A misty landscape with a forest of tall trees on a hill overlooking a body of water. The scene is hazy and atmospheric, with the trees appearing as dark silhouettes against the light mist. The water in the foreground is calm with subtle ripples.

# Event attribution: the emerging science of attributing causes to extreme events

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13IMSC, 8 June 2016

*Photo: F. Zwiers (Strait of Juan de Fuca)*

# Introduction

- Enormous interest in event attribution
  - Event and media driven
  - Questions are mostly retrospective
- Requires “rapid response” science
  - Places high demands on process understanding, data, models, and statistical methods
  - Recently assessed by US National Academies of Science
- Critical aspect of the the WCRP Grand Challenge

# Event attribution



*Photo: F. Zwiers (Jordan River, gathering storm)*

# Event attribution

- The public asks: Did human influence on the climate system ...
  - Cause the event?
- Most studies ask: Did it ...
  - Affect its odds?
  - Alter its magnitude?
- Some think we should reframe the question ...
  - Rather than “Did human influence ...” (which requires comparison with a counterfactual world)
  - Ask “How much (eg, of a given storm’s precipitation) is due to the attributed warming (eg, in the storm’s moisture source area)” (after Trenberth et al, [2015](#))

# Most studies

- Compare factual and “counterfactual” climates
  - Counterfactual → the world that might have been if we had not emitted the ~600GtC that have been emitted since preindustrial
- These studies almost always
  - Define a class of events rather than a single event
  - Use a probabilistic approach
- Shepherd ([2016](#)) defines this as “risk based”
  - Contrasts it with a “storyline” based approach
  - i.e., analysis of the specific event that occurred

# “Framing” event attribution studies

- Event type
  - Class vs individual
- Analysis approach
  - “risk based” or “storyline”
- Event definition
  - What spatial scale, duration, etc
- Which risk-based question
  - Did climate change alter the odds, or the magnitude?
- What factors should be taken into account
  - “Conditioning”
  - e.g., coincident SST anomaly pattern, circulation, etc

The NAS Report ([2016](#)) struggled with these distinctions

# Risk based questions

- Did human influence alter its likelihood

$$Prob(E|forcing) \text{ vs } Prob(E|\neg forcing)$$

$$Prob(E|forcing, SST) \text{ vs } Prob(E|\neg forcing, \widetilde{SST})$$

- Did human influence alter its magnitude

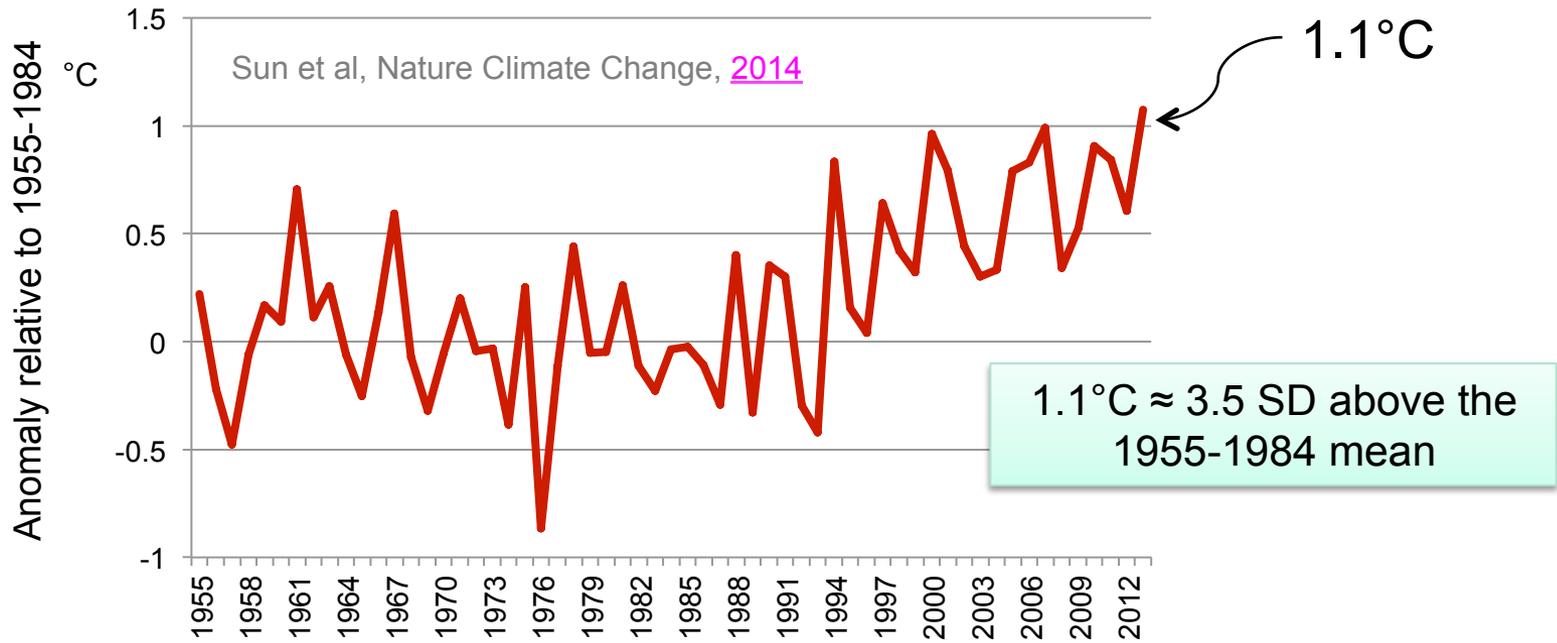
$$f(M|E, forcing) \text{ vs } f(M|E, \neg forcing)$$

$$f(M|E, forcing, SST) \text{ vs } f(M|E, \neg forcing, \widetilde{SST})$$

# China's Summer of 2013



# How rare was JJA of 2013?



- Estimated event frequency
  - once in 270-years in control simulations
  - once in 29-years in “reconstructed” observations
  - once in 4.3 years relative to the climate of 2013
- Fraction of Attributable Risk in 2013:  $(p_1 - p_0)/p_1 \approx 0.984$
- Prob of “sufficient causation”:  $PS = 1 - ((1 - p_1)/(1 - p_0)) \approx 0.23$

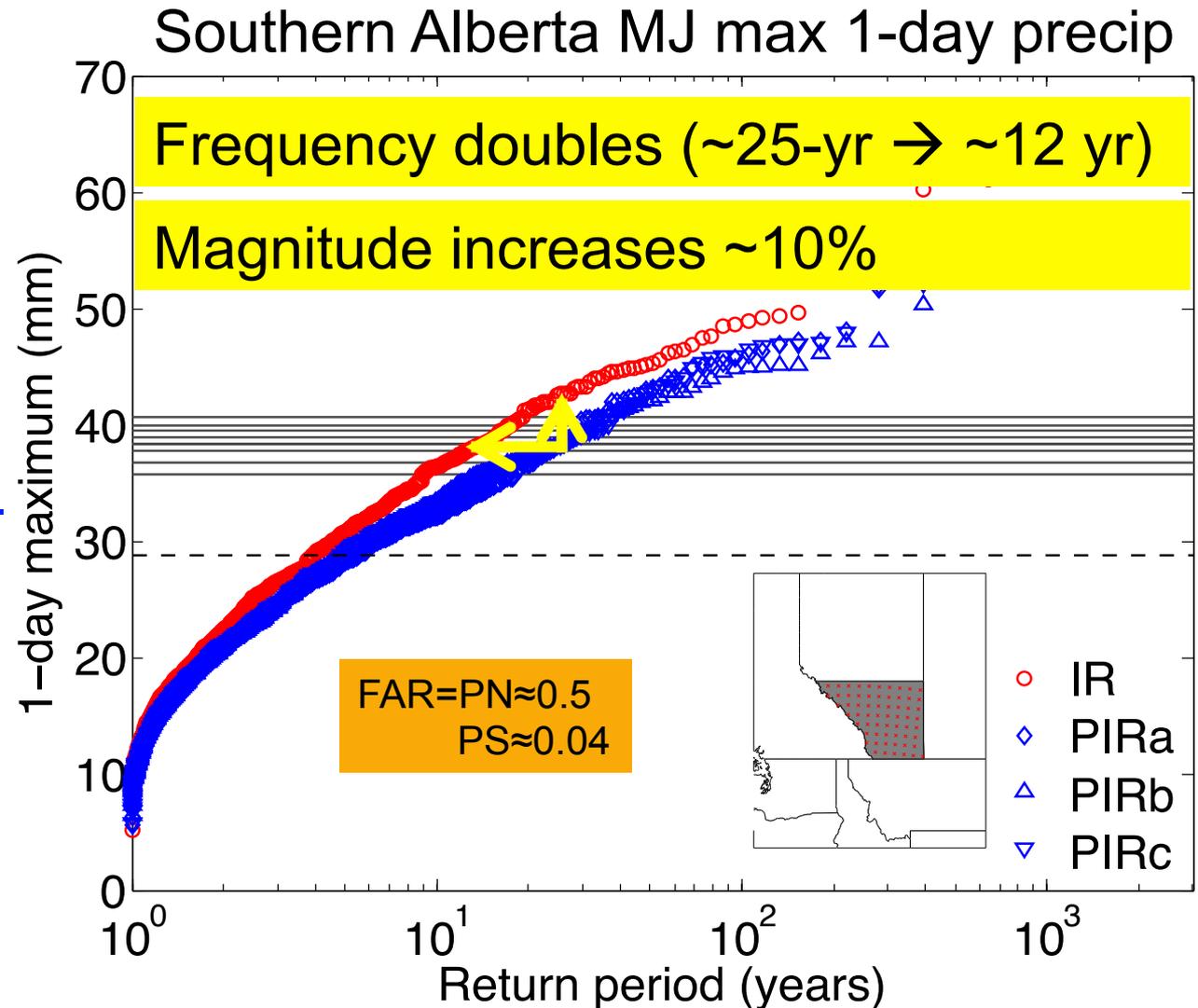
# Calgary flood, 2013



Looking towards downtown Calgary from Riverfront Avenue (June 21, 2013), courtesy [Ryan L.C. Quan](#)

# Calgary floods (Teufel et al, submitted)

Distribution of annual May-June maximum 1-day southern-Alberta precipitation in CRCM5 under **factual** and **counter-factual** conditions (conditional on prevailing global pattern of SST anomalies)



# Some unresolved issues

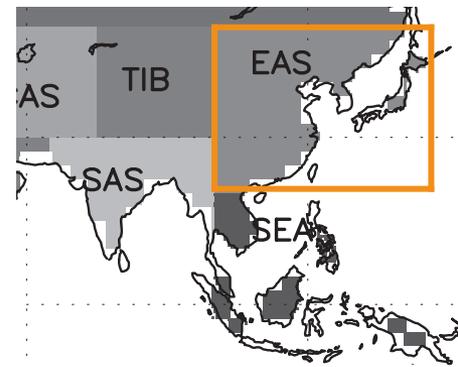


# Some unresolved issues

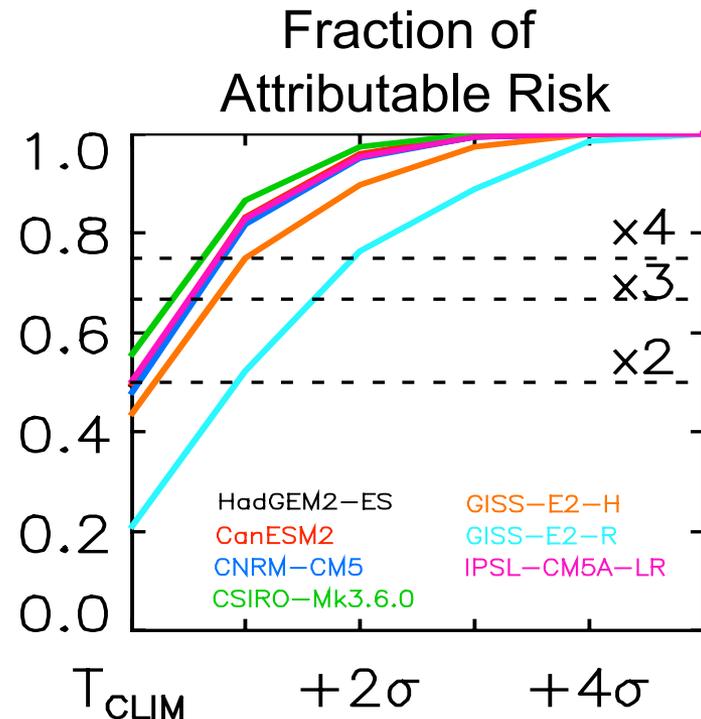
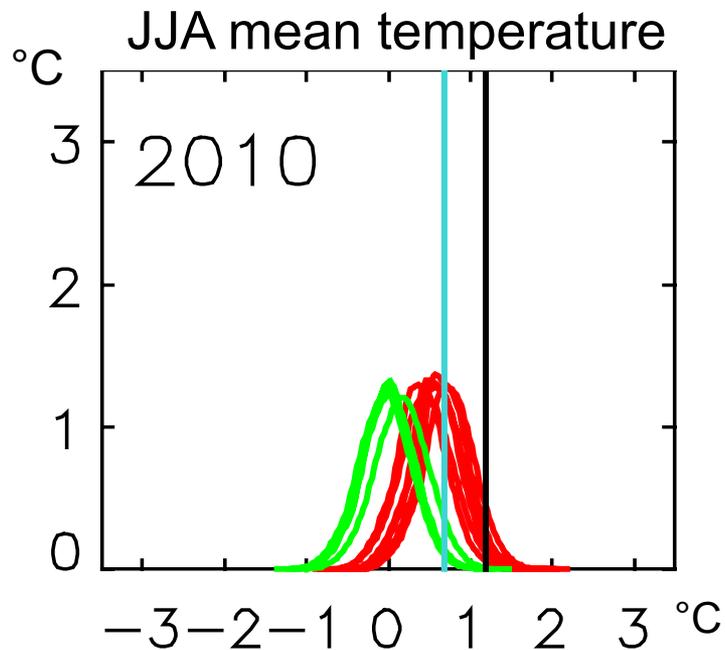
- Event characterization
  - Class vs individual, risk-based vs storyline
  - Individual is not completely synonymous with storyline
  - Data assimilation approach of Hannart et al ([2016](#))
- Event definition
- Dependence on models
- Counterfactual state specification uncertainty when conditional approach is used
- Selection bias
  - Need objective event selection criteria
- Communications
  - At each stage of the media and disaster response/recovery cycle

# Retrospective vs prospective?

- Most studies are prompted by specific events
- For the risk-based approach, we could study pre-defined events



Distribution of annual JJA temperature in the 2000's relative to 1961-90 in East Asia **with** and **without** ANT forcing



Christidis et al, 2014



**Questions?**