# CENTRE NATIONAL D'ETUDES SPATIALES

**Direction du Numérique, de l'Exploitation et des Opérations**
**Sous-direction Observation de la Terre**
**Service Missions Terre et Atmosphère**

**THEIA-MU-44-381-CNES**
Edition     : 02     Date     : 03/12/2020
Révision   : 00     Date     : 03/12/2020

Réf. :                                                    Code diffusion        : E

# GEOV2-GCM PRODUCT USER MANUAL

| **Rédigé par :** | le : 03/12/2020 | |
| --- | --- | --- |
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| **Validé par :** | le : | |
| **Pour application :** | le : | |

# BORDEREAU D'INDEXATION

| CONFIDENTIALITE : **DLP** | MOTS CLES : |
|---|---|

**TITRE DU DOCUMENT :**

**GEOV2-GCM Product User Manual**

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**RESUME :**

| DOCUMENTS RATTACHES : **Ce document vit seul.** | LOCALISATION : |
|---|---|

| VOLUME : **1** | NBRE TOTAL DE PAGES : 15 DONT PAGES LIMINAIRES : 0 NBRE DE PAGES SUPPL. : **0** | DOCUMENT COMPOSITE : N | LANGUE : **FR** |
|---|---|---|---|

**GESTION DE CONF. : Non** | **RESP. GEST. CONF. :**

**CAUSE D'EVOLUTION : Distribution des données jusque 2019**

**CONTRAT : Néant**

**SYSTÈME HÔTE :**
   **Microsoft Word 14.0 (14.0.7174)**
   **\\bacchus\GDOC\ModeleGDOC.dot**
   **Version GDOC : v4.3.1.1**
   **Base projet : \\to05res04\GdocBasesPartagees\Projets\CST\PTSC.mdb**

# DIFFUSION INTERNE

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# MODIFICATION

| Ed. | Rév. | Date | Référence, Auteur(s), Causes d'évolution |
|---|---|---|---|
| 02 | 00 | 03/12/2020 | PACHOLCZYK Philippe        DNO/OT /TA |
| | | | VERGER Aleixandre             CREAF |
| | | | Distribution des données jusque 2019 |
| 01 | 00 | 10/07/2019 | PACHOLCZYK Philippe        DCT/ME/OT |
| | | | Création du document |

# SOMMAIRE

## LIST OF ACRONYMS

| | |
|---|---|
| ATBD | Algorithm theoretical based Document |
| AVHRR | Advanced Very High Resolution Radiometer |
| BELMANIP | BEnchmark Land Multisite ANalysis and Intercomparison of Products |
| BRDF | Bidirectional Reflectance Distribution Function |
| BS | Bare Soil |
| CACAO | Consistent Adjustment of Climatology to Actual Observations |
| CEOS | Committee for Earth Observation Satellite |
| CGLS | Copernicus Global Land Service |
| CNES | Centre National d'Études Spatiales (French Space Agency) |
| CREAF | Centre for Ecological Research and Forestry Applications |
| CYCLOPES | Carbon cYcle and Change in Land Observational Products from an Ensemble of Satellites |
| EBF | Evergreen Broadleaf Forest |
| ECV | Essential Climate Variable |
| FAPAR | Fraction of Absorbed Photosynthetically Active Radiation |
| FCOVER | Fraction of vegetation cover |
| GAC | Global Area Coverage |
| GAI | Green Area Index |
| GCOS | Global Climate Observation System |
| GEOCLIM | Climatology of Version 1 LAI, FAPAR, FCover VGT products |
| GEOV1 | GEOLAND2 Version 1 product |
| GEOV2 | GEOLAND2 Version 2 product |
| GTOS | Global Terrestrial Observation System |
| INRAE | Institut national de recherche pour l'agriculture, l'alimentation et l'environnement (National Research Institute for Agriculture, Food and Environment, France) |
| LAC | Local Area Coverage |
| LAI | Leaf Area Index |
| LPV | Land Product Validation group of CEOS |
| LTDR | Long Time Data Record |
| MODIS | Moderate Imaging Spectrometer |
| NDVI | Normalized Difference Vegetation Index |
| NIR | Near Infrared |
| NNT | Neural Network Technique |
| QC | Quality control indicator |
| QF | Quality flag |
| RMSE | Root Mean Square Error |
| SPOT | Satellite Pour l'Observation de la Terre |
| SWIR | Short Wave Infrared |
| SZA | Sun Zenith Angle |
| TOC | Top of Canopy |
| TSGF | Temporal Smoothing Gap Filling |
| VGT | VEGETATION instrument onboard SPOT satellite |
| VITO | Vlaamse Instelling voor Technologisch Onderzoek (Flemish Institute forTechnological Research), Belgium |

# 1.  BACKGROUND

## 1.1.  SUMMARY

The GEOV2 Global Change Monitoring product (GEOV2-GCM) is a global map of vegetation biophysical variables (FAPAR, LAI and FCOVER) calculated every ten days since 1981 at 0.5º resolution after resampling the 0.05º GEOV2-AVHRR products.

The GEOV2-AVHRR and GEOV2-GCM products are generated and distributed by CNES in the frame of the Theia land data center based on the algorithm developed by CREAF and INRAE [DR1].

## 1.2.  SCOPE AND OBJECTIVES

The PUM document contains:

- a description of the algorithm
- a description of the product: file format, product content, product characteristics.

## 1.3.  DOCUMENTS DE REFERENCE

DR1      Algorithm Theorical Basis Document - GEOV2-AVHRR : Leaf Area Index (LAI), Fraction of Absorbed Photosynthetically active Radiation (FAPAR) and Fraction of green Vegetation Cover (FCOVER) from LTDR AVHRR
**A. Verger (CREAF/INRAE)**
**THEIA-SP-44-0207-CREAF**

DR2      GEOV2-AVHRR PRODUCT USER MANUAL
PACHOLCZYK Philippe, VERGER Aleixandre
**THEIA-SB-44-369-CNES**

# 2.   ALGORITHM

## 1.1.   THE CONSIDERED PRODUCTS

The considered products are called GEOV2-GCM and include leaf area index (LAI), the fraction of absorbed photosynthetically active radiation (FAPAR) and the fraction of vegetation cover (FCOVER). They are derived from the GEOV2-AVHRR products [DR21, DR2], themselves calculated from the AVHRR-LTDR data.

## 2.1.1.   FAPAR

FAPAR corresponds to the fraction of photosynthetically active radiation absorbed by the canopy. The FAPAR value results directly from the radiative transfer model in the canopy, which is computed instantaneously. It depends on canopy structure, vegetation element optical properties and illumination conditions. FAPAR is very useful as input to a number of primary productivity models based on simple efficiency considerations (Prince 1991). Most of the primary productivity models using this efficiency concept are running at the daily time step. Consequently, the product definition should correspond to the daily-integrated FAPAR value that can be approached by computation of the clear sky daily integrated FAPAR values as well as the FAPAR value computed for diffuse conditions. To improve the consistency with other FAPAR products that are sometimes considering the instantaneous FAPAR value at the time of the satellite overpass under clear sky conditions (e.g. MODIS), a study investigated the differences between alternative FAPAR definitions (Baret et al. 2003). Results show that the instantaneous FAPAR value at 10:00 (or 14:00) solar time is very close to the daily-integrated value under clear sky conditions. To keep a higher consistency with the FAPAR definition used in the CYCLOPES, and MODIS products, the instantaneous FAPAR value at 10:00 solar time under clear sky conditions (equivalent to black-sky conditions as defined also for albedo) was used.

FAPAR is relatively linearly related to reflectance values, and will be little sensitive to scaling issues. Note also that the FAPAR refers only to the green parts of the canopy.

## 2.1.2.   Cover fraction (FCOVER)

It corresponds to one minus the gap fraction for nadir direction. FCOVER is used to separate vegetation and soil in energy balance processes, including temperature and evapotranspiration. It is computed from the leaf area index and other canopy structural variables and does not depend on variables such as the geometry of illumination as compared to FAPAR. For this reason, it is a very good candidate for the replacement of classical vegetation indices for the monitoring of green vegetation. Because of its quasi-linear relationship with reflectances, FCOVER will be only marginally scale dependent (Weiss et al. 2000). Note that similarly to LAI and FAPAR, only the green elements will be considered.

## 2.1.3.   Leaf area index (LAI)

LAI is defined as half the developed area of photosynthetically active elements of the vegetation per unit horizontal ground area. It determines the size of the interface for exchange of energy (including radiation) and mass between the canopy and the atmosphere. This is an intrinsic canopy primary variable that should not depend on observation conditions. LAI is strongly non-linearly related to reflectance. Therefore, its estimation from remote sensing observations will be scale dependent (Garrigues et al. 2006; Weiss et al. 2000). Note that LAI as estimated from remote sensing will include all the green contributors such as the understory when existing under forests canopies. However, except when using directional observations (Chen et al. 2005), LAI is not directly accessible from remote

sensing observations due to the possible heterogeneity in leaf distribution within the canopy volume. Therefore, remote sensing observations are rather sensitive to the 'effective' leaf area index, i.e. the value that provides the same diffuse gap fraction while assuming a random distribution of leaves. The difference between the actual LAI and the effective LAI may be quantified by the clumping index (Chen et al. 2005) that roughly varies between 0.5 (very clumped canopies) and 1.0 (randomly distributed leaves). Note that similarly to the other variables, the retrieved LAI is mainly corresponding to the green element: the correct term to be used would be GAI (Green Area Index) although we propose to still use LAI for the sake of simplicity.

## 2.2. THE AVHRR-LTDR DATA

The Advanced Very High Resolution Radiometer (AVHRR) sensor is an optical instrument that provides multi-spectral imaging by sensing reflected sunlight and thermal emissions.

Several AVHRR sensors have been launched since 1981, which allows getting a long time series. Table 1 gives the temporal coverage since NOAA-7 up to now, for the NOAA satellite used in GEOV2-AVHRR product.

| NOAA Satellite Number | Launch date | Ascending Node | Descending Node |
|---|---|---|---|
| 7 | 06/23/1981 | 1430 | 0230 |
| 9 | 12/12/1984 | 1420 | 0220 |
| 11 | 09/24/1988 | 1340 | 0140 |
| 14 | 12/30/1994 | 1340 | 0140 |
| 16 | 09/21/2000 | 1400 | 0200 |
| 18 | 05/20/2005 | 1400 | 0200 |
| 19 | 06/02/2009 | 2130 | 0930 |

**Table 1: Historic of the AVHRR temporal coverage used for GEOV2-AVHRR.**

The AVHRR sensor is nominally a five channel scanning sensor which images in the visible, near infrared and thermal infrared wavelength bands. Band 1 is the visible band, Band 2 is the near infrared band, and Bands 3, 4 and 5 are the thermal bands. Table 2 and Figure 1 indicate the differences of wavelength on each band for each satellite. Note that for the 7 sensors used (7, 9, 11, 14, 16, 18, 19) no SWIR band is available, preventing from improved atmospheric correction.

| Band Name | NOAA 7,8,9,10,11,12,14 | NOAA 15,16,17,18,19 | IFOV (mRad) |
|---|---|---|---|
| 1 (Red) | 0.58 - 0.68 µm | 0.58 - 0.68 µm | 1.39 |
| 2 (NIR) | 0.725- 1.10 µm | 0.725-1.0 µm | 1.41 |
| 3A | | 1.58-1.64 µm | 1.3 |

**Table 2: AVHRR spectral characteristics and instantaneous field of view.**
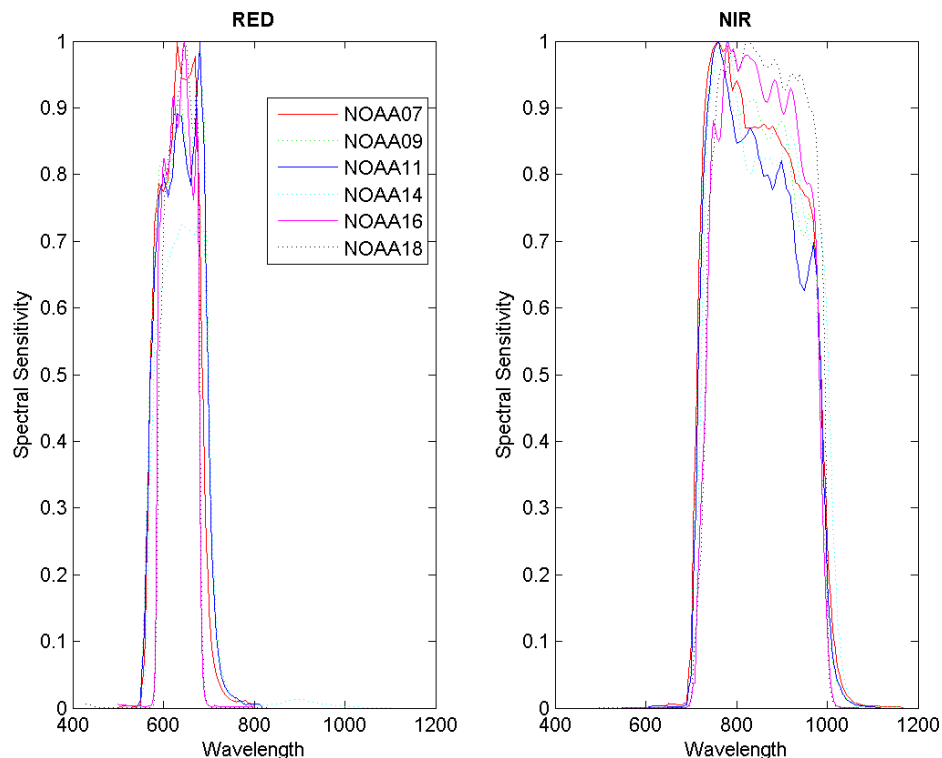
**Figure 1: NOAA07 – NOAA14 spectral responses in the RED (left) and near infrared (right) bands.**

The sensor has a small field of view, scanning across the Earth by the continuous 360 degree rotation of a flat scanning mirror. All the spectral channels are co-registered in order to measure the reflected or emitted energy from the same spot on the earth at the same time. The ground resolution is approximately 1.1 km at the vertical of the satellite from the nominal orbit altitude of about 850 km. The width of off-nadir pixels increases from 1.1 km to about 5 km at the most extreme viewing angle at the edge of the 3000 km imaging swath.

The orientation of the scan lines is perpendicular to the satellite orbit track and the speed of rotation of the scan mirror is selected so that adjacent scan lines are contiguous at the sub-satellite (nadir) position. The satellite speed and scan mirror rotation rate result in an along track pixel height of about 1.1 km. AVHRR data are broadcasted continuously as well as tape-recorded onboard the spacecraft for readout at a NOAA receiving center. The various forms of transmission and area coverage (LAC, GAC) are explained below.

- **LAC** (Local Area Coverage) is nominally 1 km resolution AVHRR imagery recorded with the on board tape recorder for subsequent transmission during the overpass of a station controlled by NOAA. Owing to the large number of data bits, only about 11 minutes of LAC can be accommodated on a single recorder. LAC imagery can only be obtained from NOAA/NESDIS and only in their formats.
- **GAC** (Global Area Coverage) data is lower resolution (4 km) AVHRR imagery. It is derived on board the NOAA satellite by subsampling and averaging the nominal 1 km resolution AVHRR imagery. Out of every 5 normal across track LAC pixels, the 5 bands of the first four are individually averaged and all the bands of the fifth pixel are ignored. In the along track direction, only every third normal line of LAC/HRPT pixels is considered; the two intervening lines are ignored. The GAC spatial resolution is loosely said to be 4 km resolution. It provides anyway a daily global coverage, which is recorded on a satellite tape recorder and then transmitted to a ground station controlled by NOAA. 115 minutes of this lower resolution imagery can be stored on a recorder, enough to cover an entire orbit of data acquisition. GAC imagery can only be obtained from NOAA/NESDIS and only in their formats.

Recently, Vermote and collaborators reanalyzed the GAC data to provide a consistent Long Term Data Record (LTDR) (Vermote and Claverie 2013; Vermote et al. 2010). The LTDR (http://ltdr.nascom.nasa.gov/ltdr/ltdr.html) provides better performances than the original GAC data due to the preprocessing improvements identified in the AVHRR Pathfinder II project and the atmospheric corrections used for MODIS.

Top of atmospheric reflectance were first calibrated using the vicarious calibration algorithm (Vermote and Kaufman 1995), cloud screening was applied using the CLAVR-1 algorithm (Stowe et al. 1999) using MODIS thresholds. Atmospheric correction was then performed using water vapor from NCEP data, ozone from TOMS data, Rayleigh scattering from NCEP atmospheric pressure simulations, and aerosols using the red (CH1).

A BRDF normalization was then achieved by applying correction parameters from POLDER in Ross-Li-Maignan model (Maignan et al. 2004). Data are provided for nadir viewing and a 45° solar zenith angle.

LTDR data are provided in hdf format at a daily temporal step and at 0.05° (5.6 km at equator) sampling interval in a latitude/longitude climate modeling grid (CMG). They are dimensioned [7200, 3600].

They correspond to a reasonable hour of ascending crossing time (close to 14:00, see Table 1). Two versions (Version 3 and version 4) for LTDR data are available. LTDR4 geometric performances were improved as compared to LTDR3 and the period has been extended to 2013 (instead of 2000 for LTDR3). Six sensors were used to cover the 1981-2013 period as described in Table 3. In order to have the longest archive with the best accuracy, we used the version 4. However, the LTDR4 dataset presents a gap lasting around almost a year (from 1st January to 2nd November 2000). On the contrary, LTDR3 is available for the entire year 2000. For the year 2000, we used all available LTDR3 and LTDR4 data.

| Satellite | Start date (doy) | End date (doy) |
|---|---|---|
| NOAA07 | 1981 176 | 1985 033 |
| NOAA09 | 1985 004 | 1988 312 |
| NOAA11 | 1988 313 | 1994 365 |
| NOAA14 | 1995 001 | 2000 366 |
| NOAA16 | 2000 306 | 2005 365 |
| NOAA18 | 2005 183 | 2009 365 |
| NOAA 19 | 2009 164 | 2019 056 |

**Table 3: Sensor used as a function of the year for LTDR data production.**

## 2.3.    INPUTS

The GEOV2-AVHRR products used as input are described in DR21, DR2.

They consist of LAI, FAPAR and FCOVER global maps calculated for 36 dekadal dates per year (5th, 15th and 25th of each month). Each map contains 7200 x 3600 pixels at a resolution of 0.05°.

The input product contains a pixel value and a quality flag (QFLAG) described as follow.

| Bit # | Description if set to 0 | Description if set to 1 |
|---|---|---|
| 0 | Unused | |
| 1 : processed | The pixel is processed (land) | The pixel is unprocessed (water) |
| 2 : climatology value | A climatology value exist for the pixel | No climatology value for the pixel |
| 3 : filling | No filling procedure | The number of valid observations at least on one side of the ±60-day period is lower than 6 and a gap filling procedure (Bit 13-14) is applied |
| 4 | Reserved | |
| 5 | Reserved | |
| 6 : input status | At least one valid data within ±60 days | No valid data within ±60 days |
| 7 : LAI status | OK | Out of range or invalid |
| 8 : FAPAR status | OK | Out of range or invalid |
| 9 : FCOVER status | OK | Out of range or invalid |
| 10 : SZA status | SZA <= 70 or latitude <= 55 | SZA > 70 and latitude > 55 |
| 11 : EBF status | Pixel is not recognized as Evergreen Broadleaf Forest | Pixel is recognized as Evergreen Broadleaf Forest |
| 12 : BS status | Pixel is not recognized as Bare Soil | Pixel is recognized as Bare Soil |
| 13 : climatology filled | Not filled | Filled with climatology |
| 14 : gap filled | Not filled | Filled with interpolation |
| 15 | Unused | |

**Table 4: Description of the quality flag for GEOV2-AVHRR LAI, FAPAR and FCOVER.**

The QFLAG bits of GEOV2-AVHRR products are calculated only if bit 1 is set to 0.

## 2.4.  OUTPUT PRODUCT

The output product contains global maps of 720 x 360 0.5° pixels, calculated by application of a 10x10 pixel merging algorithm over each input global map at each dekadal date. They include the LAI, FAPAR and FCOVER values as described previously.

## 2.5.  ALGORITHM OUTLINE

The algorithm is very simple and calculates for each square of 10 by 10 input pixels:

- The mean value of the input biophysical variables (LAI, FAPAR or FCOVER) for valid pixels
- The standard deviation of the valid values of the biophysical variables
- The percentage of land pixels (bit #1 of QFLAG)
- The percentage of valid pixels used for mean and RMSE calculation
- The percentage of suspect pixels (bit #3 of QFLAG)
- The percentage of climatology filled pixels (bit #13 of QFLAG)
- The percentage of gap filled pixels (bit #14 of QFLAG)

# 3. PRODUCT DESCRIPTION

The GEOV2-GCM AVHRR product files follow the name convention:

THEIA_GEOV2-GCM_Rnn_AVHRR_pppppp_yyyymmdd.h5

With:

- nn = version number with two digits
- pppppp = name of the biophysical variable: « LAI », « FAPAR » ou « FCOVER »
- yyyymmdd = product date,

Products are generated on day 5, 15 and 25 of each month.

## 3.1. FILE FORMAT

The LAI, FAPAR, FCOVER GEOV2-GCM Theia products are distributed in multi-band HDF-5 files containing the following layers, with pppppp = name of the biophysical variable: « LAI », « FAPAR » or « FCOVER » :

- pppppp-MEAN : mean value of the biophysical variable
- pppppp-STDEV : standard deviation of the biophysical variable
- FRAC-LAND : percentage of land pixels
- FRAC-VALID : percentage of valid pixels
- FRAC-SUSPECT : percentage of suspect pixels
- FRAC-CLIMATO : percentage of climatology filled pixels
- FRAC-FILLED : percentage of gap filled pixels.

Each file corresponds to a global map.

TIPS: You can download and install HDF5 library from http://www.hdfgroup.org.

The library comes with useful tools that could be used to discover the organization and contents of the hdf5 files.

You can also download a java viewer called HDFView from the same URL. This tool is more user friendly oriented than the line commands.

## 3.2. PRODUCT CONTENT

The physical range of LAI-MEAN, LAI-STDEV, FAPAR-MEAN, FAPAR-STDEV, and FCOVER-MEAN, FCOVER-STDEV is given in Table 5.

The physical values are retrieved by:

DN = PhyVal* ScalingFactor + Offset

where the scaling factor and the offset are given in Table 5.

The range of variation and resolution proposed are presented in Table 5. Invalid value is set to 255.

| Variable | Physical Minimum | Physical Maximum | Max DN value | Scaling factor | Offset |
|---|---|---|---|---|---|
| LAI | 0.0 | 7.0 | 210 | 30 | 0 |
| FAPAR | 0.0 | 0.94 | 235 | 250 | 0 |
| FCOVER | 0.0 | 1.0 | 250 | 250 | 0 |

**Table 5: Minimum, maximum values and associated resolution for LAI-MEAN, LAI-STDEV, FAPAR-MEAN, FAPAR-STDEV, and FCOVER-MEAN, FCOVER-STDEV products.**

The percentages (FRAC-LAND, FRAC-VALID, FRAC-SUSPECT, FRAC-CLIMATO and FRAC-FILLED) are given between 0 to 100.

# 3.3.    PRODUCT CHARACTERISTICS

## 3.3.1.    Projection and grid information

The product is displayed in a regular latitude/longitude grid (plate carrée) with the ellipsoid WGS 1984 (Terrestrial radius=6378km). The resolution of the grid is 0.5°.

The reference is the centre of the pixel. It means that the longitude of the upper left corner of the pixel is (pixel_longitude – angular_resolution/2)

Each file covers the entire globe which corresponds to an array of 720 lines by 360 columns.

## 3.3.2.    Temporal information

The GEOV2-AVHRR products are updated every 10 days using a moving and flexible compositing window within ± 60 days. The temporal information "YYYYMMDD" in the filename is the "actual" date corresponding to the product value. The "actual" date is the date to take in consideration for any analysis.

## 3.3.3.    Data policies

Any use of the original GEOV2-GCM AVHRR Theia products implies the obligation to include in any publication or communication using these products the following citation:

"GEOV2-GCM AVHRR was produced and distributed by CNES based on the algorithm developed by CREAF and INRAE, in the framework of the Theia Land Data Centre."

The user accepts to inform Theia about the outcome of the use of the above-mentioned products and to send a copy of any publications that use these products to the following address : theia-land@cnes.fr

## 3.3.4.    Contacts

Scientific contact : CREAF : Centre de Recerca Ecològica i Aplicacions Forestals, Barcelona, Spain.
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