Observational characteristics of atmospheric rivers from dropsondes

Alison Cobb, Allison Michaelis, Sam Iacobellis, F. Martin Ralph
& Observational Team

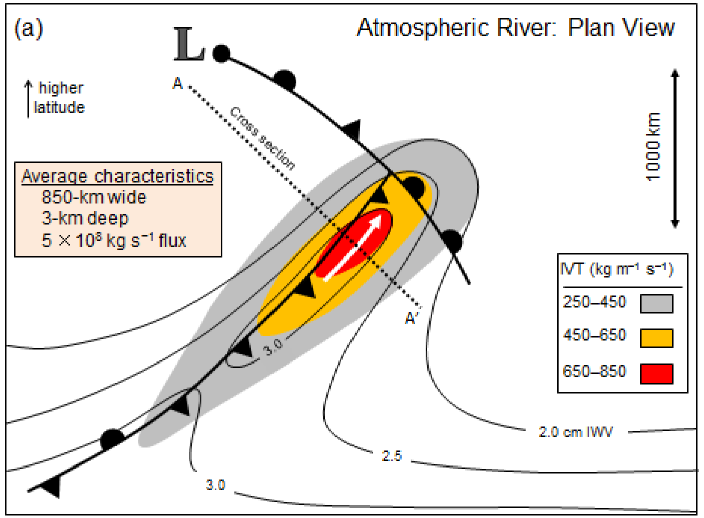
Workshop: Warm Conveyor Belts – a challenge to forecasting

Wednesday 11 March, 17:05 (10:05 Pacific time)

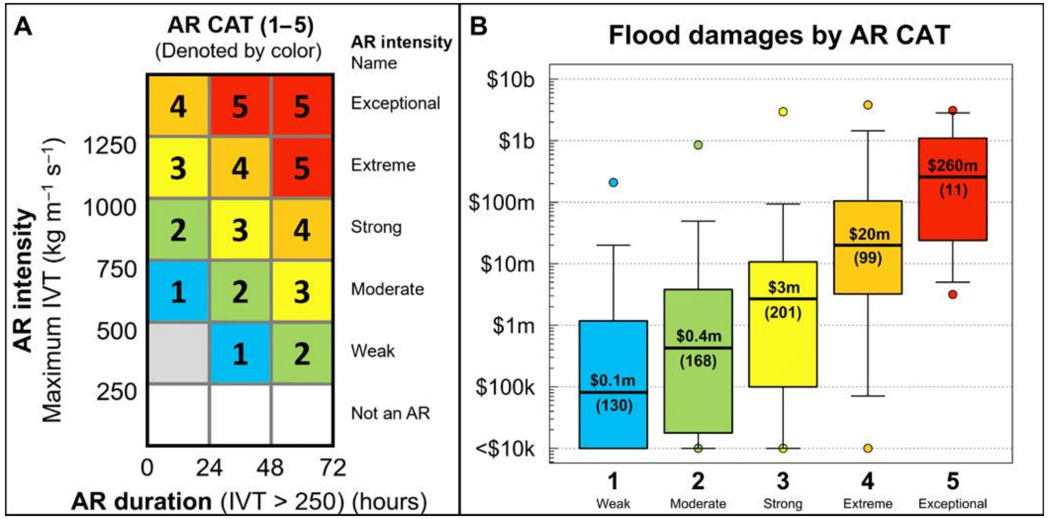
Center for Western Weather
and Water Extremes
SCRIPPS INSTITUTION OF OCEANOGRAPHY
AT UC SAN DIEGO

Motivation

- The total instantaneous water vapor flux in an average AR ~ 27 Mississippi Rivers (Ralph et al., 2017)
- Heaviest rains: 92% of West Coast’s heaviest 3-day rain events fed by ARs (Ralph & Dettinger, 2012)
- Cycles of wet and dry: 85% of multiyear precipitation variance in California (Dettinger & Cayan, 2014)



(Ralph et al., 2017)



			AR intensity Name
4	5	5	Exceptional
3	4	5	Extreme
2	3	4	Strong
1	2	3	Moderate
	1	2	Weak
			Not an AR

AR CAT	Median damage	(n)
1	$0.1m	(130)
2	$0.4m	(168)
3	$3m	(201)
4	$20m	(99)
5	$260m	(11)

(Corringham et al., 2019)

- AR scale: intensity and duration (Ralph et al., 2019)
- Flood damages increase exponentially with AR category (Corringham et al., 2019)

➢ A better understanding of AR processes: Observations

CalWater Field Studies Designed to Quantify the Roles of Atmospheric Rivers and Aerosols in Modulating U.S. West Coast Precipitation in a Changing Climate

Field seasons

CalWater-1: 2009-2011
CalWater-2: 2014-2016

Locations

California
Eastern Pacific Ocean

Sponsors

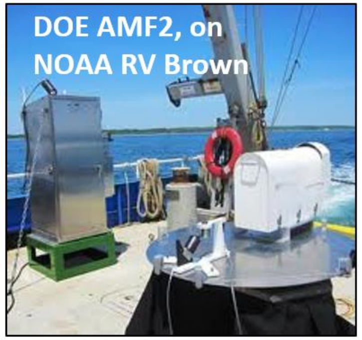
DOE, NOAA
California Energy Commission
California Dept. of Water Resources
NSF, NASA, ONR

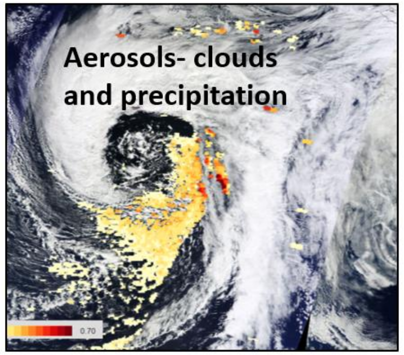
"CalWater – 2015" Field Experiment on Atmospheric Rivers & Aerosols

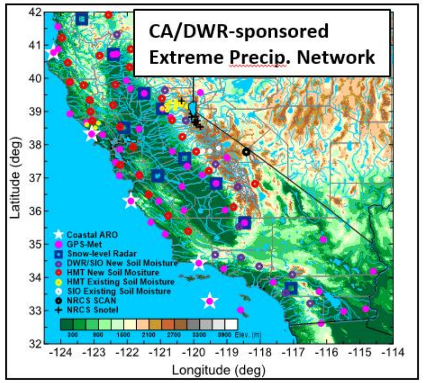
Steering Committee
Co-Chairs: F.M. Ralph
K. Prather, D. Cayan of USCD
+ NOAA, DOE, USGS, NASA
and other Univ. members

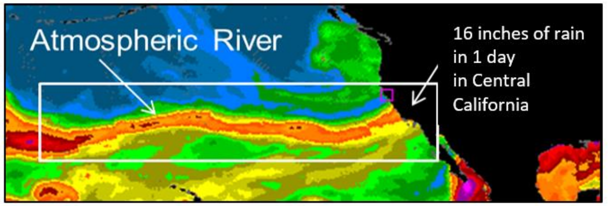
Atmospheric Sci., Chemistry, Hydrology, Oceanography

Ralph et al. 2016
Bull. Amer. Meteor. Soc.









AR Recon Atmospheric River reconnaissance

Support **water management** decisions and **flood forecasting** by developing and testing the potential of **targeted airborne and buoy** observations over the Northeast Pacific to improve forecasts of the landfall and impacts of atmospheric rivers on the U.S. West Coast at lead times of 1-5 days.

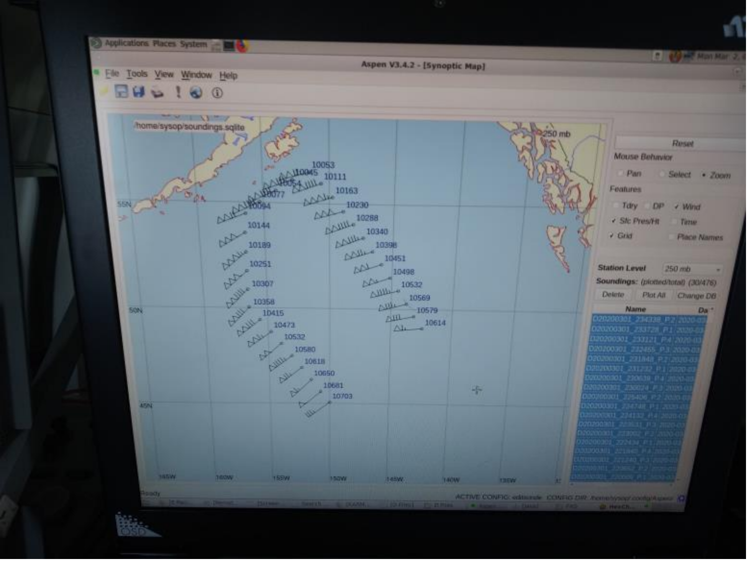
Photos taken on G-IV 1 Mar 2020

Field seasons

2016
2018
2019
***2020**

Partners and Sponsors

PI:	F. Martin Ralph *(UC San Diego/Scripps Institution of Oceanography/CW3E)*
Co-PI:	Vijay Tallapragada *(NOAA/NWS/NCEP/Environmental Modeling Center)*
Primary Sponsors:	US Army Corps of Engineers, California Dept. of Water Resources, Sonoma Water
Facility Partners:	US Air Force 53rd Weather Reconnaissance Squadron, NOAA Aircraft Operations Center
Modeling Partners:	CW3E (Ralph), NCEP/EMC (Tallapragada), NRL (Doyle), NCAR (Davis), ECMWF (Pappenberger), CU Boulder (Subramanian)
Other Key Partners:	NWS Western Region, Plymouth State Univ., Univ. of Arizona, SUNY Albany

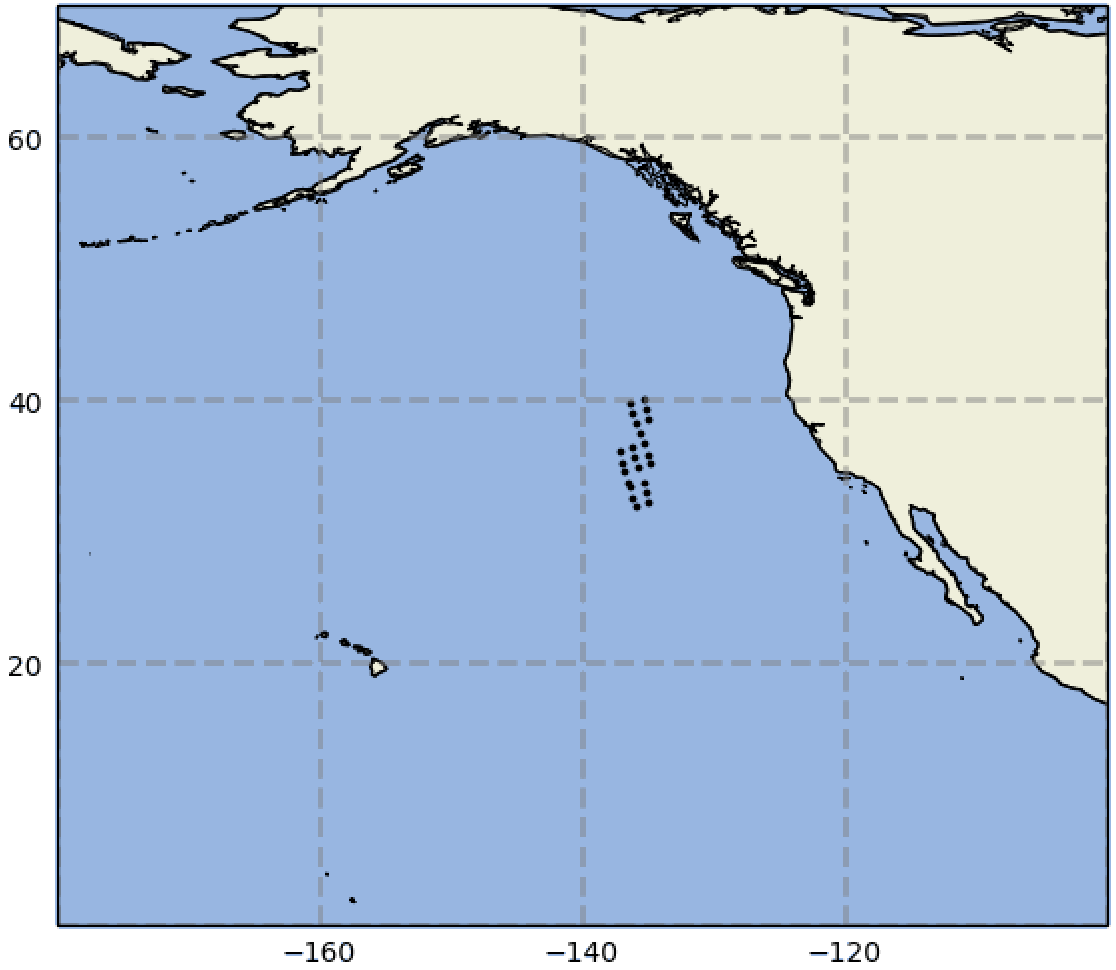

Applications Places System
Aspen V3.4.2 - [Synoptic Map]
File Tools View Window Help
/home/sysop/soundings.sqlite
250 mb
Reset
Mouse Behavior
Pan Select Zoom
Features
Tdry DP Wind
Sfc Pres/Ht Time
Grid Place Names
Station Level 250 mb
Delete Plot All Change DB
Name


First Aid Kit

Observational data

- CalWater and AR Recon:
  - 2014, 2015, 2016, 2018, 2019, 2020*
- Dropsondes
  - High vertical resolution
- Span across the width of the AR
- 25 m – 2000 m

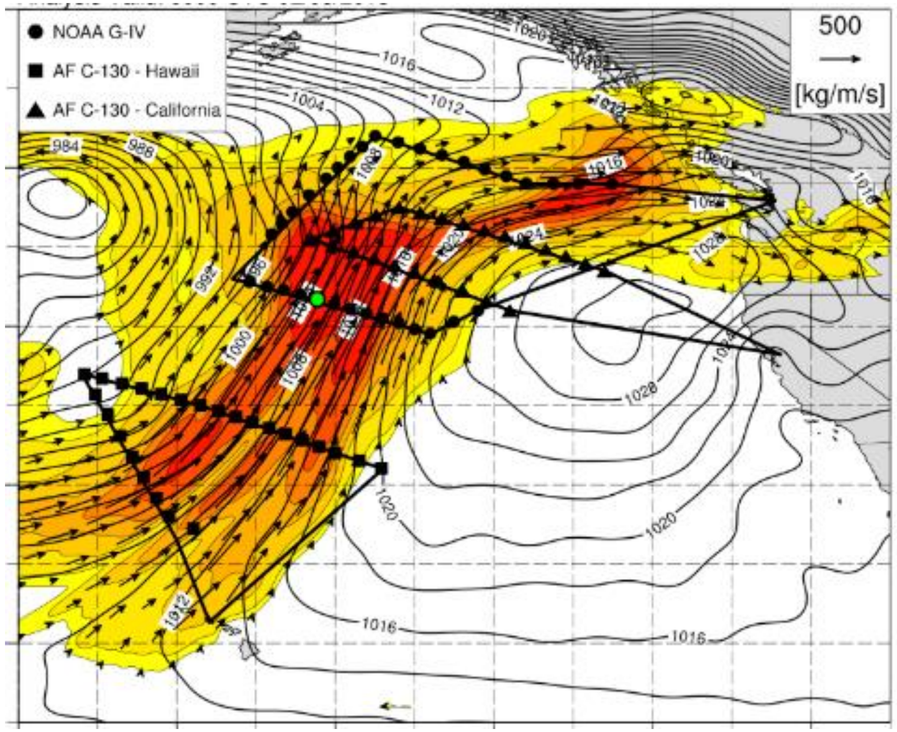
➢ **Classify dropsondes into sectors**



31 events, 1269 dropsondes

Sector identification

2-3 Feb 2018 UTC



NCEP GFS analysis
Colored contours: IVT
Contour lines: SLP

1. Separate into transects
2. Calculate IVT from dropsonde data
3. Identify dropsonde with max IVT in transect
4. Calculate percentage of max IVT in each transect
5. Allocate to sector:

Sector name	IVT limits
Non-AR cold side (NCS)	< 250 kgm^{-1}s^{-1} poleward of AR
AR cold sector (CS)	$<$ 80% max IVT and > 250 kgm^{-1}s^{-1}
AR core (C)	$>=$ 80% max IVT
AR warm sector (WS)	$<$ 80% max IVT and > 250 kgm^{-1}s^{-1}
Non-AR warm side (NWS)	< 250 kgm^{-1}s^{-1} equatorward of AR

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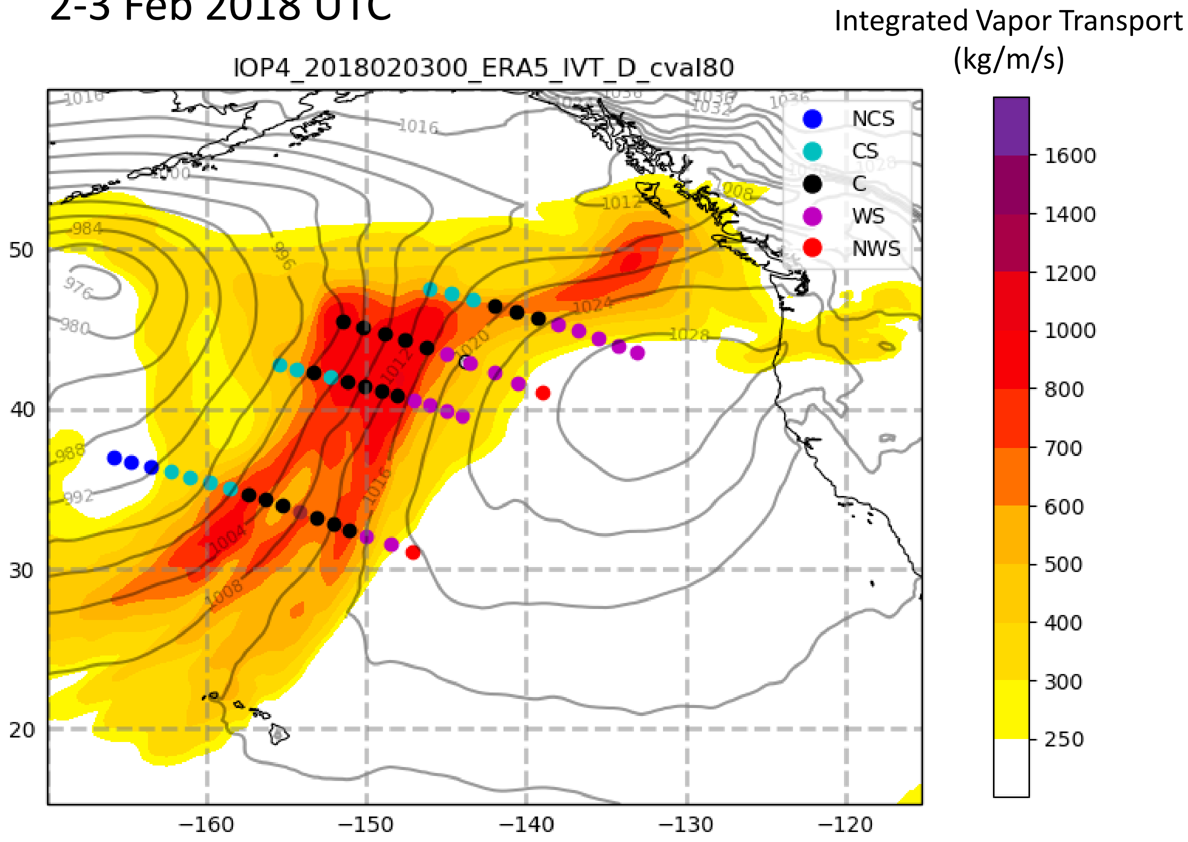

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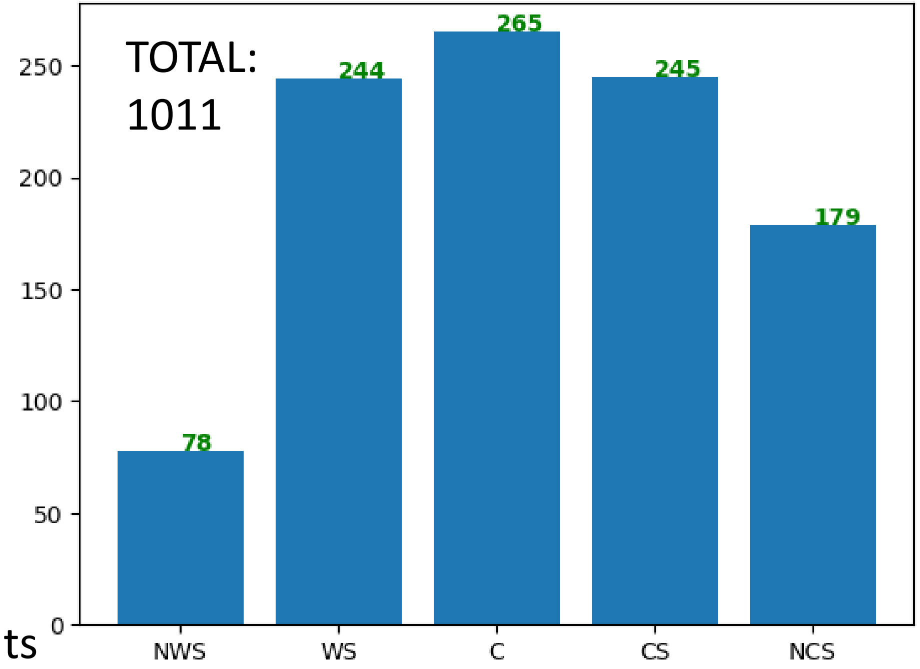
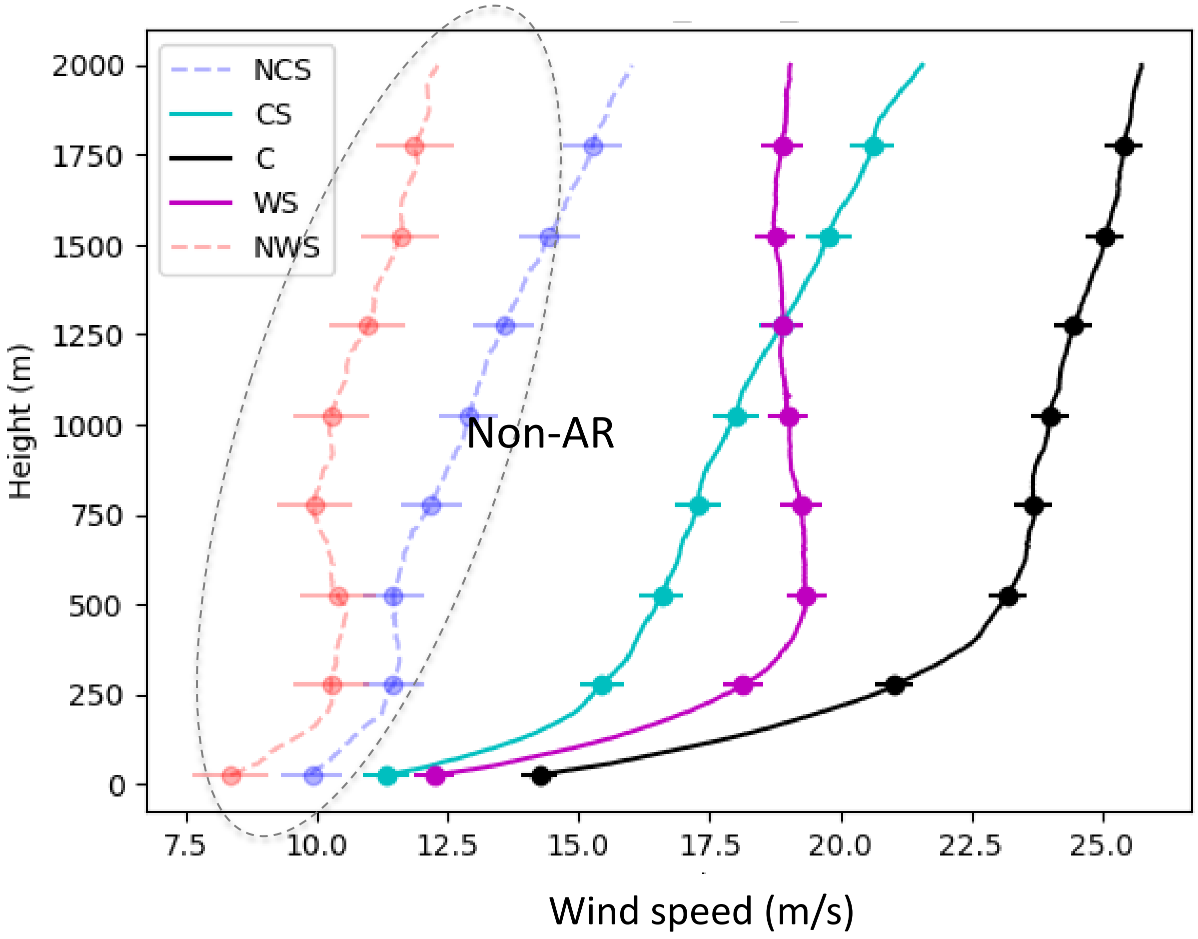


*75% and 70% same overall results

Sector composites



Bars: 95% confidence interval

Atmospheric River:

- Stronger winds

Core:

- Strongest winds
- Strong wind shear lowest 500m

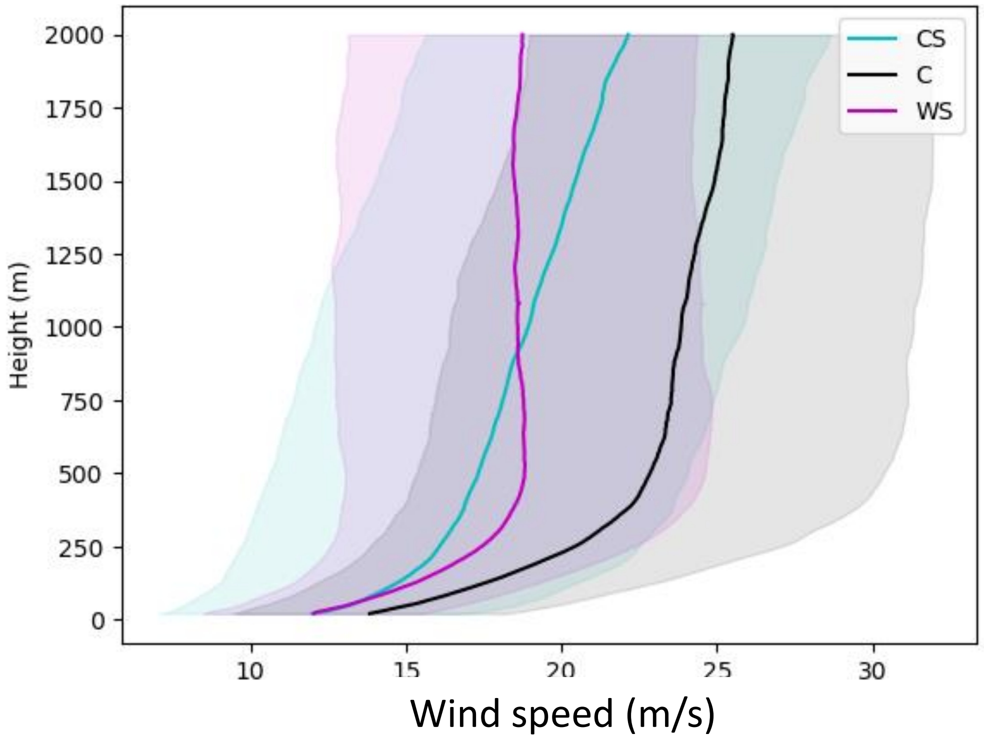
Sector composites – variability

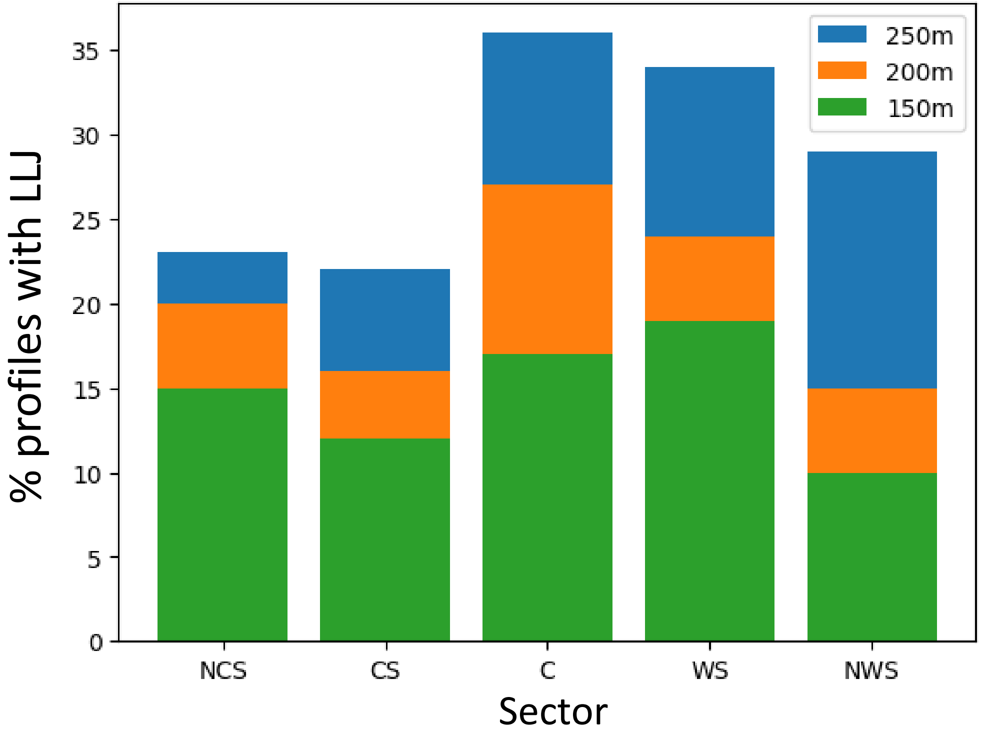
AR sectors with 1 standard deviation:

- Different magnitudes, different shapes

Presence of the low-level jet:

- Max below 1500 m > 2 ms^{-1} local min aloft
- Local min: 250 m, 200 m 150 m above max





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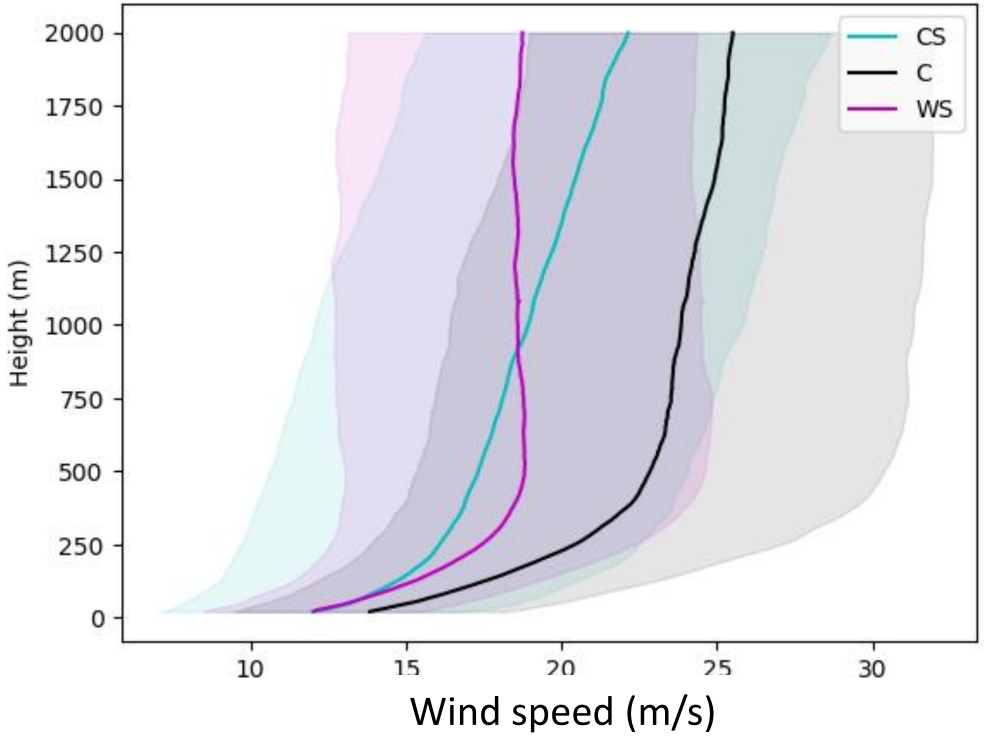

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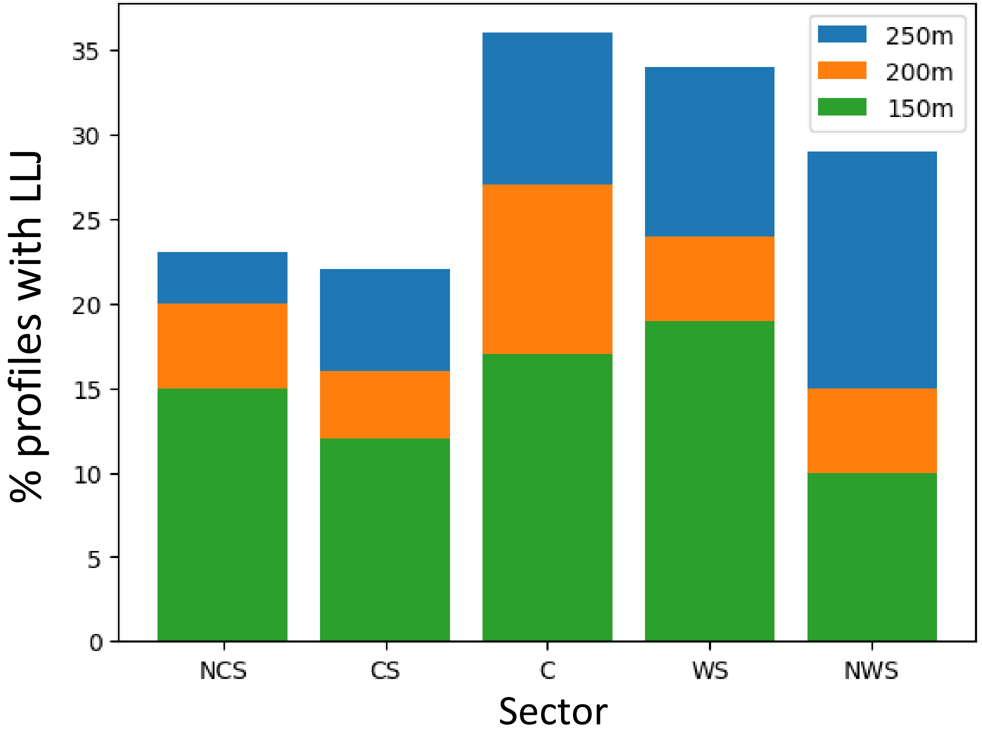

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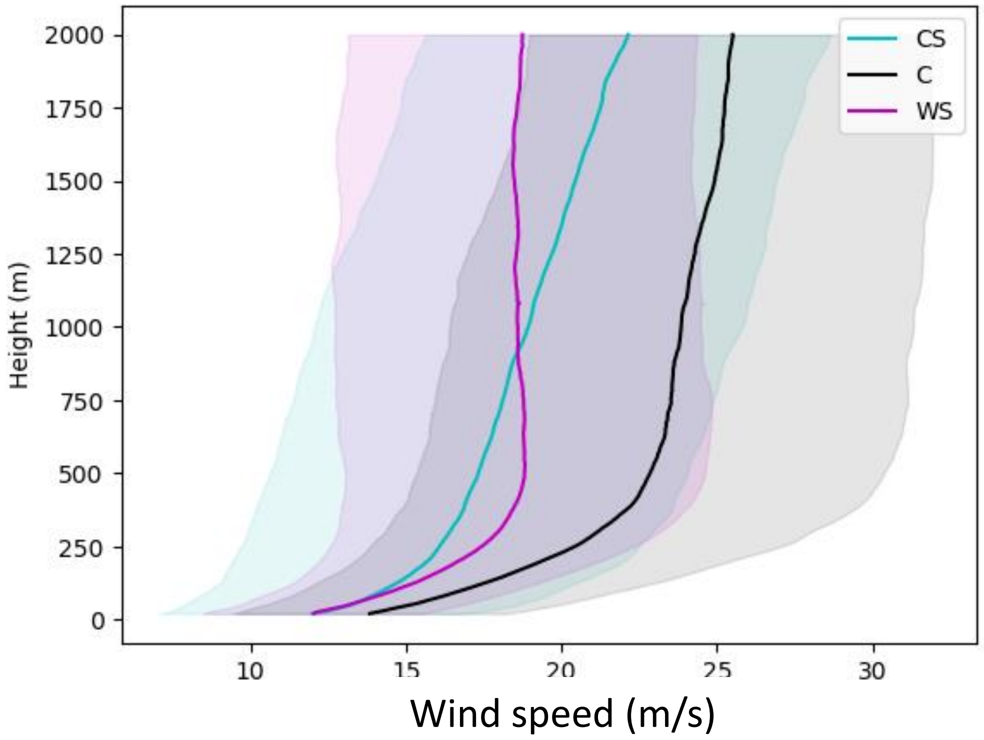

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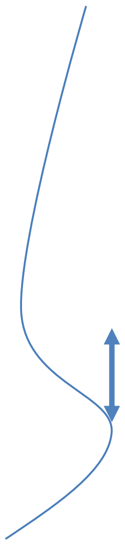
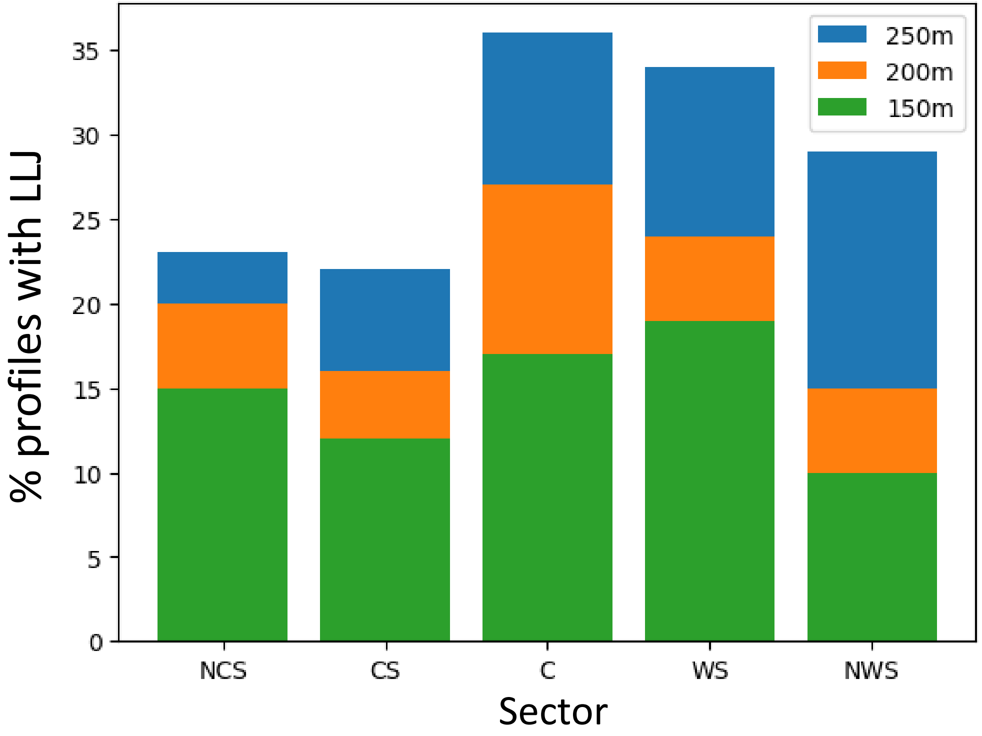
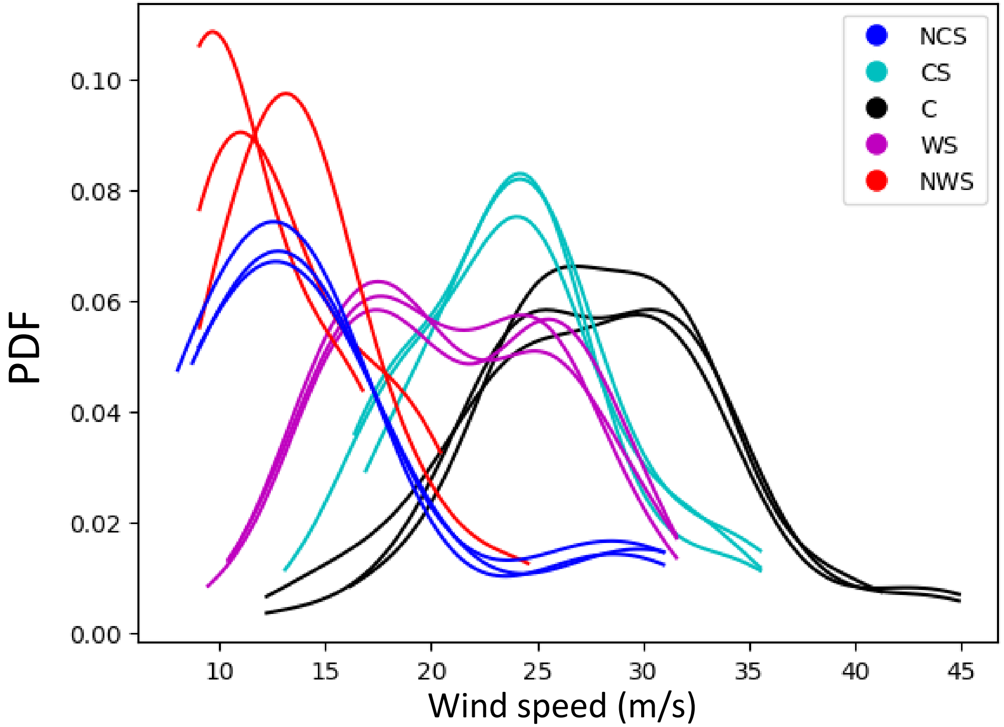




Sector composites – variability

Low-level jet wind speed PDF:

- Line for each 'local' level (250,200,150m)



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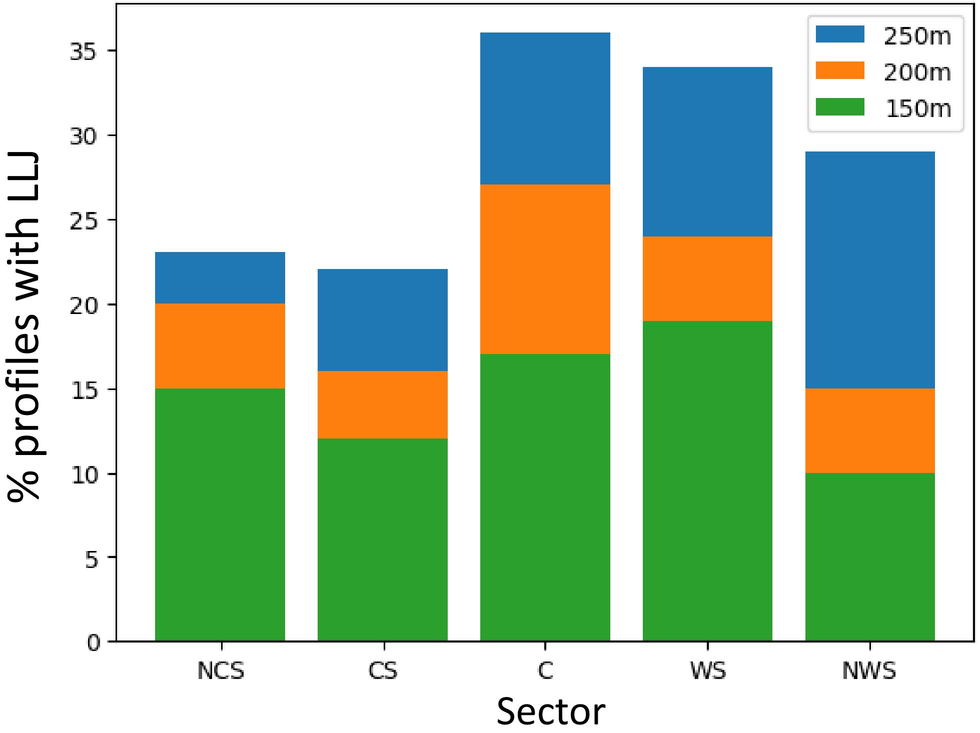
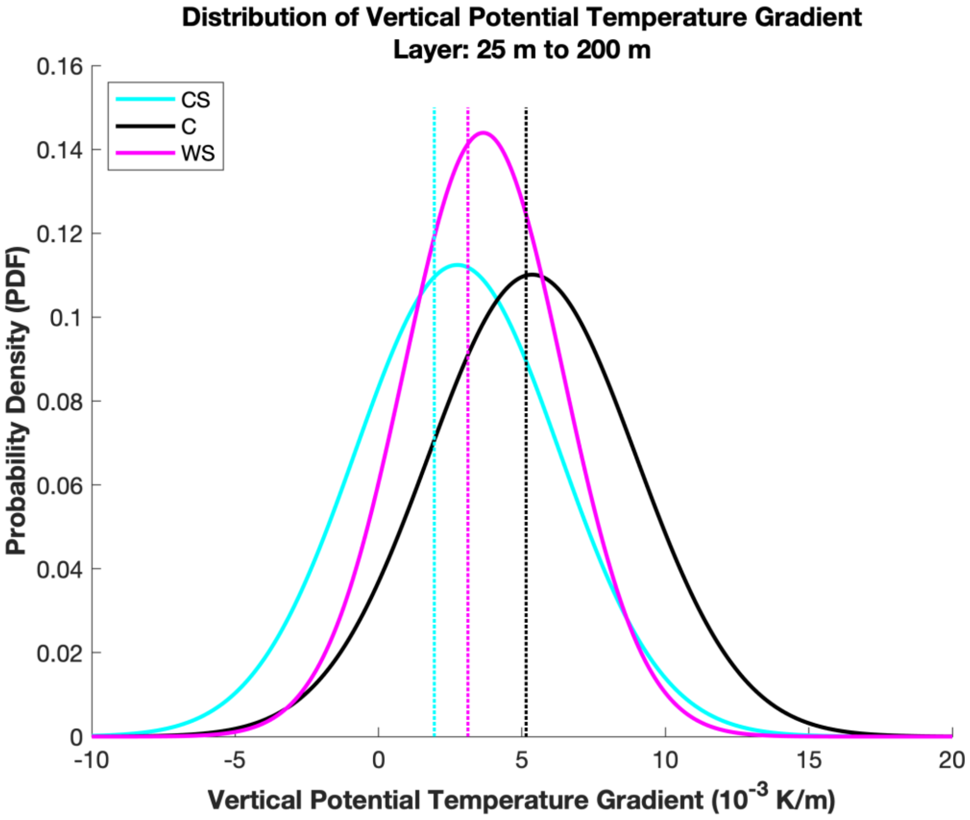
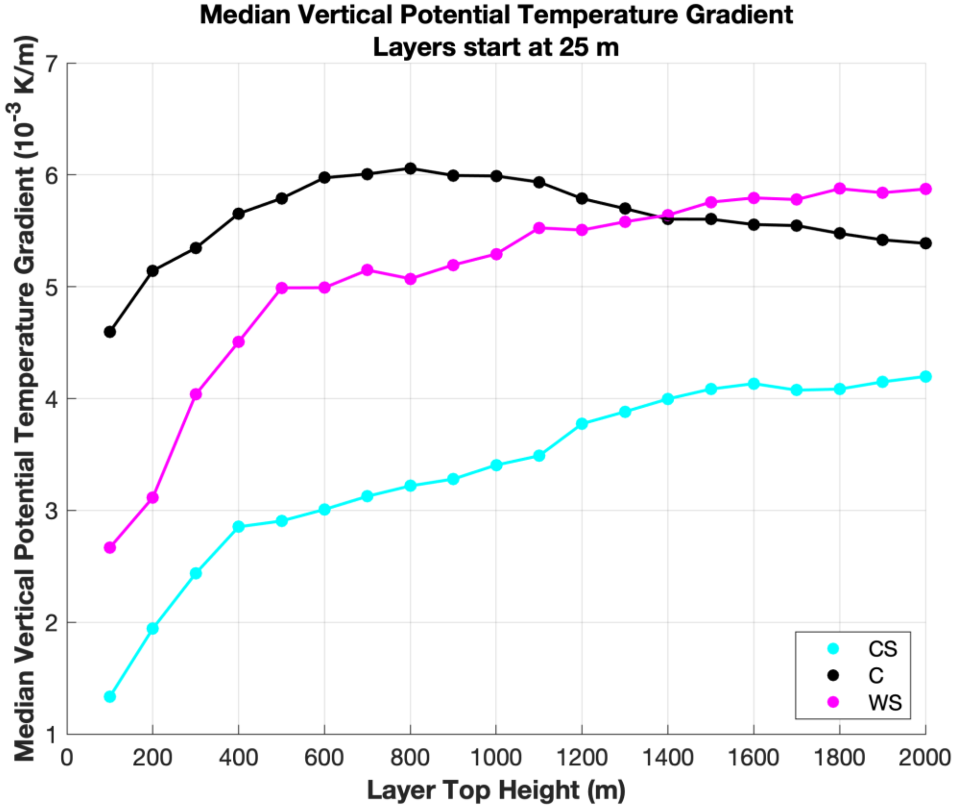


Static stability (vertical theta gradient)





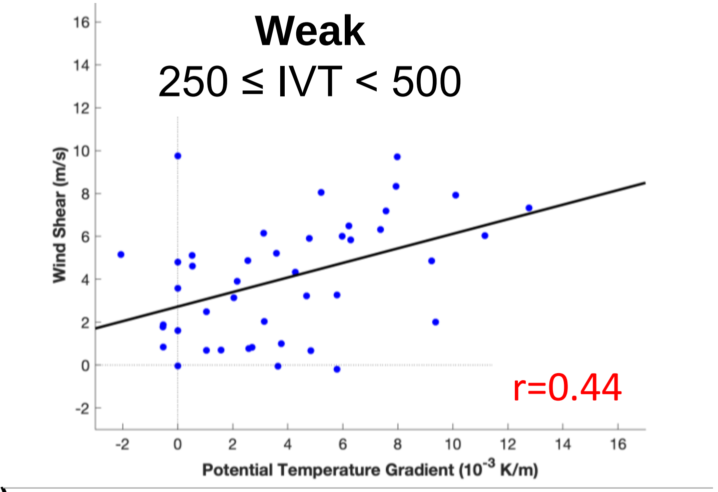
- Core shifted to higher stability
- Median theta gradient higher in core

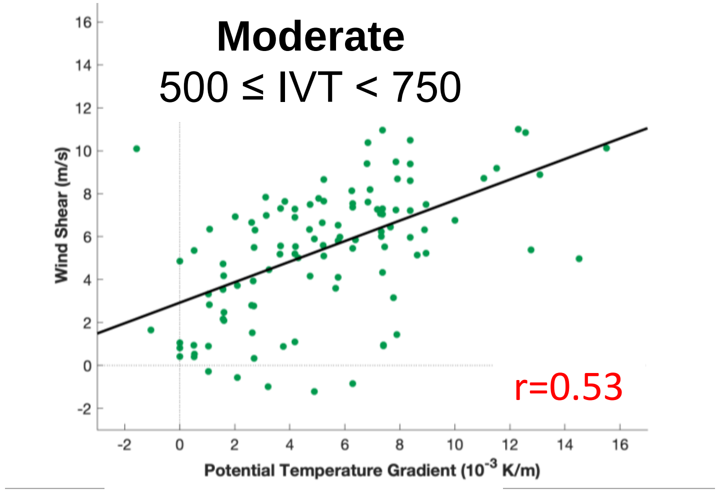
Low-level stability and wind shear in the core

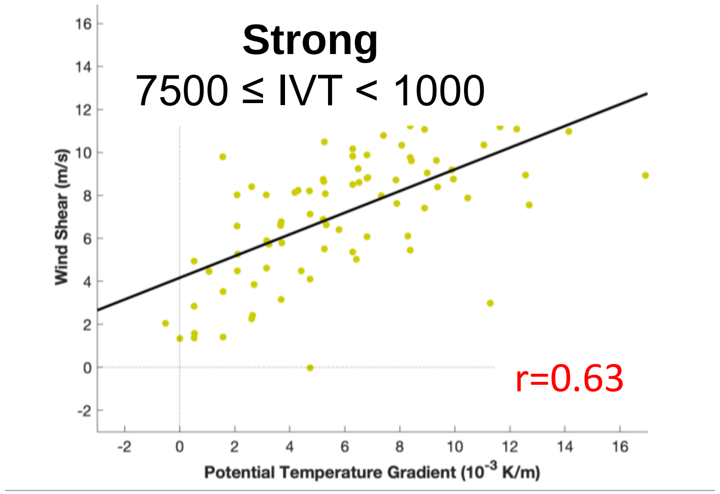
Vertical potential temperature gradient (stability)

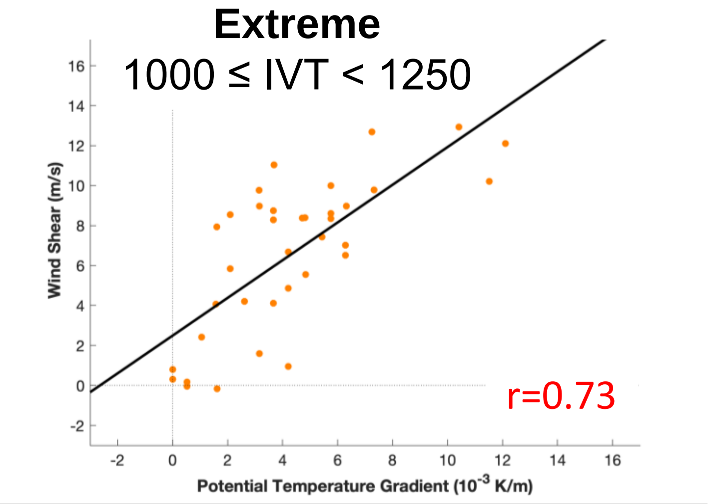
vs.

Shear (25 to 200m)





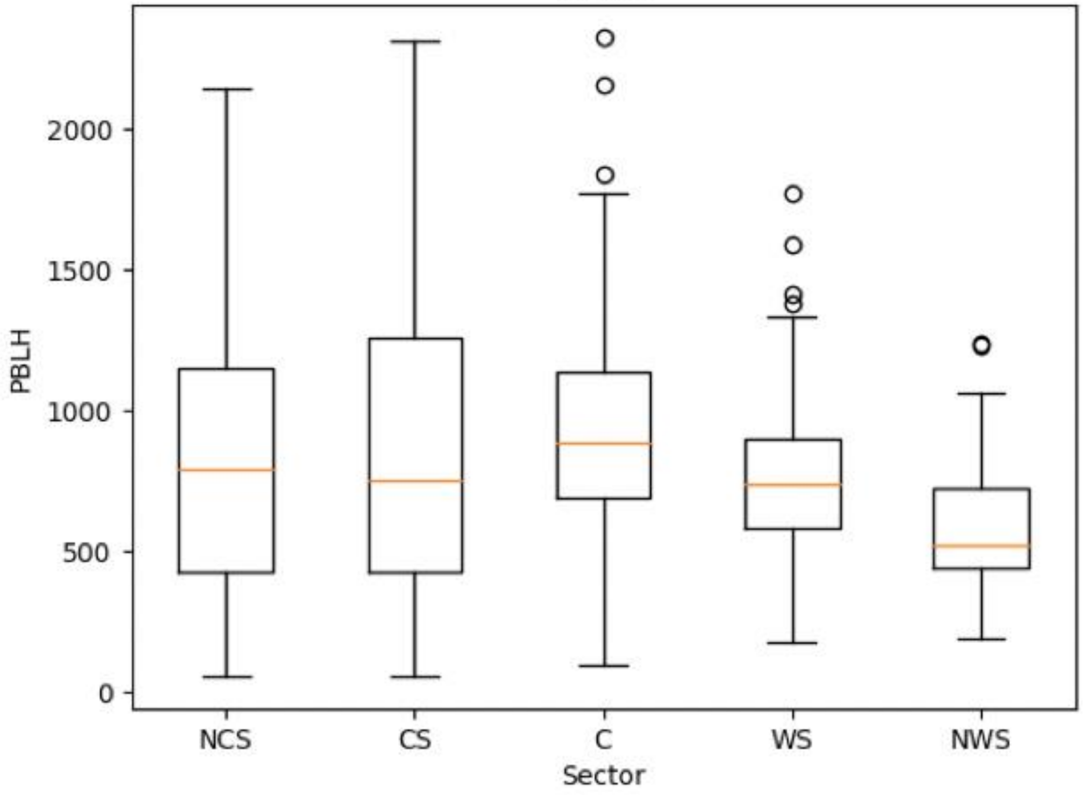




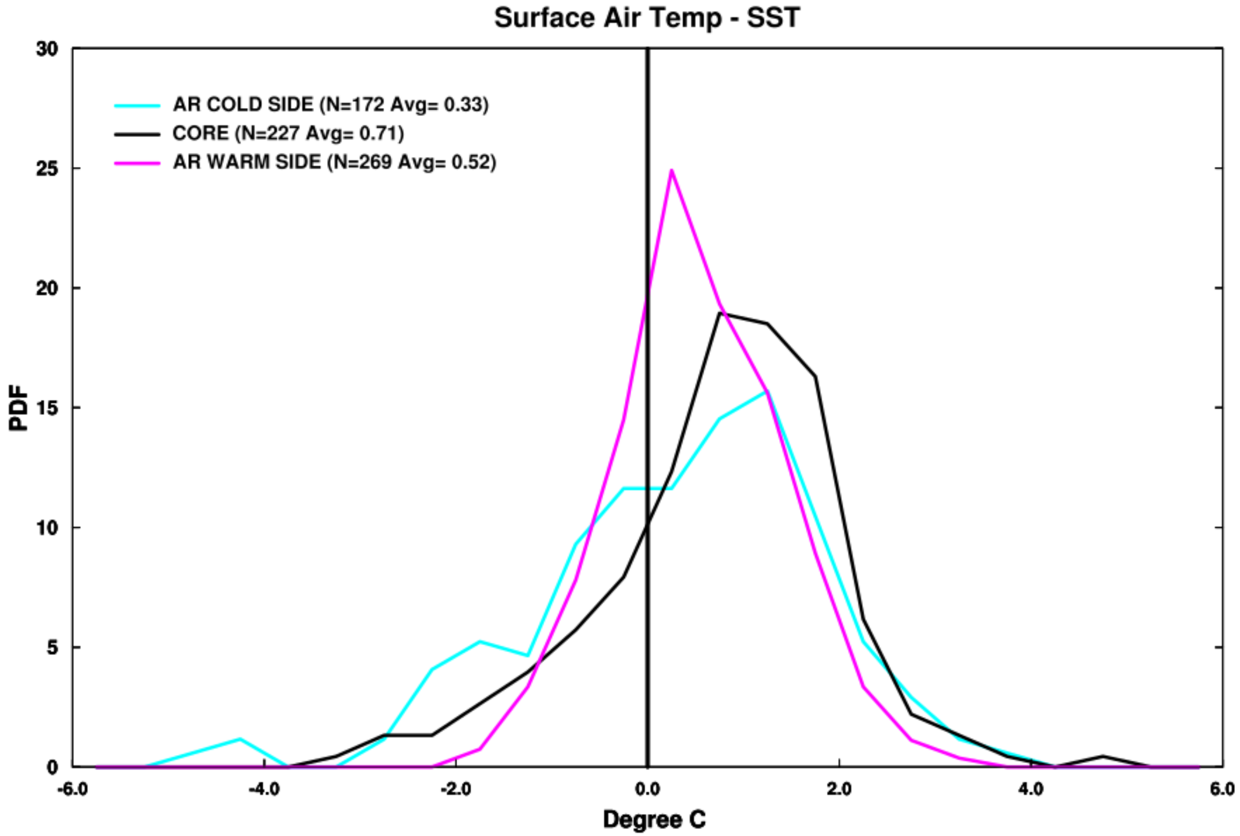
- Positive correlation Stability vs. Shear
- Correlation strengthens with IVT

PBLH and surface sensible heat flux

PBL height (Bulk Richardson number)

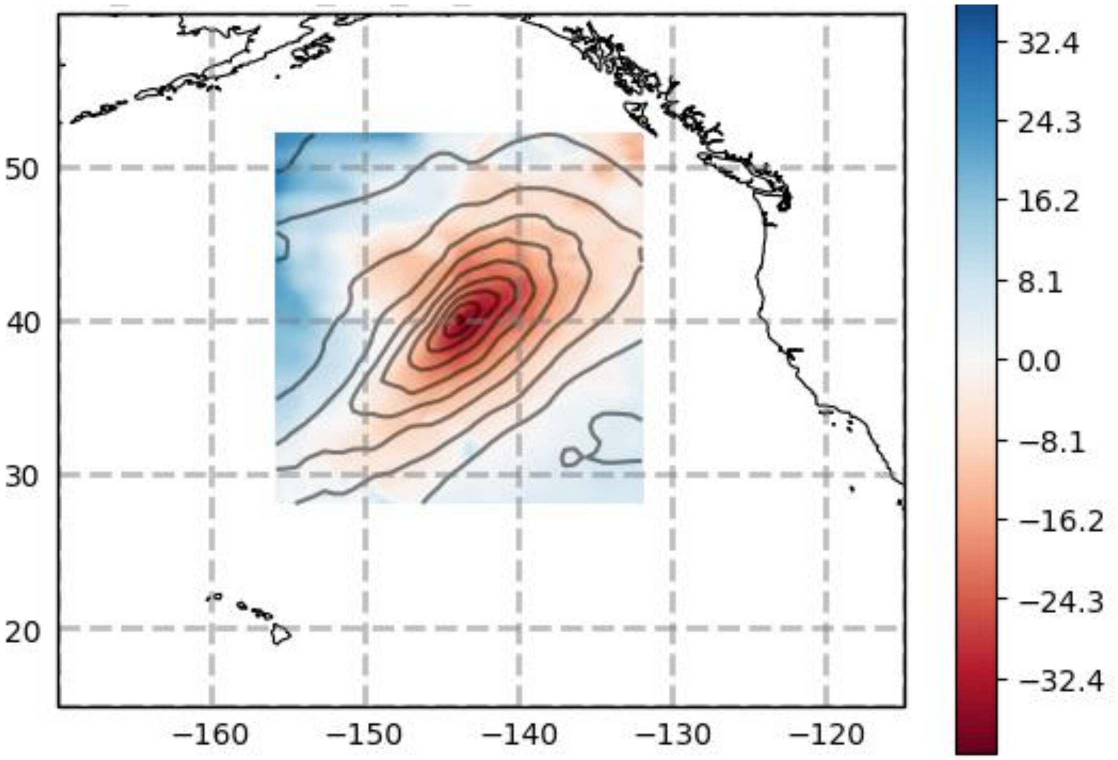


Vertical water vapor distribution
– orographic precipitation



Ocean-atmosphere interaction

Surface sensible heat flux

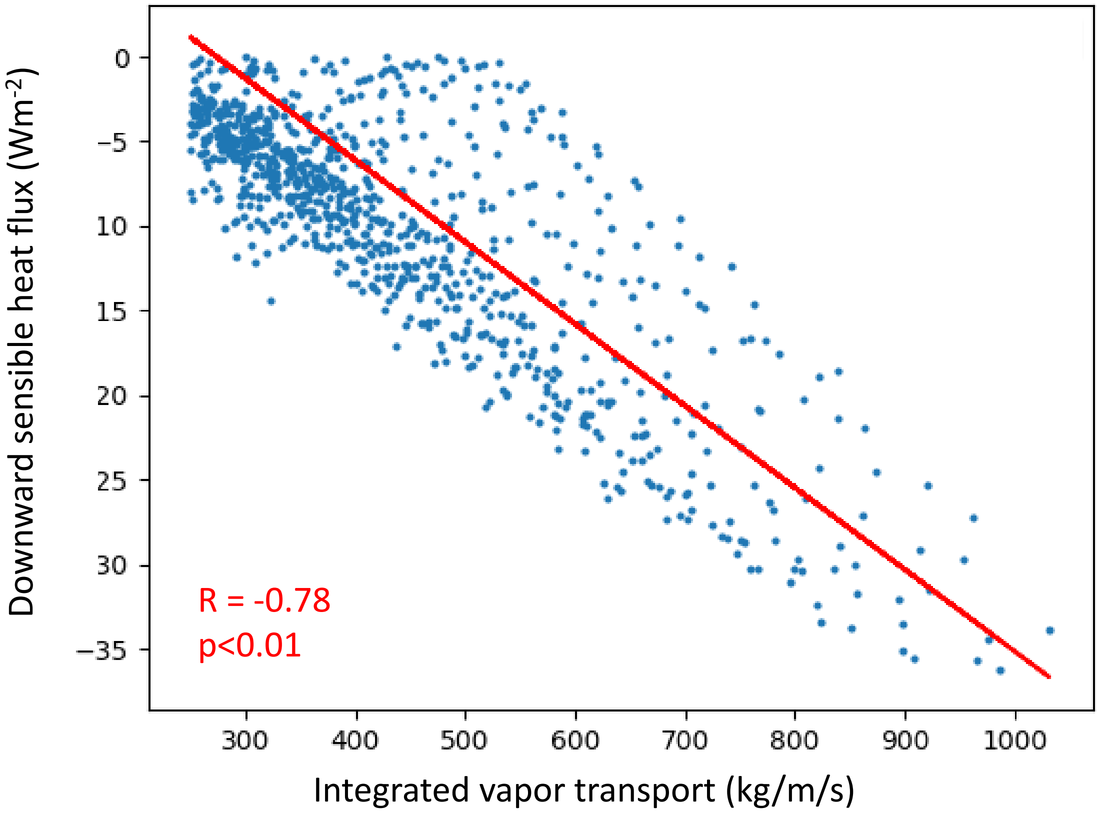


18 cases composited

MERRA2 reanalysis

Colored contours: surface sensible heat flux (Wm^{-2})

Contour lines: IVT



In 18 cases, downward sensible heat flux significantly negatively correlated with IVT

SCIENTIFIC REPORTS

OPEN Ocean variability and air-sea fluxes produced by atmospheric rivers

Toshiaki Shinoda[1], Luis Zamudio[2], Yanjuan Guo[1,3], E. Joseph Metzger[4] & Chris W. Fairall[5]

Summary

- Importance of ARs: heaviest rains, cycles of wet and dry
- Need for more observations – CalWater & AR Recon

- 1269-1011 dropsondes split into different sectors of ARs

- AR vertical composites (wind):
  - Spread
  - Clustering

- Static stability & wind shear – positive correlation
- Planetary boundary layer height & T_air – SST difference
- Surface sensible heat flux and ocean-atmosphere interactions

Future work

- Continue clustering vertical composite profiles (e.g. temperature inversions)
- Boundary layer height and vertical distribution of water vapor
  - ➢Effect on orographic precipitation
  - ➢Boundary layer profile in models & forecast error
- Further examine the cases with strong negative correlation between IVT and surface sensible heat flux
- Surface sensible heat flux impact on AR dynamics

Perspectives

- Observations
  - Forecasts & Research
  - Sampling for science vs. forecast improvement (How far upstream? Lead time?)
- Observational tools
  - High vertical resolution (dropsondes)
  - Buoy measurements – wind, pressure, SST?
  - SST from dropsondes
- Mean structure & variability
- Process studies (modelling)
- Atmospheric rivers & extra-tropical cyclones

Questions?

Contact me if interested in working with the observational datasets: accobb@ucsd.edu