Russian Boreal Forest Disturbance Maps Derived from Landsat Imagery, 1984-2000

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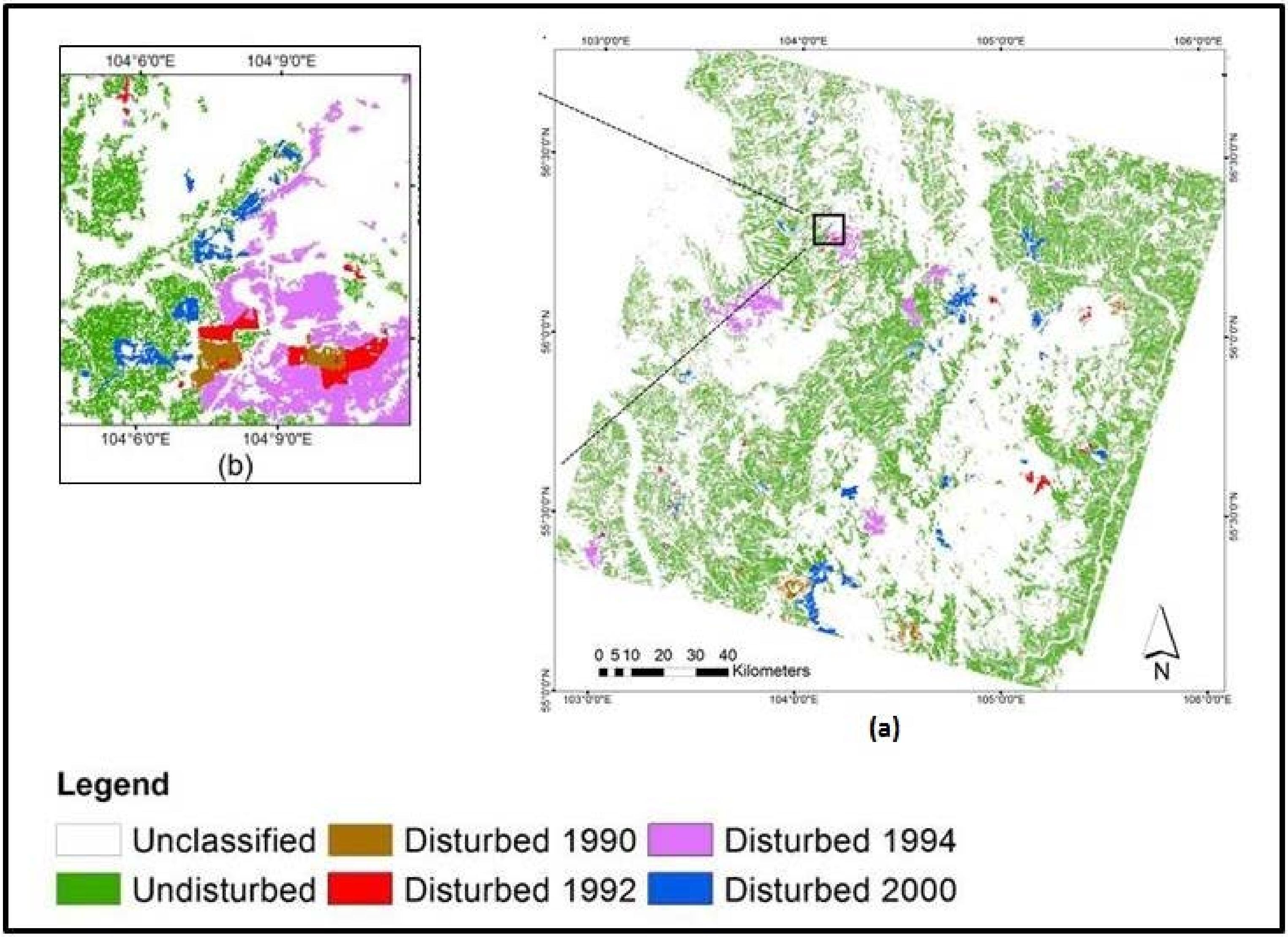
Summary

This data set provides Boreal forest disturbance maps at 30-m resolution for 55 selected sites across Northern Eurasia within the Russian Federation. Disturbance events were derived from selected high-quality multi-year time series of Landsat Thematic Mapper and Enhanced Thematic Mapper Plus images (stacks) over the 1984 to 2000 time period. Forest pixels were classified by year of latest disturbance or as undisturbed.

A time-stamped single-layer disturbance map was produced for each of the 55 Landsat stacks. Across the full extent of Russian forests, 15 classes were mapped: 14 disturbed classes represented by the individual years during which the disturbances were observed, and one undisturbed class. Not all 14 classes were mapped in each stack and the number of classes was determined by stack density.

These maps provide crucial information regarding disturbance history for the selected regions across the Russian boreal forest and are designed to serve as a training and/or validation data set for coarse resolution data products. The overall disturbance classification accuracy was assessed to be good. This data set will benefit subsequent studies on a variety of aspects of the Russian boreal forest, especially in relation to the carbon budget and climate.

There are 55 forest disturbance maps provided in GeoTIFF (.tif) format with this data set.



Disturbance map for a boreal forest site (Landsat Path 135, Row 21). Inset shows fine resolution of classifications. After Chen et al., 2014.

Citation

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1. Data Set Overview

This data set provides boreal forest disturbance maps at 30-m resolution across the Russian Federation for the years 1984 to 2000 derived from Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) imagery (stacks). MODIS Vegetation Continuous Fields (MOD44B) data for the year 2000 was used to delineate the forest areas to which subsequent processes were applied.

A time-stamped single-layer disturbance map was produced for each of the 55 Landsat stacks. Across the full extent of Russian boreal forests, 15 classes were mapped: 14 disturbed classes represented by the individual years during which the disturbances were observed, and one undisturbed class. Not all 14 classes were mapped in each stack and the number of classes was determined by stack density.

2. Data Characteristics

Spatial Coverage

The study area was 55 Landsat scenes located across the boreal forest in Northern Eurasia within the Russian Federation.

Spatial Resolution

30-m resolution for forest disturbance classes within each Landsat scene (approximately 170-km north-south by 185-km east-west)

Temporal Coverage

Data are for the periods 1984-2000

Temporal Resolution

Annual during the growing season, June-August

Study Area (All latitude and longitude given in decimal degrees)

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
The boreal forest in Northern Eurasia within the Russian Federation.	29.35547	139.0429	66.694742	41.75385

Data File Information

There are 55 GeoTIFF (.tif) files at 30-m resolution with this data set.

The files are named by the Landsat path and row number. For example, **DSM_114021** where 114 is the path and 021 is the row. The DSM_ prefix denotes these are “disturbance sample maps”.

Mapped Disturbance Classes

Across the full extent of Russian boreal forests, 15 classes were mapped: 14 disturbed classes represented by the individual years during which the disturbances were observed, and one undisturbed class. Not all 14 classes were mapped in each stack and the number of classes was determined by stack density.

Table 1. Mapped forest disturbance classes.

Class Value	Class Meaning
0	Unclassified
1	Undisturbed forest
85	Forest disturbed in 1985
86	Forest disturbed in 1986
87	Forest disturbed in 1987
88	Forest disturbed in 1988
89	Forest disturbed in 1989
90	Forest disturbed in 1990
91	Forest disturbed in 1991
92	Forest disturbed in 1992
93	Forest disturbed in 1993
94	Forest disturbed in 1994
95	Forest disturbed in 1995
96	Forest disturbed in 1996
97	Forest disturbed in 1997
98	Forest disturbed in 1998
99	Forest disturbed in 1999
100	Forest disturbed in 2000

Spatial Data and Spatial Reference Properties

Table 2. GeoTIFF properties common to all data files.

GeoTIFF Property	Common File Value
file_type	raster
file_format	GTiff
crs_proj4	+proj=utm +zone=**XX** +datum=WGS84 +units=m +no_defs The content of the proj4 string varies only by UTM Zone (**XX**). The UTM Zone for each file is given in the next table.
map_units	meters
res_x	30
res_y	30
n_bands	1
data_type	Int16
value_range_min	0

Table 3. GeoTIFF properties unique to each data file.

Filename	UTM Zone	min_x	min_y	max_x	max_y	n_cols	n_rows	Value _range _max	mapped classes
DSM_114021.tif	53	518775	6100665	721395	6297255	6754	6553	100	2000
DSM_114024.tif	53	388785	5629575	586665	5829165	6596	6653	100	1999, 2000
DSM_115025.tif	53	232755	5471205	452115	5686215	7312	7167	100	1992, 2000
DSM_117020.tif	53	272175	6250215	487395	6457905	7174	6923	100	1999, 2000
DSM_117021.tif	53	220095	6095175	452115	6314715	7734	7318	100	1999, 2000
DSM_117022.tif	52	562155	5948655	779445	6153315	7243	6822	99	1994, 1999
DSM_117023.tif	52	515685	5787945	733875	5995515	7273	6919	100	2000
DSM_121017.tif	52	417825	6710535	637245	6919965	7314	6981	100	2000

DSM_121019.tif	52	317895	6400035	536835	6612735	7298	7090	100	2000
DSM_121022.tif	51	550185	5944515	754185	6143715	6800	6640	100	1990, 2000
DSM_122021.tif	51	492075	6086385	718815	6298725	7558	7078	100	1992, 1999, 2000
DSM_123020.tif	51	439695	6240285	665415	6457095	7524	7227	100	2000
DSM_124017.tif	51	491775	6712665	705375	6922545	7120	6996	99	1999
DSM_124018.tif	51	445425	6560685	668715	6777015	7443	7211	99	1999
DSM_124021.tif	51	292695	6094365	523515	6312615	7694	7275	100	2000
DSM_127018.tif	50	526425	6557805	736215	6765135	6993	6911	100	1998, 2000
DSM_127019.tif	50	478425	6401235	701115	6619815	7423	7286	100	1998, 2000
DSM_130017.tif	50	329355	6707805	540555	6921525	7040	7124	100	2000
DSM_131020.tif	49	414315	6247845	628095	6457935	7126	7003	100	1994, 2000
DSM_133018.tif	49	339525	6555465	554745	6770685	7174	7174	95	1995
DSM_133019.tif	49	283395	6394185	510015	6624315	7554	7671	100	1995, 2000
DSM_135017.tif	48	546135	6707685	772815	6925395	7556	7257	100	2000
DSM_135018.tif	48	502395	6551985	726315	6777615	7464	7521	99	1999
DSM_135019.tif	48	455205	6407265	664305	6607785	6970	6684	100	1994, 2000
DSM_135020.tif	48	402615	6252015	631815	6465315	7640	7110	94	1990, 1992, 1994
DSM_135021.tif	48	360765	6095025	583845	6309315	7436	7143	100	1990, 1992, 1994, 2000
DSM_135022.tif	48	315015	5936355	522705	6146355	6923	7000	100	1990, 2000
DSM_137019.tif	48	278235	6393585	501015	6616395	7426	7427	100	1991, 1995, 1999, 2000
DSM_137020.tif	48	222105	6242085	447315	6468615	7507	7551	100	1991, 1995, 1998, 1999, 2000
									1991, 1992,

DSM_138021.tif	47	448185	6092235	666915	6308715	7291	7216	100	1994, 1999, 2000
DSM_140019.tif	47	353775	6402105	564195	6613785	7014	7056	100	1990, 2000
DSM_143017.tif	46	529635	6713775	737505	6924105	6929	7011	100	1992, 2000
DSM_147017.tif	45	519735	6712275	731565	6924105	7061	7061	100	2000
DSM_148019.tif	45	334875	6401595	548595	6615285	7124	7123	99	1990, 1991, 1999
DSM_151015.tif	45	310545	7015785	537315	7234875	7559	7303	99	1999
DSM_152016.tif	44	478215	6866535	691125	7078215	7097	7056	100	2000
DSM_161017.tif	42	323505	6708975	542745	6925695	7308	7224	93	1987, 1988, 1993
DSM_164017.tif	41	400635	6709365	612705	6923805	7069	7148	100	1987, 1989, 1999, 2000
DSM_165018.tif	41	262635	6558915	472815	6772905	7006	7133	99	1988, 1992, 1993, 1999
DSM_165019.tif	40	553815	6406605	769245	6618615	7181	7067	93	1986, 1988, 1993
DSM_165020.tif	40	507195	6251505	726915	6462615	7324	7037	100	1986, 1987, 1988, 1990, 1992, 1993, 2000
DSM_167018.tif	40	423045	6550785	644415	6769035	7379	7275	93	1987, 1988, 1993
DSM_170015.tif	40	336525	7015095	559935	7233405	7447	7277	100	2000
DSM_170017.tif	39	555255	6719595	751965	6922365	6557	6759	88	1988
DSM_170020.tif	39	406035	6247650	615525	6457740	6983	7003	99	1987, 1988, 1989, 1999
DSM_171016.tif	39	512985	6870015	734115	7082715	7371	7090	100	1987, 1988, 1989, 1994, 2000
DSM_171018.tif	39	408825	6556815	621225	6767985	7080	7039	100	1987, 1999, 2000
DSM_173029.tif	37	556665	4845435	741465	5037825	6160	6413	100	1986, 1988, 1989, 1991,

									1992, 1998, 1999, 2000
DSM_174017.tif	38	543300	6717750	744060	6921090	6692	6778	89	1987, 1988, 1989
DSM_175015.tif	39	259515	7019175	491115	7241715	7720	7418	100	1987, 1988, 1989, 2000
DSM_176019.tif	38	261885	6401325	475635	6616305	7125	7166	89	1988, 1989
DSM_179015.tif	38	246645	7017225	481515	7243815	7829	7553	100	1988, 2000
DSM_179016.tif	37	501795	6869205	704295	7074045	6750	6828	99	1985, 1986, 1988, 1999
DSM_182020.tif	36	375345	6246765	583185	6457485	6928	7024	95	1988, 1992, 1994, 1995
DSM_183016.tif	36	487590	6863520	697560	7075590	6999	7069	89	1988, 1989

3. Application and Derivation

These samples provide crucial information regarding disturbance history in selected regions across the Russian boreal forest and are designed to serve as a training and/or validation data set for coarse resolution data products. It can provide insights regarding the timing and locations of fire and logging events that occurred from 1985 to 2000 within the 55 selected Landsat stacks in the Russian boreal forest. Even though it is not a wall-to-wall assessment, this effort represents the first known product with this spatial resolution and geographical span before the year 2000 and could be expanded further using additional stacks. However, the current selection of stacks was considered to be a good representation of the heterogeneity of the Russian boreal forest in terms of both forest composition and disturbance regime.

Although the timing of disturbances are approximated and linked to the dates of available imagery rather than to the actual timing of disturbance, the applications of this data set include:

- An opportunity to assess variation in temporal changes in disturbance rates at decadal scales across Russia as a whole, and at finer temporal scales in European Russia, where dense stacks of Landsat data are available.
- The quantification of long-term forest disturbance history within individual Landsat scenes. While we did not provide a differentiation between fire- and logging-driven disturbances, this data set represents the basis for attribution based on extent, shape and possibly additional spectral information in the data.
- The potential to serve as a data input to studies that require information regarding the disturbance history of the Russian boreal forest.

This data set will benefit subsequent studies on a variety of aspects of the Russian boreal forest, especially in relation to the carbon budget and climate.

4. Quality Assessment

The results of the disturbance classification algorithm were evaluated through an analyst-driven double-blind validation (Chen et al., 2014). The double-blind method separates the process of mapping and random point generation from analyst-driven assessment by involving a separate set of analysts who have no *a-priori* knowledge of disturbances in the area and no prior involvement in the processing stream. These analysts are requested to examine the stack of imagery and assign the year of disturbance or undisturbed category to a set of points with no attributive information. No prior information is given to the analyst regarding the number of pixels expected to belong to a particular disturbed or undisturbed category with the varying number of points among image stacks.

The time-stamped sample points were compared with the classification results through the construction of confusion matrices and corresponding statistics including the omission and commission errors, overall accuracy and Kappa coefficient. In addition to the global accuracy assessment (*i.e.*, across the entire Russian boreal forest), the 55 maps were divided into several groups based on either geographical location (*i.e.*, European Russia, Western Siberia and Eastern Siberia) or stack density (*i.e.*, sparse or dense). For each of these groups, the evaluation statistics were also calculated and compared.

The overall accuracy, calculated based on the 55 maps across the entire Russian boreal forest, was 83.98%, along with a Kappa coefficient of 0.83. Overall commission and omission errors of the classification were low. The average omission error for all classes was 11.24%, with the lowest omission error for 1998 disturbances (0.00%). The omission error for the undisturbed class was relatively high at 55.04%. In terms of commission error, the average value was 16.28%, and the range across all classes was relatively narrower than that of the omission error, with the largest and smallest being 30.48% (for 1990 disturbances) and 1.00% (for 1995 disturbances), respectively.

The values of overall accuracy and Kappa coefficient were similar for all the maps across the entire Russian forests as well as across three major geographic regions and between dense and sparse stacks of imagery. The lowest Kappa (0.76) and overall accuracy (79.01%) were found in Western Siberia—a region dominated by wetlands. The highest Kappa (0.85) and overall accuracy (86.69%) were found in Eastern Siberia. A small difference in Kappa and overall accuracy was also registered between sparse and dense stacks of imagery. It appeared that the confusion between specific time-stamps of disturbances was slightly higher in dense stacks, whereas a smaller number of selections in sparse stacks resulted in a clearer identification of the time of disturbance.

The classifier performance was less desirable in the identification of the undisturbed class (Error of Omission: 55.04%). This may have multiple causes. First, because the number of validation points selected for each class was similar (approximately 100), and because the undisturbed class appeared in almost all classified images, the number of validation points selected from the undisturbed class in each image was small (two points). Such a small number of validation points for this particular class resulted in the high sensitivity of the undisturbed class to errors. Another potential reason involved the capability of the analysts to correctly identify disturbances. There was large inter-annual variation in the beginning and end dates for the growing season. It is possible that the presence of phenological variations confused the analysts and caused them to identify forests as disturbed when this was not the case. Also, the analysts may have been less likely to differentiate between inter-annual and seasonal variability in forest conditions and natural or anthropogenic disturbances. As a result, the analysts might have mistakenly identified the undisturbed pixels as part of the disturbed classes, which inflated the Error of Omission for the undisturbed class. Also, forests affected by insect infestation may also have shown signs of depressed growth over a period of time, but never resulted in stand mortality, thus contributing to the misclassification by the analysts.

The accuracy of these disturbance maps was also examined according to stratification by geographic region and stack density. The results suggested that regardless of the grouping criteria (*i.e.*, geographical location or stack density), the accuracy of the classification algorithm was generally consistent.

5. Acquisition Materials and Methods

Study area

The selected study area was the boreal forest in Northern Eurasia within the Russian Federation (European Russia, Western Siberia and Eastern Siberia).

- About 300 tree species are distributed across this vast area; the dominant species include *Larix sibirica* (Siberian or Russian Larch), *L. gmelinii* (Dahurian Larch), *Pinus sylvestris* (Scots Pine), *P. sibirica* (Siberian Pine), *Picea abies* (European or Norway Spruce), *P. obovata* (Siberian Spruce) and *Betula spp.* (Birch) (Tishkov 2002).
- The climate in the region is highly or extremely continental, characterized by very cold winters and warm summers (Shahgedanova 2002). Precipitation in the region is light or modest (Shahgedanova 2002).
- As with other boreal regions, wildfire is the most important disturbance agent in the Northern Eurasian boreal forest. An average area of 20,000–30,000 km2 is estimated as burned each year across the region (Goldammer and Furyaev 1996).
- In addition to wildfire, another major disturbance agent in the boreal forest of Northern Eurasia is logging.

Measurement Methods

Image Selection

This data set was derived from Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) imagery spanning the period between 1984 and 2000. MODIS Vegetation Continuous Fields (MOD44B) data for the year 2000 were used to delineate the forest areas to which subsequent processes were applied. The Vegetation Continuous Fields product was used to focus the distribution of the Landsat stacks within forested areas (defined here as all pixels with percent tree cover greater than 10%) and thus excluded large zones of croplands and grasslands in southern Russia and tundra in the north.

Preference was given to sites with Landsat images (stacks) containing the largest number of cloud-free images during the growing season (1 June through 31 August) and with near-annual observations rather than to those with the greatest number of images available since many images came from the growing season of the same year.

Selected Landsat images (stacks) for the 55 sites included 241 terrain-corrected L1T images acquired during the 1 June to 31 August growing seasons of 1984-2000. Sites were distributed across the full extent of Russian forests. European Russia, Western Siberia and Eastern Siberia had 16, 7, and 32 sites, respectively.

Figure 2. Distribution of the sites for which disturbance maps were generated. Red, blue and green represent sites in European Russia (16), Western Siberia (7), and Eastern Siberia (32), respectively. Letters in the polygons indicate the number of Landsat images in each time series stack, with 'D' and 'S' representing dense and sparse stacks. Note that the number of years (classes) of disturbed pixels was determined, in part, by the availability of Landsat images.

Image Pre-Processing and Masking

All L1T Landsat images were converted to surface reflectance using the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS, V1.1.1) (Masek et al., 2006, Feng et al., 2013). The image stacks were clipped to their common extent to eliminate the variation in exact scene coverage between different images. Although preference was given to near-cloud-free imagery, considerable amounts of cloud and cloud shadow remained. To ensure high confidence disturbances mapping, liberal masks were designed to overestimate cloud and cloud shadow presence, particularly at the edges of clouds and cloud shadows. The masked-out pixels in the Landsat images were removed from the subsequent processes.

Disturbance Mapping

The method described in Healey, *et al.* (2005), which is based on the disturbance index (DI), was adopted as the core algorithm to detect disturbed pixels from the multiple Landsat images (stack) at a site. Multiple DI images from the growing season of the same year were composited to create a single annual DI image. DI image stacks were subsequently used to map and time-stamp forest disturbances. Difference DI (ΔDI) was calculated for each two adjacent years. Based on the ΔDI and additional criteria (Chen et al., 2014) a pixel was identified as a disturbed pixel and marked by the year in which it was discovered to be disturbed (*i.e.*, the latter year in each image pair). If a pixel was disturbed multiple times as recorded by the temporal DI stack, the latest disturbance event in each stack was given precedence.

Following this protocol, a time-stamped single-layer disturbance map was produced for each site from the original Landsat images. Across the full extent of Russian forests, 15 classes were mapped: 14 disturbed classes represented by the individual years during which the disturbances were observed, and one undisturbed class. However, it is important to note that not all 14 disturbed classes were mapped for a given site and the number of classes was determined, in part, by the availability of Landsat images.

6. Data Access

This data is available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

Russian Boreal Forest Disturbance Maps Derived from Landsat Imagery, 1984-2000

Contact for Data Center Access Information:

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