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Summary

The eSurge project supplies a small number of Ocean Colour and Sediment Concentration images, Ocean Colour and Sediment concentration are both Level 2 products derived from the MERIS instrument\(^1\), a medium spectral resolution imaging spectrometer carried aboard the ENVISAT mission. These could potentially be useful for studying the aftermath of a storm surge, and products have been provided for a limited number of surges for users to test their utility.

This product is supplied by the eSurge Project, funded by the European Space Agency under the ESA Data User Element (DUE) Programme. For more information on the eSurge project go to http://www.storm-surge.info/. This handbook provides a broad introduction to the product and specifications, indicating the further literature sources where more advanced and detailed knowledge can be obtained.

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\(^1\) https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/envisat/instruments/meris
Abbreviations and Acronyms

Table 0-1 lists the acronyms and abbreviations used within this document.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Meaning</th>
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<tbody>
<tr>
<td>AOI</td>
<td>Area of Interest</td>
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<tr>
<td>BEAM</td>
<td>Basic ERS &amp; Envisat (A) ATSR and Meris Toolbox</td>
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<tr>
<td>BODC</td>
<td>British Oceanographic Data Centre</td>
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<tr>
<td>BUFR</td>
<td>Binary Universal Form for the Representation of meteorological data</td>
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<tr>
<td>CMRC</td>
<td>Coastal and Marine Research Centre</td>
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<td>DEM</td>
<td>Digital Elevation Model</td>
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<td>DMI</td>
<td>Danmarks Meteorologiske Institut (Danish Meteorological Institute)</td>
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<td>DUE</td>
<td>Data User Elements</td>
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<td>DUP</td>
<td>Data User Programme</td>
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<td>ENVISAT</td>
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<td>EO</td>
<td>Earth Observation</td>
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<td>ESA</td>
<td>European Space Agency</td>
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<tr>
<td>KNMI</td>
<td>Koninklijk Nederlands Meterologisch Instituut (Royal Netherlands Meteorological Institute)</td>
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<tr>
<td>MERIS</td>
<td>MEdium Resolution Imaging Spectrometer Instrument</td>
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<tr>
<td>NERC</td>
<td>Natural Environment Research Council (UK)</td>
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<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
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<tr>
<td>NOC</td>
<td>National Oceanography Centre</td>
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<tr>
<td>TSM</td>
<td>Total Suspended Matter</td>
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<tr>
<td>UCC</td>
<td>University College Cork</td>
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<tr>
<td>WOND</td>
<td>The weather research section of the Royal Netherlands Meteorological Institute</td>
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1. THE OCEAN COLOUR AND SEDIMENT CONCENTRATION DATA PRODUCTS (SC1, OC1)

1.1 Introduction

The eSurge project supplies a small number of Ocean Colour and Sediment Concentration images. These can be useful for studying the aftermath of a storm surge, although they are only available for a limited number of surges. They are considered together since they are both derived from the same Level 2 products from the MERIS instrument, a medium spectral resolution imaging spectrometer carried aboard the ENVISAT mission.

The eSurge project gratefully acknowledges ESA for allowing use of this data.

1.2 About the Products

1.2.1 MERIS L2 Products

MERIS was a programmable, medium-spectral resolution, imaging spectrometer operating in the solar reflective spectral range, carried aboard the ENVISAT mission. Its primary mission was the measurement of ocean colour in the open-ocean and in coastal areas, but it was also capable of estimating a wide range of other parameters. The instrument scanned the Earth's surface by the so-called "push-broom" method. Linear CCD arrays provide spatial sampling in the across-track direction, while the satellite's motion provides scanning in the along-track direction.

MERIS data are provided at 3 different levels of processing - Level 0, Level 1, Level 2 - and at 3 different spatial resolutions - Full, Reduced and Low. The products supplied by eSurge are Full-Resolution (FR) Level 2 processed images. Each individual pixel in an FR image represents an area of 260 m x 290 m.

More information on these products, including a full description of the processing, can be found in the MERIS product handbook and in the Detailed Processing Model for the MERIS Level 2 processing.

1.2.2 Ocean Colour

The eSurge ocean colour product is taken from the MERIS L2 full resolution product, but with only a subset of the colour related parameters included. These are:

Normalised water-leaving reflectances - The MERIS Level 2 radiometric unit is atmospherically corrected water leaving reflectance. The atmospheric correction applied assumes that the water is absorbing in the NIR, and include a correction for those sediment loaded waters where this assumption fails. Reflectances have been provided for 5 (out of the 15 available) radiometric bands: bands 2 (443nm), 4 (510nm), 5 (560nm), 8 (681nm) and 14 (890nm). These bands allow the

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2 [https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/envisat/instruments/meris](https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/envisat/instruments/meris)
3 [https://earth.esa.int/handbooks/meris/](https://earth.esa.int/handbooks/meris/)
4 [http://earth.eo.esa.int/pcs/envisat/meris/documentation/meris_3rd_reproc/MERIS-DPM-L2-i8r0B.pdf](http://earth.eo.esa.int/pcs/envisat/meris/documentation/meris_3rd_reproc/MERIS-DPM-L2-i8r0B.pdf)
generation of both true colour (red: band 8; green: band 5; blue: band 2) and false colour (red: band 14; green: band 8; blue: band 4) composite images.

**Chlorophyll 1/2 content** - These are the MERIS algal pigment indices I and II, measuring the concentration in $\log_{10}(\text{mg/m}^3)$ of phytoplankton (algae) in the water. The algal pigment index I is derived by the direct relationship between the ratio of the blue and green signal leaving the water surface and the concentration of algal pigments. The relationship, based on published data, is valid over clear waters and spans a concentration range from mg/m$^3$ to tens of g/m$^3$. The algal pigment index II is part of a suite of oceanic products derived by inverting a model of the optical properties of the ocean by the use of a neural network. The other oceanic products are suspended matter and yellow substance.

1.2.3 Sediment Concentration

The eSurge Sediment Concentration product is also a subset of the MERIS L2 full resolution product, containing the MERIS total suspended matter (TSM) parameter. MERIS TSM is a measurement of the suspended sediments concentration in $\log_{10}(\text{g/m}^3)$. It is derived by inverting a model of the optical properties of the ocean by the use of a neural network. The model describes suspended matter as a scattering particle with very little absorption for which a more appropriate name would be “total suspended mineralic matter concentration.”

1.3 From Data to Product

To generate the data sets available on the eSurge website, the following steps have been followed:

- A subset of L2 images relevant to storm surge events have been selected.
- The MERIS ‘.N1’ format data files have been converted to NetCDF files, following the CF v1.4 conventions, using the ESA BEAM software.
- From each BEAM output file, two eSurge files have been generated, to include only the relevant parameters (see section 2.2 for full details).

Section 2 describes the resulting output file.

1.4 Product Validation

There is an extensive literature on validation of MERIS data, with several workshops having been held on the subject. As starting points, we recommend looking at the ESA's overall Envisat validation page\(^5\), their MERIS Validation page\(^6\), the MERIS Product Control Service\(^7\) and the GlobColour validation page\(^8\).

No independent validation has been performed by the eSurge project. A set of quality flags is provided with the data set. See section 2 for further details.

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5 https://earth.esa.int/envisat/m-s/envisat_mission_2001/CalVal/
6 https://earth.esa.int/envisat/m-s/envisat_mission_2001/CalVal/7MERISV.pdf
7 http://earth.eo.esa.int/pcs/envisat/meris
8 http://www.globcolour.info/validation
1.5 Potential Uses of these data in Storm Surge Applications

These products are mainly useful for studying the aftermath of a storm surge, e.g. in looking at the amount of sediment washed out to sea.
2. PRODUCT DETAILS

2.1 Technical Description

2.1.1 File Type

Each ocean colour and suspended sediment file is a classic format NetCDF (.nc) file. More information on NetCDF can be found in the NetCDF users guide.\(^9\)

2.1.2 File Names

To maintain compatibility with the source data, the files provided by eSurge retain the original file name format used for Envisat products, but with an additional suffix to distinguish between the two product types:

\[
\text{MER_FR__2PNUPAyyyyymmdd__HHMMSS_ttttttttttttttttttttttttttttttttttPccc_OOOOO_aaaaa_QQQQ_ppp.nc}
\]

Where:

- **MER_FR** signifies this is the full resolution MERIS data
- **2PNUPA** signifies that this is the Level 2 product (2P), originally provided in NRT (N), processed by the UK-PAC (UPA)
- **yyyyymmdd** is the year, month and data of acquisition.
- **HHMMSS** is the start time of the acquisition (hrs, mins, secs).
- **tttttttt** is the time (in seconds) of acquisition
- **P** is the phase of the mission
- **ccc** is the cycle number within that mission phase.
- **OOOO** is the relative orbit number within the cycle.
- **aaaaa** is the absolute orbit number.
- **QQQQ** is a numerical wrap-around counter for quick file identification.
- **ppp** has been added to the Envisat format to distinguish between the two types of files provided in the eSurge database:
  - **col** is used for ocean colour files.
  - **tsm** is used for sediment concentration (total suspended matter) files.
- **.nc** is the suffix for a netCDF file.

Further information of the Envisat parameters (cycle number etc) is given in the MERIS product handbook.

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\(^9\) [https://www.unidata.ucar.edu/netcdf/docs/netcdf.html](https://www.unidata.ucar.edu/netcdf/docs/netcdf.html)
2.1.3 File Sizes

The size of each image depends upon the file type – since fewer parameters are provided for the sediment concentration, this file is smaller. As a rough guide, the file size is:

- ~250Mb/image for the ocean colour product
- ~150Mb/image for the sediment concentration product

2.1.4 Global Attributes

The NetCDF global attributes include:

- Conventions (i.e. netCDF 1.4)
- TileSize
- start_date
- stop_date
- title
- History.

2.2 File Contents

2.2.1 Ocean Colour

The Ocean colour files provide the following variables:

- reflec_2: normal surface reflectance, band 2, in units dl. Scale factor and offset are given in the netCDF file.
- reflec_4: normal surface reflectance, band 4, in units dl. Scale factor and offset are given in the netCDF file.
- reflec_5: normal surface reflectance, band 5, in units dl. Scale factor and offset are given in the netCDF file.
- reflec_8: normal surface reflectance, band 8, in units dl. Scale factor and offset are given in the netCDF file.
- reflec_16: normal surface reflectance, band 16, in units dl. Scale factor and offset are given in the netCDF file.
- algal_1: chlorophyll 1 content in mg/m³.
- algal_2: chlorophyll 2 content in mg/m³.
- l2_flags: level 2 classification and quality flags.
- latitude: latitude of the tie points against WGS 84, in degrees.
• **longitude**: longitude of the tie points against WGS 84, in degrees.
• **lat_corr**: DEM latitude corrections, in degrees.
• **lon_corr**: DEM longitude corrections, in degrees.
• **lat**: latitude coordinate in degrees_north
• **lon**: longitude coordinate in degrees_east

All parameters are in grids of [y x] points, where y and x are along-track and across-track pixel location.

### 2.2.2 Sediment Concentration (Total Suspended Matter)

The sediment concentration files provide the following variables:

• **total_susp**: total suspended matter in g/m³.
• **L2_flags**: level 2 classification and quality flags.
• **Latitude**: latitude of the tie points against WGS 84, in degrees.
• **Longitude**: longitude of the tie points against WGS 84, in degrees.
• **lat_corr**: DEM latitude corrections, in degrees.
• **lon_corr**: DEM longitude corrections, in degrees.
• **lat**: latitude coordinate in degrees_north
• **lon**: longitude coordinate in degrees_east

All parameters are in grids of [y x] points, where y and x are along-track and across-track pixel location.

### 2.2.3 More information

More information on the file contents, for example the values of the L2_flags variable, can be found in the MERIS product handbook¹⁰

¹⁰ [https://earth.esa.int/handbooks/meris/](https://earth.esa.int/handbooks/meris/)
2.3 Accessing the Product

For many storm cases (events) where storm-surges are reported to have arisen, data have been collected and made available through the eSurge web-service (see www.storm-surge.info shown in figure 2-1). We would encourage users to look up these events and the suite of data products contained on the facility database.

Figure 2-1: Accessing the data on the eSurge website (tabs encircled)

Figure 2-2: The data access page of the eSurge website
2.3.1 Viewing the product in the eSurge website

The eSurge web-service provides users with a number of ways to explore and assess the utility of data they are interested in. Upon navigating to a storm surge event of interest (e.g. Cyclone Sidr shown in figure 2-3), the individual datasets can be previewed (figure 2-4) using the preview tab alongside the dataset name as shown encircled in figure 2-3. Alongside the dataset name also lies the link to view global attributes and dataset information through the OPeNDAP viewer (figure 2-5).

Alternatively, users can quick link to the eSurge GIS web-viewer, where they can visualise and explore all the datasets available concerning the event (figure 2-6).

Figure 2-3: The Cyclone Sidr dataset inventory on the eSurge web-service. Preview option links are encircled.
Figure 2-4: Previewing a Cyclone Sidr inundation dataset using the Preview link.

Figure 2-5: Viewing dataset metadata and information using OPeNDAP.

Figure 2-6: Exploring Cyclone Sidr datasets in the eSurge GIS web-viewer.
2.3.2 Download the product

If users are satisfied that the product suits their purposes, there is an option to download the data using the OPeNDAP dataset information window (figure 2-7). Simply click on the “Get ASCII” or “Get Binary” tab to download the data. Note that the ability to download requires registration.

Figure 2-7: downloading data using the OPeNDAP dataset information page (tabs encircled).

2.3.3 Accessing the product outside eSurge

Details of how to search for and order additional MERIS images, as well as other products supplied by ESA, are available on the ESA Earthnet page\(^\text{11}\)

2.4 Using the Product

Useful tools to work with the NetCDF SST data are Python (with netCDF4 and matplotlib libraries) and IDV for plotting. For manipulating the data NCO offers many tools, and Python offers higher level tools as well as low level manipulation of the data. Of course commercial software as Matlab and IDL also provides all capabilities

\(^{11}\) http://earth.esa.int/web/guest/data-access
2.5 Constraints on Use

These products are freely available to use, however ESA should be acknowledged in any publications. The data provided are freely available to use, however users do not have permission to redistribute the data they obtain. The free data must be obtained from the eSurge website, and the user must register their intent to use the data. User registration is essential to assess the success and performance of the eSurge web-service as it allows monitoring of data use and future tailoring of product availability to user needs. Also note that use of the data implies that the user is agreeing to give proper accreditation to both the eSurge inundation dataset providers, and the ESA in any publications arising from the data’s use.
3. FURTHER INFORMATION AND CONTACTS

For queries regarding the MERIS data, please do not hesitate to contact the European Space Agency, the product originators. ESA can be contacted through the EO-Support portal at https://earth.esa.int/web/guest/contact-us.

For queries regarding the eSurge Project, please do not hesitate to contact:

General eSurge contact: Phil Harwood
Website http://www.storm-surge.info
Email address: esurge@outlook.com

For queries regarding the European Space Agency (ESA) Data User Elements (DUE) Programme, see http://due.esrin.esa.int/
4. REFERENCES

ANNEX A: THE ESURGE PROJECT

A.1 About eSurge

Despite the potential utility of satellite data, the storm surge community has not made as much use of it as they could. Largely this is due to the lack of easy data access. Different datasets are stored in different locations, in different data formats and with different access requirements. eSurge aims to change this, bringing relevant datasets together in an east to use, web-accessible database of data products, downloadable in a standardised format.

The eSurge project is being run in two phases. During the initial Development Phase (Phase 1) we have built the database, known as SEARS (Surge Event Analysis and Repository Service), and populated it with initial data for a selection of historical surge events. This will give a useful library that can be used for assessing and improving the performance of numerical models. Whilst most of the datasets are already available, and just need to be imported into the database, others are being created during the project.

Following the launch of the SEARS database, eSurge will move into a Service Demonstration phase (Phase 2). During this phase we will continue to add more historical data, but will also look at making data available for surge events as they occur. The aim is to show that it is feasible to provide satellite data in near real time, so that it could potentially be used in forecasting and warning systems.

It is important to note that eSurge is not itself a forecasting and warning system, it is a system to make data available to forecasters. There are dedicated agencies (such as the UK Environment Agency) whose role it is to warn of impending flooding.

Making the data available is just part of the process of getting people to use it; we must also show the value of the data. To this end our partners at DMI and NOC will perform a series of experiments, focussing on the North Sea and North Indian Ocean. These will take existing models, such as DMI’s HBM model and NOC’s operational CS3X surge model, and will look at how incorporating satellite data could improve the models’ hindcast accuracy. These experiments will also investigate the best way to incorporate satellite data into models. This is a complex subject, and we do not expect to be able to resolve it in this project, but we aim to pave the way for future work.
A.2 The eSurge Consortium

The eSurge consortium consists of CGI (UK), the National Oceanography Centre (UK), the Danish Meteorological Institute (DK), University College Cork’s Coastal and Marine Research Centre (IRL) and the Royal Dutch Meteorological Institute (NL).

Consultants to Government and Industry (CGI) was founded in 1976, and is a global IT and business process services provider delivering business consulting, systems integration and outsourcing services. With 72,000 professionals operating in 400 offices in 40 countries, CGI fosters local accountability for client success while bringing global delivery capabilities to clients’ front doors. CGI applies a disciplined and creative approach to achieve an industry-leading track record of on-time, on-budget projects and to help clients leverage current investments while adopting new technology and business strategies. As a result of this approach, our average client satisfaction score for the past 10 years has measured consistently higher than 9 out of 10. We have a dedicated international Space and Satcoms business with over 300 specialists and a long track record in delivering mission critical software systems across the Space sector, and in particular for Navigation and GNSS systems. We have worked on many ESA Earth Observation projects, including GlobWave, CCI, GECA, PALSAR and many others.

The National Oceanography Centre (NOC) is a wholly owned centre of the Natural Environment Research Council (NERC). The NOC was formed by bringing together the NERC-managed activity at Liverpool’s Proudman Oceanographic Laboratory and the National Oceanography Centre, Southampton, creating the UK’s leading institution for sea level science, coastal and deep ocean research and technology development. The NOC hosts both the National Tidal and Sea Level Facility, and the Permanent Service for Mean Sea Level (since 1933), and contributes to the Storm Tide Forecasting Service (STFS), developing operational tide-surge models that provide UK coastal flood warning (in partnership with the Met Office and the Environment Agency). It has been at the forefront in developing interfaces to data sources and information. NOC have been involved in ESA funded projects such as COASTALT, GlobColour and GlobWave.

The Danish Meteorological Institute (DMI) is a public institute, providing meteorological, oceanographic and related services for the people of the Kingdom of Denmark (Denmark, the Faroe Islands and Greenland). DMI’s area of activity comprises forecasting and warning services as well as continuous monitoring of weather, sea state, climate, and related environmental conditions in the atmosphere, over land and in the sea. As such, it has national responsibility for carrying out storm surge model forecasts and issuing warnings for Danish areas to the Danish coastal authorities and the public in general. DMI is part of the Baltic Sea Operational Oceanographic System (BOOS) and North West Shelf Operational Oceanographic System (NOOS). DMI play the role as the real-time in-
situ sea level centre for the BOOS and NOOS communities. In the MyOcean project DMI leads the Baltic Model Forecasting Centre providing real time ocean forecasting for the Baltic Sea. DMI is part of the High Resolution Local Area Modelling (HIRLAM) developing consortium within numerical weather predictions. DMI is operationally running a number of numerical forecast models for European and Arctic regions, alongside regional and large scale ocean models (HBM and HYCOM). DMI is part of a collaboration developing a coupled atmosphere, ocean and sea ice climate model (EC-Earth), whilst a high resolution coupled ocean and ice forecast model (HYCOM/CICE) is currently being developed at the institute.

The **Coastal and Marine Research Centre (CMRC)** in **University College Cork** was established in 1994 to undertake research into coastal and marine resource management. It is part of the Environmental Research Institute (ERI) and the Irish Maritime and Energy Resource Cluster (IMERC). Research and consultancy in the CMRC is undertaken by staff with a range of specialist backgrounds, all of whom work collaboratively in a project orientated environment. The Centre’s expertise and skill sets are highly regarded both nationally and internationally. Fundamental and applied research in the CMRC is organised according to five specialist areas of interest: marine geomatics; applied remote sensing and GIS; marine and coastal governance; coastal processes and seabed mapping and marine ecology. The CMRC works with data from a wide range of satellite EO instruments including MERIS, MODIS, SAR and higher resolution optical datasets (e.g. Landsat, IRS, SPOT, and IKONOS) for land, coastal and marine applications. It lies at the forefront of geomatics research with Europe and internationally, with an ability to work with a variety of data in projects such as FP7 NETMAR, FP6 InterRisk and FP5 DISMAR. It has a track record of engaging end users and stakeholders in projects, organising the CoastColour users’ workshop in 2008 and, was part of the organising committee for the European Space Agency’s *Space innovation Powering Blue Growth* Conference held in Cork in April 2013. The CMRC is currently being merged with sister centres in University College Cork under the banner of Beaufort Research. For further information see [www.beaufortresearch.ie](http://www.beaufortresearch.ie).

The **Koninklijk Nederlands Meteorologisch Instituut**, KNMI, (Royal Netherlands Meteorological Institute) is a government agency operating under the responsibility of the Dutch Ministry of Transport. It provides weather observations, weather forecasts and vital weather information, whilst carrying out applied and fundamental research in support of its operational tasks and as a global change research centre. Skilled and experienced groups, specialising in diverse topics such as instrument development and electronic read-out, automation, computing, operations control and quality control are employed within the institute, providing quality controlled, and cost effective data acquisition and data processing services. As an operational meteorological data centre and research institute in one, KNMI combines its international networks and collaborative projects in a practical way. It is an active member of the World Meteorological Organisation (Geneva, CH), the European Centre for Medium-range Weather Forecasts (Reading, UK) and the European Organisation for the Exploitation of Meteorological Satellites (Darmstadt, G), and Eumetsat’s Ocean and Sea Ice Satellite Application Facility (SAF).
For more information on this product please contact the ESA EO-Support portal at:

https://earth.esa.int/web/guest/contact-us.

For more information on eSurge please contact Phillip Harwood, eSurge Project Manager, at

esurge@outlook.com