Modeling and Extremes in the West

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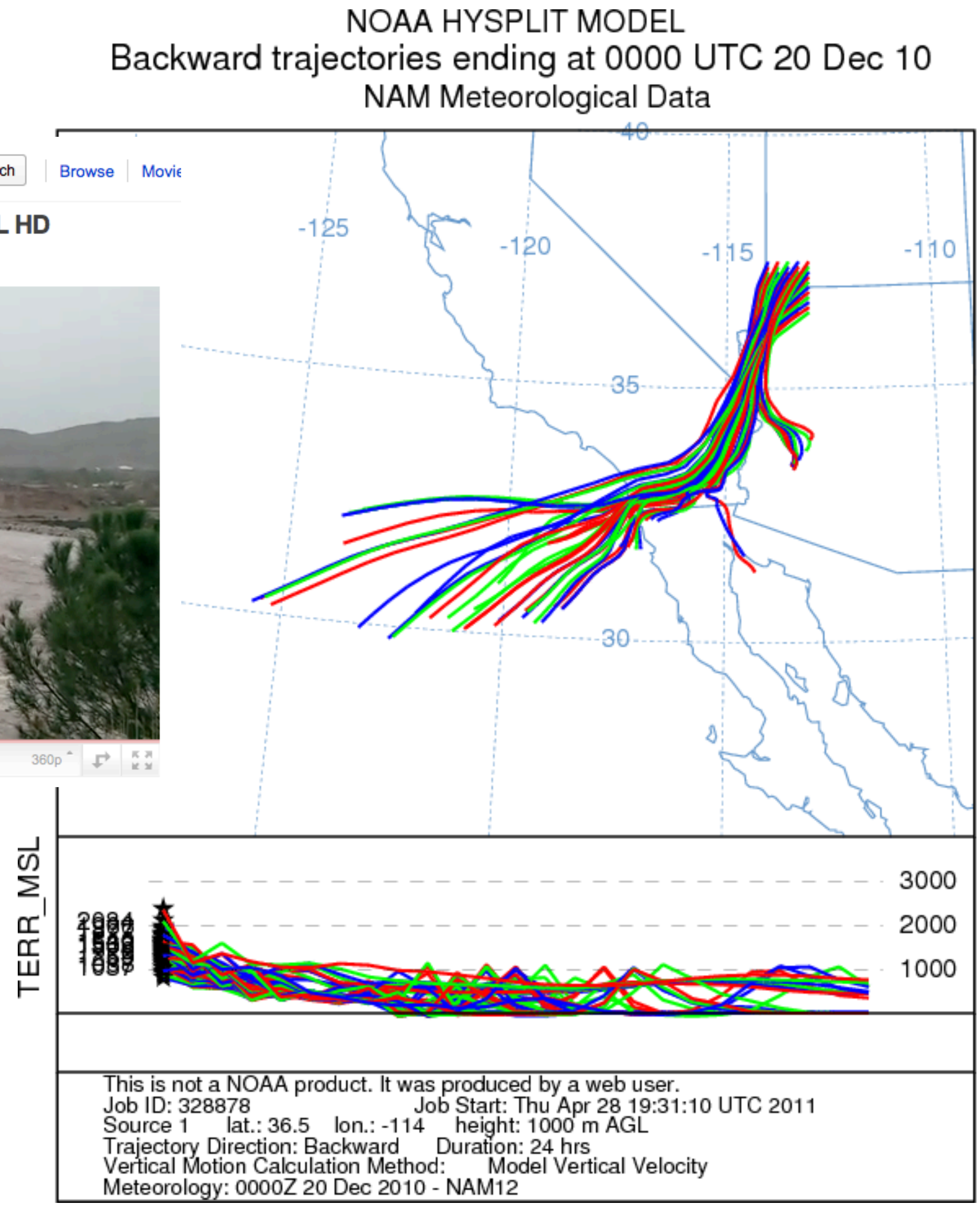
NOAA HYSPLIT MODEL
Backward trajectories ending at 0000 UTC 20 Dec 10
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Job Start: Thu Apr 28 19:31:10 UTC 2011
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Trajectory Direction: Backward Duration: 24 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 0000Z 20 Dec 2010 - NAM12

Topics

What use are ultra-high resolution models (< 2km…no convective parameterization)?

Do we need Really Large Ensembles ? … Characterizing the tails of the distribution through brute force….

- Initial Condition ensembles
- Perturbed physics (CPDN, regCPDN)
- What about hydrologic model uncertainty?

Can we improve Modeling Methodology for climate-change Hydrology (coupling; bias correction; calibration; nesting; choice of cases…)

How do we model the interactions of other Regional Forcings/feedbacks; Ecological change; disturbance (fire, etc)?

Others?

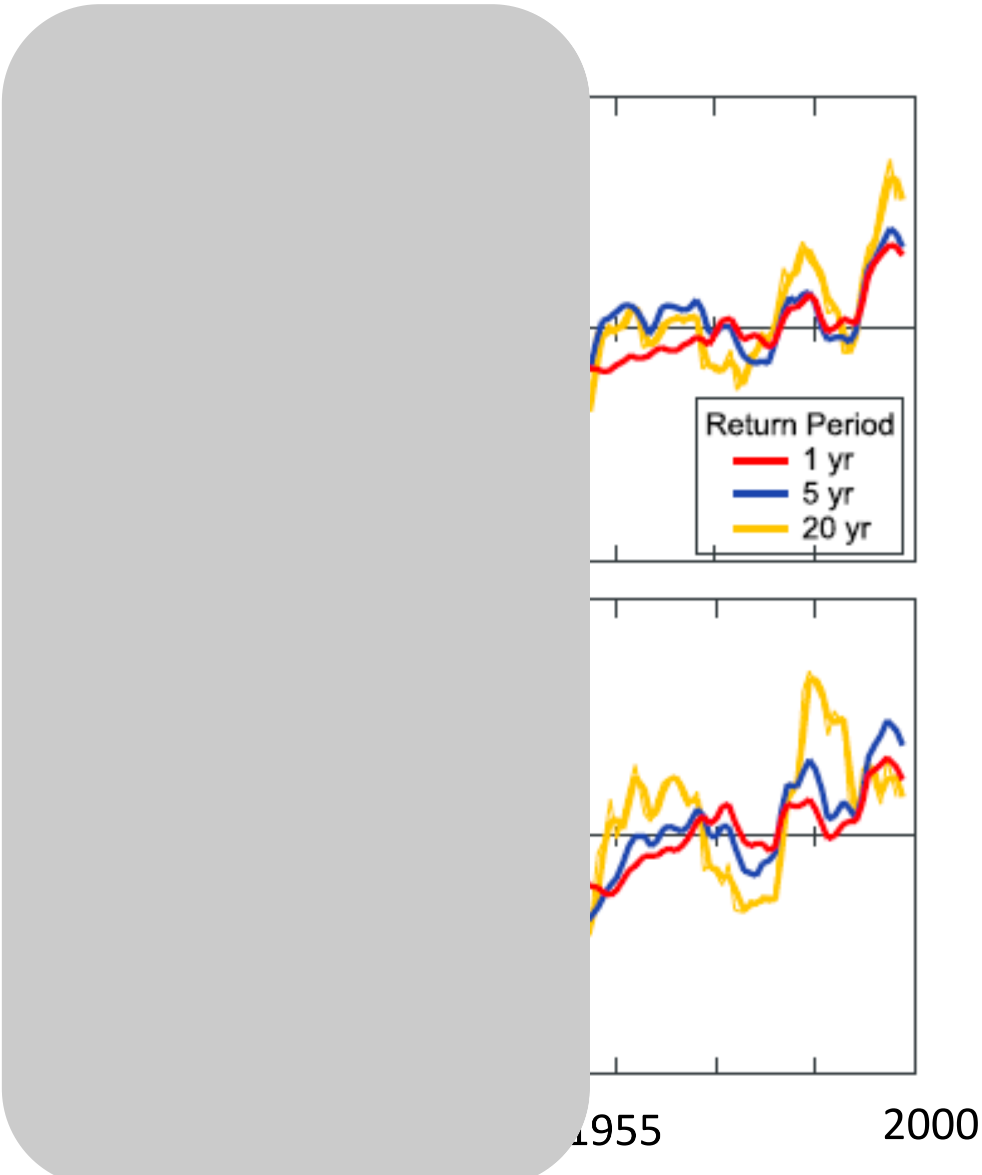
We are aware of the science

I'll focus on a framework for evaluating

- Where the science is now and will be soon…
- What are the various models/methodolgies good for?
- What are the unmet (evolving) user needs ?
- What are the next steps to take…?

- Tools <---> Problems?

What happened before 1951? (Kunkel et al, 2003)



This plot shows the trend in an index of 1-day and 5-day maximum precipitation compiled from stations across the United States

Note the strong upward trend from 1950-2000.

… and the "V" shape when looked as over the whole century.

Note: Min et al, 2011 analyze trends over 1951-1999

Temporal variations of extreme precipitation events in the United States: 1895–2000 Kenneth E. Kunkel, David R. Easterling, Kelly Redmond, Kenneth Hubbard GEOPHYSICAL RESEARCH LETTERS, VOL. 30, NO. 17, 1900, doi:10.1029/2003GL018052, 2003

Where were these precipitation extremes located (compared to the long-term average)?

1990-2000

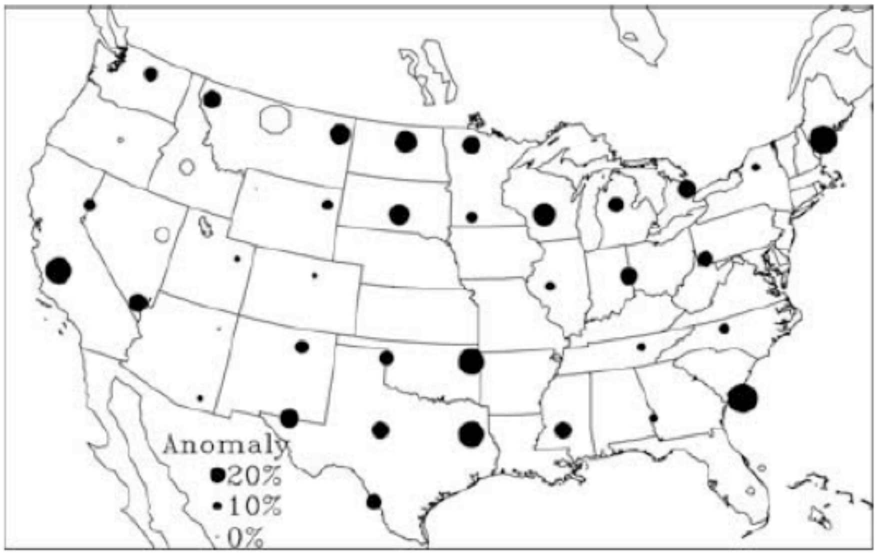


Figure 4. Map of frequency anomalies (compared to the period average) of the Extreme Precipitation Index during 1990–2000 for 1-day, 1-year events on a 4° latitude by 5° longitude grid. Filled-in (open) circles indicate positive (negative) anomalies.

1895-1905

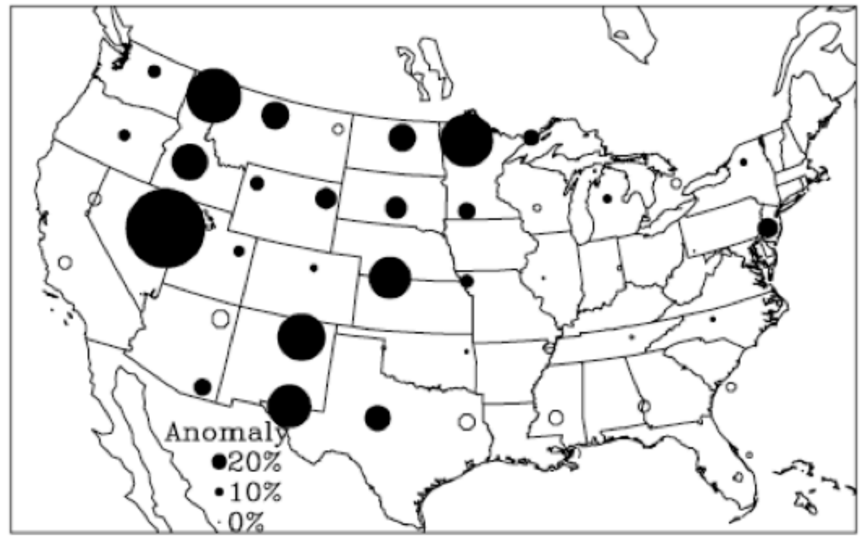


Figure 3. Map of frequency anomalies (compared to the period average) of the Extreme Precipitation Index during 1895–1905 for 1-day, 1-year events on a 4° latitude by 5° longitude grid. Filled-in (open) circles indicate positive (negative) anomalies.

Temporal variations of extreme precipitation events in the United States: 1895–2000
Kunkel et al. 2003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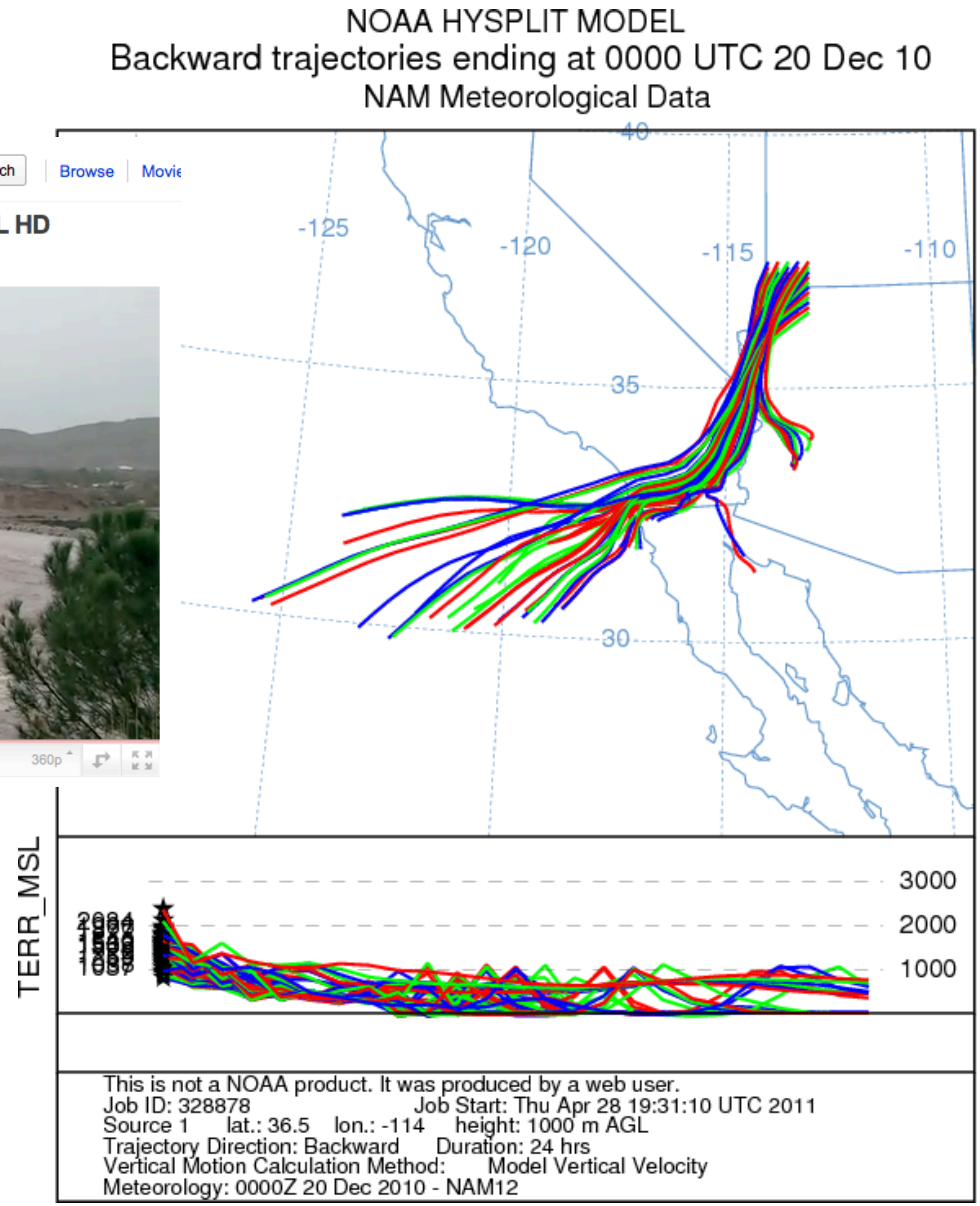
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Models

100-300km	“global” CGCM/ESM
15-50km	“regional” RCM
1-6km	“cloud permitting”

Methodology of prediction/projection

1. Initialized forecast [ensemble; Decadal Prediction]
2. Free-running projection [e.g. CMIP3 and much of CMIP5]
3. Downscaling vs adaptive or nested grid

Evolving Methods to study extremes with models

Brute force: simulate everything and pick out the extremes, or model the whole distribution. [Caveat: Extreme generating processes may not be captured at these scales]

Model Event-based: Pick extremes from a larger scale simulation and try to model them in detail. [Caveat: Errors of omission]

Historic Event-based case studies: Pick historic cases and ask "what-if" the environment were changed. "pseudo-global-warming"; Better for convective scale. Not so good for AR or winter snowpack that rely on global circulation patterns (storm tracks; jets; etc).

Model Composite-environment: Pick composite environments from larger scale simulations and model intensely

Bottlenecks in getting good hydrologic model simulations

Climate Model Bias: Why can't we just couple climate models to hydrology models? Yet…. We are applying LARGE bias corrections to climate models to force them into hydrology models. How is this better than a simple "delta" approach applied to the historic data?

Coupling: Bias-correction and lack of historical data to perform bias correction in non-T non-P fields leads to often very awkward approaches.

Hydrologic Model Calibration: Calibration needs to be re-thought to make it more compatible with physical hydrology of climate change.

Model-based methods to characterize the tails of the distribution…

Ensembles of opportunity [CMIP3; CMIP5]

Perturbed Physics Ensembles[CPDN; regCPDN]

Conjecture: Most work with CMIP3 models on fitting extreme value distributions simply does not have enough data for a reliable fit.

We do not take advantage of long control runs of the models to estimate the probability distribution of Extremes

Will higher resolution models solve (most of) our problems?

No. Not by itself.

Models are best used to address well-posed questions. Preferably questions about processes and phenomena, not just “CDFs”.

Using models to study extremes will need NEW METHODOLOGIES

Models can reveal structural uncertainty in our knowledge

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Others?

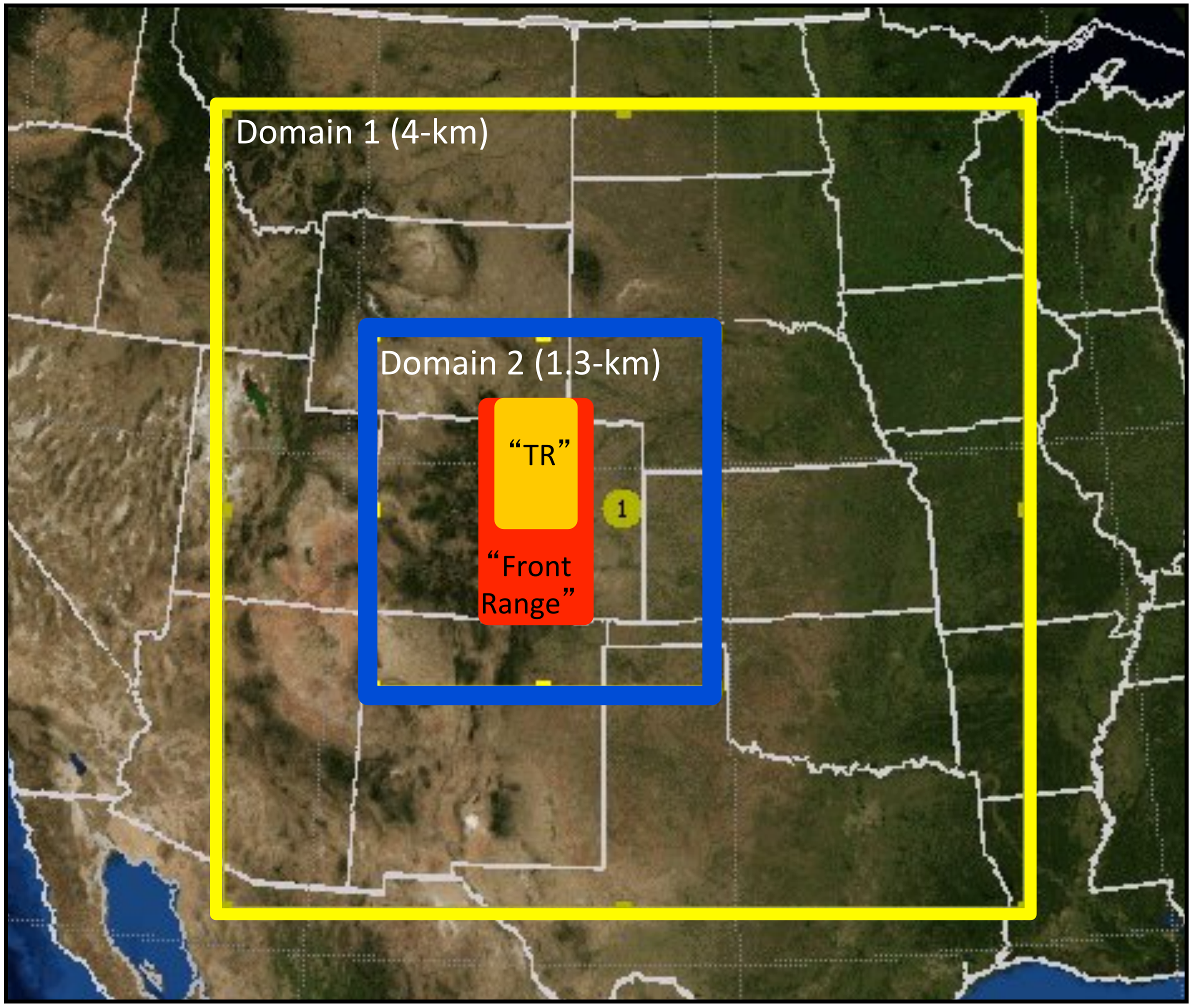


Figure 1: Map of West-Central United States showing the case selection target region ("TR", orange box), the CO Front Range region used for analysis ("Front Range", red box); the outer 4-km WRF model domain ("Domain 1"; yellow box), and the inner 1.3-km WRF model domain ("Domain 2"; blue box).

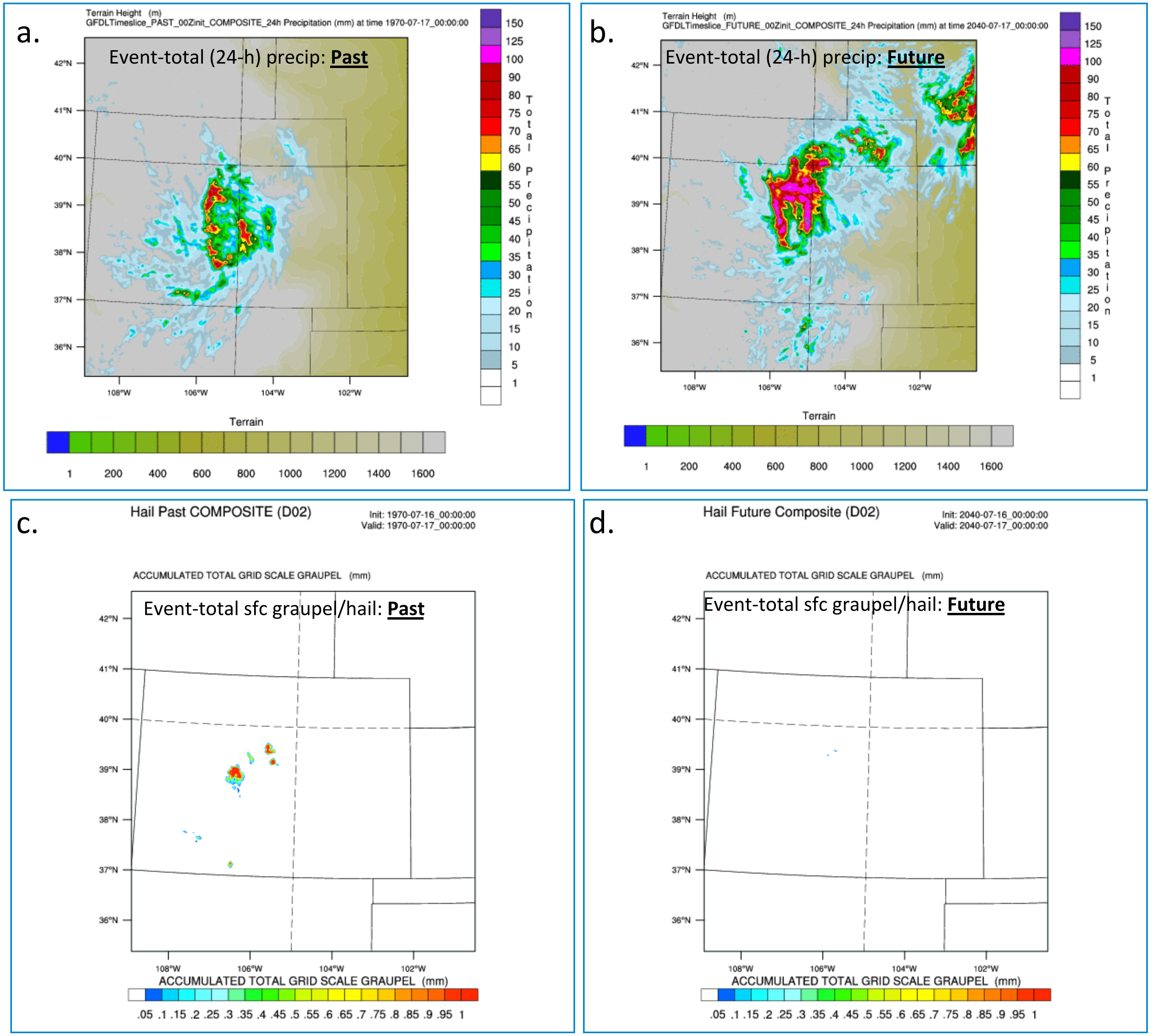
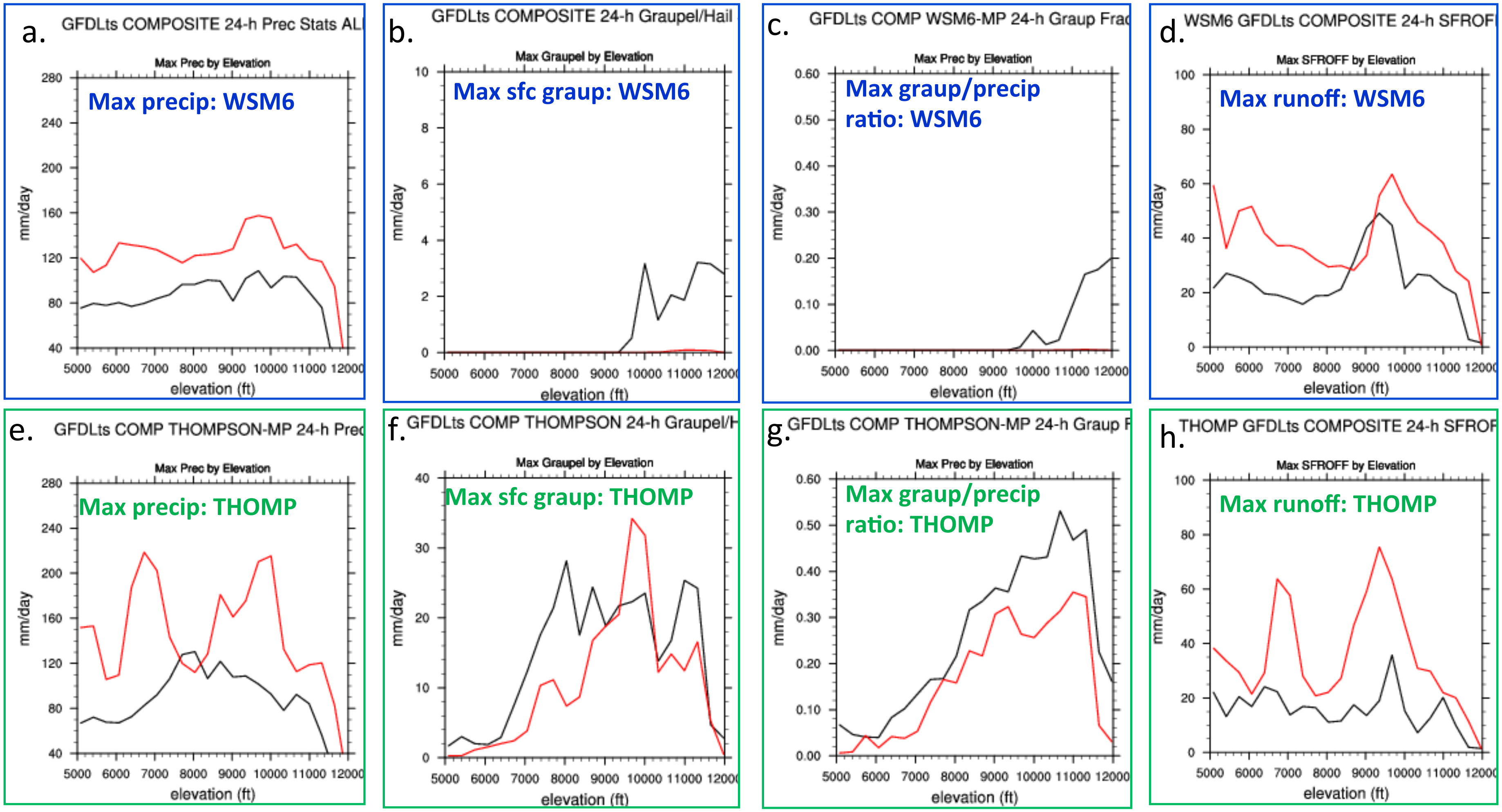


Figure 2: a) Event-total (24-h) accumulated precipitation (mm) for PAST-WSM6; b) as in a) but for FUT-WSM6; c) Event-total (24-h) accumulated surface graupel/hail (mm) for PAST-WSM6; d) as in c) but for FUT-WSM6.



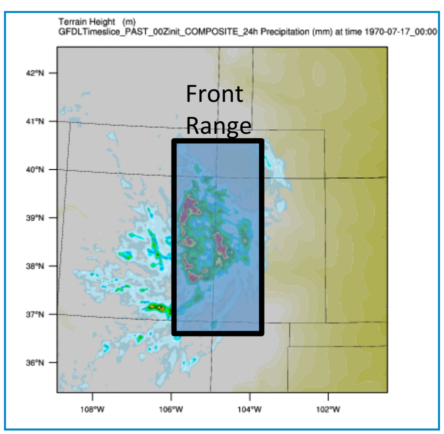
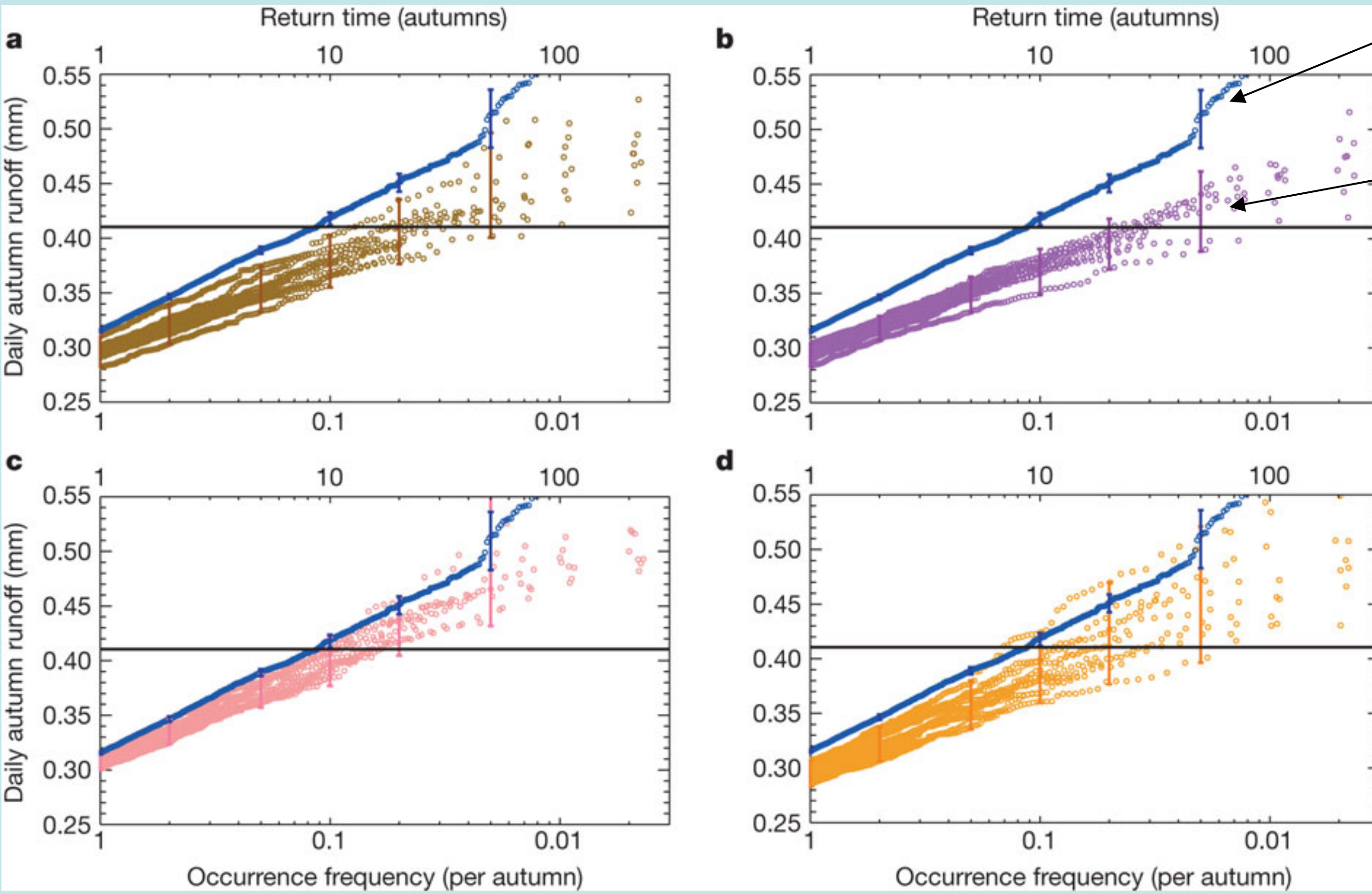


Figure 10: a) Maximum gridpoint event-total precipitation (mm/day, y-axis) vs. elevation (feet, x-axis) for PAST-WSM6 (black) and FUT-WSM6 (red); b) as in a) except for maximum accumulated surface hail/graupel (mm), c) as in a) except for the maximum ratio of graupel/total precipitation (mm/mm); d) as in a) except for maximum surface runoff (mm); e) as in a) except for PAST-THOMP (black) and FUT-THOMP (red); f) as in b) except for PAST-THOMP (black) and FUT-THOMP (red); g) as in c) except for PAST-THOMP (black) and FUT-THOMP (red); h) as in d) except for PAST-THOMP (black) and FUT-THOMP (red); i) geographical depiction of “Front Range” region included in analysis (as shaded/labeled).

Cooler Ocean Temperatures in "1900" lead to lower simulated extremes....

Change in occurrence frequency of daily river runoff for England and Wales autumn 2000.



Autumn 2000 conditions

Autumn "1900" Conditions from one GCM

Fraction of Attributable Risk= 1 - N(1900)/N (2000)

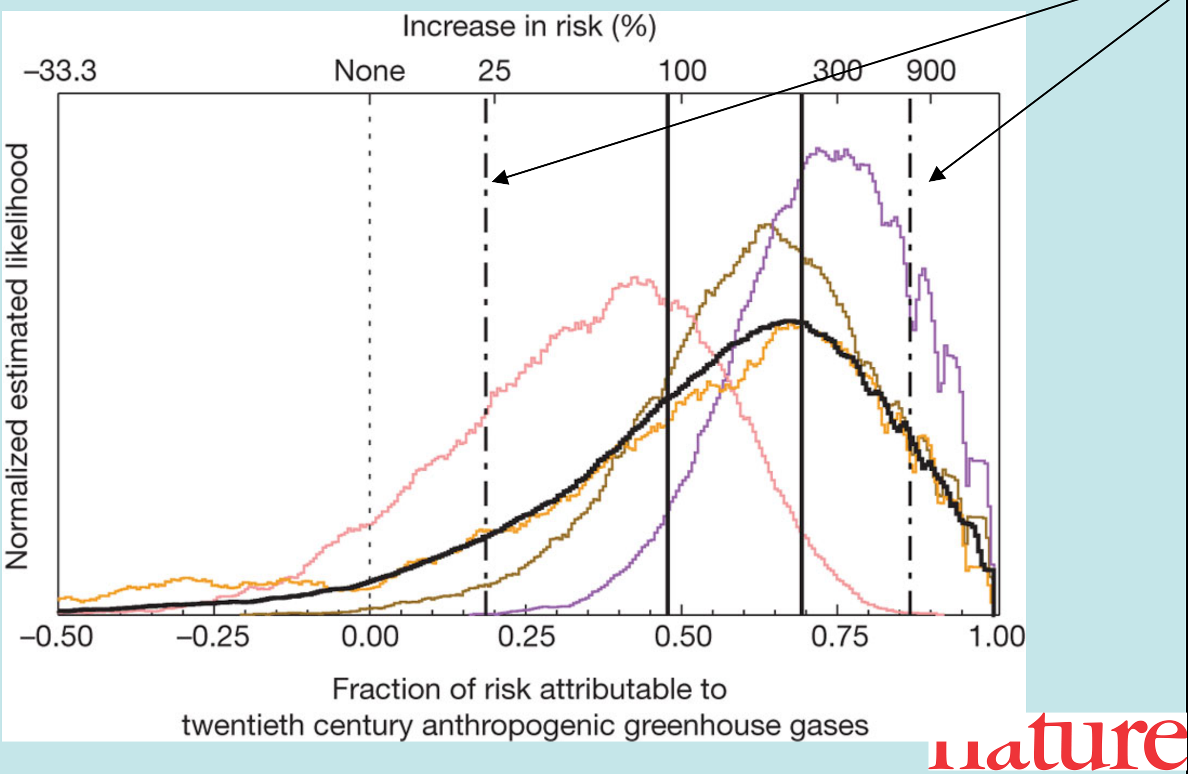
P Pall *et al.* *Nature* **470**, 382-385 (2011) doi:10.1038/nature09762

nature

Fraction of Attributable Risk (FAR)

Roughly -- # of events (with GHG forcing)/# events (natural variations only)
It is uncertain….you get a distribution of FAR with varying likelyhood
For tails… very sensitive to estimate of the denominator…..

Attributable risk of severe daily river runoff for England and Wales autumn 2000.



P Pall *et al. Nature* **470**, 382-385 (2011) doi:10.1038/nature09762

10 and 90 % confidence interval

100% increase in risk = 0.5 FAR

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Can we improve Modeling Methodology for climate-change Hydrology (coupling; bias correction; calibration; nesting; choice of cases…) ?

How do we model the interactions of other Regional Forcings/ feedbacks; Ecological change; disturbance (fire, etc)?

What can we provide? What sorts of questions CAN we address? (Mike will lead the modeling for water needs tomorrow).

What can we do better with existing tools and datasets?

What can be developed in the next 5 years

What can we reasonably exclude?

Advances in extreme value estimation-- the role of models.

Why do we use EV theory in the first place rather than just the raw histograms?

Because GEV constrains the shape of the extreme value distribution, so the estimates are more reliable (less uncertain) given the sample.

If we had a better theory of the shape of the precipitation distribution -- esp. the tails-- we could get an even better estimate of the tails with the small amount of data we have.

Mike Anderson CDWR

- Processes vs probabilities
- Adaptation: Time = options
- Right processes at right scale
- Decision Support Tools
- Knowledge and Experience
- Thresholds and consequences
- Communication….

JJ-

- Need a new Bible