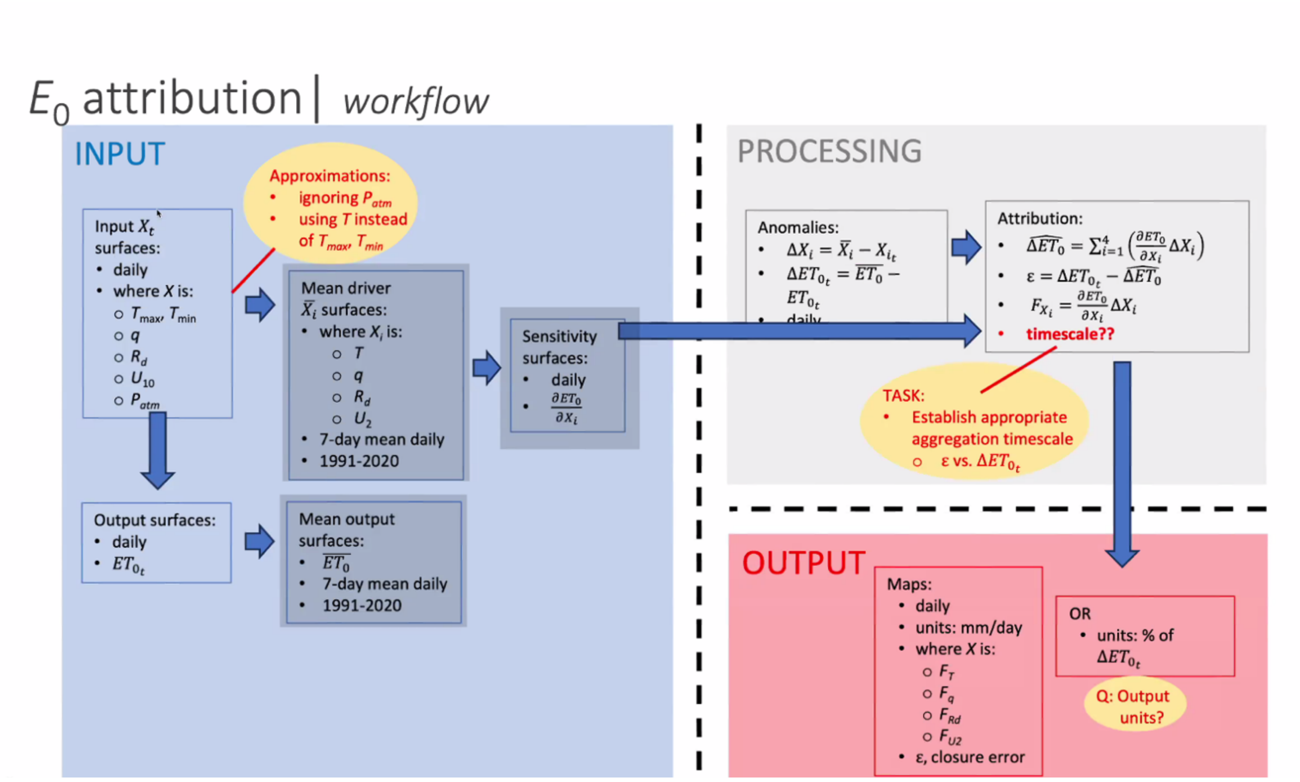
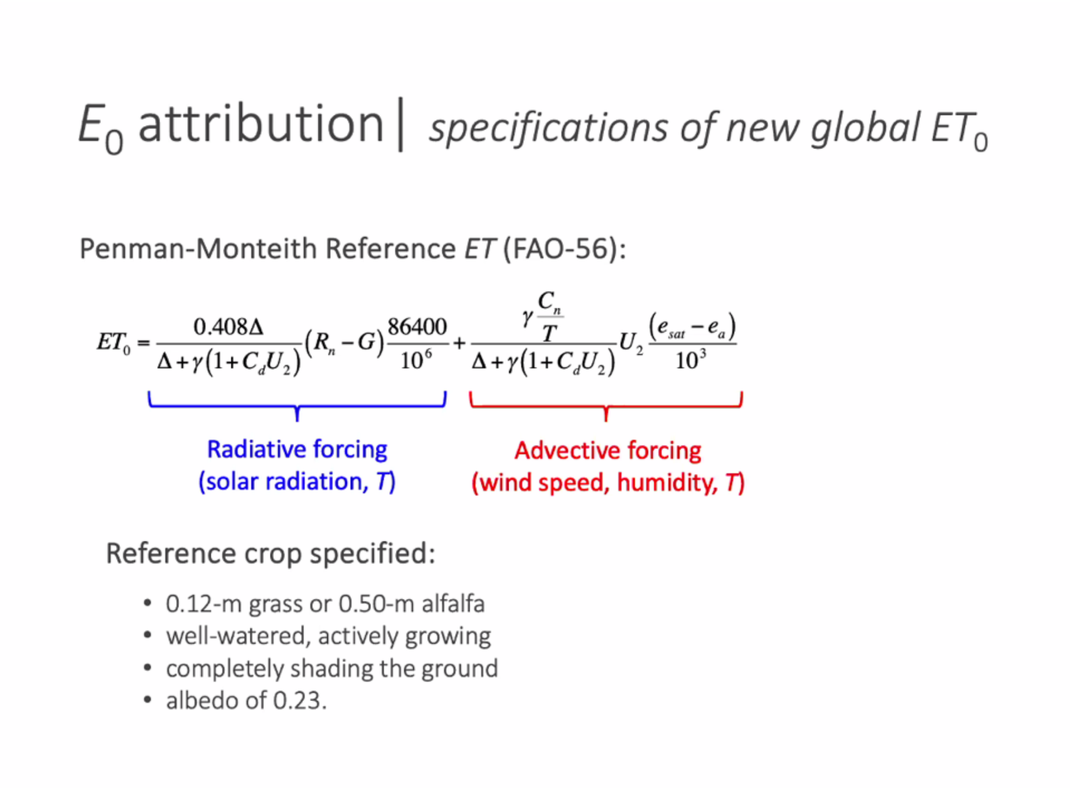
FLASH DROUGHT PROJECT MEETING
19 NOVEMBER 2024

Tess Parker
Jess Bhardwaj
Mike Hobbins
Apologies: David Hoffmann (ouch!)

- Jess will set up a new public GitHub repository for this project and send Mike the link.
- This will give us a place to collect Mike's Fortran code and the documentation for the workflow.
- All code is in Fortran, wrapped in a shell script.
- I've included some screenshots from Mike's presentation, as memory-joggers!



- Also a place for Mike to drop his slide deck from today, which gives examples of the decomposition and various graphics.
- The process involves:
    - Calculating the Penman-Monteith Reference ET (FAO-56)



This has 7 drivers:

Min and Max temperature at 2 m
Specific humidity at 2 m
Downward SW at the surface
U and V wind vectors at 10 m
Surface pressure

- For attribution purposes, approximations are made to result in 4 drivers:

E_0 attribution | *approximations*

ET_0 equation changes relative to EDDI:

$$ET_o = \frac{0.408x10^{-6}\Delta(R_n - G) + \gamma \frac{C_n}{T + 273.15} U_2(e_{sat} - e_a)}{\Delta + \gamma(1 + C_d U_2)}$$

$$\begin{array}{l} T = f(T_{min}, T_{max}) \\ e_a = f(P_{atm}(t), q) \\ \Delta = f(T_{min}, T_{max}) \\ R_n = f(SW_{dn}, e_a, T_{min}, T_{max}) \\ \hline ET_0 = f(T_{min}, T_{max}, P_{atm}, T, SW_{dn}, q, U_2) \end{array} \quad \Rightarrow \quad \begin{array}{l} T = average\ of\ hourly\ T \\ e_a = f(elev, q) \\ \Delta = f(T) \\ R_n = f(SW_{dn}, e_a, T) \\ \hline ET_0 = f(T, SW_{dn}, q, U_2) \end{array}$$

Temperature at 2 m
Specific humidity at 2 m
Downward SW at the surface
U and V wind vectors at 10 m

- These approximations result in a closure error ε, when diagnosing changes in ET_0, due to the approximations and assumption of linearity around the mean:

Drought monitoring | *diagnosing demand side - concept*

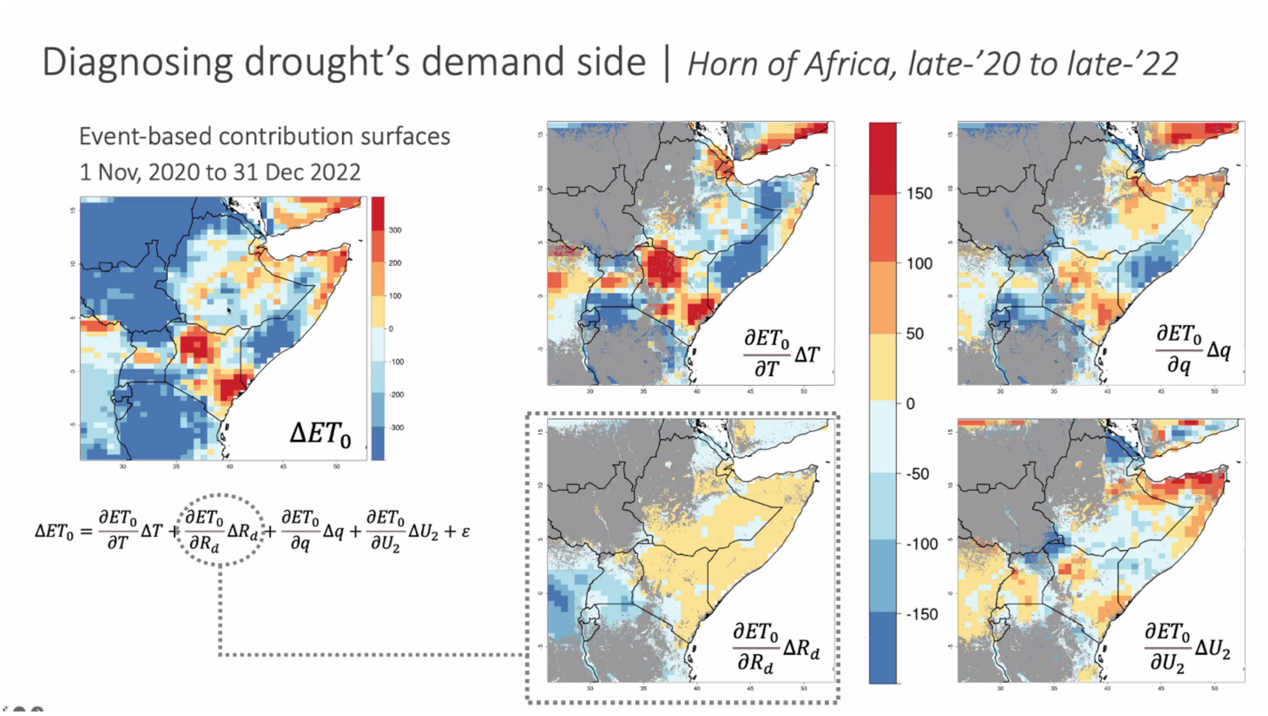
Q: How much are changes in E_0 due to each driver's changes?

$$\Delta ET_0 = \frac{\partial ET_0}{\partial T}\Delta T + \frac{\partial ET_0}{\partial R_d}\Delta R_d + \frac{\partial ET_0}{\partial q}\Delta q + \frac{\partial ET_0}{\partial U_2}\Delta U_2 + \varepsilon$$

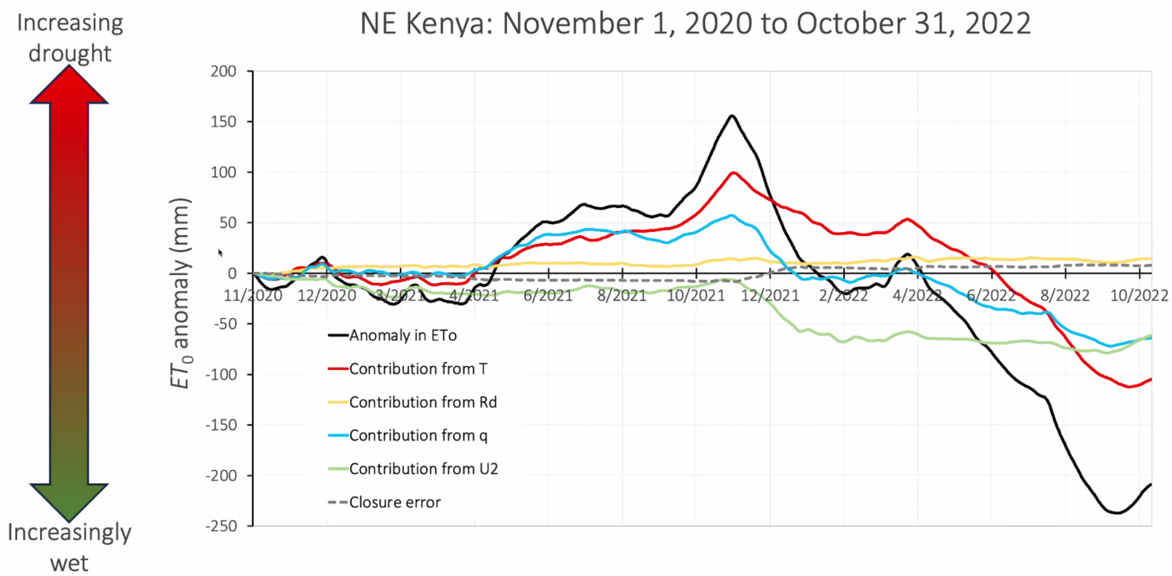
Computation outline:

- Convert daily ET_0 data to 7-day running means
- For each day in year, i: $\frac{\partial ET_0}{\partial T_i} = f\{\bar{T}, \overline{R_d}, \bar{q}, \overline{U_2}\}_i$
- Contribution from each driver (e.g., T), $\mathrm{Cont}(T) = \sum_{day=start}^{end} \left[\frac{\partial ET_0}{\partial T_i}\Delta T_i\right]$

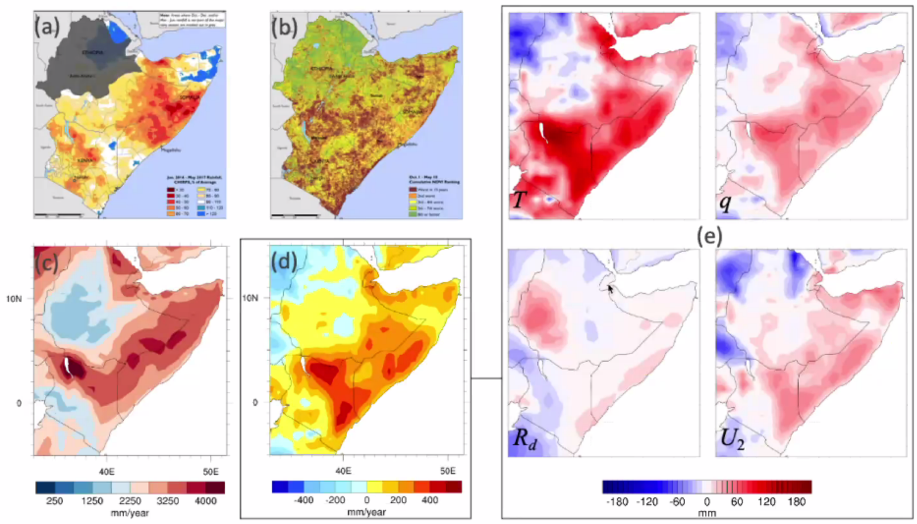
- Mike's slides show various ways of visualising the information – spatial maps, timelines for an area or a single pixel. The closure error may be more or less significant depending on the case – for a single pixel, ε may be large compared to the other contributors, but over a larger area may be small compared to the largest driver – thus the signal to noise ratio is high.
- Presentation of precipitation anomalies together with changes in ET_0 give both the supply and demand side of drought. The variations in the importance of these over time could be interesting, both for flash drought and longer duration drought.
- Maps of P-ET_0 could be a useful addition to these plots.
- Note that NDVI is also used along with precipitation and the drivers of evaporative demand.
- There are regional and seasonal differences in all these metrics.
- The decomposition is also useful when looking at wildfire.



Diagnosing drought's demand side | *NE Kenya, 2020-2022*

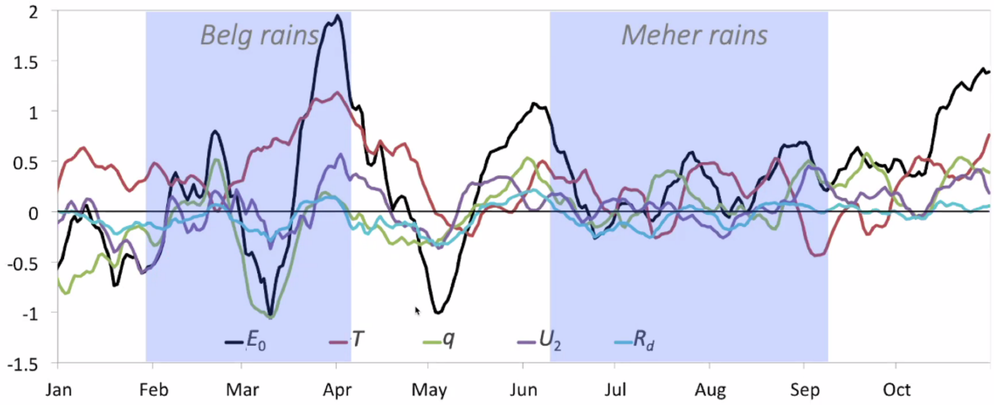


E_0 attribution | *2016/2017 drought in the Horn of Africa*



(a) % of 30-year (1981–2010) mean annual Prcp, June '16 -May '17
(b) cumulative NDVI ranking, October 1, '16 -May 10, '17 (wrt 2003-2016)
(c) 1981–2010 mean annual ET_0 in (c)
(d) 12-month (June 1, '16 to May 31, '17) ET_0 anomaly (wrt (c))
(e) contributions (mm) to ET_0 anomaly (in (d)) from each driver.

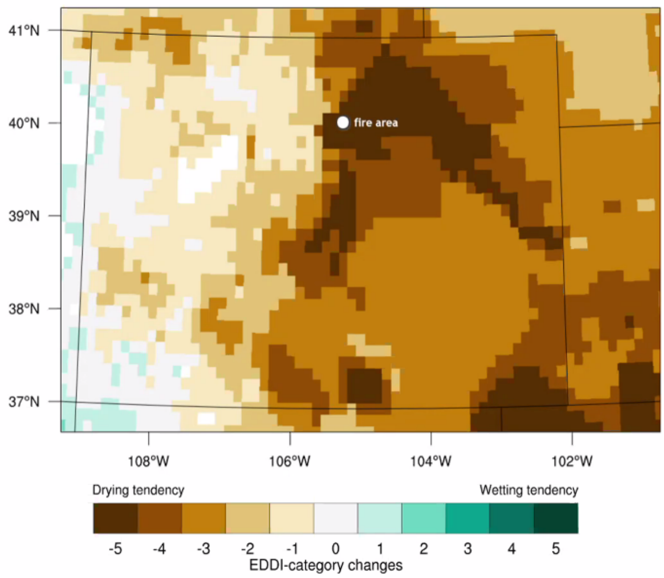
E_0 attribution | *2016/2017 drought in the Horn of Africa*



Contributions to changes in 10-day mean daily ET_0 (mm depth) of each driver's changes. Changes are wrt 1981-2010 climatological mean of moving 10-day window.

Attribution of E_0 | *wildfire*

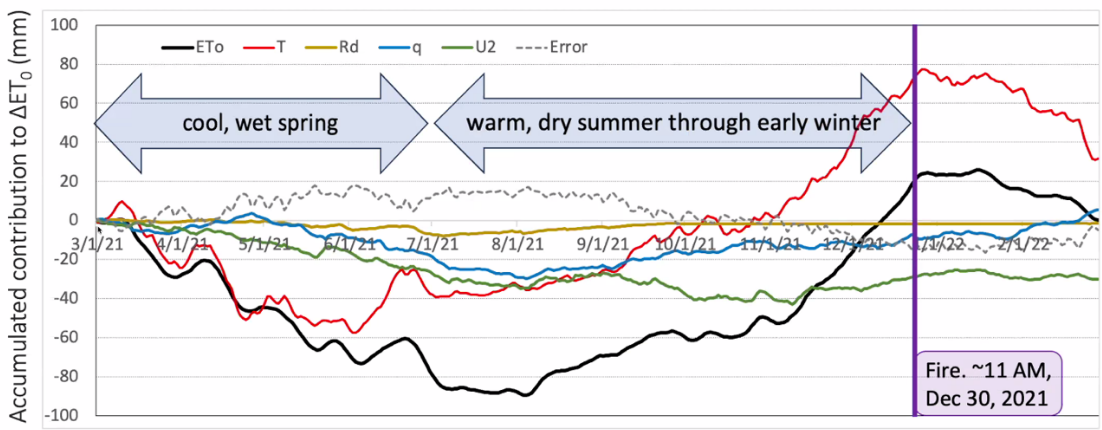
3-month changes in 6-month EDDI, Dec 30, 2021.



Rapid swing from wet to dry conditions prior to the Marshall Fire.

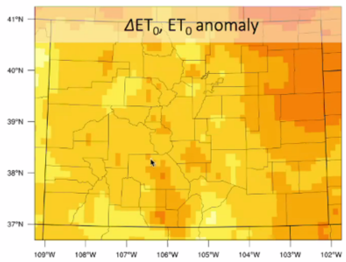
Attribution of E_0 | *wildfire*

Decomposition of demand conditions prior to Marshall Fire, Boulder Co., CO.



$$\Delta ET_0 = \Delta T\frac{\partial ET_0}{\partial T} + \Delta R_d\frac{\partial ET_0}{\partial R_d} + \Delta U_2\frac{\partial ET_0}{\partial U_2} + \Delta q\frac{\partial ET_0}{\partial q} + \varepsilon$$

Attribution of E_0 | *wildfire*



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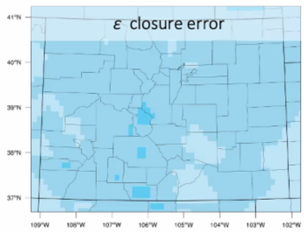
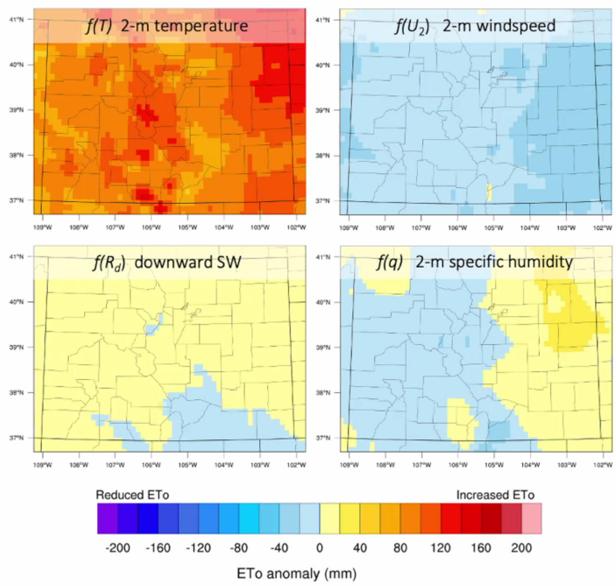
Decomposition of ET_0 anomaly, 03/01/2021 to 12/30/2021





- Mike has a paper in preparation on the work in Africa.
- Will also collapse down to Southern Africa (south of Zimbabwe?) to a point, and compare to global SSTs to look at the predictability of the demand side of drought. Forecasts of opportunity as well as possible reasons of opportunity, e.g. ENSO signal.

- Jess highlighted Georgy Falster's paper on the 2017-2019 drought, where SST cannot explain the severity of the drought (https://doi.org/10.1016/j.wace.2024.100734).
- Mike emailed two of his recent papers: DOI: 10.1175/JHM-D-11-0101.1 and DOI 10.13031/trans.59.10975.

ACTION ITEMS:

1. Jess to set up the public GitHub repository for this project and send us the link.
2. Mike to upload his Fortran code and shell script wrapper, update the README with process and workflow documentation, and upload his slide deck from today.
3. Set up a test bed for converting the Fortran code to Python.
   3.1. Do this in steps, converting each piece of code separately.
   3.2. Decide on a reference period and area, and replicate the Fortran results using the same data, to test the new pieces of code.
4. Meet in the week of 20-24 January 2025, after AMS. Tess to send an invite/Zoom link.

PROJECT OUTLOOK:

1. Complete the code migration to Python.
2. Utilise the code for several areas of research interest:
   2.1. Flash drought
   2.2. Multi-year drought
   2.3. Thirst waves
   2.4. Fire weather
3. Do a baseline study of daily variability of ET_0 – where, how and why does it vary? (The two papers Mike sent outline the techniques for this, as they are slightly different.)
4. For all of these research interests, investigate the synoptic-dynamics and underlying processes/weather systems behind the results.