ATOMMS Status Report
IROWG 2012

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Rationale: Observational Needs for Climate

Climate models are wrong in ways that we don't yet know.

When you don't understand something, you measure it

Need observations as complete as possible to **determine the atmospheric state** and what is actually happening, ***independent of models***

Can we achieve this via satellite to satellite occultations?

Climate: Is the atmosphere getting wet or dry?. Pick your database (ECMWF-interim, NASA-MERRA, ERA40, Japan-JRA, NCEP)

Dessler & Davis, 2010

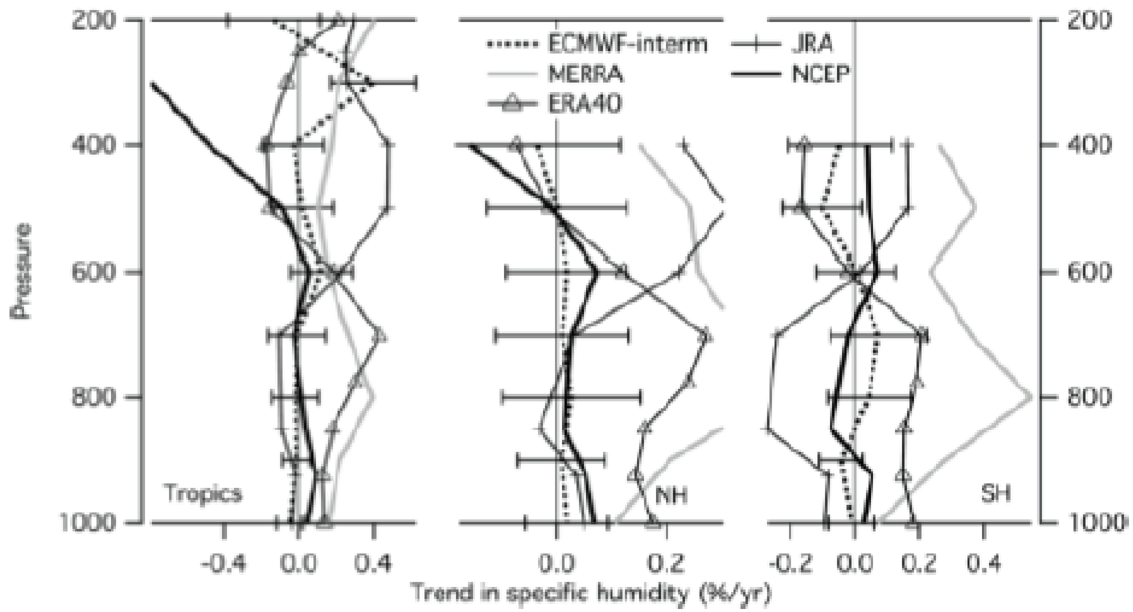
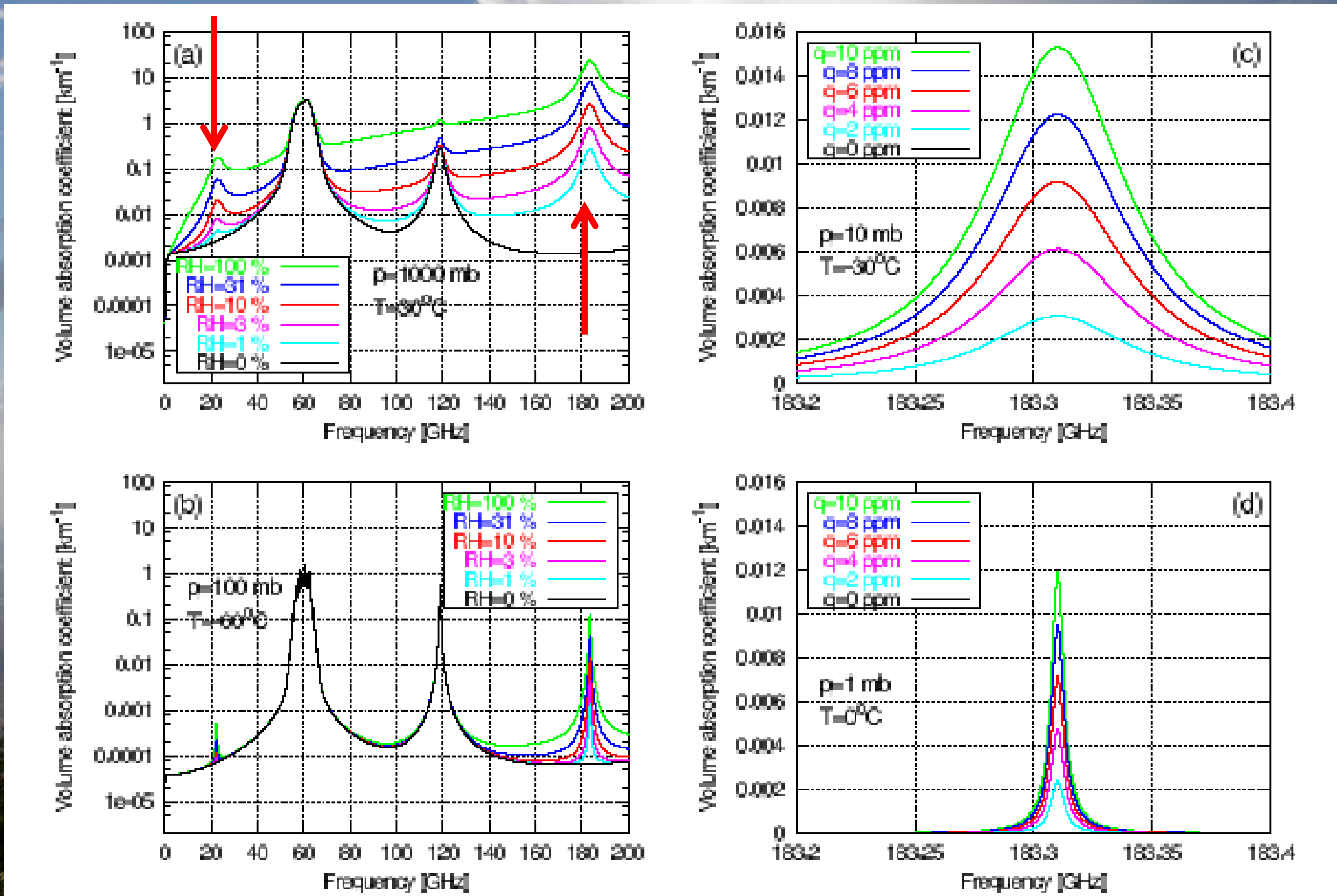


Figure 1. Plots of the trends in specific humidity in the different reanalyses, over the time periods discussed in the text (1979 onward, except for the ECMWF-interim, which begins in 1989). The plots are divided into three geographical regions: tropics (20°S–20°N), NH (20°N–50°N), and SH (20°S–50°S). Trends are divided by the average specific humidity over the entire time period, so they are expressed in percent per year. The 95% confidence interval for trends in the ERA-interim reanalysis are shown for illustration purposes.

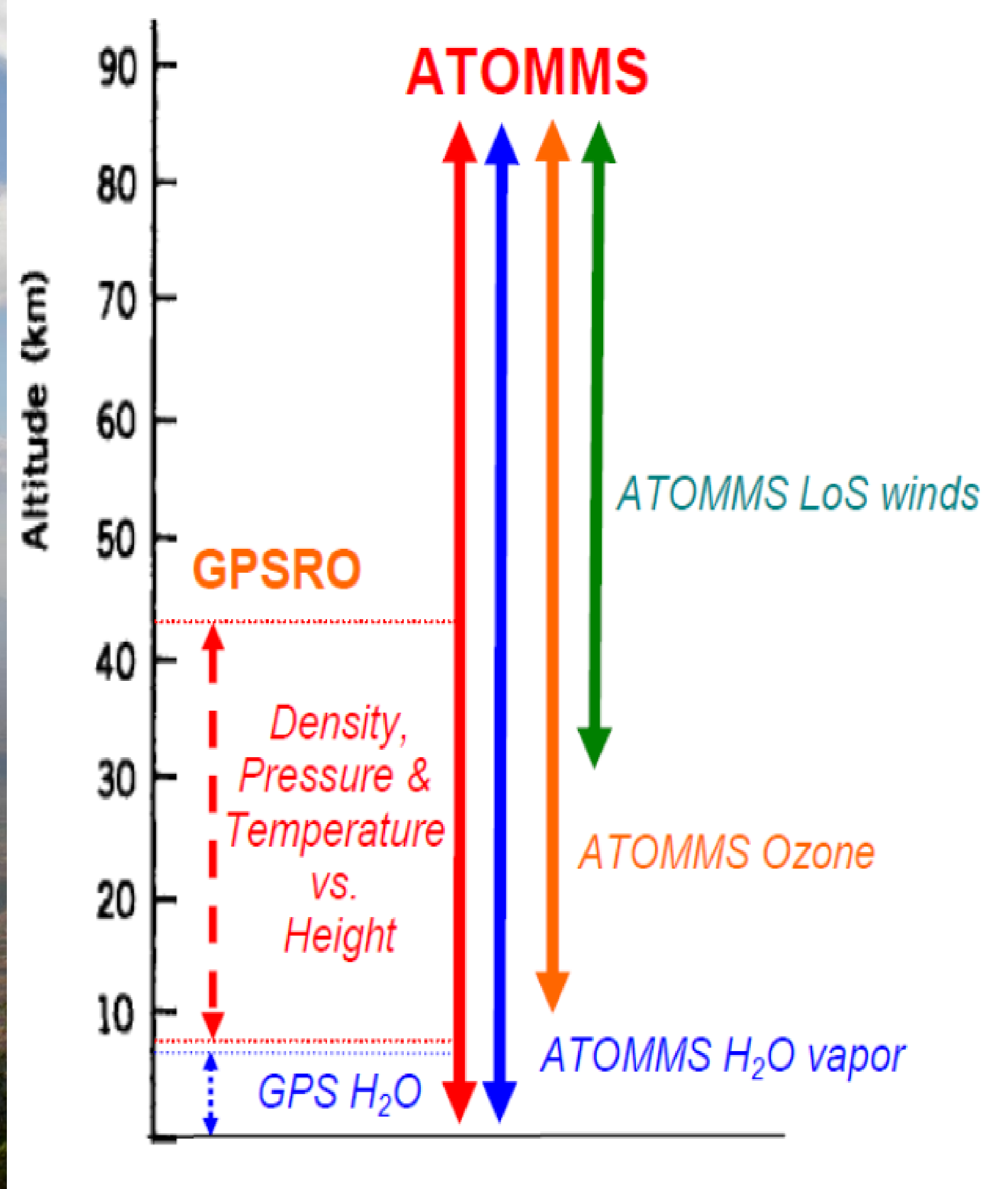
Atmospheric Spectrum below 200 GHz



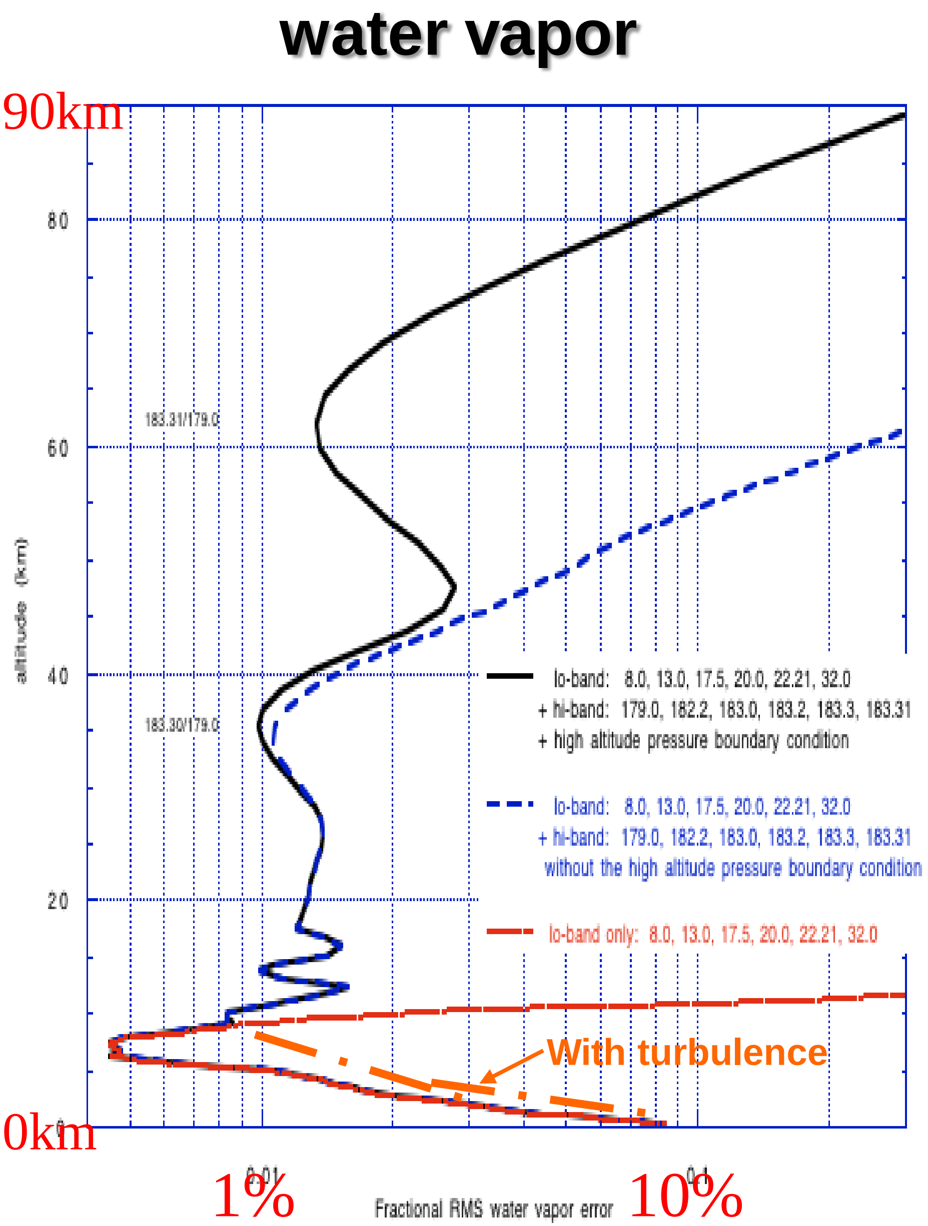
ATOMMS vs. GPS

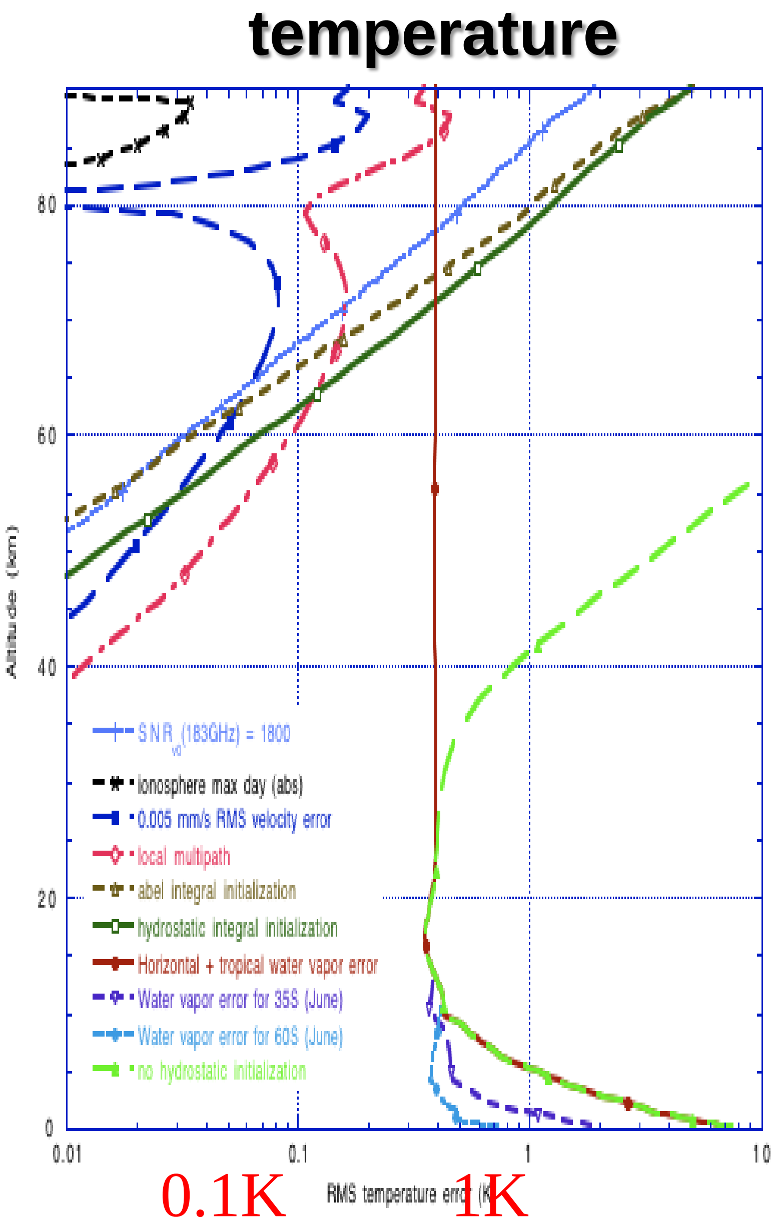
Profiles

- H_2O vapor, temperature & pressure *simultaneously*
- O_3 and H_2O isotopes
- LoS winds >mid strat
- Sees thru clouds
- Very little sensitivity to ionosphere
- Profiles extend to ~mesopause
- Requires new transmitters in orbit



Precision of Individual ATOMMS Profiles

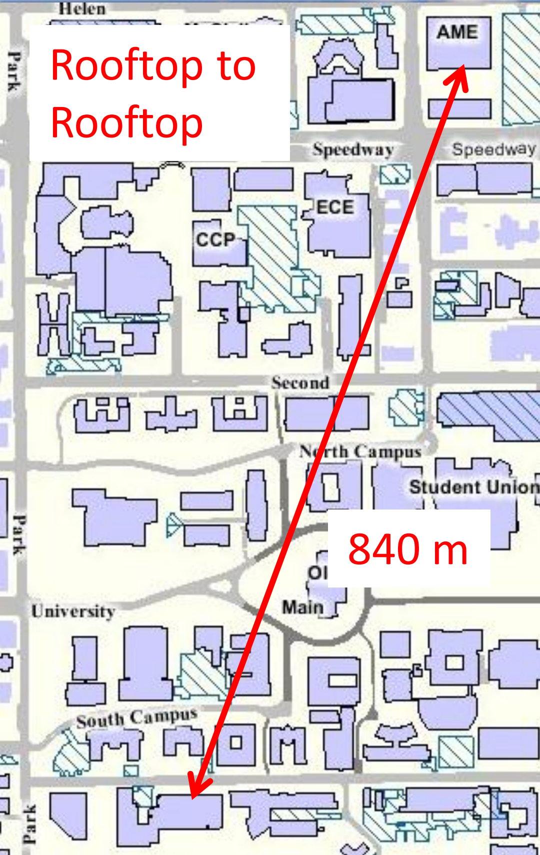




Field Measurement Summary

- **Water vapor measurements & Spectroscopy**
- **Turbulence measurements**
- **Cloud & rain water measurements**
- **August 18, 2011 measurements**
  - **Movie**
  - **Droplet & Rainfall inferences**
  - **Turbulence**
  - **Water vapor estimates**
- **Conclusions**

3 Field Test Geometries



- Rooftop: 840 m
- Lemmon to Bigelow: 5.4 km
- Hopkins to Lemmon: 84 km


View of Mt. Lemmon from Mt. Bigelow

View from Mt Hopkins to Mt. Lemmon

Deployed Instrument Photos

Mt. Hopkins

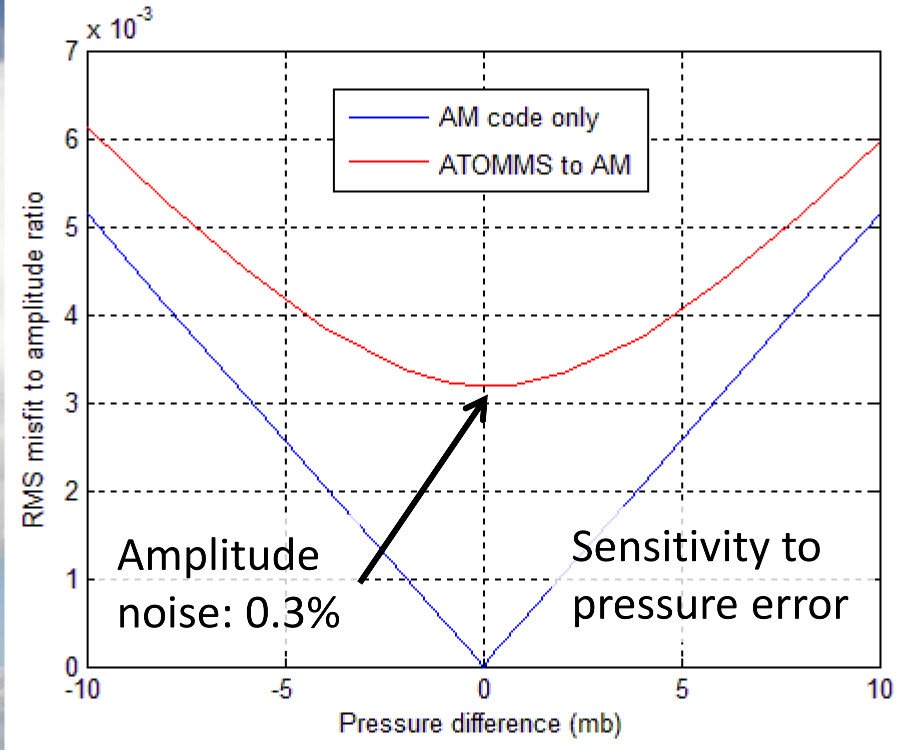
Mt. Lemmon

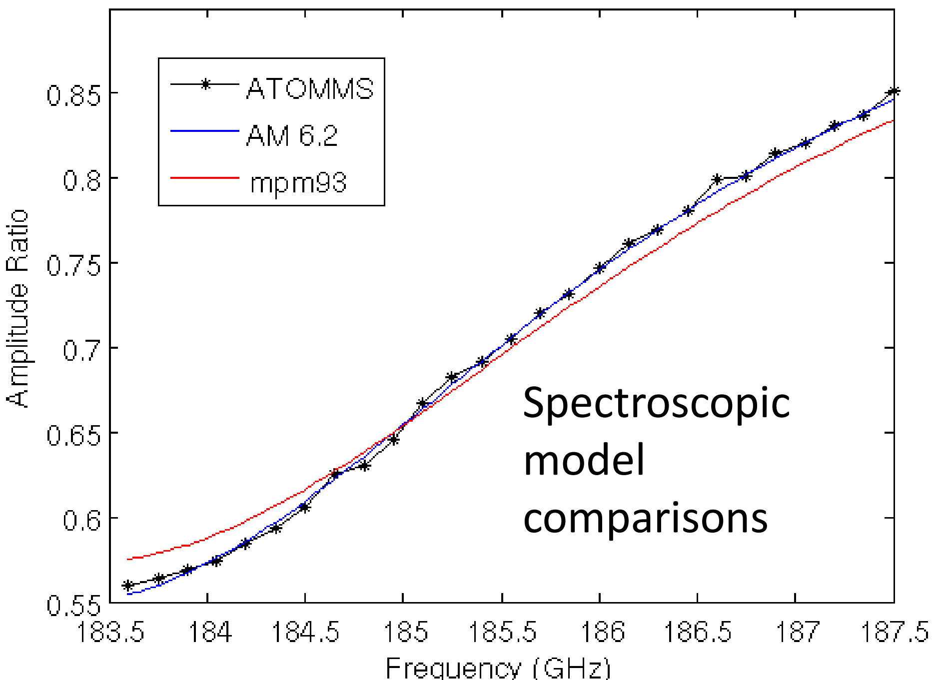
Mt. Lemmon

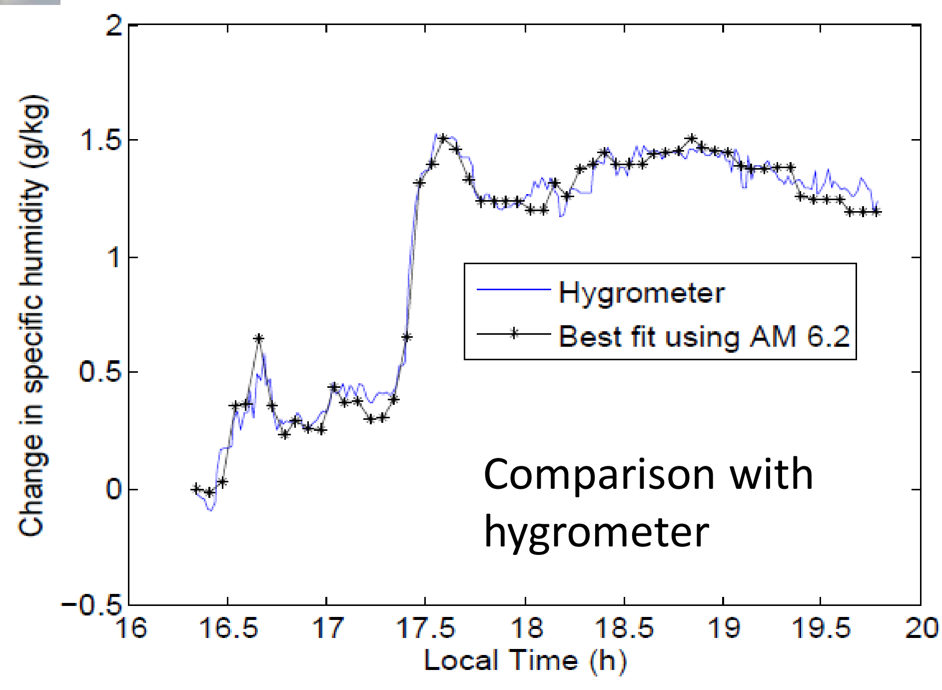
Mt. Bigelow

Spectroscopy & Water Vapor Retrievals

- 840 m Rooftop measurements

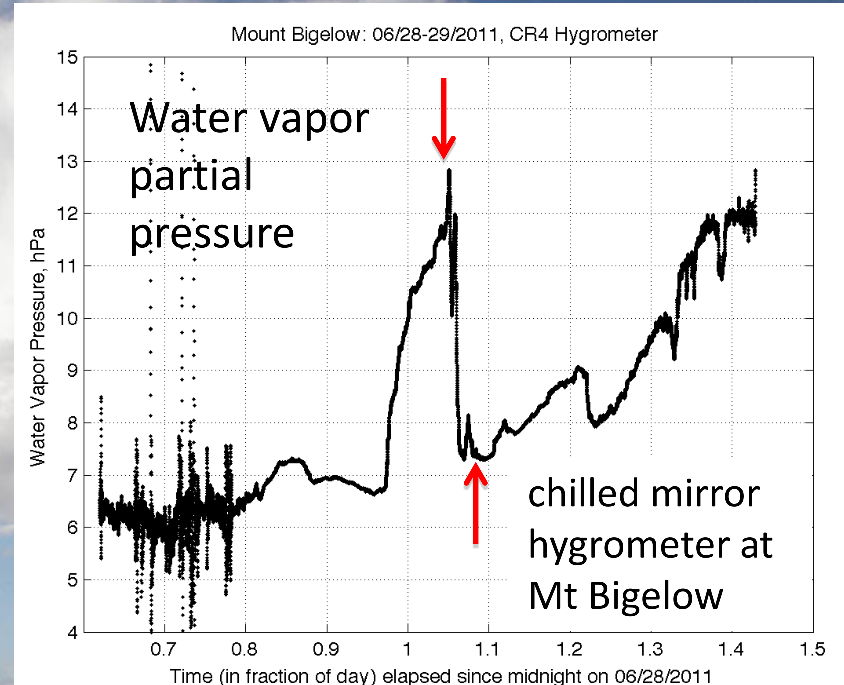


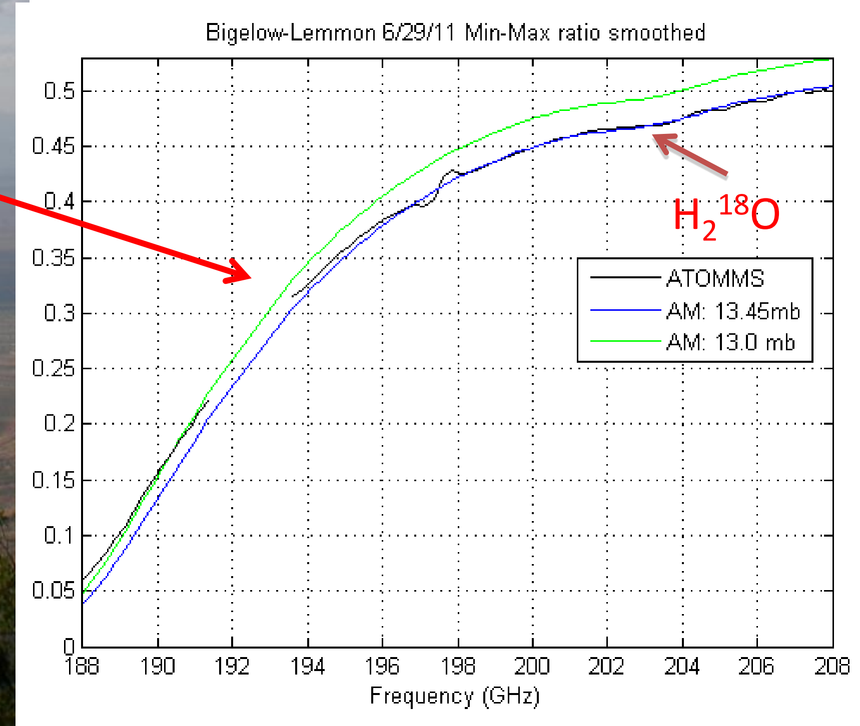




Water Vapor June 28-29, 2011

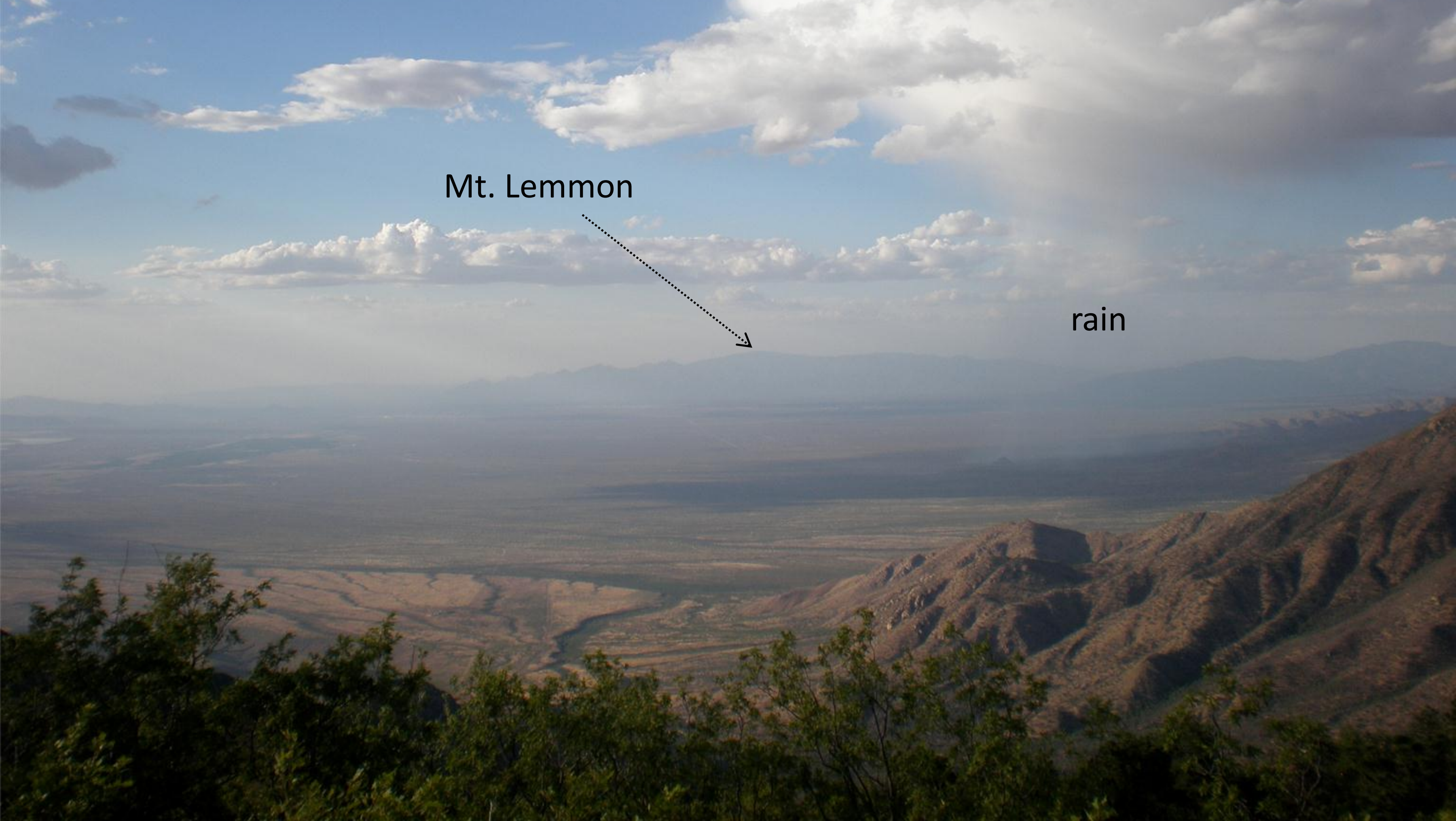
- 22 & 183 GHz systems
- Mt. Bigelow to Mt. Lemmon
- Arrows indicate times of max and min water vapor
- Used to generate water vapor ratio spectrum
- Evaluate spectroscopy farther from line center & at lower pressure
- First ATOMMS measurement of $H_2{}^{18}O$ isotope



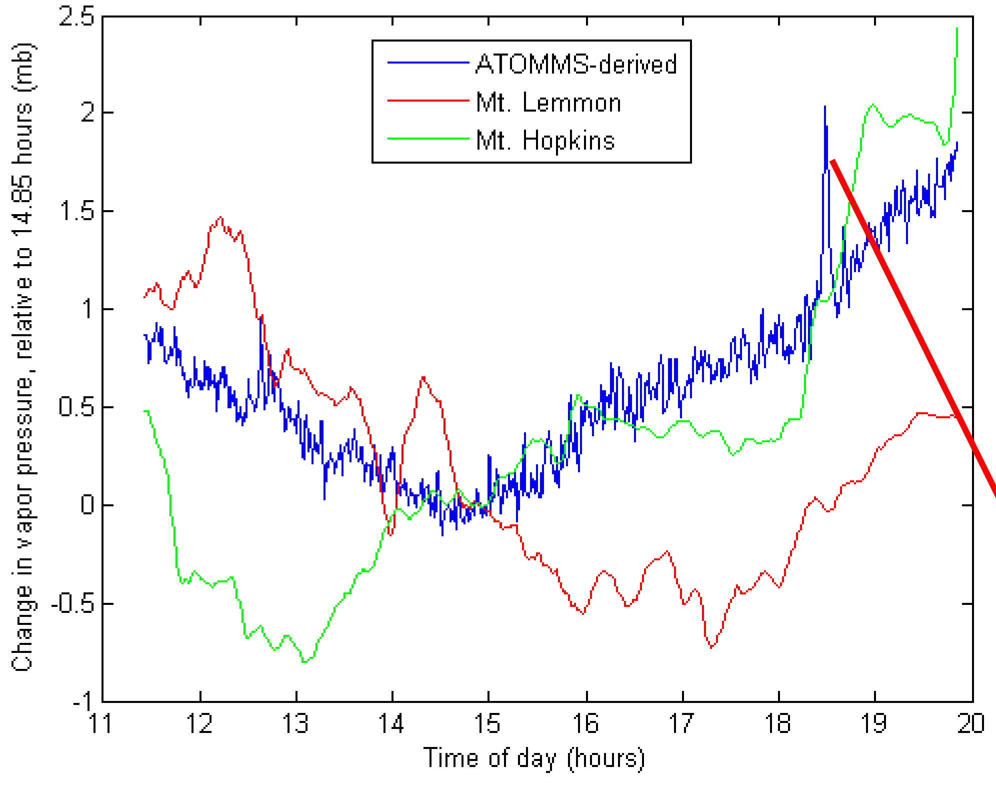


84 km 18-24 GHz Measurements

View from Mt. Hopkins to Mt. Lemmon July 2, 2011



22 GHz Water Vapor Measurements

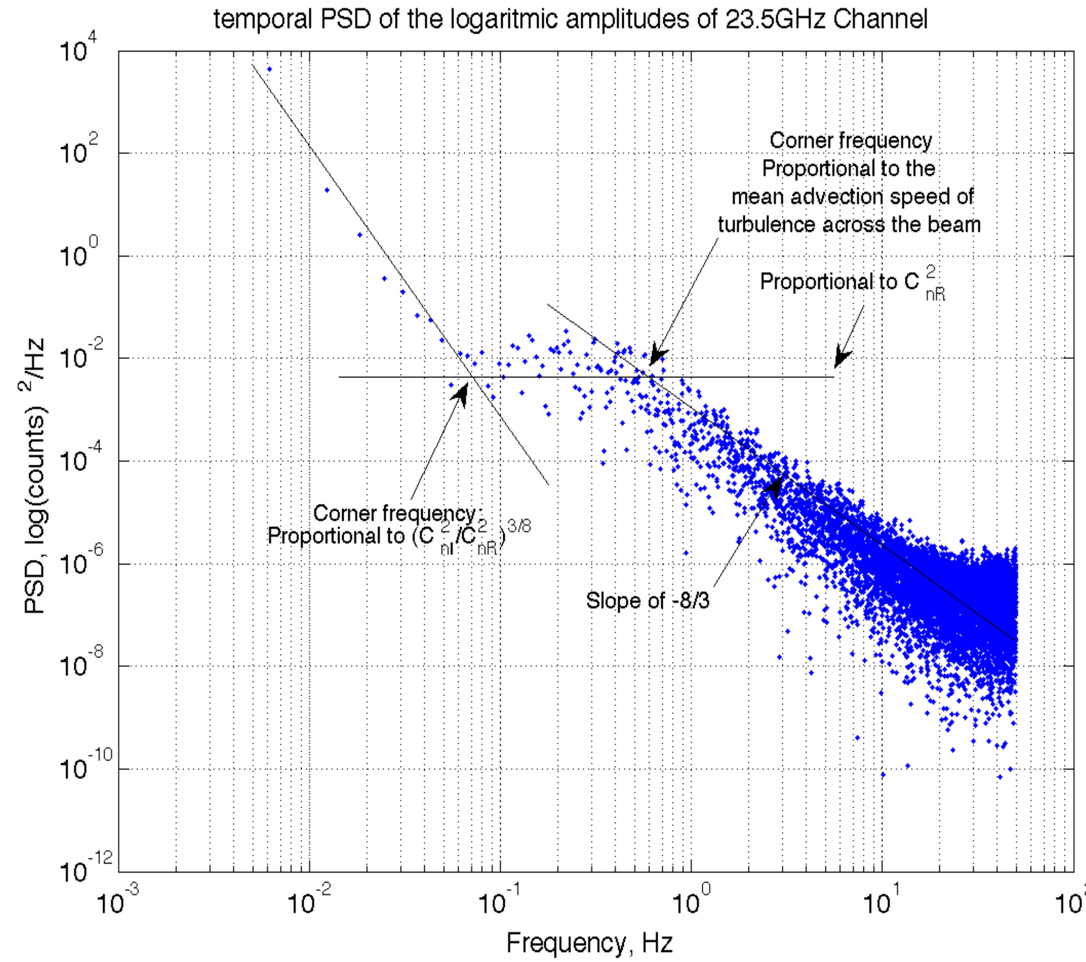


- *Blue line: change in water vapor derived from the 8 channels of ATOMMS 22 GHz system and comparisons with AM model spectra using average pressure & temperature measured at Mt. Hopkins & Mt Lemmon.*
- *Red line: water vapor measured at Mt. Lemmon.*
- *Green line: water vapor measured at Mt. Hopkins.*

Atmospheric Turbulence

- Atmospheric turbulence causes amplitude and phase scintillations in occultation signals
- Scintillations are a source of noise when trying to isolate the water vapor absorption signature
- We need to know how the scintillations will limit the accuracy of observations from orbit
- The best way to estimate this prior to orbit is via aircraft occultation measurements
- Scintillation measurements between rooftops & mountaintops are shown here

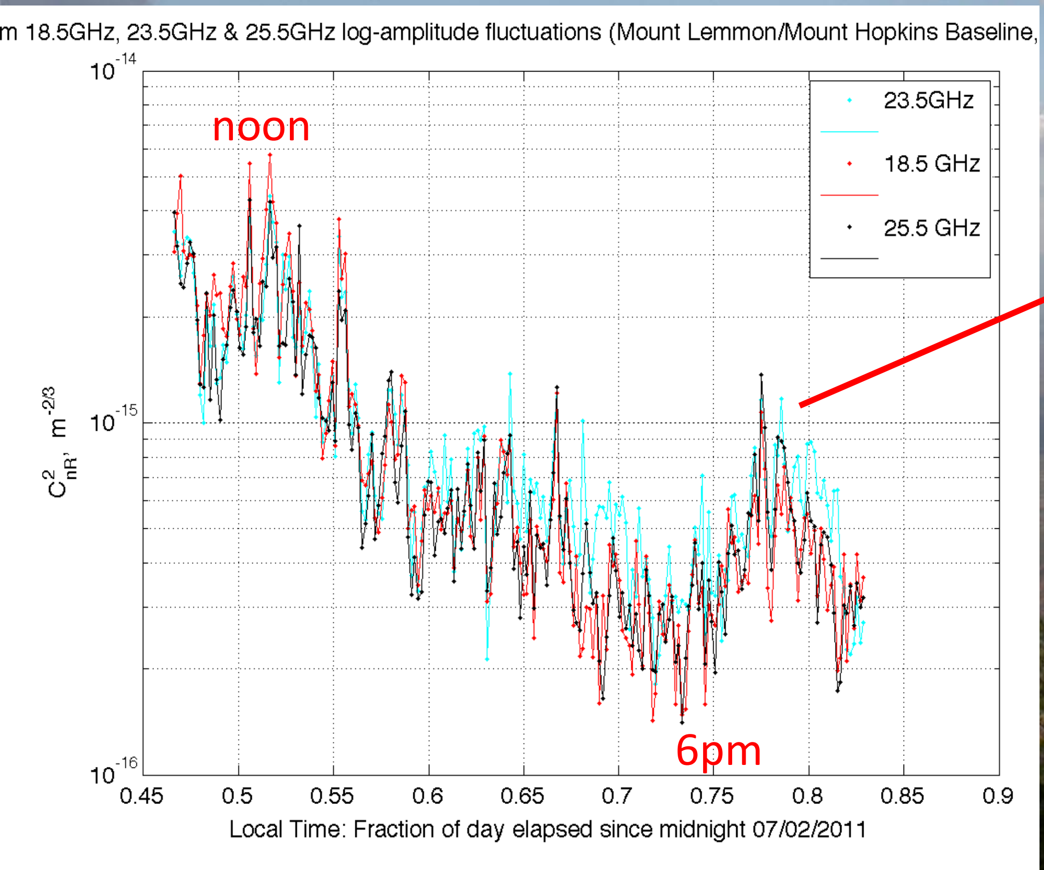
Turbulence Measurements



- *PSD of 150 sec of log amplitude fluctuations at 23.5 GHz.*
  - *PSD 6 mHz frequency resolution*
- *10-ms amplitude estimates (50 Hz Nyquist rate).*

Time evolution of turbulence intensity

- C_{nr}^2 maximum around noon, then decrease
- Relative maximum as thunderstorm came near in late afternoon



August 2010 & 2011 Mt. Bigelow & Lemmon Field Experiments

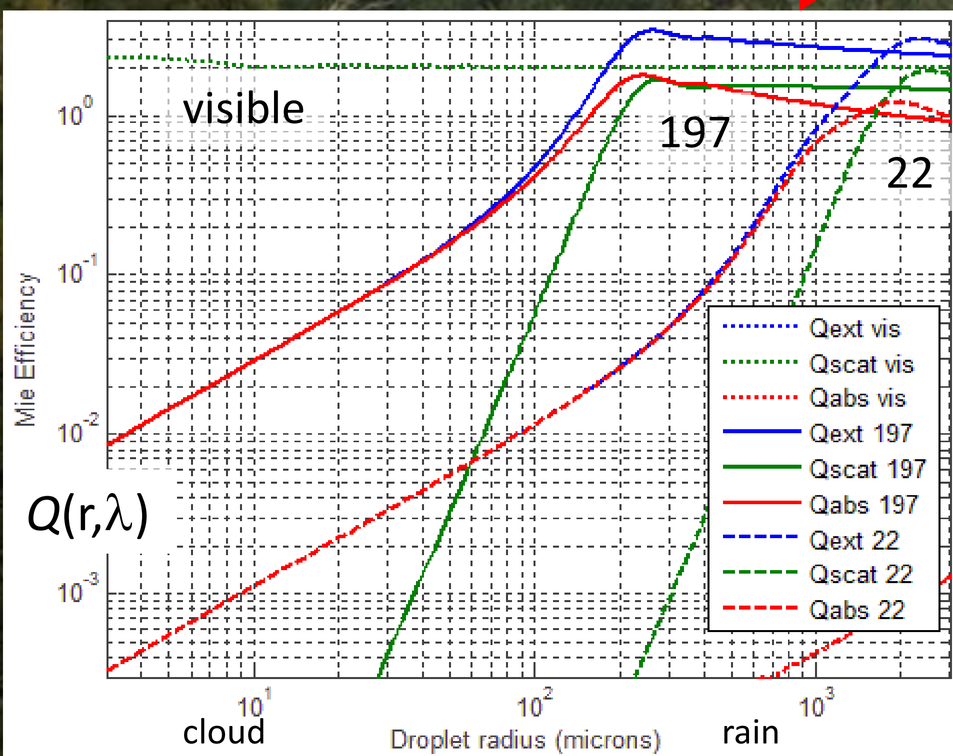
Mt Lemmon

Mt Bigelow

Attenuation due to Cloud & Rain Drops

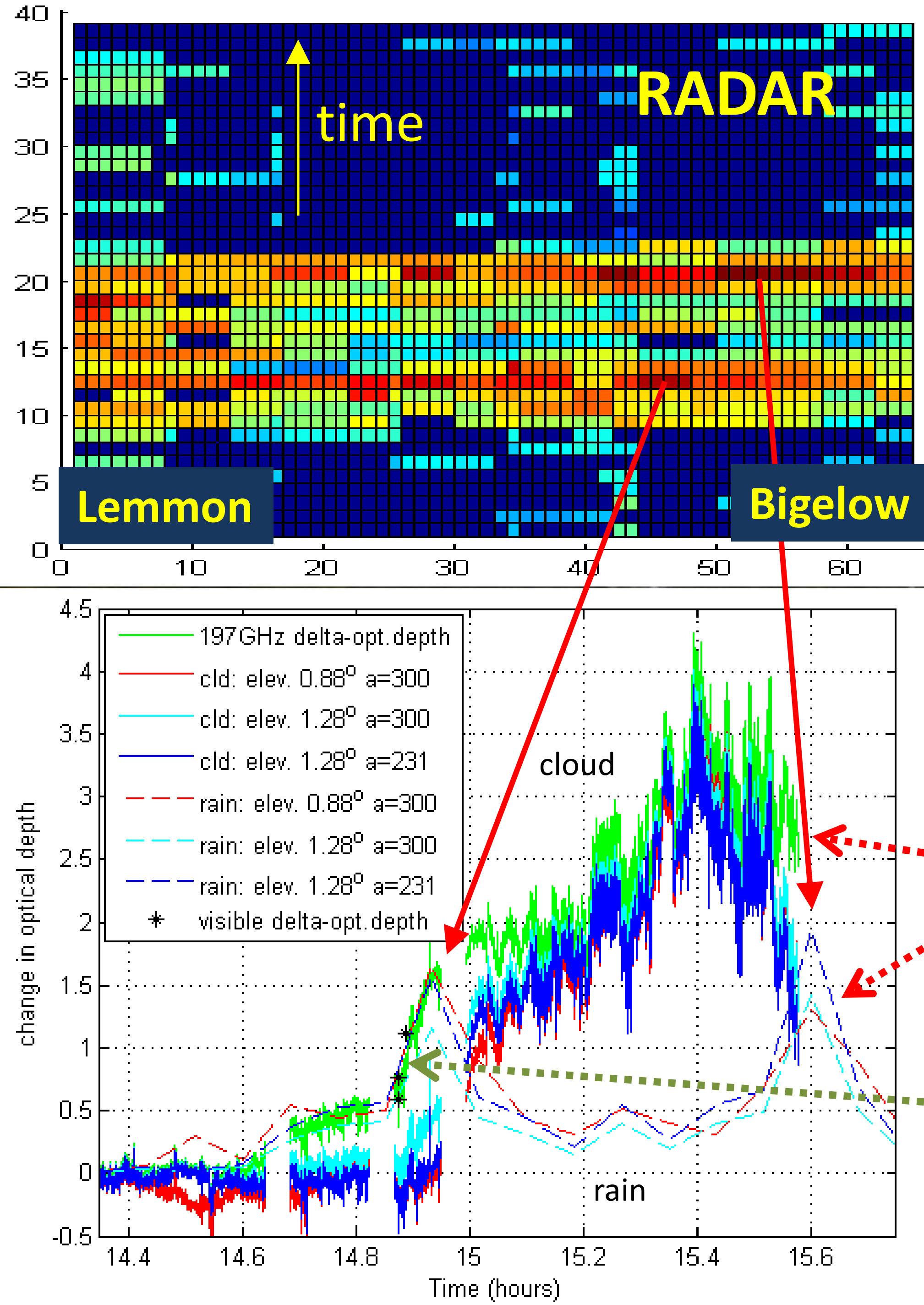
Extinction coefficient

$$k(D,\lambda) = \int \sigma(D)n(D)dr = \int Q(D,\lambda)\frac{\pi}{4}D^2 n(D)dD$$



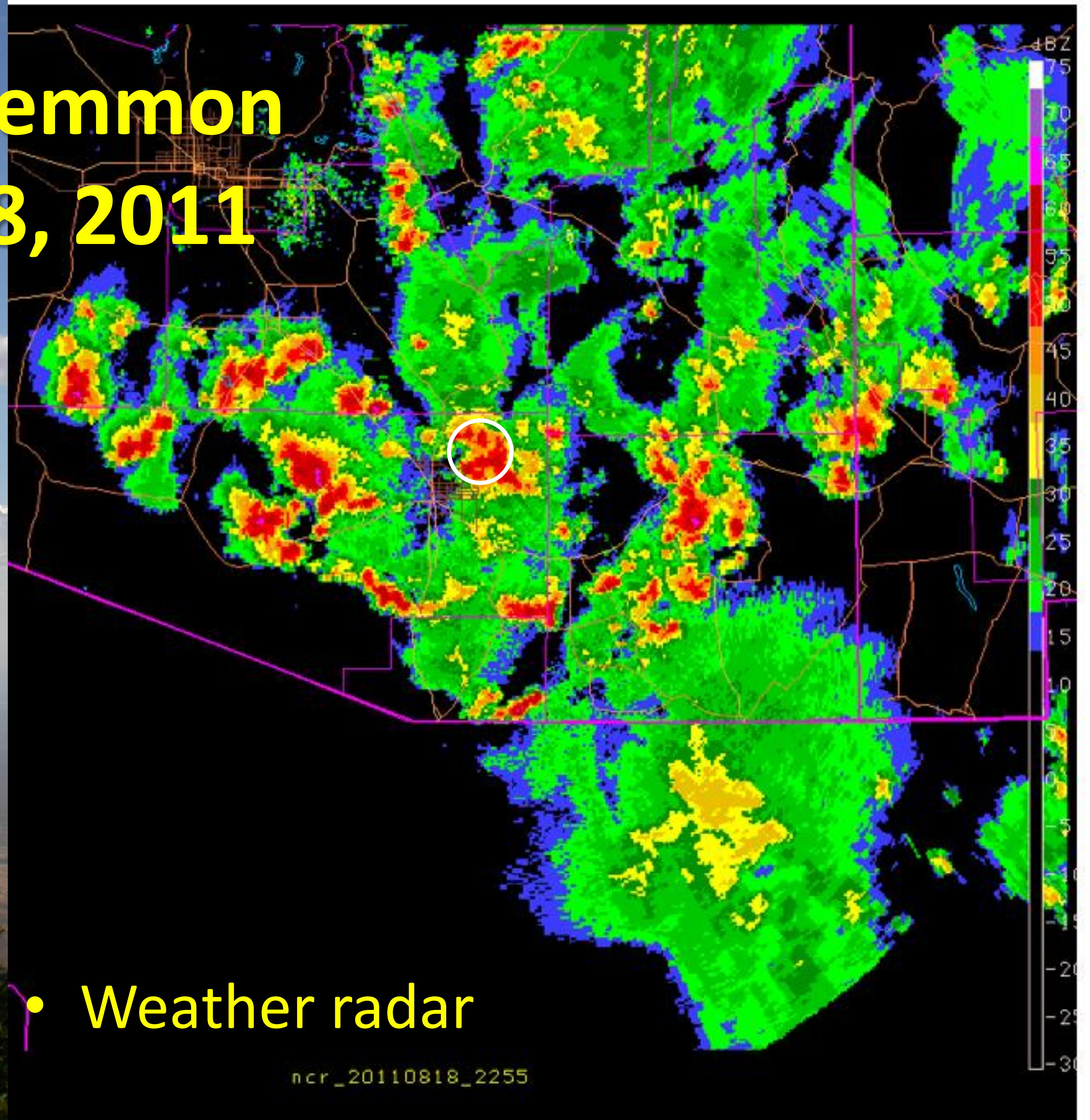
Use Mie scattering theory to interpret ATOMMS, radar and visible measurements

Clouds & Rain August 28, 2010



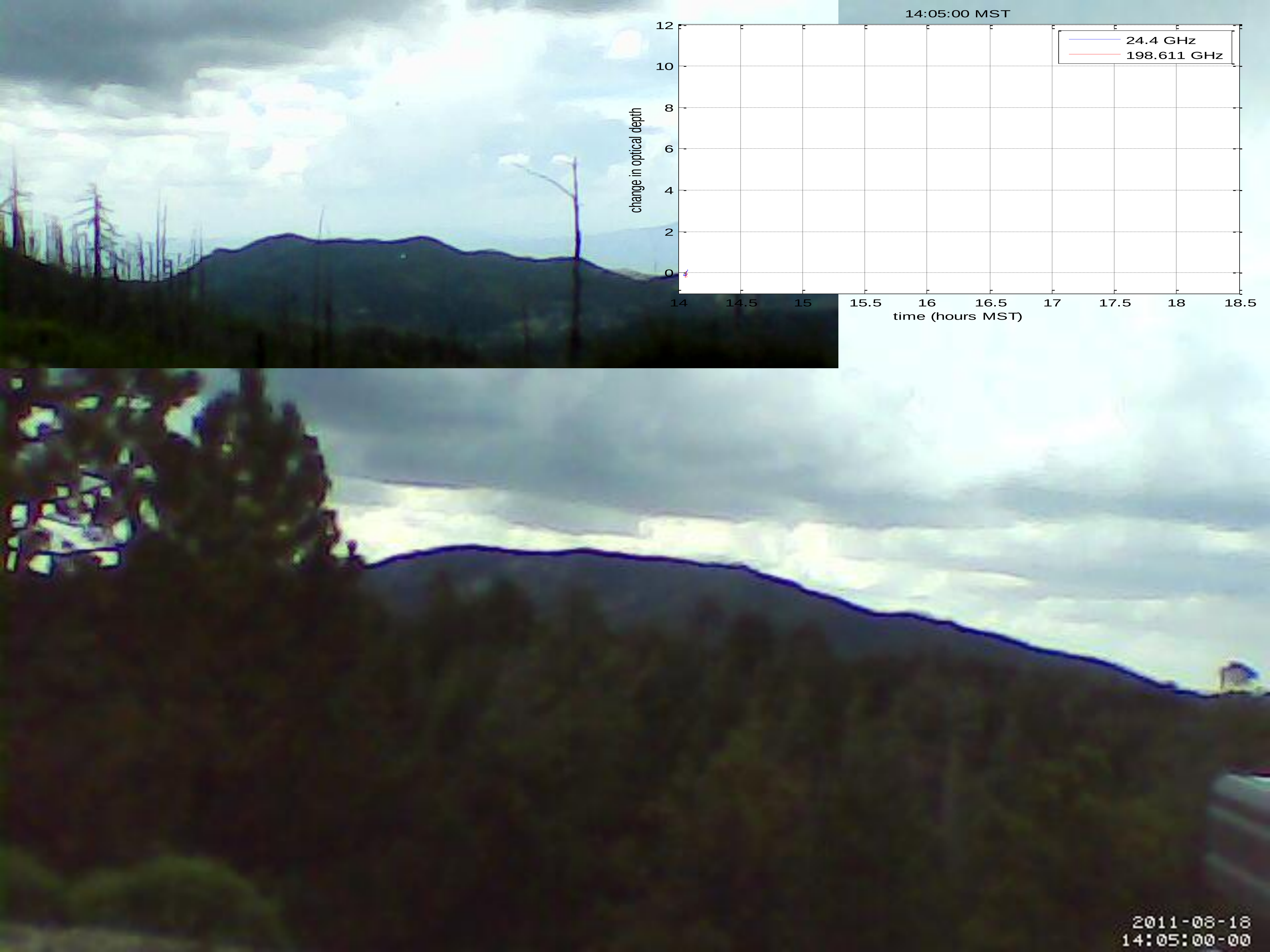
- Simultaneous 197 GHz, weather radar & visible obs.
- Separate cloud & rain
- τ (197 GHz) ~ τ (visible)
  => Rain at onset
- Consistent with radar

Bigelow-Lemmon August 18, 2011



- Weather radar

5 minute images



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24.4 GHz
198.611 GHz
change in optical depth
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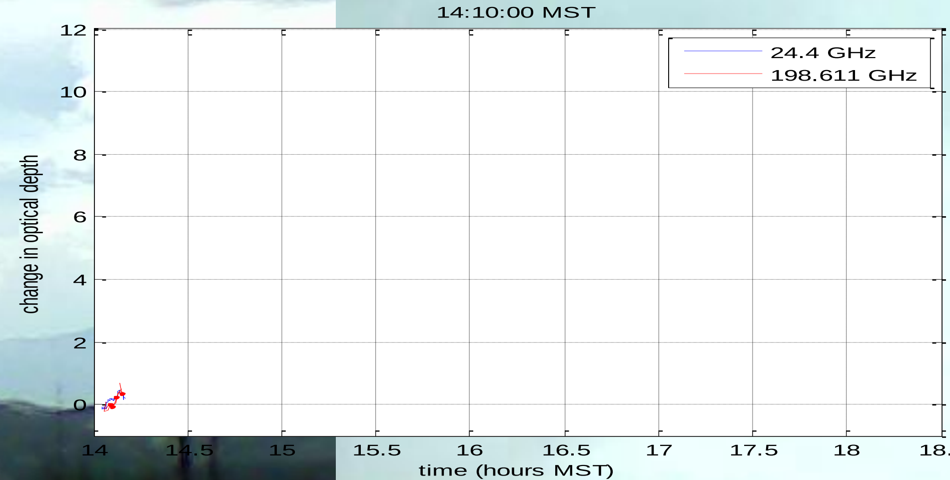
time (hours MST)
2011-08-18
14:05:00-00



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time (hours MST)

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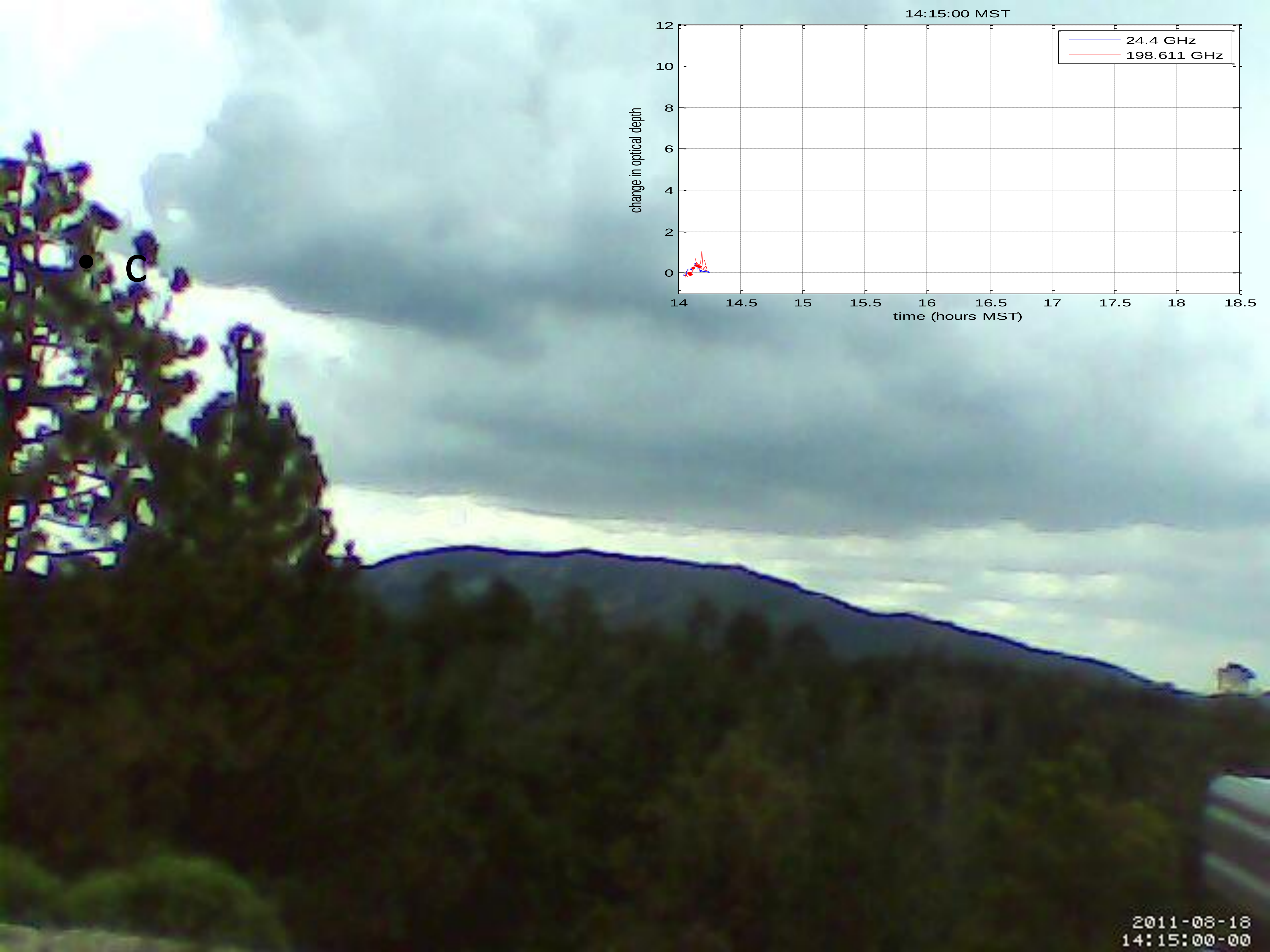

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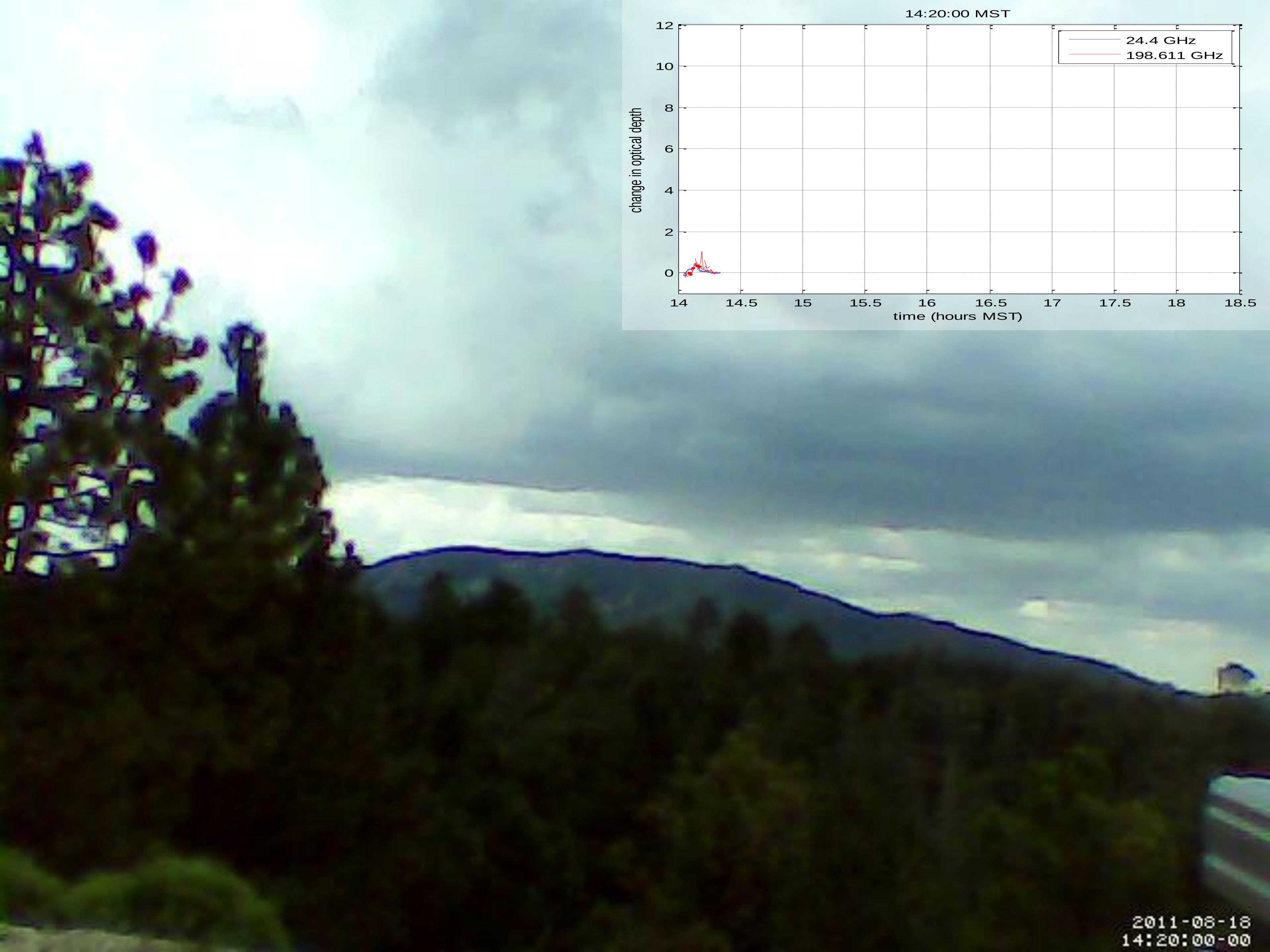
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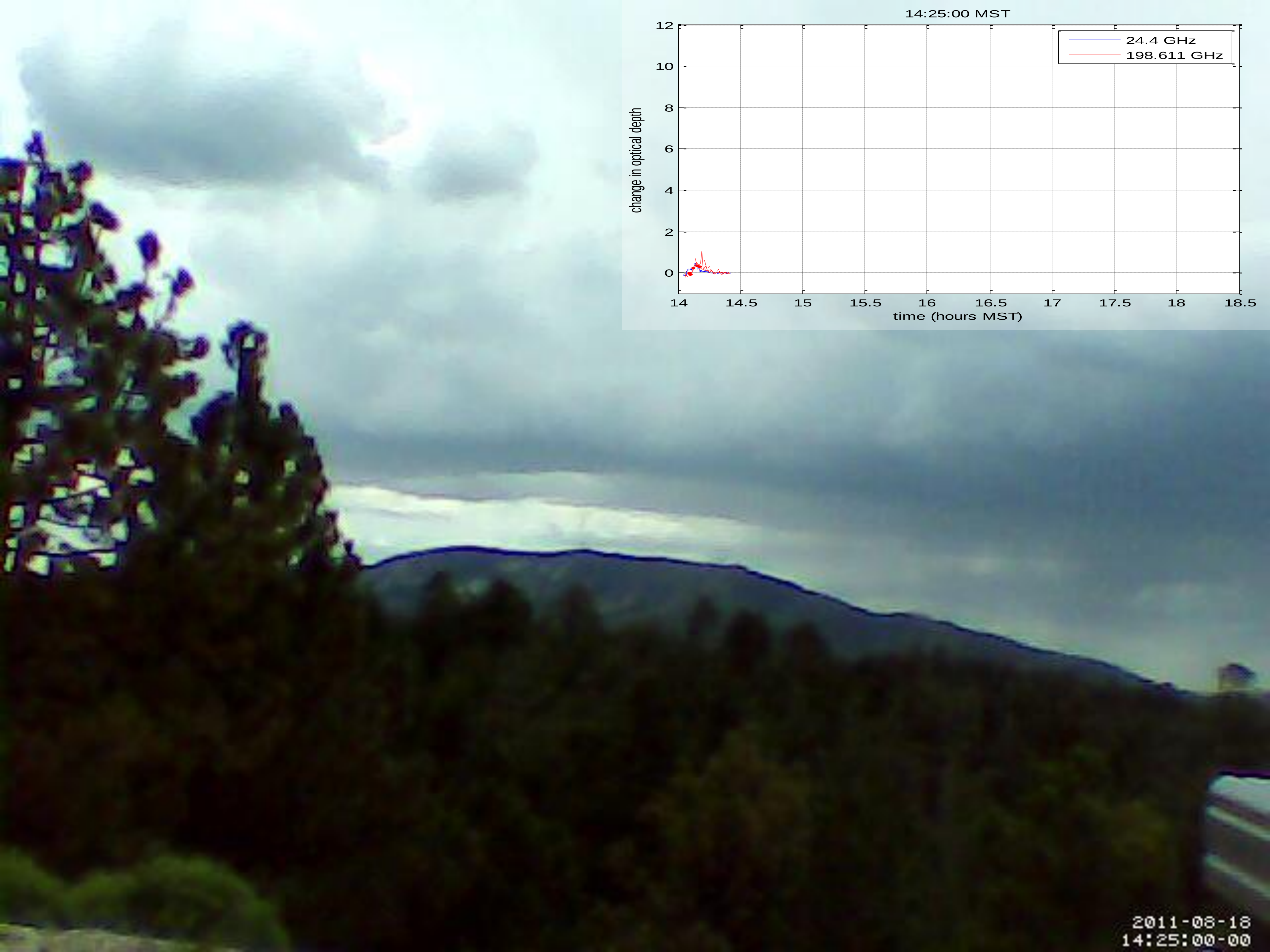
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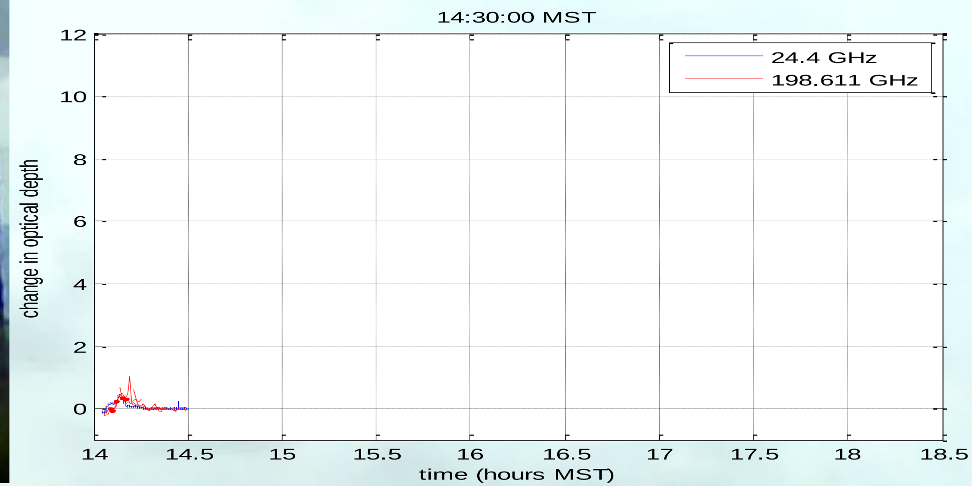

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198.611 GHz
change in optical depth
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time (hours MST)

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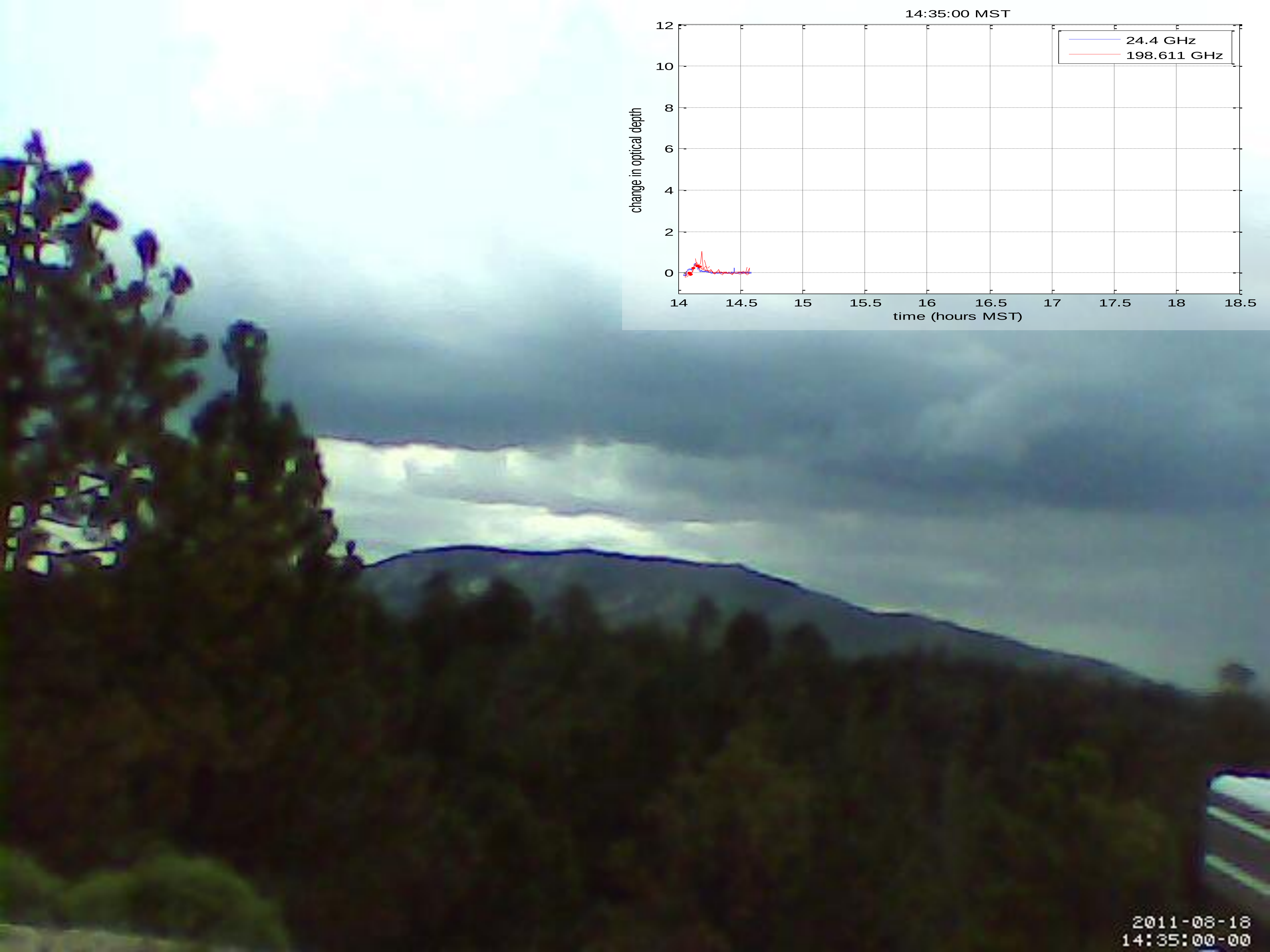
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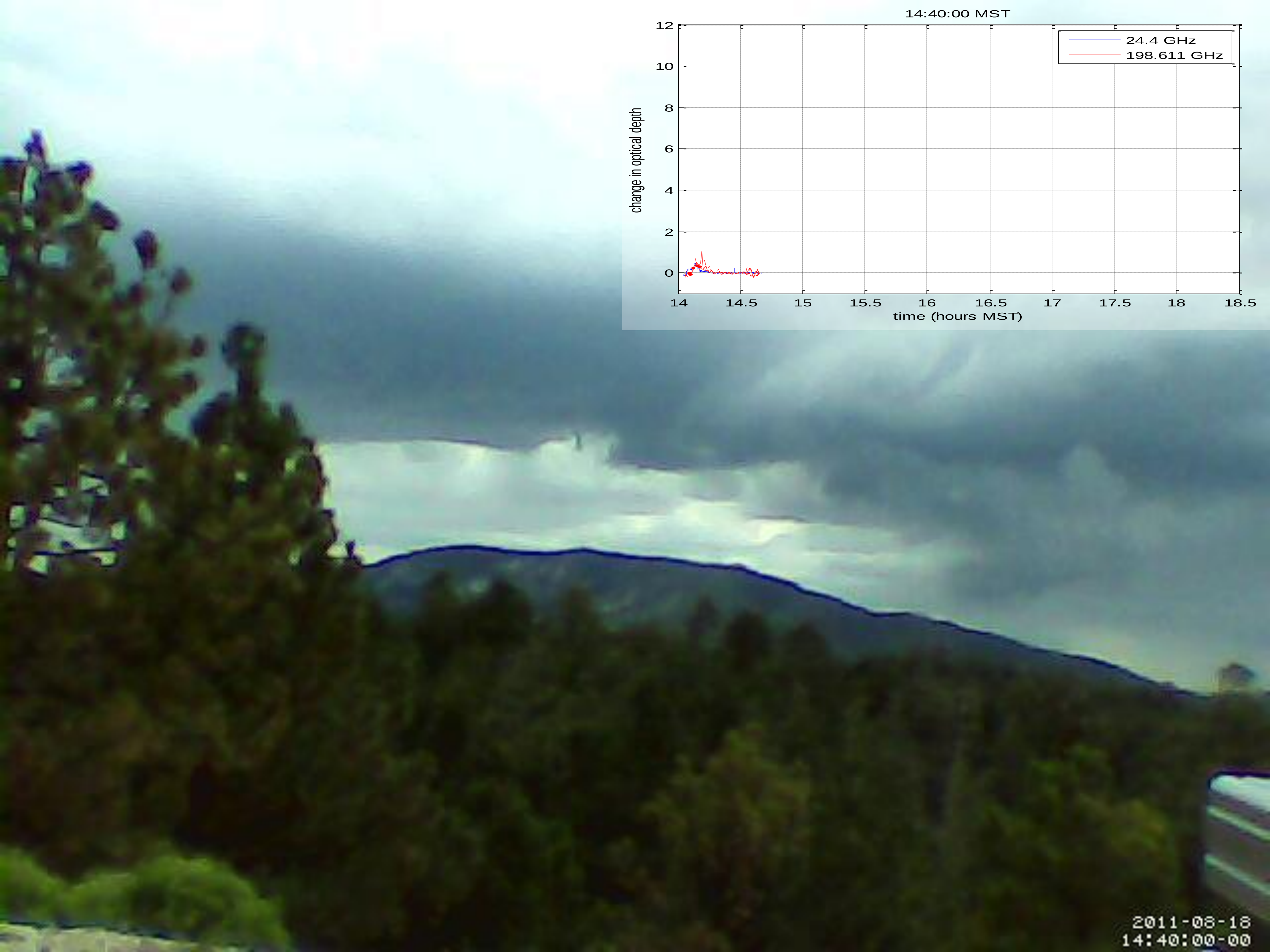

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198.611 GHz
change in optical depth
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time (hours MST)
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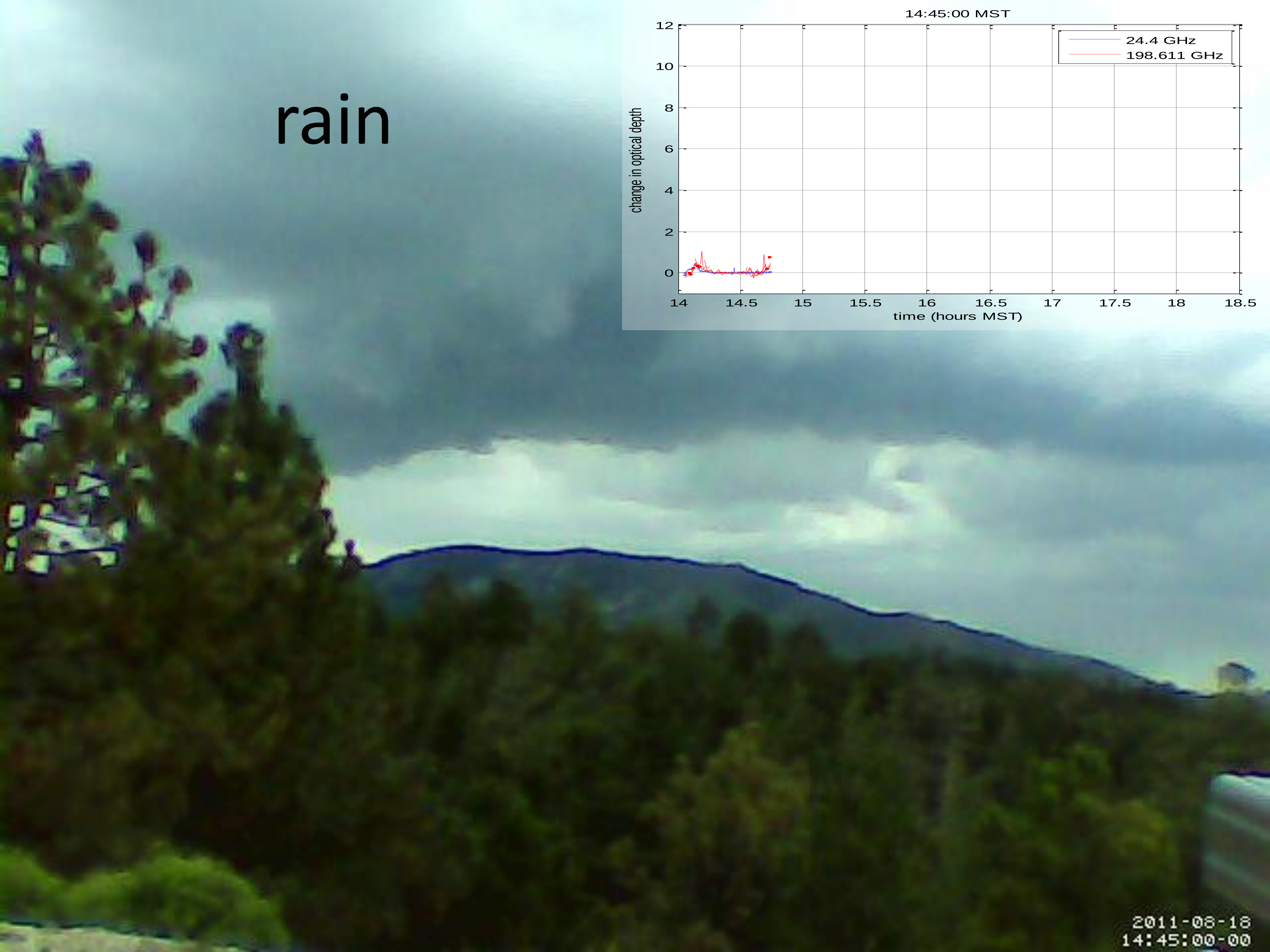
rain



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time (hours MST)
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2011-08-18
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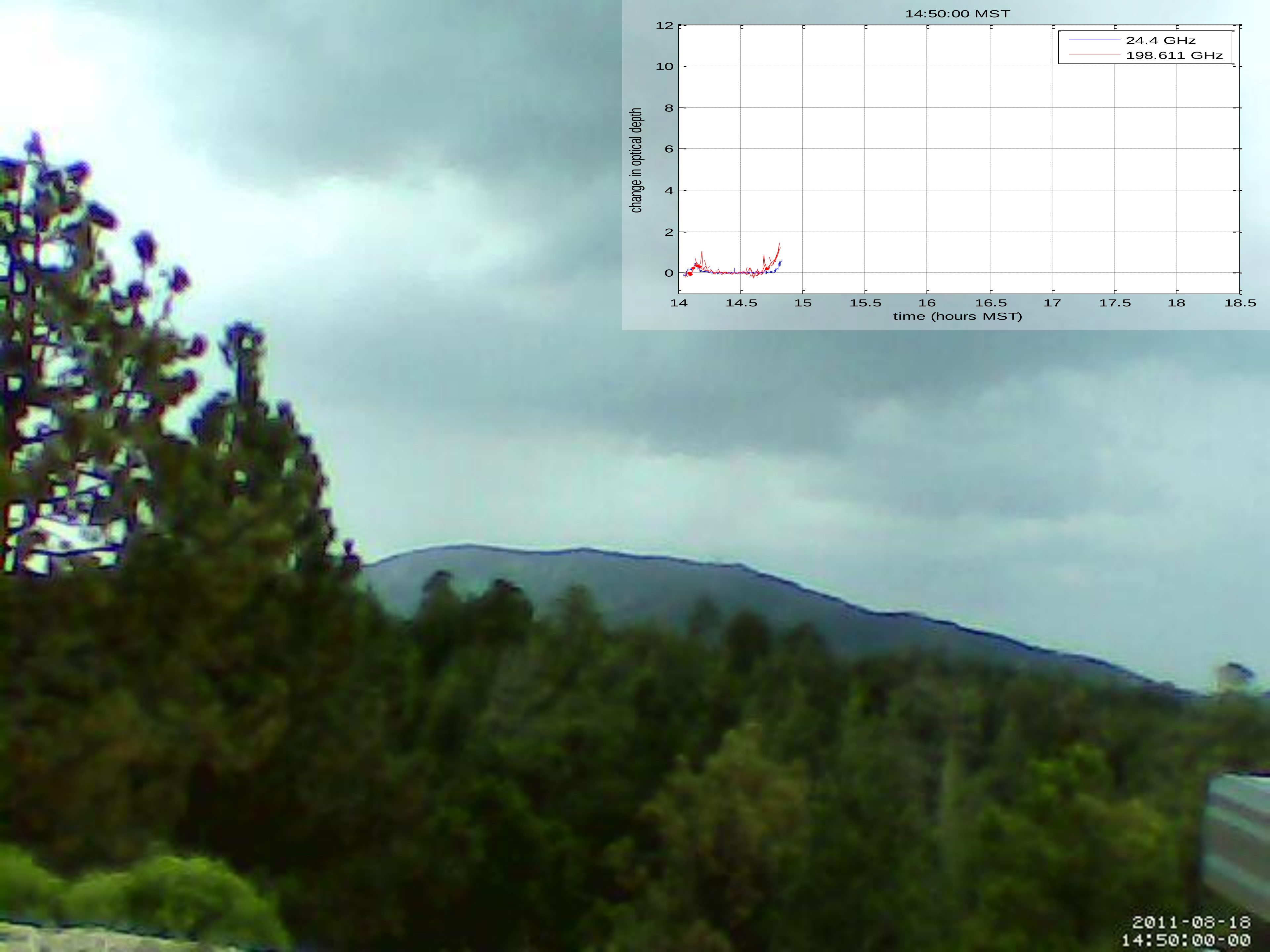

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time (hours MST)
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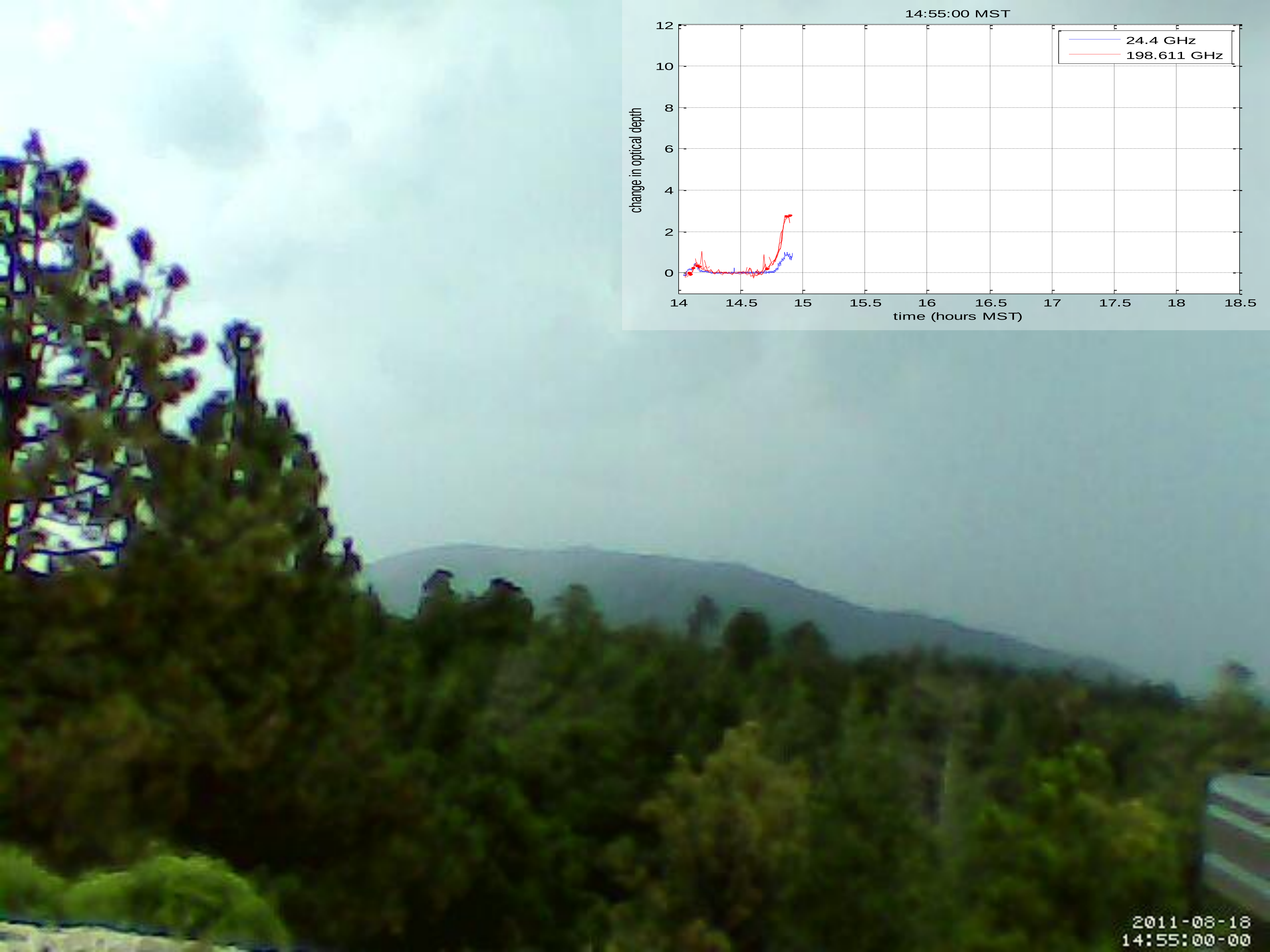
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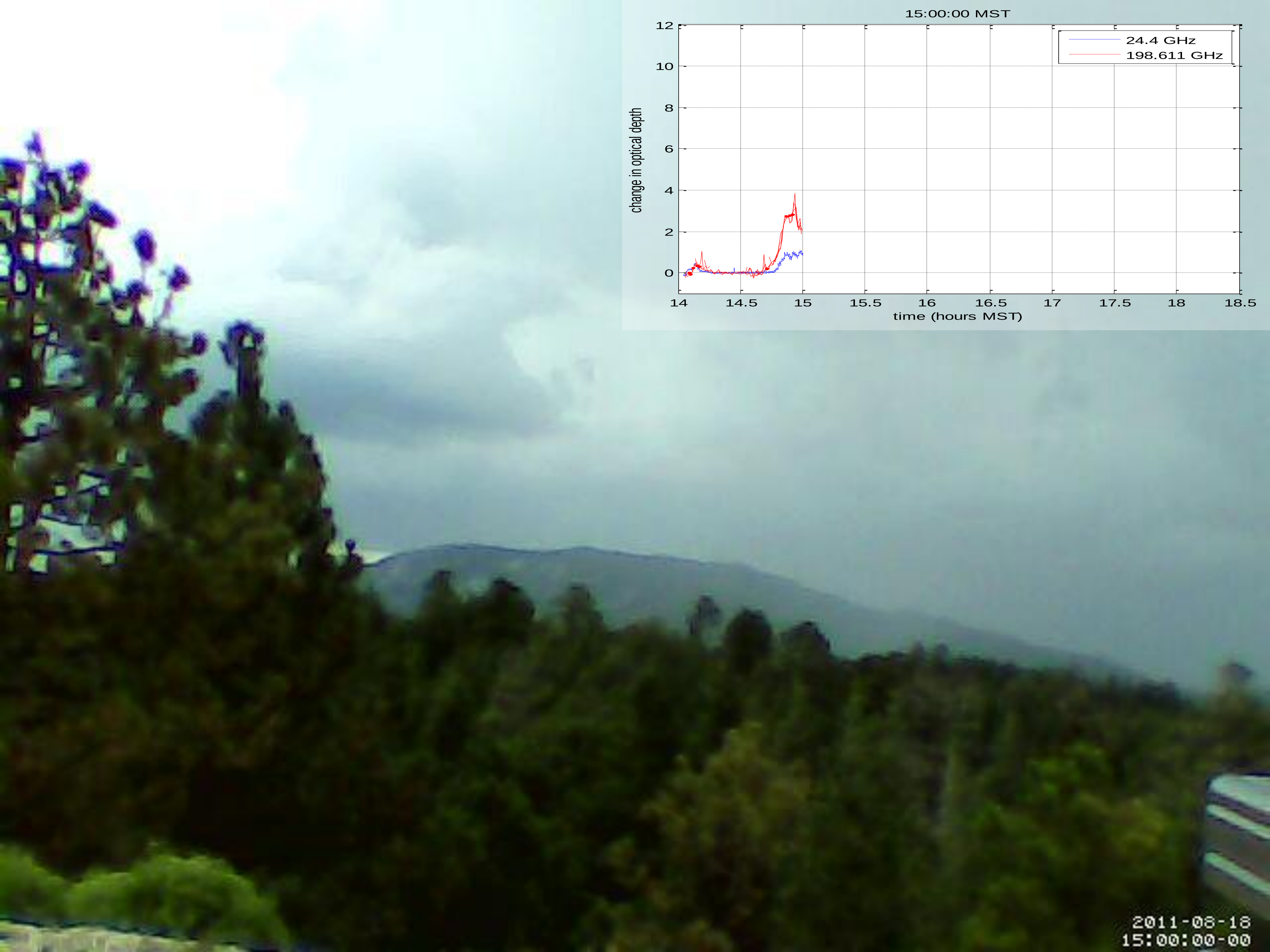
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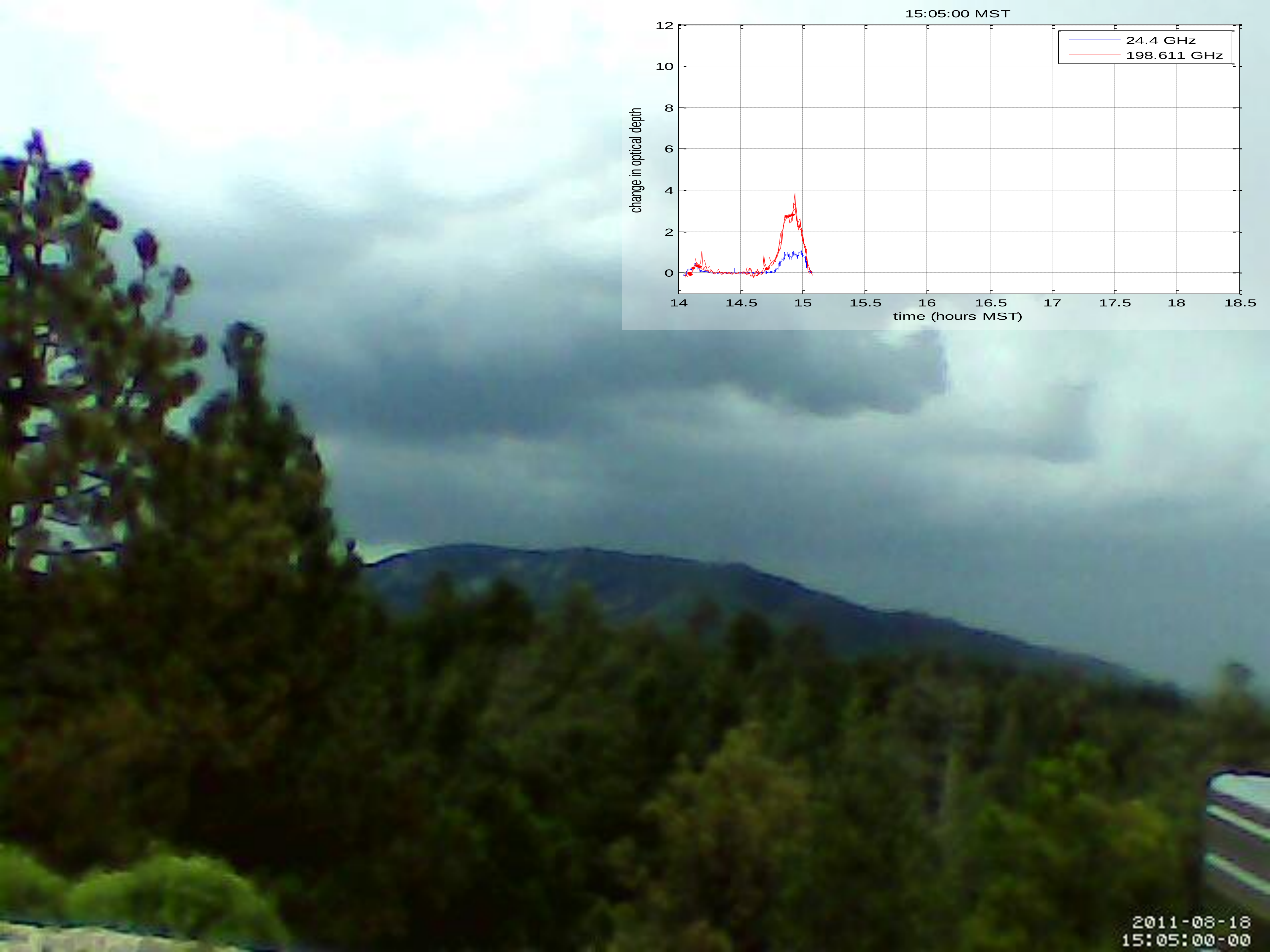
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198.611 GHz
change in optical depth
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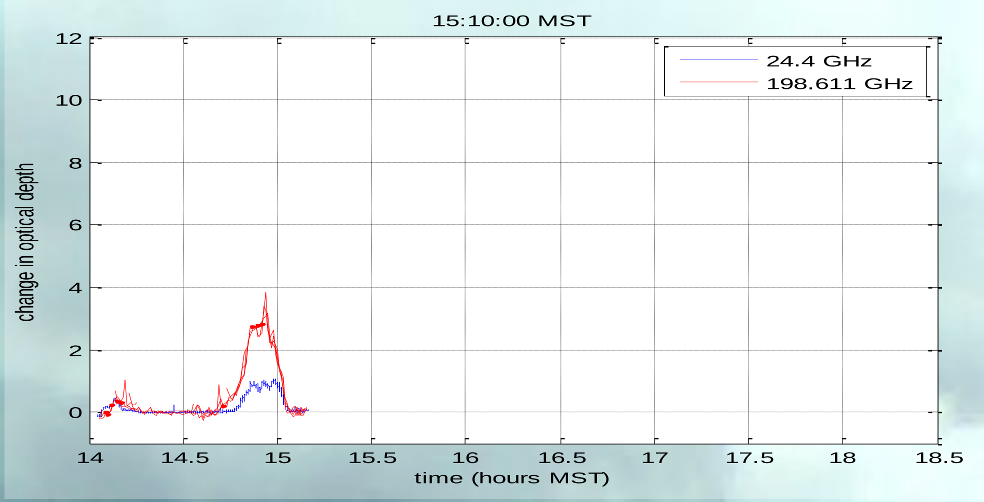
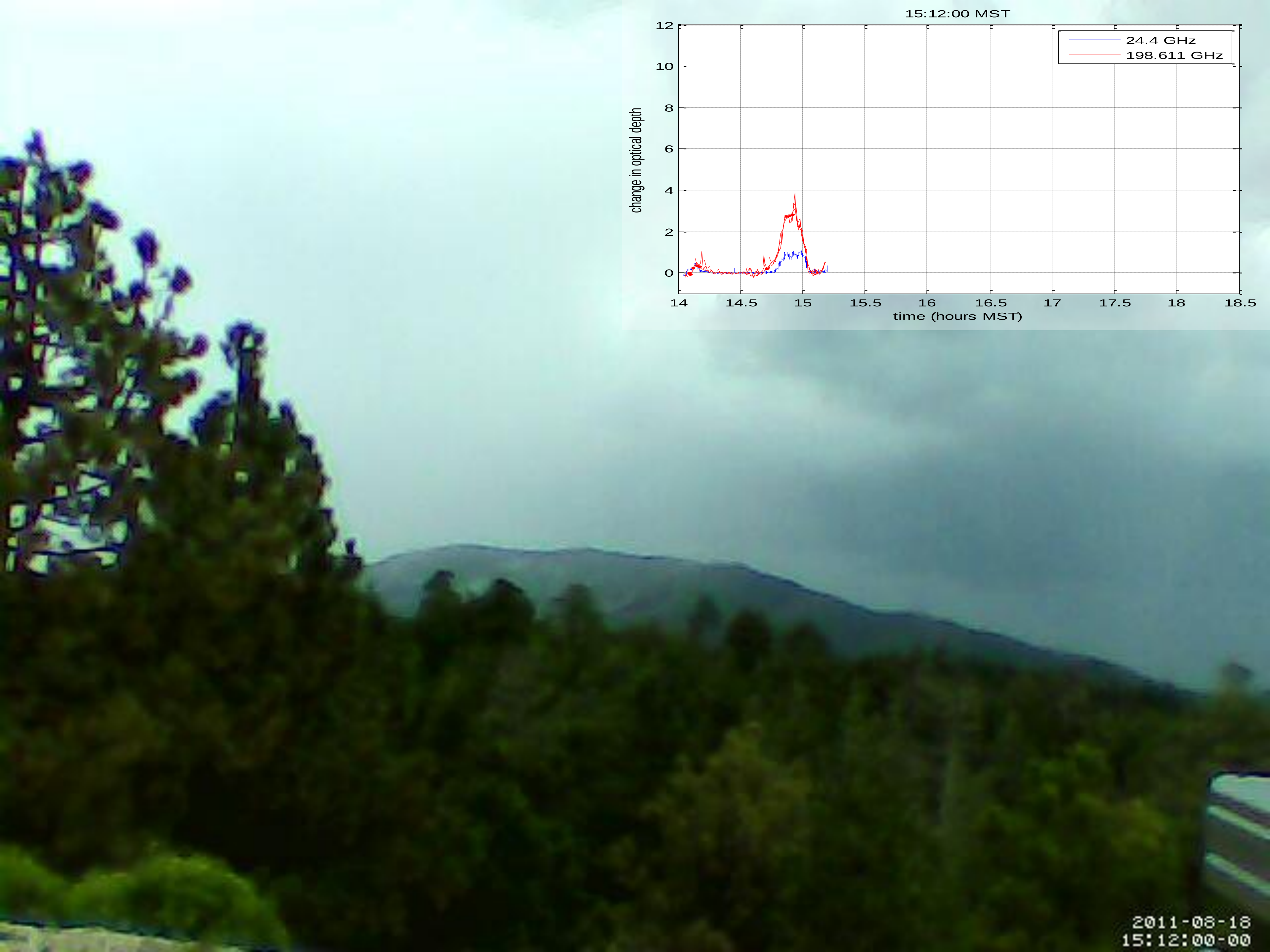
time (hours MST)
2011-08-18
15:05:00-00

2 minute images





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time (hours MST)
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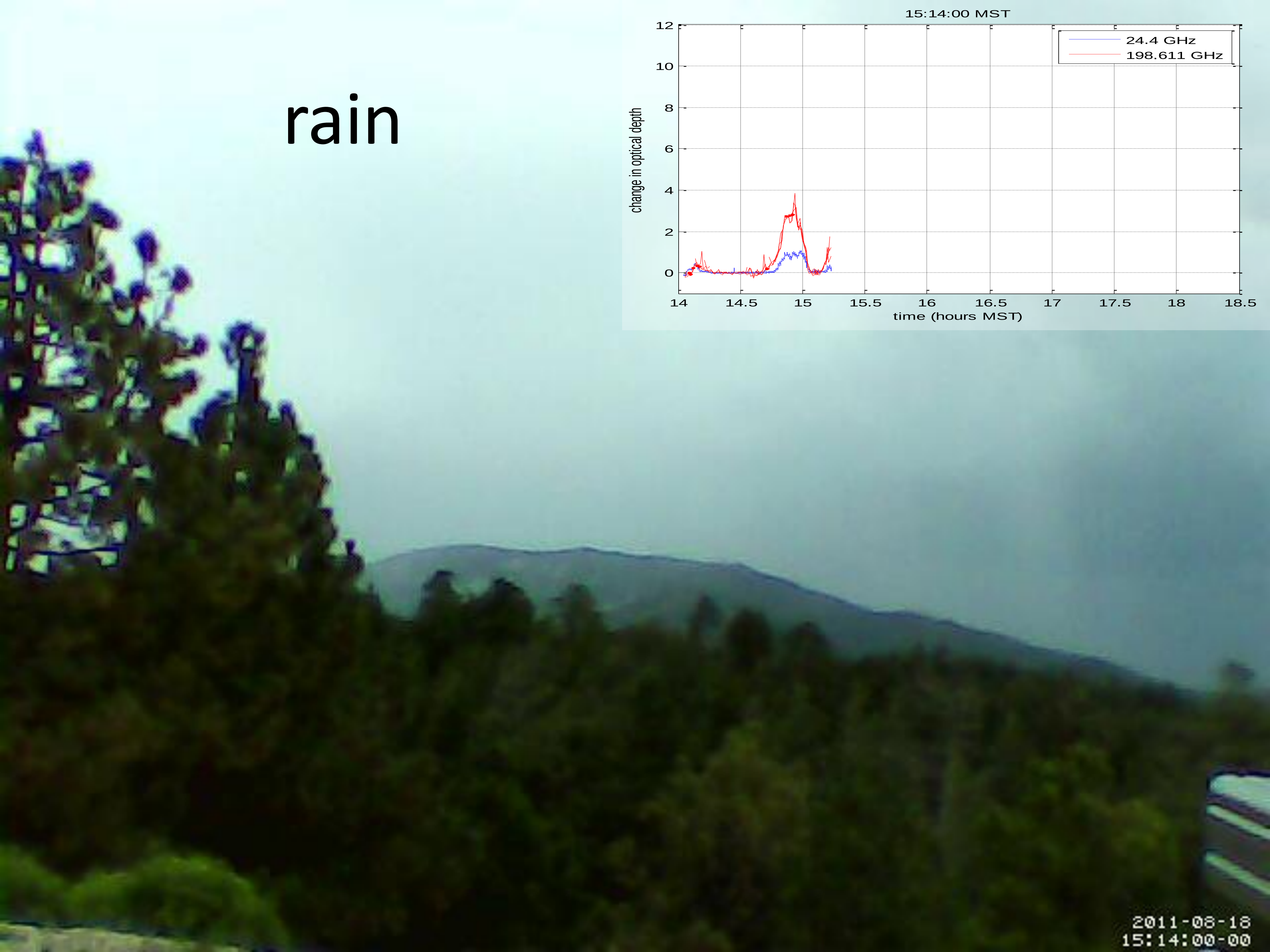
rain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15:14:00-00
15:14:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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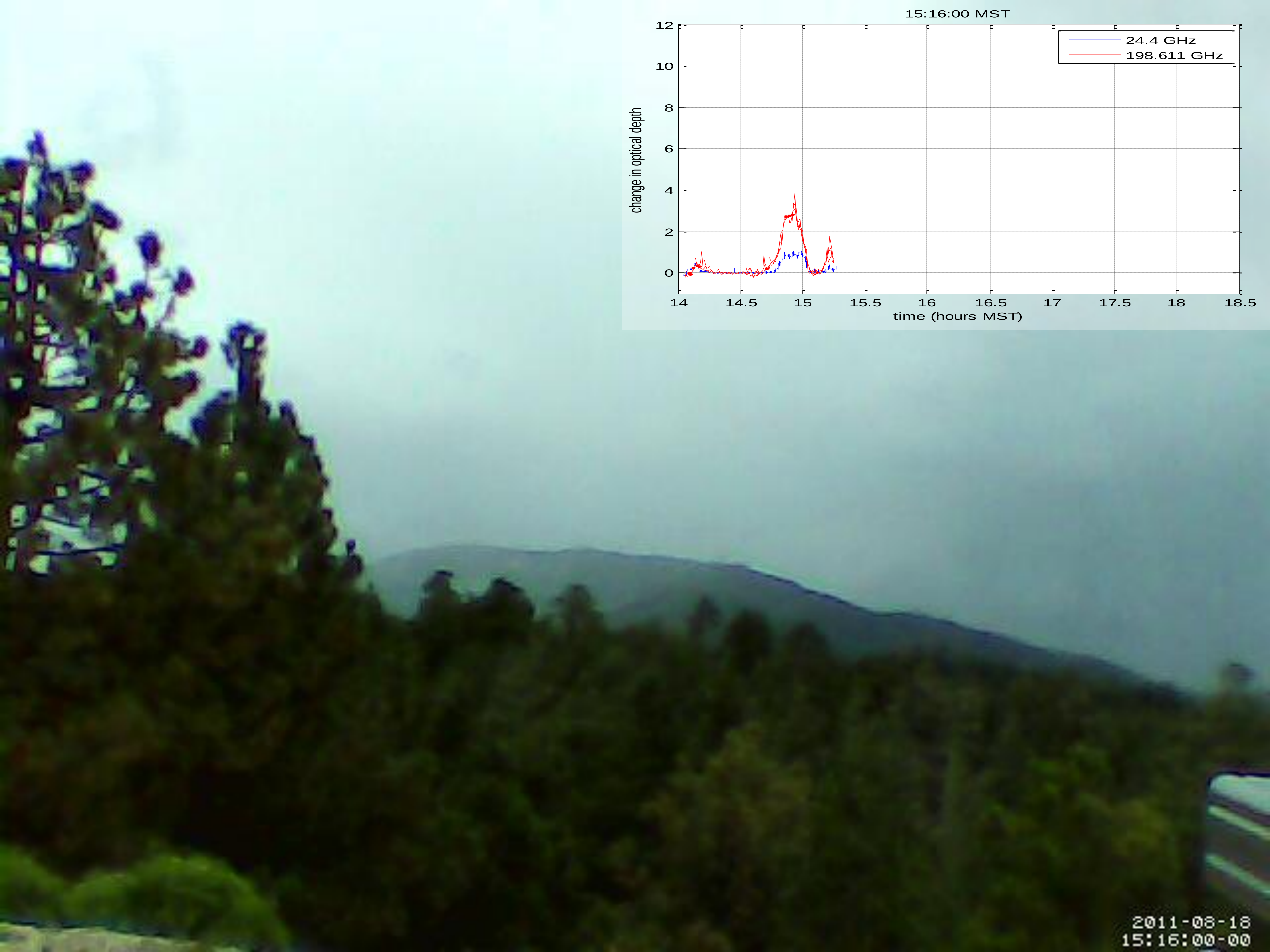

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change in optical depth
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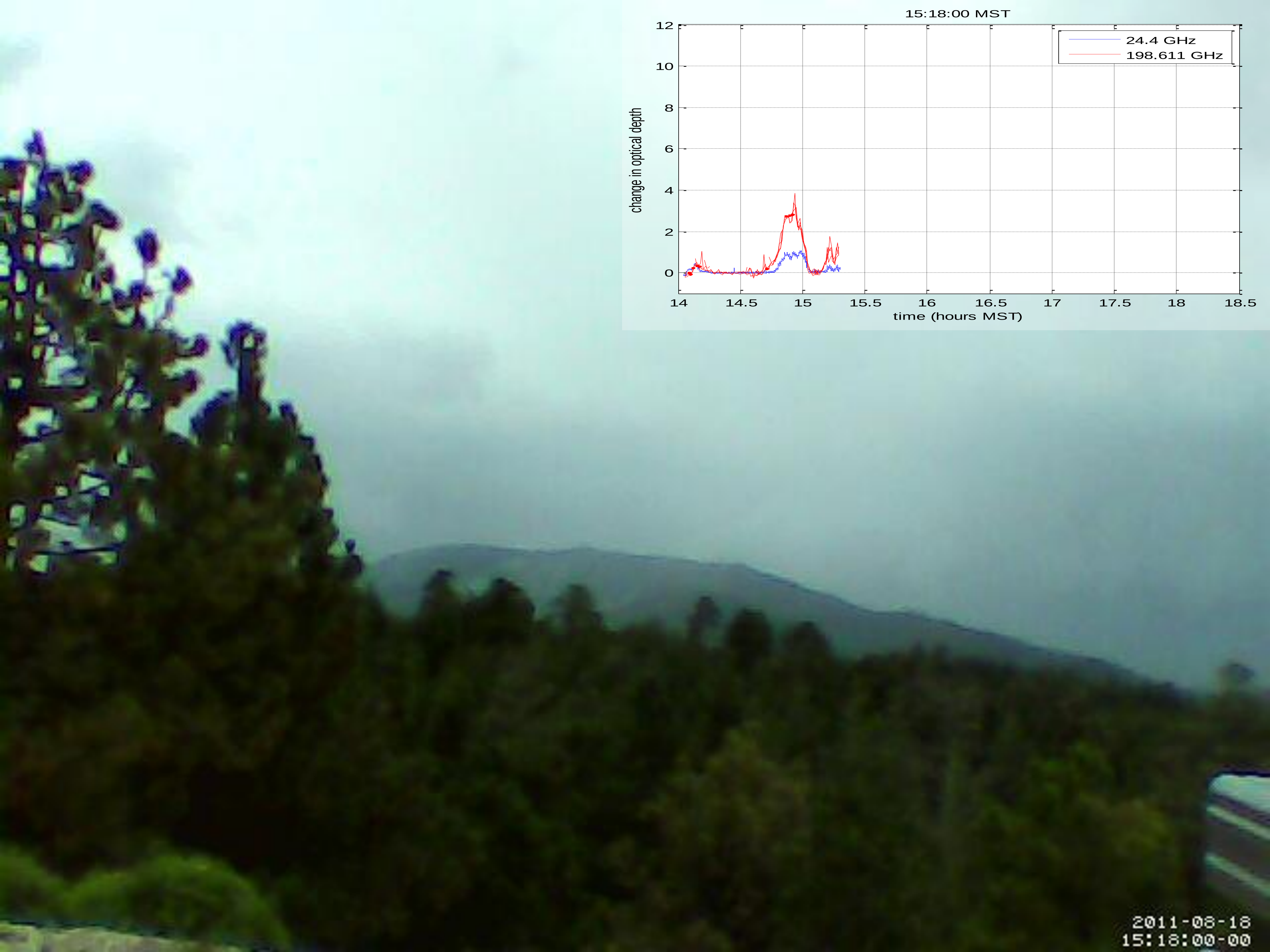

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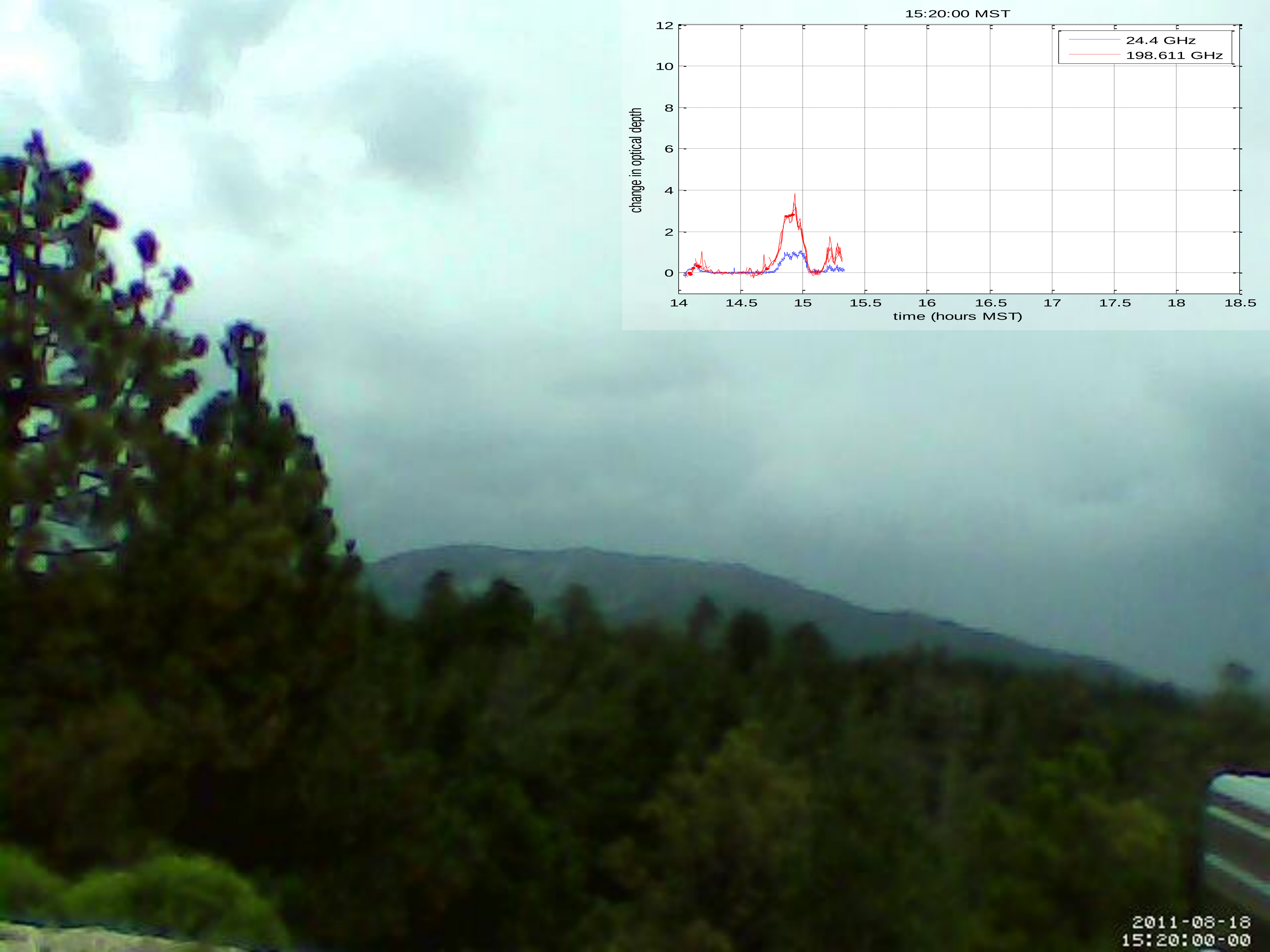
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time (hours MST)
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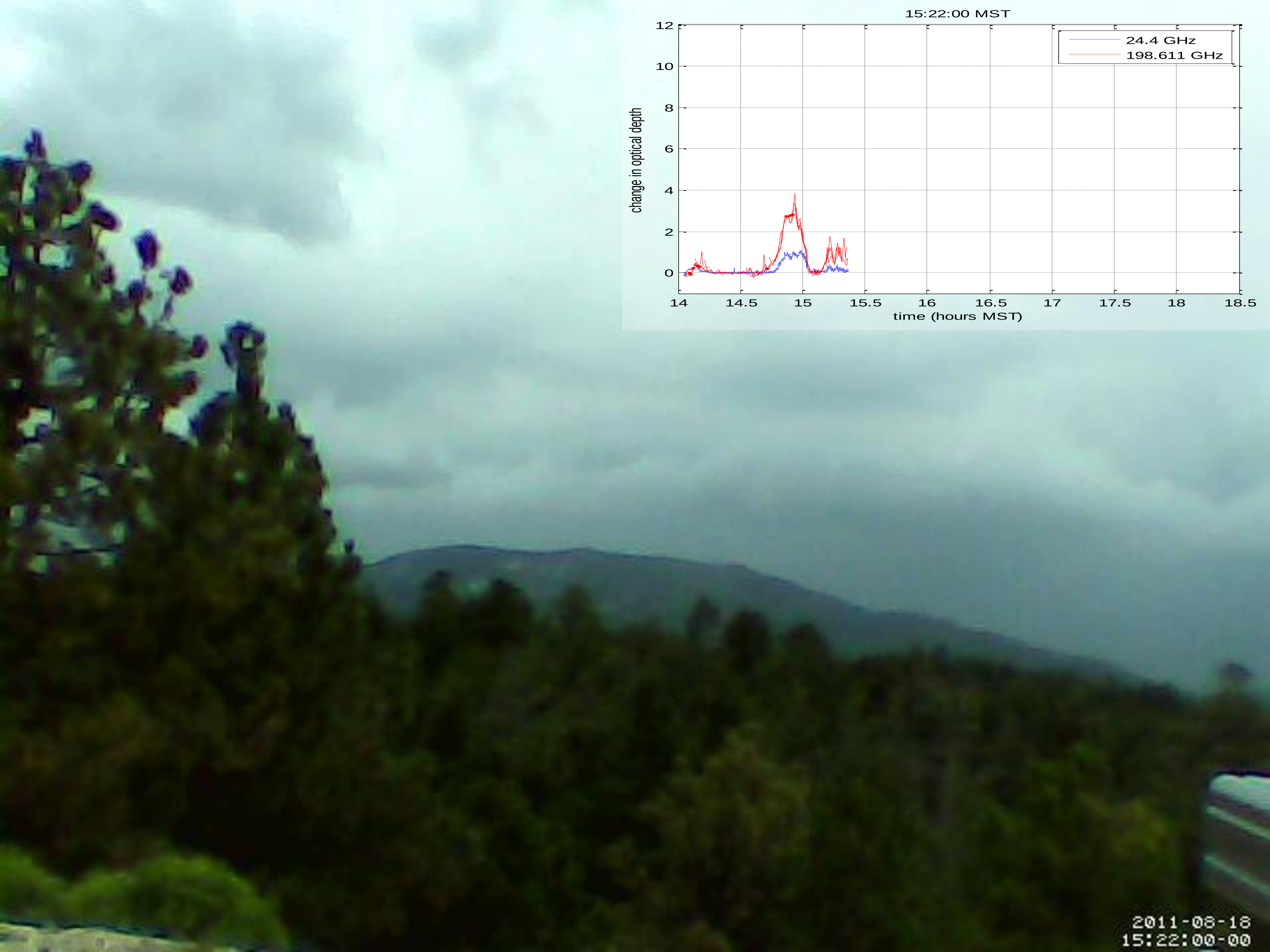
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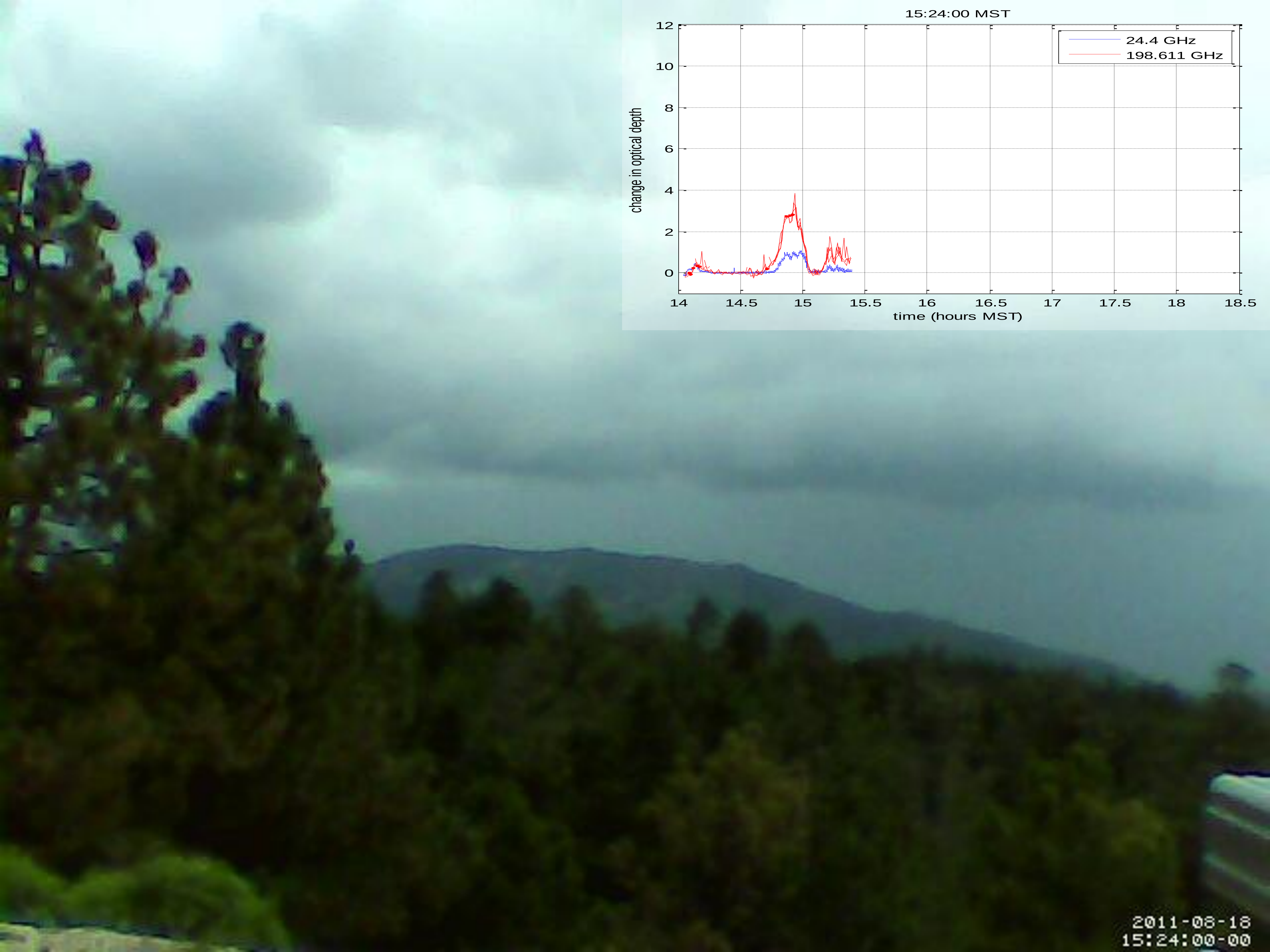
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198.611 GHz
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time (hours MST)
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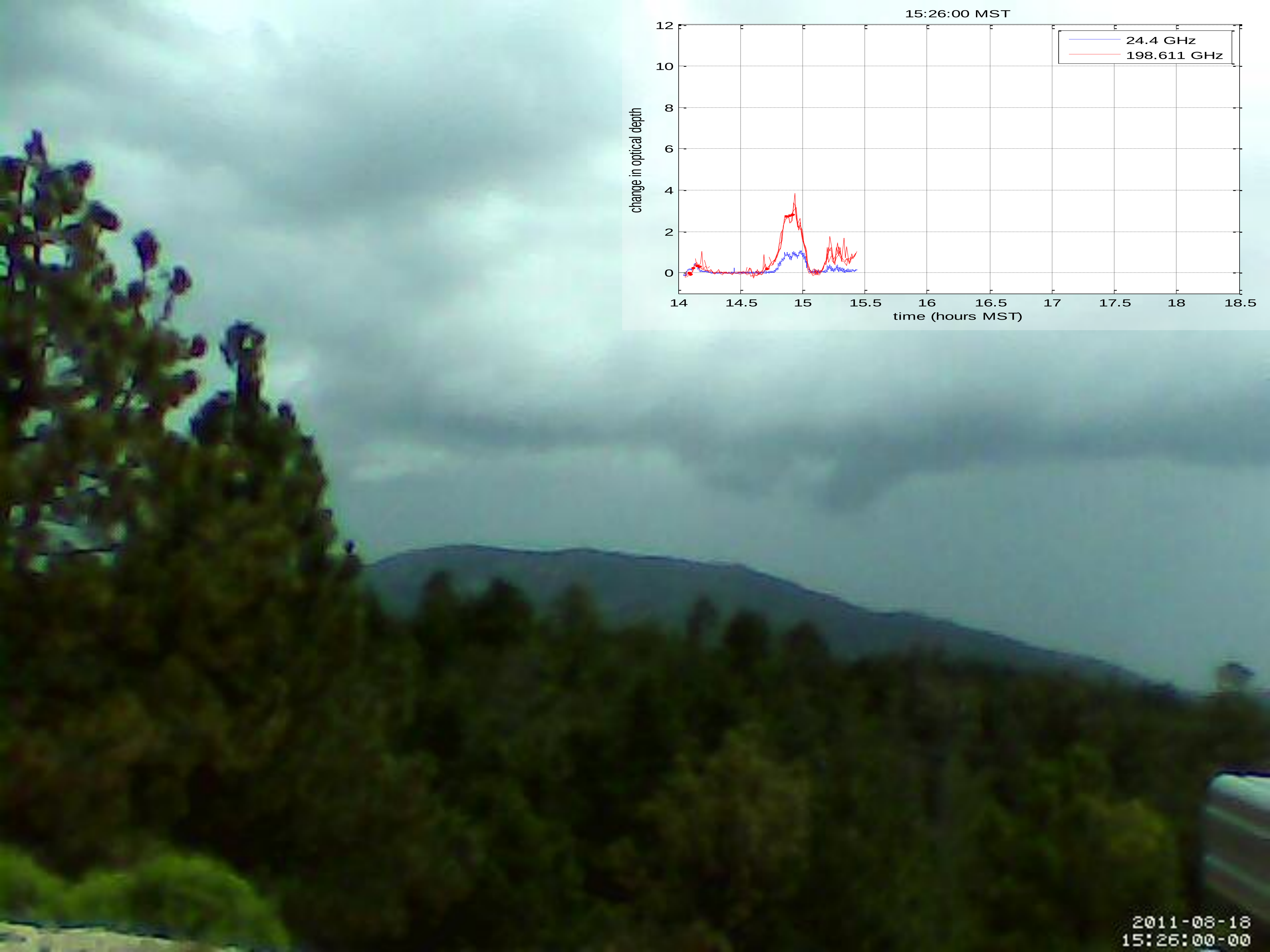
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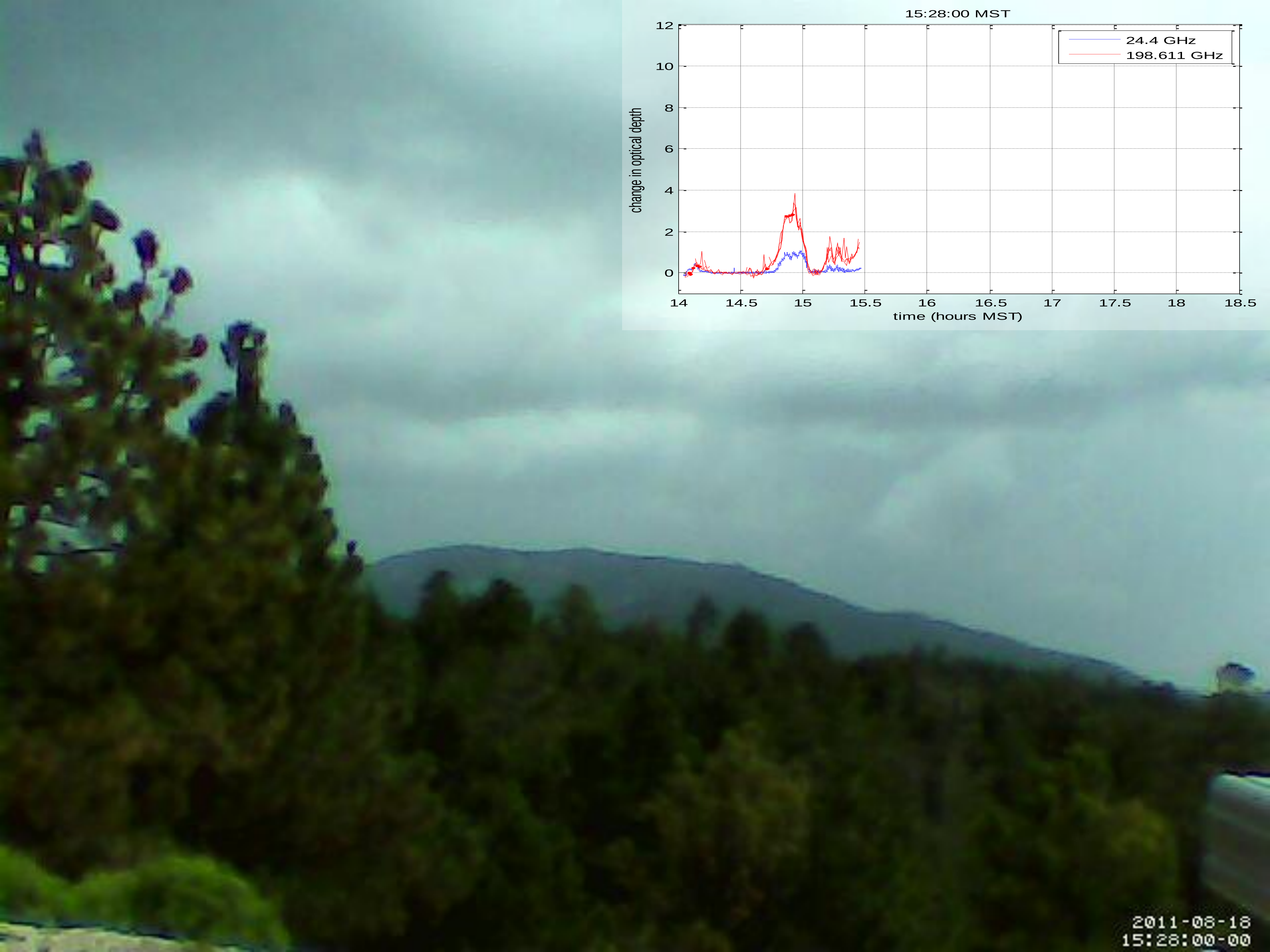
time (hours MST)
24.4 GHz
198.611 GHz
2011-08-18
15:26:00-00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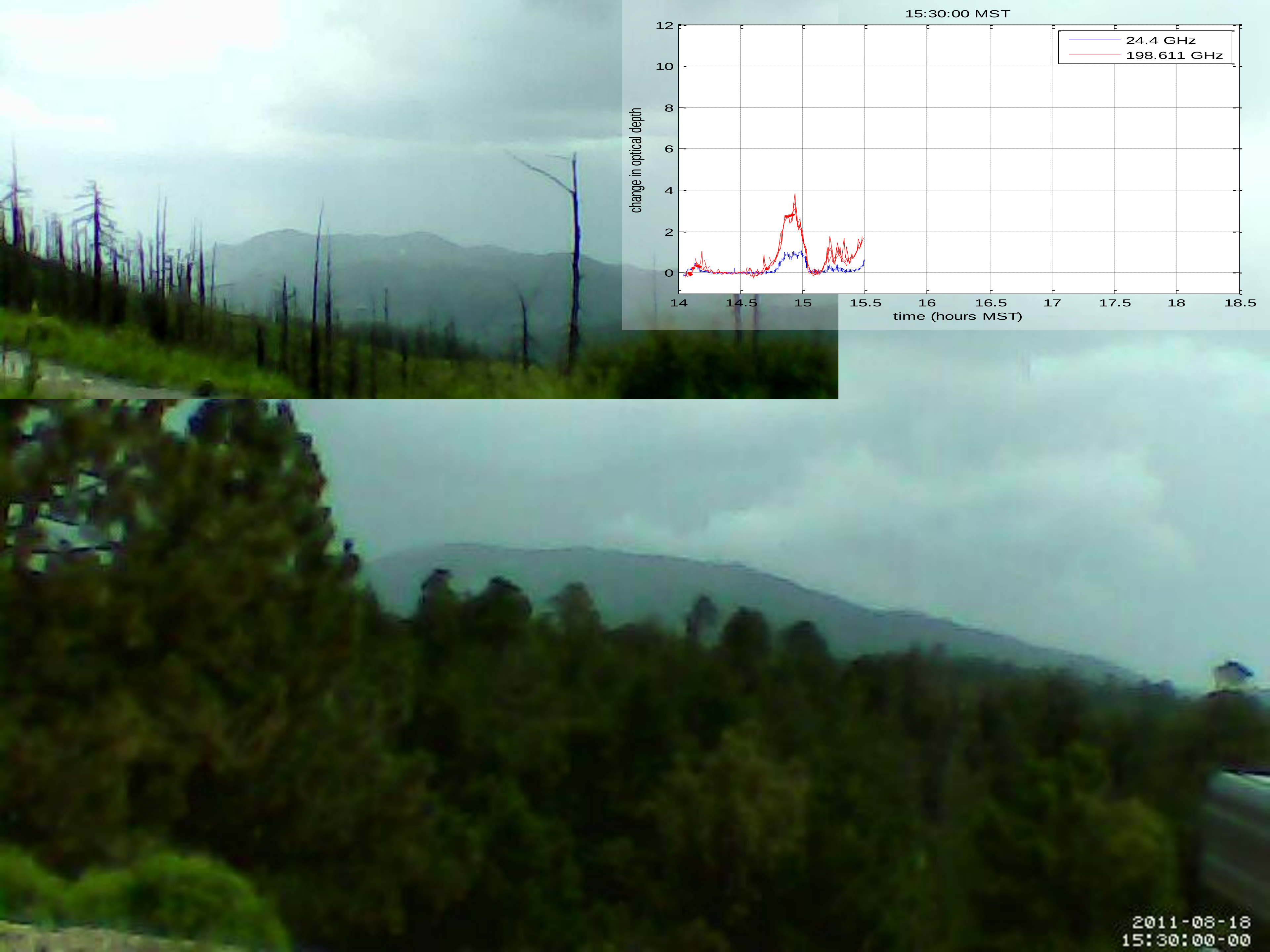
15:30:00 MST
24.4 GHz
198.611 GHz
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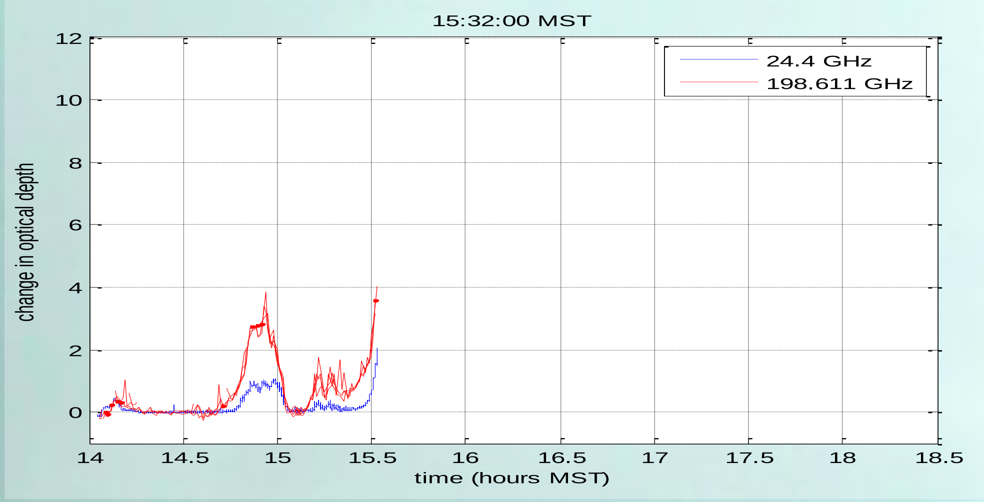
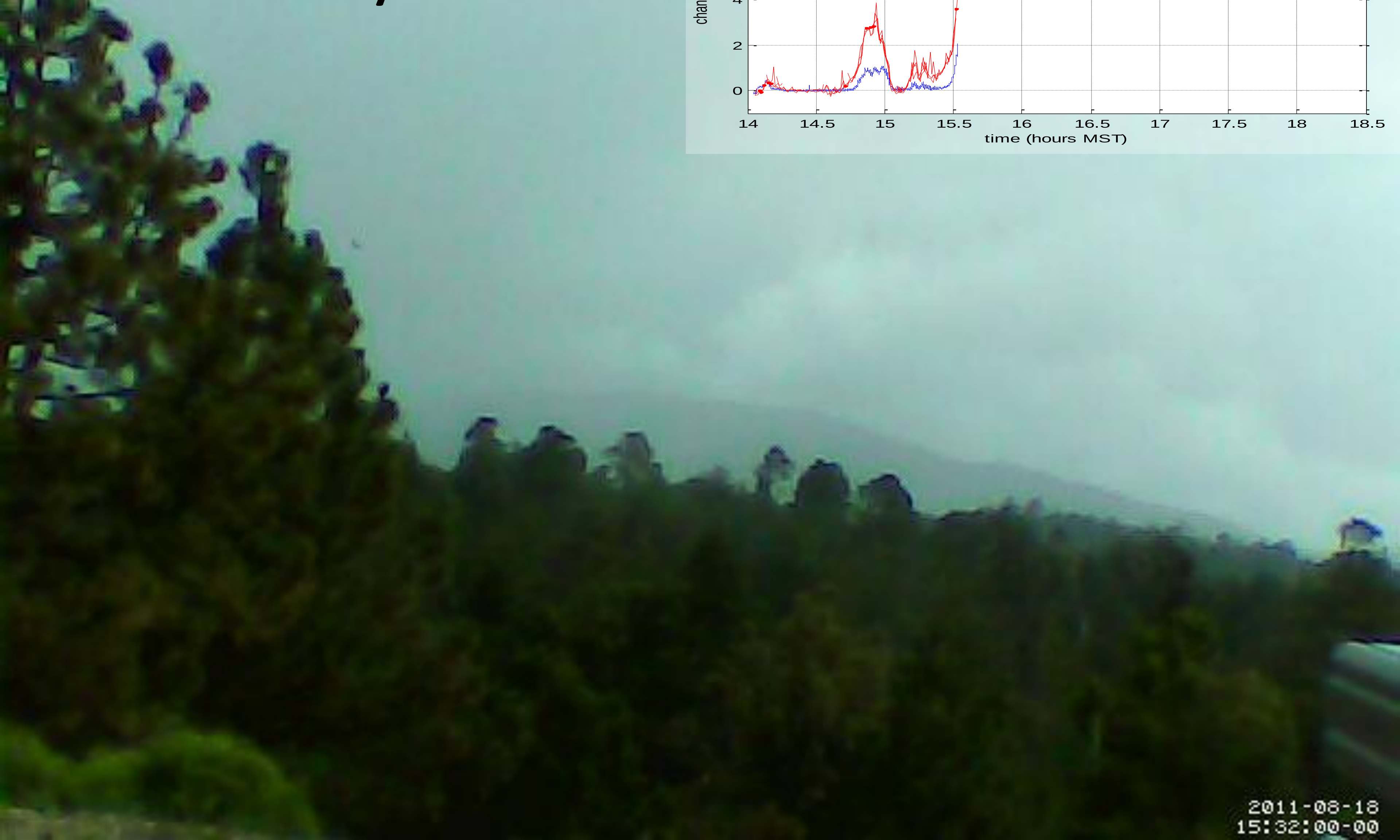
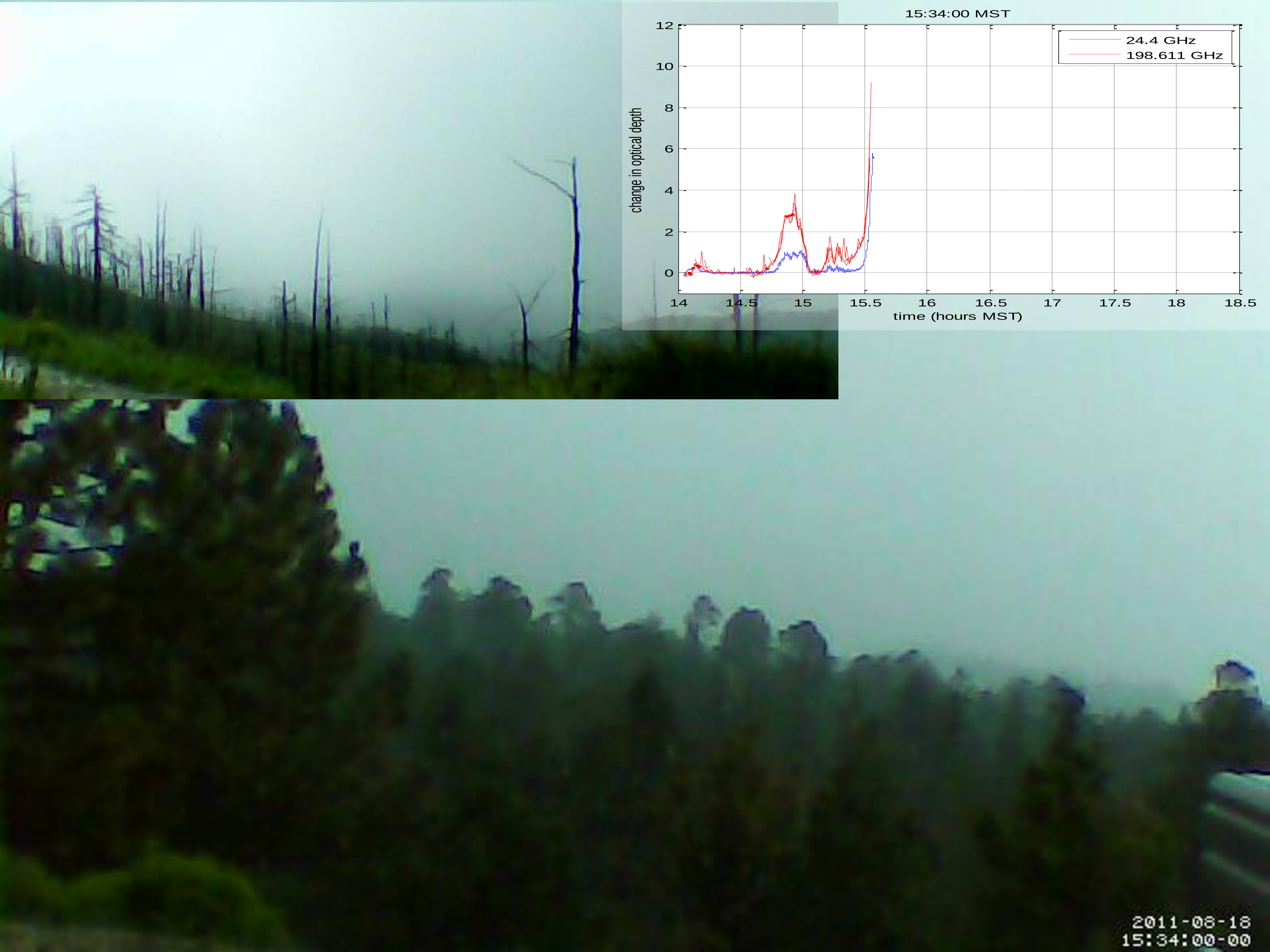
time (hours MST)
2011-08-18
15:30:00-00

Onset of heavy rain



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198.611 GHz
change in optical depth
time (hours MST)
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16.5
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17.5
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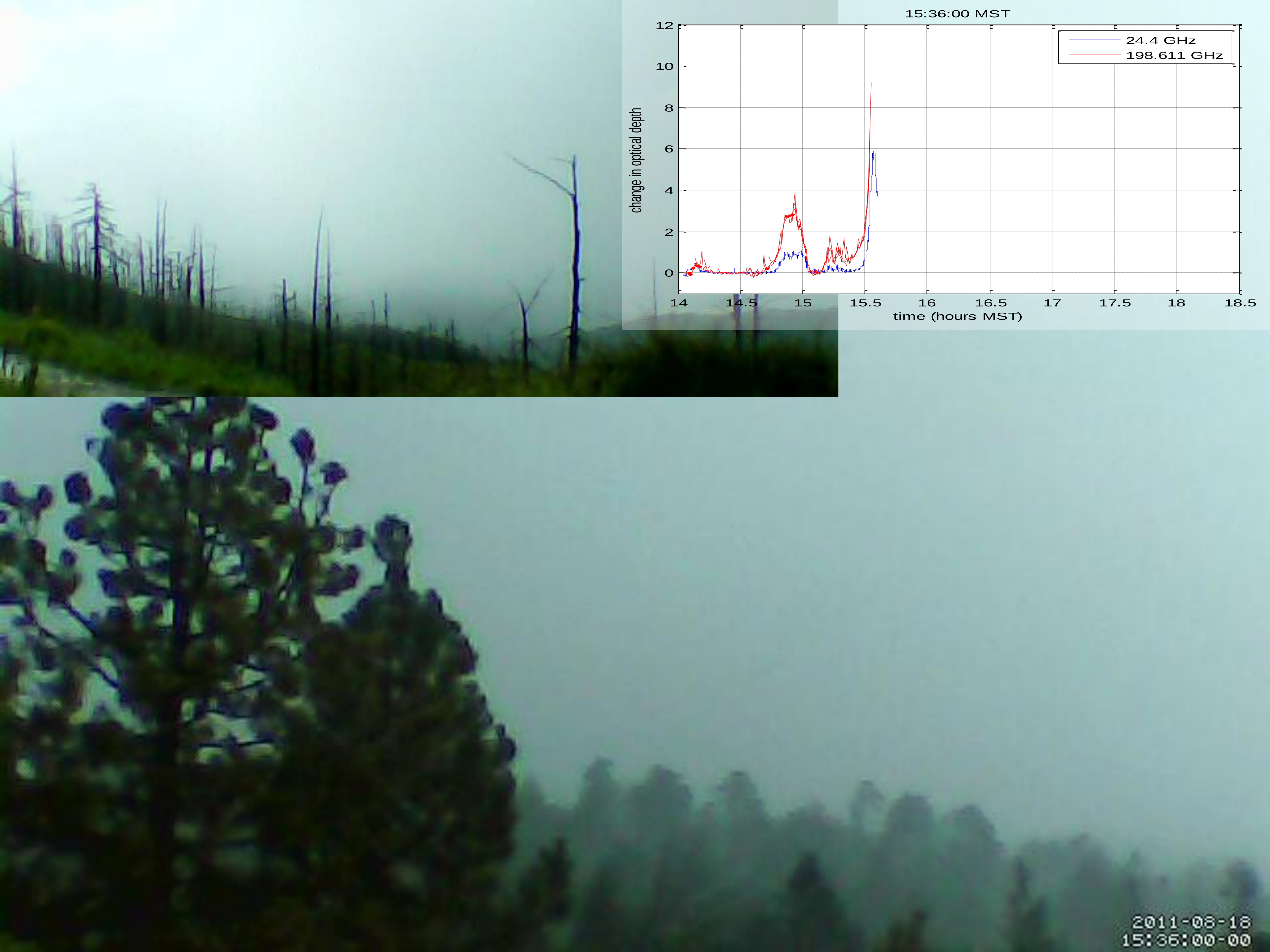
18.5
2011-08-18
15:34:00-00


15:36:00 MST
24.4 GHz
198.611 GHz
change in optical depth
0
2
4
6
8
10
12
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14.5
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15.5
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16.5
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17.5
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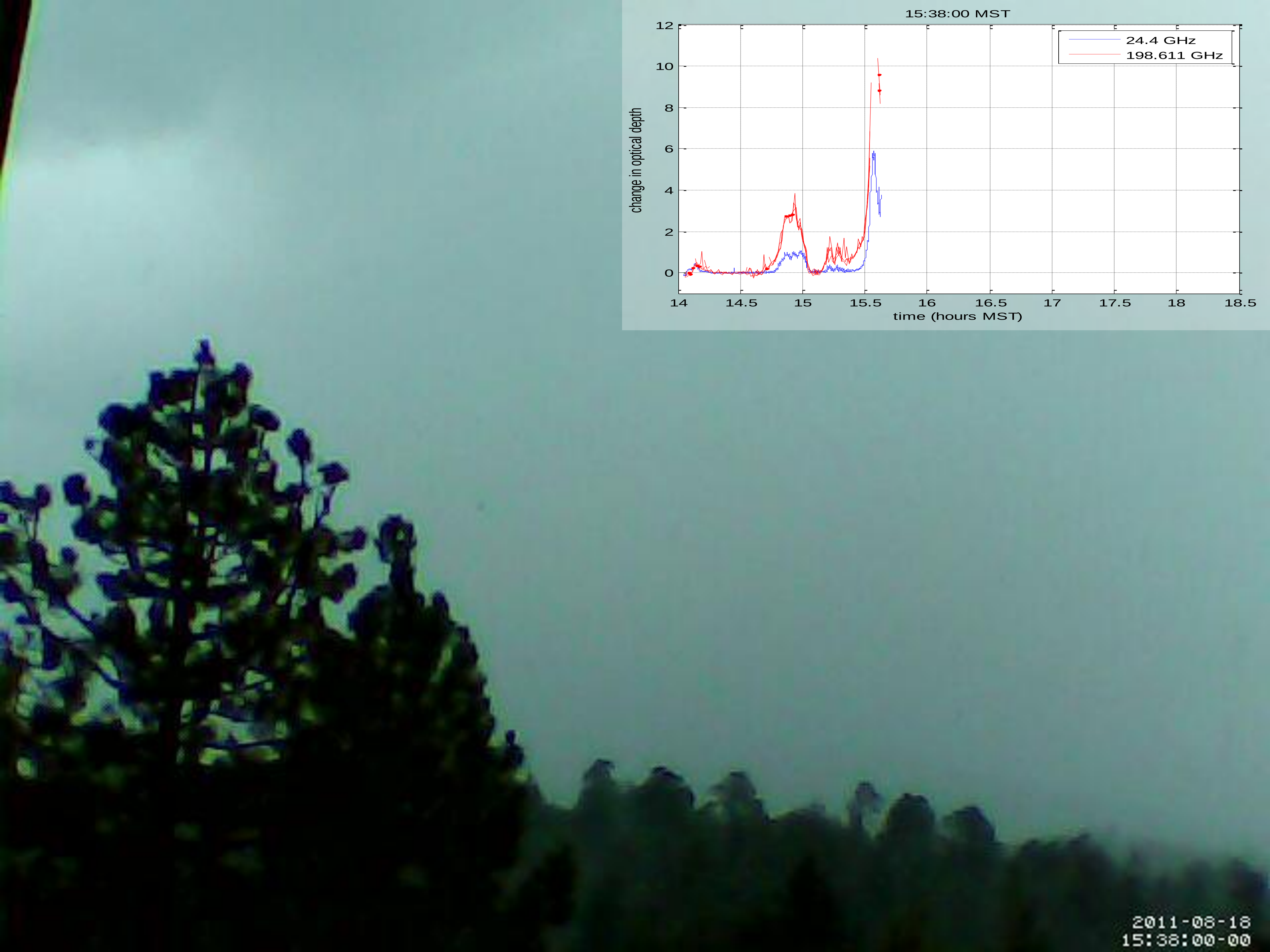
18.5
time (hours MST)
2011-08-18
15:36:00-00


15:38:00 MST
24.4 GHz
198.611 GHz
change in optical depth
12
10
8
6
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14.5
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15.5
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16.5
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17.5
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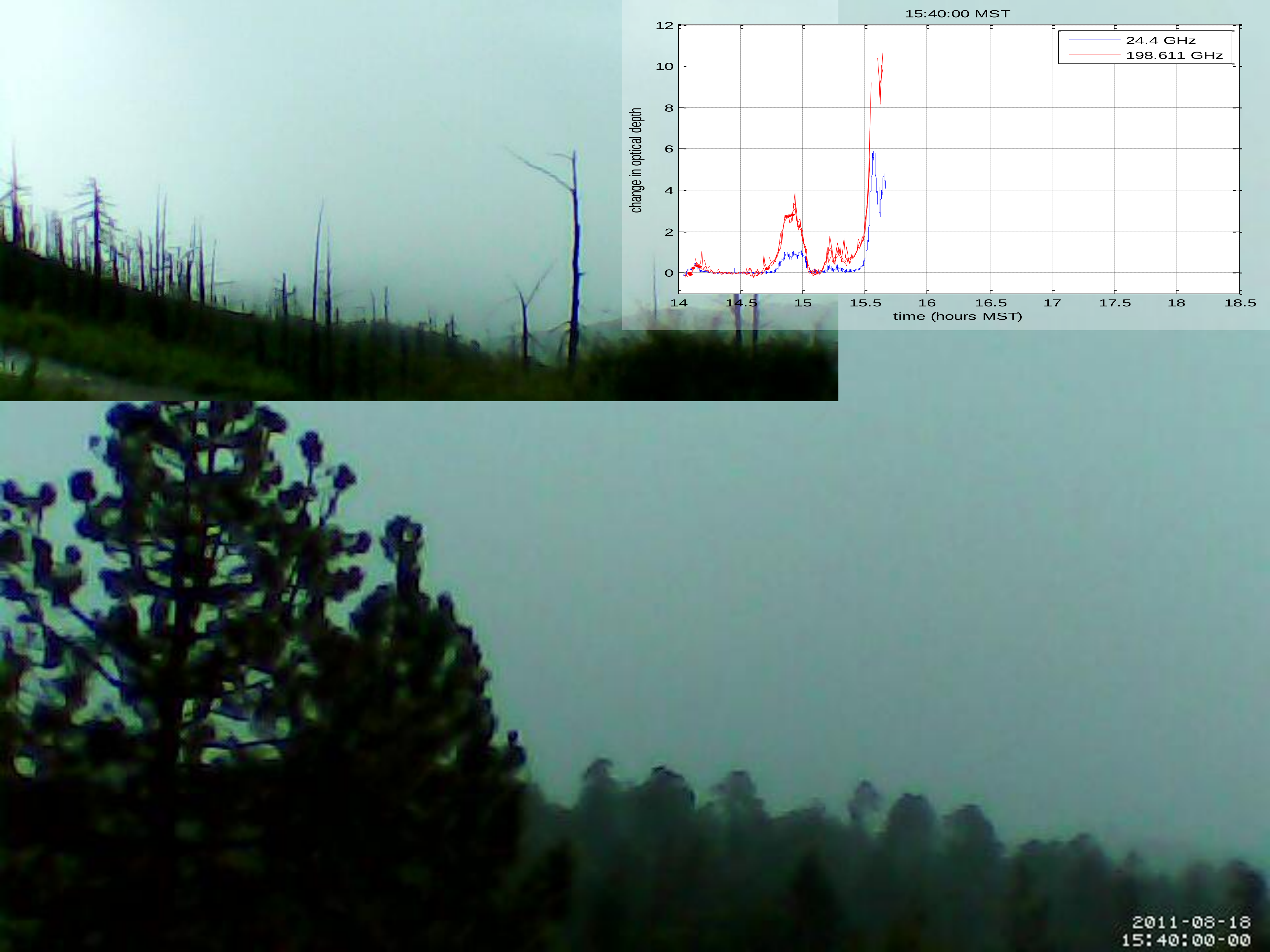
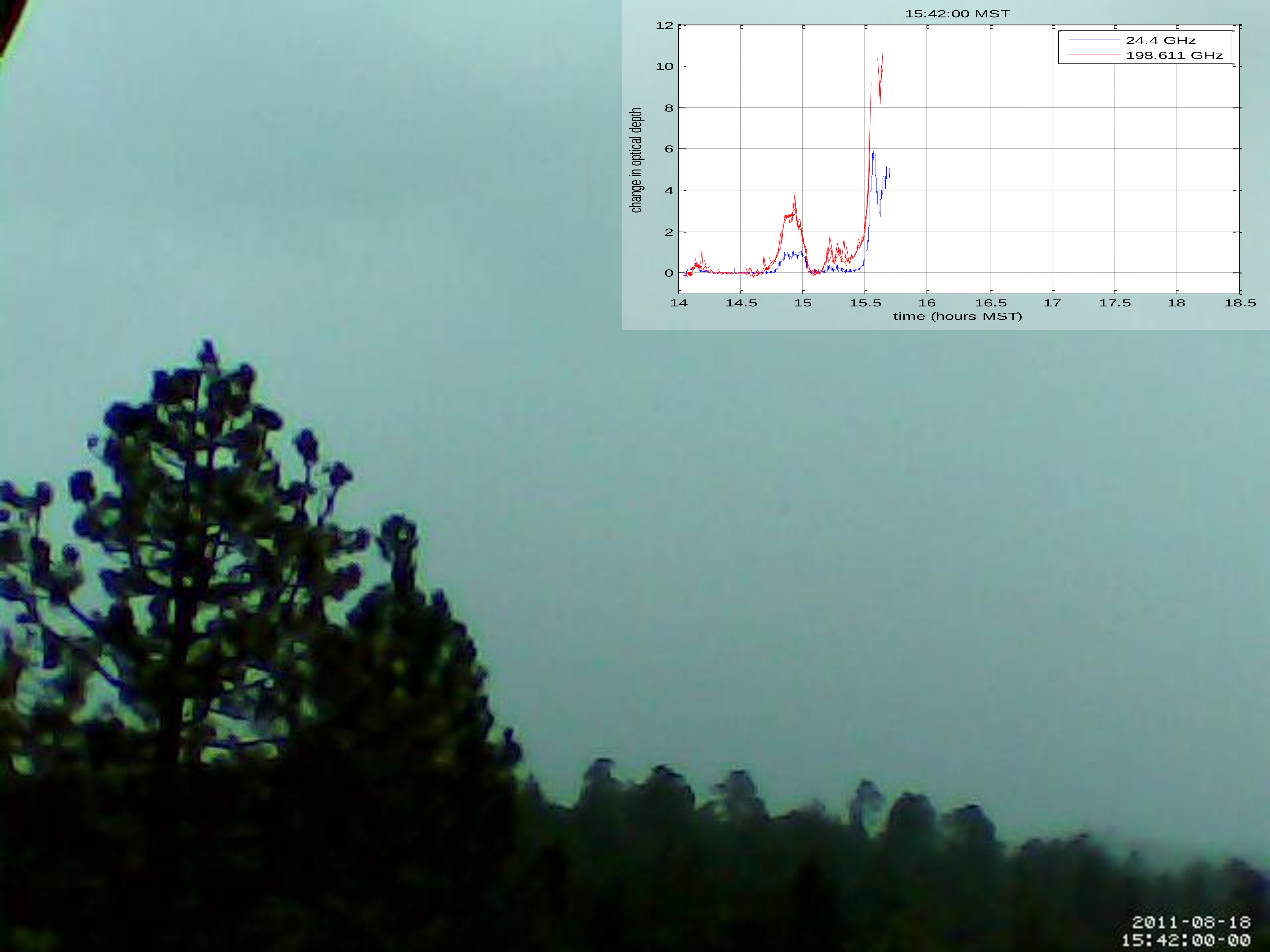
18.5
time (hours MST)
2011-08-18
15:38:00-00


15:40:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
15:40:00-00


15:42:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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14.5
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16.5
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17.5
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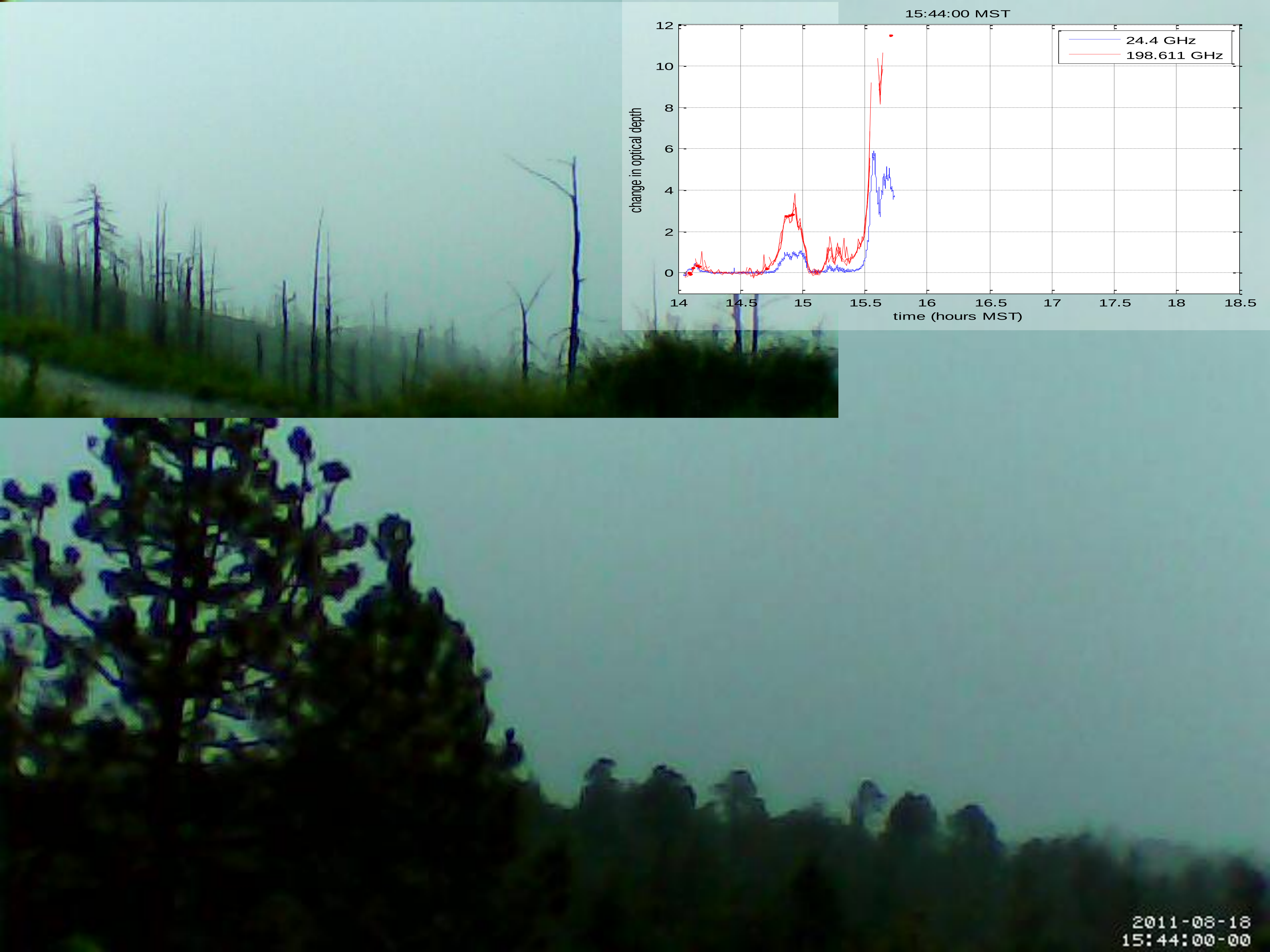
18.5
2011-08-18
15:42:00-00



15:44:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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14.5
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15.5
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16.5
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17.5
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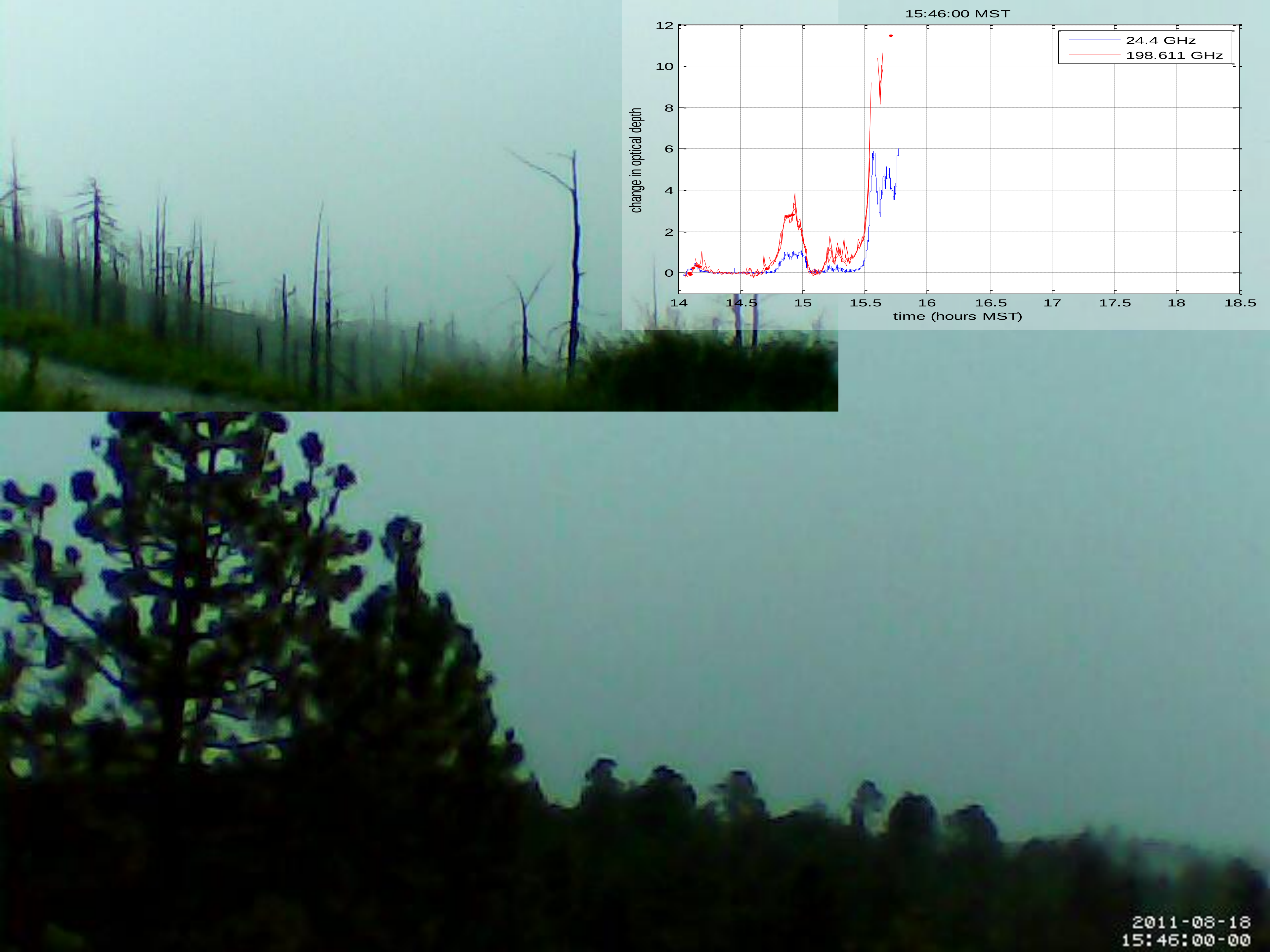
18.5
2011-08-18
15:44:00-00


15:46:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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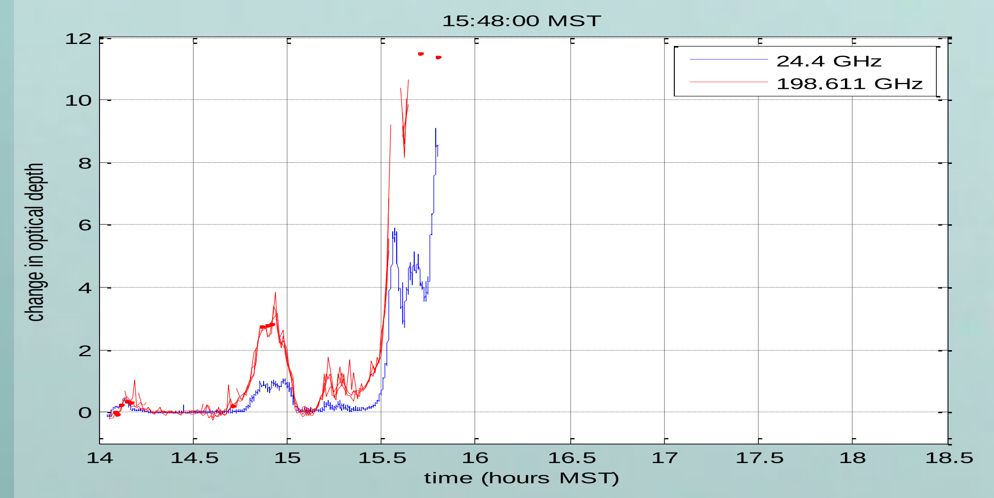
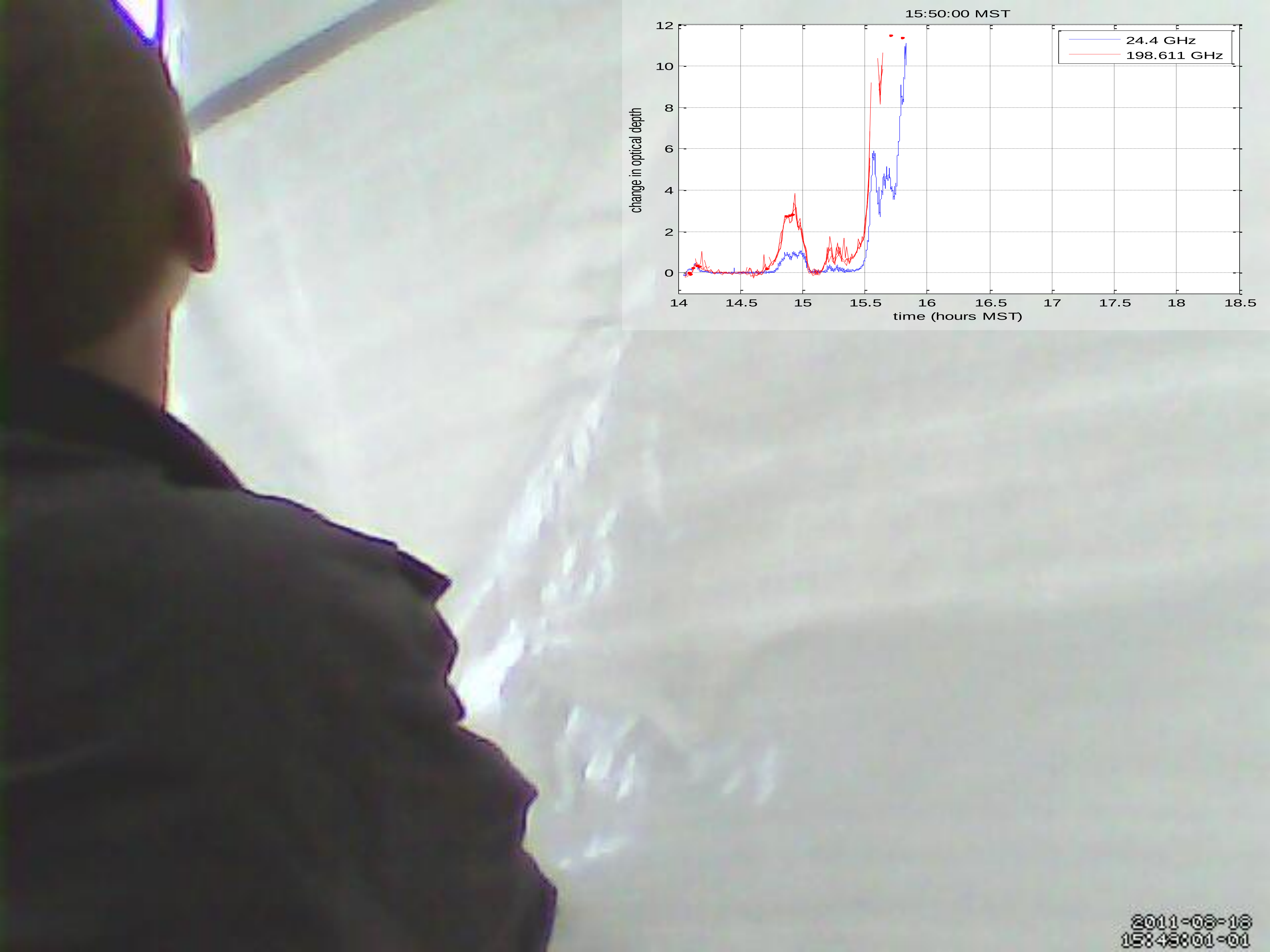
18.5
2011-08-18
15:46:00-00

VERY heavy rain





15:50:00 MST
24.4 GHz
198.611 GHz
change in optical depth
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17.5
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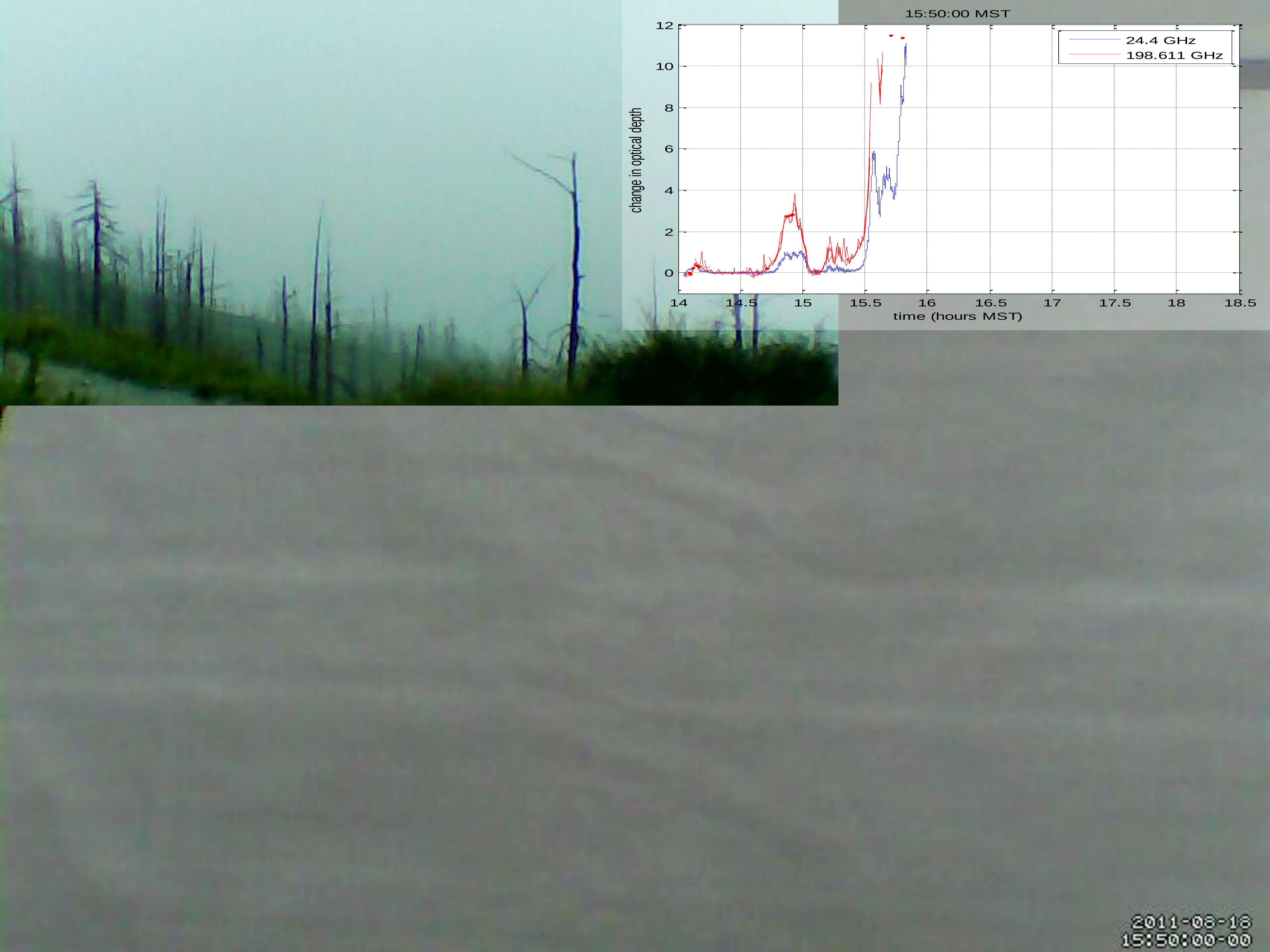
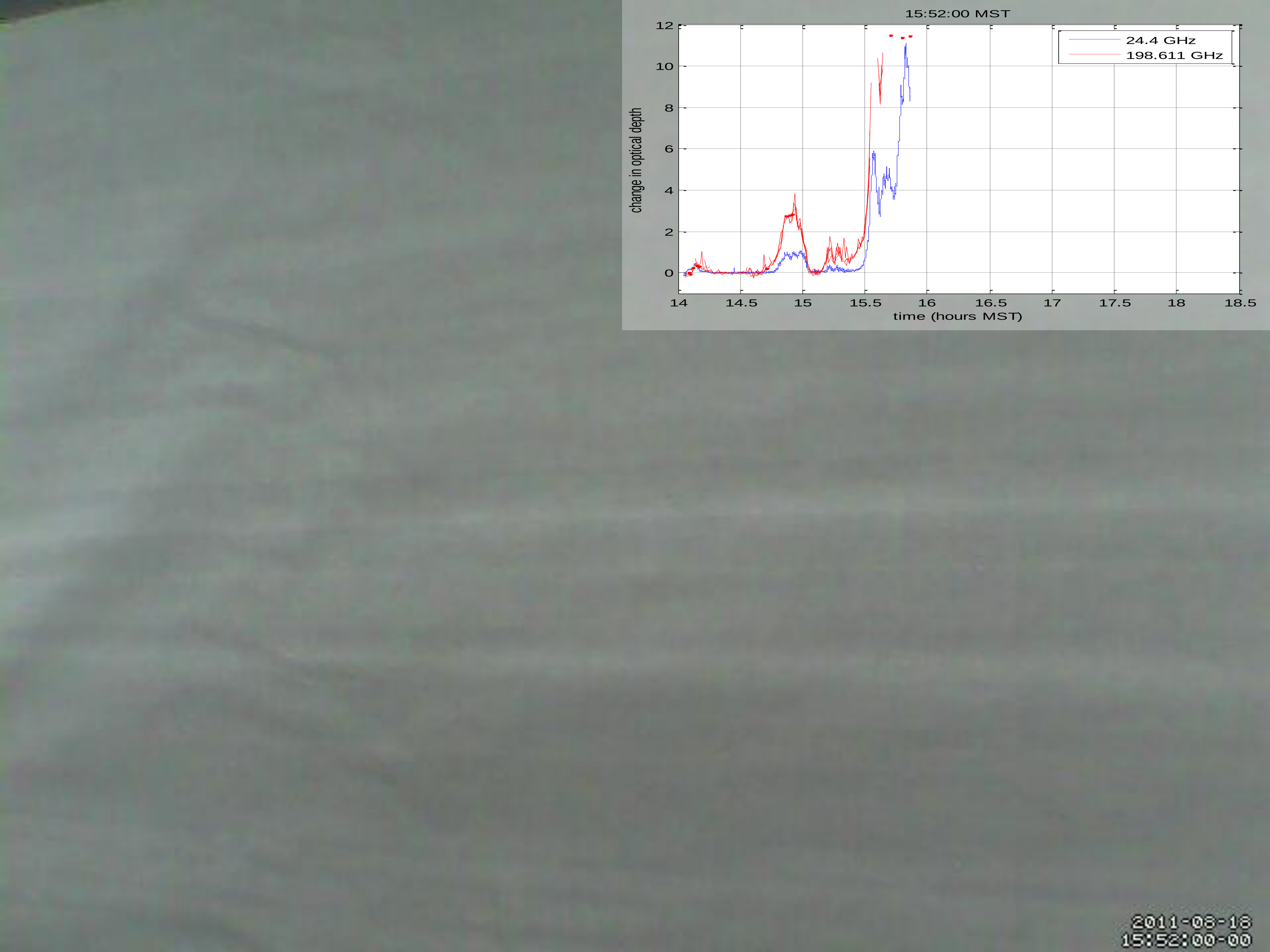
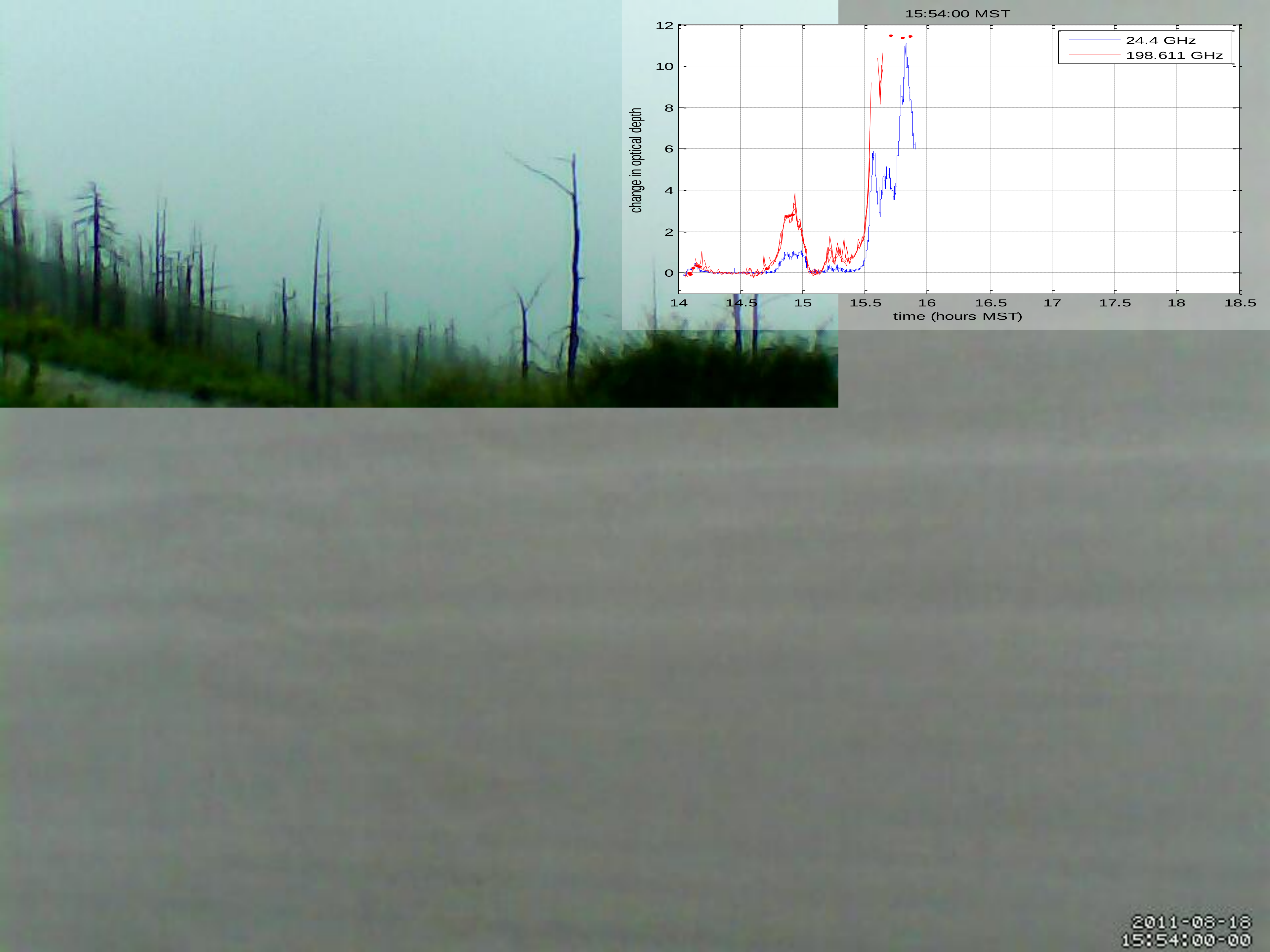
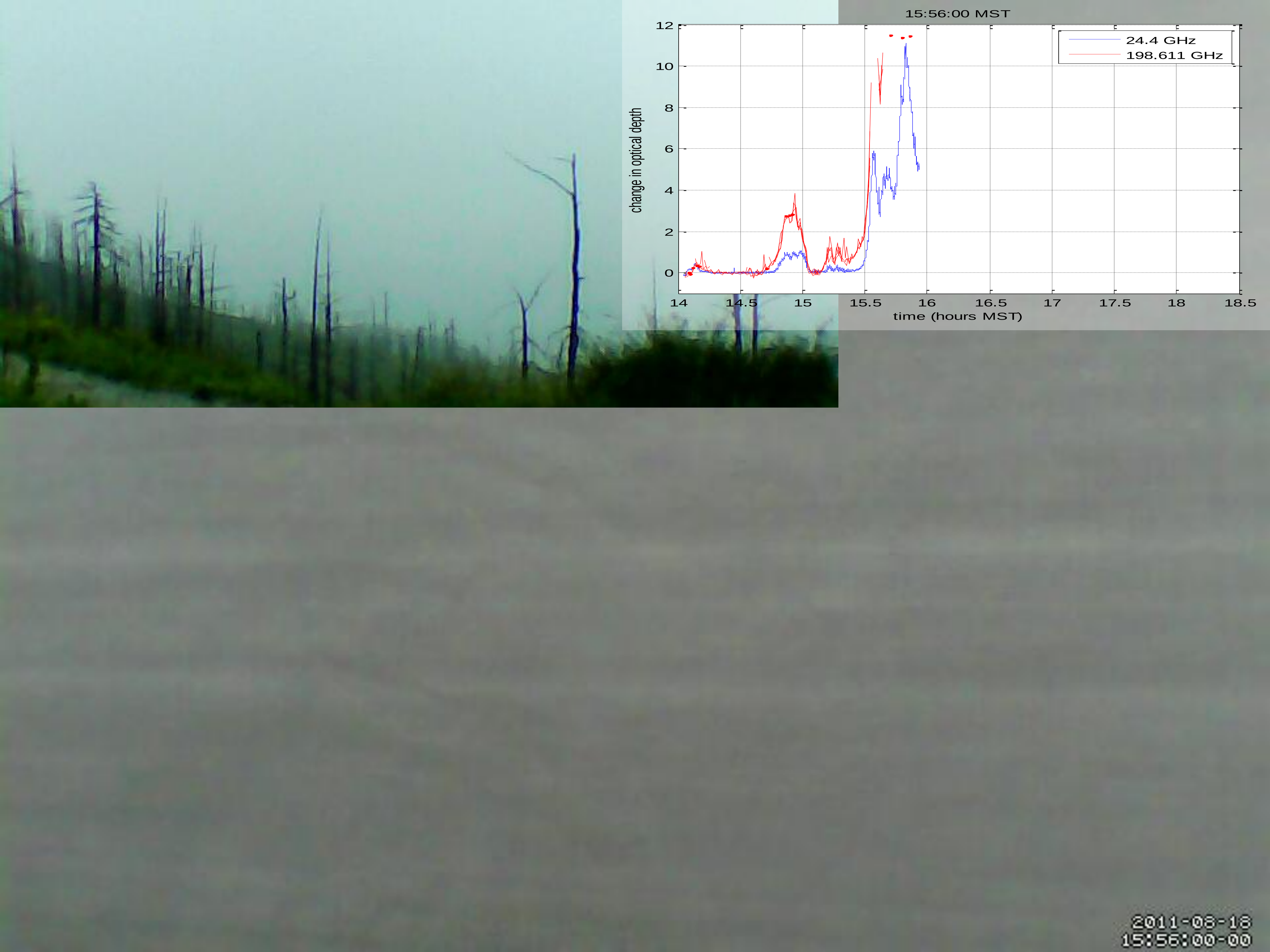
18.5
time (hours MST)
2011-08-18
15:45:01-01


15:50:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
15:50:00-00


15:52:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
15:52:00-00


15:54:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
15:54:00-00



15:56:00 MST
24.4 GHz
198.611 GHz
change in optical depth
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17.5
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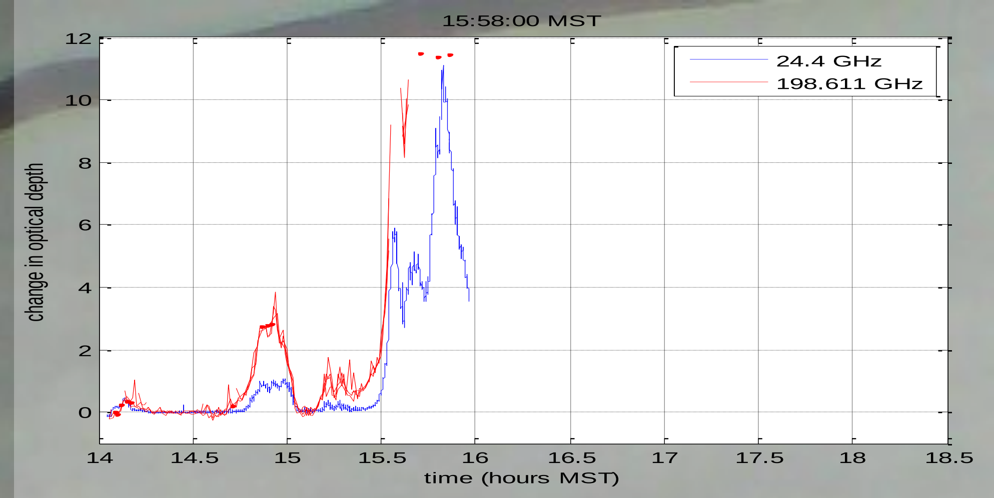
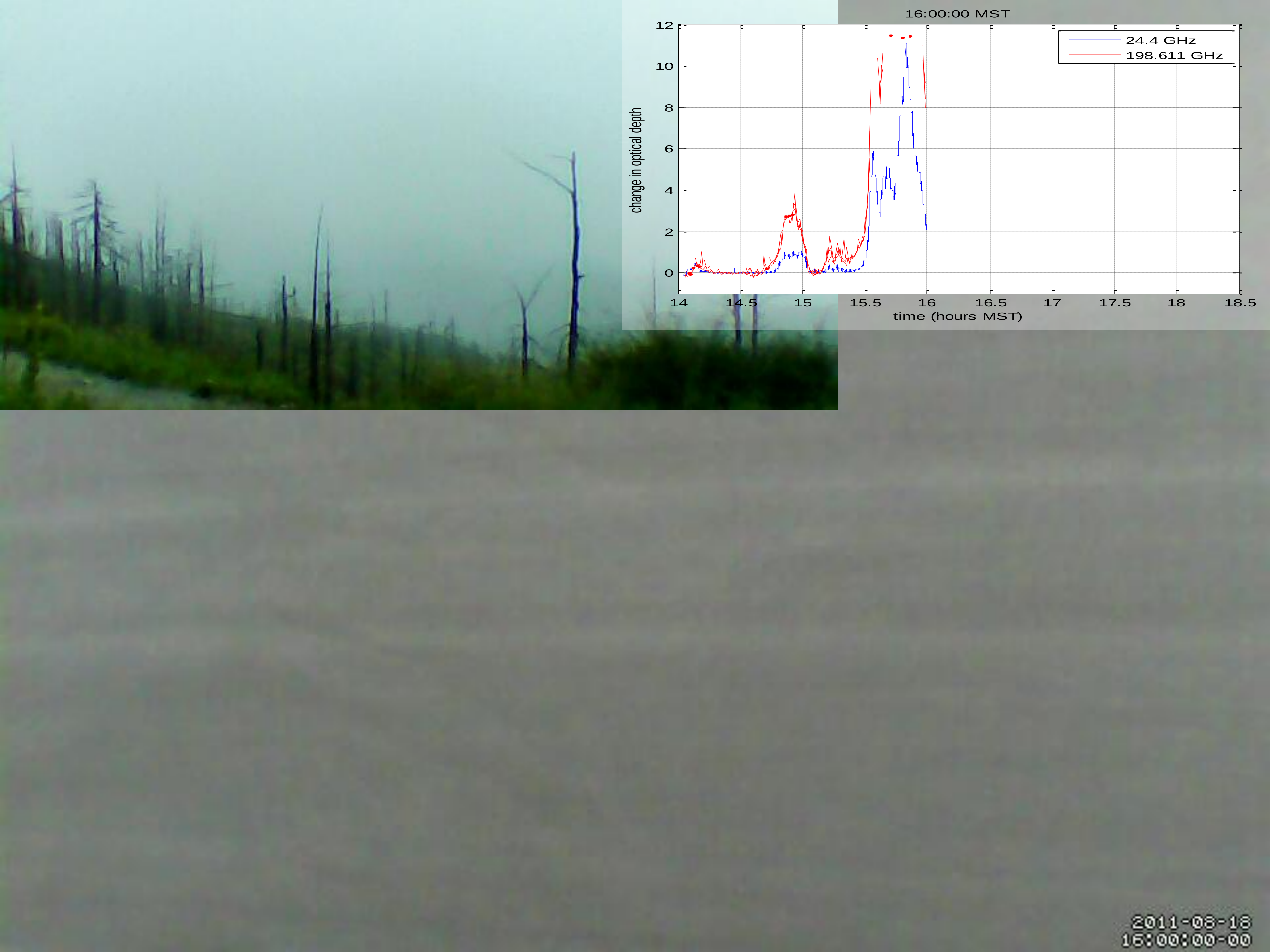
18.5
time (hours MST)
2011-08-18
15:56:00-00

- Extremely windy




16:00:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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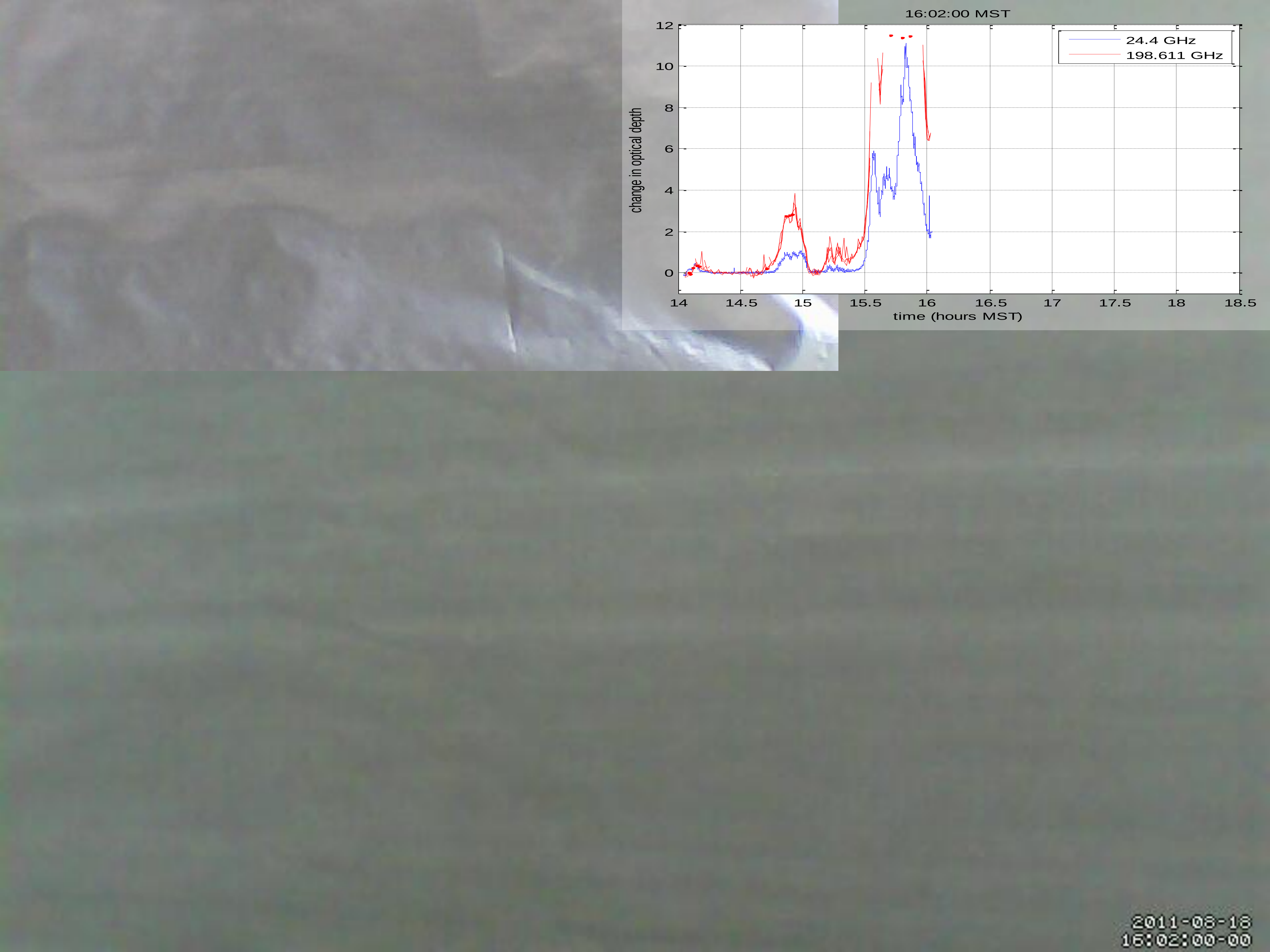
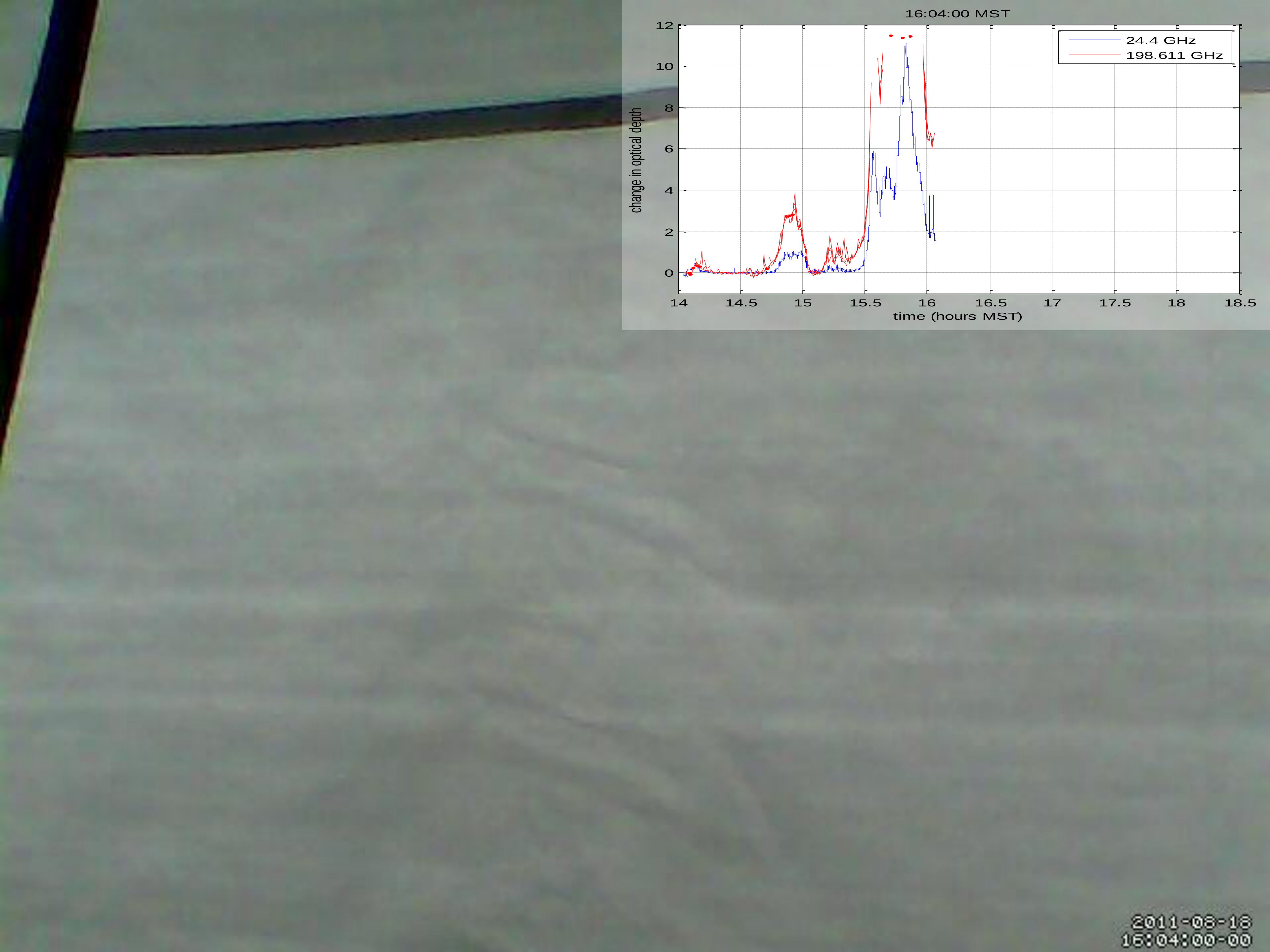
2011-08-18
16:00:00-00


16:02:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
16:02:00-00


16:04:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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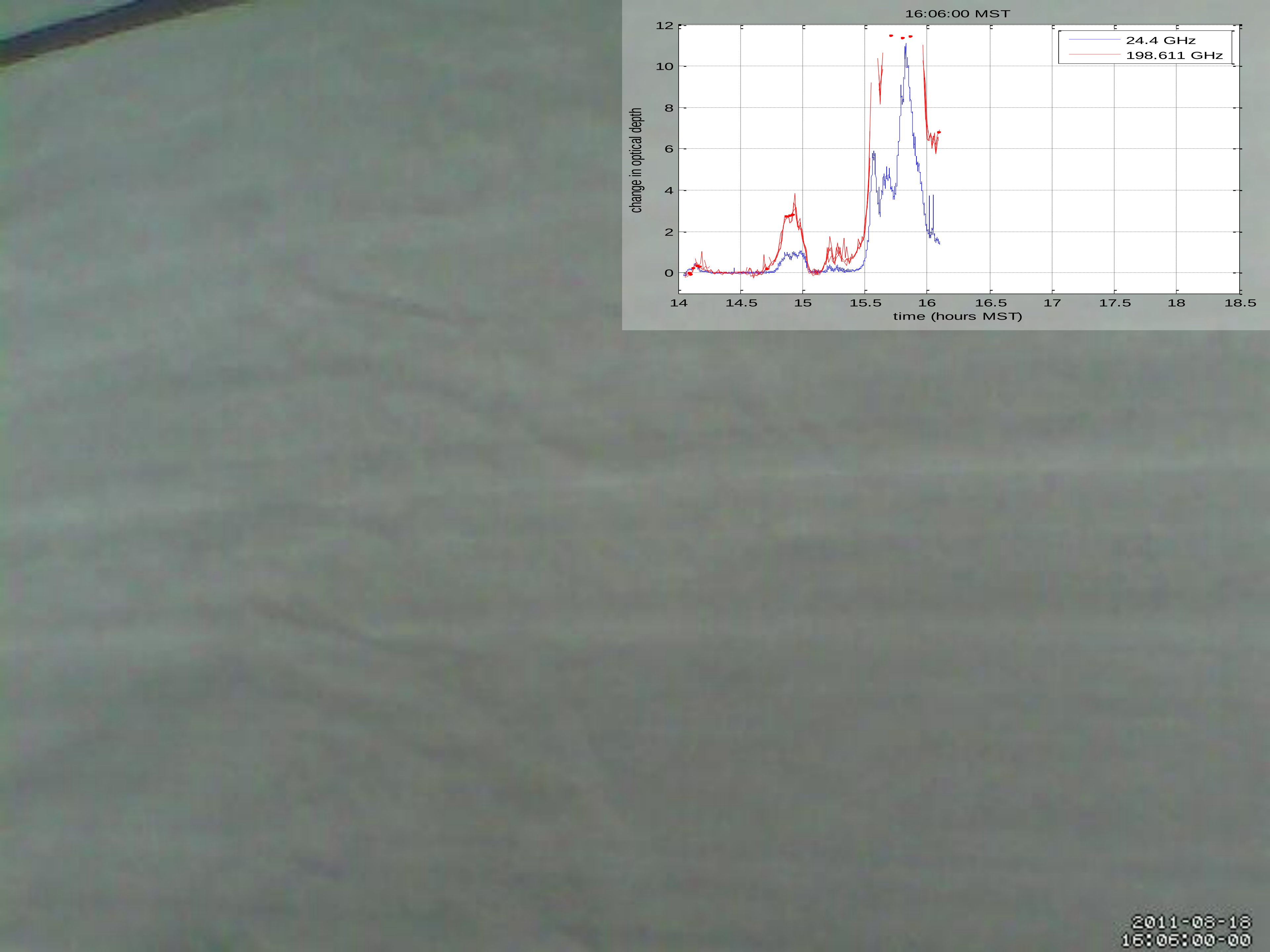
18.5
2011-08-18
16:04:00-00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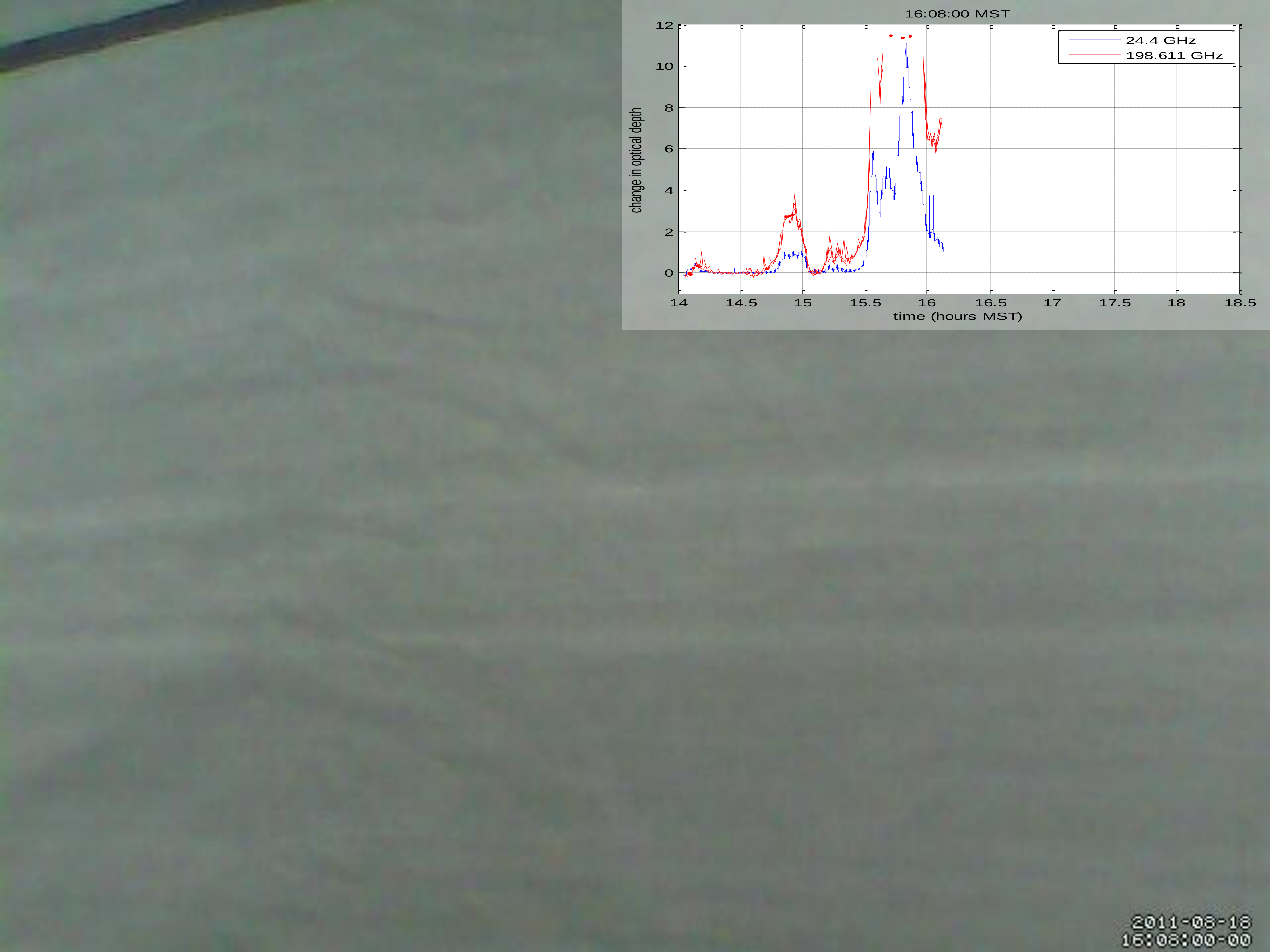
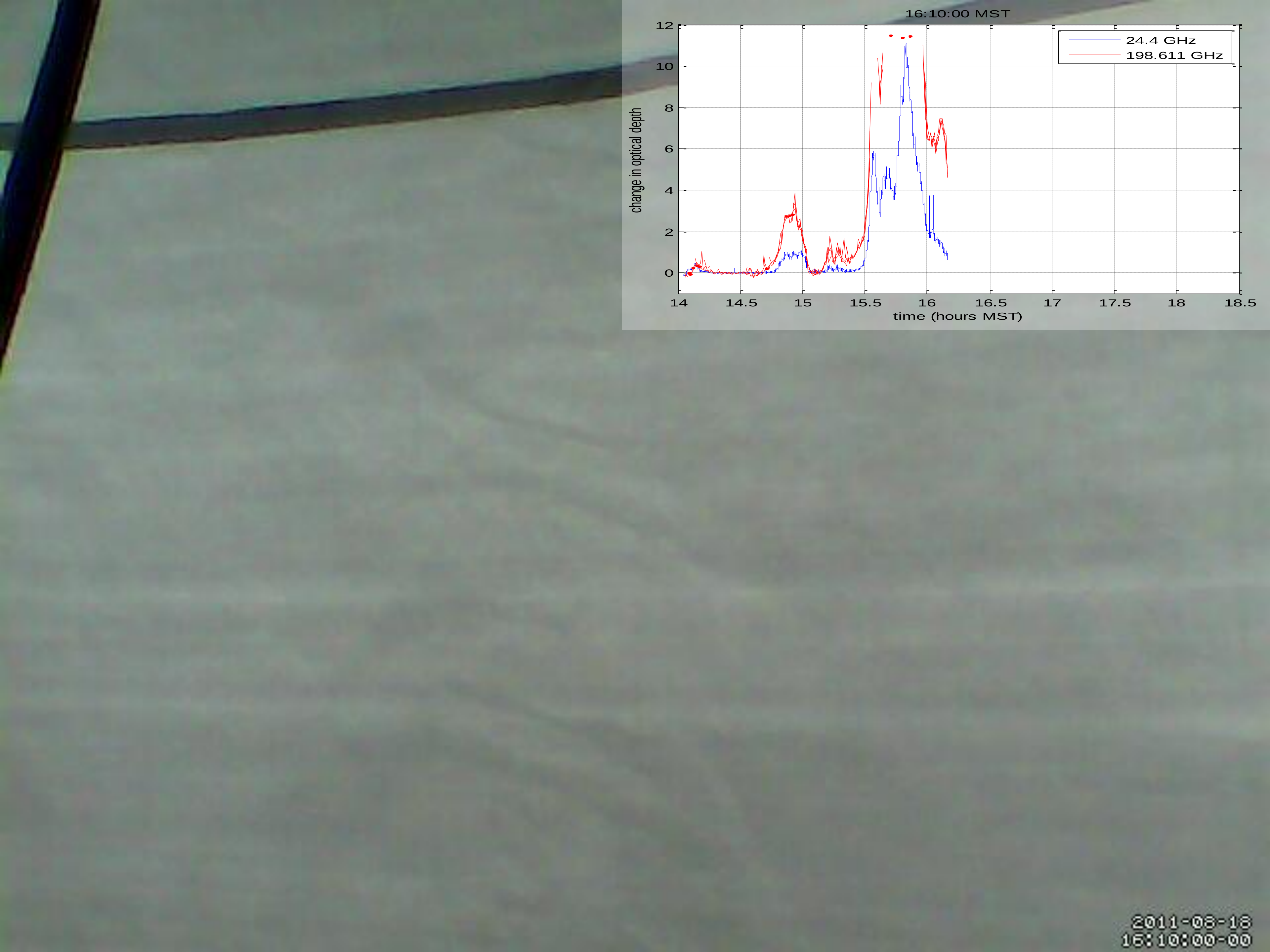
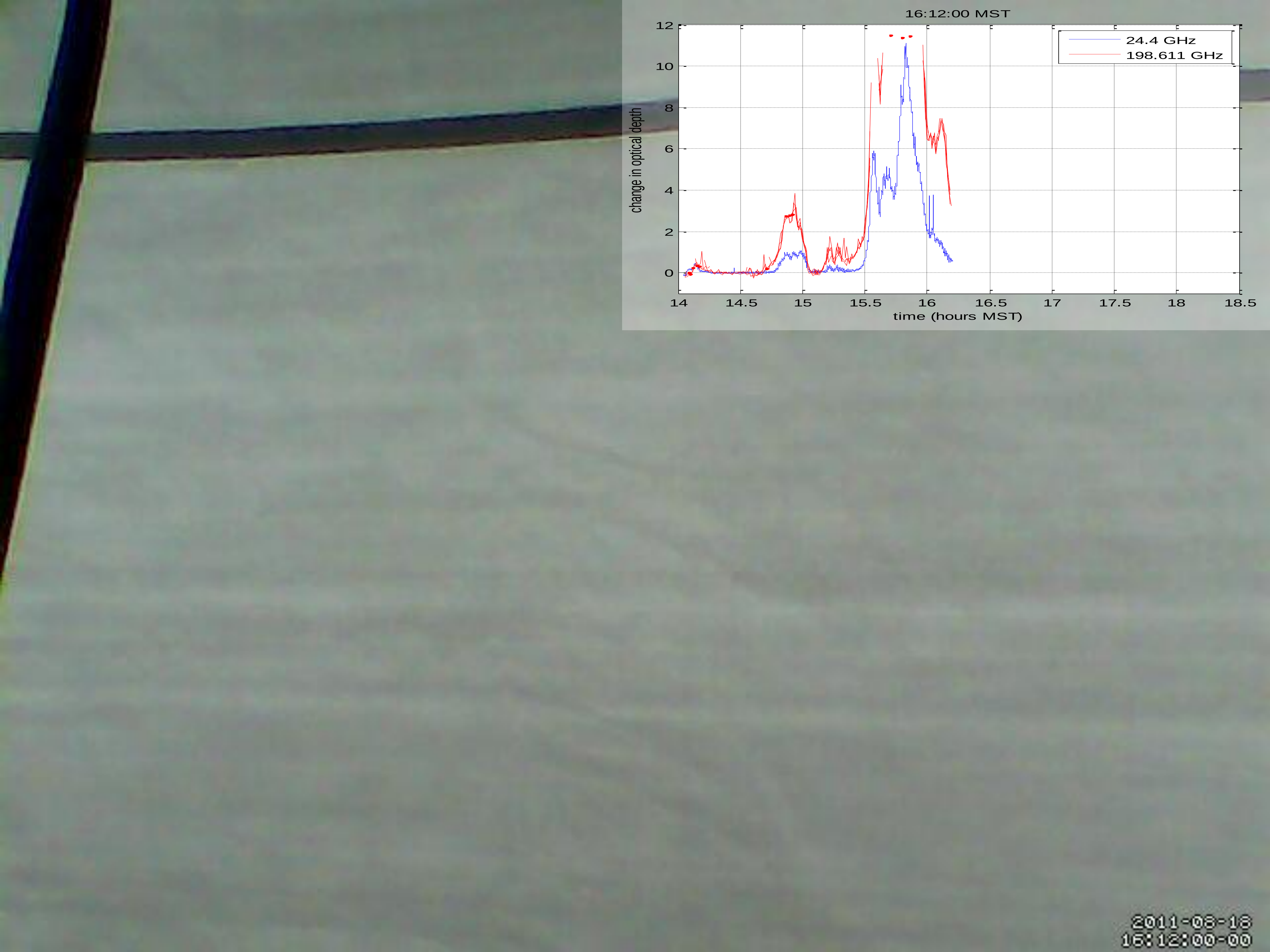
change in optical depth
24.4 GHz
198.611 GHz
time (hours MST)
2011-08-18
16:06:00-00


16:08:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
16:08:00-00


16:10:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
16:10:00-00


16:12:00 MST
24.4 GHz
198.611 GHz
change in optical depth
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17.5
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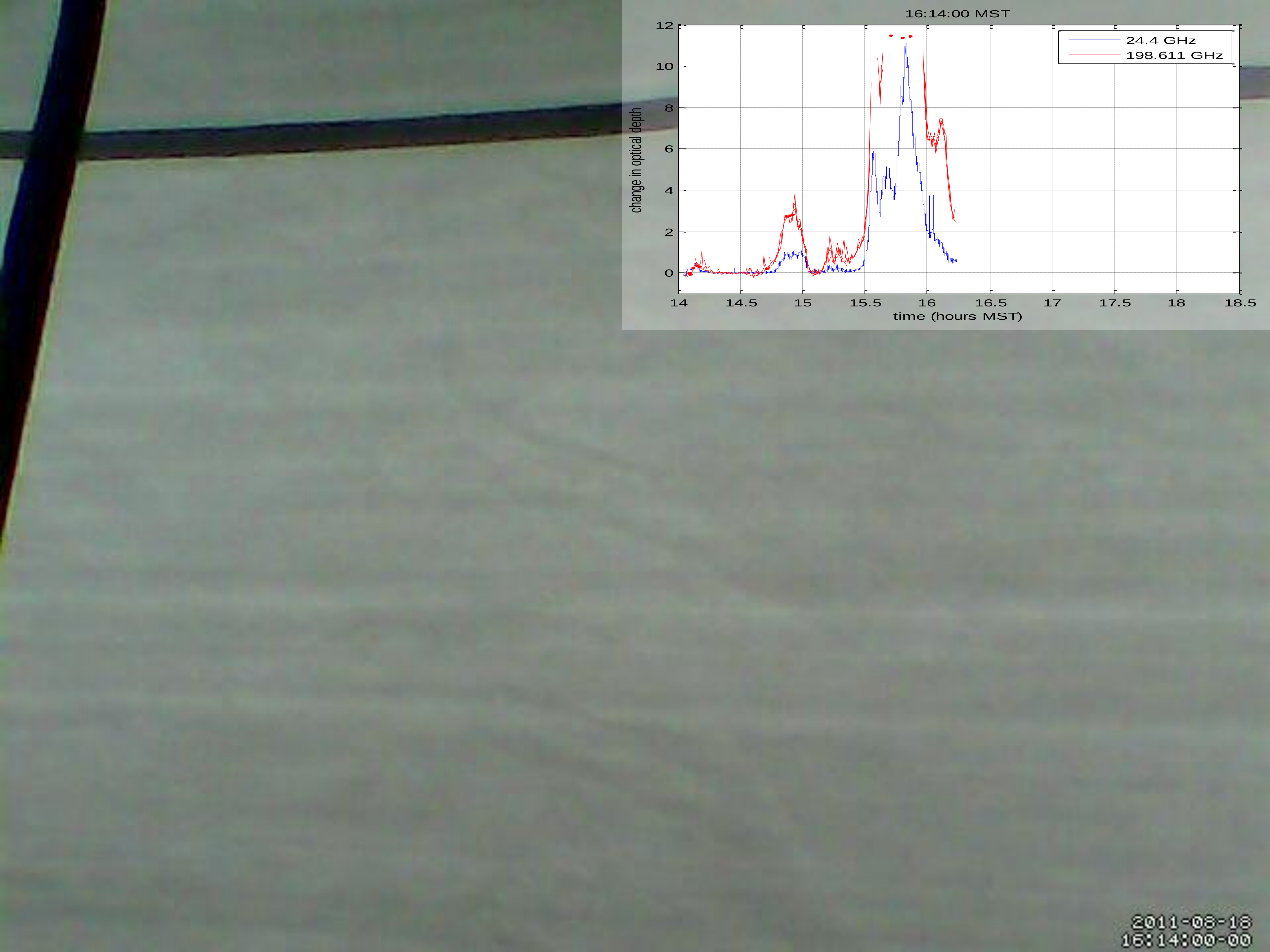
18.5
time (hours MST)
2011-08-18
16:12:00-00


16:14:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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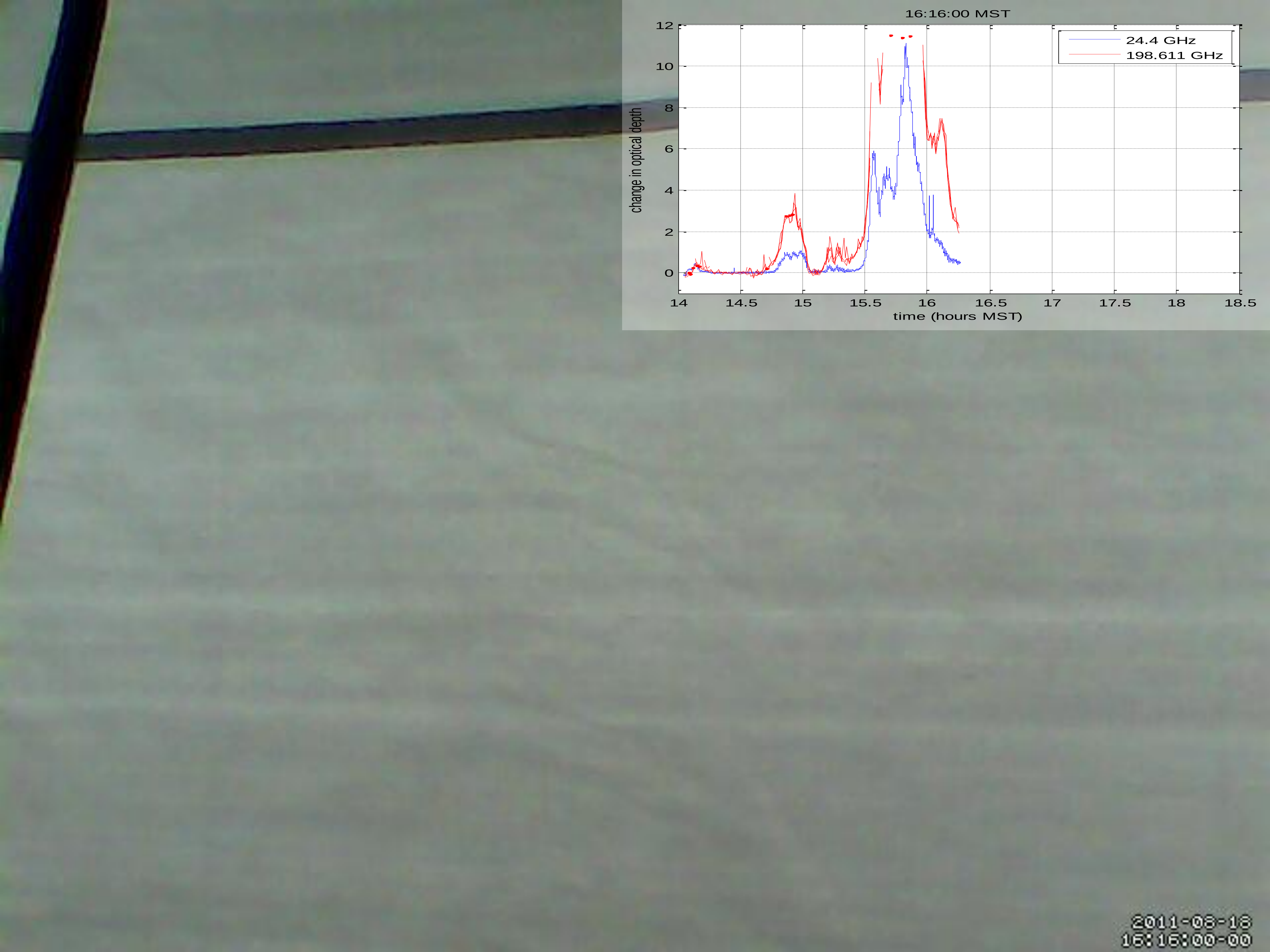
2011-08-18
16:14:00-00


16:16:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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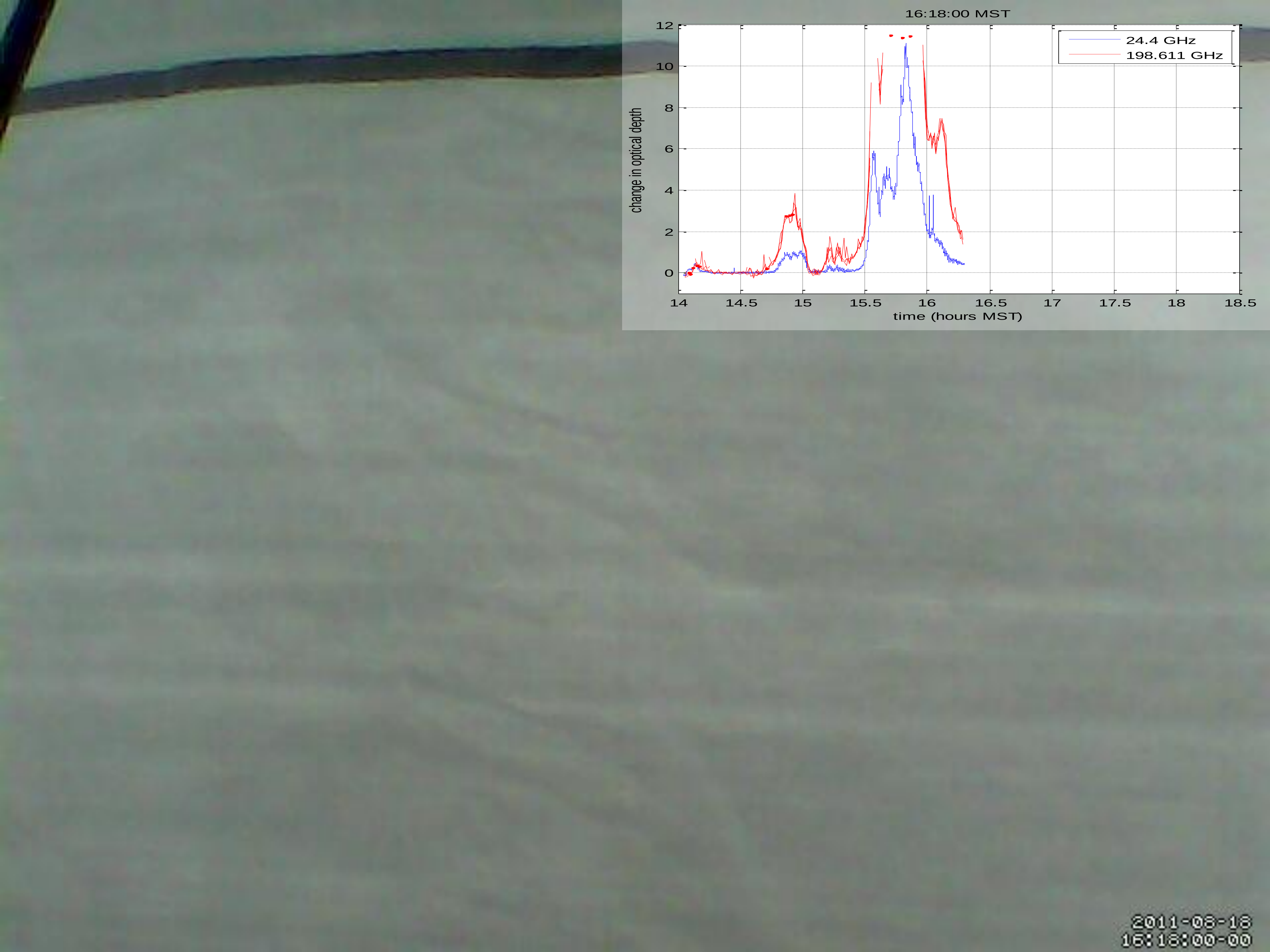
2011-08-18
16:16:00-00


16:18:00 MST
24.4 GHz
198.611 GHz
change in optical depth
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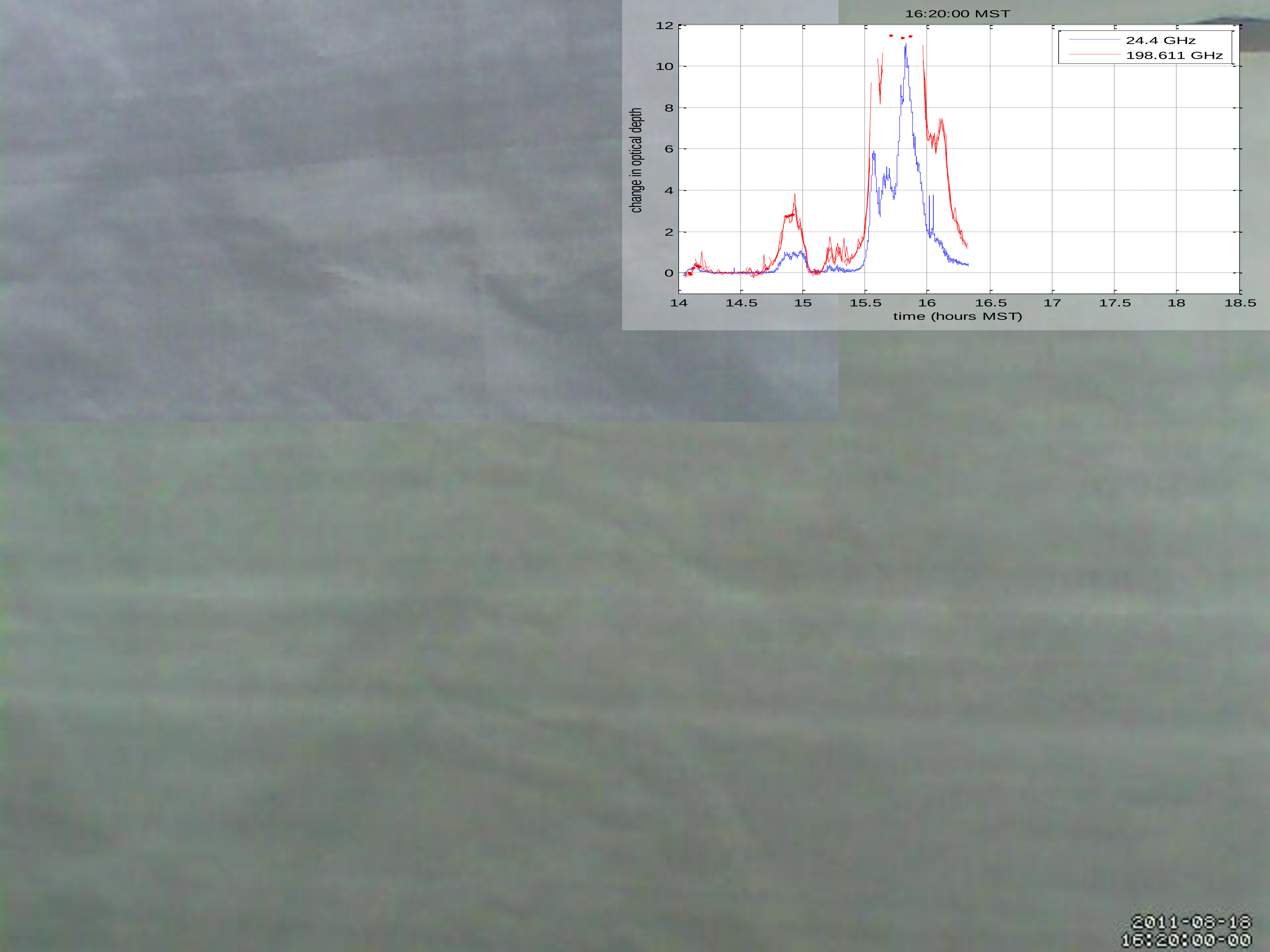
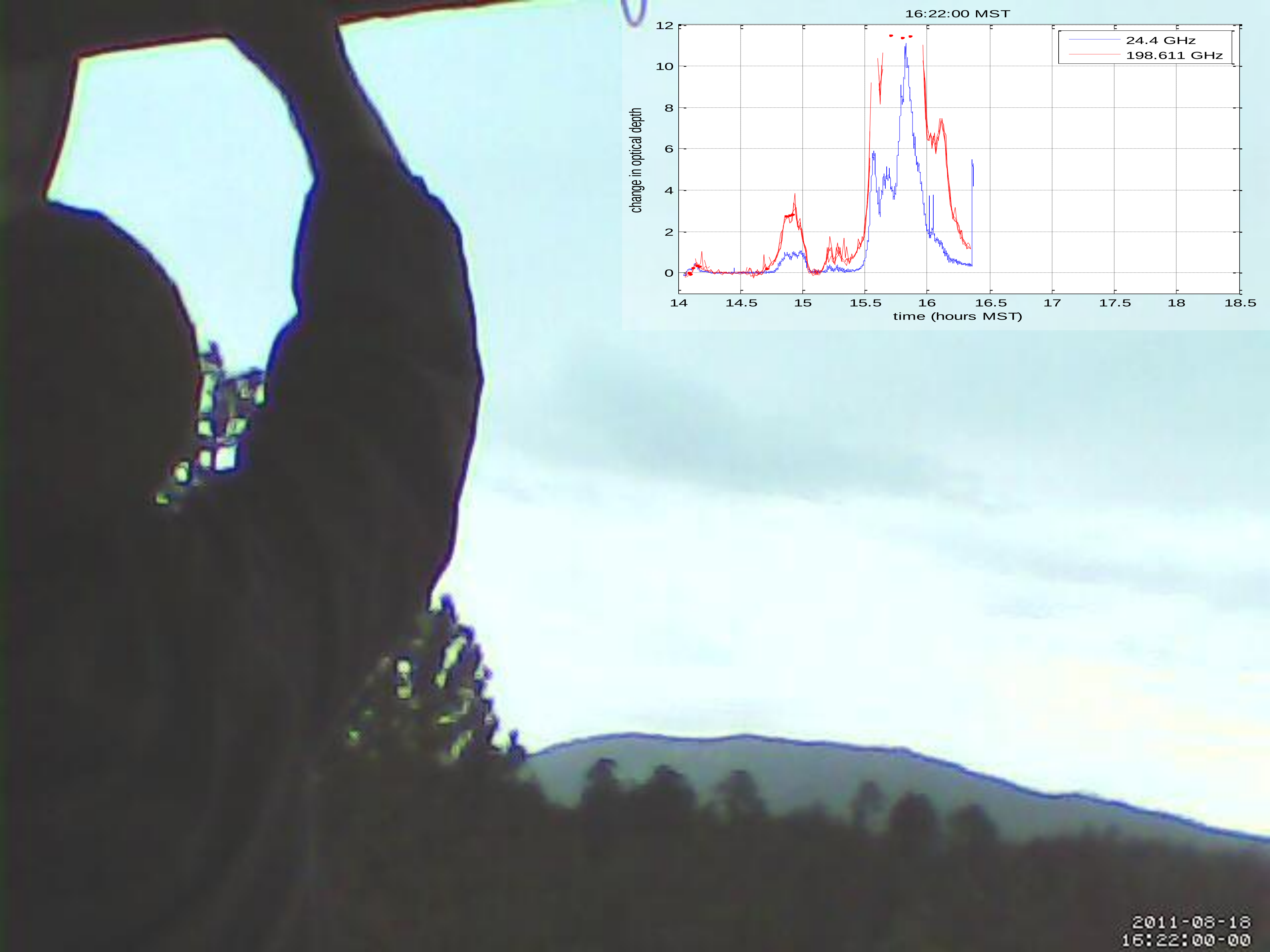
18.5
time (hours MST)
2011-08-18
16:18:00-00


16:20:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
16:20:00-00


16:22:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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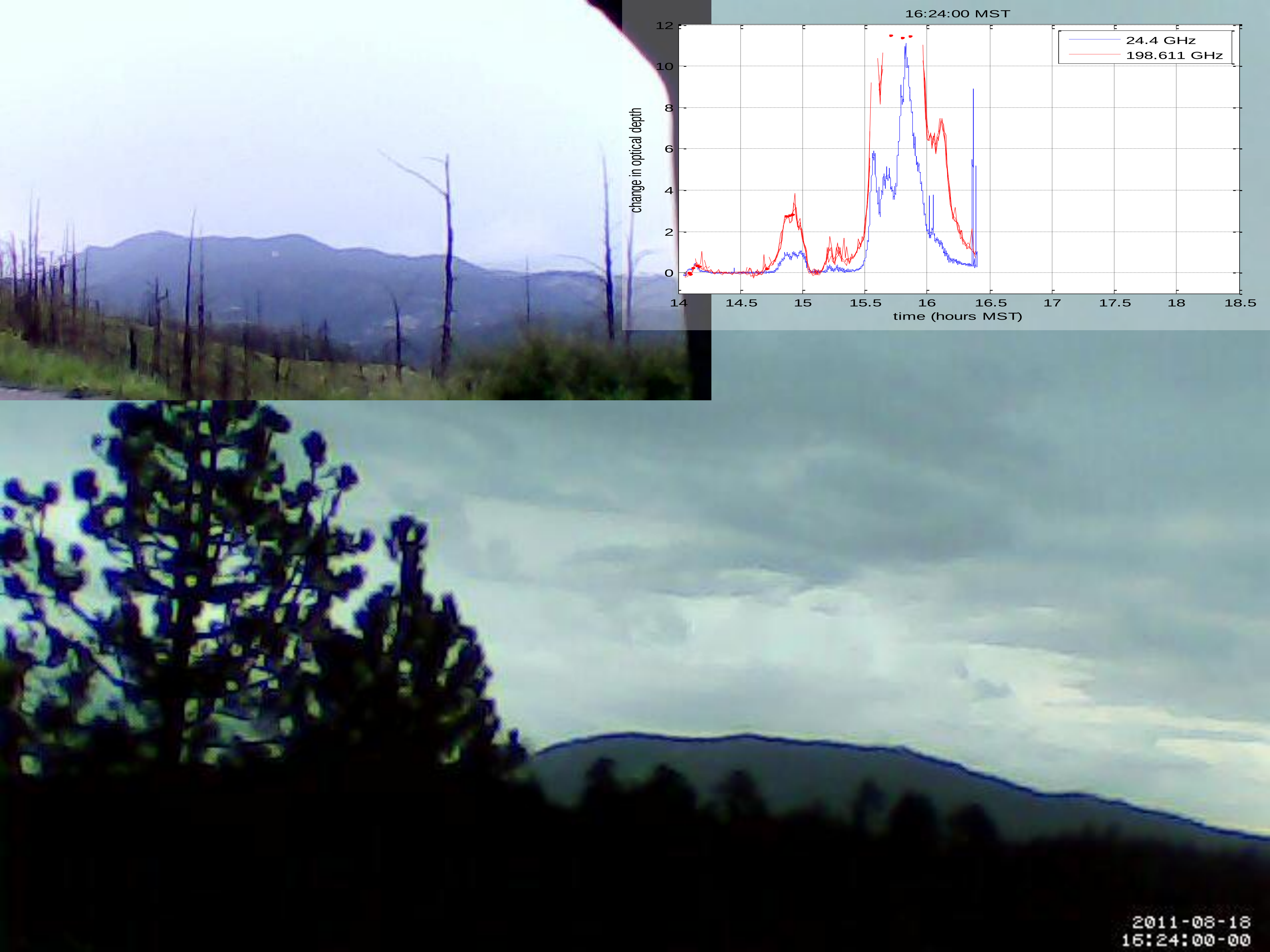
2011-08-18
16:22:00-00



16:24:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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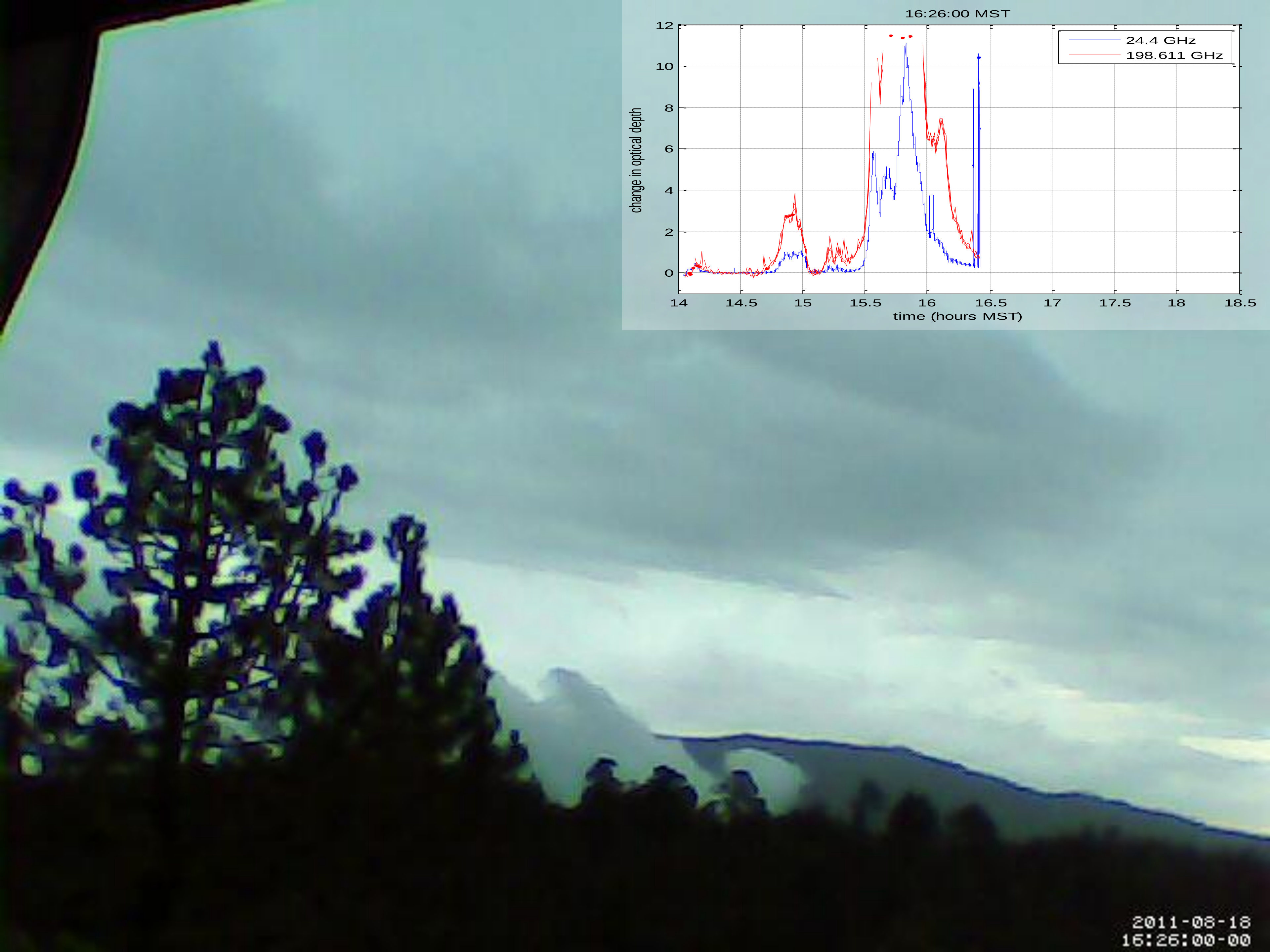
2011-08-18
16:24:00-00


16:26:00 MST
change in optical depth
24.4 GHz
198.611 GHz
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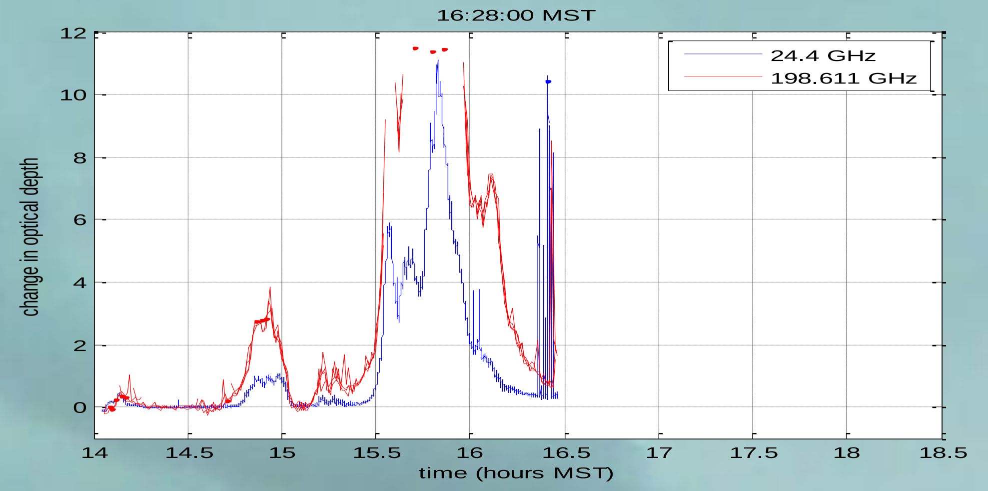
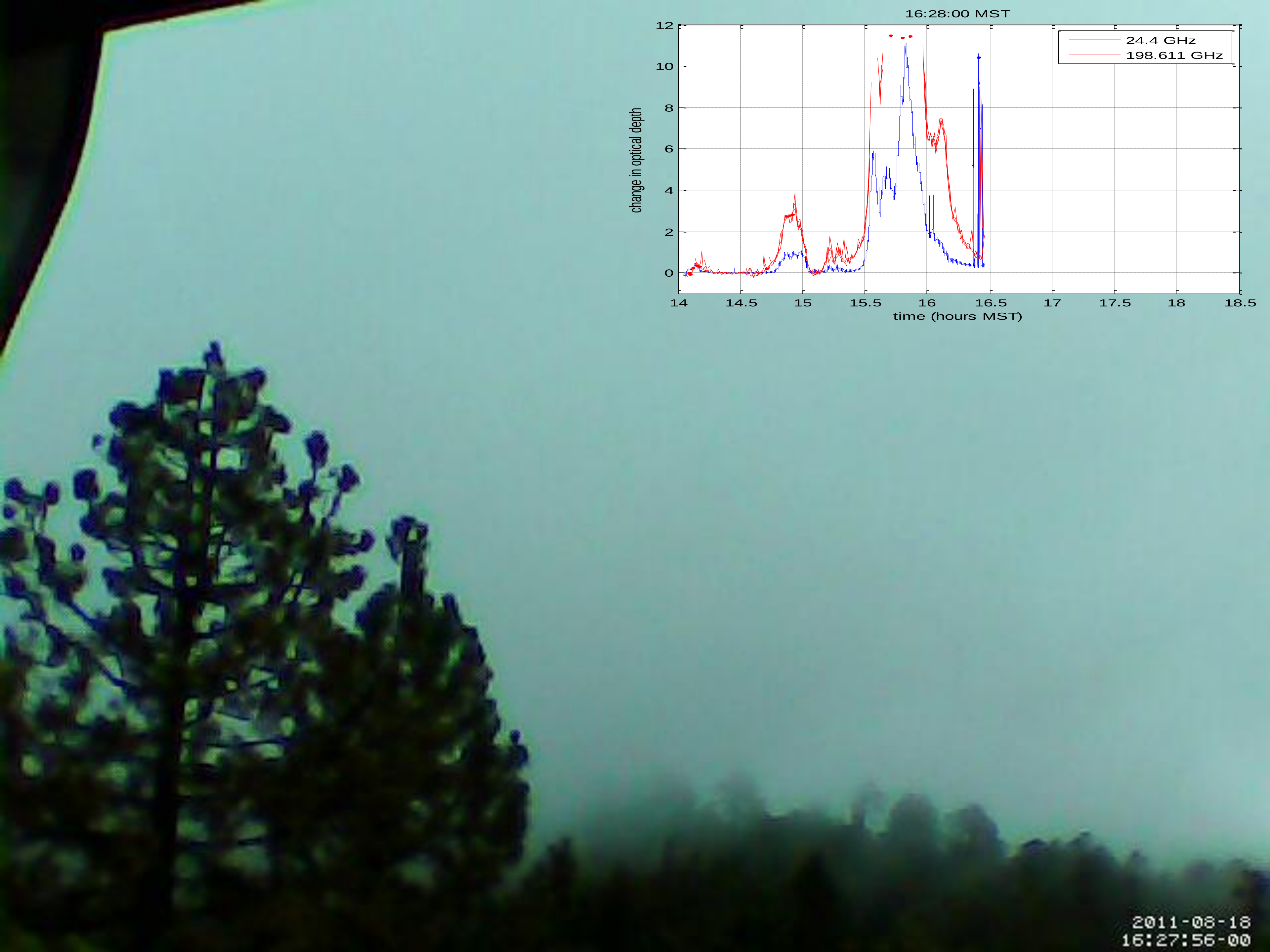
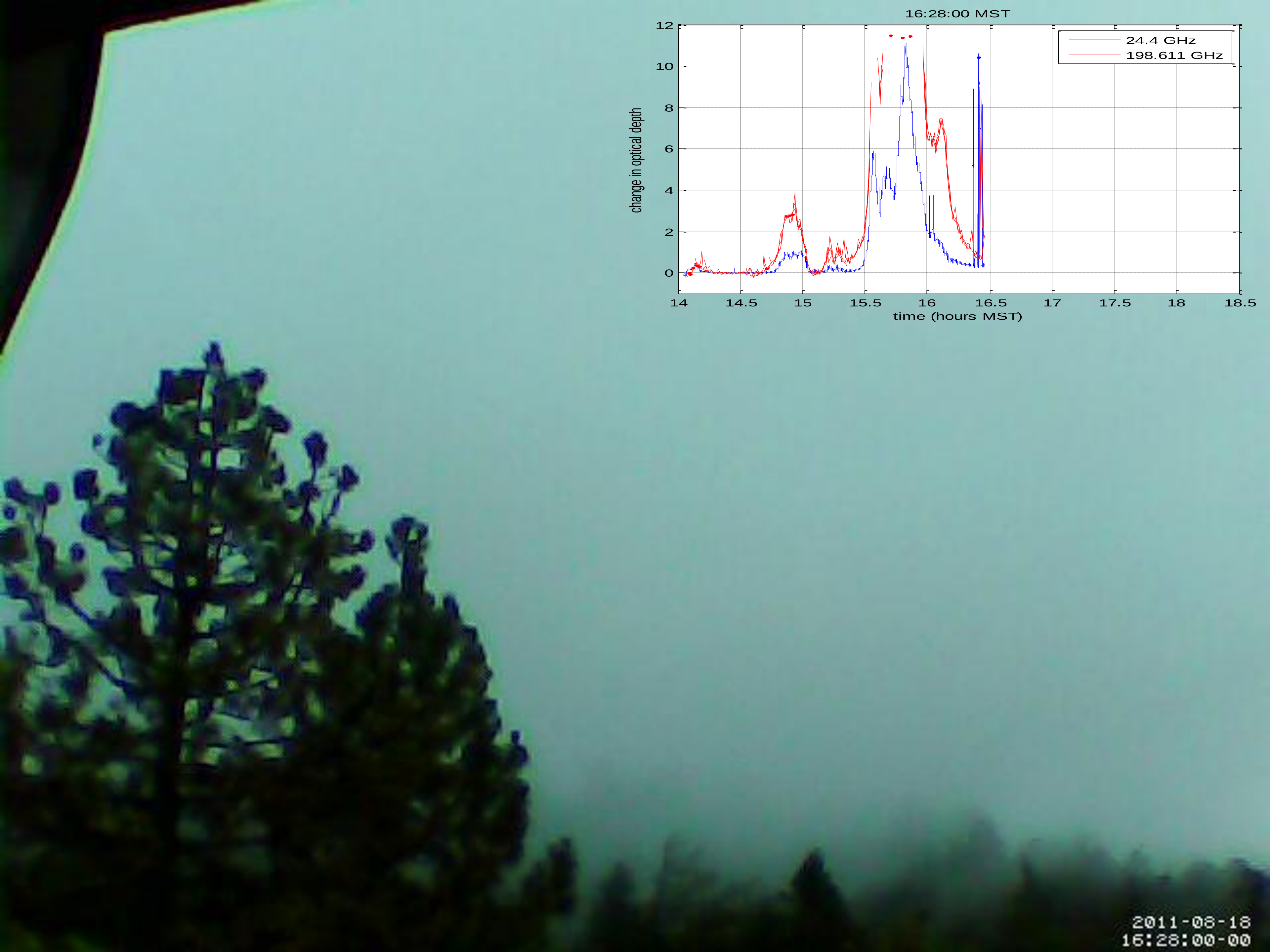
18.5
time (hours MST)
2011-08-18
16:26:00-00

30 second images




16:28:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
16:27:56-00


16:28:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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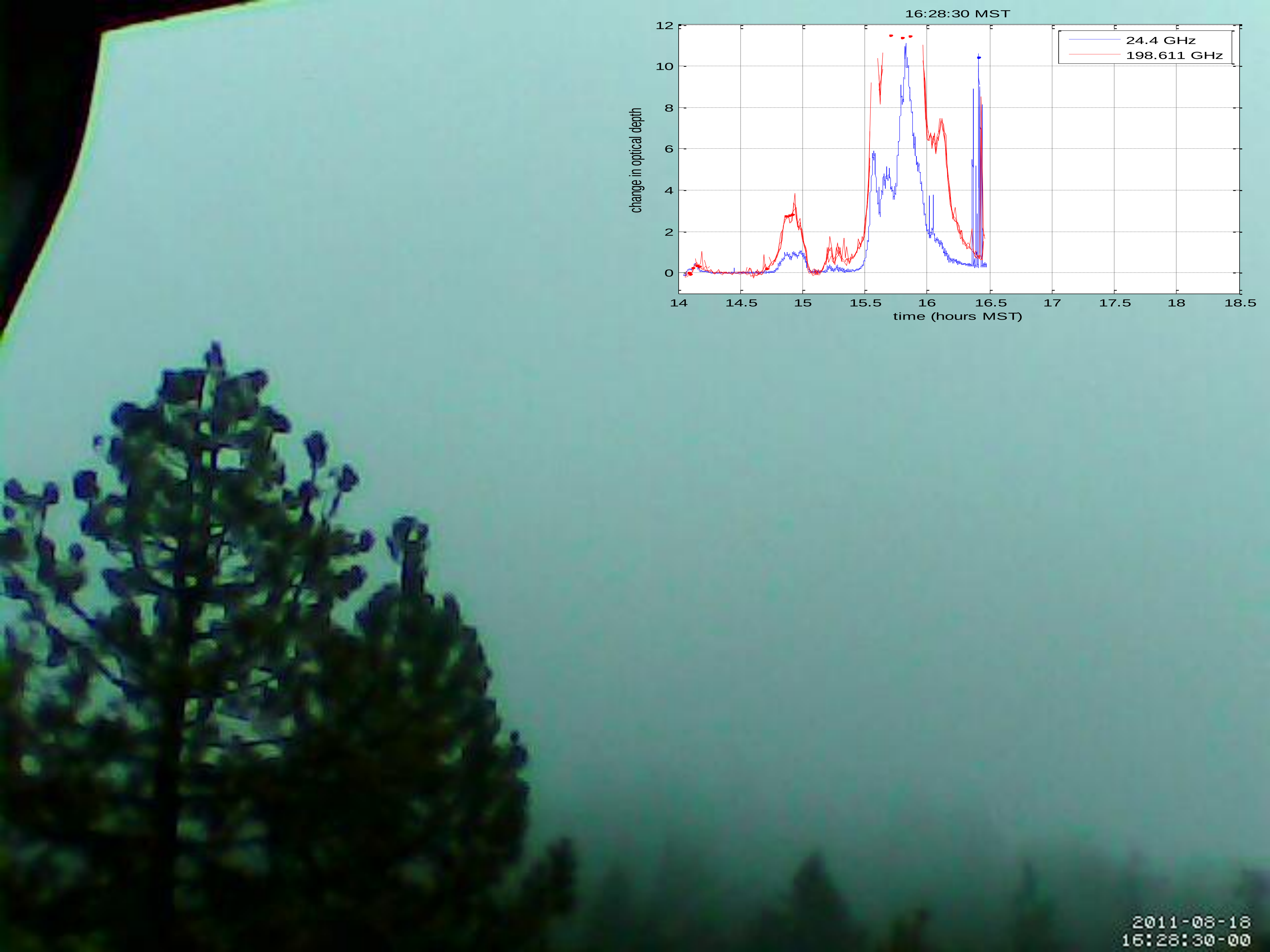

16:28:30 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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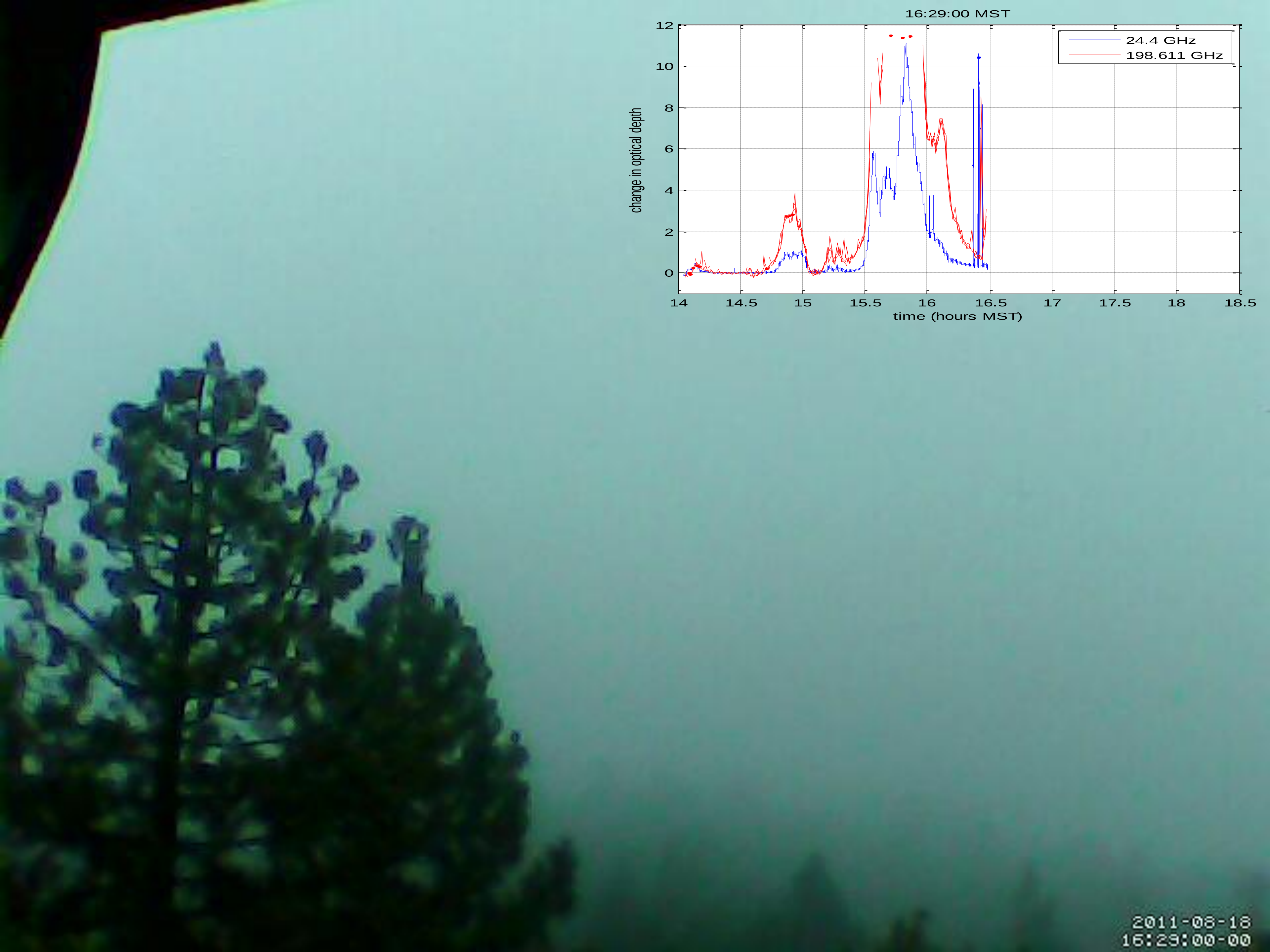
2011-08-18
16:28:30-00


16:29:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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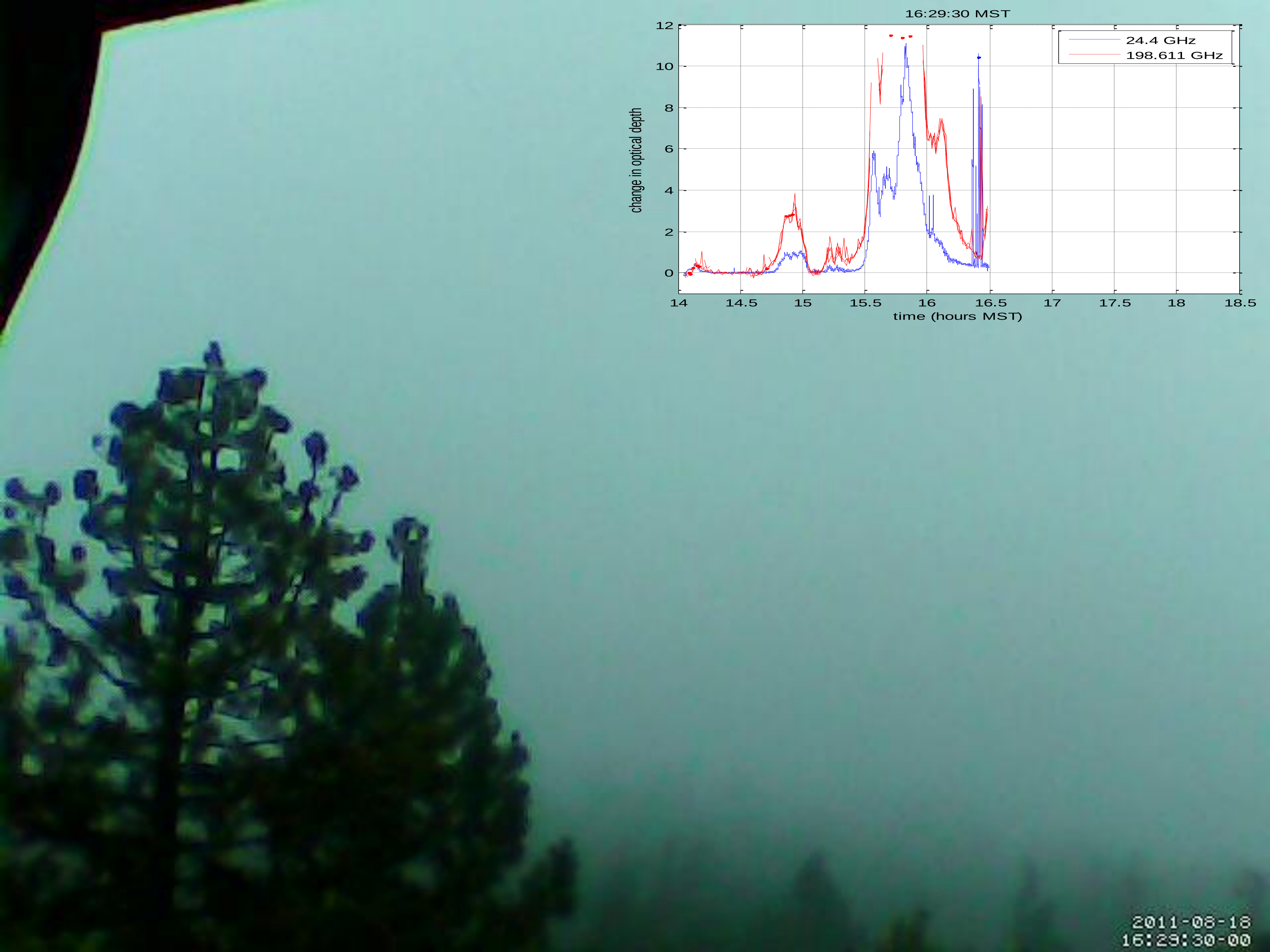
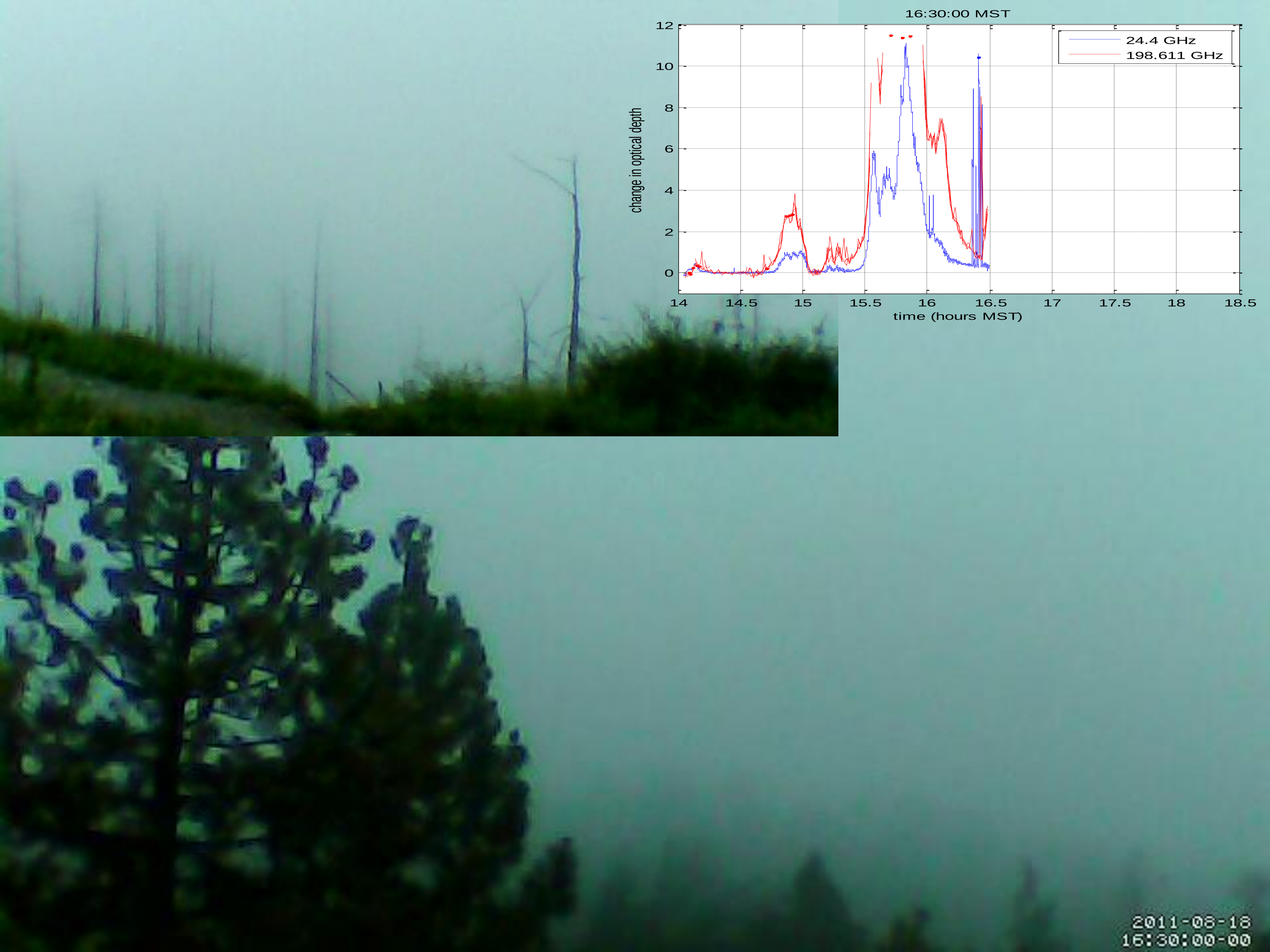
2011-08-18
16:29:00-00


16:29:30 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
2011-08-18
16:29:30-00


16:30:00 MST
24.4 GHz
198.611 GHz
change in optical depth
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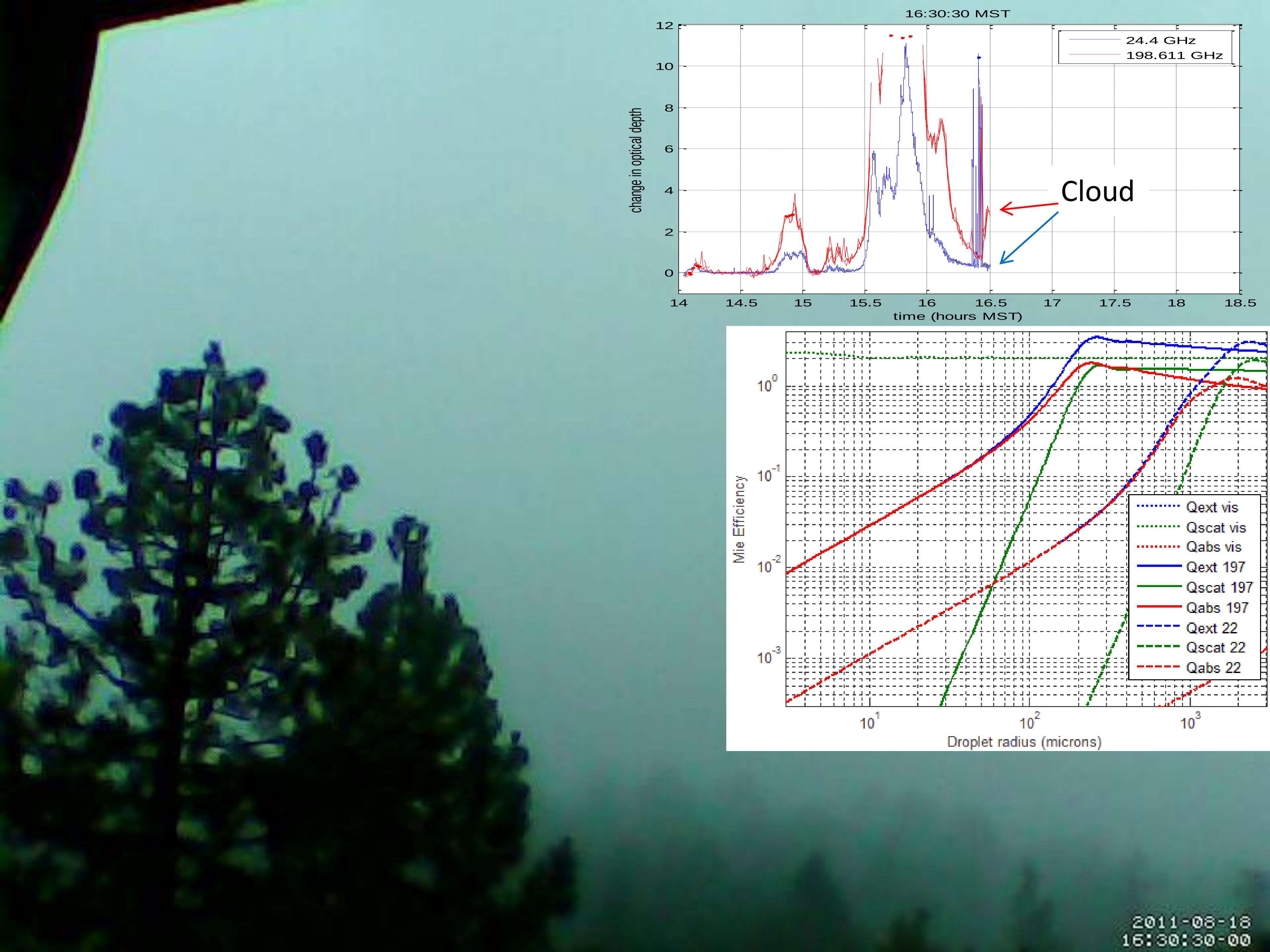
time (hours MST)
2011-08-18
16:30:00-00


16:30:30 MST
24.4 GHz
198.611 GHz
change in optical depth
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18.5
time (hours MST)
Cloud
Mie Efficiency
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10^{-1}
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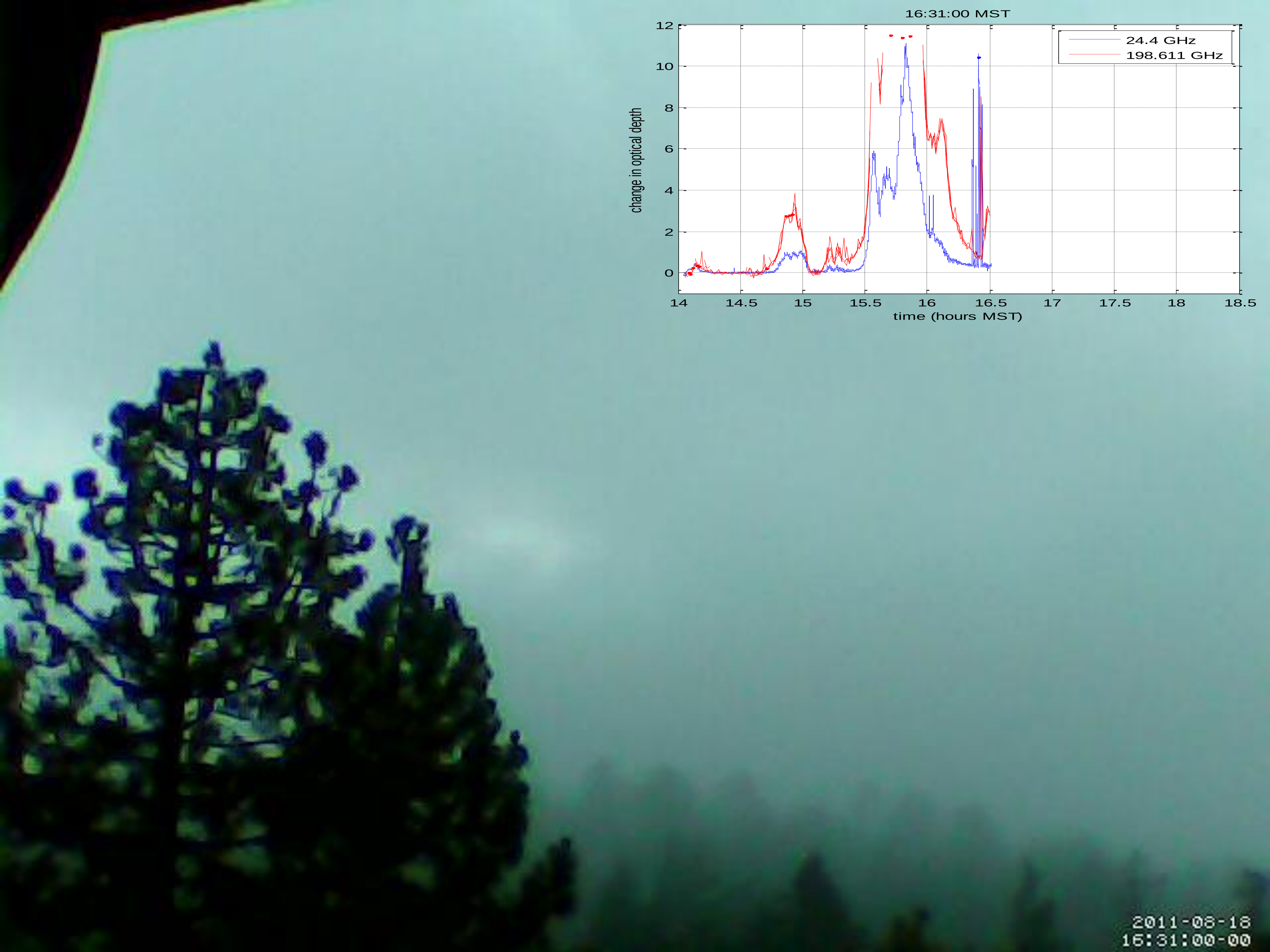
10^{-3}
10^{1}
10^{2}
10^{3}
Droplet radius (microns)
Qext vis
Qscat vis
Qabs vis
Qext 197
Qscat 197
Qabs 197
Qext 22
Qscat 22
Qabs 22
2011-08-18
16:30:30-00


16:31:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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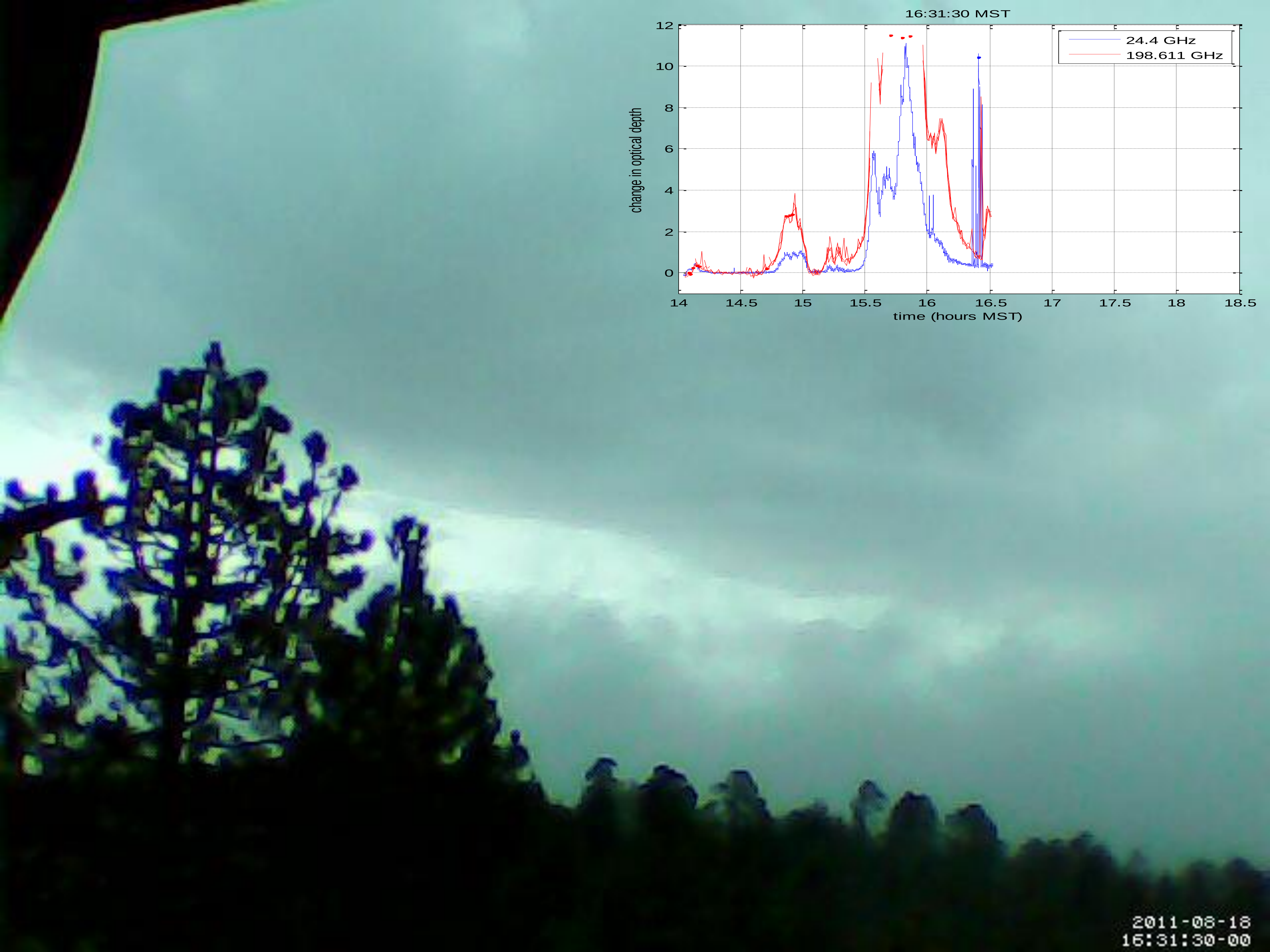
2011-08-18
16:31:00-00


16:31:30 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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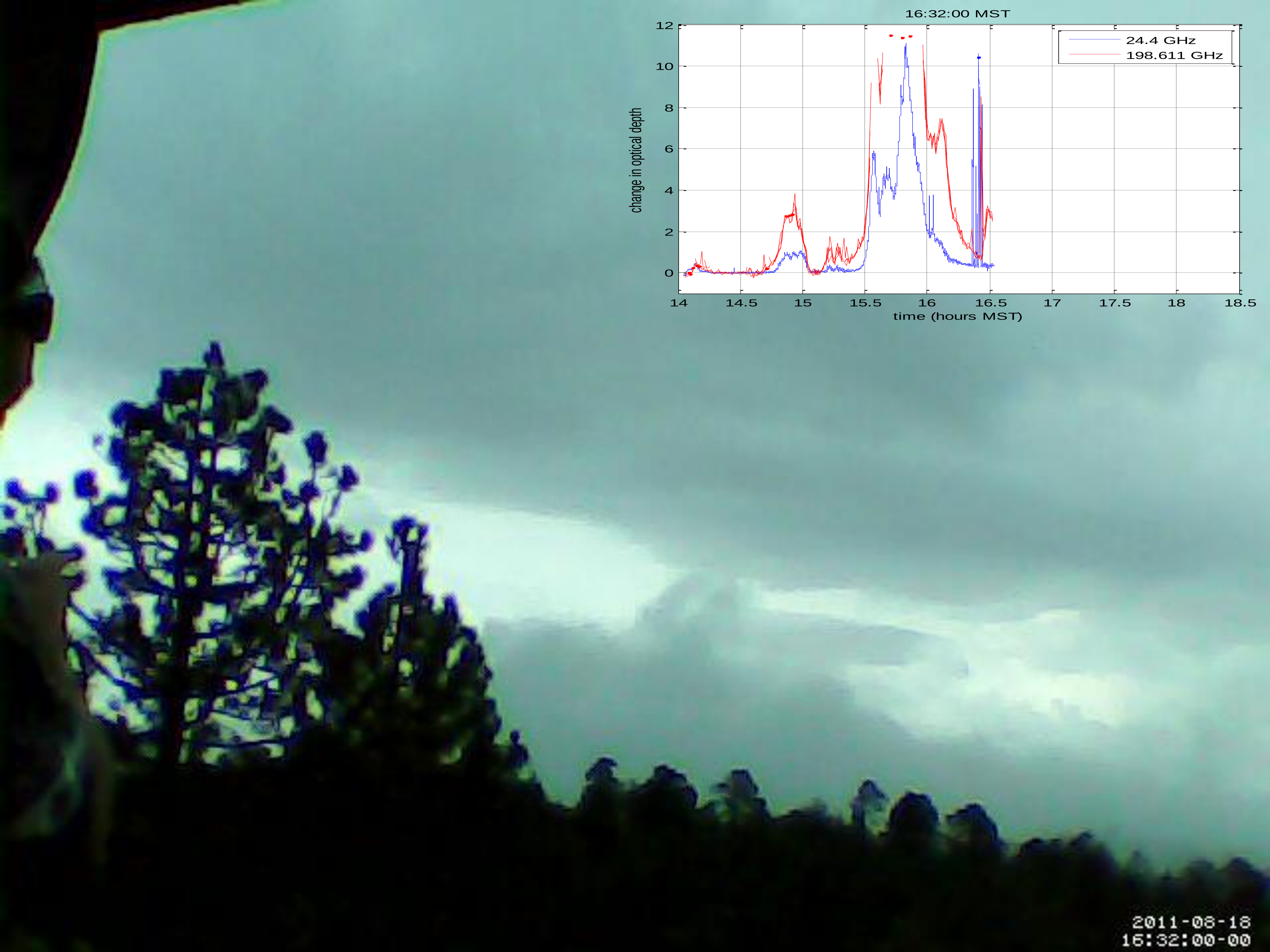
2011-08-18
16:31:30-00



16:32:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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18.5
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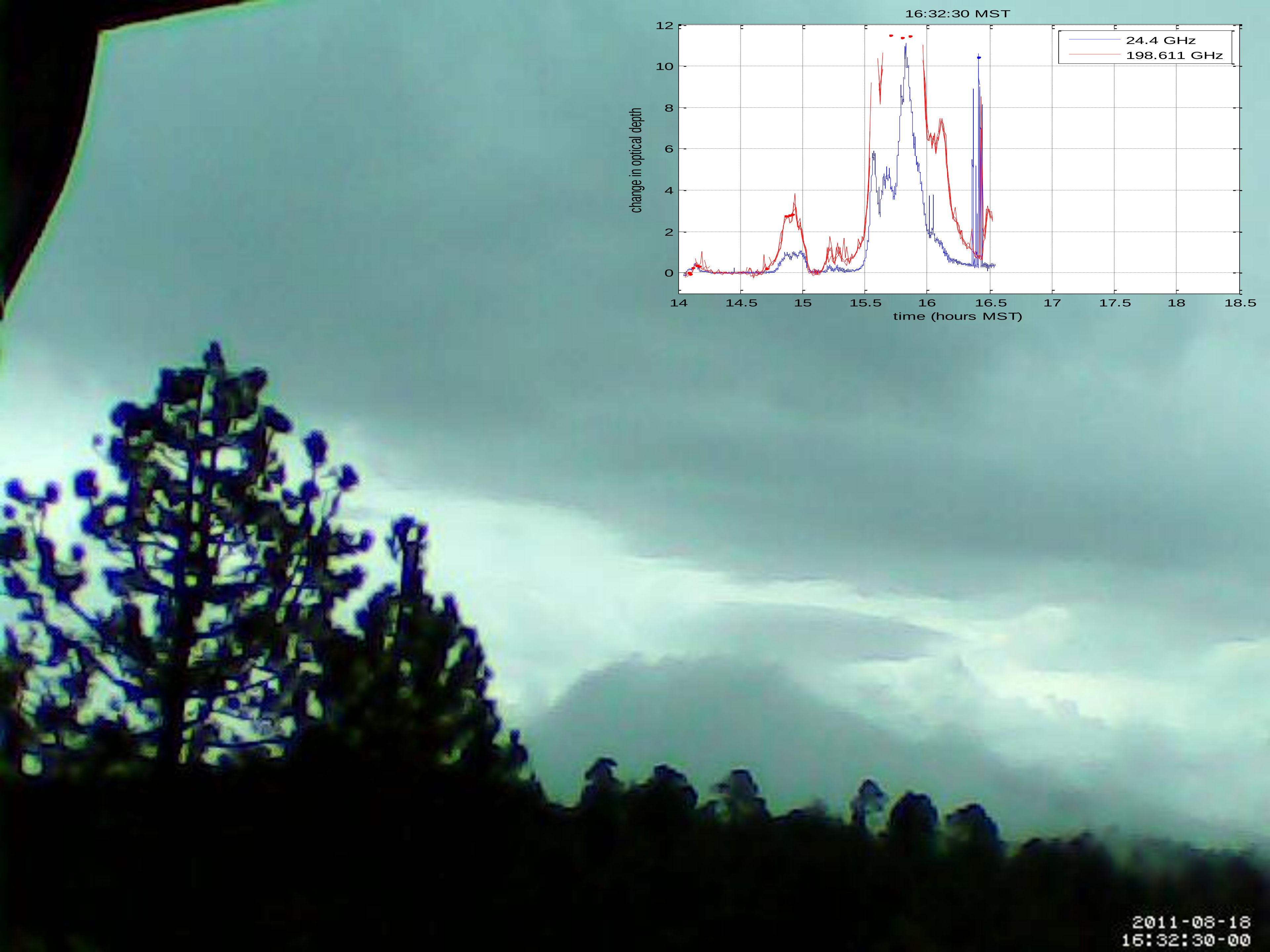
2011-08-18
16:32:00-00


16:32:30 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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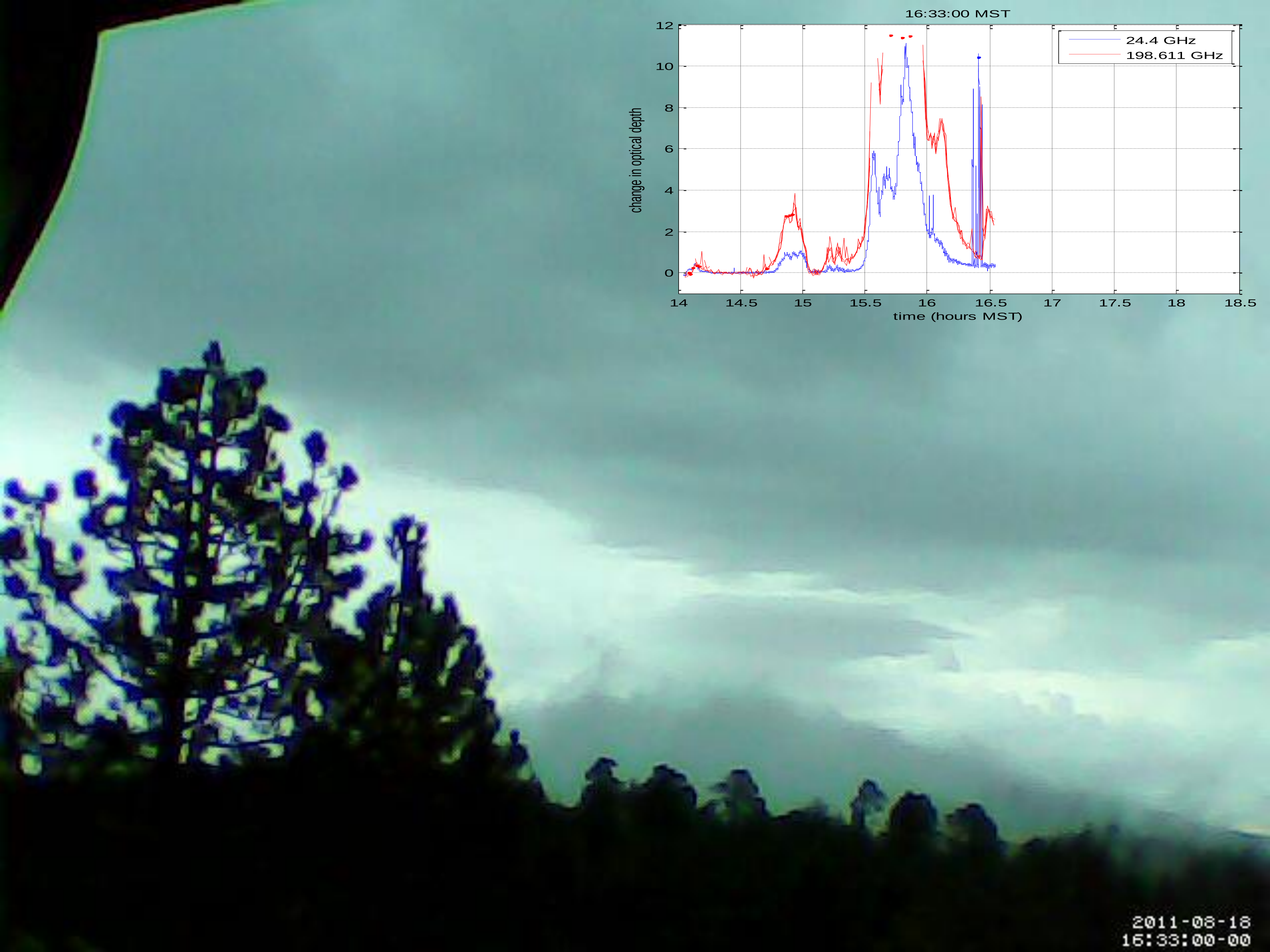
2011-08-18
16:32:30-00


16:33:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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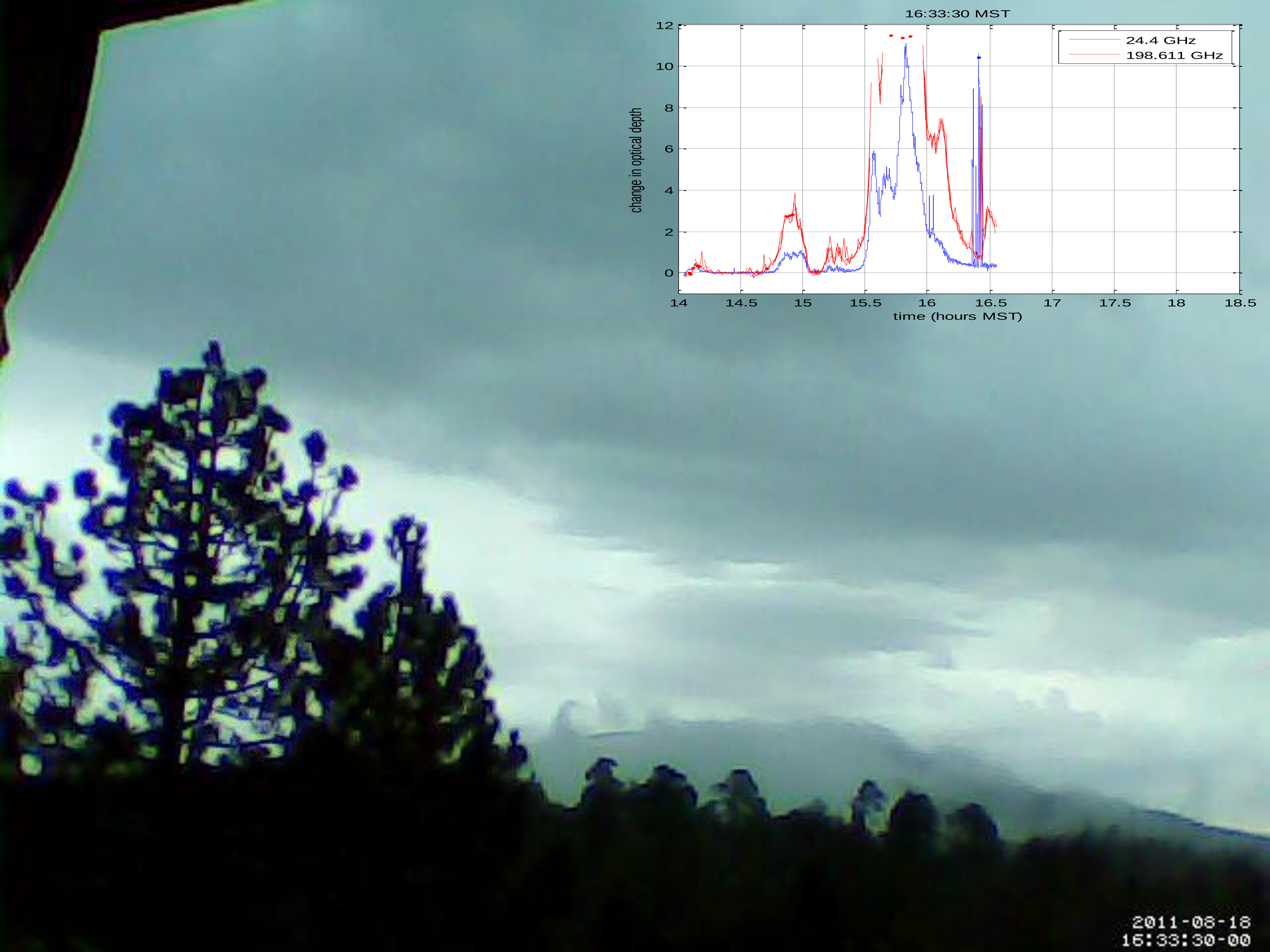
2011-08-18
16:33:00-00


16:33:30 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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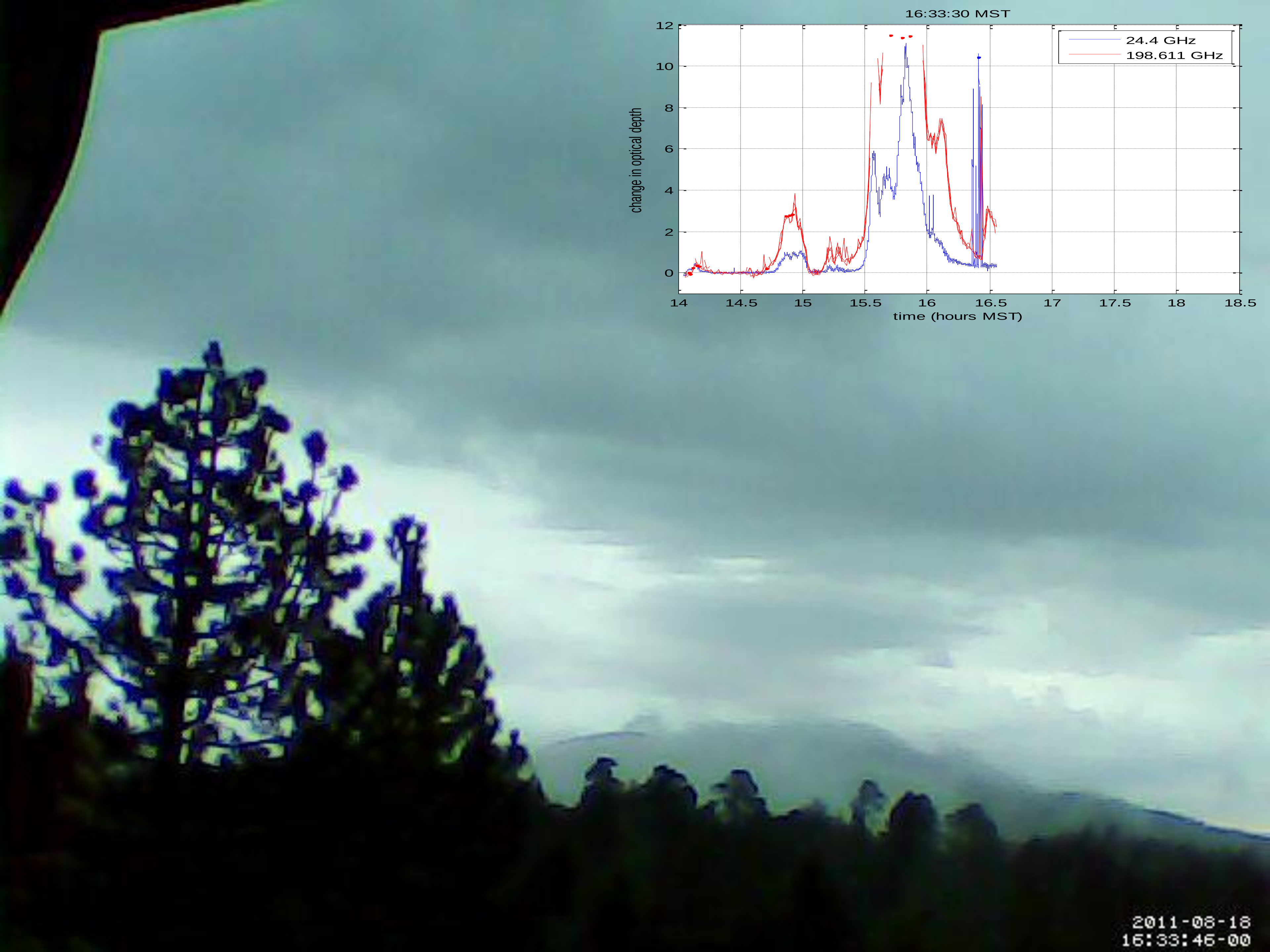
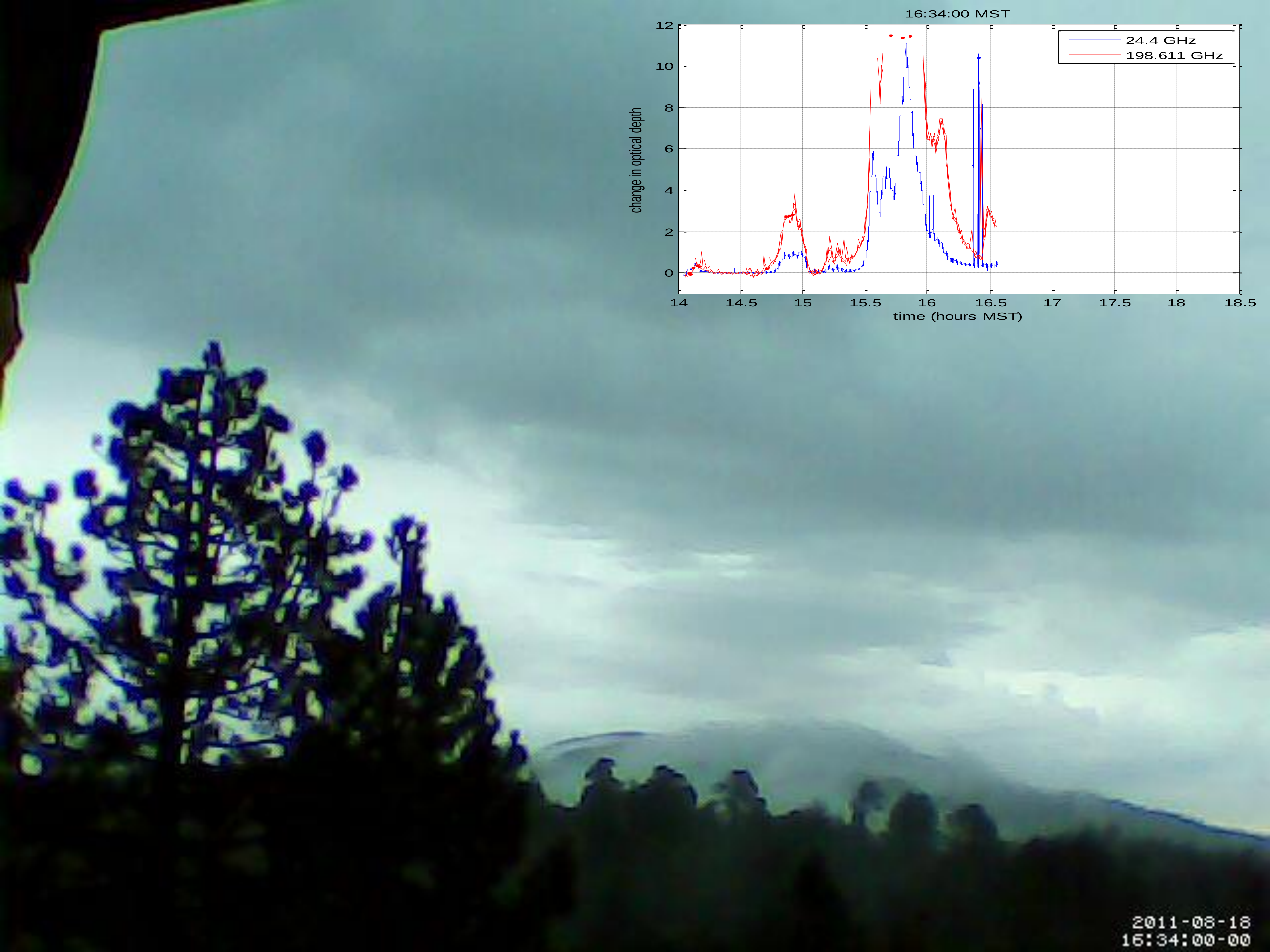
2011-08-18
16:33:30-00


16:33:30 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
16:33:46-00



16:34:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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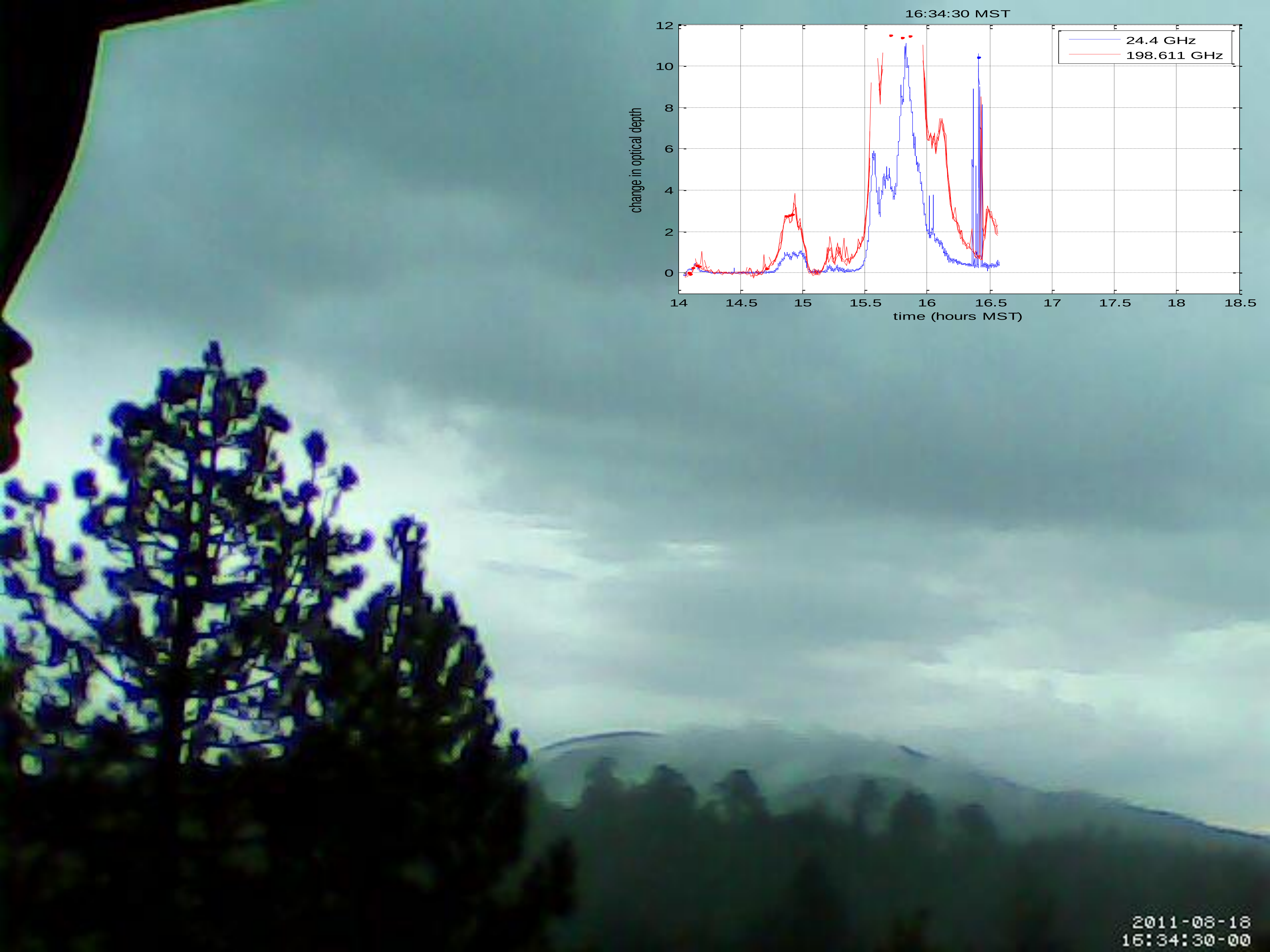
2011-08-18
16:34:00-00



16:34:30 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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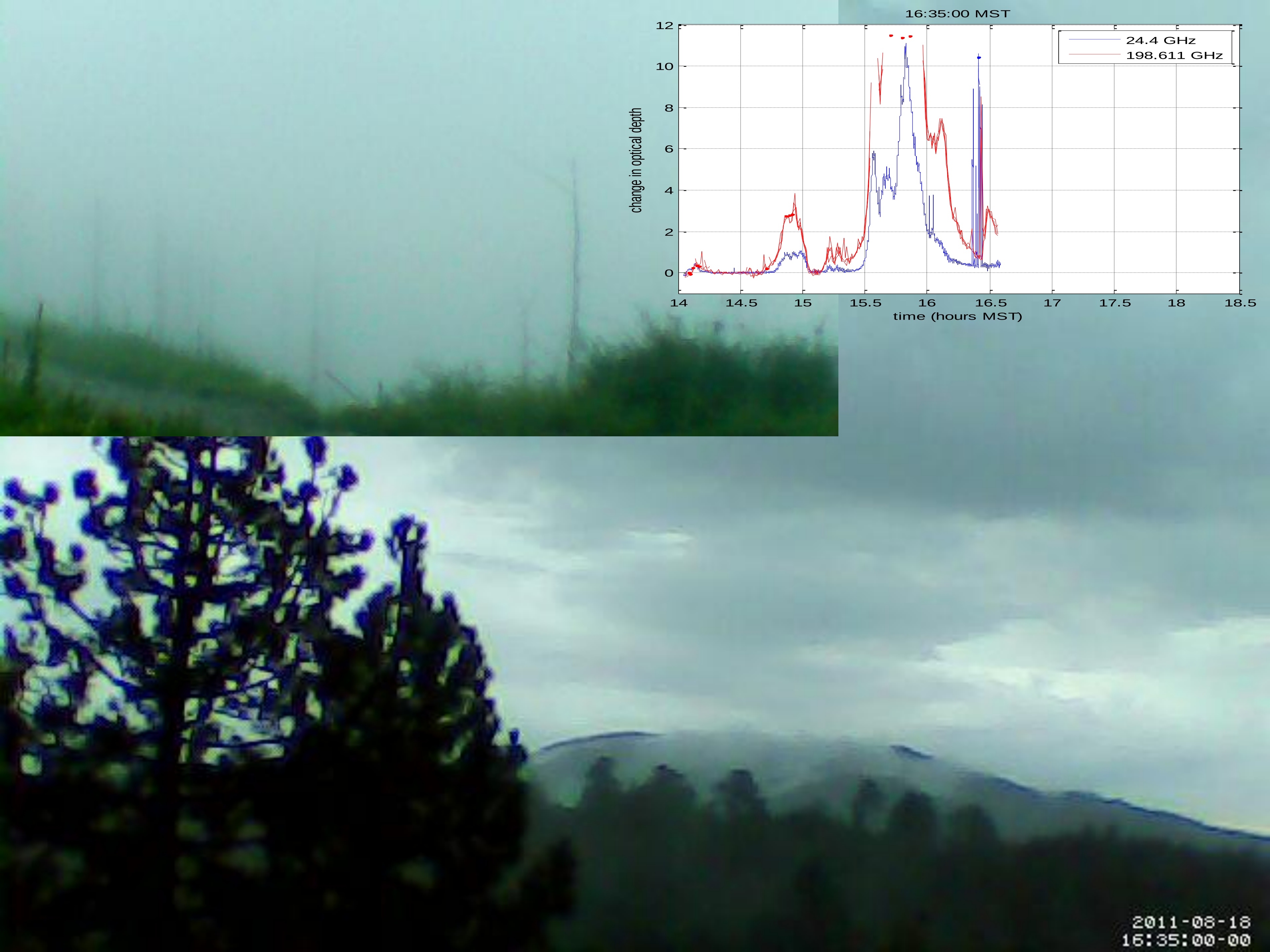
2011-08-18
16:34:30-00


16:35:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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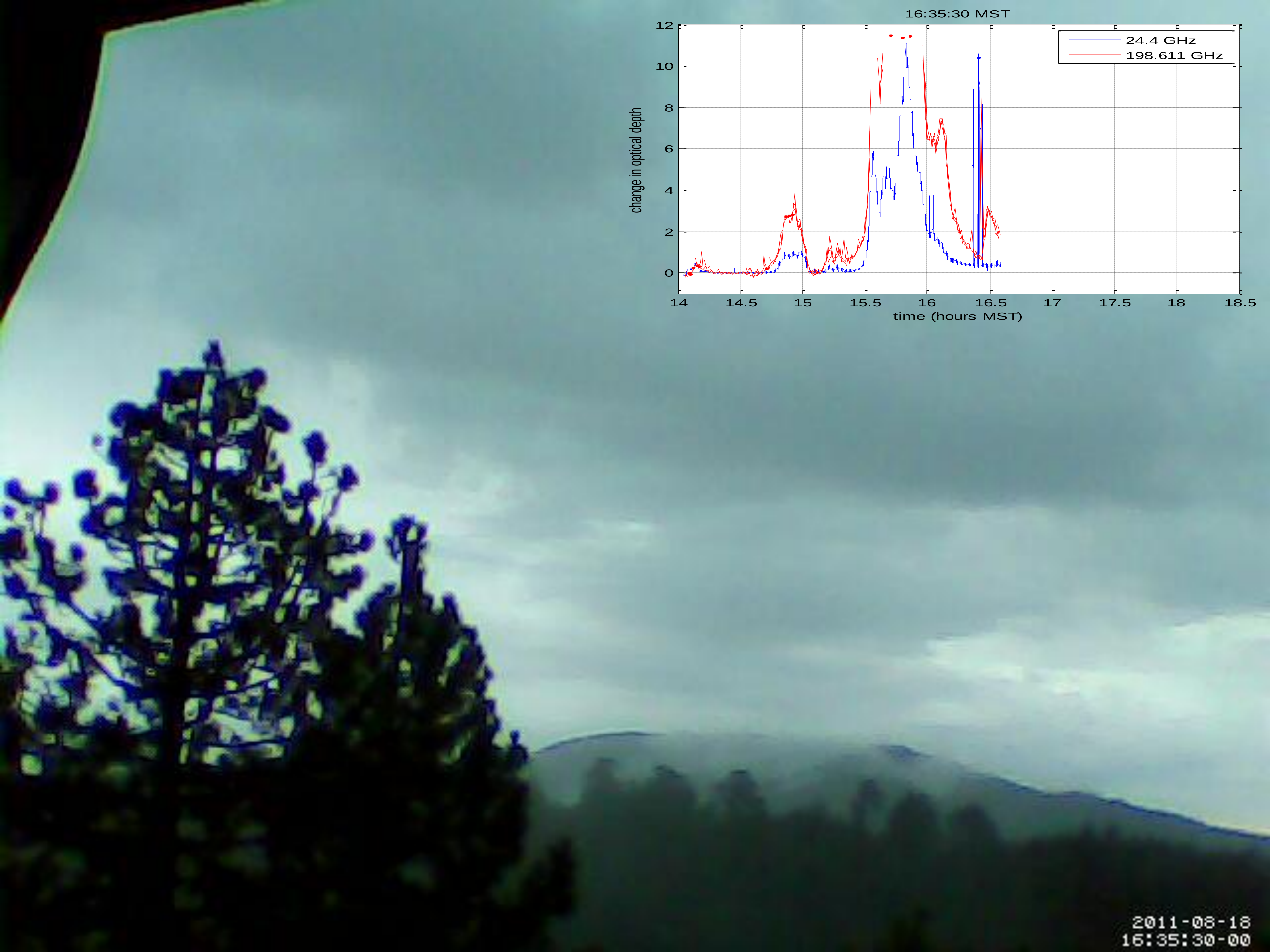
16:35:00-00



16:35:30 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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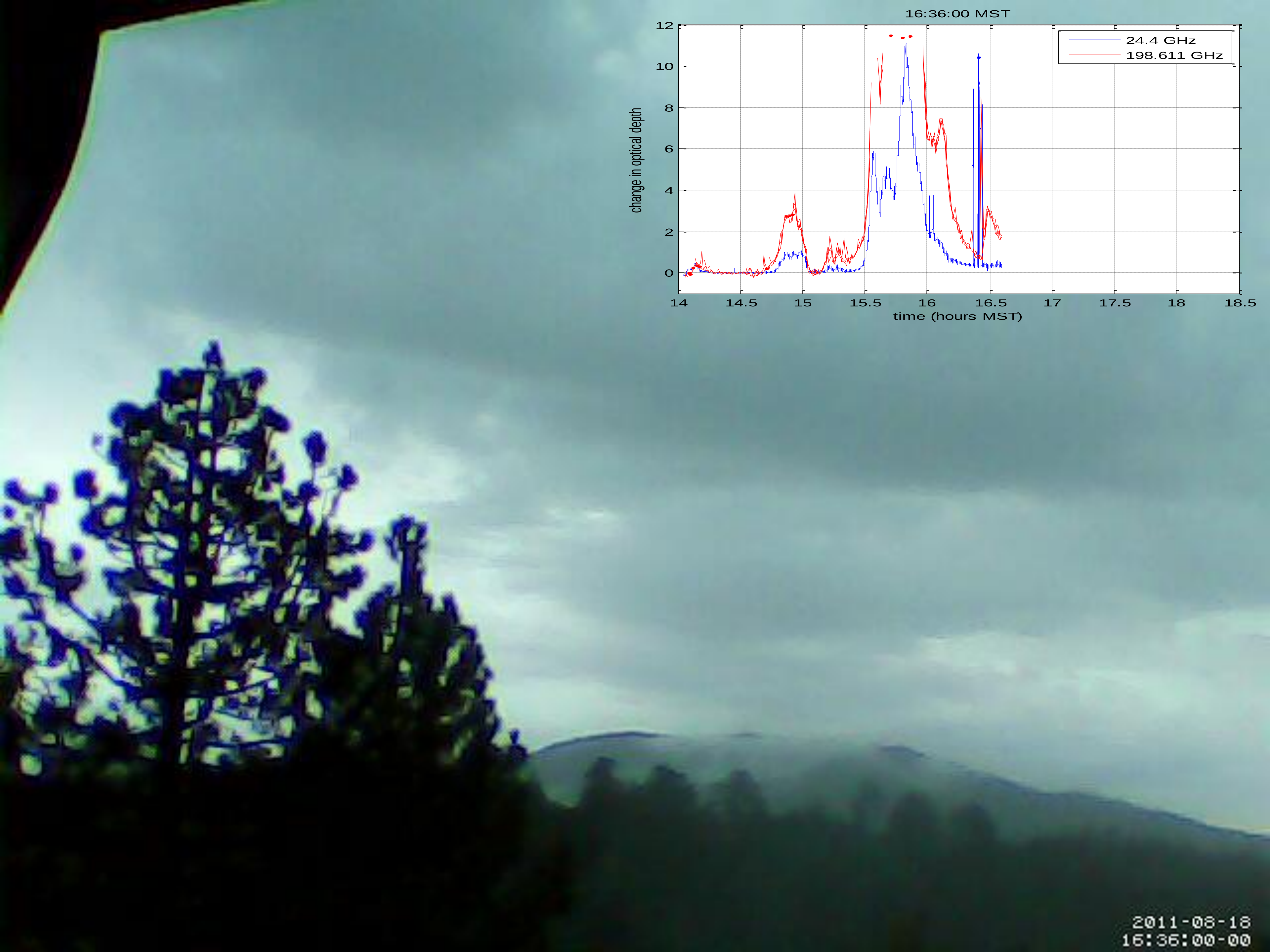
2011-08-18
16:35:30-00


16:36:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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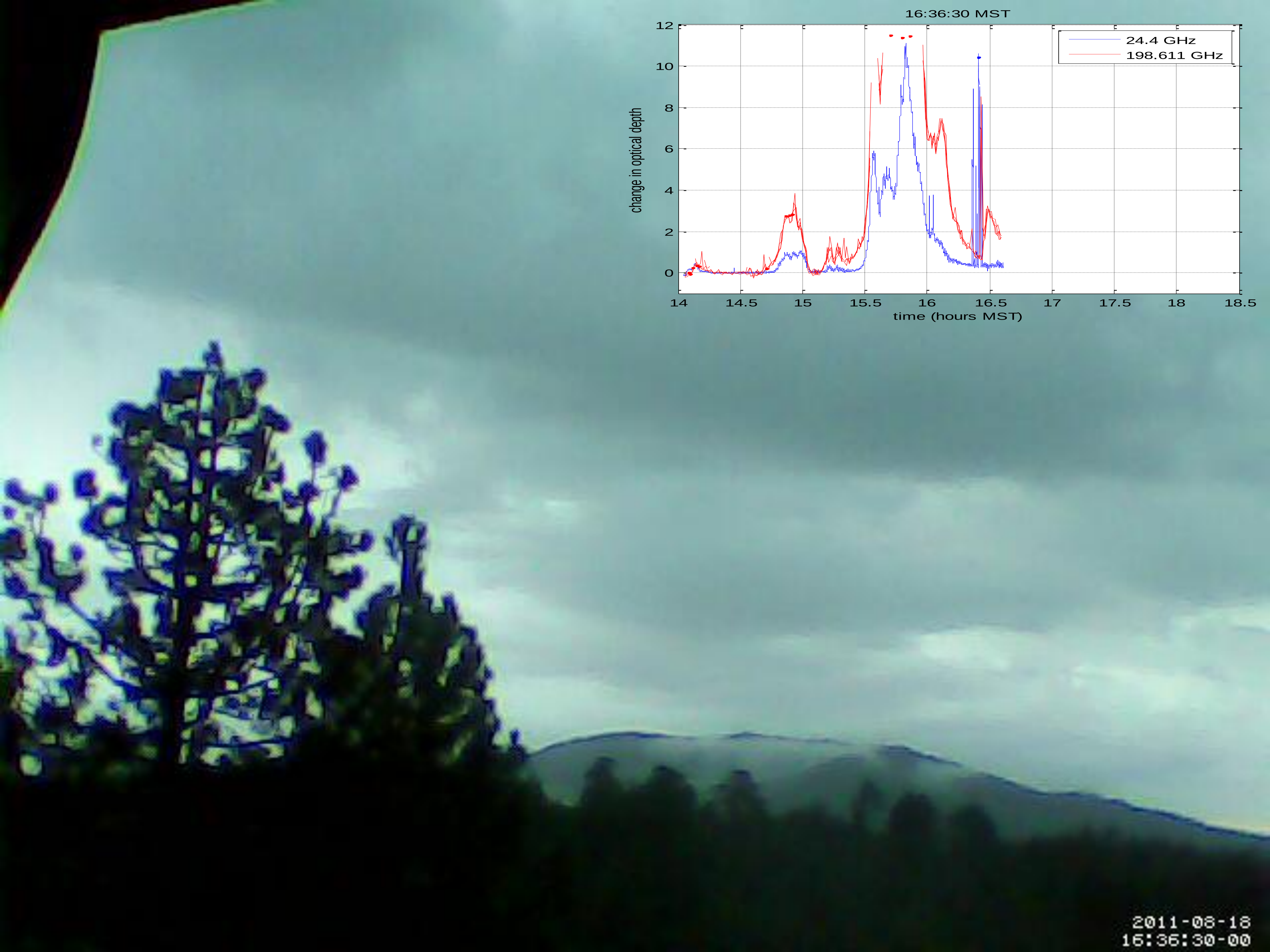
2011-08-18
16:36:00-00



16:36:30 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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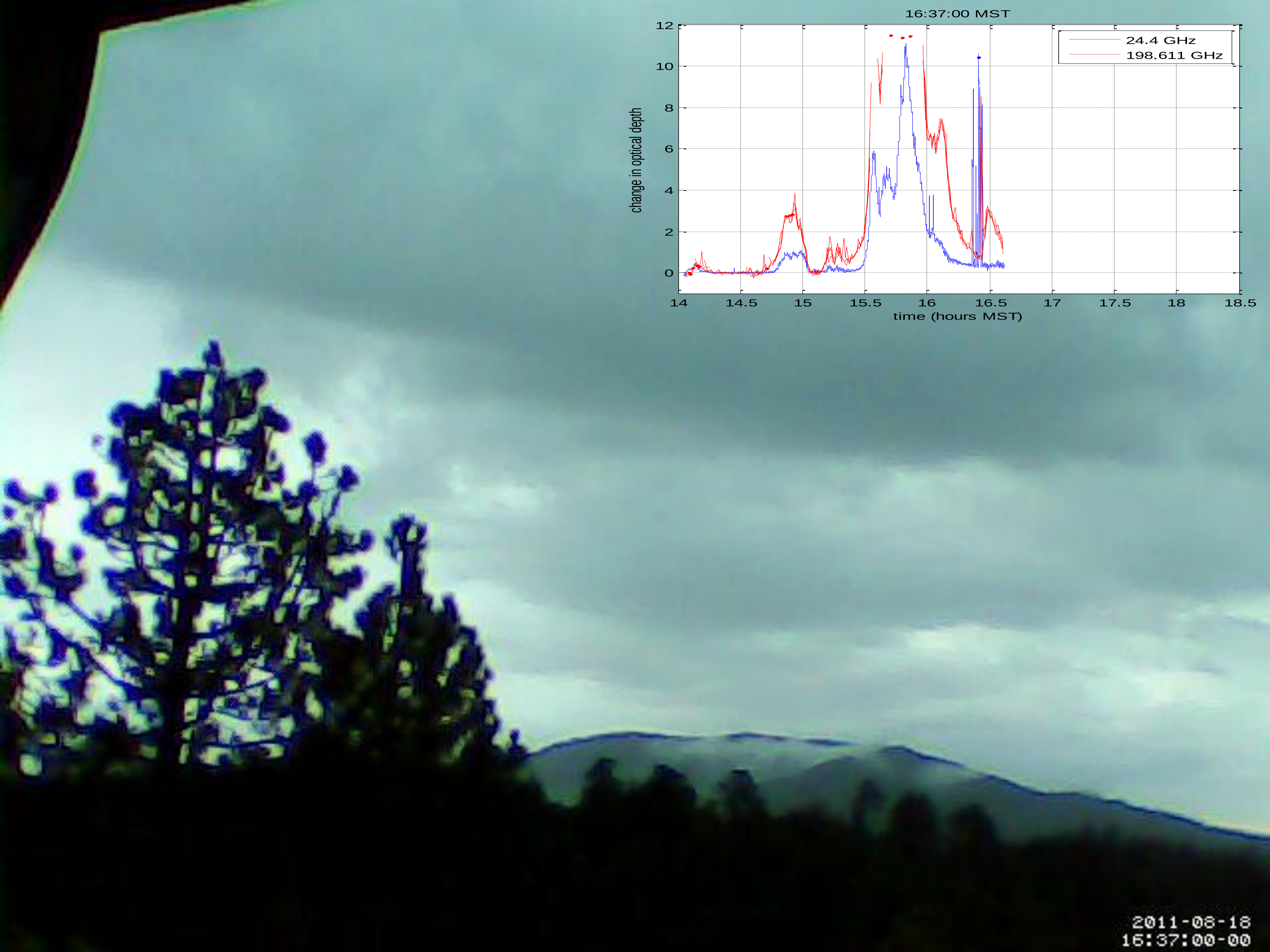
2011-08-18
16:36:30-00



16:37:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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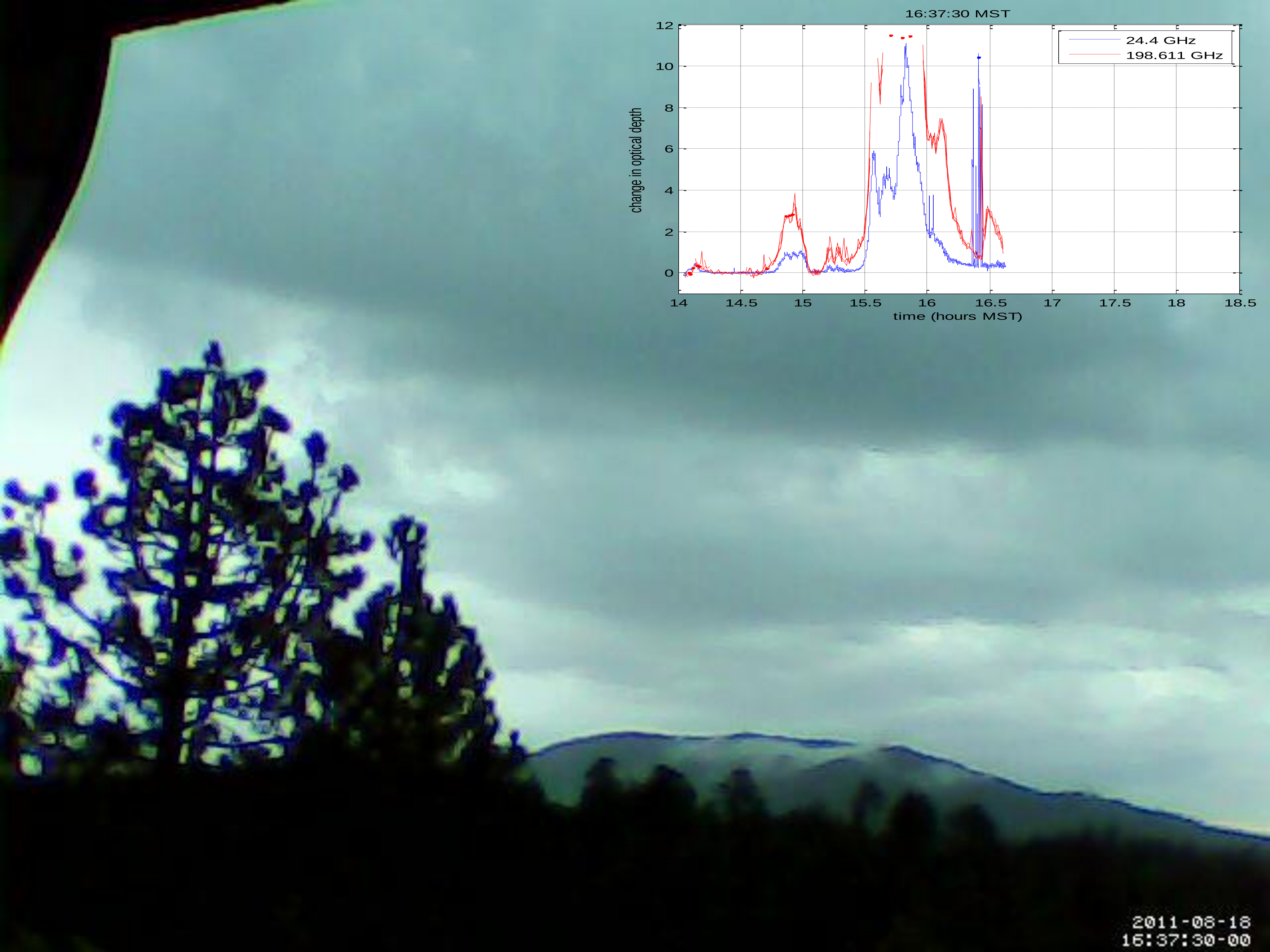
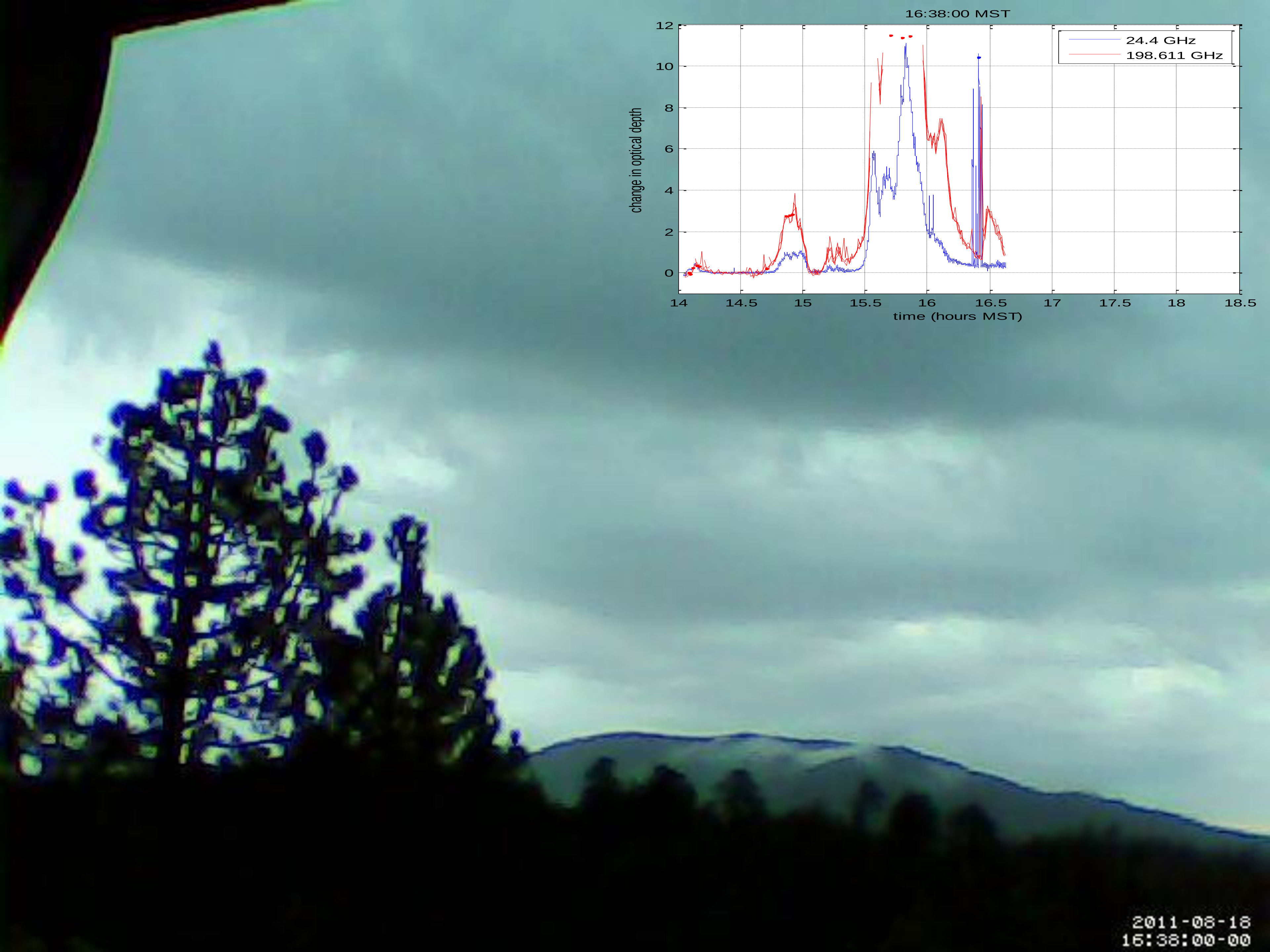
2011-08-18
16:37:00-00



16:37:30 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
16:37:30-00


16:38:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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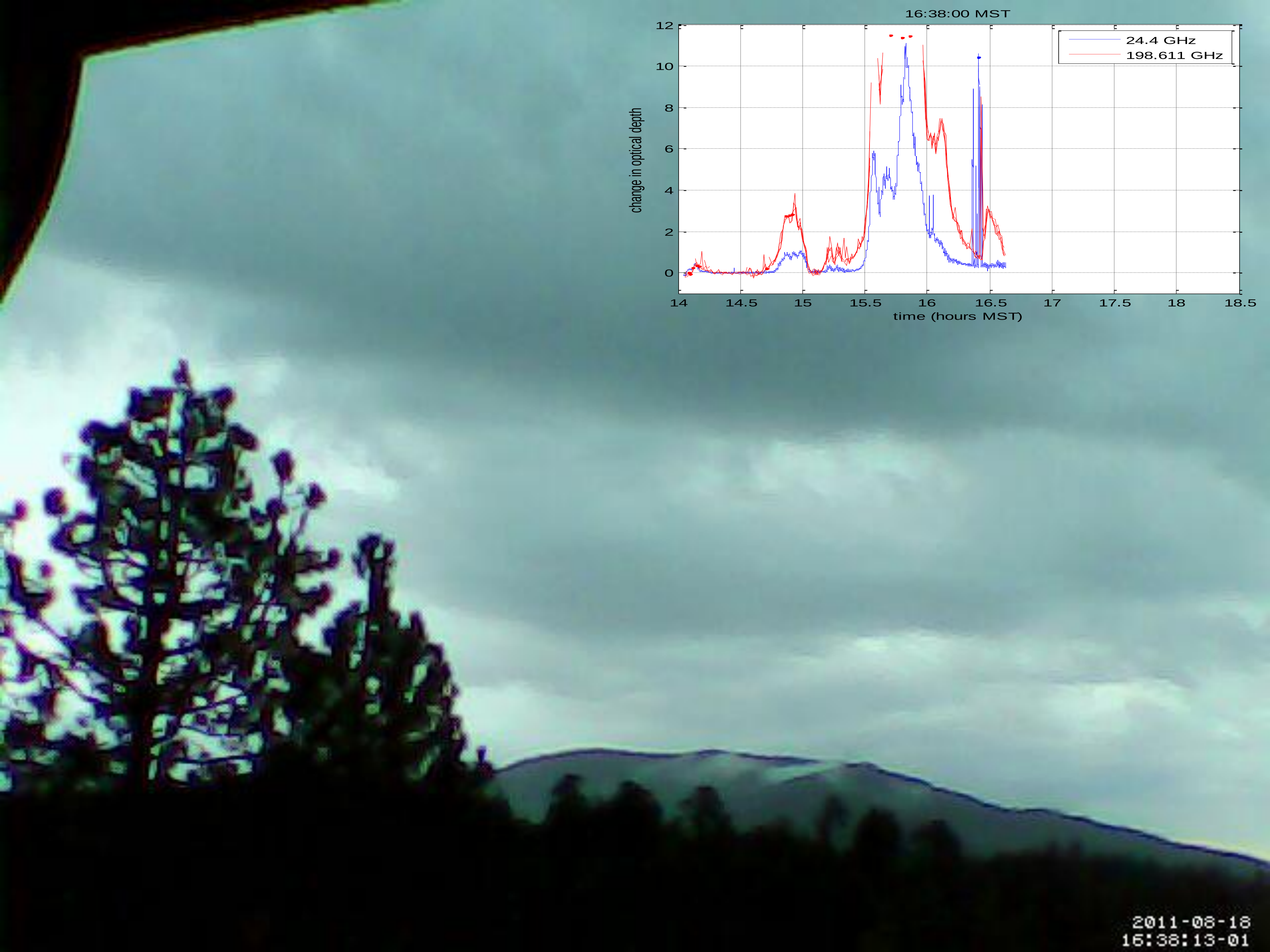
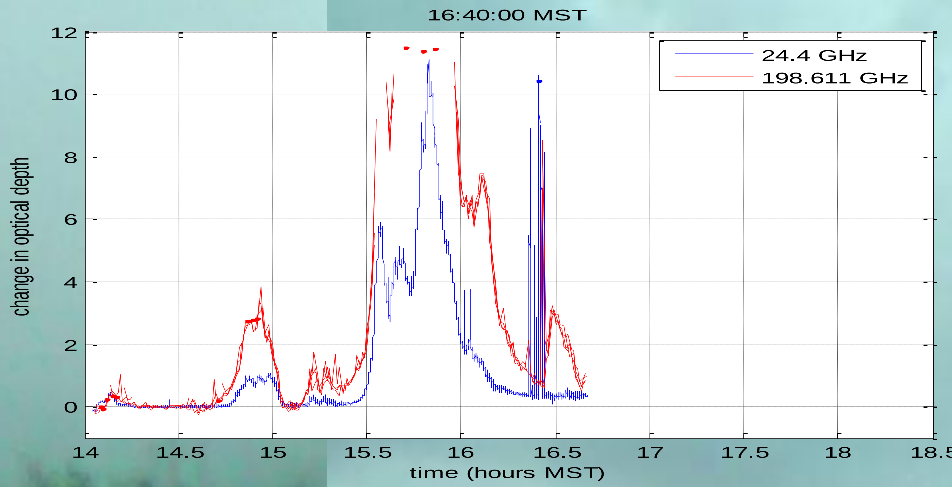
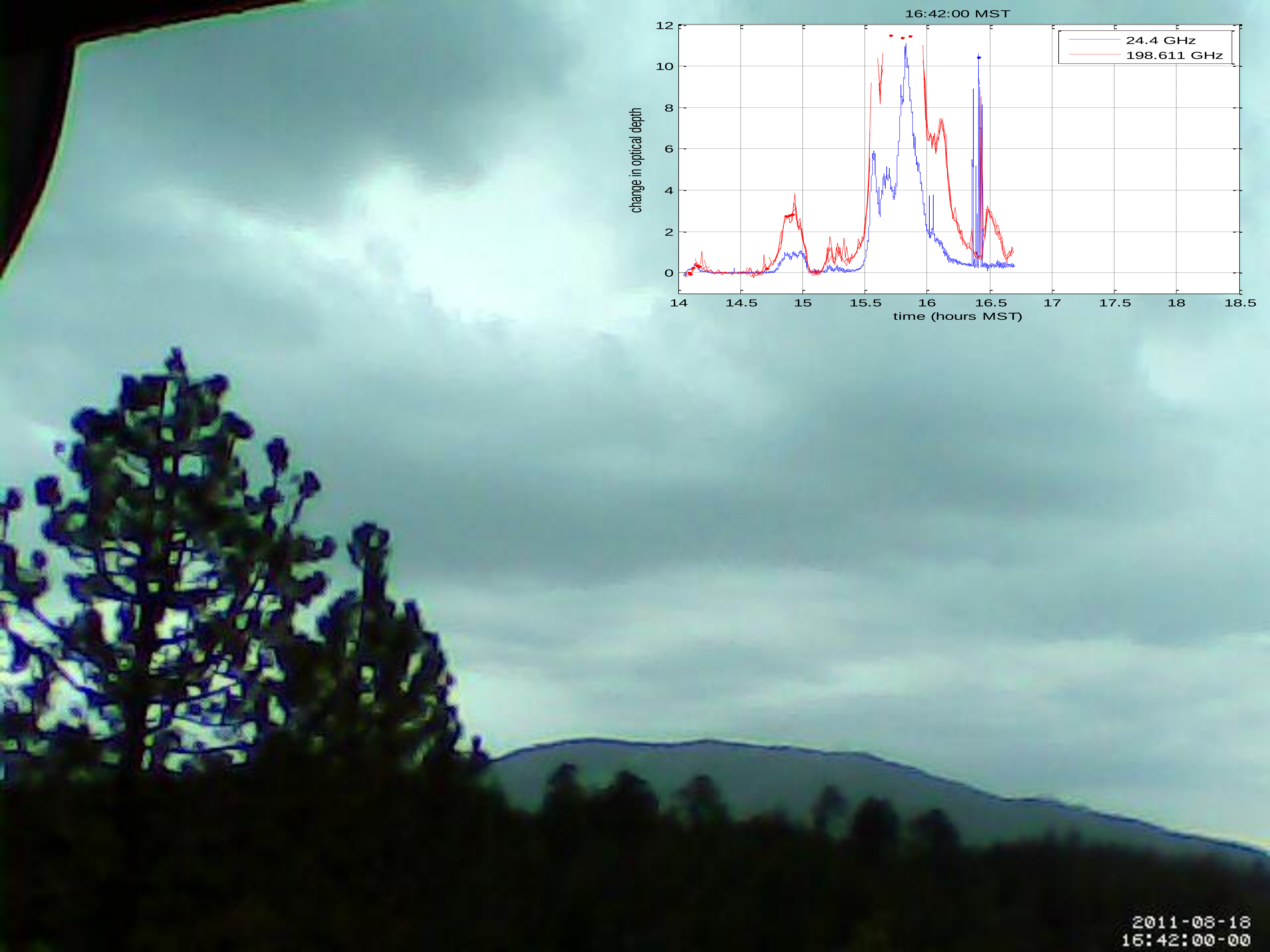
2011-08-18
16:38:00-00



16:38:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
16:38:13-01



2 minute
images


16:42:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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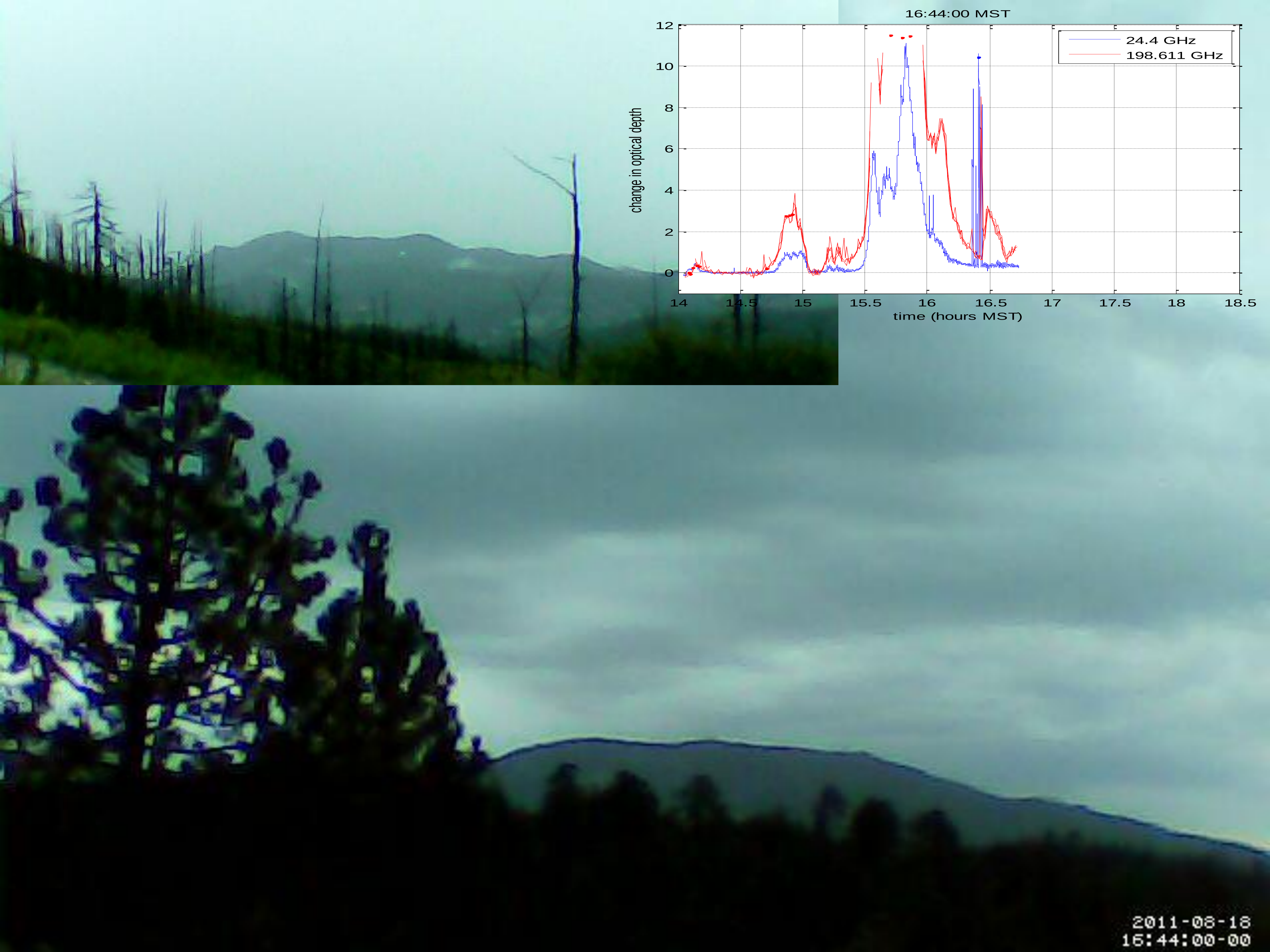
2011-08-18
16:42:00-00



16:44:00 MST
24.4 GHz
198.611 GHz
change in optical depth
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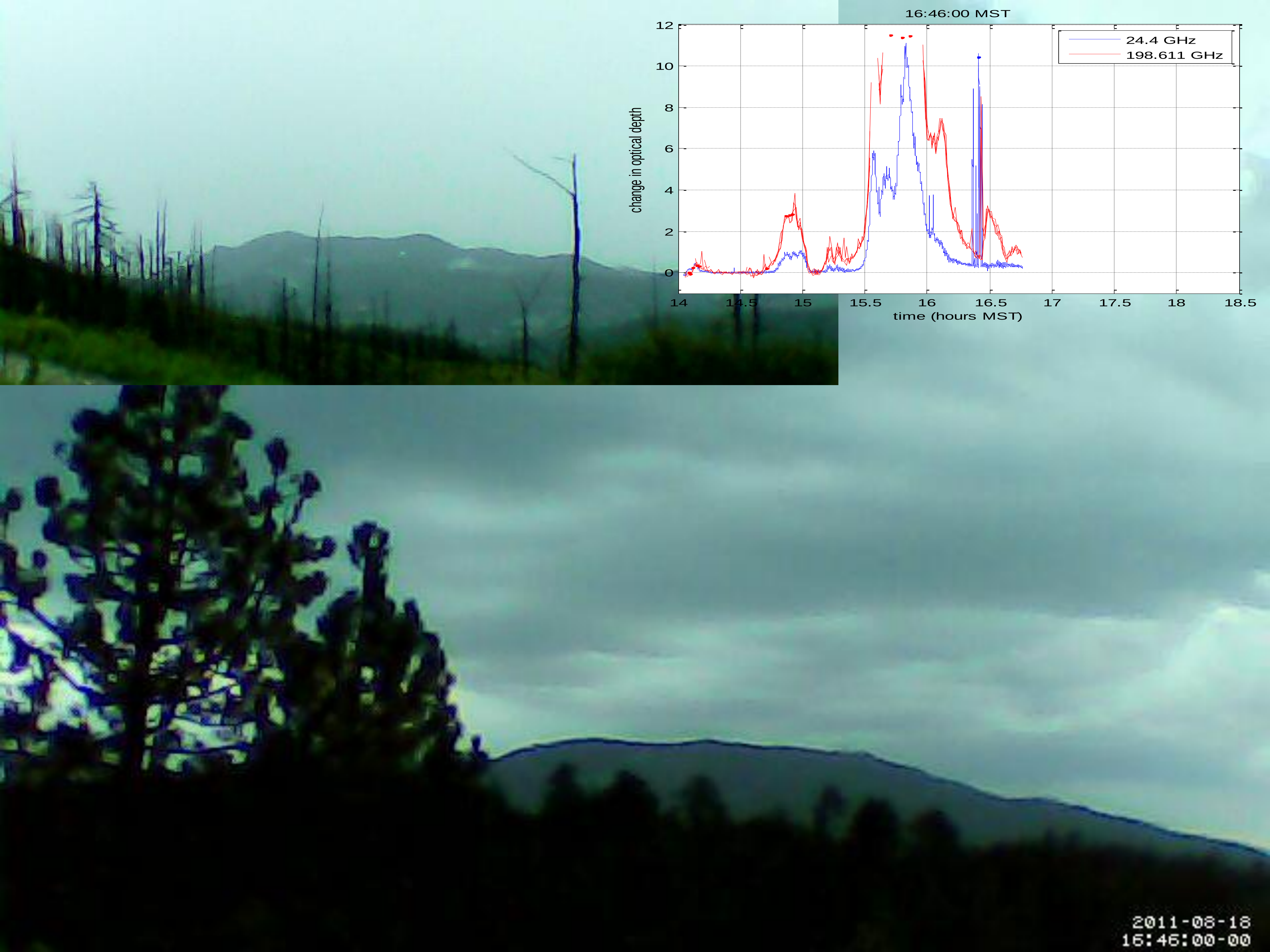
time (hours MST)
2011-08-18
16:44:00-00


16:46:00 MST
24.4 GHz
198.611 GHz
change in optical depth
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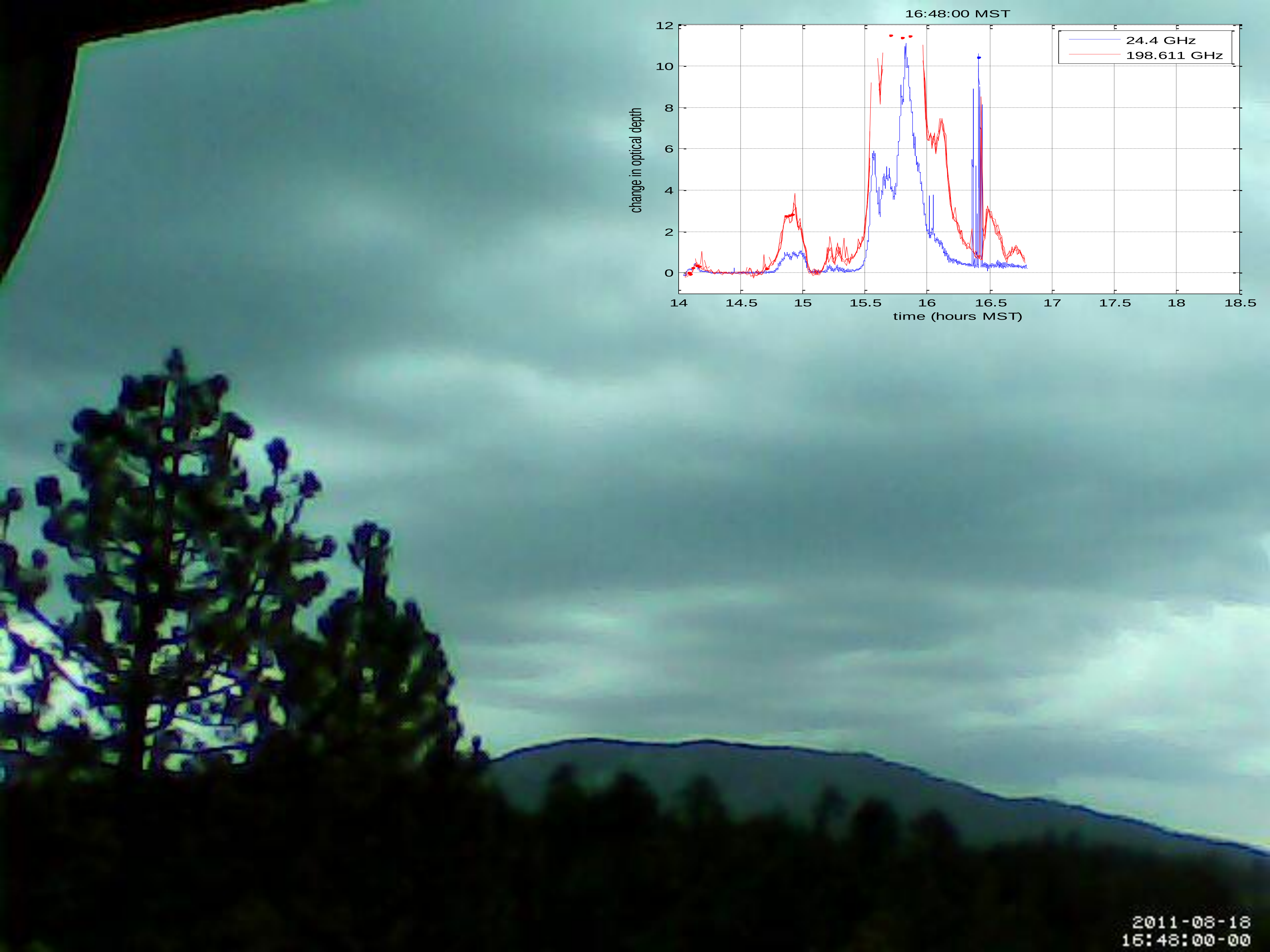
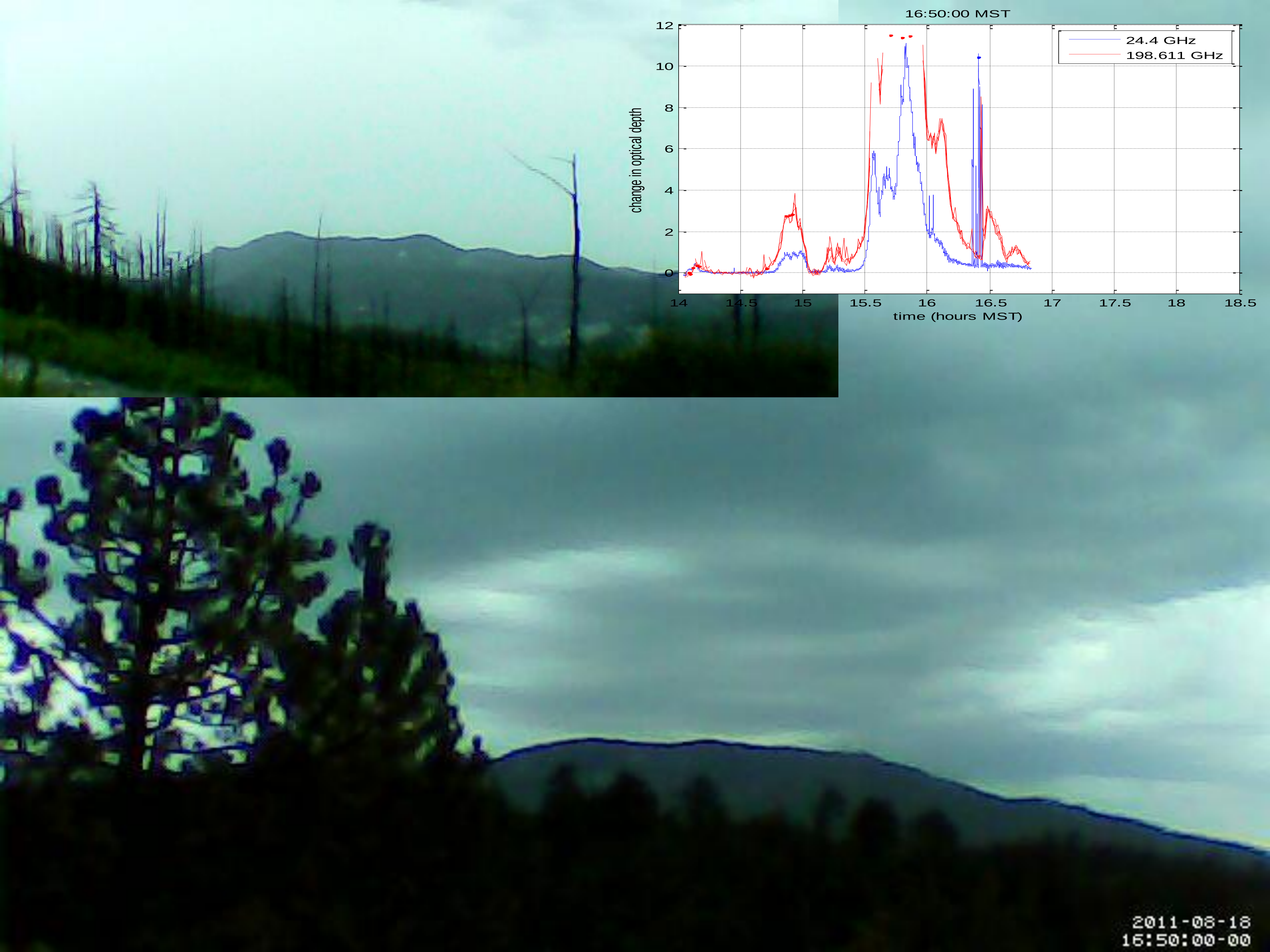
18.5
time (hours MST)
2011-08-18
16:46:00-00



16:48:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
16:48:00-00


16:50:00 MST
change in optical depth
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16.5
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17.5
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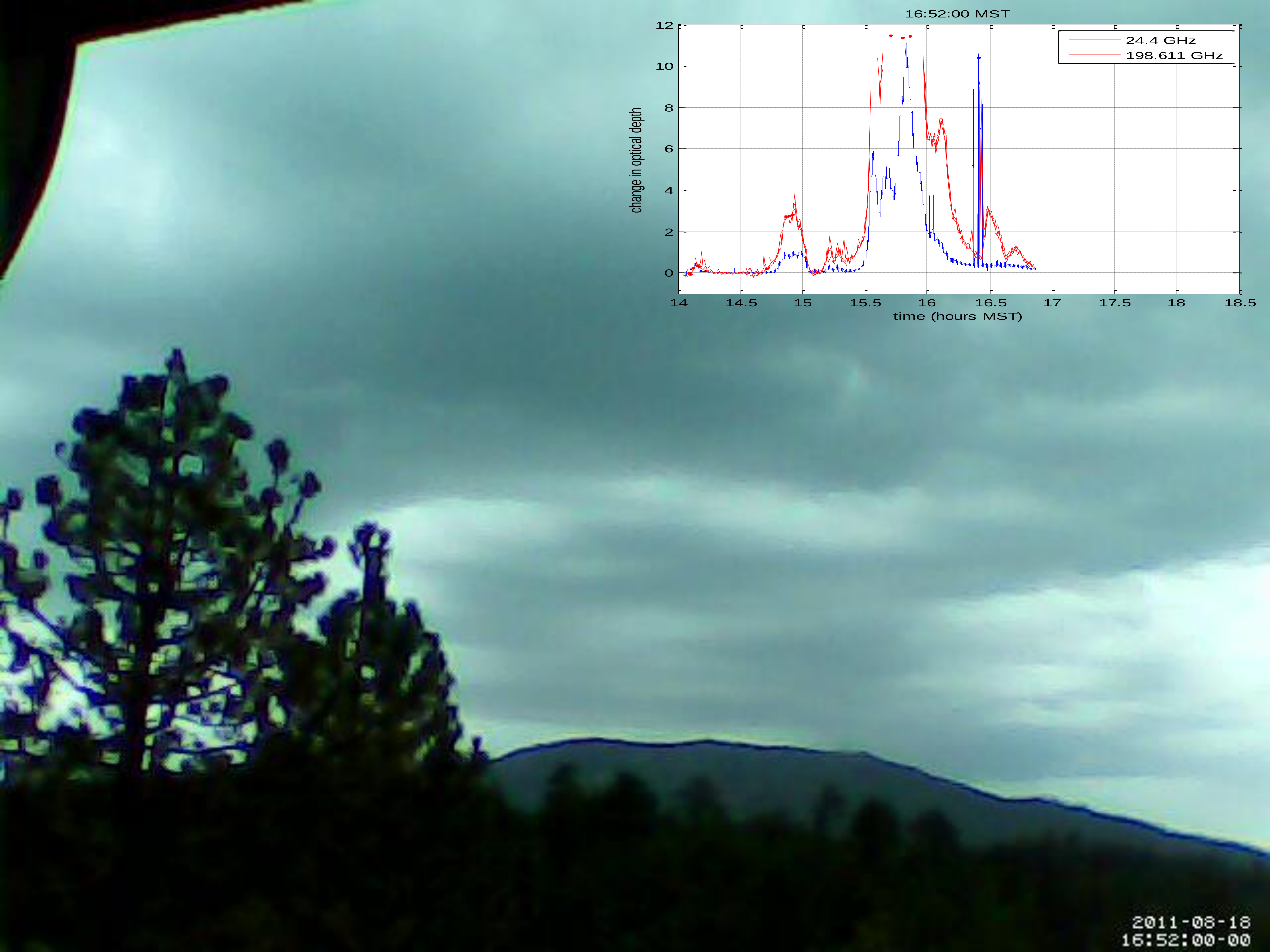
18.5
time (hours MST)
24.4 GHz
198.611 GHz
2011-08-18
16:50:00-00



16:52:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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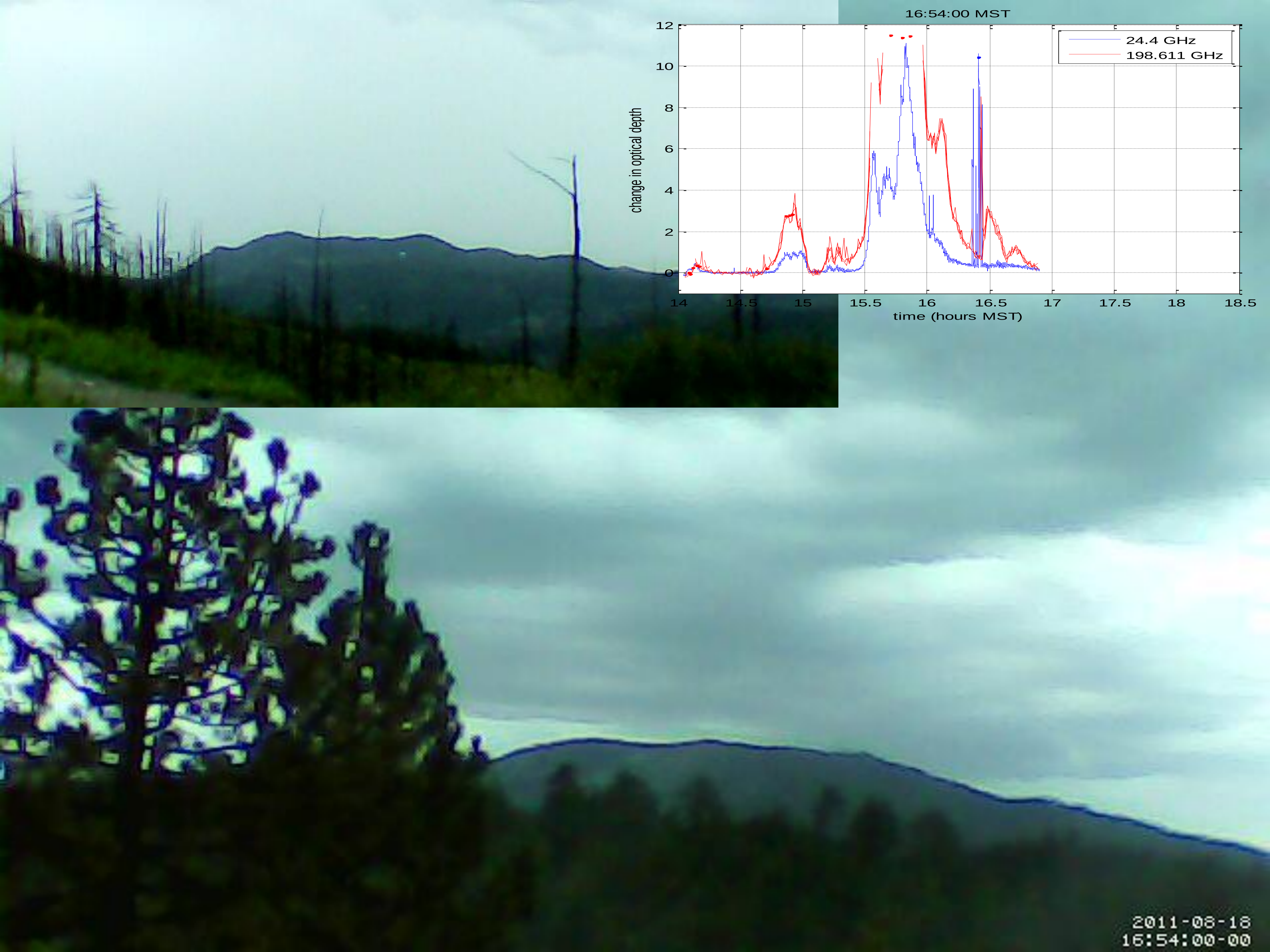
2011-08-18
16:52:00-00


16:54:00 MST
change in optical depth
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16.5
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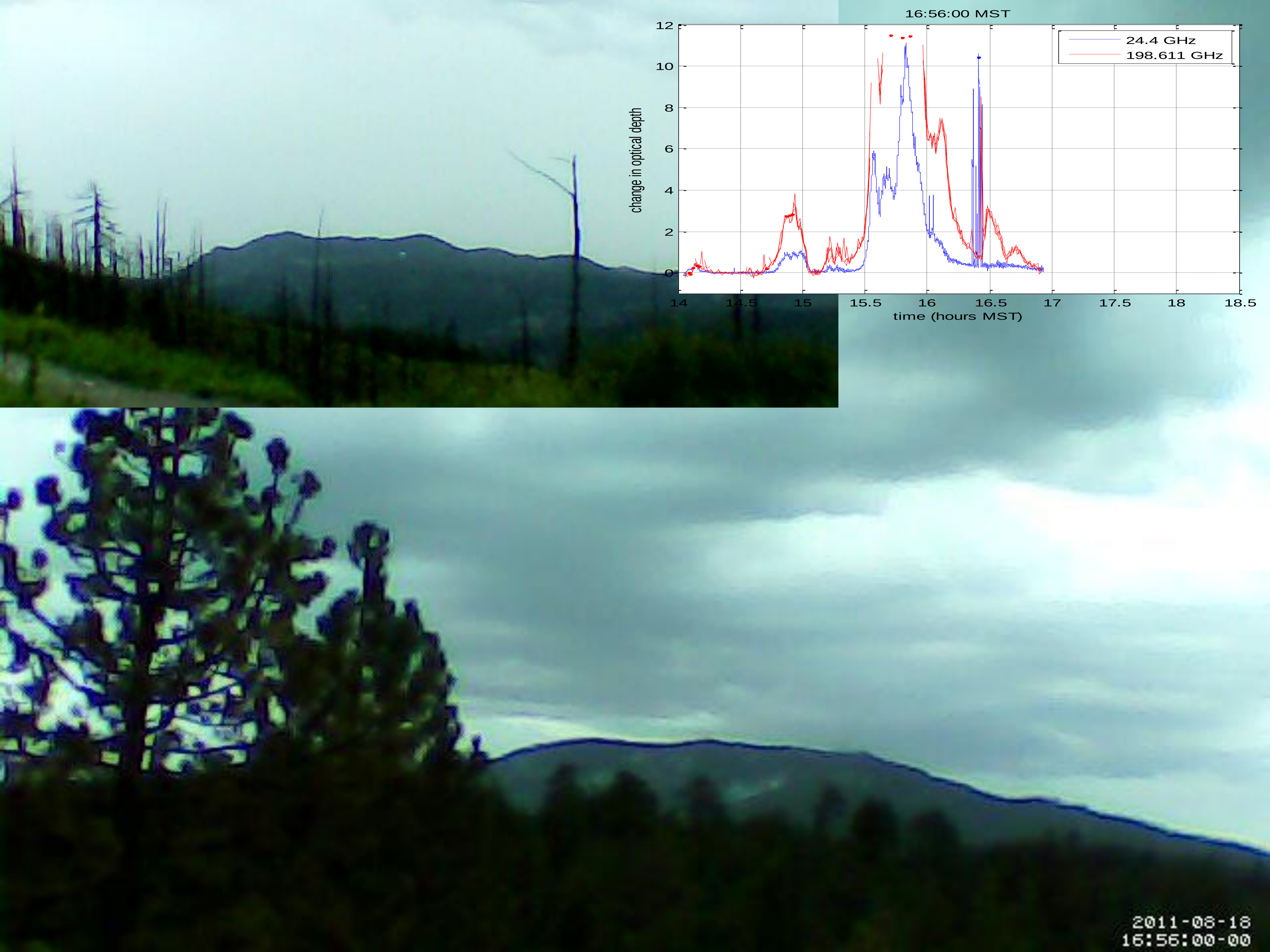
18.5
time (hours MST)
24.4 GHz
198.611 GHz
2011-08-18
16:54:00-00


16:56:00 MST
24.4 GHz
198.611 GHz
change in optical depth
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17.5
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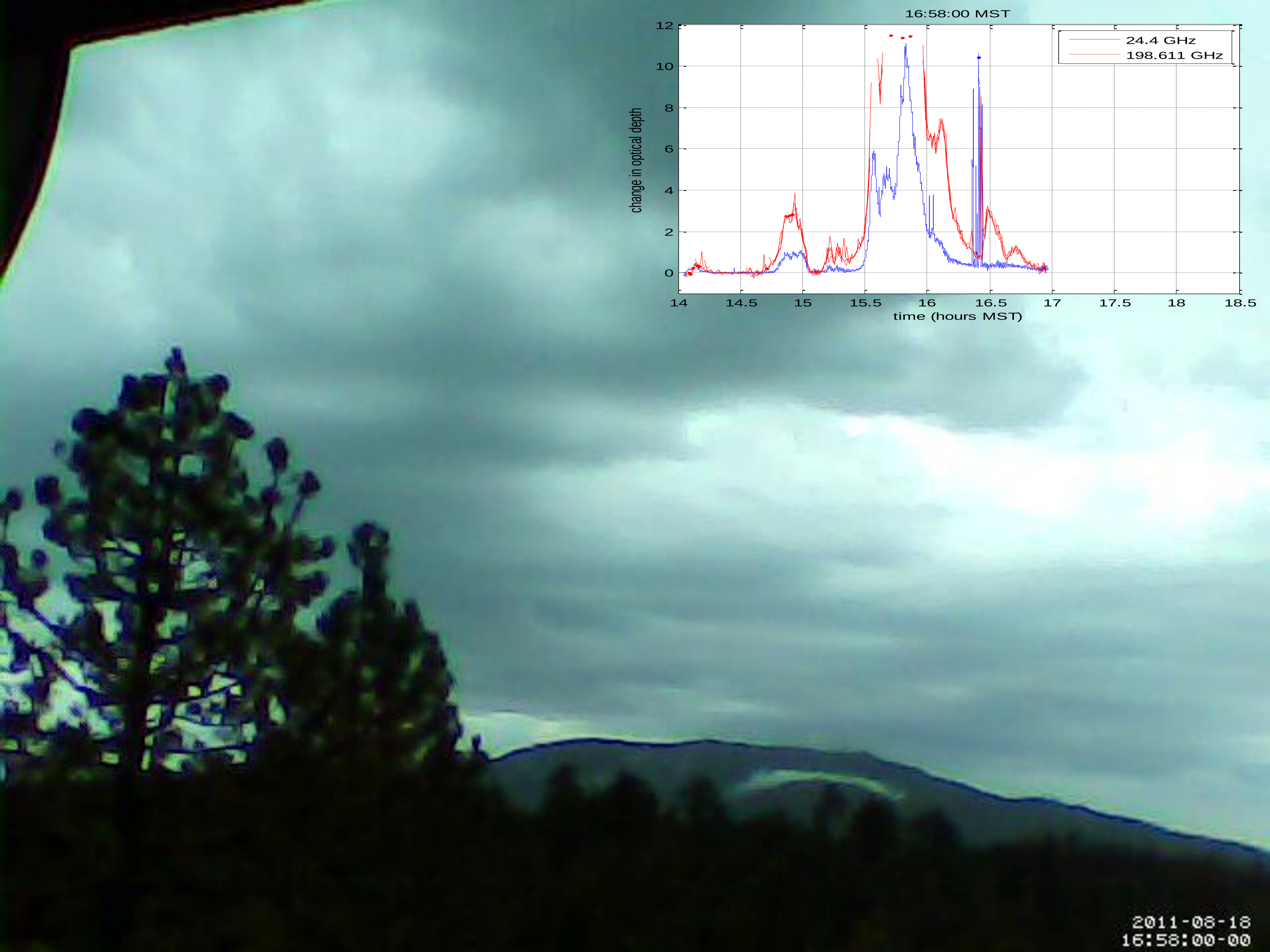
18.5
time (hours MST)
2011-08-18
16:56:00-00


16:58:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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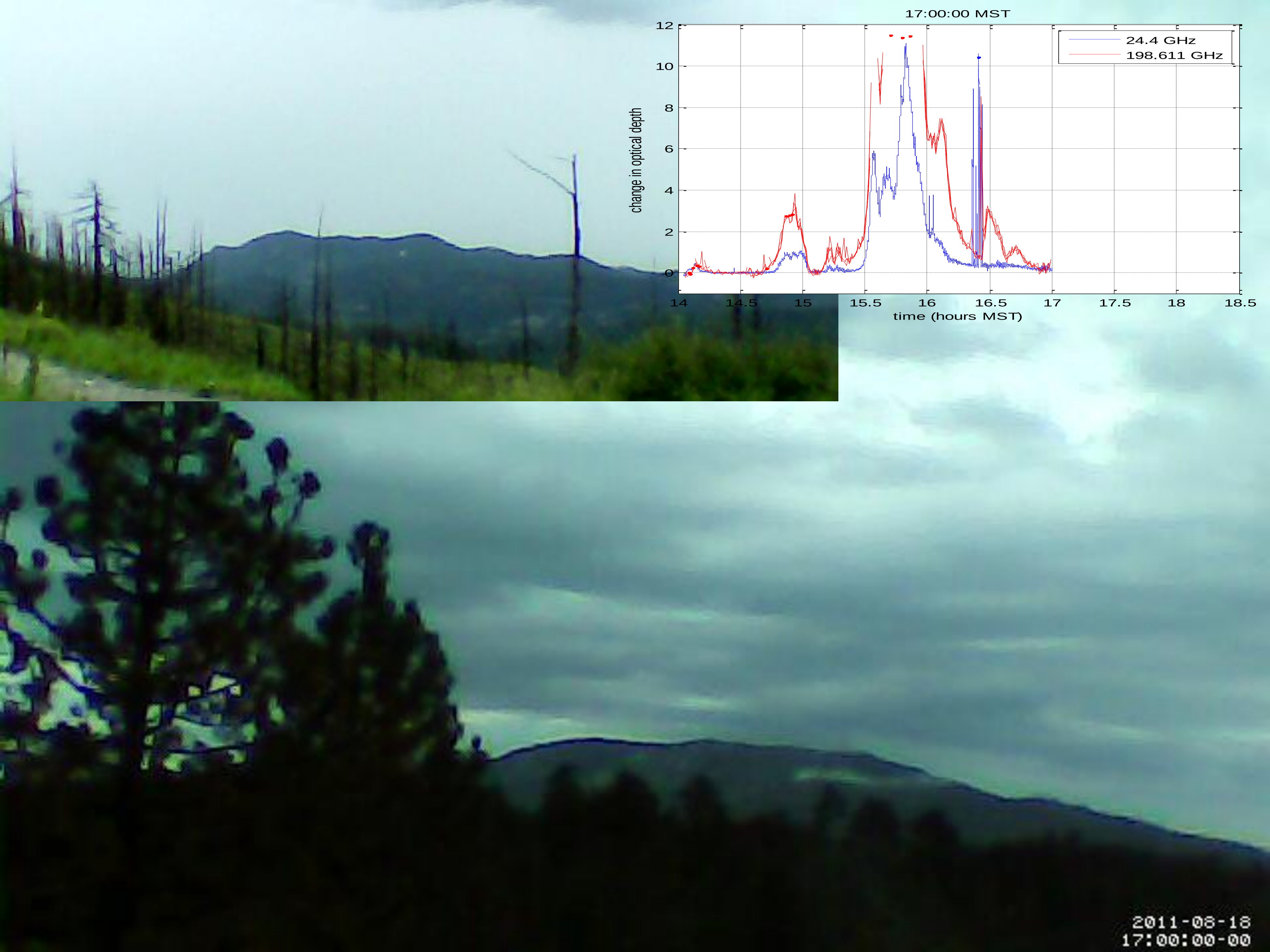
2011-08-18
16:58:00-00


17:00:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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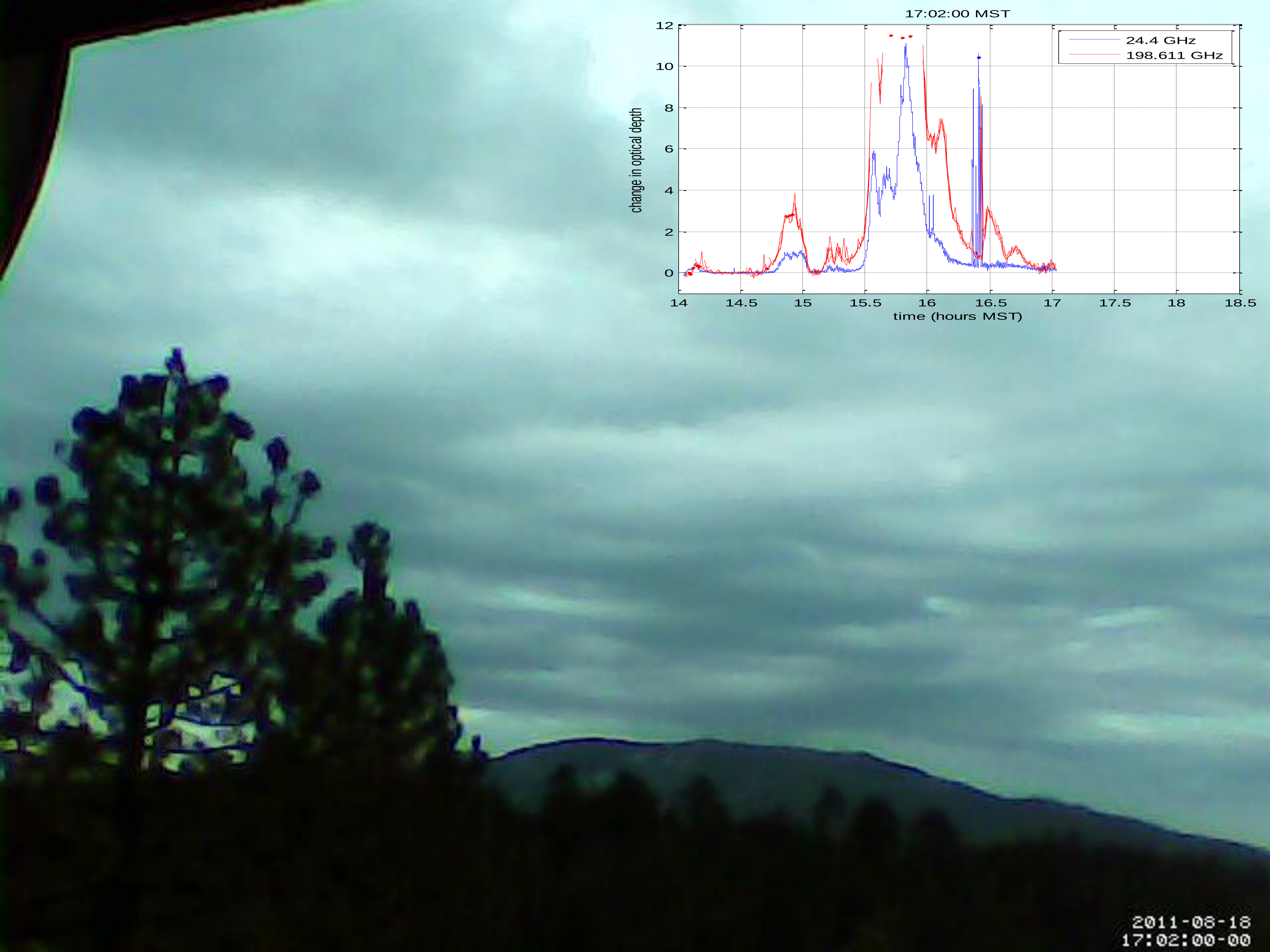
2011-08-18
17:00:00-00


17:02:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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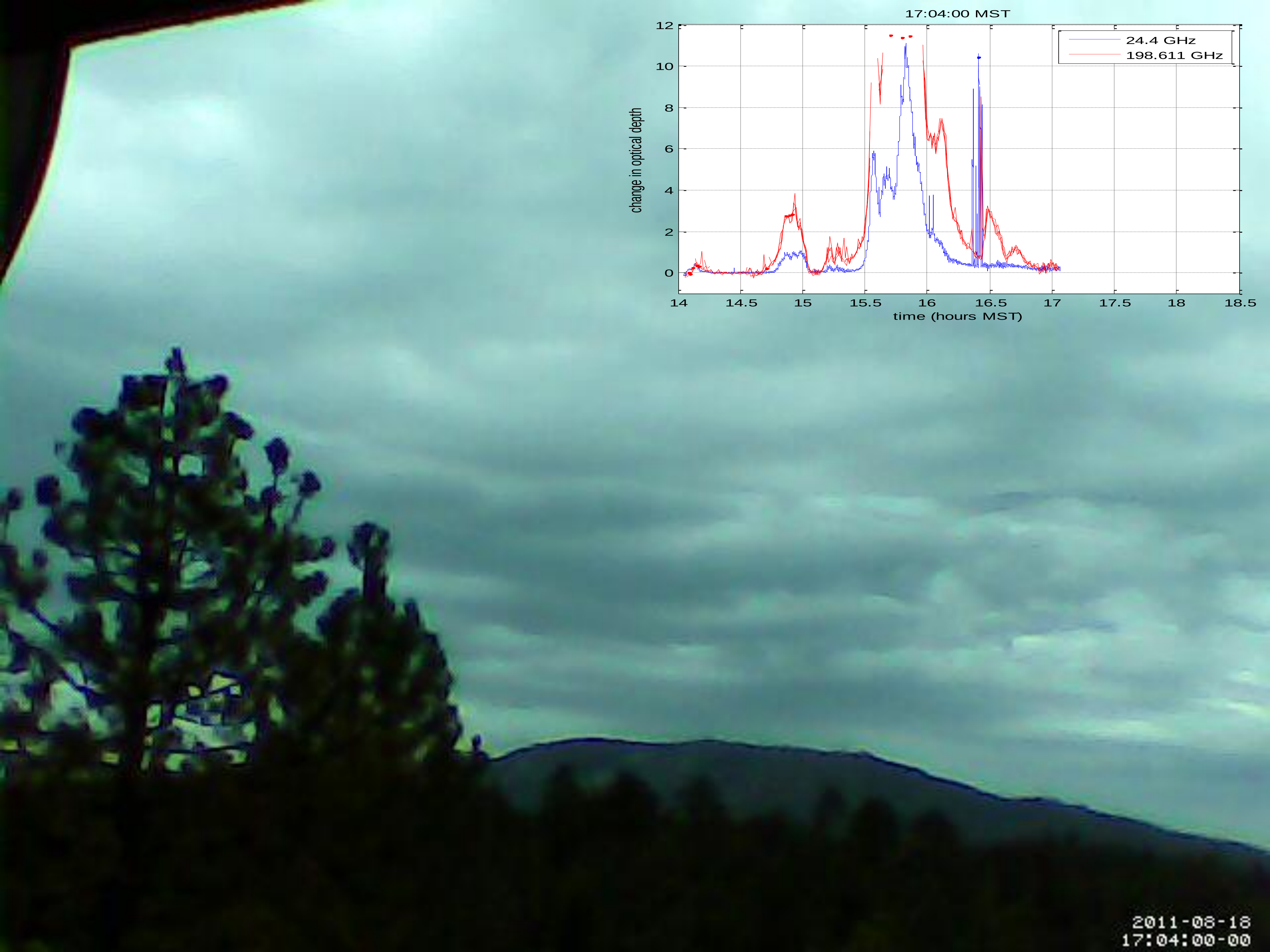
2011-08-18
17:02:00-00


17:04:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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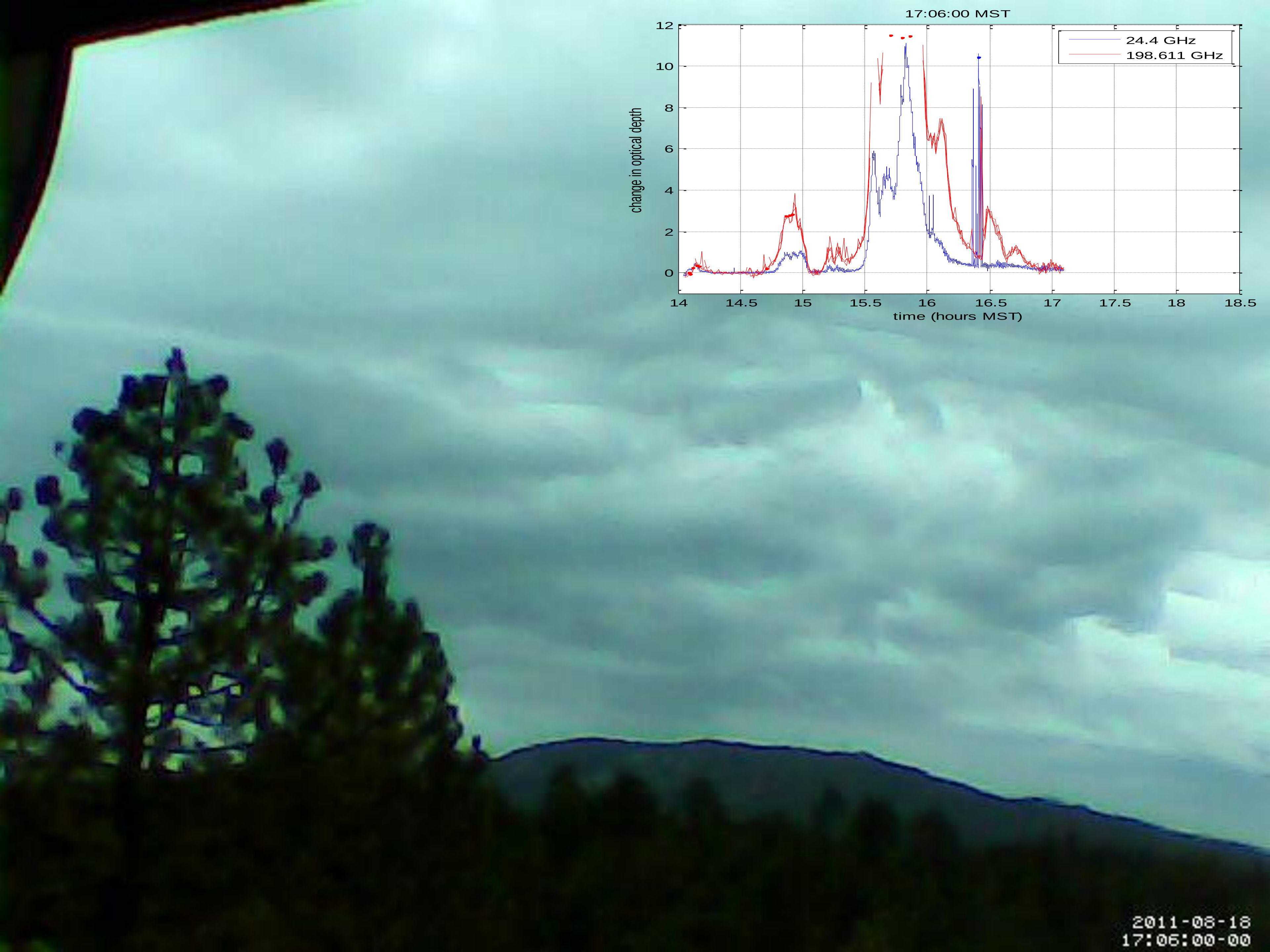
2011-08-18
17:04:00-00


17:06:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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17.5
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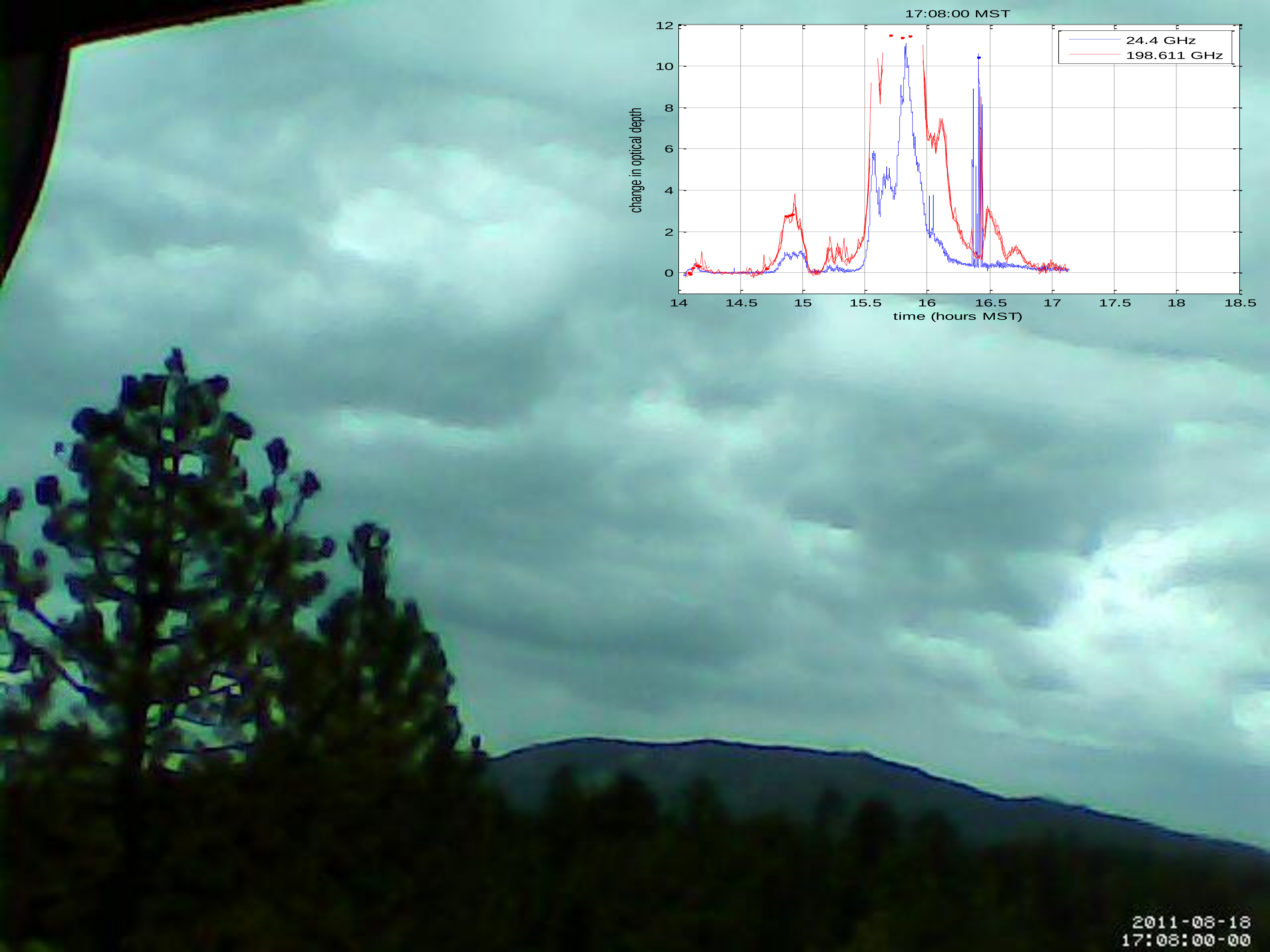
18.5
2011-08-18
17:06:00-00


17:08:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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14.5
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16.5
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17.5
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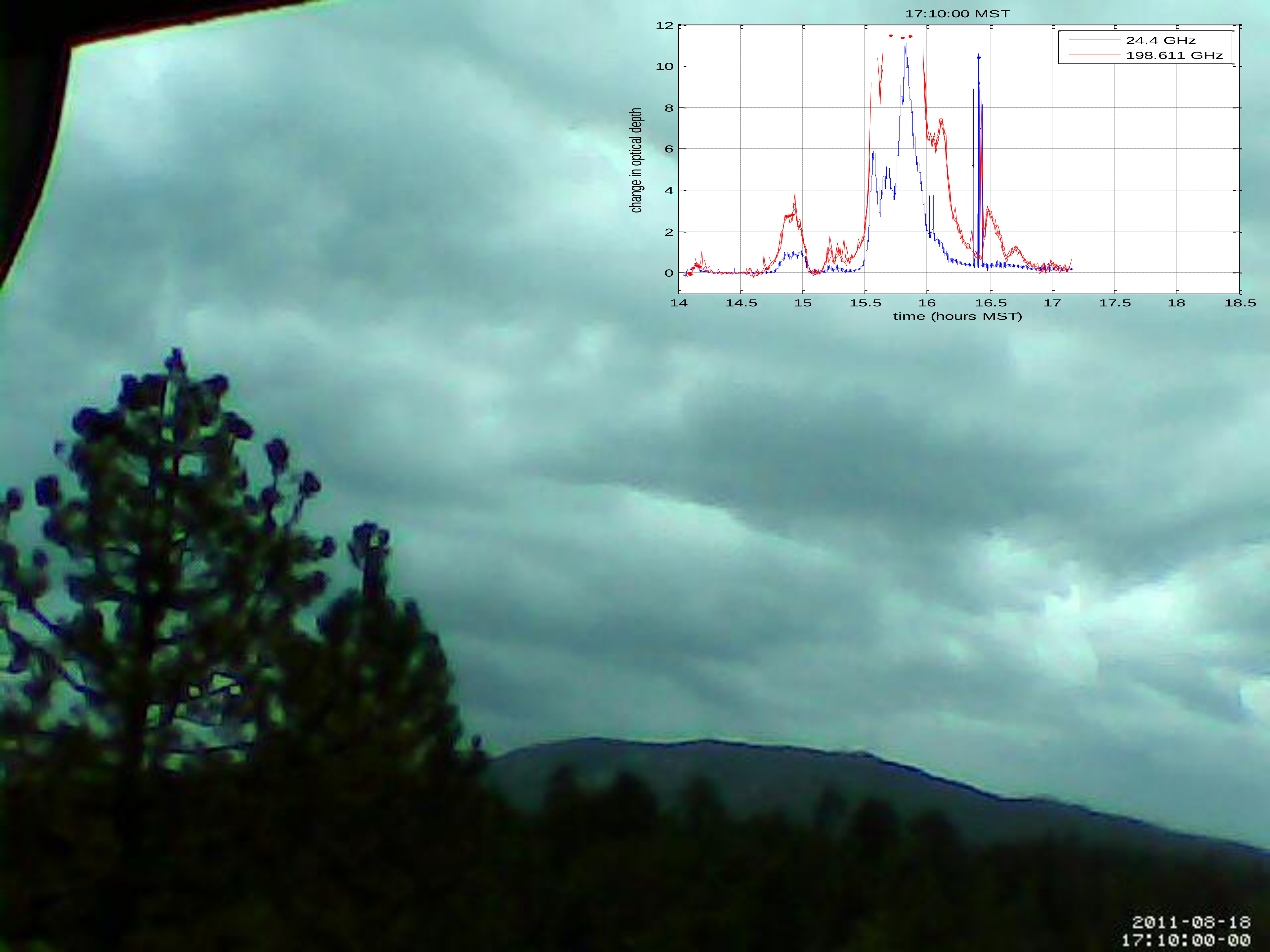
18.5
2011-08-18
17:08:00-00


17:10:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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17.5
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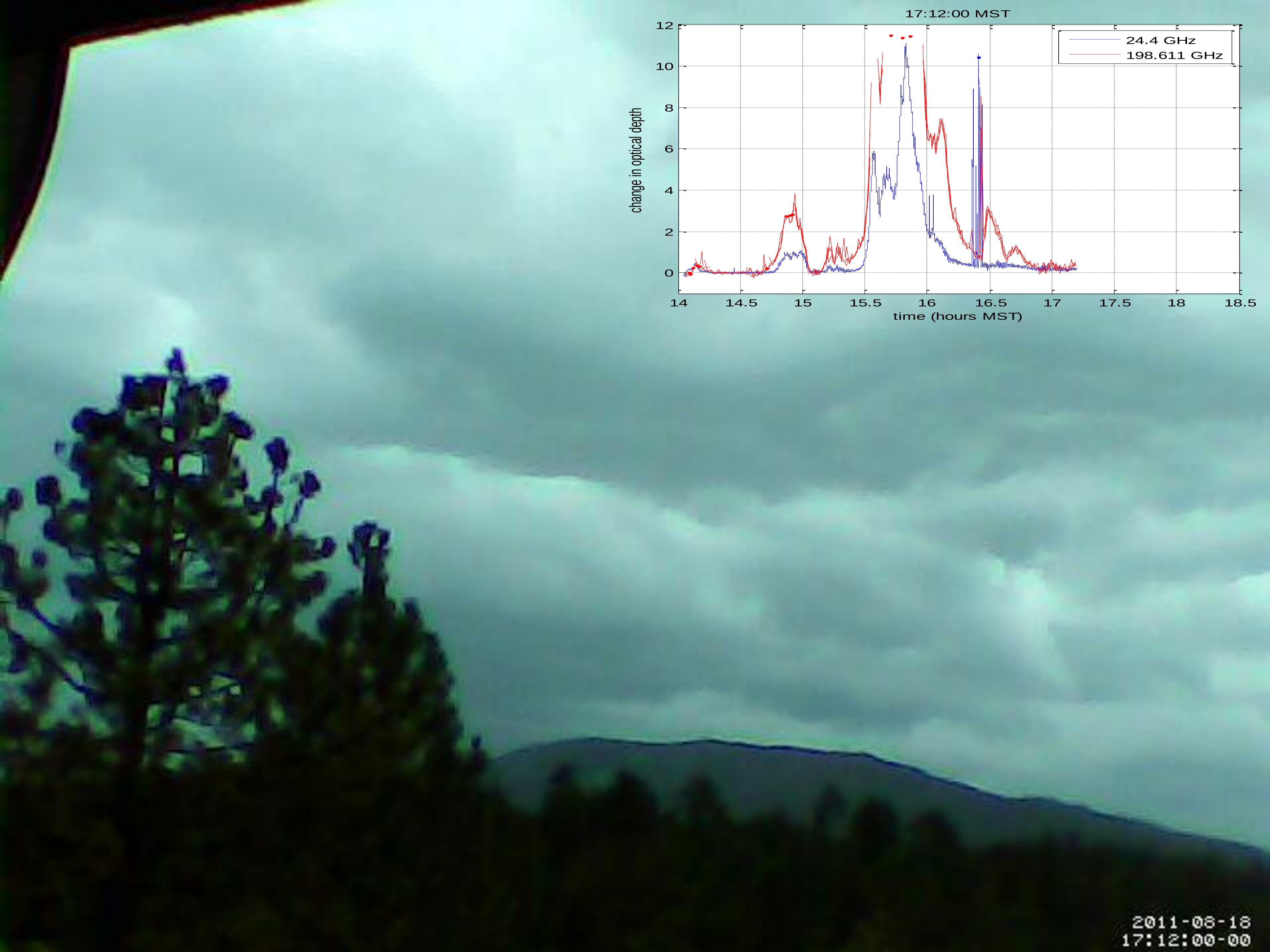
18.5
2011-08-18
17:10:00-00


17:12:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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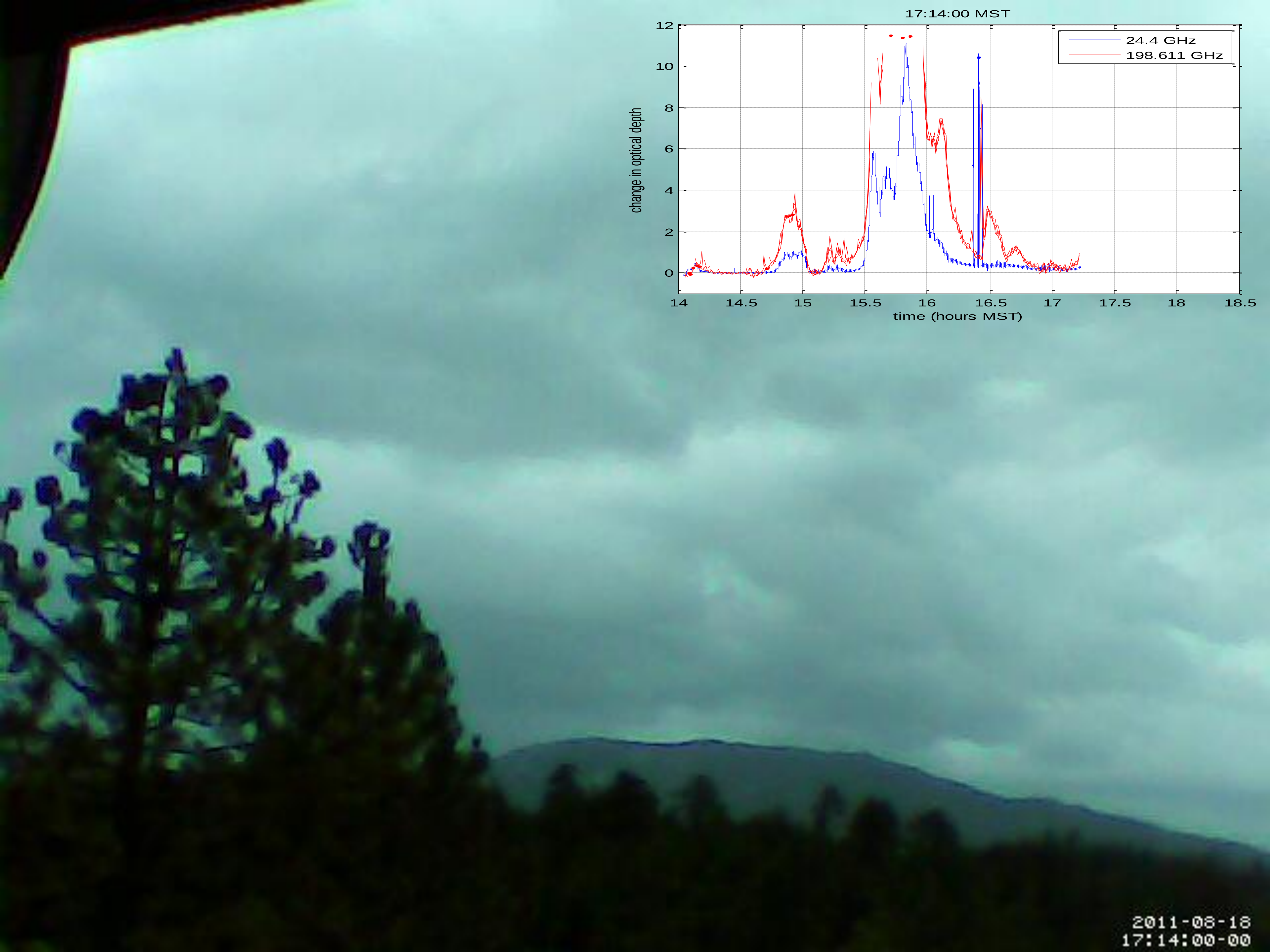
18.5
2011-08-18
17:12:00-00


17:14:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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17.5
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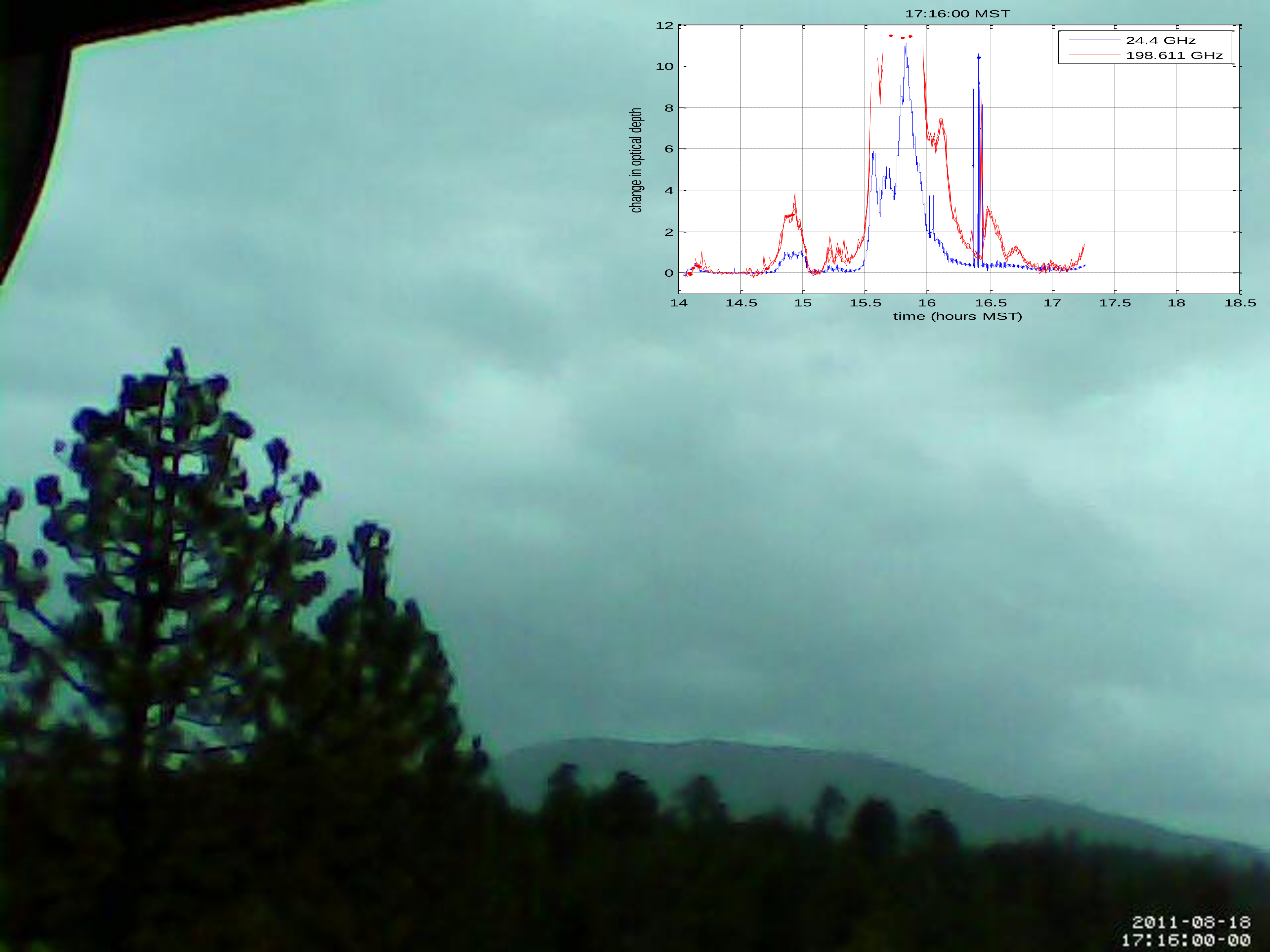
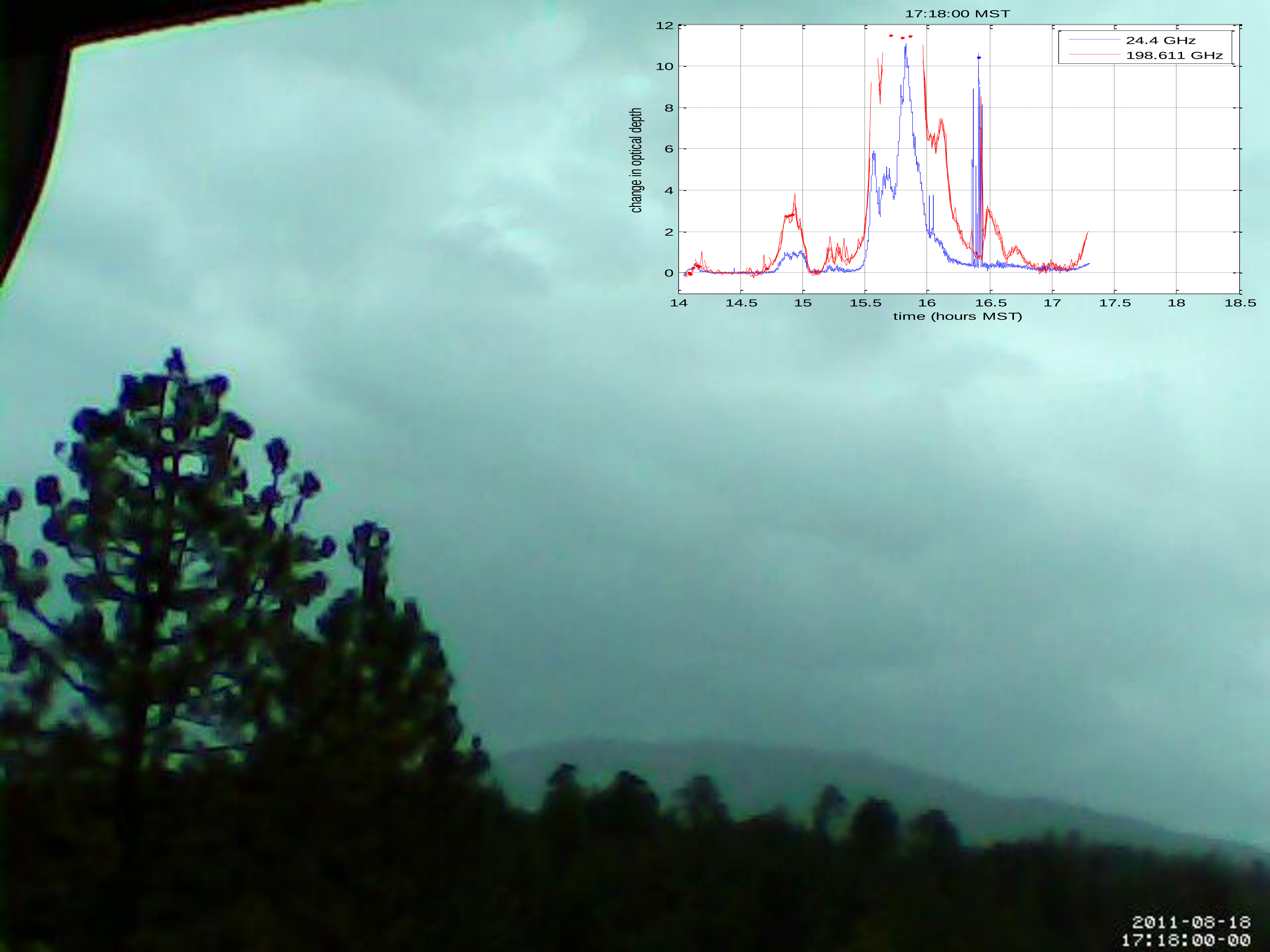
18.5
2011-08-18
17:14:00-00



17:16:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
2011-08-18
17:16:00-00


17:18:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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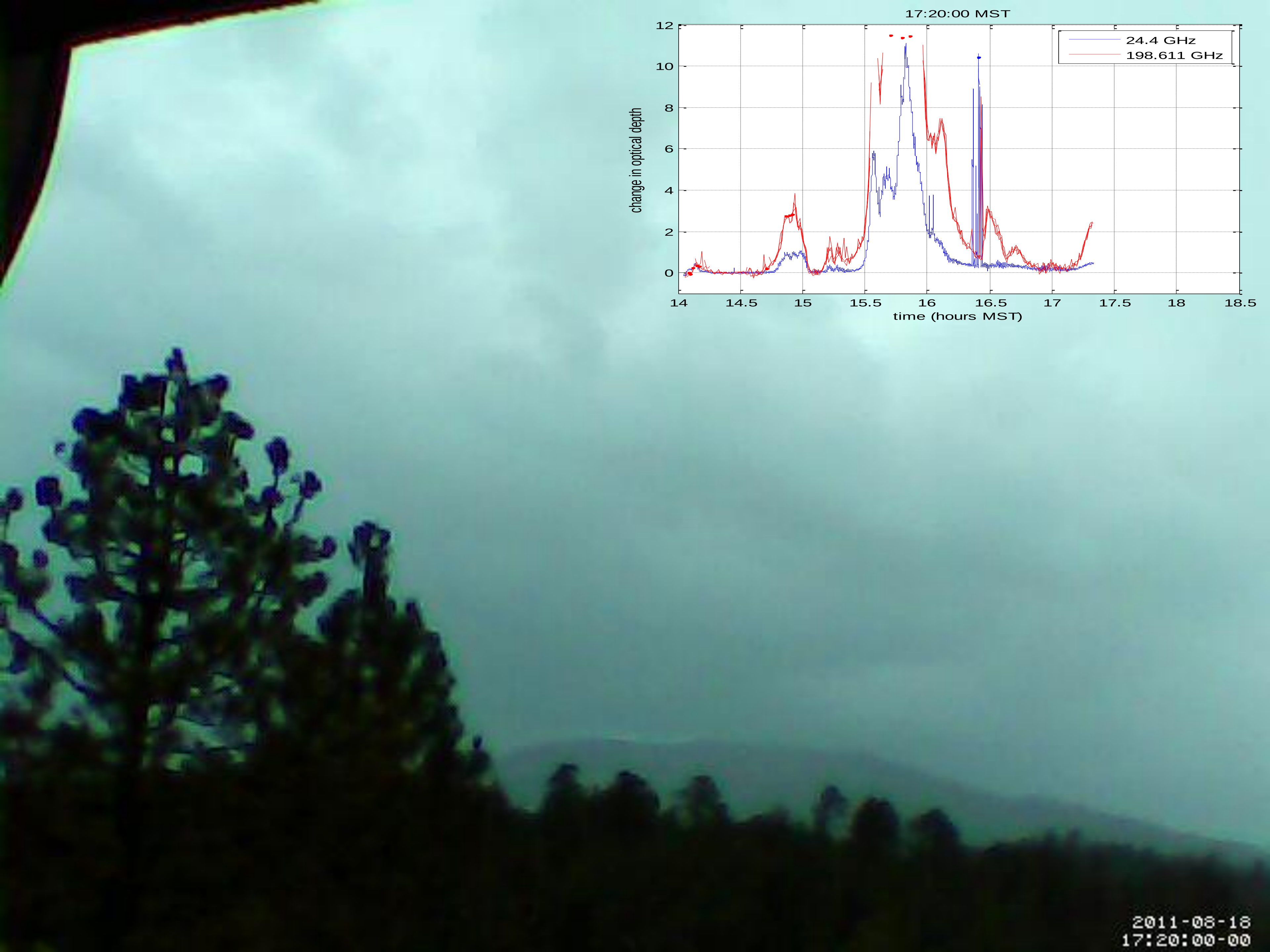
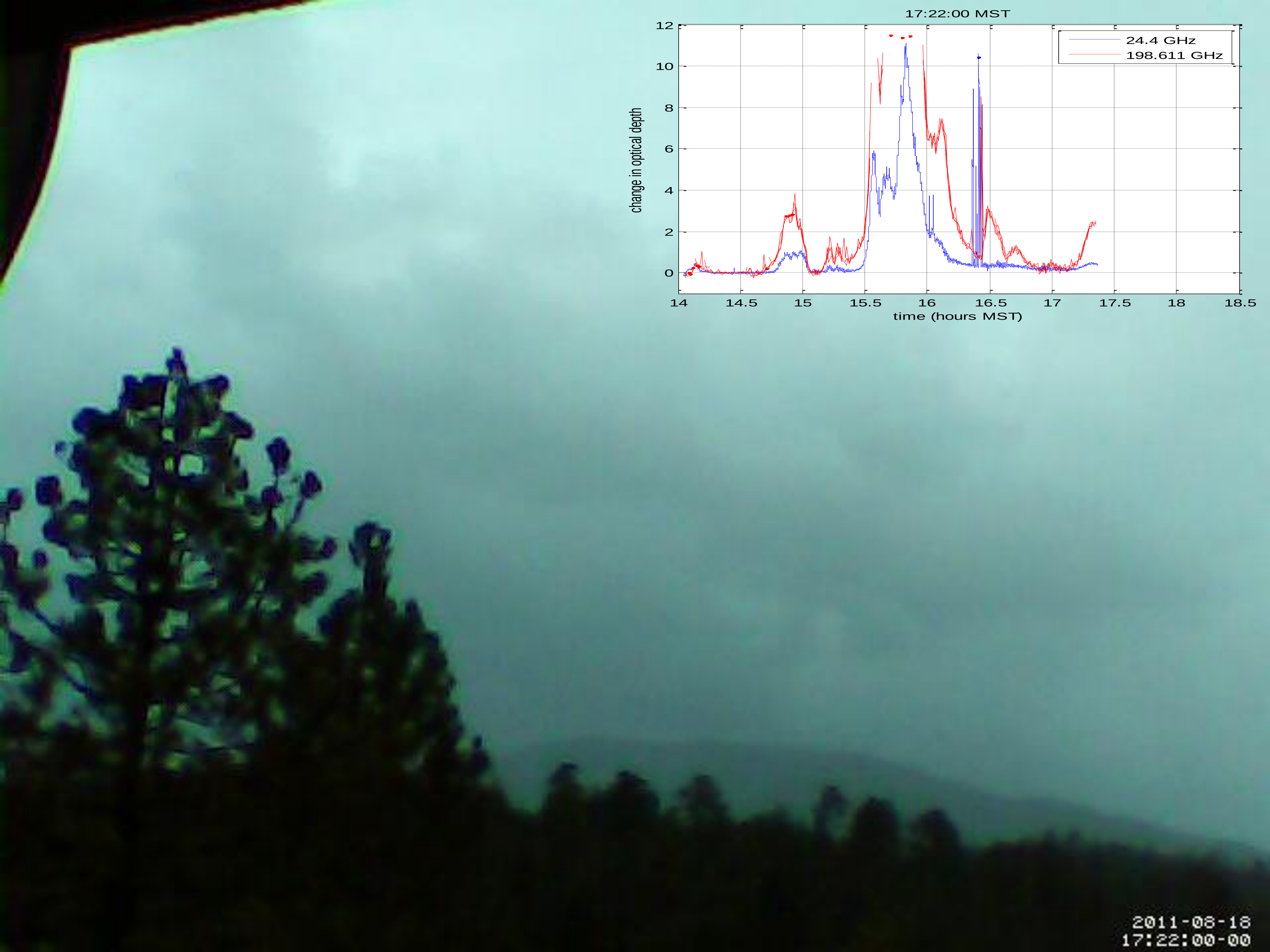
2011-08-18
17:18:00-00


17:20:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
0 2 4 6 8 10 12
14 14.5 15 15.5 16 16.5 17 17.5 18 18.5
2011-08-18
17:20:00-00



17:22:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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14.5
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15.5
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16.5
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17.5
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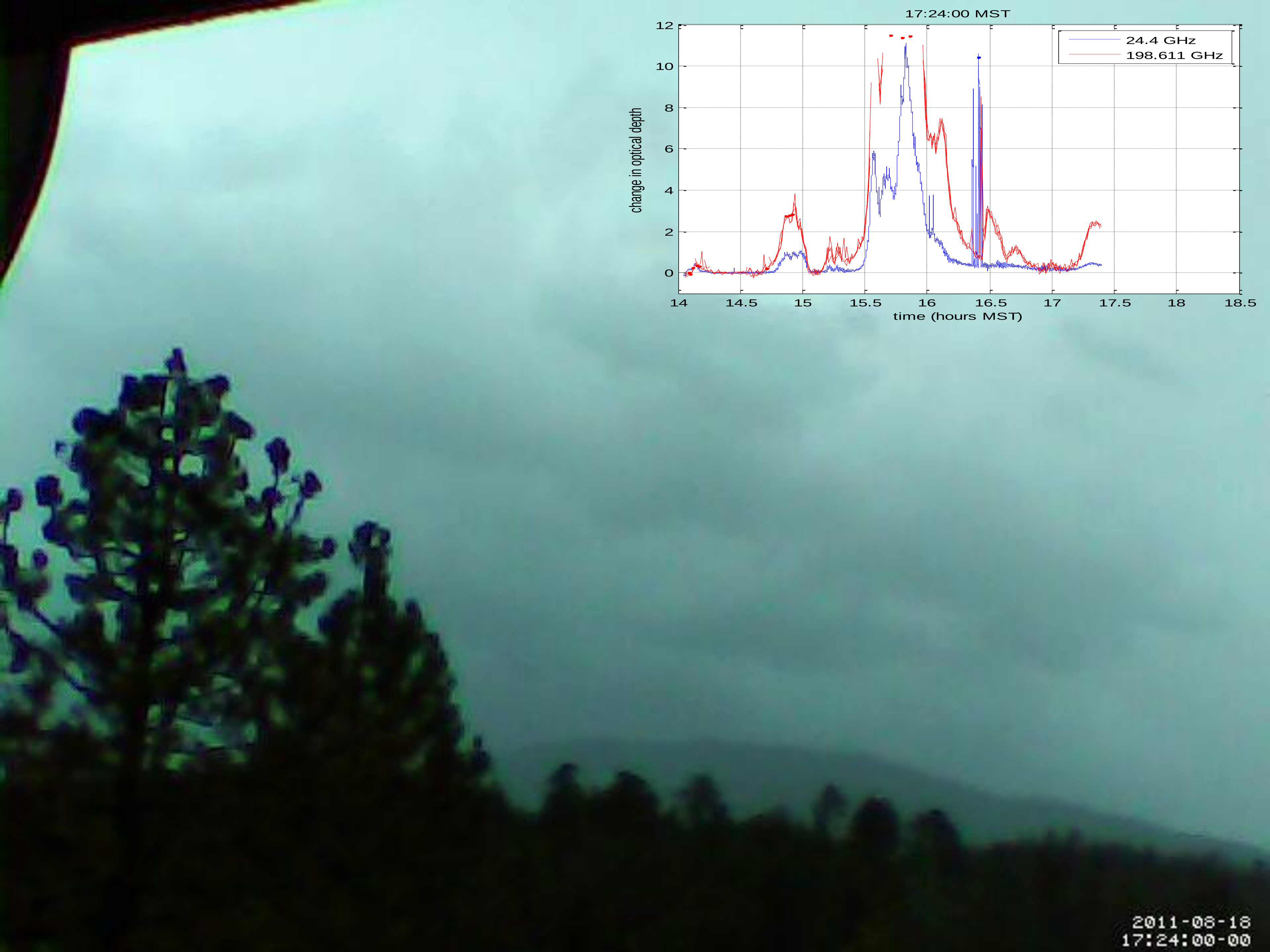
18.5
2011-08-18
17:22:00-00



17:24:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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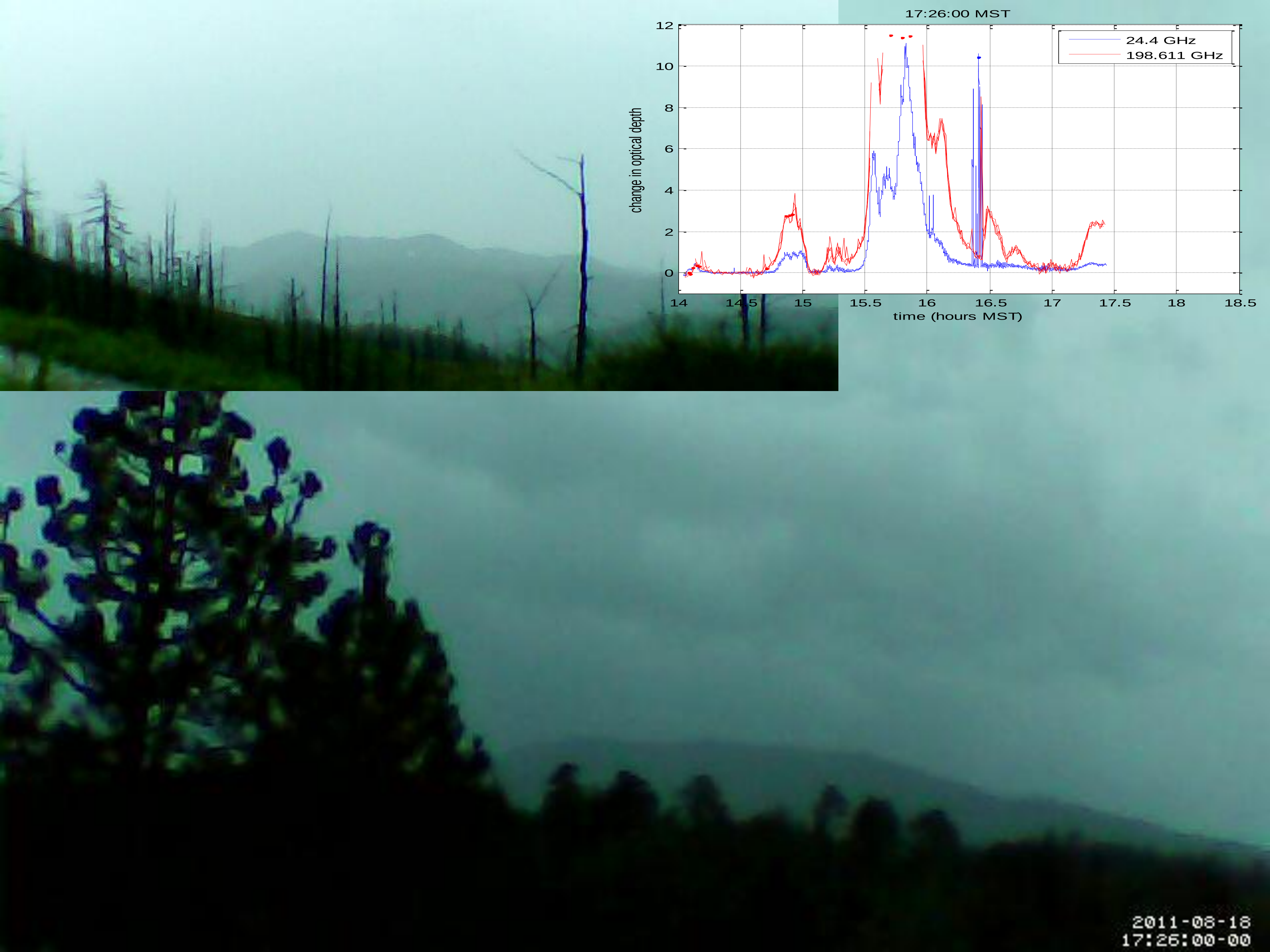
2011-08-18
17:24:00-00


17:26:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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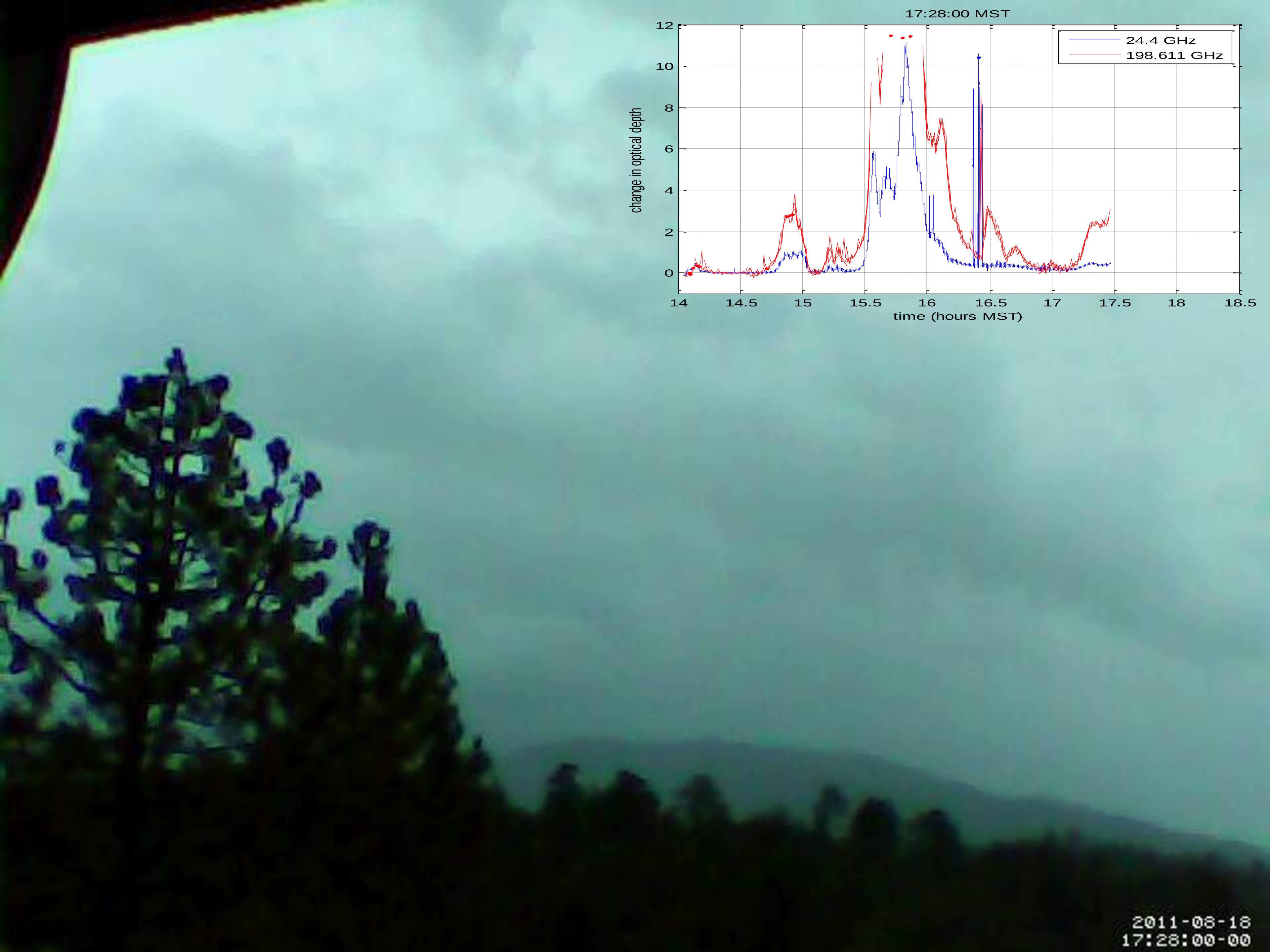
2011-08-18
17:26:00-00



17:28:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
12
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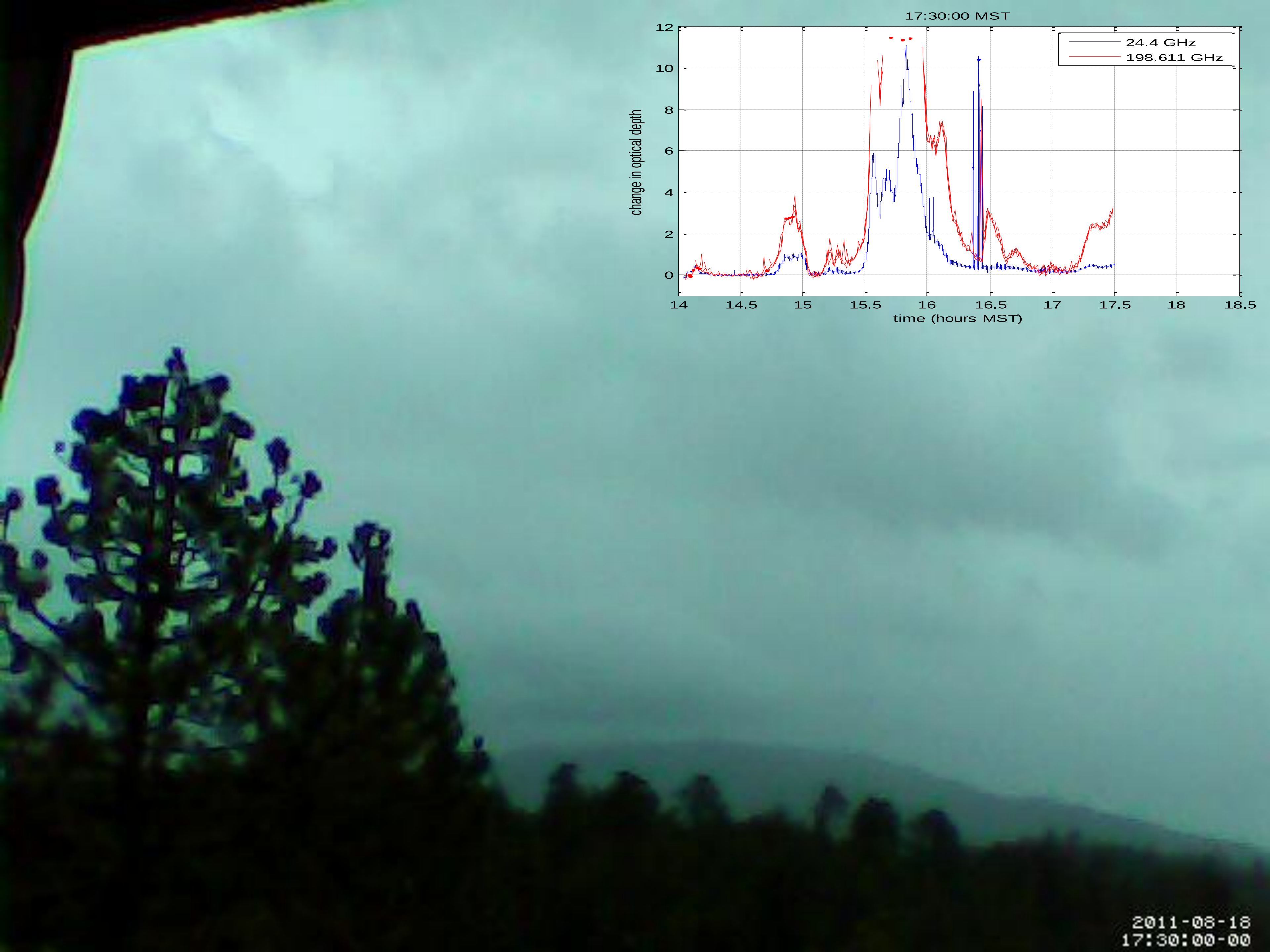
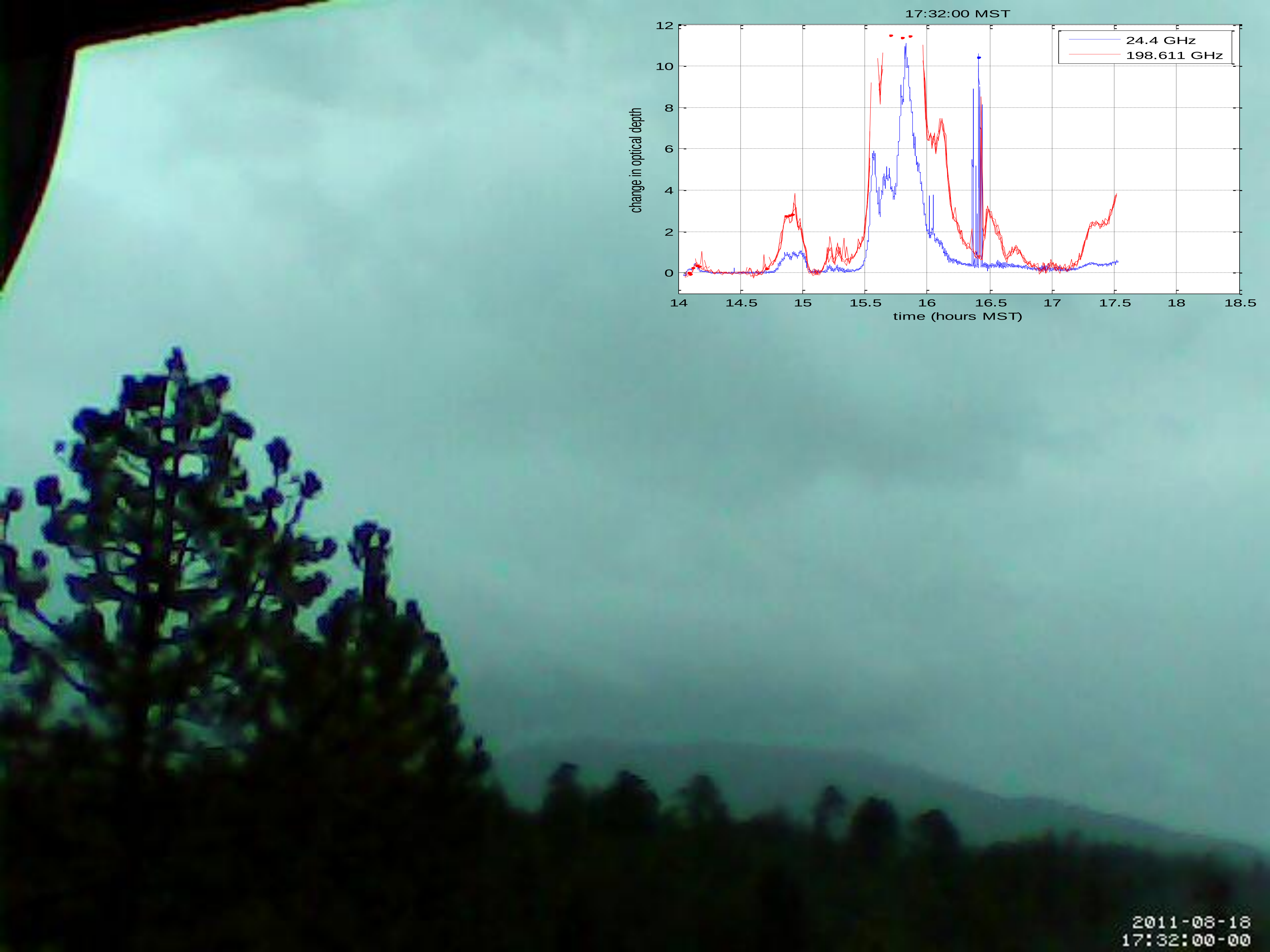
18.5
2011-08-18
17:28:00-00


17:30:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
2011-08-18
17:30:00-00



17:32:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
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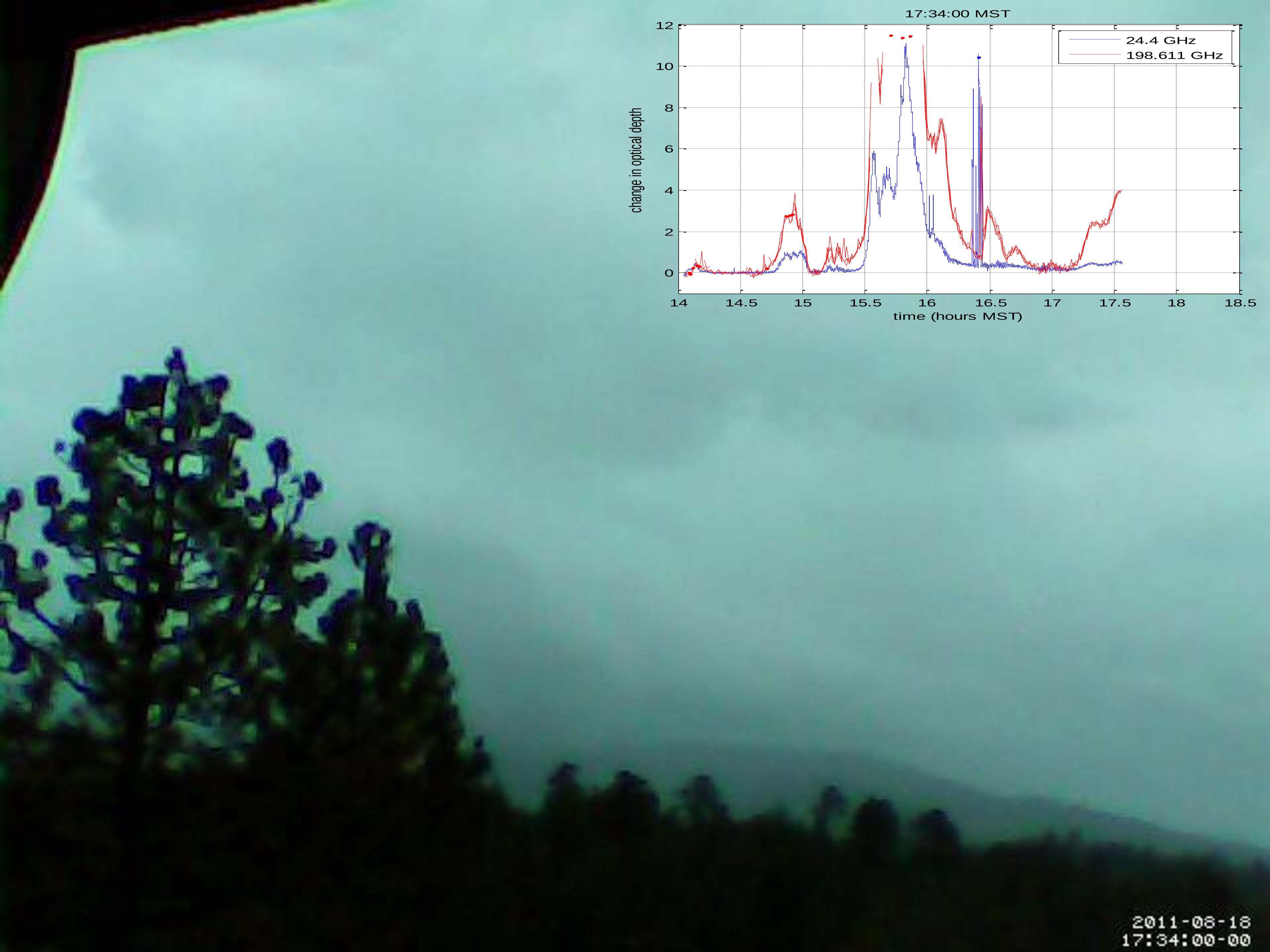
18.5
2011-08-18
17:32:00-00


17:34:00 MST
24.4 GHz
198.611 GHz
change in optical depth
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16.5
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17.5
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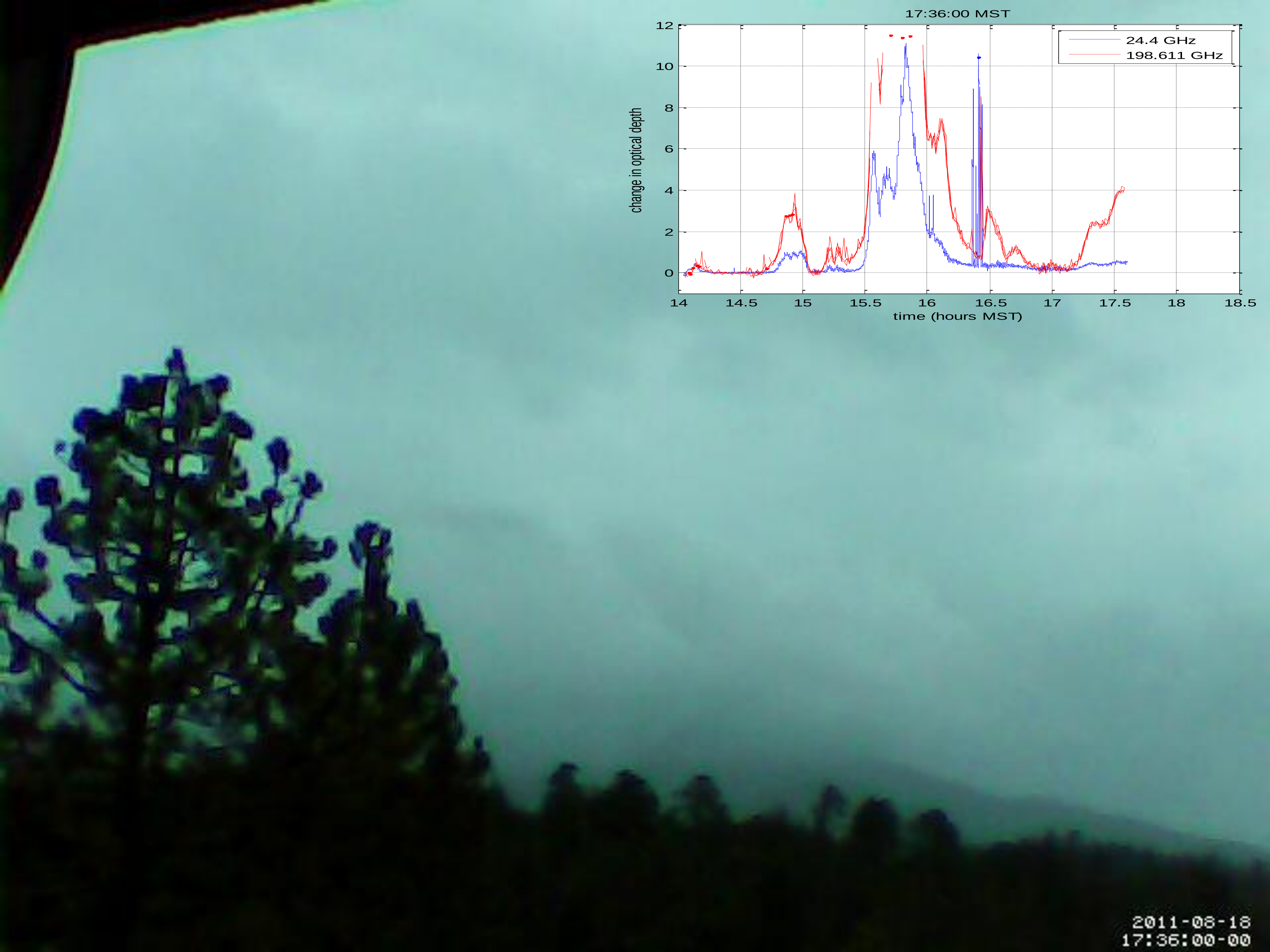
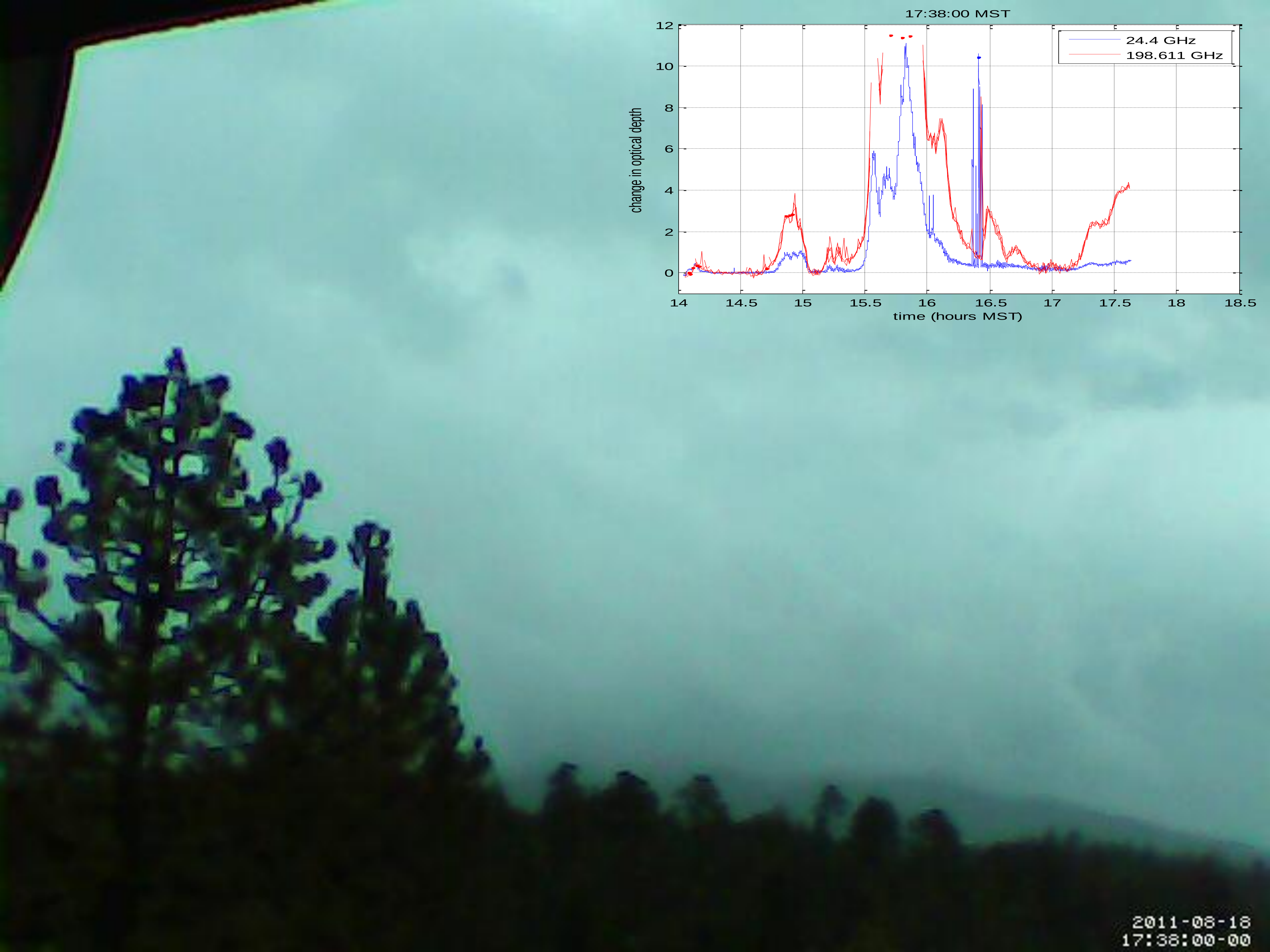
18.5
time (hours MST)
2011-08-18
17:34:00-00


17:36:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
17:36:00-00


17:38:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
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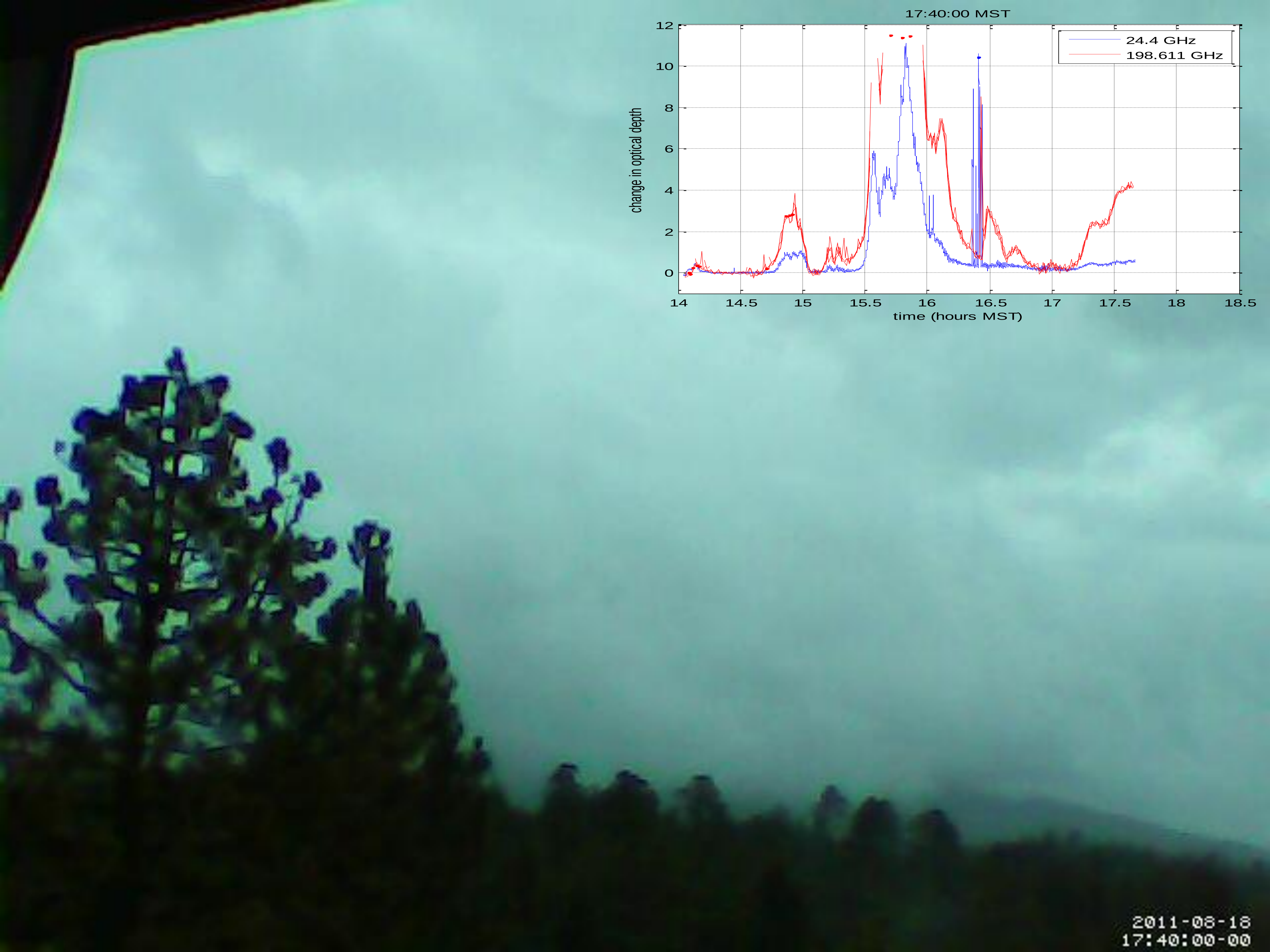
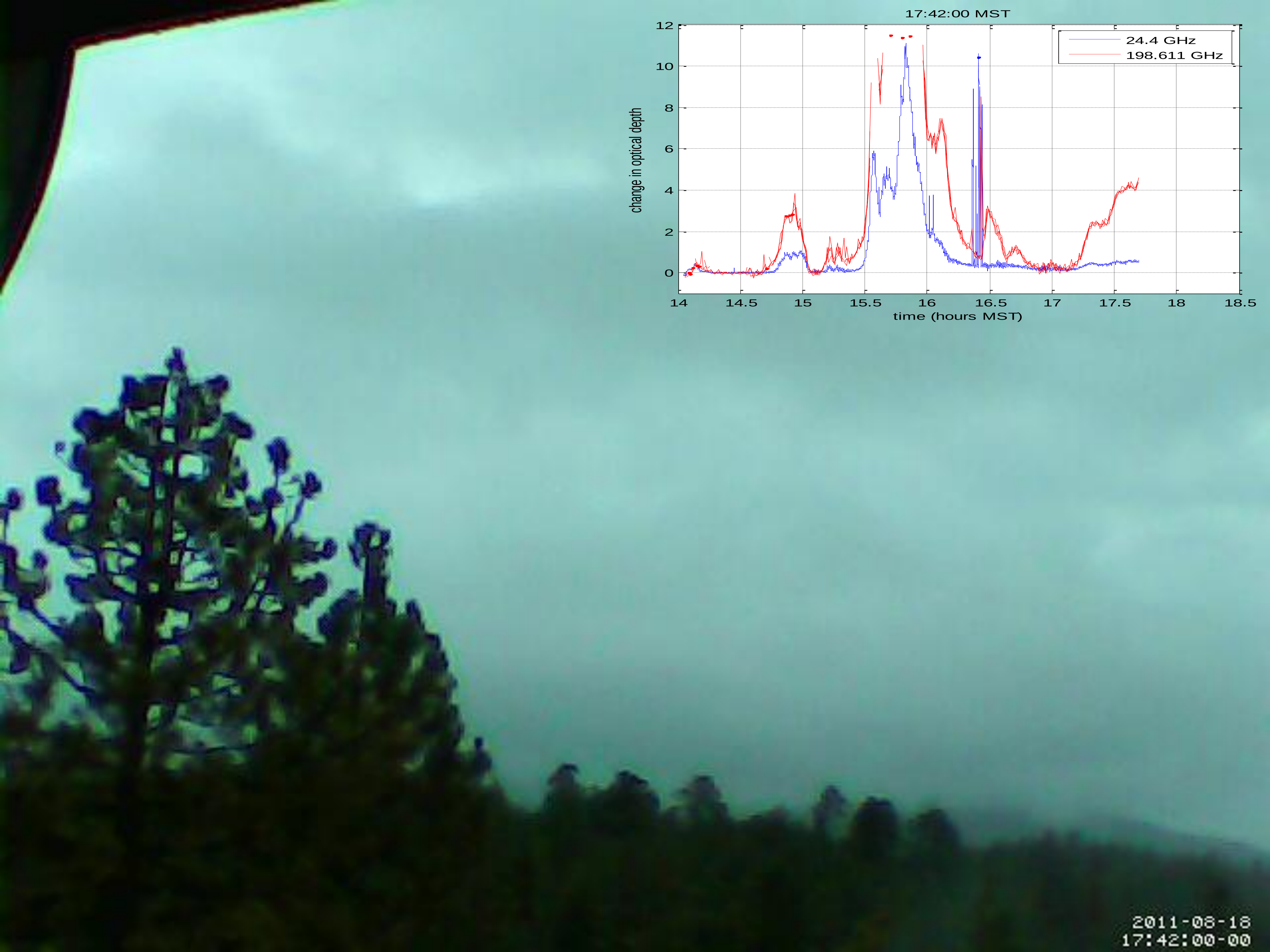
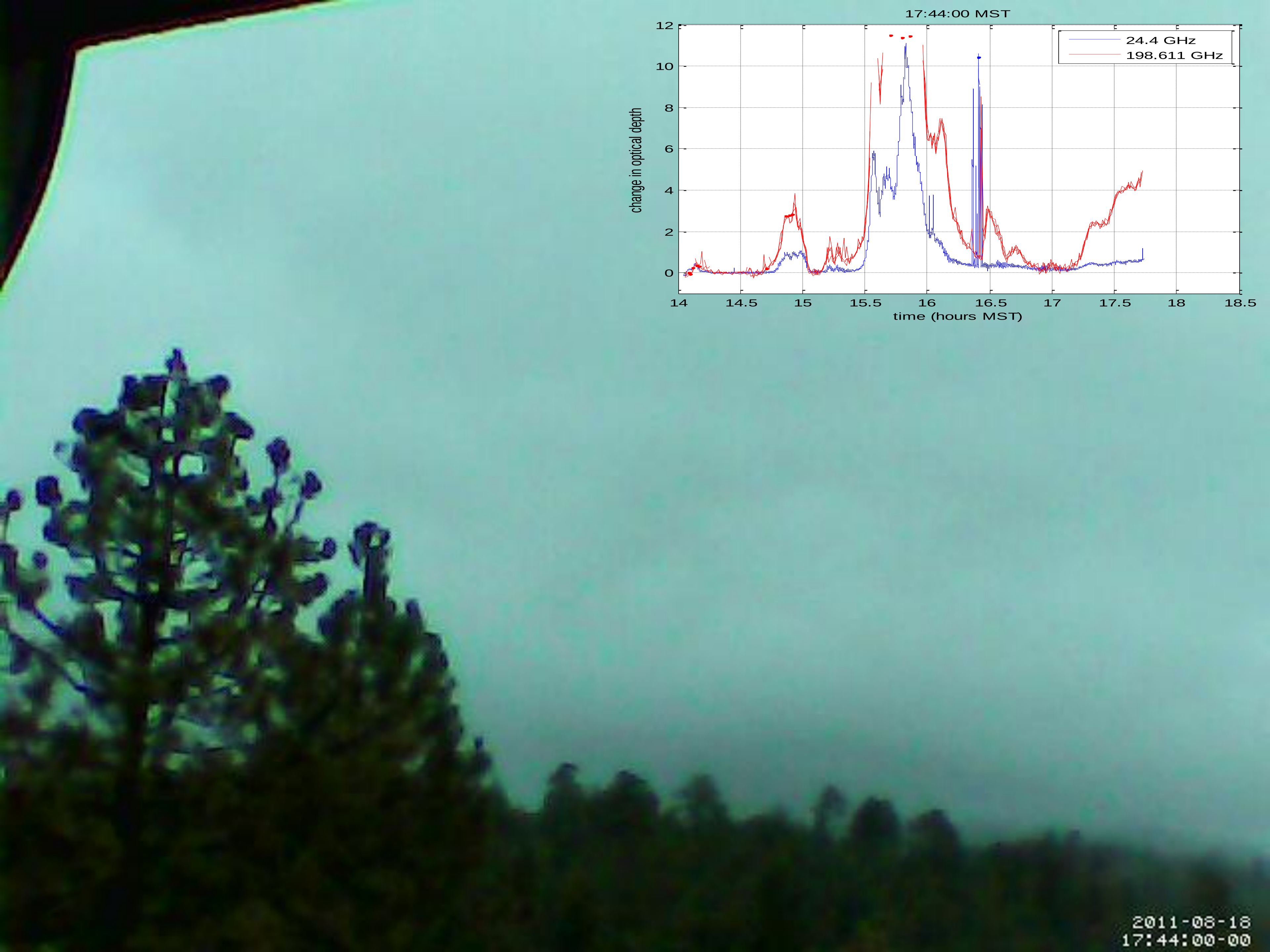
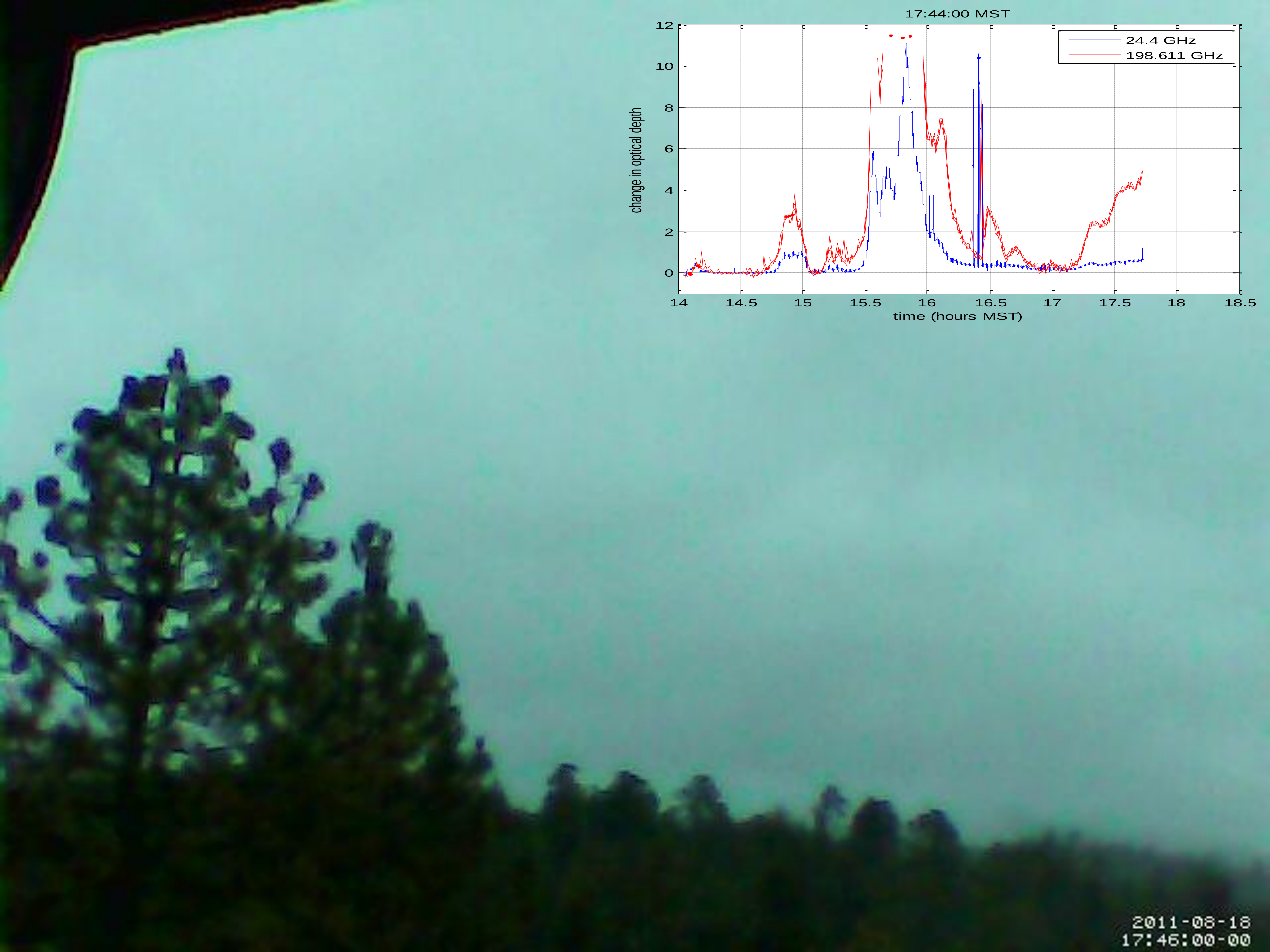
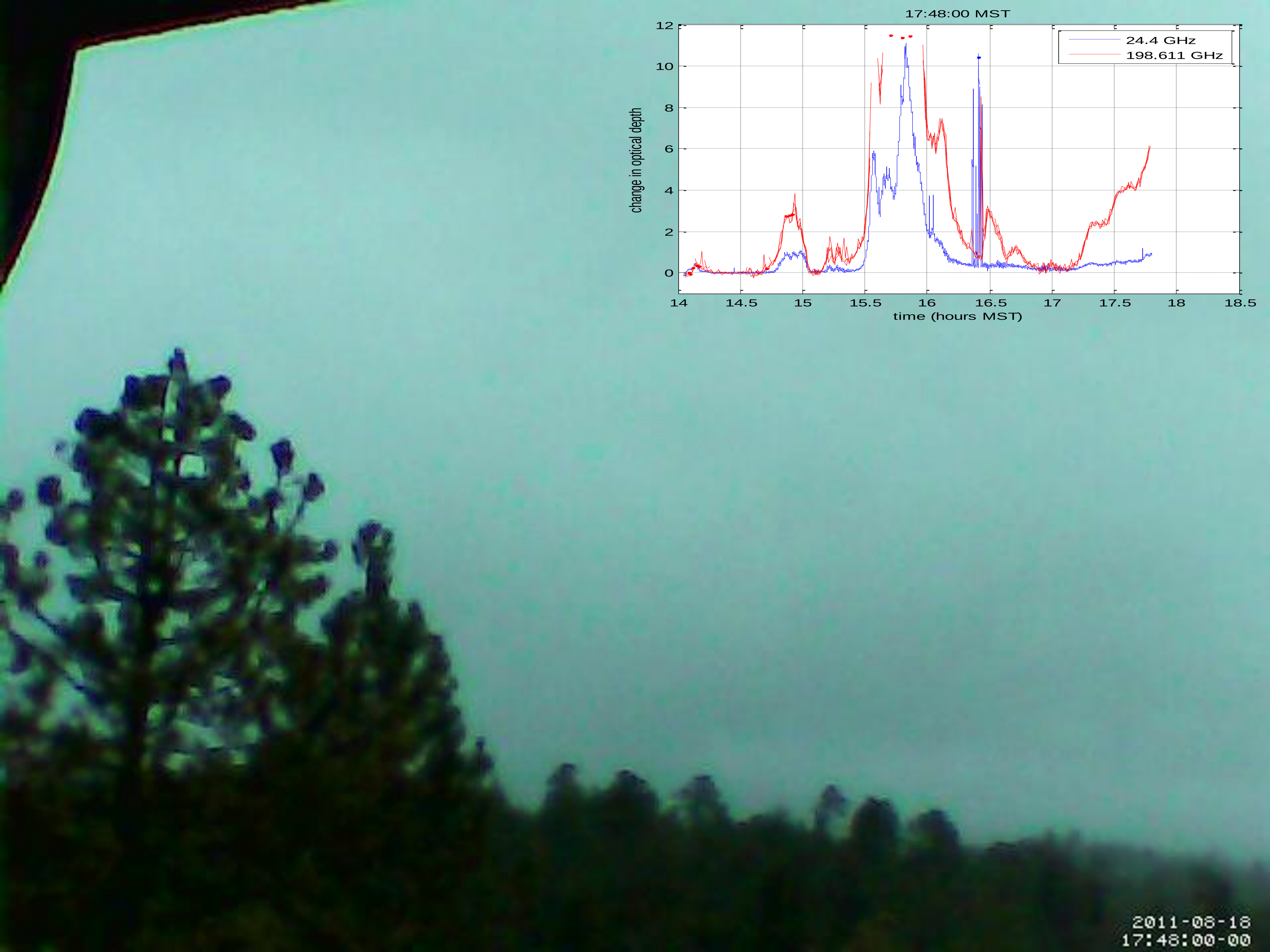
18.5
2011-08-18
17:38:00-00

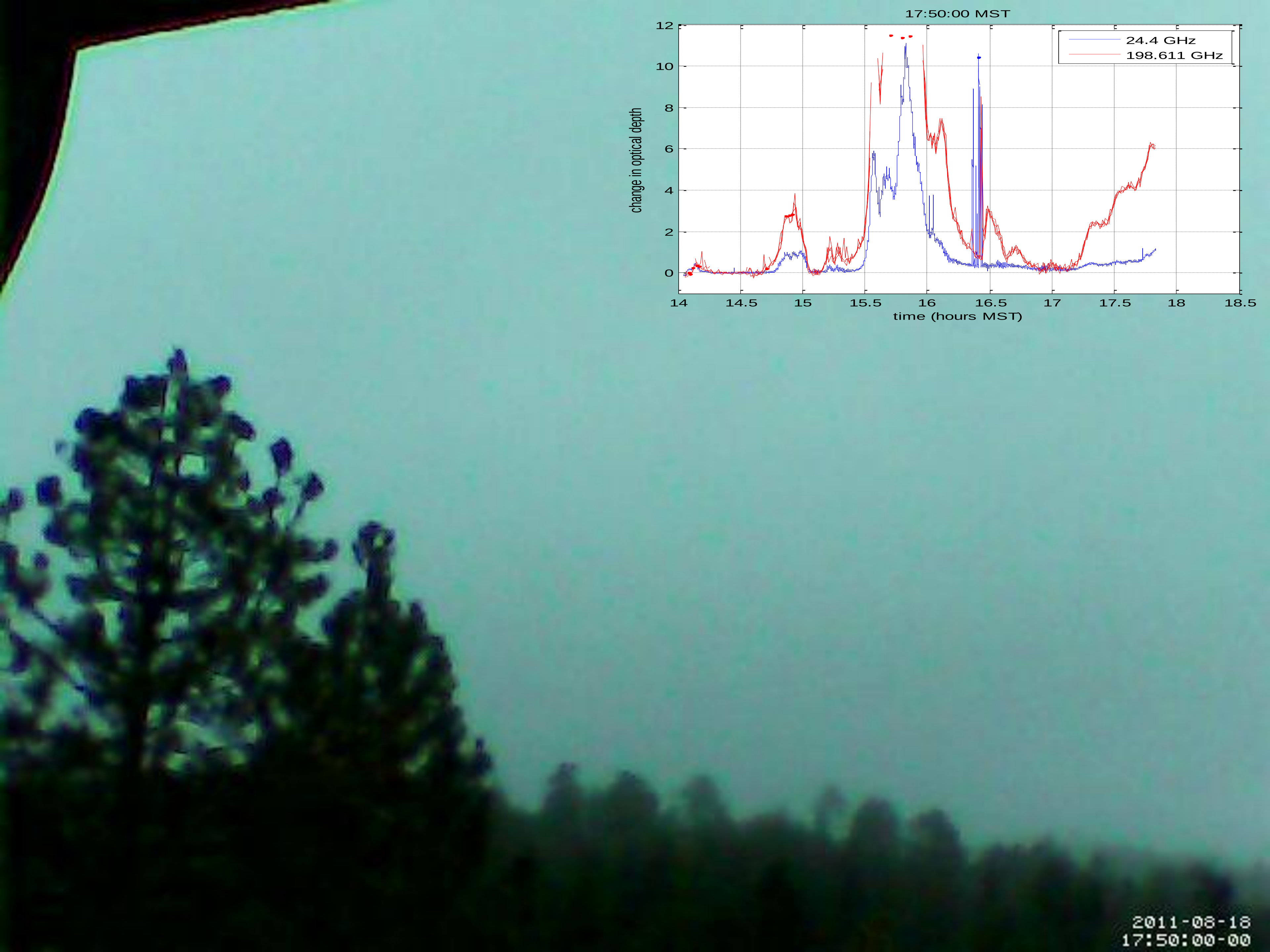

17:40:00 MST
change in optical depth
time (hours MST)
24.4 GHz
198.611 GHz
0
2
4
6
8
10
12
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
2011-08-18
17:40:00-00

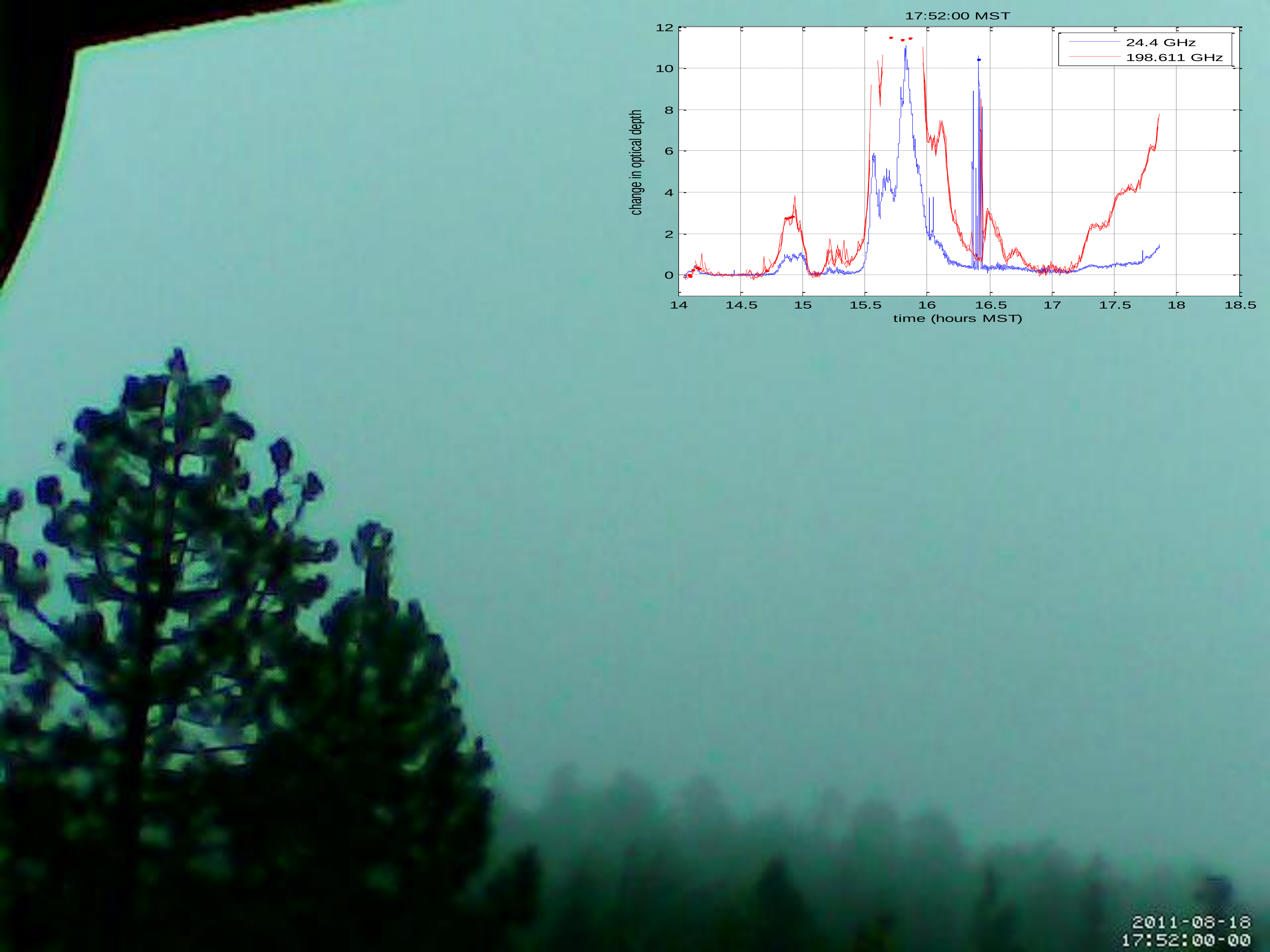

17:42:00 MST
change in optical depth
0
2
4
6
8
10
12
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
time (hours MST)
24.4 GHz
198.611 GHz
2011-08-18
17:42:00-00

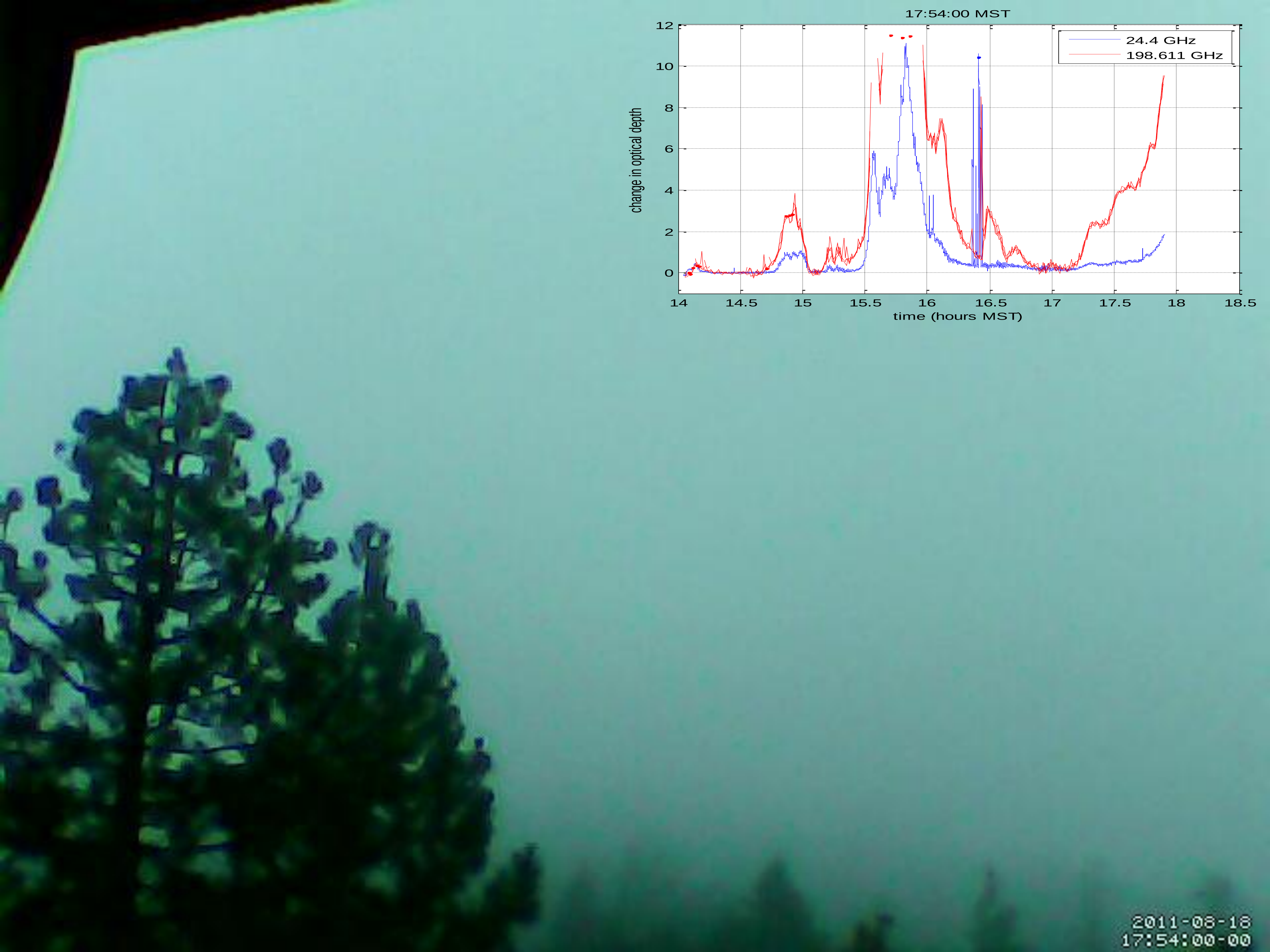

17:44:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
0
2
4
6
8
10
12
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
2011-08-18
17:44:00-00

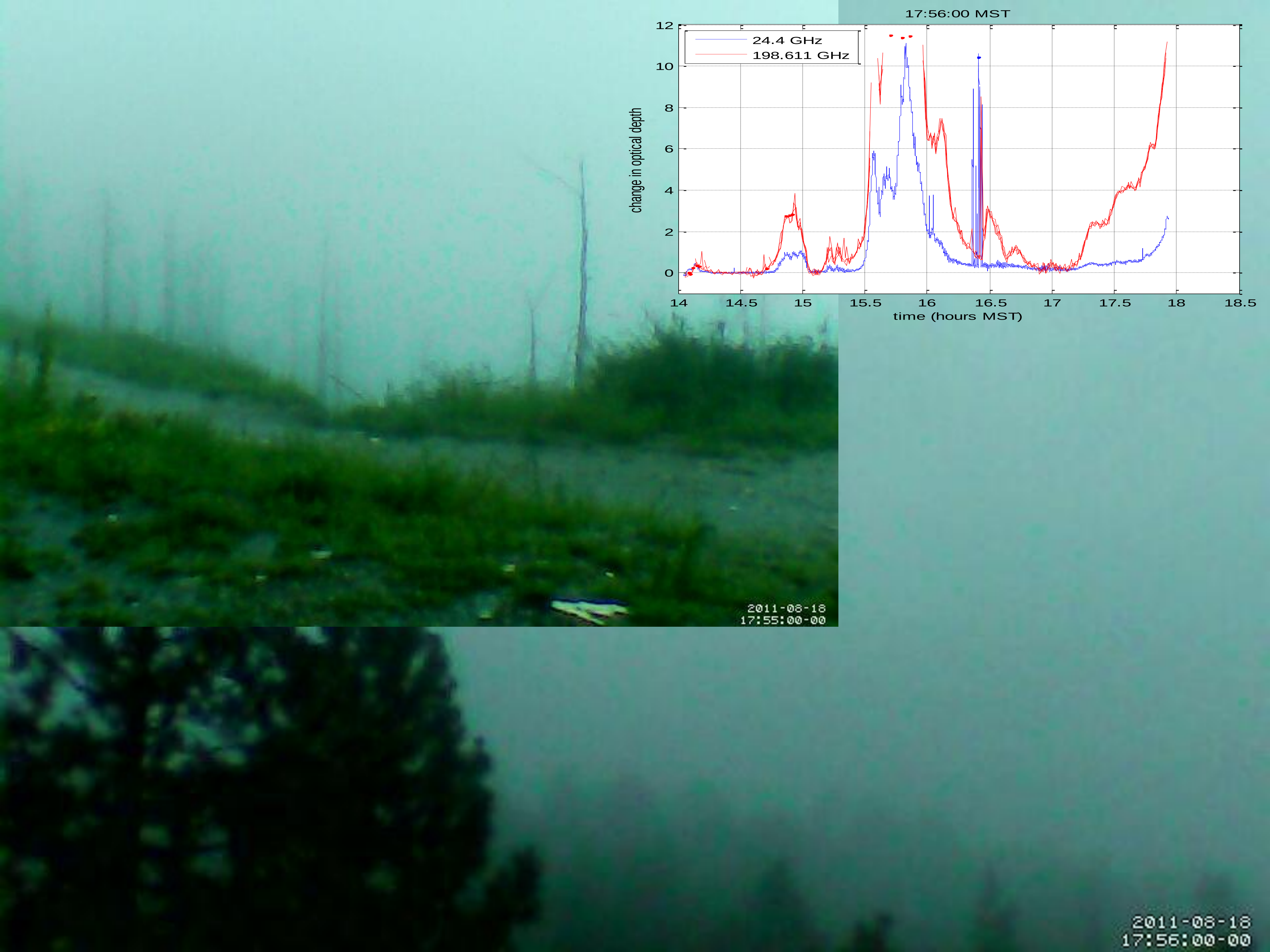

17:44:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
0
2
4
6
8
10
12
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
2011-08-18
17:46:00-00

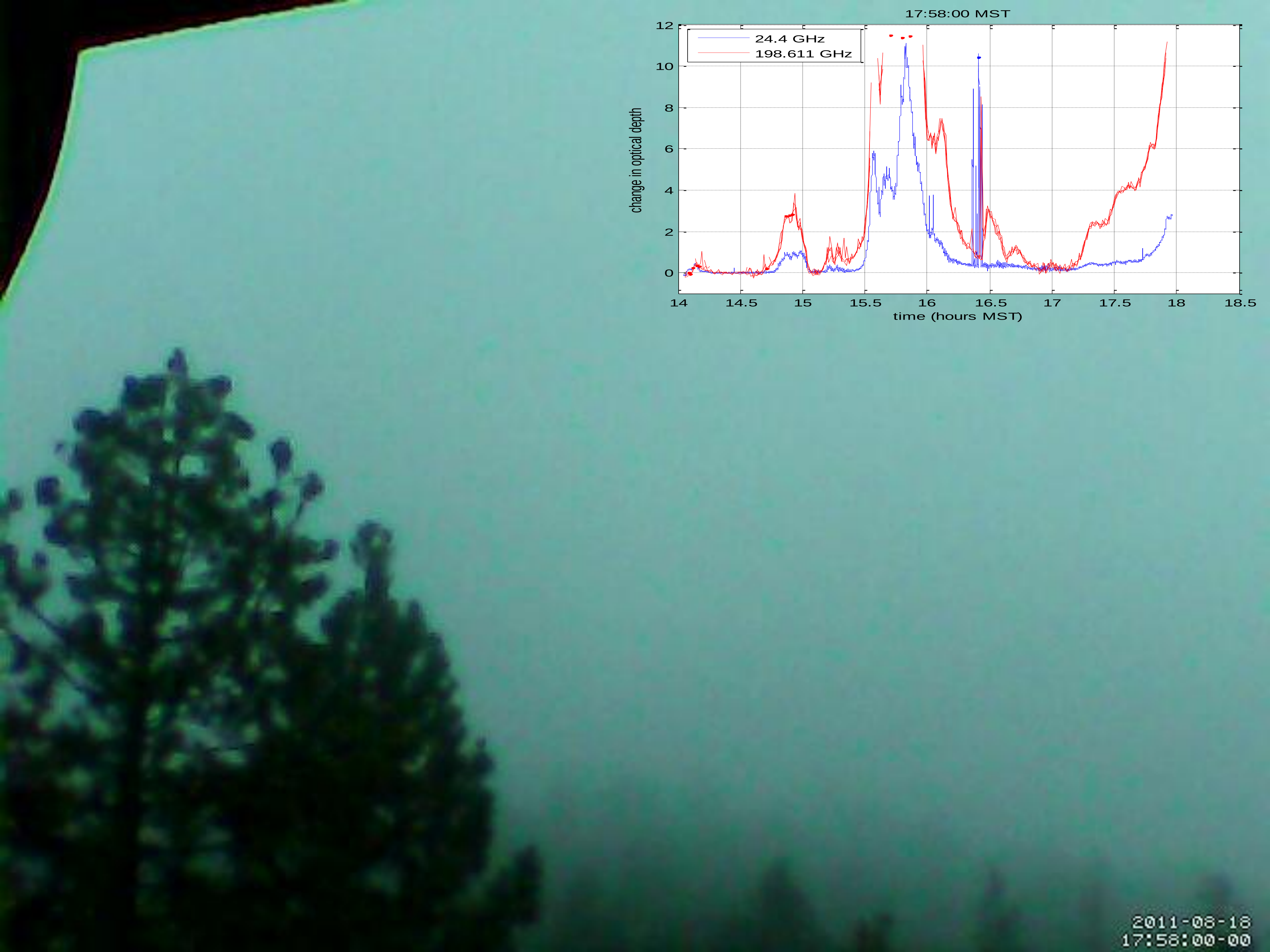

17:48:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
17:48:00-00

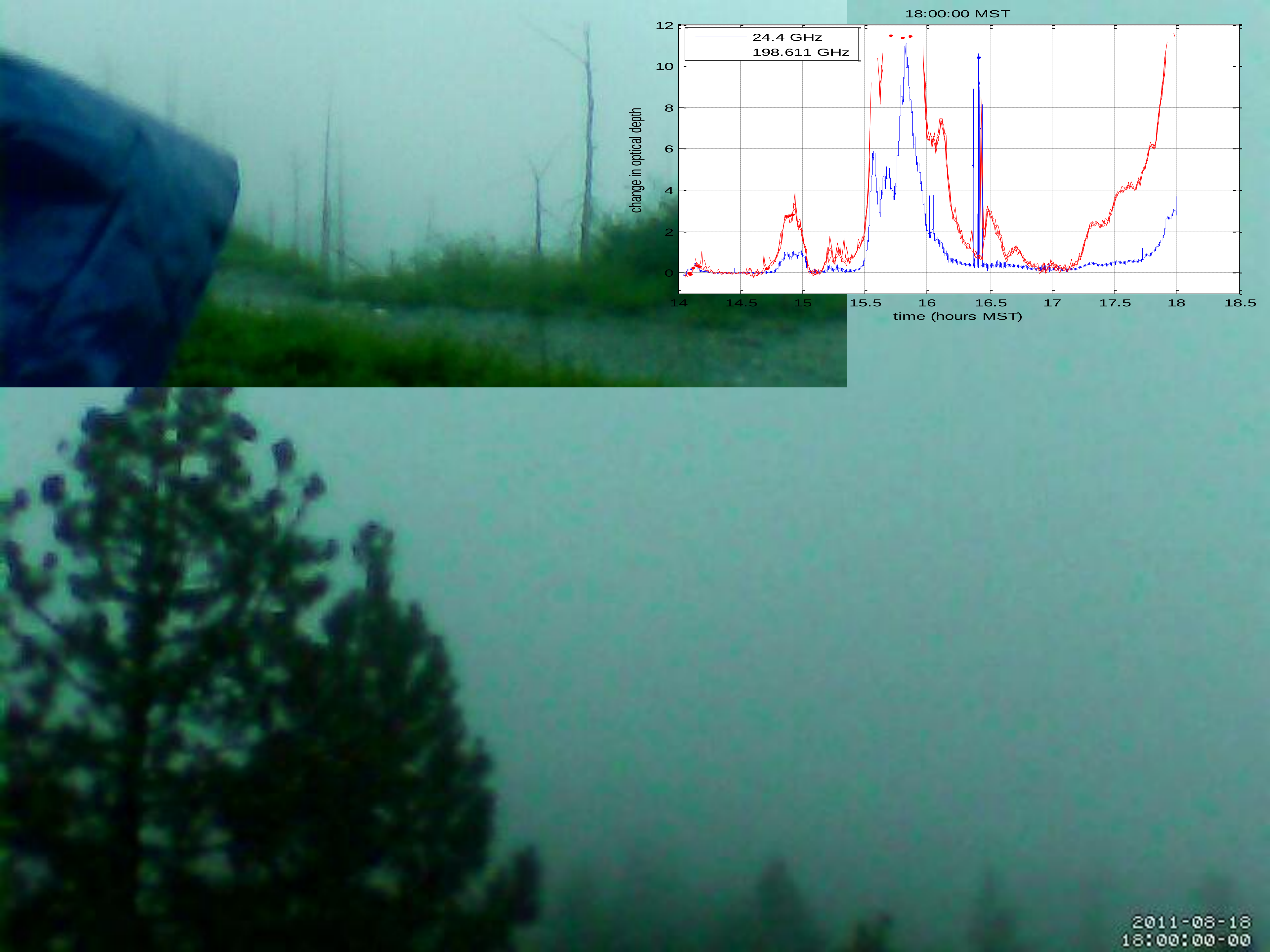

17:50:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
17:50:00-00

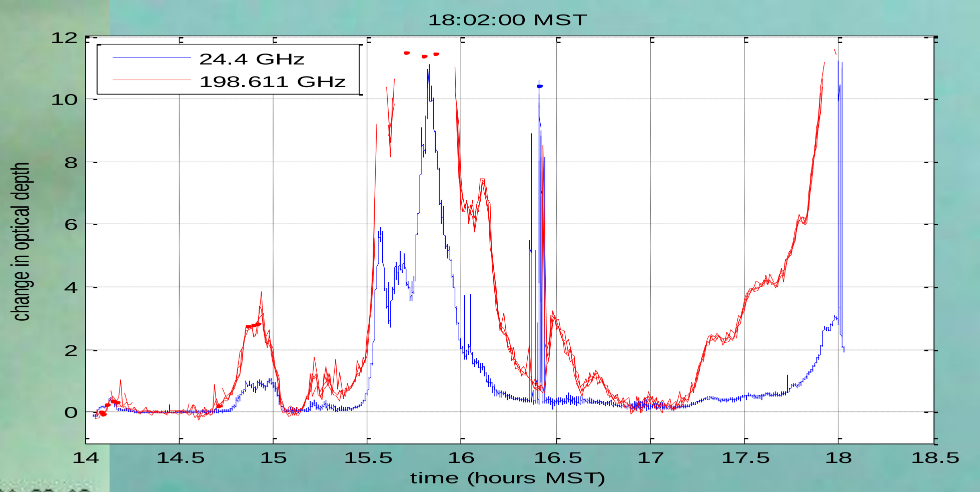

17:52:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
0
2
4
6
8
10
12
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
2011-08-18
17:52:00-00


17:54:00 MST
24.4 GHz
198.611 GHz
change in optical depth
0
2
4
6
8
10
12
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
time (hours MST)
2011-08-18
17:54:00-00

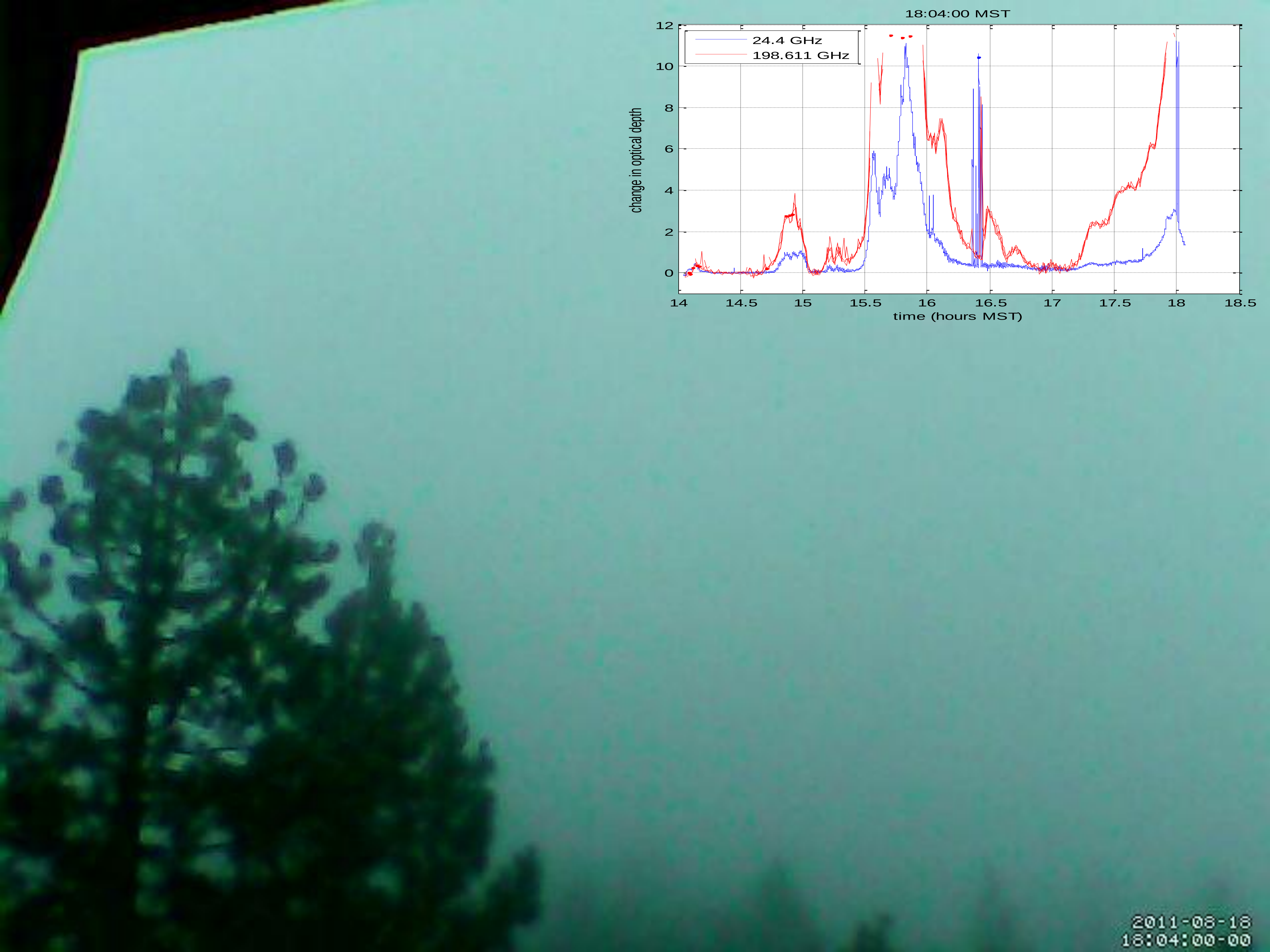

17:56:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
0
2
4
6
8
10
12
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
2011-08-18
17:55:00-00
2011-08-18
17:56:00-00

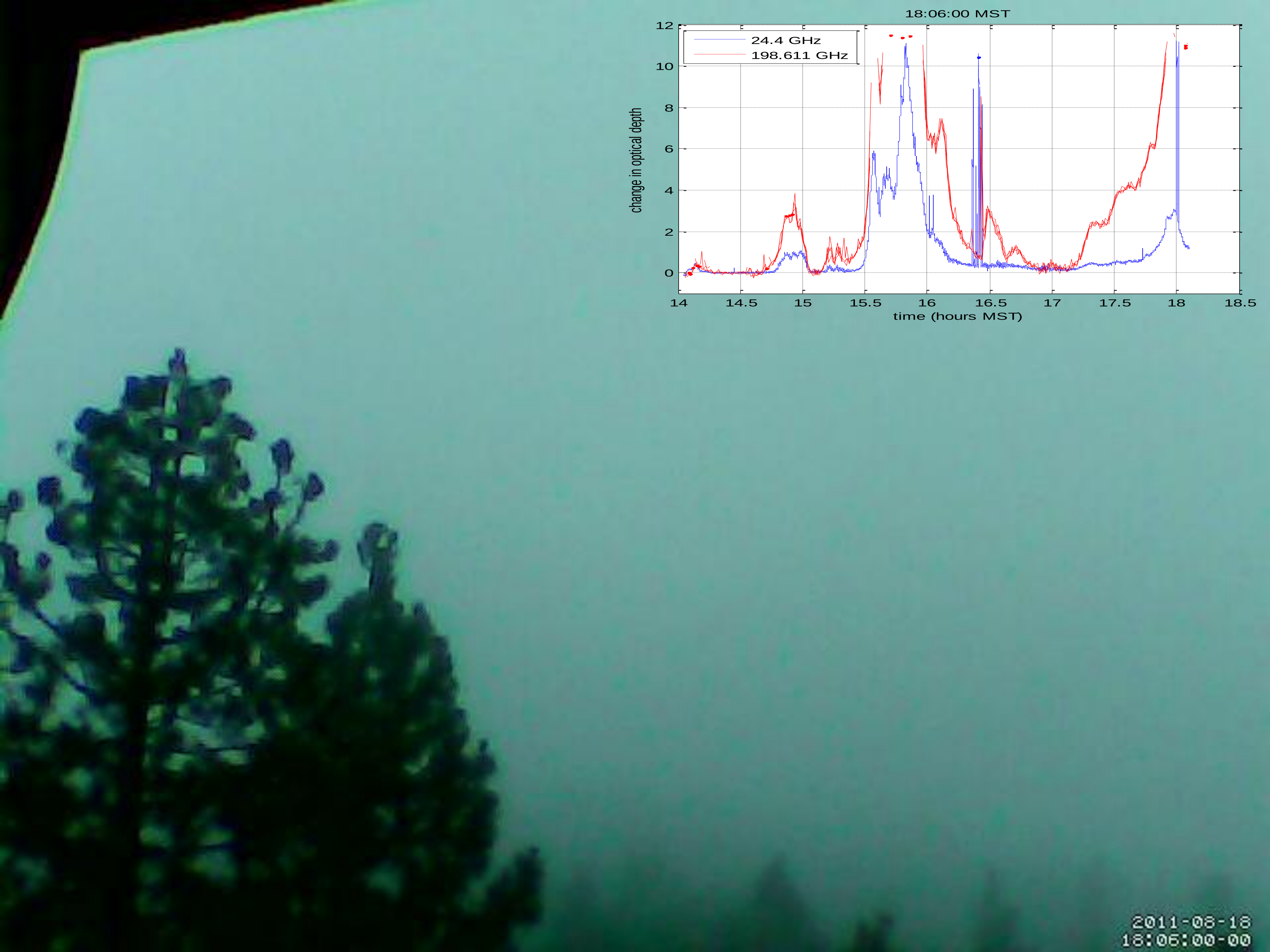

17:58:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
0
2
4
6
8
10
12
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
2011-08-18
17:58:00-00

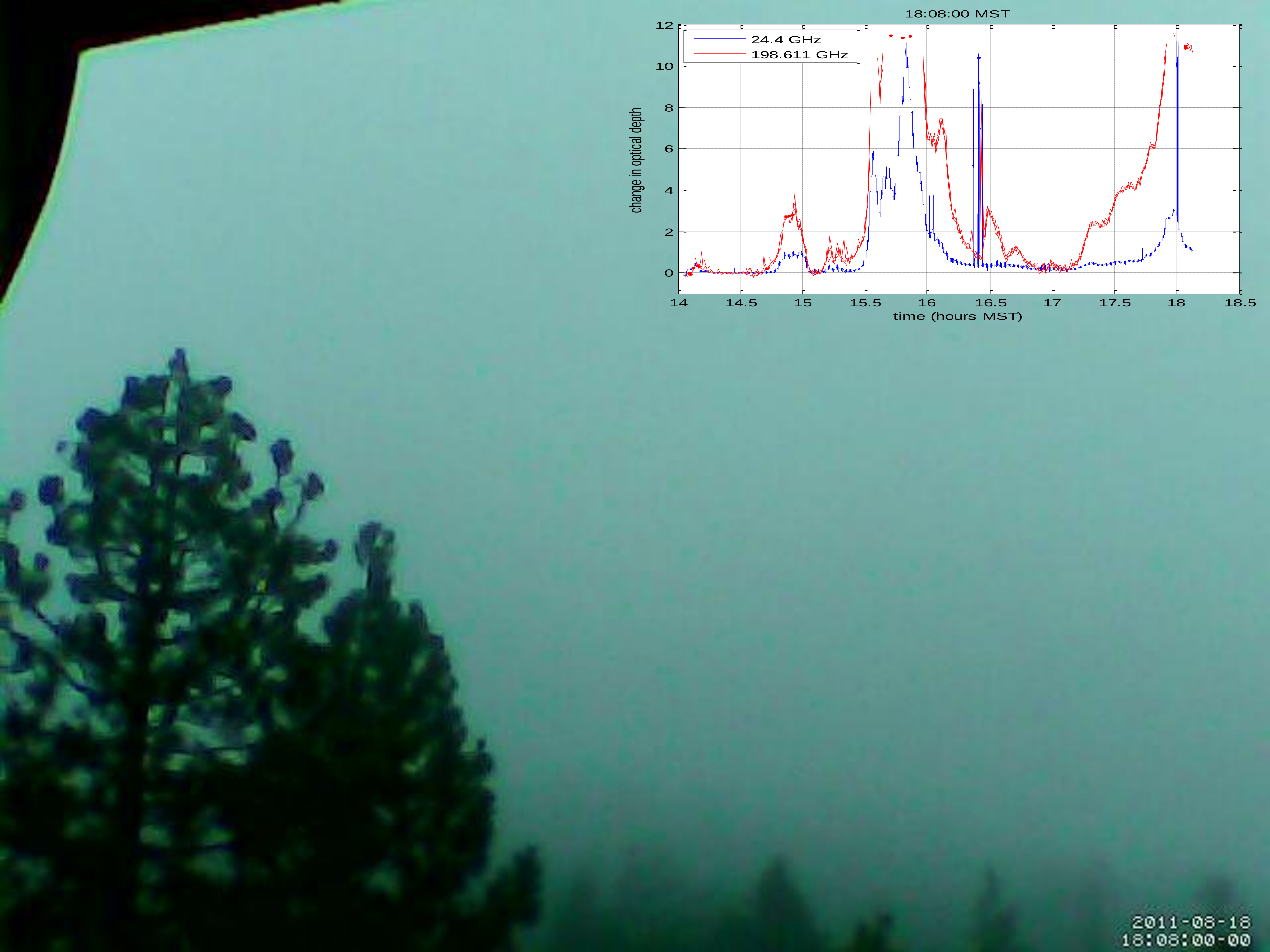

18:00:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
0
2
4
6
8
10
12
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
2011-08-18
18:00:00-00


2011-08-18
18:00:47-00

18:02:00 MST
24.4 GHz
198.611 GHz
change in optical depth
0
2
4
6
8
10
12
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
time (hours MST)

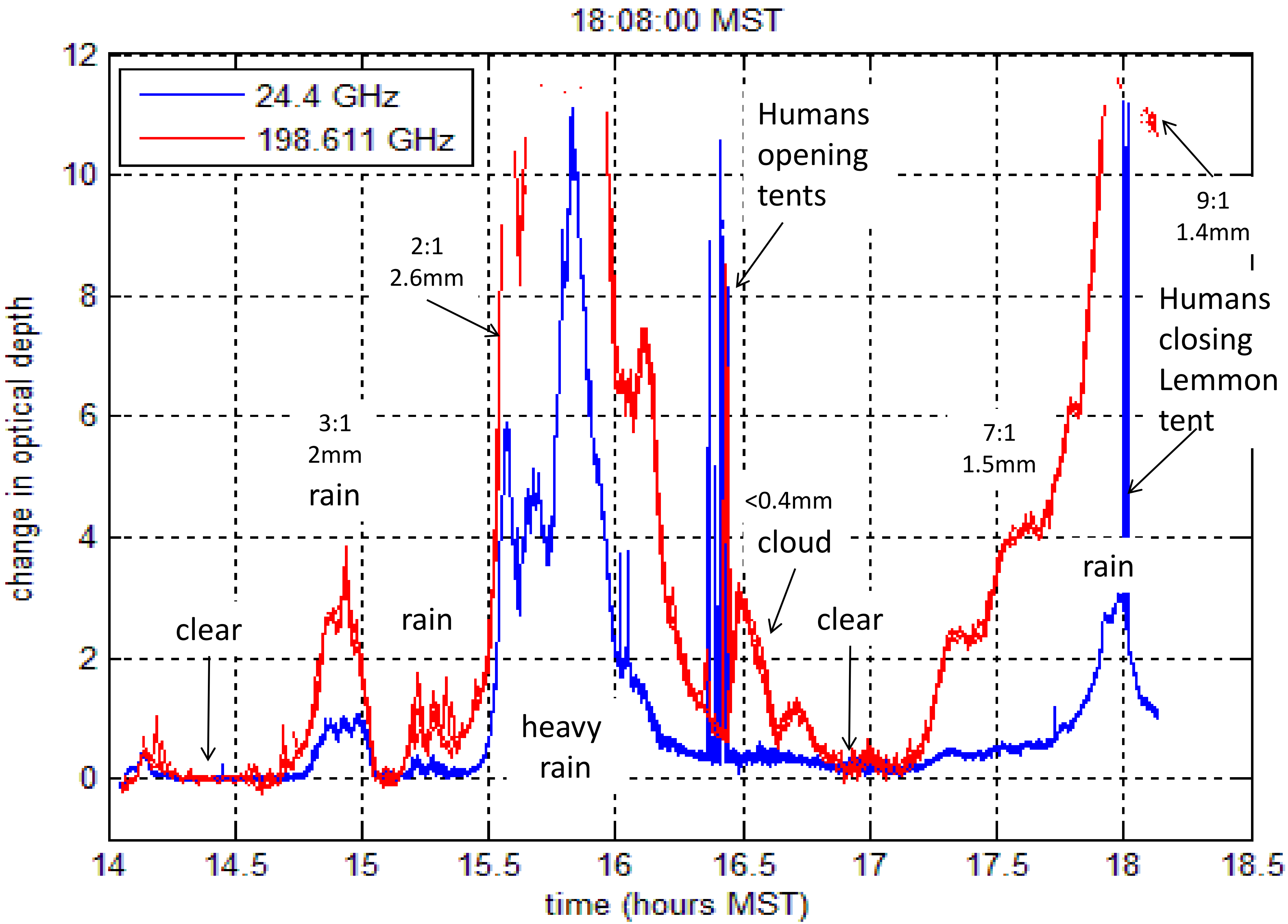
2011-08-18
18:02:00-00


18:04:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
18:04:00-00


18:06:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
0
2
4
6
8
10
12
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
2011-08-18
18:06:00-00


18:08:00 MST
24.4 GHz
198.611 GHz
change in optical depth
time (hours MST)
2011-08-18
18:08:00-00

Summary of August 18, 2011 large opacity variations

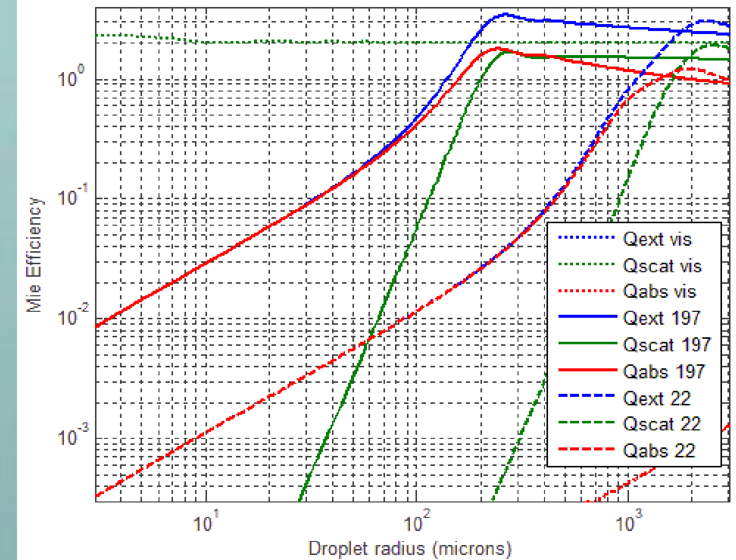


Crude estimate of maximum rainfall

- At 15:50: $\tau_{24.4\ GHz} = 10.5$
- Assume $\tau_{198.6\ GHz} / \tau_{24.4\ GHz} = 2:1$ (3:1) based on measured ratio at onset of heavy rainfall
- Implies droplet radius of ~1.3 (1.0 mm)
- Fall speed: 7.6 m/s (6.5 m/s)
- Mass density: 2.7 g/m^3 (3.2 g/m^3)

=> Rainfall: 53 mm/hr (55 mm/hr)

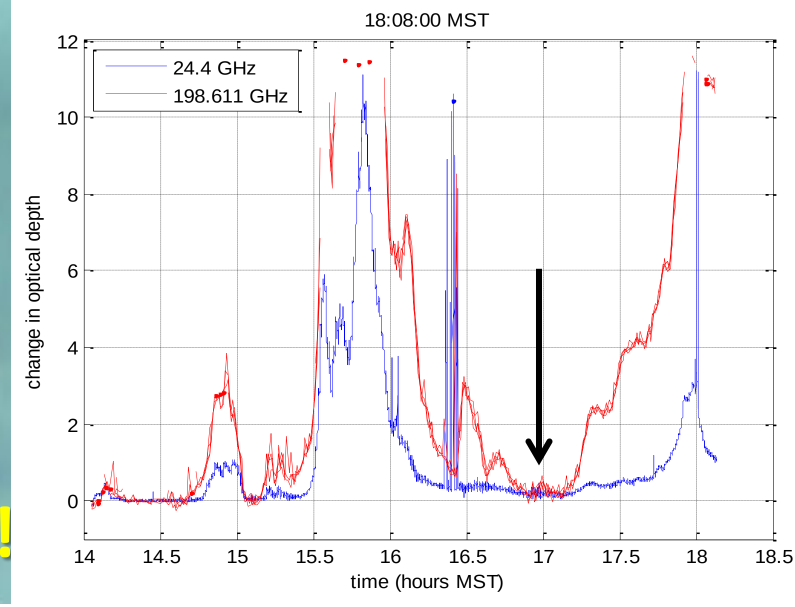
- Reasonable agreement with our local, precise rainfall measurements
- Rainfall rate measured at nearby Scout Camp was 46.4 mm per hour.

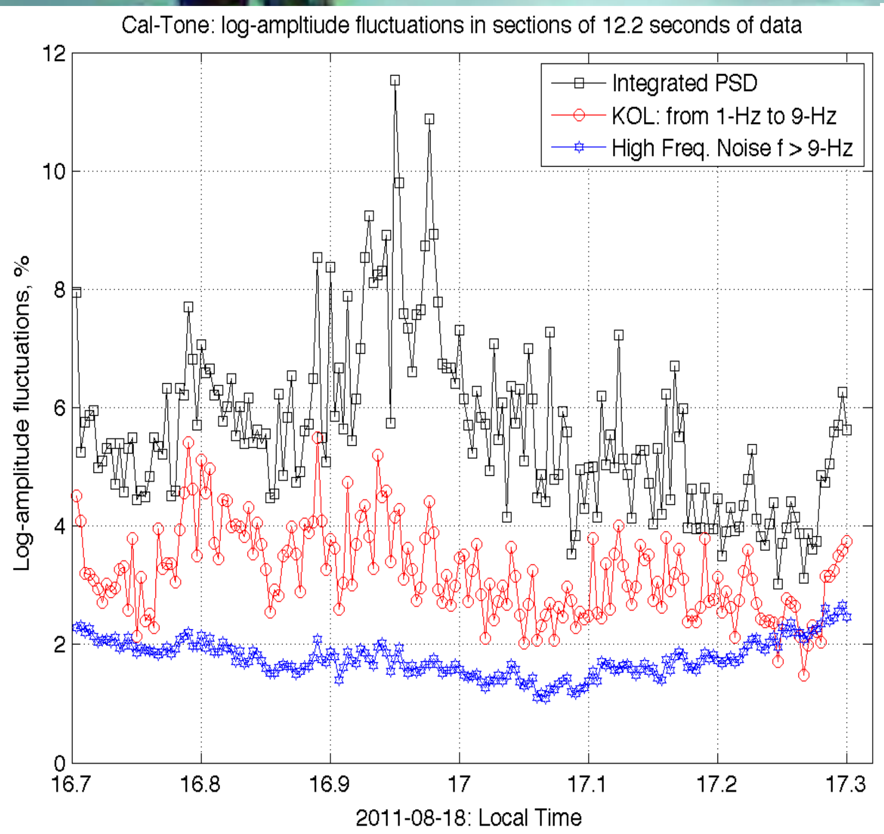


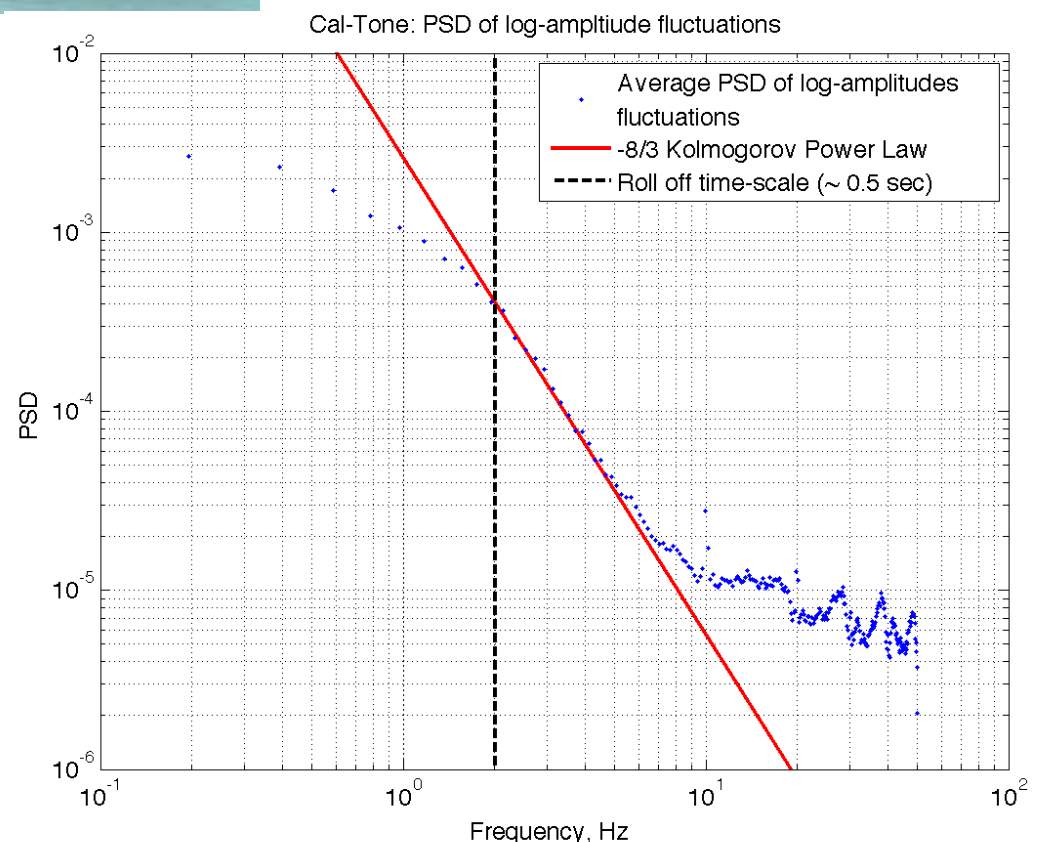
2011-08-18
15:48:00-00

Turbulence in Clear Air

- Amplitude variations ~6%
- FFT spectra shows 3 intervals
- Middle interval is Kolmogorov
- Equivalent C_n^2: 3e-13 $m^{-2/3}$ (LARGE!

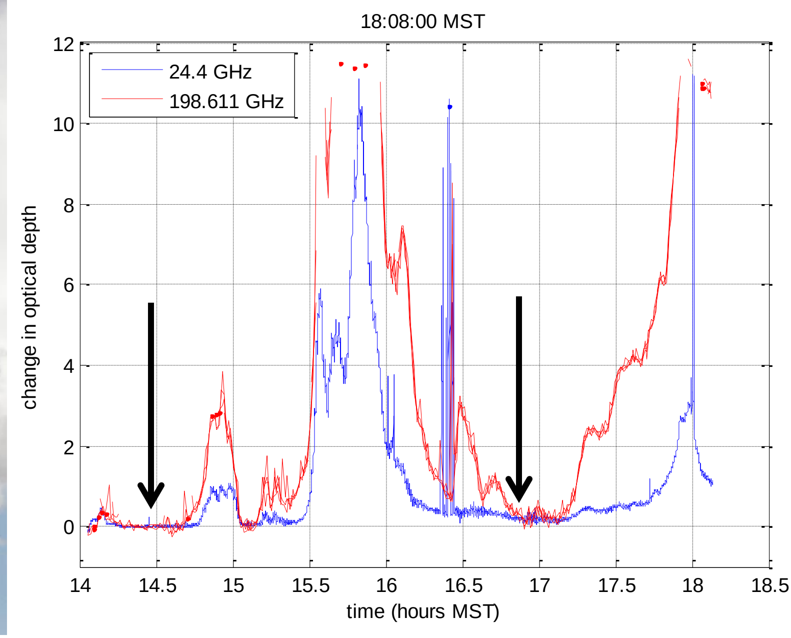


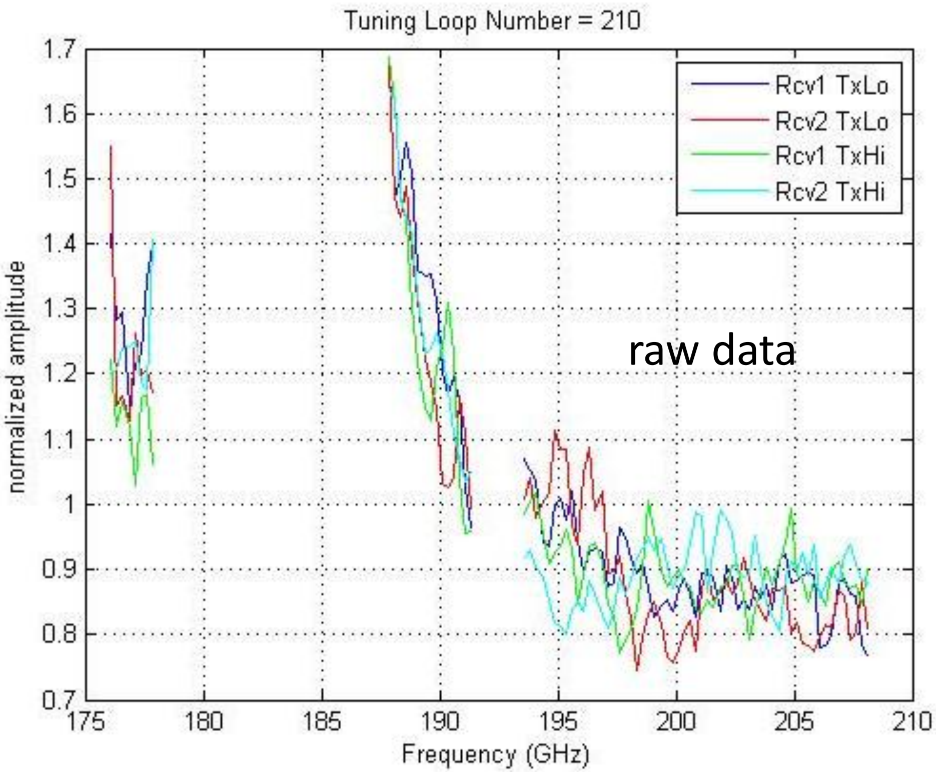


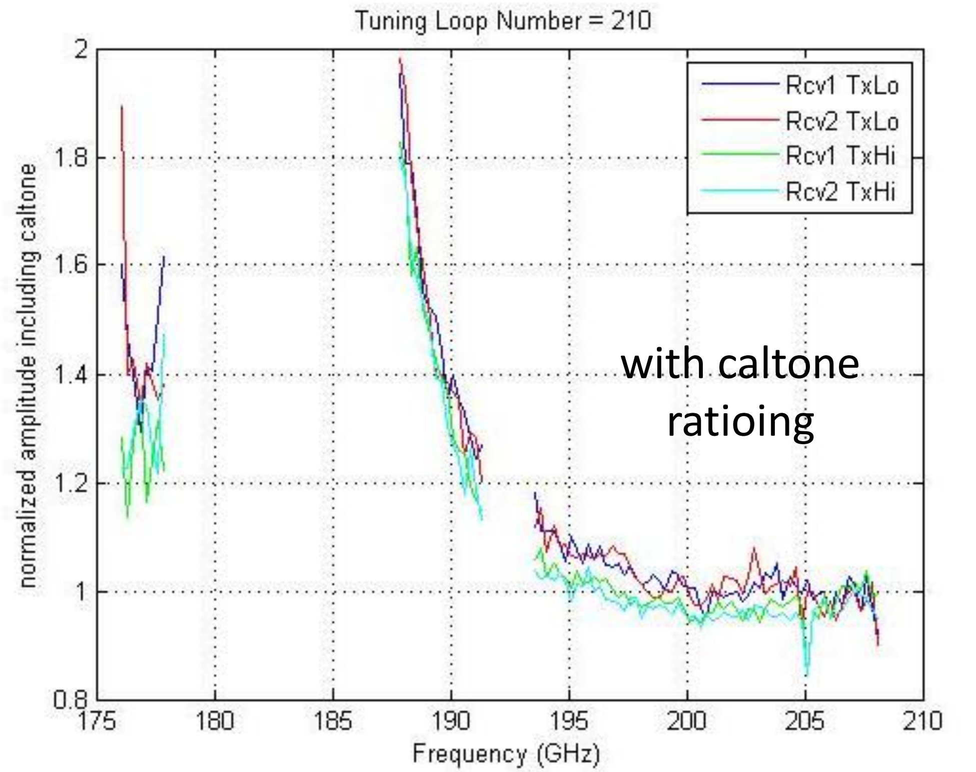


Cal-Tone Attenuation of Scintillations

- Ratio of 16:54 vs. 14:20 spectra
- Without & with normalization by caltone

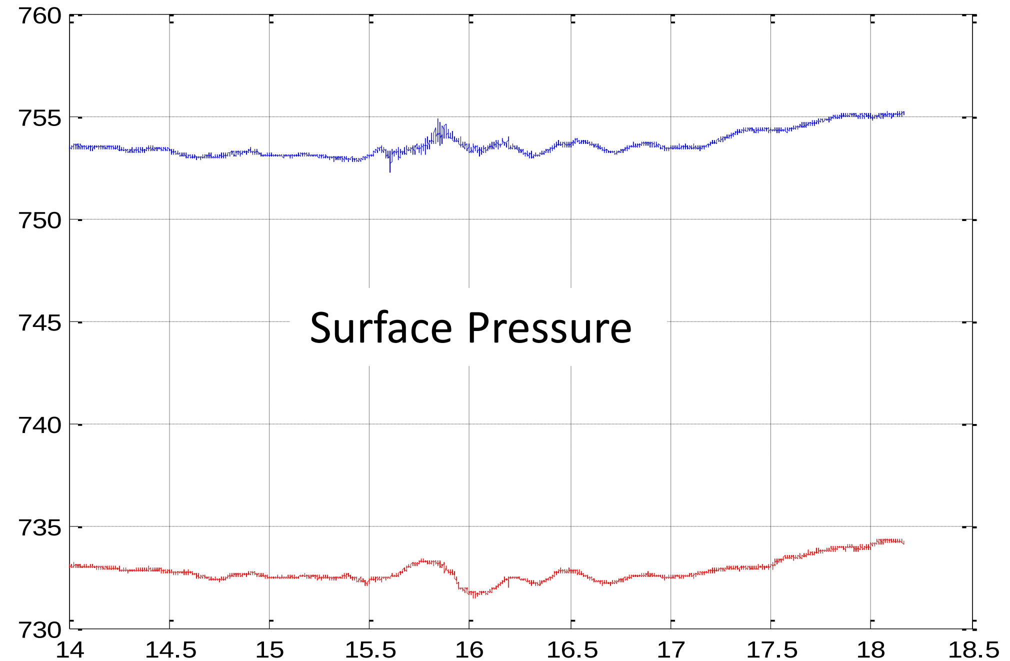


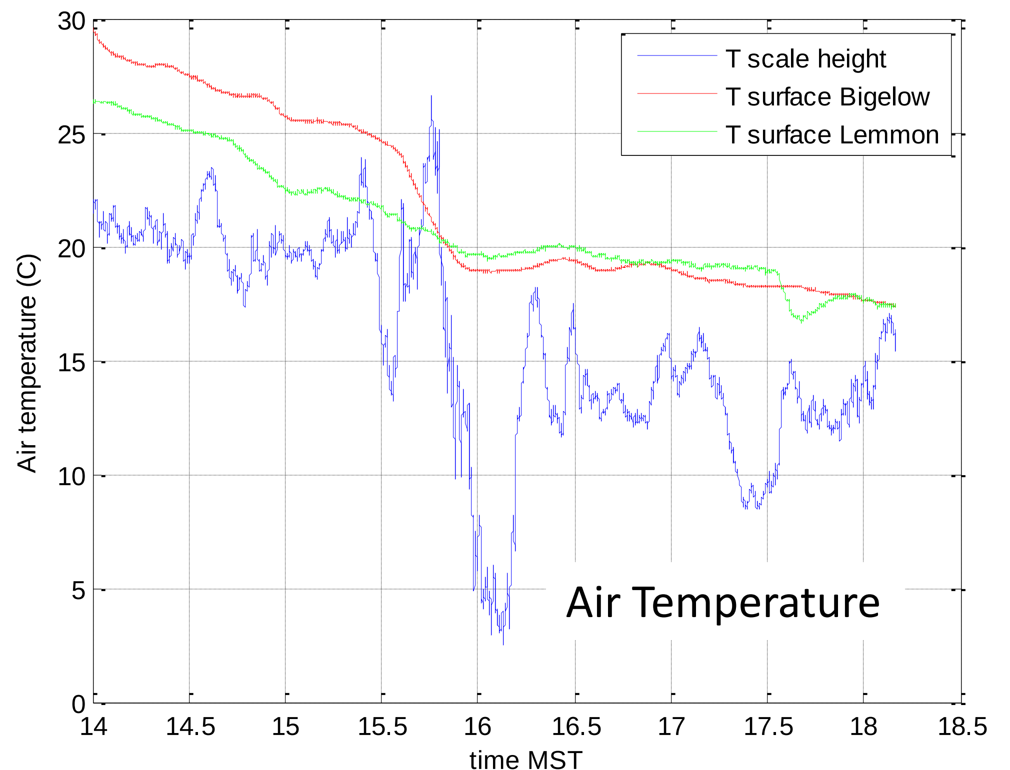


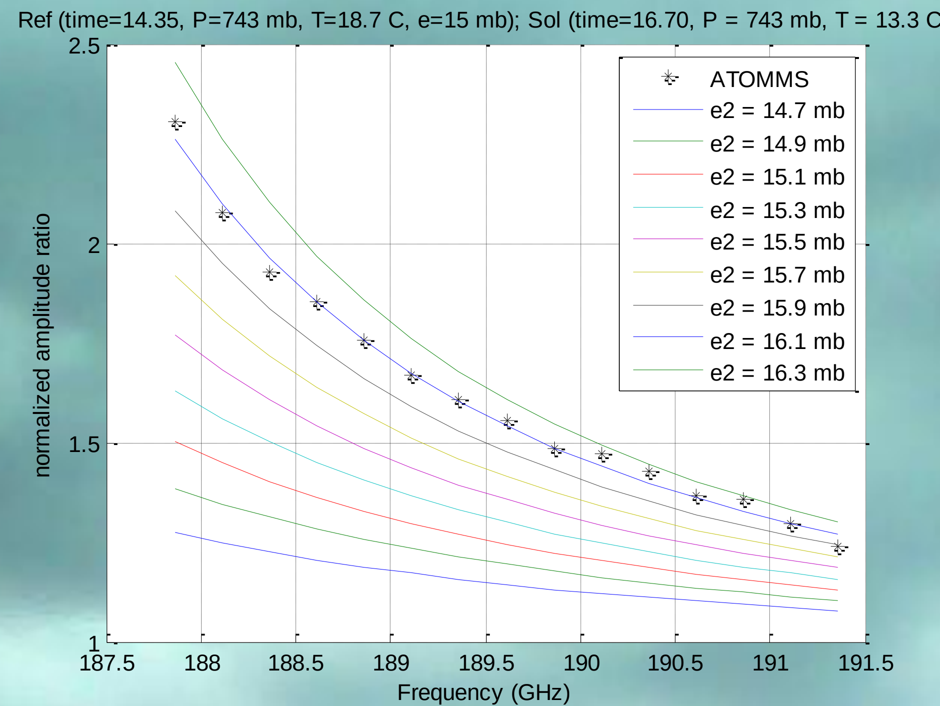


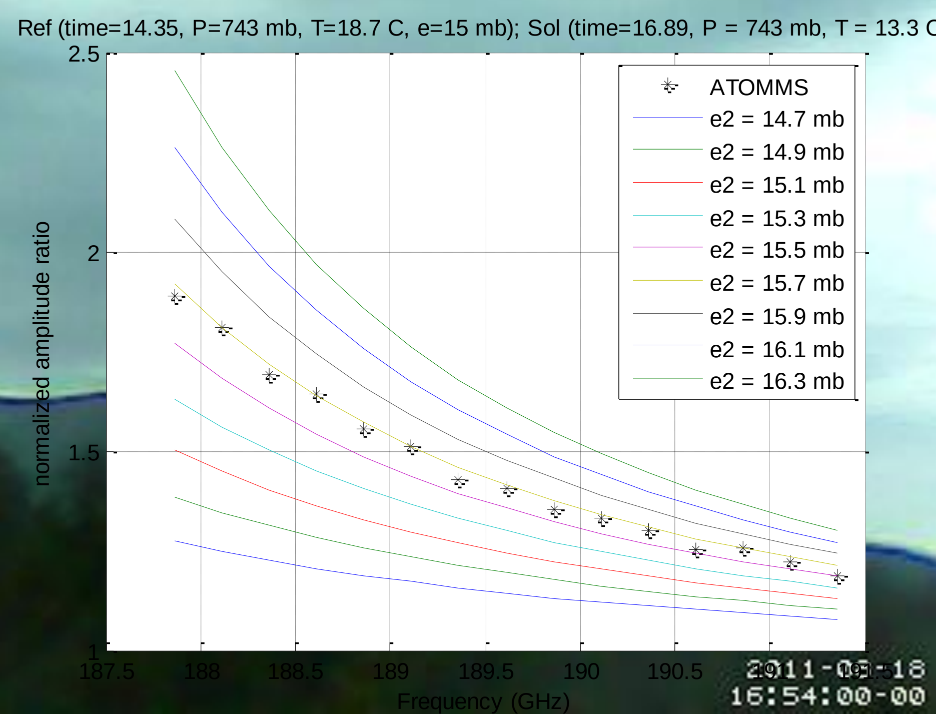
Thermodynamic Conditions

- Surface pressure is representative of pressure along signal path
- Surface air temperature is NOT representative of air temperature over the mountain valley
- Estimate average air temperature along signal path from the pressure scale height









- Sensitive to water vapor variations of ~0.1 mb which is < 1% absolute

2011-06-18
16:54:00-00

Summary

- **Instrument is working well in the field**
  - High dynamic range: Max τ measured so far ~11
    - Can push this further with longer integration time
  - Water vapor retrievals working
    - 183 GHz results equivalent to better than 1%
  - Scintillations due to turbulence are generally in expected range
    - Ratioing reduced scintillations
- **Powerful ground tool for atmospheric research**
  - H_2O, T, P, spectroscopy, droplet size distribution, radar interpretation, hydrology, turbulence
  - Looking to deploy instrument in mountains for extended periods
    - **Issues: clear line of sight, power, internet, security, lightning protection**

Aircraft to Aircraft Demonstration

- **Instrument presently too heavy for WB-57 nose**
  - Identified mechanical changes to lighten instrument
- **Problem with compact optics design**
  - Modifying optics design to separate 22 & 183 GHz optics
- **Conducted review for NSF**

  => Need more funds
- Transferring NSF grant to U. Colorado next month
  - **Work with LASP, NSF & NASA to obtain funds needed to perform the air-to-air demo**