

"Many hands make light work"

Strength in numbers: using climate ensembles to study extreme weather phenomena on long timescales

Colin Zarzycki (@weatherczar) Penn State University <u>czarzycki@psu.edu</u>











Extremes: what do we mean?







- Weather extremes disproportionately harm health and welfare if...
 - 1. Rare
 - 2. Severe
- Extremes generally transient, occur over short timescales (hours to days)
 - Changes in the climate mean only *implicitly* include these changes

The "rarity problem"



• Weather extremes disproportionately harm health and welfare if...

• Rare

- Generally, climate model <u>~30-200 yrs</u>
- One climate realization may not be sufficient to directly simulate tail phenomena

LIVESCIENCE HEALTH PLANET EARTH STRANGE NE

Live Science > Planet Earth

Hurricane Sandy Was 1-in-700-Year Event

By Elizabeth Howell, LiveScience Contributor | July 12, 2013 01:06pm ET

MURRICANE FLORENCE

FULL COVERAGE AS FLORENCE IMPACTS THE EAST COAST

Florence Extreme 3-Day Rainfall: 0.1% Probability Event

North Carolina saw 8.04 trillion gallons of rainfall

By Gavrielle Jacobovitz Published Sep 21, 2018 at 4:11 PM | Updated at 5:01 AM EDT on Sep 22, 2018

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A Once-In-50-Year Storm Blacked Out The Entirety Of South Australia

Sophie Kleeman Sep 29, 2016, 5:00am - Filed to: meteorology • Share f y in N &



Couth Australia a state with a nonvestion of about 17 million, was hit by a massiva storm

What role do ensembles play?



How many members do we need before we "run out of predictive skill" for historical N. Atlantic hurricane activity?



Roberts et al., in prep.

HadGEM3 ensemble 1979-2014, results courtesy Malcolm Roberts (UK Met Office)

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Northeastern U.S. winter storms

- NE'rn US vulnerable to wintertime extratropical cyclones (ETCs)
 - Precipitation (rain/snow/ice)
 - Wind
 - Surge
- Host of impacts
 - Risks to health and welfare
 - Structural damage
 - Power grid failures
 - Massive transportation disruption
 - Lost spending/productivity







Defining a metric of societal relevance



- Storms can classified using NOAA <u>Regional Snowfall</u> (<u>Precipitation</u>) Index (<u>RSI</u>) (Squires et al., BAMS, 2014)
 - <u>Collocation</u> of magnitude/spatial extent of snowfall (precipitation) AND population density = <u>IMPACT</u>
 - 6-hrly precip. integrated along cyclone trajectory
 - Precip. weighted by population



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Example: Blizzard of 2016 (#snowzilla)



Automated tracking (TempestExtremes + ESTA)



Application: CESM Large Ensemble





What do tracked storms look like?





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czarzycki@psu.edu – CLIVAR Large Ensemble Workshop, Boulder, CO, July 2019

Looking to the century ahead...





Zarzycki, 2018, GRL

czarzycki@psu.edu – CLIVAR Large Ensemble Workshop, Boulder, CO, July 2019 **PennState** Looking to the century ahead... LENS snowstorms/decade (RSI>=1 RSI<=5) 99.0% 2.2 1.8 1.2 Snowstorm freq. by category 30 ALL snowstorms 1990-2005 1.0 10 2026-2035 2071-2080 10 0.8 0 20 30 Storms per year 1990-2015 LENS snowstorms/decade (RSI>=1 RSI<=2) 98.6% 0.6 30 **WEAK** snowstorms 0.4 10 0.2 0 10 20 30 1990-2015 snowstorms/decade (RSI>=3 RSI-61.8% 0.0 2 3 5 **STRONG RSI** category snowstorms Reduction odds (decade) using bootstrapping 2 3 4 5

What does thermodynamics tell us?



LENS ensemble mean days/year supporting snow



What if we ignore precipitation partitioning?





What if we ignore precipitation partitioning?









Summary



- Parallelized algorithm to objectively track winter storms
 - Dataset "agnostic"
- Snowstorms <u>decrease</u> in NEUS by 2080
 - Mean snowfall ~-25-50%
 - Decrease overwhelmingly driven by "weaker" or "moderate" events
 - Temperature and moisture deltas push/pull extreme snowstorm climate signal
- LENS critical for credibility in projecting events with returns O(~10-100 years) (i.e., Cats. 4-5)

czarzycki@psu.edu – CLIVAR Large Ensemble Workshop, Boulder, CO, July 2019

Food for thought...



- 1. Sub-daily (2D) output "cheap" storagewise but massively important for objective weather quantification
- 2. Continued development of parallelized analysis tools to make "big data" problems tractable
 - github.com/ClimateGlobalChange/tempestextremes
 - github.com/zarzycki/esta
- 3. Should we include structural uncertainty in our tracking/quantification methods? "ensemble of ensembles?"



Thanks!

- Objective algorithm to track winter storms
- Snowstorms <u>significantly</u> <u>decrease</u> in NEUS by 2080 in LENS
 - Decrease overwhelmingly driven by "weaker" or "moderate" events
 - Temperature and moisture deltas push/pull extreme snowstorm climate signal
- LENS = credibility projecting events with returns O(~10-100 years) (i.e., Cats. 4-5)



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