***TERRA Instructions***

***Install:***

1. Close any open Igor windows
2. Run Install.bat
3. Open Igor
4. Click on Analysis -> Load TERRA
5. A menu labelled TERRA should now be displayed in the Analysis menu
6. If this is not the case, manual install is required
   1. Close Igor
   2. Copy Covariance\_Kriging.ipf, DateTimeConversions.ipf, KrigData.ipf, ExtrapolateUp.ipf to Documents/WaveMetrics/Igor Pro 6 User Files/User Procedures
   3. Copy KrigLoader.ipf to Documents/WaveMetrics/Igor Pro 6 User Files/Igor Procedures
   4. Copy KrigingAircraftData.ihf to Documents/WaveMetrics/Igor Pro 6 User Files/Igor Help Files
   5. Open Igor and check that menus have now loaded

***Getting Started:***

1. Load concentration and timestamp waves (columns) into Igor using Data -> Load Waves
2. Run one of the kriging functions on the Analysis -> TERRA menu
   1. Quick kriging: box flights krigs concentration data from box flights using a range of 300, nugget of 0 and sill of 1
   2. Quick kriging: screen flights krigs concentration data from flight screens using a range of 300, nugget of 0 and sill of 1
   3. Variogram and full kriging: box flights krigs concentration data from box flights using a user determined range, sill and nugget
   4. Variogram and full kriging: screen flights krigs concentration data from flight screens using a user determined range, sill and nugget
3. Choose timestamp and concentration waves from the drop down menus
4. Choose flight you want to look at (NOTE: Data from multiple flights can be loaded into one wave. The function is able to pick out the timestamps for only the flight you enter)
5. Enter sampling interval of the data
   1. If the sampling interval is greater than 1 you will be prompted to decide whether you want to insert NaN values into the timestamps where the instrument was not recording or whether you want to assume that the instrument read value continues to be valid until the subsequent reading
   2. If you choose the Value option a measurement read by the instrument will be valid for a length of time equal to the sampling interval. If another reading occurs early that value will replace the previous recorded one. If a gap in the data longer than the sampling interval occurs the remaining timestamps will be filled with NaNs.
6. Choose whether the data is gas or particle data
7. Enter the molar mass of the quantity. If you are using particle data this value does not matter. You can enter 1 or any other value and it will have no effect on the results.
8. Enter the background of the quantity you are measuring. You are able to change the background value after the analysis if necessary.
9. Choose the units of your data
   1. If the data is a gas the options include ppt, ppb and ppm
   2. If the data is particles the units must be ug/m^3
10. Choose whether to load the data from online or a local location
    1. Online connects to the oil sands archive on the Environment Canada networks
    2. If you are not connected to the Environment Canada network you must choose a local location
       1. Online files must be copied to a location on your machine for the flights you wish to look at.
       2. There are a number of directories labelled by flight number.
       3. If you choose Local in the data window you will be prompted for the location of your local directory
       4. Choose the directory which contains all of your flight directories. DO NOT choose the flight directory itself or you will encounter an error.
11. Programs may take a few minutes to run depending on the flight and the data
12. Three plots will be loaded showing profiles, the screen and results

***Analyzing Results:***

\*For full kriging ONLY a variogram plot will appear. The user can adjust the sill, nugget and range and then click “Rerun fit” until the line appears to fit the points displayed. These fit values will be used for the subsequent kriging.

On the right side of the window is the **screen plot**:

* In the middle of the panel the kriged screen is displayed
  + The screen is coloured according to the concentration data
  + The black points show the flight track
  + The gray area at the bottom shows the ground
  + In the case of box flights each side of the box will be labelled with its direction
* In the case of box flights – above the screen is a line plot showing the mixing ratio at the top of the box – this will be used to calculate the emission rate through the top of the box
* At the bottom of the panel are several line plots indicating the surface concentration value at each location along the box/screen using different fitting methods.
  + The black line uses a constant value – The concentration at the lowest point on the screen is assumed to be constant from that point to the ground.
  + The green line uses a linear fit – Points up to a height of 300 m (this can be changed later) are fit to a line which extends to the surface.
  + The red line uses an exponential fit – Points up to a height of 300 m (this can be changed later) are fit to an exponential function which extends to the surface.
  + The purple line uses the background value – Below the flight path the concentration is assumed to be the background value everywhere.
  + The green-brown line uses a linear interpolation – The concentration linearly changes between the value at the lowest point on the screen and the background value at the ground.
* Above the line plots is another line plot that will be blank initially. As extrapolation methods are chosen for different sections of the data this will fill with the surface value using the method chosen by the user.

Along the right side of the panel are a series of buttons:

* **Show Wind/Air Screens** – displays the wind and air flux screens that were used for this flight
* **Show Time Series** – displays a time series of the concentration data for this flight
* **Show Vertical Profile** – displays vertical profiles of the concentration (in red), pressure, temperature and dew point temperature for the entire flight (not just the box or screen time period)
  + Vertical profiles for a specific time period of the flight can be obtained by using “Choose Time Period”. Default times are the beginning and end of the flight
  + Vertical profiles for a specific area can be obtained using “Choose Area”. A map will appear showing the flight path. Select an area of the map using the marquee box (click and drag) then choose “Area Selection Complete”. The profiles will update to only use data points from this area.
* **Reset Axis** – Screens and plots can be zoomed using the marquee box in Igor (click and drag). In order to reset to the original view select “Reset Axis”.
* **Print Values** – Drag pink C cursor from the top left corner of the panel onto any of the flight locations (black dots) on the screen plot. Click “Print Values” and the timestamp and concentration of this point will be printed to the Command Window.
* **Obtain Emission Plume** – Use edge detection to find the plume in the screen. When the button is clicked a new screen will pop up showing where the computer estimates the plume location to be. The user can decide whether to use the filled or unfilled screen using the pop up menu at the top right of the panel. Areas in colour on the screen indicate the plume, areas in black and white are not part of the plume. If several locations inside the plume area are not considered part of the plume and should be, the user can click “Fill Plume” to have the computer attempt to fill more of the area. To manually add areas to the plume click and drag a box over the area you want to add to the plume and click “Add Section to Plume”. To manually remove sections of the plume click and drag a box over the area you want to remove and click “Remove Section from Plume”. When you have finished selecting the plume area click “Obtain Plume Emission” which will print the emission rate to the command window.
* **Obtain Emission Selected Section** – Click and drag a box over a section of the screen and click “Obtain Emission Selected Section”. This will print out the box location and emission rate through this area of the screen. If no marquee box is present on the screen a dialog will pop up asking for the box dimensions. This can also be used on final, filled screens by selecting a marquee box on the final screen and entering “GetScreen()” into the Command Window.
* **Obtain Average Selected Section** – Click and drag a box over a section of the screen and click “Obtain Average Selected Section”. This will print out the box location and average concentration in this screen. If no marquee box is present on the screen a dialog will pop up asking for the box dimensions. This can also be used on final, filled screens by selecting a marquee box on the final screen and entering “averageScreen()” into the Command Window.
* **Change Top Mixing Ratio** – Change the mixing ratio at the top of the box (used for calculating the emission rate through the top of the box) to a constant value. This can be reset to the initial values (where the top mixing ratio is the concentration at the top of the box at each location) by entering NaN.
* **Change Background** – Change the value used as the background. This will affect some fits to the ground
* **Extrapolate Upwards** – Increase the height of the screen by extrapolating upwards. When the button is clicked a dialogue will pop up asking whether a new extrapolation is being created and the height to extrapolate to. This also gives the option to revert to the original screen if a previous extrapolation has been run.
  + A new screen and profiles plot will be created that work similarly to the original versions of these plots.
  + At the top of the panel on the right side of the screen are the extrapolated values at the top of the new screen. The colours are the same as those given for the extrapolated values to the ground.
  + In the middle is a plot that will be blank initially. As with the extrapolation to the ground, this will display the top value using the user selected extrapolation method
  + Click Set Profiles to choose which fit to use.
  + Click Done to save changes and return to the previous screens.
* **Set Profiles** – Use blue A and B cursors on the bottom line plot to select a horizontal region of the screen. Click “Set Profiles” to set an extrapolation method for that section of the screen. This will add a line to the middle plot showing the surface value using the chosen method.
* **Calculate Emission Rates** – Fill the screen to the ground using the method(s) chosen by Set Profiles. If no method was chosen for an area of the screen a constant value will be used (equivalent to using Set Profile -> Constant). A completed screen will be displayed and the emission rate will be printed in the Command Window. The emissions panel will be updated to show the emission rates as well.
* **Help** – Opens a help file that contains information on how to use various buttons and functions.

On the top left of the screen is the **profiles plot**:

* Plot shows in more detail the results of the extrapolation to the ground at each point, displaying Height vs Concentration. It starts at the final point on the screen. The s value of this point is displayed on the bottom left corner of the plot.
  + A different point can be viewed by clicking the “Previous” or “Next” button.
  + A different point can also be chosen by entering a horizontal grid square and hitting enter
  + Initially data is fit up to a height of 300 m above the surface. This height can be changed by entering a new height and clicking “Rerun”.
  + On the plot:
    - Red points represent the concentration at each grid square in the screen at the given s location up to the chosen height.
    - Thick black line represents the bottom of the flight path at the given s location
    - Red line shows the exponential fit
    - Green line shows the linear fit
    - Thin black line shows a constant value to the surface
    - Purple line shows the background value below the flight path
    - Green-brown line shows a linear interpolation between the concentration at the bottom of the flight path and the background at the surface

On the bottom right of the screen is the **emissions panel**:

* Emission rate equations are shown with variable definitions for mass balance and air flux.
* Table shows the numerical values of these variables for this run of the function.
* Eair,H is the horizontal/lateral emission rate of air
* Eair,V is the vertical emission rate of air (through the box top)
* XTop is the average mixing ratio at the top of the box
* MR is the molar mass ratio (between molar mass of gas and molar mass of air)
* EC,H is the horizontal/lateral emission rate of the quantity
* EC,V is the vertical emission rate of the quantity
* EC,M is the change in mass within the box volume
* EC is the total emission rate
* In the case of screens some of these values will be left blank as they are not applicable (Eair,V, XTop, EC,V, EC,M)
* Some of these values will be displayed as NaNs when the program is initially run. Before “Calculate Emission Rates” has been run the emission rates have not been calculated so NaN values will be displayed for those entries in the table.

***Other Tools:***

On the Analysis menu, TERRA -> Show Kriging History

* Displays a table showing the completed runs of the program (a line is created every time “Calculate Emission Rates” is run
* Table contains information about the inputs used and the resultant emission rates

On the Analysis menu, TERRA -> Show plots

* Regenerates the three main plots if they have been closed. Data displayed will be from the most recent run of the functions. It is not possible to regenerate the plots from a previous run.

On the Data menu, Save Waves -> Export to KML File functions

* Export coordinates to a Google Earth KML file – Takes latitude, longitude, altitude and concentration values and creates a flight track coloured by concentration. Colour scale is exported as a jpeg image.
* Export wind to a Google Earth KML file – Takes latitude, longitude, altitude, wind speed and wind direction values and creates a flight track made up of arrows. Direction shows wind direction and size indicates wind speed.
* Export a matrix screen to a Google Earth KML file – Takes a matrix wave (one of the screens, ScreenF for the filled screen, ScreenU for the unfilled screen) and exports it to be displayed in 3D in Google Earth. Colour scale is exported as a jpeg image.
* Export a wind screen to a Google Earth KML file – Takes a matrix wave wind screens and exports them to be displayed in 3D in Google Earth. Direction shows wind direction and size indicates wind speed.