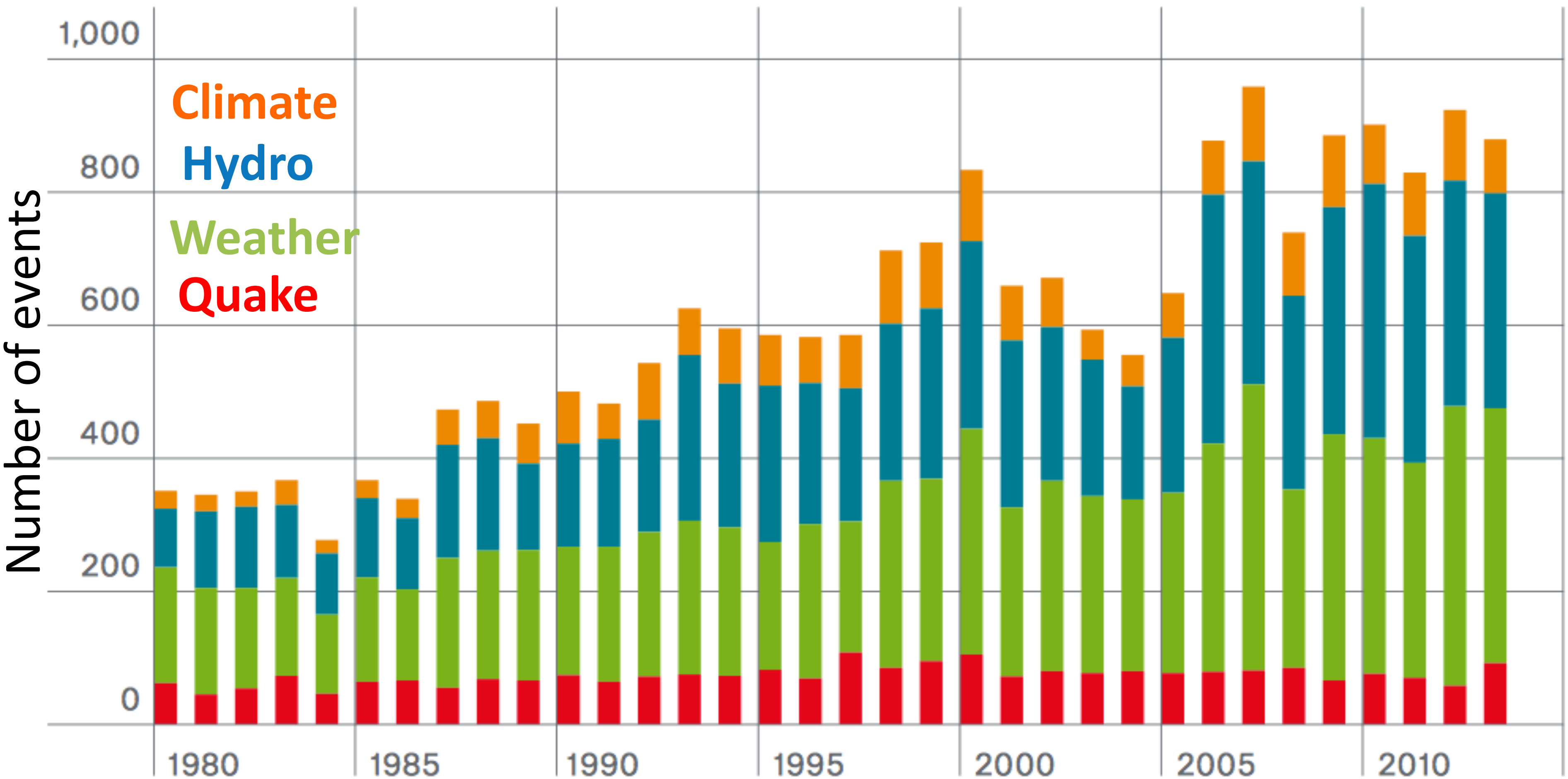
Pathways Connecting Physics and Climate Resilience

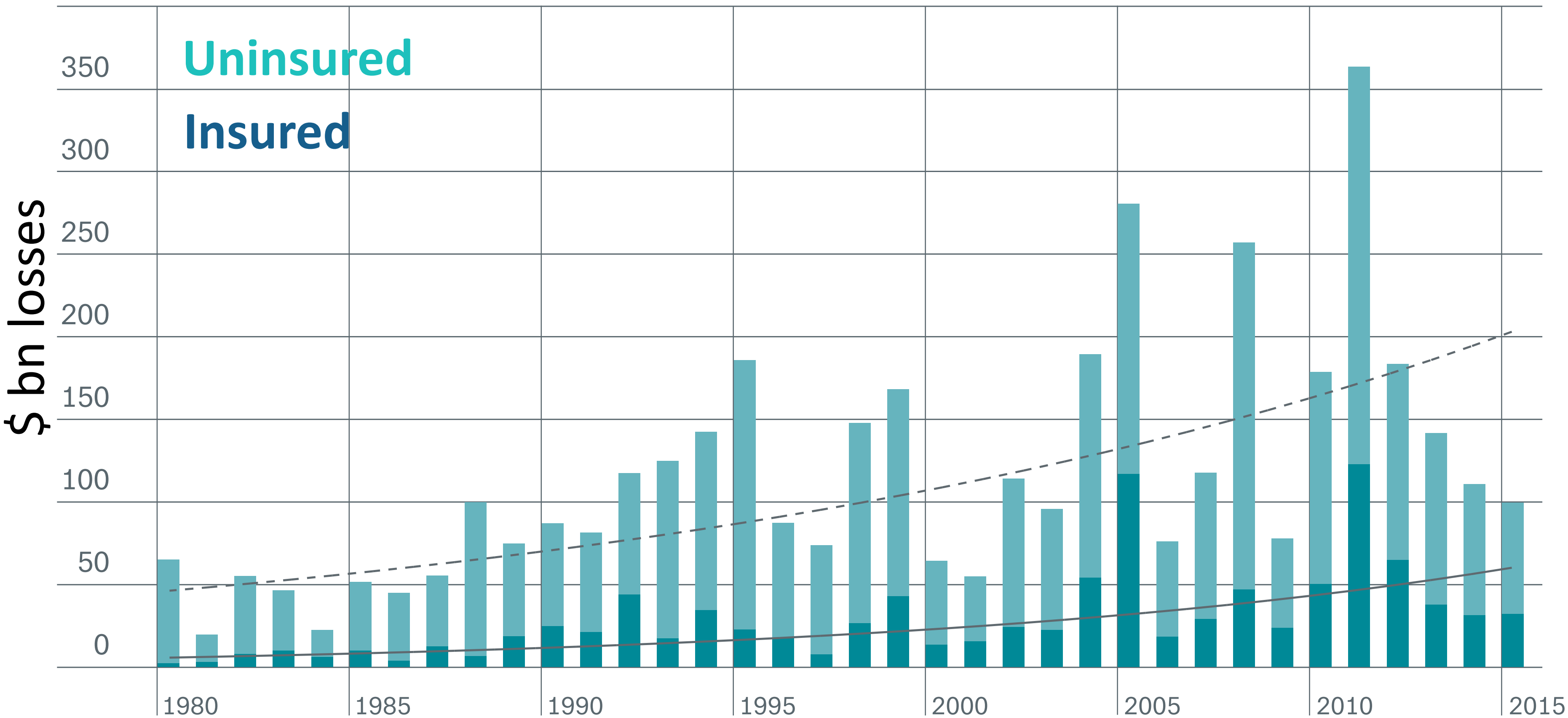
James Done

Increasing Number of Events



Munich Re 2014

Increasing Losses



Munich Re 2014

Technical and Scientific Advances

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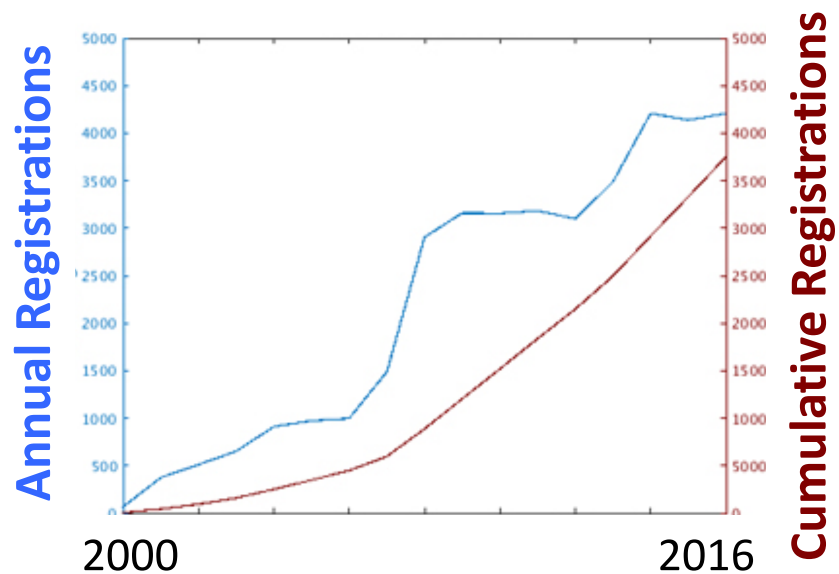
- Highest quality science

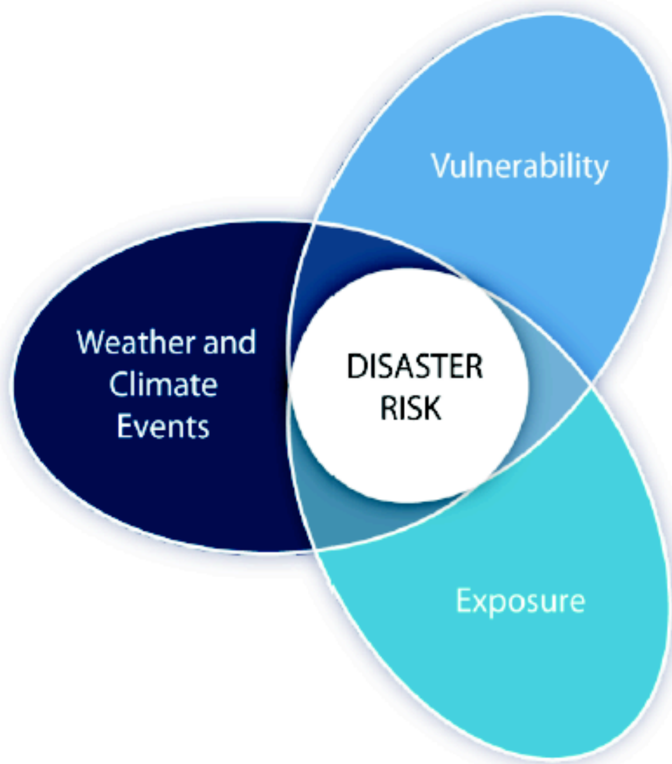
Rank	Institution	C/N = citations per paper	N = number of papers	C = number of citations
1	NCAR (NATL CTR ATMOSPHERIC RES)	34.92	4,718	164,732
2	HARVARD UNIV	29.81	1,908	56,878
3	PRINCETON UNIV	28.13	1,701	47,857
4	UNIV WASHINGTON	25.16	3,967	99,813
5	UNIV COLORADO BOULDER	25.04	5,233	131,049

- Most widely-used community models



- Next-generation instruments, and datasets

Physics is one of many factors



Adapted from IPCC SREX, 2012

Connecting Physics and Resilience

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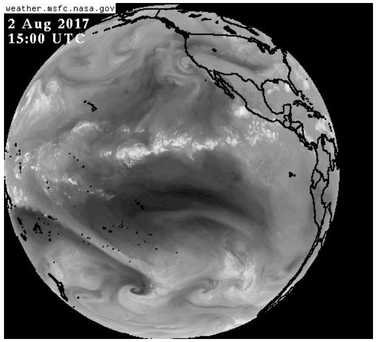
- Incorporate physics into weather and climate risk assessment.

- Risk management practice informs the physically-based approaches.

The Mother Lode:
Capacity to understand mesoscale phenomena at the global scale.



Pathway 1: TC Footprinting

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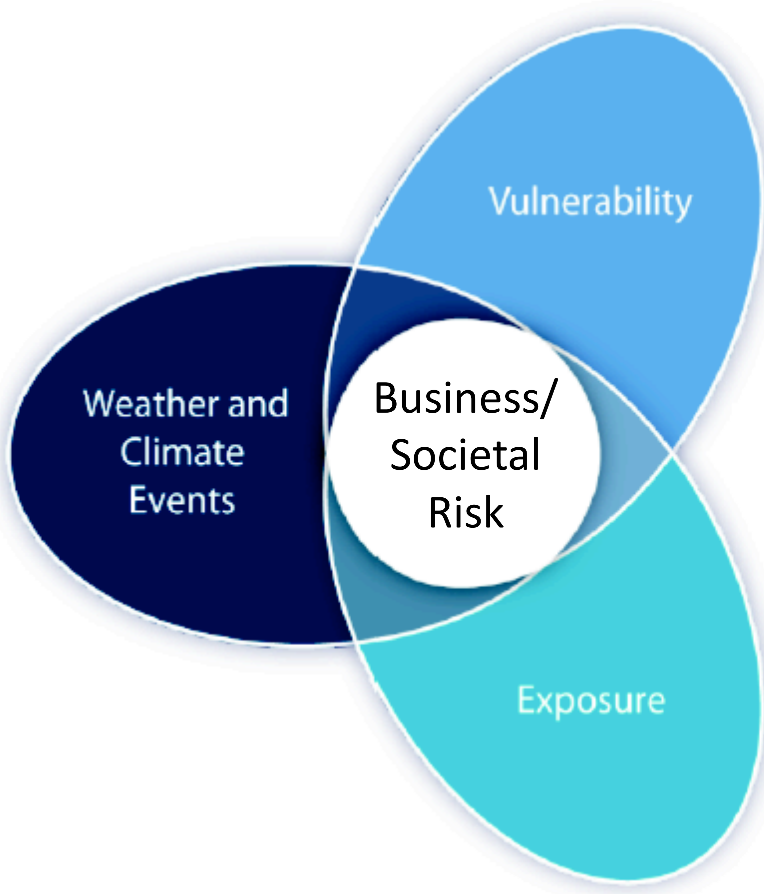
Stakeholder:	The reinsurance industry
Need:	Understand losses
Current practice:	Gradient wind
Hypothesis:	Terrain effects drive TC wind losses
Physics:	Terrain effects
Results:	New view of footprints and wind climate
Resilience action:	Optimize reinsurance portfolios

Thanks to Ming Ge (NCAR), Yuqing Wang (U. Hawaii),
Geoff Saville and Ioana Dima-West (Willis Towers Watson)

Minimizing Risk



Adapted from IPCC SREX, 2012

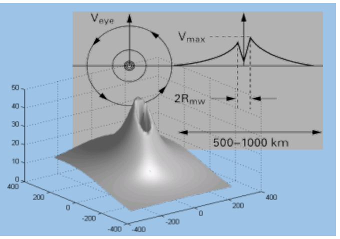
The Need for Historical Footprints

- Understand inland wind decay.
- Understand historical losses.
- Quantify wind risk in regions of sparse data
- Validate catastrophe models.

Current Practice

Parametric radial wind profiles:

- fast, but smooth fields, surface wind factors.



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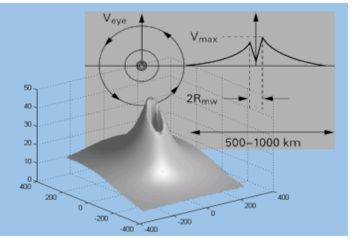
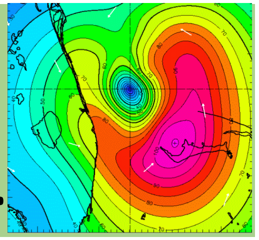


Spatial analysis of observations:

- asymmetries, but few storms, globally inconsistent.



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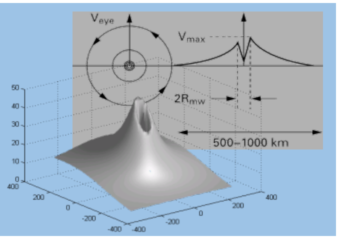

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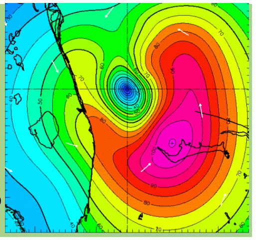
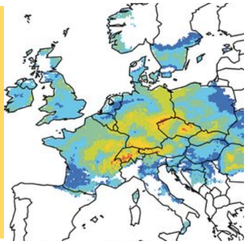


Geostatistical spatial modeling:

- fast, only applied to European windstorm so far.



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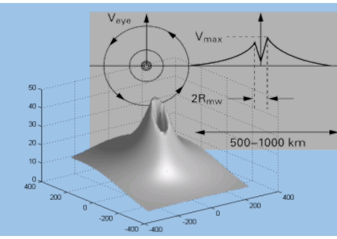

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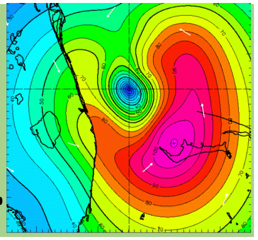

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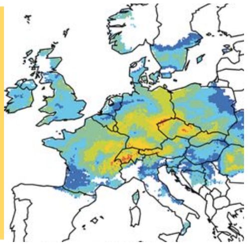
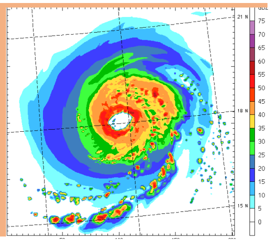


Numerical modeling:

- many physical processes, but slow, track error.



Adding Physical Processes

Historical track data

(EBTrACS and JTWC)

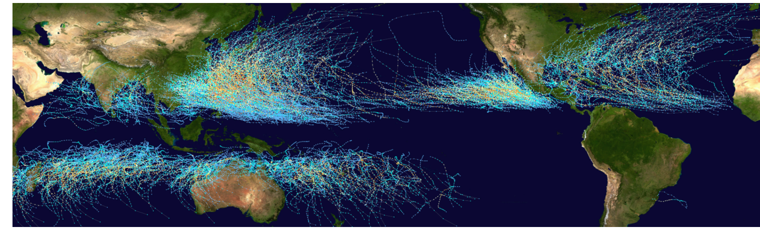
↓

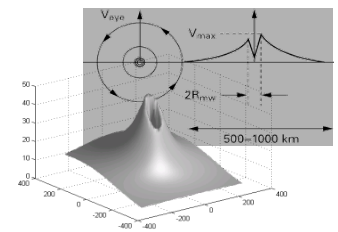
Holland et al. (2010)

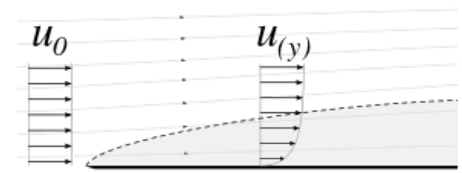
parametric pressure profile

↓

Kepert and Wang (2001) numerical boundary layer model.







Fast, some topographic and roughness effects, no track error, but missing processes (e.g., strong thermal effects).

The KW01 Boundary Layer

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Diagnoses boundary-layer flow using dry equations of motion for a given pressure field.

- High-order turbulence scheme
  - prognostic TKE, turbulence dissipation.
  - diagnostic length scale (<80m).
- Ignores strong thermal effects.
- Rapidly achieves steady state.

Modifications to KW01

1. Allow storms to move:
   - add environment pressure gradient to TC forcing,
   - add storm translation velocity to horizontal advection.

Modifications to KW01

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1. Allow storms to move:
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2. Allow storms to change intensity and size:
   - update pressure gradient and allow winds to respond,
   - force gradient winds at model top.

Modifications to KW01

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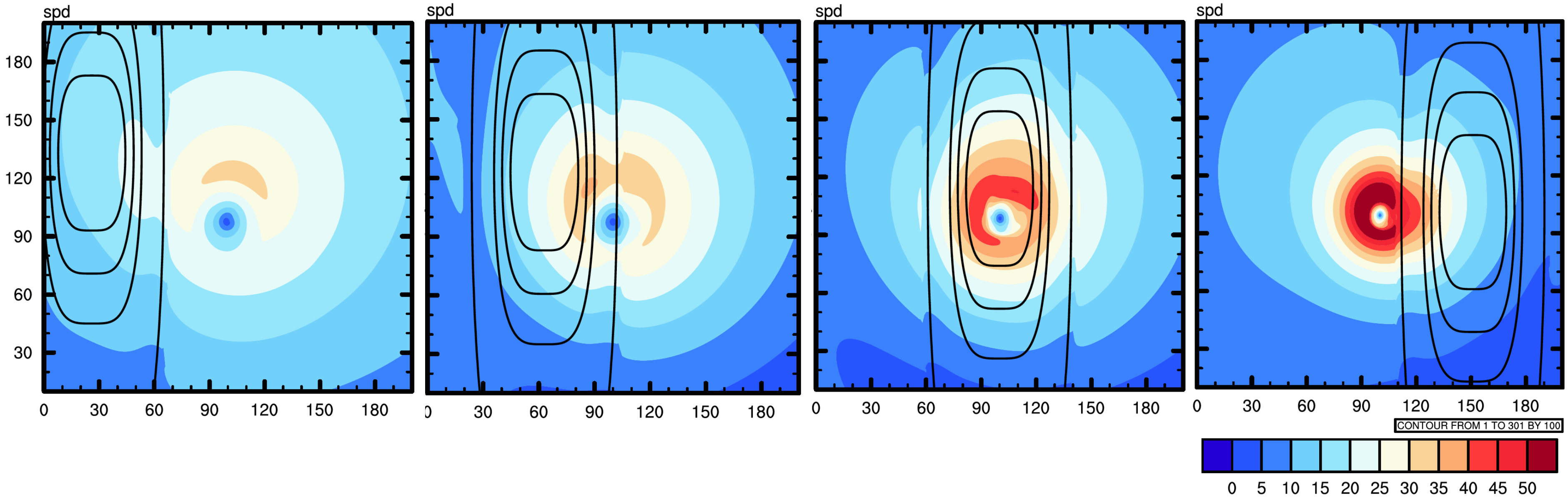
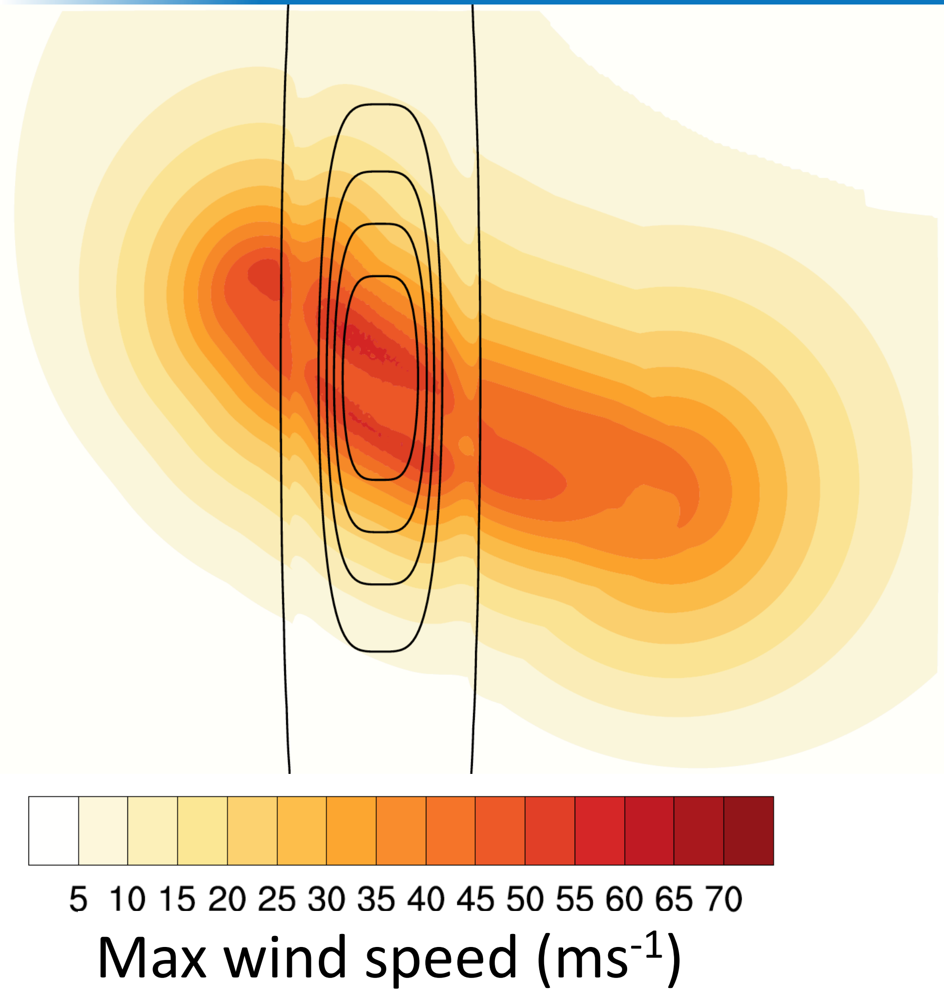
   - add environment pressure gradient to TC forcing,
   - add storm translation velocity to horizontal advection.
2. Allow storms to change intensity and size:
   - update pressure gradient and allow winds to respond,
   - force gradient winds at model top.
3. Include some topographic effects:
   - included in model equations.
4. Include variable surface roughness effects:
   - drag coefficient = f(terrain height).

Passing Over an Idealized Hill



Ike Encounters a Surprise Island



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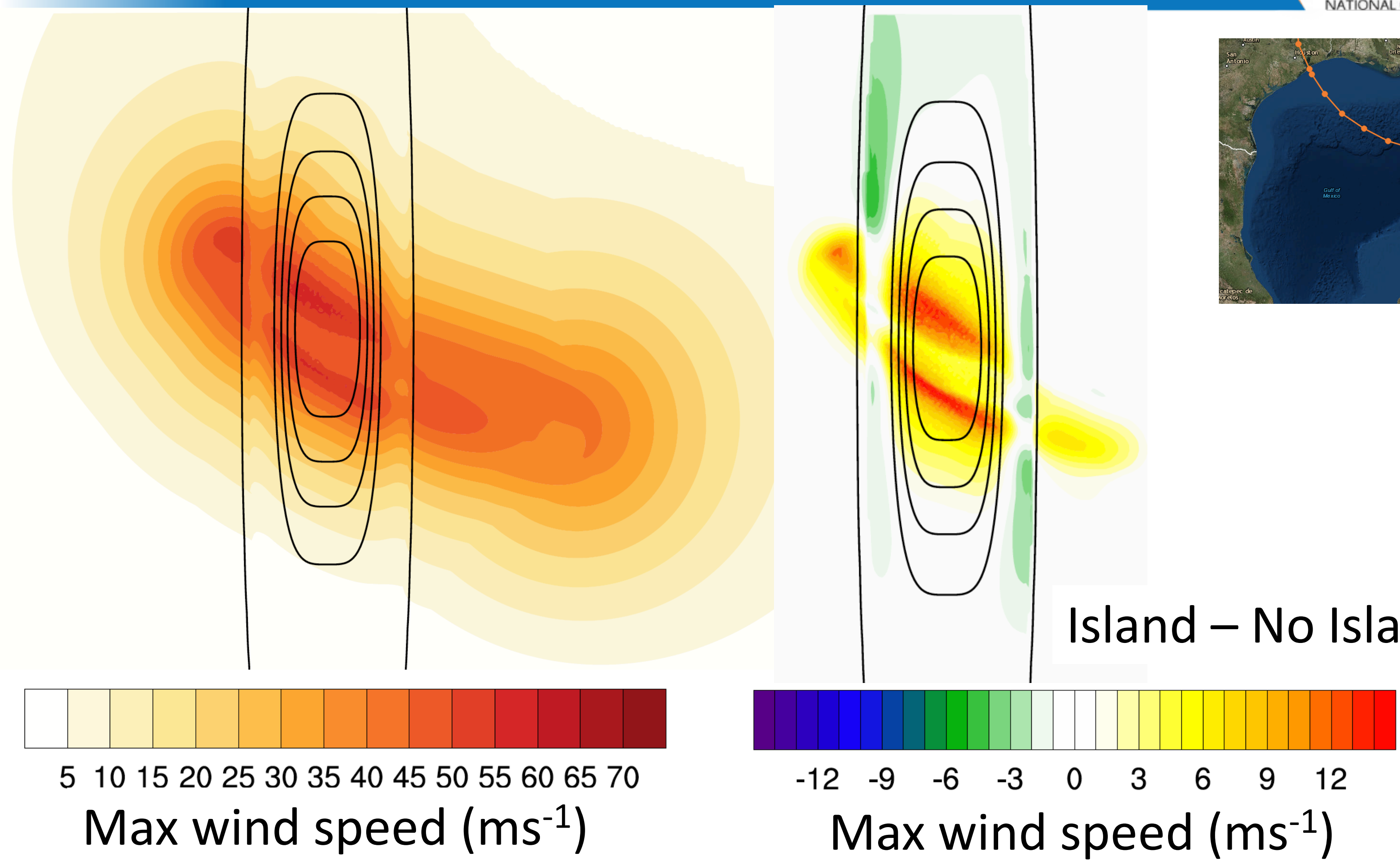
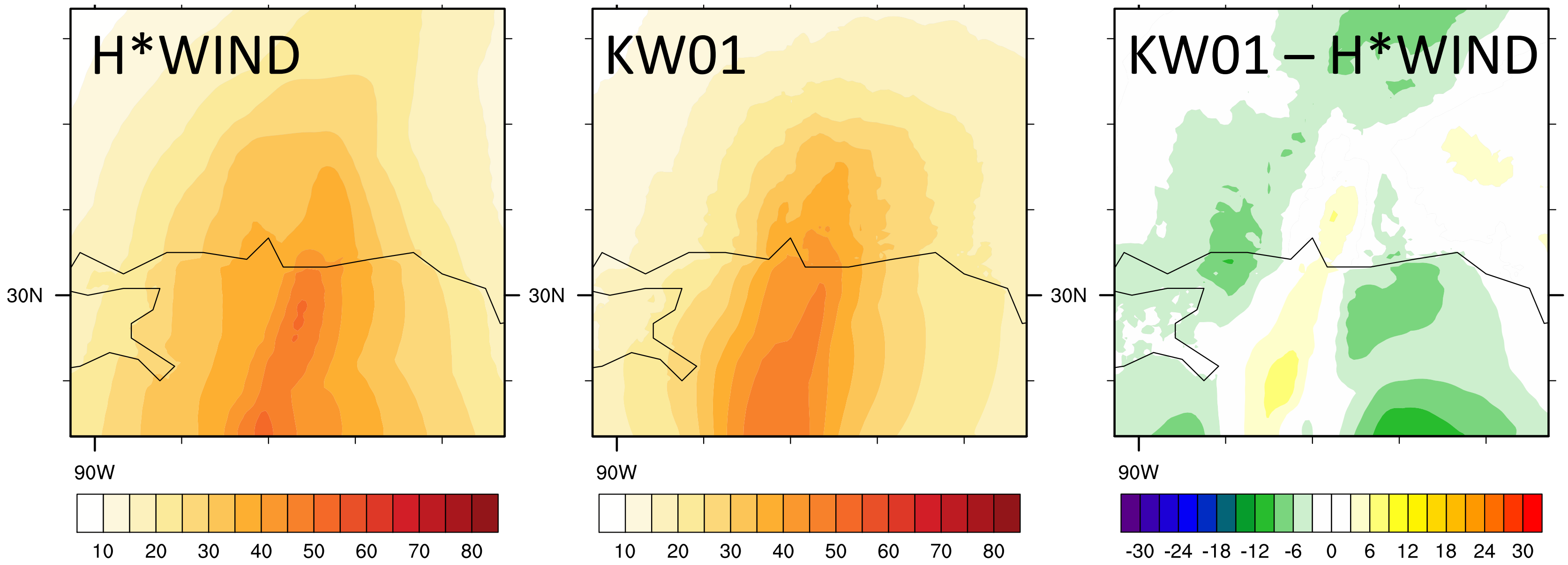
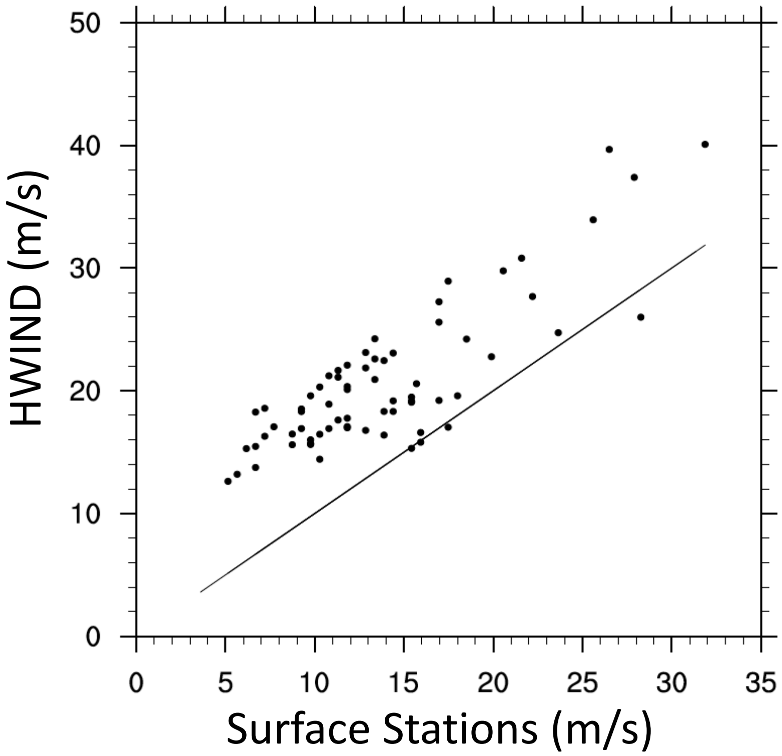


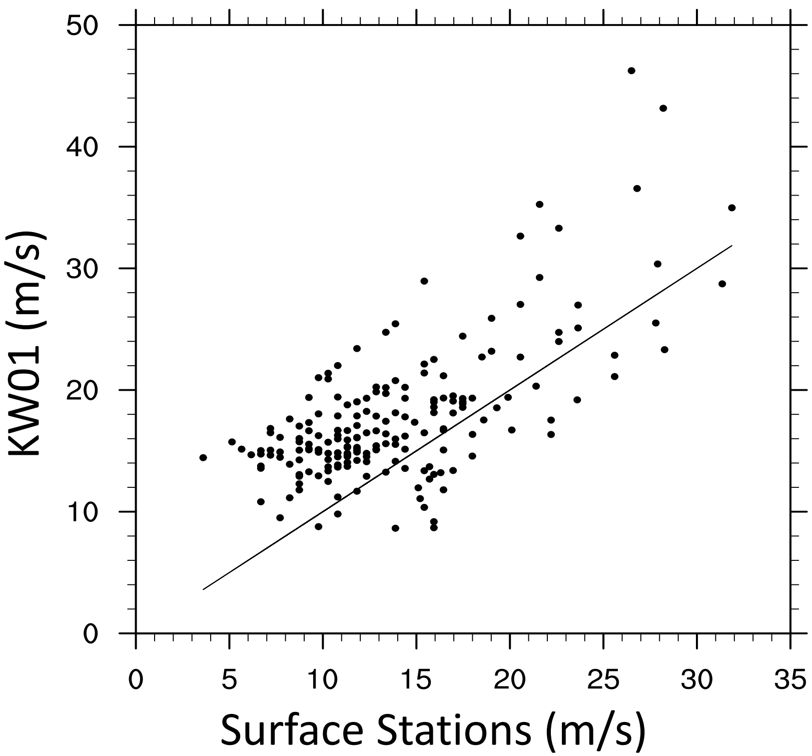
Ivan footprint similar to HWIND



- HWIND has greater asymmetry.
- HWIND adjusts land data for open terrain.
- KW01 includes smaller scales.

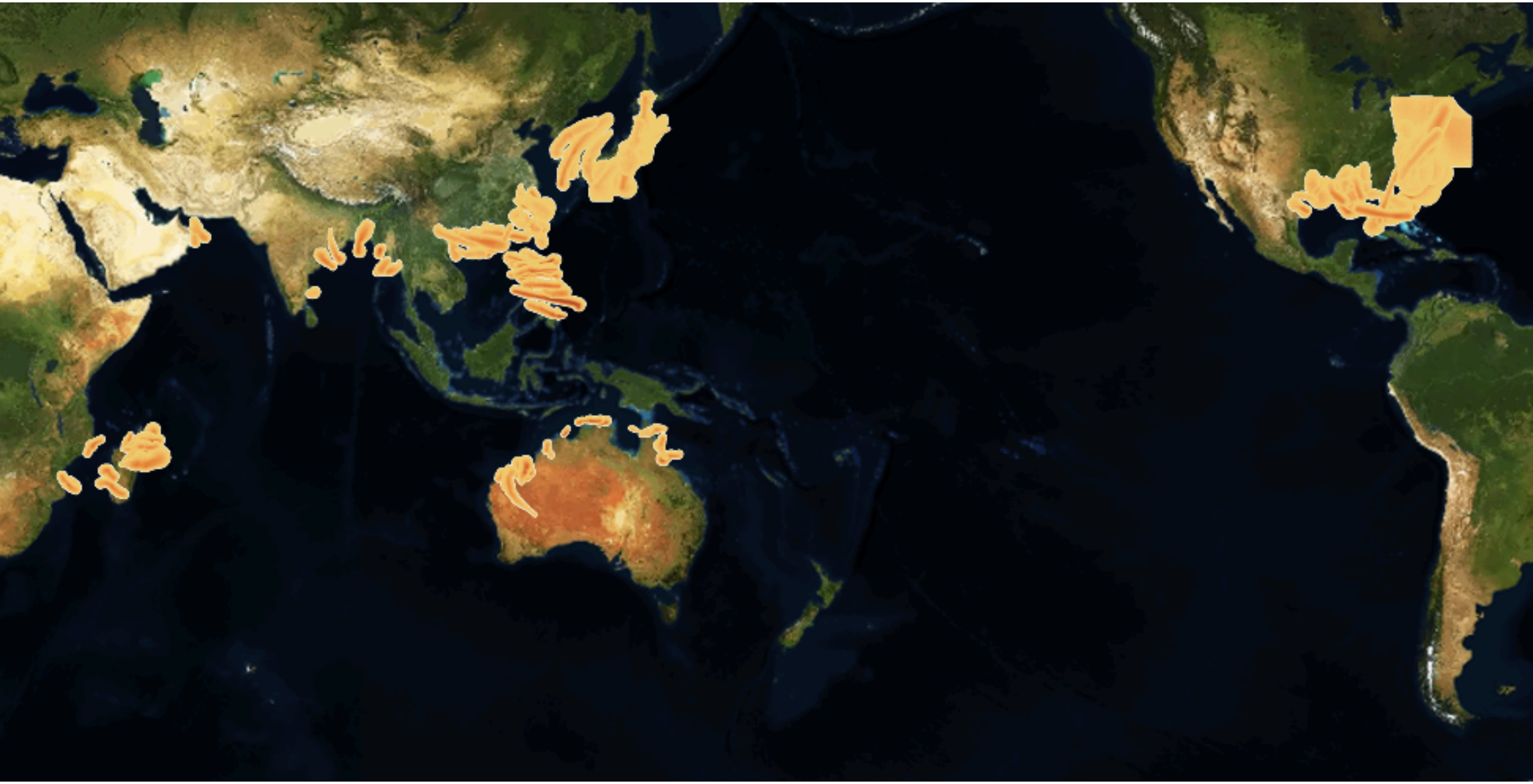
Comparison with station data



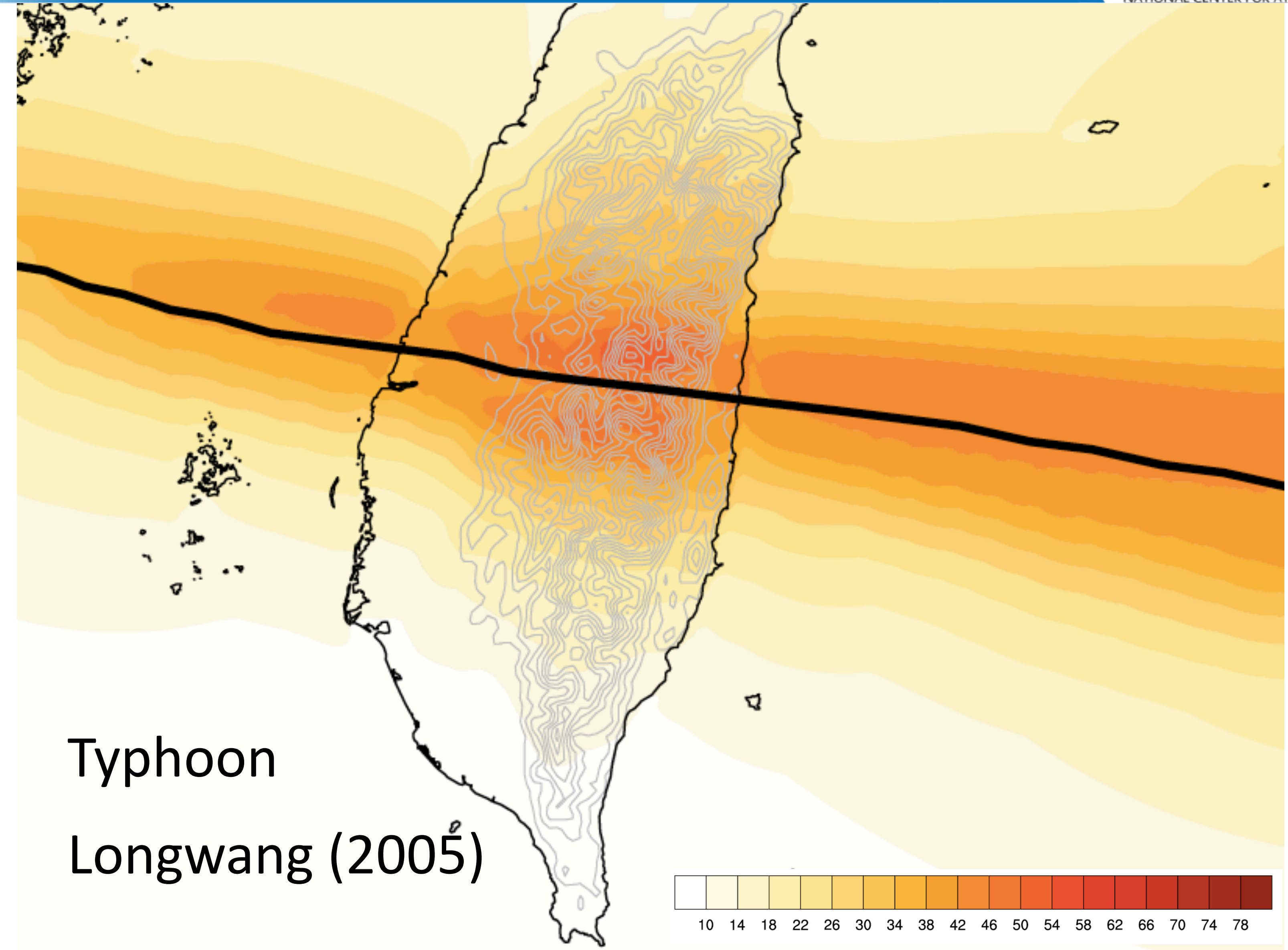


- HWIND and KW01 have high bias.
- KW01 comparable to HWIND.
- KW01 has potential to outperform analyses in complex terrain.

Results: 250 Footprints

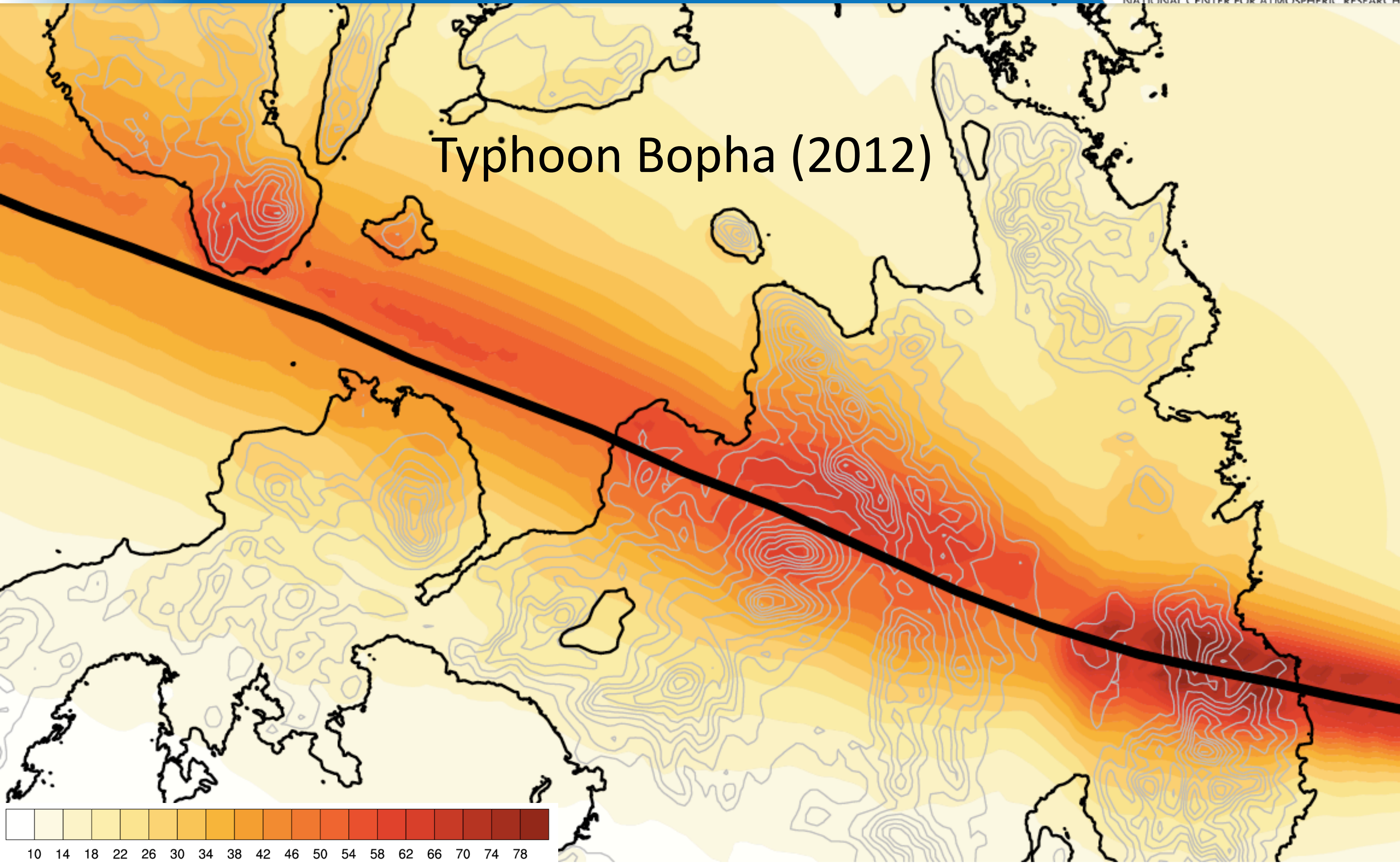


Results: High Terrain

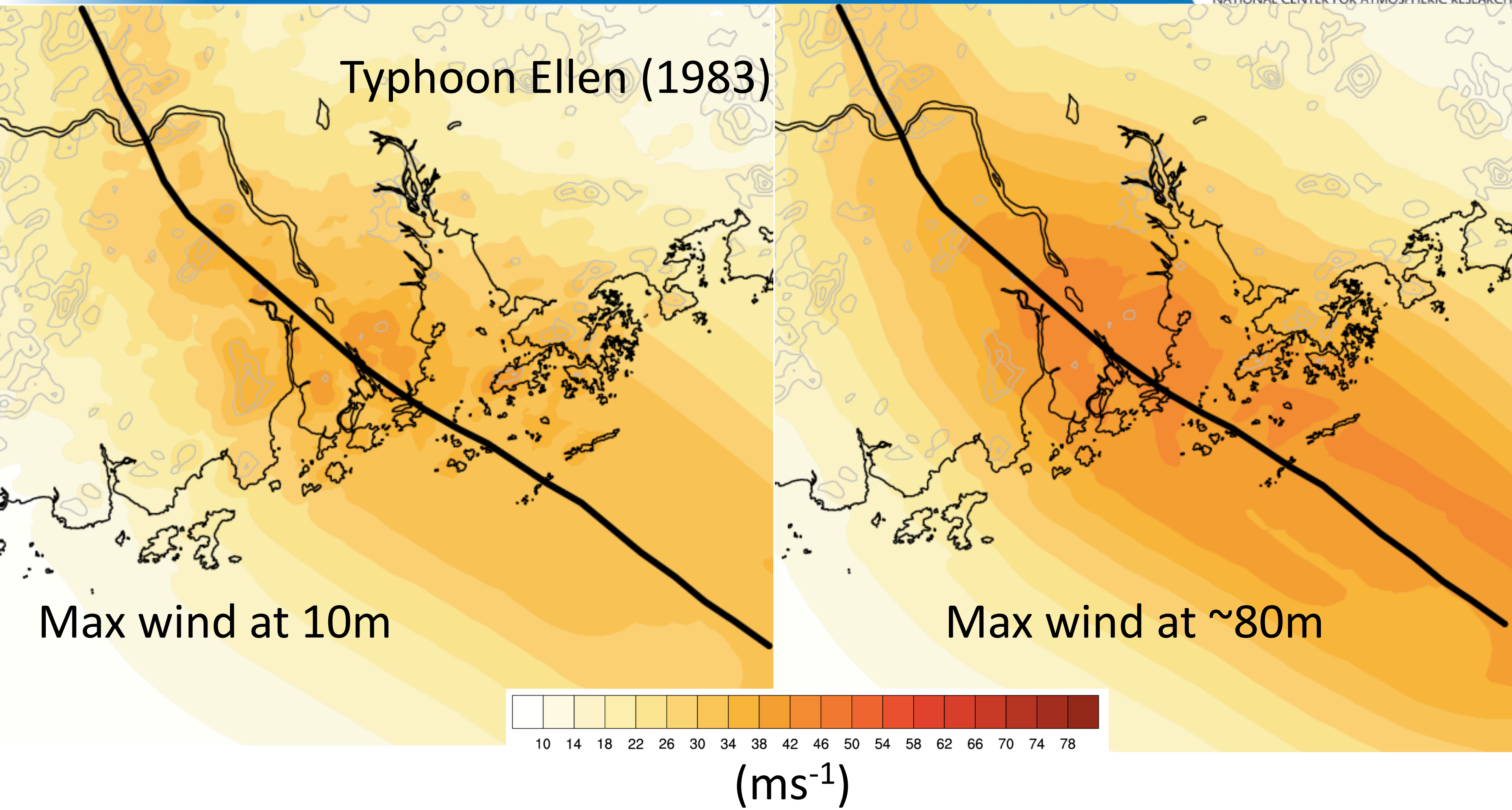


Typhoon Longwang (2005)

Results: Complex Topography



New views of wind risk aloft



Results: New View of Wind Climate

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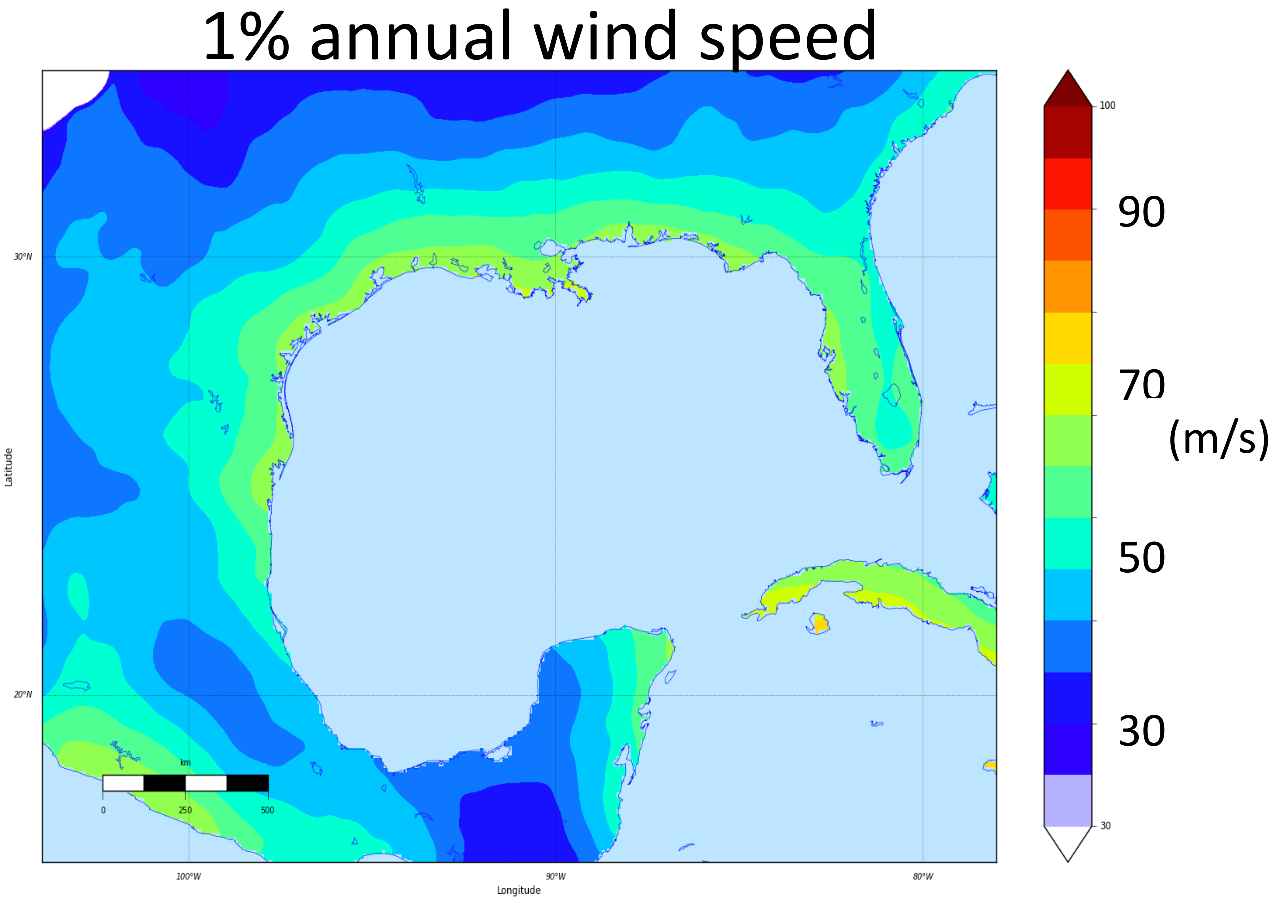

- New view of wind climate
- Optimized global exposure for business/societal resilience

Pathway 2: Mitigating Wind Loss

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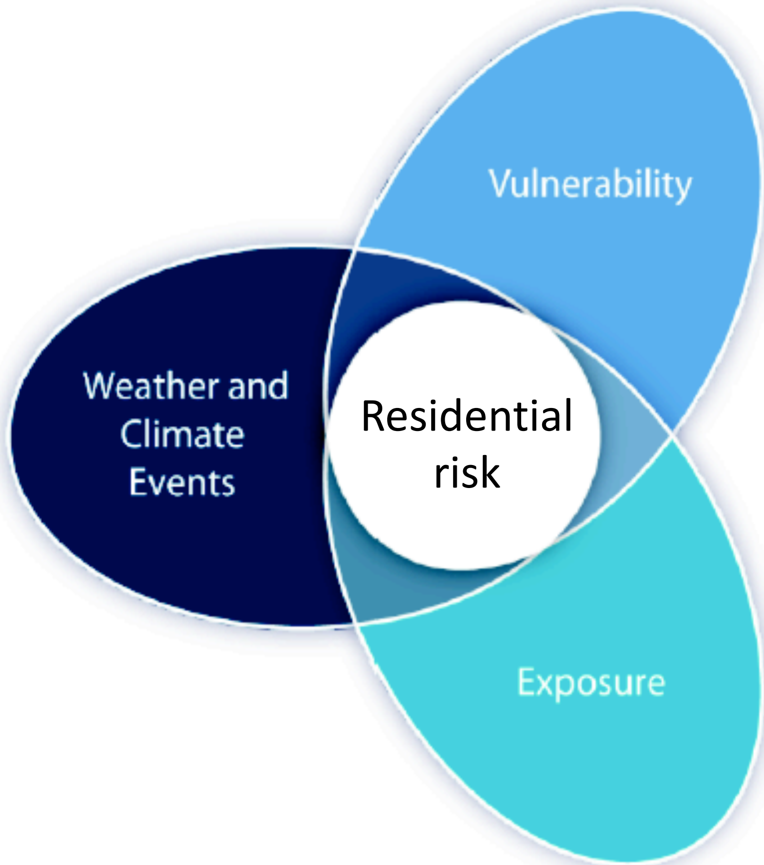
Stakeholder:	FL division of emergency management
Need:	Effectiveness of the building code
Current practice:	Code based on wind speed
Hypothesis:	Losses also driven by other wind effects
Physics:	Multiple wind field parameters
Results:	Quantified loss reductions
Resilience Action:	Informed building code updates, policy

Thanks to Jeff Czajkowski (U. Penn), Kevin Simmons (Austin College)

Minimizing Risk



Adapted from IPCC SREX, 2012

Loss Data

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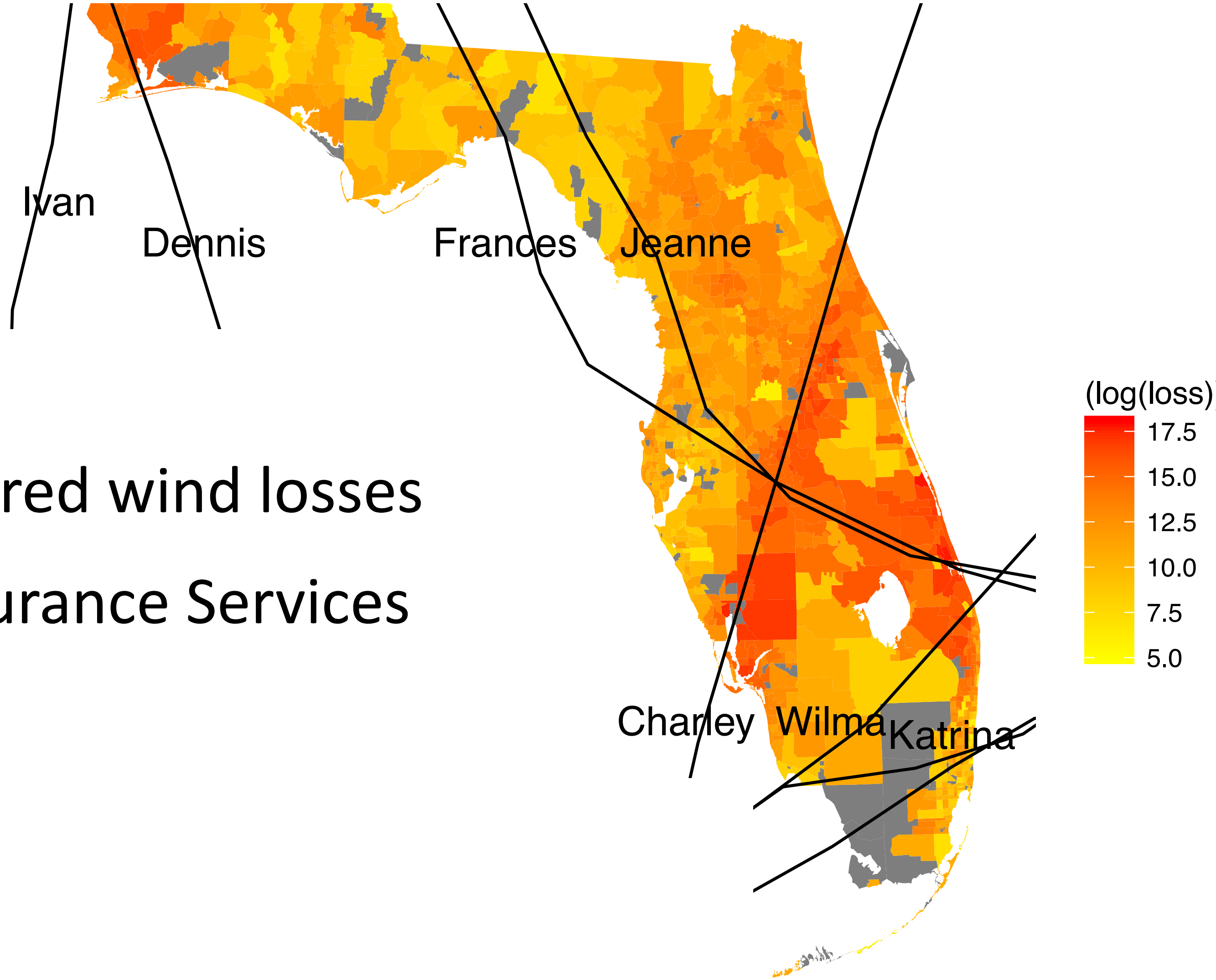
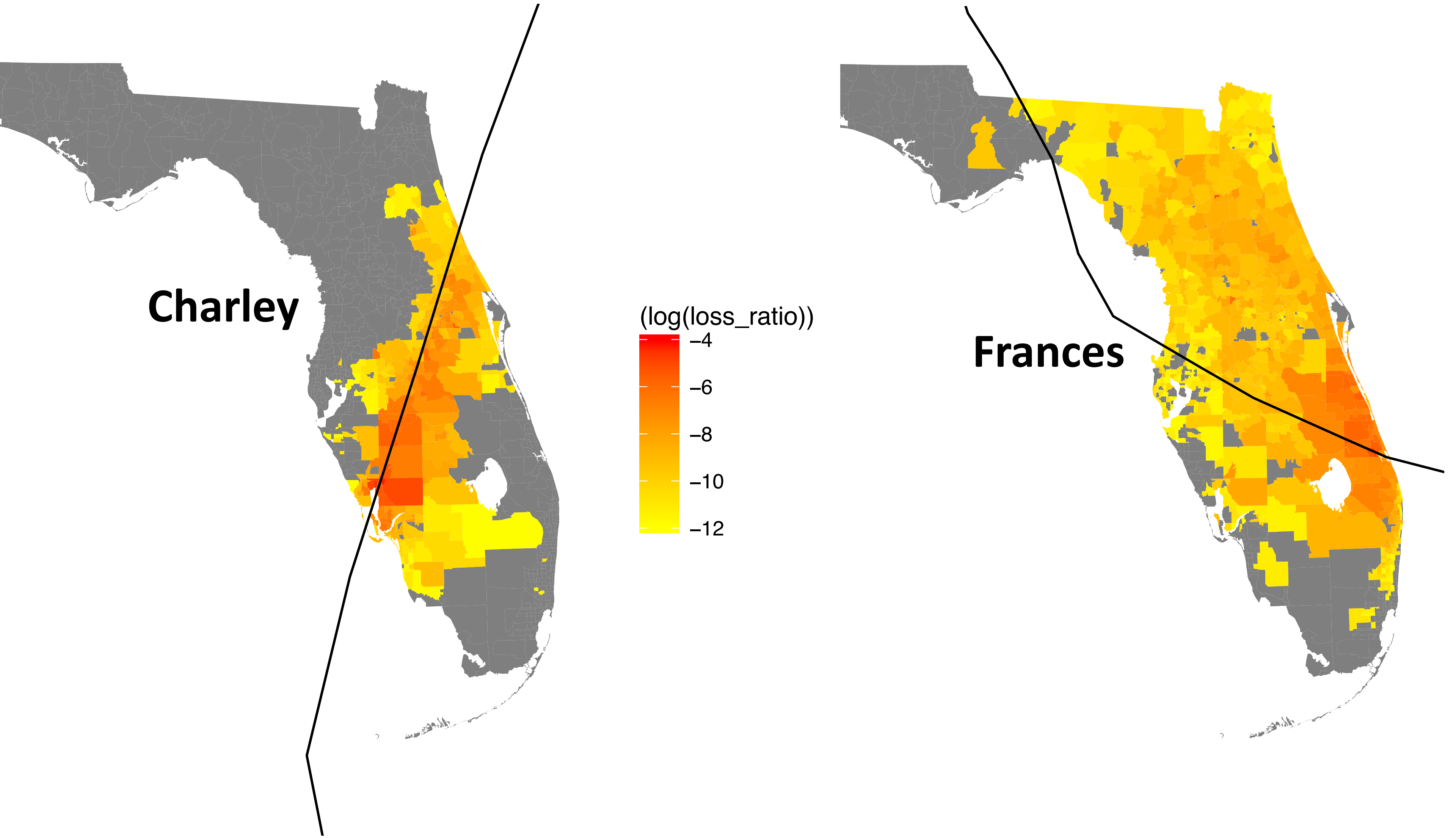
- Florida insured wind losses
- Source: Insurance Services Office

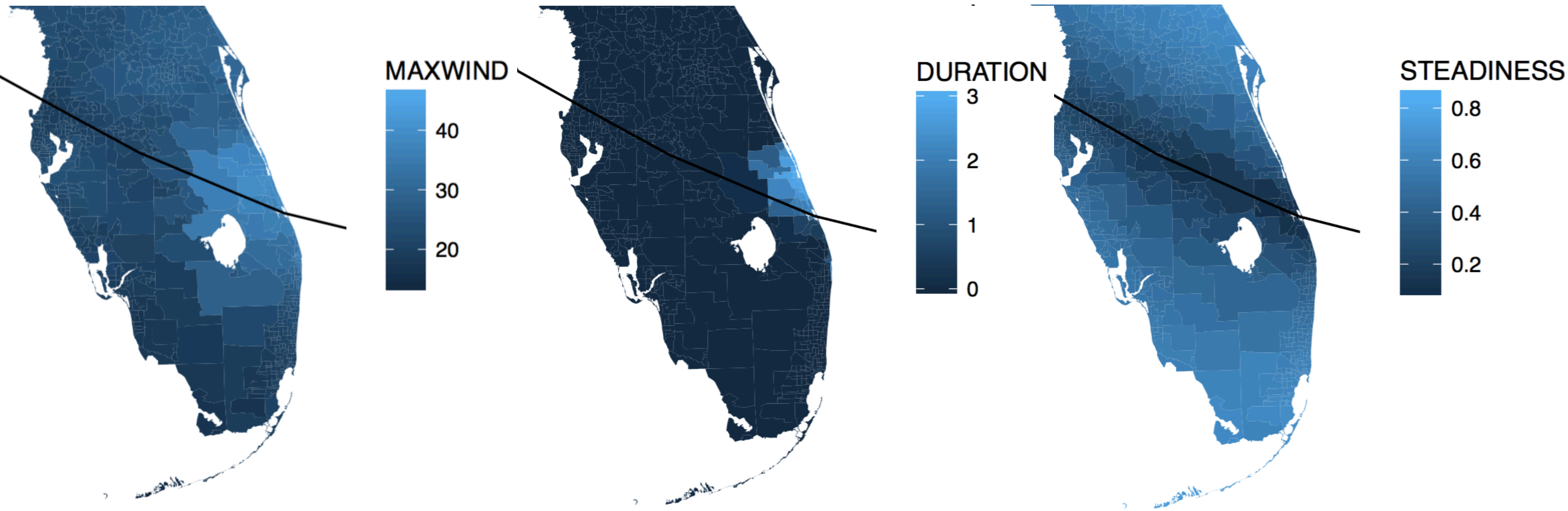


Losses by hurricane



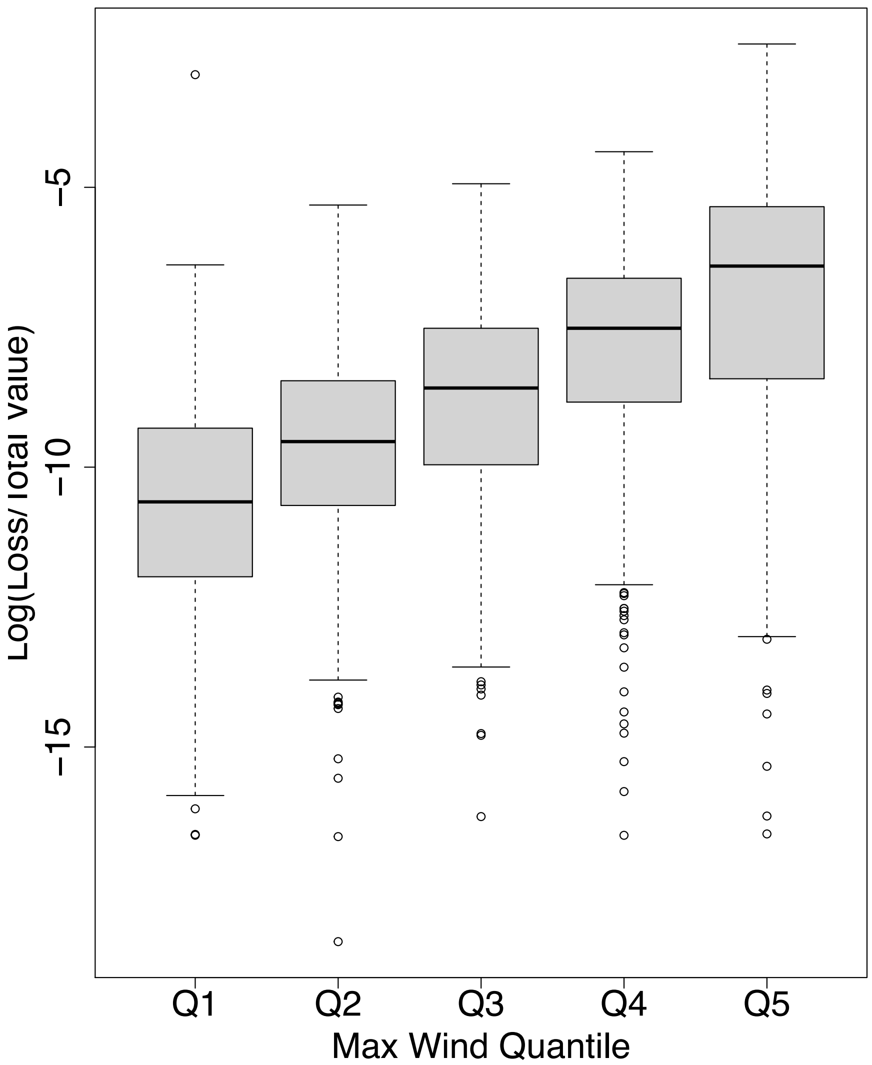
Adding Physical Processes

Hurricane Frances (2004)

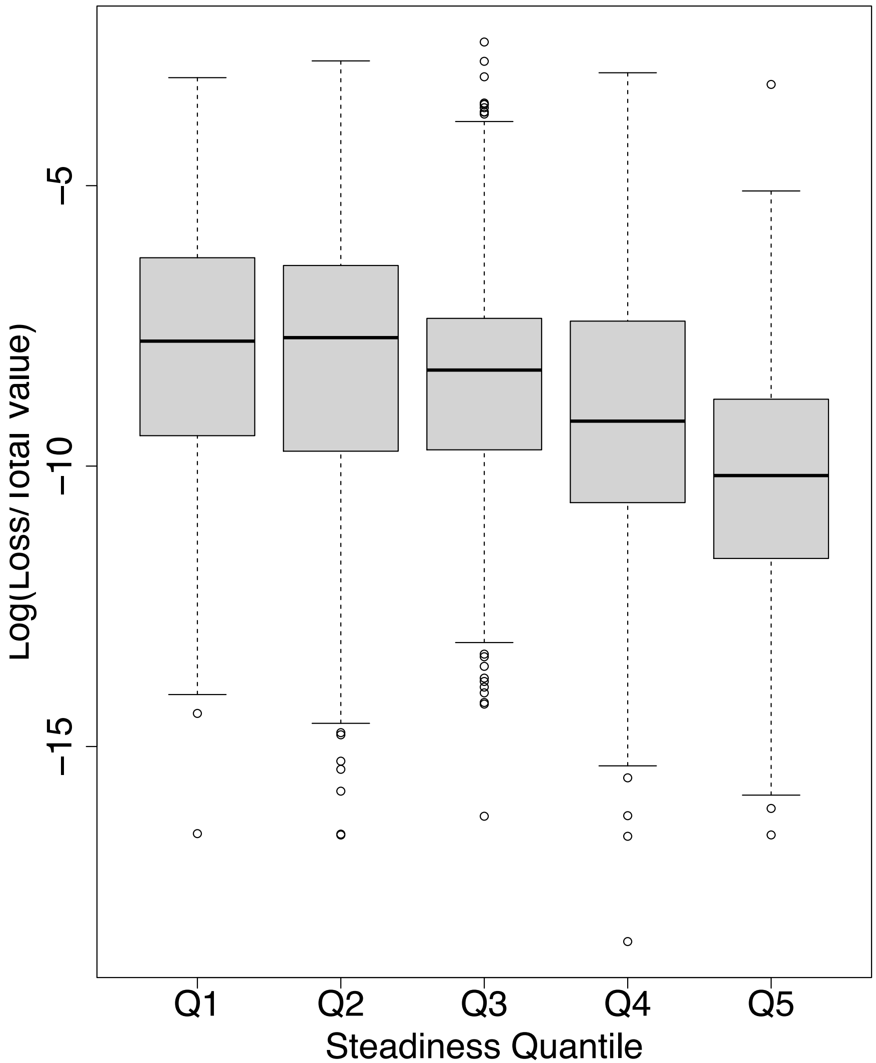


Data source: NOAA H*WIND

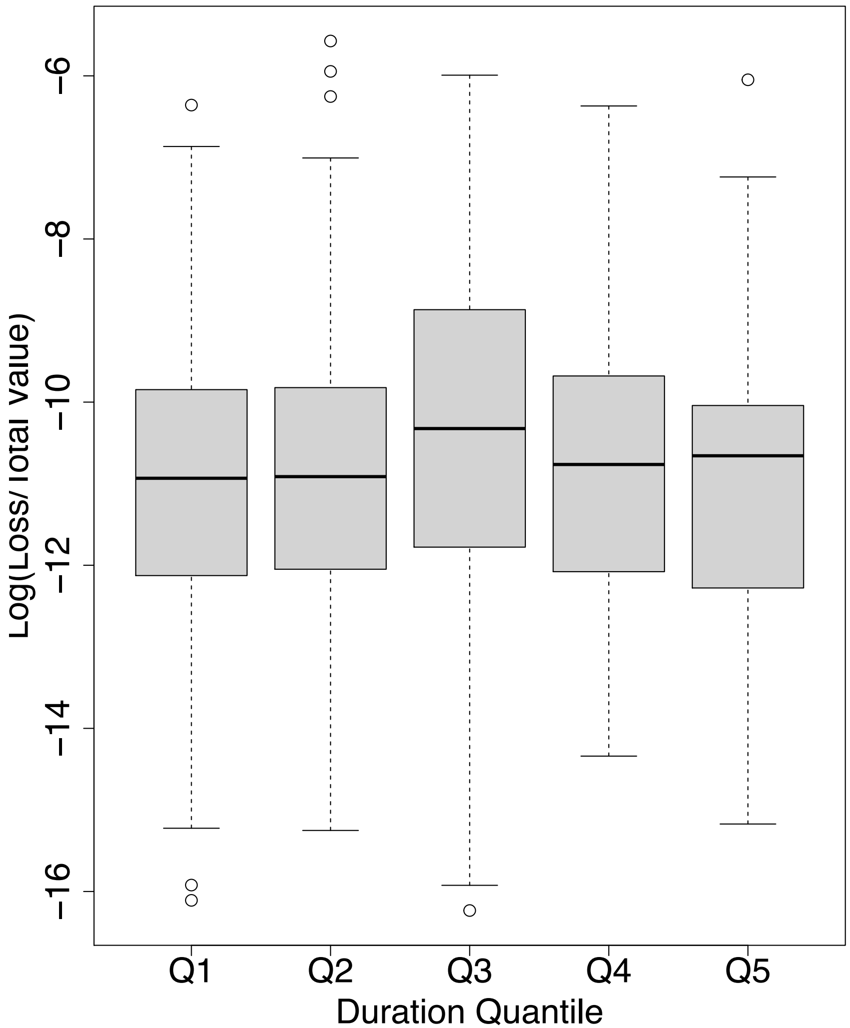
Loss increases with wind speed



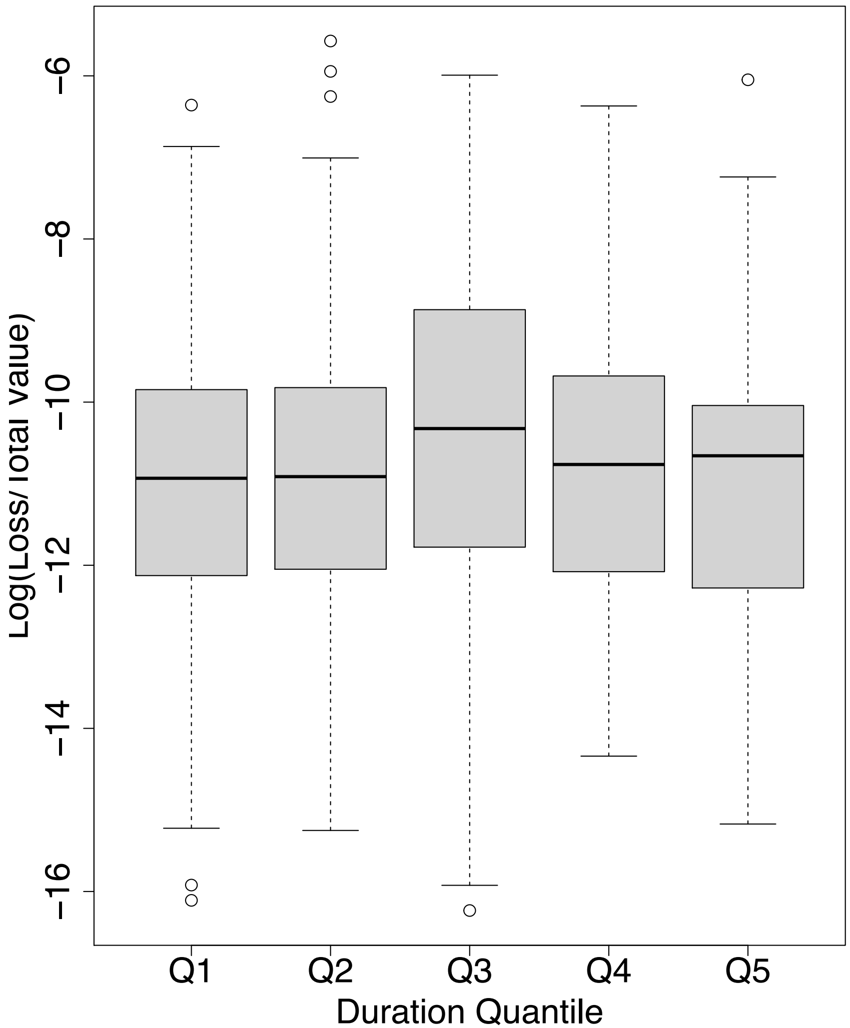
Loss decreases with steadiness

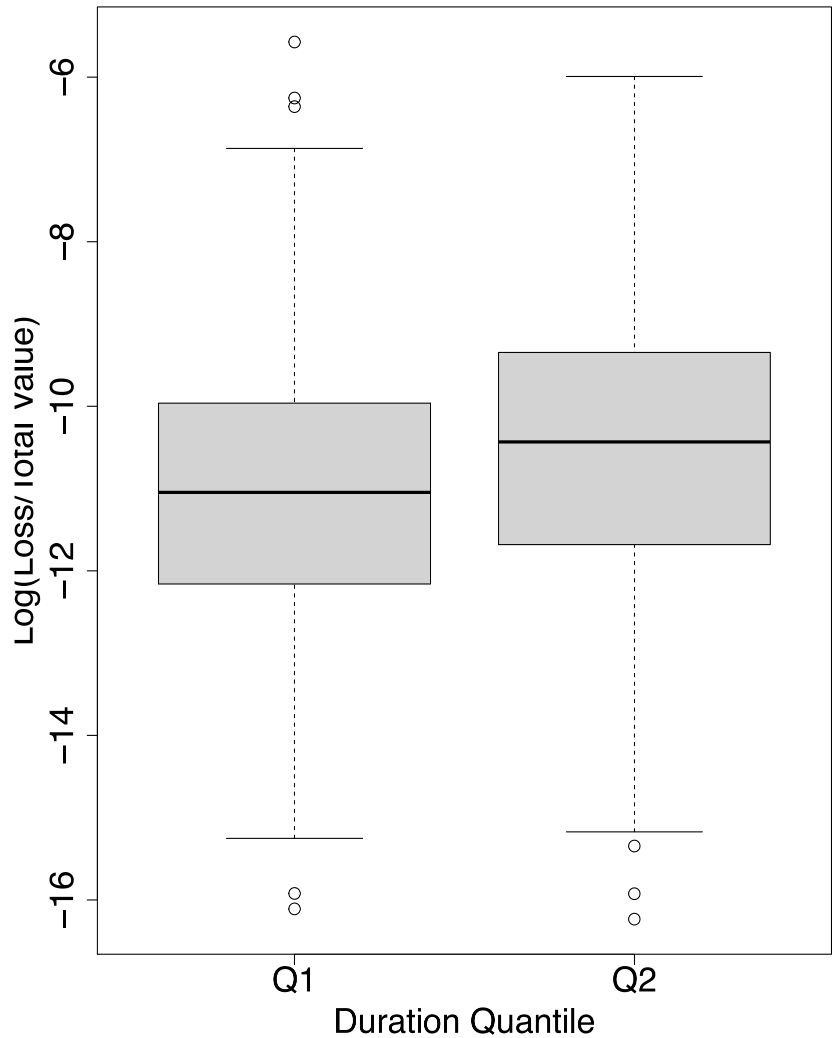


Duration vs. Loss



Duration important at low speeds





Quantifying Loss Reduction

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major_hurricane
minor_hurricane
high_duration
high_steadiness

Ln(losses) = f(categorical wind factors +
exposure and vulnerability factors +
interaction effects +
time and space fixed effects)

built_2000s = 1 if homes built in the 2000s

Multiple wind parameters drive loss

Parameter	Coefficient	Significance
	Estimate	Pr > |t|
major_hurricane	2.49	<.0001
minor_hurricane	1.76	<.0001
high_duration	0.50	<.0001
high_steadiness	-0.78	<.0001
built_2000s	-1.13	<.0001
# obs	10564	
r^2	0.34	

- Loss sensitive to wind speed, then steadiness, then duration.
- Homes built to code drive down losses by 68% compared to homes not built to code.

Done et al. (2017)

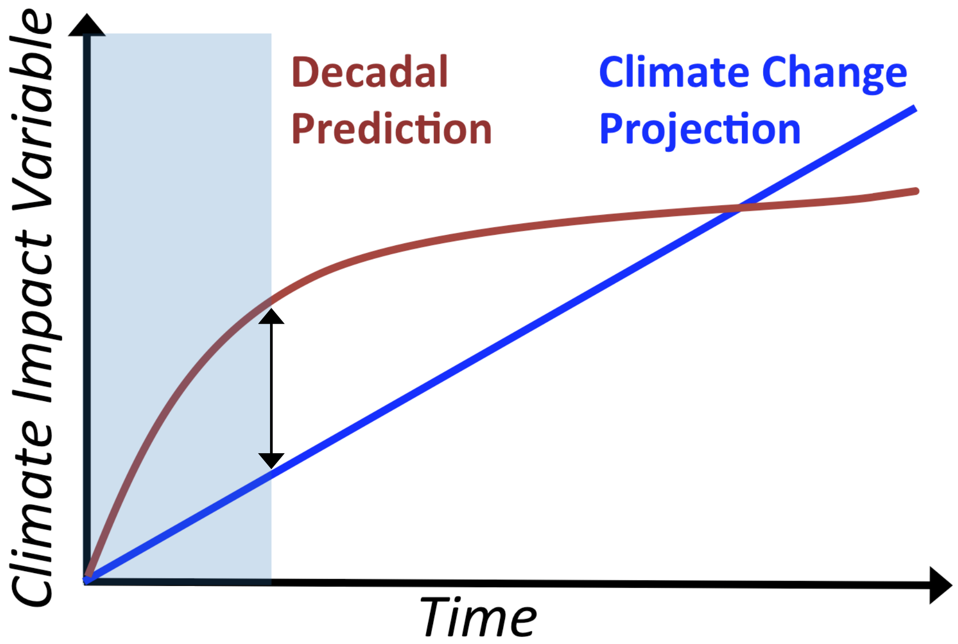
Pathway 3: UDECIDE

Understanding Decision Climate Interactions on Decadal Scales

Stakeholders:	Water resource and flood control managers
Need:	Operations, modest infrastructure
Current practice:	Daily, seasonal forecasts and climate change
Hypothesis:	Decadal prediction is useful
Physics:	Remote controlled local, decadal climate
Results:	Intersection of need and decadal prediction
Resilience Action:	Informed operations, medium-term planning

Thanks to the UDECIDE team

Why Decadal Prediction?



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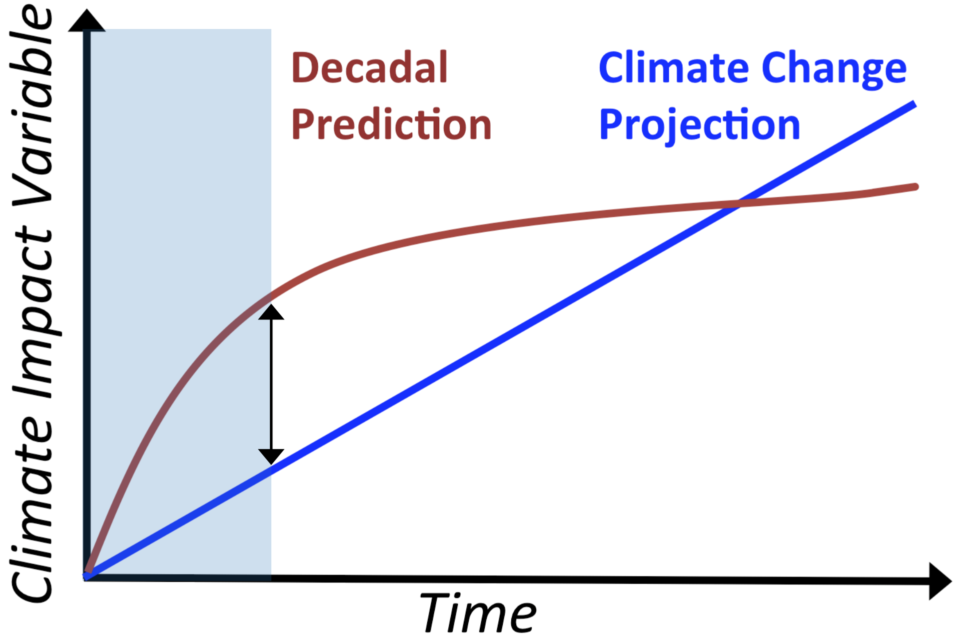
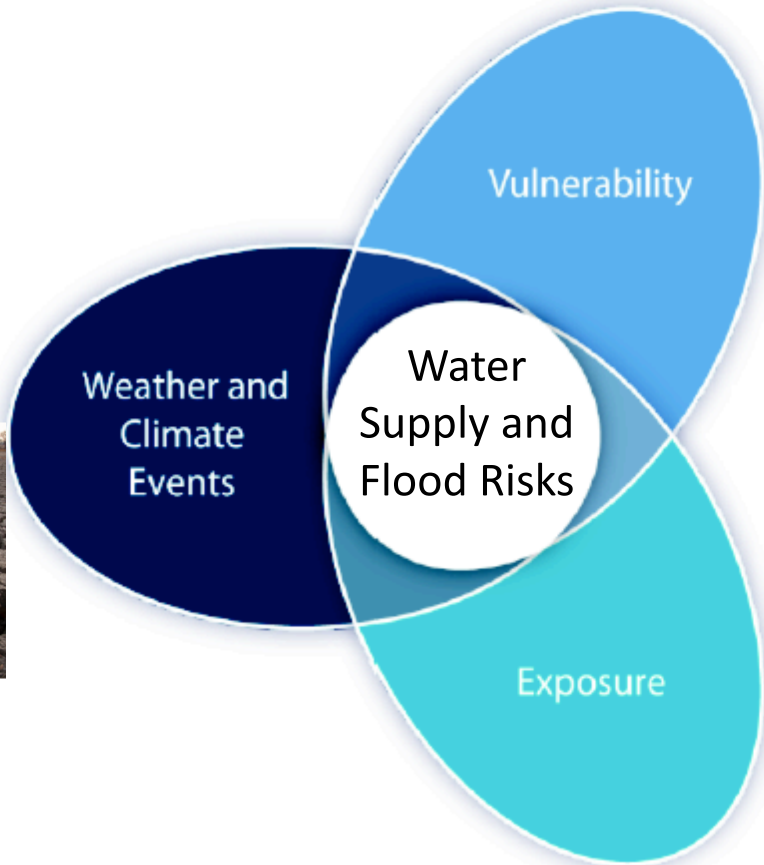


NCAR is Sponsored by NSF

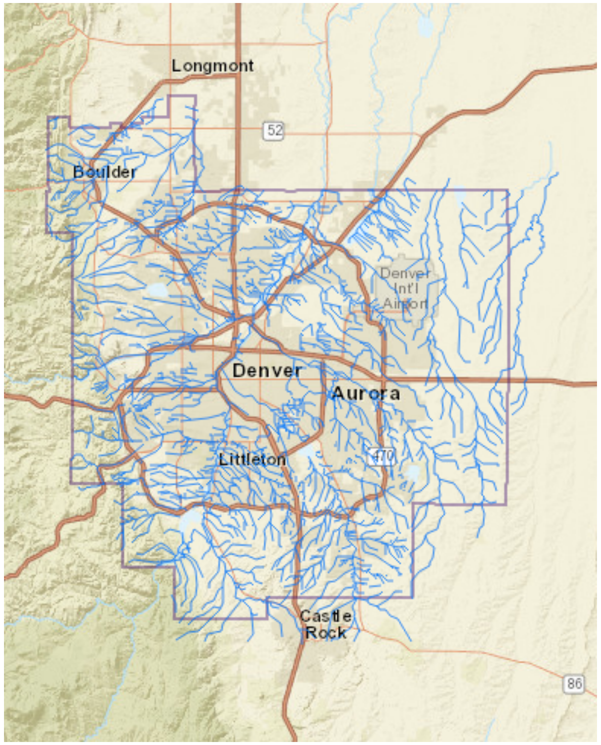
Minimizing supply risk, and flood risk

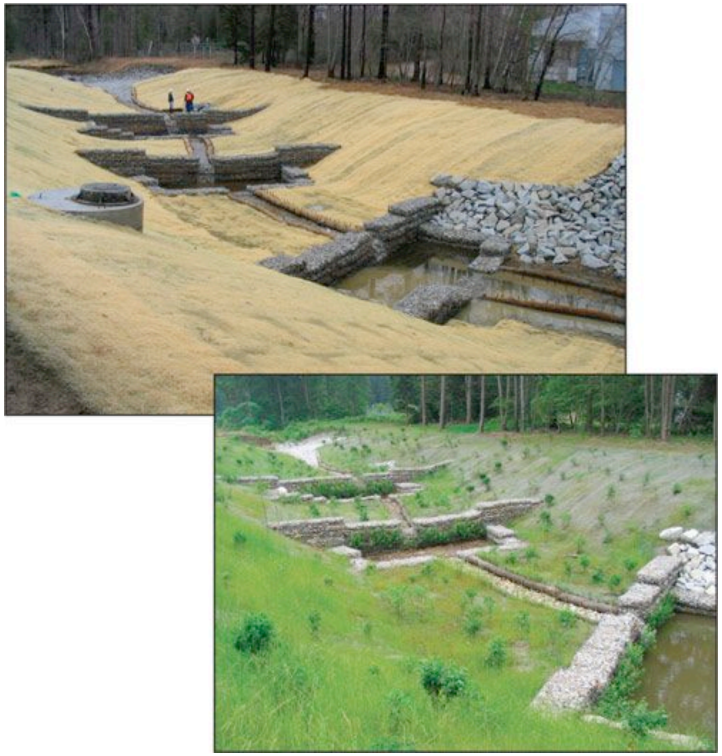


Adapted from IPCC SREX, 2012

The Need: UDFCD

Peak flow and sustained high flow likelihoods, for the design and construction of natural channels.





Heather Lazrus

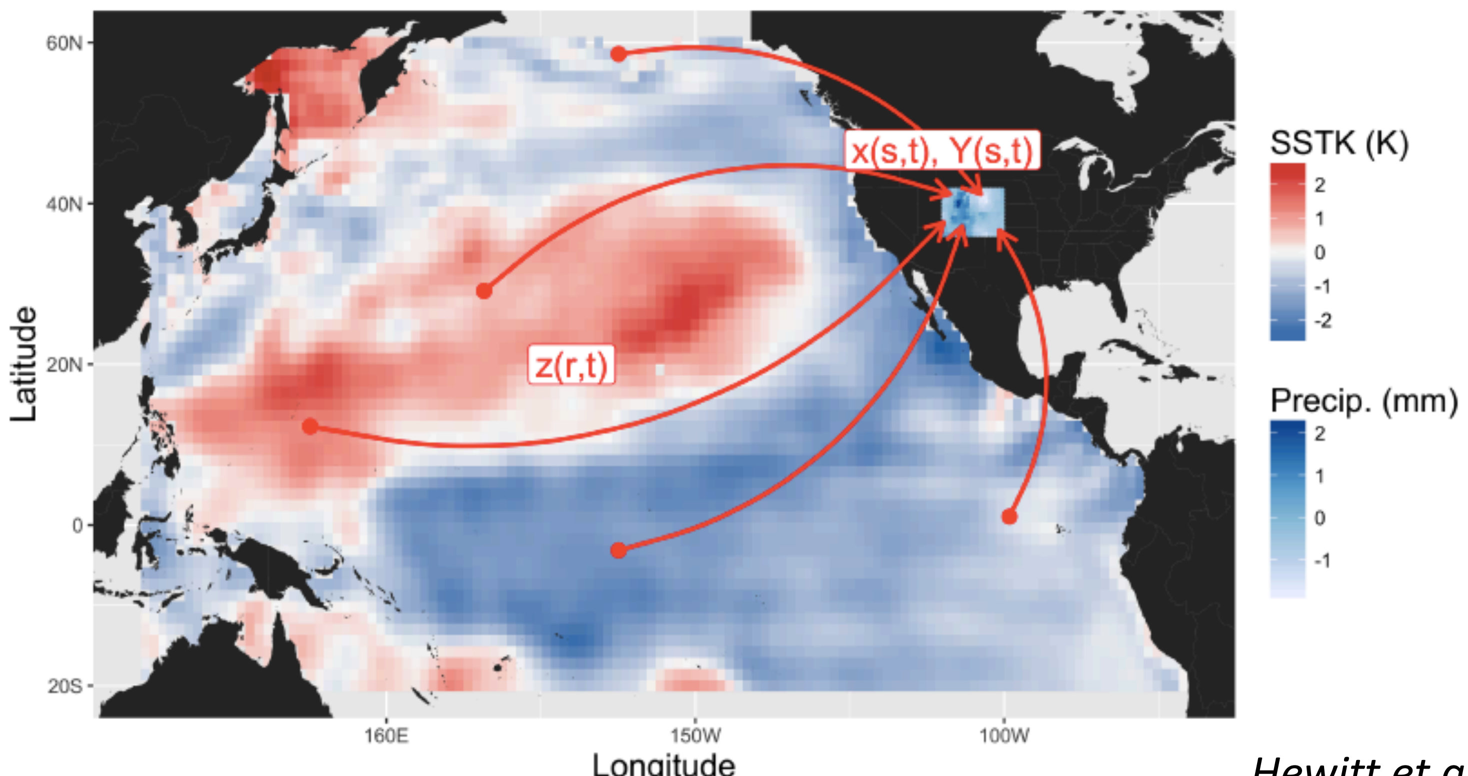
The Need: CA and Denver Water

Number and characteristics of big precipitation events, for drought relief and reservoir management.

Heather Lazrus

Can SSTs Predict Precipitation?

$$\underbrace{Y(\mathbf{s},t)}_{\text{Std. Precip. anomaly}} = \underbrace{\mathbf{x}(\mathbf{s},t)^T\beta}_{\text{Local effects}} + \underbrace{w(\mathbf{s},t)+\varepsilon(\mathbf{s},t)}_{\text{Spatial + Independent error}} + \underbrace{\int_{\mathcal{D}_Z} z(\mathbf{r},t)\alpha(\mathbf{s},\mathbf{r})d\mathbf{r}}_{\text{Teleconnection effects}}$$



Hewitt et al. (2017)

Correlations: SST and Precipitation

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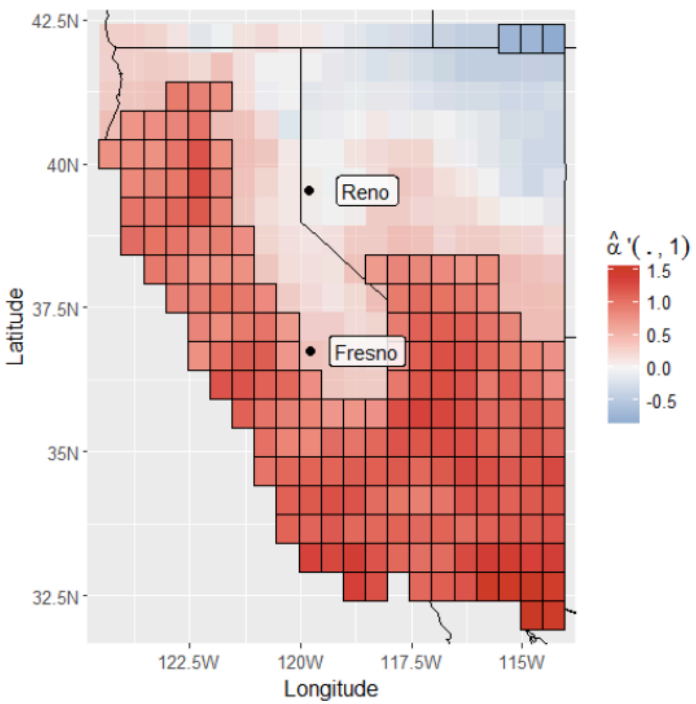
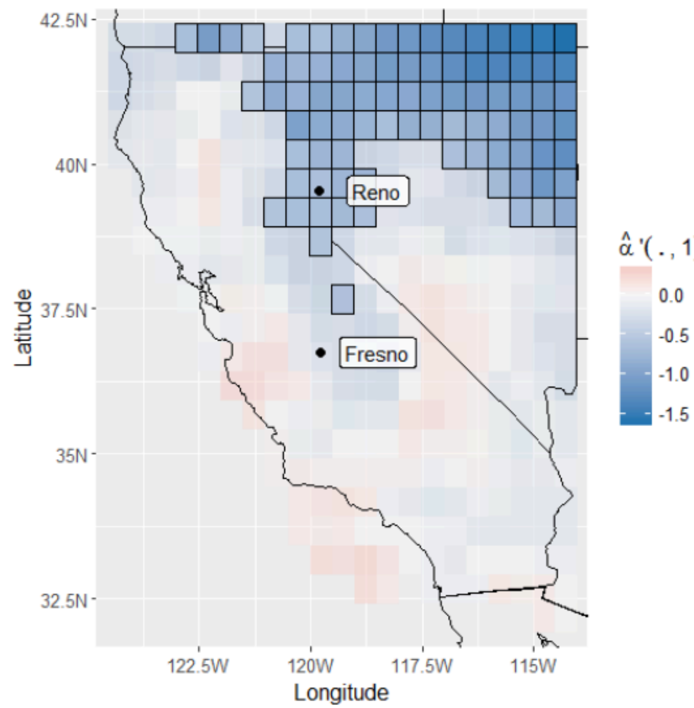
Model with remote effects only.



Model with remote + local effects

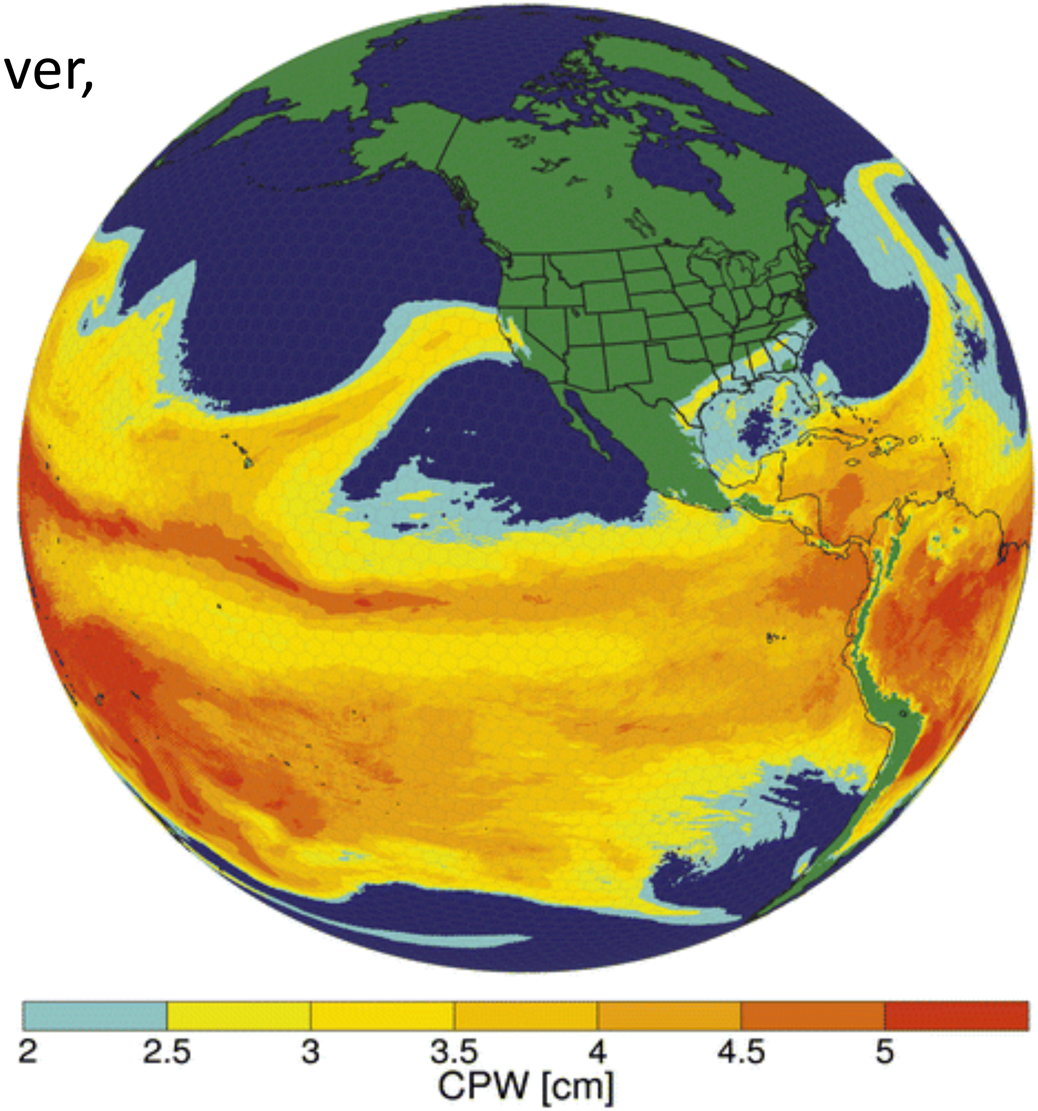


Casey Shafer, Josh Hewitt, Jennifer Hoeting (CSU)

Planned MPAS Experiment

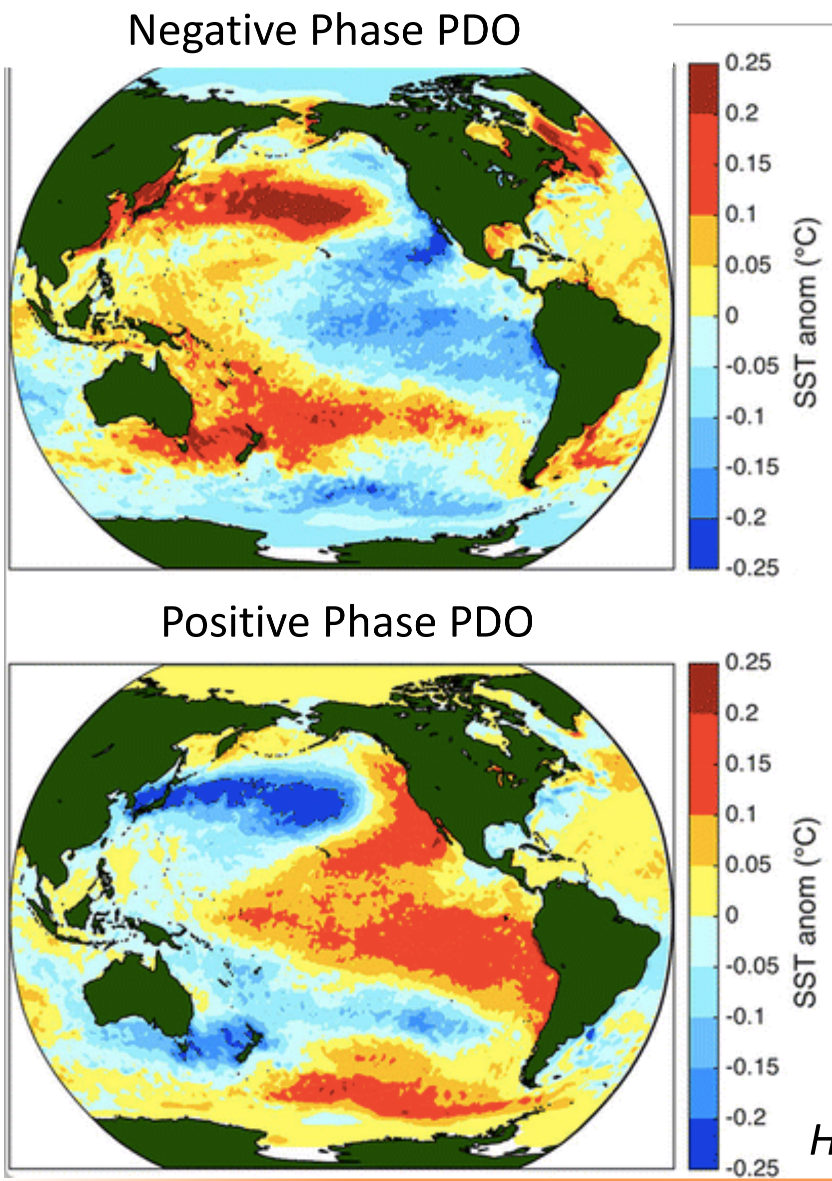
Atmospheric River,

MPAS



Hagos et al (2015)

Decadal Remote Controls on ARs



AR characteristics:

- timeseries analysis
- rain/snow ratio, freezing level.

Henley et al (2015)

Attributes of Successful Pathways

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- Physical science informed by needs
- Compatible with management practice
- Two-way
- A key component of a broader effort.

Significant advances expected through understanding mesoscale phenomena at global scales.

Collaborate through C3WE Capacity Center for Climate and Weather Extremes

NCAR is sponsored by the National Science Foundation