Pathways Connecting Physics and Climate Resilience

James Done
Increasing Number of Events

Number of events

- Climate
- Hydro
- Weather
- Quake

Munich Re 2014
Increasing Losses

Overall and insured losses 1980 to 2015 (in US$ bn)

Overall losses* (2015 values)
Of which insured losses* (2015 values)

Trend overall losses
Trend insured losses
* Values adjusted for inflation using the Consumer Price Index (CPI) of each country and taking into account fluctuations in exchange rates

Source: Munich Re NatCatSERVICE

Munich Re 2014
Technical and Scientific Advances

- Highest quality science
- Most widely-used community models
- Next-generation instruments, and datasets

<table>
<thead>
<tr>
<th>Rank</th>
<th>Institution</th>
<th>C/N = citations per paper</th>
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</table>
Physics is one of many factors

Adapted from IPCC SREX, 2012
• 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

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

Max wind speed (ms⁻¹)
Ike Encounters a Surprise Island

Max wind speed (ms$^{-1}$)

Island – No Island

Max wind speed (ms$^{-1}$)
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

Typhoon Bopha (2012)
New views of wind risk aloft

Typhoon Ellen (1983)

Max wind at 10m

Max wind at ~80m

(ms$^{-1}$)
Results: New View of Wind Climate

• New view of wind climate
• Optimized global exposure for business/societal resilience
Pathway 2: Mitigating Wind Loss

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

Residential risk

Weather and Climate Events

Vulnerability

Exposure

Adapted from IPCC SREX, 2012
• Florida insured wind losses
• Source: Insurance Services Office
Losses by hurricane

Charley

Frances

(log(loss_ratio))

-4

-6

-8

-10

-12

MMM Seminar – Aug 3, 2017
Adding Physical Processes

Hurricane Frances (2004)

Data source: NOAA H*WIND
Loss increases with wind speed
Loss decreases with steadiness
Duration vs. Loss

Log(Loss/Total Value)

Duration Quantile

Q1  Q2  Q3  Q4  Q5
Duration important at low speeds

- Duration important at low speeds

Log(Loss/Total Value) vs. Duration Quantile

- Q1
- Q2
- Q3
- Q4
- Q5

-6
-8
-10
-12
-16

Q1 Q2 Q3 Q4 Q5 Duration Quantile
Quantifying Loss Reduction

\[
\text{Ln}(\text{losses}) = f(\text{categorical wind factors} + \text{exposure and vulnerability factors} + \text{interaction effects} + \text{time and space fixed effects})
\]

\[
built_{2000s} = 1 \text{ if homes built in the 2000s}
\]
### Multiple wind parameters drive loss

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coefficient</th>
<th>Significance</th>
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<tr>
<td>built_2000s</td>
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<td>r^2</td>
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</table>

- 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: 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?

![Graph showing decadal prediction and climate change projection.](image)
Why Decadal Prediction?

Decadal Prediction

Climate Change Projection

Climate Impact Variable

Time

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NSF

Colorado State University

Wharton University of Pennsylvania

DENVER WATER

STATE OF CALIFORNIA
Minimizing supply risk, and flood risk
The Need: UDFCD

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

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

Heather Lazrus
Can SSTs Predict Precipitation?

\[ Y(s, t) = x(s, t)^T \beta + w(s, t) + \varepsilon(s, t) + \int_{D_Z} z(r, t) \alpha(s, r) \, dr \]

Std. Precip. anomaly  Local effects  Spatial + Independent error  Teleconnection effects

Hewitt et al. (2017)
Correlations: SST and Precipitation

Model with remote effects only.

Model with remote + local effects

Casey Shafer, Josh Hewitt, Jennifer Hoeting (CSU)
Atmospheric River, MPAS

Decadal Remote Controls on ARs

AR characteristics:
• timeseries analysis
• rain/snow ratio, freezing level.

Henley et al (2015)
Attributes of Successful Pathways

- 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

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