WRF Modelling of Deep Convection & Hail.

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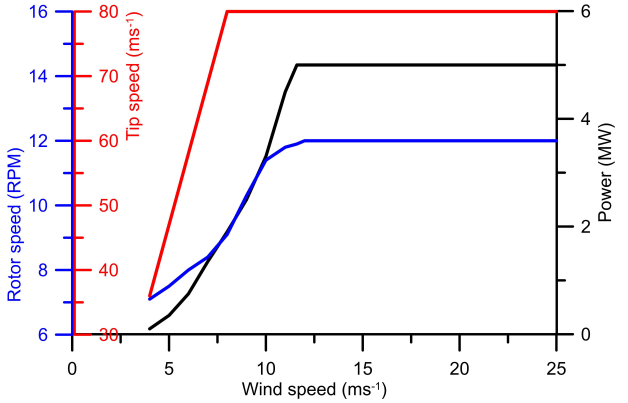
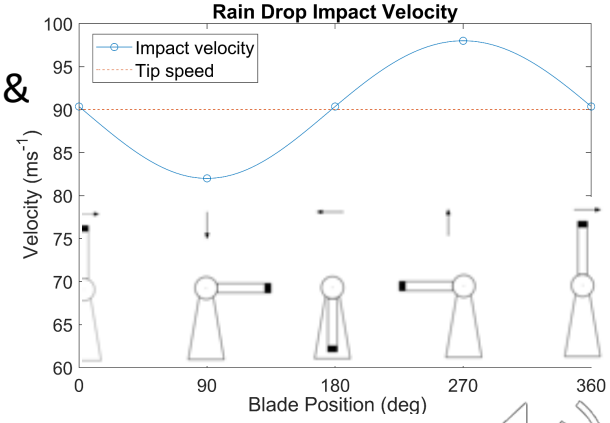
- High societal importance (insurance, energy infrastructure etc).
- Our application: Predicting wind turbine blade leading edge erosion
  - Negative impact on LCoE ($billions/yr?)
    - Loss of power production. Increase in O&M costs
    - 'Fixes' (tapes) also cause loss of power production.
- Wind turbine blade leading edge erosion
  - f(Wind speed) ∴ rotor speed ∴ closing velocity (kinetic energy)
  - f(Precipitation rate) ∴ # impacts
  - f(Hydrometeor type) ∴ material response
  - f(Hydrometeor diameter) ∴ fall velocity, momentum exchange & material response





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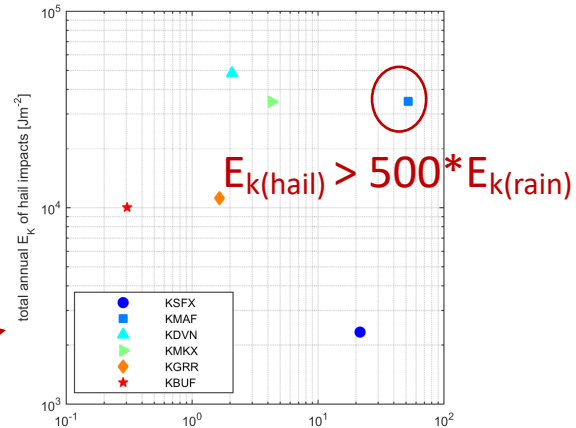
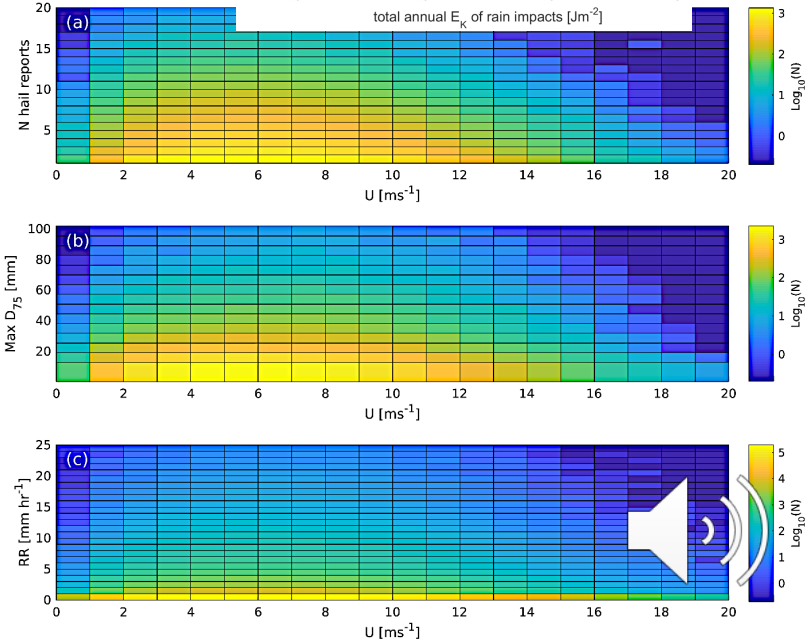
WRF Modelling of Deep Convection & Hail

- Empirical estimates of accumulated kinetic energy transfer:
  - RADAR for RR, hail occurrence & 75th percentile hail diameter (D_{75})
  - RADAR or ERA5 for wind speed
  - DSD: Marshall-Palmer for rain & exponential (hail)
- In SGP: Results
  - Dominance of hail in KE transfer (*Wind Energy Science* **5** 331-347).
  - Joint probabilities heavy RR & large hail frequent & high RPM wind speeds (*J of Physics* doi:10.1088/1742-6596/1618/3/032046).
- Research questions:
  - Can WRF be used to PREDICT likely severity of LEE?
  - Does WRF exhibit fidelity v. RADAR/ASOS:
    - Marginal probabilities of drivers?
    - Joint probabilities of drivers (e.g. Pr{hail|U})?
    - Spatial variability in joint probabilities?

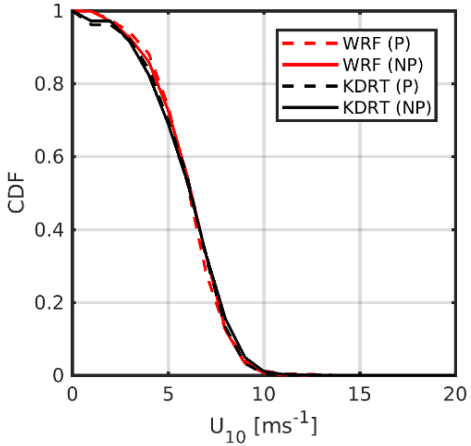
SIMULATIONS W/ MILBRANDT-YAU MICROPHYSICS





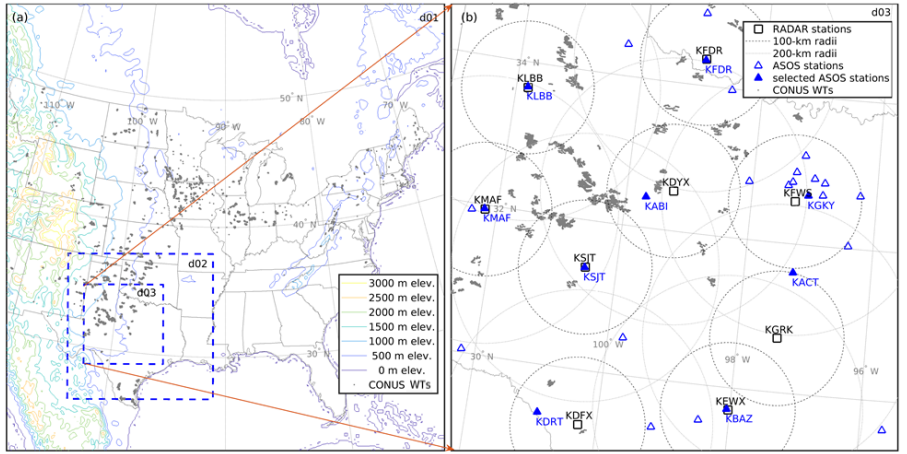
WRF Modelling of Deep Convection & Hail

- 8 June - 2 July 2014:
  - Positive bias in reflectivity & hail occurrence.
  - Wind speed (10-m) v ASOS: corr = 0.63
  - Precipitation: CDF from RADAR reproduced
  - Wind speed: CDF|PPT reproduced



- RADAR Hail: Odds ratio (θ) > 1 skillful

$$\theta = \frac{1}{1-H} \Big/ \frac{1}{1-F}$$

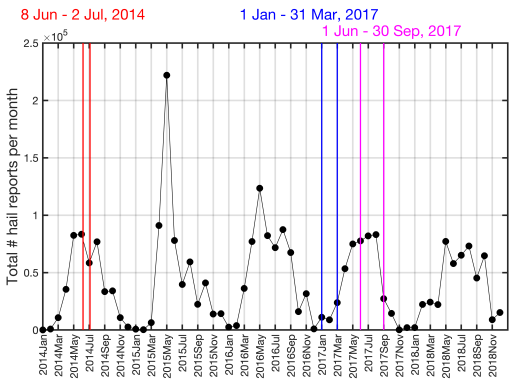


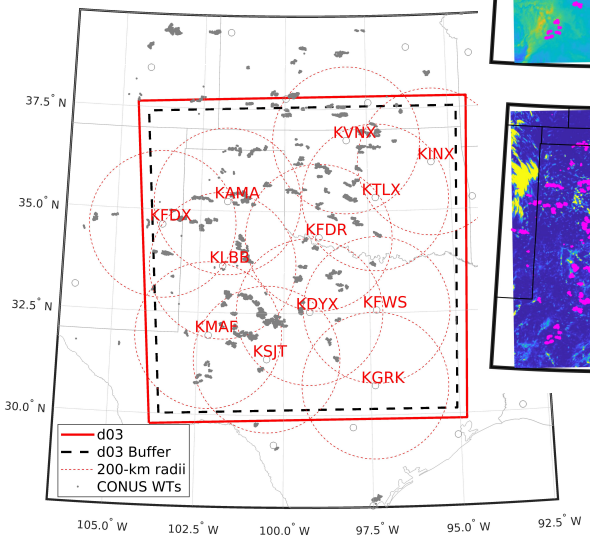
RADAR	IC w/in 100 km	# hr w/ hail	θ: All	θ: Intense
KDFX	248	54	4.91	9.35
KDYX	2833	59	2.77	3.47
KEWX	0	49	4.80	11.5
KFDR	1111	64	2.79	2.49
KFWS	6	77	6.85	6.37
KGRK	0	63	10.5	25.2
KLBB	2360	92	4.78	4.91
KMAF	1895	94	2.66	4.88
KSJT	1792	48	0.89	1.06

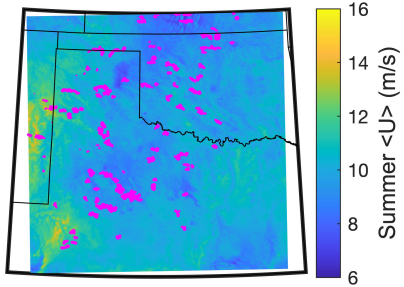
JAMC doi: 10.1175/JAMC-D-20-0033.1.

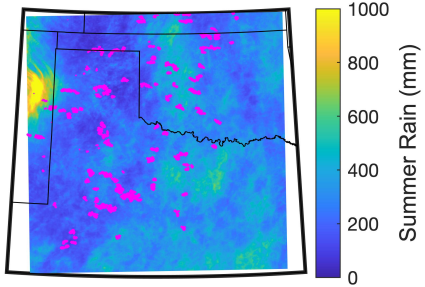
WRF Modelling of Deep Convection & Hail: 1 Jan–31 Mar 2017, 1 Jun–30 Sep 2017

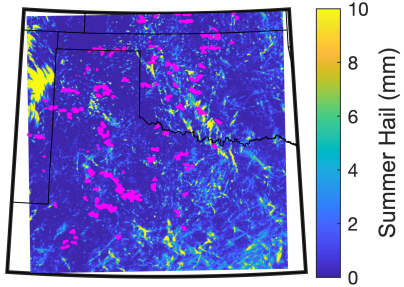
- Clear spatial gradients in LEE drivers!
- Further evaluation (with larger sample):
  - Is positive bias in REFL & hail pathological for MILBRANDT-YAU? (fully double moment)
  - LEE drivers & wind gusts (v ASOS)
- Compute
  - Accumulated KE & spatial variability in LEE potential
  - Joint distribution of Hail|U, Hail diameter|U, RR|U

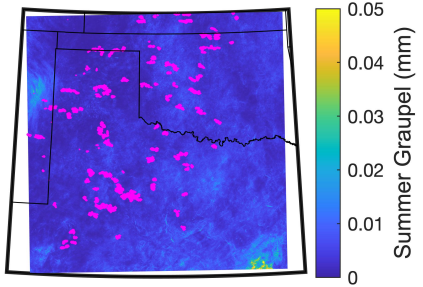












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