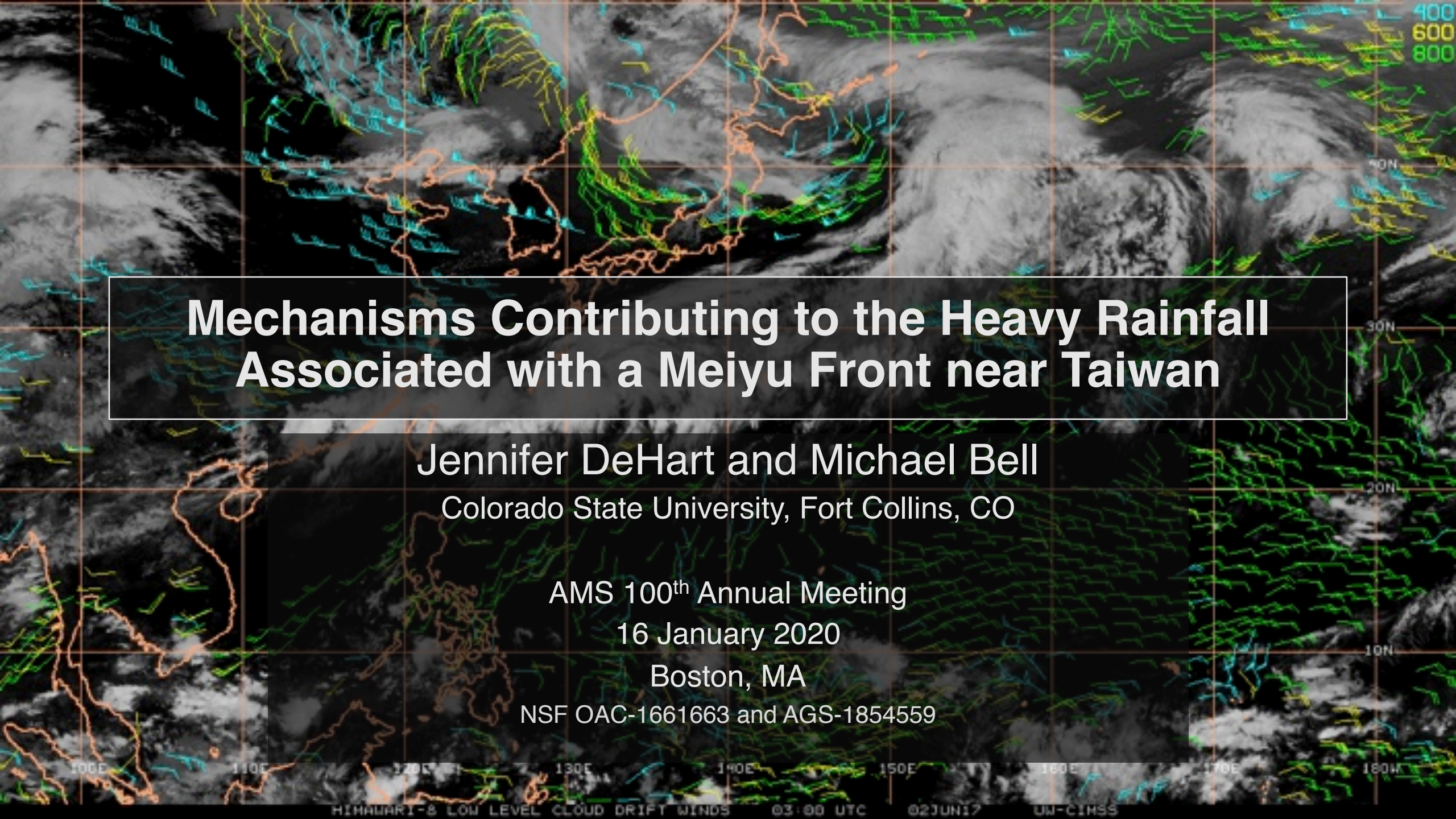


Mechanisms Contributing to the Heavy Rainfall Associated with a Meiyu Front near Taiwan

Jennifer DeHart and Michael Bell

Colorado State University, Fort Collins, CO

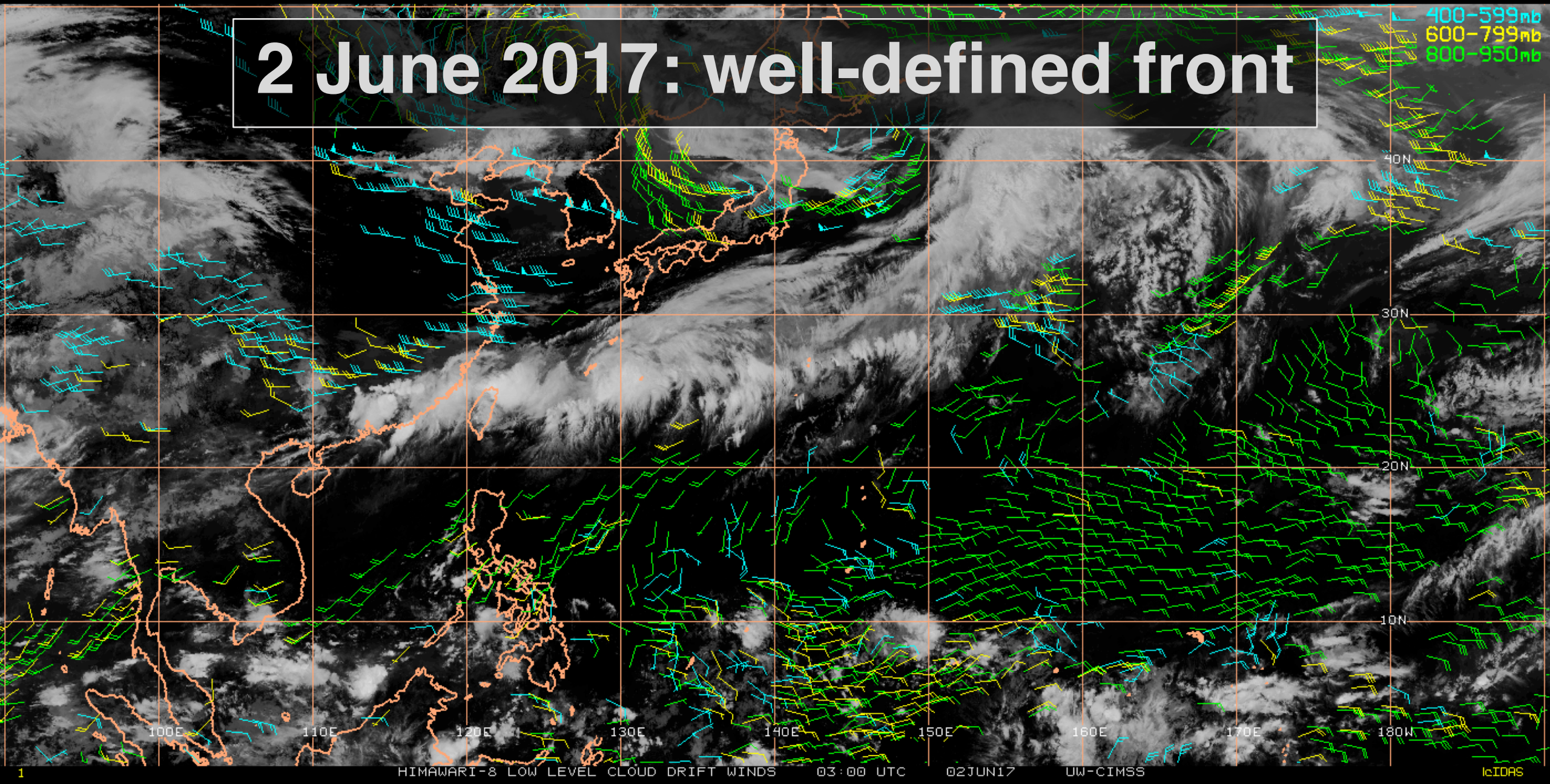
AMS 100th Annual Meeting

16 January 2020

Boston, MA

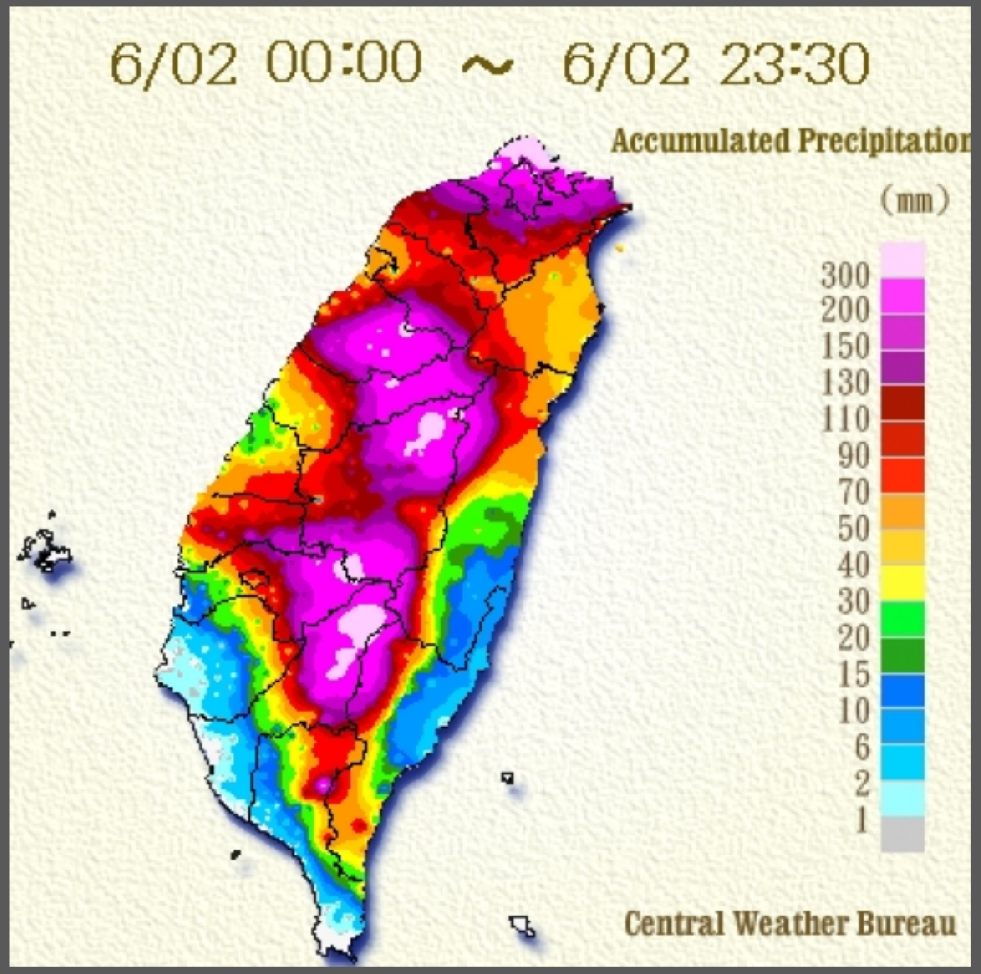
NSF OAC-1661663 and AGS-1854559

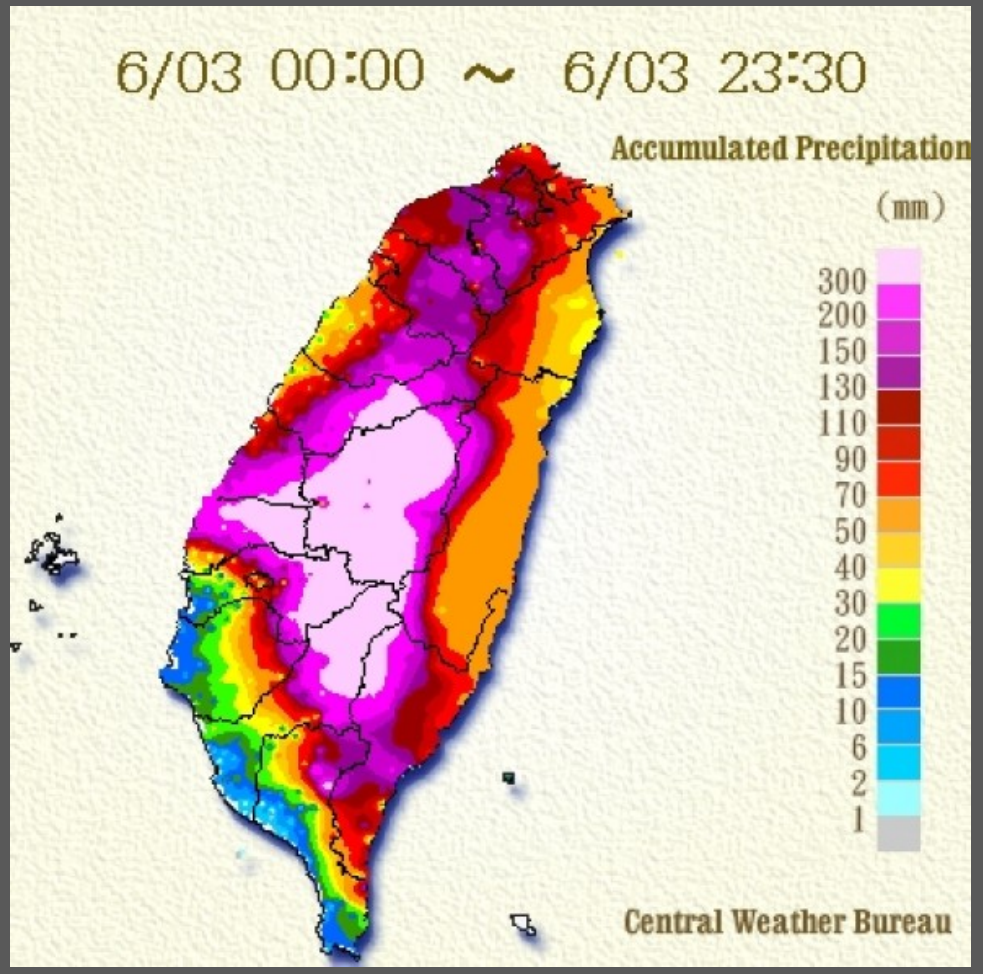
2 June 2017: well-defined front



03 UTC on 2 June: IR, low-level winds (c/o CIMSS)

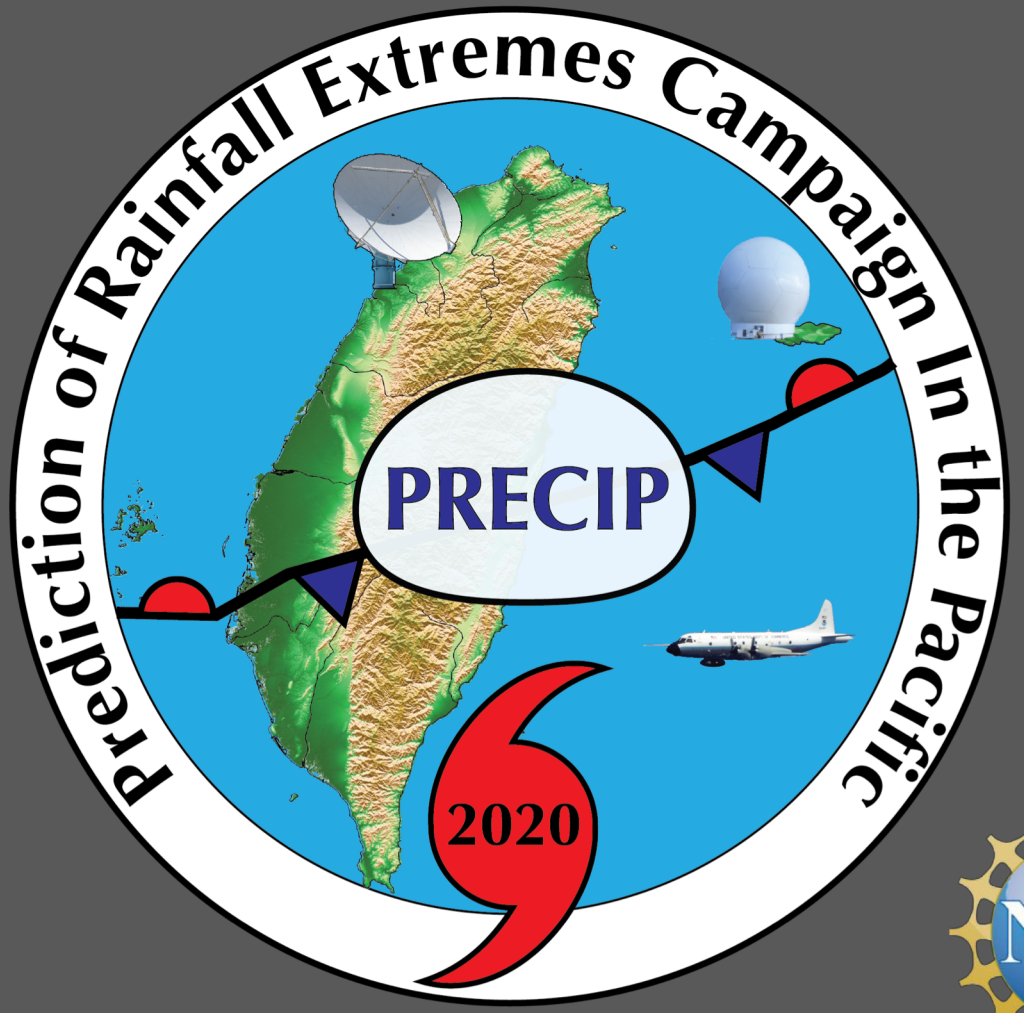
Widespread heavy rainfall across Taiwan on 2-3 June





Motivates the PRECIP campaign

- PRECIP goal:
  - Identify the universal processes that produce heavy rainfall



Overarching questions

- What mechanisms were responsible for heavy rainfall in the June 2017 case?
- What processes were important at different spatial and temporal scales?

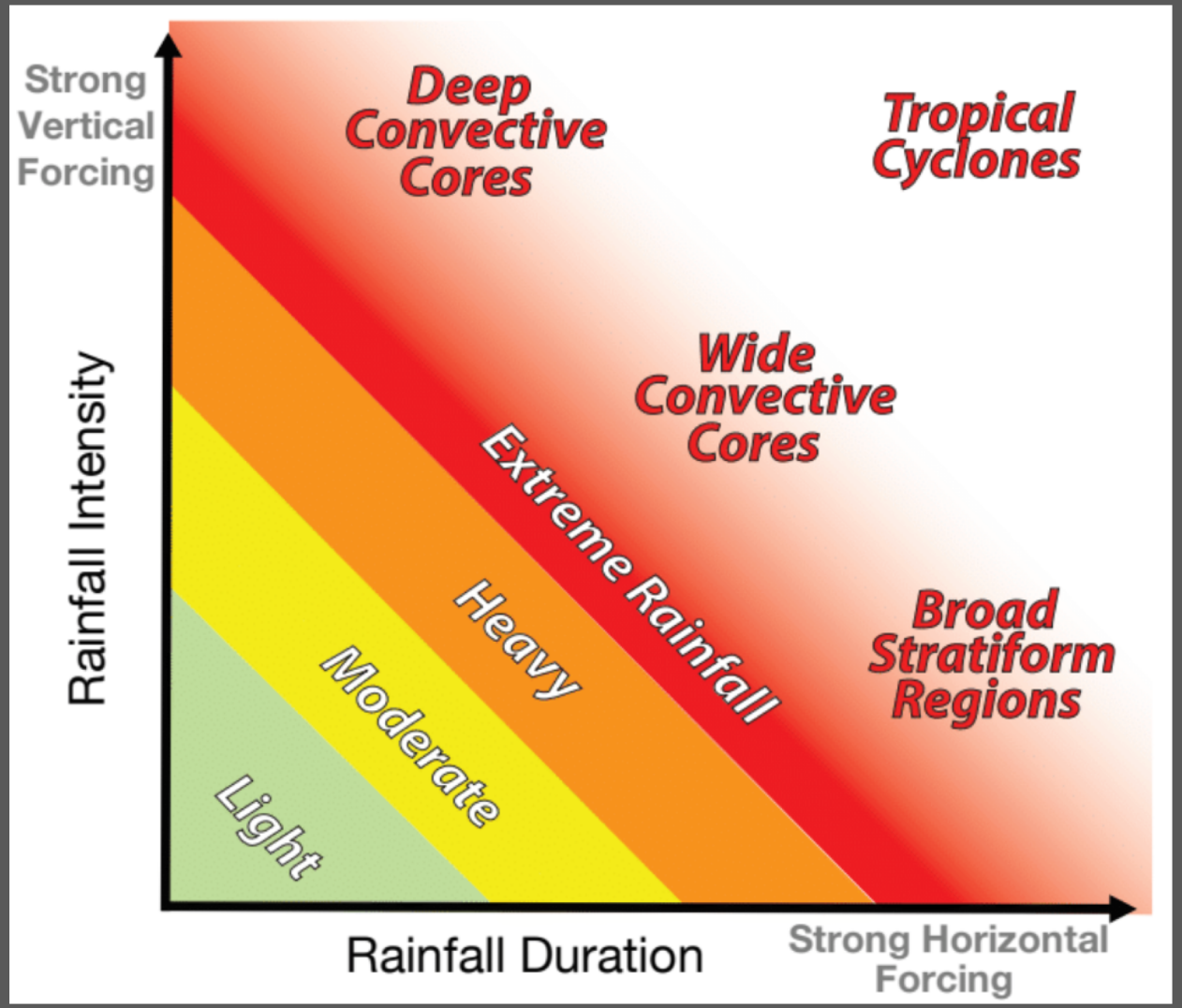
Overarching questions

- **What mechanisms were responsible for heavy rainfall in the June 2017 case?**
- **What processes were important at different spatial and temporal scales?**

- Prior studies have examined large-scale forcing, cloud morphology, effect of cold pools, orographic influences
  - Sampe and Xie 2010, Xu and Zipser 2015, Chen et al. 2018

Mechanisms behind heavy rainfall

- PRECIP hypotheses
  - Rainfall duration is related to horizontal moisture transport
  - Rainfall intensity is related to vertical forcing



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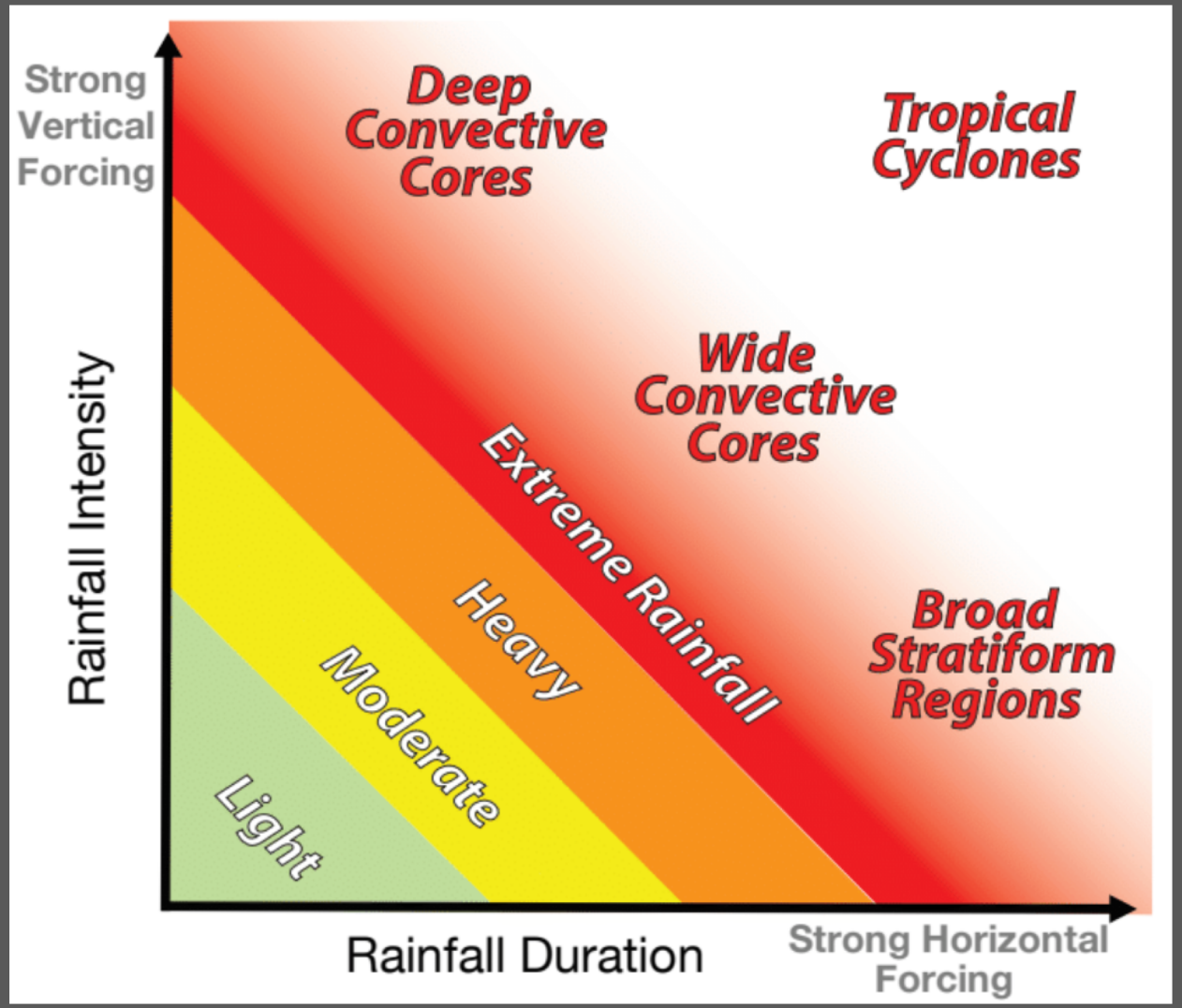


Possible intense rainfall forcings

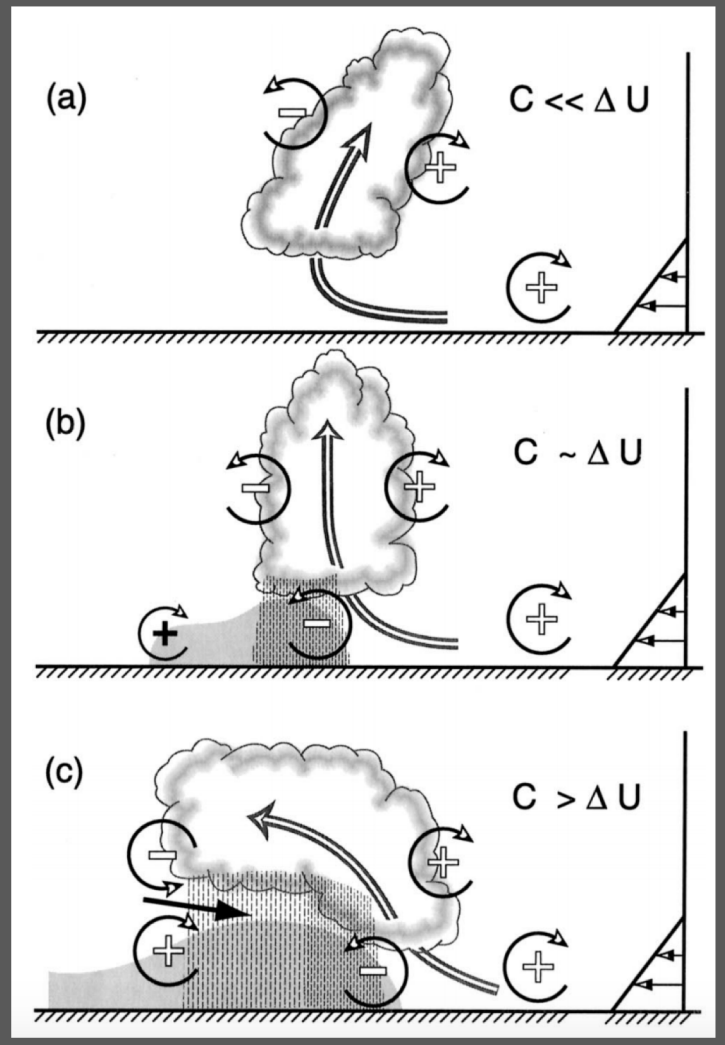
- RKW theory
- Vertical moisture flux
- Instability, efficient microphysical processes

$$R = Ewq\,.$$

Doswell 1996

Possible intense rainfall forcings

- **RKW theory:** convection maximizes when cold pool and environmental shear balance
- Vertical moisture flux



Possible intense rainfall forcings

- RKW theory
- **Vertical moisture flux:** the more moisture fluxed upward, the greater the chance of condensation and precipitation

$$R = Ewq.$$

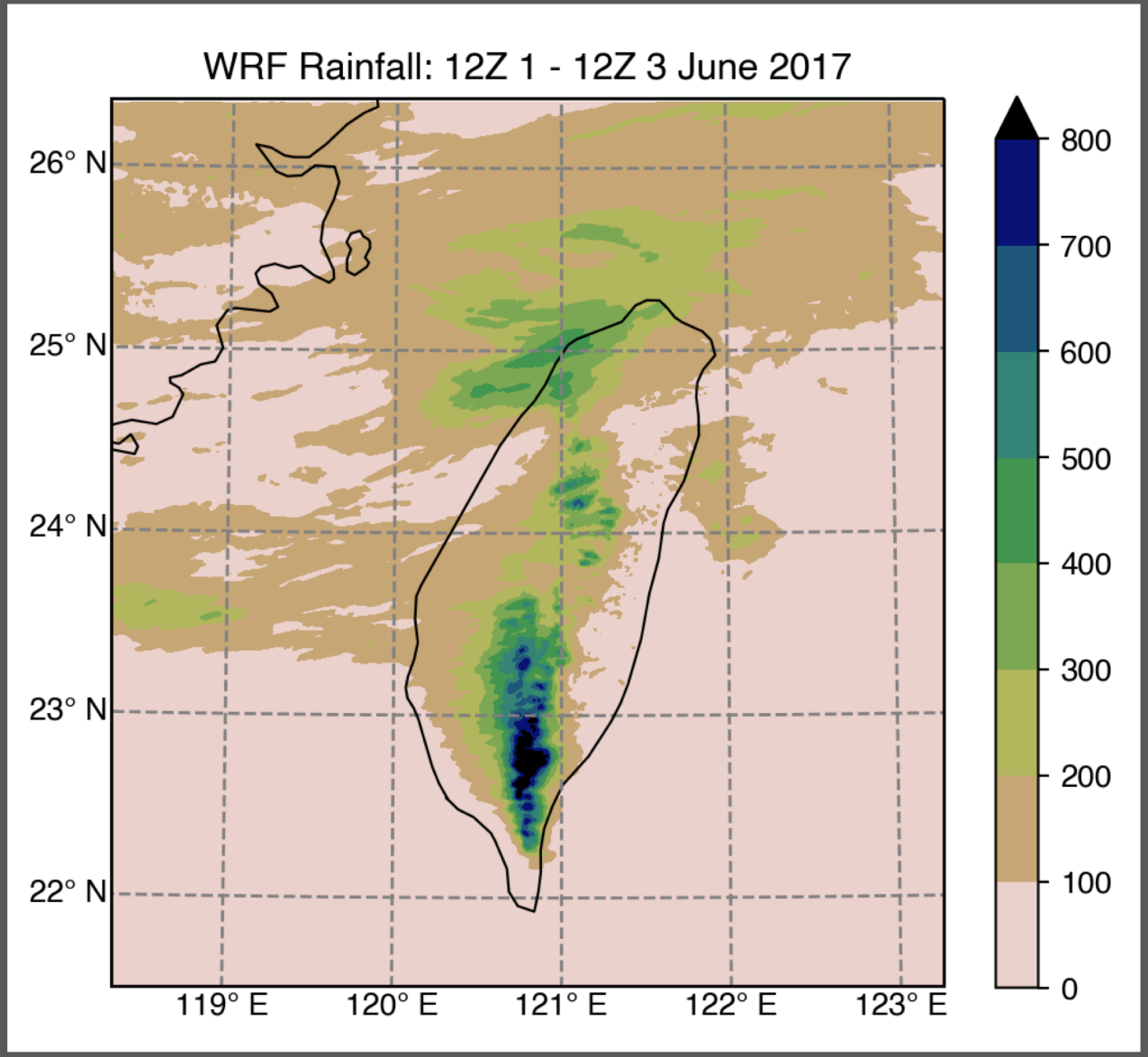
Doswell 1996

WRF Simulations

- Domains: 6, 2, 2/3 km
- MP: Thompson aerosol aware

- 12Z 6/1 – 12Z 6/3
- 20 TST 6/1 – 20 TST 6/3

- **Total rain is similar spatially, but the maximum rainfall is further south and lower in magnitude**

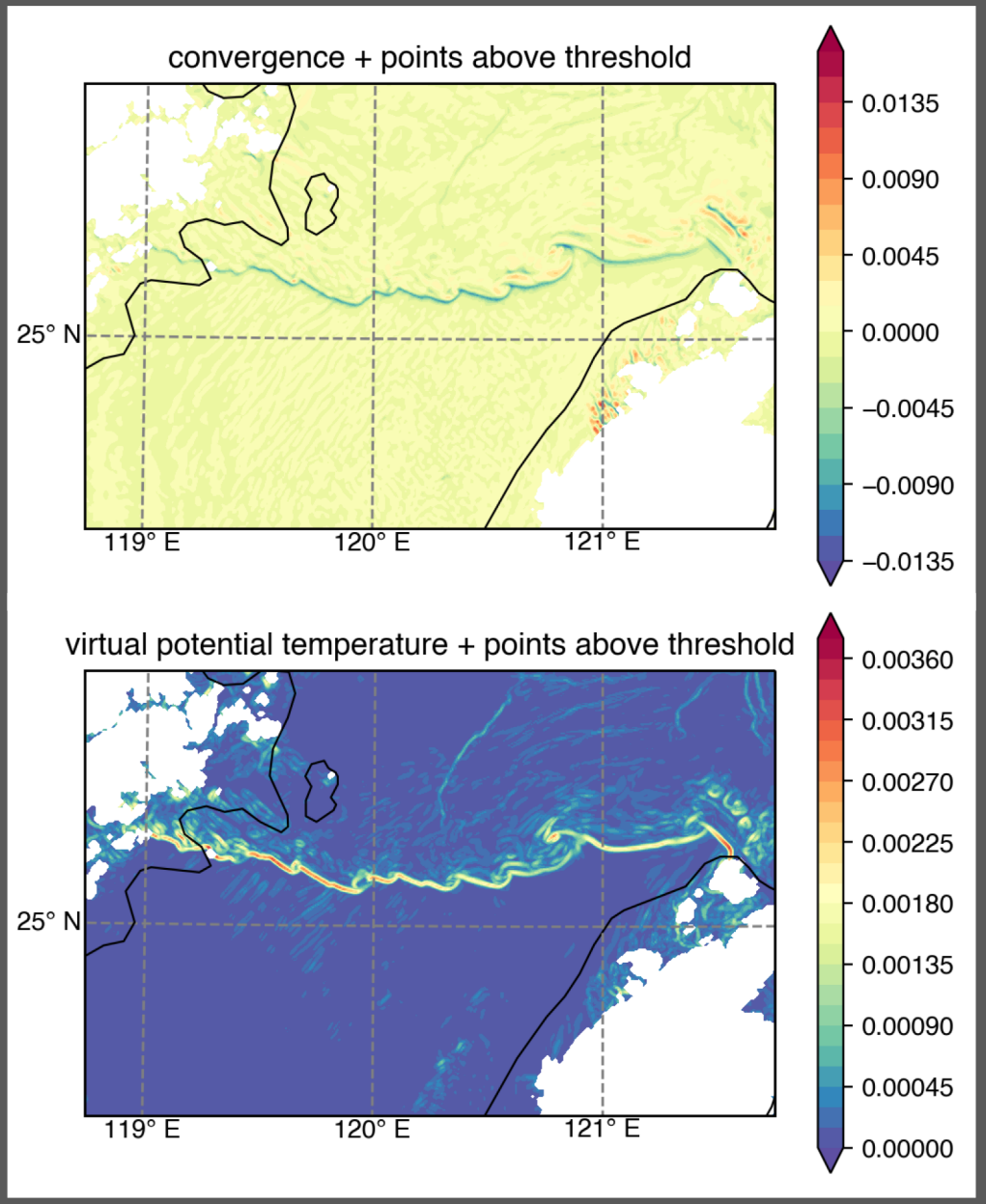


Identify the front

1. Use convergence + gradient in virtual potential temperature at 975 hPa

$$\theta_p = \theta(1 + 0.608 q_v - q_{cloud} - q_{rain})$$

2. Thresholds
    1. convergence: < -0.0025
    2. θ_V gradient: > 0.00075



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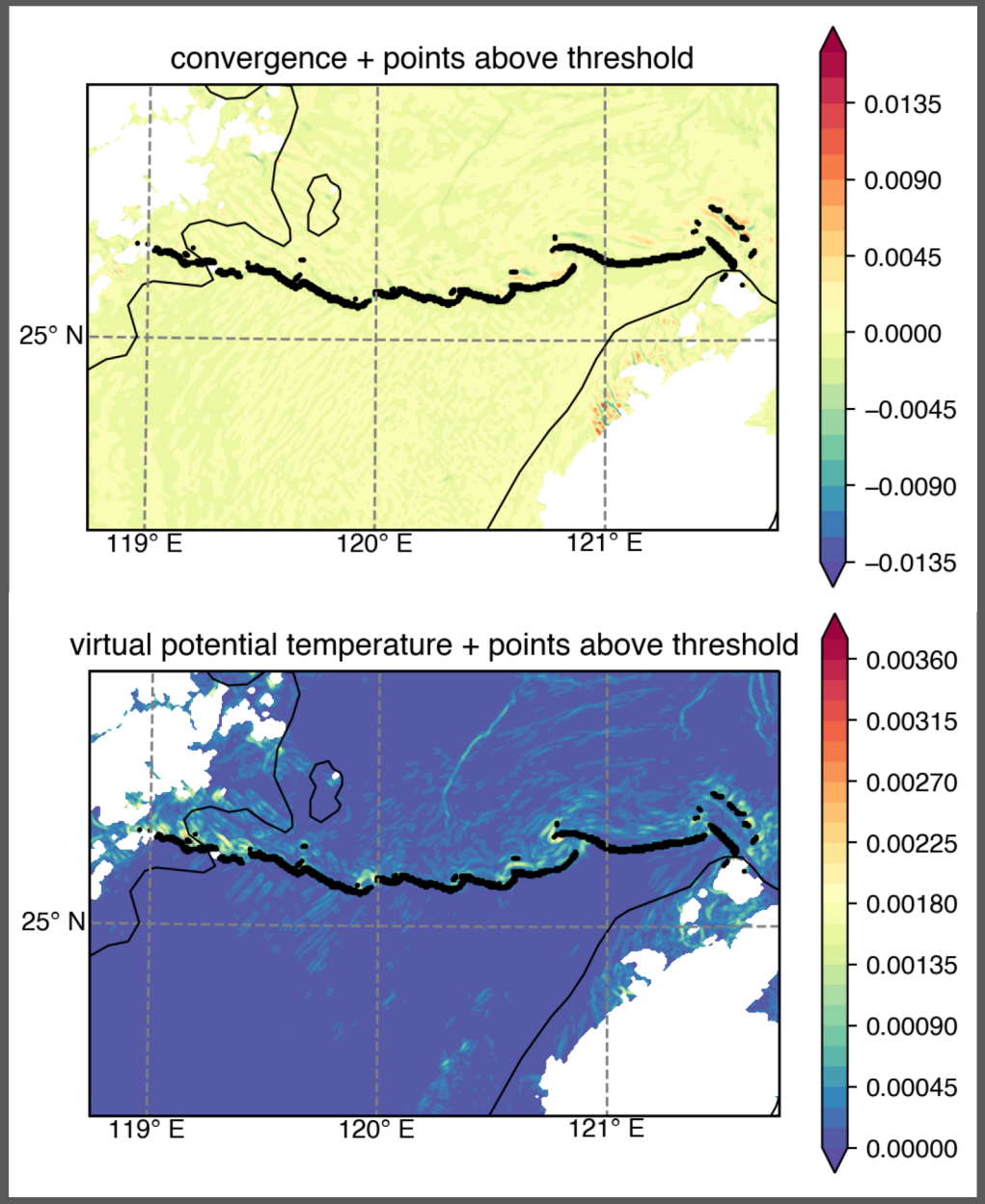
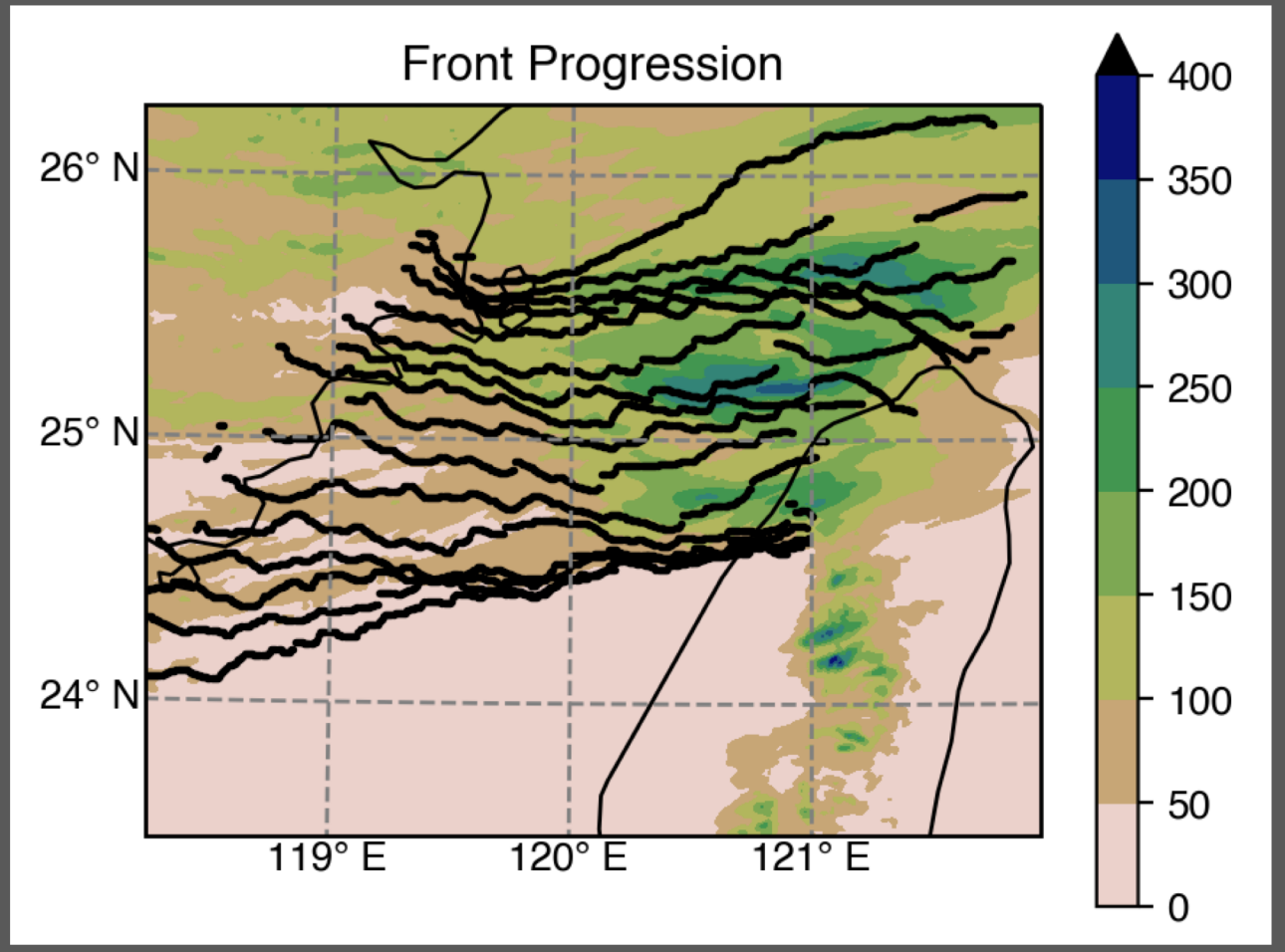


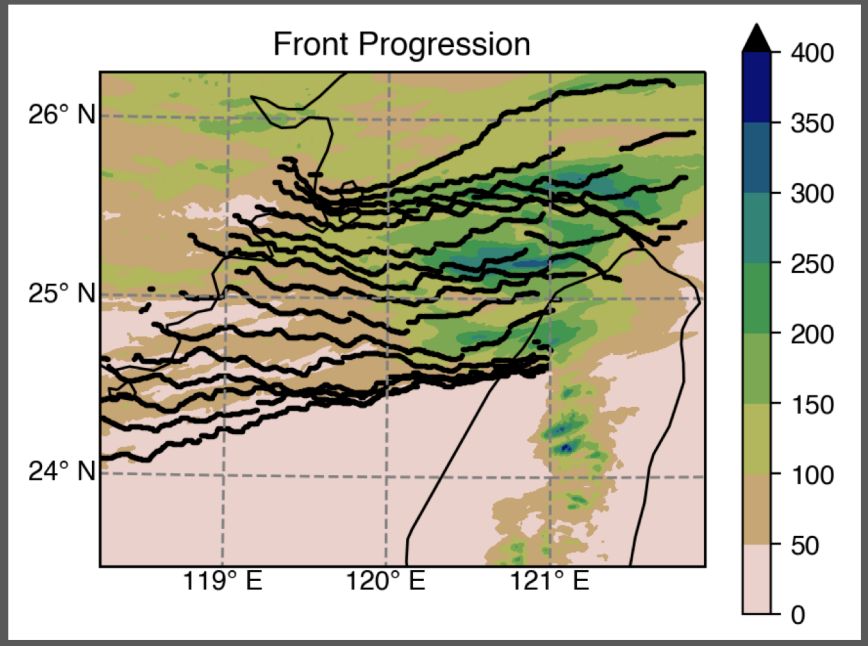
Identify the front

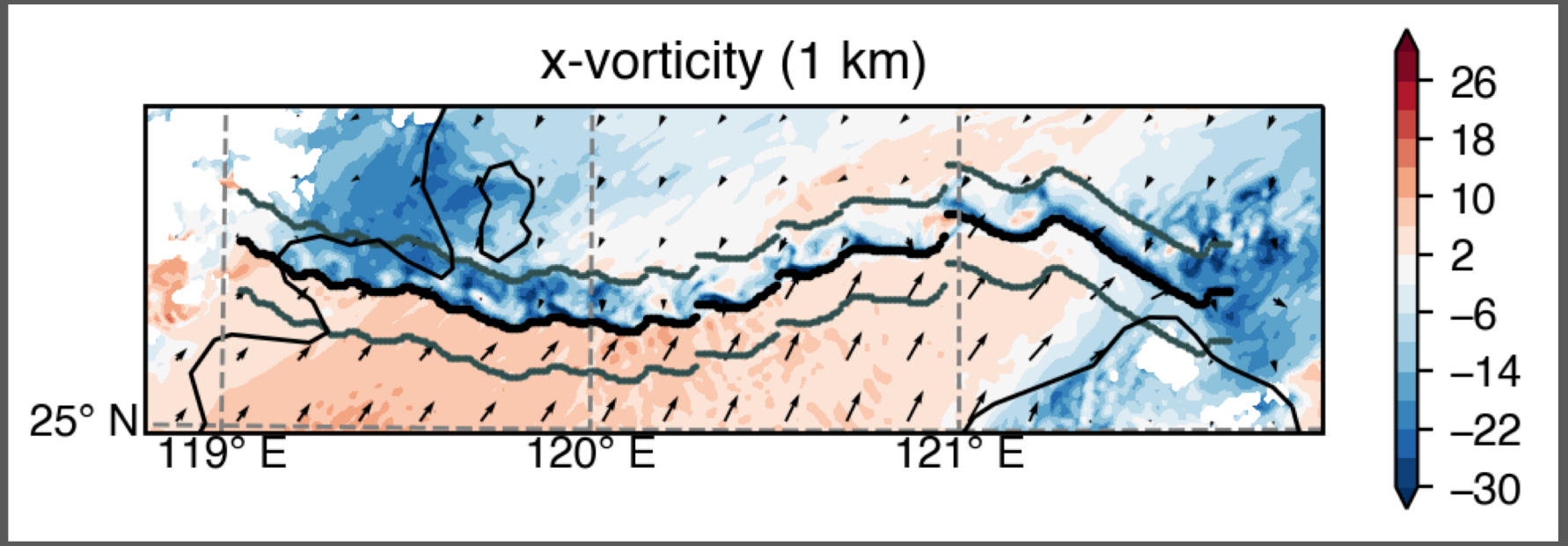
After additional processing and filtering, we can reasonably track the front through time.



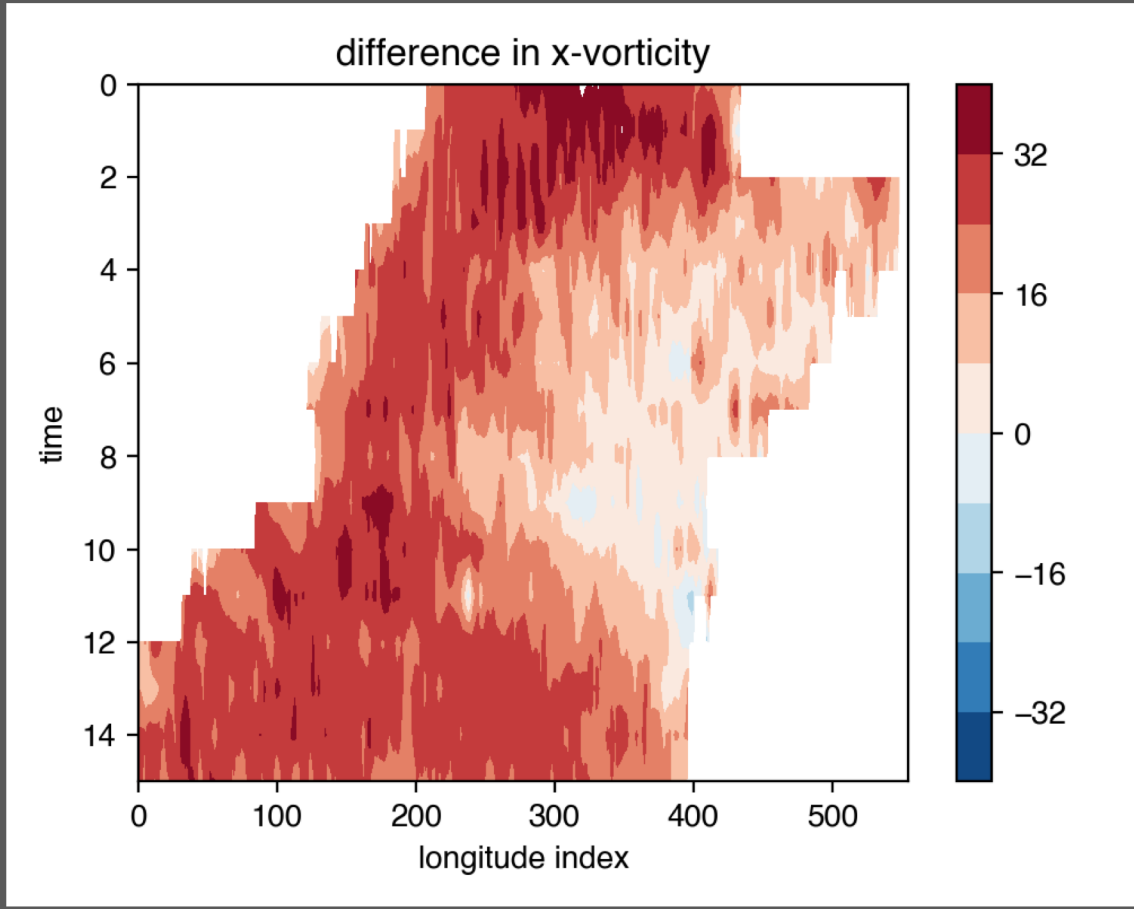
RKW Theory

Compare the difference in x-vorticity across the front to evaluate RKW theory





Vorticity difference is stronger *before* and *after* the heaviest rainfall



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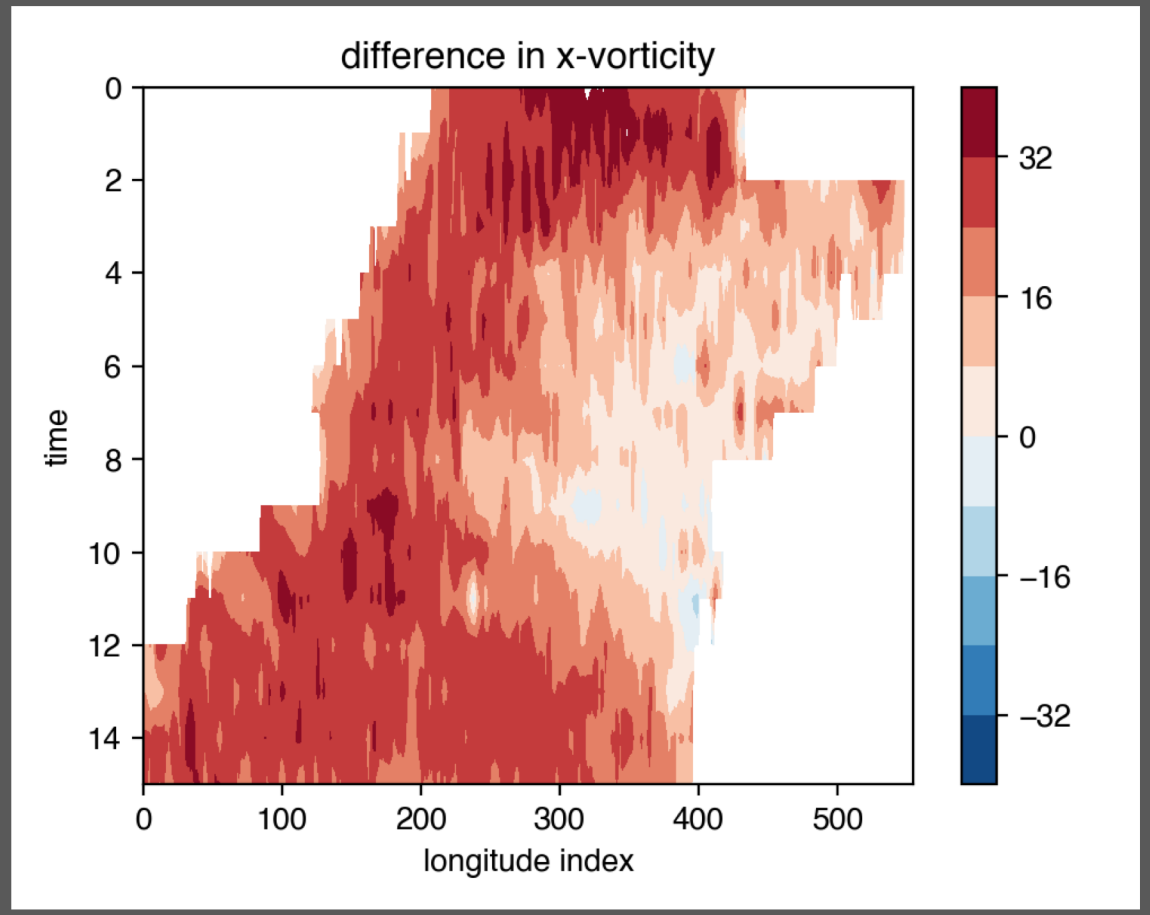
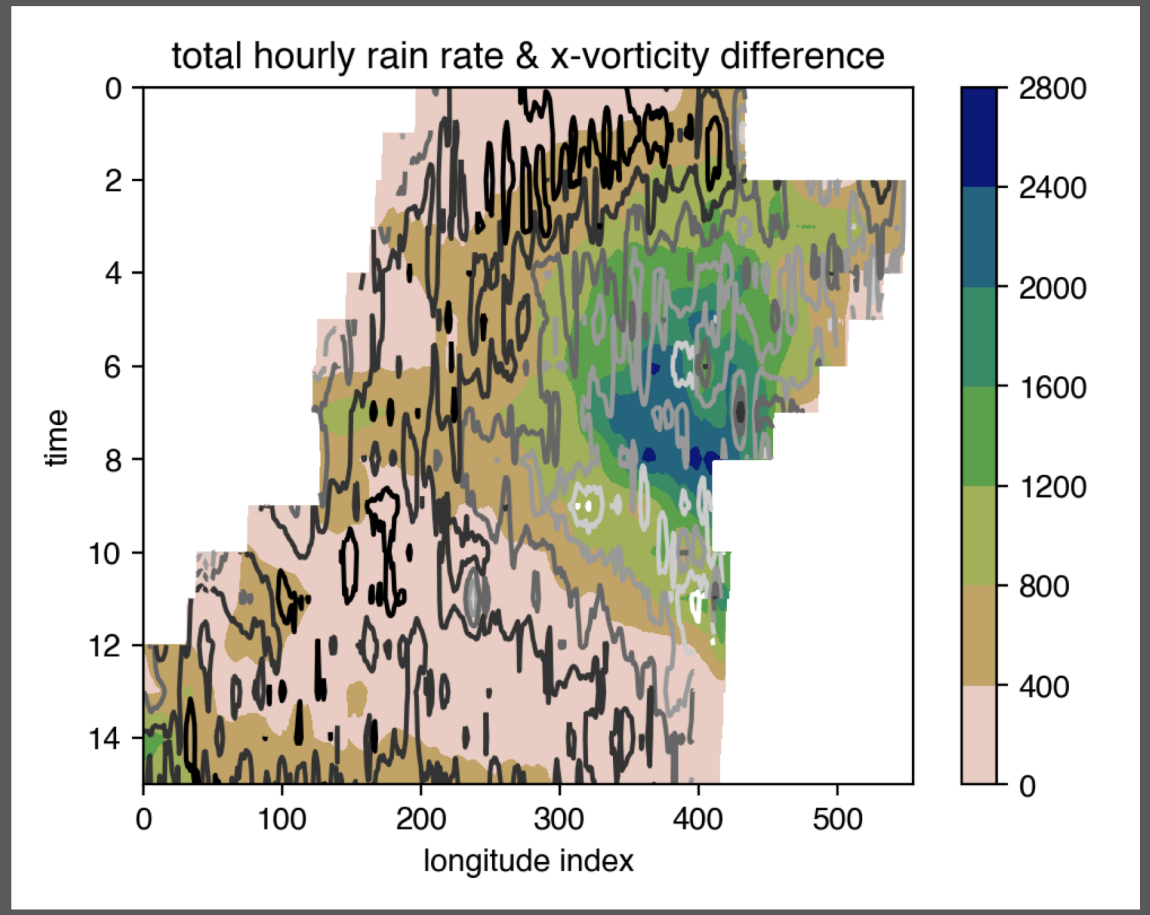
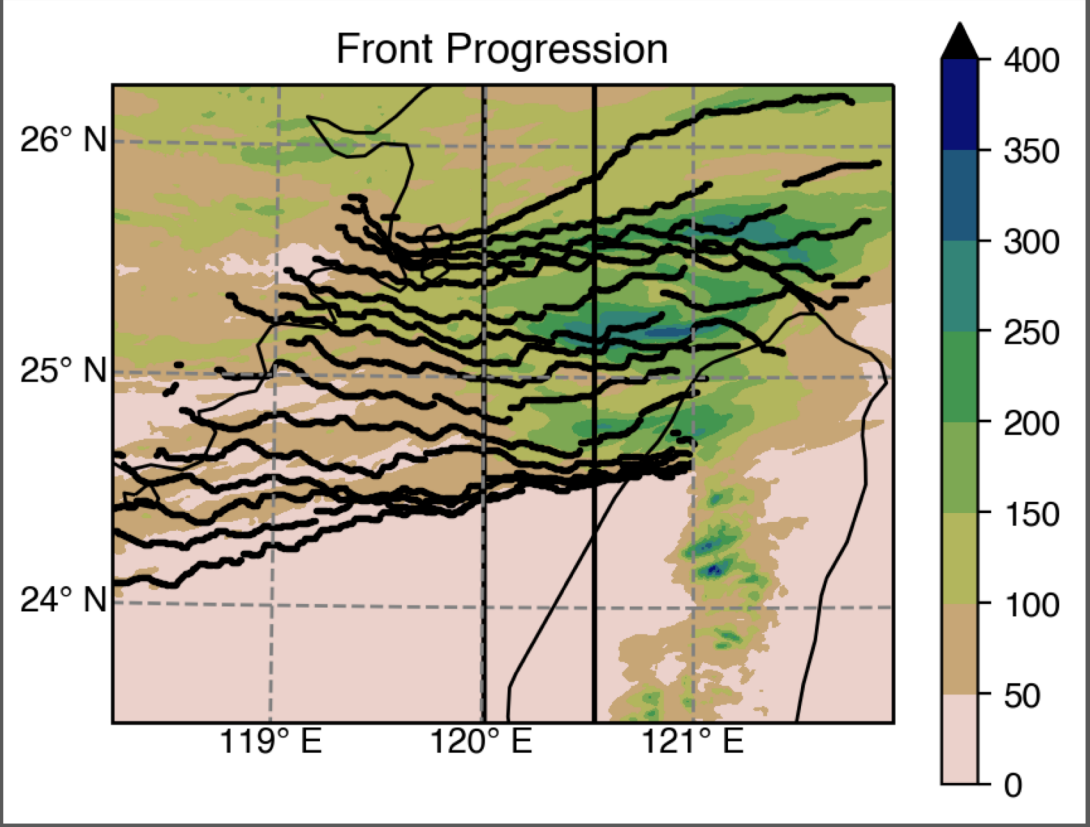


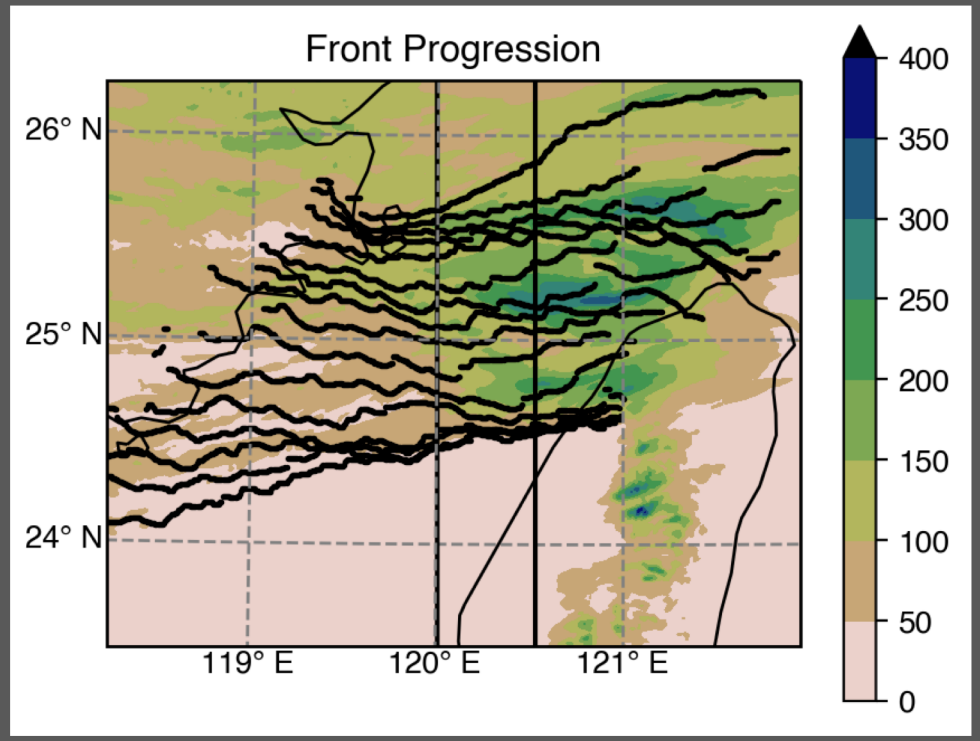


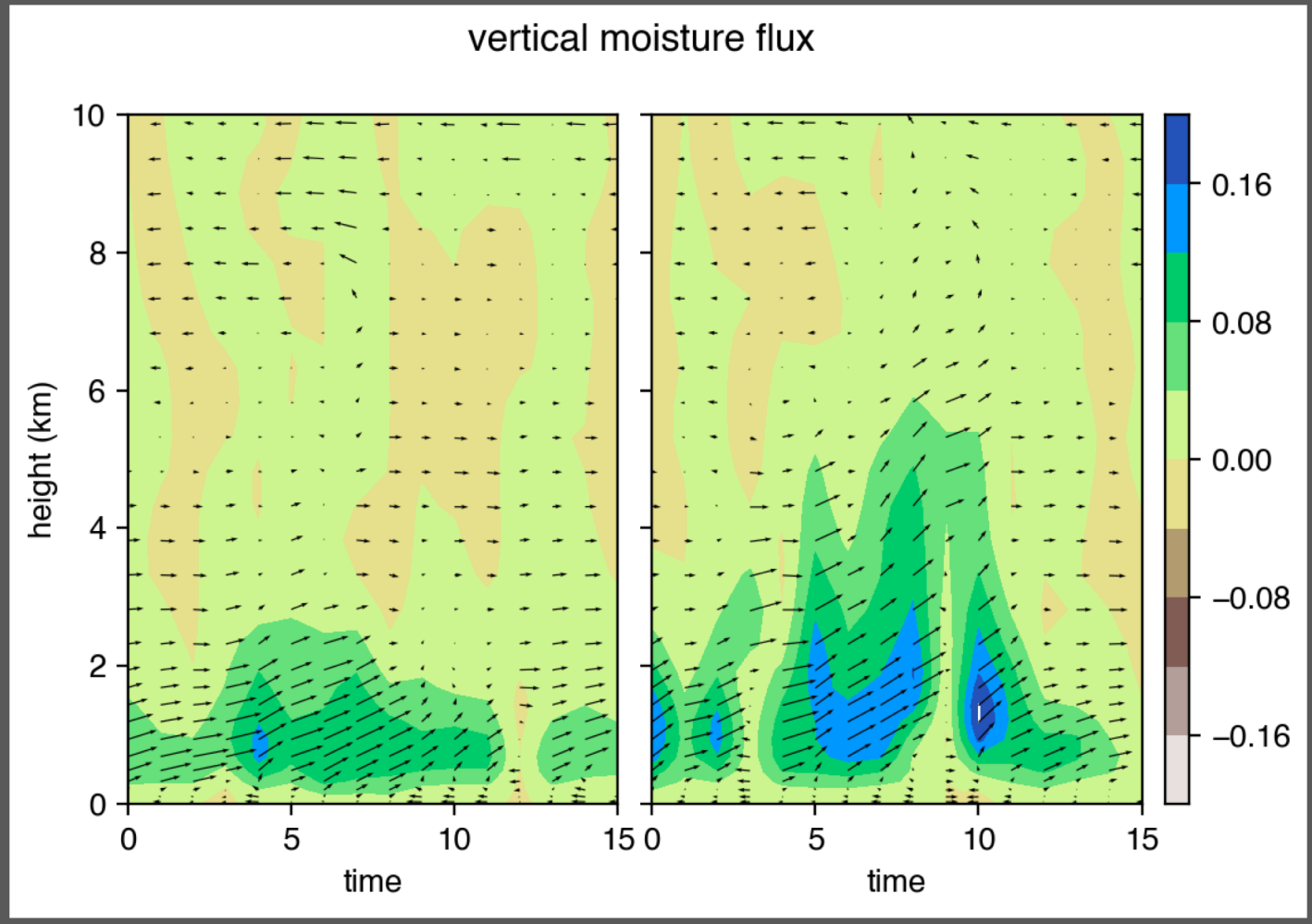
Vertical Moisture Flux

Comparing vertical profiles of vertical moisture flux *at* the front at 2 locations



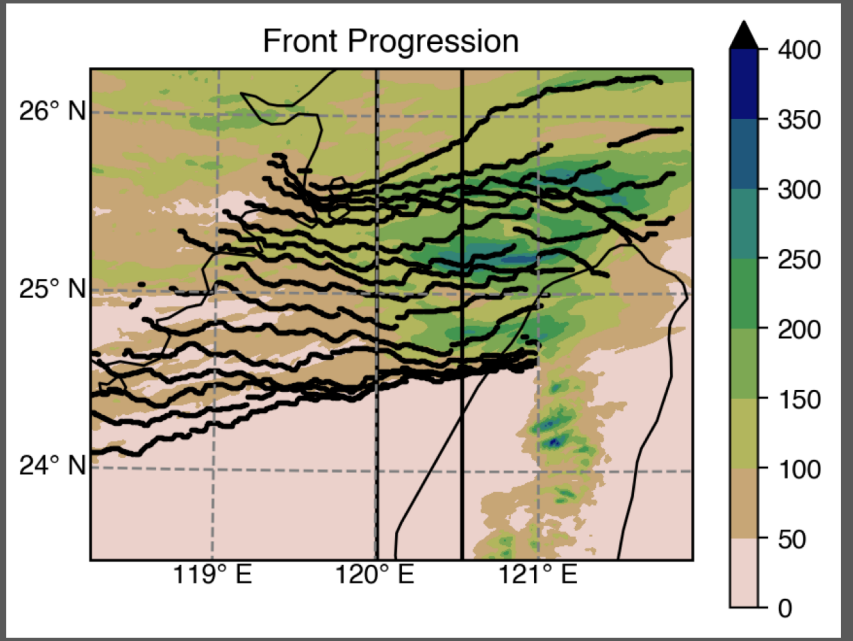
Vertical moisture flux correlates with greater rainfall

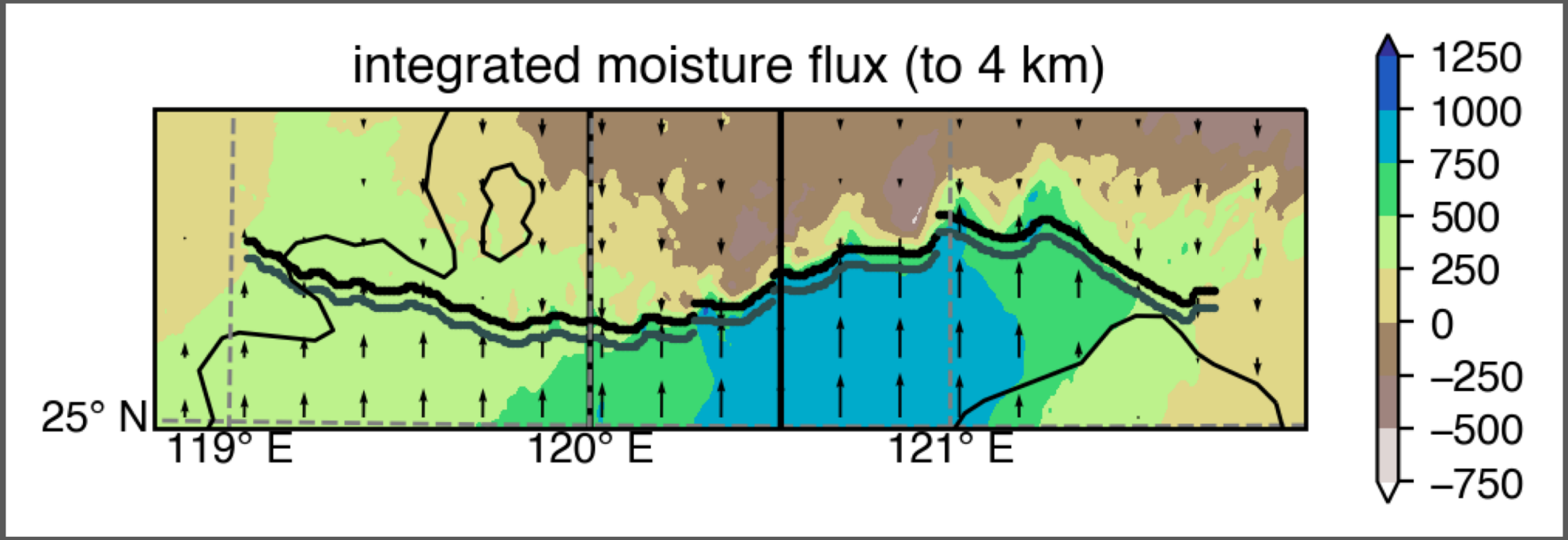




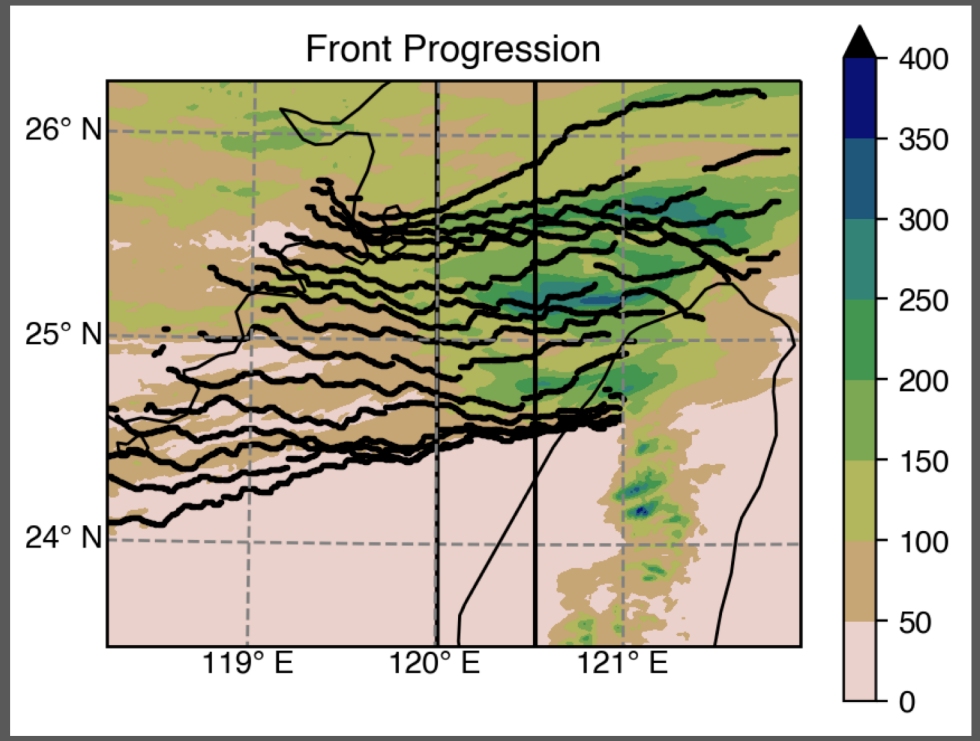
Horizontal Moisture Flux

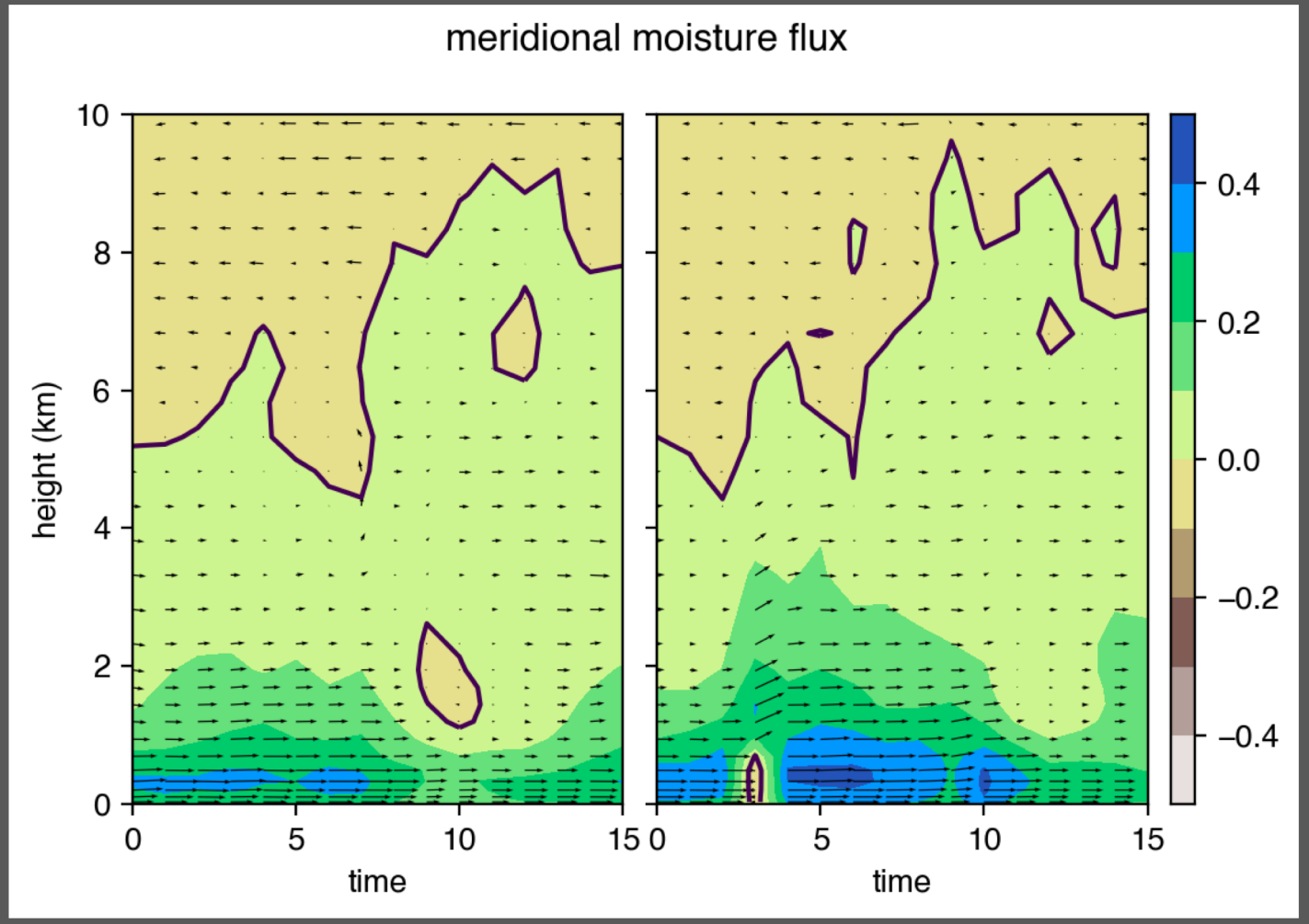
Compare the vertical profiles of horizontal moisture flux ahead of the front



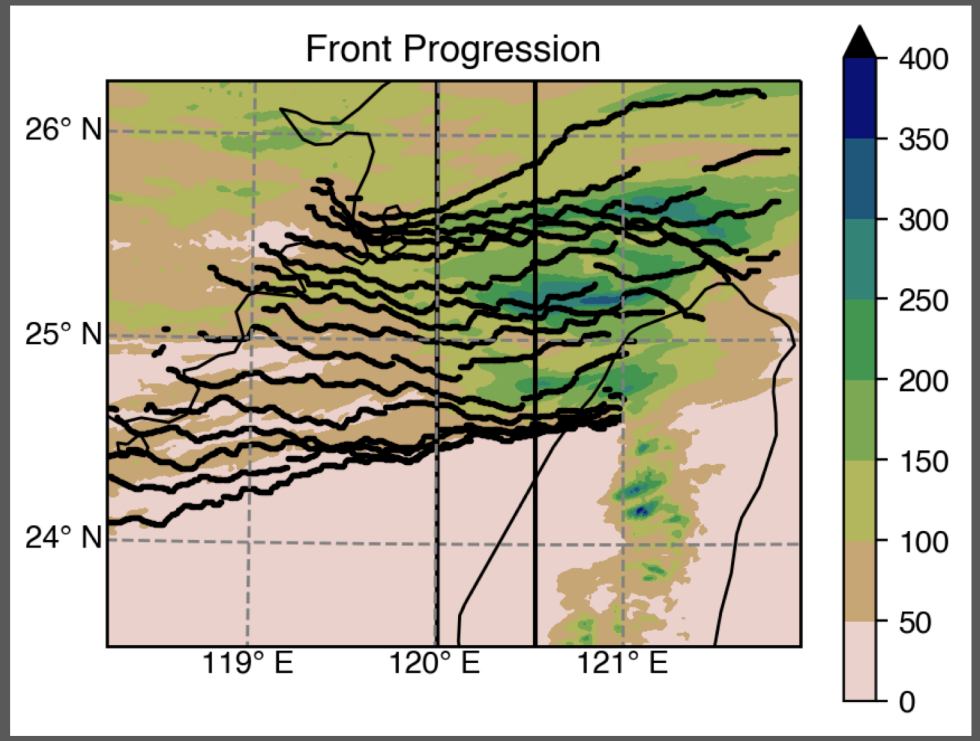


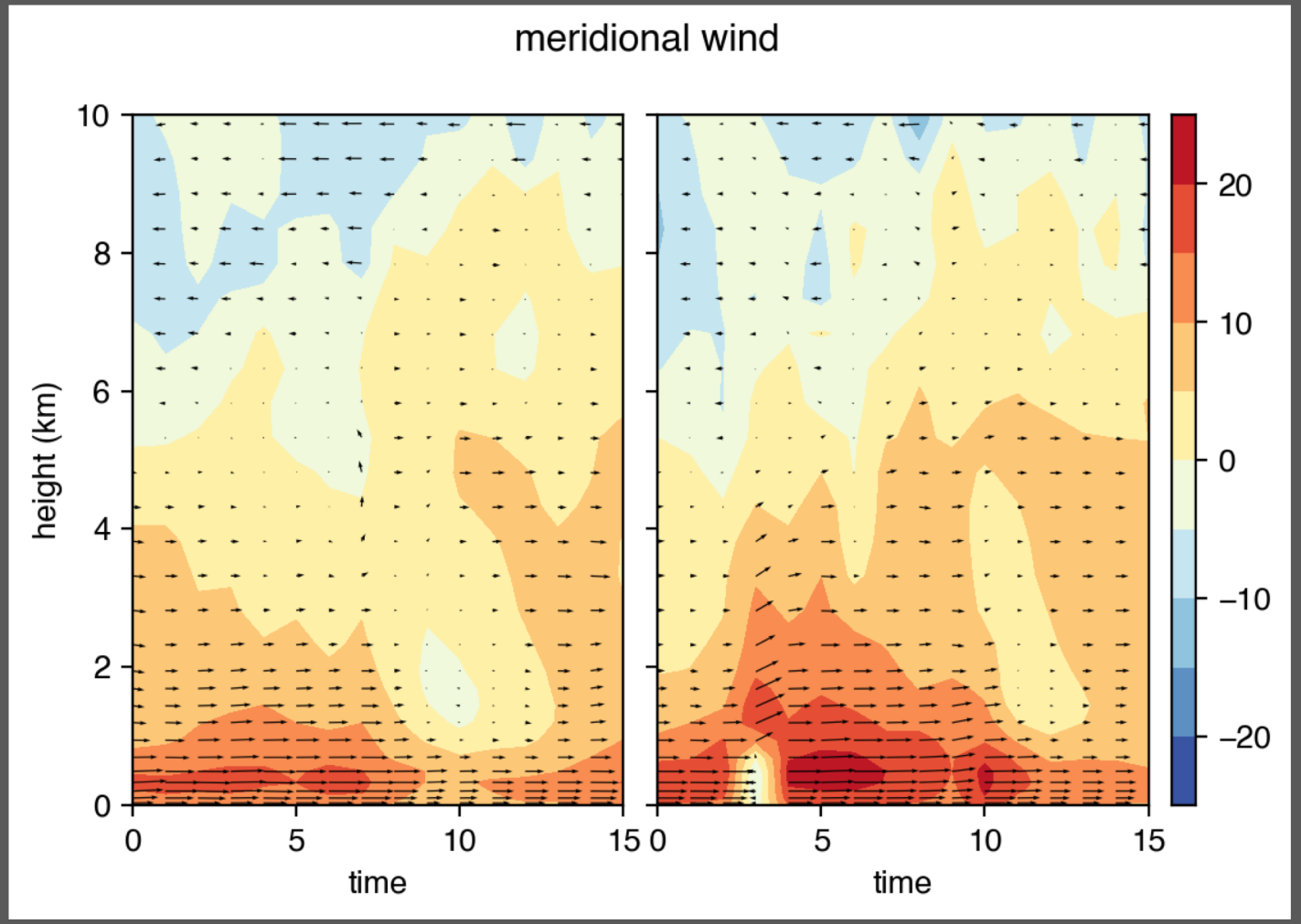
Horizontal moisture flux ahead of front correlates with greater rainfall



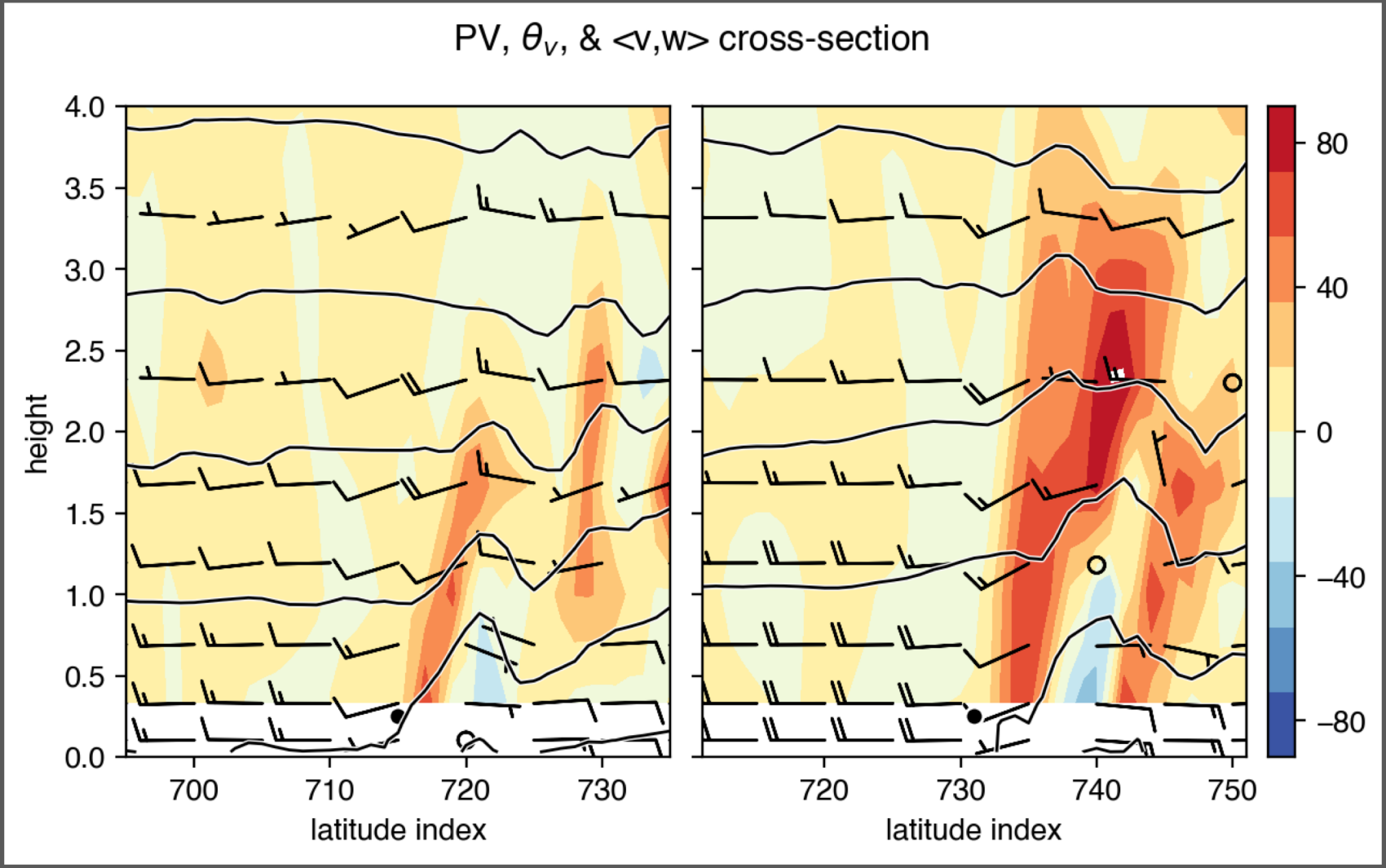


Moisture flux dominated by wind





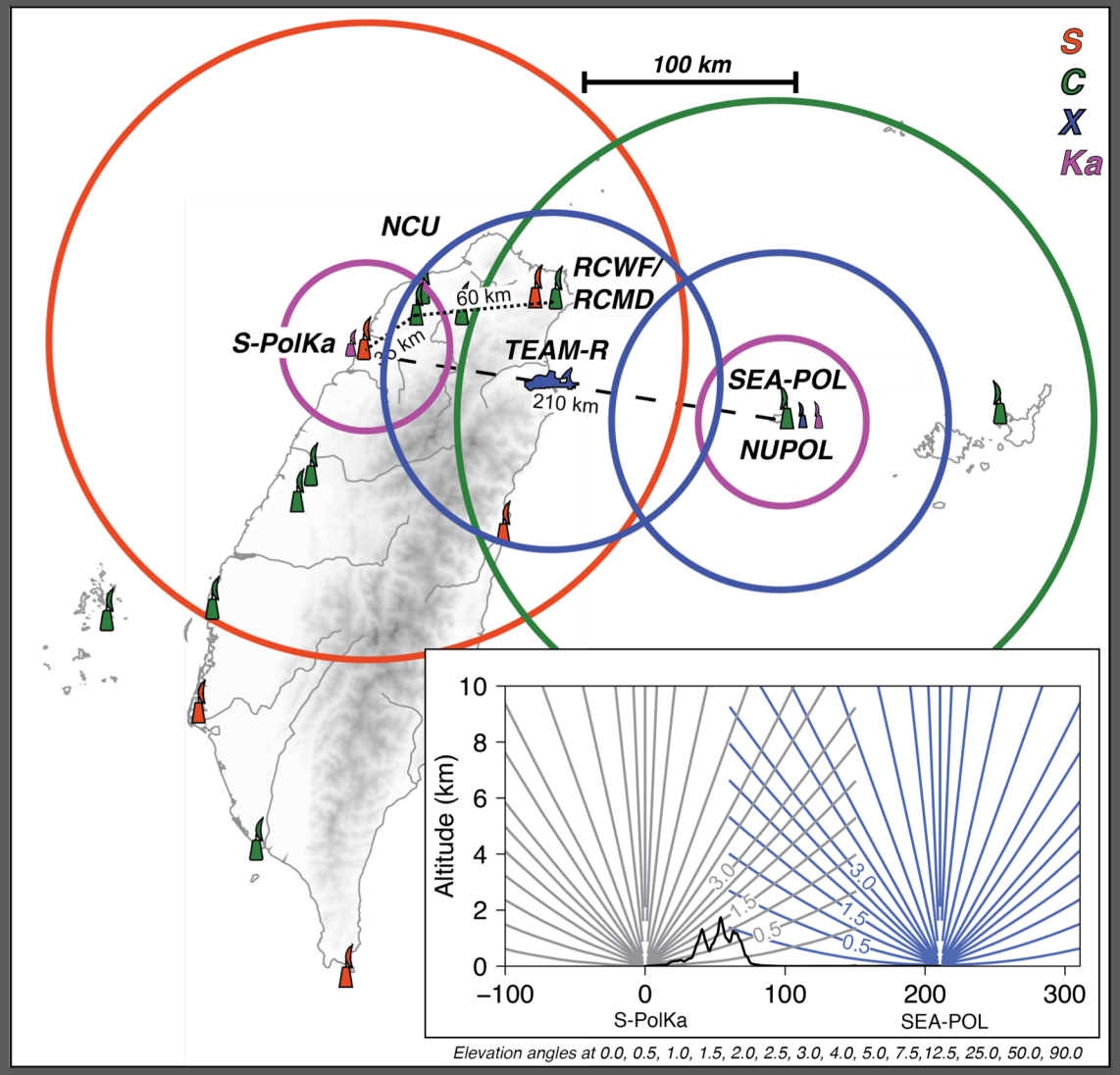
Suggests isentropic ascent / PV framework might be applicable

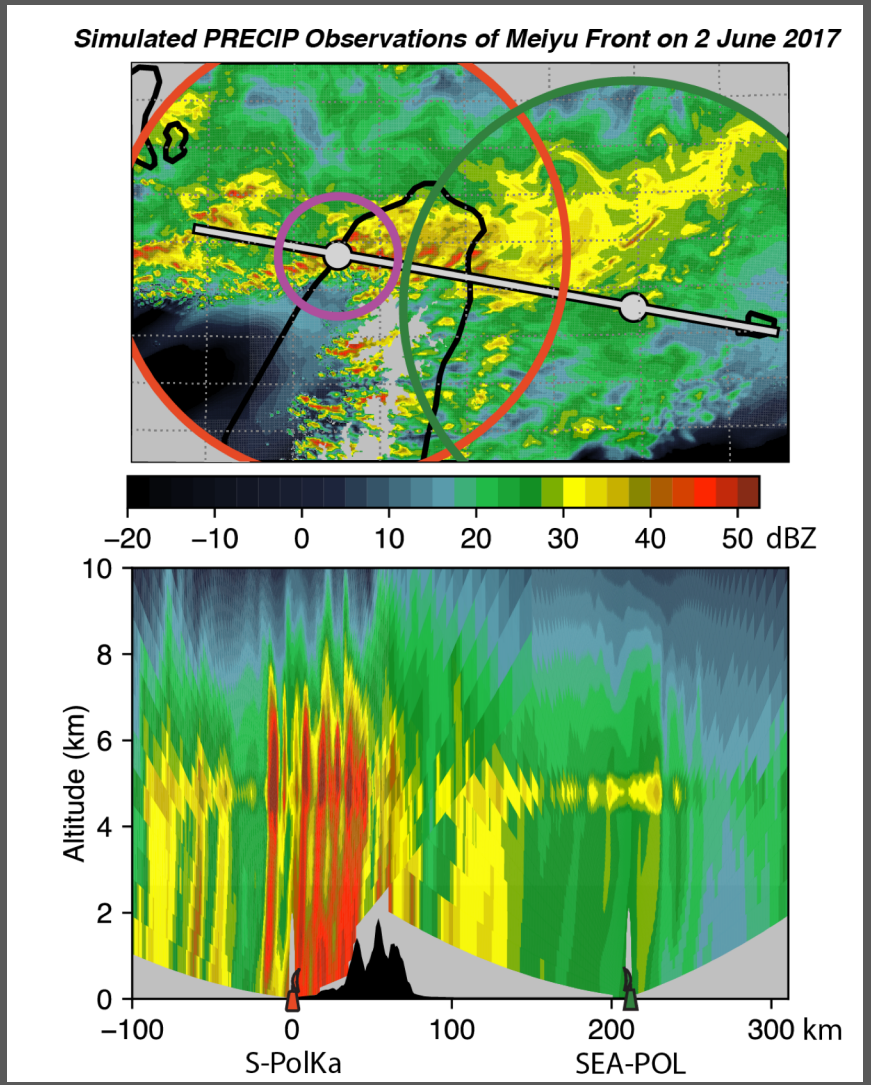


Aforementioned analysis is from a numerical simulation

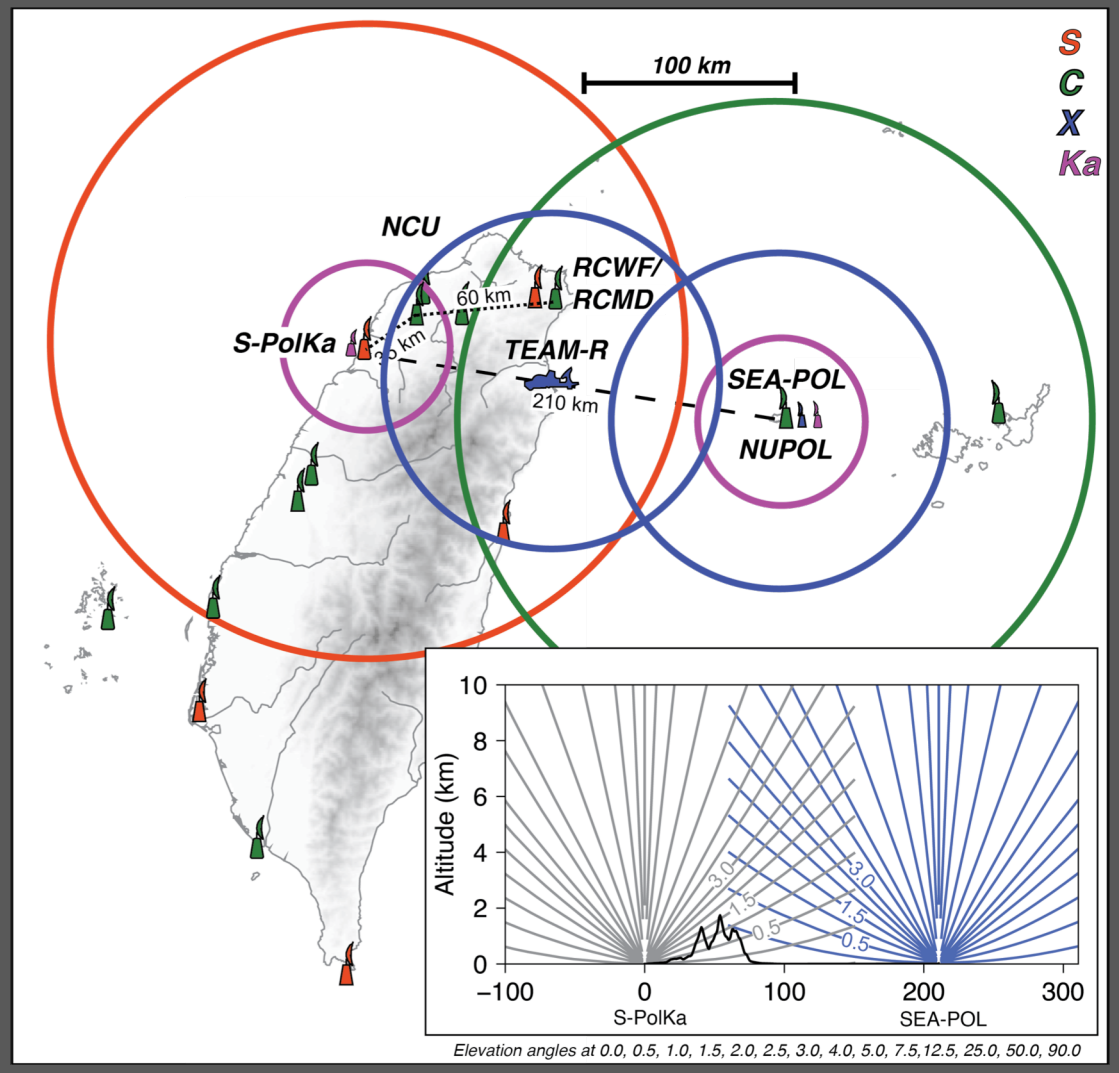
- PRECIP will assess whether the relative importance of these mechanisms is similar in the real world
  - *And* observe bulk microphysical processes

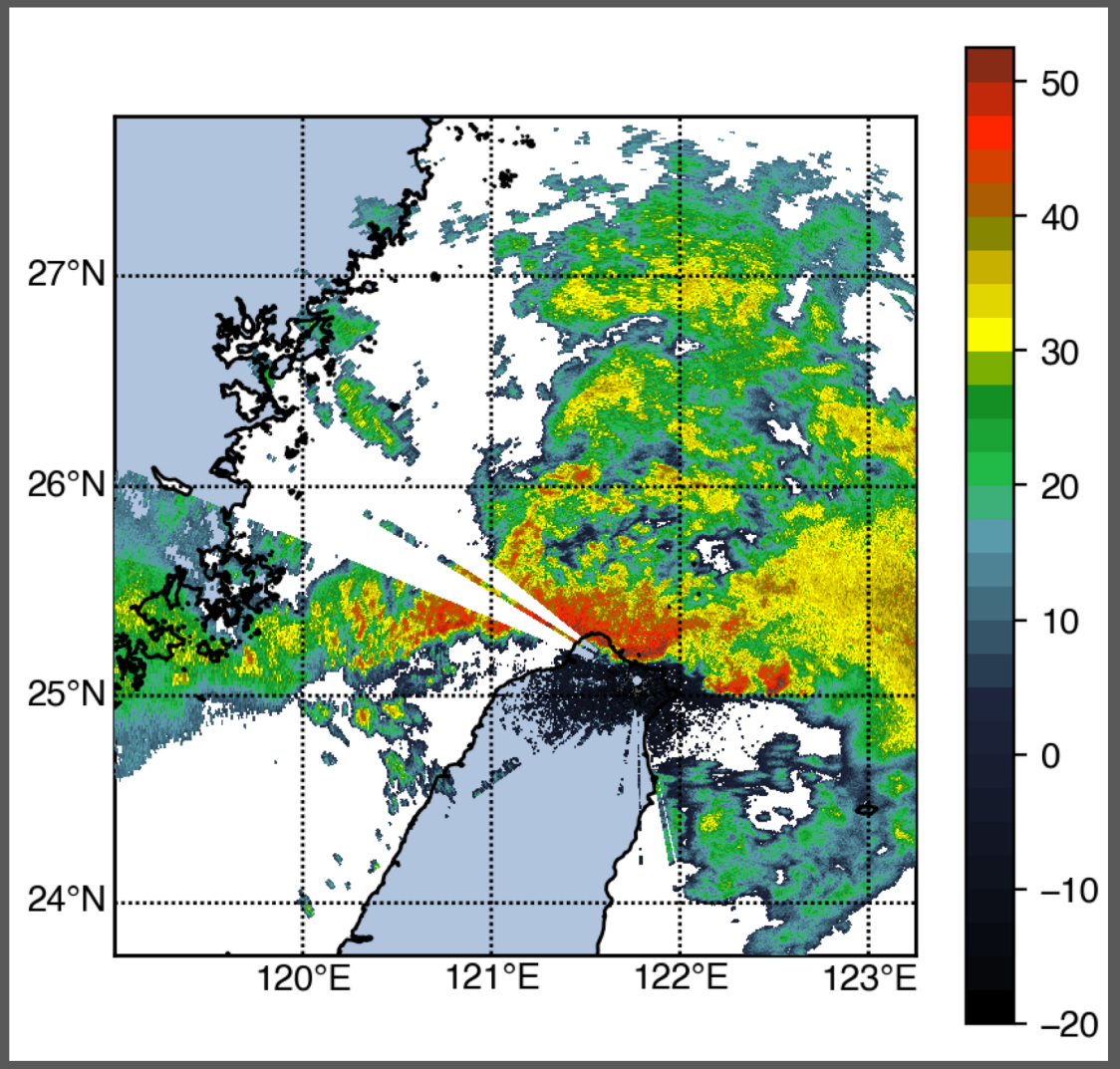
PRECIP radar plan



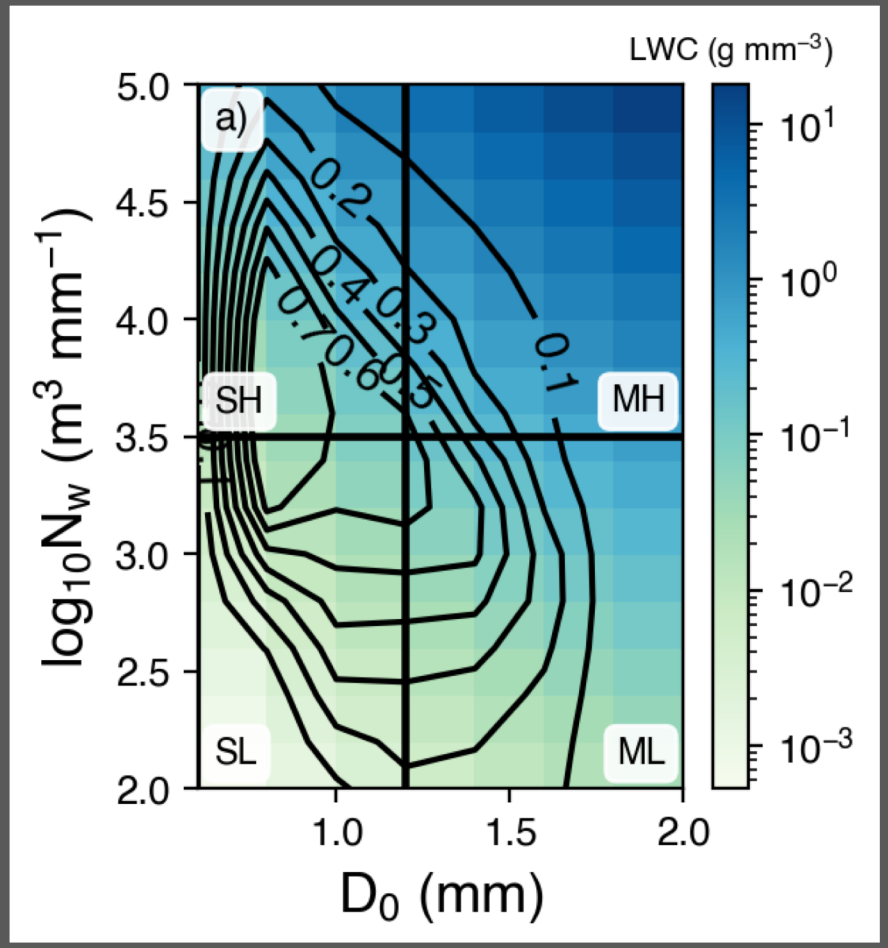


We've begun preliminary analysis of radar data from 2 June case

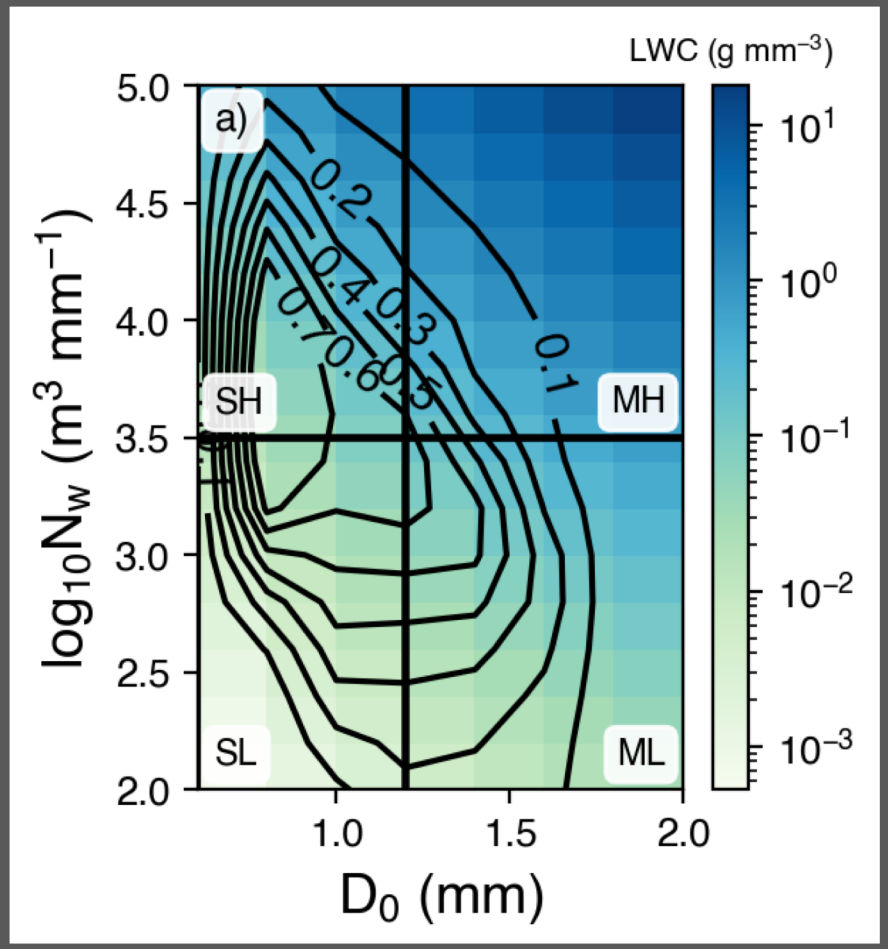


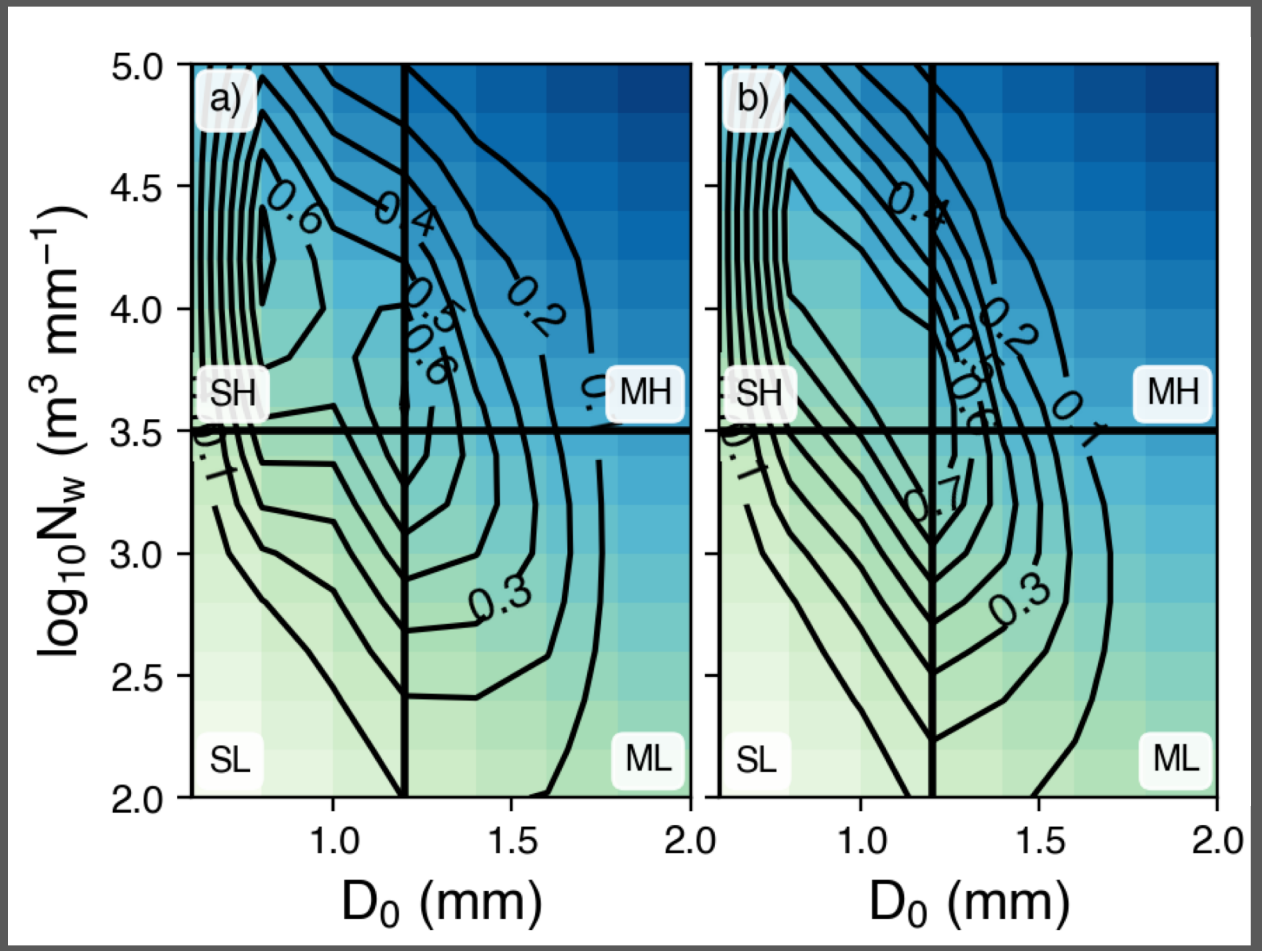


Estimate DSD parameters with CSU RadarTools package



Similar distribution as Hurricanes Harvey (2017) and Florence (2018)





DeHart and Bell 2020, in review

Summary

- **What mechanisms were responsible for heavy rainfall in the June 2017 case?**
  - RKW theory does not appear important
  - Vertical and horizontal moisture flux correlate with hourly rainfall
- **What processes were important at different spatial and temporal scales?**
  - Horizontal moisture flux appears important at both

Possible intense rainfall forcings

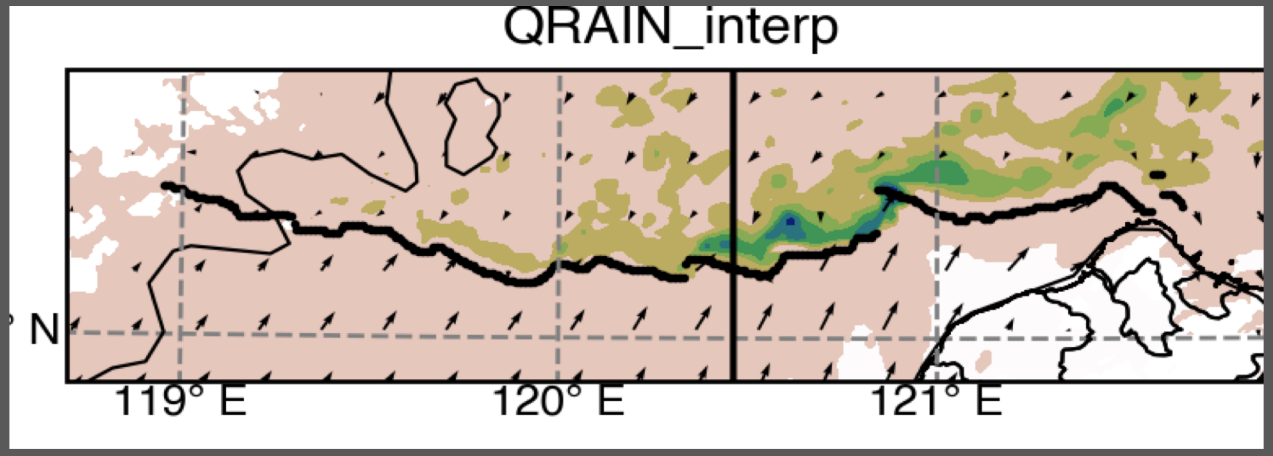
- RKW theory
- **High instability**: need lack of stability to support ascent, but generally greater instability leads to stronger ascent, which favor strong precipitation processes
- Vertical moisture flux

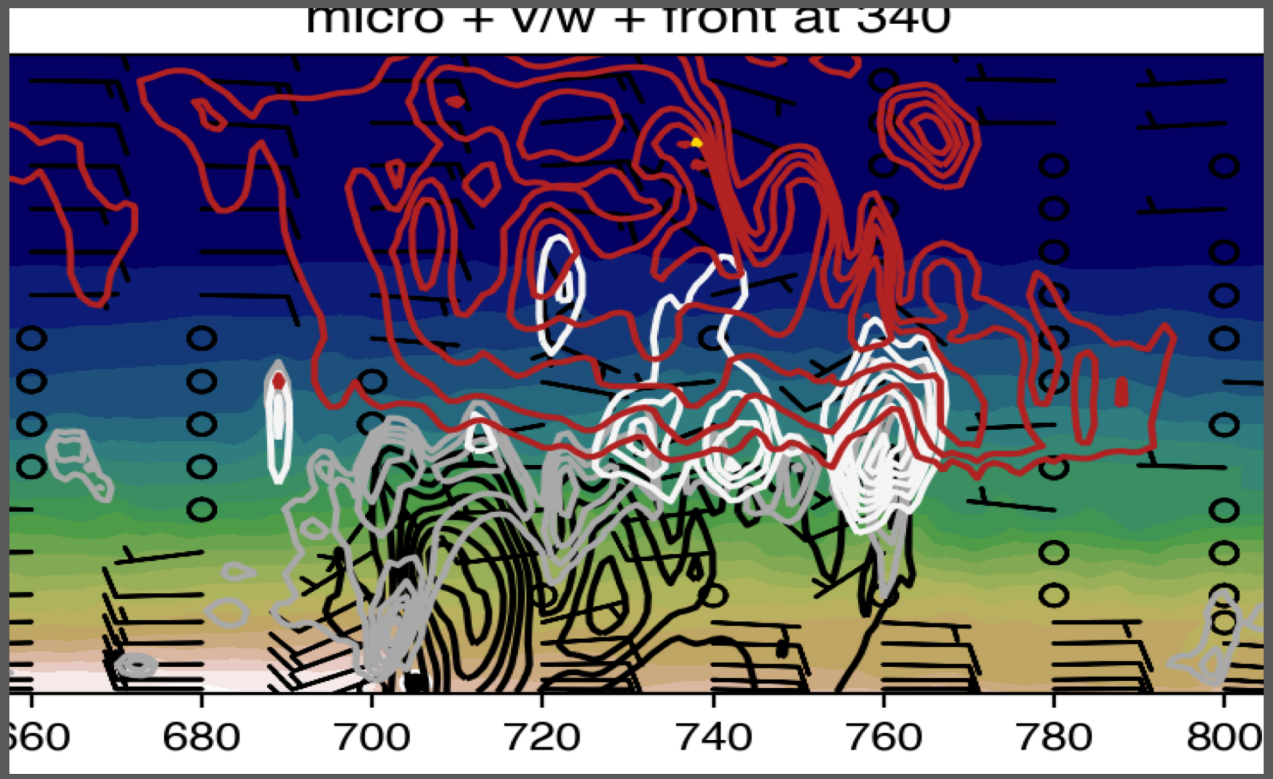
$$R = Ewq.$$

Doswell 1996

Identify the front

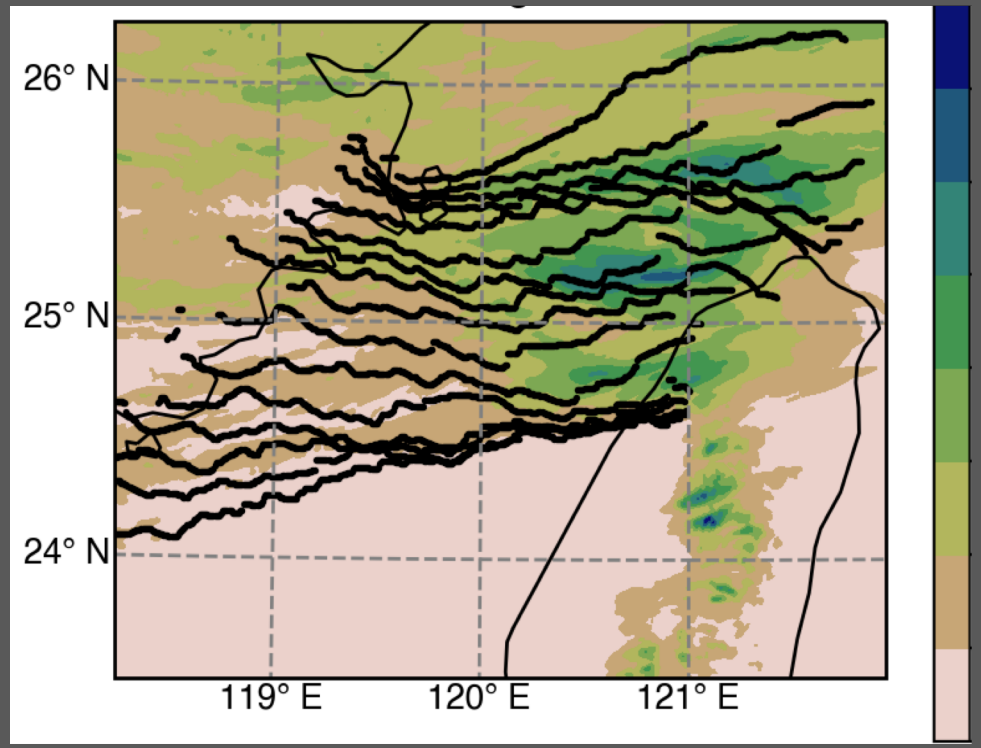
1. Find median q_V value over all points, find point at each longitude closest to that value
2. Remove single bad points
3. Smooth and interpolate
4. Reasonable!

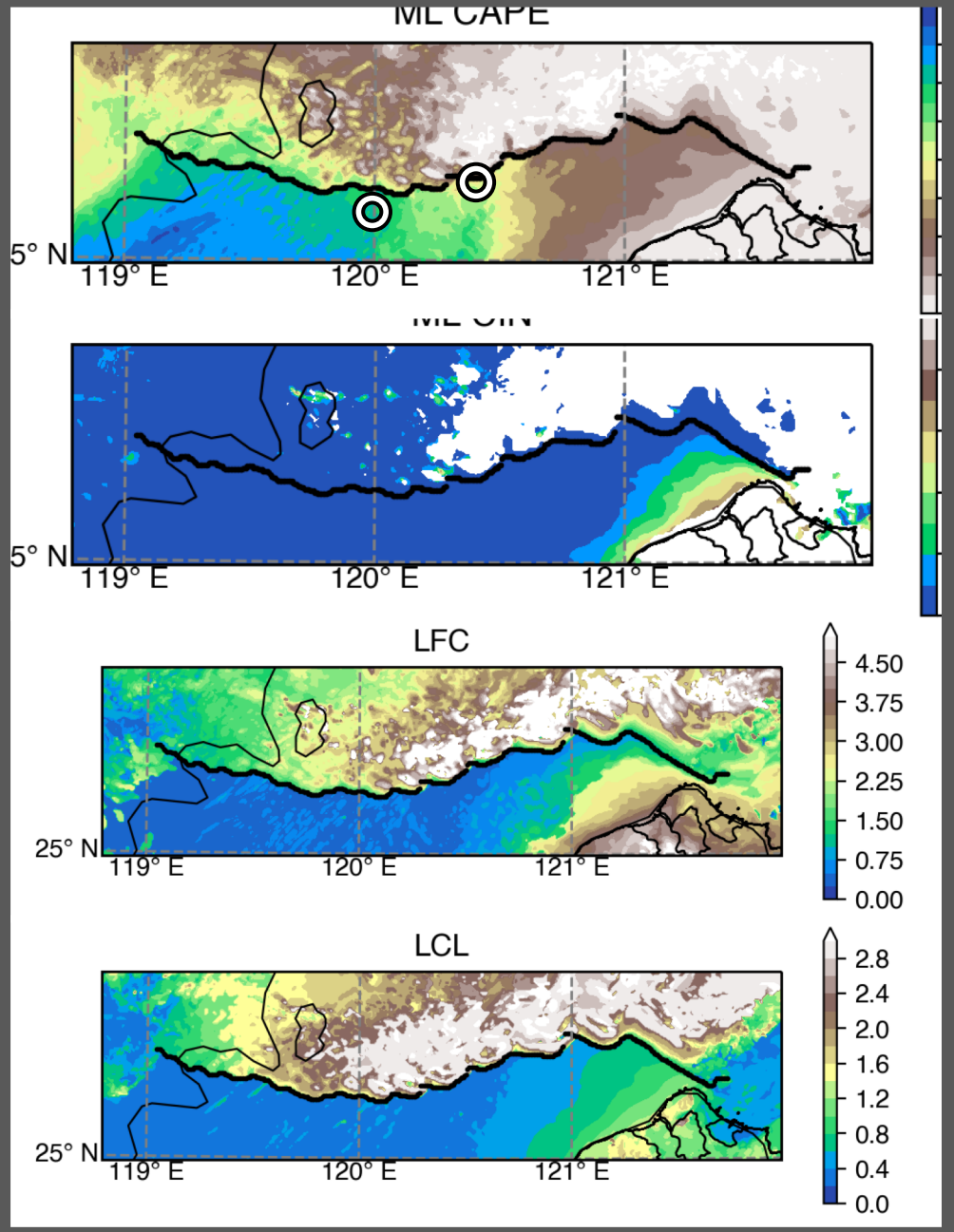




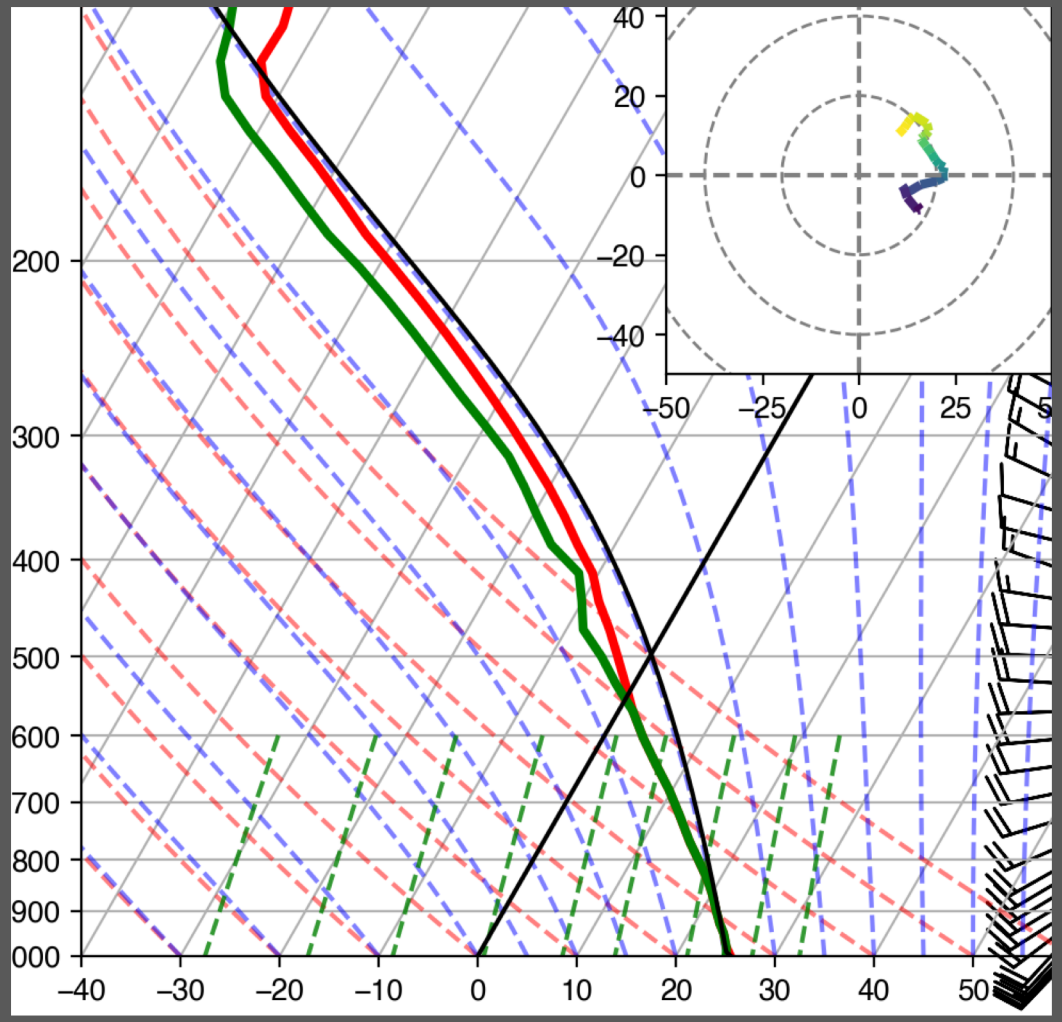
Instability

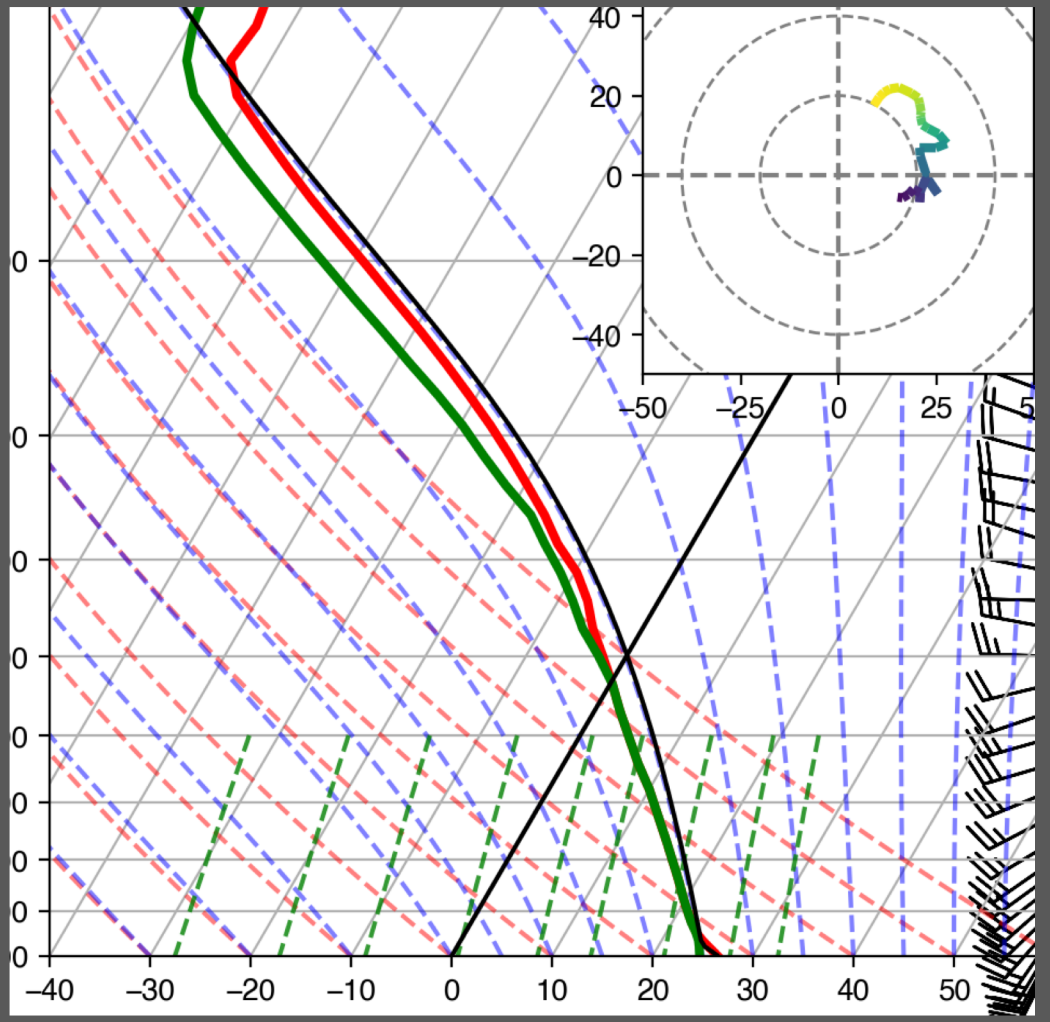
Instability offset from rainfall





Instability





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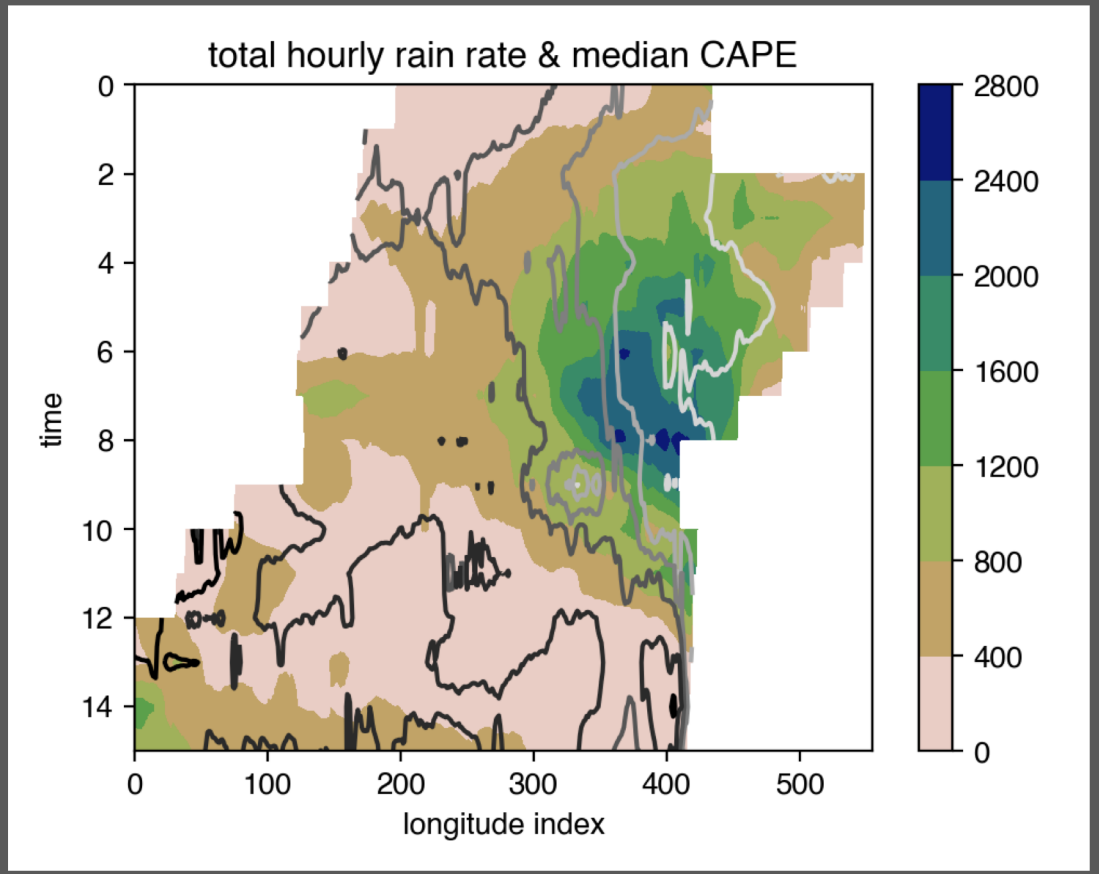

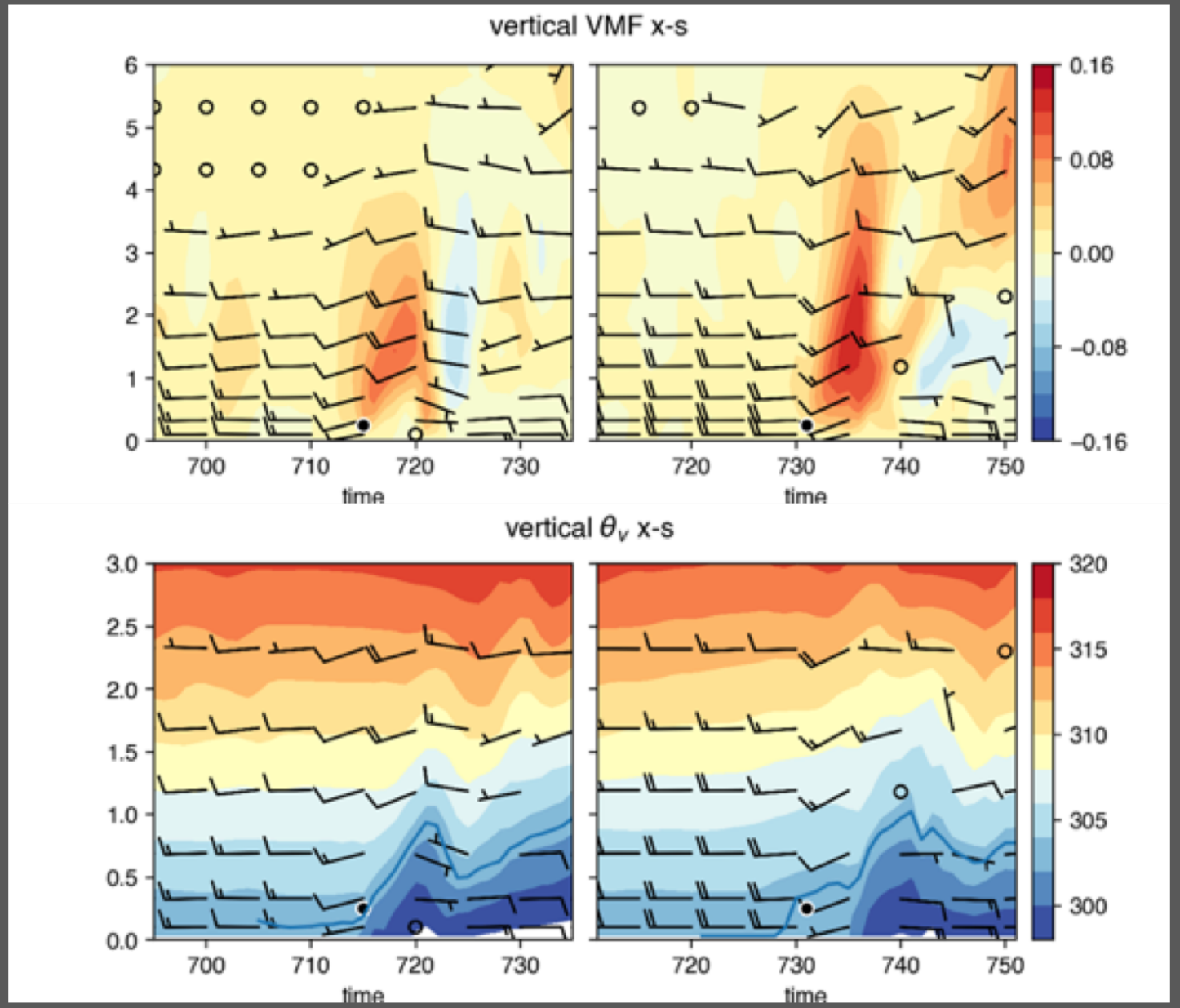
vertical VMF x-s
6
5
4
3
2
1
0
700
710
720
730
time
720
730
740
750
time
0.16
0.08
0.00
−0.08
−0.16
vertical θ_v x-s
3.0
2.5
2.0
1.5
1.0
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310
305
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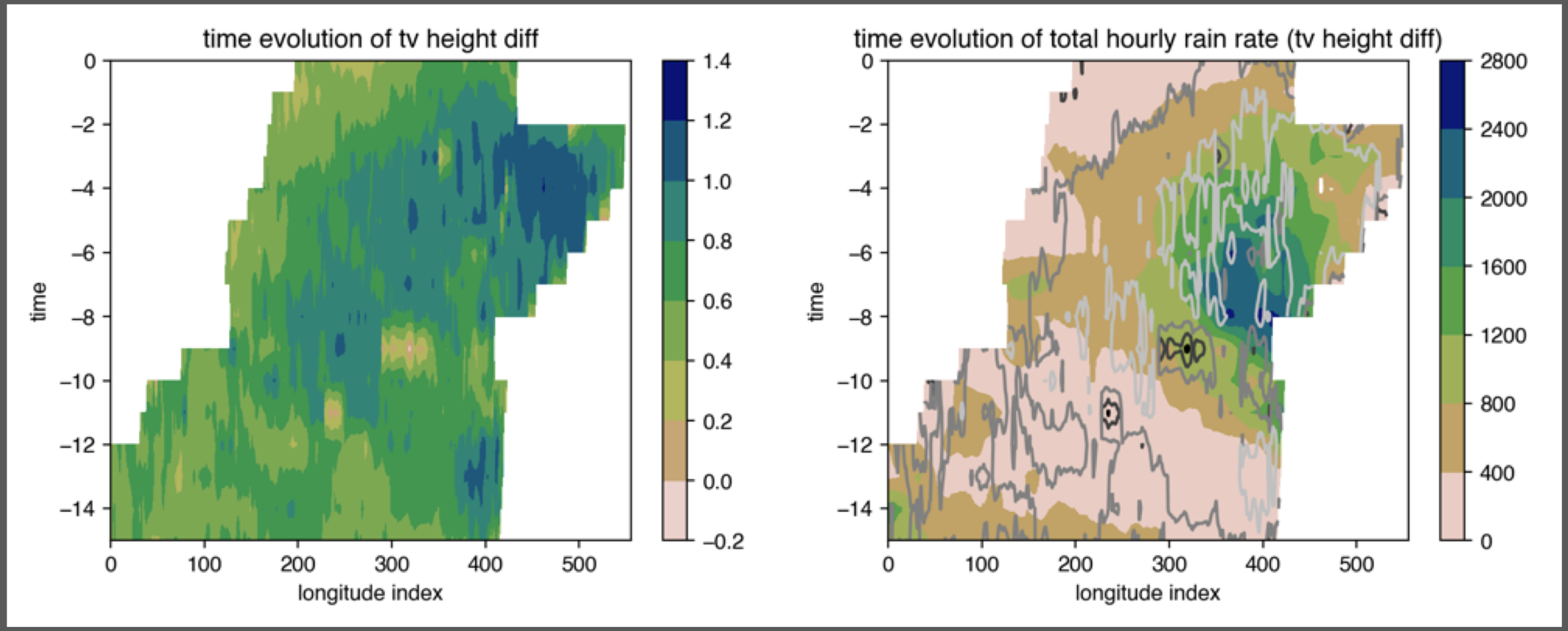
time evolution of tv height diff
time
longitude index
0
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−4
−6
−8
−10
−12
−14
0
100
200
300
400
500
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
time evolution of total hourly rain rate (tv height diff)
time
longitude index
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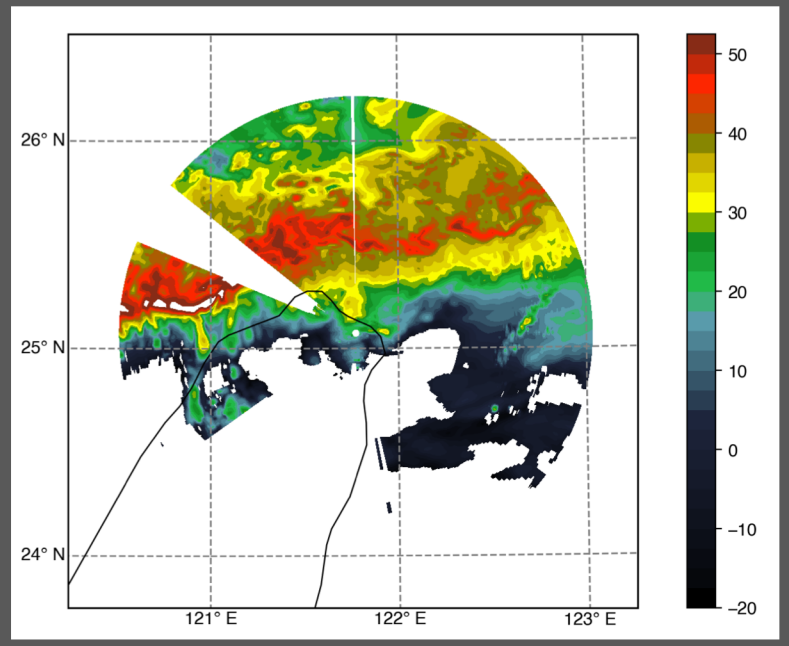
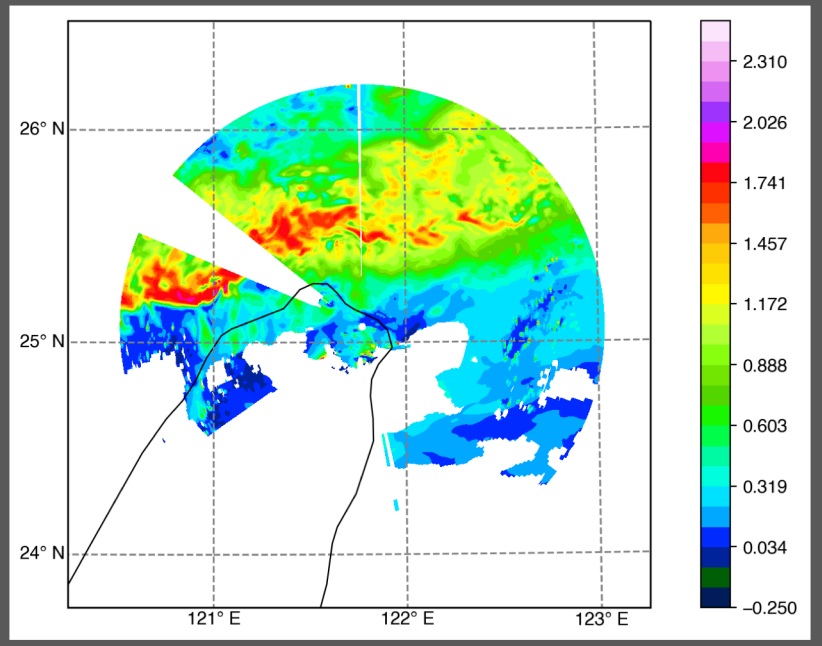
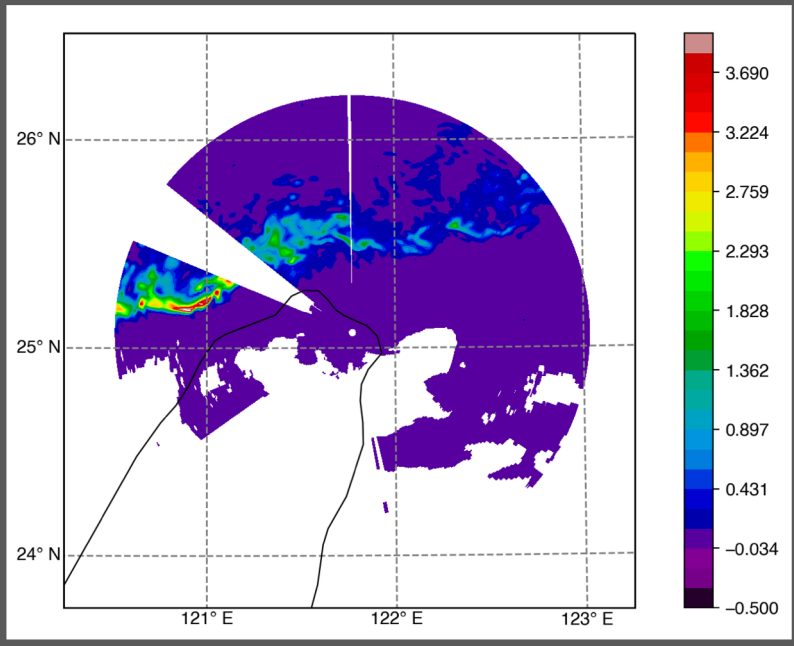
2400
2000
1600
1200
800
400
0

CRSIM output







PRECIP will search for universal processes