Estimating and Monitoring Effects of Area Burned and Fire Severity on Carbon Cycling, Emissions, and Forest Health and Sustainability in Central Siberia

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Cooperating Institutions

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Institute of Chemical Kinetics and Combustion, Siberian Branch, Russian Academy of Sciences, Novosibirsk, Russia

Russian Forest Service and Aerial Forest Protection Service (Avialesookhrana), Moscow, Krasnoyarsk, Yartsevo and Govorkovo

USDA Forest Service--
- Research and Development, Washington, DC
- Fire Sciences Laboratory, Missoula, Montana
- Sequoia National Forest, California

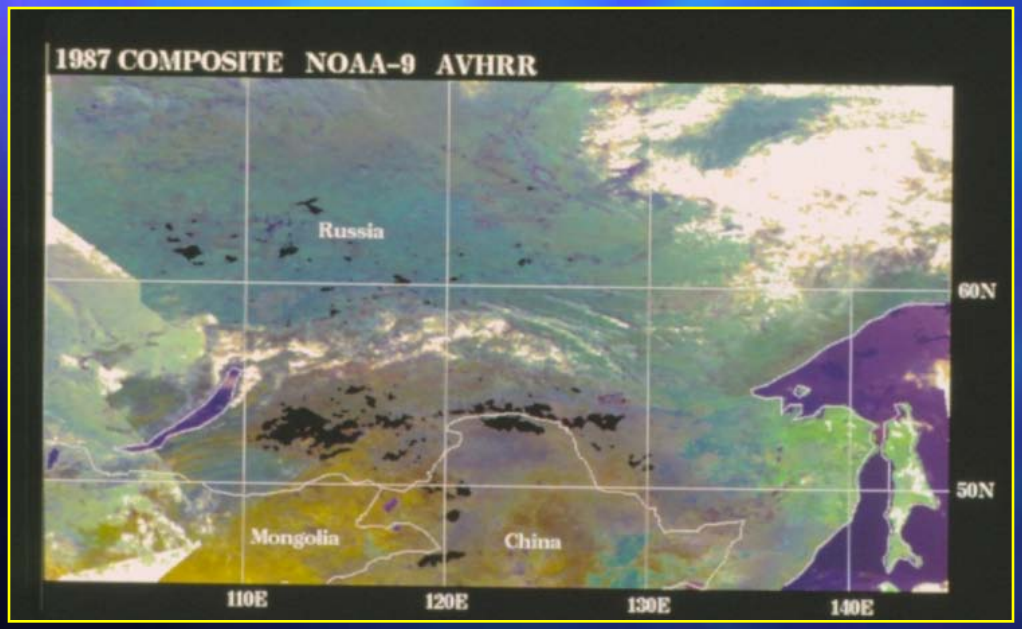
Canadian Forest Service, Sault Ste. Marie, Ontario, Canada

Background

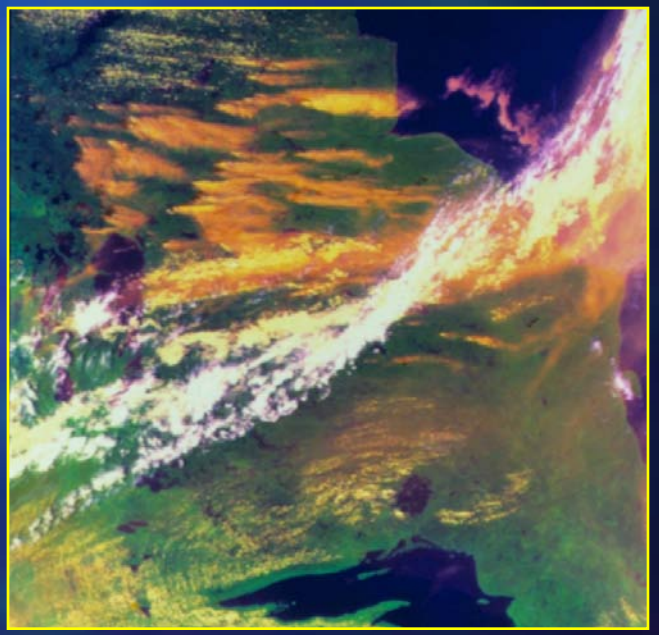
- Globally there are about 1.2 billion ha of boreal forest and woodlands
- Over 30% of global terrestrial biomass is in boreal forests, 2/3 of this in Russia.
- Wildland fire affects some 14 to 15 million ha of boreal forest annually.

Average burned areas, 1990-1999 (million ha)	
Canada	2.7
USA (w/o Alaska)	1.5
Russia	12.0

Siberia/Mongolia border

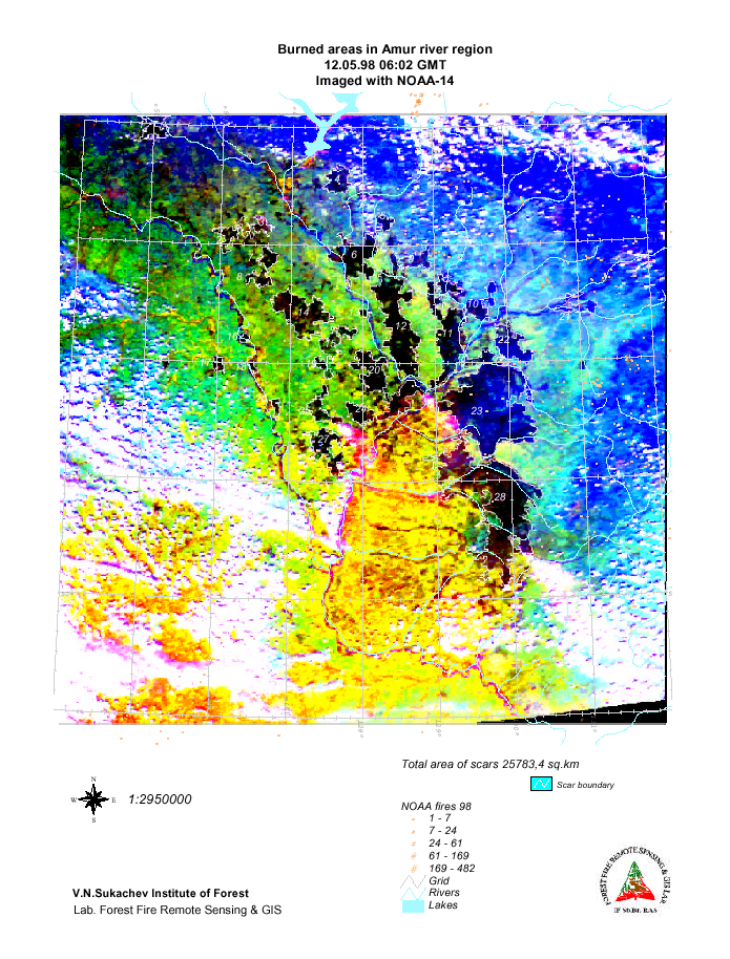


NW Ontario, Canada



Boreal Burned Areas and Emissions, 1998

	Burned Area (ha)	Emissions (Tg)
Russia	13.3 X10^6	135-190
North America	4.6 X 10^6	52-55
TOTAL	17.9 X 10^6	187-245



High-Latitude Fire Characteristics

Crown fire types (jack pine, spruce/fir)

- fast spread rates
- high degree of fuel consumption
- sustained high energy release rates
- towering convection columns
- upper troposphere/lower stratosphere injection

High-Latitude Fire Characteristics

Surface fire types (scotch pine, deciduous, some larch)

- Variable spread rates
- Low to moderate degree of fuel consumption
- Short fire return interval
- Crown fires under severe conditions
- Fuel accumulation may be an issue
- climate change/carbon budget implications

Fire in the Russian Boreal Forest

- F ually in Russian bor r.
- F ominated by sur d severity of sur ars and among regions; again, sta
- Few data are av rity to effects on emissio se and recovery.
- Emissions from c hose from low-severity surface fire.

Fire in the Russian Boreal Forest

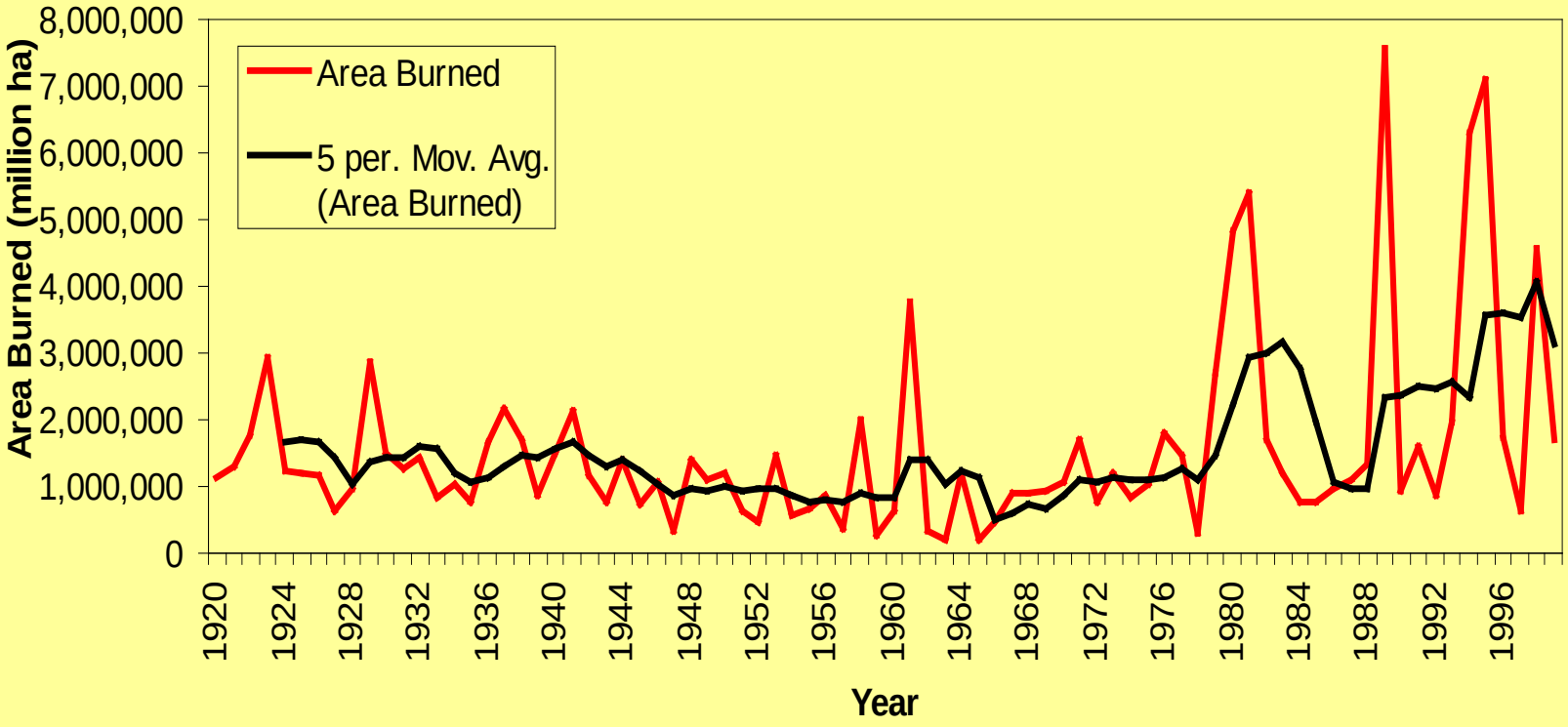
- Perhaps 12 million ha burn annually in Russian boreal forest, but statistics are poor.

- Fires in the Russian boreal are dominated by surface fire, but the percentage and severity of surface fire vary greatly among years and among regions; again, statistics are poor.

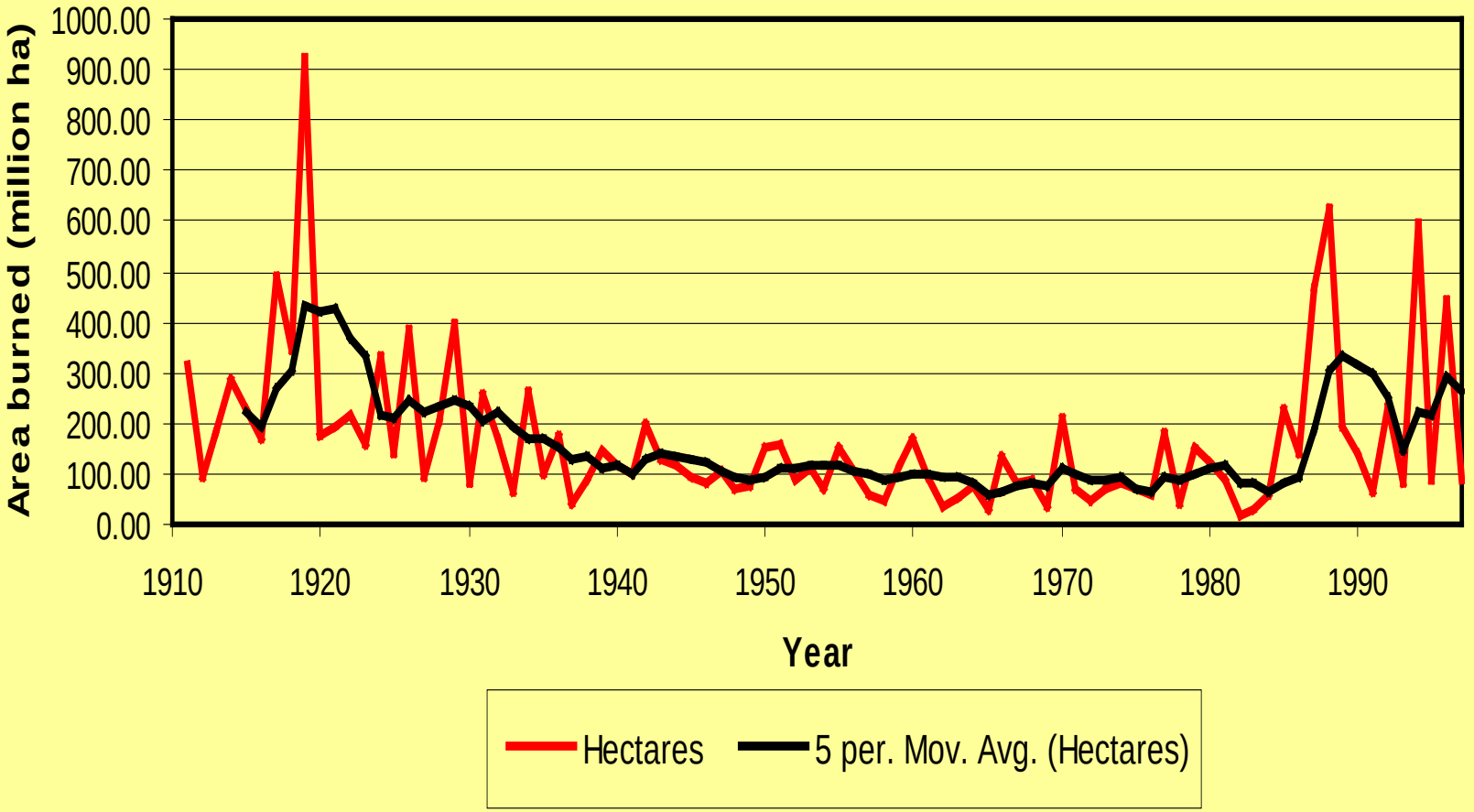
- Limited data available linking fire severity to effects on emissions or ecosystem response and recovery.

- Emissions from crown fire could be 10X those from low-severity surface fire.

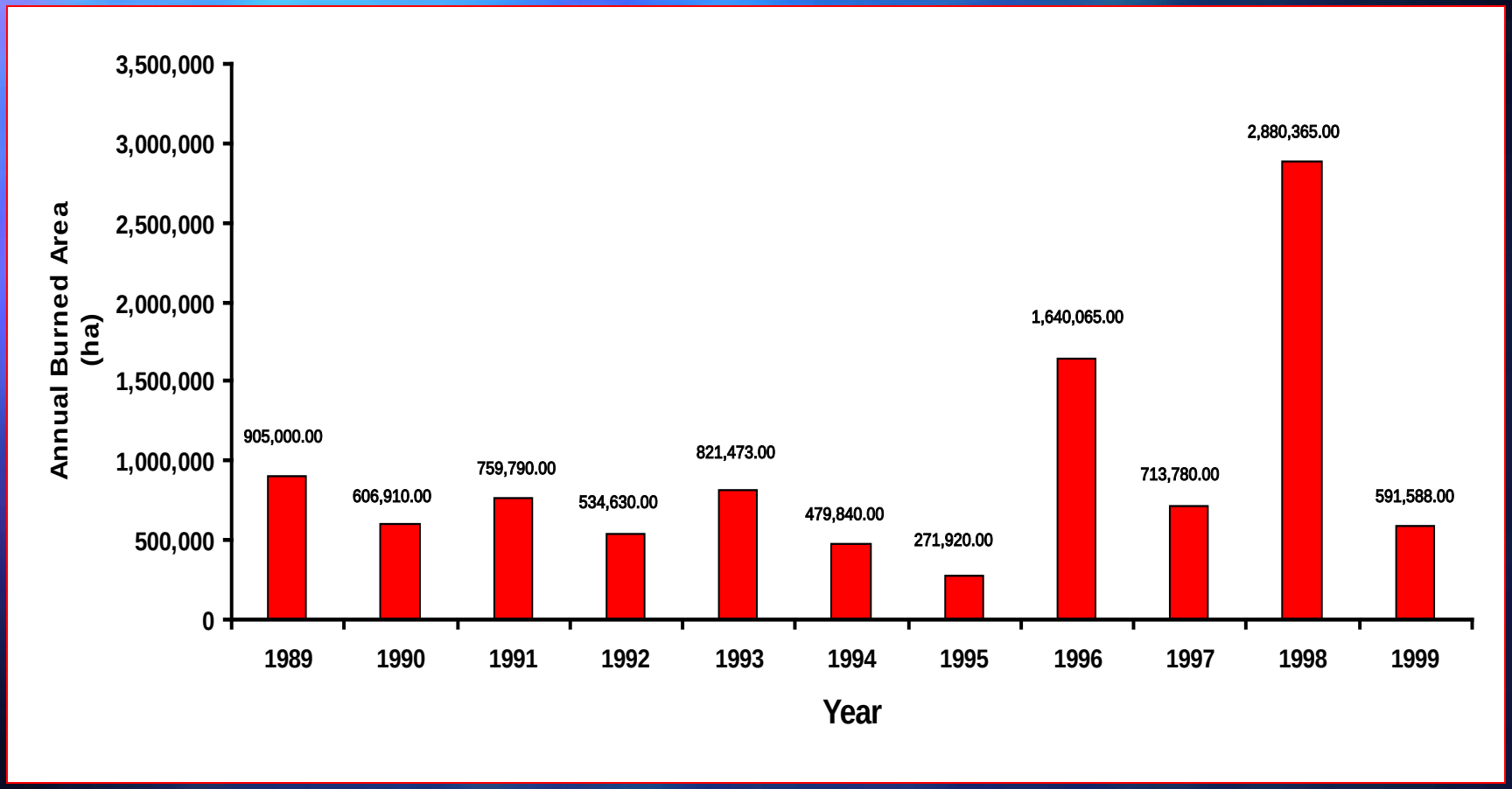
Annual Area Burned in Canada



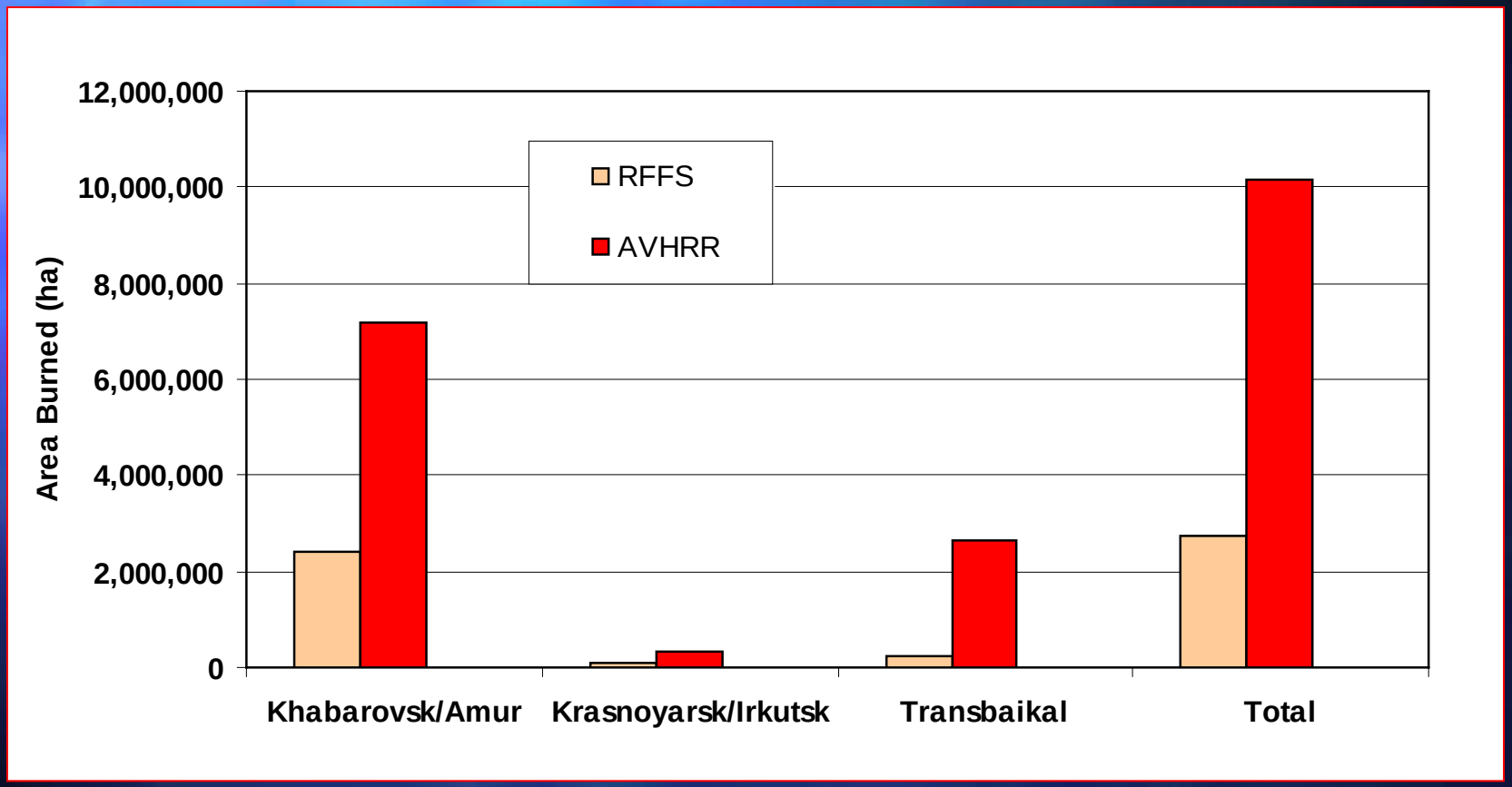
Annual area burned on USFS Land



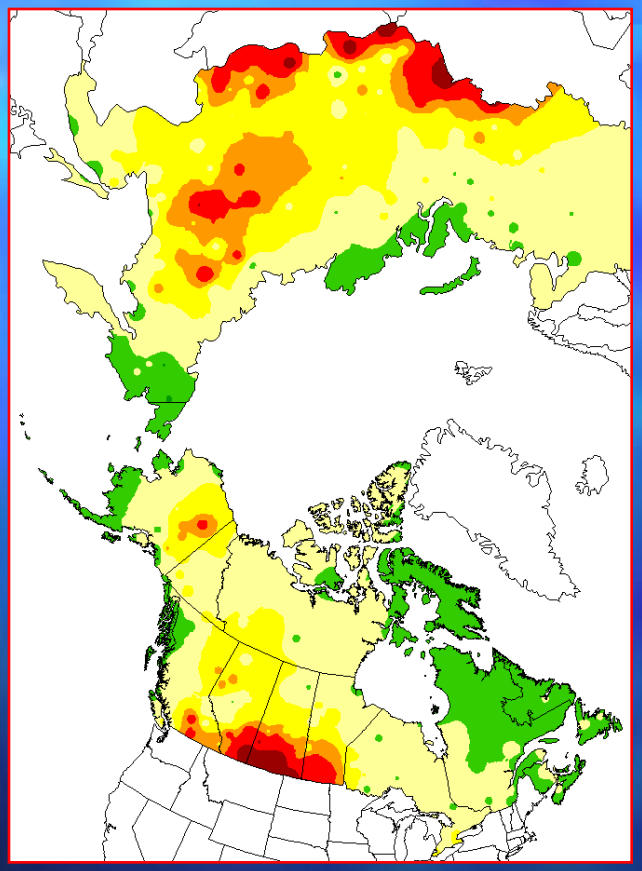
Estimated annual area burned in wildfires for non-European Russia



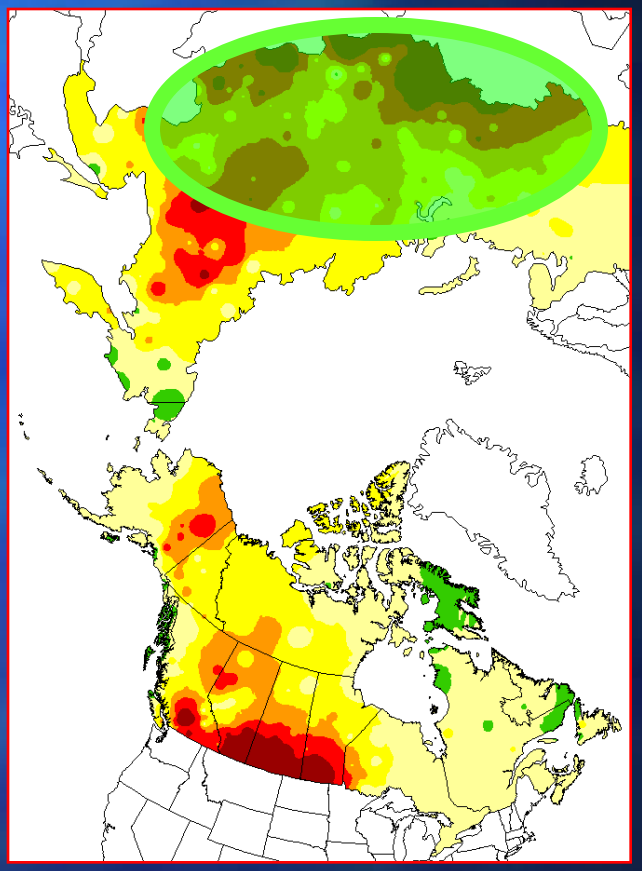
A comparison of annual burn area estimates for 1998: remote sensing data vs. Russian estimates



Potential Effect of Climate Change on Fire Hazard in the Boreal Zone



Historical Fire Weather



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Ecosystem and Carbon Cycle Monitoring Needs

- Ability to accurately monitor and model extent, severity, and effects of fire will be crucial for assessing impacts of boreal forest on global carbon cycles and effects of fire on forest health and sustainability.

- Changing climate or management practices have great potential to alter the amount and severity of fires in these ecosystems.

- Such changes would affect forest health and productivity, and could have substantial impacts on global carbon balance.

Research Goals

- Develop and validate methods for remote-sensing-based estimates of fire areas and fire severity and intensity for forests of Central Siberia through multi-stage sampling

- Gather quantitative data and develop models on effects of fire severity on fire emissions, carbon cycling, and ecosystem processes.

- Combine experimentally derived process data and models with remote-sensing to develop regional estimates of fire areas, fire severity, and the impact of fire on carbon balance, emissions, and forest health.

Research Approach

- Combine multi-scale satellite, aircraft, and ground data, to test and improve on current AVHRR-based approaches for estimating the spatial extent of fires and to develop and validate methods to estimate spatial patterns of burn severity.

- Use ground data from replicated experimental fires to quantify and model impacts of fire severity and seasonality on fire behavior, emissions, carbon storage, fuel dynamics, and ecosystem damage and recovery.

- Refine regional estimates of fire impacts on fuel dynamics, ecosystem processes, and carbon and trace gases by linking models developed from experimental data to spatial estimates of extent, intensity, and timing of fires.

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(Russian FIRE BEAR Project)

Results for 2001


2001 Field Program

(4 ha plots - 200x200 m)

Plot 3 - July 23, 2001

Plot 3 - July 26, 2001

Low-intensity fires

Plot 19 - July 28, 2001

Plot 6 - July 30, 2001

Comparison between the high-intensity fire of 2000

Plot 14 - July 18, 2000

Low

High

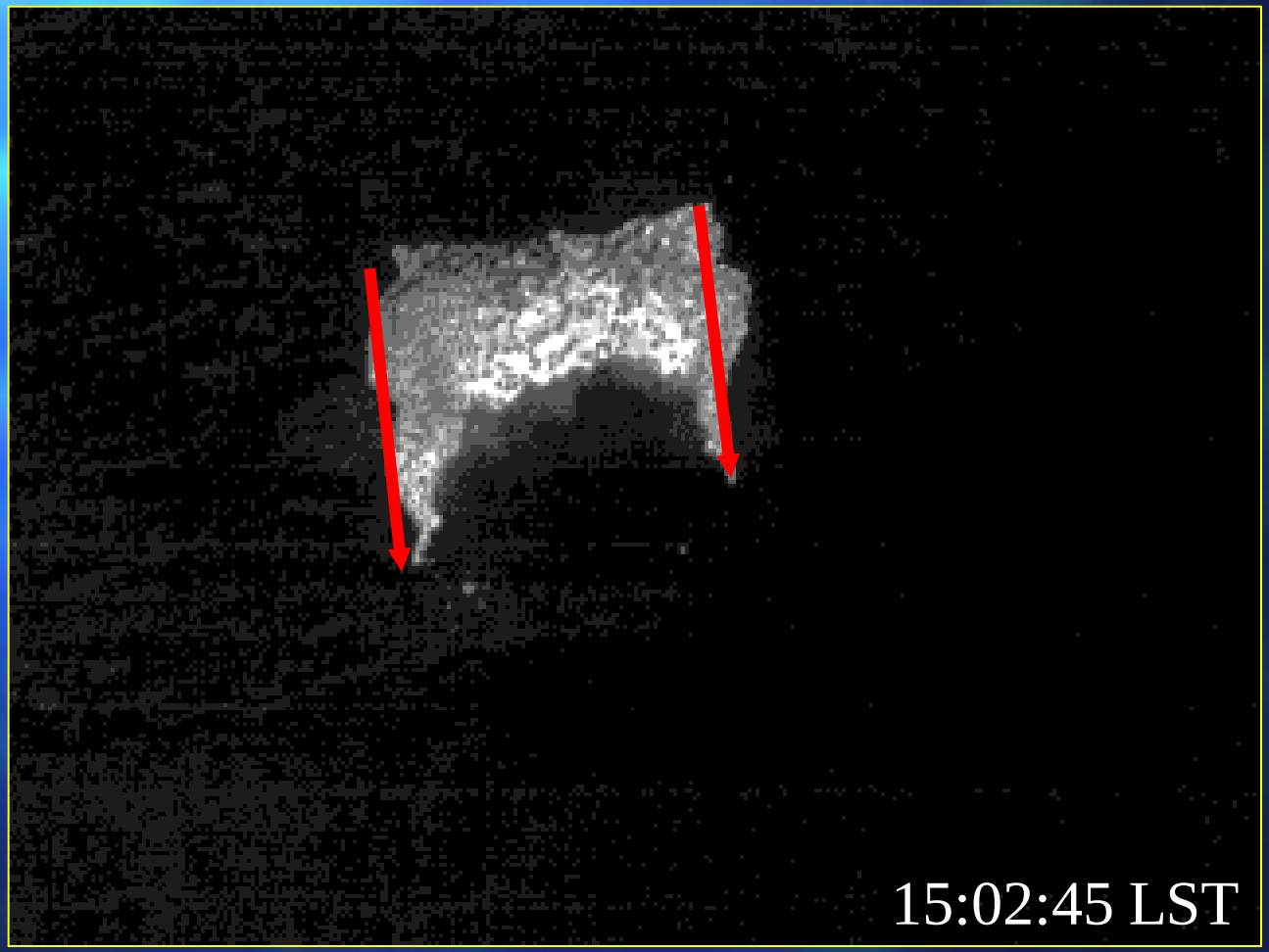
Fireline Intensity (kW/m)

Crown fire

Digital Infrared imagery

Image methodology developed by Ji-zhong Jin

Digital Infrared imagery



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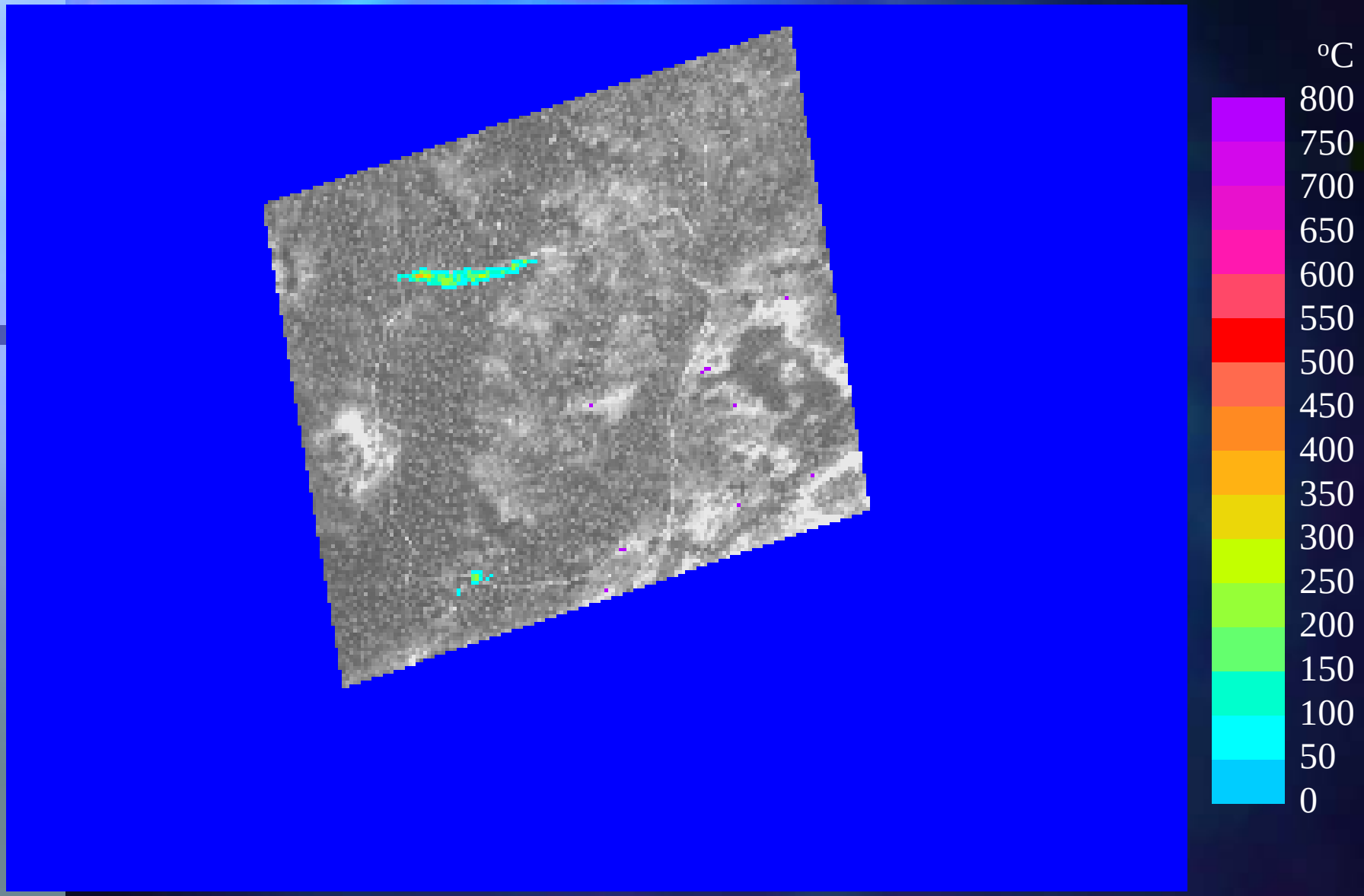

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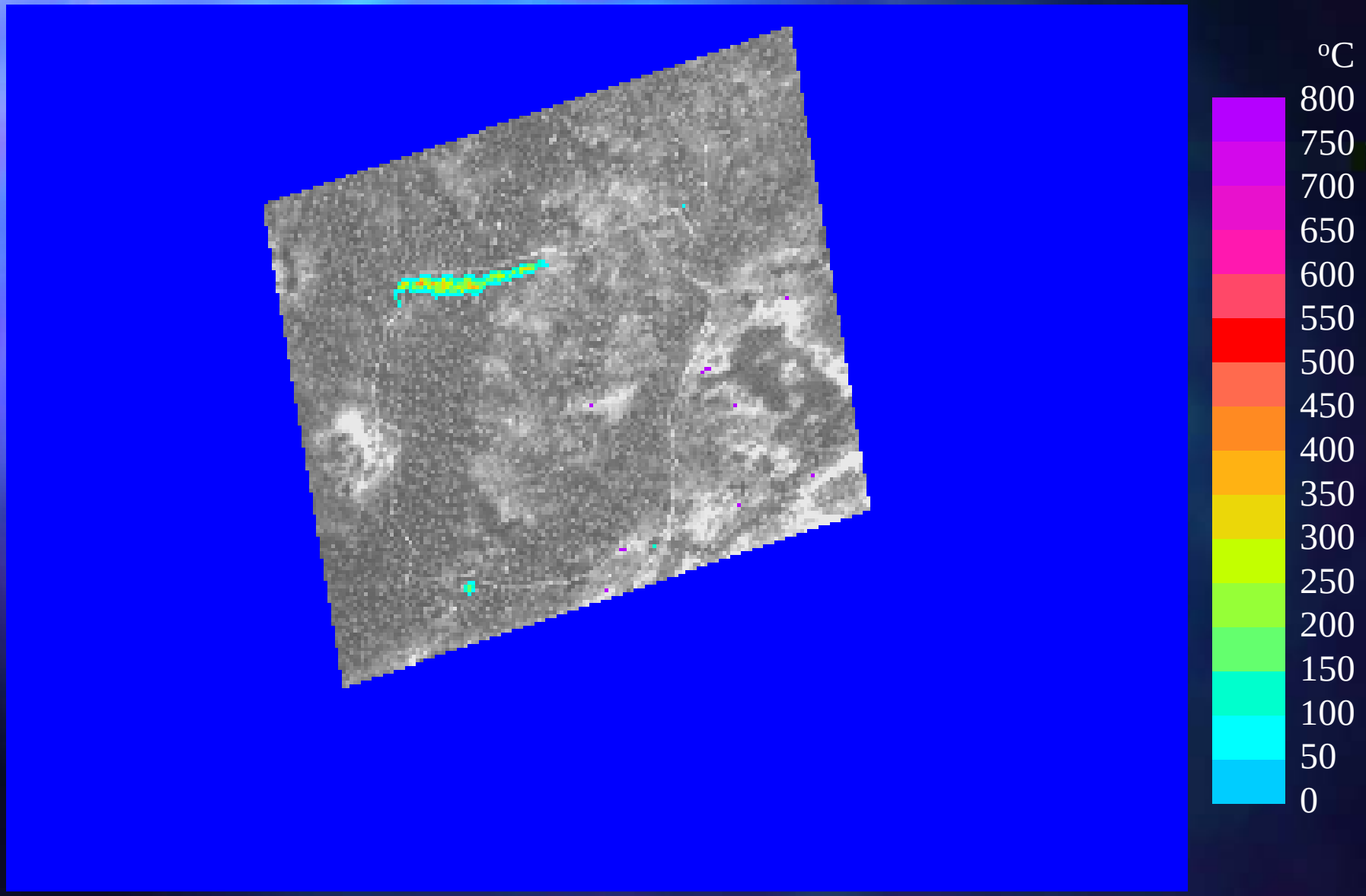

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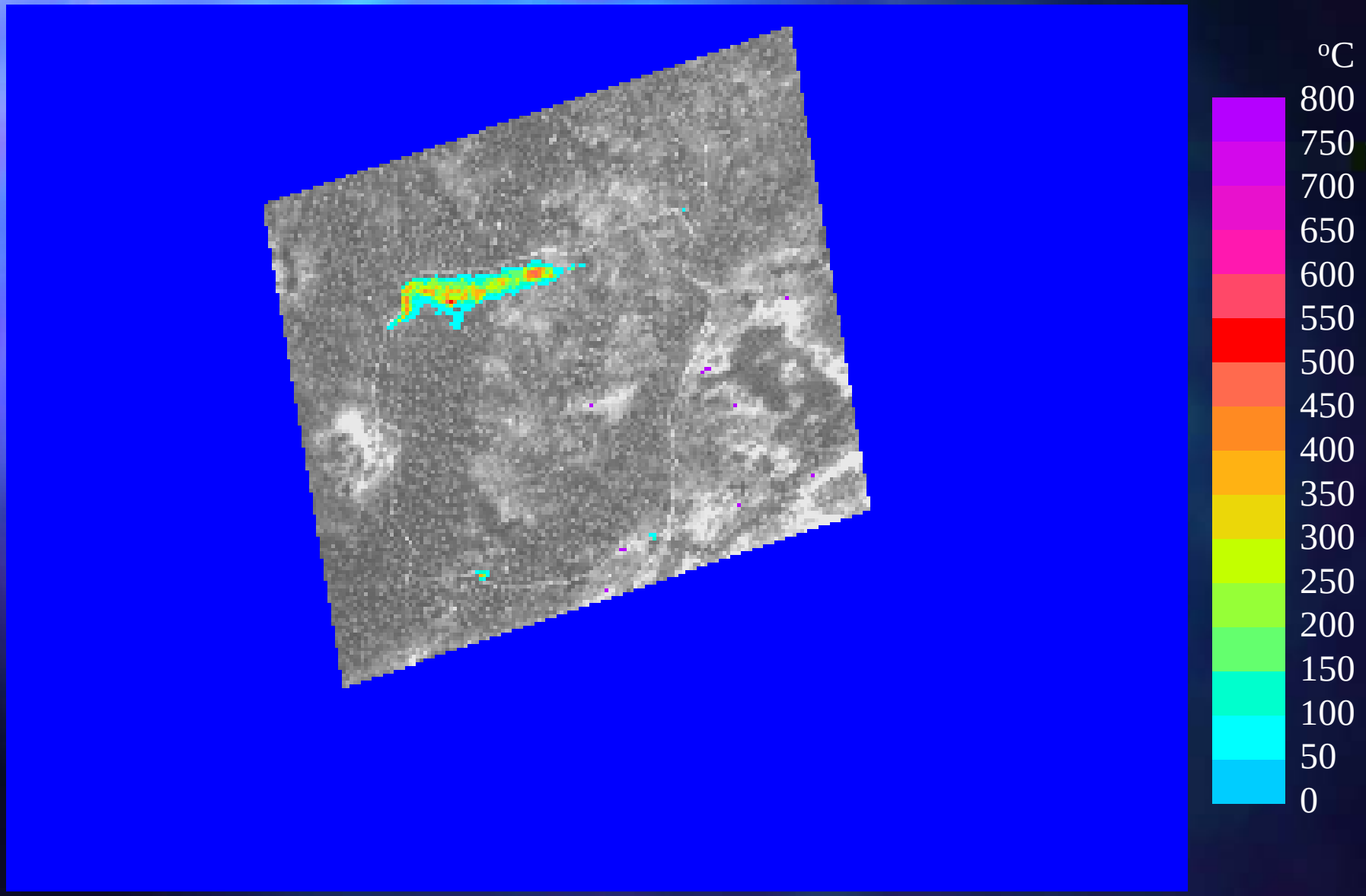

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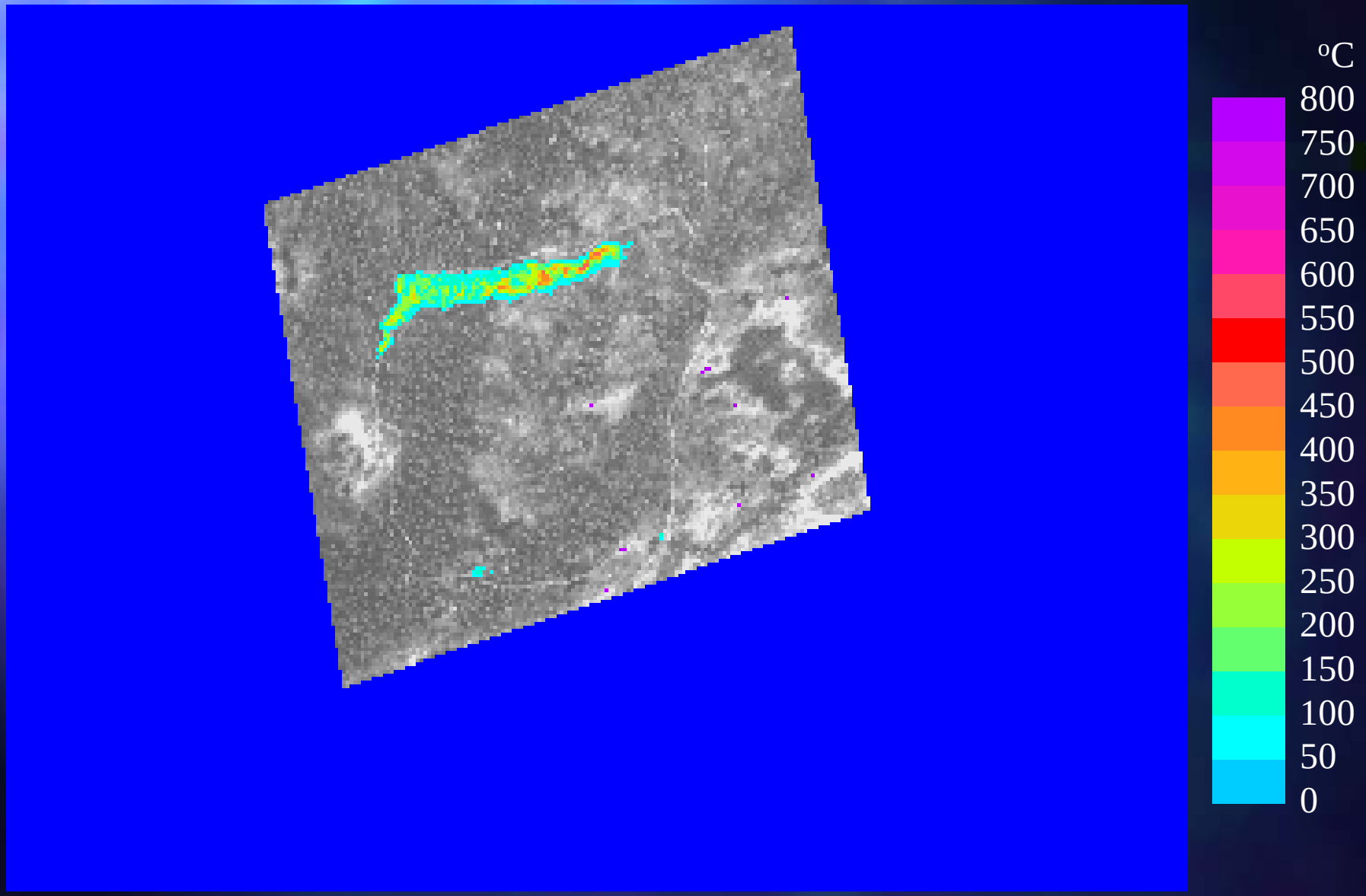

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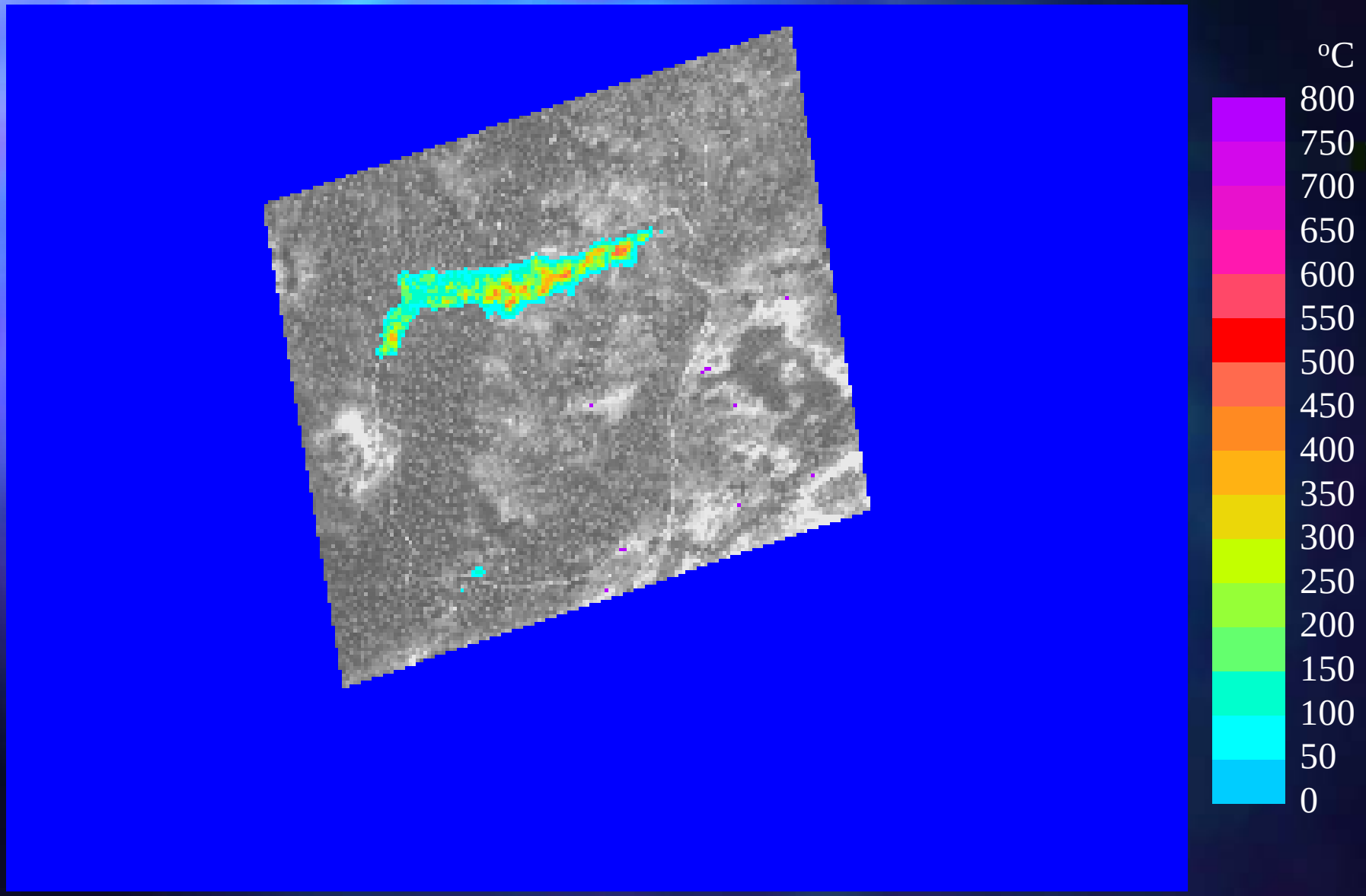

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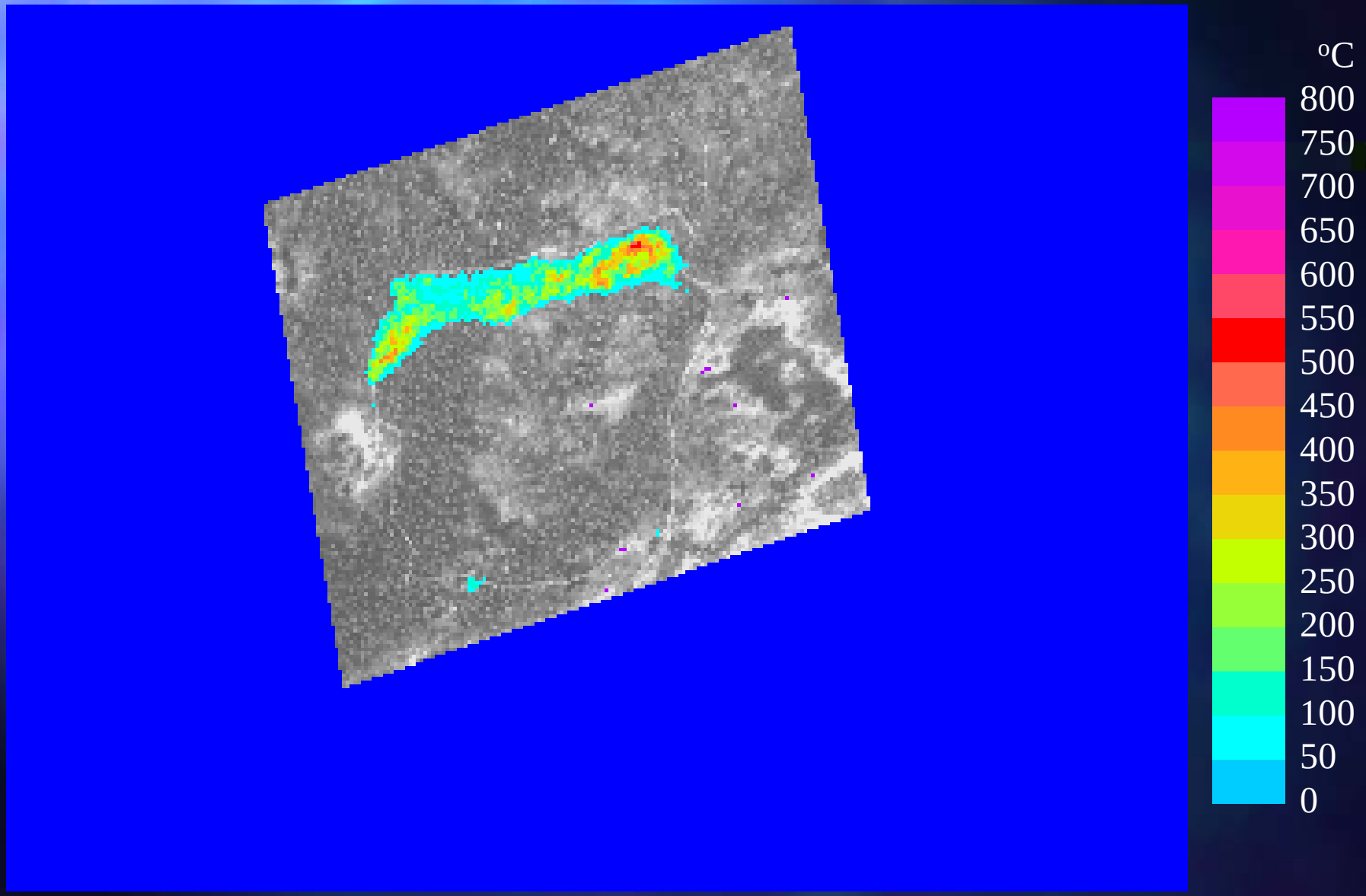

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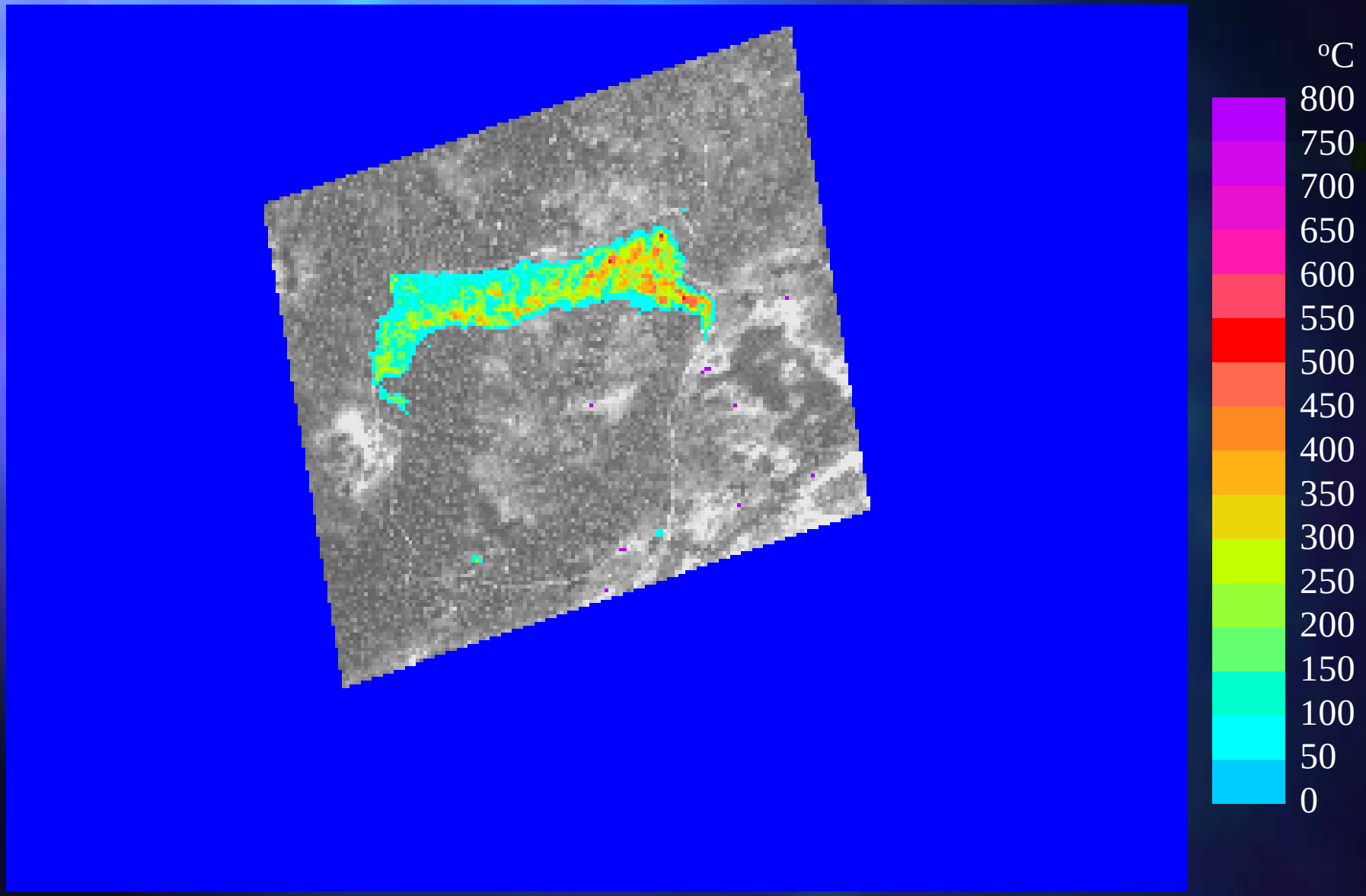

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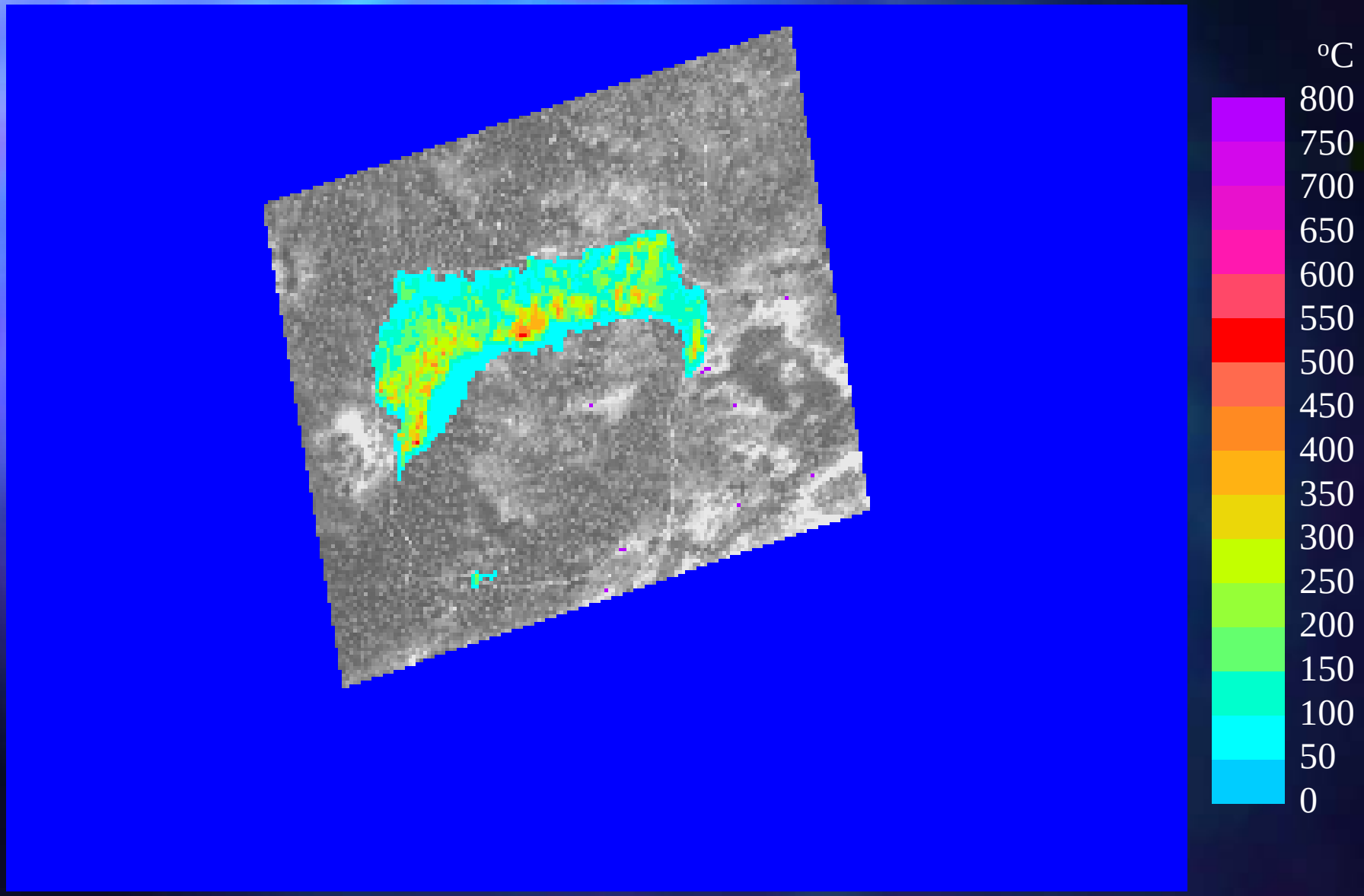

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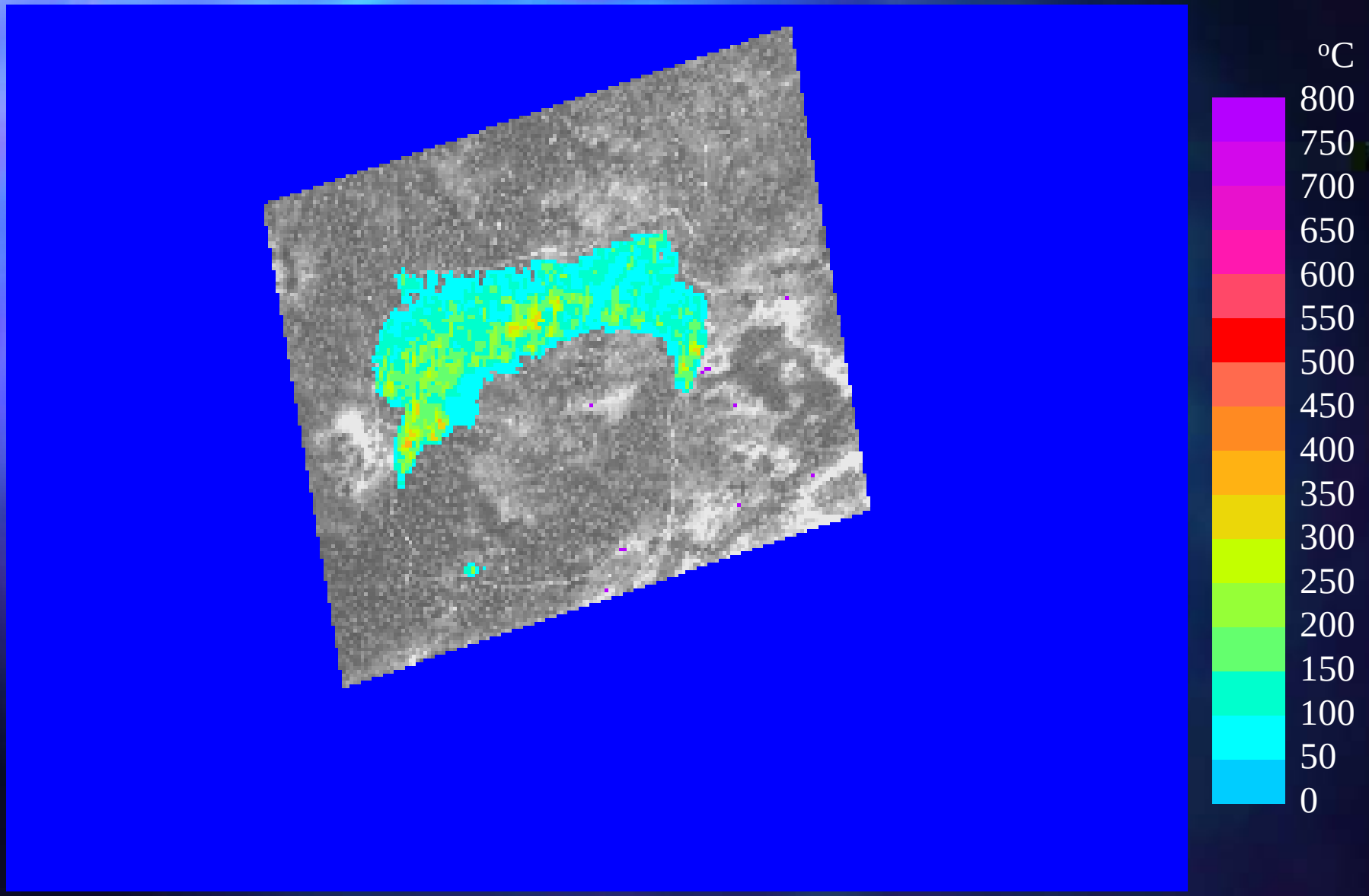

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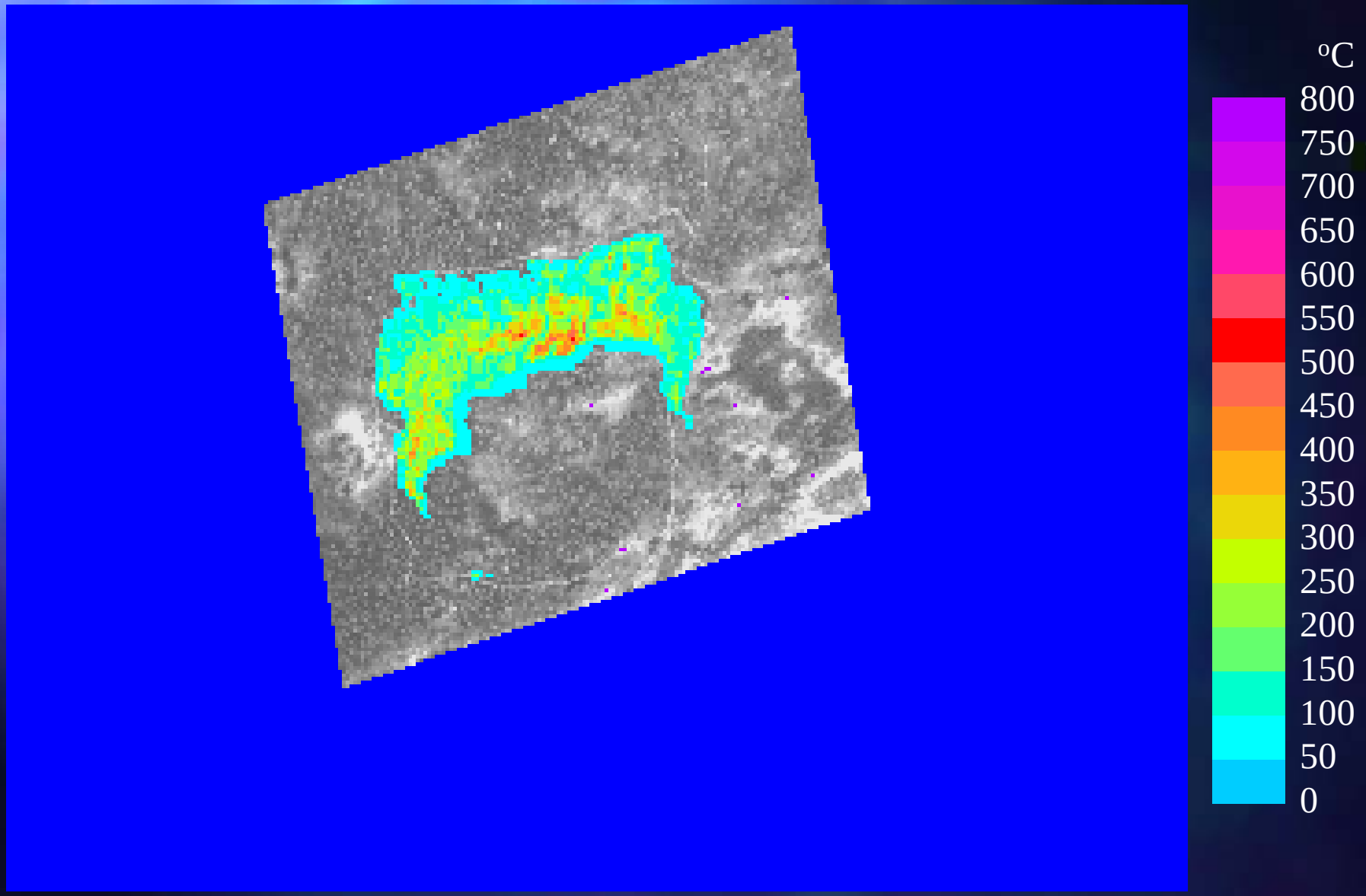

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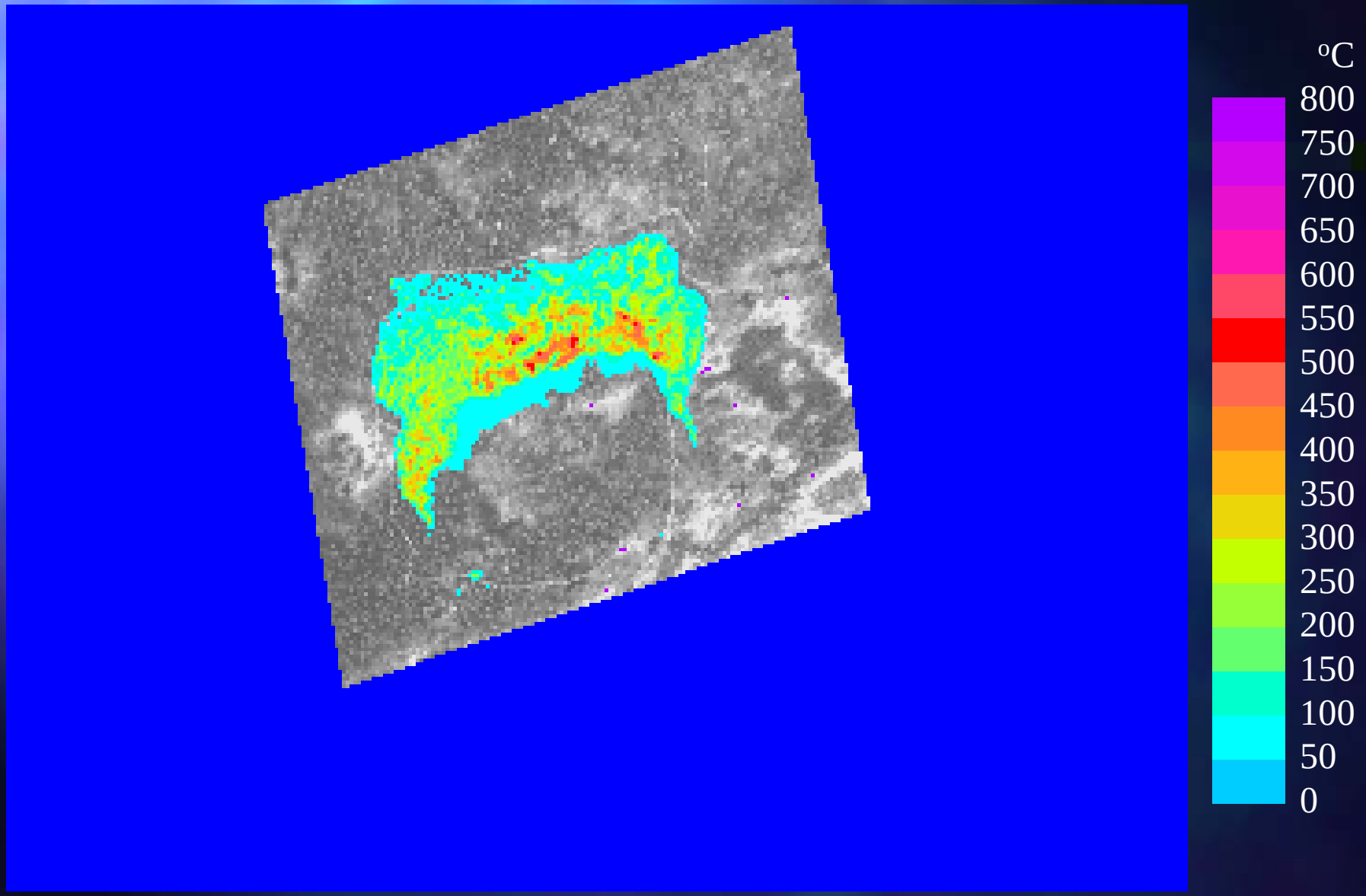

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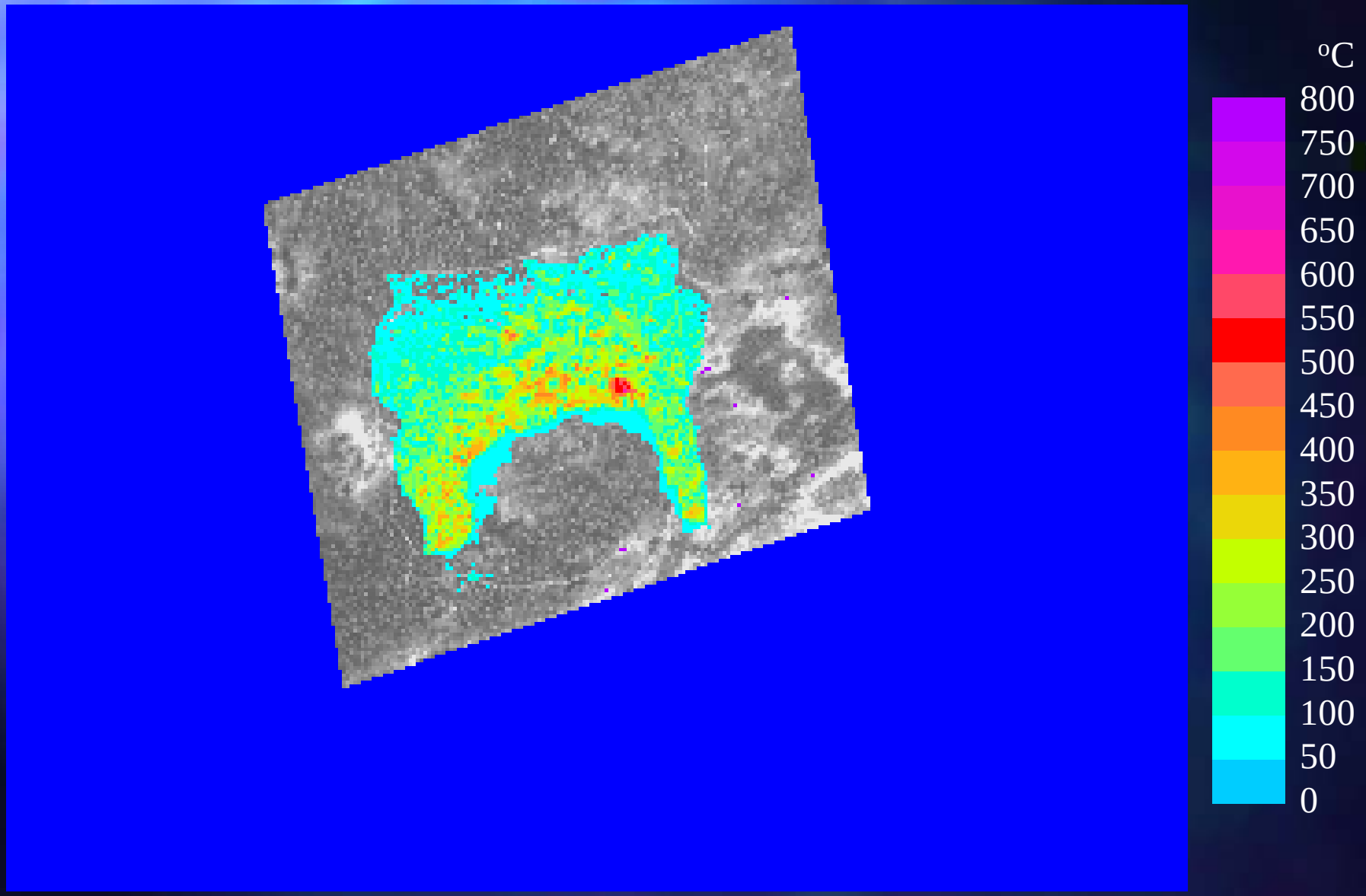

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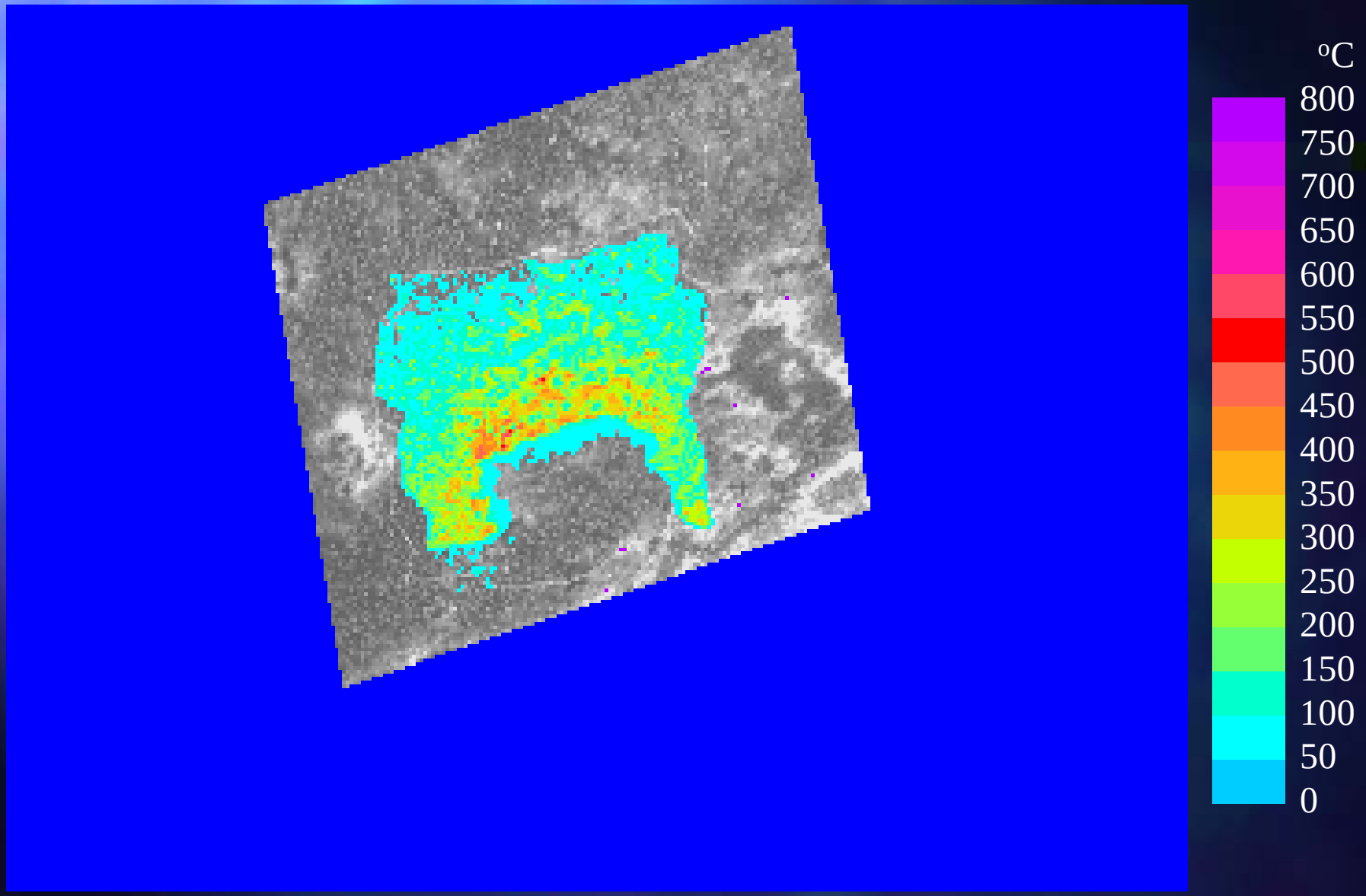

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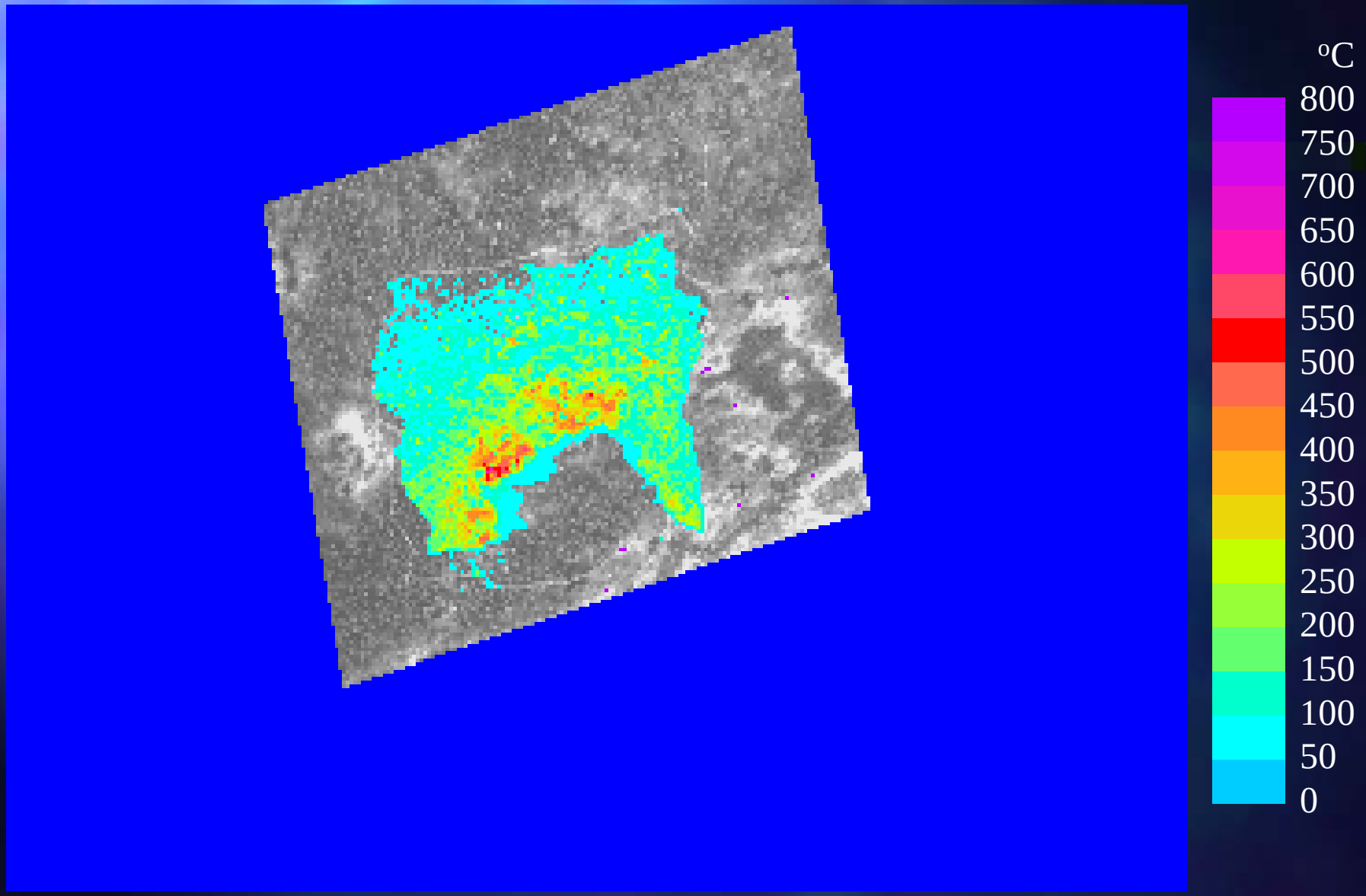

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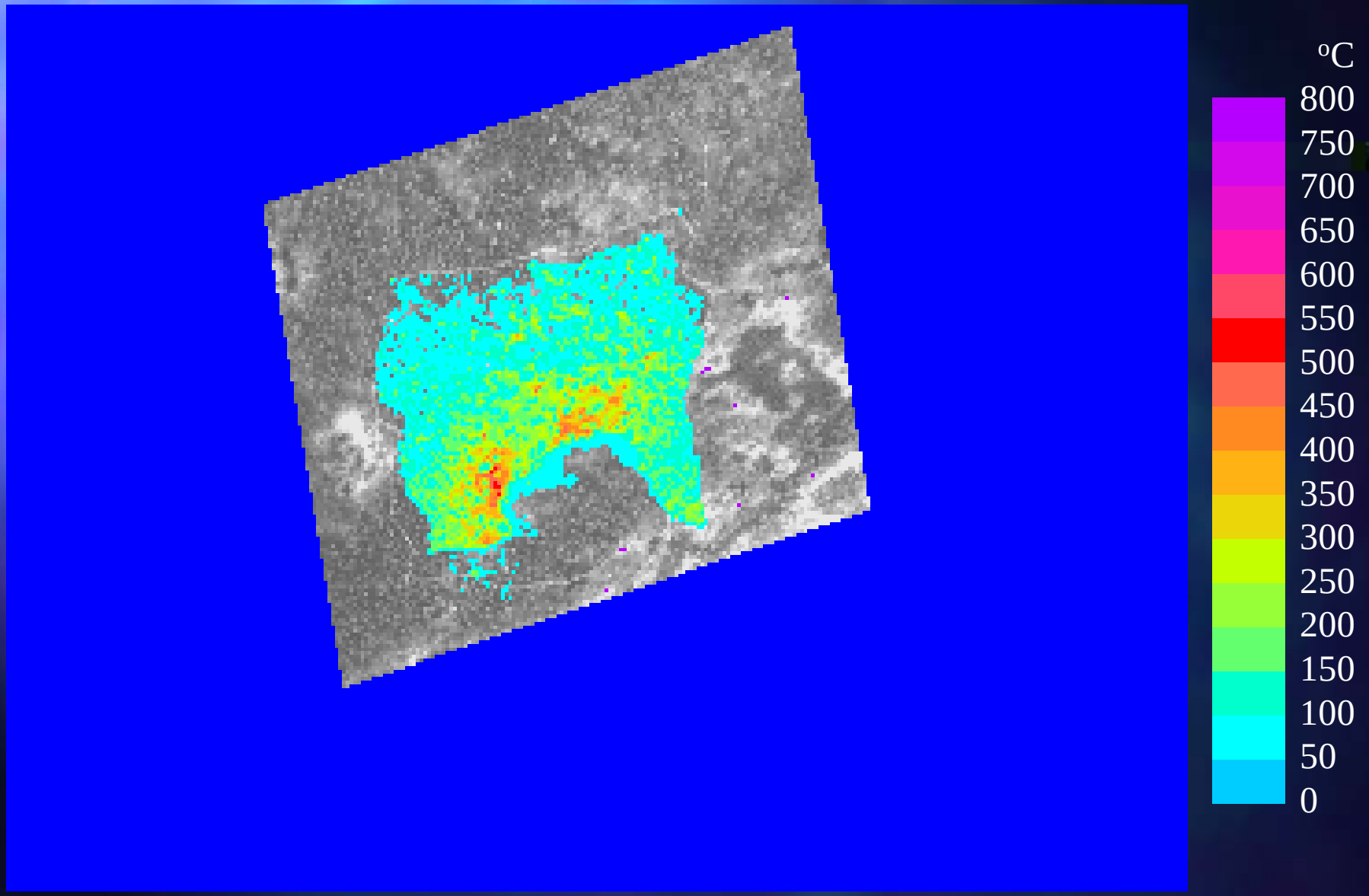

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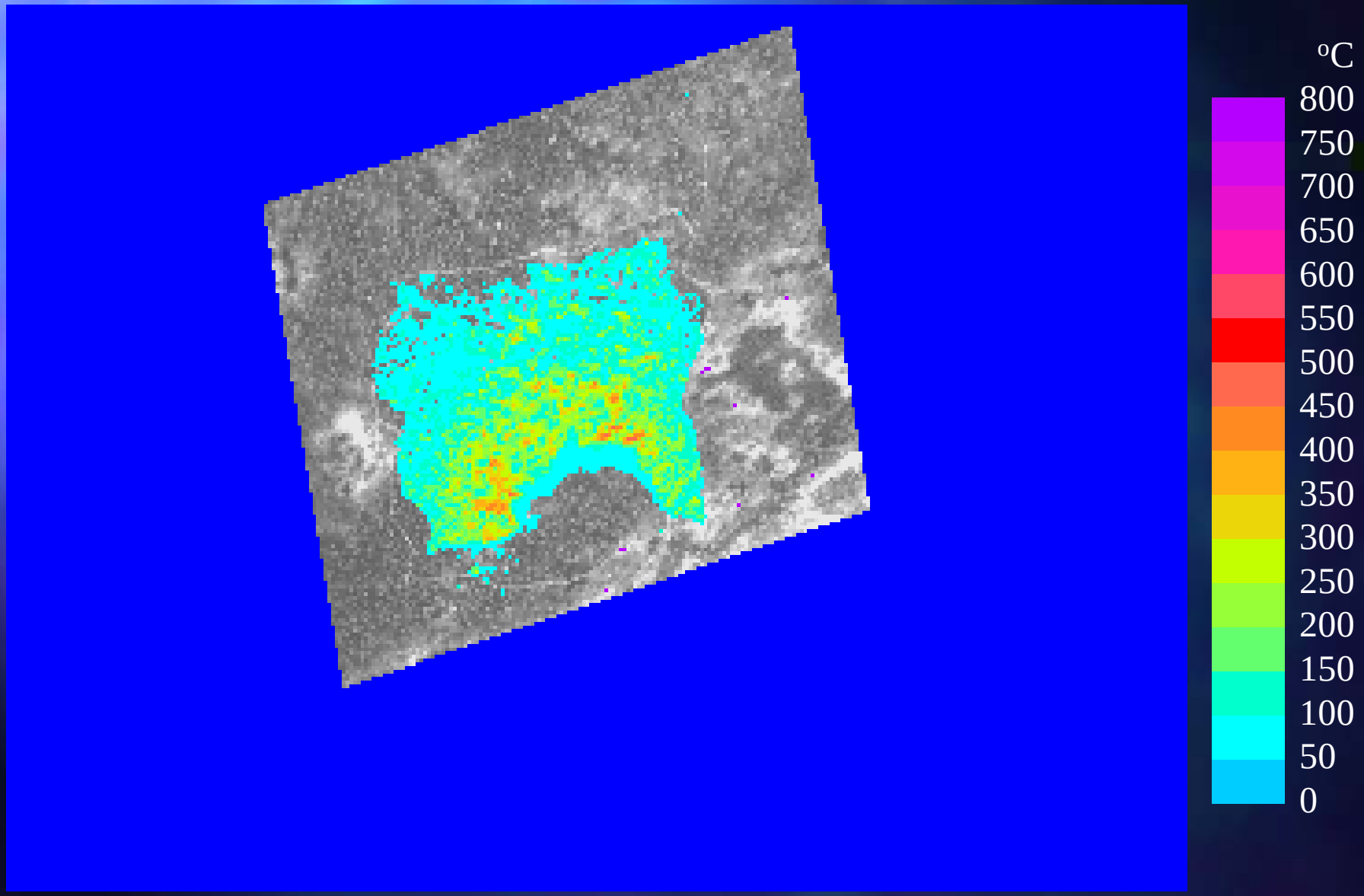

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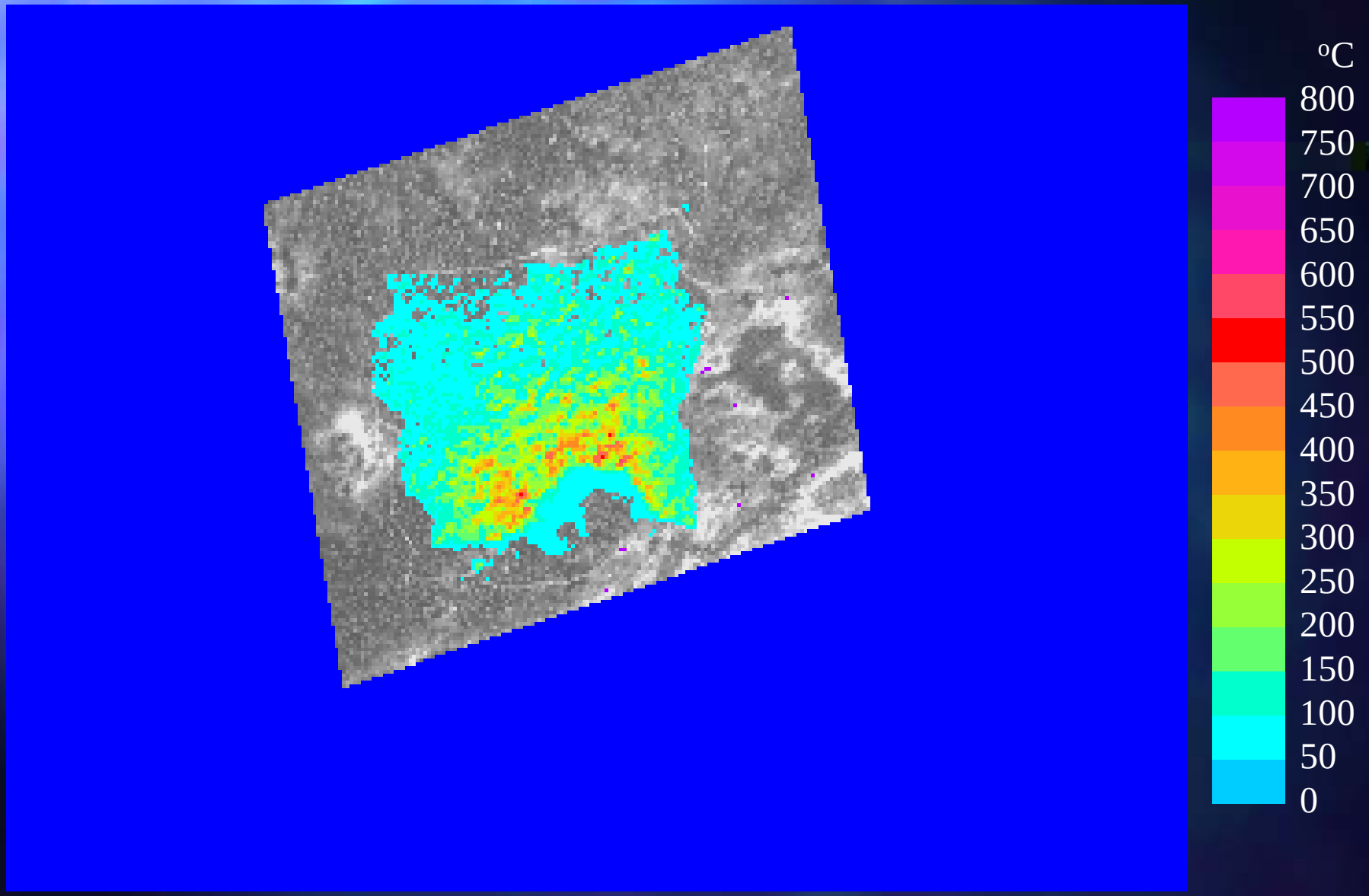

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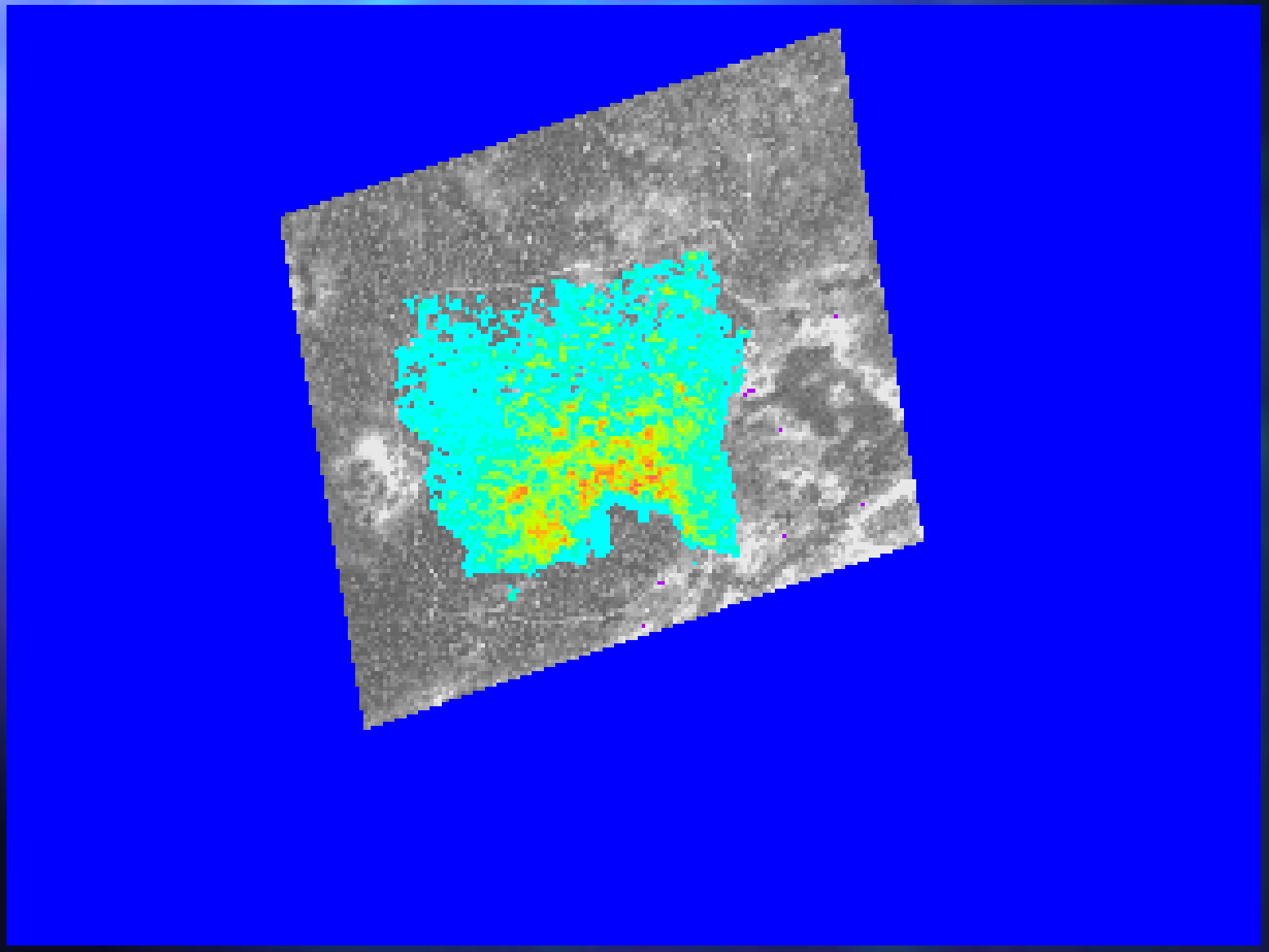

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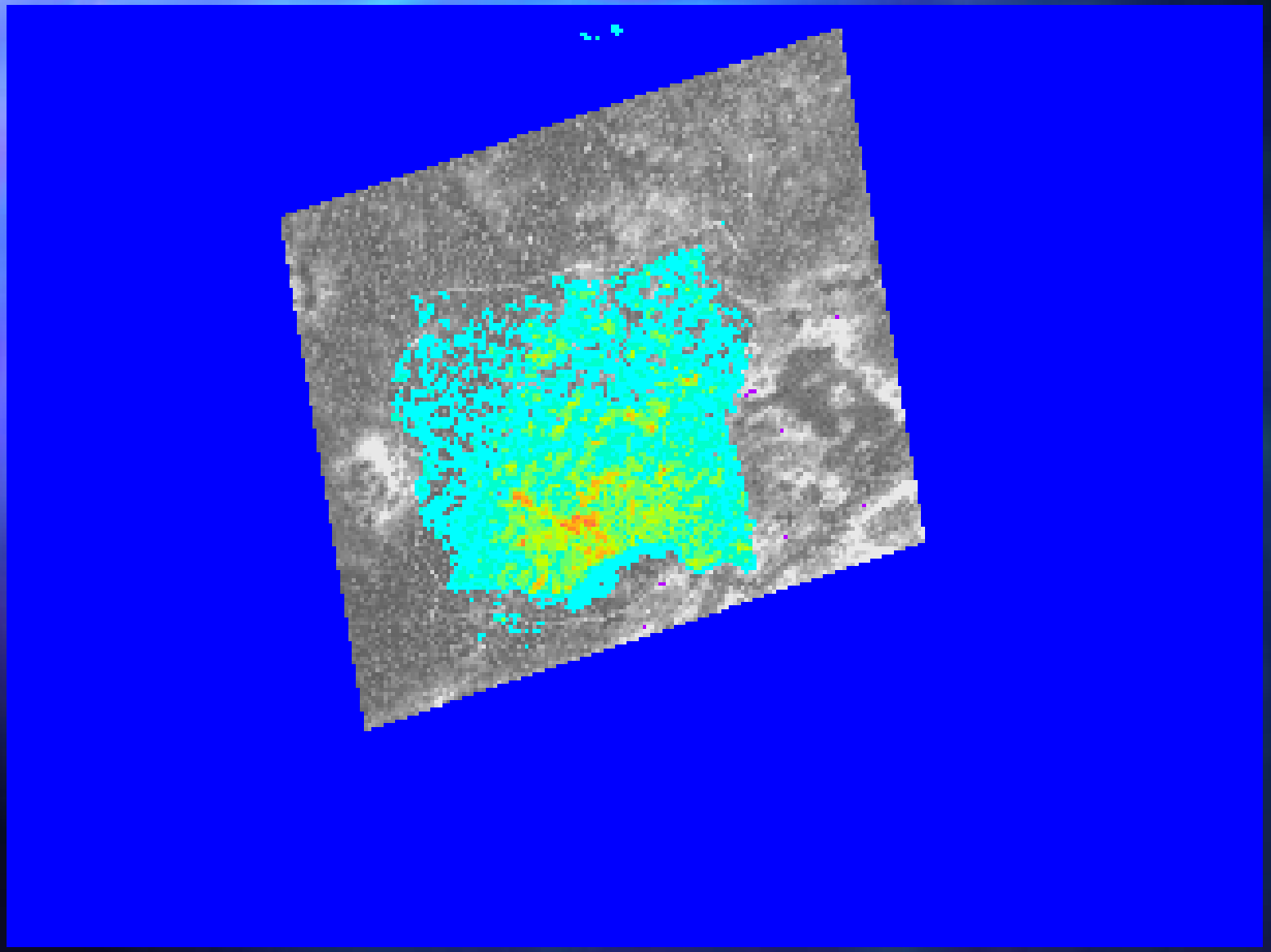

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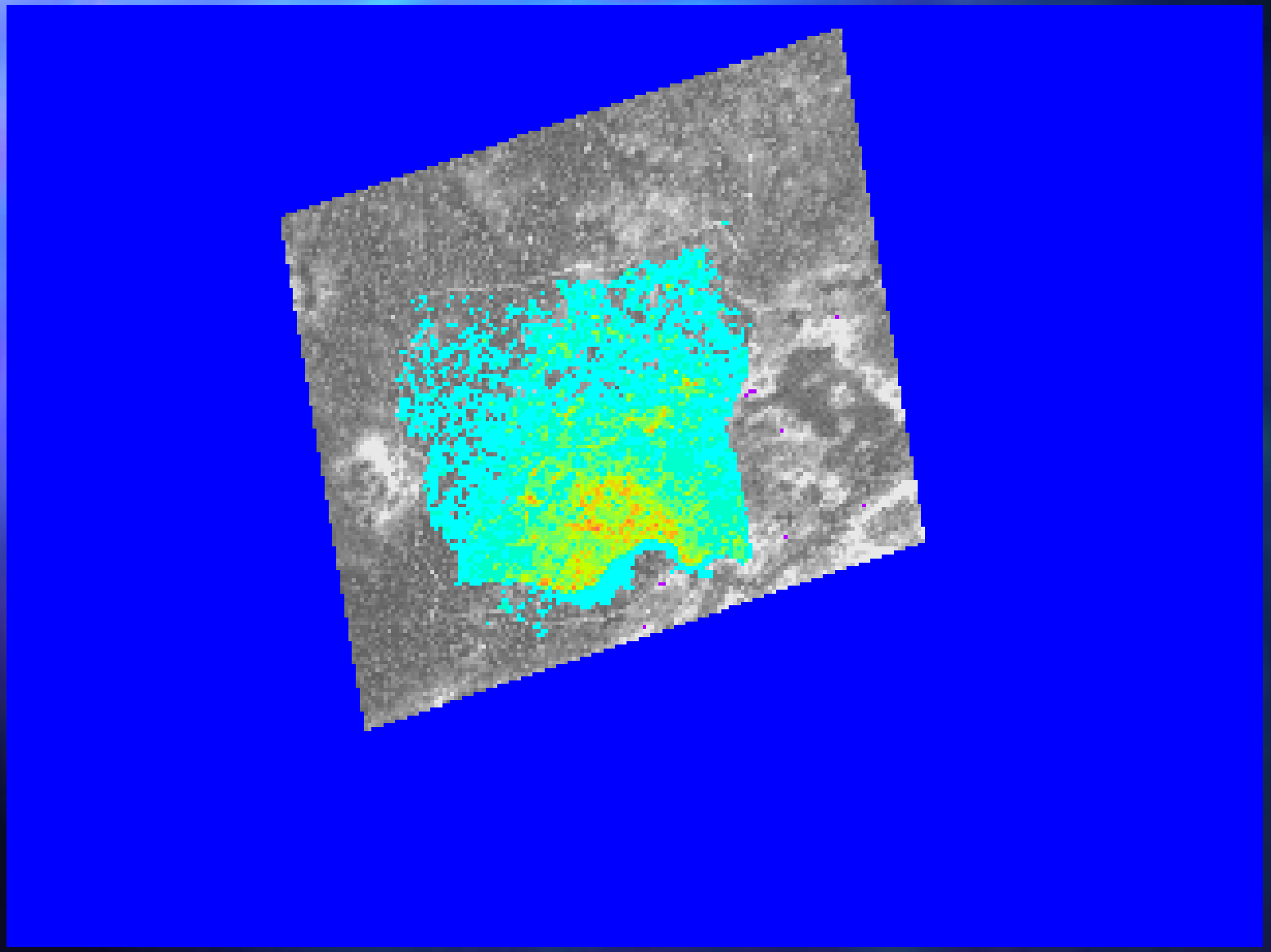

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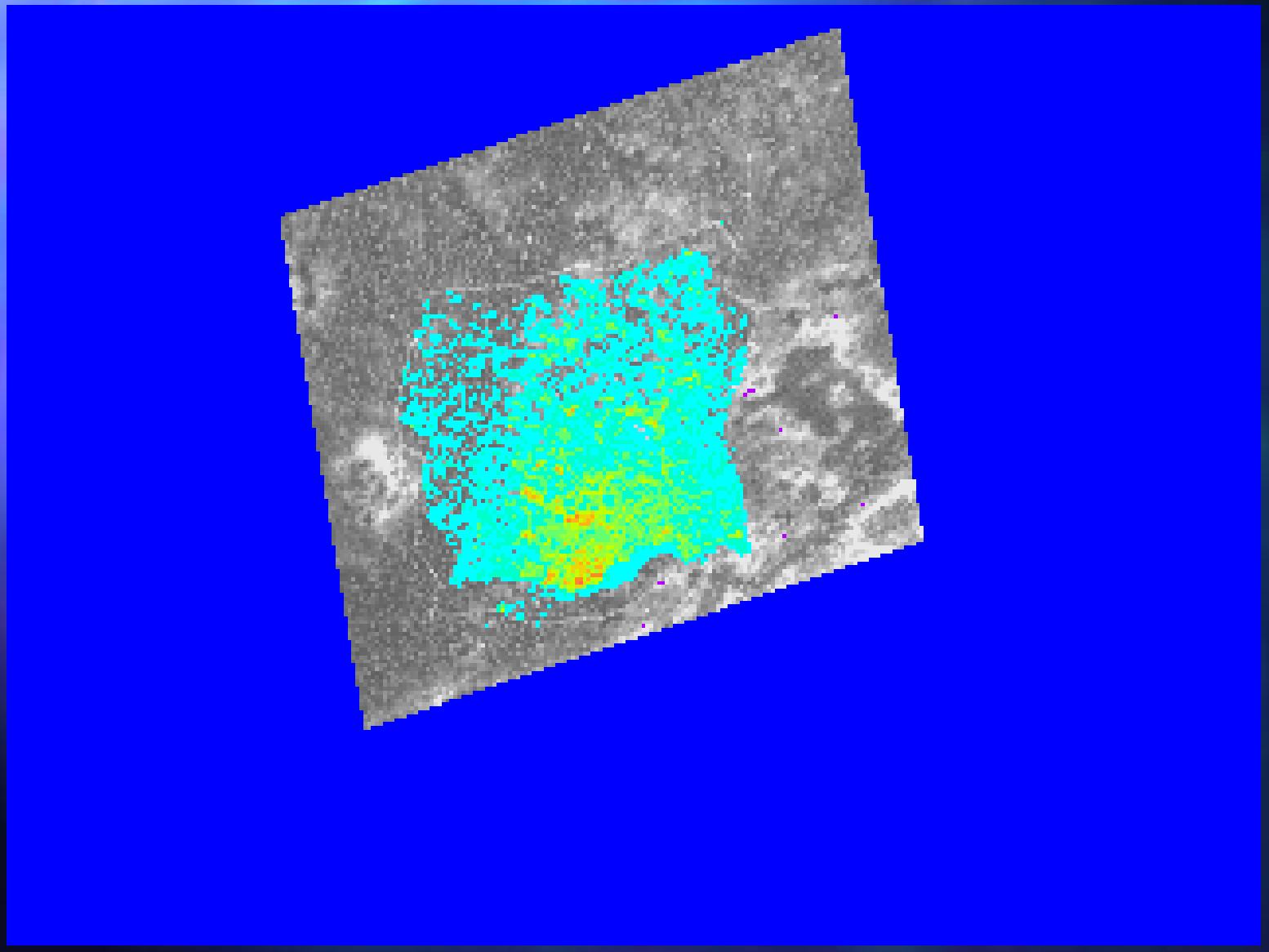

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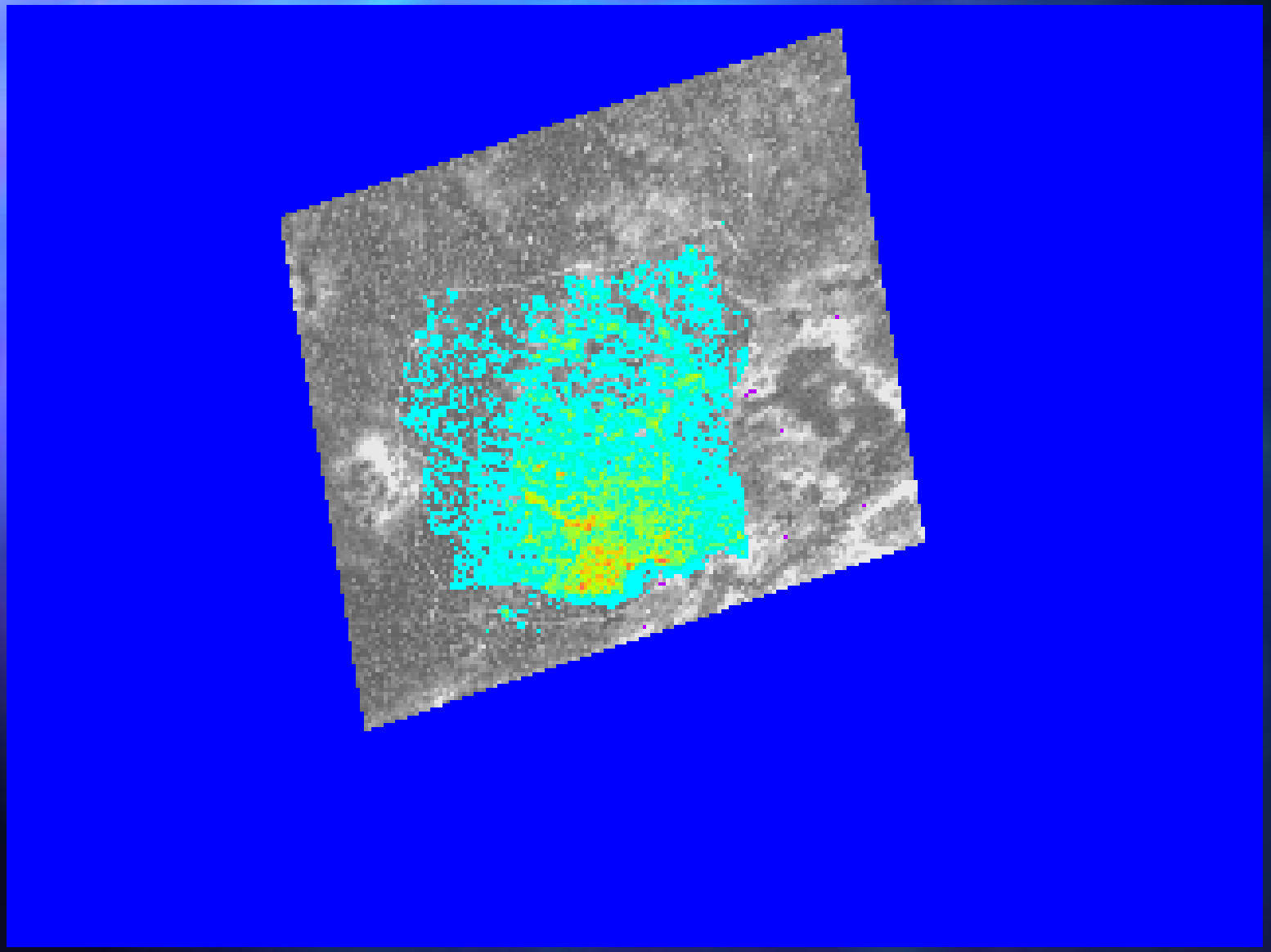

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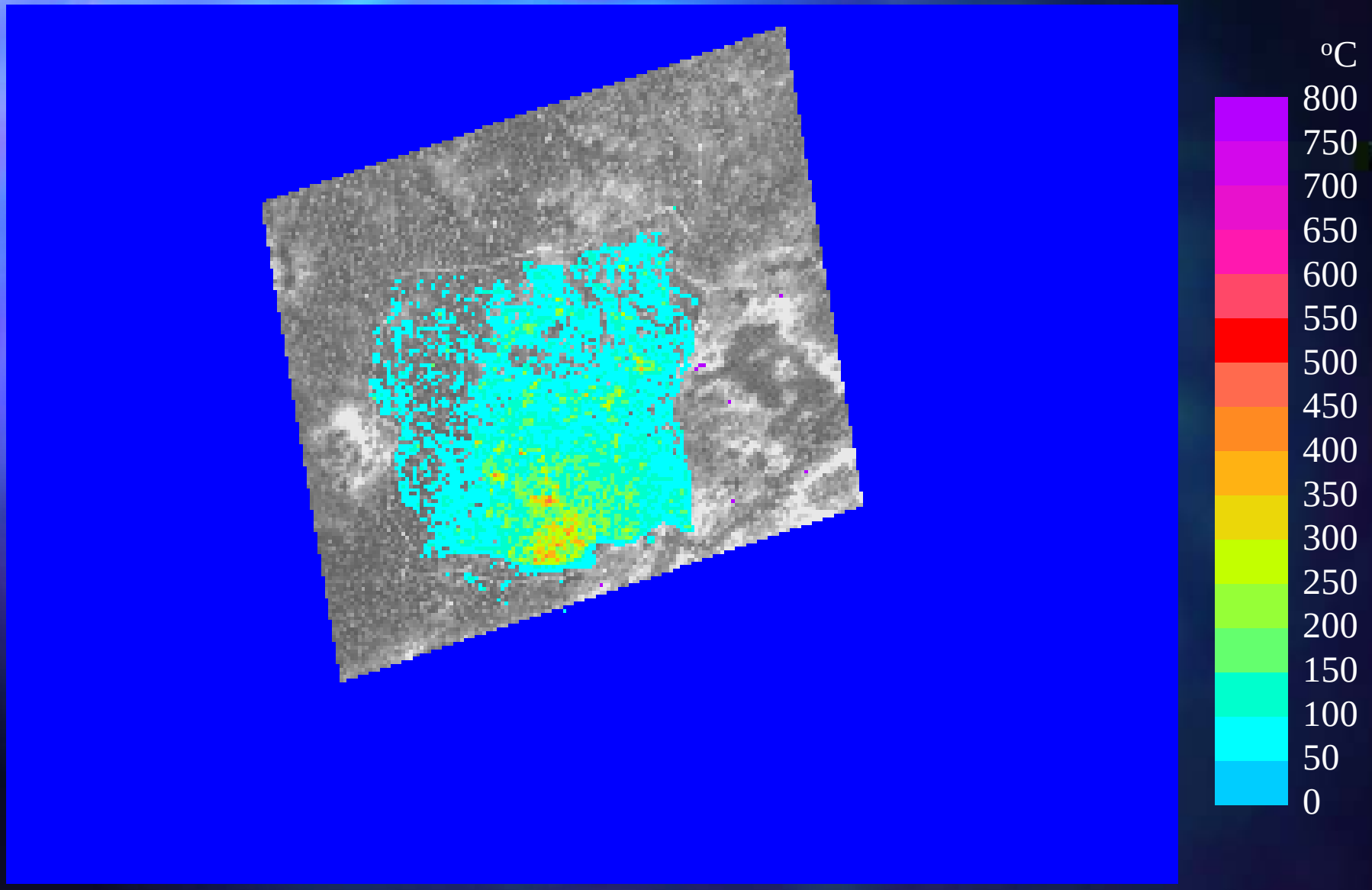


Fire Spread Time

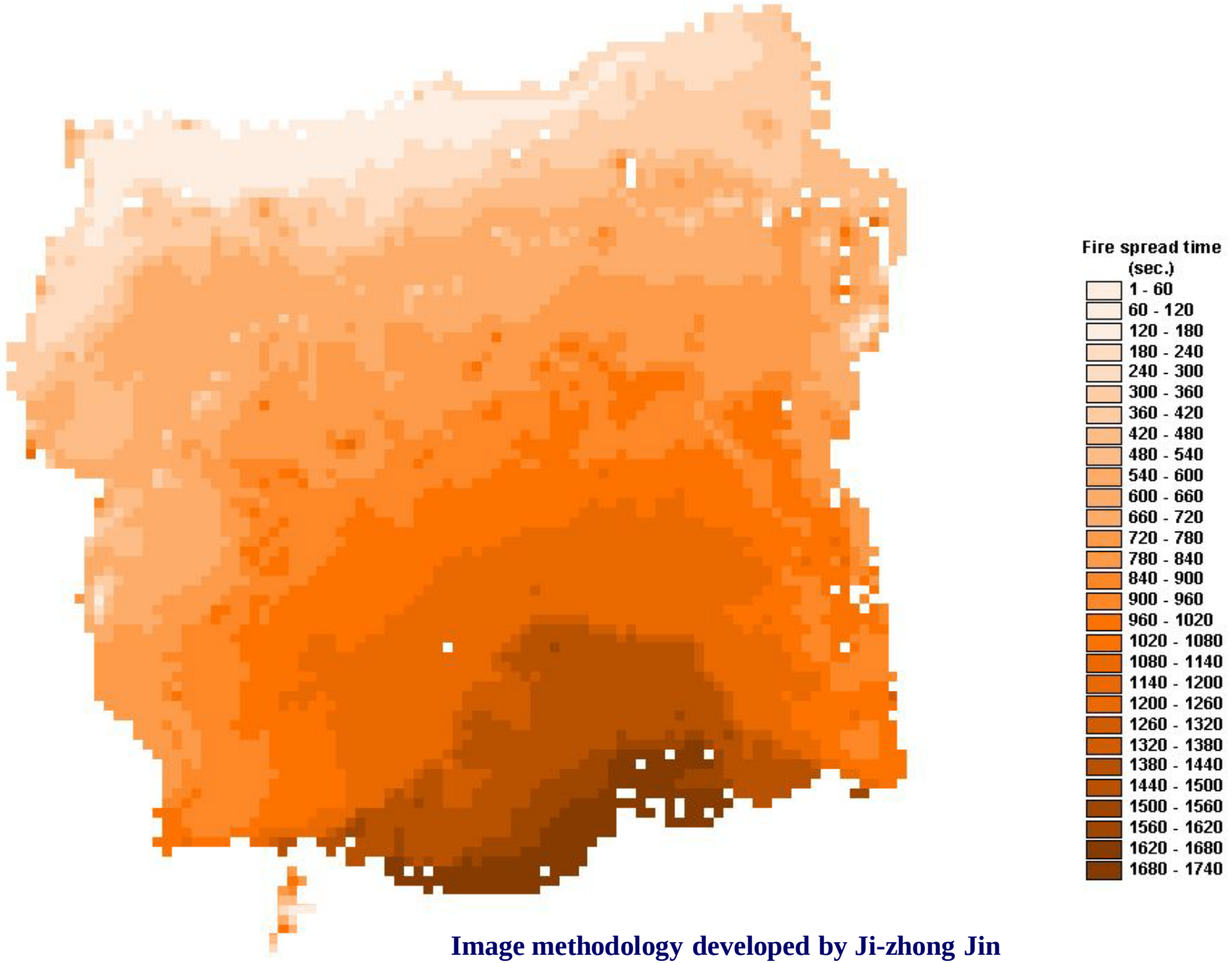
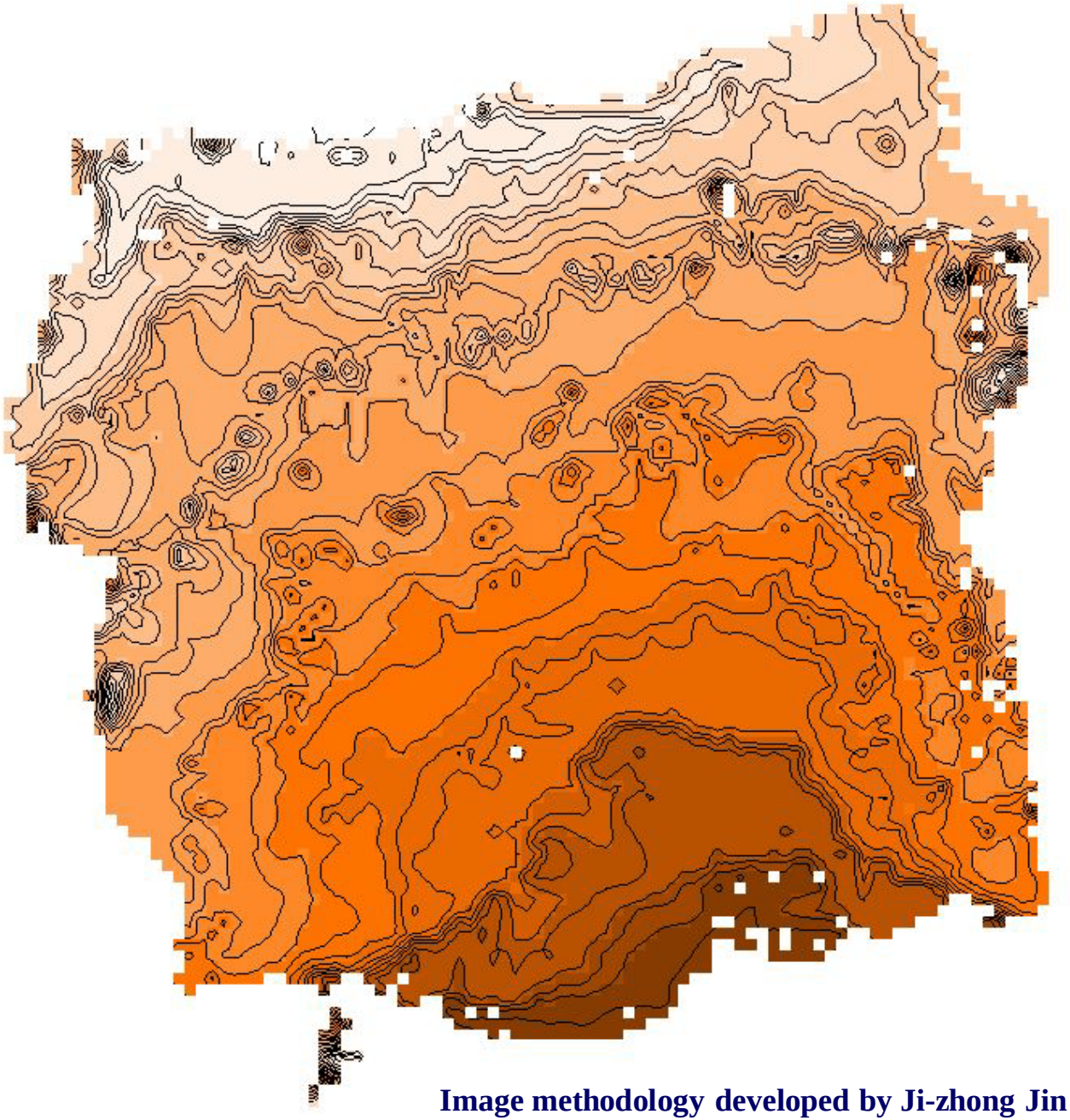


Image methodology developed by Ji-zhong Jin

Fire Spread Time

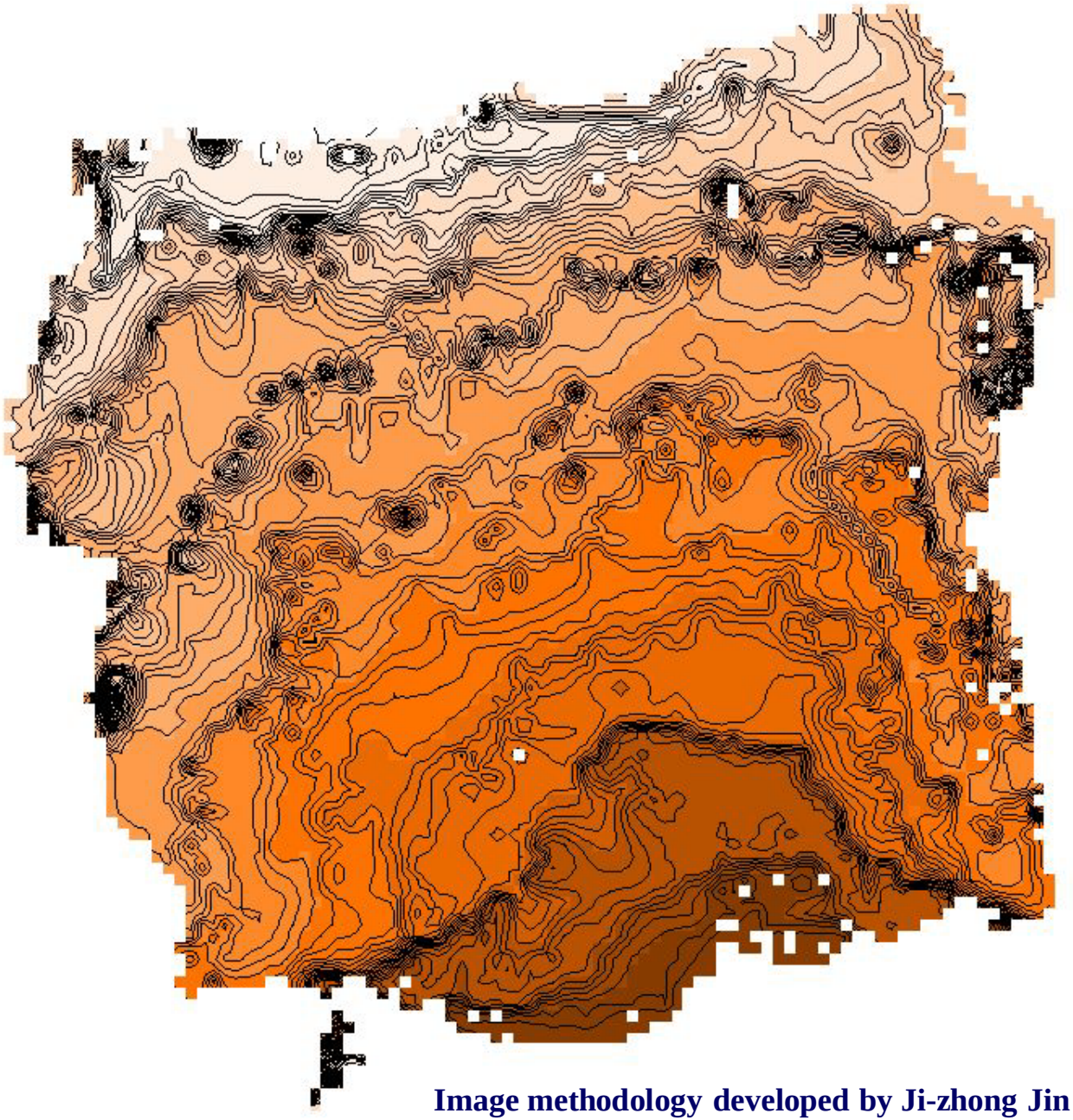


Fire spread time (sec.)
1 - 60
60 - 120
120 - 180
180 - 240
240 - 300
300 - 360
360 - 420
420 - 480
480 - 540
540 - 600
600 - 660
660 - 720
720 - 780
780 - 840
840 - 900
900 - 960
960 - 1020
1020 - 1080
1080 - 1140
1140 - 1200
1200 - 1260
1260 - 1320
1320 - 1380
1380 - 1440
1440 - 1500
1500 - 1560
1560 - 1620
1620 - 1680
1680 - 1740

Image methodology developed by Ji-zhong Jin

Contours of spread time interval 60 sec.

Fire Spread Time

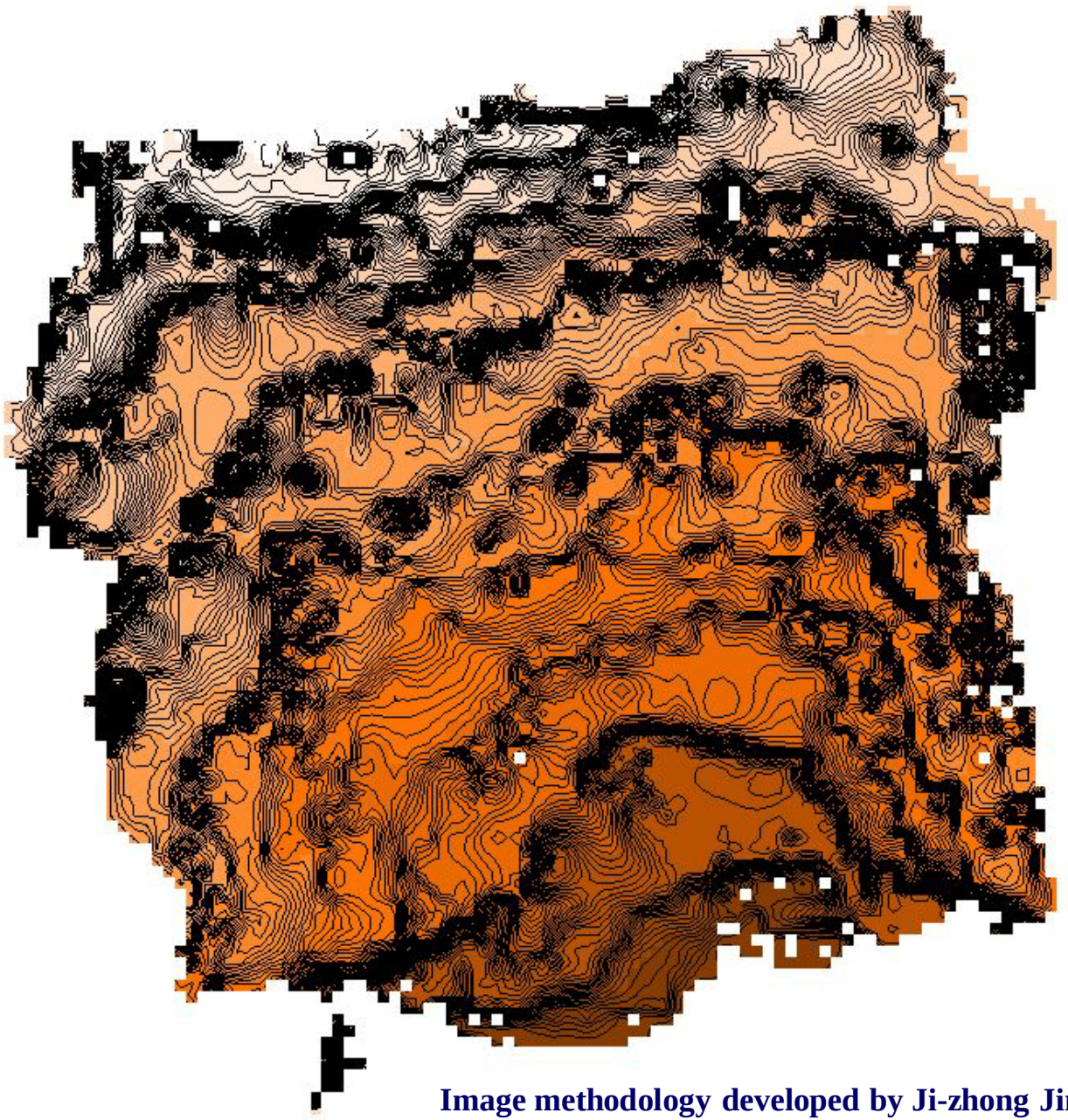


Fire spread time (sec.)
1 - 60
60 - 120
120 - 180
180 - 240
240 - 300
300 - 360
360 - 420
420 - 480
480 - 540
540 - 600
600 - 660
660 - 720
720 - 780
780 - 840
840 - 900
900 - 960
960 - 1020
1020 - 1080
1080 - 1140
1140 - 1200
1200 - 1260
1260 - 1320
1320 - 1380
1380 - 1440
1440 - 1500
1500 - 1560
1560 - 1620
1620 - 1680
1680 - 1740

Image methodology developed by Ji-zhong Jin

Contours of spread time interval 30 sec.

Fire Spread Time



Fire spread time (sec.)
- 1 - 60
- 60 - 120
- 120 - 180
- 180 - 240
- 240 - 300
- 300 - 360
- 360 - 420
- 420 - 480
- 480 - 540
- 540 - 600
- 600 - 660
- 660 - 720
- 720 - 780
- 780 - 840
- 840 - 900
- 900 - 960
- 960 - 1020
- 1020 - 1080
- 1080 - 1140
- 1140 - 1200
- 1200 - 1260
- 1260 - 1320
- 1320 - 1380
- 1380 - 1440
- 1440 - 1500
- 1500 - 1560
- 1560 - 1620
- 1620 - 1680
- 1680 - 1740

Image methodology developed by Ji-zhong Jin

Contours of spread time interval 10 sec.

Rate of Spread (m/min)

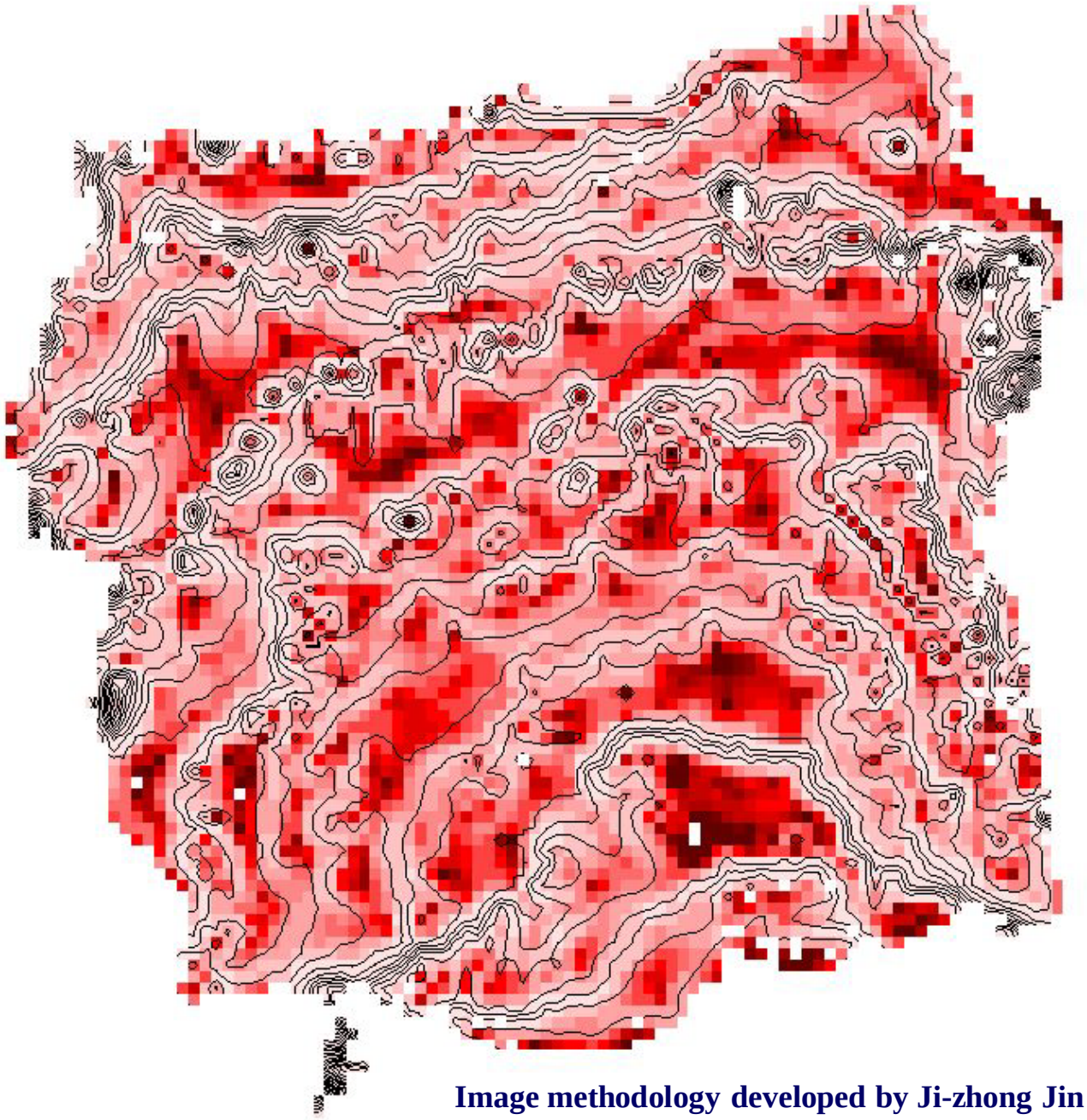
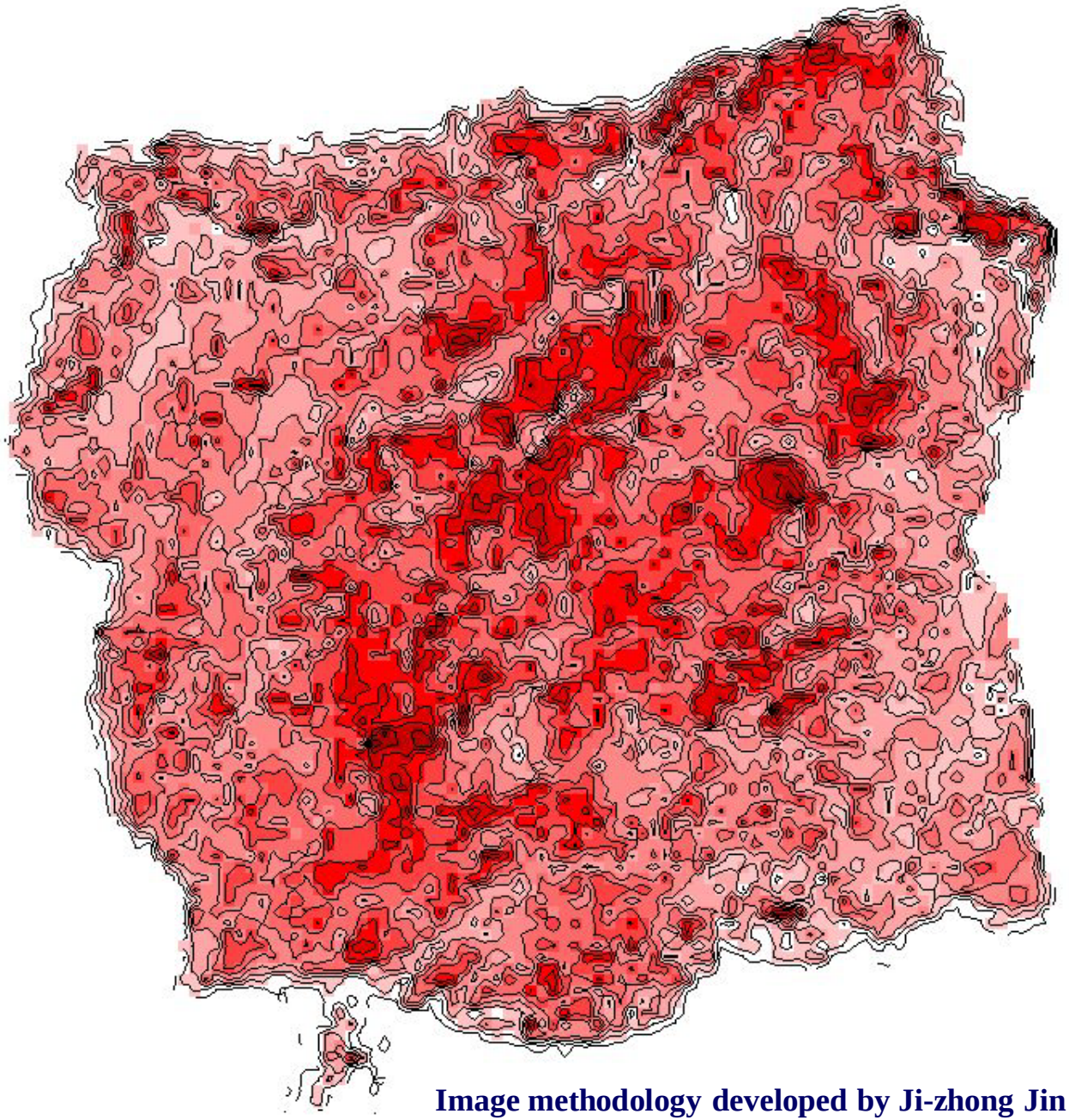


Image methodology developed by Ji-zhong Jin

Contours of spread time
interval 60 sec.

Recorded Maximum Temperature for Each Pixel

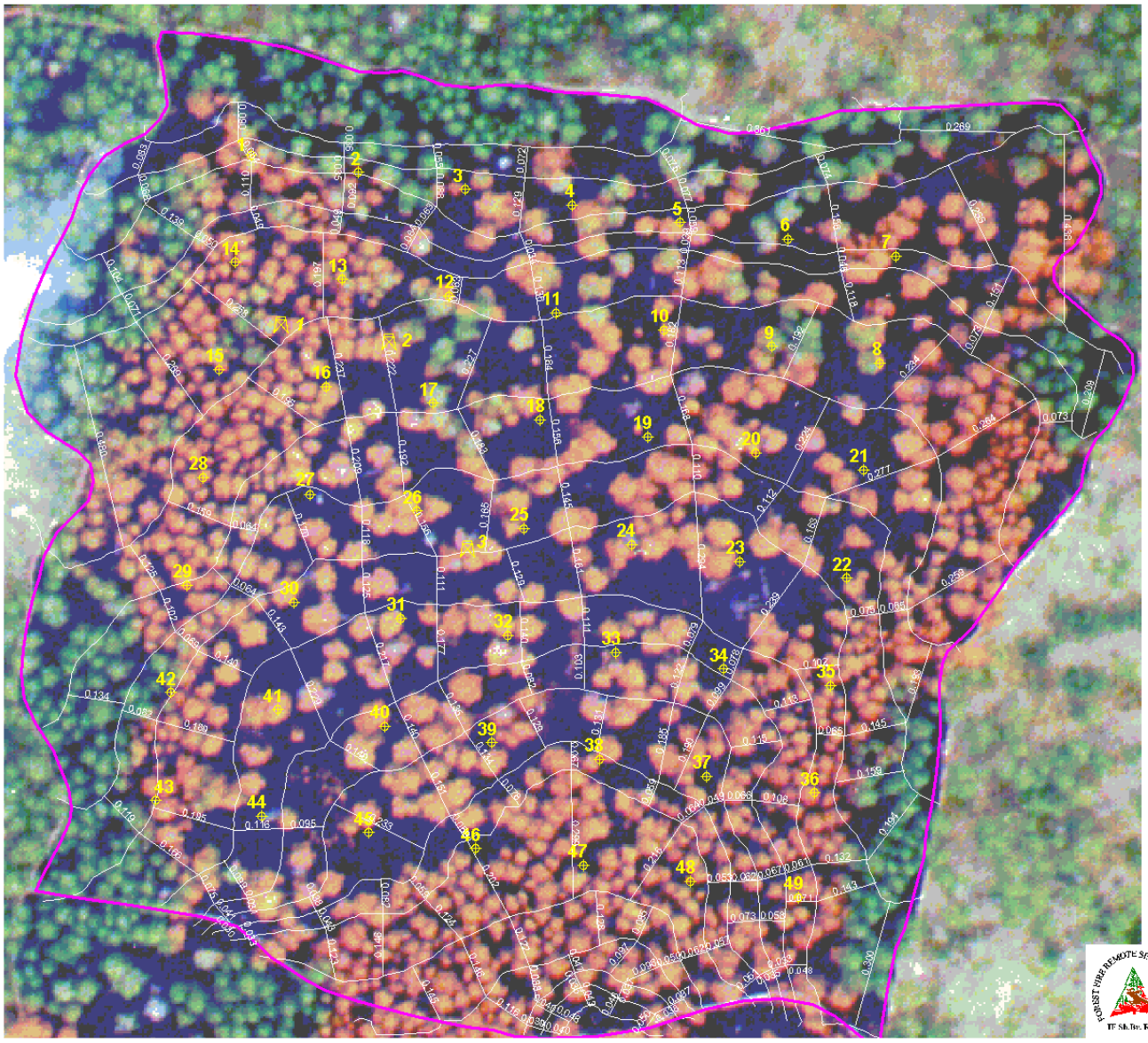


Temperature degree (c)
100-150
150-200
200-250
250-300
300-350
350-400
400-450
450-500
500-550
550-600
600-650
650-700
700 +

Image methodology developed by Ji-zhong Jin

Contours of temprature interval 50 C

IR Results



Plot 14

Thermo-couple tower
Control point
Plot 14 boundary
Fire spread rate
Fire edge with 100 sec. time interval

1:1240

V.N.Sukachev Institute of Forest Sib. Br. RAS
Fores Fire Remote Sensing & GIS Lab.
e-mail: boss@ksc.krasn.ru

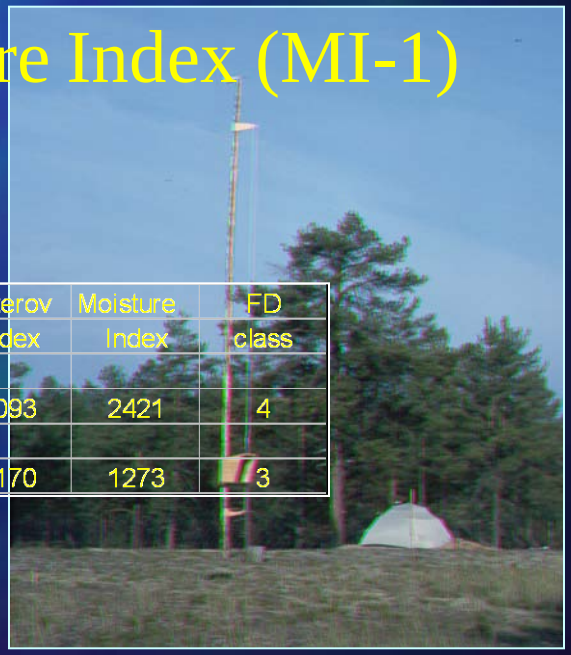
Fire weather and Canadian Forest Fire Weather Index System component values at time of burning

	Date			Temp	RH	Wind	Rain	Canadian Forest Fire Weather Index System						
Plot	Month	Day	Time	(oC)	(%)	(km/h)	(mm)	FFMC	DMC	DC	BUI	ISI	FWI	DSR
14	7	18	15:00	26.4	21	1.6	0	92.4	50.5	390	76.4	6.5	20.4	5.64
13	7	26	16:30	24.2	45	3.6	0	89.2	36.1	401	58.9	4.6	13.6	2.77

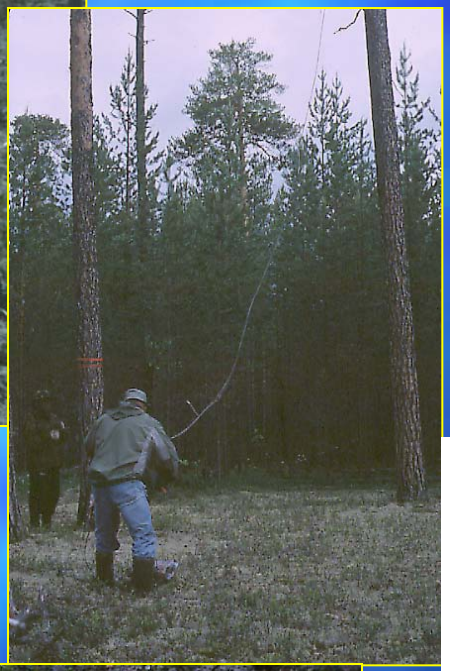
Fire severity model

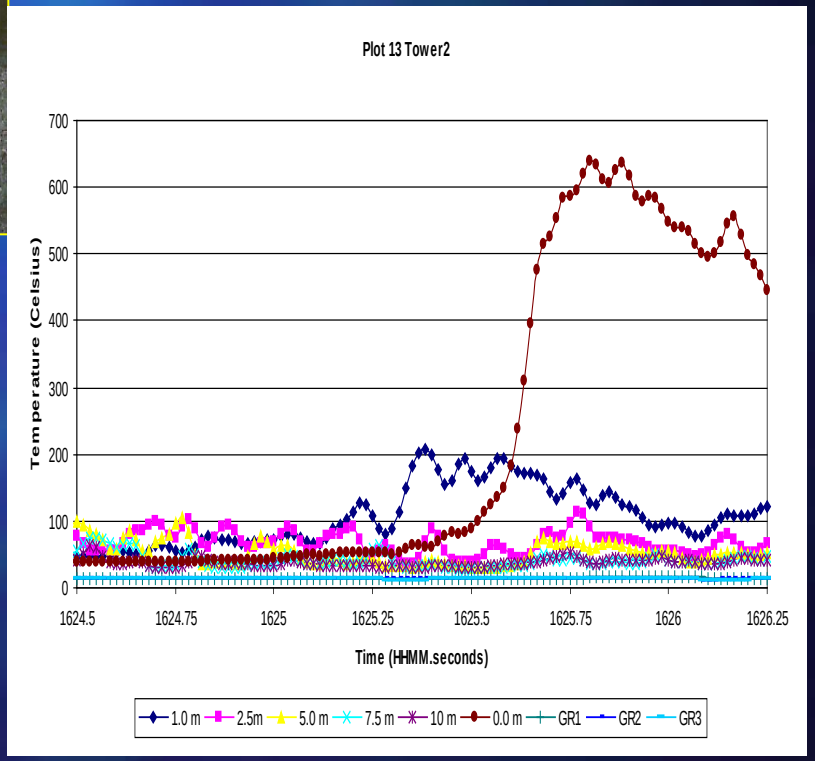
Russian Nesterov Index and Moisture Index (MI-1) values at time of burning

	Date			Temp	RH	Wind	Rain	Nesterov	Moisture	FD
Plot	Month	Day	Time	(oC)	(%)	(km/h)	(mm)	Index	Index	class
14	7	18	15:00	26.4	21	1.6	0	2093	2421	4
13	7	26	16:30	24.2	45	3.6	0	1170	1273	3



Thermocouple Harnesses





Fuel (carbon) sampling

Fire behavior data from 2000 field season:

Fuel component (kg/m^2):	Plot 13	Plot 14
Down woody (0-6.9 cm in diameter)	0.0911	0.0822
Down woody ($7.0 cm in diameter)	0.3087	0.3556
Litter	0.0130	0.0256
Forest floor	0.7740	0.9884
Total fuel consumption:	1.1868	1.4518
Fire behavior:		
Depth of burn (cm)	4.7	6.4
Rate of spread (m/min)	1.0	9.0
Fireline intensity (kW/m)	228	2548

Carbon release: 5.93-7.25 t/ha

Quantitative values

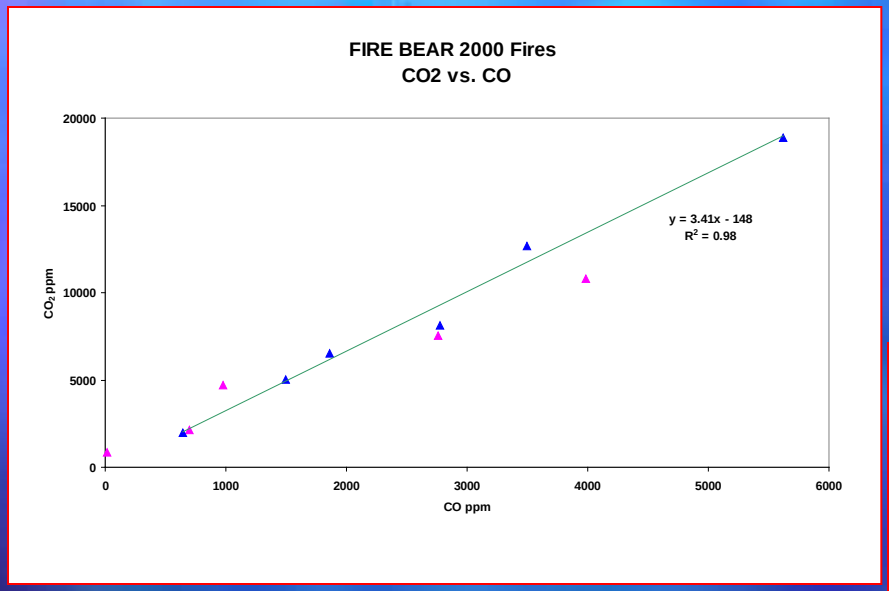
Emission Sampling

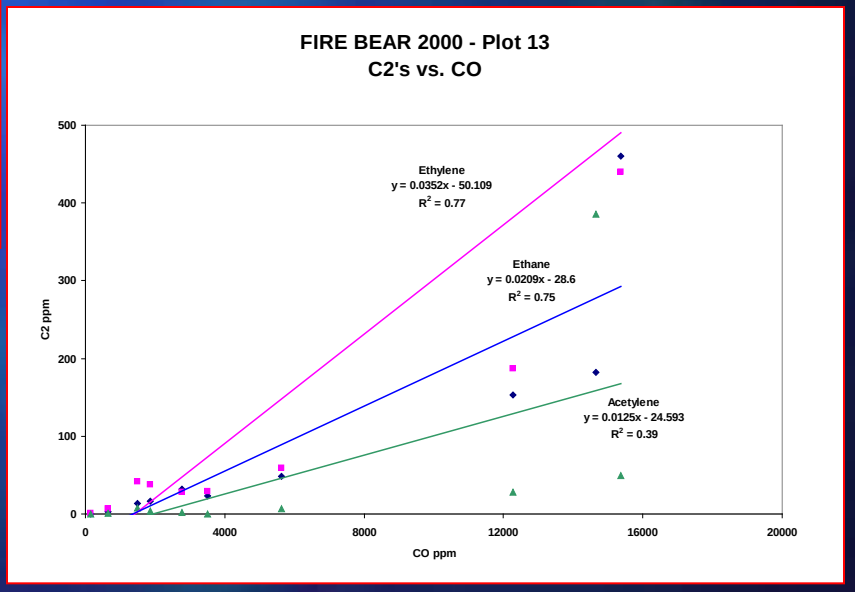
Russian ground team

Aerial sampling

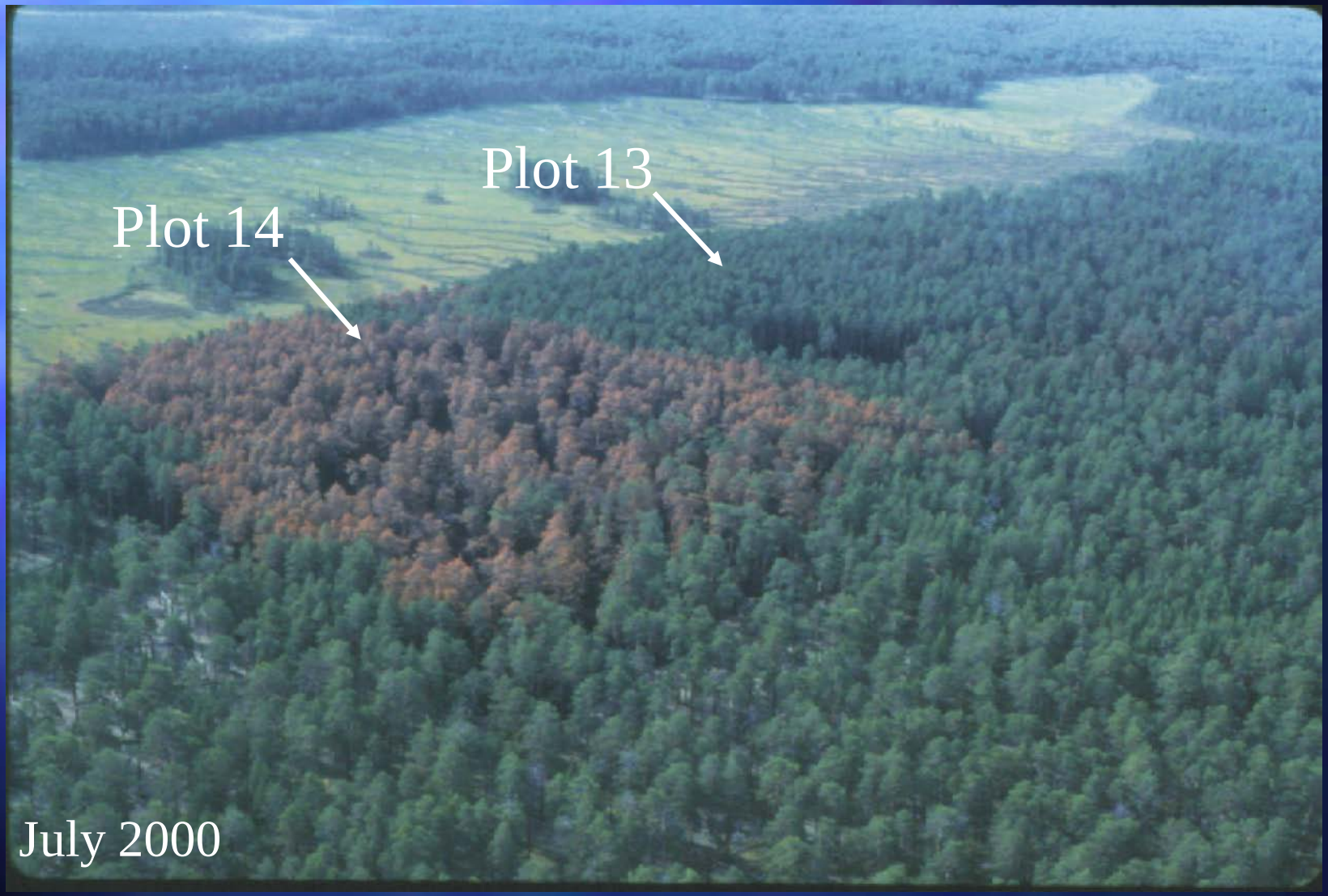
USFS ground team

Emission Results

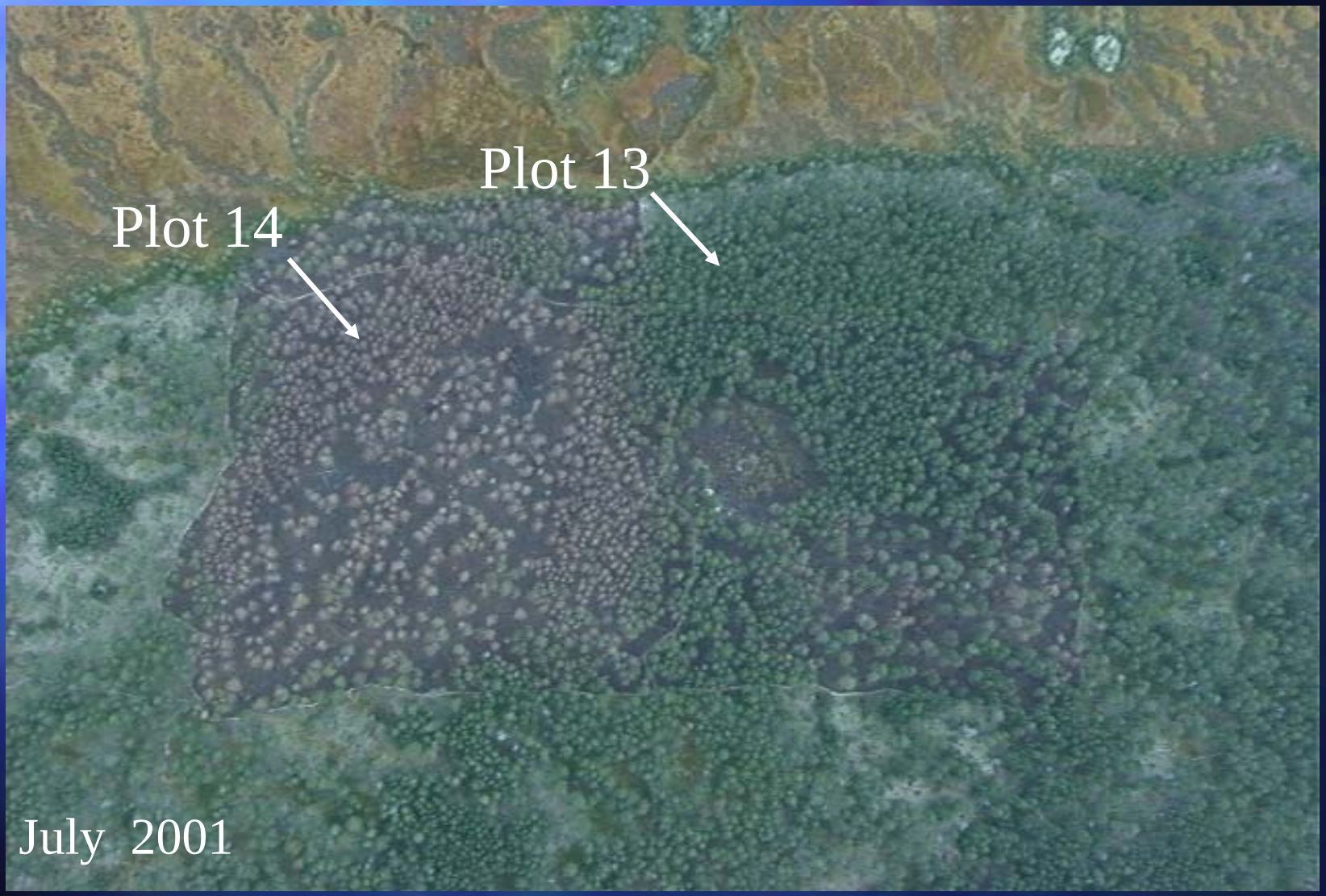




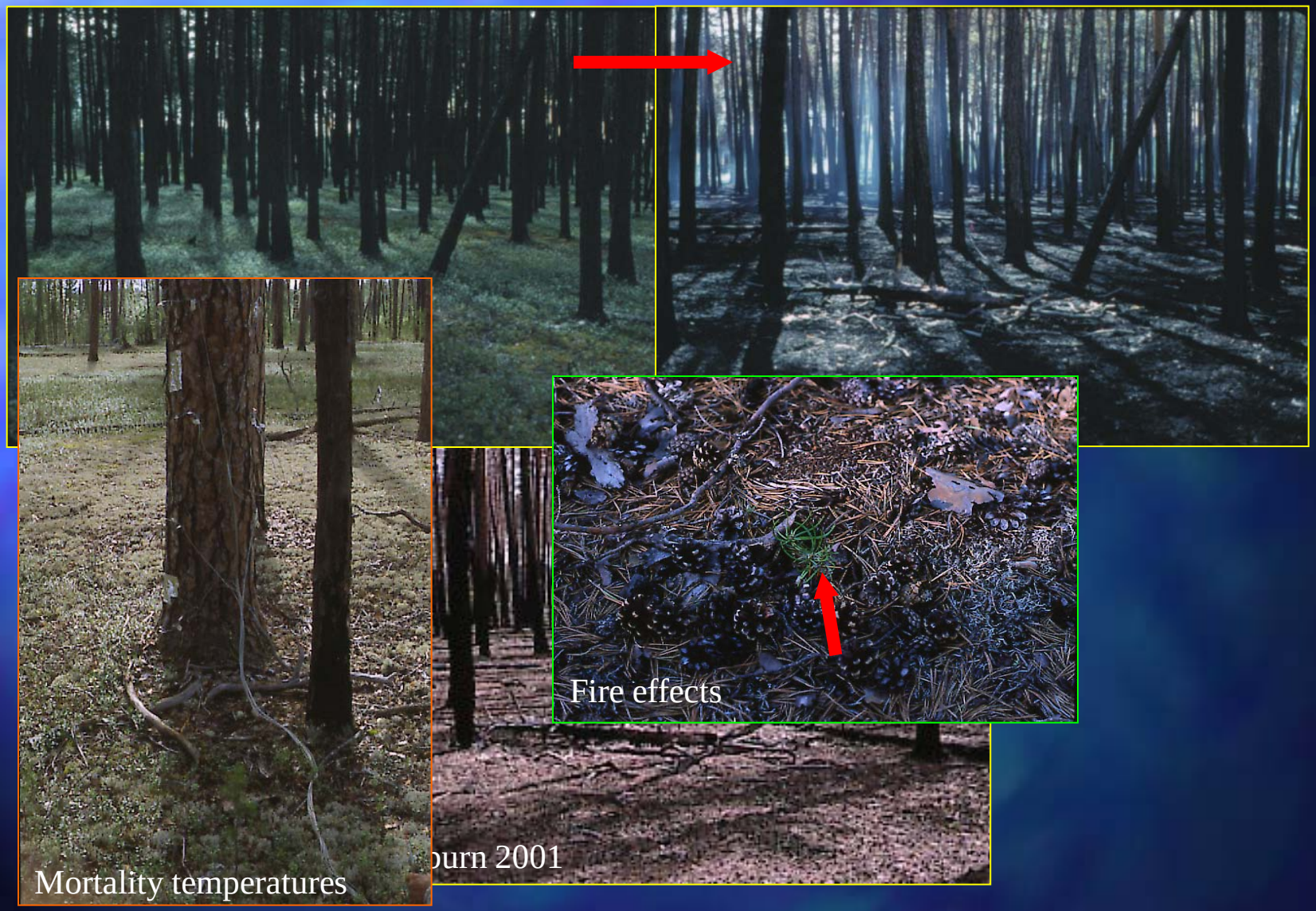
Aerial shot of Plots 13 and 14



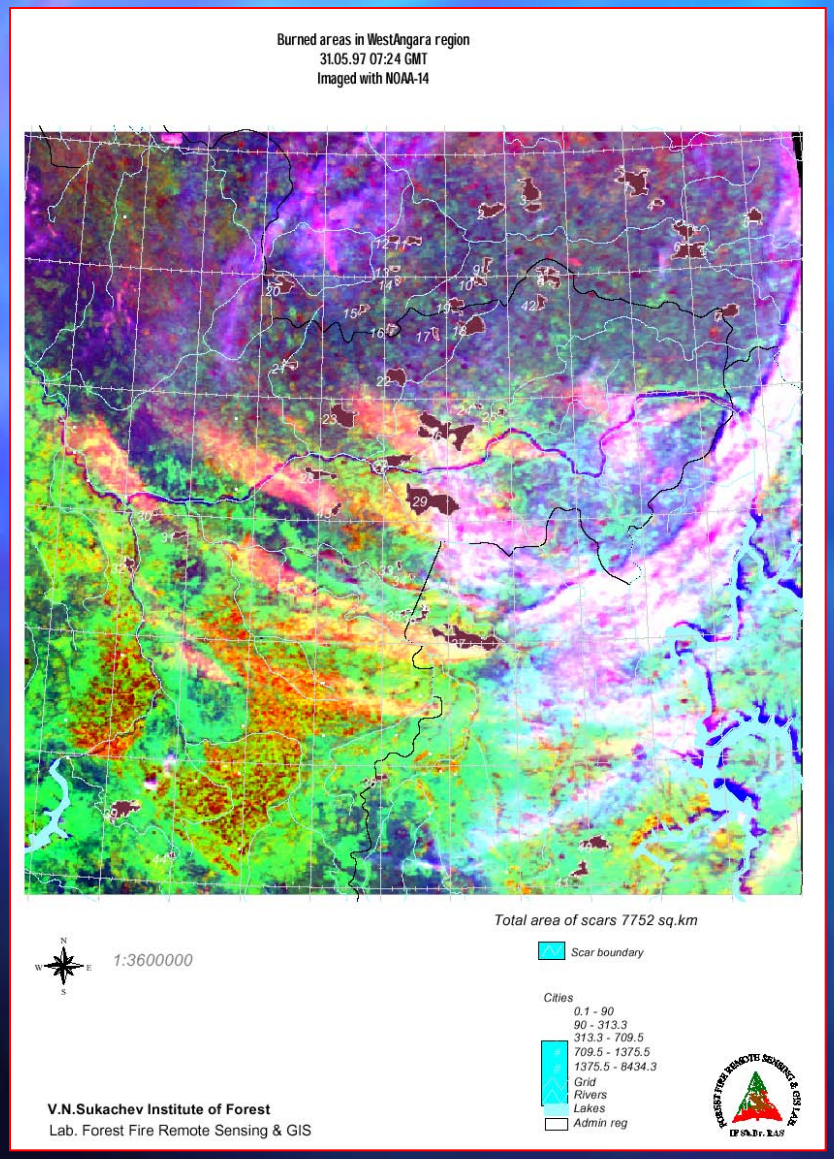
Aerial shot of Plots 13 and 14

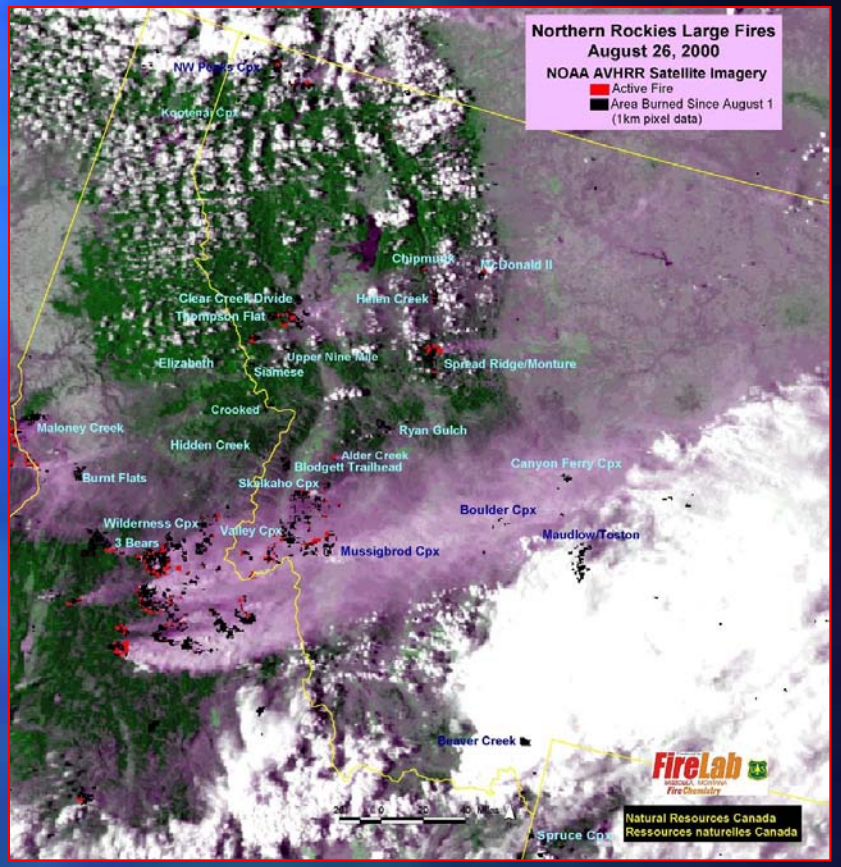


Fire effect - ecosystem functioning



Remote sensing analysis





Work Plans

- Summer 2001
  - Conduct and monitor experimental fires at Yartsevo
  - Secondary site development at Govorkovo
- Winter 2001-2002
  - Analysis of ground data (fire behavior and emissions)
  - Develop draft paper on initial fuel consumption and carbon release values for Siberian surface fires
  - Imagery analysis (AVHRR, MODIS, Landsat) to continue fire area/severity validation
  - Exchange visits to discuss methods and present results
- Summer 2002
  - Conduct and monitor experimental fires at Govorkovo (spring) and at Yartsevo (summer)
  - Monitor wildfires from air tied to ground sampling


Plot 14
Thank You