Rainfall and PET

University of Oklahoma/HyDROS

Module 2.3

Outline – Day 2

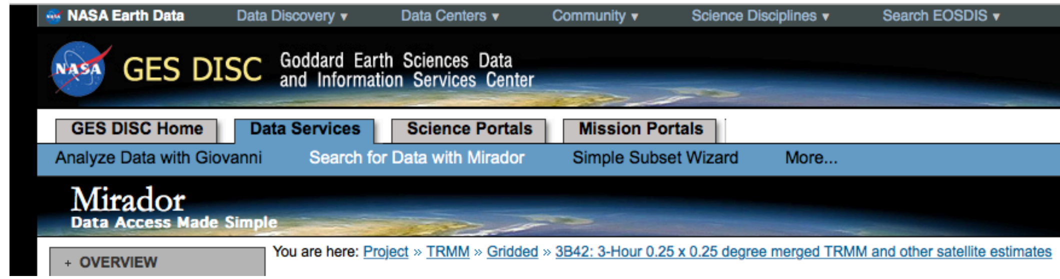
EF5 OVERVIEW

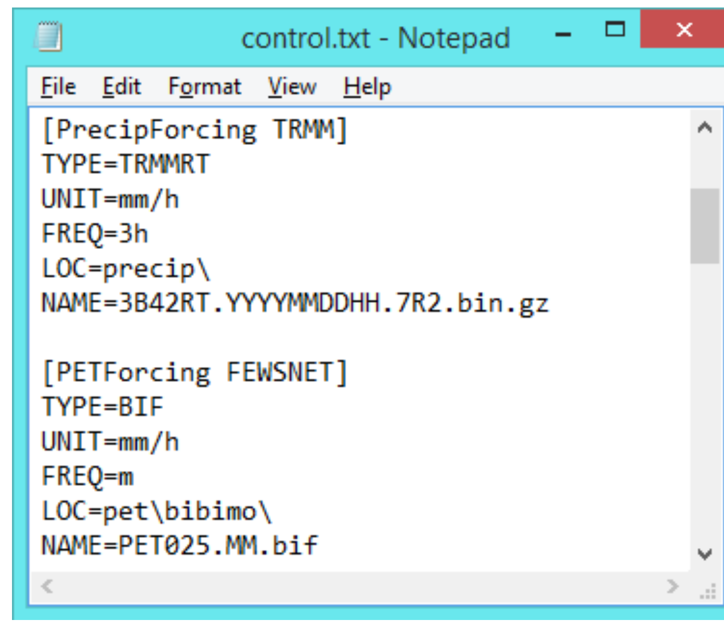
DEM DERIVATIVES

RAINFALL AND PET

- Satellite meteorology
- TMPA data
- PET data
- Visualize rainfall and PET grids
- Prepare EF5 to use example rainfall and PET grids

AUTOMATIC CALIBRATION





Rainfall Information

We need observations of the rain that is falling so our model can produce runoff in response to the rain

- We call this rainfall "forcing"

Rainfall is typically measured using rain gauges (point measurements), but we are using <u>distributed</u> hydrological models so we need <u>distributed</u> rainfall information

Satellites to the rescue! Satellites can see clouds, cloud top temperatures and in some cases cloud structures

Two ways for satellites to observe rainfall information

Passive

Instrument is only receiving information; think of this as being in a well lit room

Infrared measurements from GEO satellites or microwave measurements from LEO satellites (TRMM Microwave Imager)

Active

Instrument transmits information and then receives information in return; think of this as using a flash light in a dark room so you can see

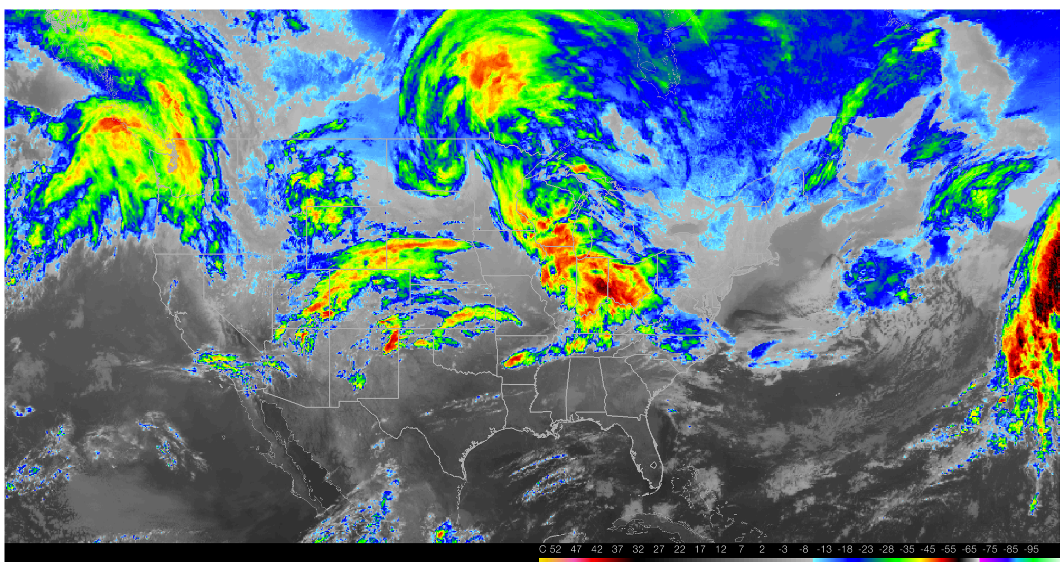
Examples include precipitation radar on TRMM, GPM

Satellite Meteorology

Passive measurements can occur over many wavelengths; this reveals different information in each spectrum

Infrared spectrum is used to derive cloud top temperatures

Then other relationships relate cloud top temperatures to rain rates

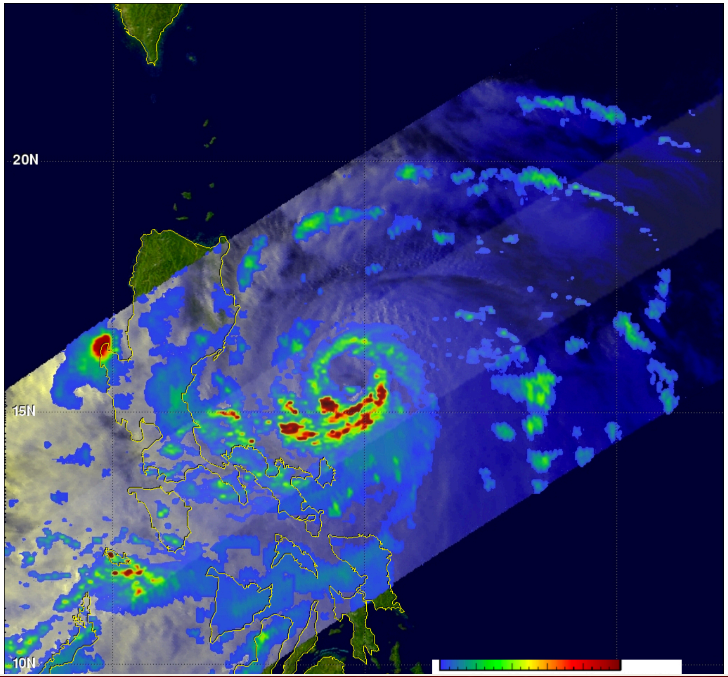


Passive measurements can occur over many wavelengths revealing different information in each spectrum

Multi-channel microwave measurements to see through cloud layers

More complicated relationships between brightness temperatures and rain rates

TRMM calibrates microwave measurements to precipitation radar measurements



“Typhoon Nesat Threatens the Philippines”, available at pmm.nasa.gov/mission-updates/trmm-news/typhoon-nesat-threatens-philippines, April 2015

Measurements made on geosynchronous satellites

Pros:

- Rapid updates (~1-15 minutes)
- Good resolution (~1-4 km^2)
- Good coverage (nearly global)

Cons:

- Cannot see through clouds
- Precipitation may not be reaching the ground!

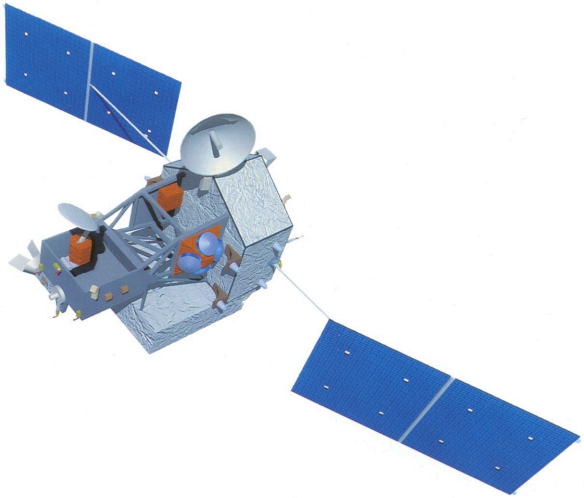
Measurements made on low Earth orbit satellites

Pros:

- Multiple wavelength measurements can often measure through clouds to the ground
- Better resolution (<1 km^2)

Cons:

- Long revisit time (~hours to days)
- Incomplete global coverage
- Narrow swaths



"About TRMM", available at trmm.gsfc.nasa.gov/overview_dir/background.html, April 2015

Let's combine LEO and GEO measurements!

Tropical Rainfall Measurement Mission – Multi-Satellite Precipitation Analysis (TMPA)

Uses many passive microwave satellites with probability-matching to the core TRMM satellite

Gaps in LEO satellite coverage filled with data from GEO satellites

TRMM Multisatellite Precipitation Analysis

- TRMM stands for Tropical Rainfall Measurement Mission
- Available every 3-hours, on a 0.25° x 0.25° grid from 50°N to 50°S
- Also known as "TRMM RT" or "TRMM real-time"

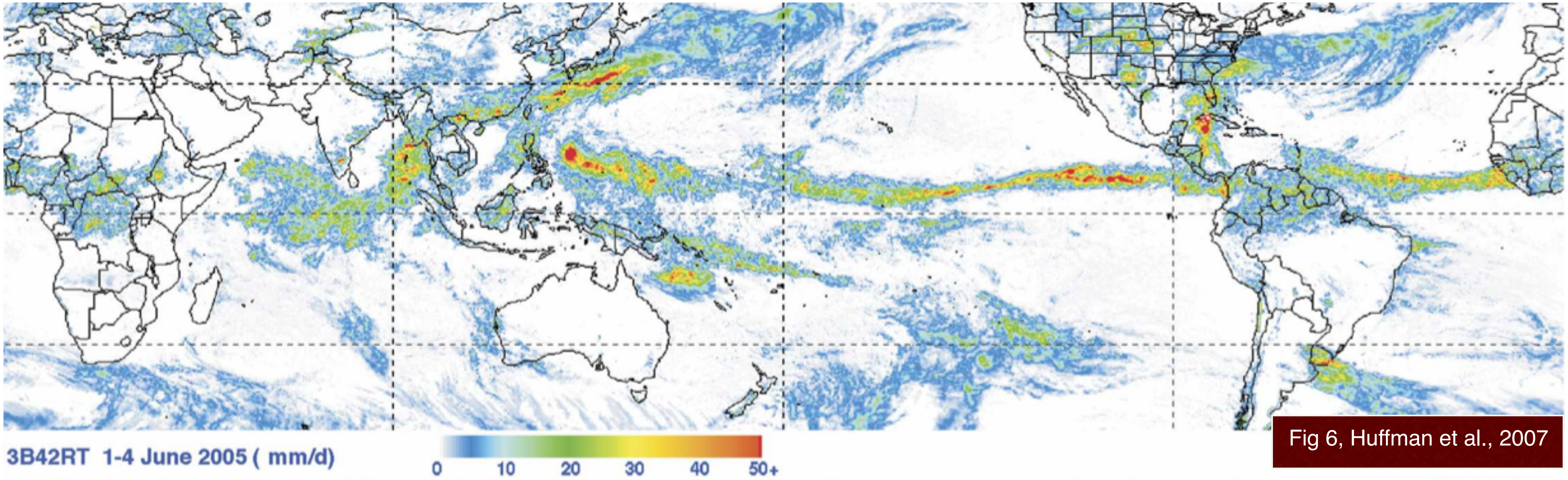


Fig 6, Huffman et al., 2007

TMPA

Alternatives to “real time” data

If you are doing historical work and want better precipitation estimates, there is a gauge-corrected TMPA product available

3-hourly estimates summed to monthly, rain gauge data accumulated on 1° x 1° grid for a month (TMPA bias-adjusted and 3-hourly products are rescaled)

Also known as “TRMM V6” or “TRMM V7”

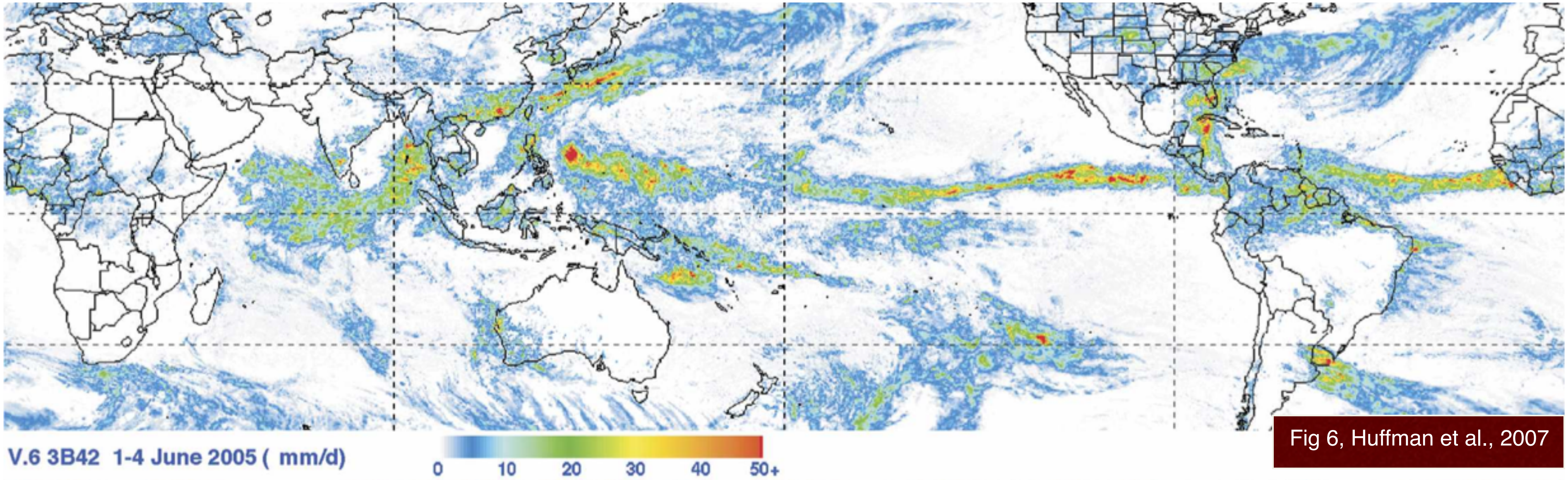


Fig 6, Huffman et al., 2007

So how do you get TMPA data?

NASA's servers

Real time feed:

ftp://trmmopen.gsfc.nasa.gov/pub/merged/mergeIRMicro/

Older data:

ftp://disc2.nascom.nasa.gov/ftp/data/s4pa/TRMM_RT/TRMM_3B42RT.007/

Gauge corrected product:

ftp://disc2.nascom.nasa.gov/ftp/data/s4pa/TRMM_L3/TRMM_3B42/

Potential Evapotranspiration

“Forcing” isn’t just precipitation – the model also needs to know how much water is lost to the atmosphere due to evaporation and transpiration

Important for droughts and water resources management

- Not so important for rainfall-driven flooding events
- We prefer to use monthly averages because this greatly reduces data requirements for running hydrological models
- This means one set of 12 files (one for each month) fulfills the PET requirement for running the model anywhere in the world

Potential Evapotranspiration

We use global monthly mean PET

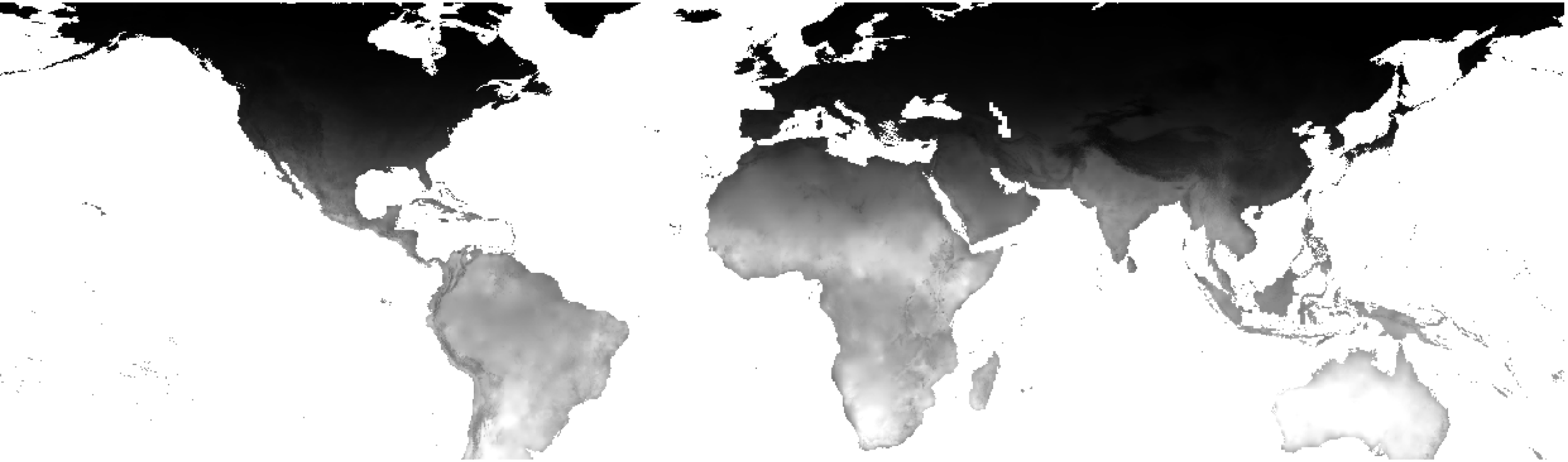
- They cover the world, from -180 to +180 degrees longitude, and from -90 to +90 degrees latitude
- The daily PET is calculated on a spatial basis using the Penman-Monteith equation
- Then this data is standardized in accordance with the Food and Agriculture Organization’s published research
- The actual data is produced by the U.S. Geological Survey and the U.S. Agency for International Development

http://earlywarning.usgs.gov/fews/downloads/

Visualizing Precipitation and PET

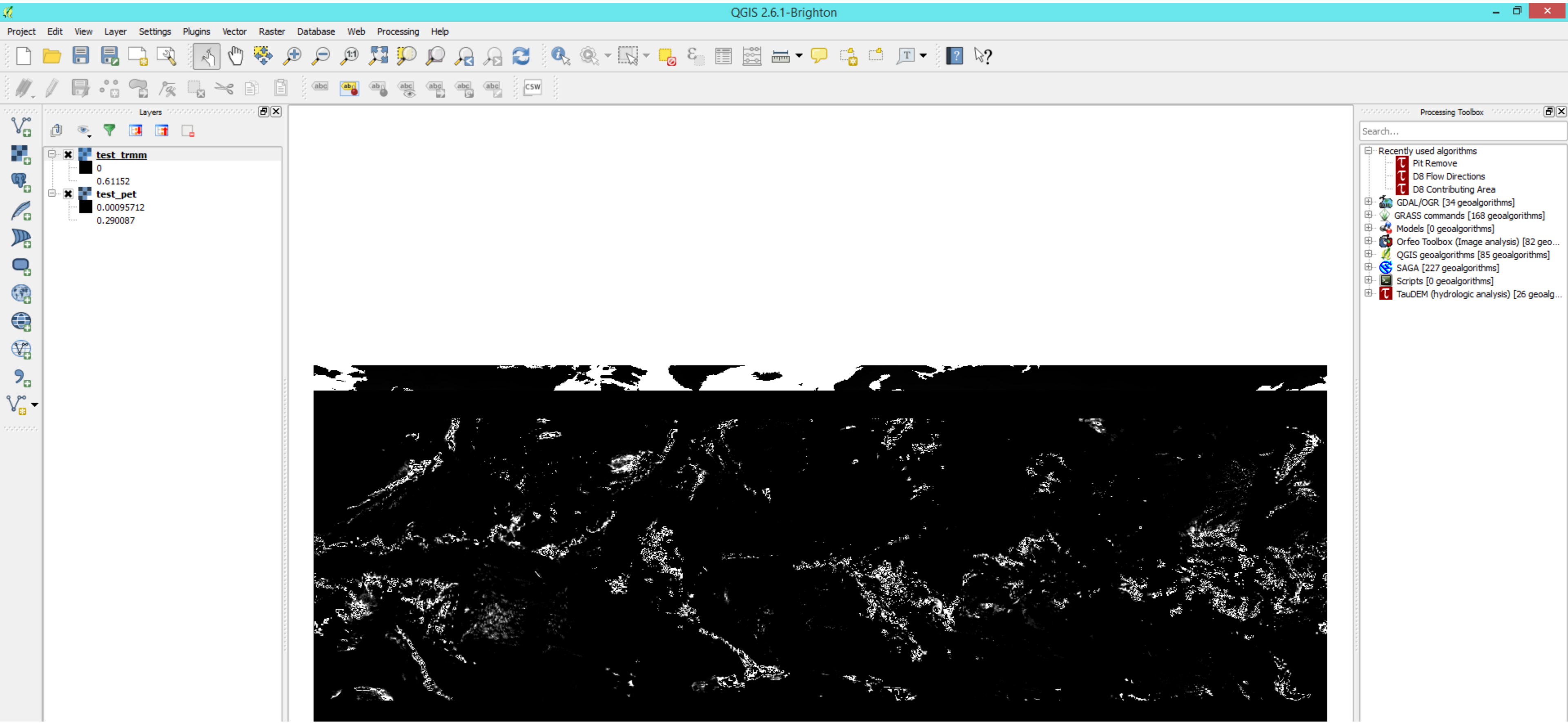
Open QGIS and go to "Layer" → "Add Layer" → and "Add Raster Layer…"

Navigate to `\EF5_training\data\PET` **and add** `test_pet.asc`

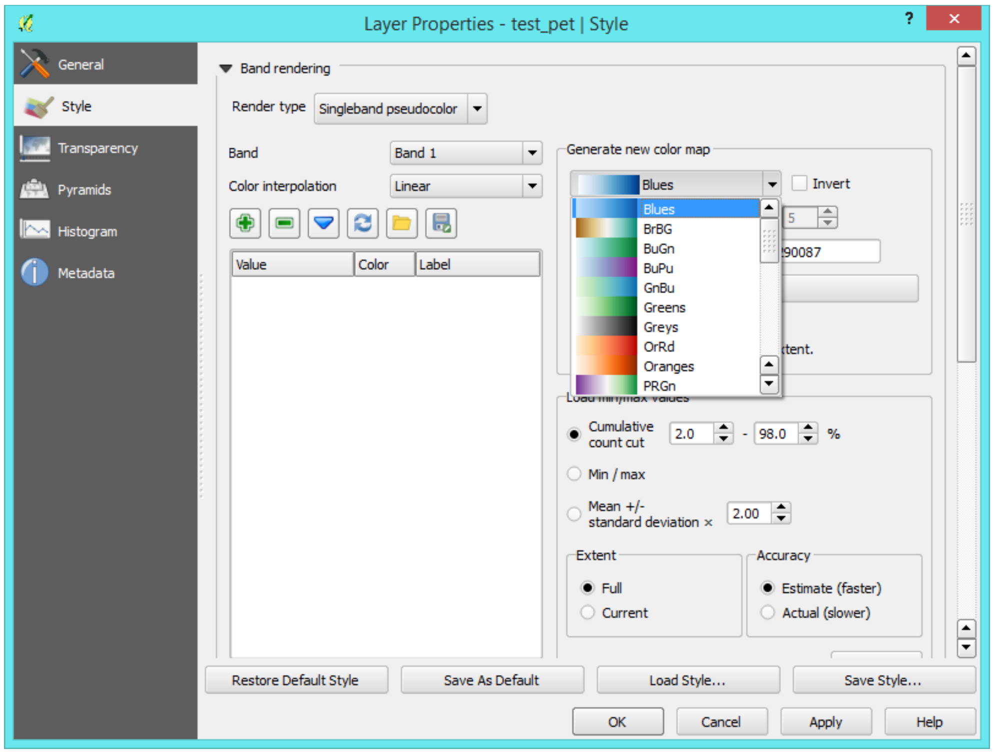


Visualizing Precipitation and PET

Now from `\EF5_training\data\TRMM` add `test_trmm.asc`



Visualizing Precipitation and PET

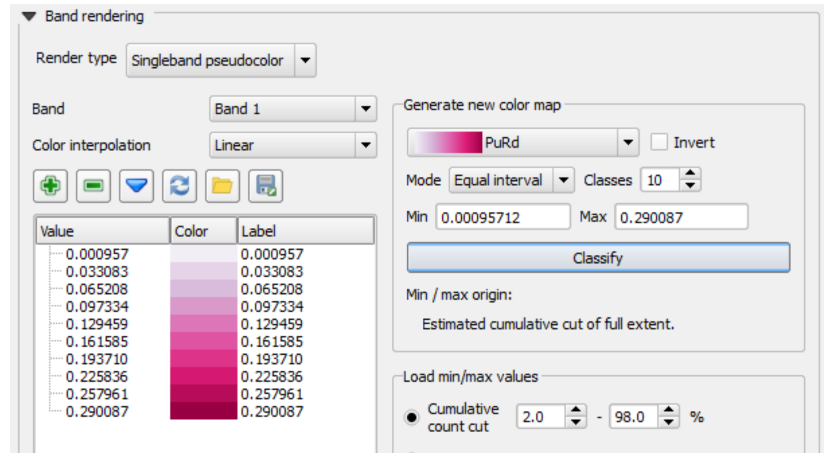


You can right-click on either layer, select "Properties" and then in the "Style" tab, select "Singleband pseudocolor"

Play around with the color options until you feel comfortable that you can tell what's happening in both the precipitation and PET grid

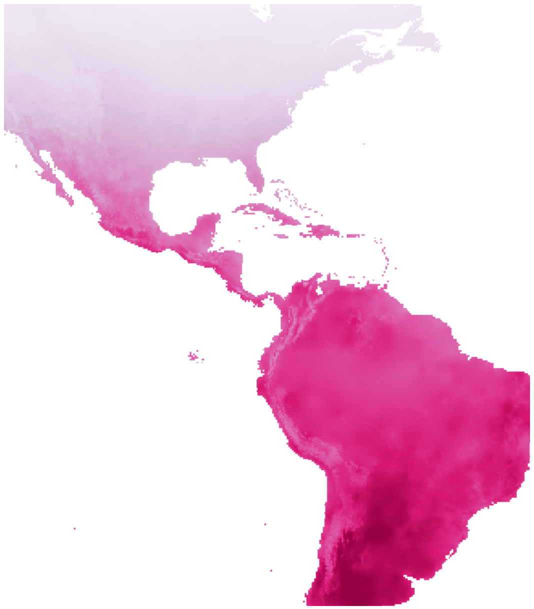
Visualizing Precipitation and PET

Think of looking at the PET as a sort of "sanity check"



This is a grid from January, summer in the Southern Hemisphere, so the sun angle is higher there and PET should be higher, too

Sure enough, that's what I see



You can use the "Identify Features" tool to click around and prove it to yourself, if you want →

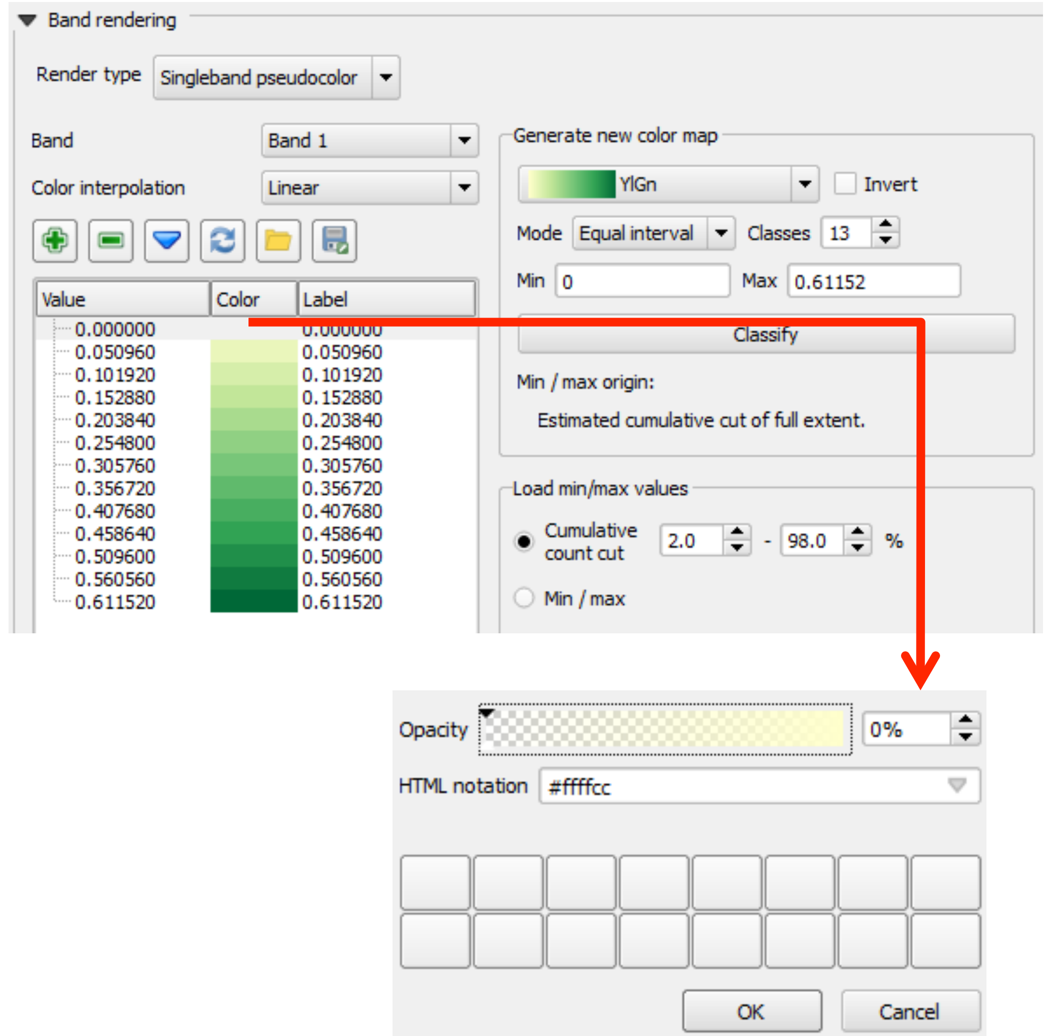
Visualizing Precipitation and PET

You can also play with the colors in the precipitation file

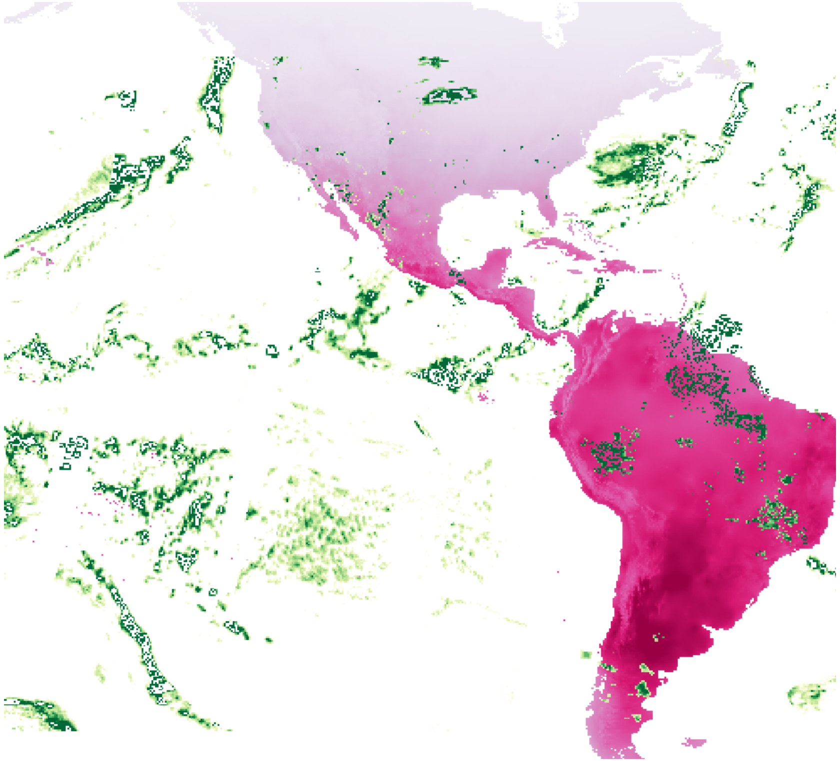
I right-clicked and selected "Properties"

Then I used a yellow-green "YlGn" color map, and right-clicked on the color for values of 0.000000

You can turn "Opacity" to "0%" so that the areas where precipitation is zero disappear from the map



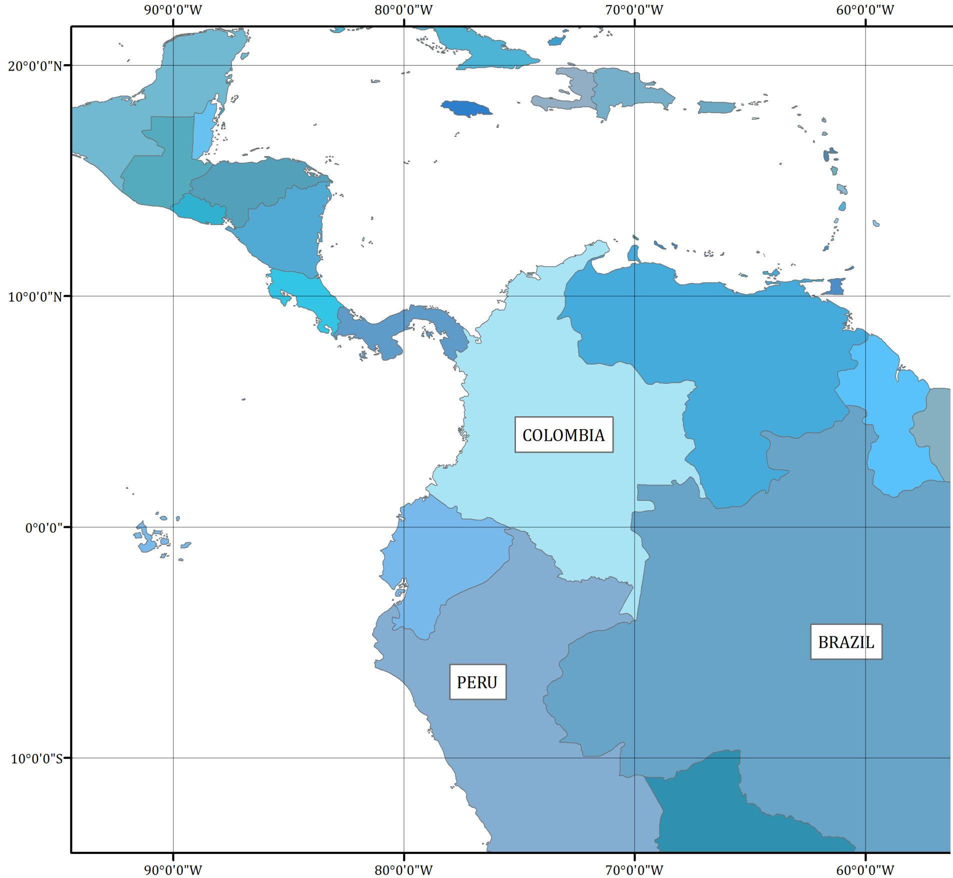
And here's the final result:

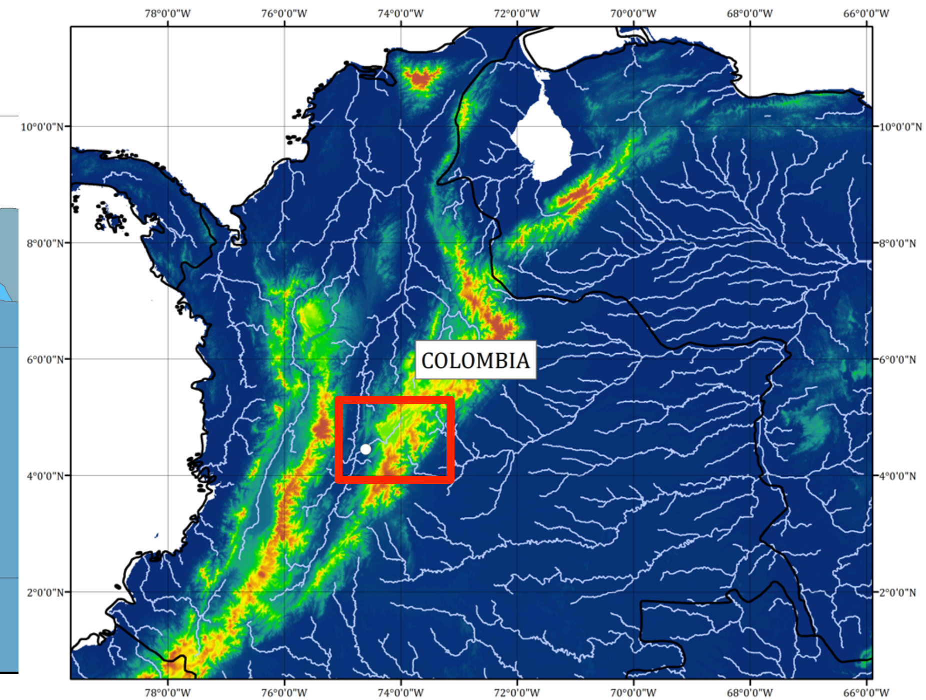


Looks like what we would expect precipitation systems to look like, so that's a good thing!

Example 2

Let's get our precipitation and PET data ready for use in the Bogota River example

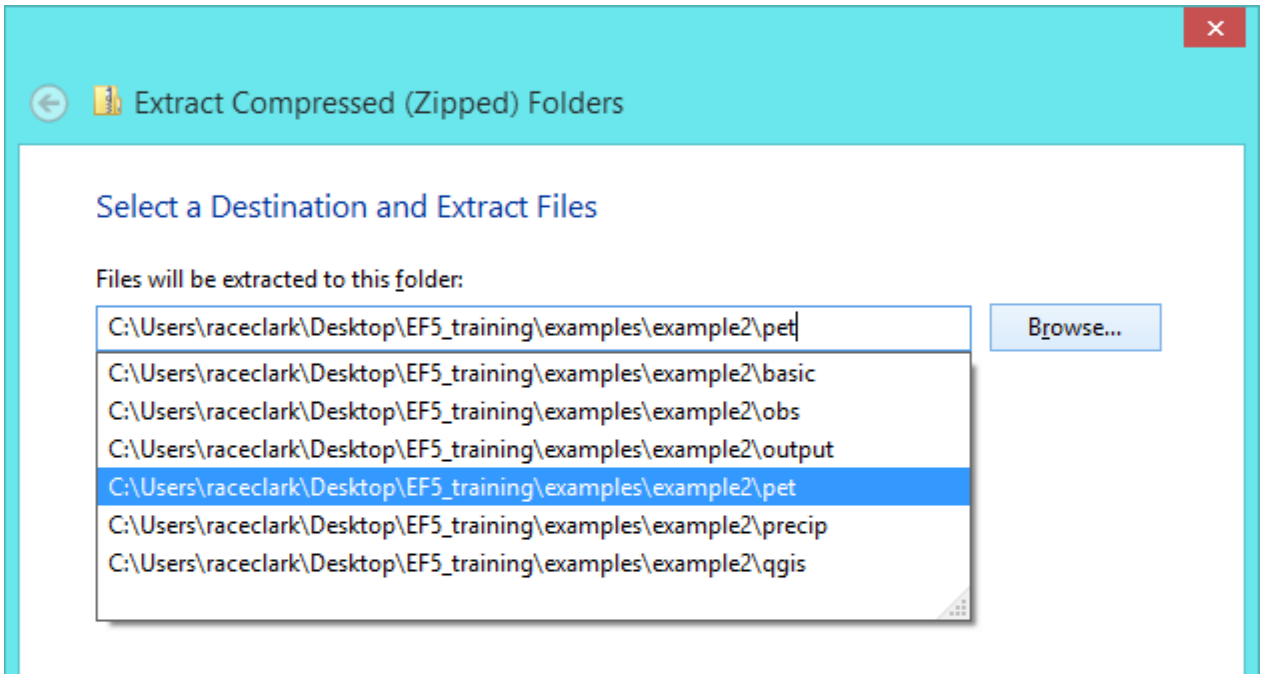




Unzip Precipitation and PET

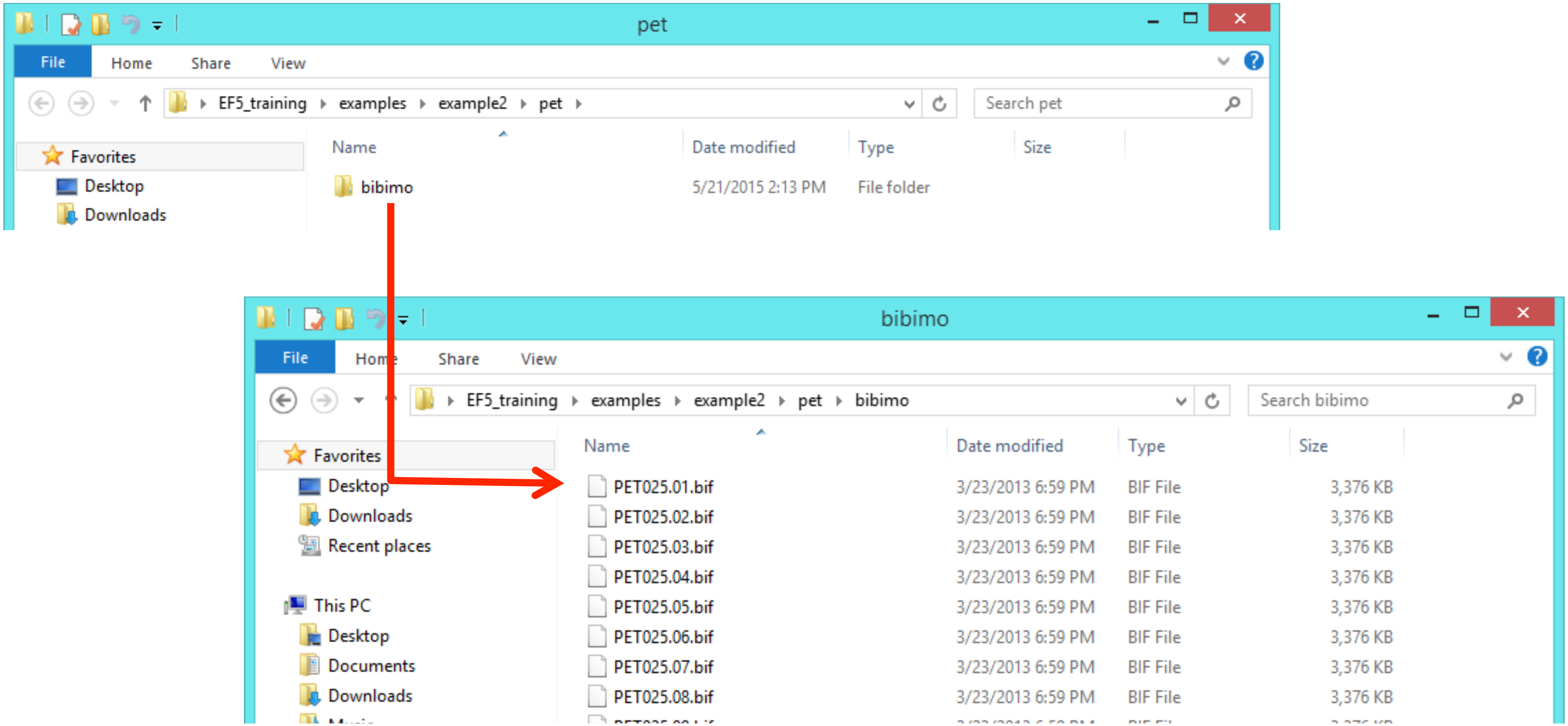
In `\EF5_training\data\PET`, you have a file called `bibimo.zip`

- Right-click, and click “Extract All…”
- Extract to `\EF5_training\examples\example2\pet`



Unzip Precipitation and PET

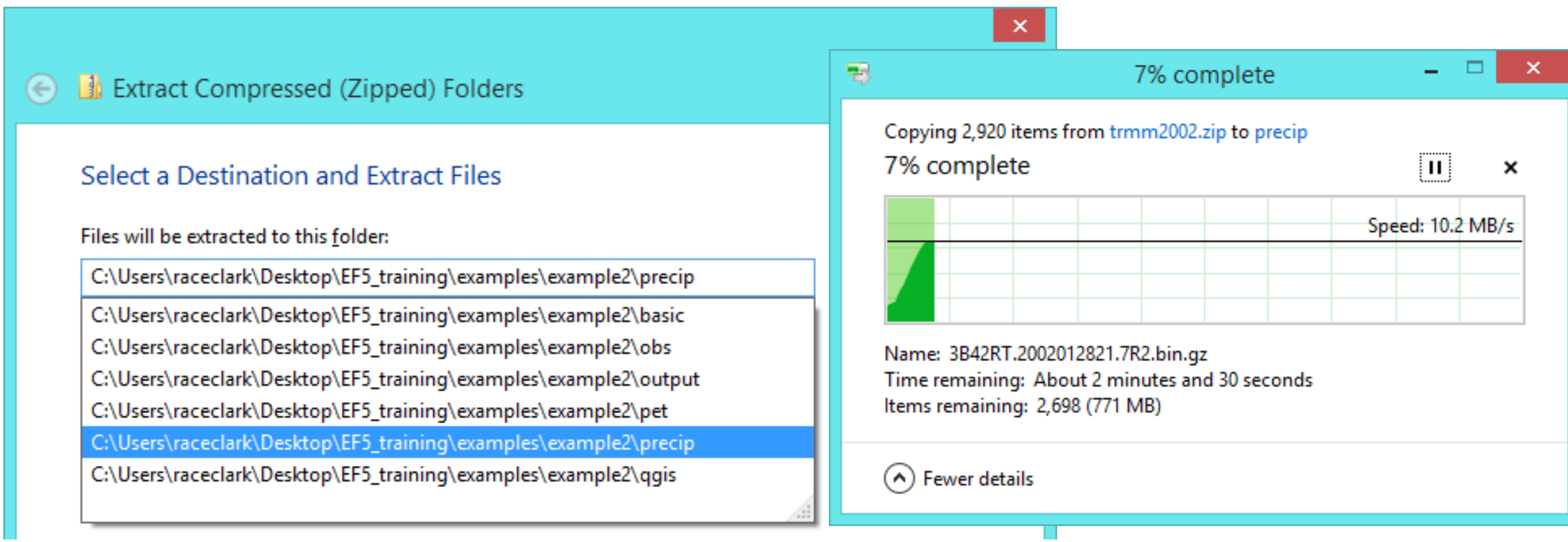
You should see this pop up after the unzip process is complete:



Unzip Precipitation and PET

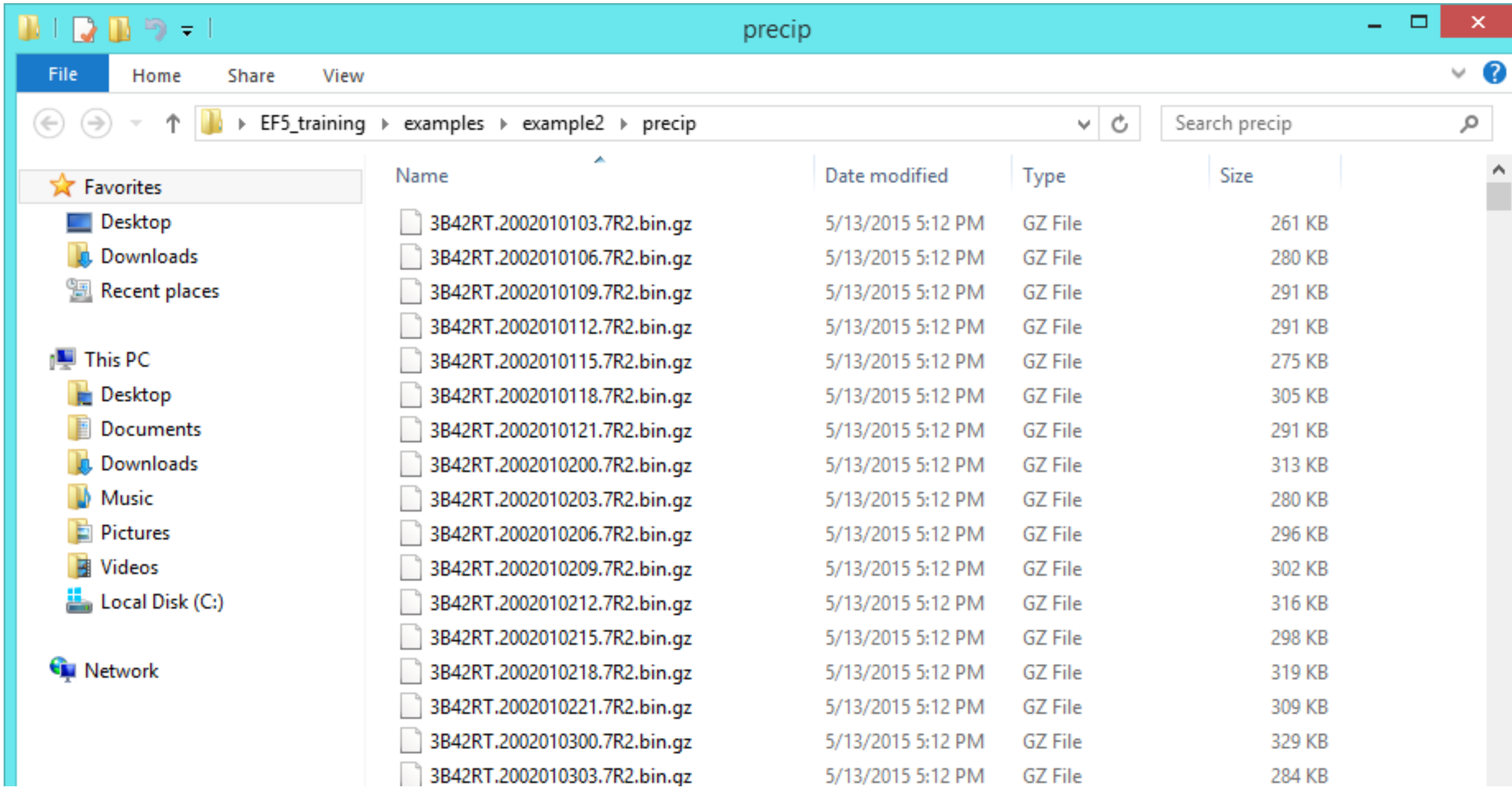
In `\EF5_training\data\TRMM`, you have a file called `trmm2002.zip`

- Right-click, and click “Extract All…”
- Extract to `\EF5_training\examples\example2\precip`
- This process can take a while



Unzip Precipitation and PET

You should see this pop up after the unzip process is complete:



The PrecipForcing Block

Open `control.txt` in `EF5_training\examples\example2`

In the PrecipForcing block, we see

- The name of the block is `TRMM`
- `TYPE` is `TRMMRT` (This depends on what type of precipitation you're using, so if you use the gauge-corrected TRMM data instead, you would put `TRMMV7` here. For a full list of options, see the EF5 Readme included in the training materials)
- `UNIT` is `mm/h` (millimeter per hour; these are the units of the precipitation data)
- `FREQ` is `3h` (every three hours; this is how frequently new precipitation files are available)

control.txt - Notepad

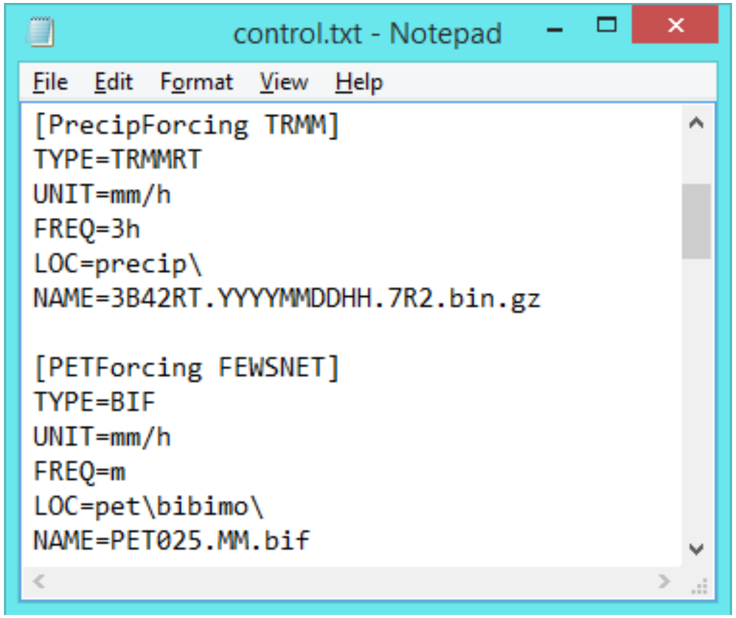
File Edit Format View Help

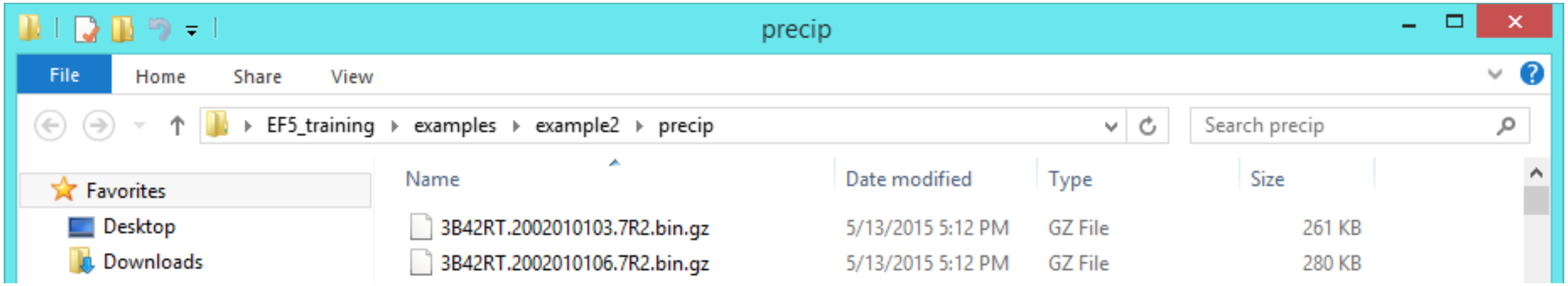
```
[PrecipForcing TRMM]
TYPE=TRMMRT
UNIT=mm/h
FREQ=3h
LOC=precip\
NAME=3B42RT.YYYYMMDDHH.7R2.bin.gz

[PETForcing FEWSNET]
TYPE=BIF
UNIT=mm/h
FREQ=m
LOC=pet\bibimo\
NAME=PET025.MM.bif
```

The PrecipForcing Block

- LOC is precip\ (this is where the precipitation files are located relative to the control.txt file)
- NAME is 3B42RT.YYYYMMDDHH.7R2.bin.gz (The naming scheme of the precipitation files must include date and time information, so that EF5 knows *when* in the simulation the precipitation occurs. YYYY translates to a four-digit year, MM to a two-digit month, MM to a two-digit day, and HH to a two-digit hour. So the final file names are 3B42RT.2002010103.bin.gz, 3B42RT.2002010106.bin.gz, etc., and sure enough, these match what we see in the screenshot below)

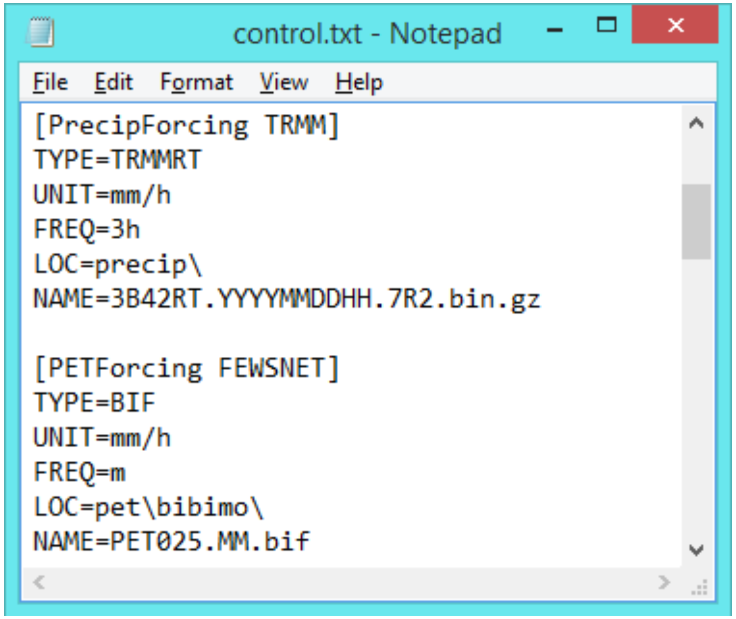




The PETForcing Block

In the PETForcing block, we see

- The name of the block is FEWSNET
- TYPE is BIF (this is a binary version of an ESRI ASCII grid)
- UNIT is mm/h (millimeter per hour; these are the units of the PET data)
- FREQ is m (every month; this is how frequently new PET files are available)
- LOC is pet\bibimo\ (this is where the PET files are located relative to the control.txt file)

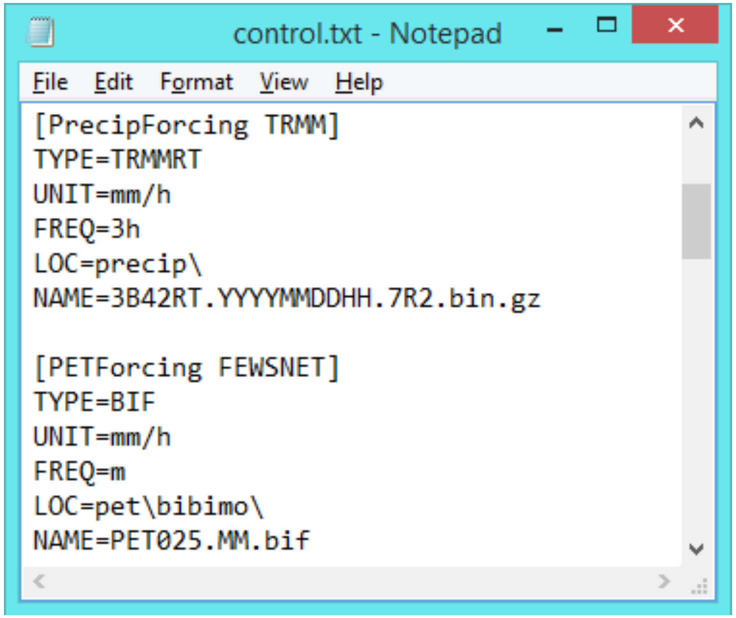


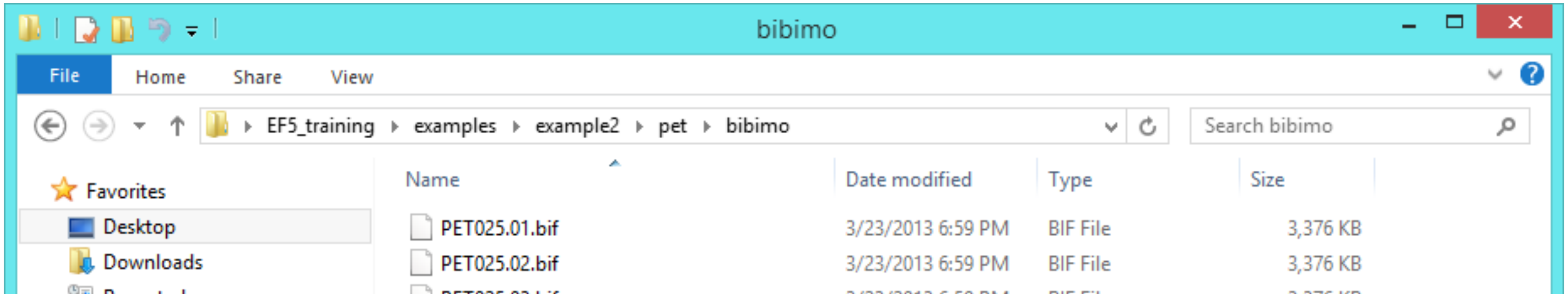

```
[PrecipForcing TRMM]
TYPE=TRMMRT
UNIT=mm/h
FREQ=3h
LOC=precip\
NAME=3B42RT.YYYYMMDDHH.7R2.bin.gz

[PETForcing FEWSNET]
TYPE=BIF
UNIT=mm/h
FREQ=m
LOC=pet\bibimo\
NAME=PET025.MM.bif
```

The PETForcing Block

- `NAME` is `PET025.MM.bif` (As with precipitation, the naming scheme of the PET files <u>must</u> include date and time information, so that EF5 knows *when* in the simulation the precipitation occurs. `MM` translates to a two-digit month, so the final file names are `PET025.01.bif`, `PET025.02.bif`, etc., and sure enough, these match what we see in the screenshot below)

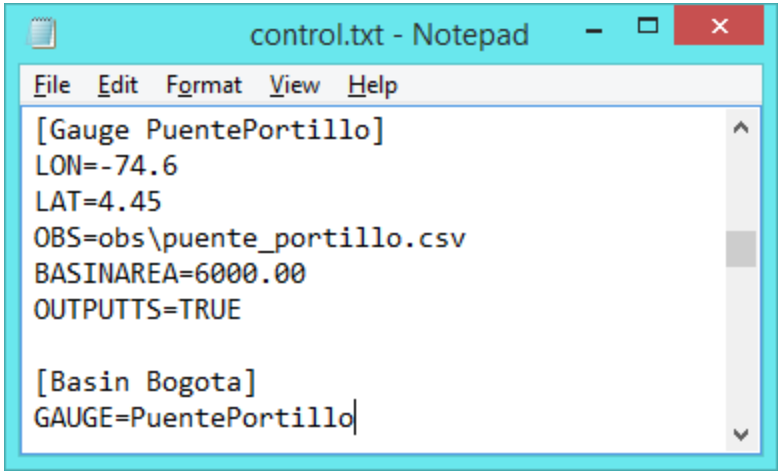




The Gauge and Basin Blocks

In the Gauge block, we see

- The name of the block is `PuentePortilo`
- `LON` should be `-74.6` (this is the longitude of the gauging station in degrees, where degrees west are negative; remember we used this longitude in QGIS in Module 2.2)
- `LAT` should be `4.45` (this is the latitude of the gauging station in degrees, where degrees south are negative; remember we used this latitude in QGIS in Module 2.3)

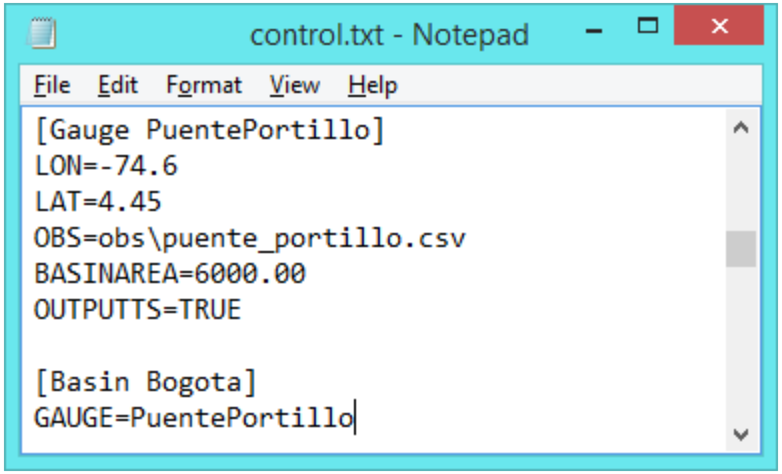



```
[Gauge PuentePortillo]
LON=-74.6
LAT=4.45
OBS=obs\puente_portillo.csv
BASINAREA=6000.00
OUTPUTTS=TRUE

[Basin Bogota]
GAUGE=PuentePortillo
```

The Gauge and Basin Blocks

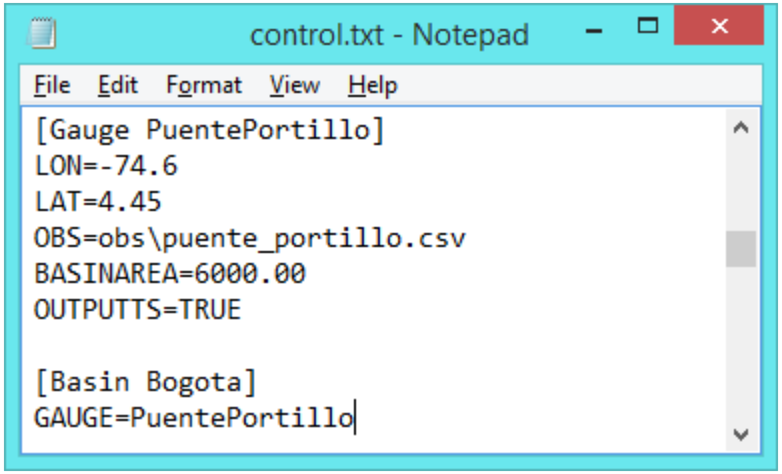
- OBS should be obs\puente_portillo.csv (this is the file path to the observations relative to control.txt; from there, you enter the obs folder and then see puente_portillo.csv)
- BASINAREA should be 6000.00 (this tells EF5 the approximate value to search for in the FAC grid when finding the gauge outlet, in km²)
- OUTPUTTS should be TRUE (you can run EF5 for multiple gauges simultaneously by adding additional Gauge blocks to the control file; this option tells EF5 which sets of results to actually output to file)



The Gauge and Basin Blocks

In the Basin block, we see

- The name of the block is `Bogota`
- `GAUGE` should be `PuentePortillo` (this is the name of the gauge block to be included in this Basin block)



The Gauge and Basin Blocks

Basin blocks are not physical basins; they are just a collection of gauges that you want EF5 to model together

Multiple Basin blocks are possible; each gauge must be included in a Basin block

EF5 then has a Task block (which we'll get to in Module 2.4), and in that Task block, you can tell EF5 which Basin block to model

One final comment on the Gauge and Basin blocks: you do <u>not</u> need to use the actual names of the gauges or basins over which you are modeling

control.txt - Notepad

File Edit Format View Help

```
[Gauge Ex1]
LON=-90.00
LAT=45.00
OBS=obs\ex1.csv
BASINAREA=500.00
OUTPUTTS=FALSE

[Gauge Ex2]
LON=-74.6
LAT=4.45
OBS=obs\puente_portillo.csv
BASINAREA=6000.00
OUTPUTTS=TRUE

[Gauge Ex3]
LON=-64
LAT=-10
OBS=obs\ex3.csv
BASINAREA=4900.00
OUTPUTTS=TRUE

[Gauge Ex4]
LON=64
LAT=32
OBS=obs\ex4.csv
BASINAREA=45000.00
OUTPUTTS=FALSE

[Basin Bas1]
GAUGE=Ex3
GAUGE=Ex2

[Basin Bas2]
GAUGE=Ex1
GAUGE=Ex4
```

Additional PrecipForcing Options

In TYPE 6 values are possible:

- ASC
  This is the ESRI ASCII grid format, with header as shown →
- TIF
  Float32 GeoTiff grid
- TRMMRT
  TRMM real-time binary format grid
- TRMMV7
  TRMM 3B42V7 HDF5 grid
- MRMS
  Multi-Radar Multi-Sensor binary grid (generally only used in the USA)

```
File  Edit  Format  View  Help
ncols         124
nrows         144
xllcorner     11.025
yllcorner     -30.0833333333333
cellsize      0.125
NODATA_value  -9999
-9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999
-9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999
```

```
control.txt - Notepad
File  Edit  Format  View  Help
[PrecipForcing TRMM]
TYPE=TRMMRT
UNIT=mm/h
FREQ=3h
LOC=precip\
NAME=3B42RT.YYYYMMDDHH.7R2.bin.gz

[PETForcing FEWSNET]
TYPE=BIF
UNIT=mm/h
FREQ=m
LOC=pet\bibimo\
NAME=PET025.MM.bif
```

In UNIT, you can use y for year, m for month, d for day, h for hour, u for minute, and s for second, along with m for meters, cm for centimeters, and mm for millimeters

Numbers are also allowed before the time, like mm/3hr

Additional PrecipForcing Options

In FREQ, you can use y for year, m for month, d for day, h for hour, u for minute, and s for second

Numbers are also allowed here, like 3h

In NAME, the available date and time codes are

YYYY for year (like 2014, 2015, etc..), MM for month, DD for day, HH for hour, UU for minute, and SS for second (each running like this: 01, 02, 03 etc..)

Do not use YYYY, MM, DD, HH, UU, and SS in the filename outside of marking the appropriate date and time

control.txt - Notepad

```
[PrecipForcing TRMM]
TYPE=TRMMRT
UNIT=mm/h
FREQ=3h
LOC=precip\
NAME=3B42RT.YYYYMMDDHH.7R2.bin.gz

[PETForcing FEWSNET]
TYPE=BIF
UNIT=mm/h
FREQ=m
LOC=pet\bibimo\
NAME=PET025.MM.bif
```

Additional PETForcing Options

In the PETForcing block, three `TYPE` values are available:

- **ASC**

  This is the ESRI ASCII grid format, with header as shown →

- **BIF**

  A binary version of the ESRI ASCII grid format

- **TIF**

  Float32 GeoTiff grid

```
ncols         124
nrows         144
xllcorner     11.025
yllcorner     -30.083333333333
cellsize      0.125
NODATA_value  -9999
-9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999
-9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999
```

`UNIT`, `FREQ`, and `NAME` operate identically to the PrecipForcing block

control.txt - Notepad

```
[PrecipForcing TRMM]
TYPE=TRMMRT
UNIT=mm/h
FREQ=3h
LOC=precip\
NAME=3B42RT.YYYYMMDDHH.7R2.bin.gz

[PETForcing FEWSNET]
TYPE=BIF
UNIT=mm/h
FREQ=m
LOC=pet\bibimo\
NAME=PET025.MM.bif
```

Additional Gauge Options

In the Gauge block, there are some other options available:

- CELLX and CELLY

  These are the x- and y-coordinates of the gauge in the topographical files instead of `LAT` and `LON`
- BASINAREA

  This is actually optional, but recommended, as EF5 will search the topographical files for a nearby FAC cell corresponding to the area you enter
- OUTPUTTS

  Tells EF5 to output the time series for this gauge
- WANTDA

  Tells EF5 to do data assimilation for the gauge
- WANTCO

  Tells EF5 to include the time series in a combined output file

For `OUTPUTTS`, `WANTDA`, and `WANTCO`, values of `YES`, `NO`, `TRUE`, and `FALSE` are allowed. `WANTCO` defaults to `NO` and the others default to `YES`

The Bottom Line

EF5 will tell you if the control file has a problem

If a file is missing, or a file path is incorrect, or a part of the task block doesn't match the rest of the control file, etc., you will get an error that should identify where the problem is

Then open up your control file and try to fix it!

Control file errors are there to help you, so always remember: don't panic

Coming Up….

The next module is

Automatic Calibration

You can find it in your `\EF5_training\presentations` **directory**

Module 2.3 References

Allen, R. G., L. S. Pereira, D. Raes, and M. Smith, (1998). Crop evapotranspiration – Guidelines for computing crop water requirements. *Irrigation and Drainage Paper 56*. Rome: FAO UN. http://www.fao.org/docrep/ x0490e/x0490e00.htm

EF5 Training Doc 4 – EF5 Control File, (March 2015).

Huffman, G. J., R. F. Adler, D. T. Bolvin, et al, (2007). The TRMM Multi-satellite Precipitation Analysis: Quasi-Global, Multi-Year, Combined-Sensor Precipitation Estimates at Fine Scale. *J. Hydrometeor.*, 8: 1, 38-55.

Shuttleworth, J. 1992. Evaporation. In *Handbook of Hydrology*, ed. D. Maidment, 4.1-4.53, New York: McGraw-Hill.