UNIVERSITÀ
DEGLI STUDI DI TRIESTE

CALMET-CALPUFF modeling system

http://www.src.com

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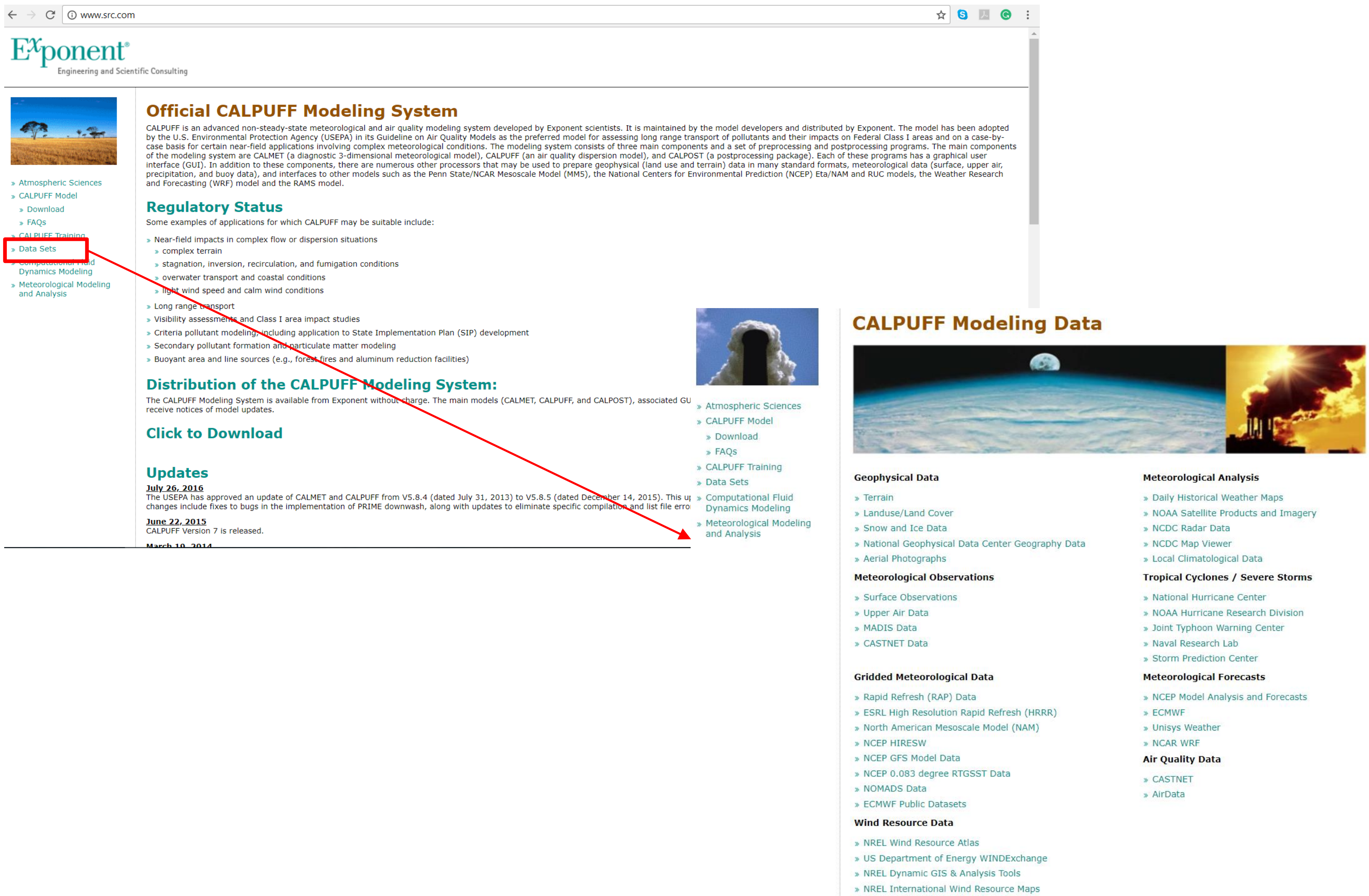
You can find all the information on the website
http://www.src.com

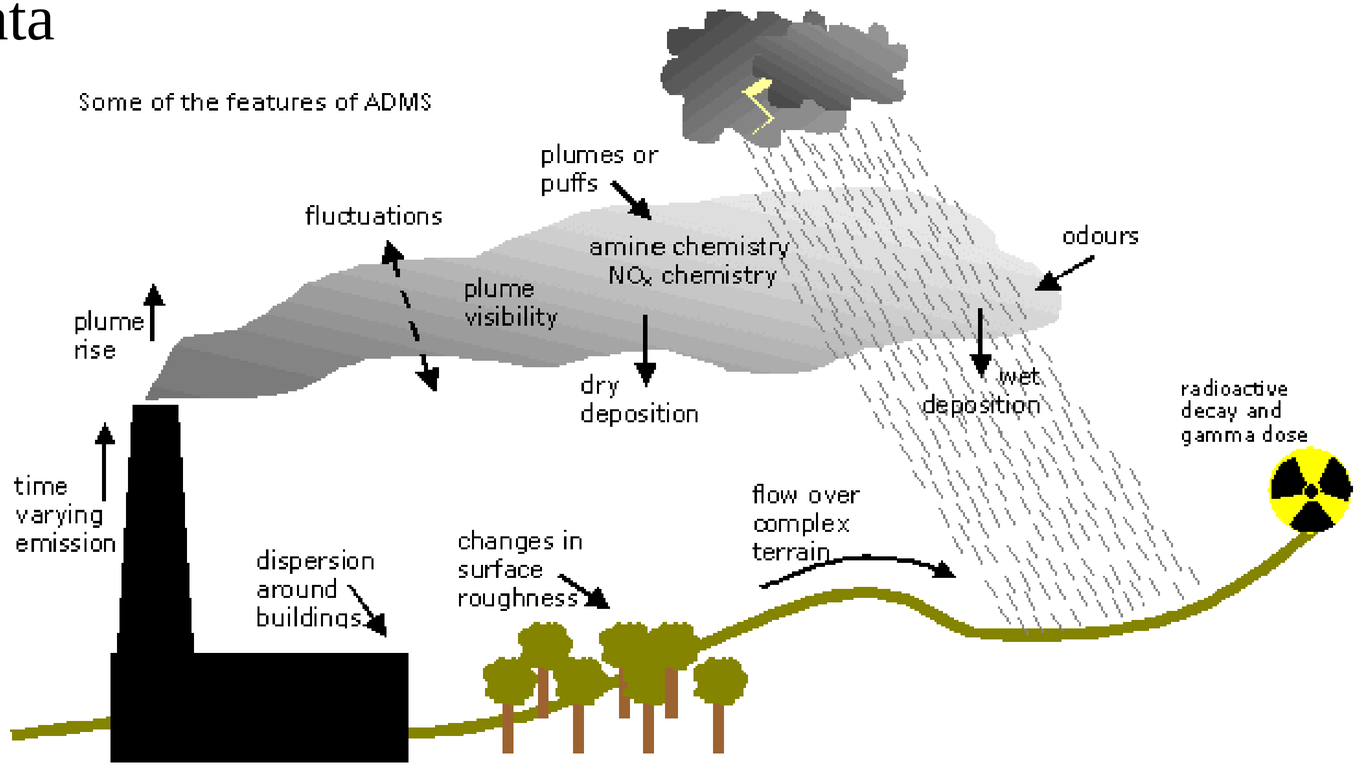


Outline of our course

1) Calmet-Calpuff model
2) Case study on Sydney, Asutralia
3) Case study on Monfalcone, Italy

Data requirements for Air Quality Model (AQM)

1) Meteorological data (Wind, Temperature, Humidity, …)
2) Geophysical data (Terrain, Land use)
3) Emission data

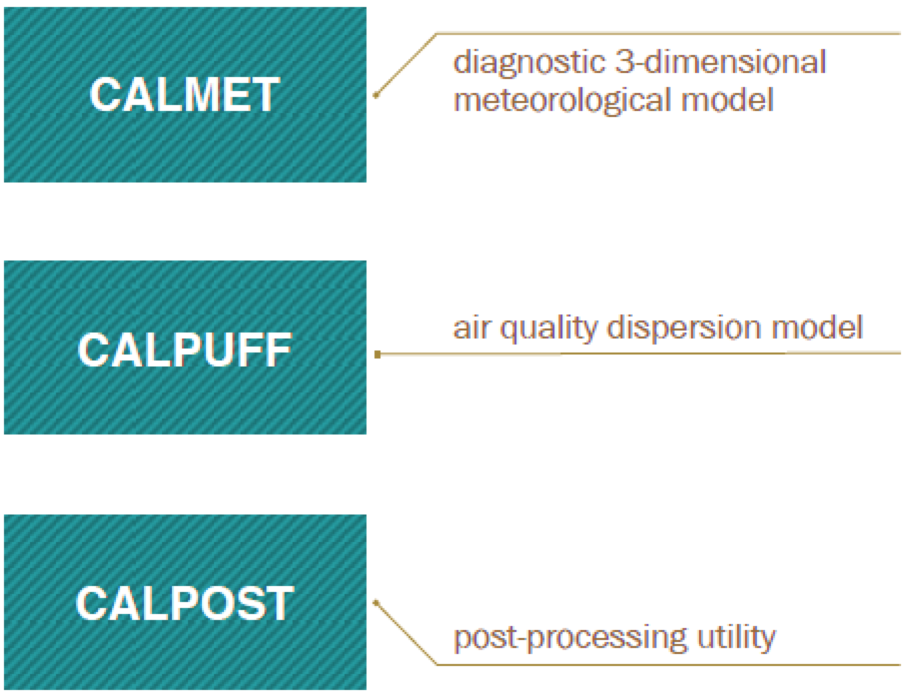


The CALPUFF Modelling System

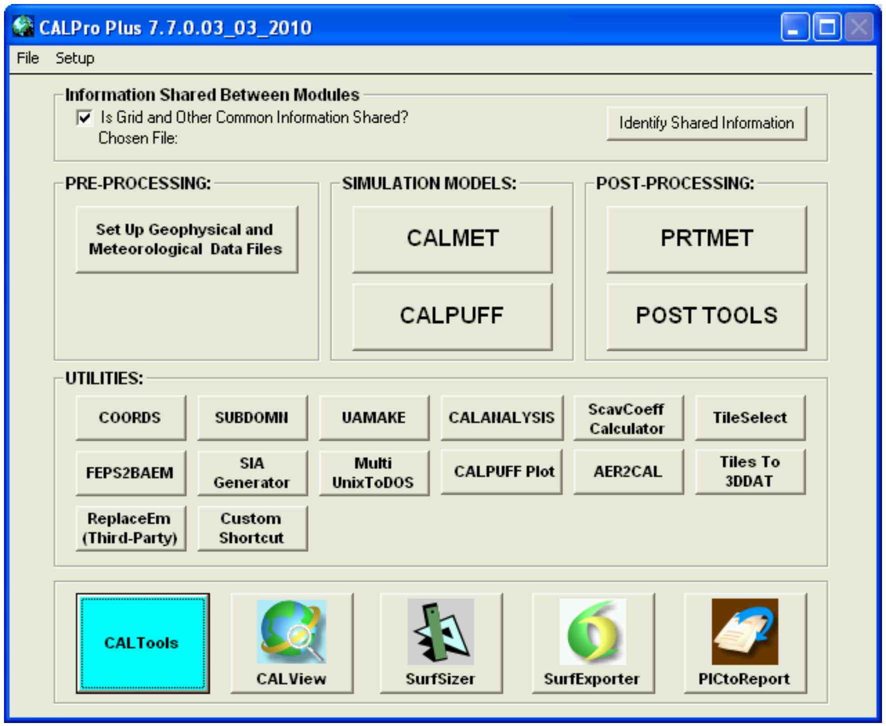
After running the CALMET model, inputs to CALPUFF must be prepared.

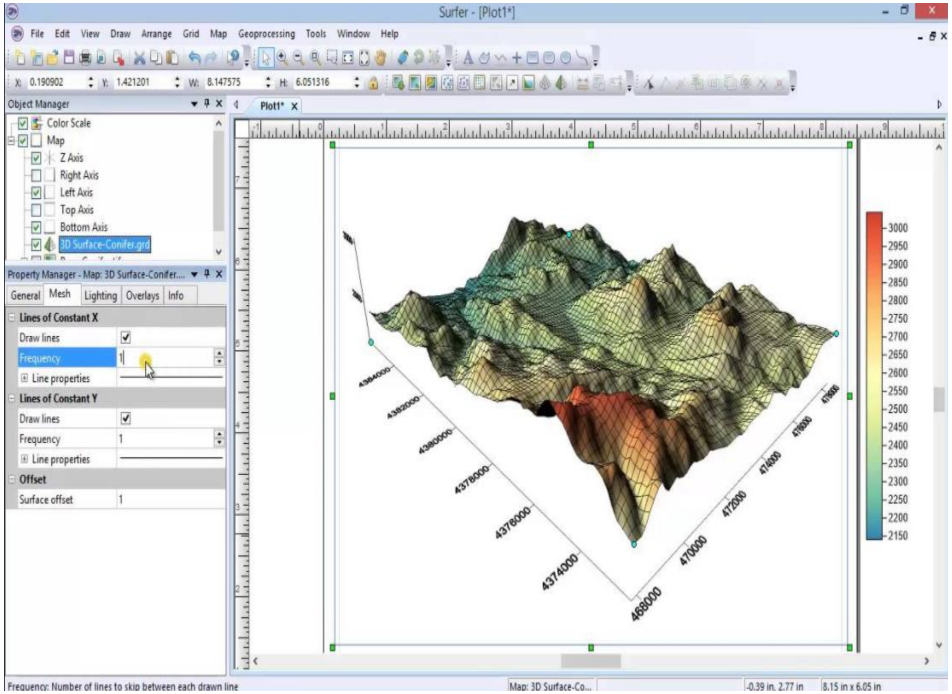
The CALPUFF air quality dispersion model requires CALMET model output and a properly formatted CALPUFF input control file.

The CALPUFF input control file contains a vast array of options for defining a dispersion model.



CALPro GUI & SURFER





CALMET (diagnostic meteo processor)

- **Input data**: P, Elevation m.s.l, T, wind direction, wind speed, vertical velocity, relative humidity at different levels and every *three* hours
- **Output data**: U, V, W wind components, T and all the micrometeorological variables on a specified grid and *every* hour

HOW DOES IT WORK?

Initial-guess wind field → Prognostic code output

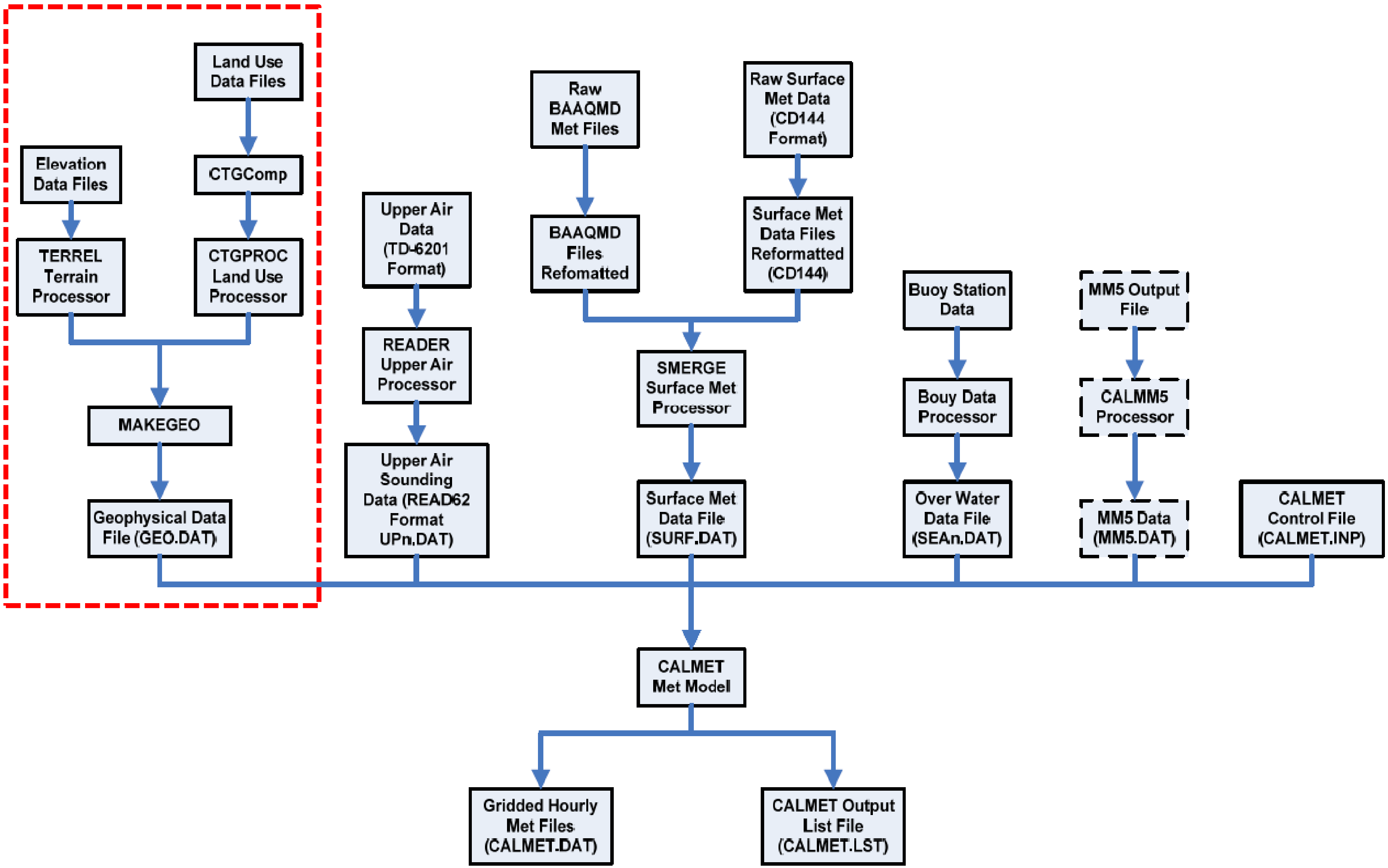
Compute Terrain effects →
- Refinement by interpolation
- Blocking effect
- Divergence minimization

Step 1 wind field

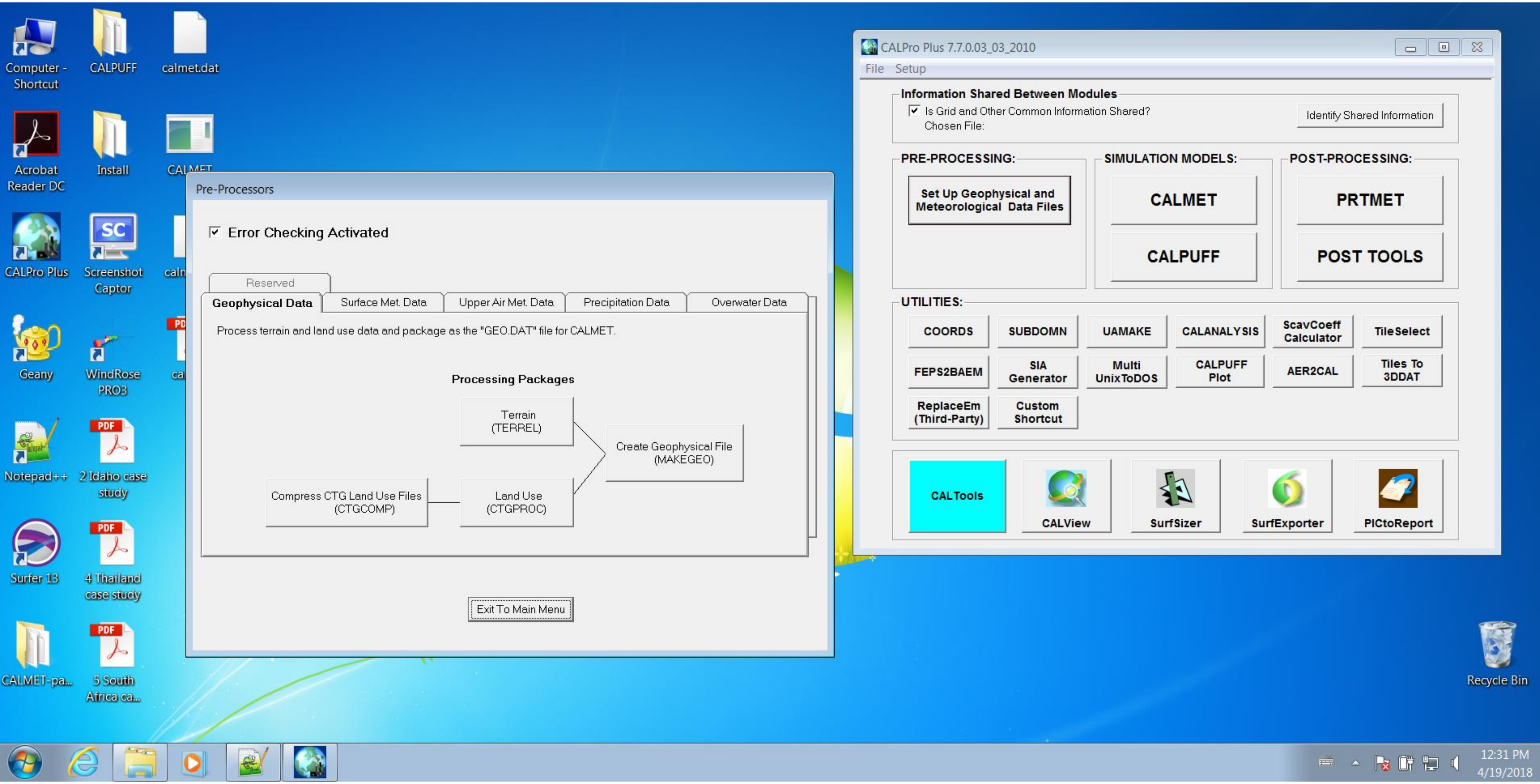
Objective analysis

Step 2 (Final) wind field

Meteorological data processing flowchart

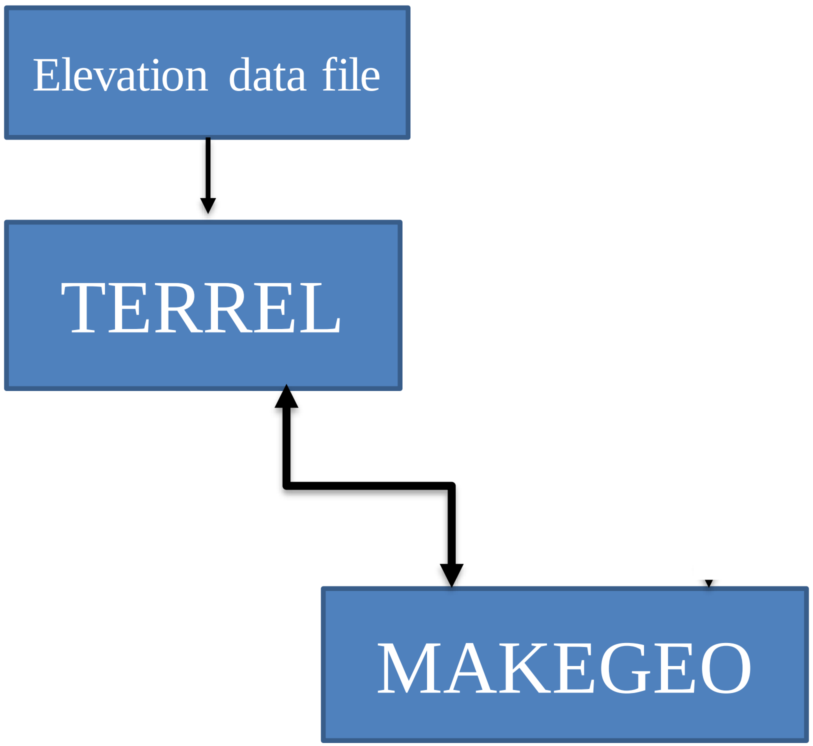


Preprocessors GUI



1) Geophysical Processors

- ✓TERREL ⟹ Terrain Preprocessor
- ✓CTGPROC ⟹ Land Use Data Preprocessor
- ✓**MAKEGEO** ⟹ **Geo.dat**



TERREL database, you can find them here

www.src.com/calpuff/data/terrain.html

Exponent
Engineering and Scientific Consulting

- Atmospheric Sciences
- CALPUFF Model
  - Download
  - FAQs
- CALPUFF Training
- Data Sets
- Computational Fluid Dynamics Modeling
- Meteorological Modeling and Analysis

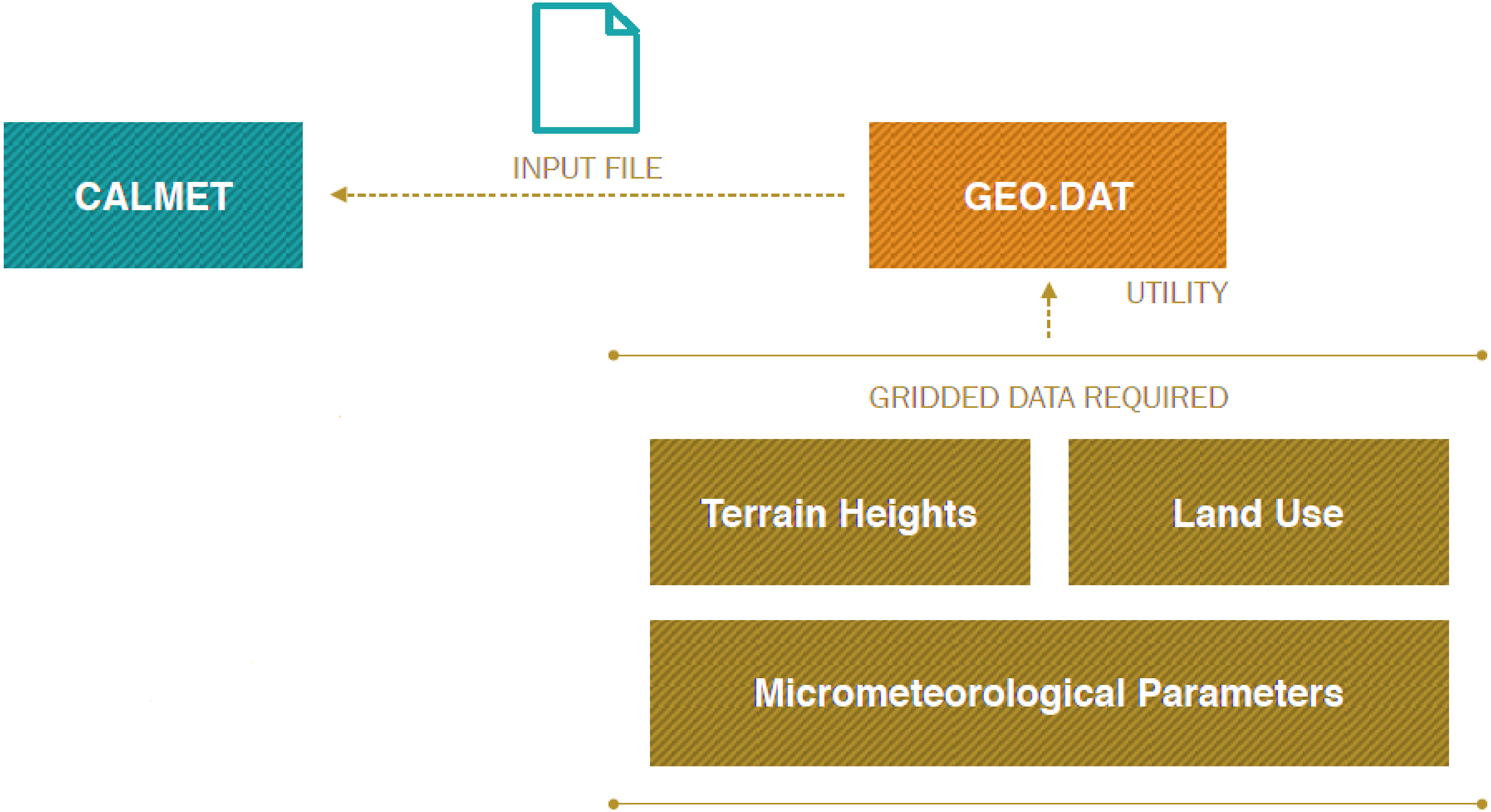
Terrain Data

Data Set	Coverage	Resolution	Data format	Date of data	TERREL dataset keyword
GMTED2010 [1]	Global	30 arc-second (~1 km) 15 arc-second (~500m) 7.5 arc-second (~250m)	GeoTIFF	2010	GEOTIFF
ASTER [1]	Global	1 arc-second (~30m) 1° by 1° tiles	GeoTIFF	2011	GEOTIFF
SRTM30 [2]	Global	SRTM30: 30 arc-second (~1 km)	SRTM	2000	GTOPO30
SRTM3 [1]	Global	SRTM3: 3 arc-second (~100m)	SRTM	2000	GEOTIFF
GTOPO30 [1]	Global	30 arc-second (~1 km)	DEM	1996	GEOTIFF
SRTM1[1]	U.S.	SRTM1: 1 arc second (~30m)	SRTM	2000	GEOTIFF
NED [3]	U.S.	2 arc-second (Alaska), 1 arc-second (U.S., most of Canada, Mexico, Hawaii, portions of Alaska) 1/3 arc-second (U.S., Hawaii, and portions of Alaska), or 1/9 arc-second (limited areas of U.S.)	ArcGrid, GridFloat, or IMG	updated continually as new data become available	GEOTIFF[3]
CDED [4]	Canada	0.75 arc-second (~23m) 3 arc-second (~100m)	DEM	2007	CDED
IFSAR [1]	Alaska		GeoTIFF	2010, 2012	GEOTIFF

[1]Through the USGS Earth Explorer site, the following terrain data sets can be downloaded:

Digital Elevation

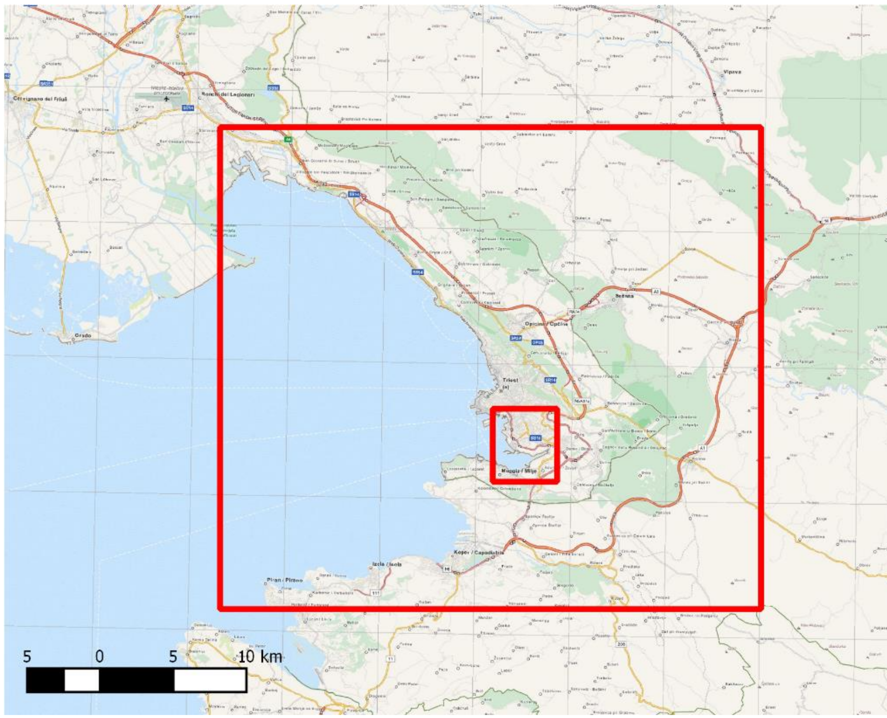
CALMET Primer: Geophysical Data

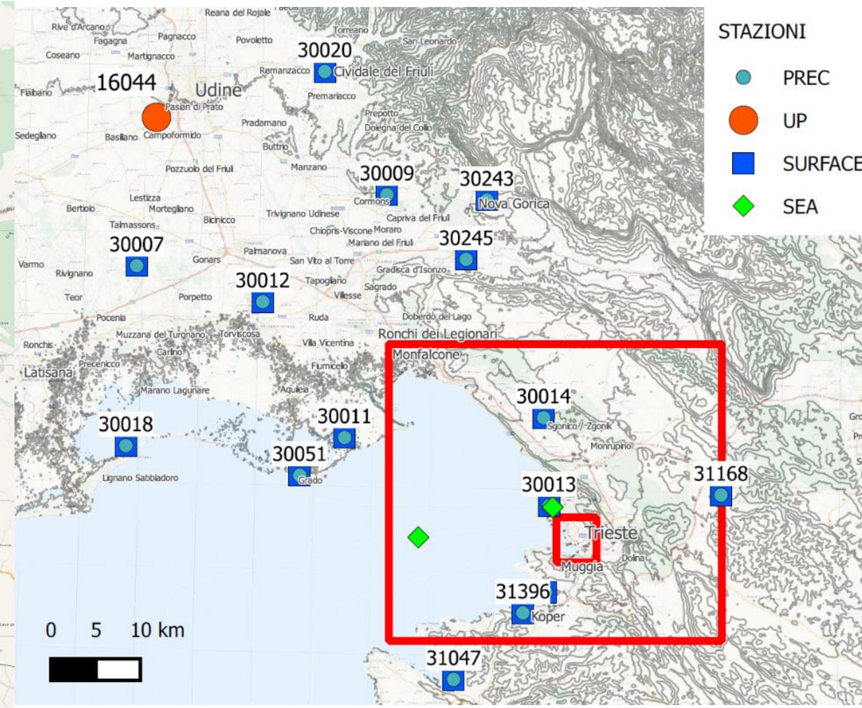


2) Meteorological Data Preprocessors

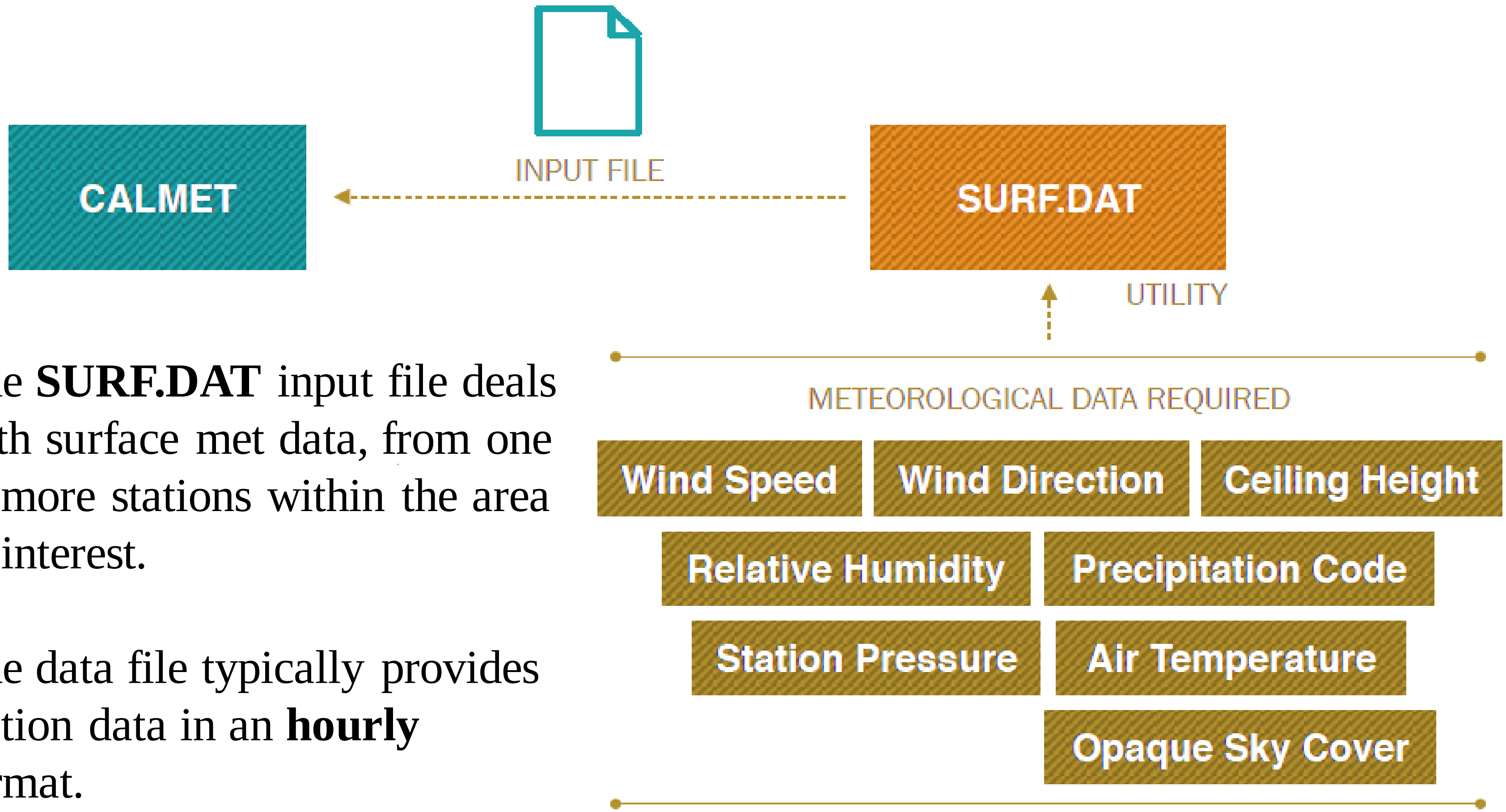
- ✓ READ62 Upper Air Preprocessor (UPn.dat)
- ✓ PMERGE Precipitation Data Preprocessor (pricip.dat)
- ✓ SMERGE Surface Meteorological Data Preprocessor (surf.dat)
- ✓ Over water data file (SEAn.dat)
- ✓ …

Receptor sites around Trieste





CALMET Primer: Surface Met Data



The **SURF.DAT** input file deals with surface met data, from one or more stations within the area of interest.

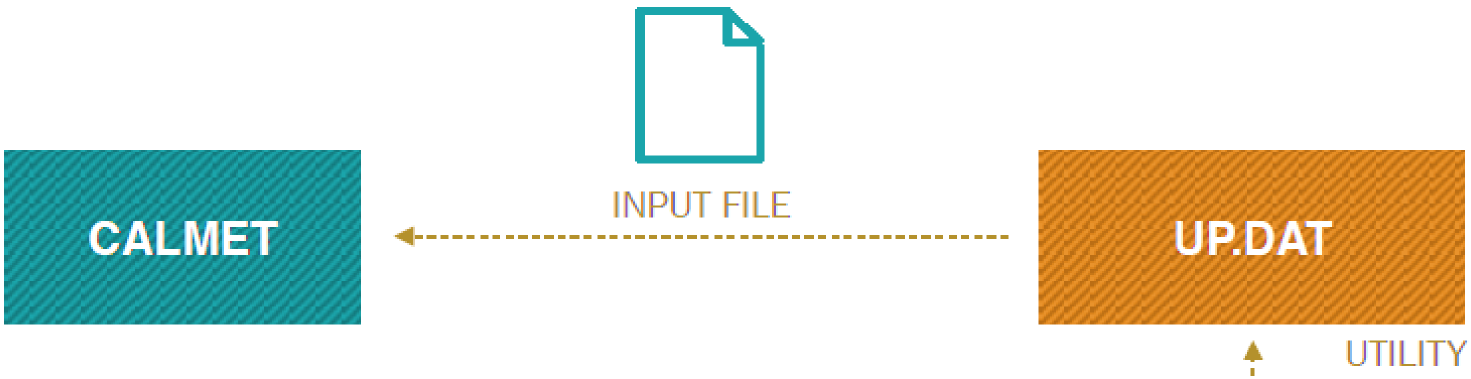
The data file typically provides station data in an **hourly** format.

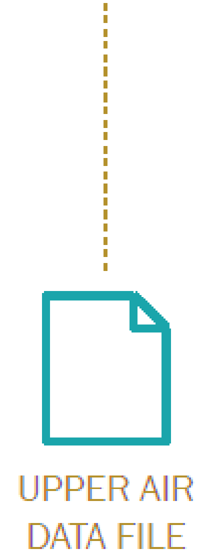
Sample “surf.dat” file

C:\CALPUFF\LUNESS\From-Anna\esercitazione\surf.dat - Notepad++ [Administrator]

```
SURF.DAT         2.0                       Header structure with coordinate parameters
 1
 Produced by User
NONE
  2008   1   0   2008 366  23    0   15
 14607
 14609
 14611
 14612
 14613
 14614
 14618
 14620
 14651
 14843
 15647
 15996
 15732
 15768
 14845
2008   1   0
    2.300   60.000   82     0  269.550   87 1021.300    0
    0.700   16.000   82     0  276.150   48 1017.800    0
    4.300   31.000   82     0  276.150   60 1025.500    0
    1.200    0.000   82     0  269.350   87 1026.900    0
    7.400   77.000   82     0  278.750   53 1022.000    0
    5.400   76.000   82     0  275.150   57  994.800    0
    3.200   68.000   82     0  277.650   65 1023.400    0
    4.200   58.000   82     0  274.250   66 1009.700    0
    1.800   36.000   82     0  277.050   67 1021.700    0
```

CALMET Primer: Upper Air Data

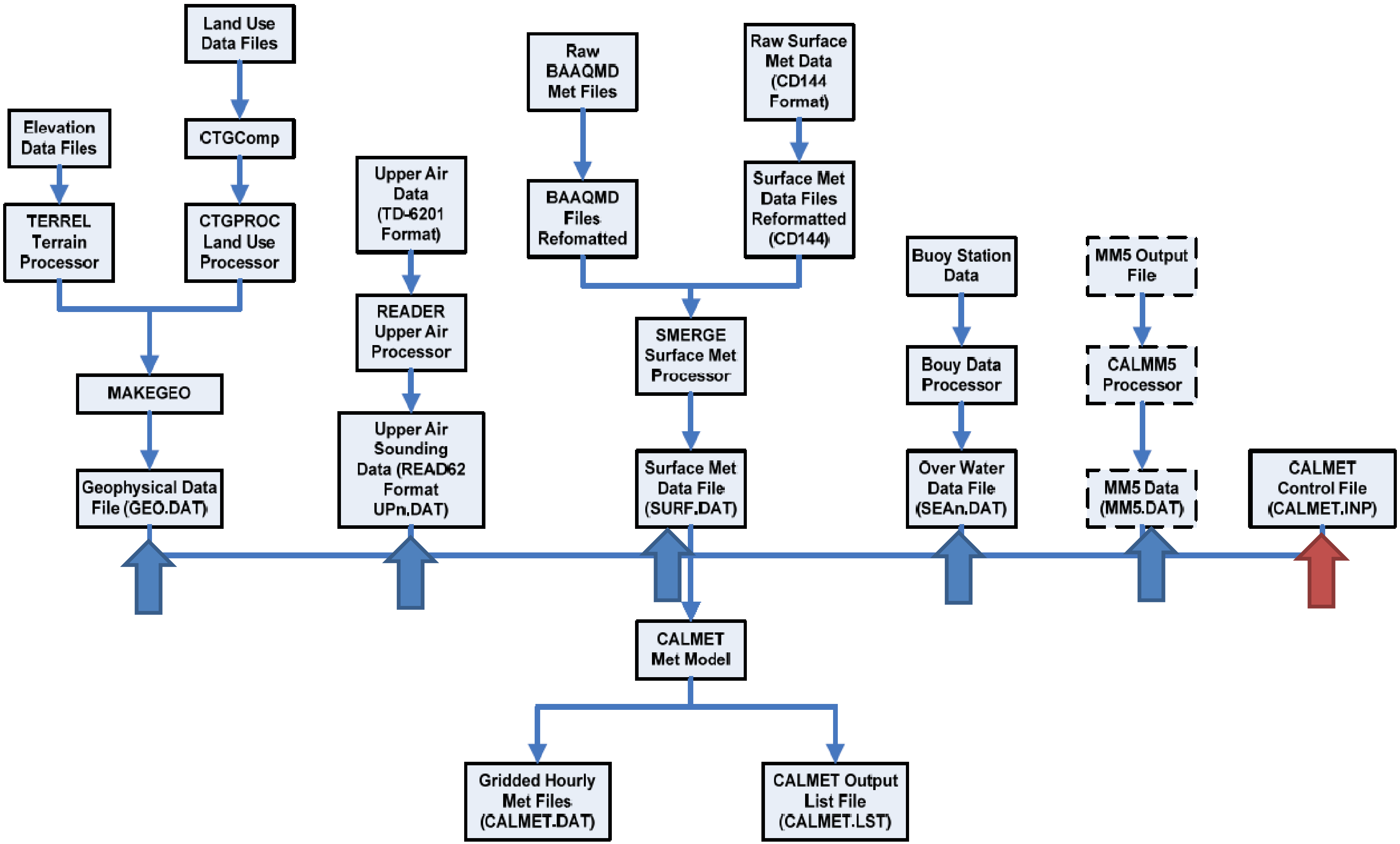




Upper air data can be incorporated into the CALMET model to blend surface station data with meteorology further aloft.

Twice-daily rawinsonde data files are used to generate an UP.DAT file. Upper air sites are typically sparse.

Meteorological data processing flowchart



CALMET Primer: Control File

The CALMET input file contains a large variety of model option, parameters, and I/O settings.

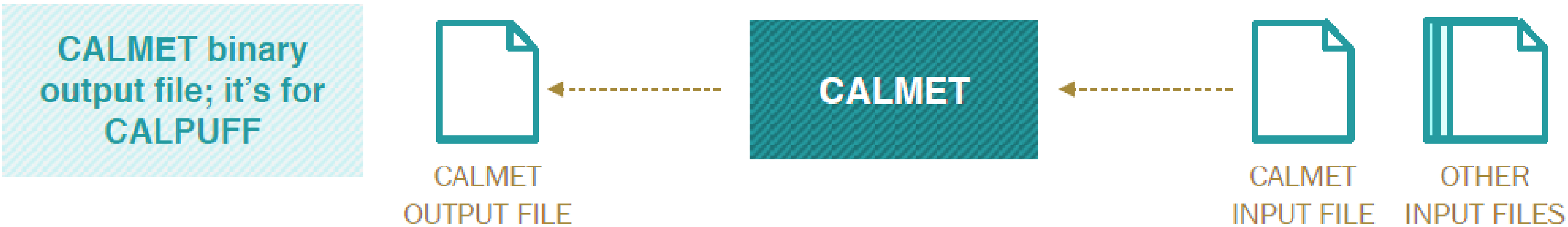
These controls are split across several input groups:

- 1 / Temporal Parameters
- 2 / Grid & Levels
- 3 / Output Options
- 4 / Met Data Options
- 5 / Wind Field Options & Parameters
- 6 / Mixing Height, Temperature, Precipitation Parameters
- 7 / Station Parameters

CALMET.INP looks like this

```
CALMET.INP      2.1             Hour Start and End Times with Seconds
CALMET MOD6 TEST CASE -
30x30 1km km meteorological grid -
1hr met data  ----------------
Run title (3 lines) ------------------------------------------
                    CALMET MODEL CONTROL FILE
                  --------------------------
--------------------------------------------------------------------------------
INPUT GROUP: 0 -- Input and Output File Names
Subgroup (a)
------------
Default Name  Type          File Name
------------  ----          ---------
GEO.DAT       input    ! GEODAT=GEO.DAT       !
SURF.DAT      input    ! SRFDAT=SURF.DAT      !
CLOUD.DAT     input    * CLDDAT=            *
PRECIP.DAT    input    ! PRCDAT=PRECIP.DAT    !
WT.DAT        input    * WTDAT=             *
CALMET.LST    output   ! METLST=CALMET.LST     !
CALMET.DAT    output   ! METDAT=CALMET.DAT    !
PACOUT.DAT    output   * PACDAT=            *
All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
         T = lower case      ! LCFILES = T !
         F = UPPER CASE
NUMBER OF UPPER AIR & OVERWATER STATIONS:
    Number of upper air stations (NUSTA)  No default     ! NUSTA =  1  !
    Number of overwater met stations
                                 (NOWSTA) No default     ! NOWSTA =  2  !
NUMBER OF PROGNOSTIC and IGF-CALMET FILEs:
    Number of MM4/MM5/3D.DAT files
                                 (NM3D) No default       ! NM3D =  0  !
    Number of IGF-CALMET.DAT files
                                 (NIGF)   No default     ! NIGF =  0  !
                       !END!
--------------------------------------------------------------------------------
```

CALMET Primer: Model Execution



The CALMET model is to be run with the input file and the associated input data files. CALMET.DAT contain hourly gridded fields of micro-meteorological parameters and 3D wind and Temp. it also contain geophysical data.

There are several other types of input data files that could be used, <u>depending on model settings:</u>

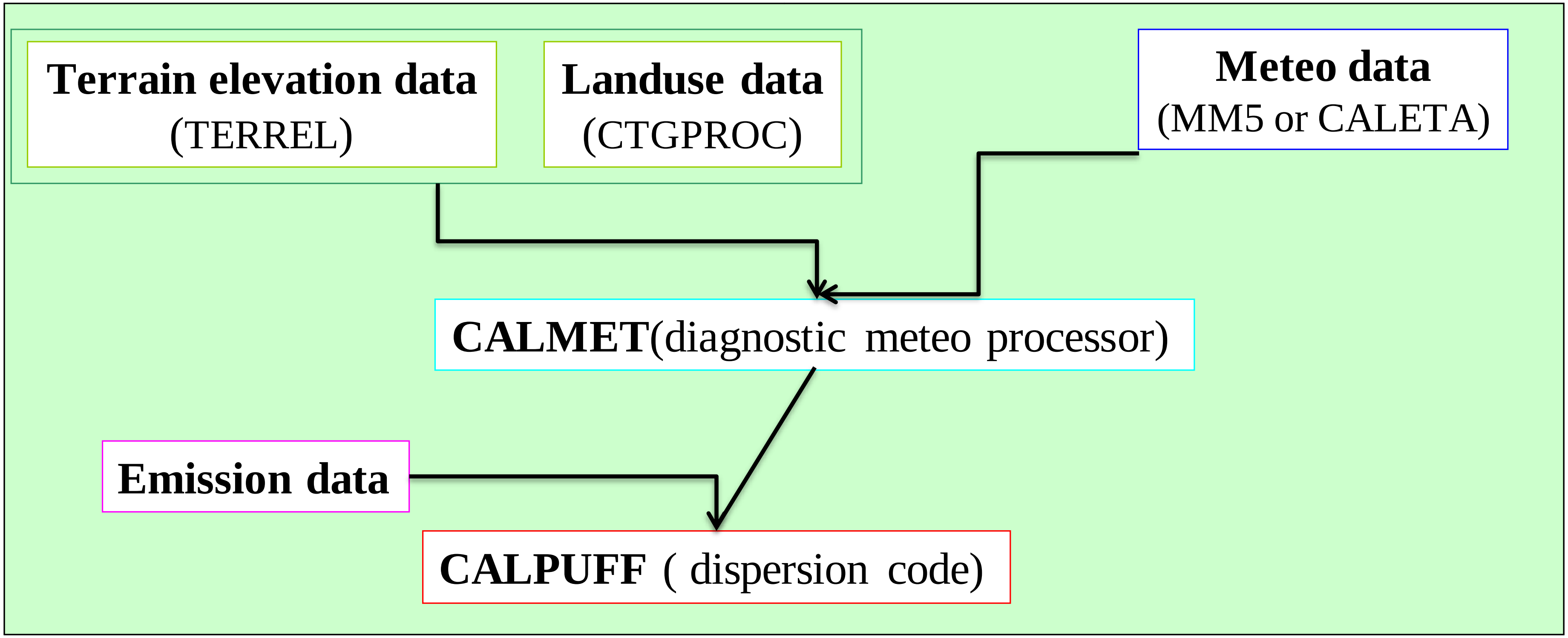
Precipitation Data File | **Overwater Station Files** | **Gridded Cloud Field File**

Preprocessed Met Data for Diagnostic Wind Module | **Hourly Gridded Wind Fields**

CALPUFF modeling

CALPUFF Modeling System

- Developed in the 90’s by Sigma Research Corporation (now part of the Earth Tech, Inc.) as air quality modeling system
- Proposed by U.S. EPA as a *Guideline* model for regulatory applications
- 3 main components and a set of preprocessing and postprocessing programmes



CALPUFF modelling

- CALPUFF is a multi-layer, multi-species non-steady-state puff dispersion model that can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, transformation, and removal. CALPUFF is designed to be applied on different scales from tens of meters to hundreds of kilometers (far-field).

- It includes algorithms for sub-grid scale effects, such as complex terrain, as well as, longer range effects, such as pollutant removal due to wet scavenging, dry deposition, and chemical reactions. CALPUFF can handle various types of emission source characterization, such as point, volume, line, and area sources. The non-steady-state nature allows CALPUFF to account for causal effects and non-straight-line trajectories.

- More importantly, CALPUFF can account for spatially varying meteorological conditions with a three-dimensional wind field. As such, in many situations CALPUFF is capable of producing more accurate results than other models, such as AERMOD.

- The advantages of the model over a Gaussian-based model is that it can realistically simulate the transport of substances in calm/stagnant conditions, complex terrain and coastline regions with sea.

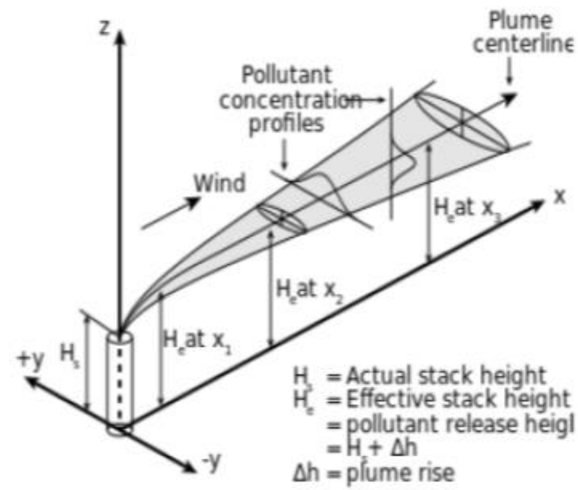
CALPUFF is a Lagrangian puff model

$$C = \frac{Q}{2\pi u \sigma_y \sigma_z} exp\left(\frac{-y^2}{2\sigma_y^2}\right)\left[exp\left(\frac{-(h-z)^2}{2\sigma_y^2}\right) + r_G exp\left(\frac{-(h+z)^2}{2\sigma_y^2}\right)\right]$$

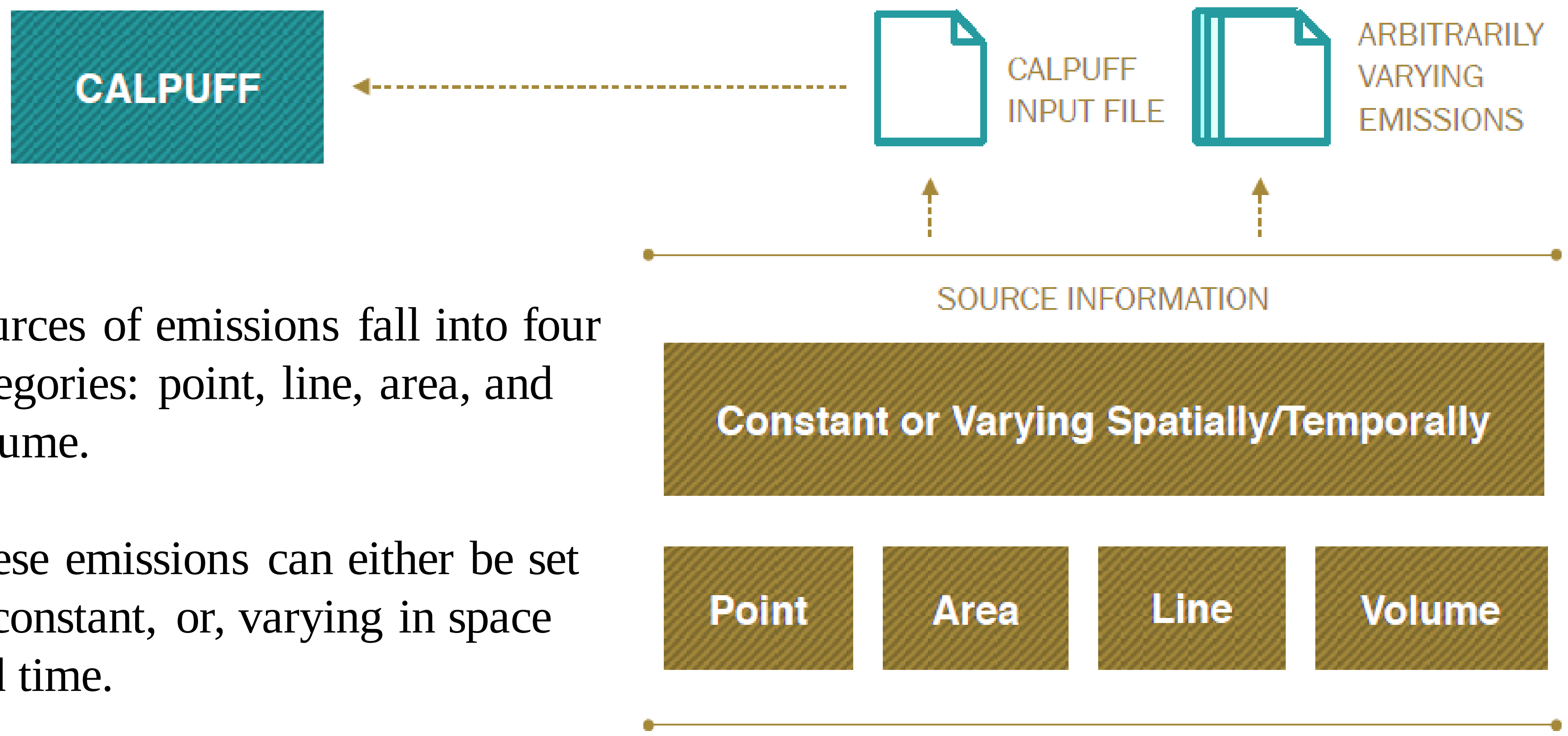
Where,
C is the species concentration at a location (x, y, z)
Q is the source emission rate
u is the average wind speed normal to the box
h is the effective source height to which the plume has risen
r_G is the ground refection coefficient where

$$0 \leq r_G \geq 1$$

y is the crosswind distance
z is the receptor height above ground
σ_x is the standard deviation (m) of the Gaussian distribution in the along-wind direction
σ_y is the standard deviation (m) of the Gaussian distribution in the cross-wind direction
σ_z is the standard deviation (m) of the Gaussian distribution in the vertical direction



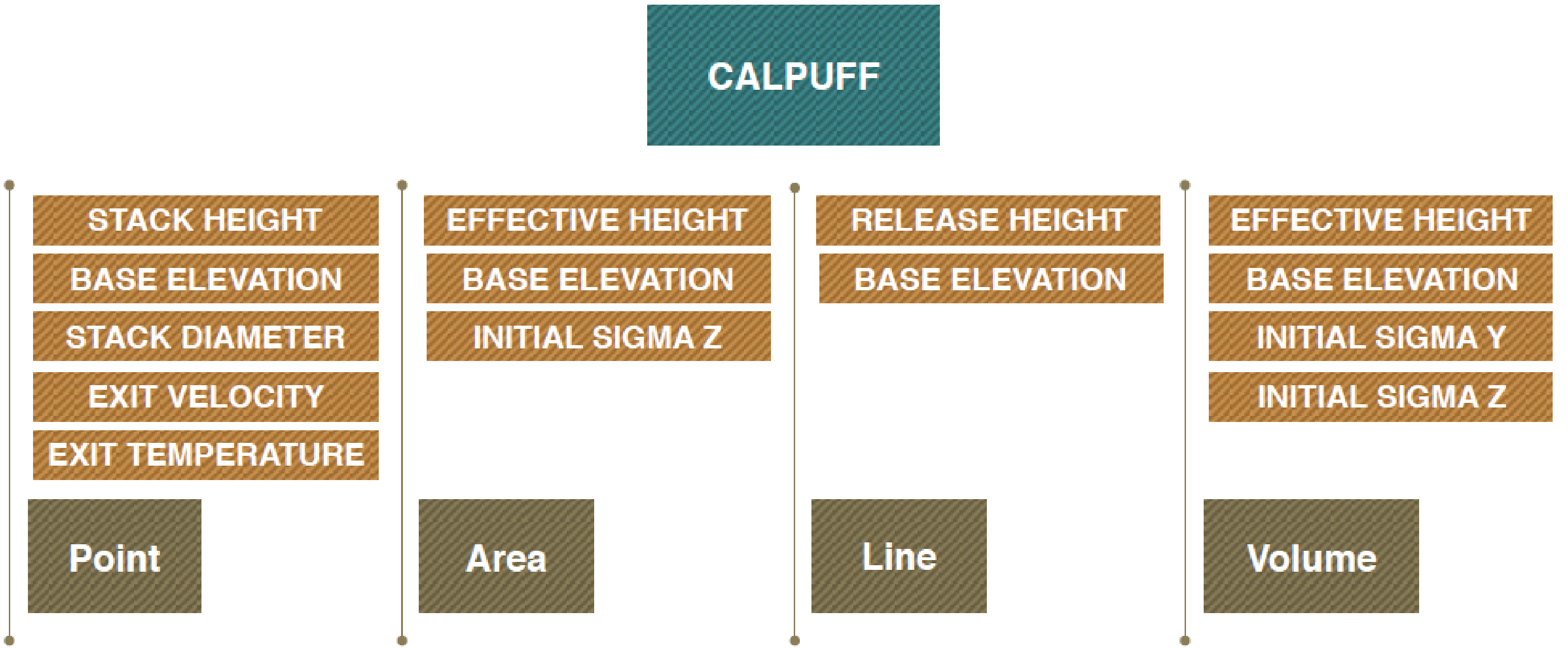
CALPUFF Primer: Sources



Sources of emissions fall into four categories: point, line, area, and volume.

These emissions can either be set as constant, or, varying in space and time.

CALPUFF Primer: Source Parameters



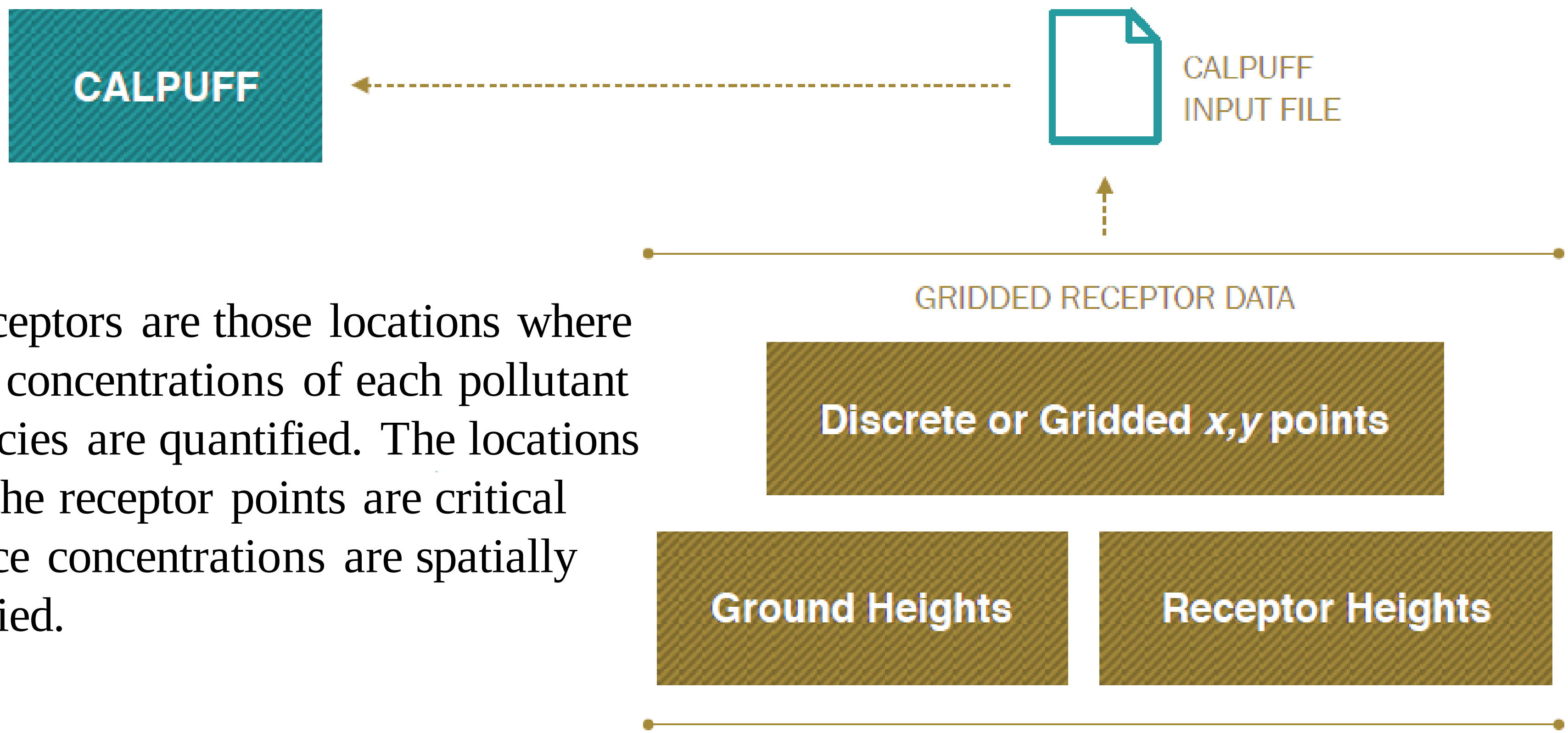
Example, For the **rising plume**:

- Exit velocity 25-75 m/sec
- Exit temperature 100-300 °C
- Initial radius 25-75 m
- Ground elevation 2550 m
- Emission height a.g. 100 m

Point Source:

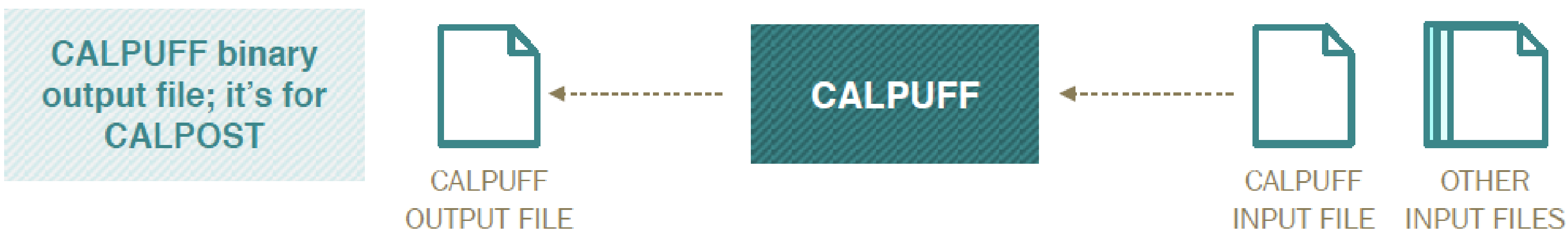
Point Source Name	X (km)	Y (km)	Stack Ht (m)	Base Elev (m)	Stack Diam (m)	Exit Vel. (m/s)	Temp (°K)	Emiss. Rate (g/s)
P1	1671.527	-896.092	200.0	5	8	30	800	10

CALPUFF Primer: Receptors



Receptors are those locations where the concentrations of each pollutant species are quantified. The locations of the receptor points are critical since concentrations are spatially varied.

CALPUFF Primer: Model Execution

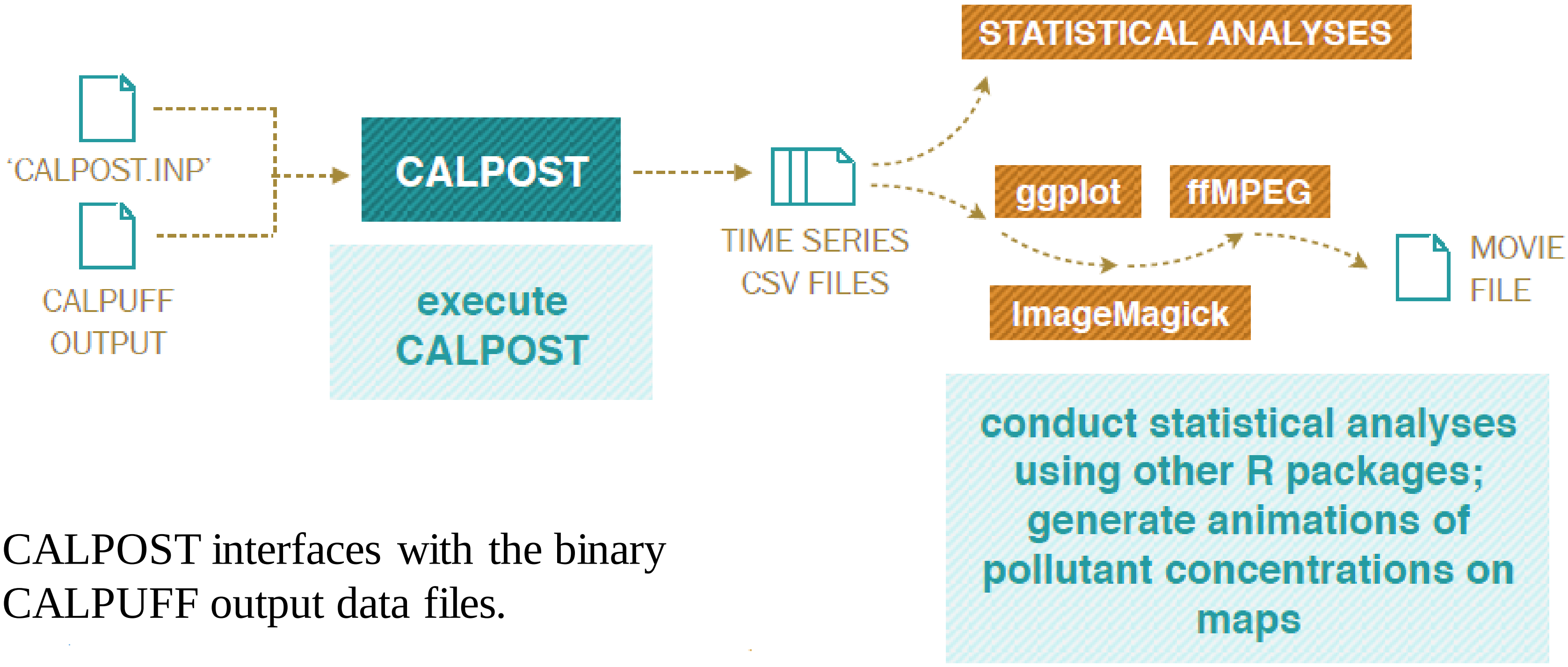


The **CALPUFF** model is to be run with the input file and the associated input data files.

There are several other types of input data files that could be used, depending on model settings:

- Coastline Data File
- Hydrogen Peroxide Data
- Ozone Data
- Ammonia Data
- Background Conditions
- Arbitrarily Changing Point, Area, Line, or Volume Sources

Analyzing the CALPUFF Output with CALPOST



CALPOST interfaces with the binary CALPUFF output data files.

Install these software!

1. **CalWindRose**

   - wind rose plotting software

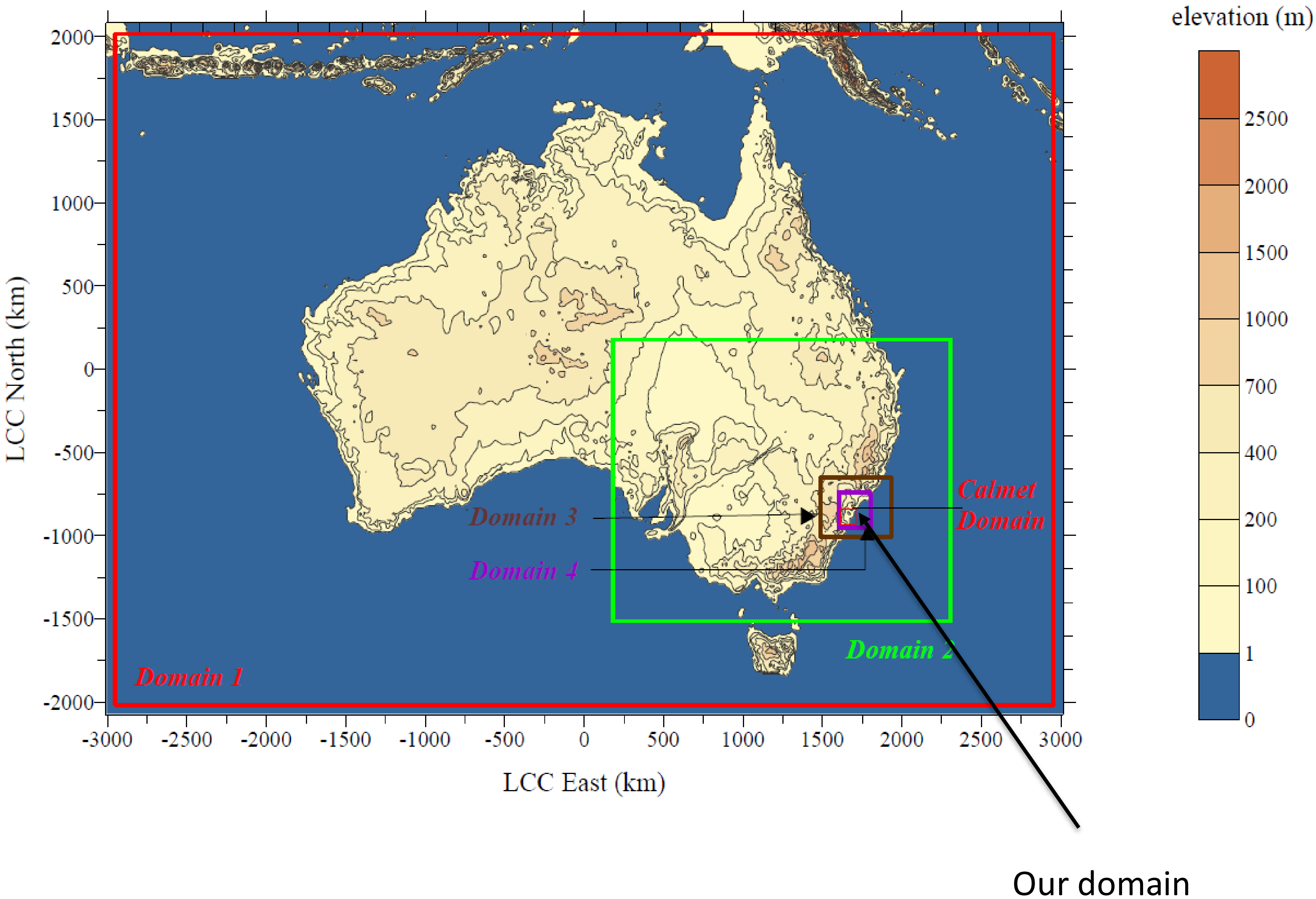
   - Display wind roses directly from SURF.DAT

2. **Surfer**

   - Display vector/contour/3-D perspective plots

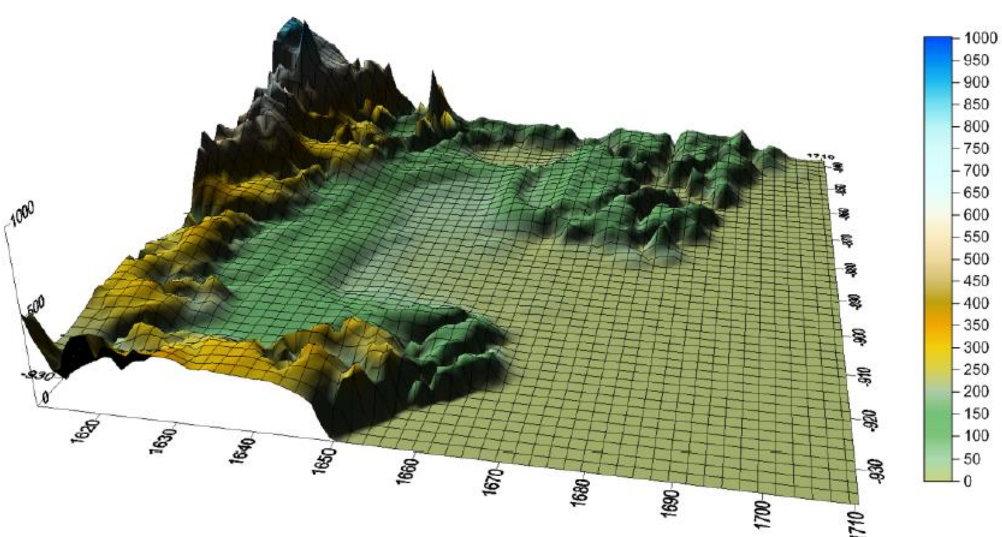
Case study 1
Sydney, Australia

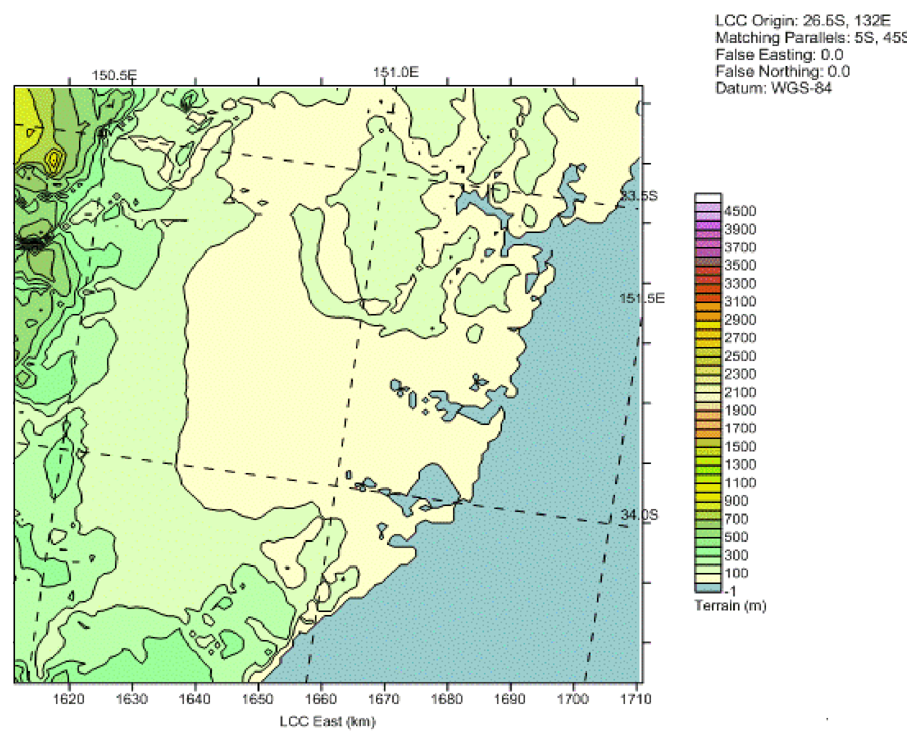
- This exercise includes 3 separate sections. The first section involves meteorological and geophysical processing. You will be required to use CALPUFF PROfessional GUI (CALPRO) to assist you in the preparation of the required input files for the CALMET model. The second section involves meteorological modeling using CALMET while the third section involves dispersion modeling using CALPUFF and post-processing using CALPOST. In this section you will model the effects of SO2 from a point source on the model domain and graphically plot the results.


elevation (m)
2500
2000
1500
1000
700
400
200
100
1
0
2000
1500
1000
500
0
-500
-1000
-1500
-2000
LCC North (km)
-3000
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
LCC East (km)
Domain 1
Domain 2
Domain 3
Domain 4
Calmet Domain
Our domain

PART 1, Create geophysical data

1) Process the geophysical data using the CALPRO GUI- Edit the screens for **CTGPROC** (landuse.dat), **TERREL** (terrain.dat) and **MAKEGEO**. Combine the Land Use and terrain files into a GEO.DAT file (MAKEGEO) for the Sydney region. Note: Use the model default values wherever you are not sure. (Geo.dat is given)



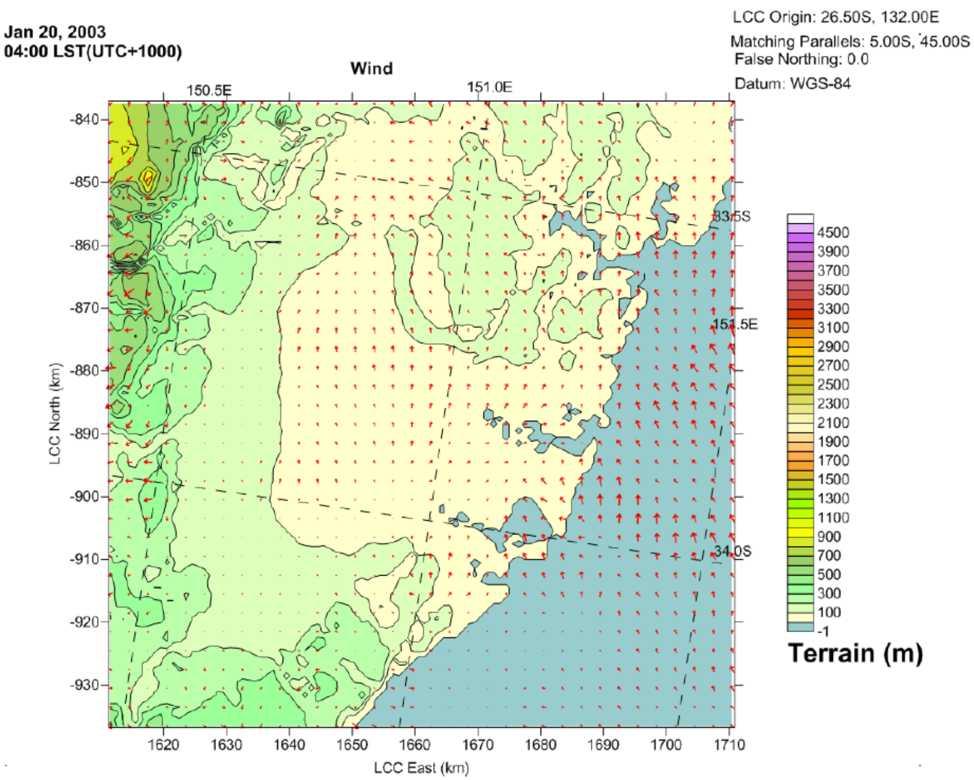


PART 2, CALMET simulations

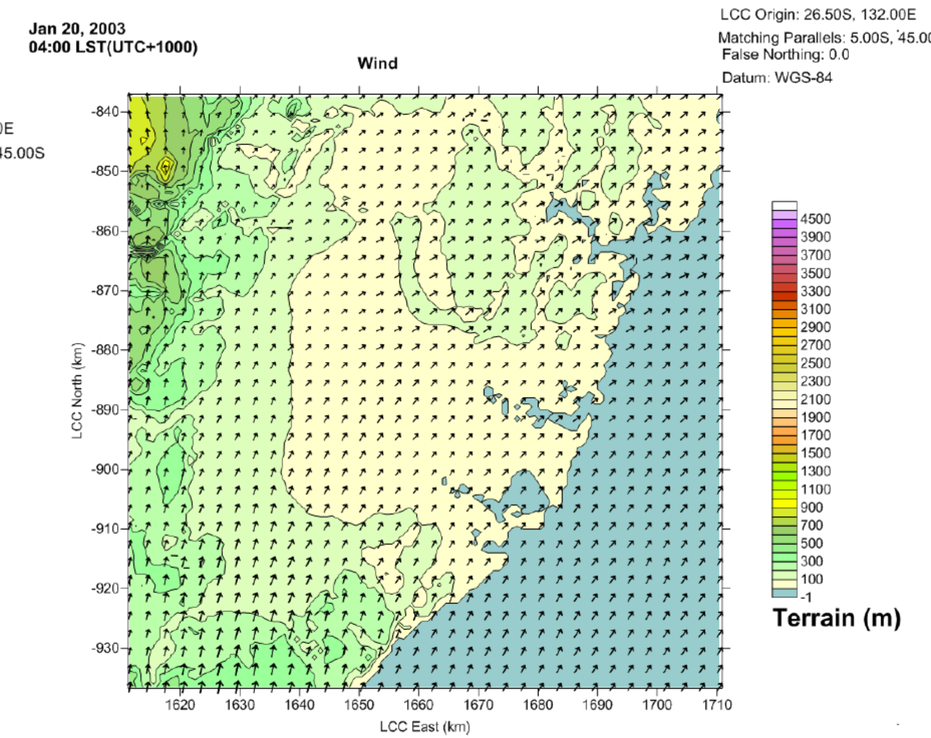
2.1) Conduct simulations of the wind flow in the Sydney region using CALMET. The file CALMET.INP is already setup and provided on the folder in the Sydney directory.

2.2) Display vector plots of the CALMET wind fields using PRTMET and SURFER

Layer 1



Layer 10



Part 3: CALPUFF/CALPOST simulations

3.1) **Step 1: CALPUFF Runs,** Using the 3-D meteorological fields computed with CALMET in Part 2, conduct CALPUFF simulations of a single fictitious tall point source in the Sydney Metropolitan region.

3.2) **Step 2. CALPOST run** Compute the 9 hour-average concentrations using CALPOST. Create plot files with CALPOST and contour plots with SURFER.