Turbulence Statistics in Thunderstorm Clouds

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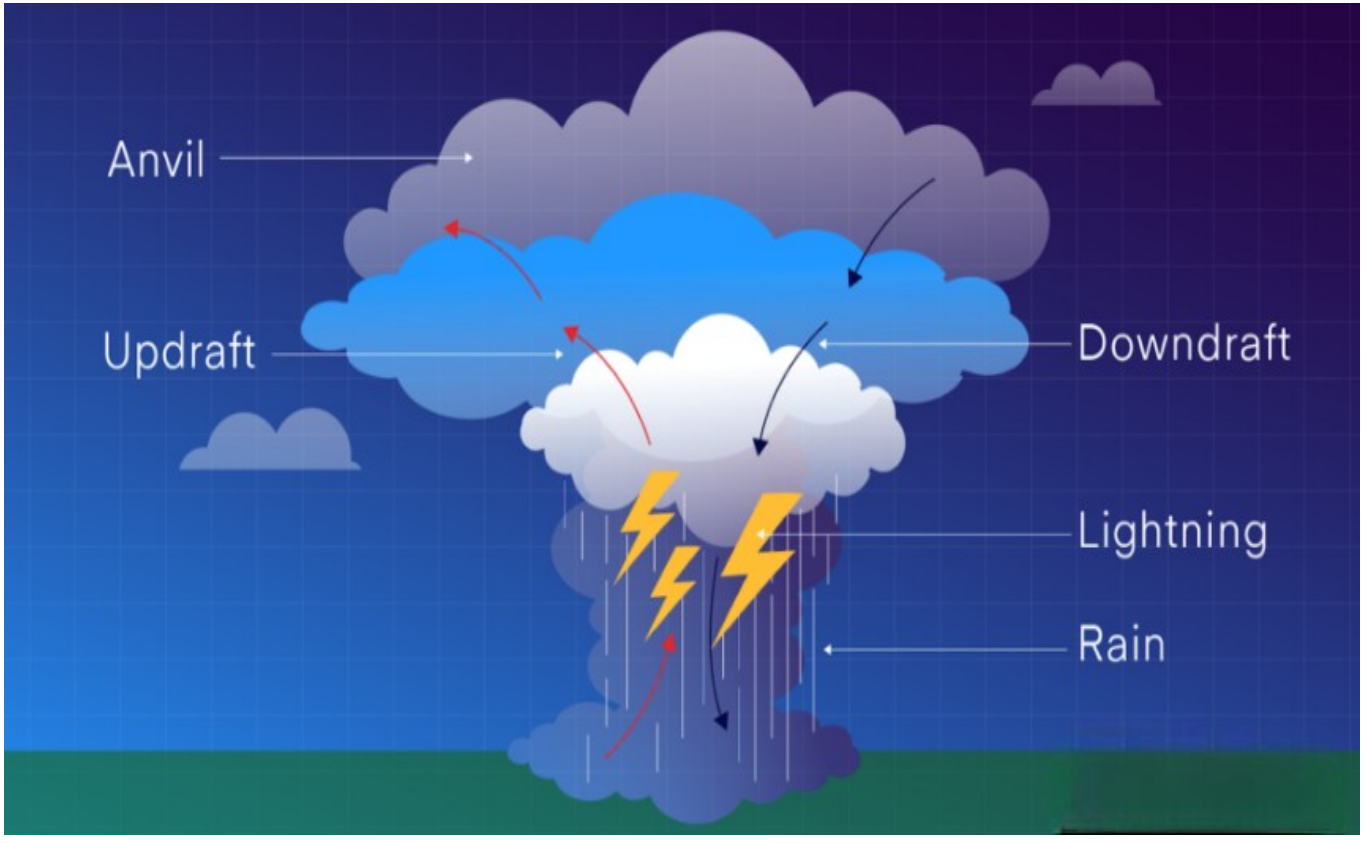
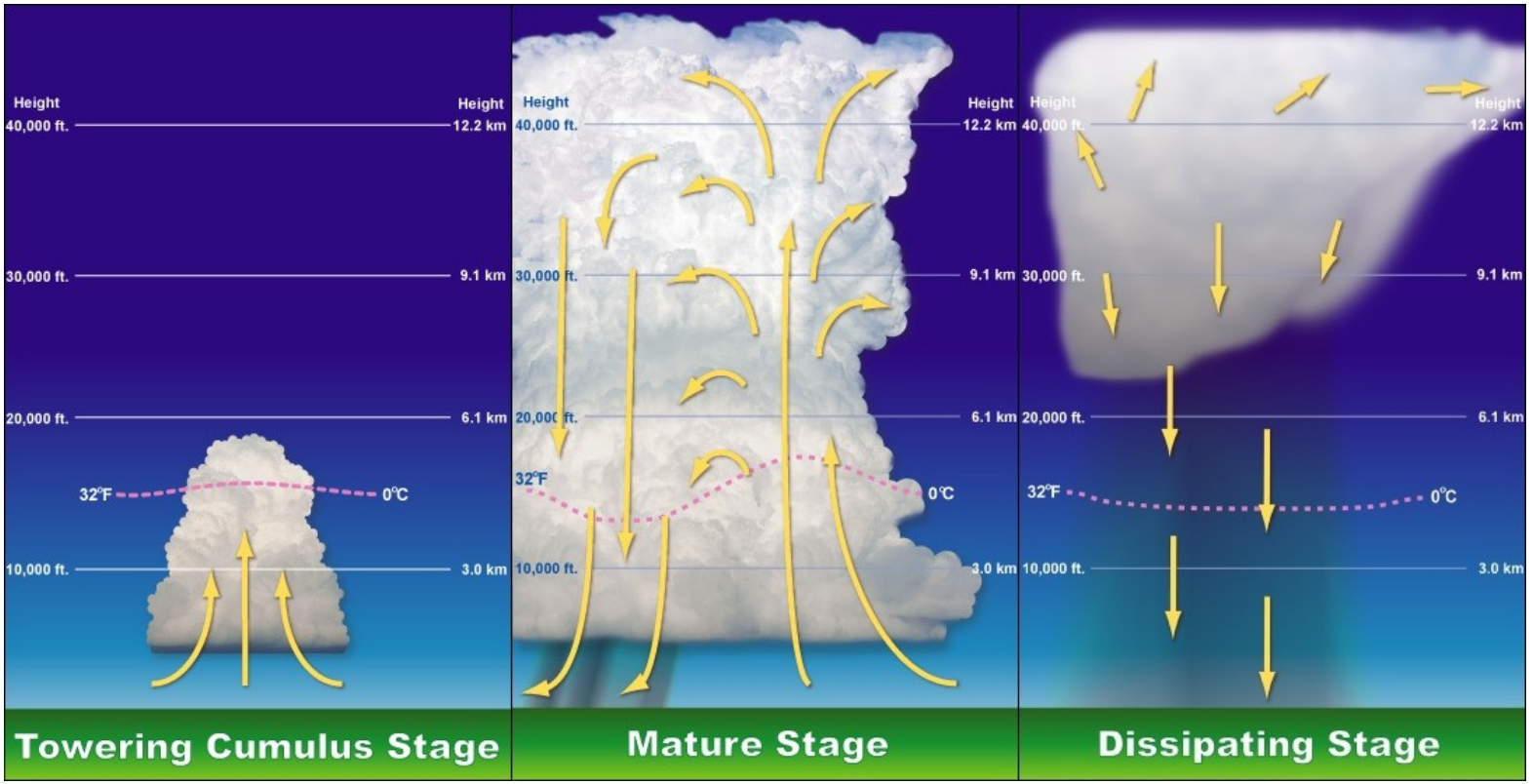
http://www.tohsep.com/SevereWeather/Thunderstorms

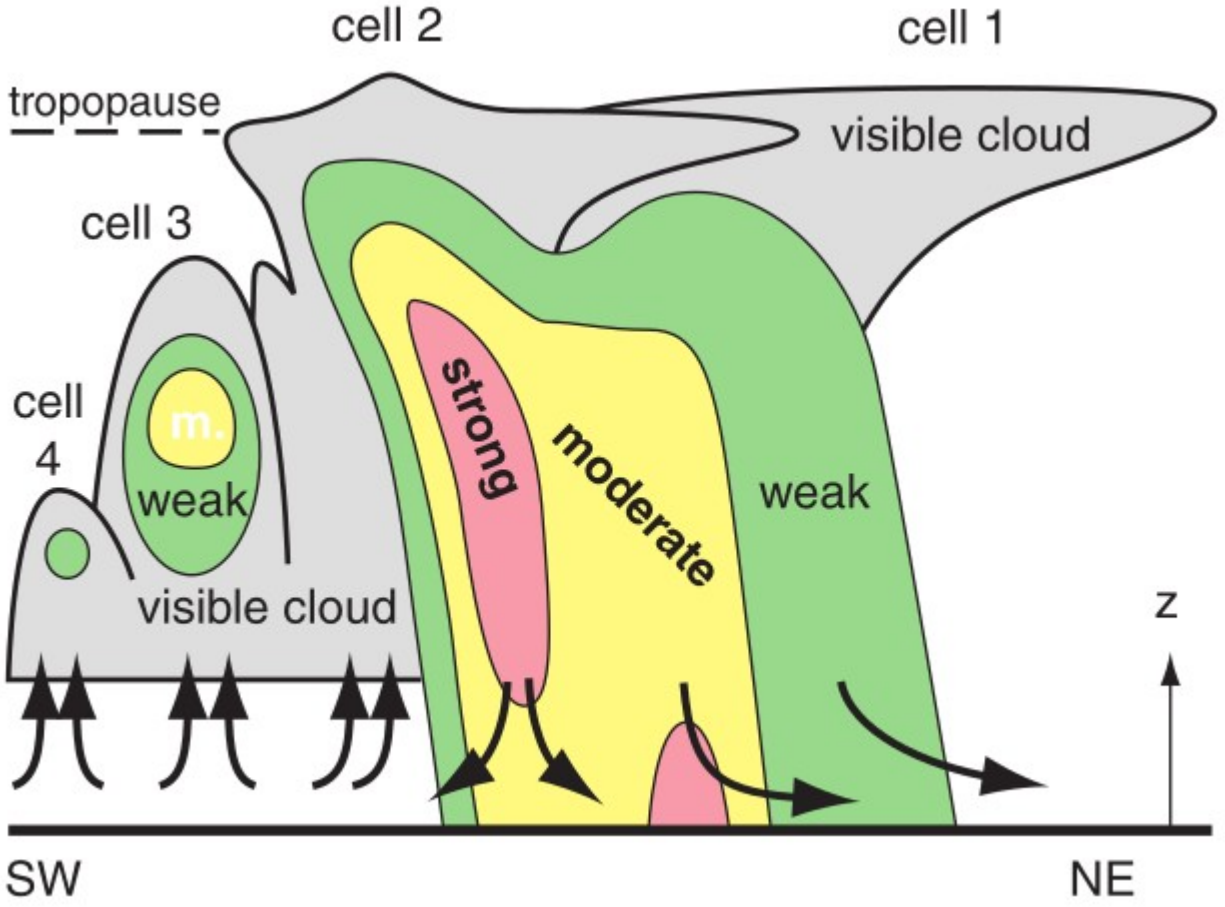


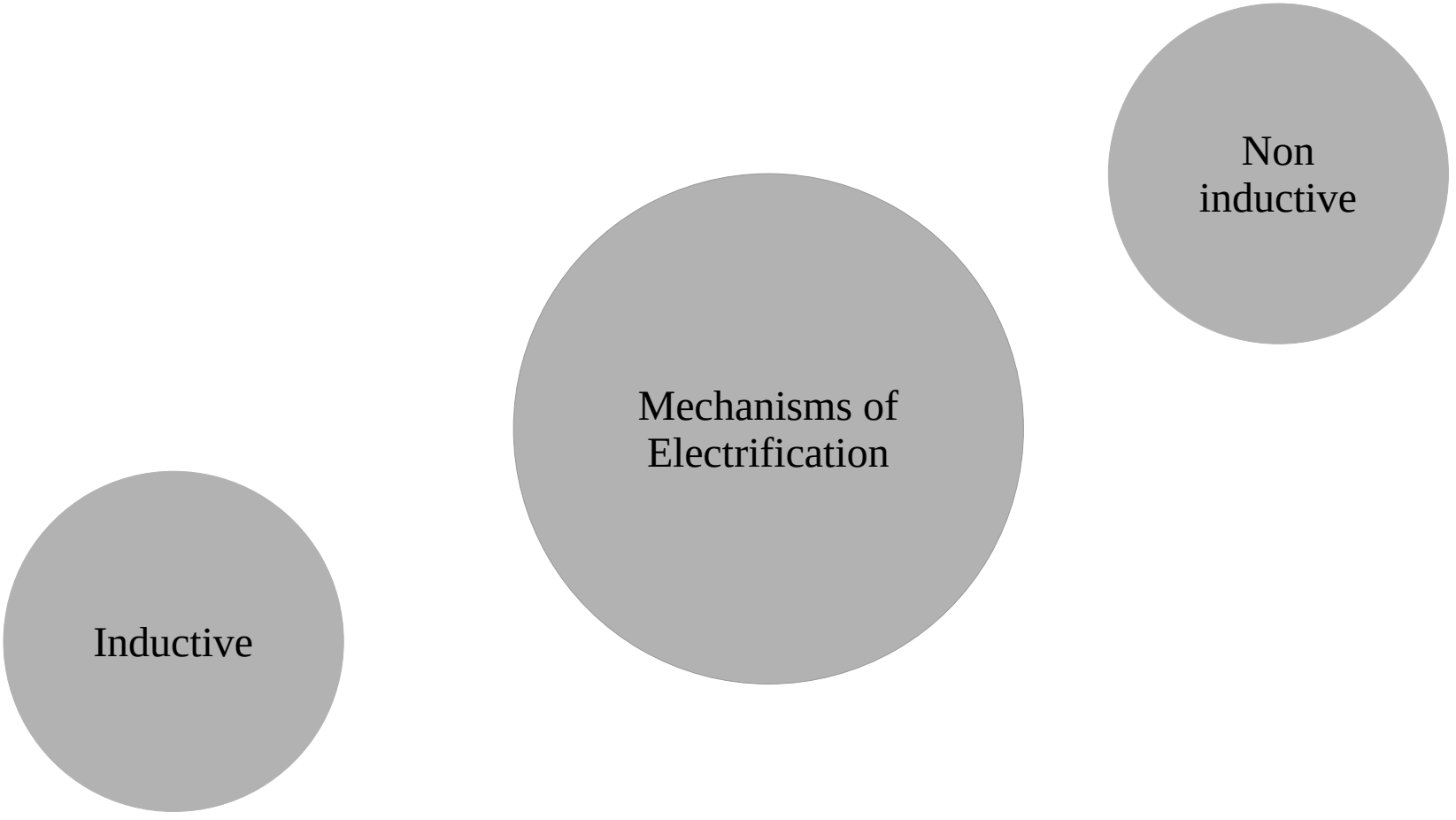
https://pilotinstitute.com/types-of-thunderstorms-aviation/



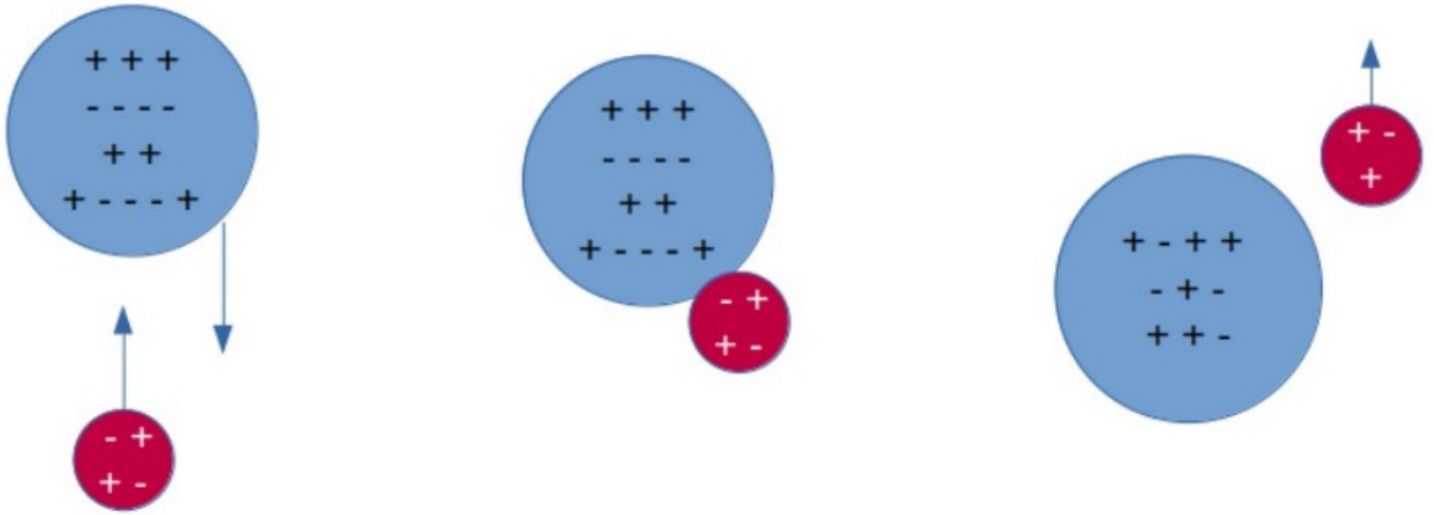
~ Cell ~ Byers-Braham Cell

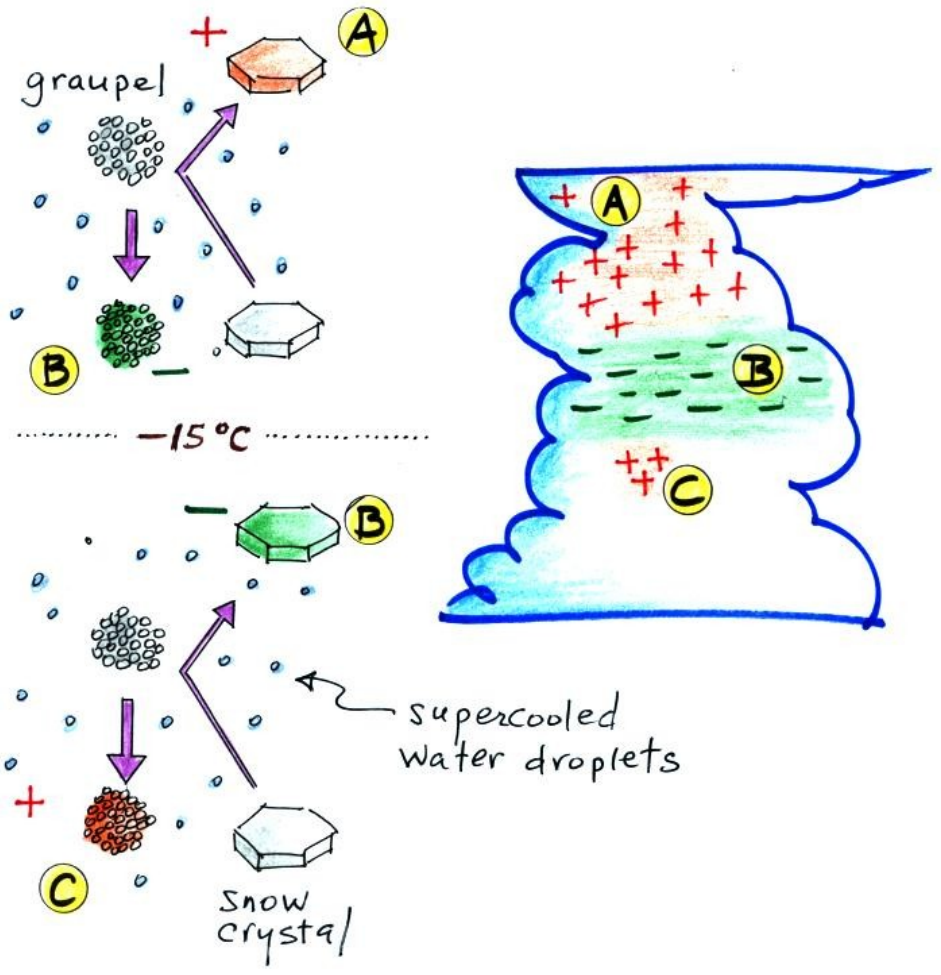
The Thunderstorm Project in Ohio - 1947

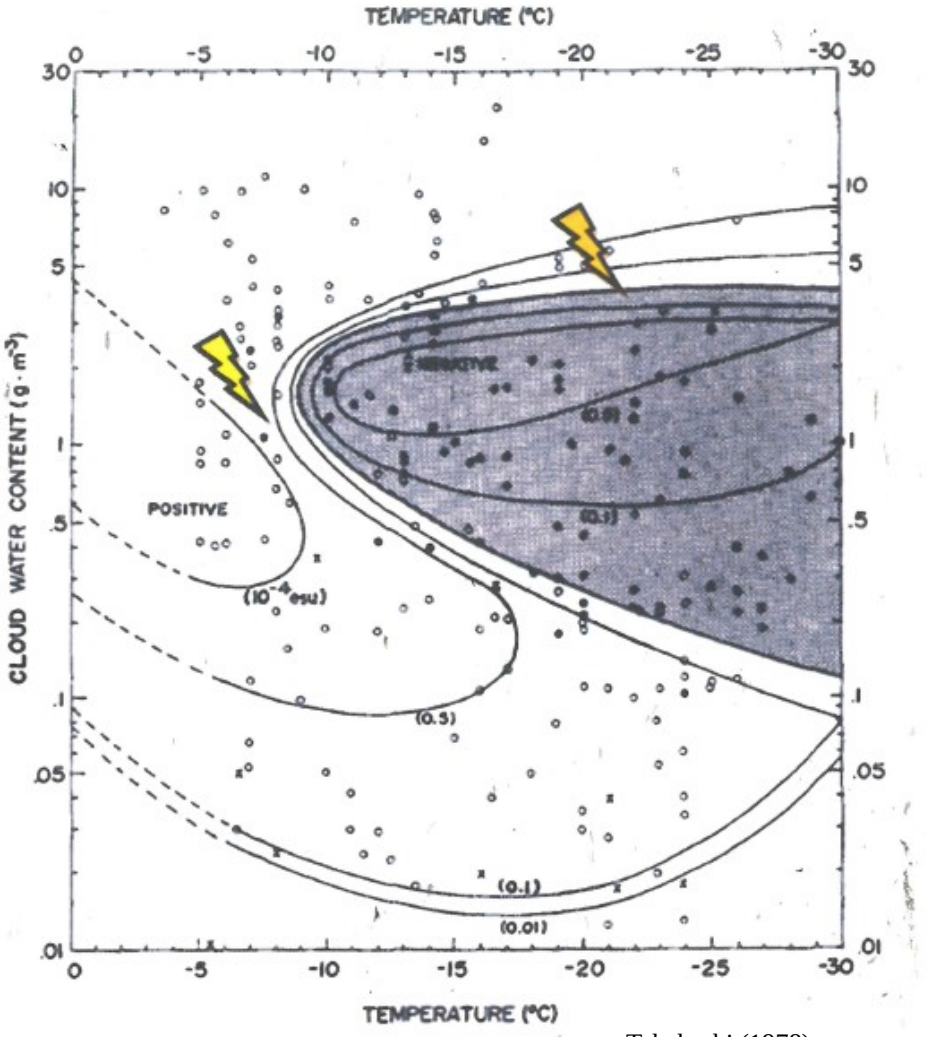

cell 2
cell 1
tropopause
visible cloud
cell 3
cell
4
m.
weak
strong
moderate
weak
visible cloud
z
SW
NE


Non inductive
Mechanisms of Electrification
Inductive

E

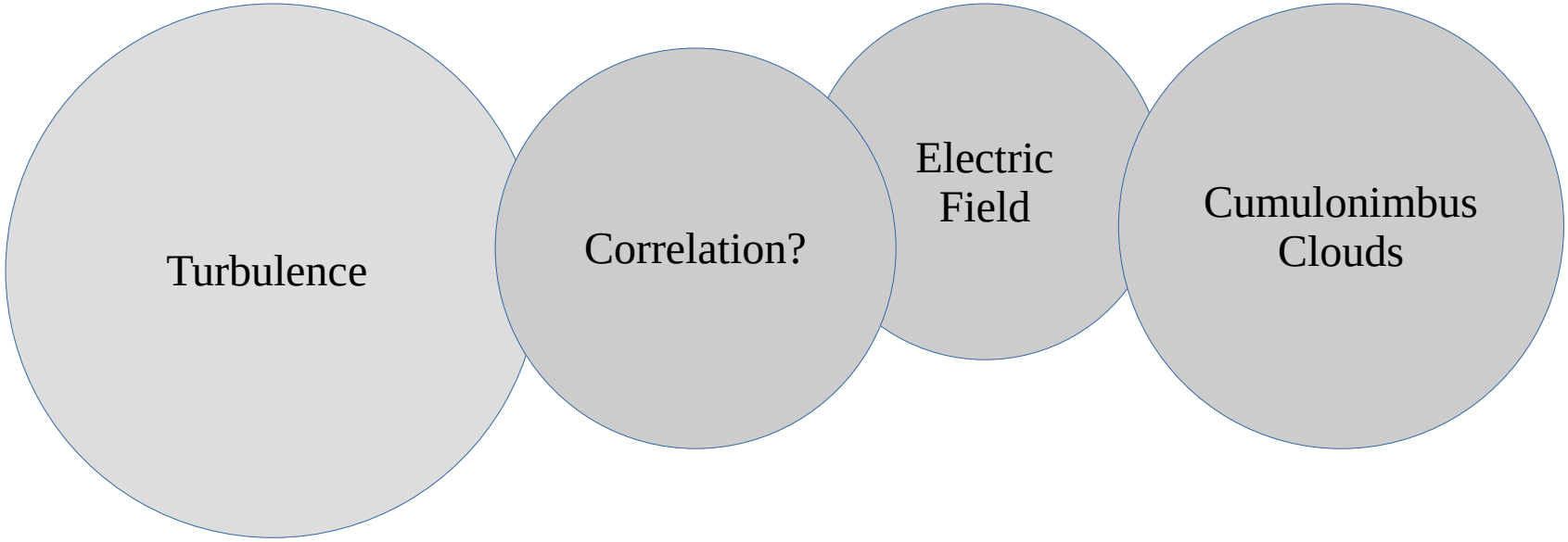






http://www.atmo.arizona.edu/students/courselinks/spring15/atmo589/ATMO489_online/lecture_11/lect11_cloud_electrification.html

Takahashi (1978)



Geophysical Research Letters

RESEARCH LETTER
10.1029/2021GL095923

Assessment of Turbulence Intensity in Different Spots of Lightning Flash Propagation

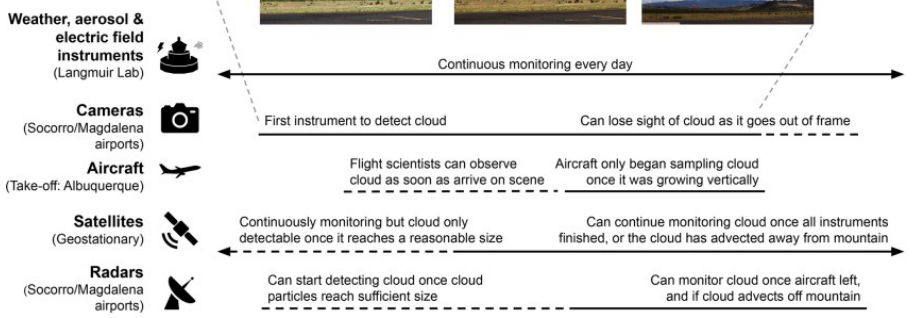
Jessica C. S. Souza[1] **and Eric C. Bruning**[1]

[1]Department of Geosciences, Atmospheric Science Group, Texas Tech University, Lubbock, TX, USA

Key Points:

- Observations of turbulence intensity along flash propagation support inertial range eddies' role in

DCMEX



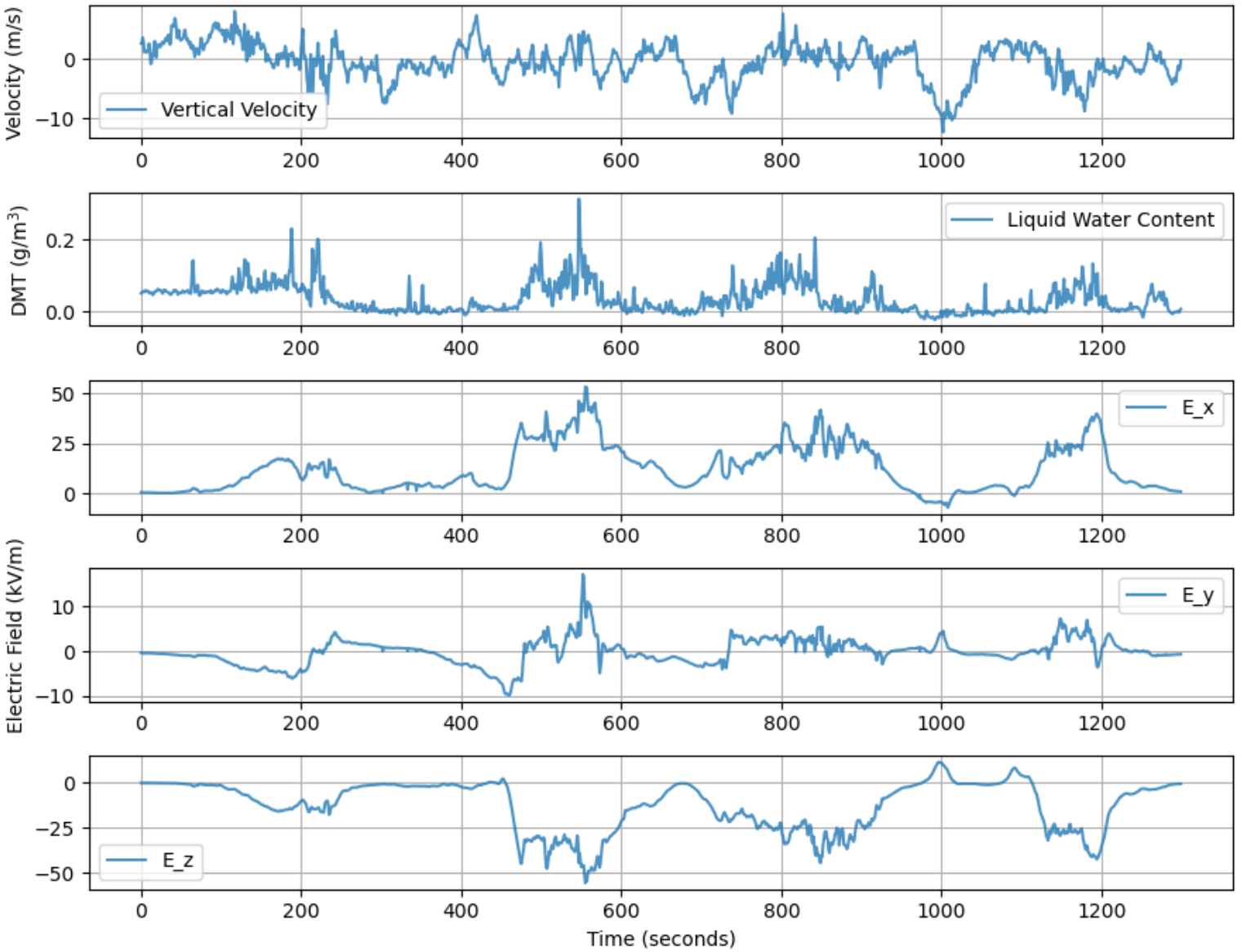
TIM
SEVERE STORMS FIELD CAMPAIGN

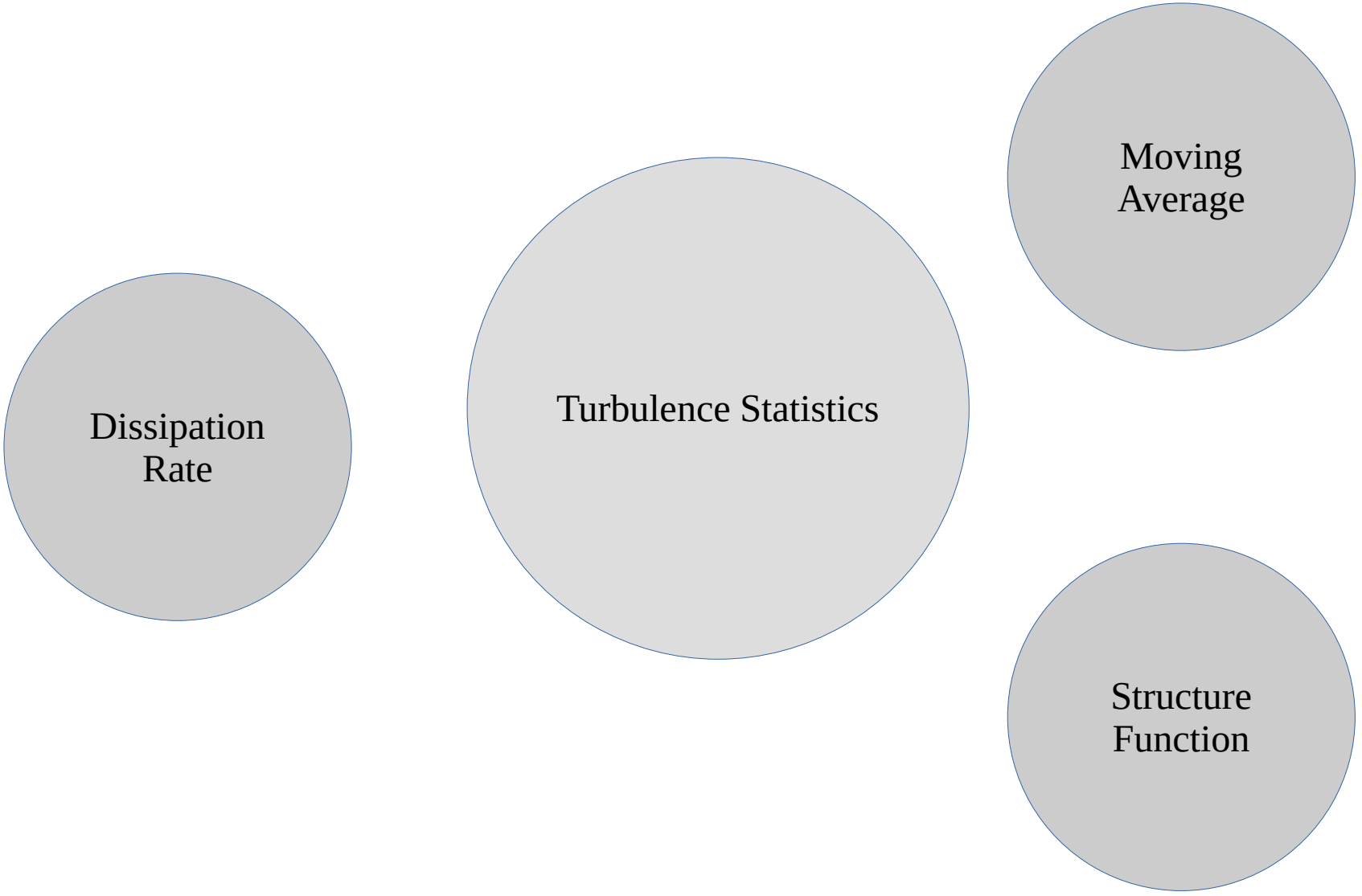
Severe Thunderstorm Electrification and Precipitation Study (STEPS)

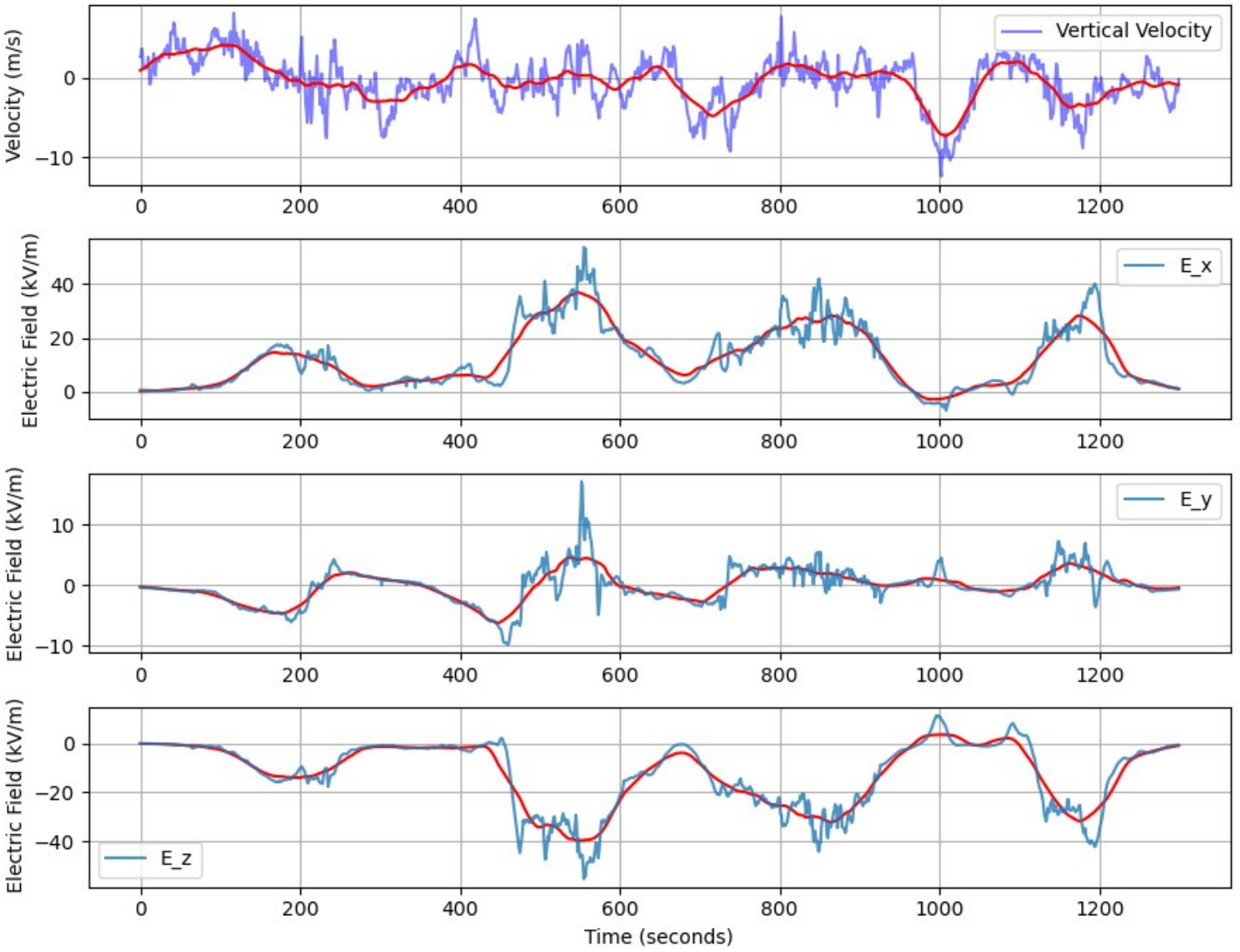
- 22 May through 9 July, 2000, Goodland(Kansas)
- Precipitation, storm electrification studies and hydrometeor identification studies
- Convective storms – Mature stage

Flight Number	Date	Time (UTC)
747	5/25/00	23:25-00:20
748	5/26/00	22:01-22:35
750	6/01/00	00:38-01:49
751	6/03/00	23:49-01:05
752	6/06/00	23:51-01:12
753	6/09/00	21:13-22:29
754	6/11/00	21:26-22:36
755	6/12/00	23:26-23:57
756	6/20/00	00:17-01:45
757	6/22/00	23:29-01:09
758	6/23/00	22:24-23:39
759	6/25/00	00:48-02:17
761	6/29/00	22:33-23:54

https://archive.eol.ucar.edu/projects/t28/projects/steps_2000/


Velocity (m/s)
Vertical Velocity
DMT (g/m^3)
Liquid Water Content
Electric Field (kV/m)
E_x
E_y
E_z
Time (seconds)


Moving Average
Dissipation Rate
Turbulence Statistics
Structure Function


Velocity (m/s)
Vertical Velocity
Electric Field (kV/m)
E_x
Electric Field (kV/m)
E_y
Electric Field (kV/m)
E_z
Time (seconds)

Structure Function

$$S_2(r) = \left\langle [u(x+r) - u(x)]^2 \right\rangle$$

- Measures how a physical quantity like velocity changes with scale (space or time).

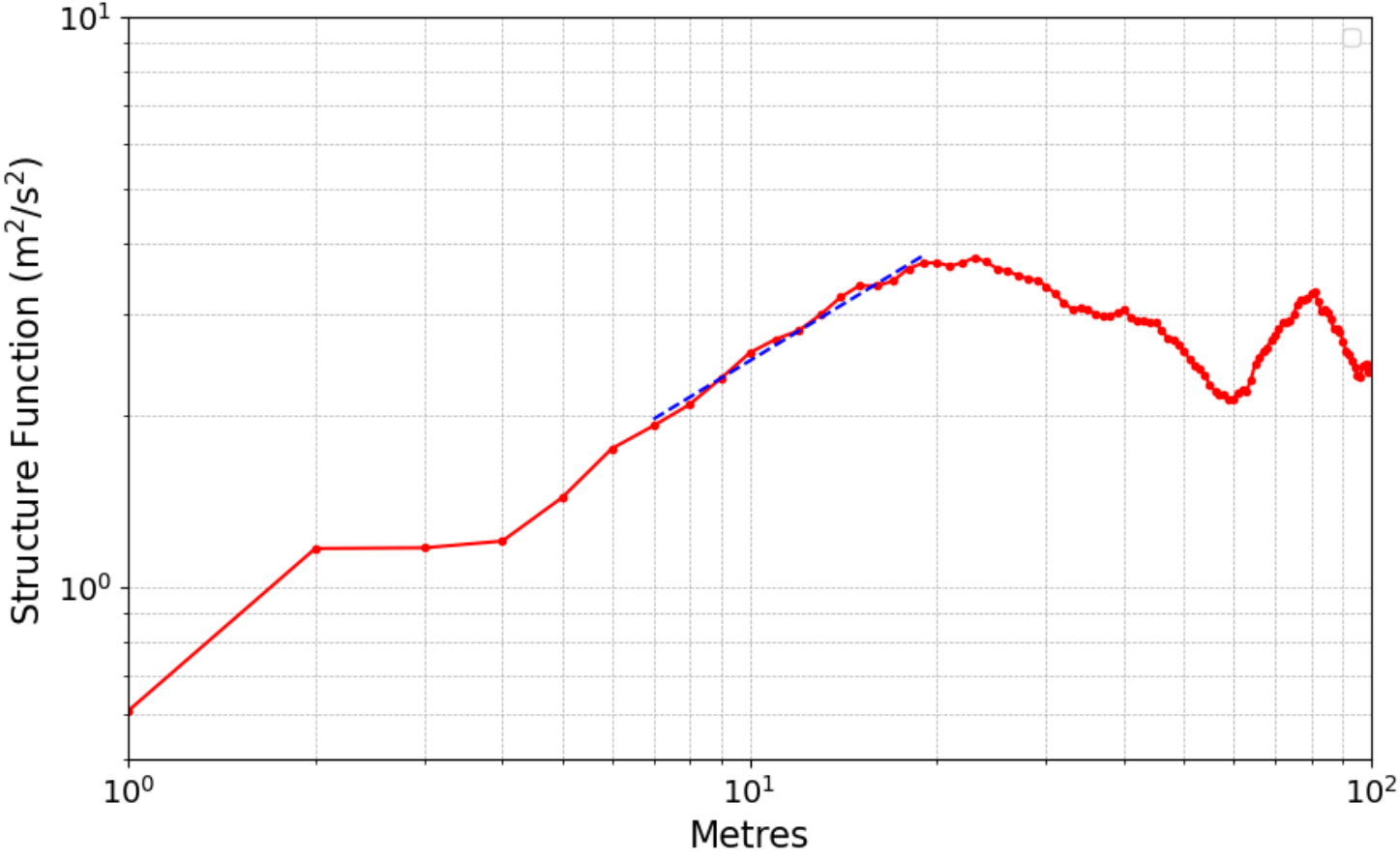
Dissipation

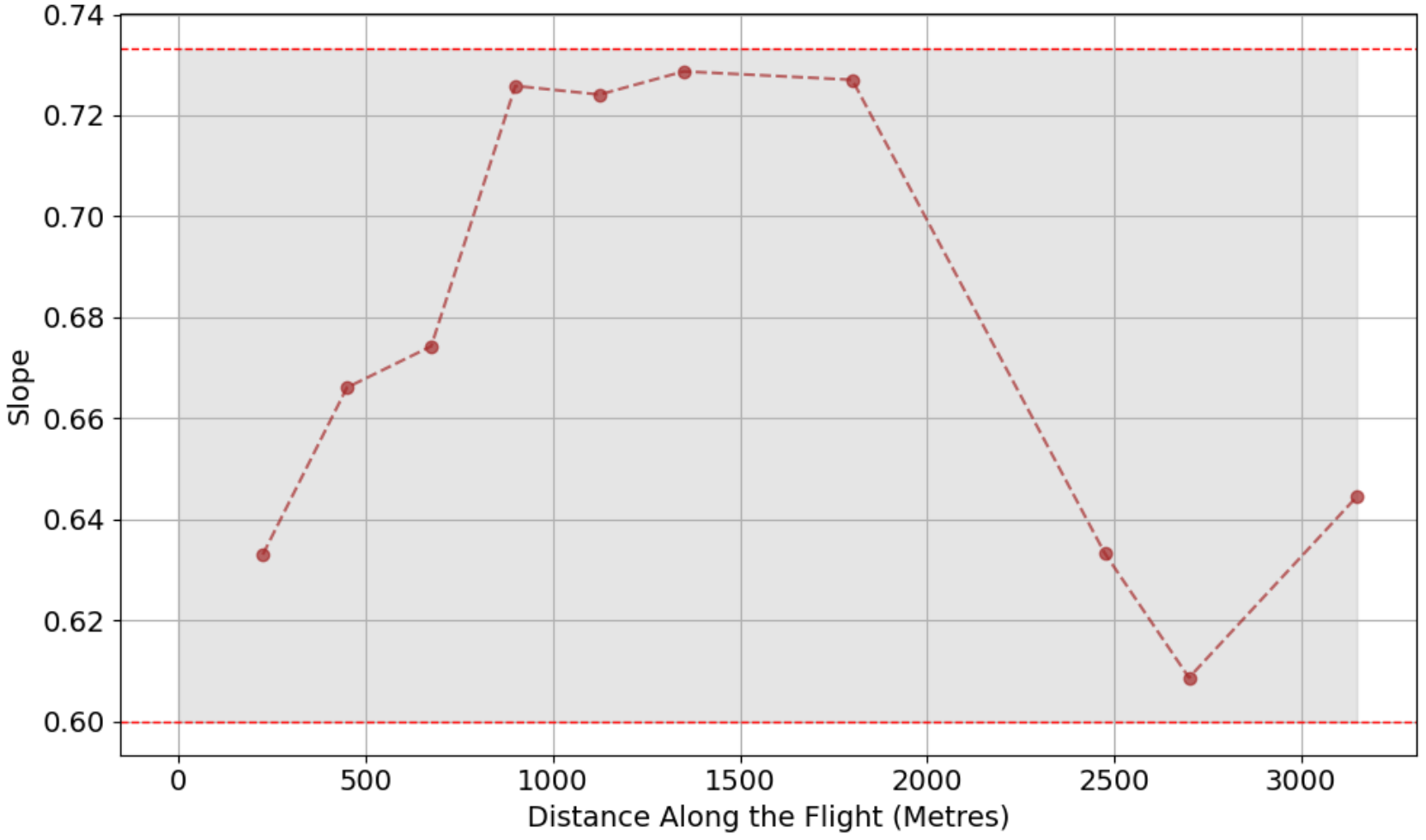
- In the inertial subrange of turbulence(between large energy-containing scales and small dissipative scales), Kolmogorov's 1941 theory (K41) states.

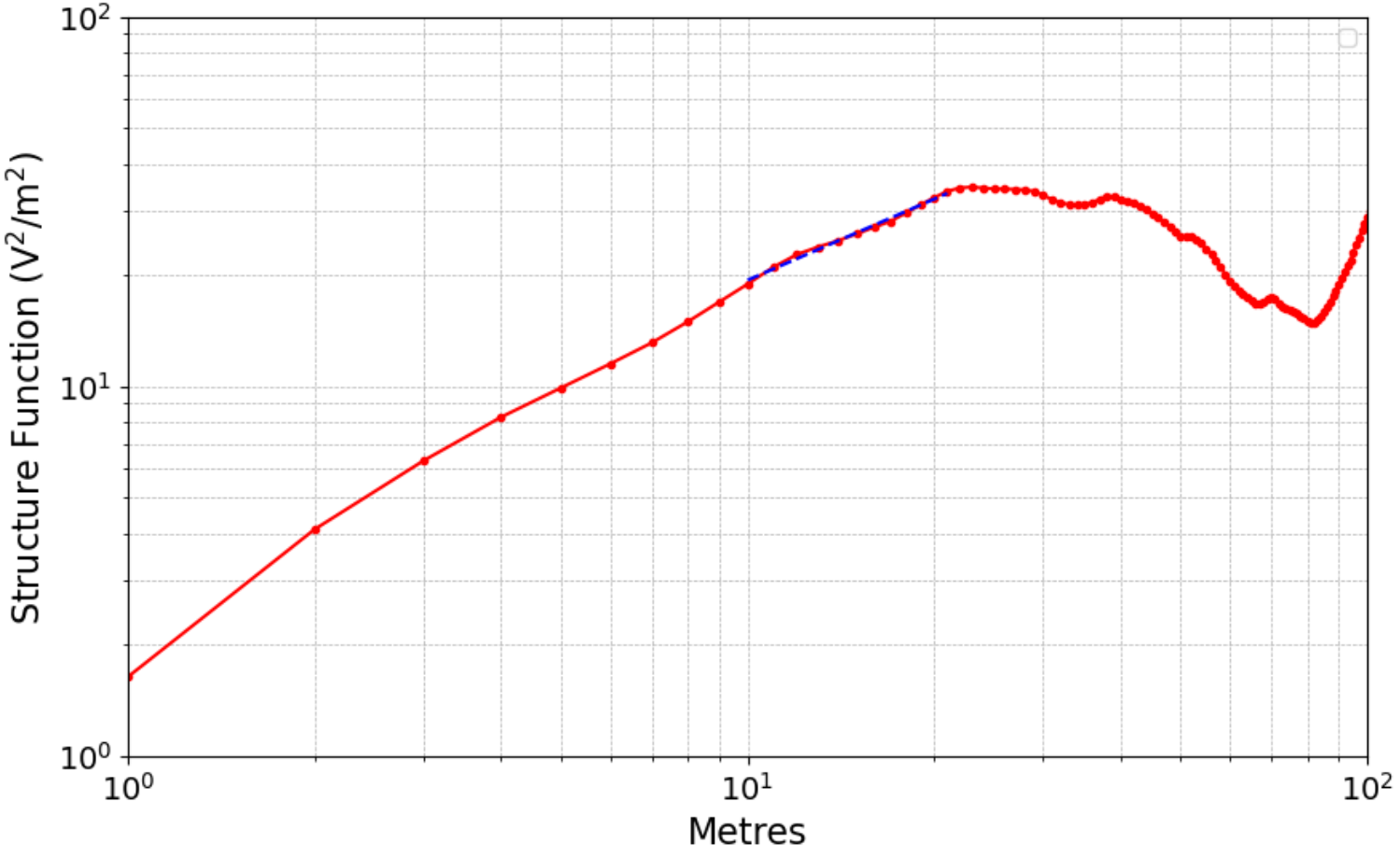
$$S_2(r) = C\,\varepsilon^{2/3}\,r^{2/3}$$

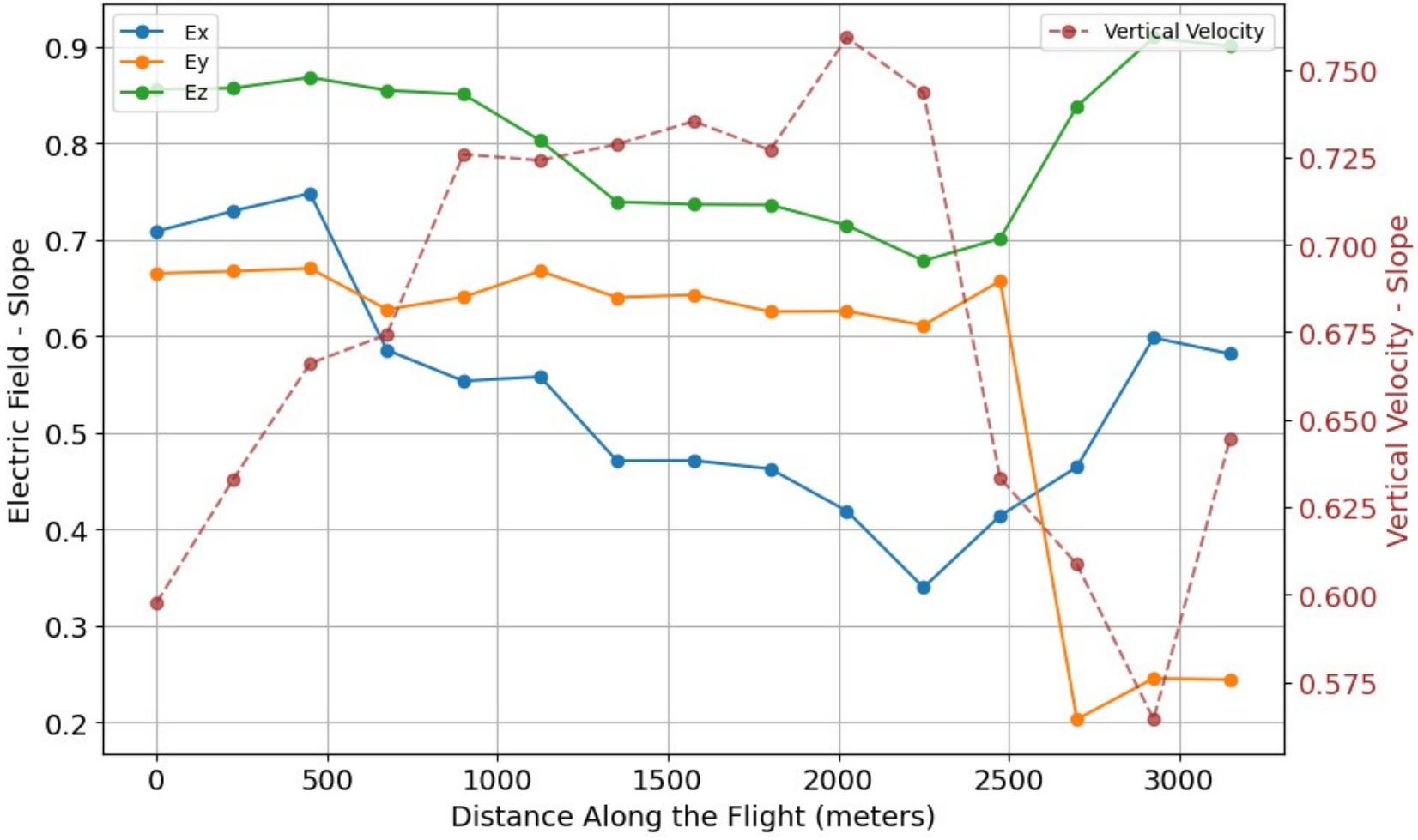
$$\log_{10} S_2(r) = \alpha \log_{10} r + \log_{10} A$$

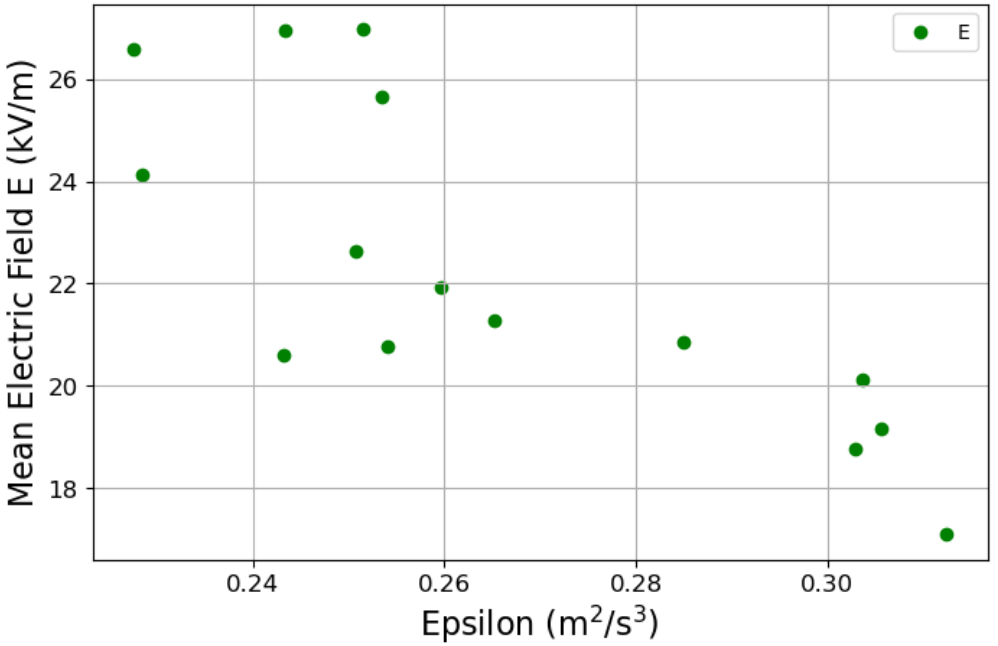
$$\varepsilon = \left(\frac{A}{C}\right)^{3/2}$$

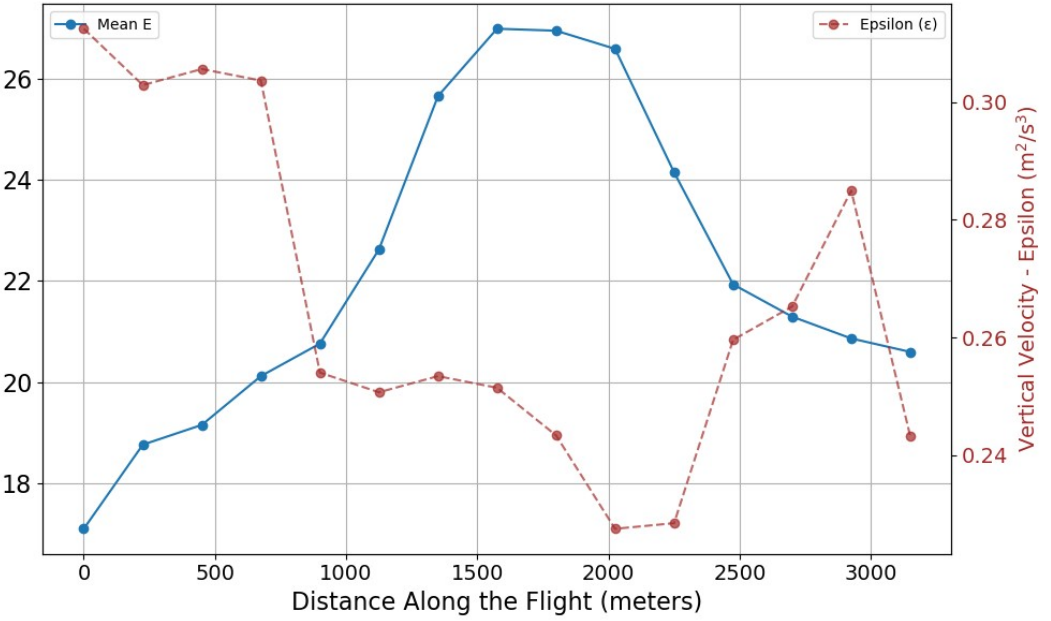

10^1
10^0
Structure Function (m^2/s^2)
10^0
10^1
10^2
Metres


0.74
0.72
0.70
0.68
0.66
0.64
0.62
0.60
Slope
0
500
1000
1500
2000
2500
3000
Distance Along the Flight (Metres)


10^2
10^1
10^0
Structure Function (V^2/m^2)
10^0
10^1
10^2
Metres


Ex
Ey
Ez
Vertical Velocity
Electric Field - Slope
Vertical Velocity - Slope
Distance Along the Flight (meters)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.750
0.725
0.700
0.675
0.650
0.625
0.600
0.575
0
500
1000
1500
2000
2500
3000


E
Mean Electric Field E (kV/m)
26
24
22
20
18
0.24
0.26
0.28
0.30
Epsilon (m²/s³)


Mean E
Epsilon (ε)
26
24
22
20
18
0.30
0.28
0.26
0.24
Vertical Velocity - Epsilon (m²/s³)
0
500
1000
1500
2000
2500
3000
Distance Along the Flight (meters)

Conclusions

- The strength of EF is higher in region of high LWC
- EF shows inverse correlation with dissipation
- Lightning? Regions of weak turbulence (More data)
- Future plans - extension of current calculation data to the 3 stages of thunderstorm