New Horizons Encounter with (486958) Arrokoth: Derived Shape Models and Surface Maps – Overview

This data set contains the New Horizons Arrokoth Encounter Geology and Geophysics Science Theme Team derived shape models and maps of albedo, elevation, modeled surface temperature, and elevation.

Arrokoth Shape Models

These models are detailed in Porter, et al. (2019), Beyer, et al. (2019), and Spencer, et al. (2020). The file ARROKOTH_CSD.PDF, which defined the coordinate system used by the New Horizons Team for (486958) Arrokoth (provisional designation 2014 MU_{69}), is included in the documentation for these data.

All .obj files are considered to have units of kilometers. The orbital period is 0.6632553 days. The pole orientation is RA = 317.4880752 and DEC = -24.8876496 in the International Celestial Reference Frame (ICRF). The prime meridian is 184.4589465 (at epoch = BODY2486958_PM).

MU69_FR2KF_HIPOLY.OBJ

This is a high-polygon-count global shape of Arrokoth made up of 100,678 facets. For a lower-polygon-count version, please see MU69_FR2KF_LOPOLY.OBJ. The creation of this model is discussed in Porter, et al. (2019), and also published in Spencer, et al. (2020).

MU69_FR2KF_HIPOLY_SPICE.BDS

This is a SPICE binary digital shape kernel file that can be used with the NAIF SPICE toolkit and in USGS image processing software (ISIS). This file was converted from the mu69_fr2kf_hipoly.obj model.

MU69_FR2KF_LOPOLY.OBJ

This is a simplified version of the MU69_FR2KF_HIPOLY.OBJ file, containing 1962 facets.

MU69_FR2KF_LOPOLY_SPICE.BDS

This is a SPICE binary digital shape kernel file that can be used with the NAIF SPICE toolkit and in USGS image processing software (ISIS). This file was converted from the MU69_FR2KF_LOPOLY.OBJ model.

MU69_ASP_CA04_06_ICP_SMOOTH.OBJ

This is the best-resolution surface terrain model of part of the illuminated surface of Arrokoth during the New Horizons encounter. This model contains 33,758 facets.

The surface represented in this file was created from running the Ames Stereo Pipeline (ASP) on stacked, deconvolved versions of the CA04 and CA06 observations. The deconvolved version of

CA04 had to be 2x reduced in pixel scale so that the pixels could be placed back into the original image and processed. The resulting model was cleaned and obviously-bad edge points were eroded. An Iterated Closest Point (ICP) algorithm was run to match this model as a rigid object with the spin-negative face (the side of Arrokoth that was illuminated during the encounter) of the mu69_fr2kf_hipoly.obj global shape model as well as possible. Additional edge artifacts were trimmed back, and smoothing was applied.

This model was discussed separately in the Beyer, et al. (2019) abstract, and appears as a download in the Supplemental Material to the Spencer, et al. (2020) paper.

MU69_ASP_CA04_06_ICP_SPICE_V01.BDS

This is a SPICE binary digital shape kernel file that can be used with the NAIF SPICE toolkit and in USGS image processing software (ISIS). This file was converted from the MU69_ASP_CA04_06_ICP_SMOOTH.OBJ model.

MU69_MERGED.OBJ

This is the best 'merged' shape model of Arrokoth, which is a combination of both the global shape model (MU69_FR2KF_HIPOLY.OBJ), and the stereo digital elevation model (DEM) that covers part of the illuminated surface of Arrokoth (MU69_ASP_CA04_06_ICP_SMOOTH.OBJ). This model contains 107,506 facets.

The global shape model (MU69_FR2KF_HIPOLY.OBJ) had its spin-negative face eroded so that there were no overlaps between it and the stereo DEM MU69_ASP_CA04_06_ICP_SMOOTH.OBJ. These two objects were then manually joined together with polygons. Local smoothing was then applied to the seam to provide a smooth join. Since the stereo model has a much smoother transition at the neck than the global shape model, the equatorial region of the neck in the MU69_FR2KF_HIPOLY.OBJ was also smoothed to provide a better transition from the stereo model to the shape model. The +Z part of the neck (on the un-illuminated side of Arrokoth) was left as a cusp (there is no imaging of this area, so this cusp is purely a feature of the modeling).

This MU69_MERGED.OBJ shape model was discussed separately in the Beyer, et al. (2019) abstract, and appears as a download in the Supplemental Material to the Spencer, et al. (2020) paper. Some artifacts may remain where the two models were merged.

MU69_MERGED_SPICE.BDS

This is a SPICE binary digital shape kernel file that can be used with the NAIF SPICE toolkit and in USGS image processing software (ISIS). This file was converted from the above MU69_MERGED.OBJ file.

MU69_MERGED_BROWSE.PNG

An image with different views of the MU69_MERGED model for reference.

Arrokoth Surface and Subsurface Temperature Simulations

This dataset was created by Orkan Umurhan.

This dataset contains temperature solutions for Kuiper Belt Object (KBO) 2014 MU69 (Arrokoth) based on a fit to the 'low polynomial' shape model with 1962 facets (MU69_FR2KF_LOPOLY.OBJ), also within this repository. The New Horizons team created the shape model using images from the LOng-Range Reconnaissance Imager (LORRI) and the Multispectral Visible Imaging Camera (MVIC) instruments on the New Horizons spacecraft.

The temperature solutions in this dataset correspond to the putative best fit solutions presented in Grundy, et al. (2020). The H1, H4, and H10 directories each contain 301 temperature files representing 300 equally spaced epochs over a single orbit of Arrokoth around the Sun. The temperature file with data for January 1, 2019 is shown in the figures in Grundy, et al. (2020).

The filename for each solution contains a Julian Date timestamp indicating the date of the predicted temperatures. For example, the 'JD_2458485_temperature.dat' file predicts the 15.9-hour-averaged temperature on that day, which is the day of the Arrokoth encounter (Julian Date 2458485 <--> January 1, 2019).

Each temperature file is a tab separated text file containing 1962 rows and 98 columns. Each value is a predicted temperature in units of K. Rows correspond to the facet number in the low-poly shape model found in this repository. Columns correspond to several non-uniformly spaced depth levels below the surface.

A text table in each data directory, z_depth.dat, indicates meters of depth for each of 98 levels below the surface. The depth levels descend from the surface (0 meters).

All solutions have the following input assumptions for the temperature model:

emissivity = 0.9 <--> material emissivity
albedo = 0.06 <--> material albedo
thermal inertia = 'Go' = 2.54 tiu (1 tiu = J m^{-2} s^{-1/2} K^{-1},
where tiu stands for thermal inertia units)

The thermal inertia (sqrt[K * rho * Cp]) is based on the assumption that mean properties of Arrokoth are:

rho = 250 kg/m^3 <--> mean density
Cp = 350 J/kg/K <--> specific heat at constant pressure
omega = 6.73e-10 s^{-1} <--> Arrokoth's orbital frequency
e = 0 <--> eccentricity
f_sun = 0.6 W/m^2 <--> mean typical solar irradiance at the orbit of Arrokoth

The values for rho are supported by mechanical/structural analyses performed by Keane, et al. (2021). Albedo comes from Hofgartner, et al. (2021).

The thermal solutions in this dataset are constructed on the assumption that all layers within H meters of the surface are characterized with a thermal inertia 'Go' quoted, with all layers below described by a thermal inertia 'Gb' = 1 tiu.

Solutions for each of the three data directories (H1, H4, and H10) are derived accordingly. For example 'H4' corresponds to solutions in which the thermal inertial equals 'Go' for all layers between 0 and 4 meters from the surface, and where the thermal inertial = 'Gb' for all layers below 4 meters. The other directories correspond to one meter (H1) and ten meter (H10) transitional depths. Grundy, et al. (2020) showcased solutions in the H4 data directory.

Note that each 'z_depth.dat' file in each 'Hn' directory (n=1,4,10) has different values. We recommend interpolation methods to do fixed-depth comparisons across solutions of differing values of H.

The first column in the document 'JD_SubSolarLatitudes.dat' contains the Julian Date, while the second column contains the corresponding subsolar latitude (in degrees, ranging from -90 to 90) based on the cartographic coordinates defined for Arrokoth. These values were used in determining facet illumination for every timestep across one orbital period.

Arrokoth Albedo and Normal Reflectance

These data were contributed by Jason Hofgartner and are described by Hofgartner, et al. (2021).

CA06_STACK_ALBEDO.IMG and .LBL

This image is the mean (incidence angle average) hemispherical albedo map of Arrokoth as defined in Hofgartner, et al. (2021), and is the data behind figure 4, right panel, in that paper. This image has numeric values with these characteristics: Minimum=-69.036, Maximum=58.364, Mean=0.023, StdDev=0.181

CA06_STACK_NORMAL_REFLECT.IMG and .LBL

This image contains the normal reflectance as defined in Hofgartner, et al. (2021), and is the data behind figure 2, left panel, in that paper. This image has numeric values with these characteristics:

Minimum= -285.906, Maximum=241.708, Mean=0.094, StdDev=0.750

References

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