Center for Western Weather and Water Extremes
SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO

Subseasonal to Seasonal (S2S) forecasting: see Mike DeFlorio talk on Thursday

CW3E FORECASTING CAPABILITIES

Luca Delle Monache, Forest Cannon, Alison Cobb, Bruce Cornuelle, Laurel Dehaan, Reuben Demirdjian, Liza Diaz, Jennifer Haase, Robert Hartman [1], Chad Hecht, Julie Kalansky, Brian Kawzenuk, Andrew Martin [2], Allison Michaelis, Michael Murphy, Caroline Papadopoulos, David Reynolds [3], Daniel Steinhoff, Rachel Weihs, Anna Wilson, Minghua Zheng, F. Martin Ralph

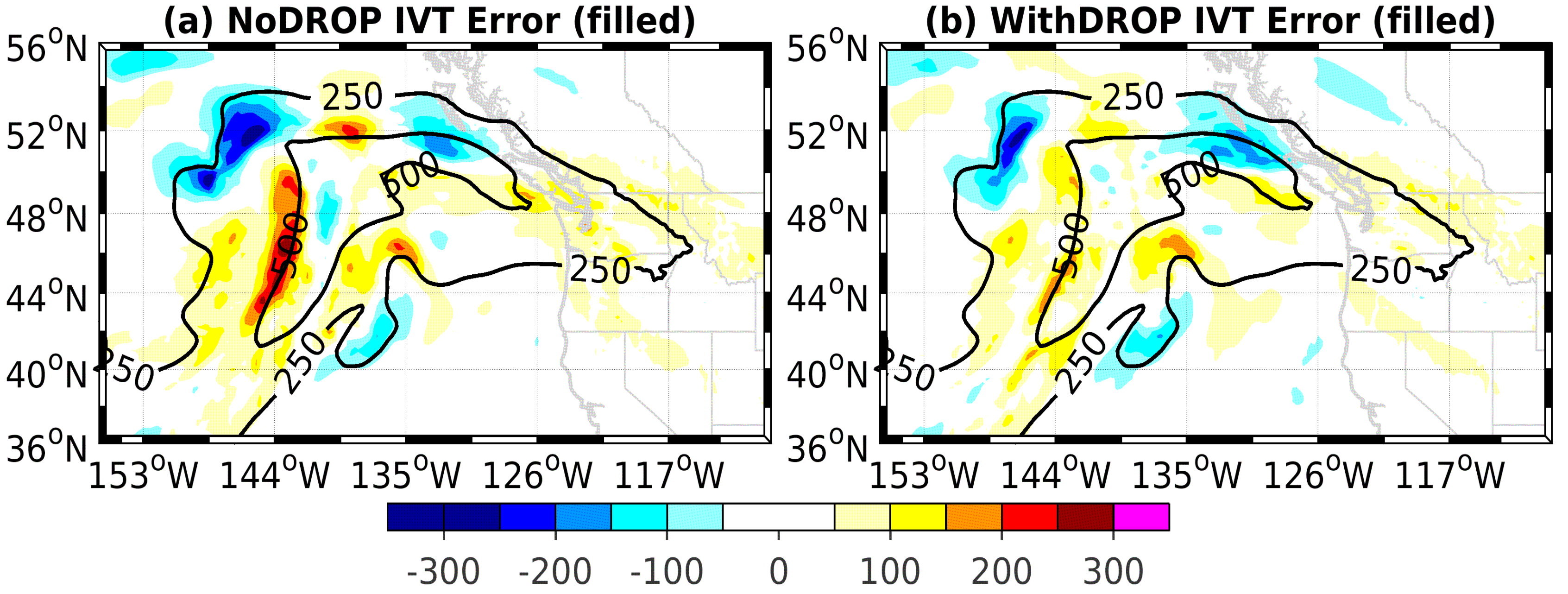
Center for Western Weather and Water Extremes (CW3E)
Scripps Institution of Oceanography, University of California San Diego
[1] Robert K. Hartman Consulting Services, Roseville, California
[2] Portland State University, Portland, Oregon
[3] University of Colorado Boulder, Boulder, Colorado

UC San Diego
SCRIPPS INSTITUTION OF OCEANOGRAPHY

CW3E FORECASTING PILLARS

- Data Assimilation
- Modeling / Forecasting
- Postprocessing / Machine Learning
- Forecast Products

IOP 7: IVT ERRORS WITH AND WITHOUT DROPSONDES ASSIMILATION



(a) Forecast error (filled, kg m^{-1} s^{-1}) of IVT in NoDROP run at 24-h forecast lead time

(b) Same as (a) but for WithDROP run

Black contours in (a) and (b) are analyzed IVT from ERA5 reanalysis data valid at 00Z, 4 February 2018

See Minghua Zheng and Tim Higgins Posters

WEATHER RESEARCH AND FORECASTING MODEL FOR WESTERN U.S.

- Science Questions
  - What are the sources of forecast error during impactful atmospheric rivers?
  - Can a tailored model better address these errors to produce more accurate forecasts of ARs and extreme precipitation?

- Societal Drivers
  - Improved forecast skill benefits decision support (e.g., FIRO)

- Project Sponsors and Partners:
  - USACE, CA DWR, SCWA, NSF XSEDE, SDSC

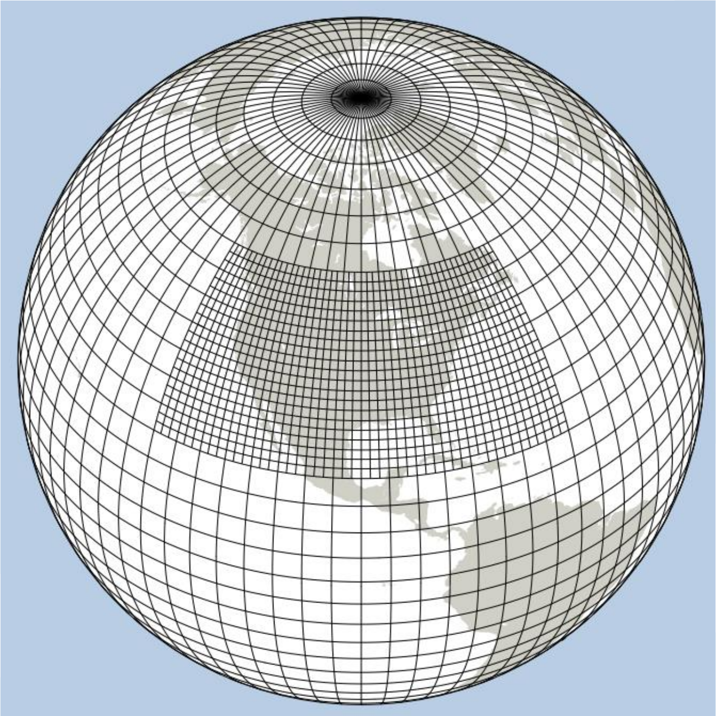
Interdisciplinary team of staff scientists, post-docs, grad students and programmers.

Computer time and disk storage on:

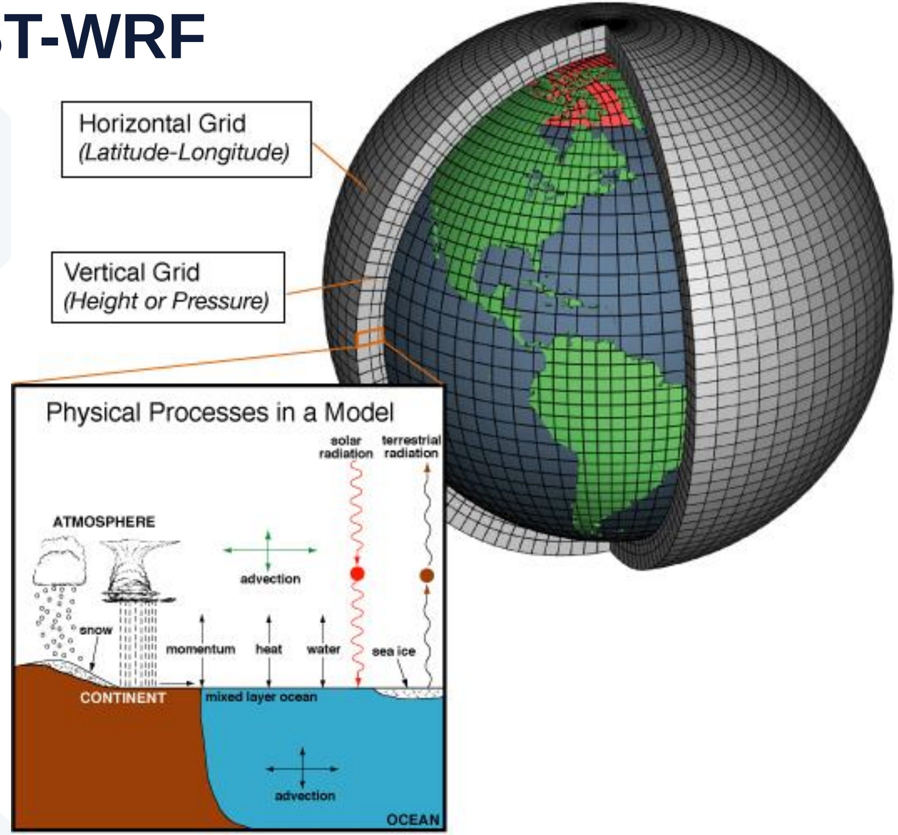
- *NSF Comet* (Near Real Time / Research)
- *USACE Onyx* (Reforecast)
- *NCAR Cheyenne* (Research)

WEATHER RESEARCH AND FORECASTING MODEL FOR WESTERN U.S.

WEST-WRF



source: http://www2.mmm.ucar.edu



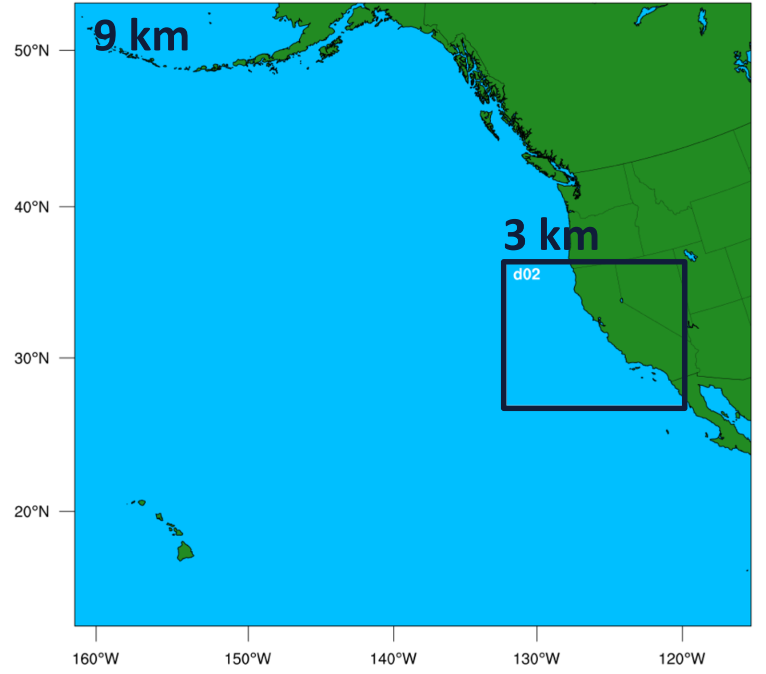
source: Wikipedia, “Numerical Weather Prediction”

WHY WEST-WRF?

CW3E has developed West-WRF to:

(1) Serve as a testbed for understanding physical processes and their relationship to forecast error

(2) Address current forecasting challenges to provide improved representation of ARs & Precipitation



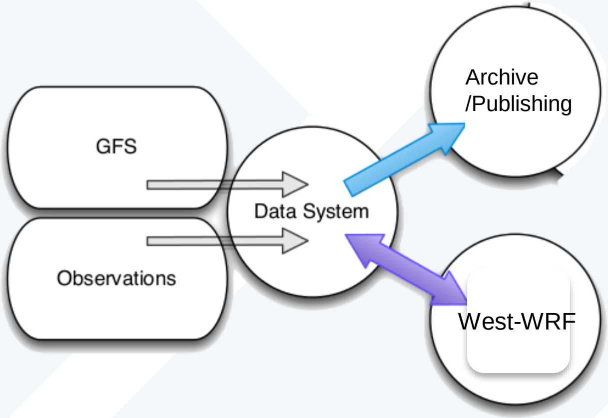
Unique Forecast Challenges Posed by Western U.S. Extreme Events

Challenge	Primary NWP Shortcoming	References
AR Landfall Characteristics	Location and strength of water vapor flux	Wick et al. (2013) Ralph et al. (2017) DeFlorio et al. (2018) Martin et al. (2018)
Extreme Precipitation Skill	Overprediction of light rain, Underprediction of extreme amounts	Ralph et al. (2010) Ralph and Dettinger (2012) Sukovich et al. (2014)
Snow level	Low precision, Biases near terrain	White et al., (2010) Neiman et al. (2014) Minder and Kingsmill (2013) Henn et al. (2018)

See Forest Cannon Talk, next session

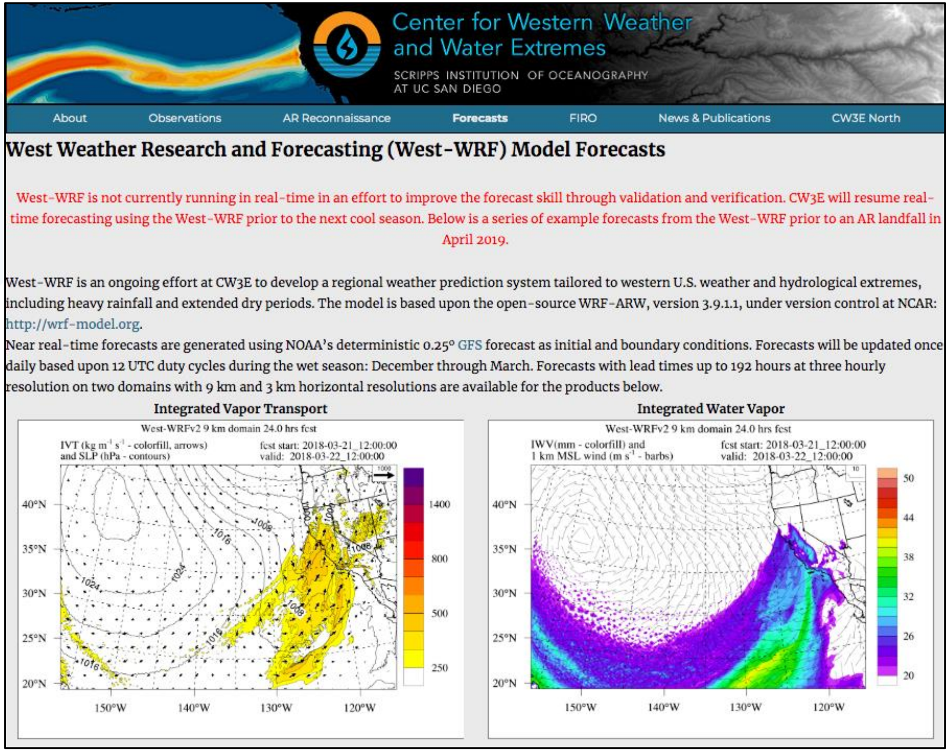
NEAR REAL-TIME (NRT) CW3E WEST-WRF FORECASTS

Automated data ingest, archiving and preprocessing system developed at SDSC with Funding from DWR



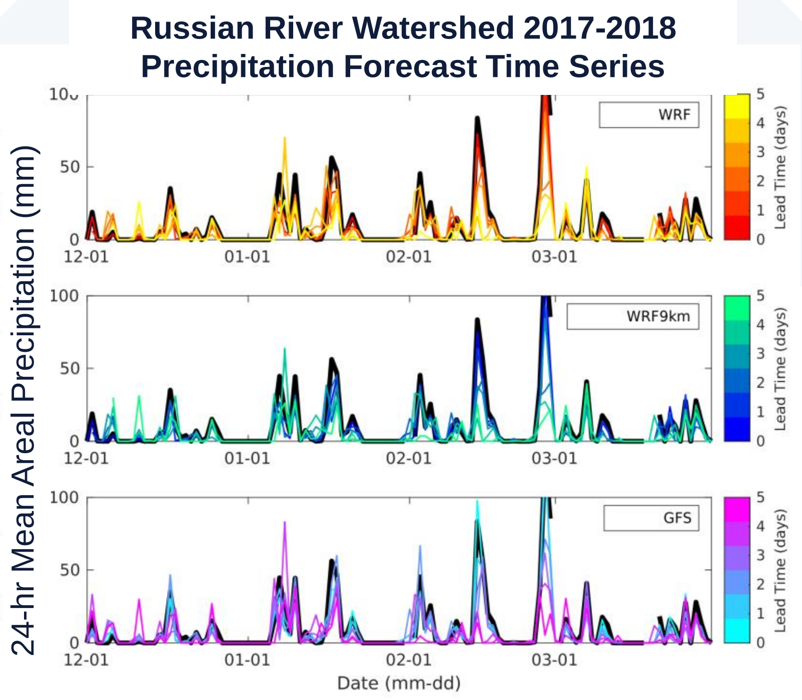
Cool Seasons (Dec – Mar) 2015, 2016, 2017, 2018, 2019:

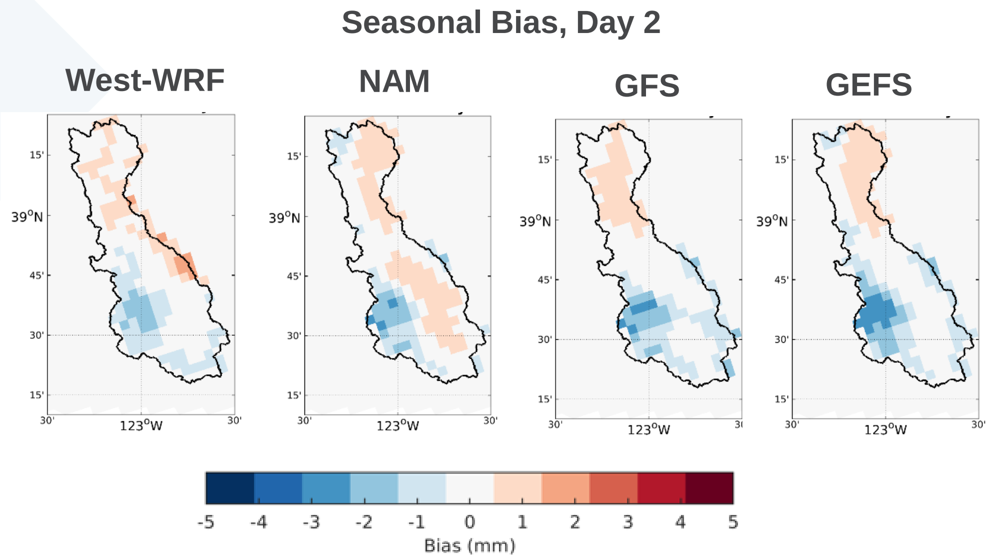
- Forecasts issued daily
- Finest spatial resolution: 3 km



- Data delivered in near-real-time
- Forecast products published real-time to cw3e.ucsd.edu

BIAS REDUCTION IN PRECIPITATION FORECAST, WATER YEAR 2017-2018

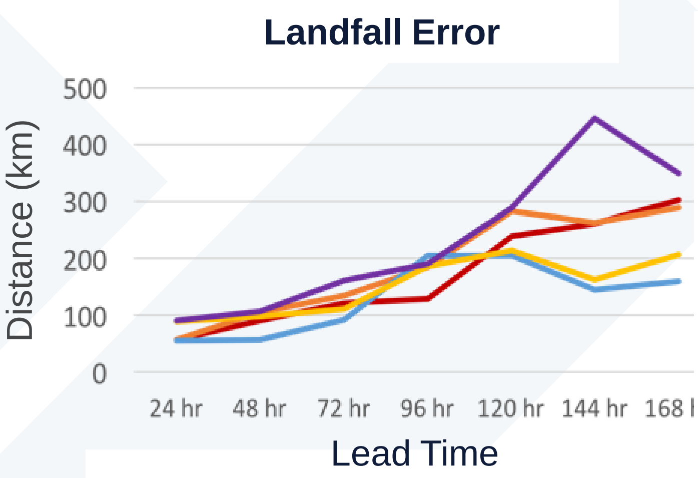


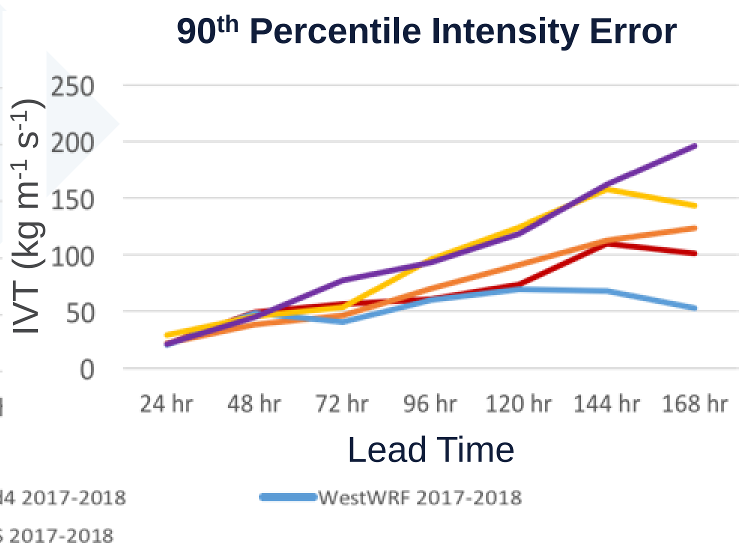


- West-WRF inherits (but reduces the impact) of major errors in GFS
- Has smallest seasonal bias in Day 2 forecast

Rachel Weihs

ERROR REDUCTION OF AR LANDFALL, WATER YEAR 2017-2018

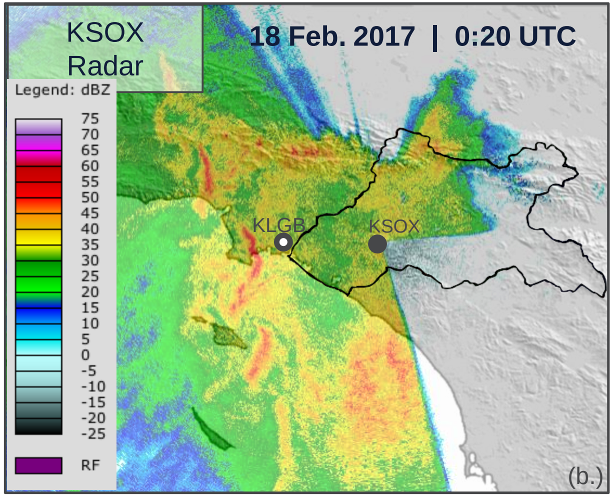




- West-WRF has smaller AR object landfall error at almost all lead times
- AR intensity prediction is as skillful or better compared to other models

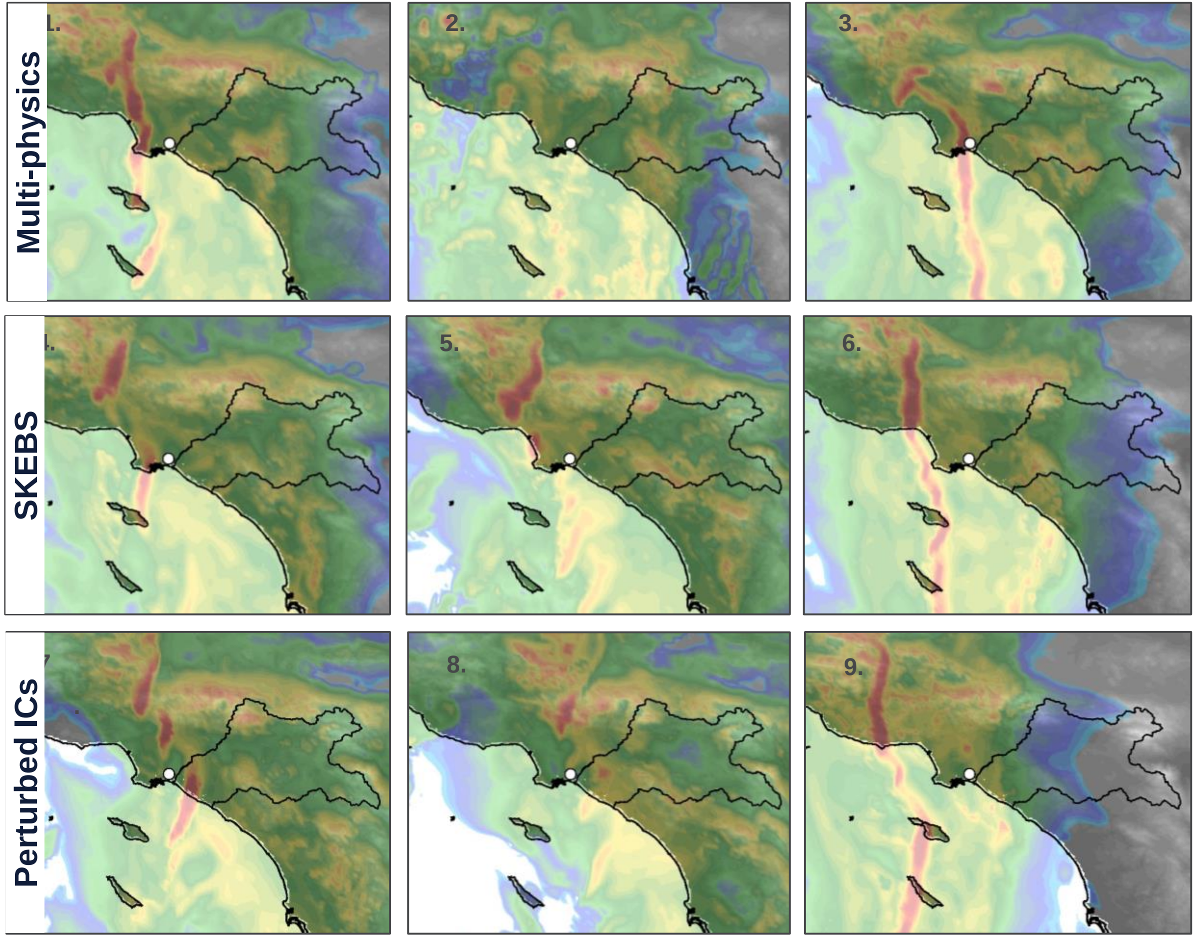
Laurel Dehaan

Comparison of West WRF with NEXRAD, 18 Feb 2017



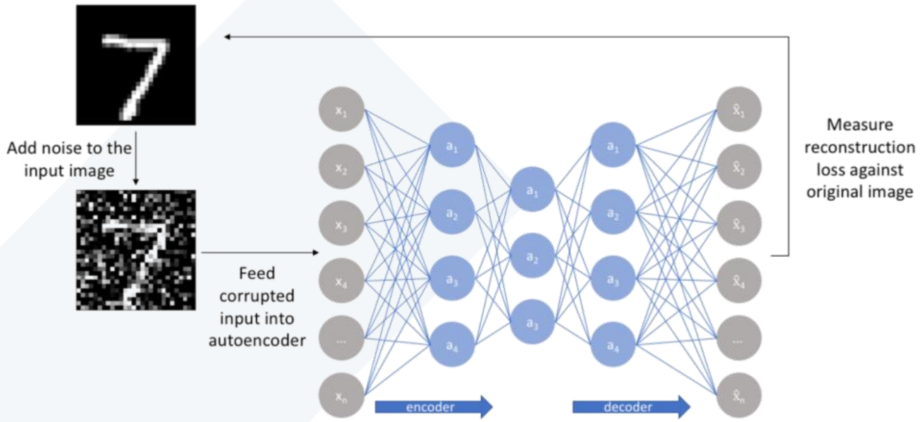
Narrow Cold-Frontal Rainband

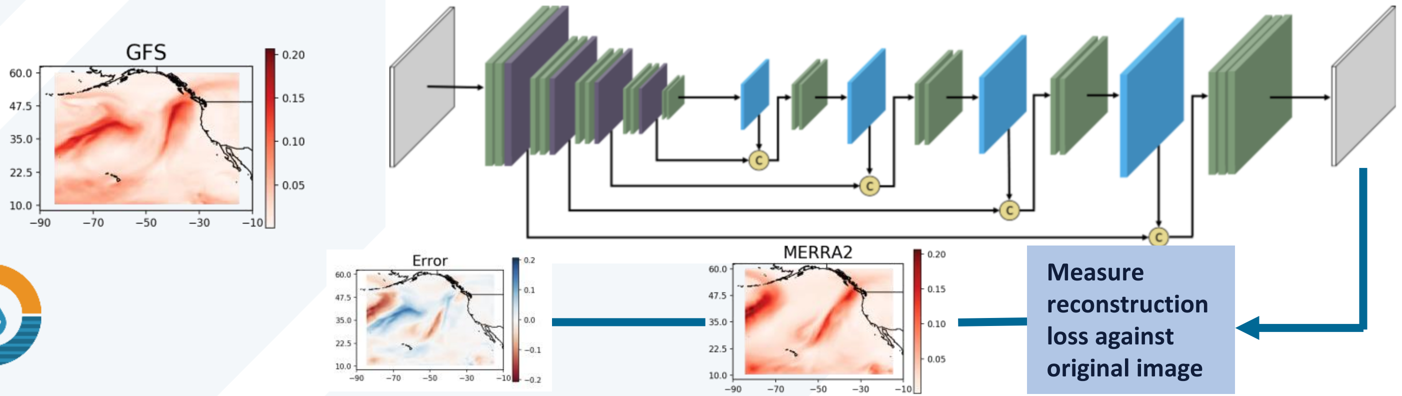
West-WRF ability to simulate narrow cold-frontal rainband (NCFR), a process associated with intense precipitation events over land



Forest Cannon

MACHINE LEARNING AT CW3E



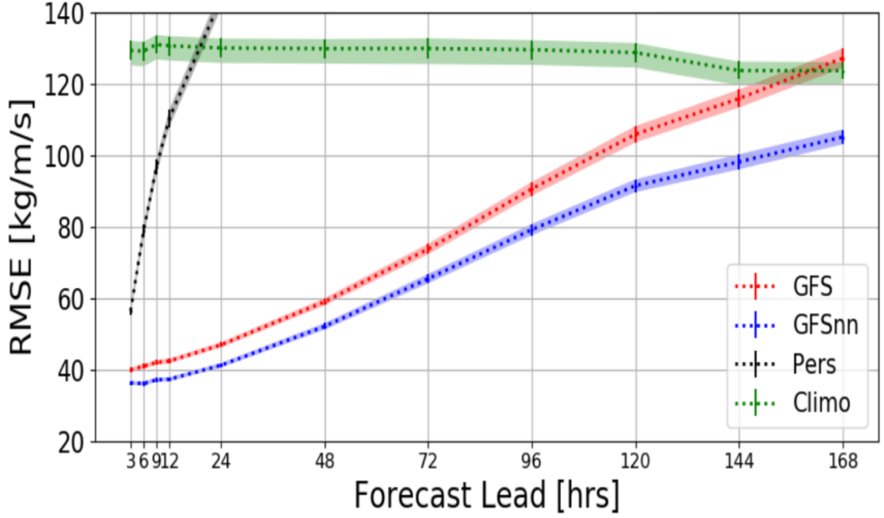


Will Chapman

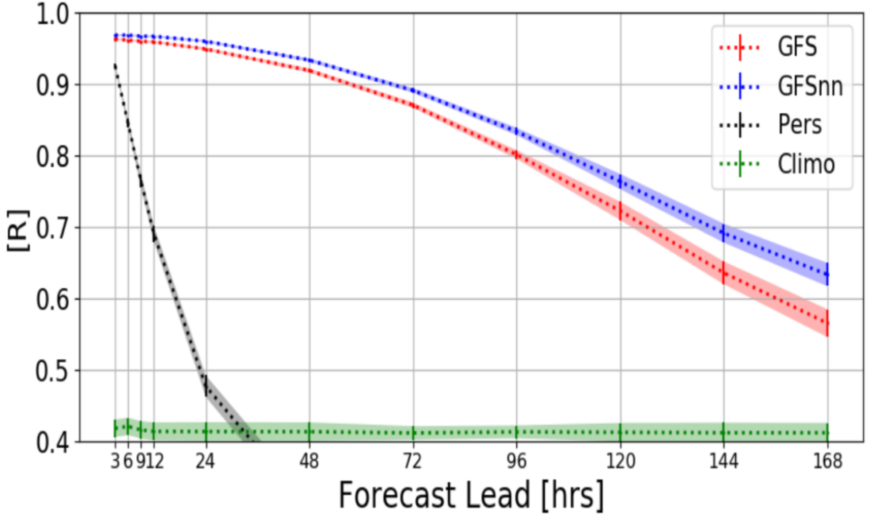
MACHINE LEARNING AT CW3E

See my poster on reforecast

RMSE



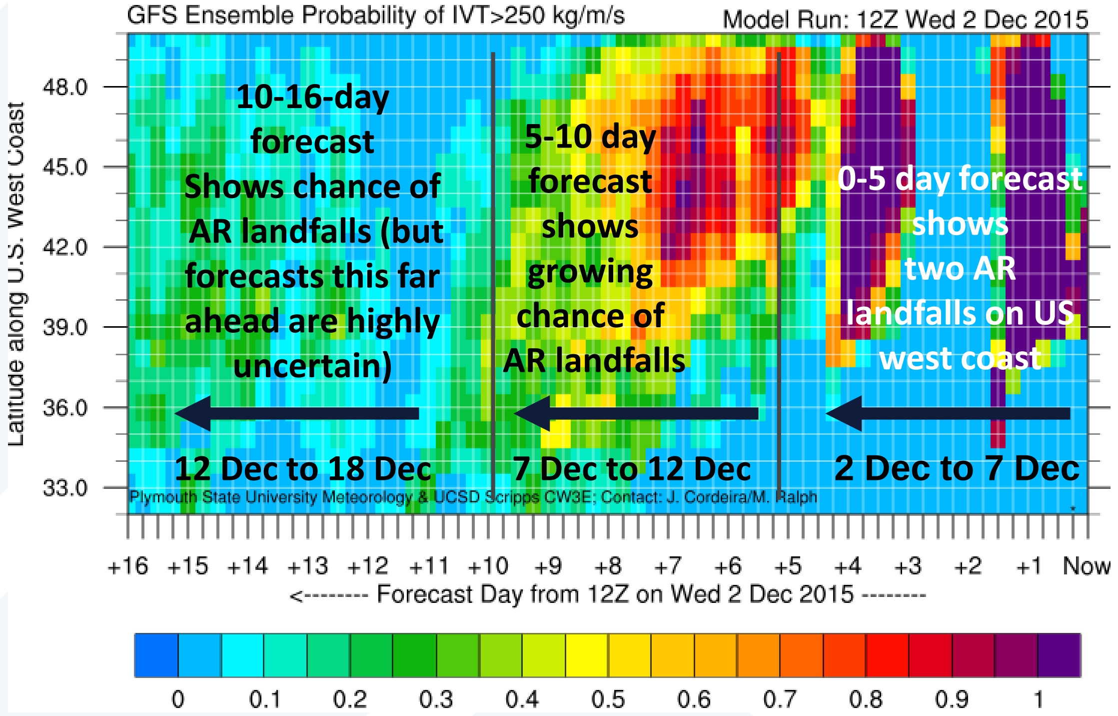
Correlation

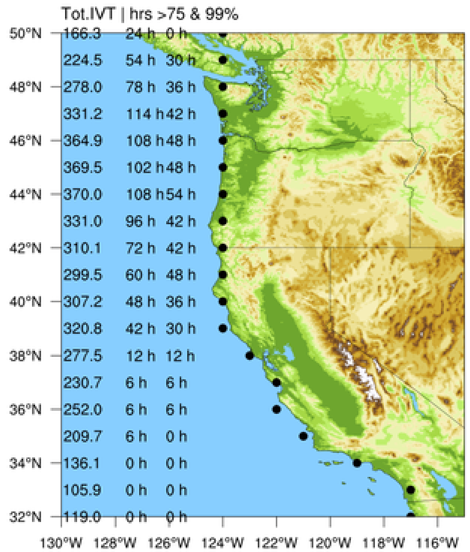


- Convolutional Neural Network
- 0-168 h IVT predictions
- ~10 years of GFS
- Ground-truth: MERRA 2

Chapman et al. 2019 (GRL, conditionally accepted)

FORECAST CHANCES OF LANDFALL OF AT LEAST WEAK ATMOSPHERIC RIVER CONDITIONS ON THE U.S. WEST COAST FROM 2-18 DEC 2015 - UPDATES AVAILABLE AT CW3E.UCSD.EDU



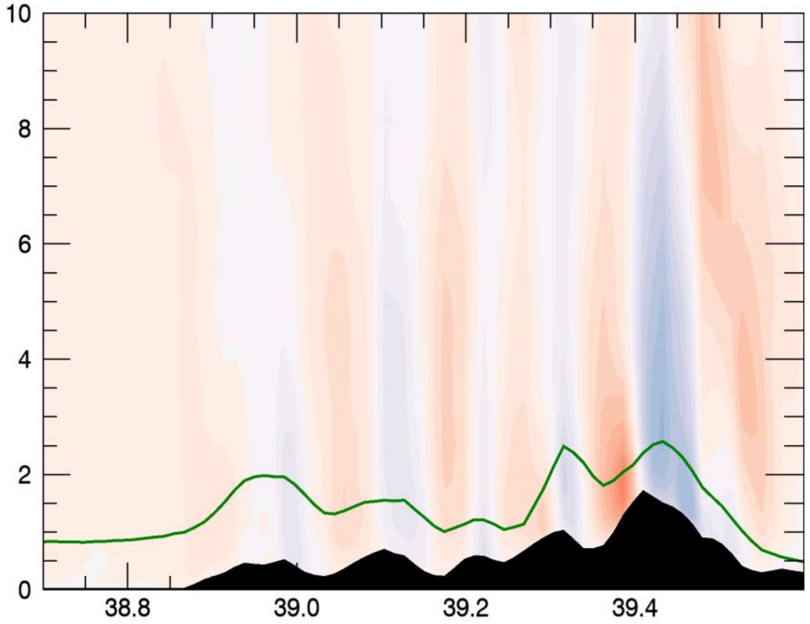


Cordeira et al. BAMS 2016

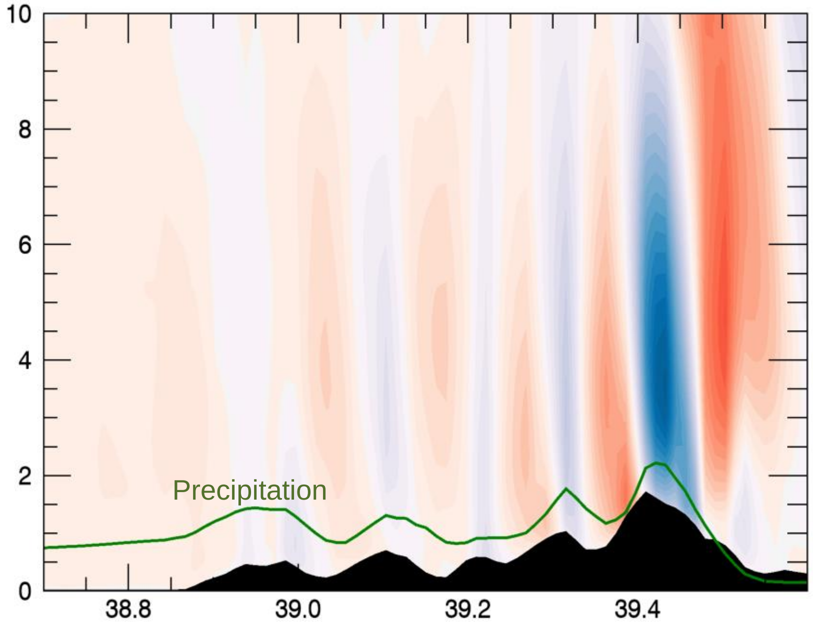
BACK-UP SLIDES

Transects of Simulation-Averaged Vertical Motion across Topography

CFSR Ensemble Composite



GFS Sensitivity “Ensemble” Composite



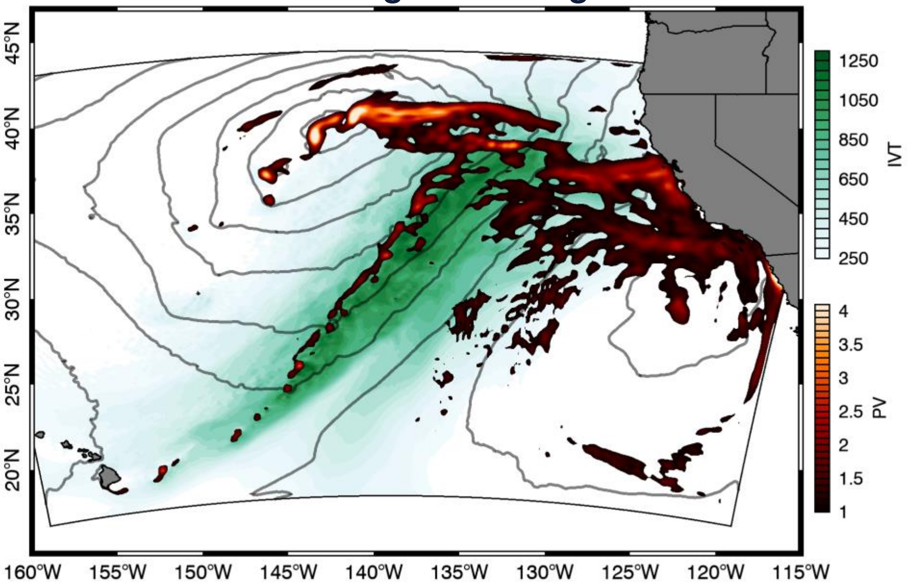
Gravity wave structure is prevalent in both simulations, yet appreciably different.

Stronger motion and smaller precipitation accumulations in GFS-Forced simulations

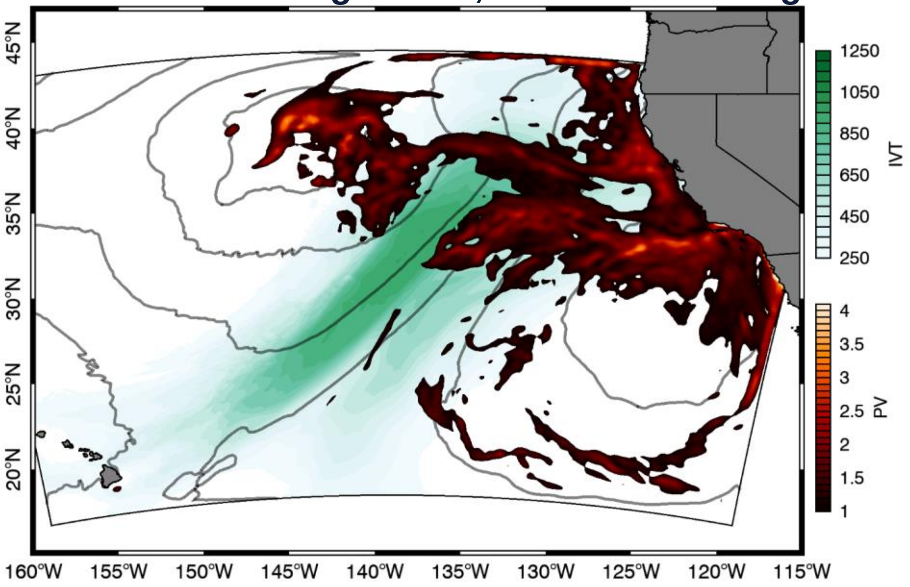
Forest Cannon

IMPACT OF PRECIPITATION MECHANISMS ON LATENT HEATING

West-WRF Original Configuration



West-WRF Configuration, No Latent Heating



Forest Cannon

Early example of use of AR Intensity Scale: 4 April 2017

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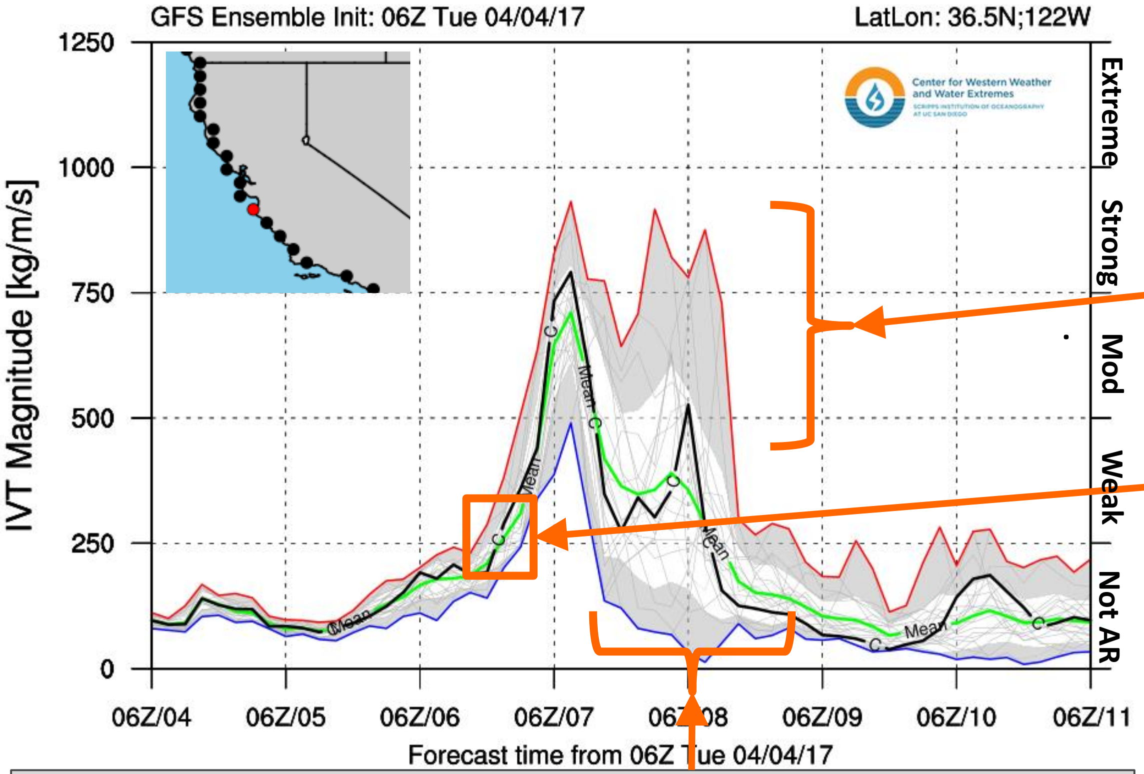


There is more uncertainty in IVT magnitude associated with the development of the mesoscale frontal wave, which creates large uncertainty in the duration of AR conditions over Monterey

Monterey, CA could experience strong AR conditions IVT> 750 kg m^{-1} s^{-1}

Magnitude of AR over Monterey

- Maximum possible IVT ~ 900 kg m^{-1} s^{-1}
- Mean IVT ~ 800 kg m^{-1} s^{-1}
- Uncertainty ~ +/– 12%

High Confidence in onset of AR conditions:

- 1 PM PT Thursday 06 April +/– 4 h

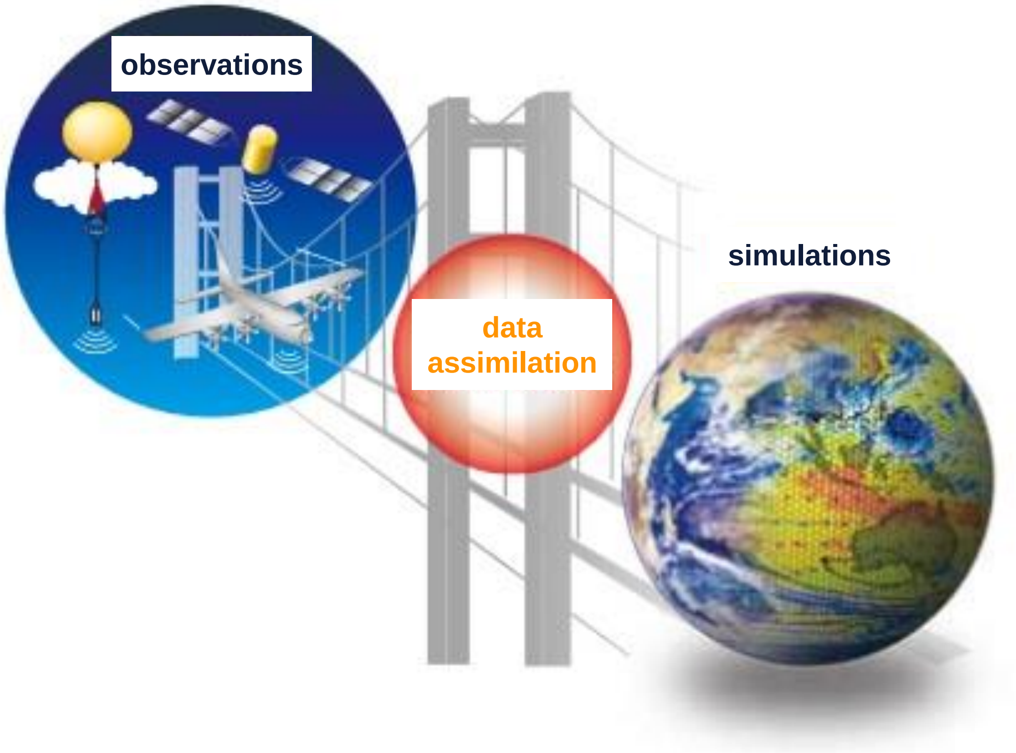
Duration of AR conditions

- Weak: ~36 hours +/– 20 h
- Moderate: ~10 hours +/– 20 h
- Strong ~3 hours +/– 3 h

For California DWR's AR Program

AR intensity scale by F.M. Ralph and collaborators
Case summary: C. Hecht 1 PM PT Tues. 04 April 2017

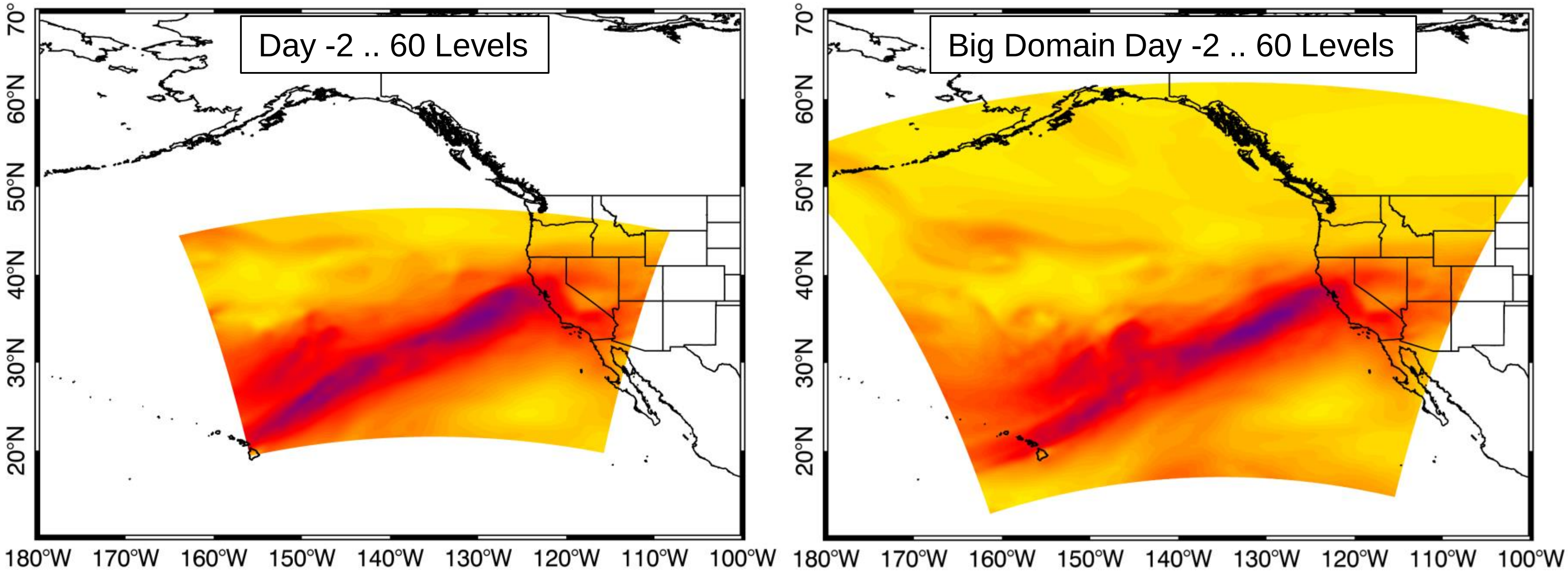
DATA ASSIMILATION



source: http://www.data-assimilation.riken.jp/en/research/index.html

SENSITIVITY TESTS: Domain Extent

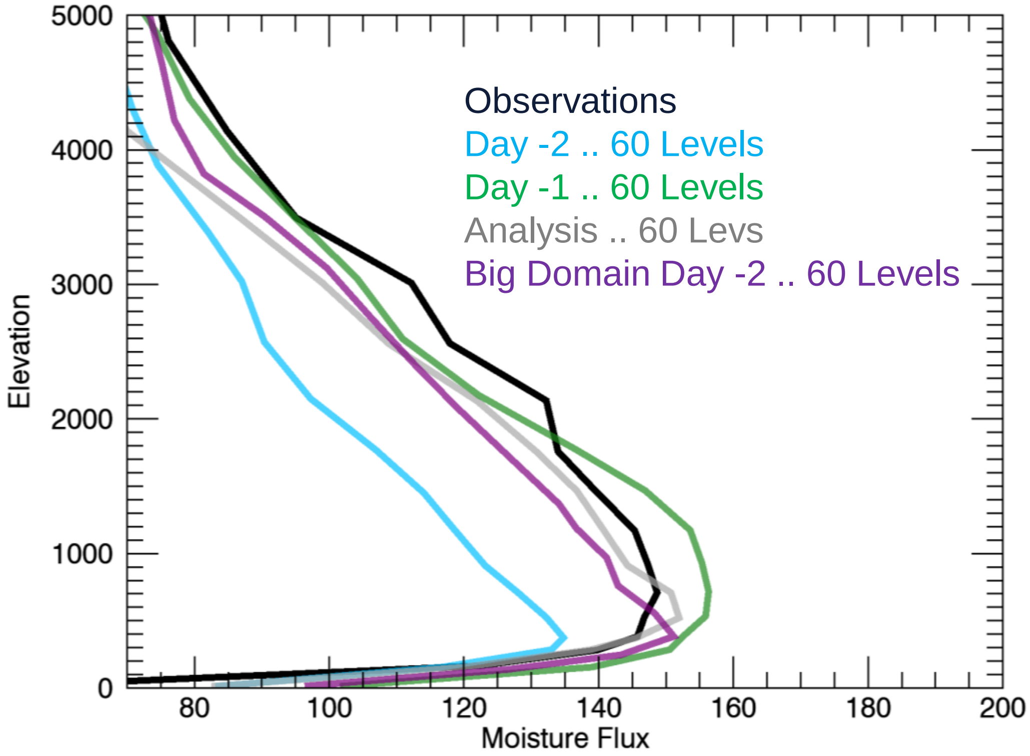
AR Event: 7 Feb 2017, 1200 (Max IVT)



Allowing domain to cover region of AR/ETC Interaction Improves Forecast at 1-3 day Lead Time

SENSITIVITY TESTS: Domain Extent

Oroville Event – BBY Sounding Comparison – Average of 18 Soundings over AR Peak



GFS IC/BC had weak AR conditions

Resolving Latent Heating Processes in AR/ETC Interaction using expanded domain may remove dependency on GFS at short/medium lead times

Day -2 Forecast Improves in AR strength…

Additional tests necessary

REFORECAST PROJECT: GOALS

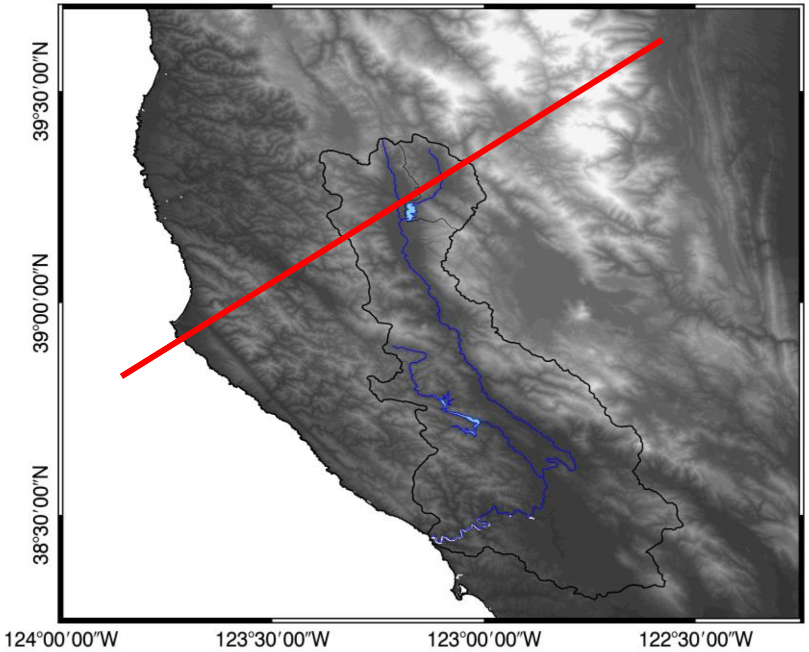
- The California-Nevada River Forecast Center (CNRFC) uses the National Centers for Environmental Predictions (NCEP) 30-year reforecast to calibrate the Meteorological Ensemble Forecast Processor (MEFP), which provides the forcings for the Hydrologic Ensemble Forecasting Service (HEFS)
- Currently using GEFS V10 reforecast (~1 degree resolution)
- **Plan to downscale GEFS 9 & 3km using West-WRF for 30-year period**
- Goals:
    - **Assess the benefits of a West-WRF high resolution reforecast to CNFRC operations**
    - Enhance CW3E predictive capabilities by exploring postprocessing techniques and machine learning to reduce raw model output biases
    - In-depth process-based studies

SENSITIVITY TESTS & WORKFLOW CONSIDERATIONS

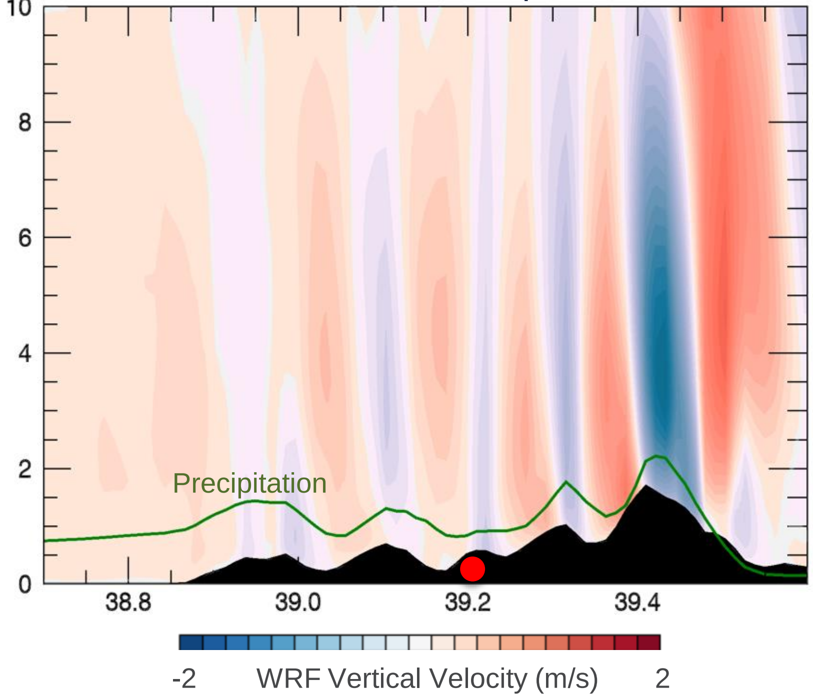
- Impact of West-WRF initialization with a digital filter
- Test of radiation schemes
- Length of 3-km run
- Vertical resolution
- Computational domain extent (for both 3 and 9 km nests)
- *Microphysics parameterization*
- *Cumulus parameterization*
- *Compilation flags for optimization*

Transects of Simulation-Averaged Vertical Motion across Topography

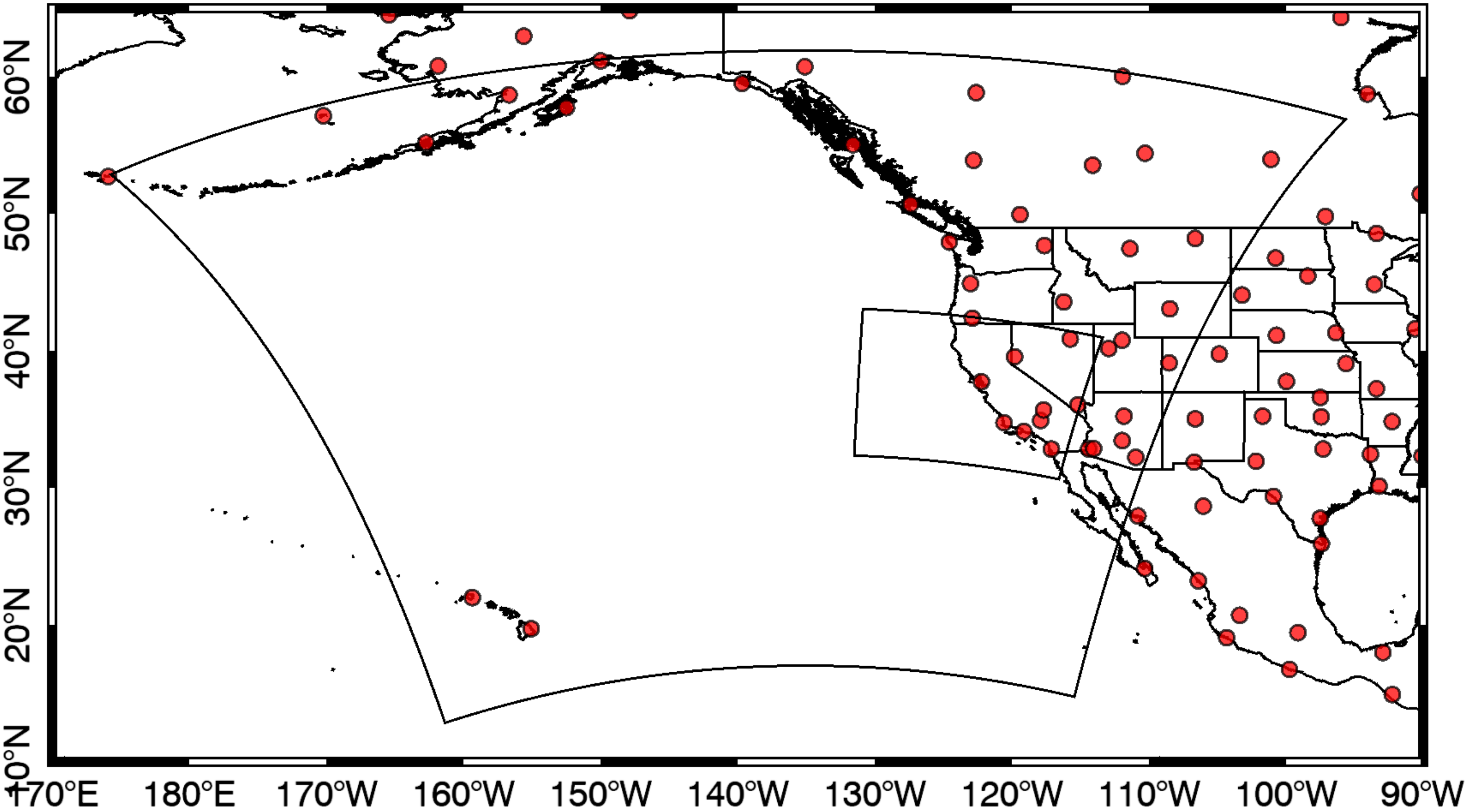
Climatological AR Orientation Across Lake Mendo



CFSR Ensemble Composite



Gravity wave structure is prevalent in all simulations. Precipitation generally responds to forced ascent… Lake Mendo is an exception in this case… Is this robust, or sensitive to vertical resolution?



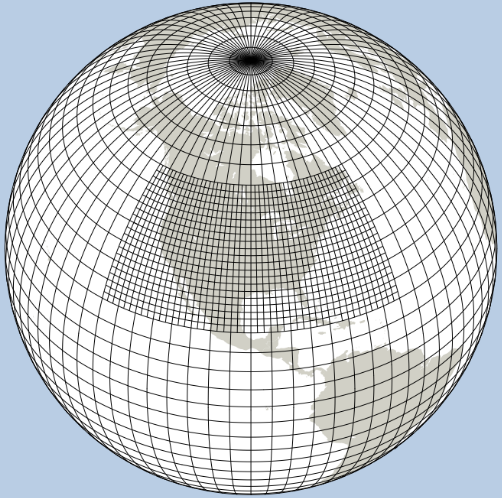
60°N
50°N
40°N
30°N
20°N
10°N
170°E
180°E
170°W
160°W
150°W
140°W
130°W
120°W
110°W
100°W
90°W

Why MPAS?

Significant differences between WRF and MPAS

MPAS
Model for Prediction Across Scales

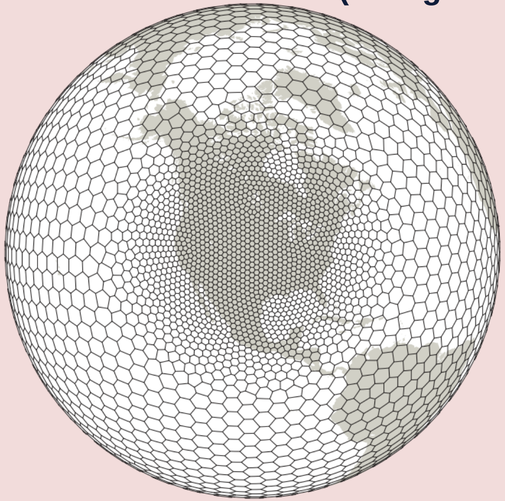
Cartesian meshes



WRF
Grid refinement through domain nesting

- Flow distortions at nest boundaries

unstructured centroidal Voronoi (hexagonal) meshes

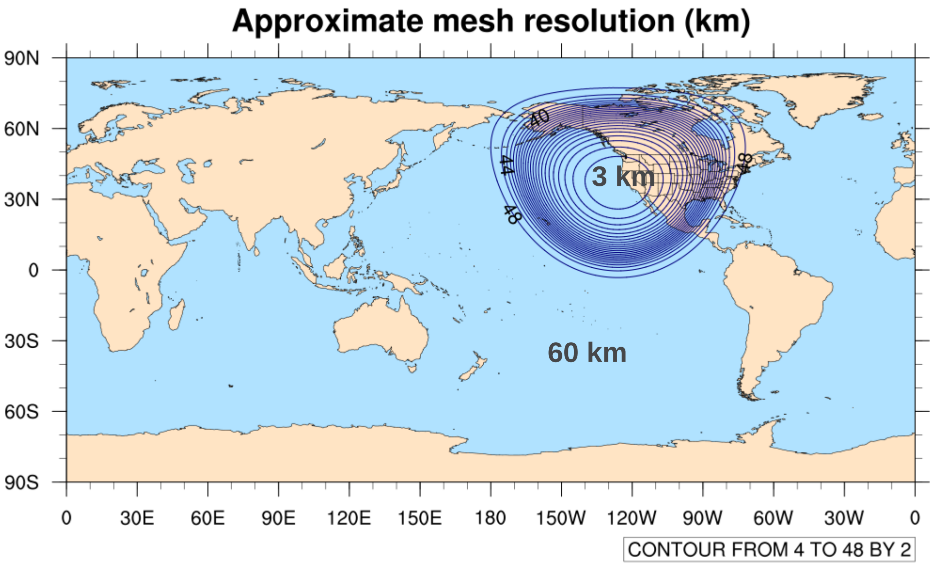


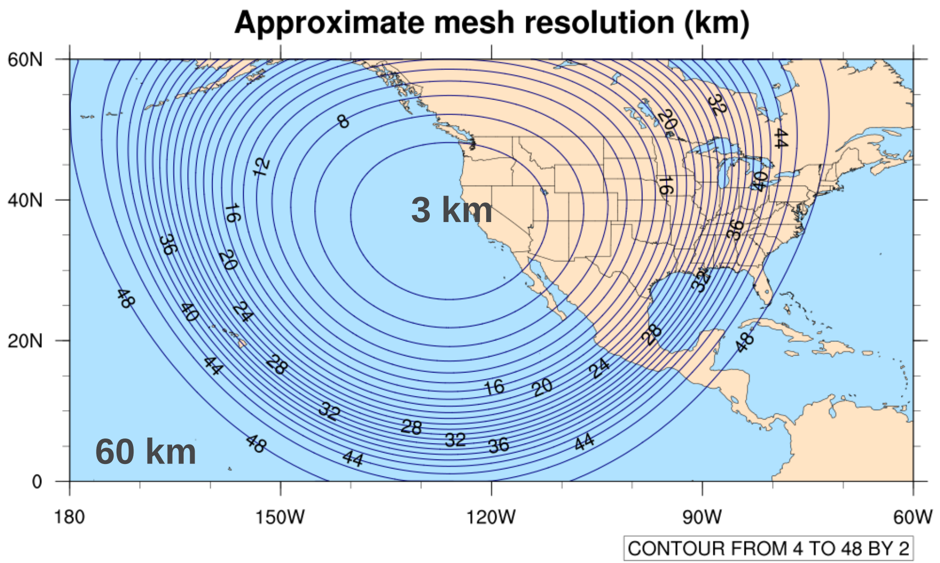
MPAS
Smooth grid refinement on a conformal mesh

- Increased accuracy and flexibility for variable resolution applications
- No abrupt mesh transitions.

Source: http://www2.mmm.ucar.edu/projects/mpas/tutorial/Boulder2018/index.html

MPAS CONFIGURATION FOR ARs AND PRECIPITATION ON THE WEST





Physics choices:

MP: Thompson; LW Radiation: RRTMG; SW Radiation: RRTMG; Surface Layer: M-O; PBL: YSU; CP: Scale-aware Grell-Freitas; Land surface: Noah

Note: Physics consistent with West-WRF, except for SW radiation (MPAS does not have Goddard option)

Allison Michaelis