Effect of terrain on spatial variability of lightning in eastern Oregon

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Lightning is a hazard to both public safety and electronic equipment. In addition, lightning can be an ignition source for wildfires in the dry-climate zones of eastern Oregon. Higher terrain is known to correlate to increased precipitation as well as increased convective activity due to an effect known as orographic lifting. The goal of this research was to explore the relationship between higher terrain and number of lightning strikes in eastern Oregon on particularly active lightning days. National Lightning Detection Network (NLDN) cloud-to-ground lightning data was used in conjunction with NASA's MERRA-2 reanalysis variables in order to explore this relationship. Digital Elevation Model (DEM) data from the Oregon Geospatial Enterprise Office as well as derived products from this dataset served as the terrain component of this analysis. The results show that elevation and meteorological data alone do not fully explain the presence of elevated lightning strike counts in the study area. It is shown that derived terrain descriptors such as slope and aspect, aggregated over a sufficiently large spatial extent, help explain higher frequencies of lightning occurrence when analyzed in conjunction with prevailing wind fields. This information is not readily apparent when using the standard slope and aspect tools in ArcGIS, but becomes visible when calculated over an area sufficiently large to capture relevant processes in thunderstorm formation. This research demonstrates that it is possible and feasible to quantify the orographic effect that leads to higher lightning counts in certain areas of eastern Oregon.

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Source: ScienceMag.org

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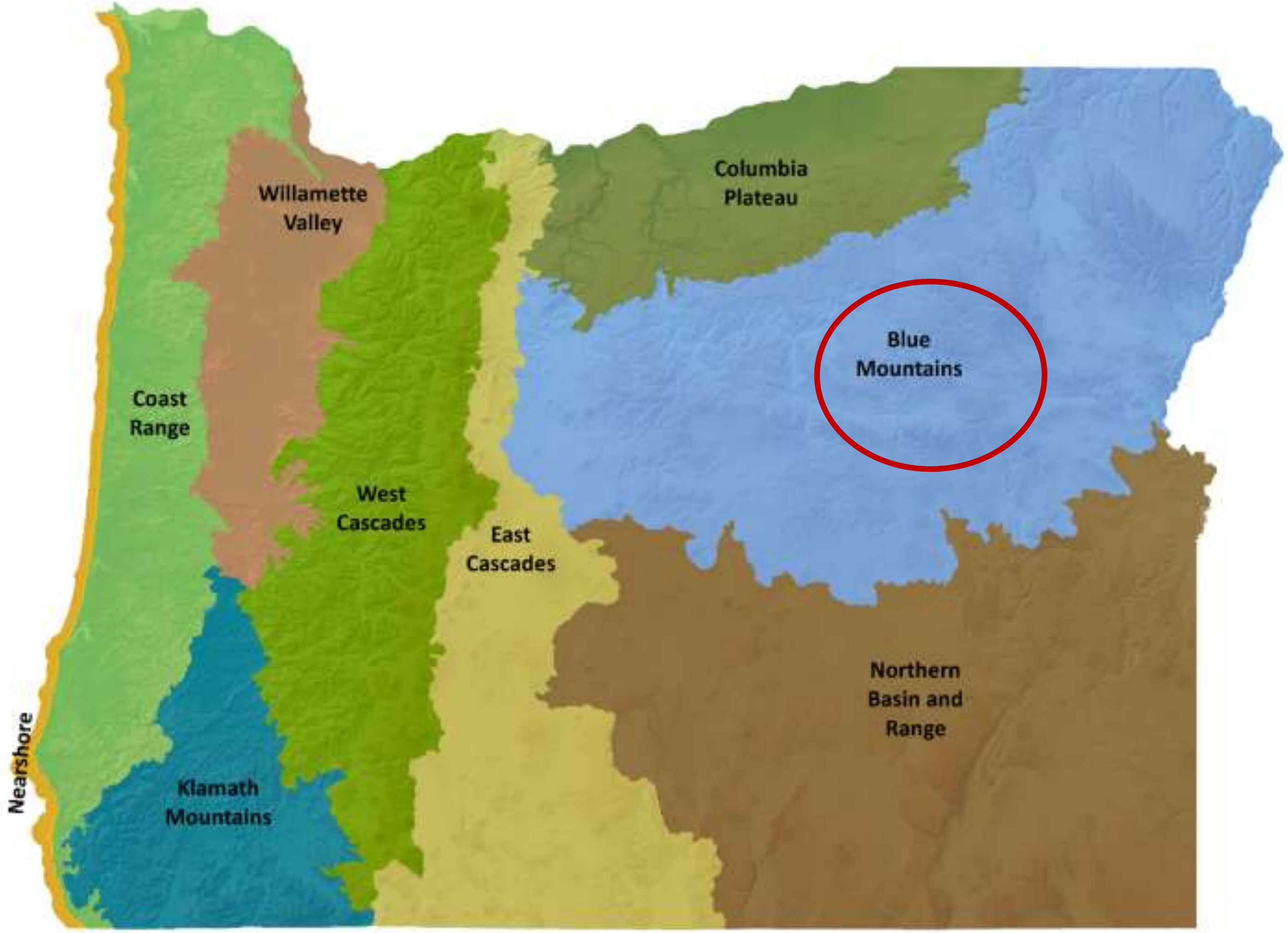


Source: OregonConservationStrategy.org

Why care about lightning?

- Lightning is a hazard
  - ➢ To public safety
  - ➢ To electronic equipment

- **In eastern Oregon** → ‘dry’ lightning is a major ignition source for summer wildfires

Source: The Robinson Library

Research objective

- <u>Higher terrain forces air to rise</u>
  - ➢ This can lead to more rainfall
  - ➢ More importantly, it can lead to more lightning

- This effect is known as **orographic lifting**

- Can the orographic lifting effect be shown using digital terrain analysis in ArcGIS?

Datasets Used

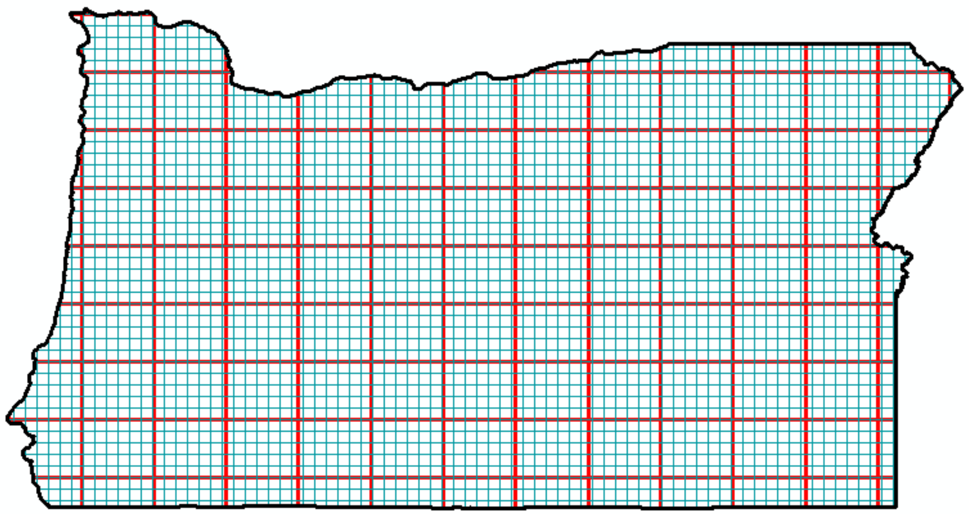
- <u>National Lightning Detection Network (NLDN)</u>
  ground sensor CG (cloud-to-ground) strike data
  - 1988-2017

- 30 meter statewide DEM from the Oregon Geospatial Enterprise Office

- Meteorological data from NASA's MERRA-2 reanalysis
  - Lower atmospheric moisture (specific humidity)
  - Vertical instability (between 10k and 19k feet)
  - Winds at 10,000 feet ('700 hPa pressure level')
    - High enough to represent real steering flow in atmosphere
      - But low enough to represent lower level airflow

Methods

- **Software used**:
  - ArcMap 10.6.1
  - MATLAB R2017b



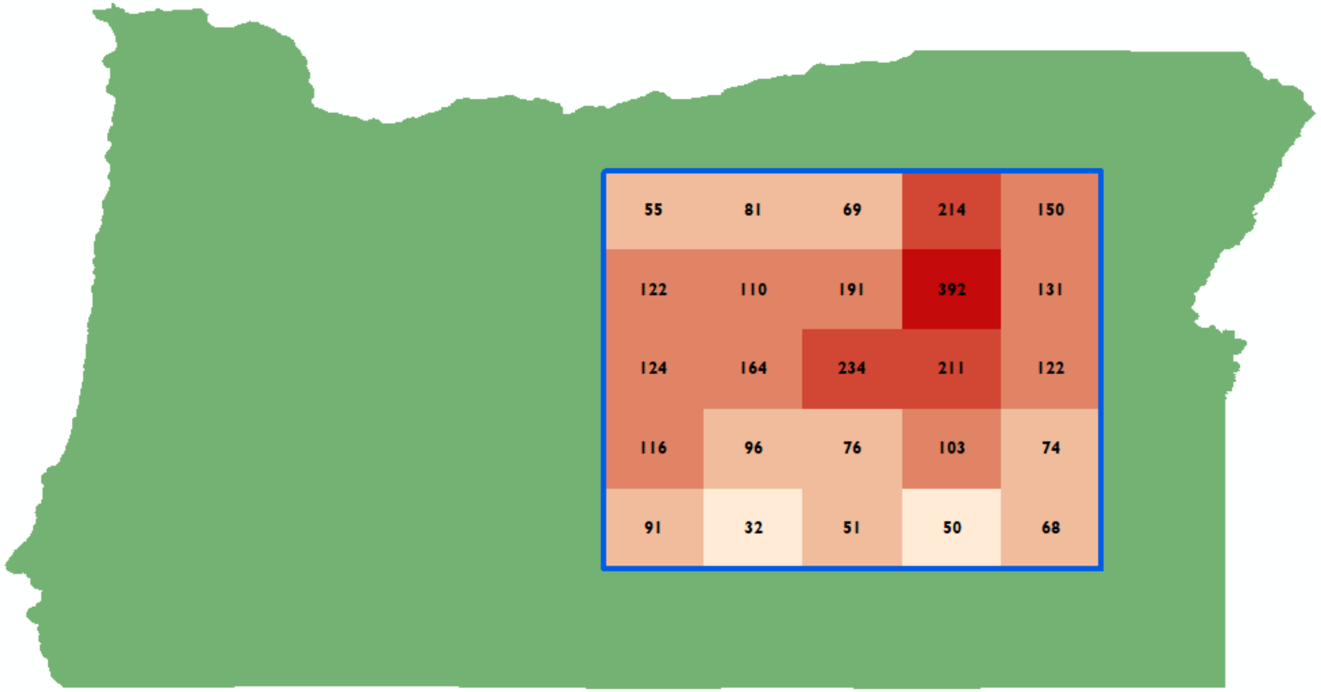
➢ Import NLDN & MERRA-2 data into MATLAB

➢ Regrid NLDN data to match MERRA-2
  - Overlaid grids in ArcMap (using Fishnet tool)
  - Performed regrid calculations in MATLAB

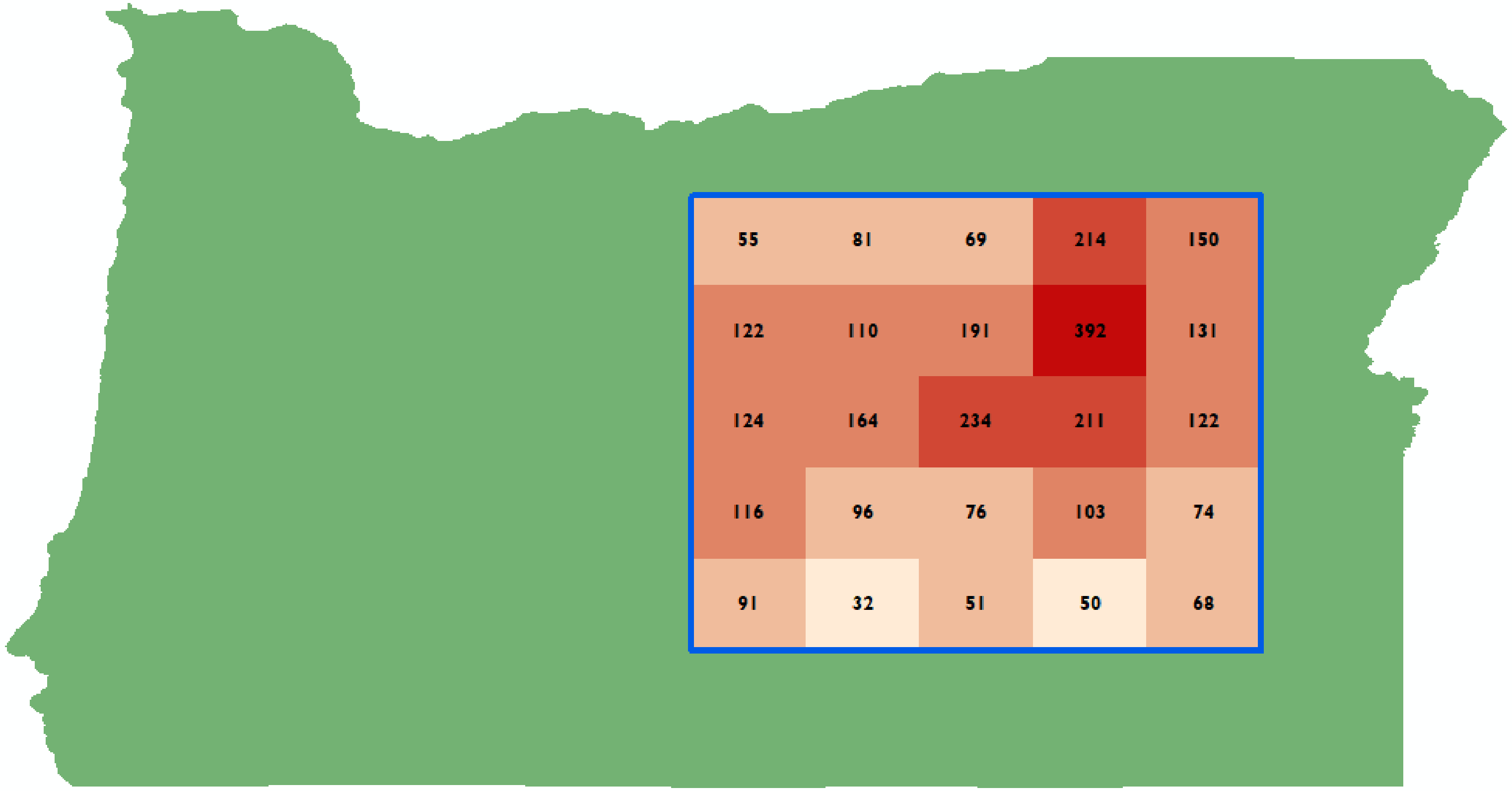
➢ Run algorithm to find grid cell (0.5 lat X 0.625 lon) with highest lightning average in eastern Oregon

Methods con't

- Isolated **top 10** days with highest lightning strike counts (from 1988 to 2017)
  - In the highest-average grid cell from previous step
- Selected 5x5 kernel to represent eastern Oregon
  - Calculated lightning strike **averages** for 25 grid cells <u>on same top 10 days:</u>

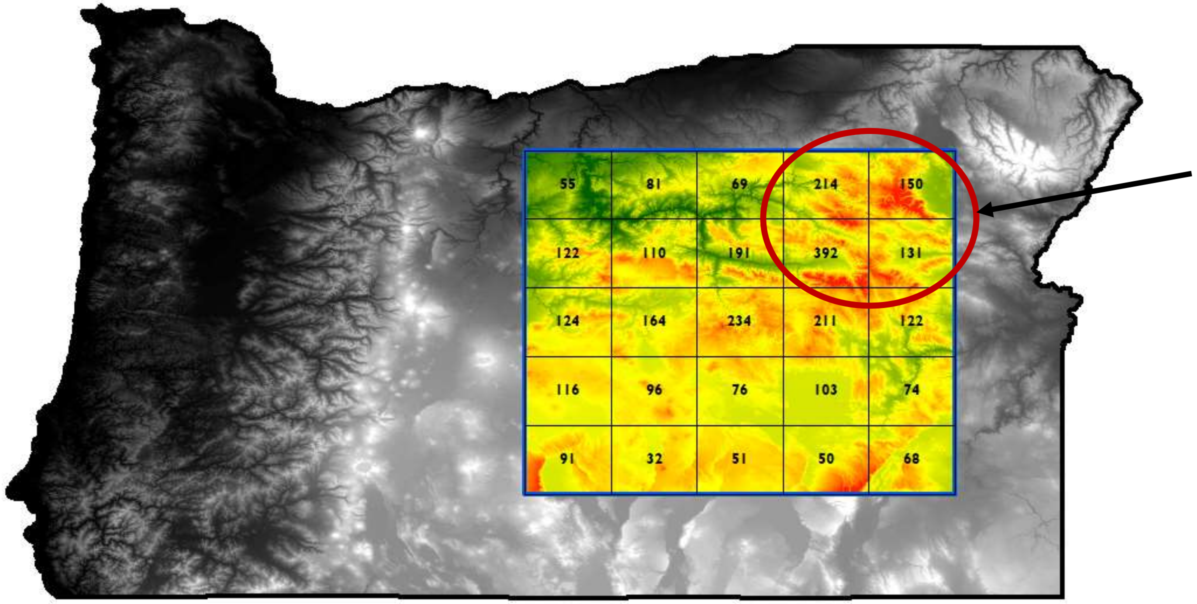


Can this pattern be explained by topography?



Methods con't

- Imported 30 meter DEM into ArcMap
- Polygonized 5x5 kernel from MERRA-2 grid
- Converted MATLAB variables into Geotiff, imported to ArcMap
  - NLDN lightning
  - MERRA-2 variables (moisture, instability, winds)

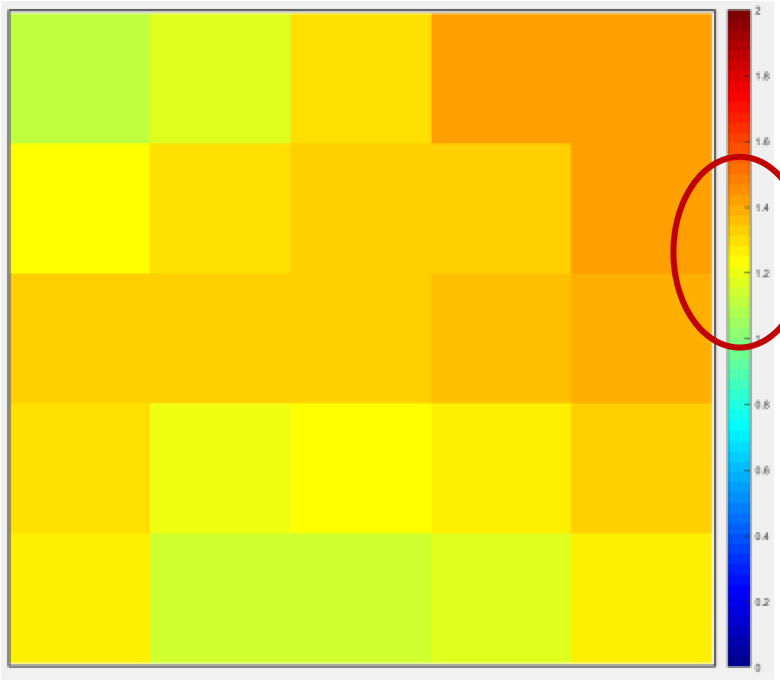


High elevation = good

But…why the differences in lightning strike counts?

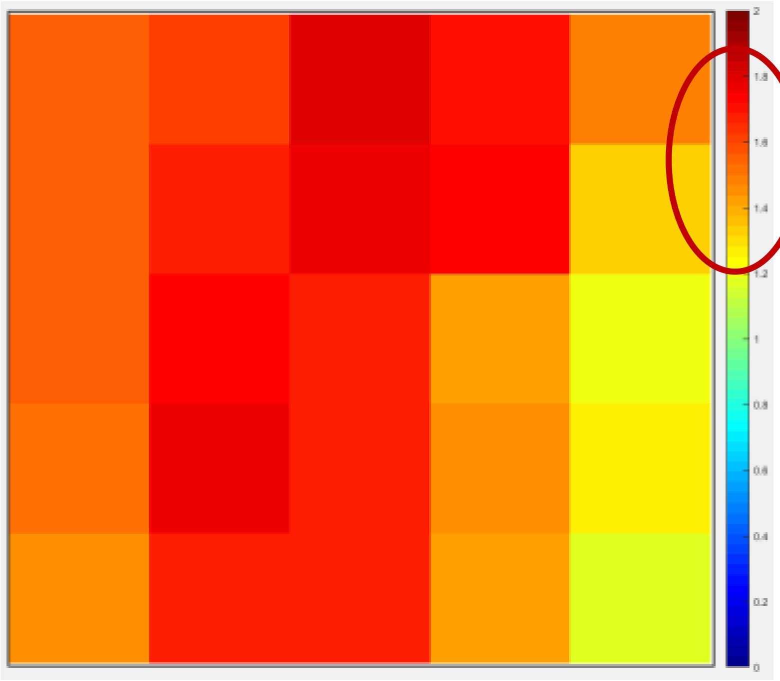
Could it be something else?

- Moisture levels?



No - lower atmospheric moisture is high (+1 to +1.5 sd's above normal) across study area

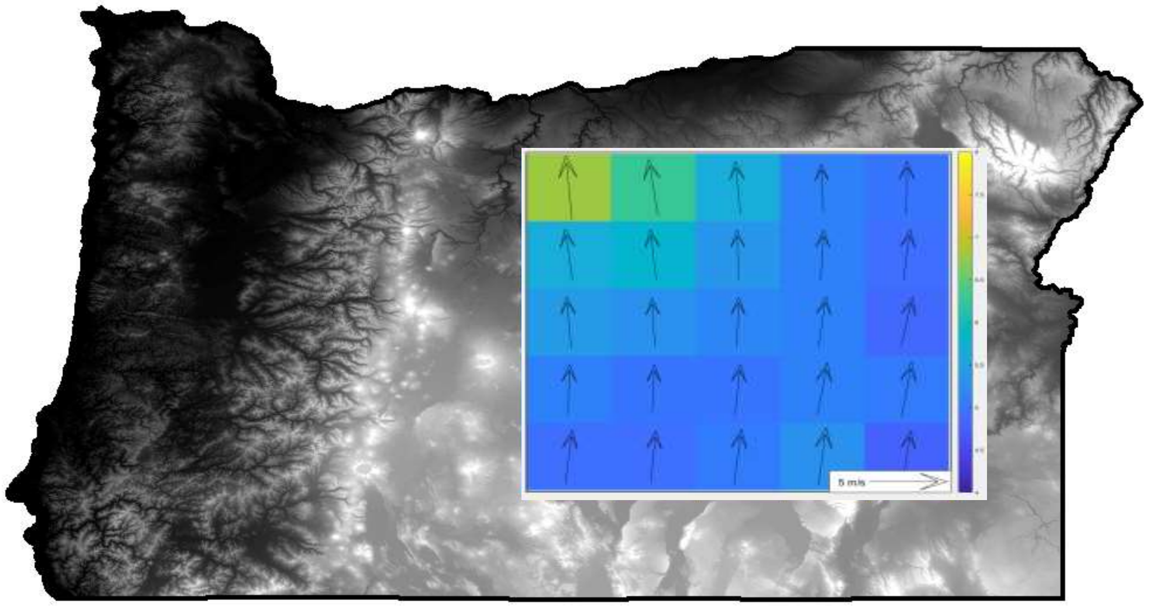
- Buoyancy differences (lapse rates)?



No – lapse rate departures are positive (+1.2 to +1.8 degrees C) across study area

Methods con't

- ➢ Let's take a look at where the winds are coming from
  - ➢ Winds at ~10,000 feet (700 hPa pressure level)
    - ➢ Averaged wind conditions for **top 10** days



Not surprisingly → air flow is southerly, i.e. warm and moist

Methods con’t

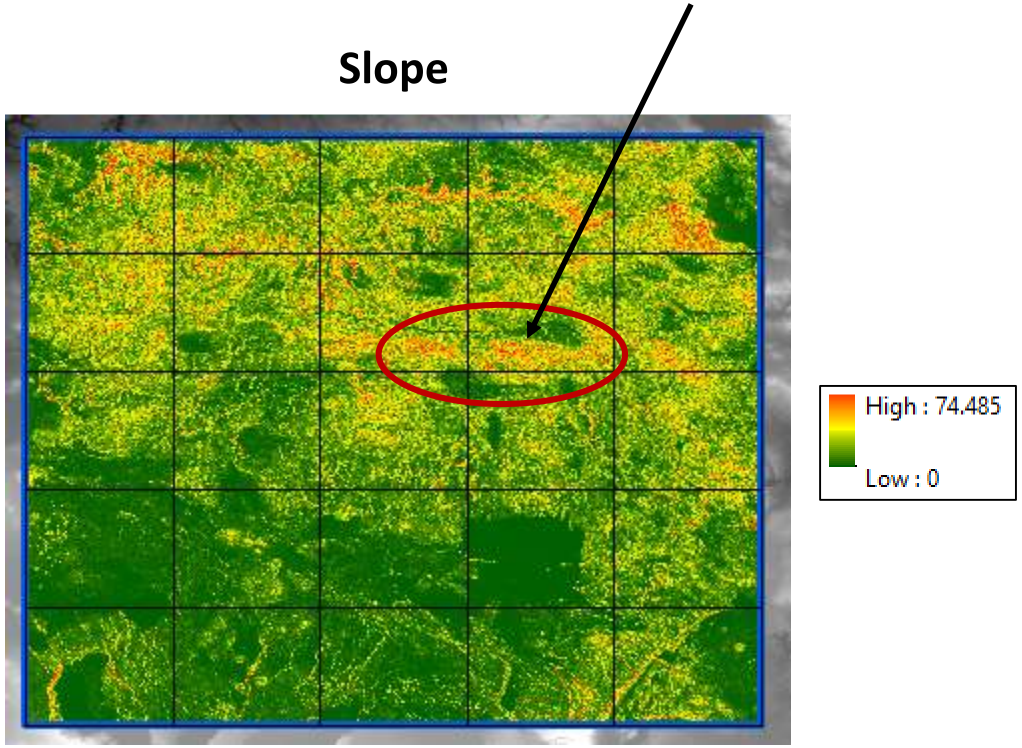
- If it’s not elevation, moisture, or lapse rates → is it slope & aspect?

Looks promising – steep slopes perpendicular to air flow

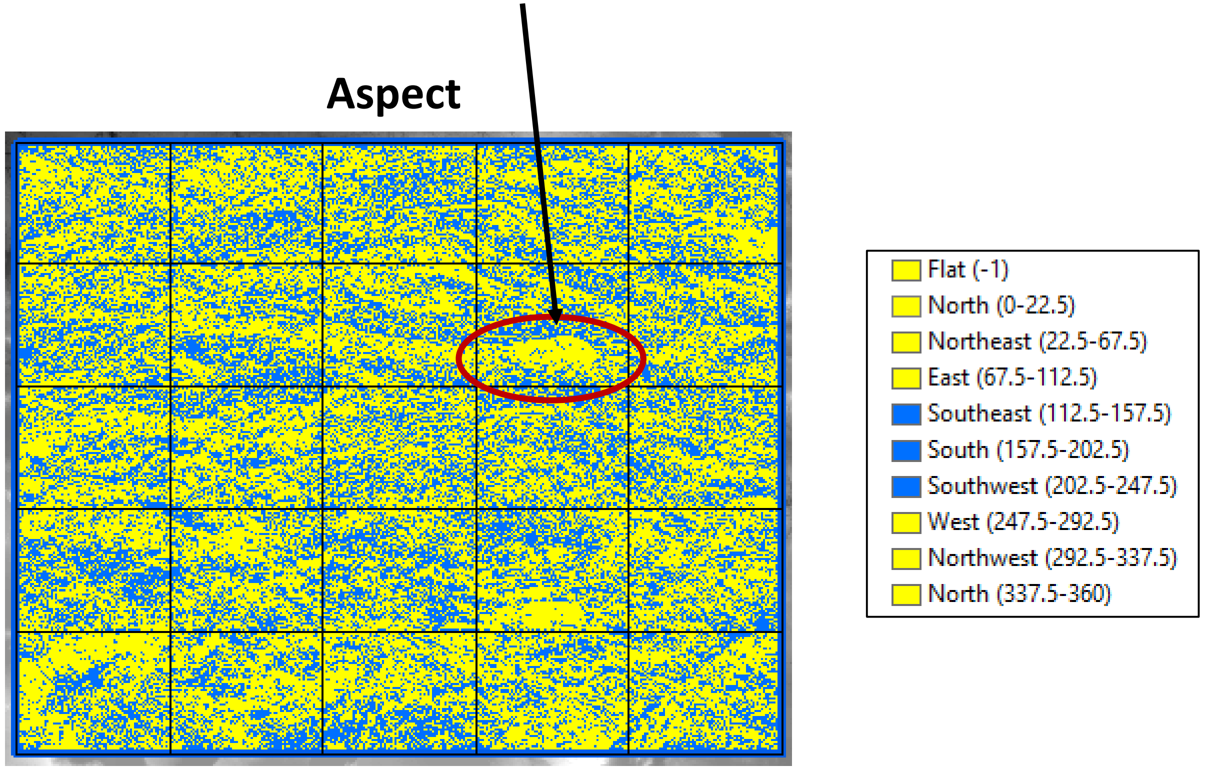
-but-

Large area of steep slopes faces the wrong direction!

Slope

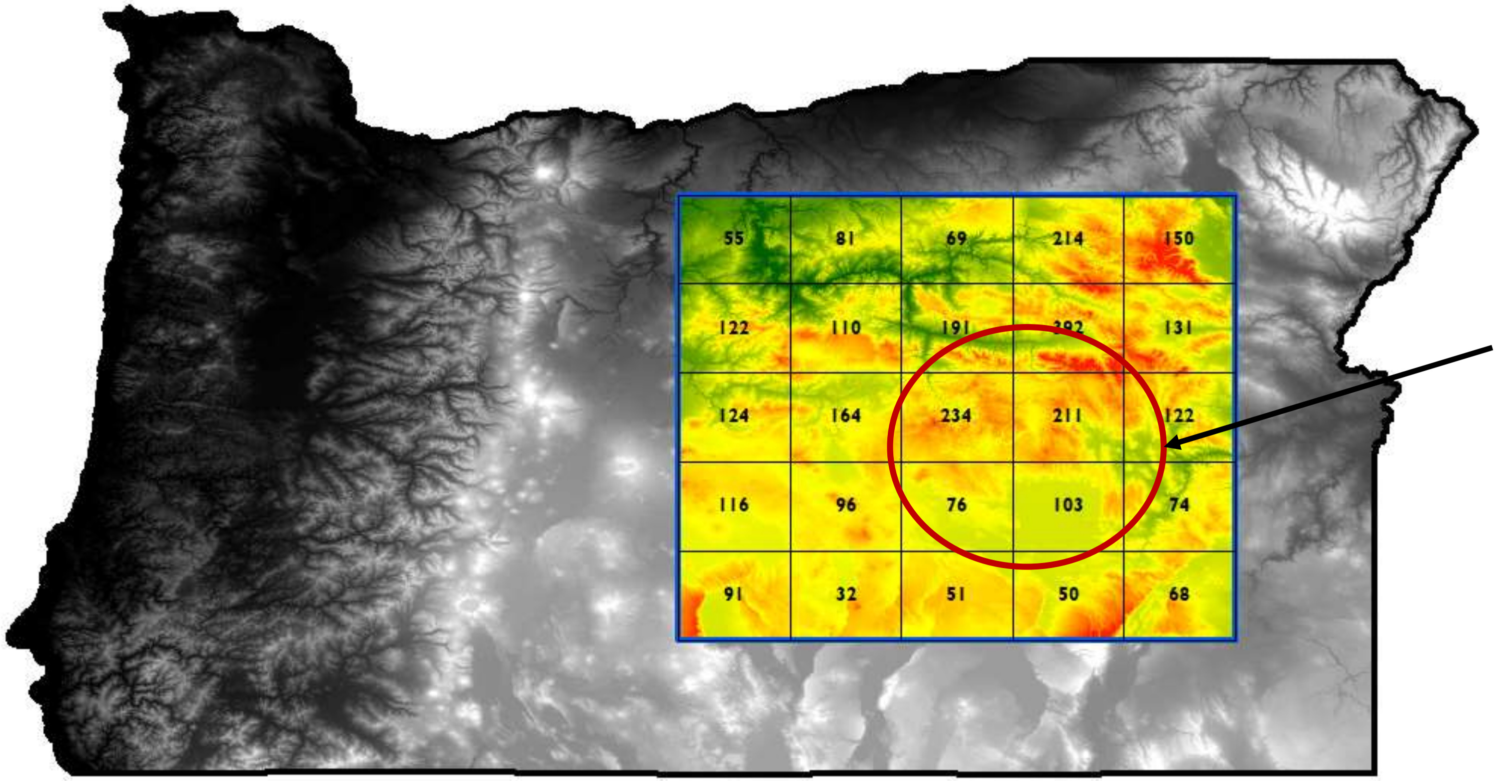


Aspect



Methods con’t

- There is clearly a substantial S-N elevation gradient leading up to the area of highest lightning strike counts – but, can we quantify it?



Zone of southerly winds “ramping up” the terrain

Methods con't

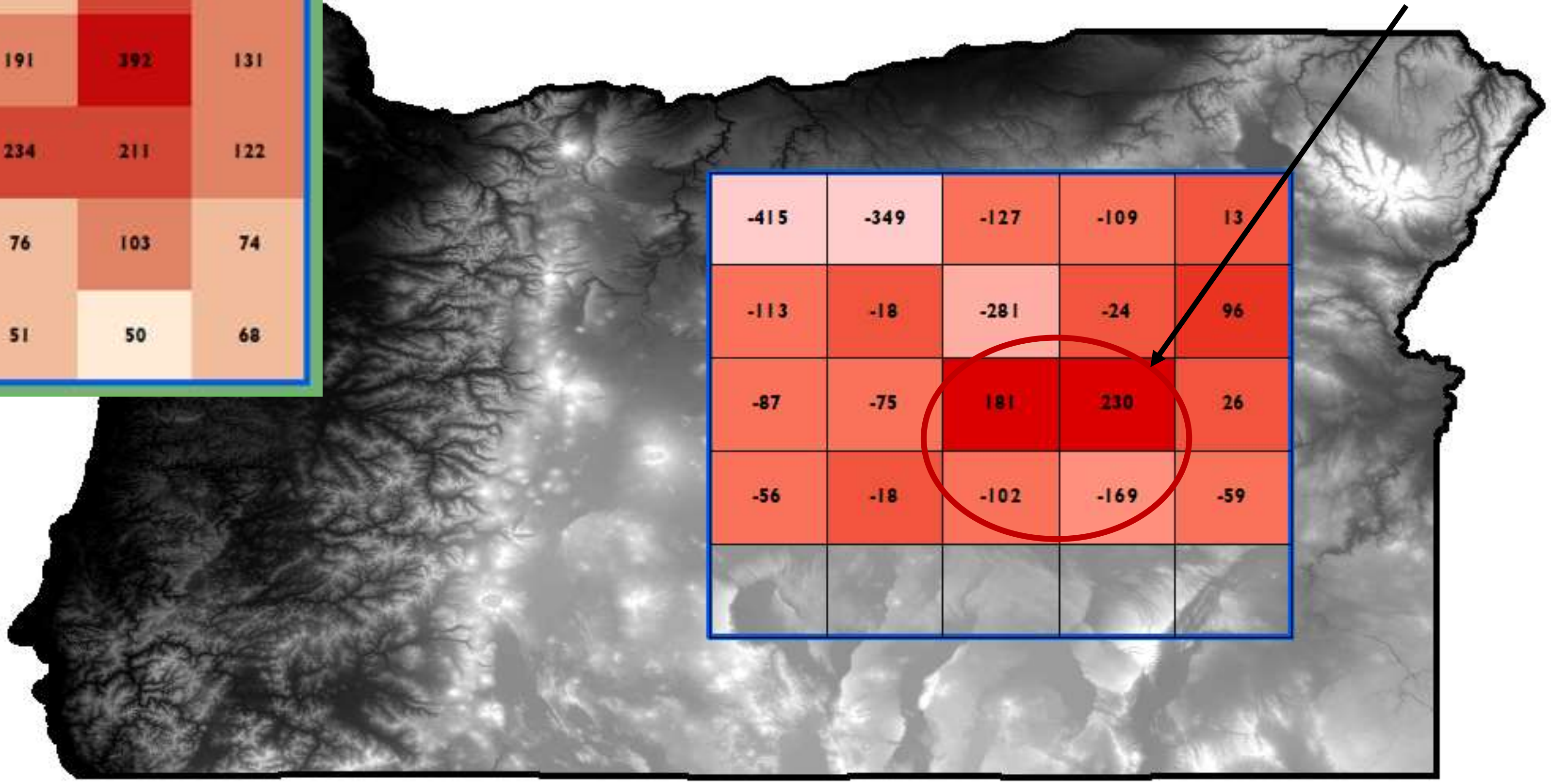
- **The solution** – calculate mean elevation difference between each grid cell and grid cell to its south
  - Zonal statistics as table, using polygonized MERRA-2 grid
  - Manually calculated elevation differences – a 'custom' slope/aspect calculation for the larger (0.5 degree X 0.625 degree) grid cell size
  - Appended difference values to MERRA-2 polygon grid, symbolized

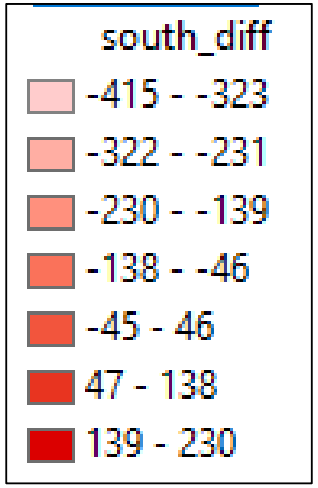
The results – part I

N-S elevation differences

Recall – lightning strike totals:

Zone of southerly winds "ramping up" the terrain

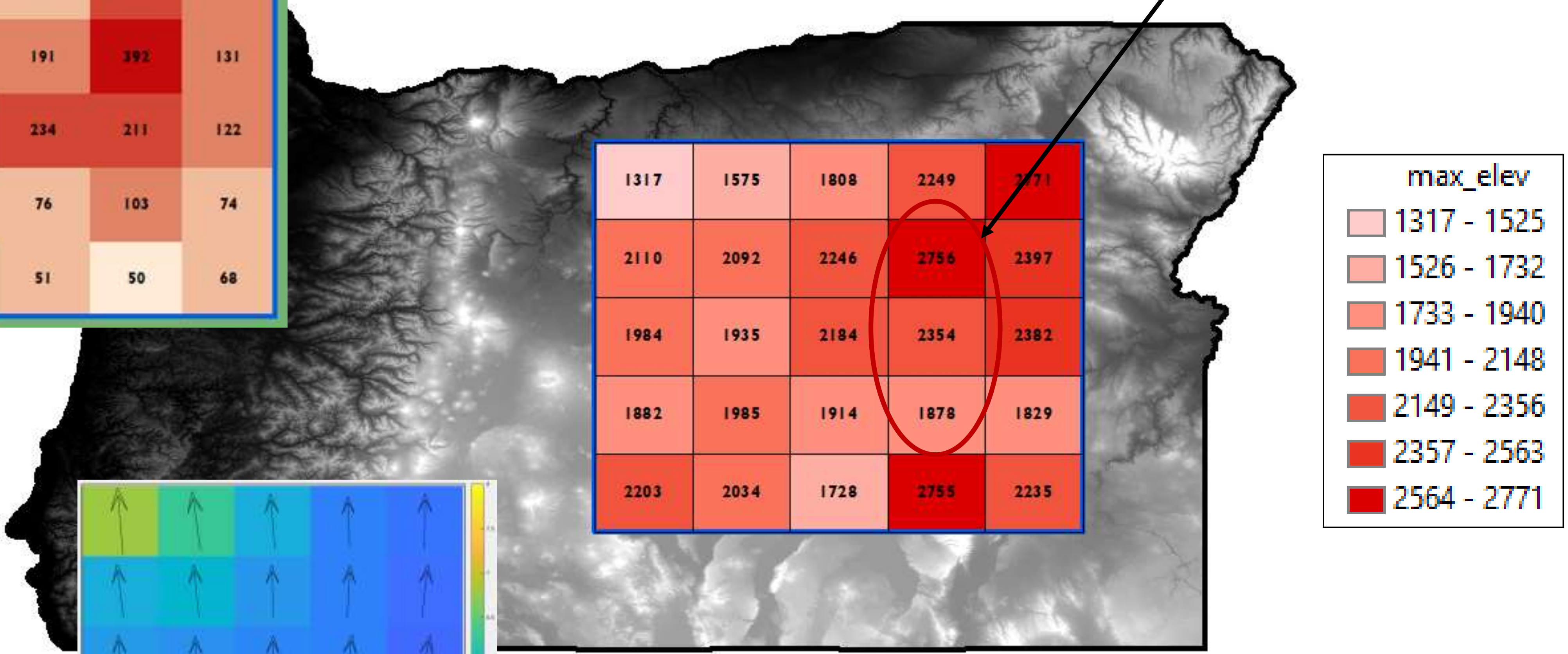




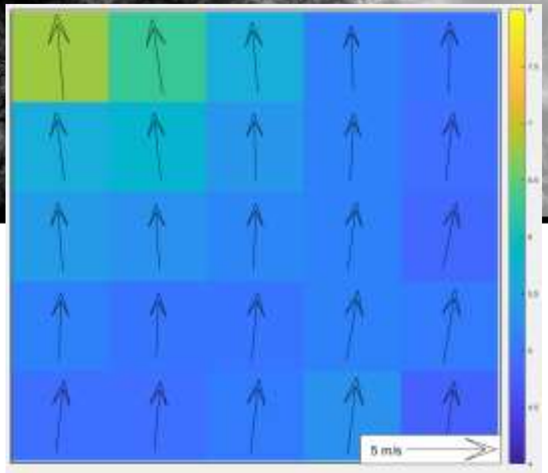
The results – part II

Recall – lightning strike totals:

Greater vertical "ramp", due to higher max elevation



Recall – winds:



Conclusion

Why do lightning strike counts vary across the study area?

- Elevation itself is not an explaining factor, without factoring in "run up" terrain
- Meteorological variables are not an explaining factor, assuming uniformly favorable values across study area
- A terrain analysis (i.e. southerly slope perpendicular to winds), in conjunction with elevation differences, can help explain the greater occurrence of lightning

Thank you!

Questions?