Modulation of Atmospheric Rivers by Mesoscale Frontal Waves and Latent Heating: Comparison of Two U.S. West Coast Events

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NIU
Portland State University
Climate Impact Lab
Rutgers Earth System Science & Policy Lab
Center for Western Weather and Water Extremes
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Mesoscale Frontal Waves & Atmospheric Rivers

- Mesoscale frontal waves (MFWs) are small-scale, wave features that form along frontal boundaries

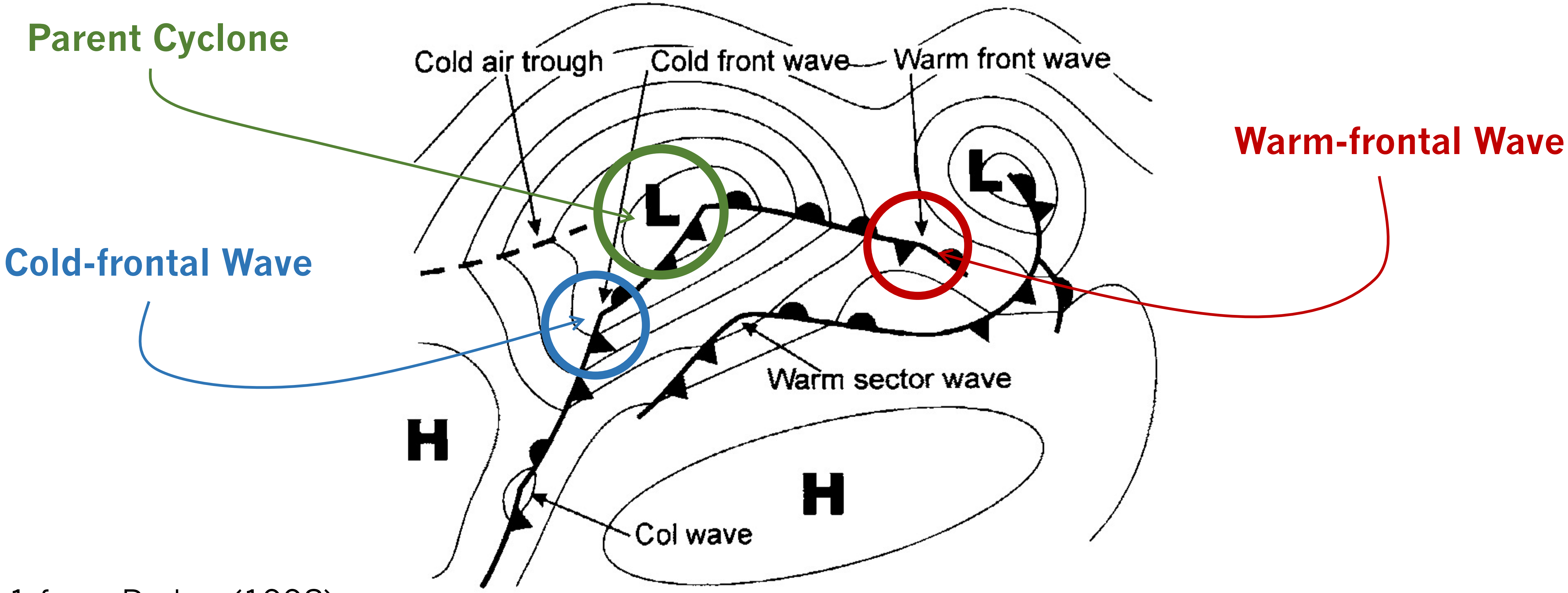


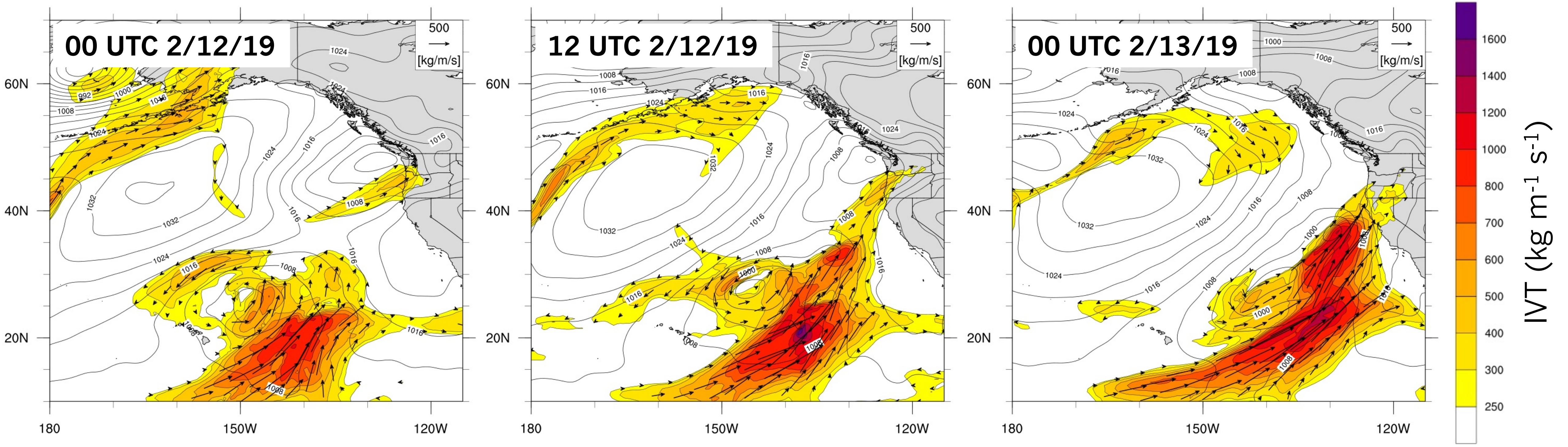
Fig. 1 from Parker (1998)

Mesoscale Frontal Waves & Atmospheric Rivers

- Mesoscale frontal waves (MFWs) are small-scale, wave features that form along frontal boundaries

- MFWs can modulate aspects of ARs (e.g., duration, strength, location, orientation), posing a difficult forecasting problem

GFS 0.5° Analysis



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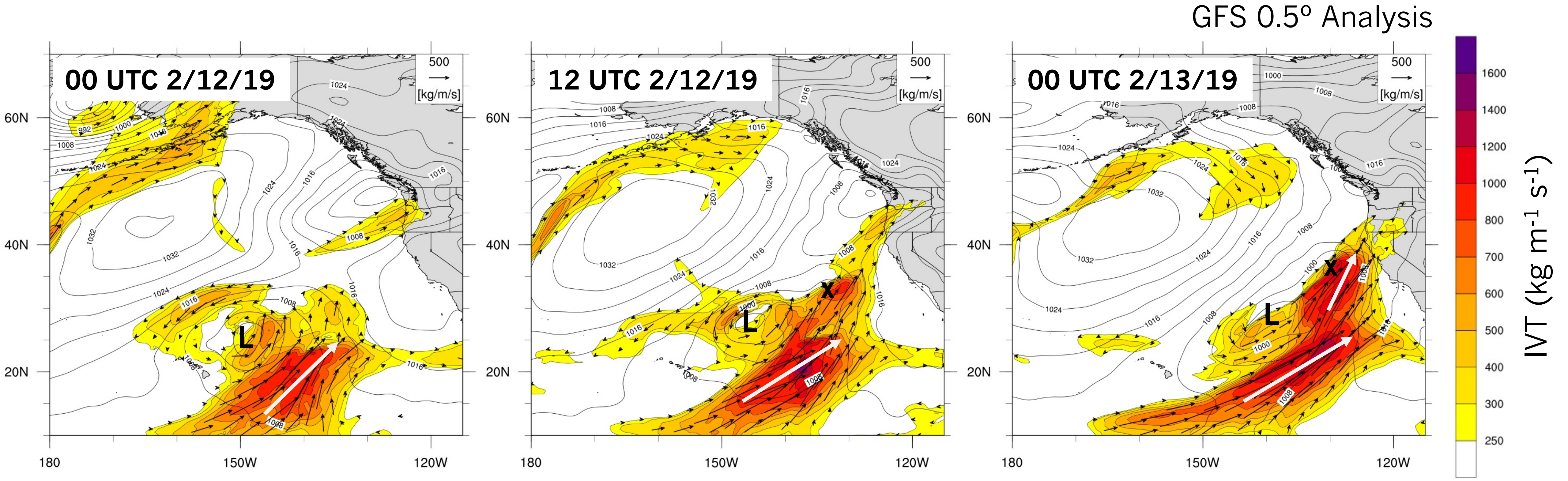
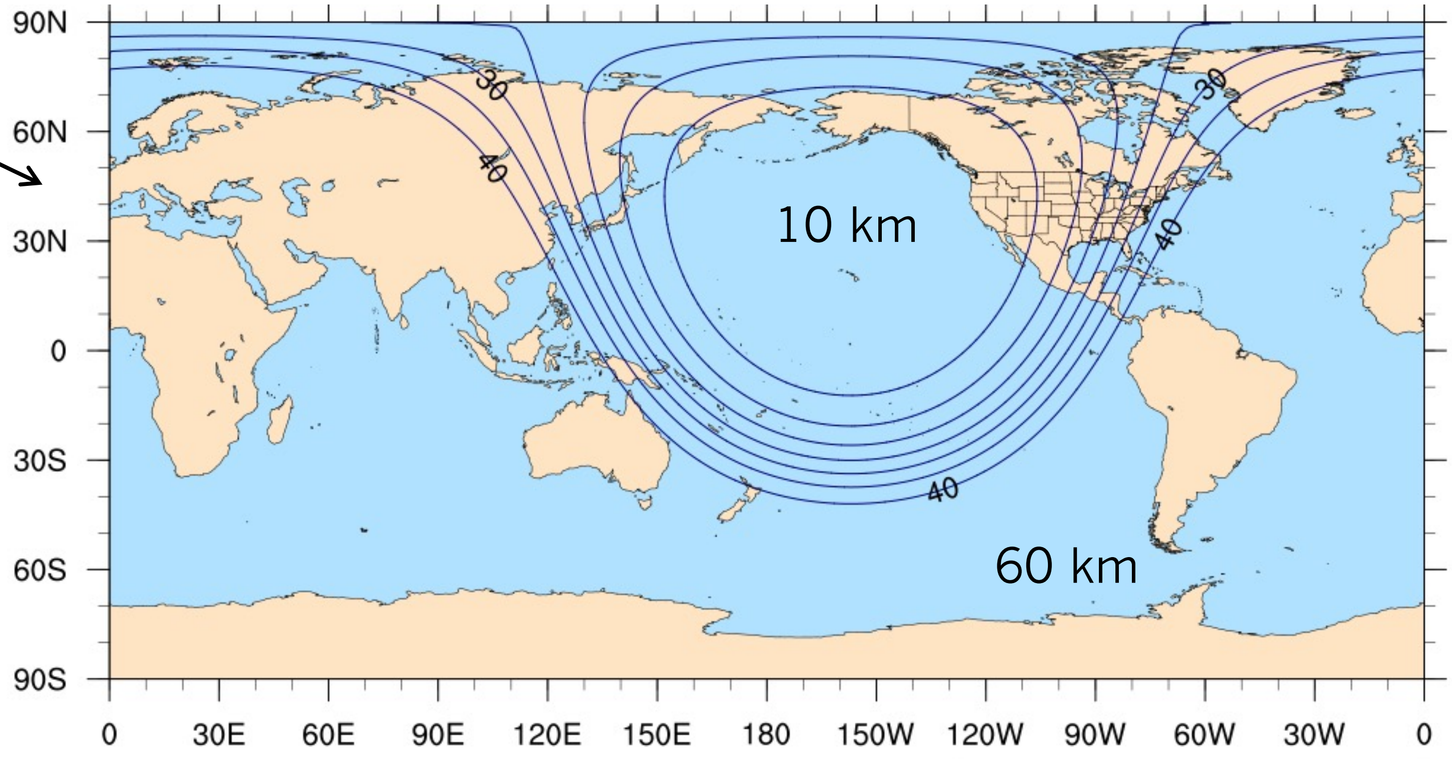


Mesoscale Frontal Waves & Atmospheric Rivers

- Mesoscale frontal waves (MFWs) are small-scale, wave features that form along frontal boundaries
- MFWs can modulate aspects of ARs (e.g., duration, strength, location, orientation), posing a difficult forecasting problem
- Several studies examining secondary cyclogenesis in North Atlantic, but more to learn about relationship between MFW formation/evolution and ARs
- **Goal:** quantify the impact of MFWs and diabatic processes on the ARs and associated landfalling precipitation
  - Cases: December 2014 (significant upper-air support) **vs.** January 2010 (primarily diabatically influenced)
  - Method: modeling case studies with and without latent heating

Model for Prediction Across Scales (MPAS)

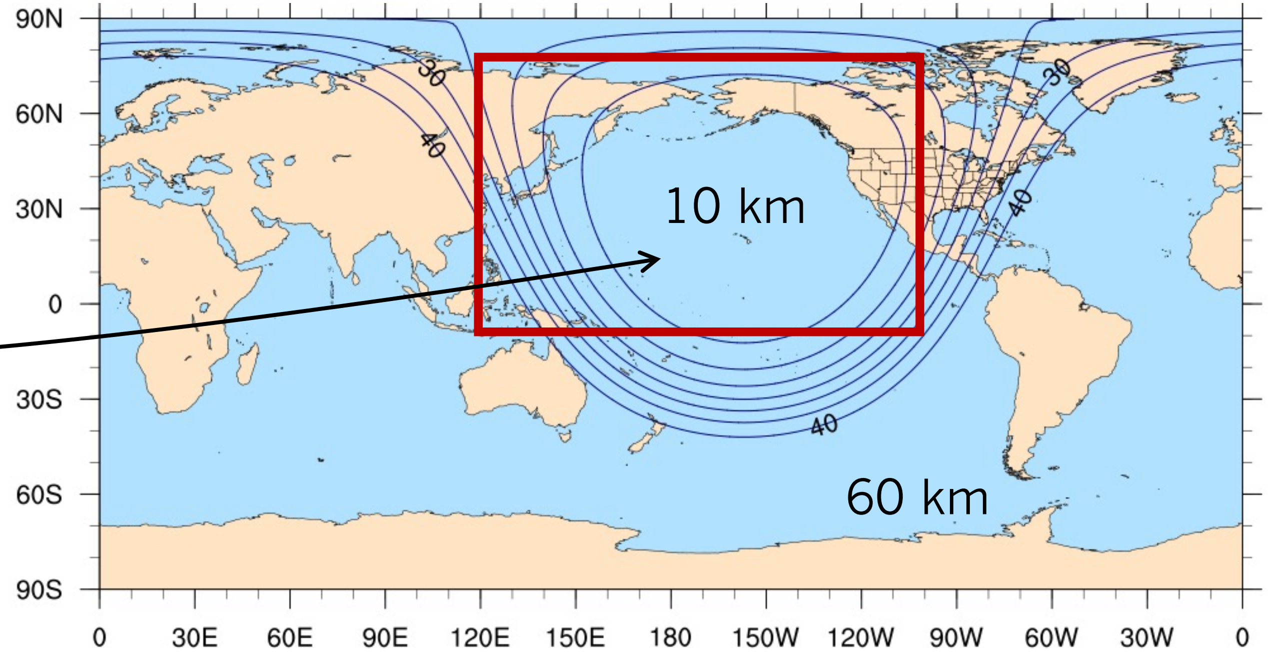
- MPAS v. 7.0
- Variable resolution mesh: 10 km centered on 30°N, 157°W, expanding to 60 km



- Physics choices:
  - Kain-Fritsch (convective)
  - WSM6 (microphysics)
  - RRTMG (radiation)
  - YSU (PBL)
  - Noah (LSM)
  - M-O (surface layer)

Model for Prediction Across Scales (MPAS)

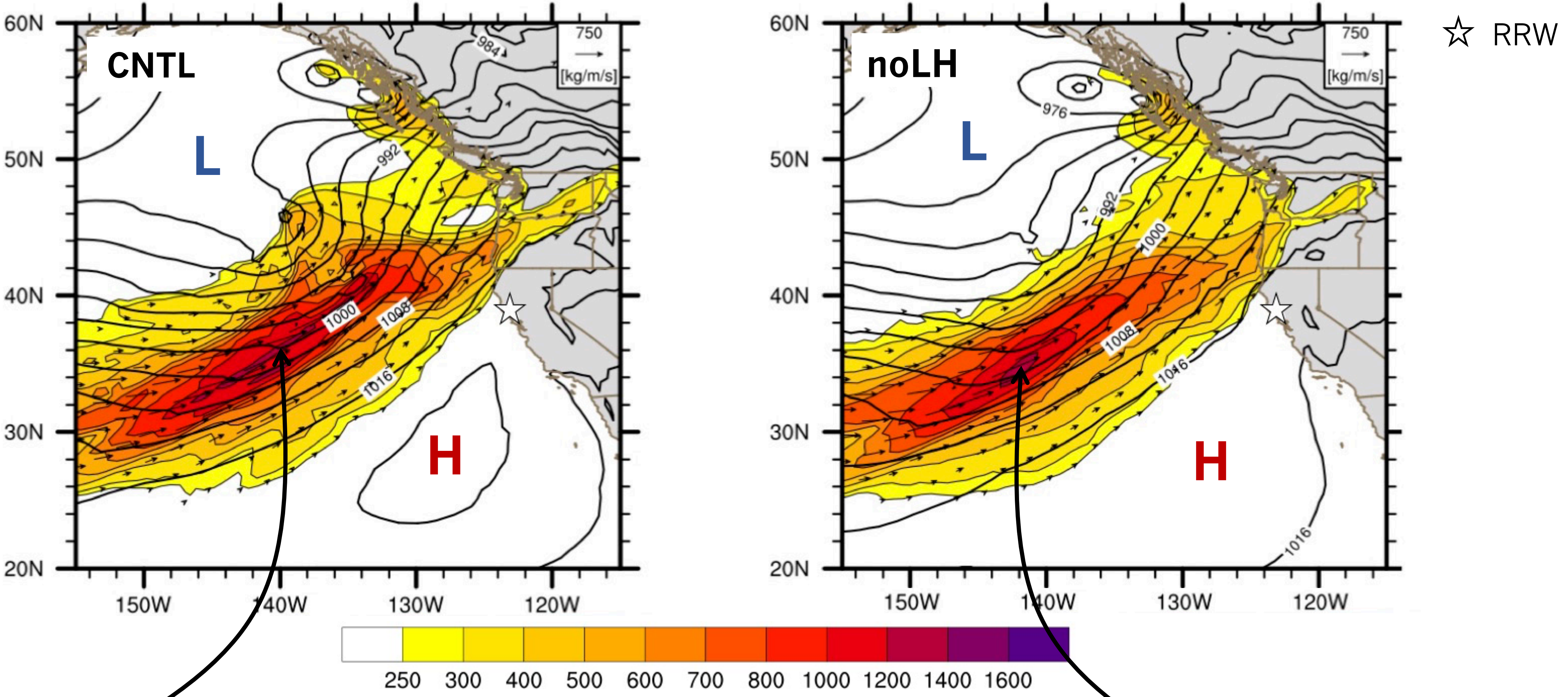
- Initial conditions/SSTs
  - ERA5 reanalysis, SSTs updated every day
  - Simulations initialized 48-h prior to MFW formation
- Output is post-processed:
  - 3-D variables interpolated to 42 pressure levels
  - All variables interpolated to 0.1°x0.1° lat-lon grid
- Experiments:
  - Control (CNTL)
  - No latent heating (noLH)*
    - Diabatic tendencies in MP, CP, and PBL schemes turned off



*Thanks to Laura Fowler (NCAR) for this configuration

00 UTC 10 December 2014

MPAS Simulations

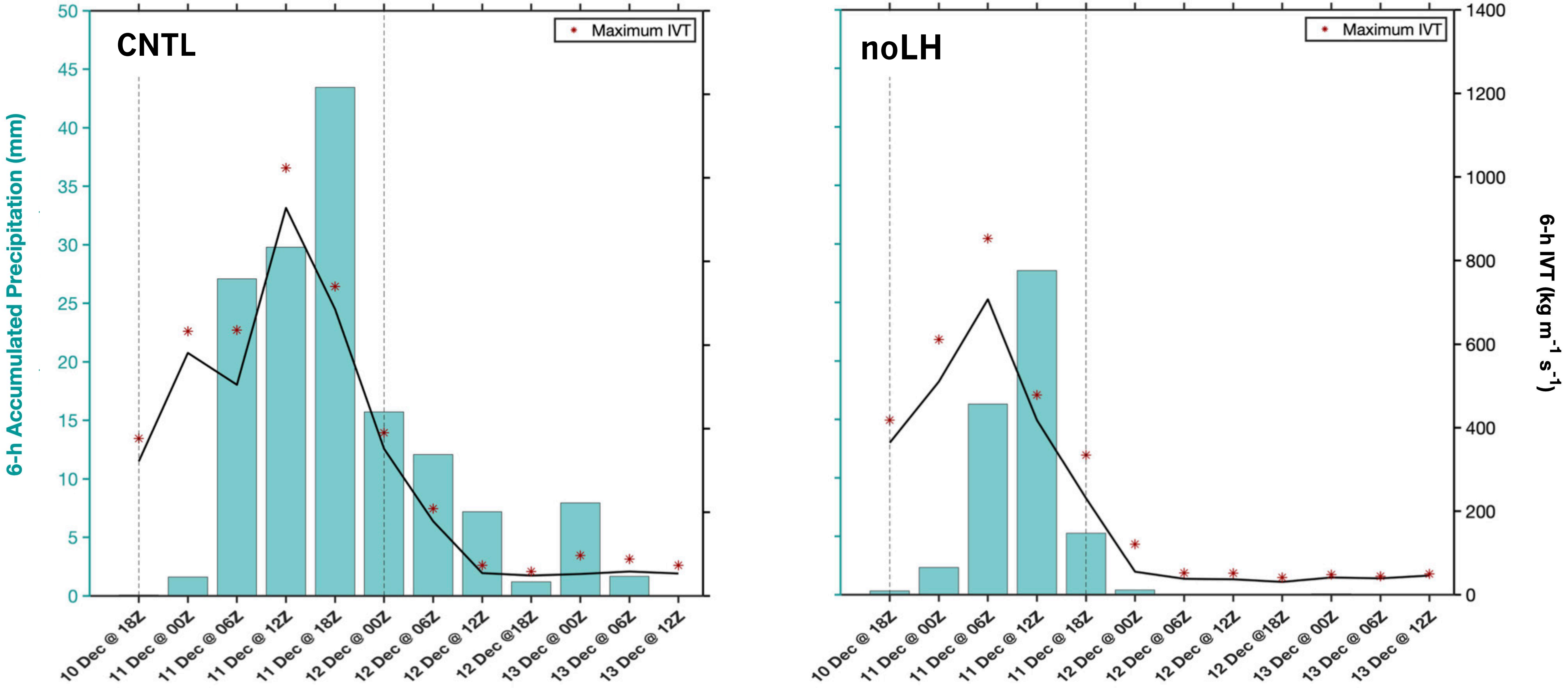


~1200–1400 kg m^{-1} s^{-1}

~1200–1400 kg m^{-1} s^{-1}

December 2014: Russian River Watershed Impacts

MPAS Simulations



6-h mean areal precipitation

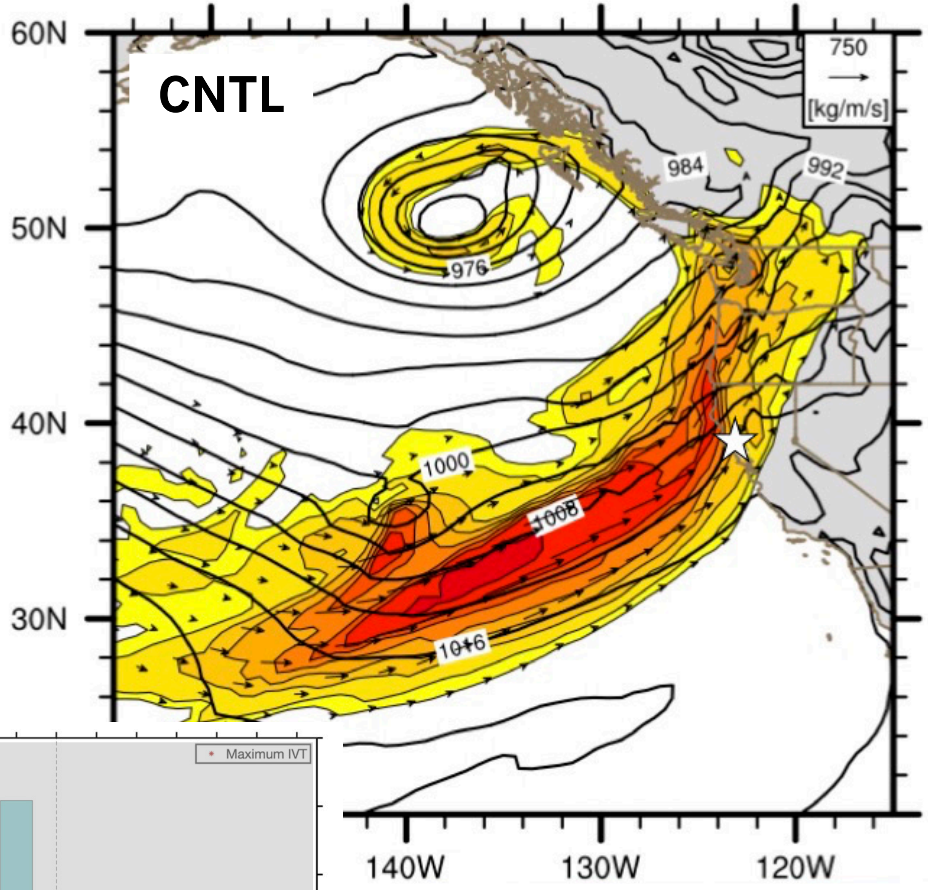
6-h mean areal IVT

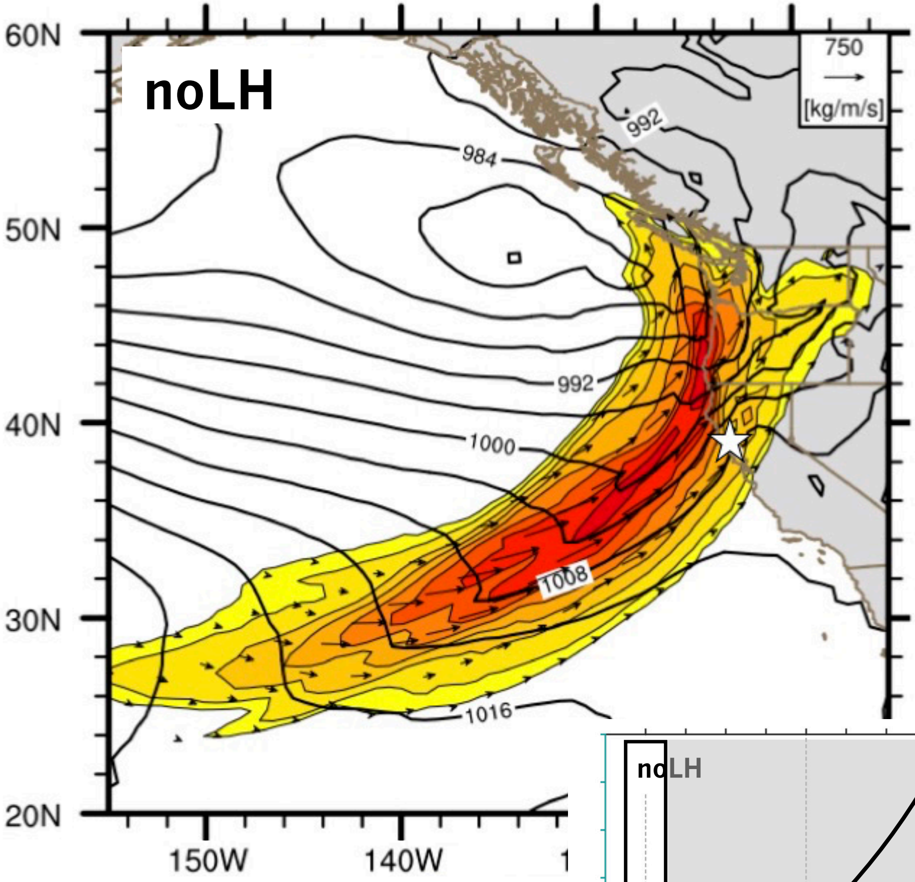
* Maximum IVT

21 UTC 10 December 2014

MPAS Simulations

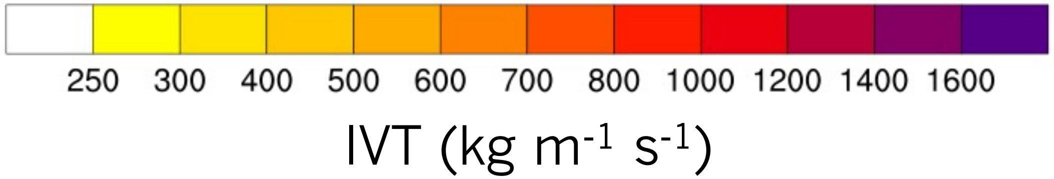
☆ RRW

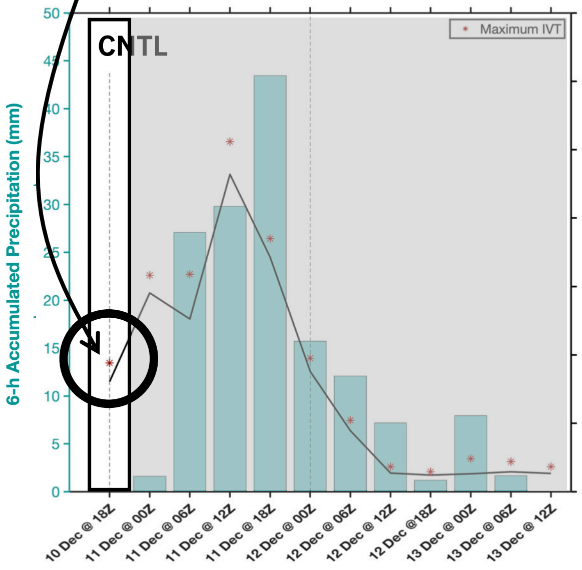


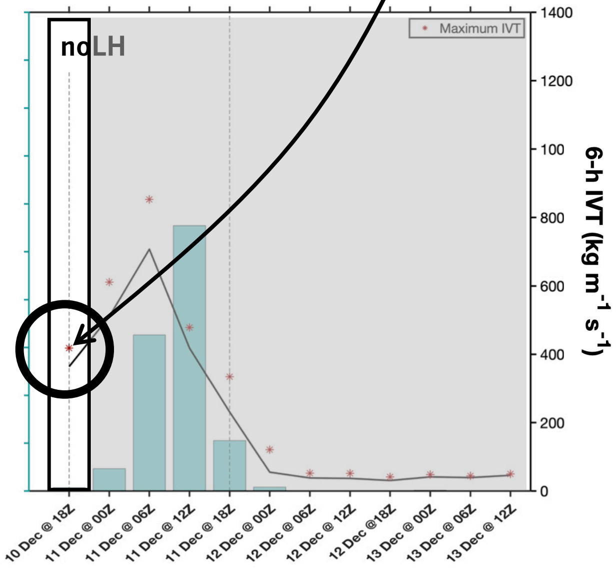


Max IVT:
~380
kg m⁻¹ s⁻¹

Max IVT:
~415
kg m⁻¹ s⁻¹



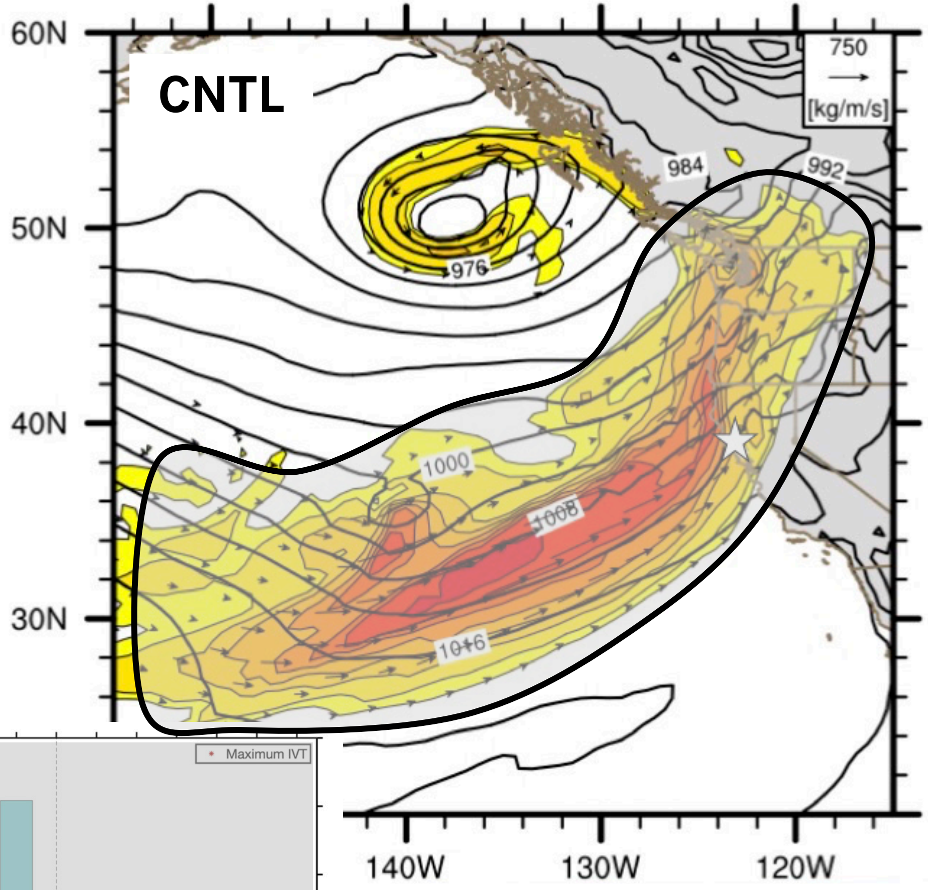


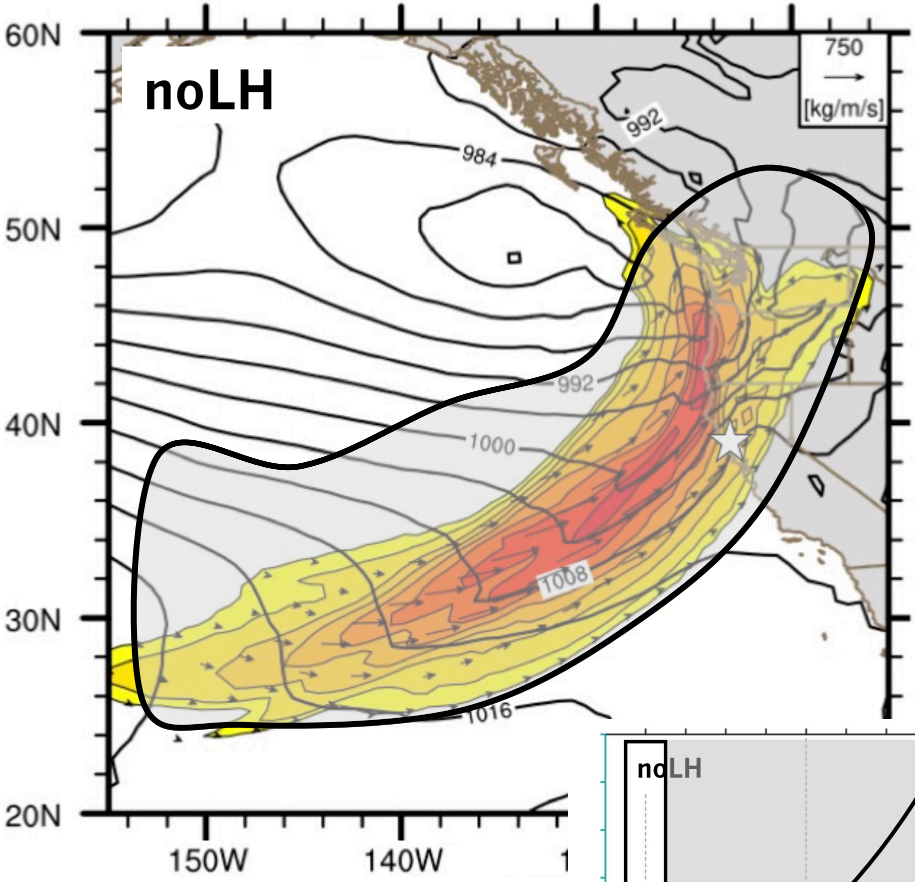


21 UTC 10 December 2014

MPAS Simulations

☆ RRW





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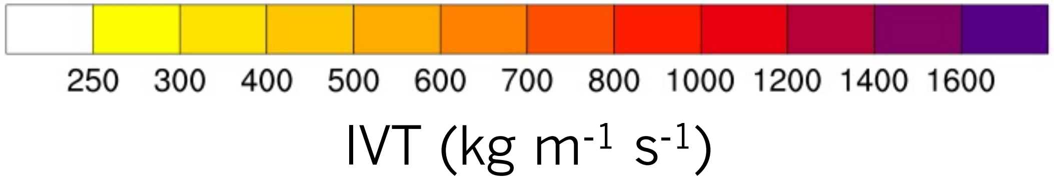

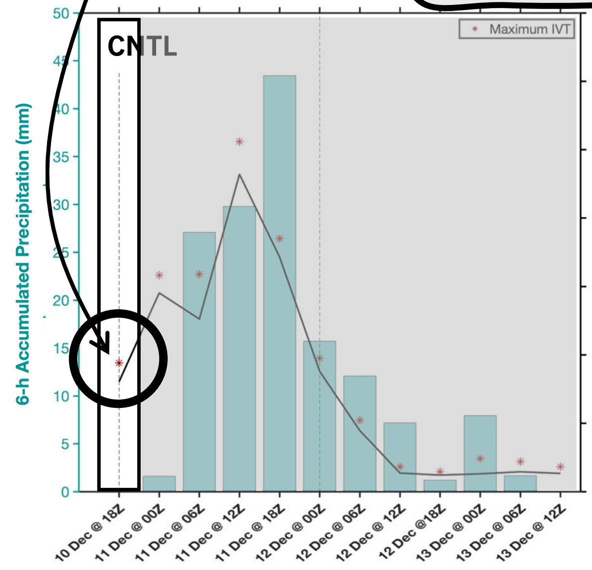

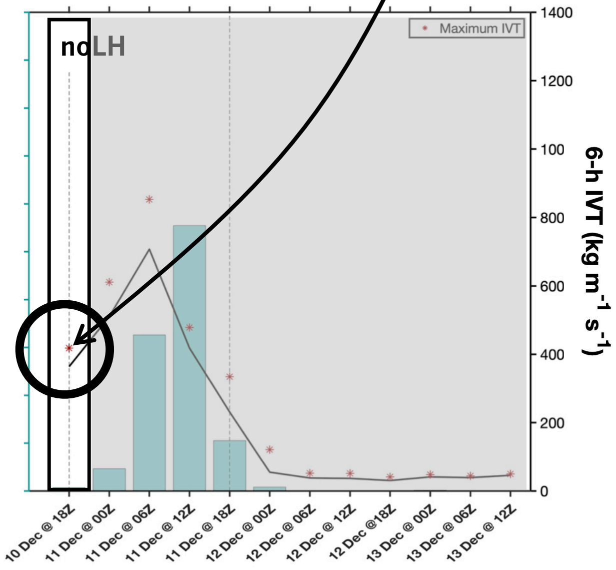

21 UTC 10 December 2014

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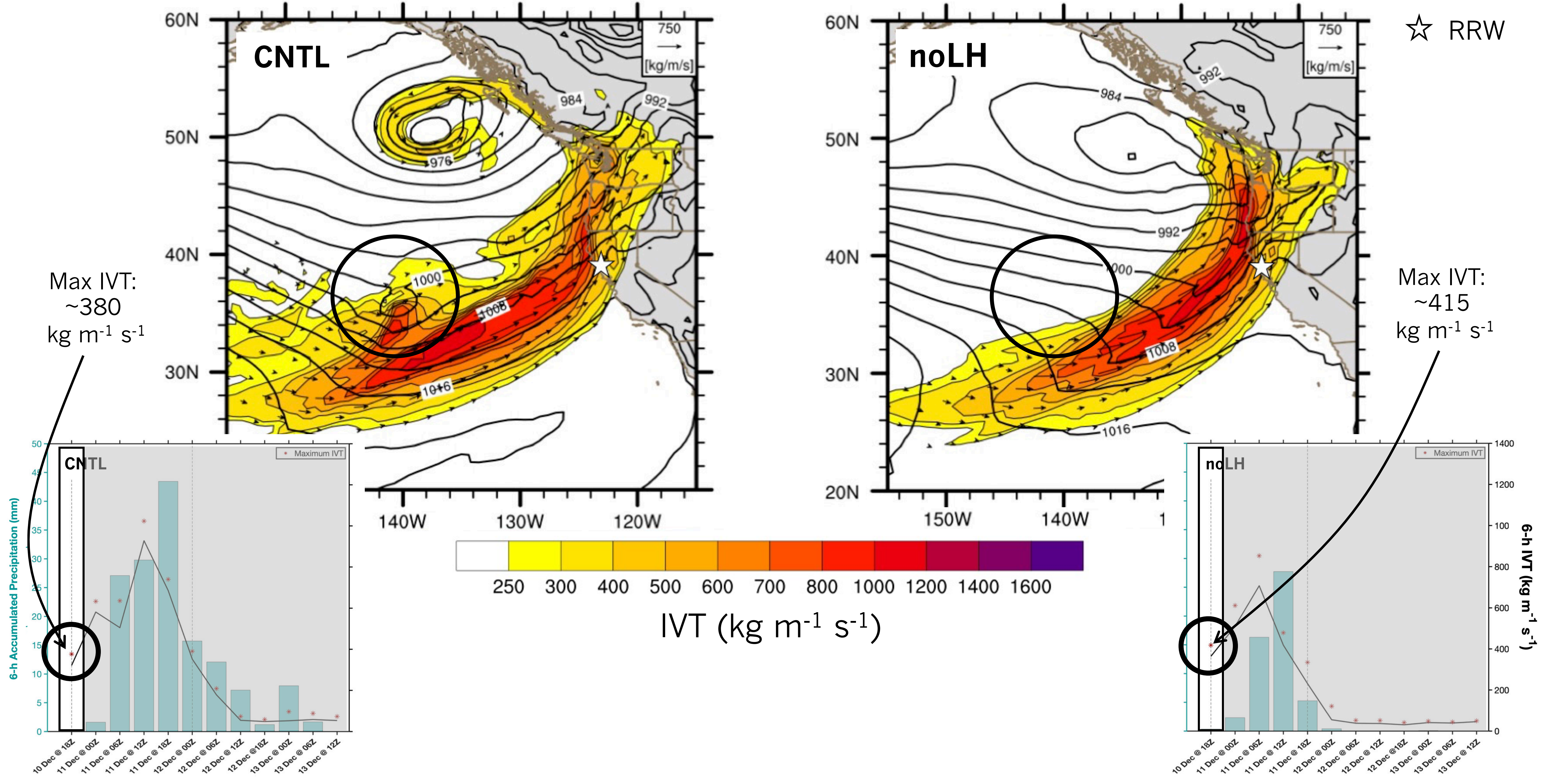
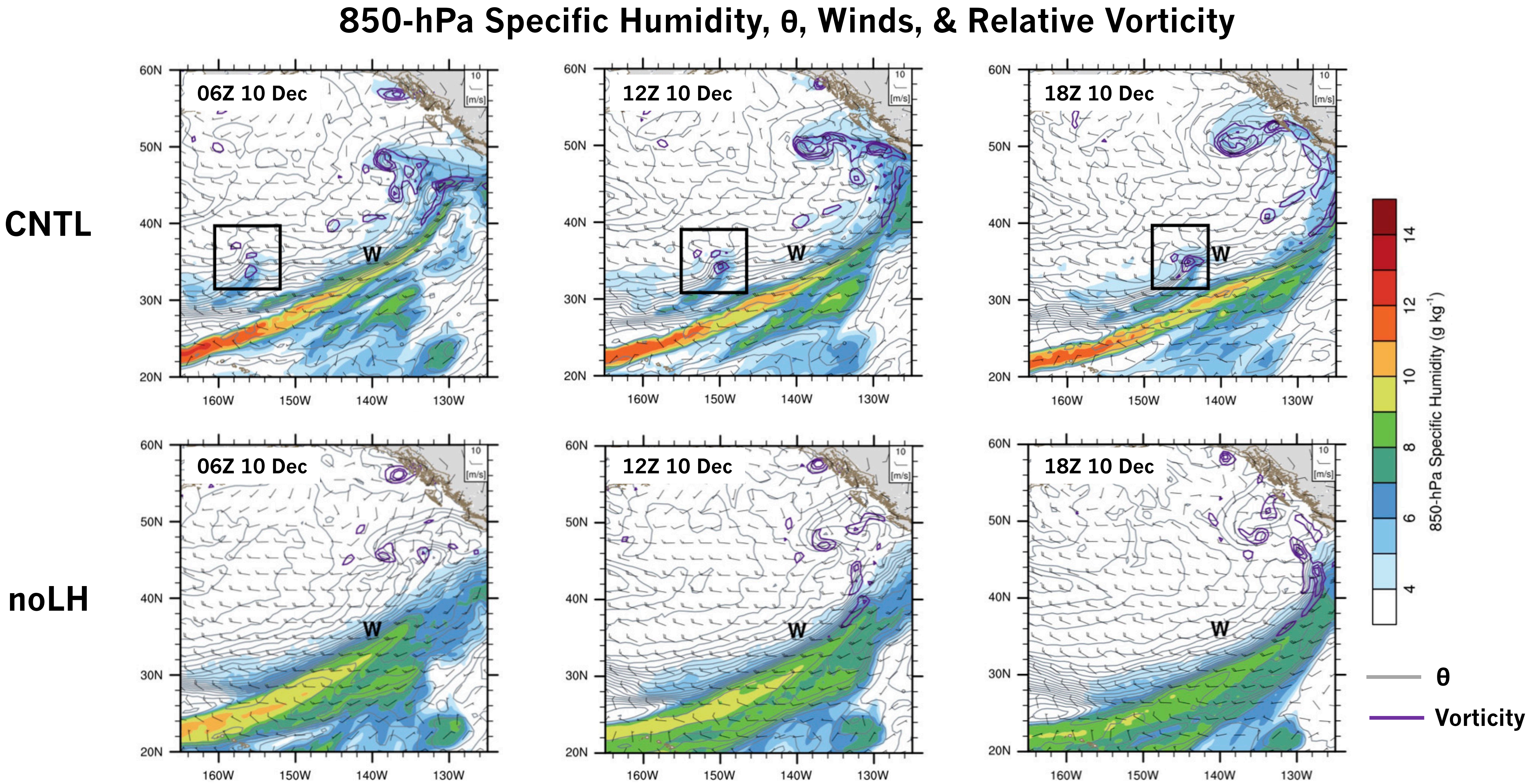
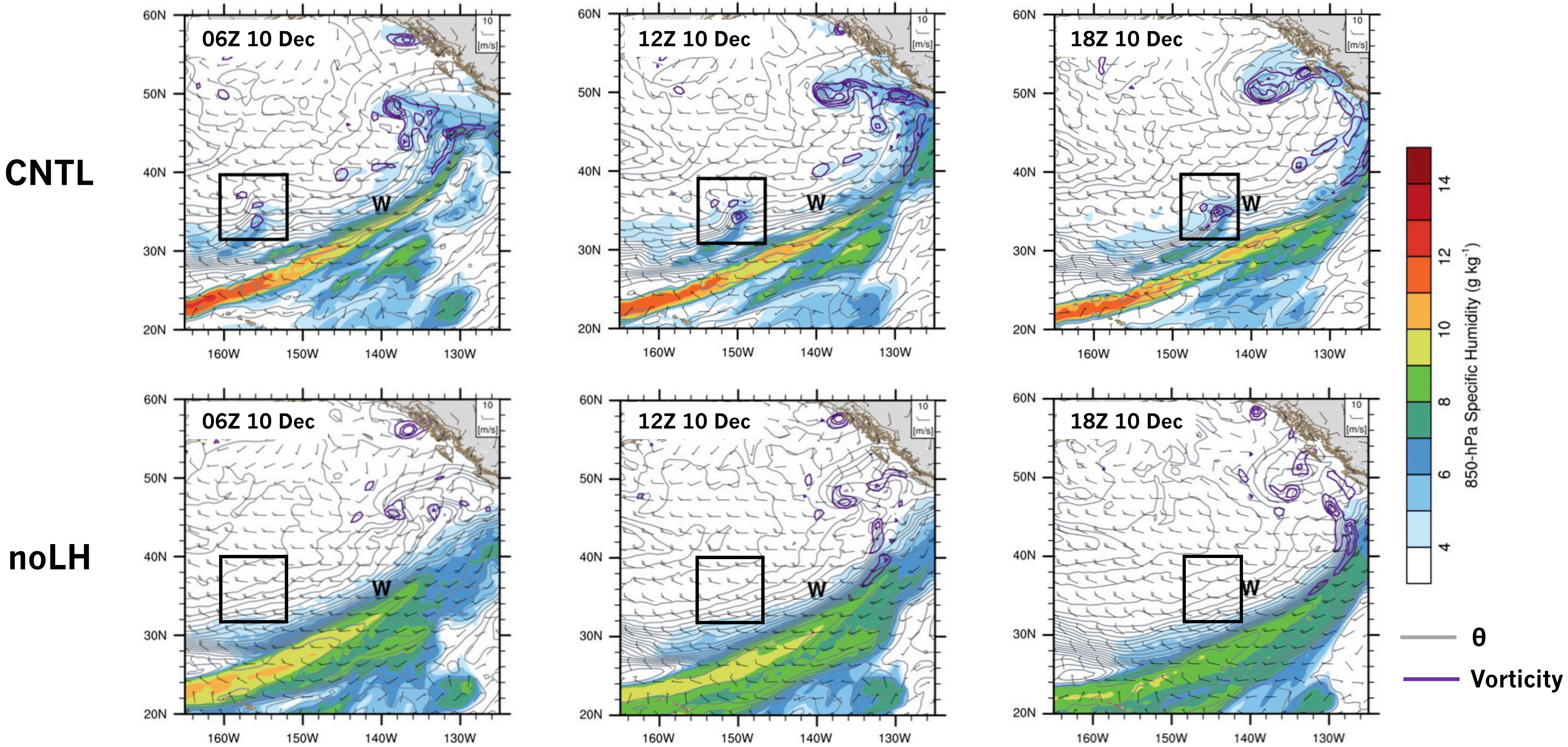


Mesoscale Frontal Wave Formation



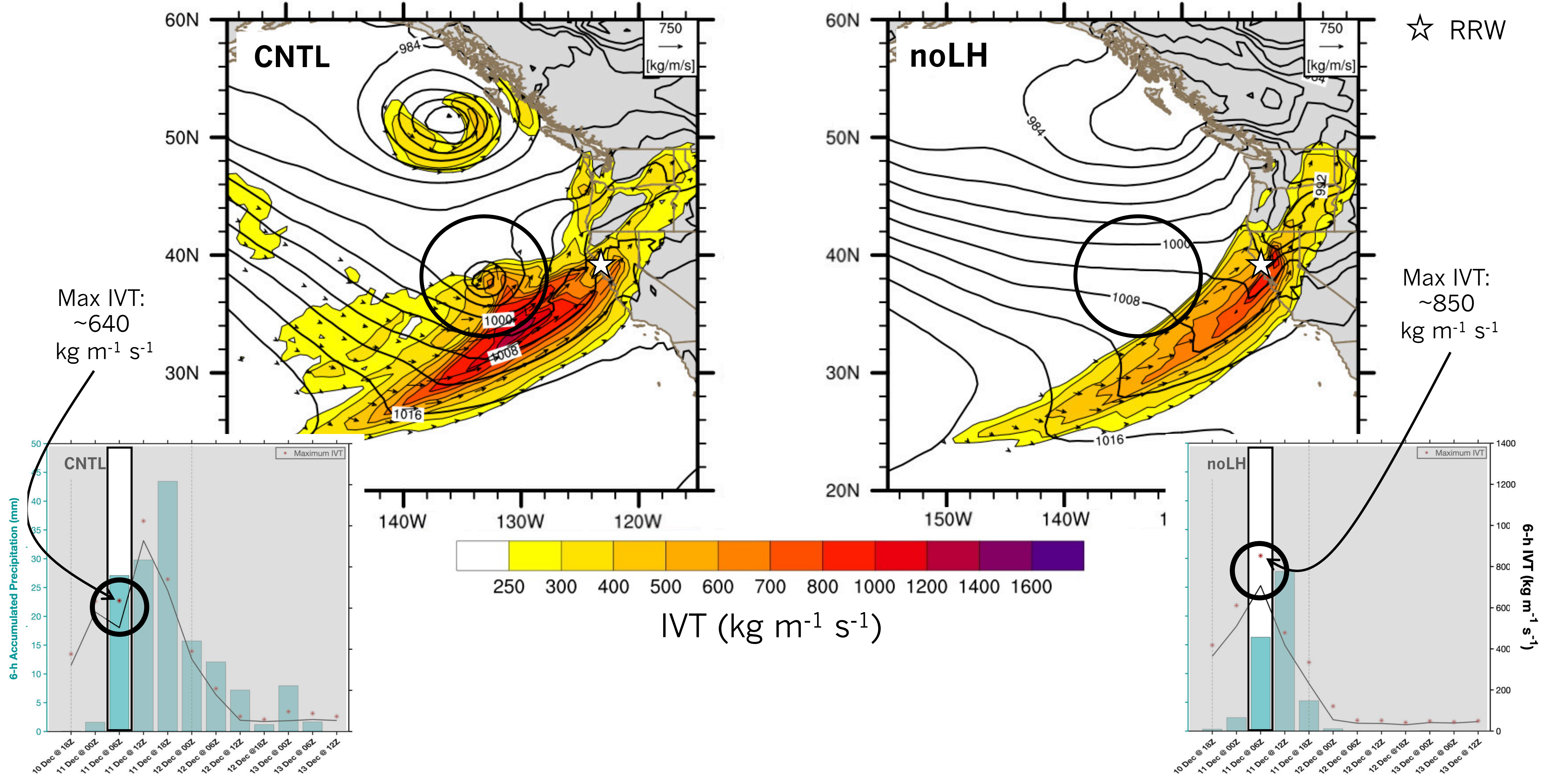
Mesoscale Frontal Wave Formation

850-hPa Specific Humidity, θ, Winds, & Relative Vorticity



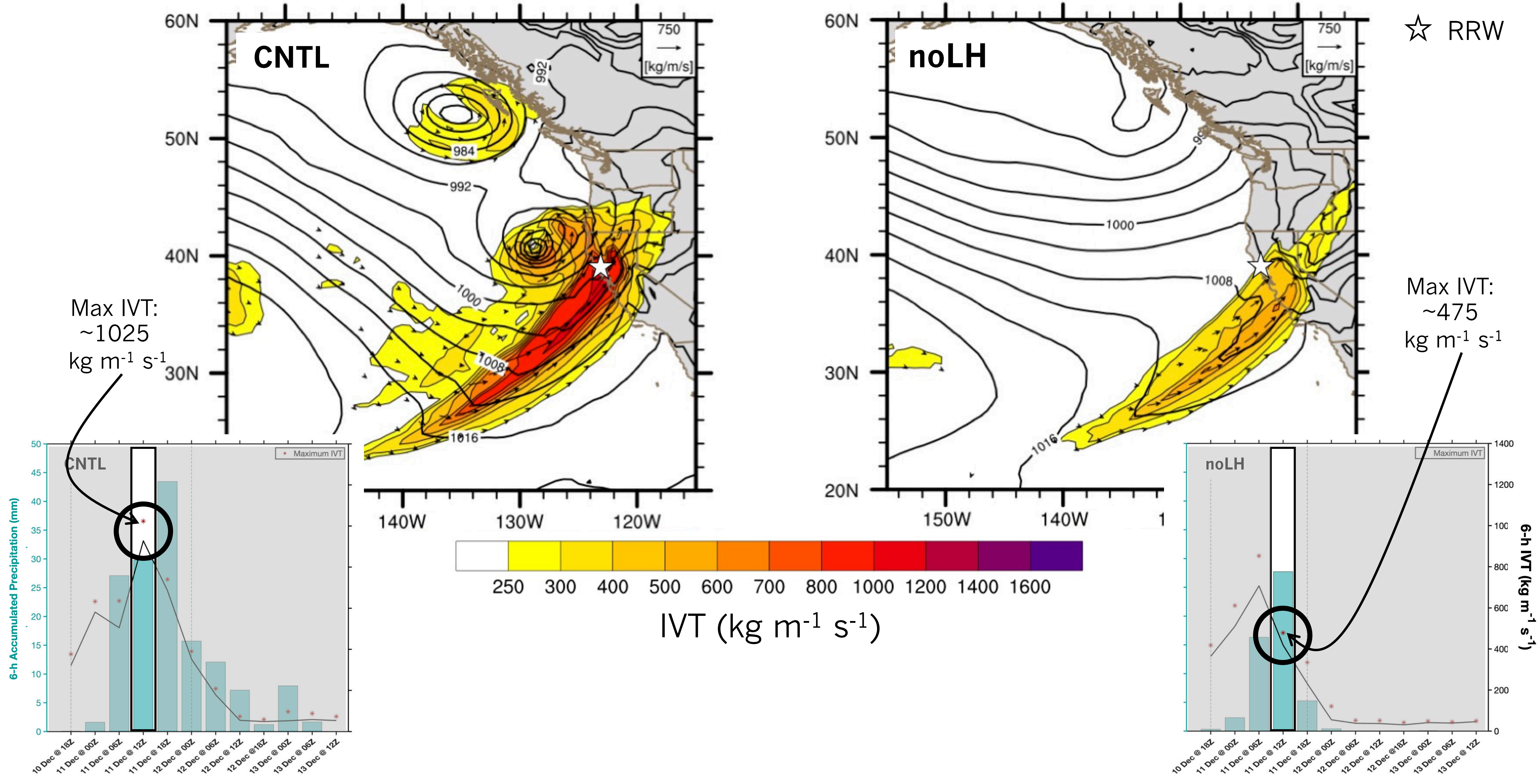
06 UTC 11 December 2014

MPAS Simulations



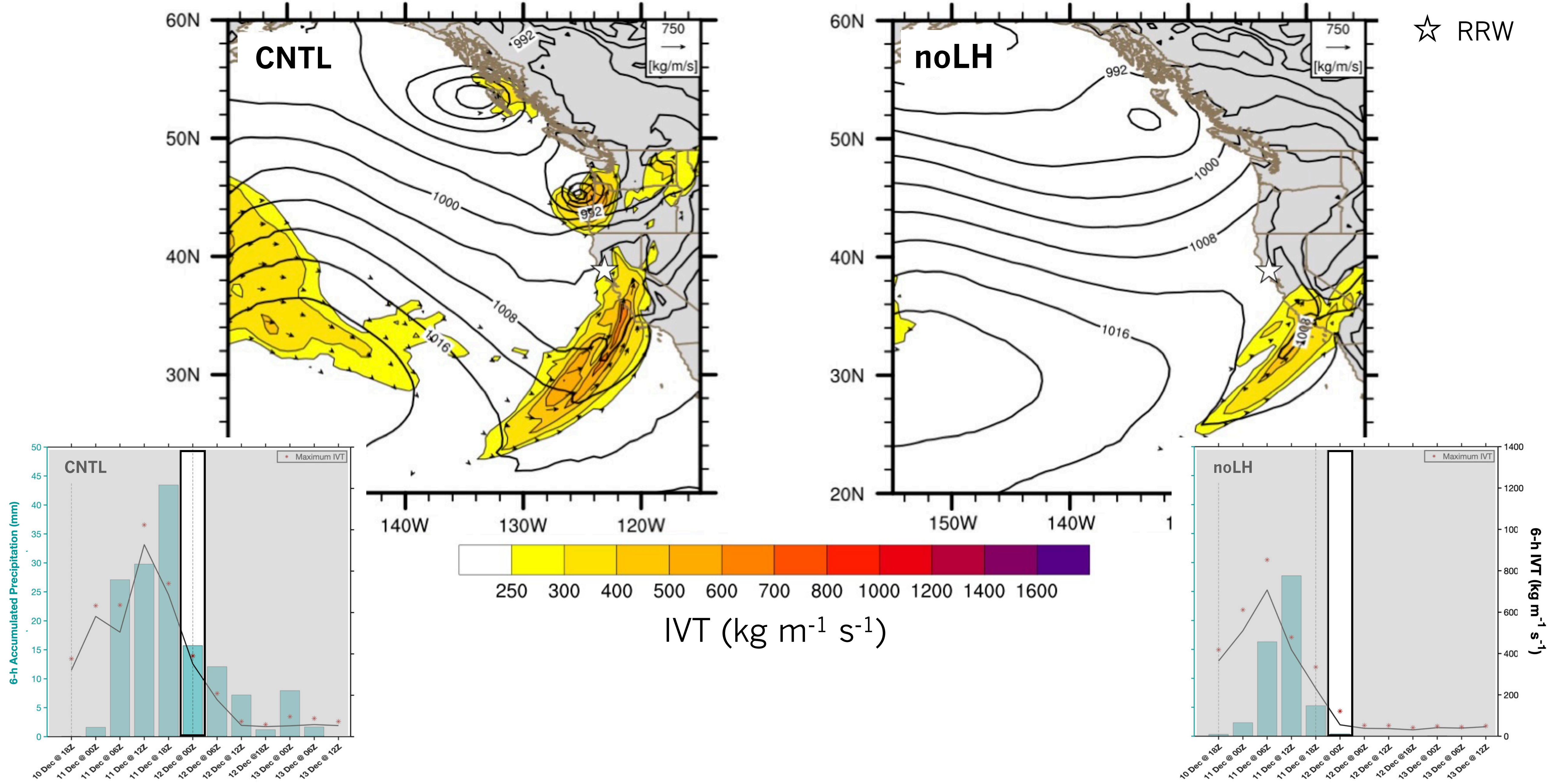
12 UTC 11 December 2014

MPAS Simulations



00 UTC 12 December 2014

MPAS Simulations



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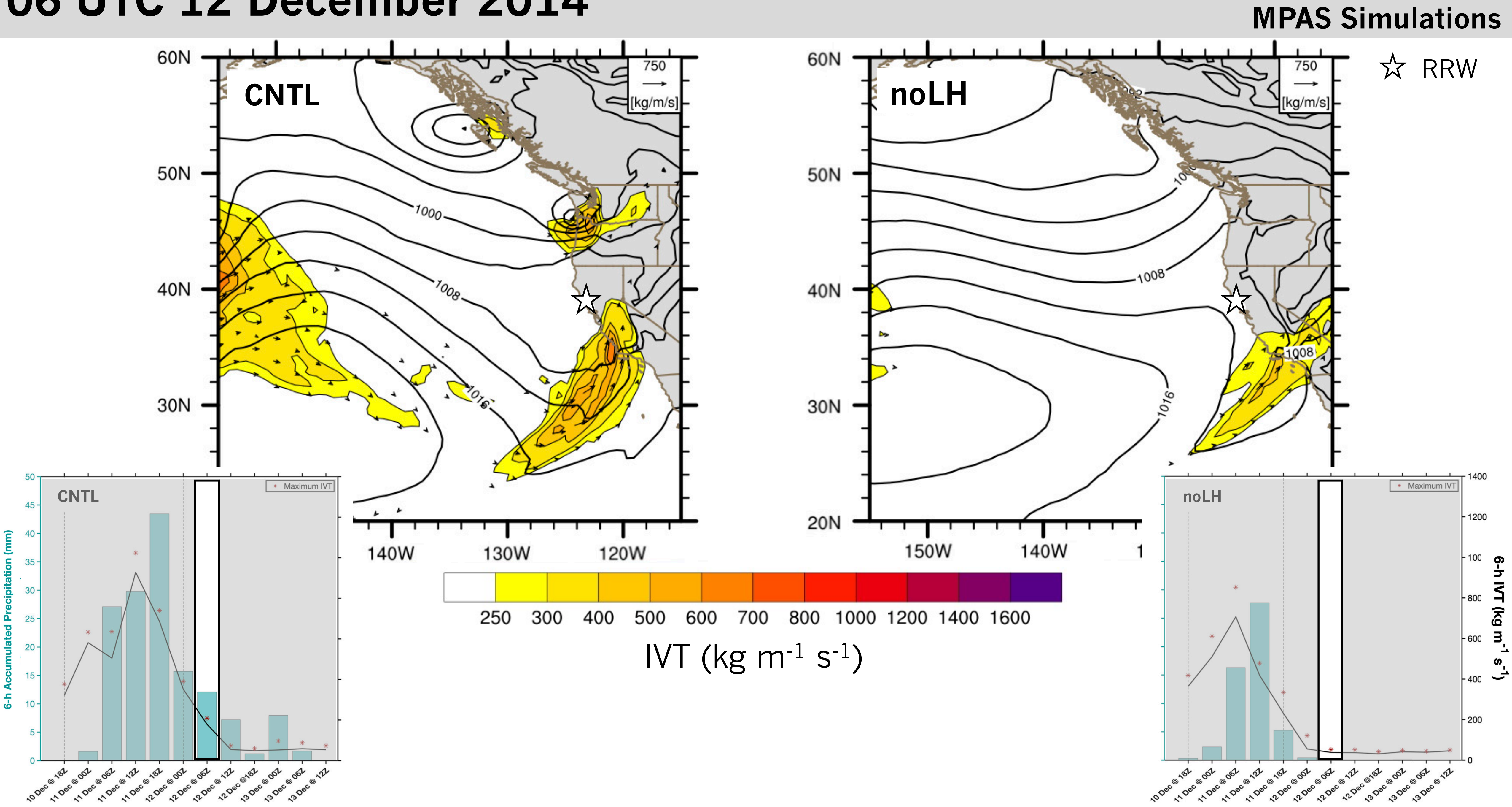
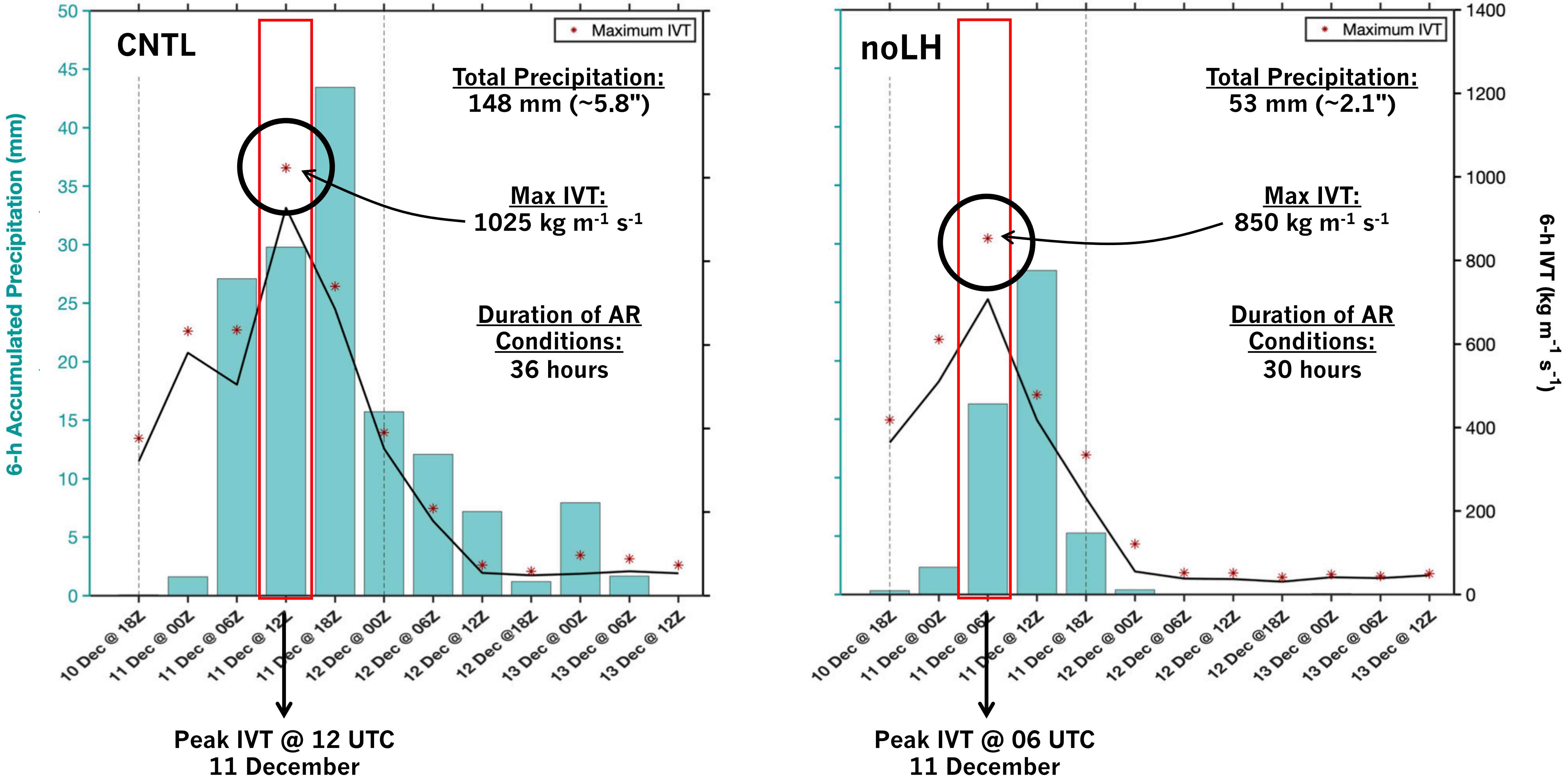


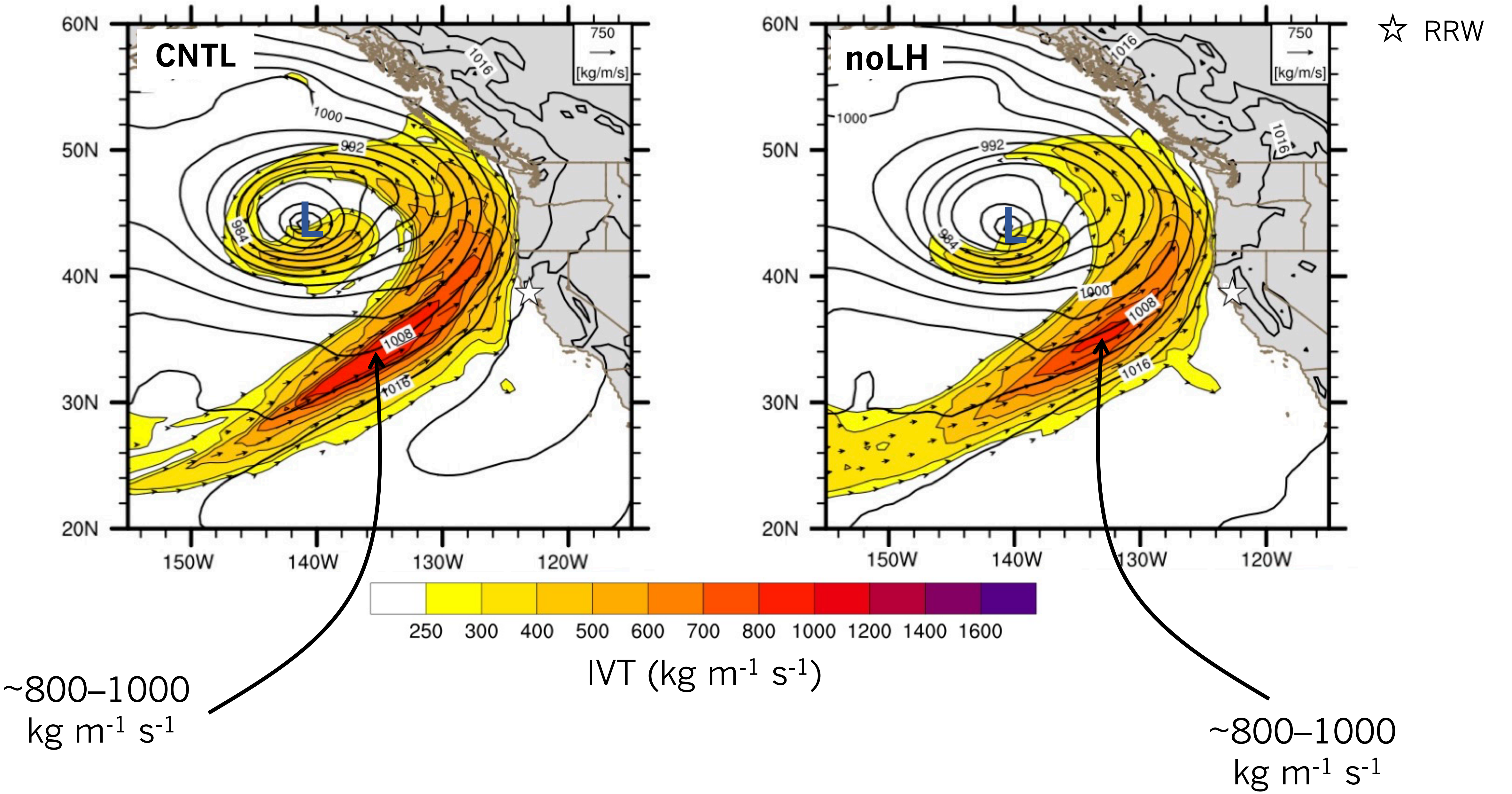
December 2014: Russian River Watershed Impacts

MPAS Simulations



12 UTC 24 January 2010

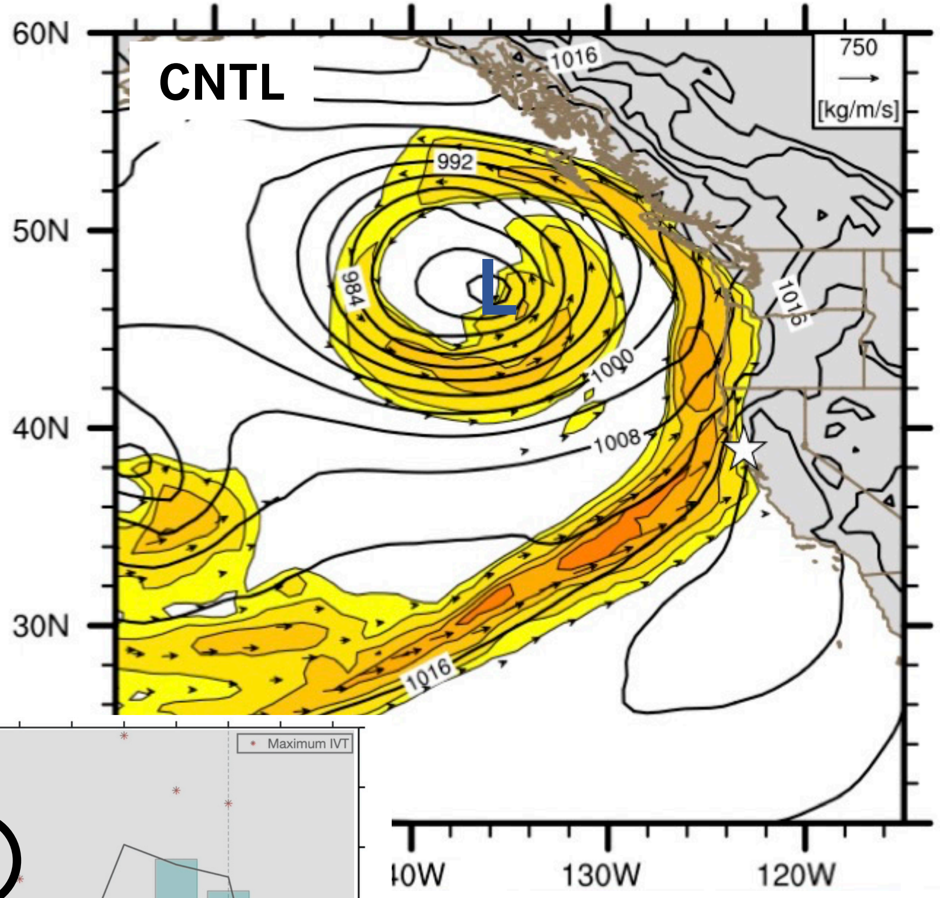
MPAS Simulations

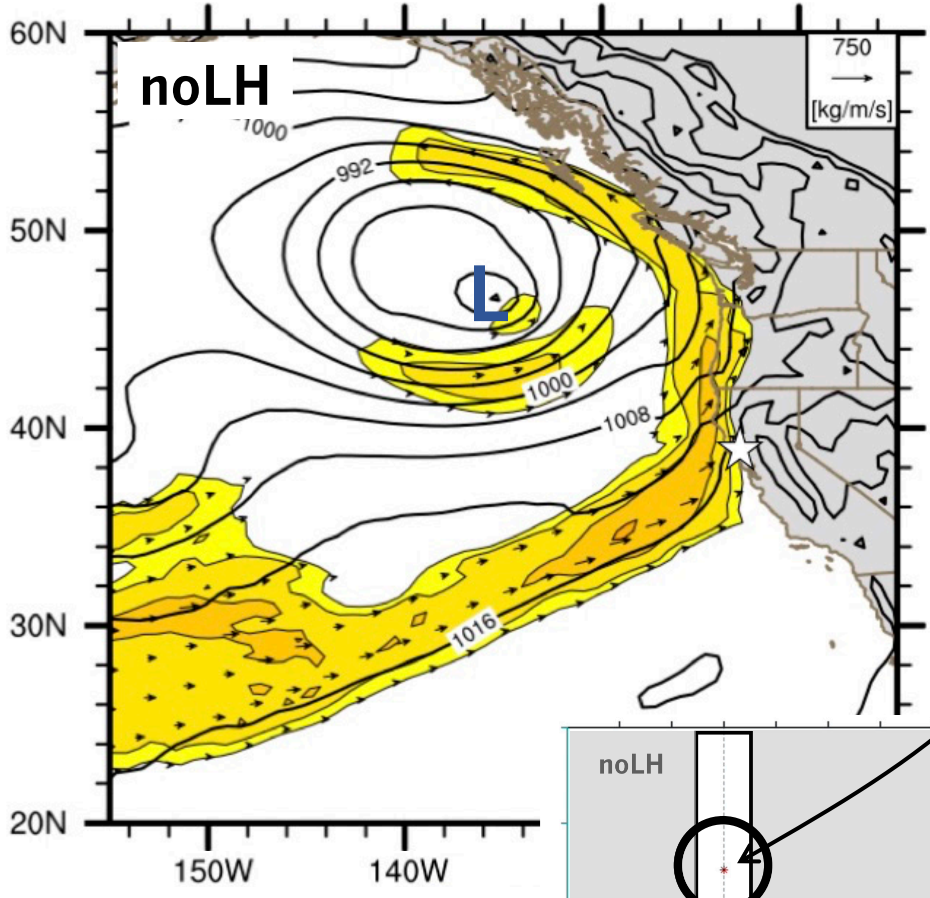


00 UTC 25 January 2010

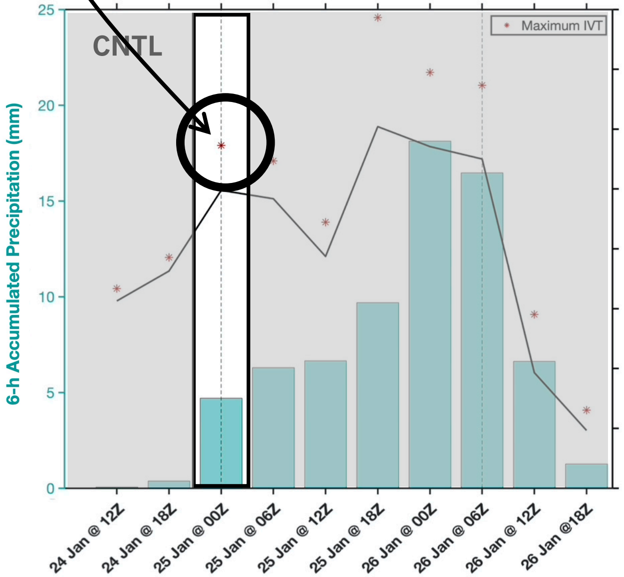
MPAS Simulations

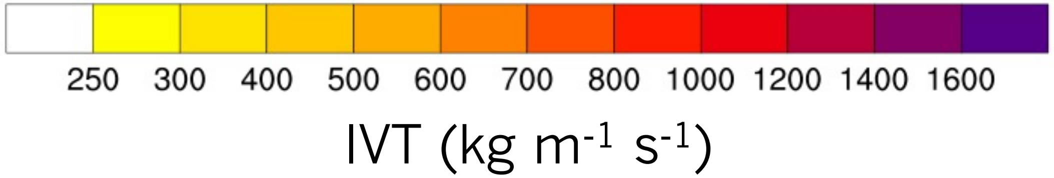
☆ RRW





Max IVT: ~285 kg m^{-1} s^{-1}





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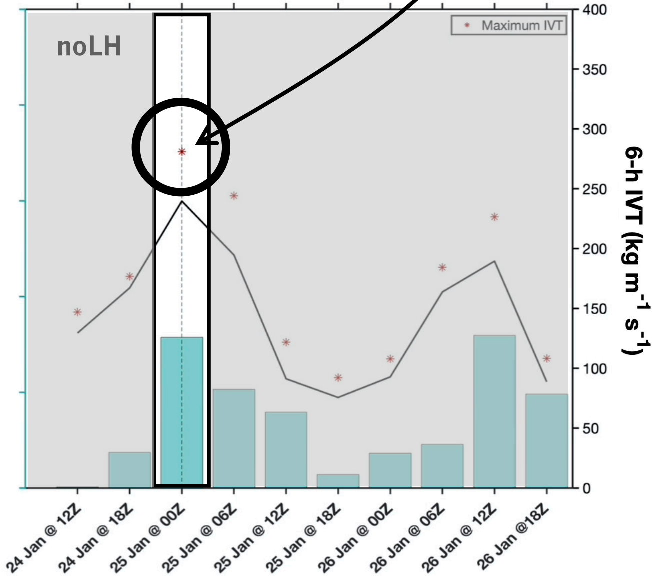

00 UTC 25 January 2010

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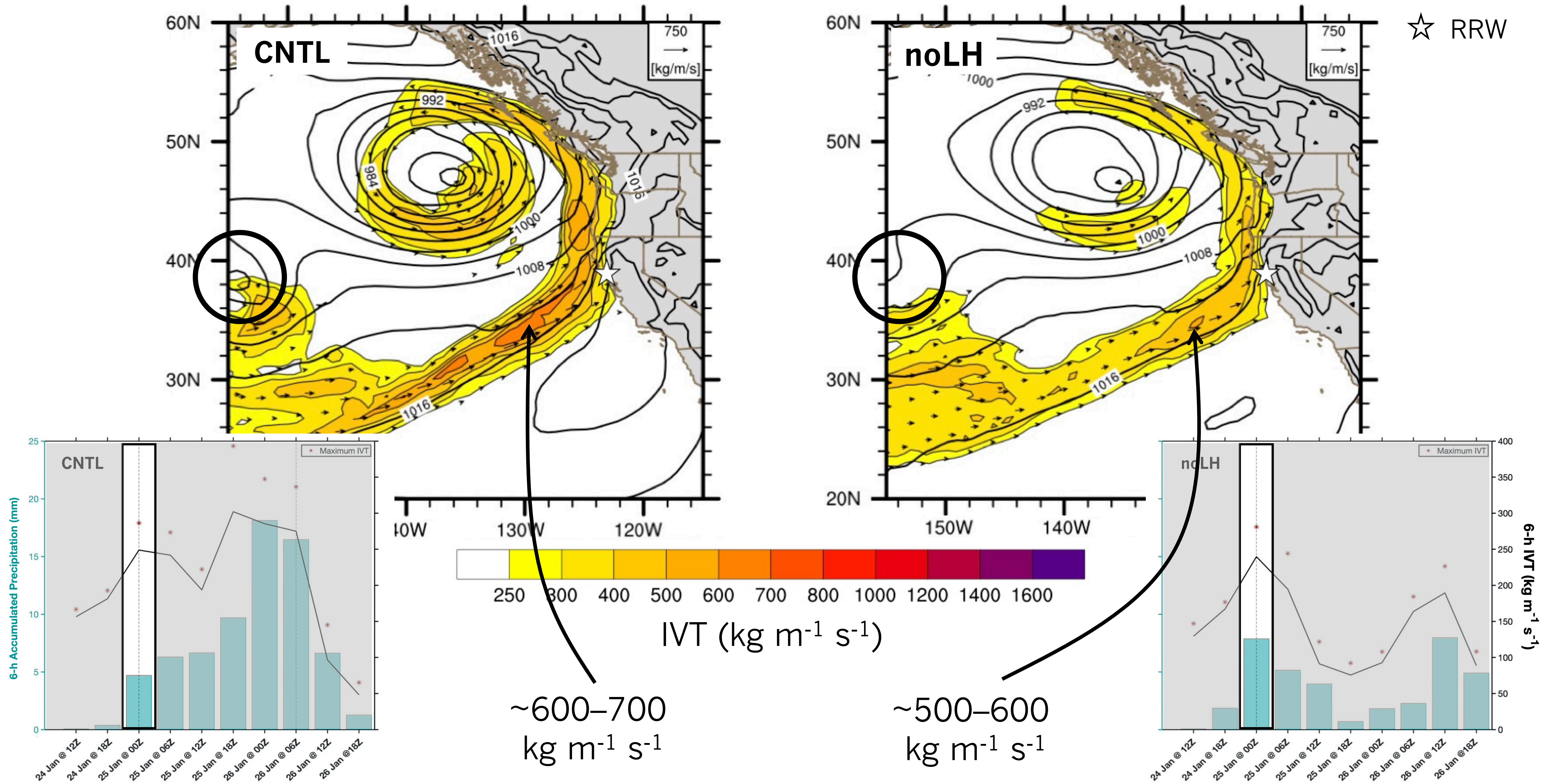

12 UTC 25 January 2010

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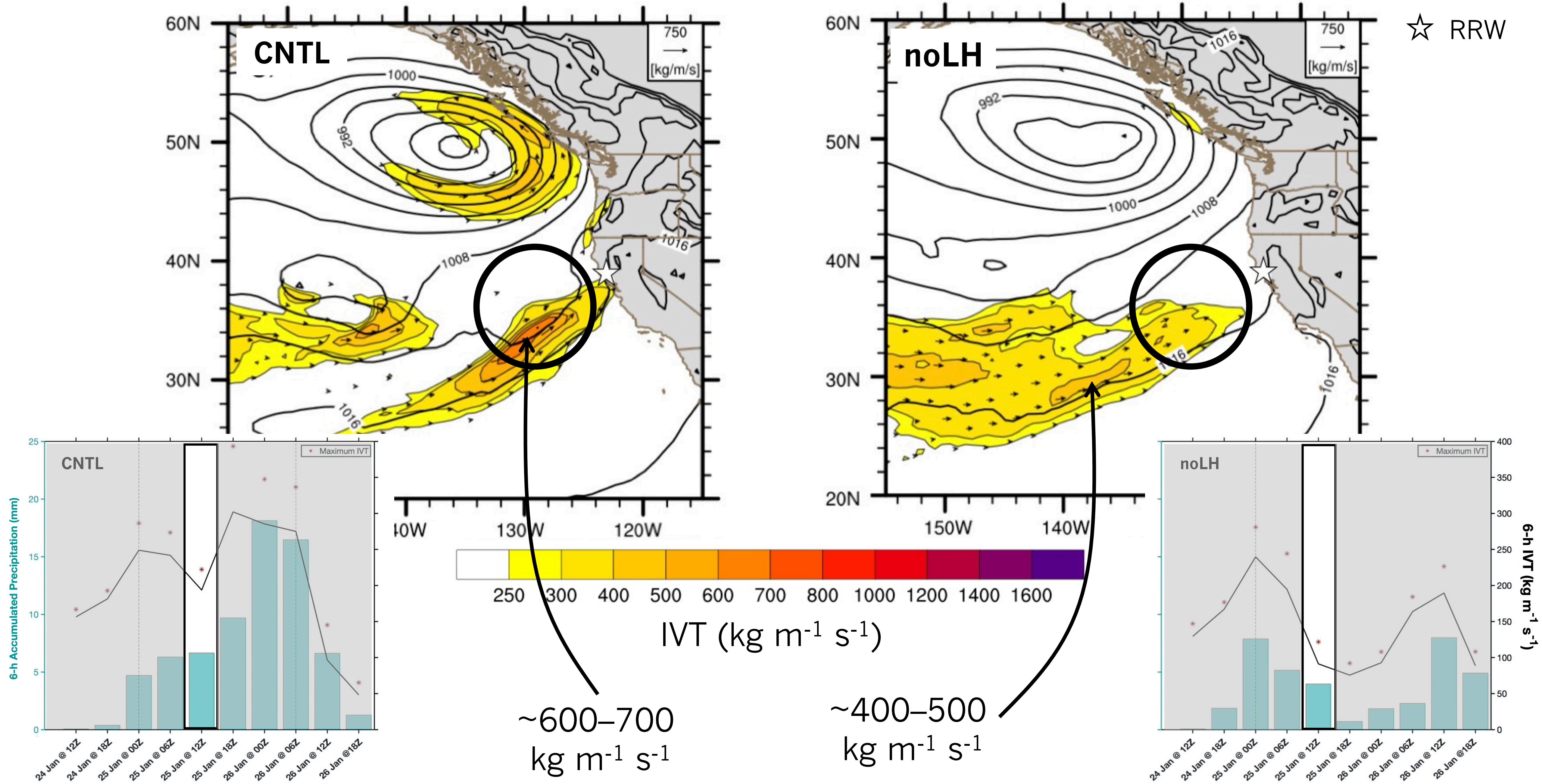
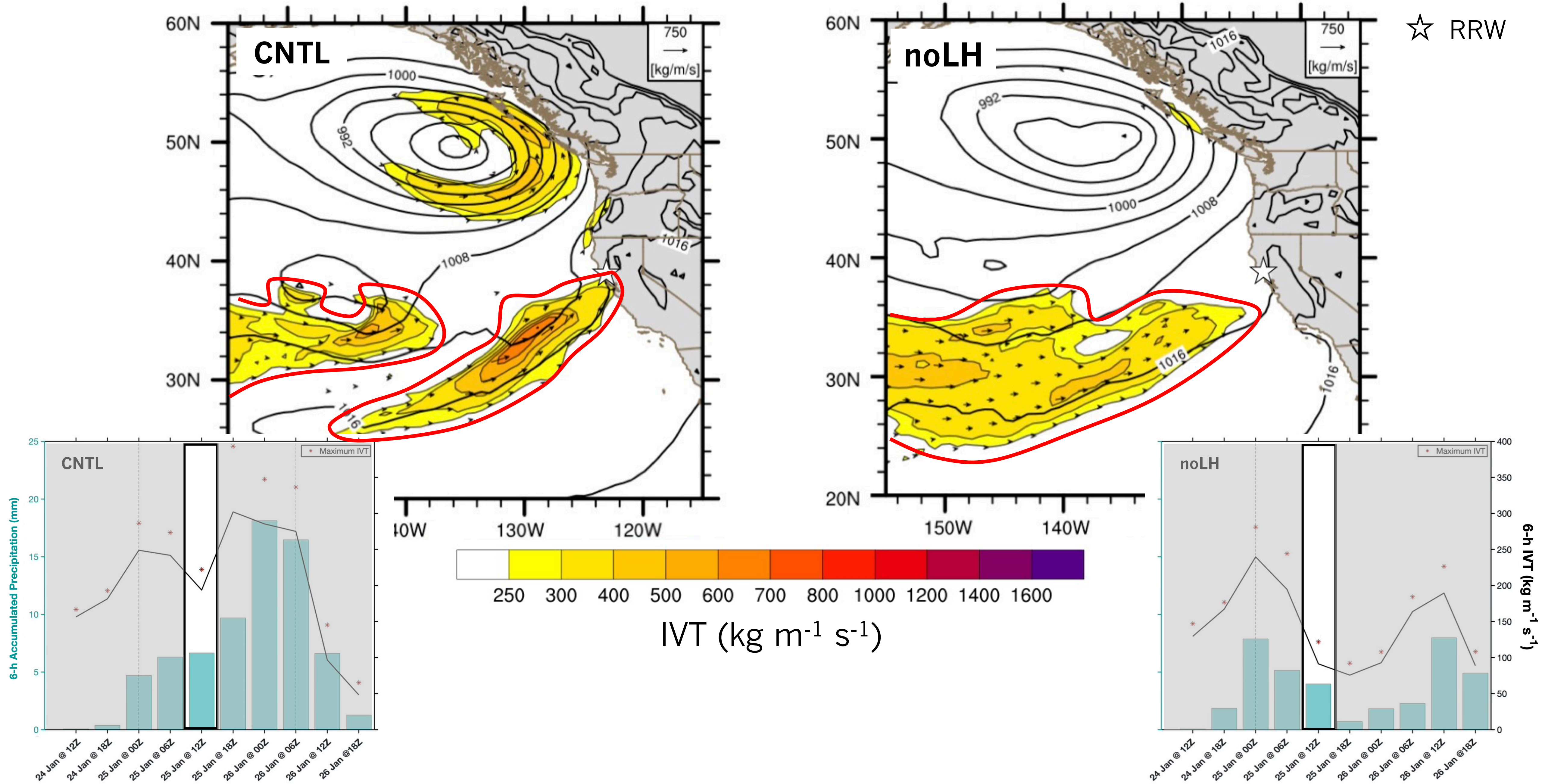


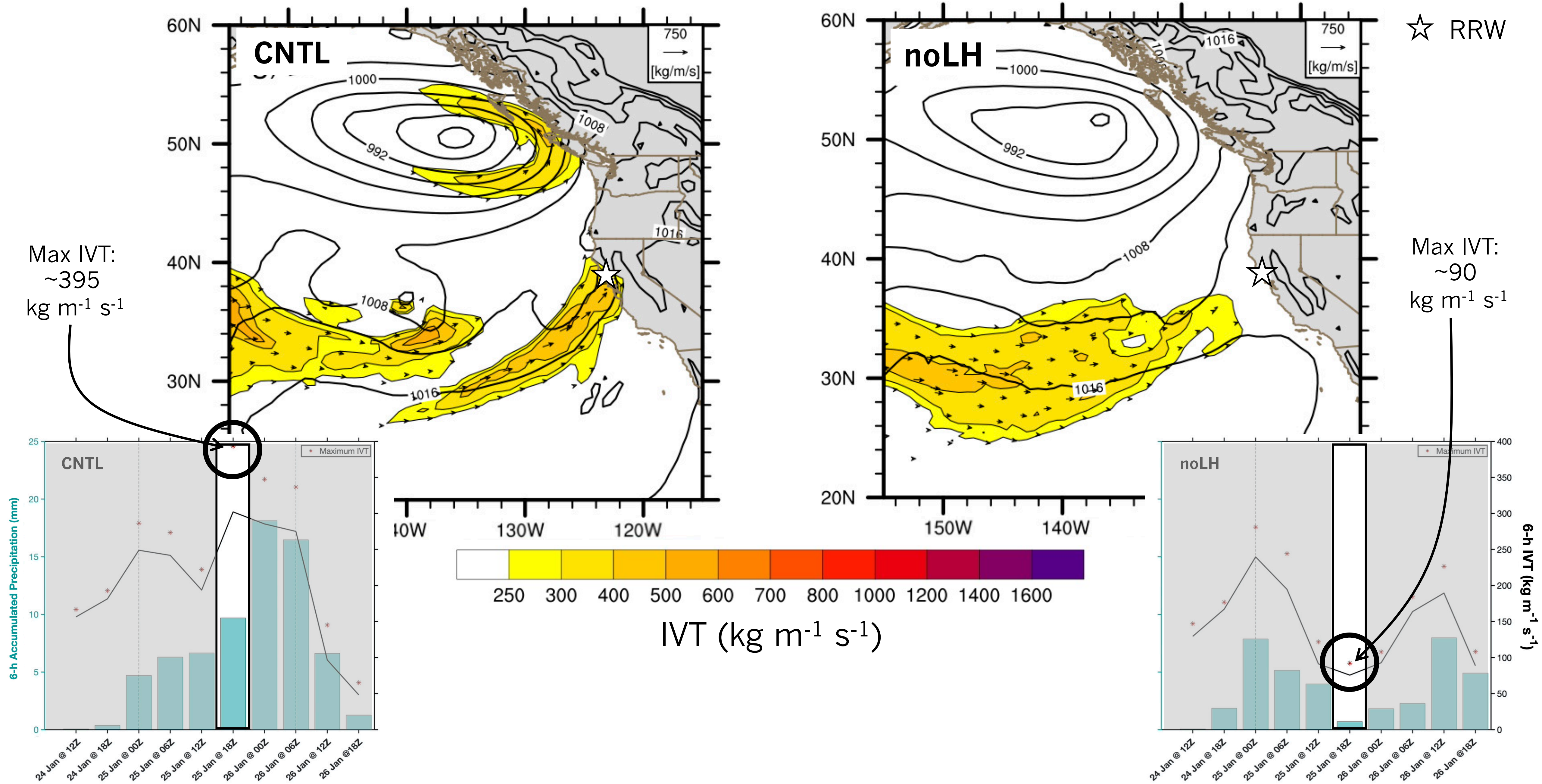
12 UTC 25 January 2010

MPAS Simulations



18 UTC 25 January 2010

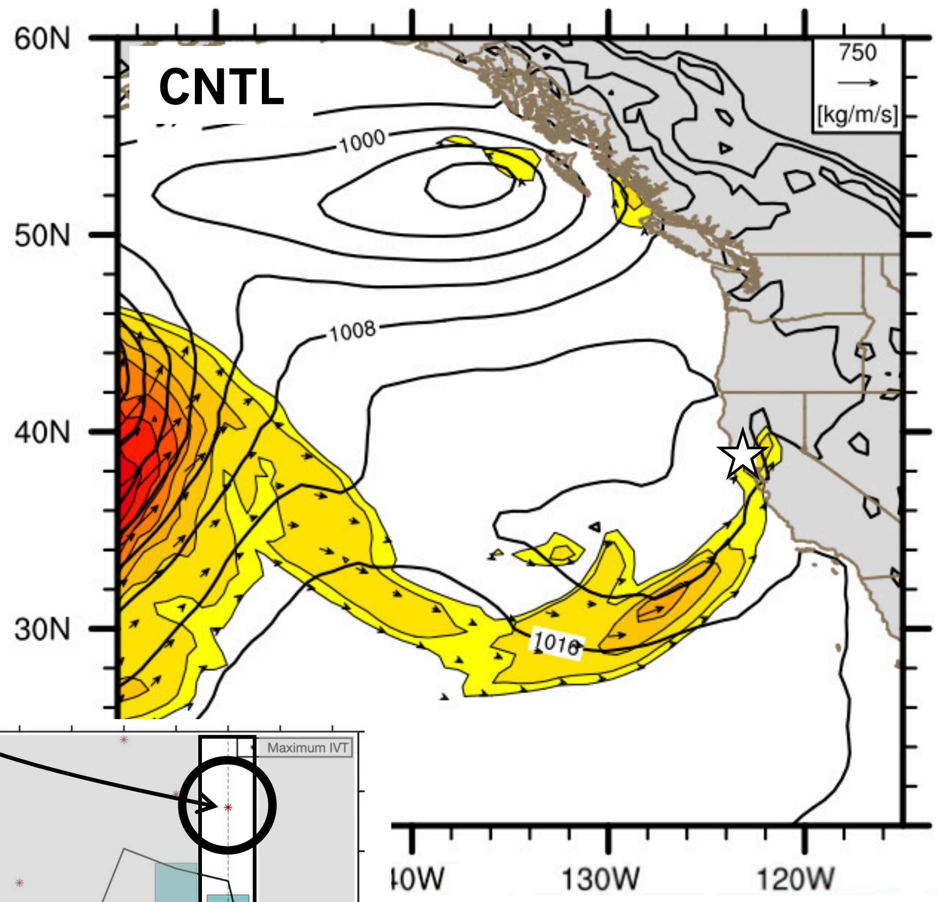
MPAS Simulations

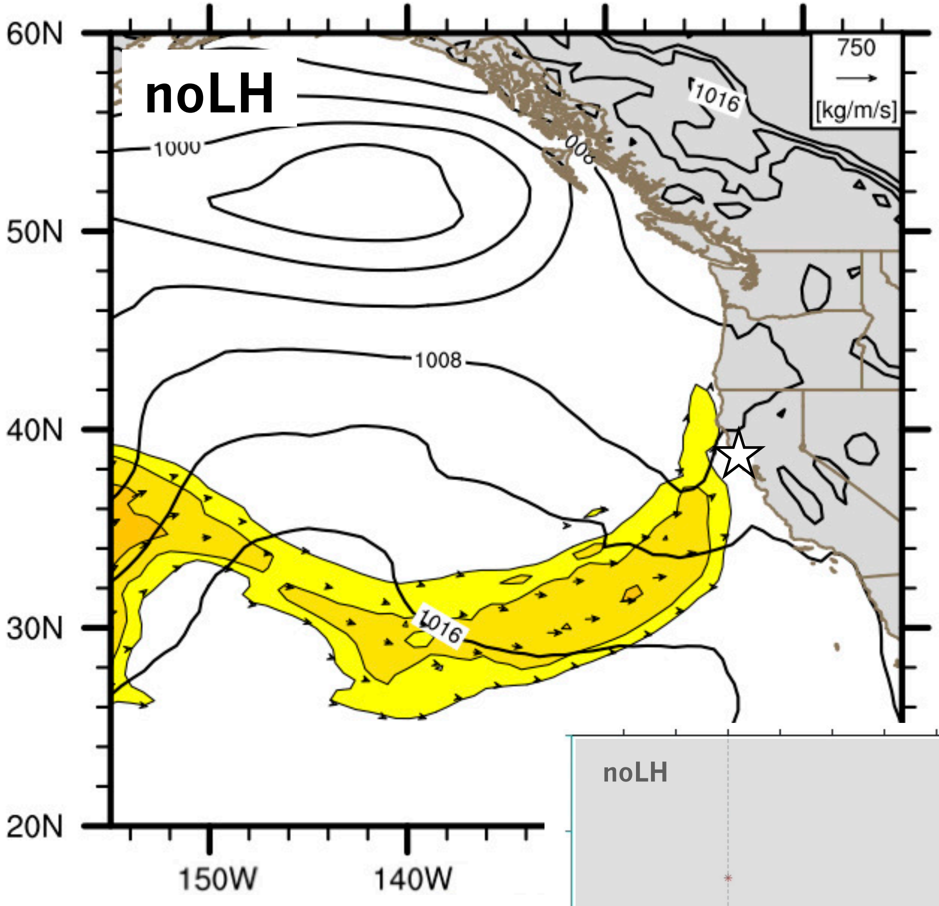


06 UTC 26 January 2010

MPAS Simulations

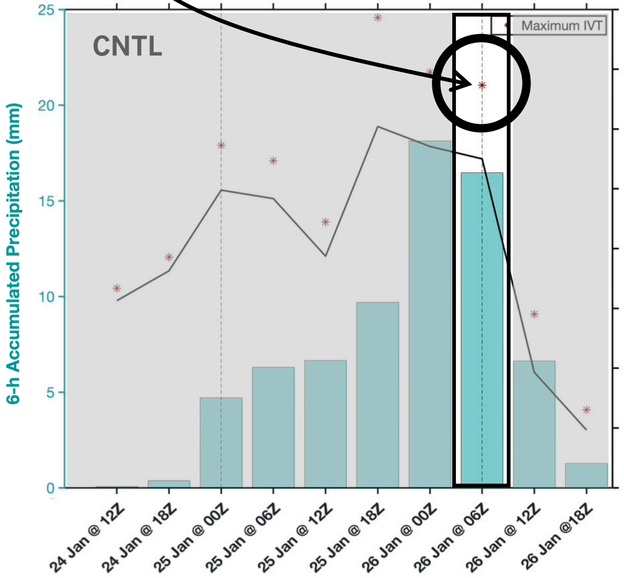
☆ RRW

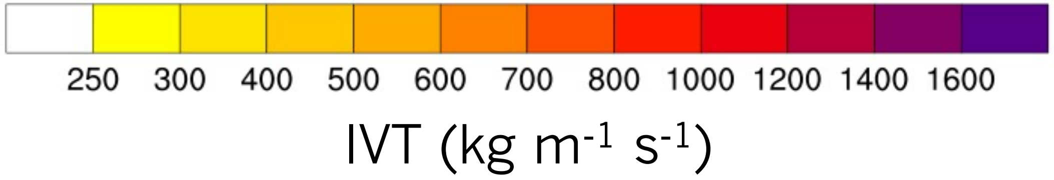


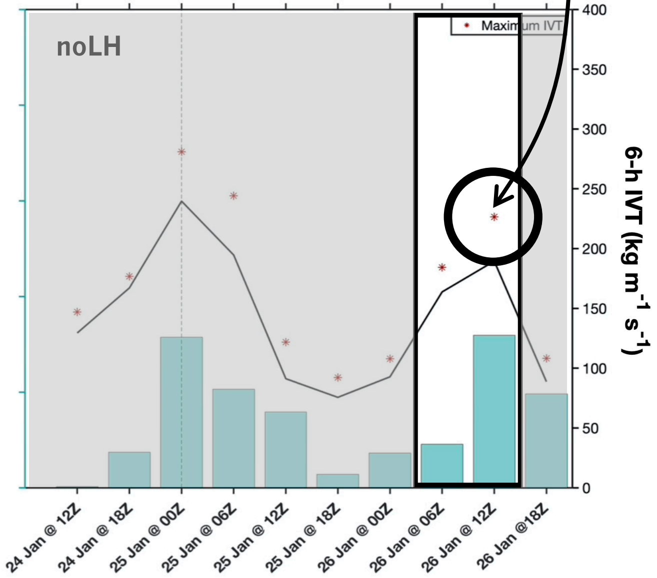


Max IVT:
~335
kg m^{-1} s^{-1}

Max IVT:
~225
kg m^{-1} s^{-1}

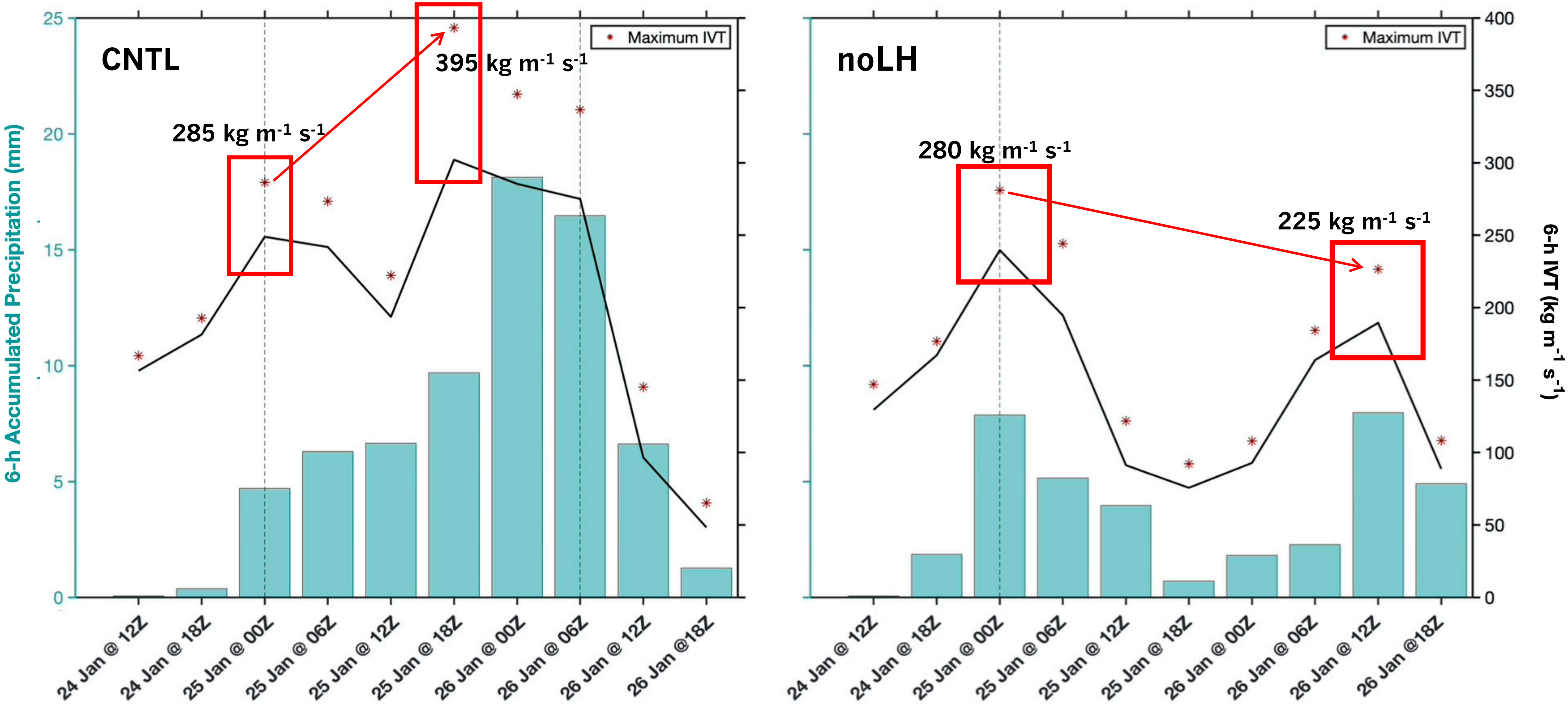






January 2010: Russian River Watershed Impacts

MPAS Simulations



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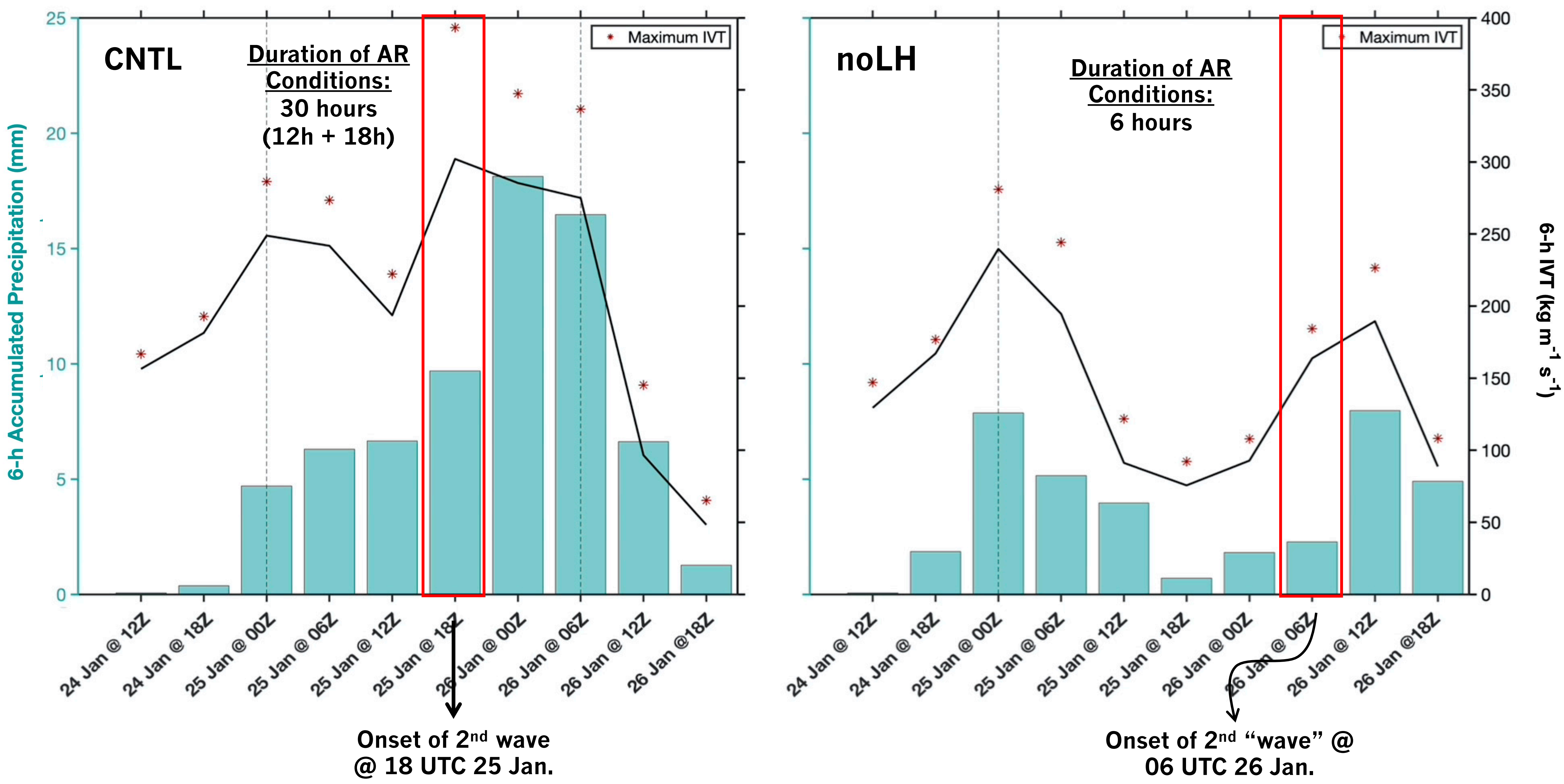

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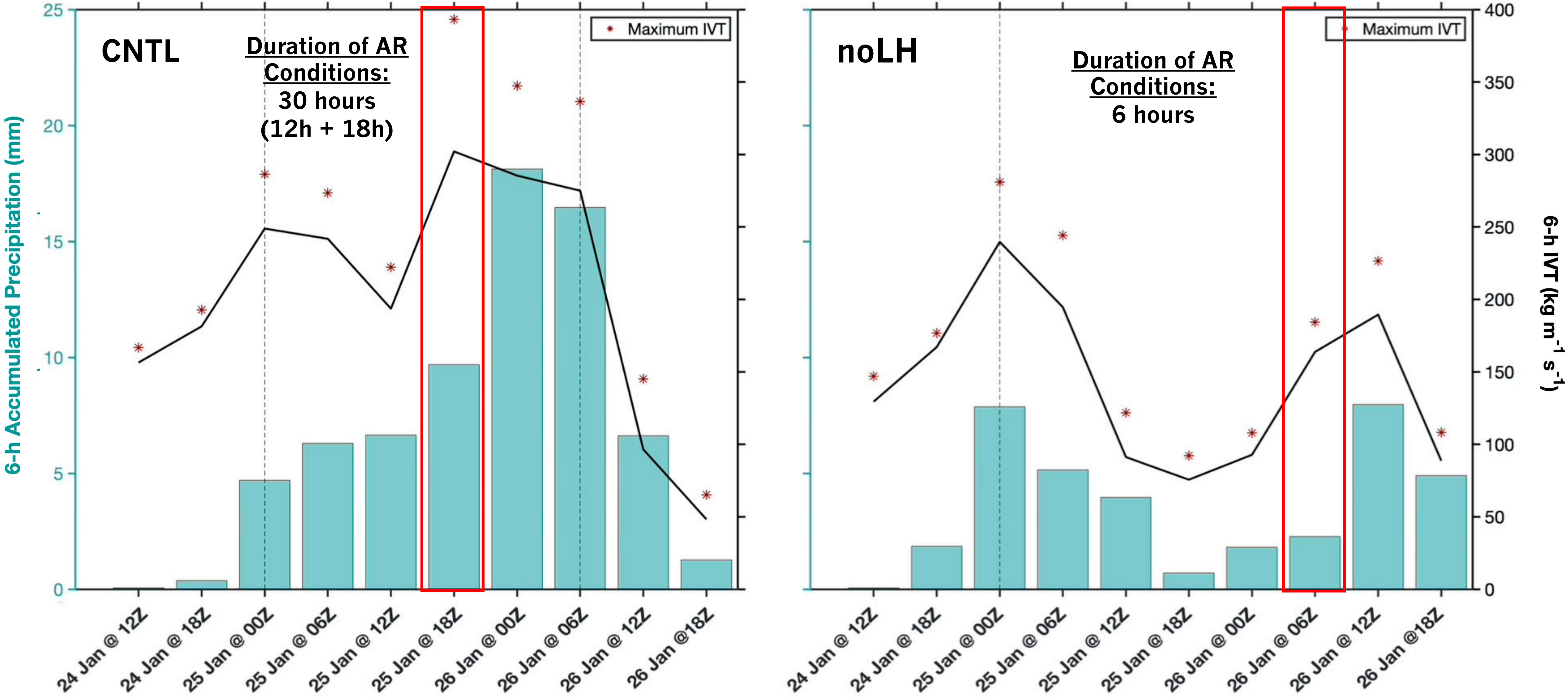

Total Precipitation:
70 mm (~2.8")

Total Precipitation:
36 mm (~1.4")

Summary & Conclusions

- Removing effects of latent heating everywhere (not isolated to MFW/AR), but experiments give good idea of the importance of diabatic processes

- Case 1: December 2014 → significant upper-air support **vs.** Case 2: January 2010 → primarily diabatically influenced

- Both cases: lack of diabatic processes caused **differences in timing, intensity, and duration** of peak AR conditions on the watershed scale
  - December 2014: AR didn't stall → weaker, shorter AR over RRW
  - January 2010: Second wave didn't intensify → weaker, shorter AR over RRW

- **More to do!**
  - Simulate more cases!