Numerical Differentiation and Thunderstorm Research

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Environmental Remote Sensing

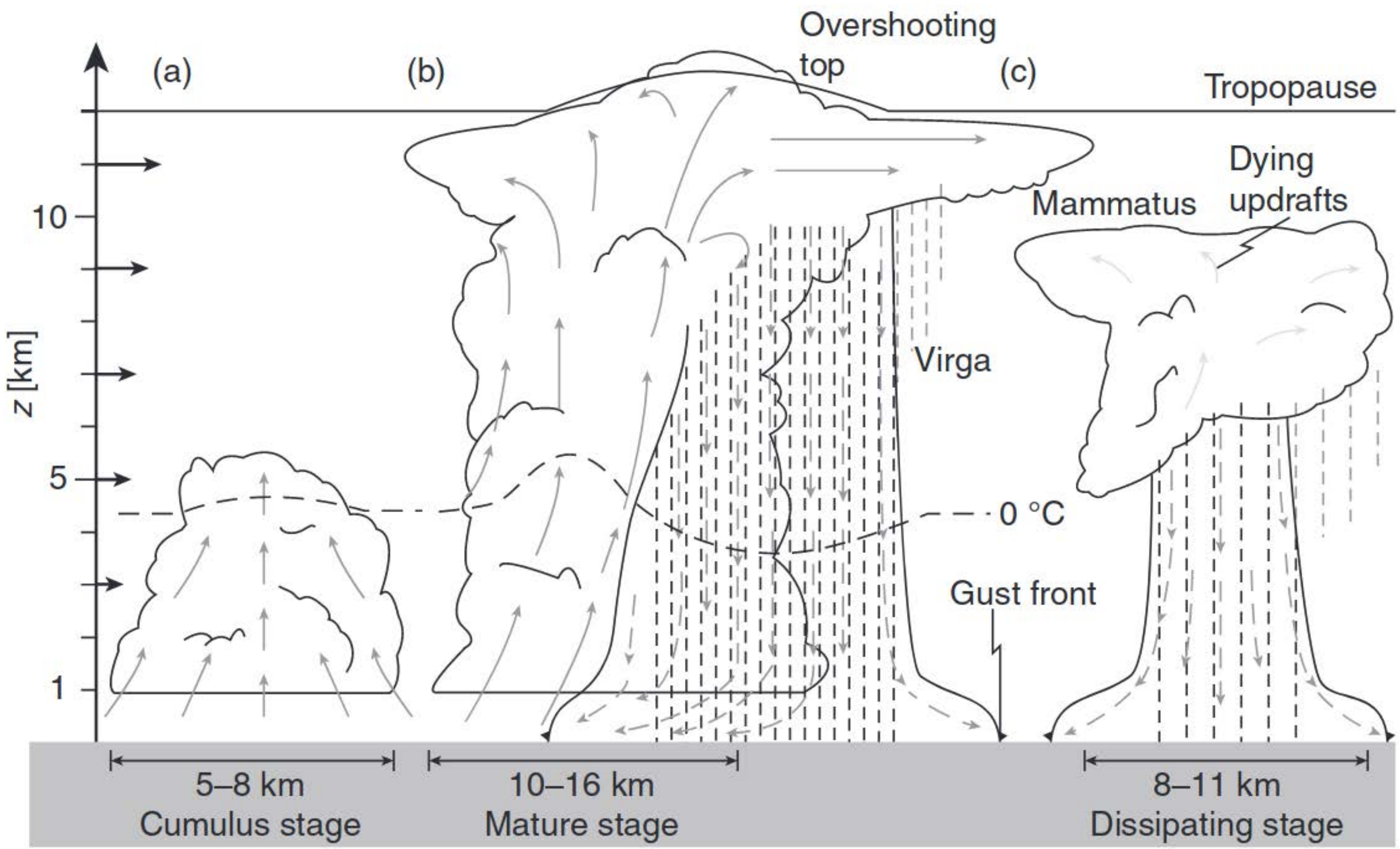
Personal background

- Msc in Environmental Science at ETH Zürich
  - Thesis at EAPS, MIT on hurricane rainfall
- PhD in Environmental Remote Sensing at EPF Lausanne and MeteoSwiss
  - Doppler velocity in radar data
  - Detection of supercell thunderstorms
  - Analysis of supercells in Alpine environment

Overview

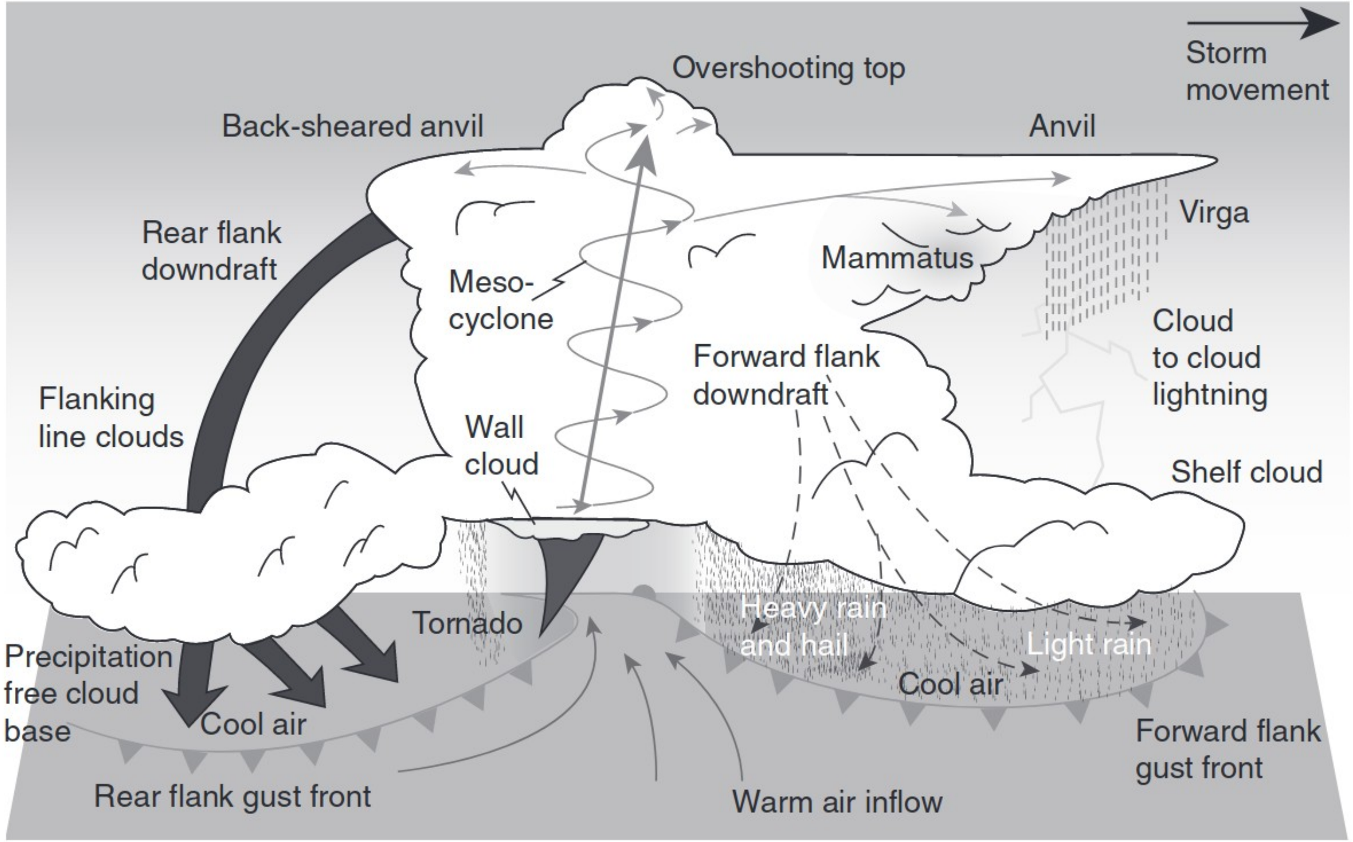
- Supercell thunderstorms
- Weather radar
- Supercells in weather radar
- Application of derivatives

Thunderstorms



Lohmann et al. (2016)

Supercell Thunderstorms



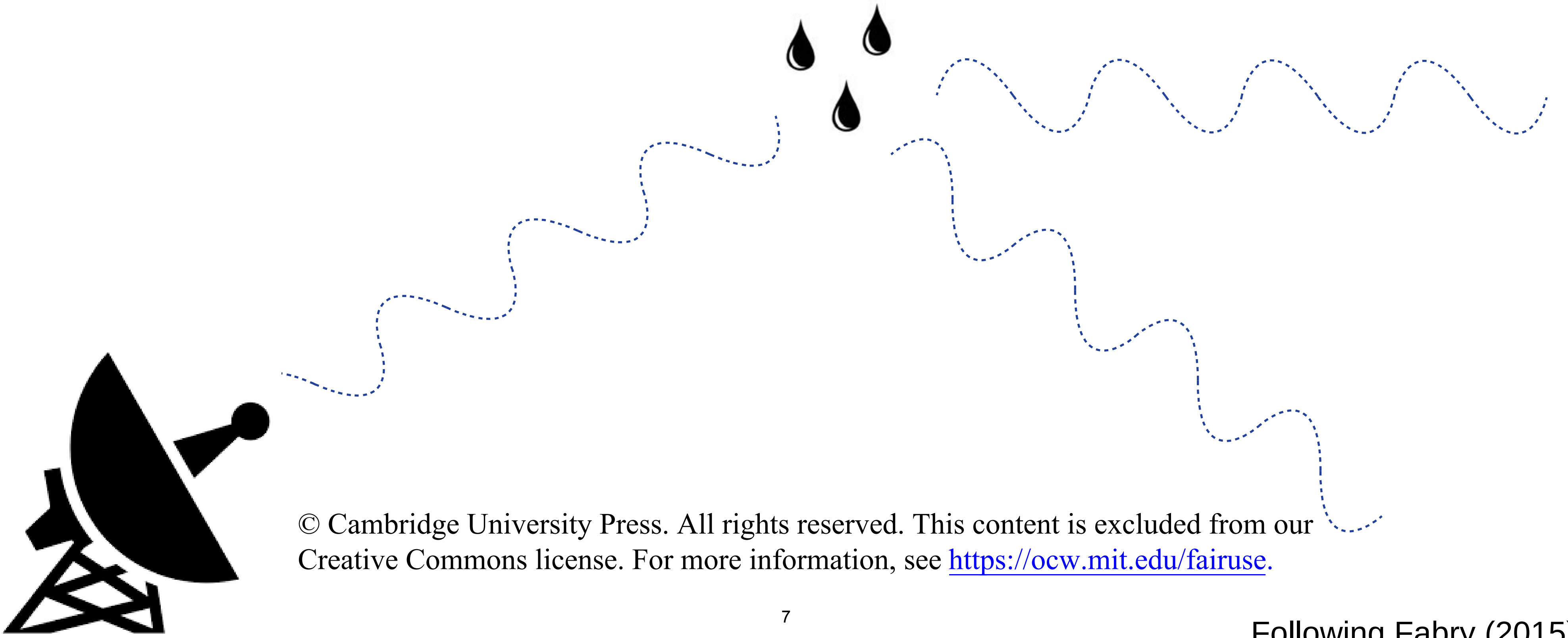
[Video](#)

Lohmann et al. (2016)

Weather radar

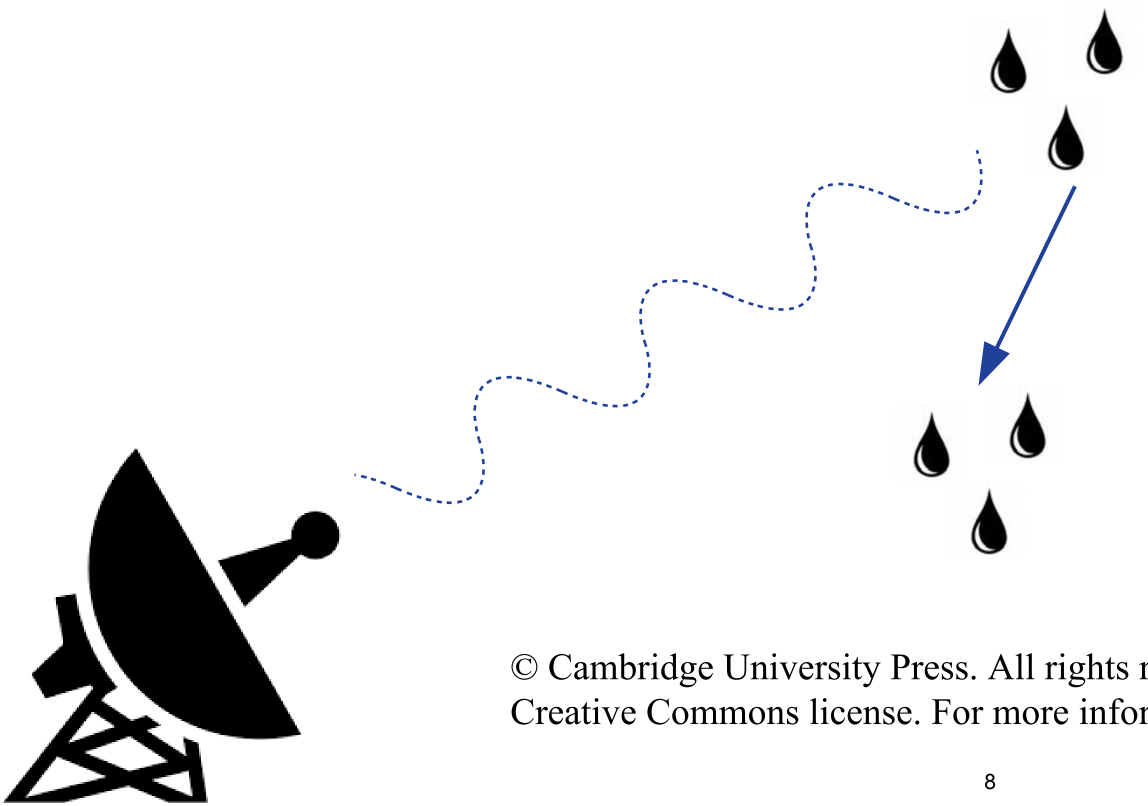
Following Fabry (2015)

Weather radar



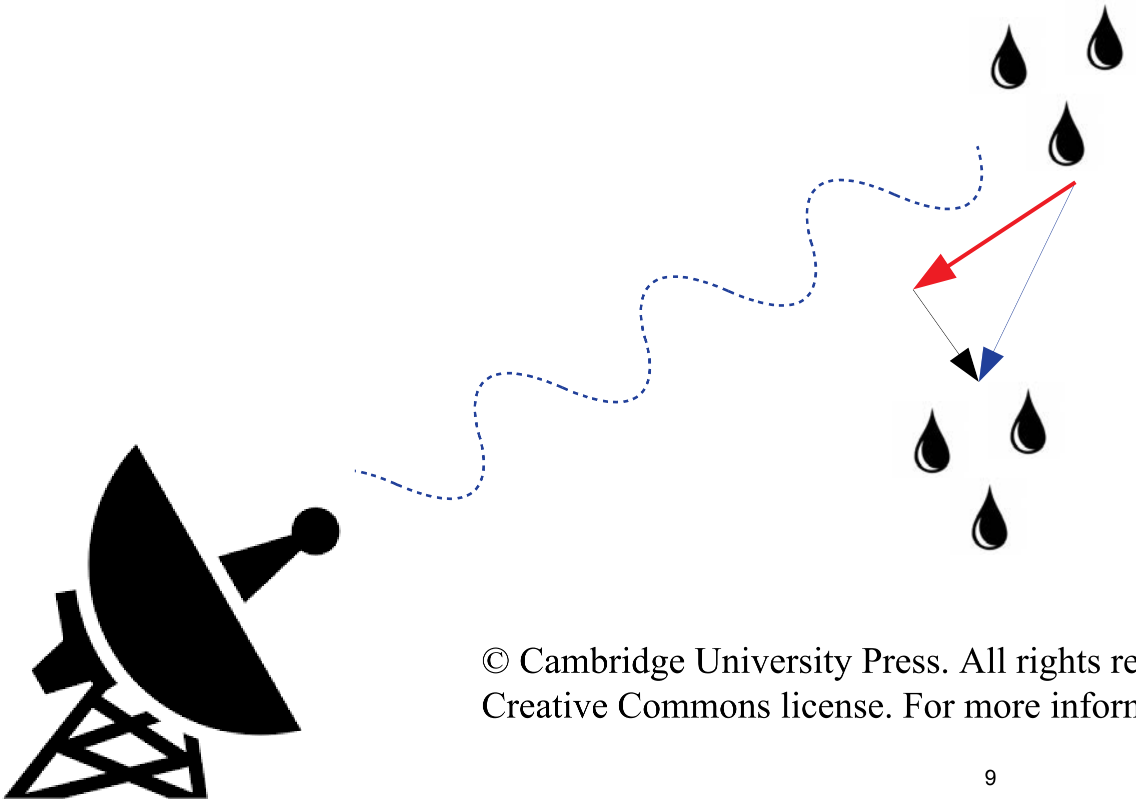
Following Fabry (2015)

Weather radar



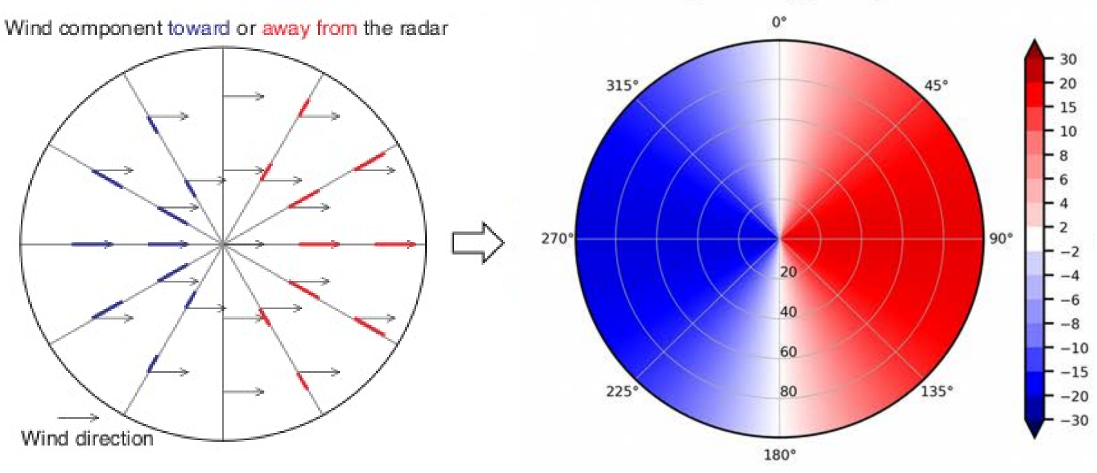
Following Fabry (2015)

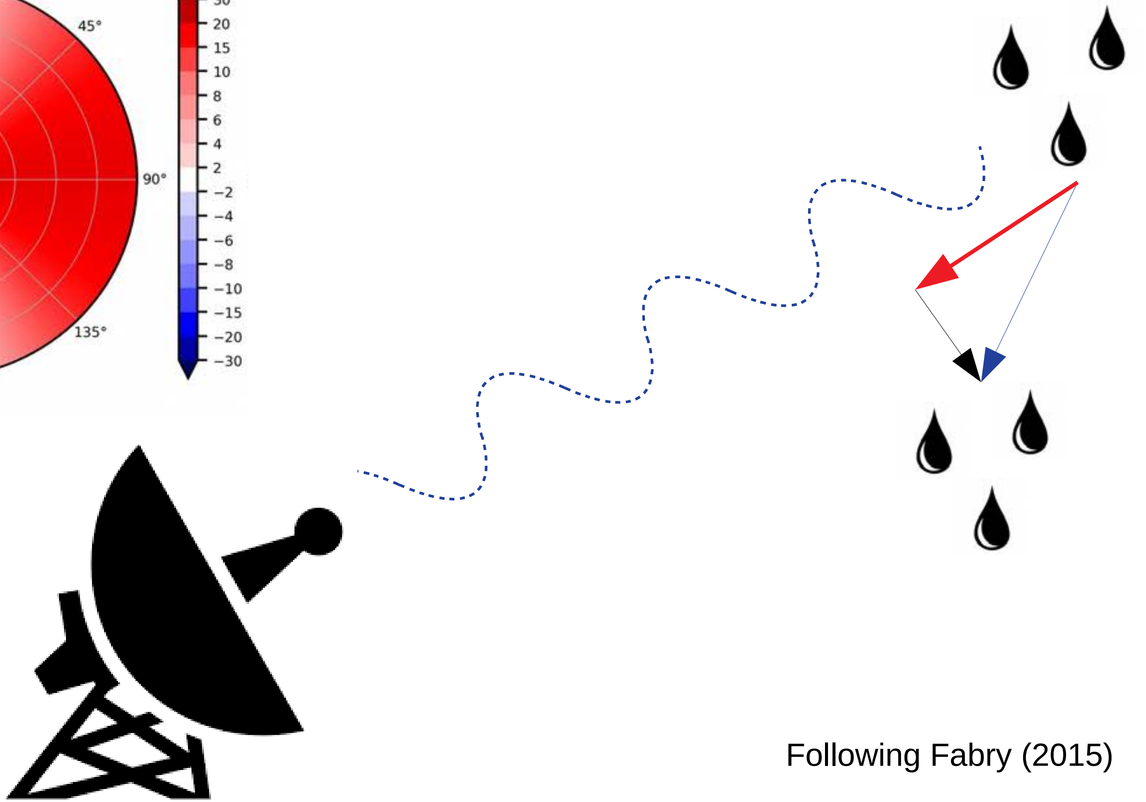
Weather radar



Following Fabry (2015)

Weather radar

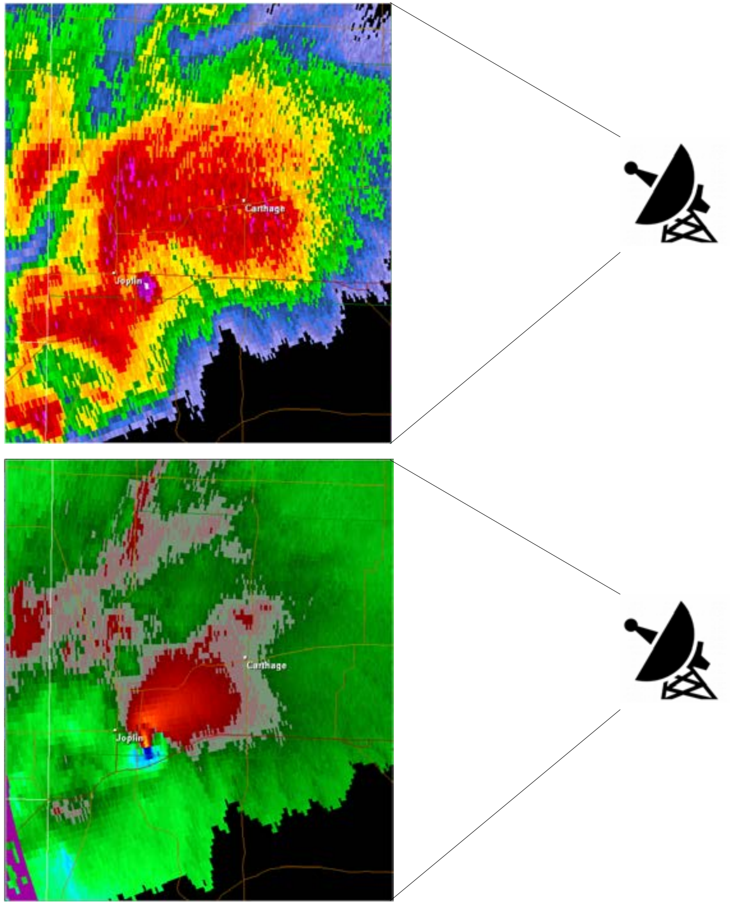




Following Fabry (2015)

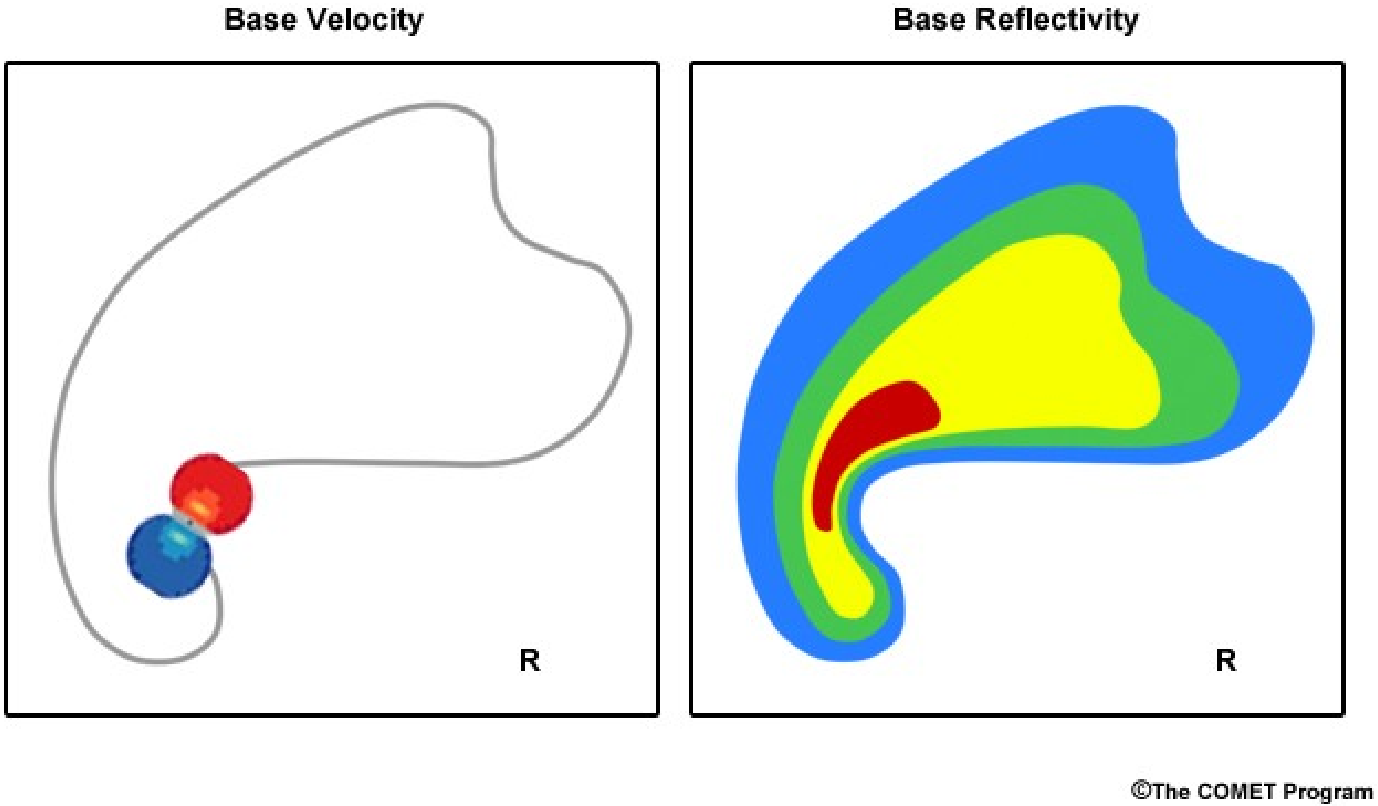
Weather radar

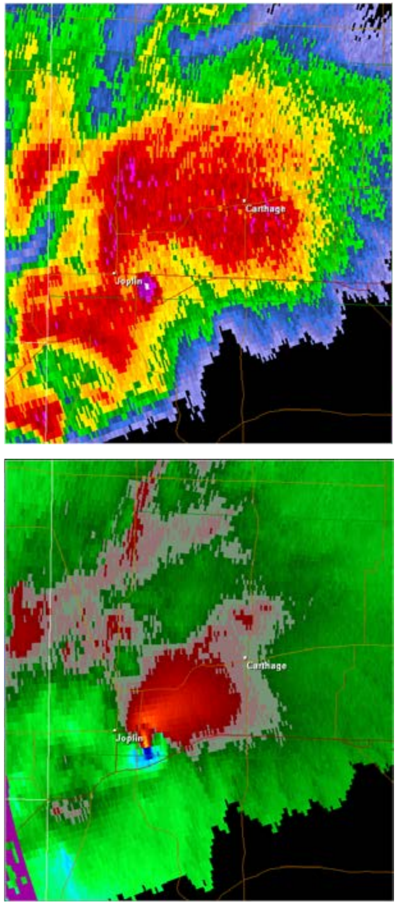
- Reflectivity Z
  - Proportional to returned power
  - $Z \sim \text{size}^6$
- Radial velocity
  - Component of movement towards radar



Courtesy of National Weather Service.

Supercells in Weather Radar

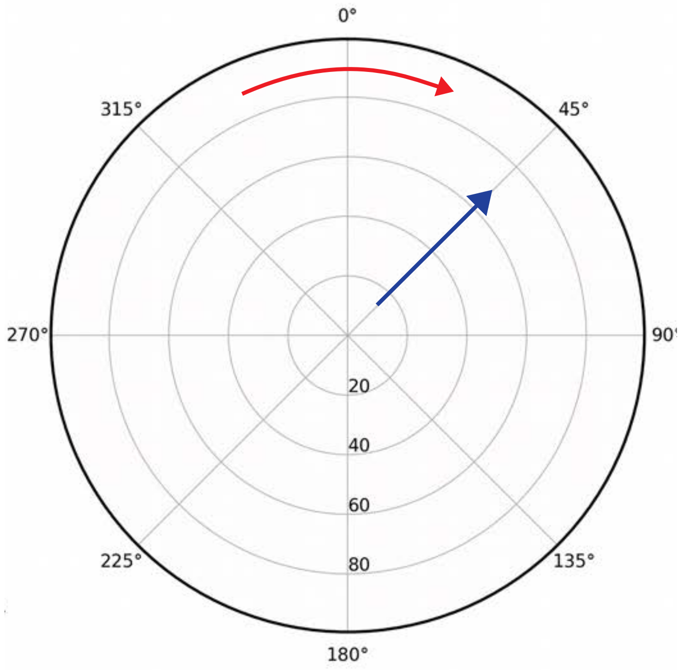




Courtesy of National Weather Service.

Derivatives in Doppler velocity

- Azimuthal derivative
  - Rotation
  - Mesocyclone, tornado
- Radial derivative
  - Divergence / convergence
  - Frontal and convective activity



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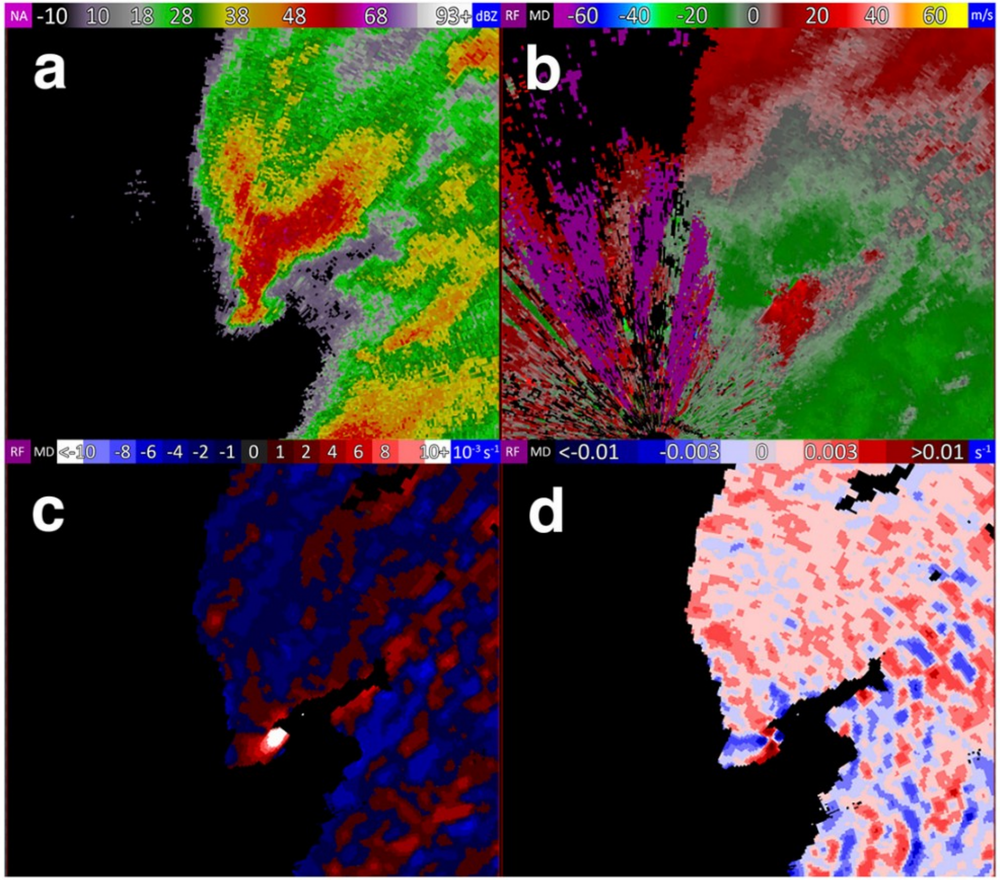
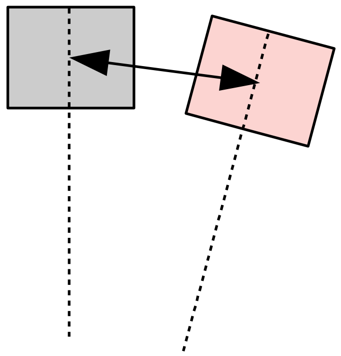


Mahalik et al. (2019)

Challenges in Azimuthal derivative

- Finite difference methods
  - Forward difference



Challenges in Azimuthal derivative

- Finite difference methods
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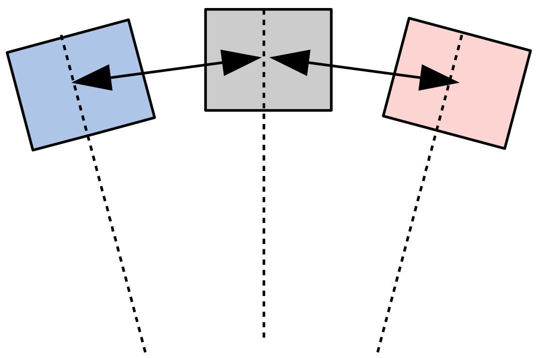
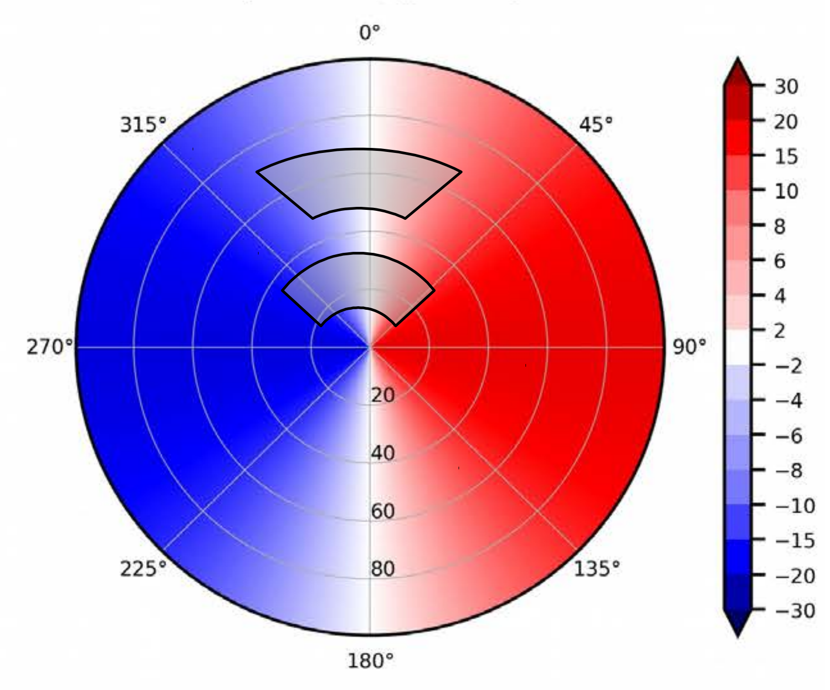
  - Centered difference



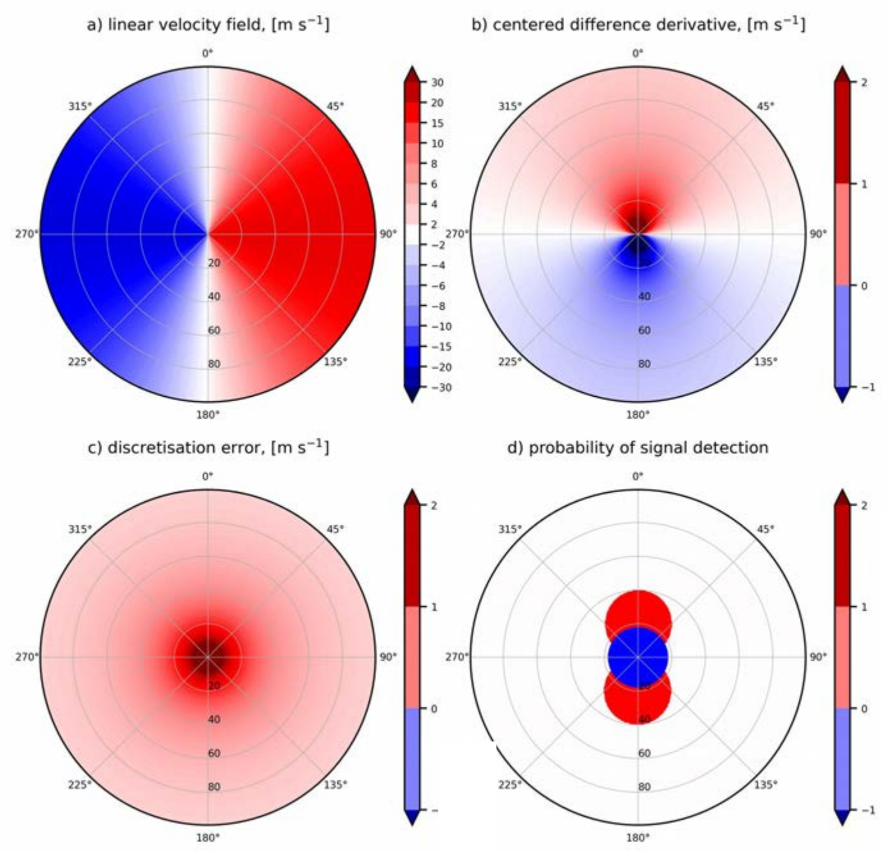
Challenges in Azimuthal derivative

- Finite difference methods
  - Forward difference
  - Centered difference
  - Linear Least Squares Derivative



Challenges in Azimuthal derivative

- False signatures of rotation
- Differing resolution
- Noise from discretisation
- Distribution of detection probability



How to continue?

- 4-D object detection and tracking problem
  - Isolating consistent rotation signatures
  - Assignment to thunderstorm cells
  - Tracking in time
  - Computer vision problem

Conclusion

- Detection of hazardous thunderstorms in radar data
- Challenges at very close and far ranges
  - Geometric issues
  - Resolution issues
  - Discretisation issues

Sources

- Lohmann, U., F. Lüönd, and F. Maahrt, 2016: An Introduction to Clouds - From the Microscale to Climate. Cambridge University Press.
- Fabry, F., 2015: Radar Meteorology. Cambridge University Press.
- Mahalik, M. C., B. R. Smith, K. L. Elmore, D. M. Kingfield, K. L. Ortega, and T. M. Smith, 2019: Estimates of Gradients in Radar Moments Using a Linear Least Squares Derivative Technique. Weather and Forecasting, 34, 415–434, doi:10.1175/waf-d-18-0095.1.

Image sources

- https://www.nbcnews.com/news/weather/stunning-supercell-thunderstorm-hovers-over-texas-n100736
  - 10.8.2020, slide 1
- Lohmann, U., F. Lüönd, and F. Maahrt, 2016: An Introduction to Clouds - From the Microscale to Climate. Cambridge University Press., slides 4-5
- Fabry, F., 2015: Radar Meteorology. Cambridge University Press., slide 10
- http://kejian1.cmatc.cn/vod/comet/radar/basic_wxradar/navmenu.php_tab_1_page_6.3.2_type_text.htm
  - 10.8.2020, slide 12
- https://commons.wikimedia.org/wiki/File:Radar_image_of_the_2011_Joplin_tornado_May_22,_2011_2248Z.png
  - 10.8.2020, slides 11-12
- Mahalik, M. C., B. R. Smith, K. L. Elmore, D. M. Kingfield, K. L. Ortega, and T. M. Smith, 2019: Estimates of Gradients in Radar Moments Using a Linear Least Squares Derivative Technique. Weather and Forecasting, 34, 415–434, doi:10.1175/waf-d-18-0095.1., slide 14