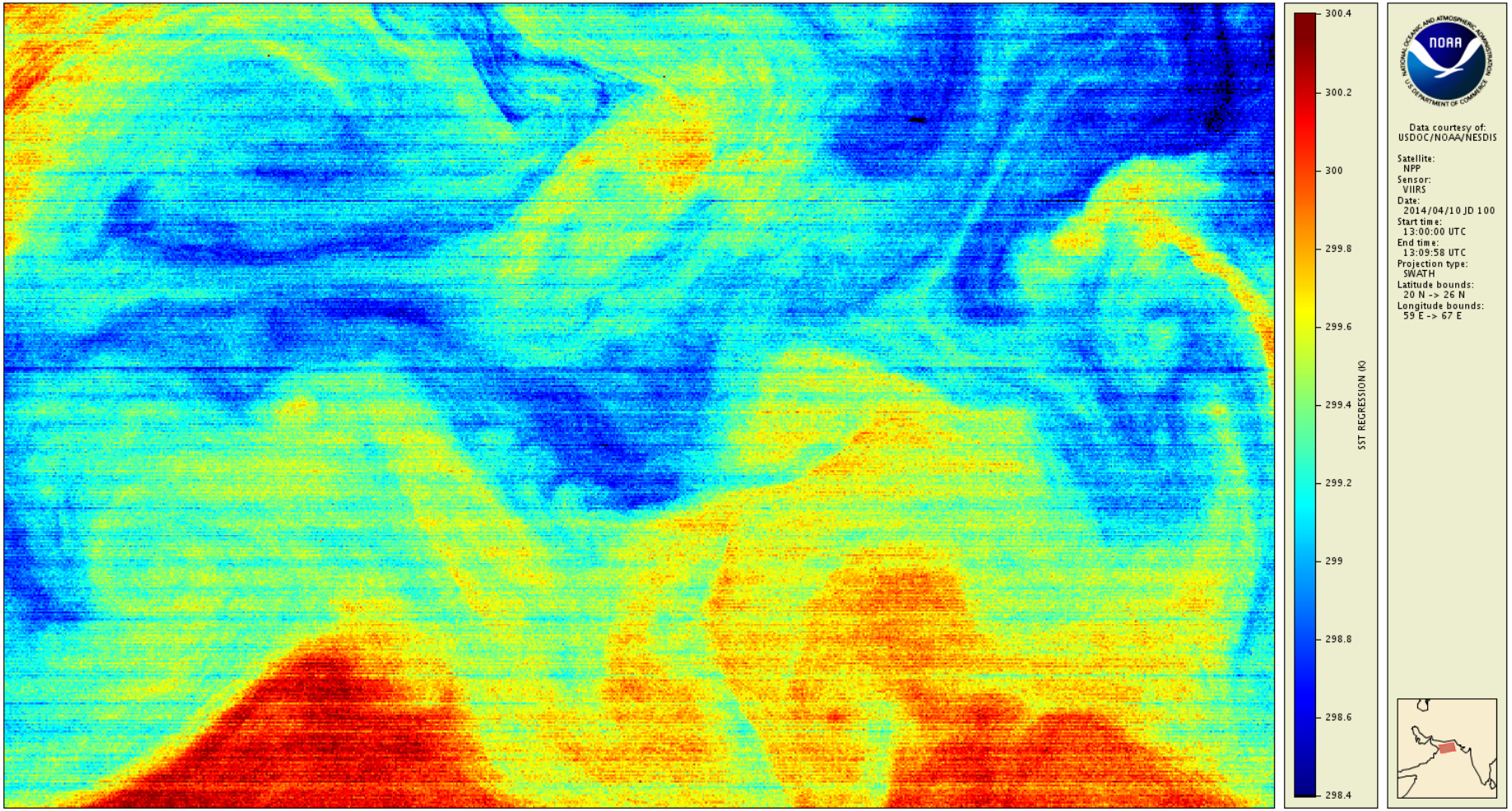
DAY – Original BT in VIIRS band M16 (12μm)



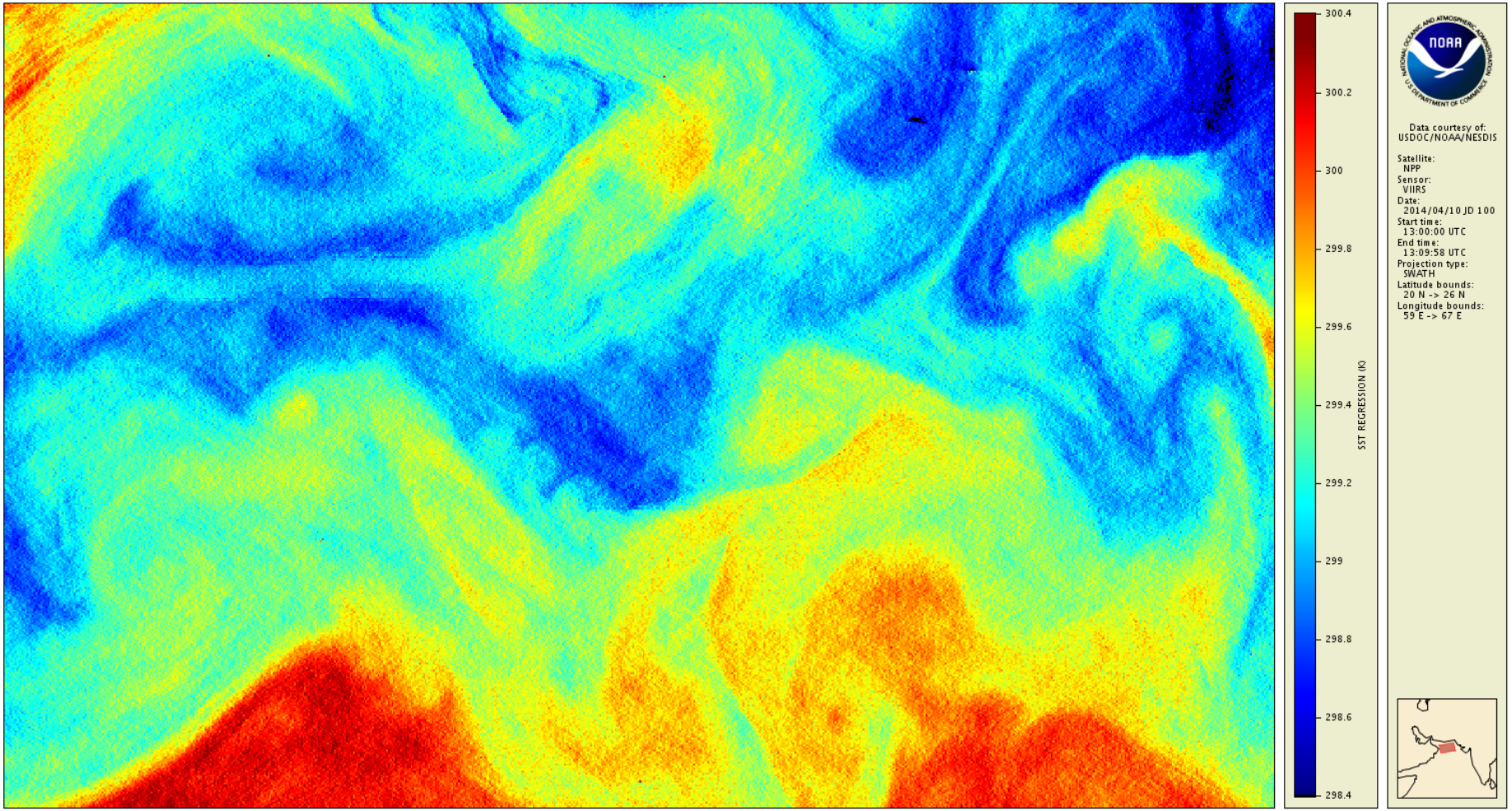
DAY – Destriped BT in VIIRS band M16 (12μm)



DAY – SST from original BTs in M15 and M16

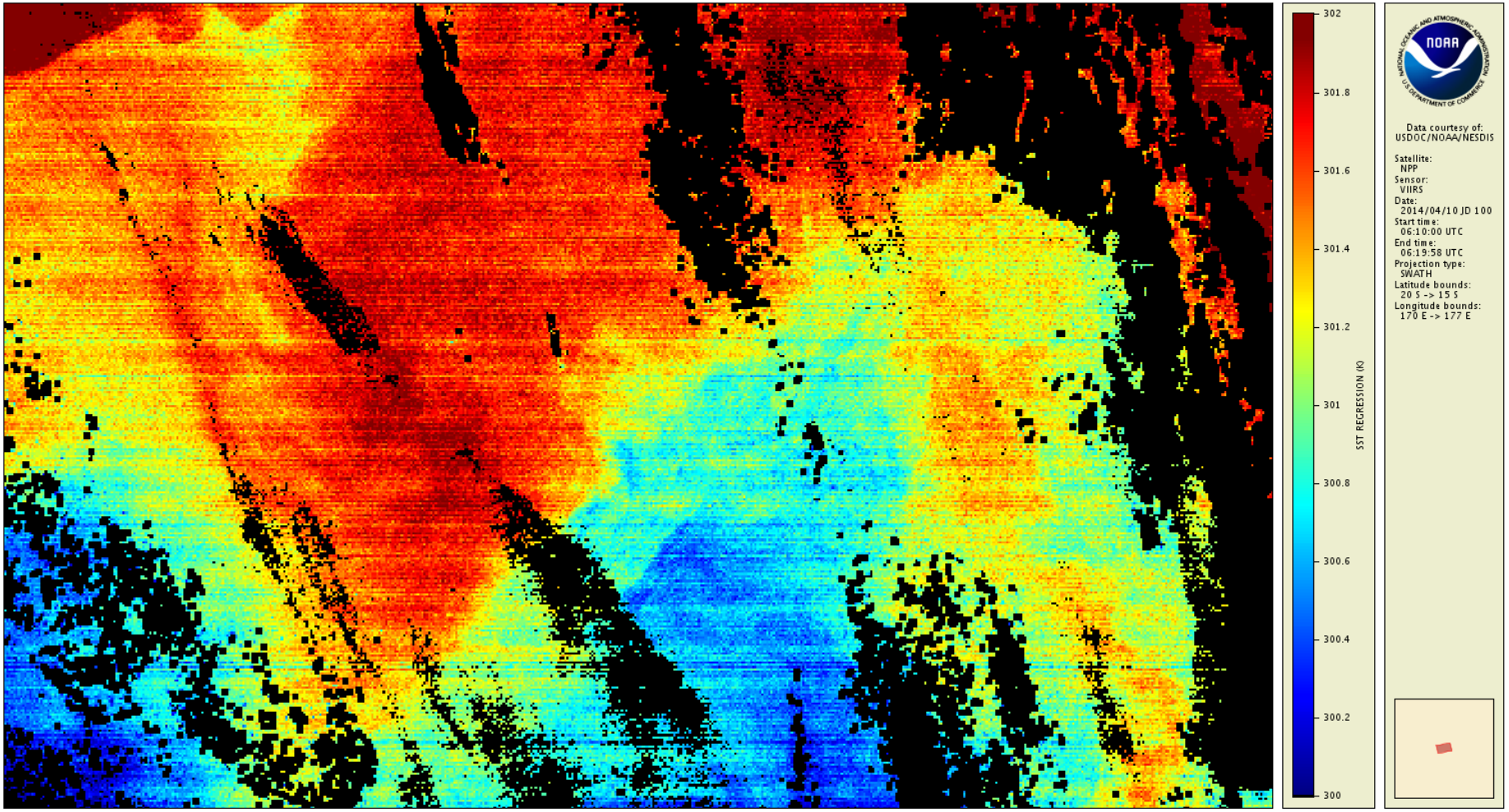


DAY – SST from destriped BTs in M15 and M16



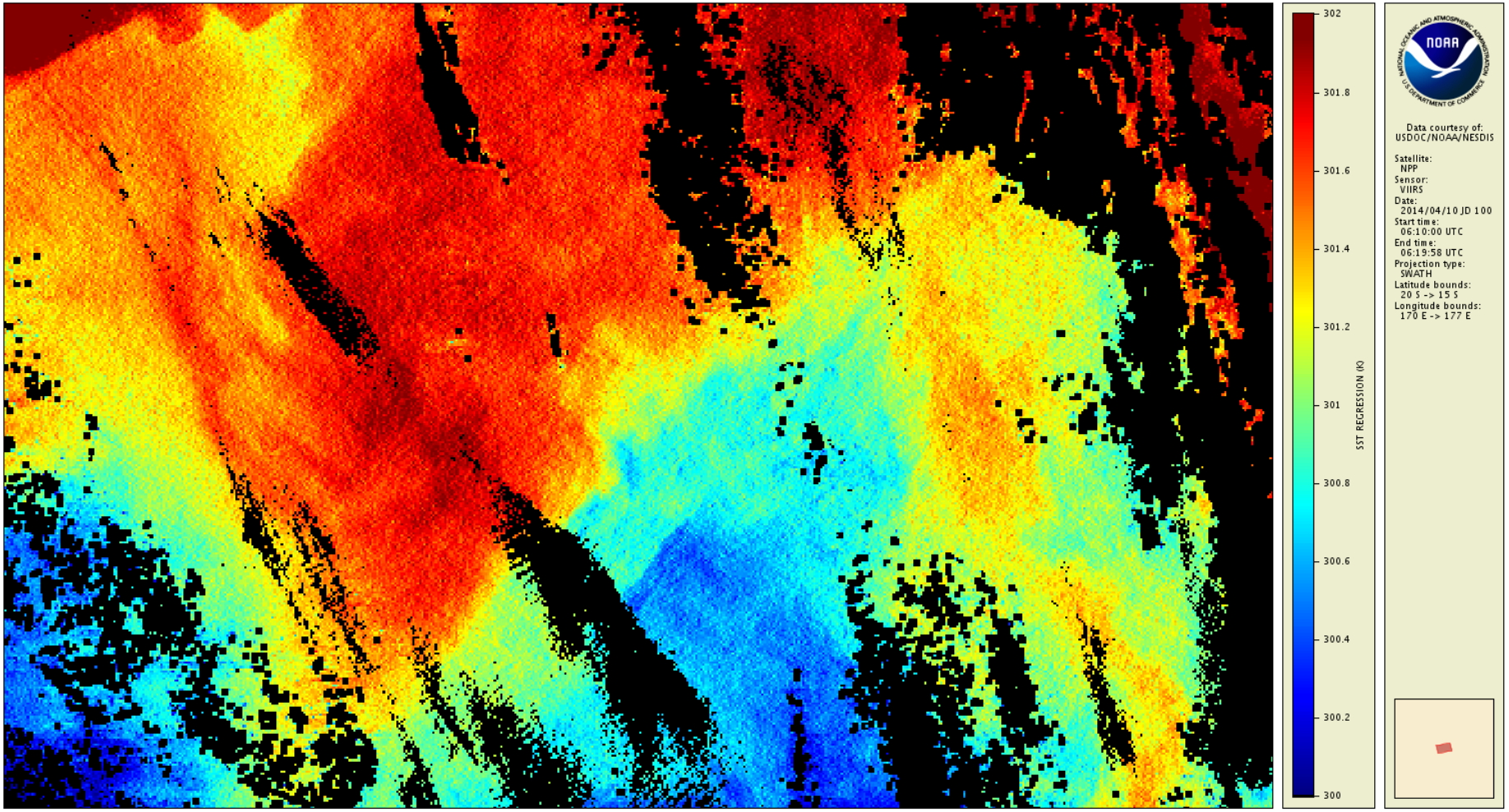
Effect of striping on ACSPO Clear-sky Mask

DAY – SST from original BTs – effect on cloud mask



Cloud mask identification affected by striping

DAY – SST from destriped BTs – effect on cloud mask



Striped artifacts in cloud mask removed

Performance – IDL vs C

	IDL	C
Test environment	Intel Xeon 3.5 GHz NVIDIA Tesla M2070 GPU gpulib, cuda libraries	Intel Xeon 3.5 GHz 8 threads fftw3, openmp libraries
Running times		
One day of VIIRS (M12, M15, M16)	6 hours	37 min
One day of MODIS (Aqua + Terra) Bands 20, 31, 32	6 hours	83 min
One day of VIIRS (M12, M15, M16) + MODIS (Aqua + Terra) Bands 20, 31, 32	**12 hours**	**2 hours**

- overall, C code is about 6 times faster
- I/O is a significant factor for C version: ≈25% time (VIIRS) and ≈40% time (MODIS)

Summary

1. Fast, operational production ready destriping code developed at NOAA
2. Capable of working with S-NPP VIIRS and Terra/Aqua MODIS
3. Initially prototyped in GPU-IDL (VIIRS: ×0.25; 2.5min/10min granule)
4. Now rewritten into C – 10 times faster than GPU-IDL for VIIRS (×0.025, 15sec/10min granule)
5. Implemented at STAR in experimental mode with Terra/Aqua MODIS – 4.5 times faster than GPU-IDL
6. Brightness temperature & SST imagery, ACSPO cloud mask, and SST gradients significantly improved

Next Steps

<u>Immediate</u>

1. Incorporate destriping code as a preprocessor for ACSPO VIIRS in NDE operations
2. Destripe “optional” IR bands (VIIRS: M13, M14; MODIS: B22, B23, B29)

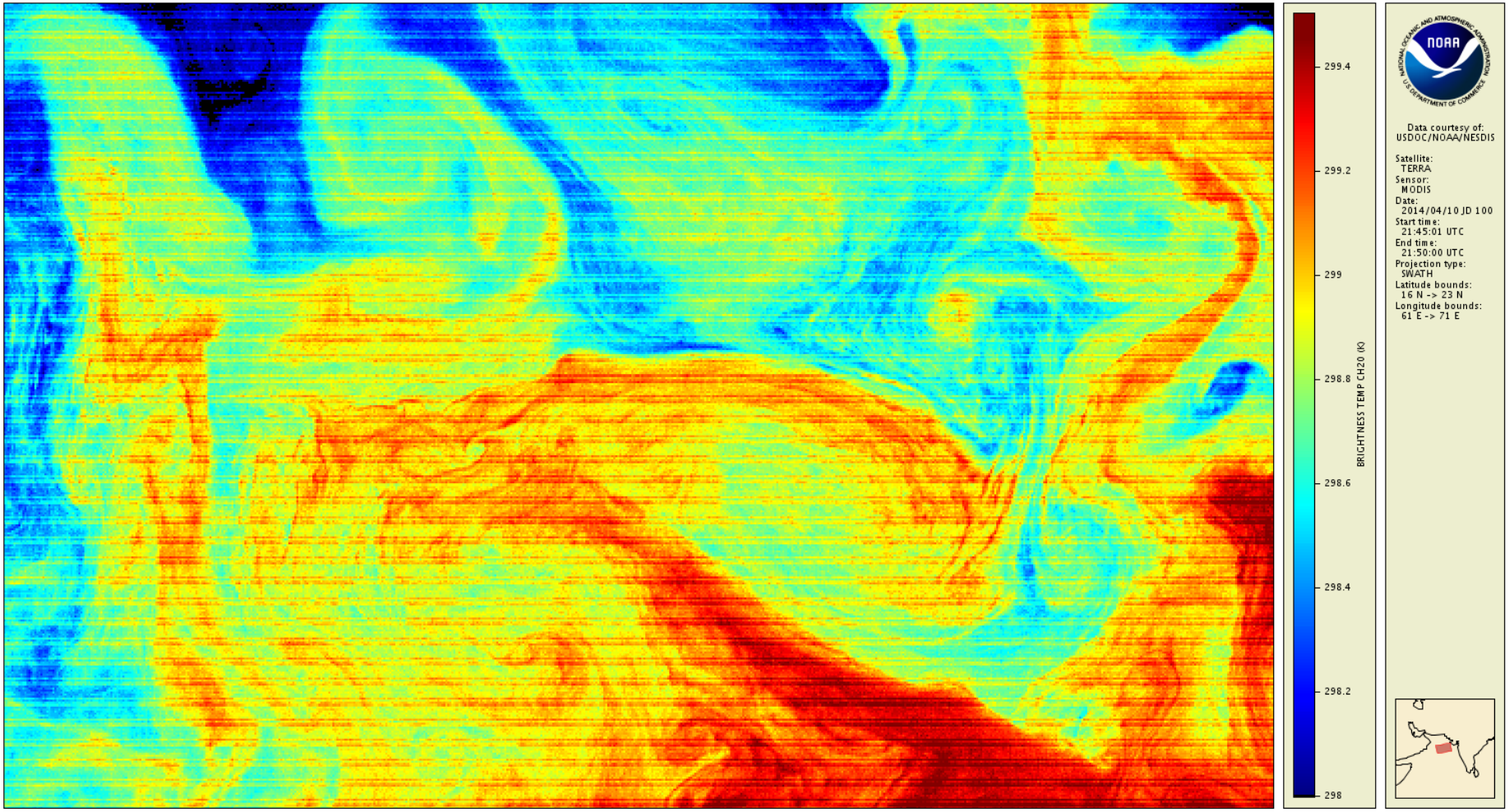
<u>Near term</u>

1. Destripe solar reflectances for ACSPO Clear-Sky Mask (VIIRS: M6/7; MODIS: B6/7)
2. Address saw-like modulations in glint areas (short wavelength bands, daytime)
3. Further optimize codes for reprocessing of historical VIIRS and MODIS data

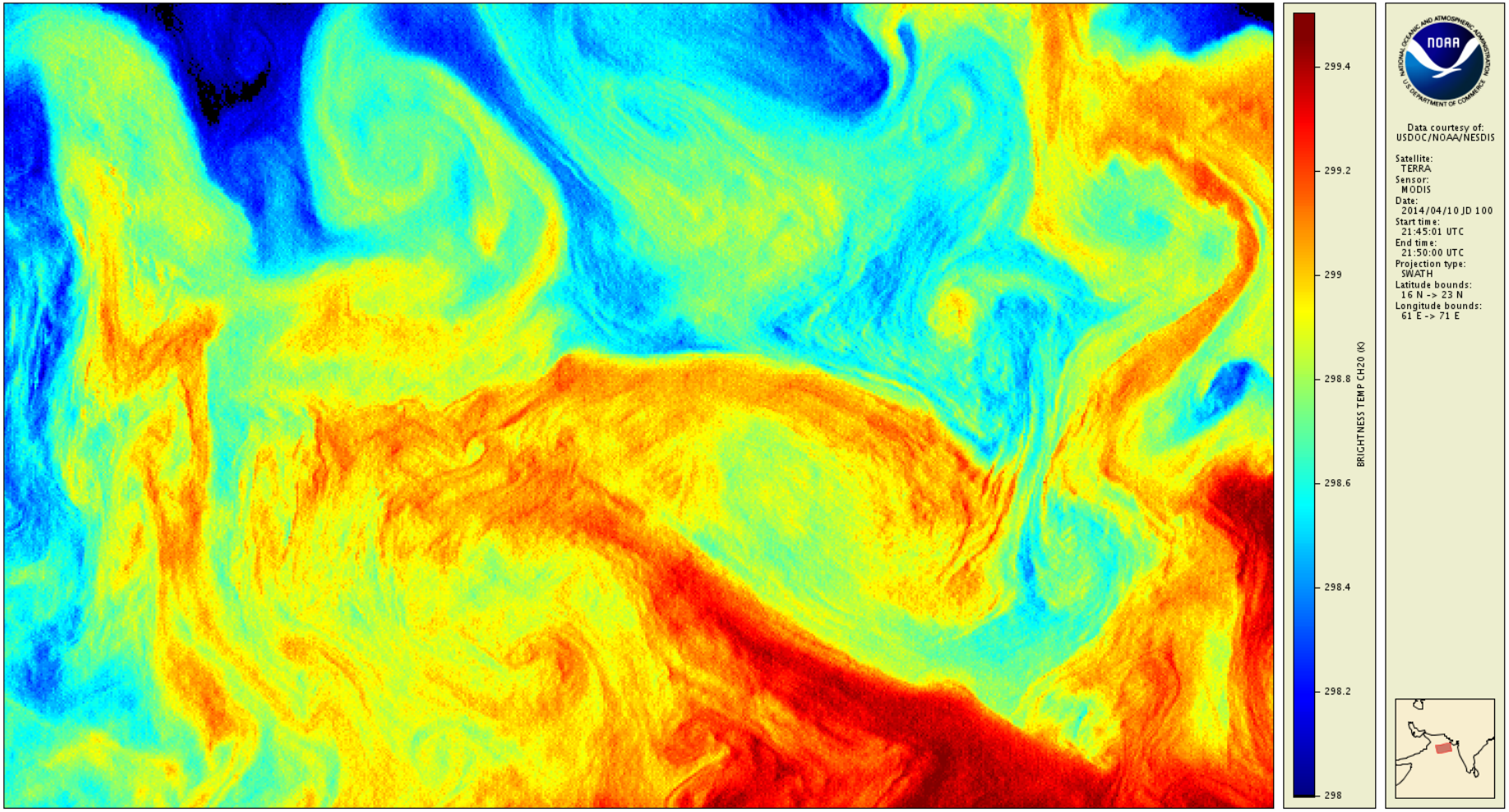
Back-Up slides

TERRA

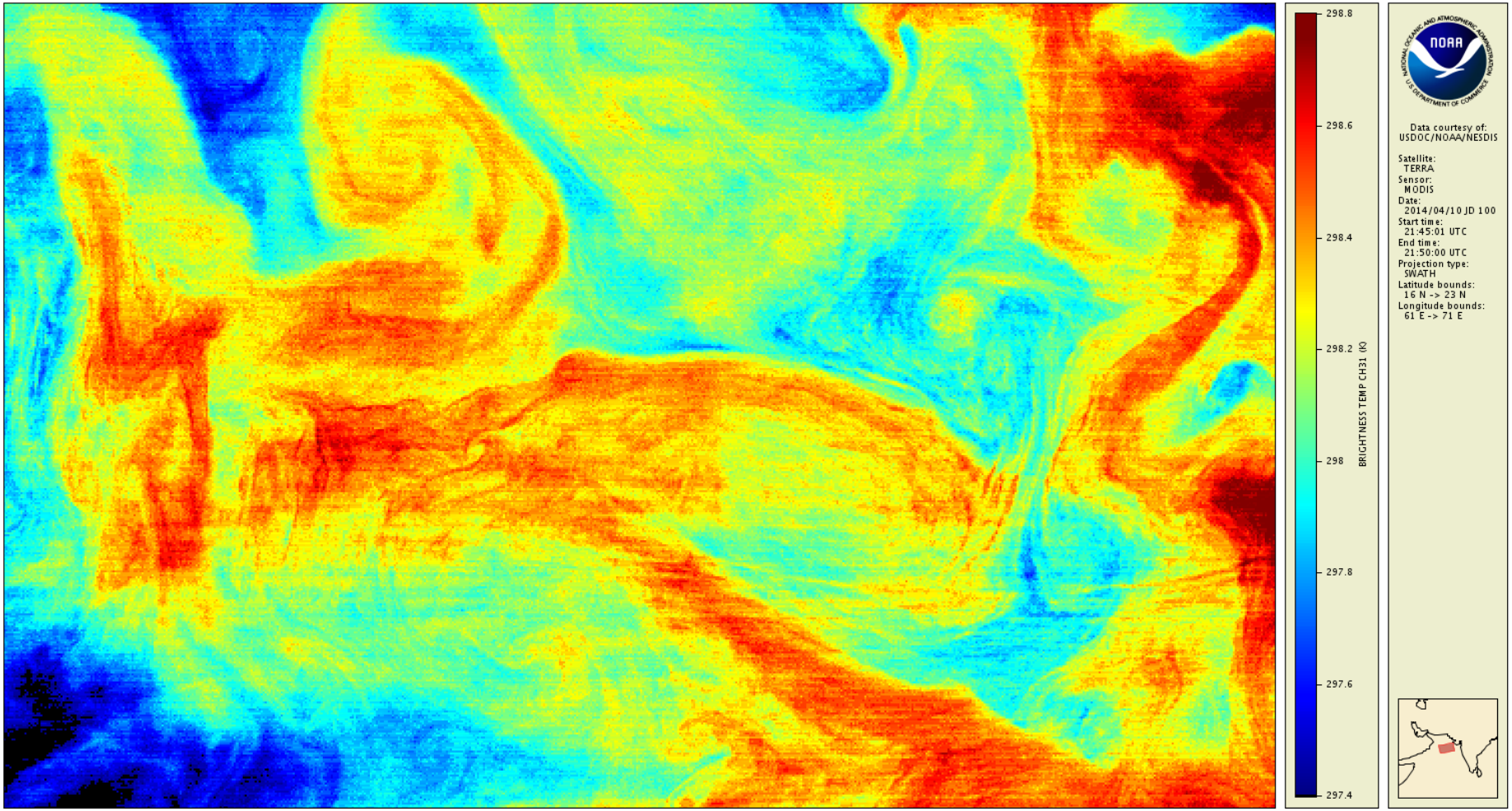
Results – MODIS Terra band 20 (3.75μm)



Results – MODIS Terra band 20 (3.75μm)



Results – MODIS Terra band 31 (11.0μm)



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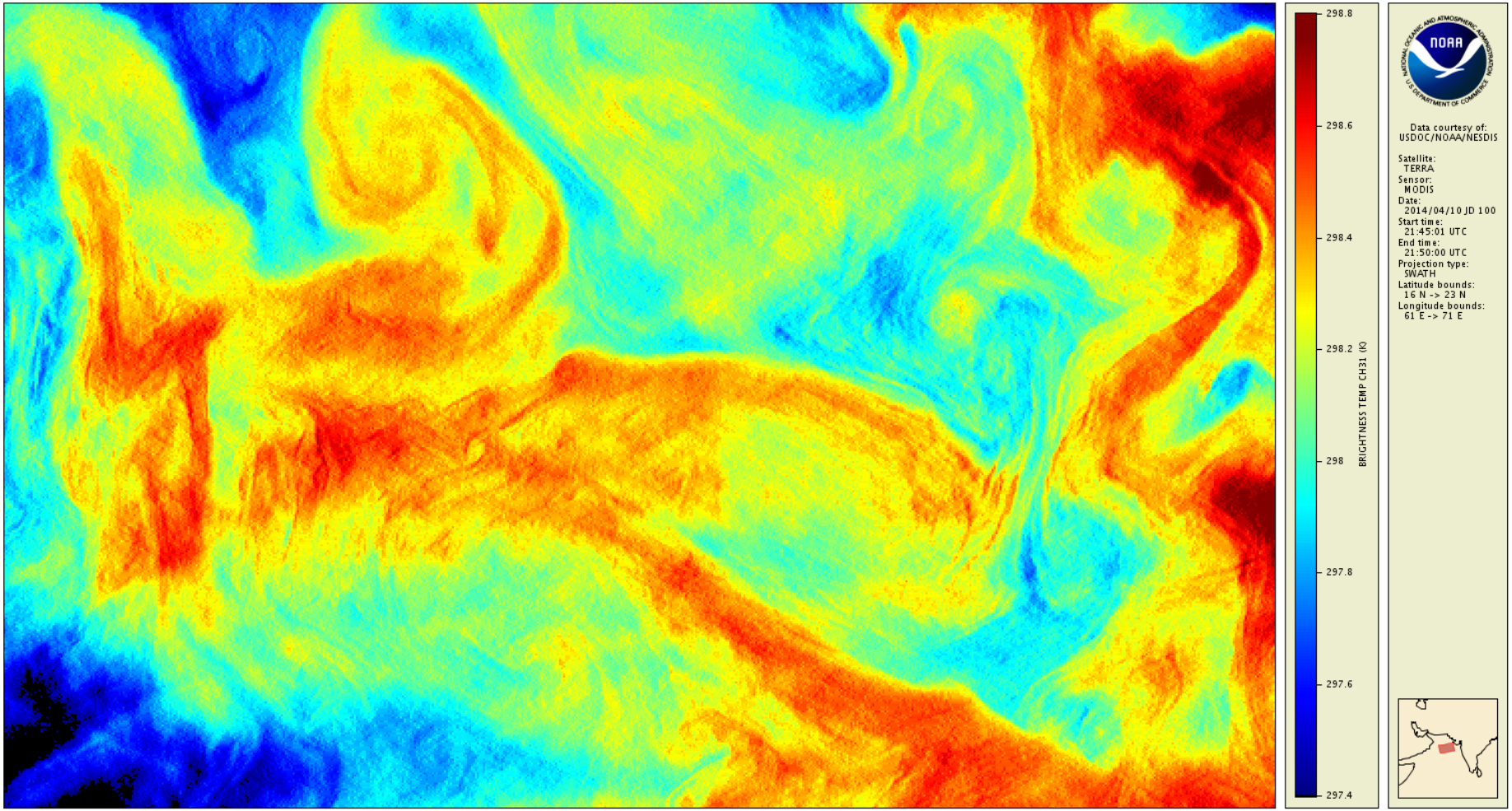

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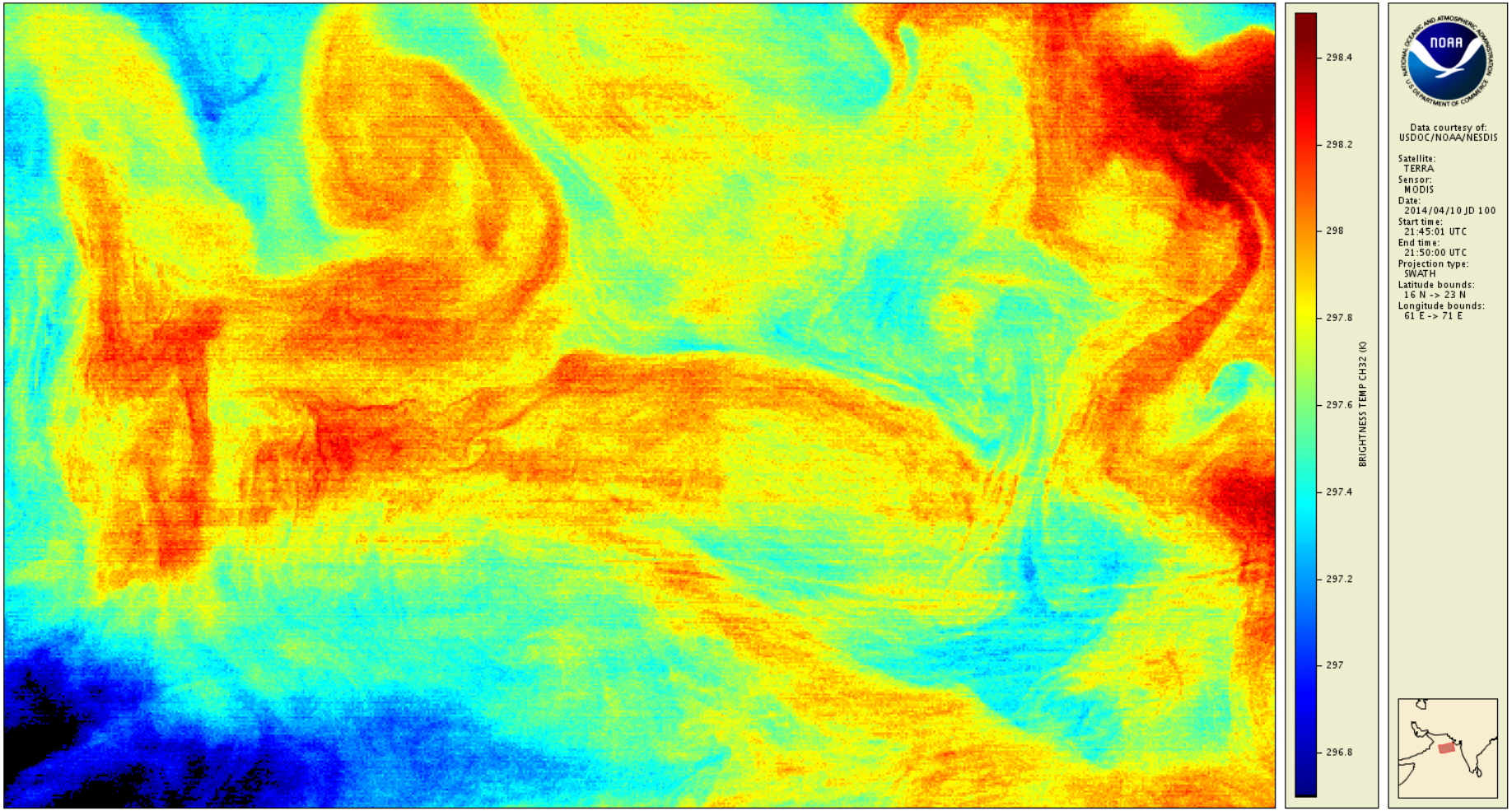

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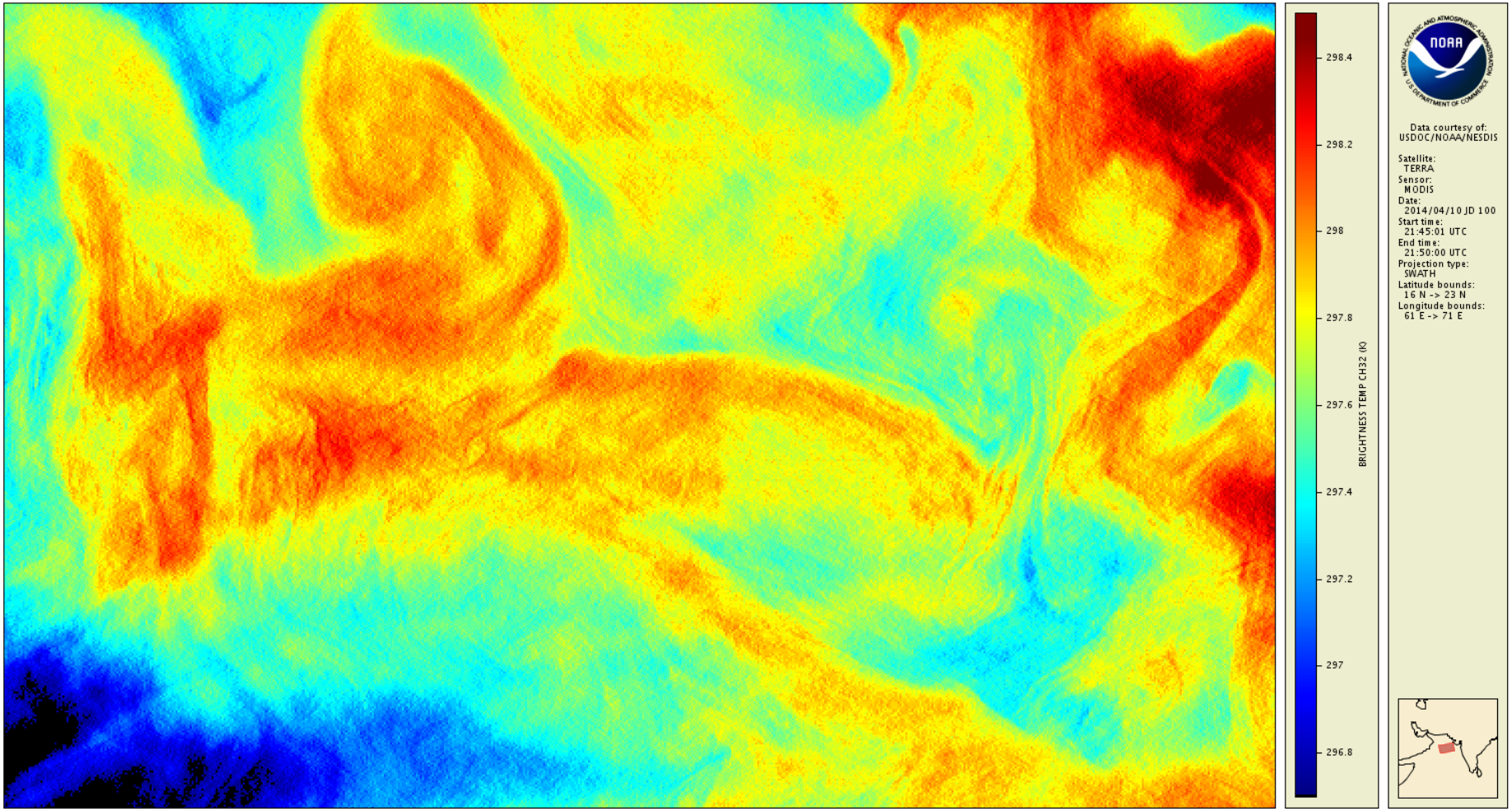
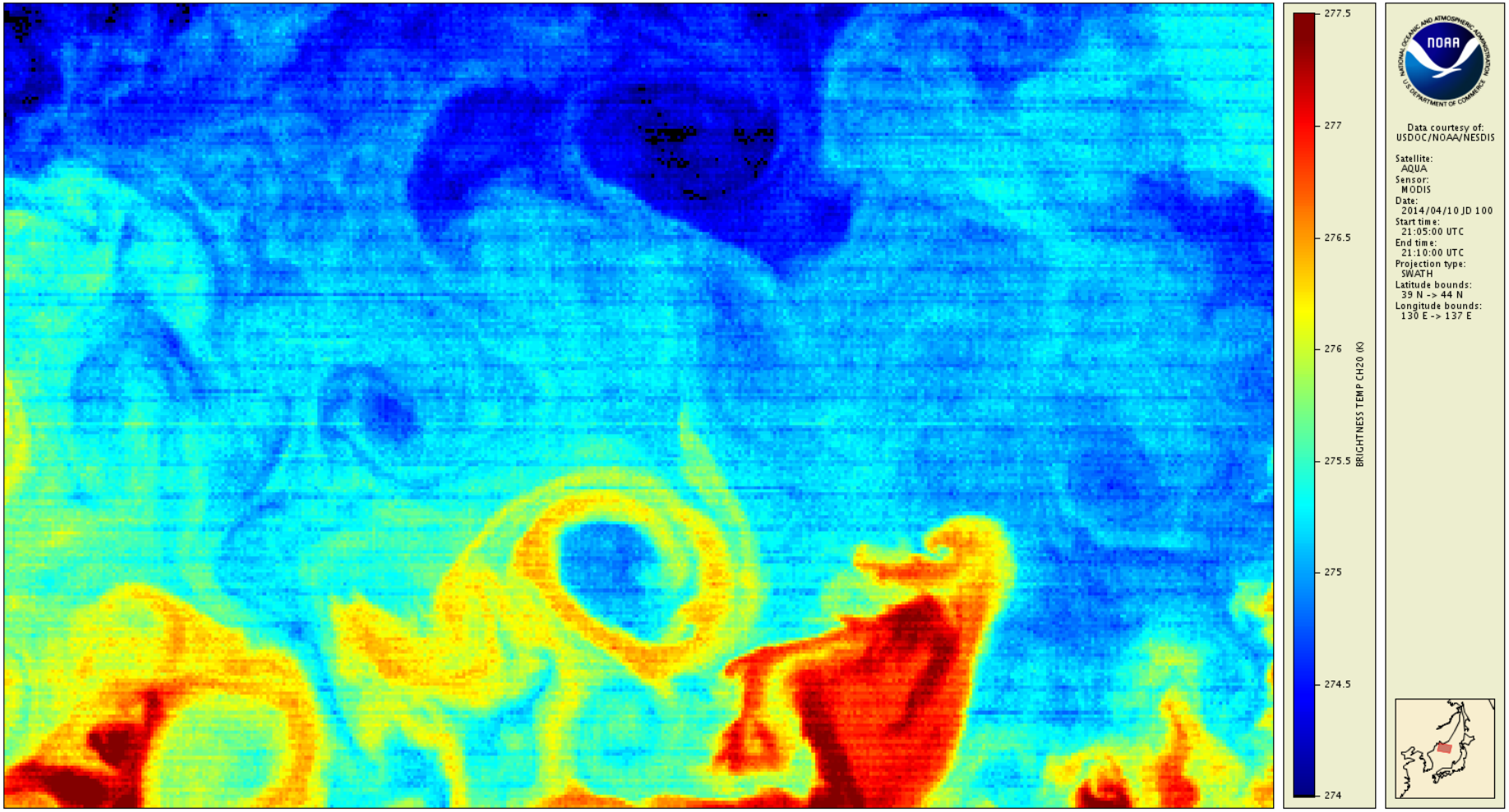
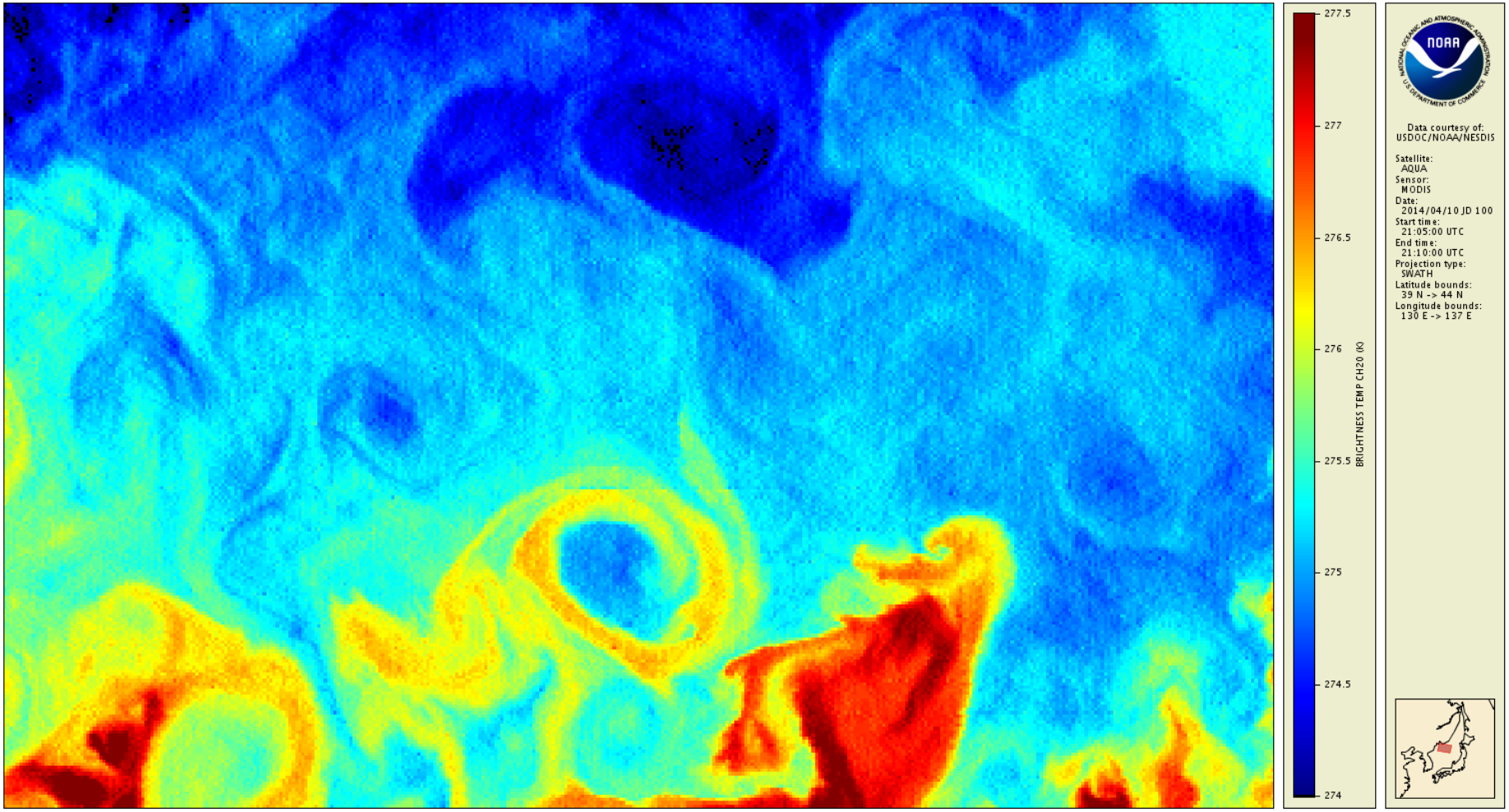


AQUA

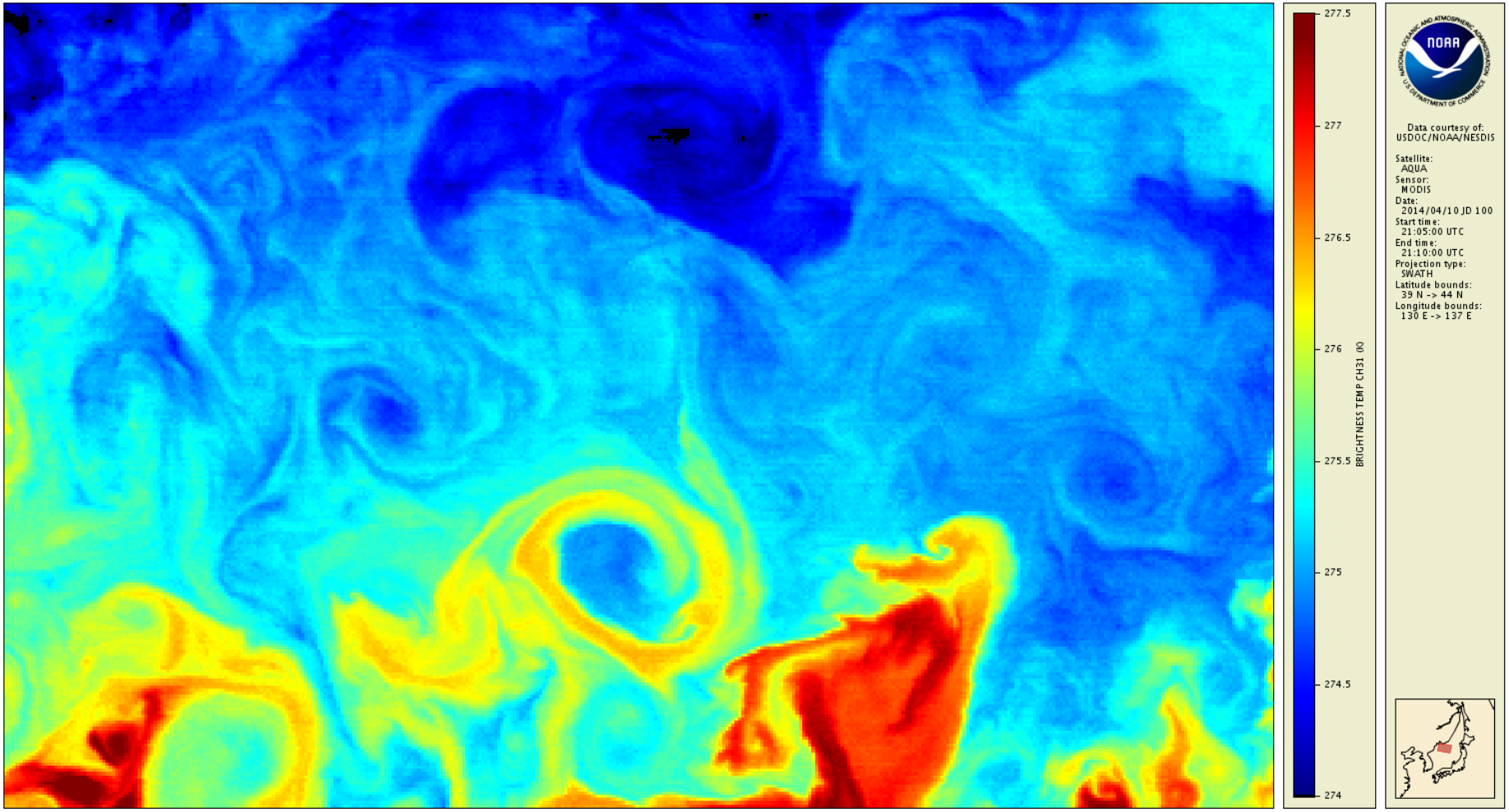
Results – MODIS Aqua band 20 (3.75μm)



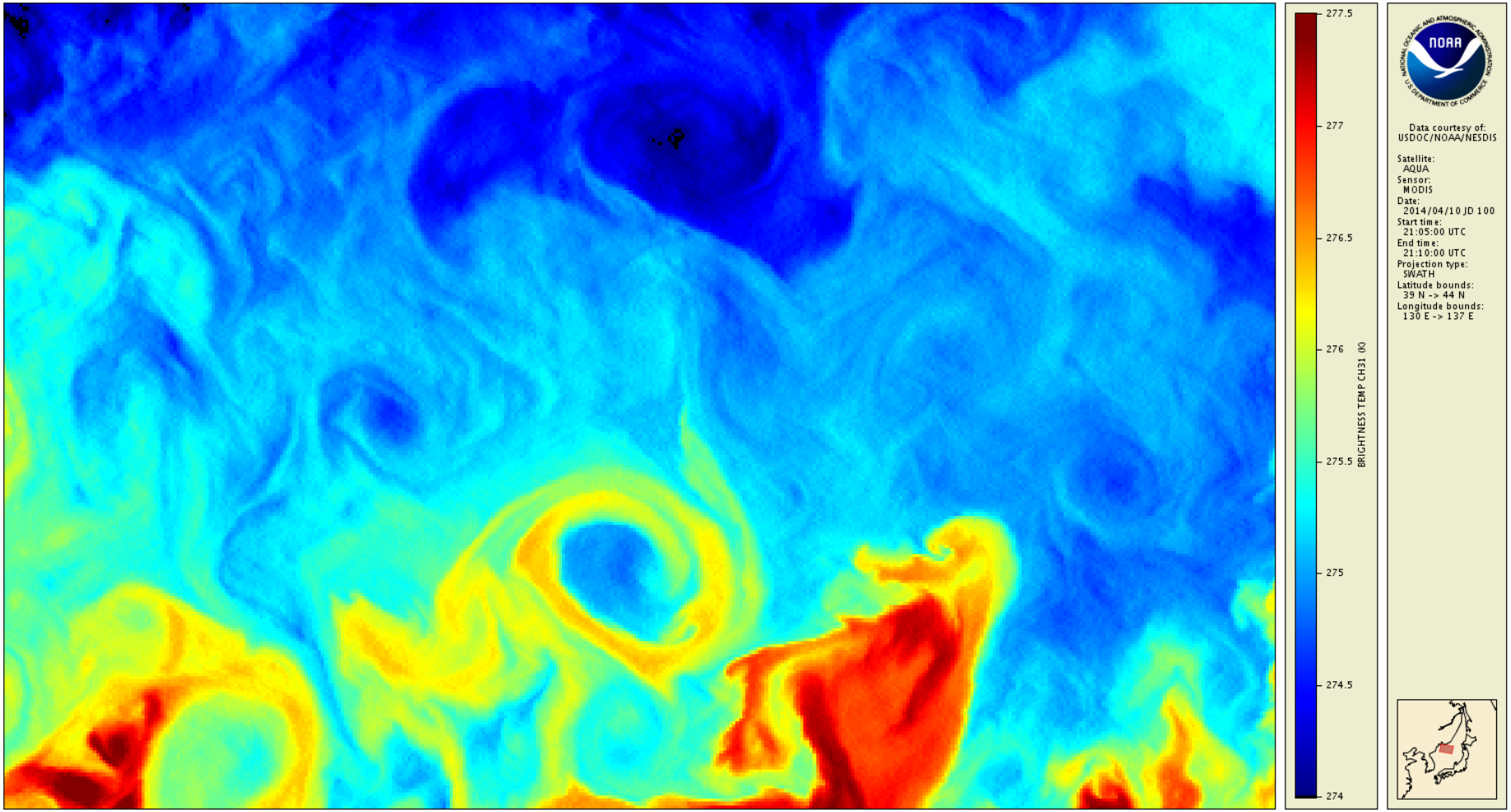
Results – MODIS Aqua band 20 (3.75μm)



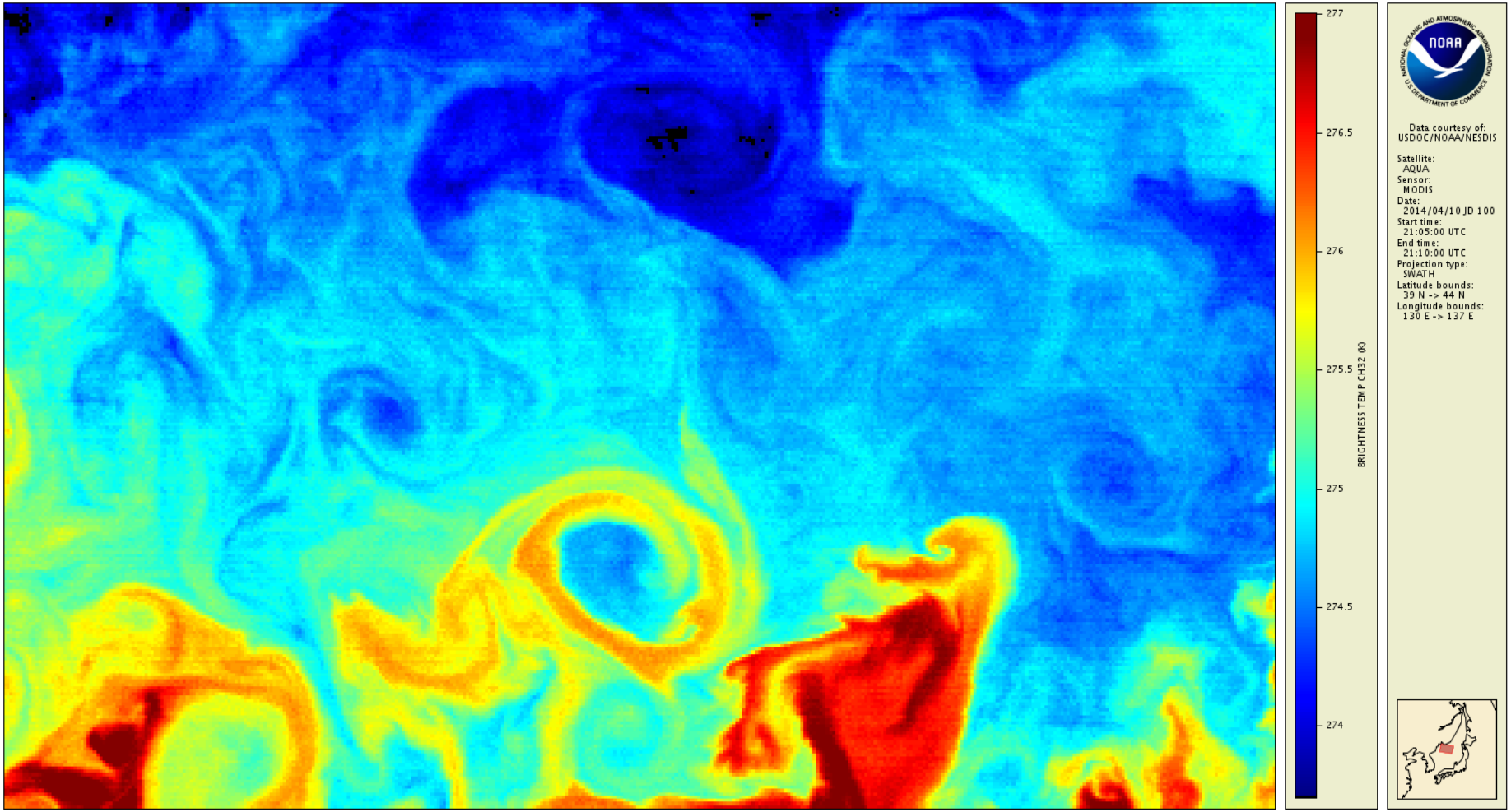
Results – MODIS Aqua band 31 (11.0μm)



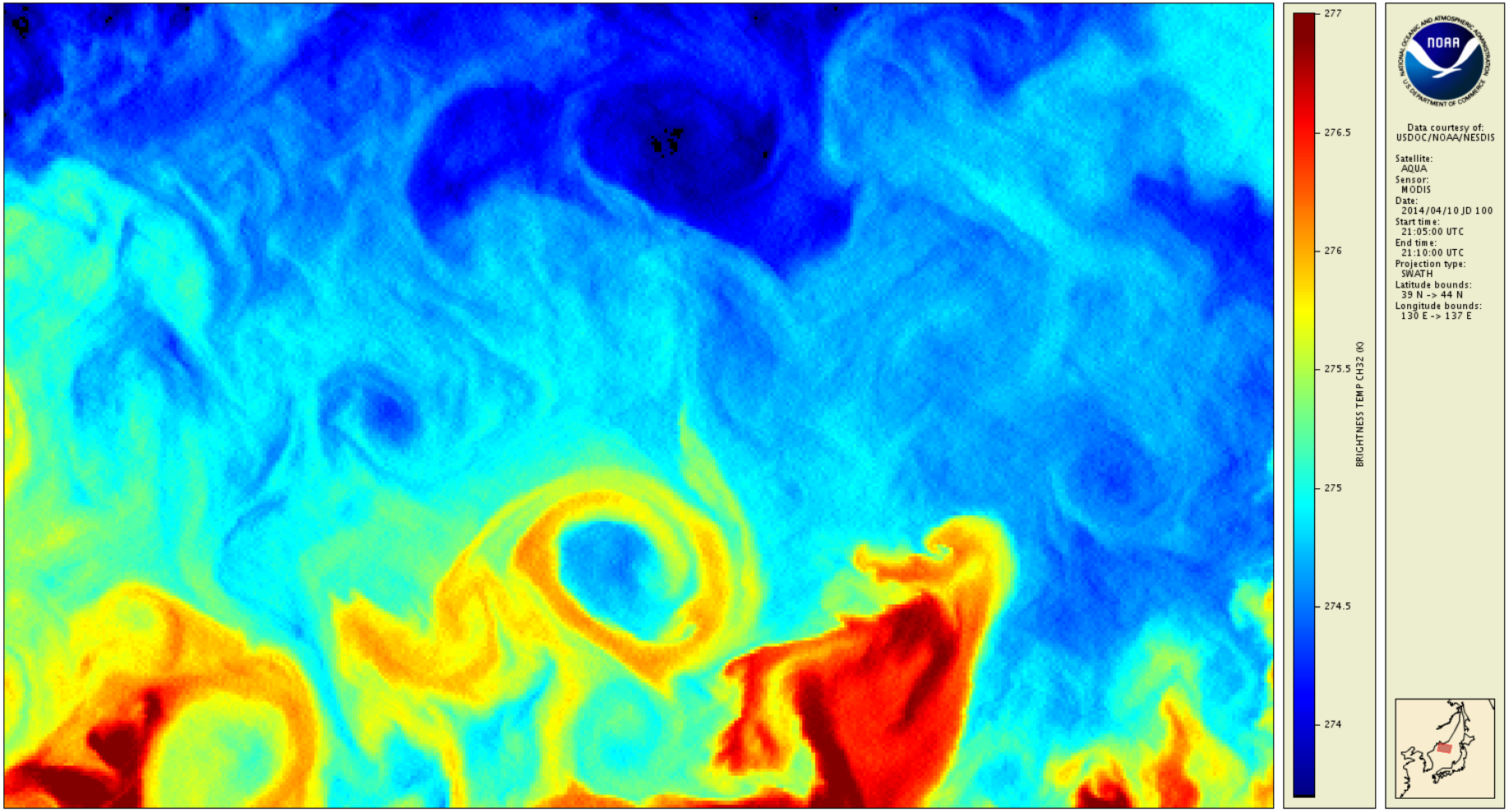
Results – MODIS Aqua band 31 (11.0μm)



Results – MODIS Aqua band 32 (12.0μm)

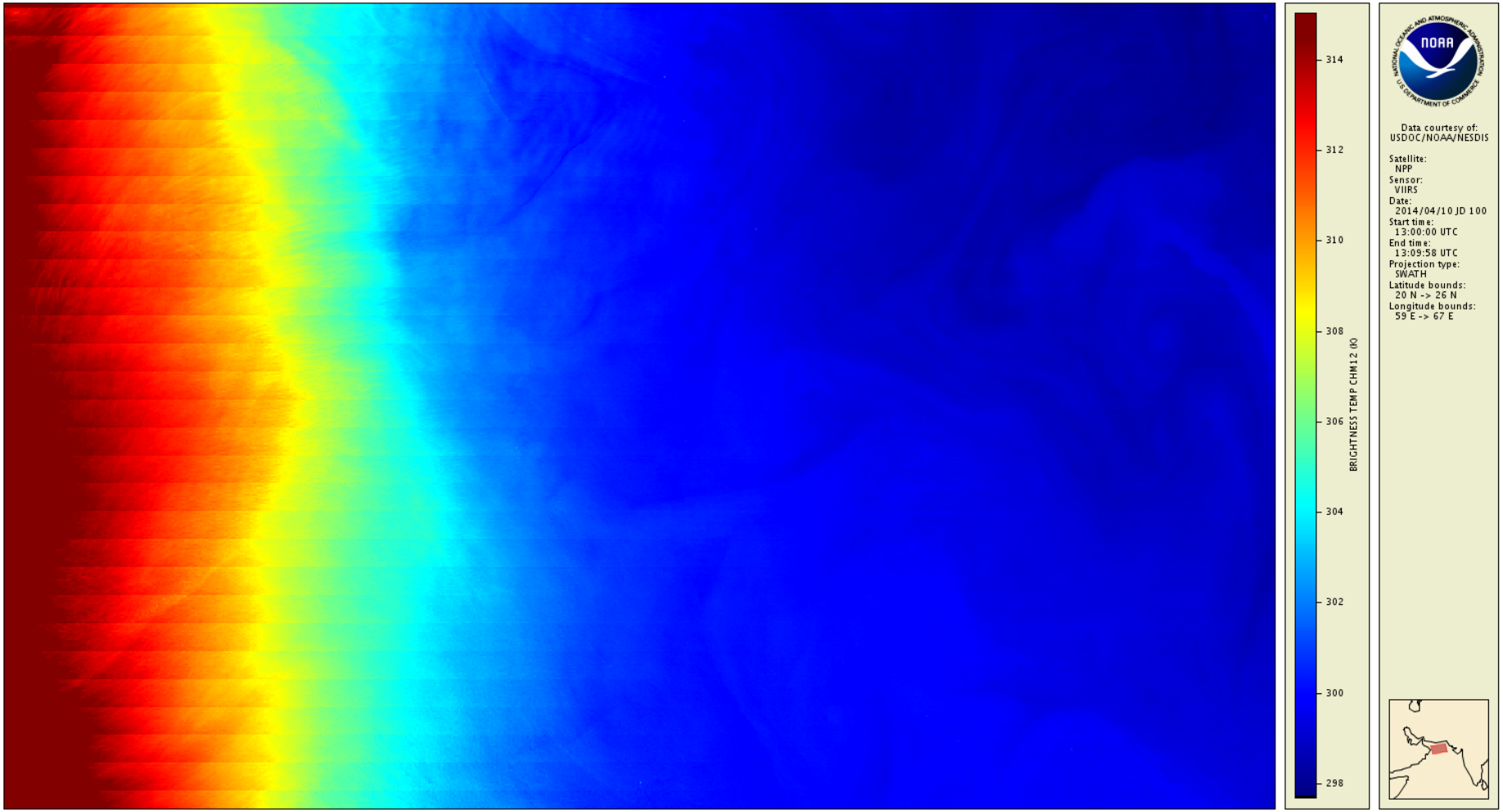


Results – MODIS Aqua band 32 (12.0μm)



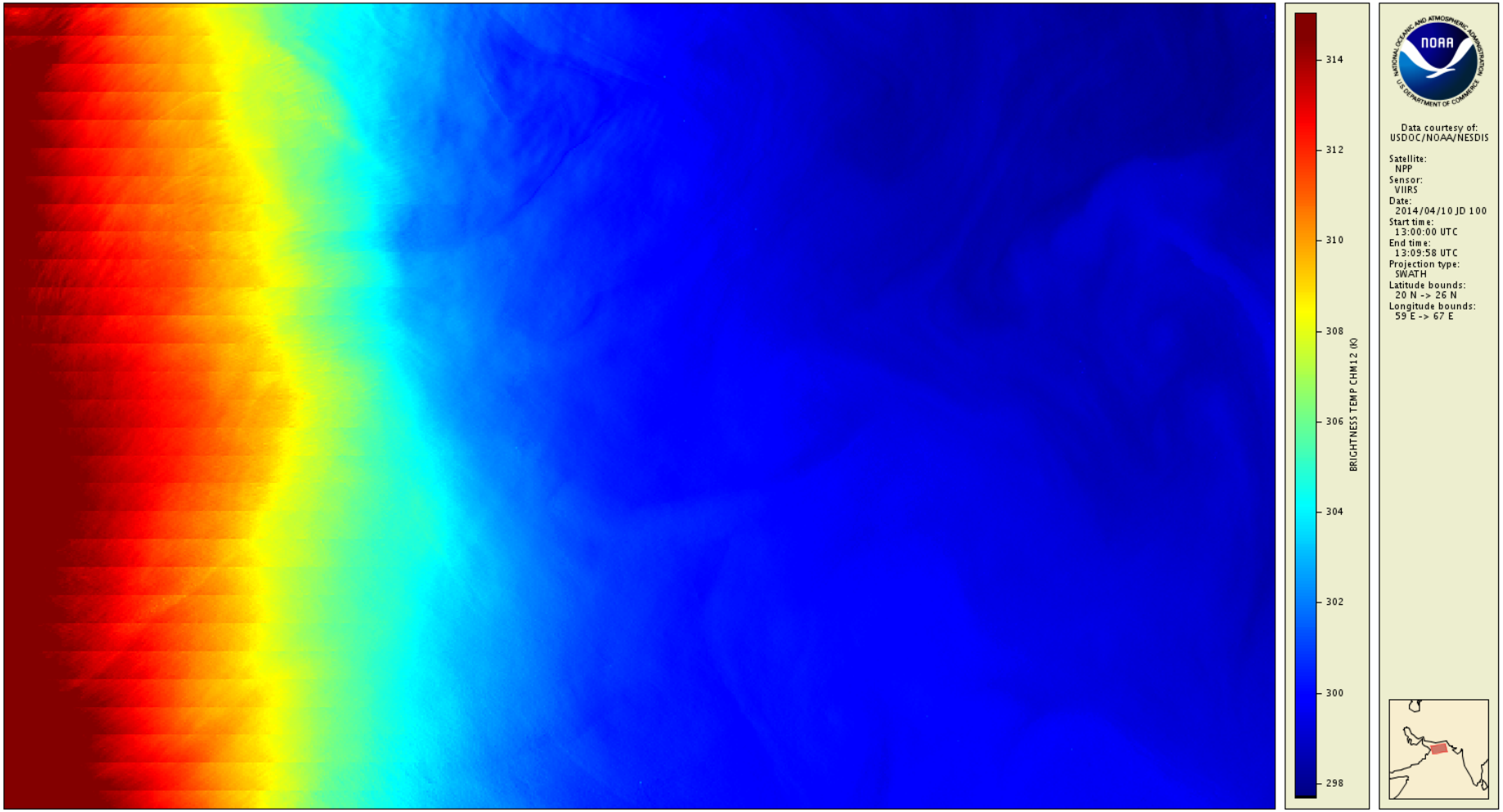
Saw-Like Structure in daytime M12

Results – VIIRS band M12 (3.7μm) – day (glint)



Striping in glint region primarily due to different viewing angle for detectors
Study: Q. Liu, C. Cao, F. Weng, *J. Atmos. Oceanic Technol.*, **30**, 2478-2487 (2013).

Results – VIIRS band M12 (3.7μm) – day (glint)



- Areas outside the glint region and onset of glint region are destriped
- High amplitude striping in the center of glint region is not removed