First ISCCP Regional Experiment (FIRE) Cirrus 1 TIROS Operational Vertical Sounder (TOVS) Langley DAAC Data Set Document

Summary:

The First ISCCP Regional Experiments (FIRE) have been designed to improve data products and cloud/radiation parameterizations used in general circulation models (GCMs). Specifically, the goals of FIRE are (1) to improve basic understanding of the interaction of physical processes in determining life cycles of cirrus and marine stratocumulus systems and the radiative properties of these clouds during their life cycles and (2) to investigate the interrelationships between the ISCCP data, GCM parameterizations, and higher space and time resolution cloud data.

To-date, four intensive field-observation periods were planned and executed: a cirrus IFO (October 13-November 2, 1986); a marine stratocumulus IFO off the southwestern coast of California (June 29-July 20, 1987) a second cirrus IFO in southeastern Kansas (November 13-December 7, 1991); and a second marine stratocumulus IFO in the eastern North Atlantic Ocean (June 1-June 28, 1992). Each mission combined coordinated satellite, airborne, and surface observations with modeling studies to investigate the cloud properties and physical processes of the cloud system.

This data set contains temperature soundings from the TOVS sensor on the NOAA-9 and NOAA-10 satellites and soundings were made for each pixel over the Cirrus IFO Network. Sounding information contains both standard levels and layer means. Cloud top heights and cloud amount*emmissivity also are included.

Table of Contents:

1. Data Set Overview:

Data Set Identification:

FIRE_CI1_TOVS: First ISCCP Regional Experiment (FIRE) Cirrus 1 TIROS Operational Vertical Sounder (TOVS) Data (FIRE_CI1_TOVS)

Data Set Introduction:

Project FIRE (First ISCCP Regional Experiment) is a U.S. cloud climatology research program to validate and improve ISCCP (International Satellite Cloud Climatology Project) data products and cloud/radiation parameterizations used in general circulation models (GCMs).

The primary emphasis of FIRE is the study of marine stratocumulus and cirrus cloud systems. These two cloud types were selected because of their recognized importance for global climate and their scientific appeal for many members of the scientific community.

This data set contains temperature soundings from the TOVS sensor on the NOAA-9 and NOAA-10 satellites and soundings were made for each pixel over the Cirrus IFO Network. Sounding information contains both standard levels and layer means. Cloud top heights and cloud amount*emmissivity also are included.

Objective/Purpose:

The objective of FIRE is to investigate the cloud properties and physical processes of the cloud systems using combined and coordinated satellite, airborne, and surface observations with modeling studies.

The goals of FIRE are (1) to improve the basic understanding of the interaction of physical processes in determining life cycles of cirrus and marine stratocumulus systems and the radiative properties of these clouds during their life cycles and (2) to investigate the interrelationships between the ISCCP data, GCM parameterizations, and higher space and time resolution cloud data.

Summary of Parameters:

Altitude
Barometric Altitude
Cloud Amount
Cloud Top Pressure
Cloud Top Temperature
Dew/Frost Point Temperature
Ozone
Precipitable Water Profiles
Radiance
Skin Temperature
Surface Pressure
Surface Temperature
Temperature Profiles
Tropopause Pressure
Tropopause Temperature
Water Vapor Mixing Profiles

Discussion:

FIRE is an on-going, multi-agency program designed to promote the development of improved cloud and radiation parameterizations for use in climate models, and to provide for assessment and improvement of ISCCP products. FIRE is forcused on two cloud types, cirrus and marine stratocumulus clouds, that have important roles in the climate system as a result of their extensive areal coverage.

Related Data Sets:

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2. Investigator(s):

Investigator(s) Name and Title:

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Space Science and Engineering Center
University of Wisconsin-Madison

Title of Investigation:

First ISCCP Regional Experiment (FIRE)

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3. Theory of Measurements:

The TOVS system consists of three instruments: the HIRS/2I, the SSU, and the MSU. All three instruments measure radiant energy from various altitudes of the atmosphere and the data are used to determine the atmosphere's temperature from the Earth's surface to the upper stratosphere.

HIRS/2: The Instantaneous Field of View (IFOV) of the HIRS/2 channels are stepped across the satellite track by use of a rotating mirror. This cross-track scan, combined with the satellite's motion in orbit, provides coverage of a major portion of the Earth's surface. The width of the crosstrack scan is 99 degrees or 2240 km and consists of 56 steps. The mirror is stepped from home position in 55 steps of 1.8 degrees. At the end of the scan (at position 56) the mirror rapidly returns to the home position and repeats the scanning pattern. Each scan takes 6.4 seconds to complete (100 milliseconds per step) and there are 42 km between IFOVs along the sub-orbital track. The optical FOV is 1.25 degrees which gives a ground IFOV of 17.4 km diameter at the nadir. At the end of the scan, the ground IFOV is 58.5 km cross-track by 29.9 km along-track.

MSU: The MSU sensors consist of two four-inch diameter antennas, each having an Instantaneous Field of View (IFOV) of 7.5 degrees. The antennas are step-scanned through eleven individual 1.84 second Earth viewing steps and require a total of 25.6 seconds to complete. The 124 km IFOV resolution at the subpoint creates an underlap of approximately 115 km between adjacent scan lines.

SSU: The SSU is a step-scanned far-infrared spectrometer with three channels in the 15 micrometer carbon dioxide absorption band (the SSU instruments have been contributed to the TIROS-N series satellites by the British government). It makes use of the pressure modulation technique to measure radiation emitted from carbon dioxide at the top of the Earth's atmosphere. The principles of operation are based on the selective chopper radiometer flown on Nimbus 4 and 5, and the pressure modulator radiometer flown on Nimbus 6. The three SSU channels have the same frequency, but different cell pressures.

The Level 1b processing flow begins with sensor data receipt by the command and Data Acquisition (CDA) stations (Wallops Island, VA and Gilmore Creek, AK) where the data are re-broadcast via communications satellites, to NOAA/NESDIS in Suitland, MD. (Level 1b data are defined as raw data that have been quality controlled and to which calibration and earth location information have been appended, but not applied.) The ephemeris data (orbital reference data) is funneled through the Advanced Earth Location Data System (AELDS) software on an IBM mainframe which feeds an IBM 921 for Level 1b production. Earth location and calibration data are appended (but not applied) to the data as part of the Level 1b processing. AELDS is a completely on-line data driven system within the preprocessing system. The earth locations are computed for specific pixels using the data time corrected for clock drift, if any. The physical algorithm used to compute earth locations is described in NESS Tech. Memo 107: Appendix C. The earth location values are computed by using the exact equations of the physical algorithm. The use of raw data time as corrected for satellite clock drifts, combined with the use of exact equations, eliminates a major source of error in the earth locations.

As part of the Level 1b processing, calibration information is also appended to the data stream. Typically, the TOVS sensors are calibrated in-flight using views of space and warm and/or cold targets as a reference. This information is included with the raw MSU data as part of the Level 1b data. Actual calibration of the data is left for the user.

4. Equipment:

Sensor/Instrument Description:

Collection Environment:

Source/Platform:

NOAA-9 and NOAA-10

Source/Platform Mission Objectives:

The TIROS-N was launched in October 1978. TIROS-N has been followed by NOAA-6 through NOAA-14, and further satellites in the series are planned. The primary instruments aboard these satellites are the Advanced Very High Resolution Radiometer (AVHRR) and the TIROS

Operational Vertical Sounder (TOVS) complex. The main objectives are:

(a) to view the global atmosphere regularly and reliably both day and night. To provide direct readout data to local ground stations within communication range of the satellite.

(b) to provide for sounding the global atmosphere regularly and reliably and to provide quantitative information for use in numerical weather prediction, and

(c) to provide for continuous viewing of weather features and for collecting and relaying meteorological data from remote platforms such as buoys, ships, automatic stations, aircraft and balloons.

Key Variables:

Altitude
Barometric Altitude
Cloud Amount
Cloud Top Pressure
Cloud Top Temperature
Dew/Frost Point Temperature
Ozone
Precipitable Water Profiles
Radiance
Skin Temperature
Surface Pressure
Surface Temperature
Temperature Profiles
Tropopause Pressure
Tropopause Temperature
Water Vapor Mixing Profiles

Principles of Operation:

The TOVS system consists of three instruments: the High Resolution Infrared Radiation Sounder (HIRS/2I), the Stratospheric Sounding Unit (SSU), and the Microwave Sounding Unit (MSU). All three instruments measure radiant energy from various altitudes of the atmosphere and the data are used to determine the atmosphere's temperature from the Earth's surface to the upper stratosphere (see Section 3).

Sensor/Instrument Measurement Geometry:

HIRS/2:
The following table contains typical values of the HIRS/2 spectral characteristics and noise equivalent differential radiance (NEdN's in units of milliWatts/m2-steradians-cm-1). There is some variation in the parameters from one HIRS/2 instrument to another.

Channel	Half-power Bandwidth (cm-1)	Maximum Scene Temperature (K)	Specified NEdN
1	3	280	3.00
2	10	265	0.67
3	12	240	0.50
4	16	250	0.31
5	16	265	0.21
6	16	280	0.24
7	16	290	0.20
8	35	330	0.10
9	25	270	0.15
10	60 17*	290 310*	0.16 0.09*
11	40	275	0.20
12	80	260	0.19
13	23	300	0.006
14	23	290	0.003
15	23	280	0.004
16	23	260	0.002

17	23 26*	280 350*	0.002
18	3500	340	0.002
19	100	340	0.001
20	1000	100A	0.10A

* In the above table, NOAA-11 and all subsequent satellites (except NOAA-12) have channels 10 and 17 at different locations in the spectrum. An * (asterisk) indicates the values for NOAA-11.

The HIRS/2 instrument uses a 15 cm diameter optical system to gather emitted energy from the Earth's atmosphere. The Instantaneous Field of View (IFOV) of all the channels is stepped across the satellite track by use of a rotating mirror. This cross-track scan in conjunction with the satellites's motion in orbit provides coverage of a major portion of the Earth's surface.

The energy received by the telescope is separated by a dichroic beam splitter into longwave (> 6.4 micrometers) and shortwave (< 6.4 micrometers) energy, controlled by field stops and passed through bandpass filters and relay optics to the detectors. In the shortwave path, a second dichroic beam splitter transmits the single visible channel to its detector.

The analog data output from the HIRS/2 sensor is digitized on board the satellite at a rate of 2880 bits per second. At this rate, there are 288 bits per step (step time = 100 milliseconds) which includes all 20 channels. The data are digitized to 13-bits precision. Essential parameters of the instrument are shown in the following table.

Parameter	Value
Calibration	Stable blackbodies (2) and space background
Cross-track scan	+/- 49.5 degrees (+/- 1120 km)
Scan time	6.4 seconds
Number of steps	56
Optical FOV	1.25 degrees
Step angle	1.8 degrees
Step time	100 milliseconds
Ground IFOV (nadir)	17.4 km diameter
Ground IFOV (end of scan)	58.5 km cross-track by 29.9 km along-track
Distance between IFOV's	42 km along-track
Data rate	2880 bits/second

MSU:
The MSU instrument was designed to make passive measurements in four regions of the 5.5 micrometer oxygen region of the spectrum. The following table shows the spectral frequencies, bandwidths and typical Noise Equivalent delta Temperature (NEdT) values of the four MSU channels, along with the optical scan properties of the MSU.

MSU instrument parameters

Characteristics	Value				Tolerance
	Ch 1	Ch 2	Ch 3	Ch 4	
Frequency (Ghz)	50.3	53.74	54.96	57.95	+/- 20 MHz
RF Bandwidth (MHz)	220	220	220	220	Maximum
NEdt (K)	0.3	0.3	0.3	0.3	Maximum
Antenna Beam Efficiency ()	>90	>90	>90	>90	
Dynamic Range (K)	0-350	0-350	0-350	0-350	

Calibration	Hot reference body and space background each scan cycle
Cross-track scan angle	+/- 47.35 degrees
Scan time	25.6 seconds
Number of steps	11
Step angle	9.47 degrees
Step time	1.84 seconds
Angular resolution	7.5 degrees (3 db)
Data rate	320 bits per second

SSU:
The SSU was supplied to NOAA by the United Kingdom Meteorological Office. It employs a selective absorption technique to make measurements in three channels. The principles of operation are based on the selective chopper radiometer flown on Nimbus 4 and 5 and the Pressure Modulator Radiometer flown on Nimbus 6.

The SSU makes use of the pressure modulation technique to measure radiation emitted from carbon dioxide at the top of the Earth's atmosphere. A cell of carbon dioxide gas in the instrument's optical path has its pressure changed (at about a 40 Hz rate) in a cyclic manner. The spectral characteristics of the channel and therefore the height of the weighting function is then determined by the pressure in the cell during the period of integration. By using three cells filled at different pressures, weighting functions peaking at three different heights can be obtained. The primarly objective of the instrument is to obtain data from which stratospheric (25 - 50 km) temperature profiles can be determined. The SSU is used in conjunction with HIRS/2 and MSU to determine temperature profiles from the surface to the 50 km level (TOVS Sounding Product).

The SSU consists of a single primary telescope (8 cm diameter) with a 10 degree Instantaneous Field of View (IFOV) which is step scanned perpendicular to the satellite subpoint track. Each scan line is composed of eight individual 4.0 second steps and requires a total of 32 seconds, including time for the mirror retrace. The 10 degree IFOV gives a resolution of 147.3 km at nadir and the stepping produces an underlap between adjacent scan lines of approximately 62 km at nadir. At the end of the scan, the ground IFOV is 244 km cross-track by 186.1 km along-track.

Manufacturer of Sensor/Instrument:

HIRS/2I
ITT
Aerospace/Communications Division
1919 West Cook Road
Fort Wayne, Indiana 46801
USA

MSU
California Institute of Technology
Jet Propulsion Laboratory
Pasadena, California

SSU
Supplied by the United Kingdom Meteorological Office

Sensor/Instrument:

The TOVS systems consists of three instruments as follows:

HIRS/2I: This instrument detects and measures energy emitted by the atmosphere to construct a vertical temperature profile from the Earth's surface to an altitude of about 40 km. Measurements are made in 20 spectral regions in the infrared band. Note that one frequency lies at the high frequency end of the visible range.

SSU: Temperature measurements from the upper stratosphere are derived from radiance measurements made in three channels using a pressure modulated gas (CO_2) to accomplish selective bandpass filtrations of the sampled radiances. The gas is of a pressure chosen to yield weighting functions peaking in the altitude range of 25 to 50 km where atmospheric pressure is from 15.1 to 1.5 mbar respectively. This gas is contained in three cells, one of which is located in the optical path of each channel.

MSU: This unit detects and measures the energy from the troposphere to construct a vertical temperature profile to an altitude of about 20 km. Measurements are made by radiometric detection of microwave energy divided into four frequency channels. Each measurement is made by

comparing the incoming signal from the troposphere with the ambient temperature reference load. Because its data are not seriously affected by clouds, the unit is used along with the HIRS/2I to remove measurement ambiguity when clouds are present.

Calibration:

Specifications:

Not applicable.

Tolerance:

Not applicable.

Frequency of Calibration:

HIRS/2: The HIRS/2 sensor can be commanded to automatically enter a calibration mode every 256 seconds. When the instrument is in the calibration mode, the mirror (starting from the beginning of a scan line) rapidly slews to a space view and samples all channels for the equivalent time of one complete scan line of 56 scan steps. Next, the mirror is moved to a position where it views a cold calibration target and data is taken for the equivalent of 56 scan steps. The mirror is then stepped to view an internal warm target for another 56 scan steps. Upon completion of the HIRS/2 calibration mode, the mirror continues its motion to the home position where it begins normal Earth scan. The total calibration sequence is equivalent to three scan lines (no Earth location data are obtained during this period).

MSU: Unlike the HIRS/2 and SSU instruments, the MSU has no special calibration sequence that interrupts normal scanning. The calibration data is included in a scan line of data. From the last Earth view position, the reflector rapidly moves 4 steps to view space, 10 additional steps to view the housing, and then returns to the home position to begin another scan line. Since each scan line requires 25.6 seconds, synchronization of MSU within the other two TOVS instruments occurs every 128 seconds (5 scan lines).

The MSU data output represents an apparent brightness temperature after a 1.84-second integration period per step. The data is quantized to 12-bit precision and combined with telemetry and step position information to produce an effective output data rate of 320 bits per second.

SSU: A calibration sequence is initiated every 256 seconds (8 scans) during which the radiometer is in turn, stepped to a position to view unobstructed space and an internal blackbody at a known temperature. This calibration mode is synchronized with the HIRS/2 instrument.

Data is sampled at the rate of 40 samples per second, and is digitized to 12-bit precision. Therefore, the SSU data rate is 480 bits per second.

Other Calibration Information:

Satellite black body temperatures are generally accurate to 2 Deg K. Atmospheric sounding temperatures have accuracies of 2.5 to 3.5 deg. Cloud top heights have accuracies of 50 MB, and the tropopause height accuracy is 100 MB.

For further details on calibration, see Section 4.5 of the NOAA Polar Orbiter Data Users Guide (Reference x).

5. Data Acquisition Methods:

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6. Observations:

Data Notes:

Not available.

Field Notes:

Not available.

7. Data Description:

Spatial Characteristics:

The sounds were taken for each pixel measured by the satellite. The size of the pixels vaied from 30 KM when the satellite was directly overhead to 70 KM when the fire array was on the edge of the satellite's view.

Spatial Coverage:

Data Set Name	Min Lat	Max Lat	Min Lon	Max Lon
FIRE_CI1_TOVS	40.00	49.00	-93.00	-89.00

Spatial Coverage Map:

There are no maps available for this data set.

Spatial Resolution:

The soundings were taken for each pixel measured by the satellite. The size of the pixels varied from 30 KM when the satellite was directly overhead to 70 KM when the FIRE array was on the edge of the satellite's view.

Projection:

Not applicable.

Grid Description:

Not applicable.

Temporal Characteristics:

Temporal Coverage:

Data Set Name	Begin Date	End Date
FIRE_CI1_TOVS	10-14-1986	11-02-1986

Temporal Coverage Map:

There are no maps available for this data set.

Temporal Resolution:

Temperature soundings were made at the overpass times of the NOAA 9 and 10 satellites when the FIRE network (Wisconsin) was in view of the satellite. There is a maximum of 4 observations times per day.

Data Characteristics:

Parameter/Variable:

The TOVS on NOAA-9 and 10 has infrared spectral channels and one visible channel. Temperature, mixing ratio, pressure heights, cloud top heights and cloud amounts (fractional coverage*cloud emmissivity) were derived from the infrared channels. A description of the derived parameters is as follows:

H01-H19 - the black body temperatures for the radiances measured by these channels.

H20 - the visible channel raw radiance mesurement. It has no meaning and should not be confused with the AVHRR visible CH.

M01-M04 - the black body temperatures for the radiances measured by the four microwave channels.

P01-P04 - precipitable water values for three layers and the total atmospheric column.

L85-L4 - the layer mean temperatures.

T100-T01 - the temperatures at specific levels from 1000 MB to 10 MB.

W100-W01 - the mixing ratios for the same levels.

Z100-Z01 - the heights of the pressure levels.

All records and parameters within this data set have been defined, including their minimum and maximum values, in the header file.

Variable Description/Definition:

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Unit of Measurement:

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Data Source:

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Data Range:

...

Sample Data Record:

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8. Data Organization:

Data Granularity:

A general description of data granularity as it applies to the IMS appears in the EOSDIS Glossary.

Data Format:

The data are in native binary data format (Standard Data Format, SDF). The data set contains 76 binary data files.

9. Data Manipulations:

Formulae:

Derivation Techniques and Algorithms:

...

Data Processing Sequence:

Processing Steps:

...

Processing Changes:

...

Calculations:

Special Corrections/Adjustments:

...

Calculated Variables:

...

Graphs and Plots:

Images are not available for this data set.

10. Errors:

Sources of Error:

...

Quality Assessment:

Data Validation by Source:

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Confidence Level/Accuracy Judgement:

...

Measurement Error for Parameters:

...

Additional Quality Assessments:

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Data Verification by Data Center:

The Langley DAAC performs an inspection process on this data received by the data producer via ftp. The DAAC checks to see if the transfer of the data completed and were delivered in their entirety. An inspection software was developed by the DAAC to see if the code was able to read every granule. The code also checks to see if every parameter of data falls within the ranges which are included in the granule. This same code extracts the metadata required for ingesting the data into the IMS. If any discrepancies are found, the data producer is contacted. The discrepancies are corrected before the data are archived at the DAAC.

11. Notes:

Limitations of the Data:

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Known Problems with the Data:

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Usage Guidance:

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Any Other Relevant Information about the Study:

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12. Application of the Data Set:

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13. Future Modifications and Plans:

There are no plans for future modifications of these data sets.

14. Software:

Software Description:

Sample read software are available.

Software Access:

The software can be obtained through the Langley DAAC. Please refer to the contact information below. The software can also be obtained at the same time the user is ordering these data sets.

15. Data Access:

Contact Information:

Langley DAAC User and Data Services Office
NASA Langley Research Center
Mail Stop 157D
Hampton, Virginia 23681-2199
USA
Telephone: (757) 864-8656
FAX: (757) 864-8807
E-mail: support-asdc@earthdata.nasa.gov

Data Center Identification:

Langley DAAC User and Data Services Office
NASA Langley Research Center
Mail Stop 157D
Hampton, Virginia 23681-2199
USA
Telephone: (757) 864-8656
FAX: (757) 864-8807
E-mail: support-asdc@earthdata.nasa.gov

Procedures for Obtaining Data:

The data are available from the Langley Data Center web site.

Data Center Status/Plans:

The Langley DAAC will continue to archive this data. There are no plans to reprocess.

16. Output Products and Availability:

There are no output products available at this time for this data set.

17. References:

Kidwell, K.B., 1995. NOAA Polar Orbiter Data User's Guide, U.S. Dept. of Commerce, NOAA/NESDIS, Washington, D.C., 410 pp.

Planet, W.G. (Editor), revised October 1988, Data Extraction and Calibration of TIROS-N/NOAA Radiometers, NOAA Technical Memorandum NESS 107 Revision 1, 130 pp.

Sorlie, Susan E. (Editor). Langley DAAC Handbook. NASA/Langley Research Center, Hampton, Virginia, June 27, 1994.

18. Glossary of Terms:

EOSDIS Glossary.

19. List of Acronyms:

AELDS - Advanced Earth Location Data System
AVHRR - Advanced Very High Resolution Radiometer
CDA - Command and Data Acquisition
DAAC - Distributed Active Archive Center
FIRE - First ISCCP Regional Experiment

GCM - General Circulation Model
HIRS/2 - High Resolution Infrared Radiation Sounder
IFO - Intensive Field Observations
IFOV - Instantaneous Field of View
ISCCP - International Satellite Cloud Climatology Project
LaRC - Langley Research Center
MSU - Microwave Sounding Unit
NASA - National Aeronautics Space Administration
NEdT - Noise Equivalent delta Temperature
NESDIS - National Environmental Satellite, Data, and Information Service
NOAA - National Oceanic and Atmospheric Administration
SSU - Stratospheric Sounding Unit
TIROS - Television and Infrared Radiometer Orbiting Satellite
TOVS - TIROS Operational Vertical Sounder
URL - Uniform Resource Locator

EOSDIS Acronyms.

20. Document Information:

Document Revision Date:
August 15, 1997; November 24, 1997; July 1999
Document Review Date:
...
Document ID:
...
Citation:
...
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