Precipitation extremes under climate change: intensity, duration and phase

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ASCE workshop on Engineering Methods for Precipitation under a Changing Climate Climate model simulations predicted increases in the intensity (and frequency) of precipitation extremes roughly 25 years ago

#### Simulated changes in daily rainfall intensity due to the enhanced greenhouse effect: implications for extreme rainfall events

HB Gordon, PH Whetton, AB Pittock, AM Fowler, MR Haylock



Observations have since confirmed an increase in intensity of precipitation extremes with global warming



Sensitivity (%) of annual maximum daily precipitation per °C warming of surface temperature at that latitude over 1901-2010 (records > 30 years)

O'Gorman, Curr. Clim. Chang. Reports, 2015

# At the regional level: more stations show increases than decreases



Relationship of extreme daily precipitation to global-mean surface temperature (records >30 years over 1900-2009; nonstationary extreme value analysis) Solid blue: positive Solid red: negative Open: no relationship Solid gray: too short

Westra et al, J. Climate, 2013

### Projections over 21st century show further increases in intensity except over subtropical oceans



Increase in water vapor tends to increase precipitation extremes everywhere, but modulated by changes in winds



Weaker increase in precipitation extremes in Northern Summer over land (due to wind changes - reliable?)



# Uncertainty in projected changes in precipitation extremes is largest in tropics



Standard deviation across models of the sensitivity of precipitation extremes to temperature  $(\%/^{\circ}C)$ 

What about changes in the duration of extreme precipitation events?

## Intensity curves shift upwards with warming by constant amount on a log scale: suggests little change in temporal behavior



Kao and Ganguly, JGR, 2010

Modest decrease in duration of extreme precipitation events linked to changes in westerly winds (1%/°C decrease in duration versus 6%/°C increase in intensity)



percentile of 3-hourly precipitation)

Dwyer & O'Gorman, GRL, submitted

### Similarly, little change in duration of extreme rainfall events in model that resolve atmospheric convection



Summertime rainfall extremes over Wales and England; Chan et al, ERL, 2016

Caution I: cloud microphysics important for subdaily precipitation extremes below 22°C (72F) (and not well represented even in high-resolution models)



Cloud-resolving simulations from Singh & O'Gorman, GRL, 2015

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Studies of precipitation statistics versus temperature in present-day climate find reduced duration with warming...



Precipitation event duration versus temperature for rain gauges in Germany

Haerter et al, JGR, 2010

... but such studies not directly relevant to climate change!

#### What about daily snowfall extremes?

- Compare warm climate (2081-2100) to control climate (1981-2000) in simulations with 20 climate models under RCP8.5 scenario
- Daily snowfall in liquid water equivalent
- Extremes measured by 20-year return values (calculated by fitting GEV distribution to annual maxima)

O'Gorman, Nature, 2014



Only shown over land where greater than 5cm per year in control climate



Mean snowfall decreases (due to change in precipitation type) except where very cold!





Extremes have smaller percent changes than mean!

# Conclusions: precipitation extremes under climate change

- Intensity: widespread increases with warming, but changes in winds modulate the response (e.g. in summer in Northern hemisphere)
- Duration: evidence so far is for smaller changes in duration than intensity (-1%/°C versus +6%/°C)
- Phase: daily snowfall extremes respond differently as compared to seasonal snowfall totals

Simplest expectation for precipitation extremes under climate change ("Rule of thumb")

Increase in intensity of 6% per degree Celsius global warming for a given duration and return period

Notes:

- Implies different changes in frequency for different durations
- Typical duration doesn't change very much

#### Recent review paper:

Curr Clim Change Rep (2015) 1:49–59 DOI 10.1007/s40641-015-0009-3

EXTREME EVENTS (A SOBEL AND SJ CAMARGO, SECTION EDITORS)

#### **Precipitation Extremes Under Climate Change**

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