Statistical Downscaling of Climate Extremes

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Overview

- Projection of changes in extremes
- Statistical downscaling of extremes
  - Data and method
  - N.A. winter season only
- GCM simulated changes in extreme precipitation
- Some conclusions

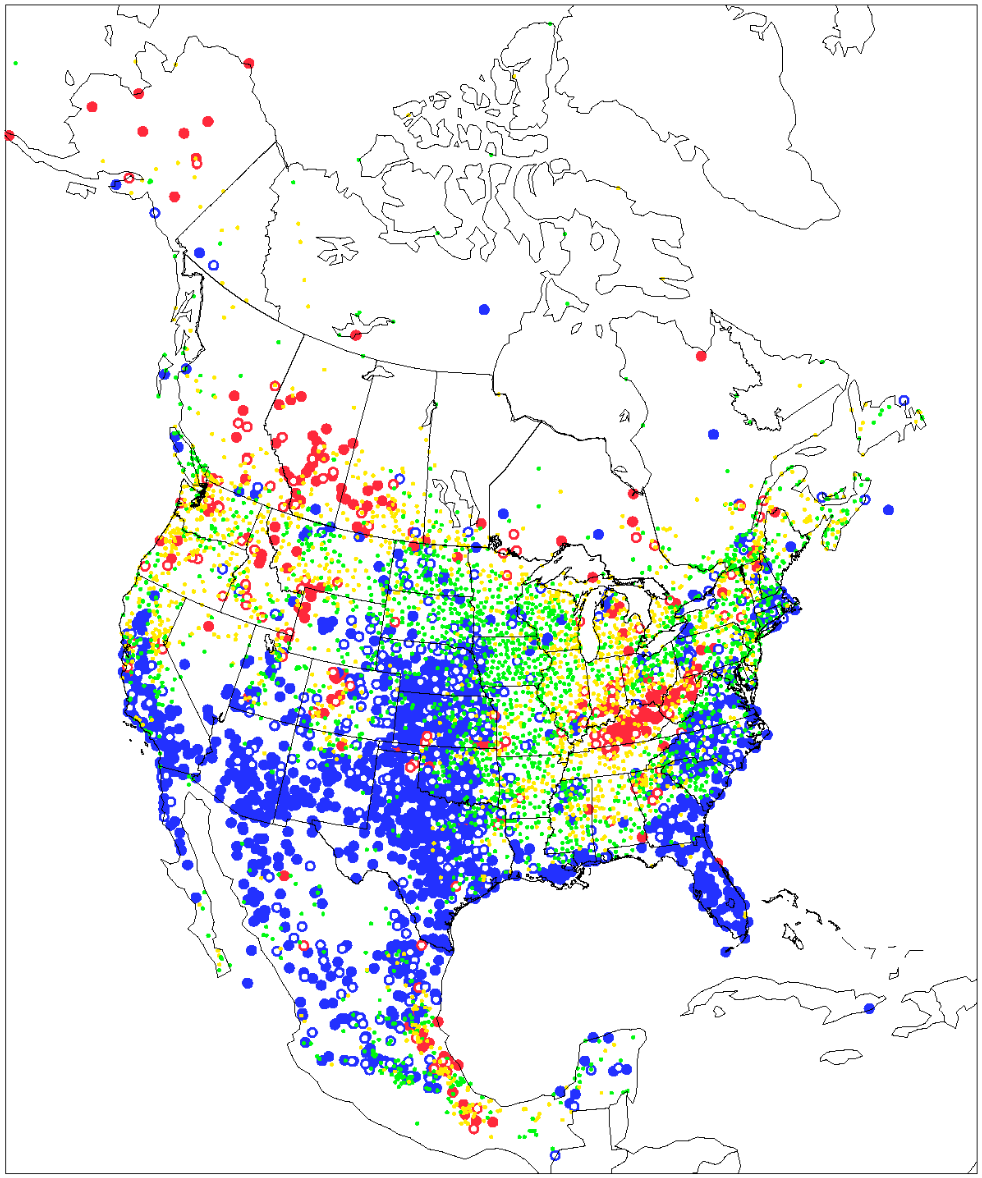
Projection of changes in extremes

- GCM output
  - Extremes not reliably simulated
  - Grid size too large
- RCM output
  - Extremes not much more reliable
  - Grid size still large
  - Area extremes/point extremes
- Statistical downscaling

Statistical downscaling

- Regression
  - Need to have good predictors
- Condition/Assumptions
  - Good relationship
  - Relationship valid in the future
- Advantages
  - Easy to use
  - Can have good skill
- Problems
  - Inherent problems from large-scale field

Influence of EL Nino on extreme



Generalized Linear Model

- Simple linear regression not valid for extremes
- GLM considers extreme value distribution
- Software available
  - S-plus functions (Coles, 2001)
  - NCAR extreme-tool-kits (based on R, Rick Katz)
  - Home grow FORTRAN codes

Modeling Extreme Values

GEV distribution function

$$G(y) = \begin{cases} \exp\{-\exp[1-(y-\mu)/\sigma]\} & ,\xi = 0, (EV-I) \\ \exp\{-[1-\xi(y-\mu)/\sigma]^{1/\xi}\}, & \xi > 0, y \le \mu + \sigma/\xi (EV-II) \\ \exp\{-[1-\xi(y-\mu)/\sigma]^{1/\xi}\} & ,\xi < 0, y \ge \mu - \sigma/\xi (EV-III) \end{cases}$$

Introduce co-variates

$$\mu = \alpha + \beta_i x_i$$

$$\log(\sigma) = \theta + \phi_i x_i$$

Regression coefficients
Estimated by MLE

$$L = \prod_i^n \sigma^{-1} \exp\{-(1-\xi \frac{y_i - \mu}{\sigma})^{1/\xi}\}(1-\xi \frac{y_i - \mu}{\sigma})^{1/\xi + 1}$$

Use *r* largest values to improve model fitting

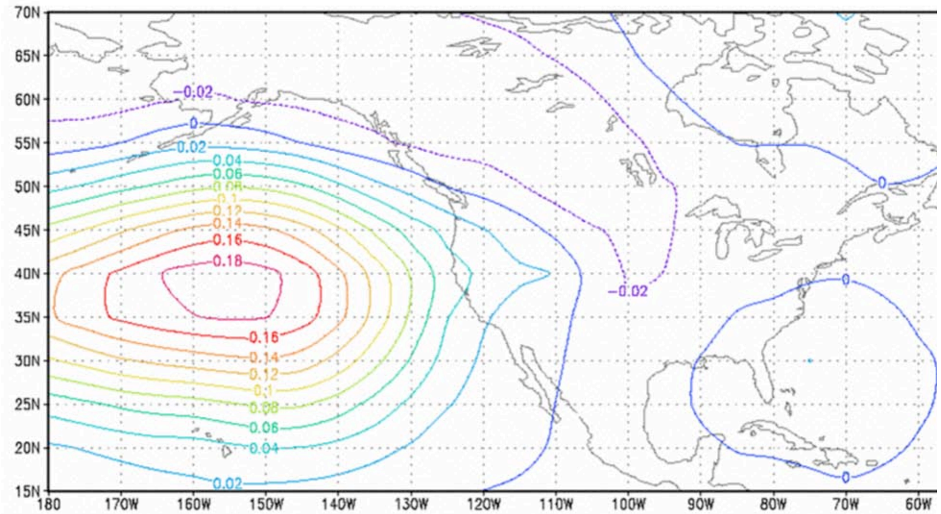
Data

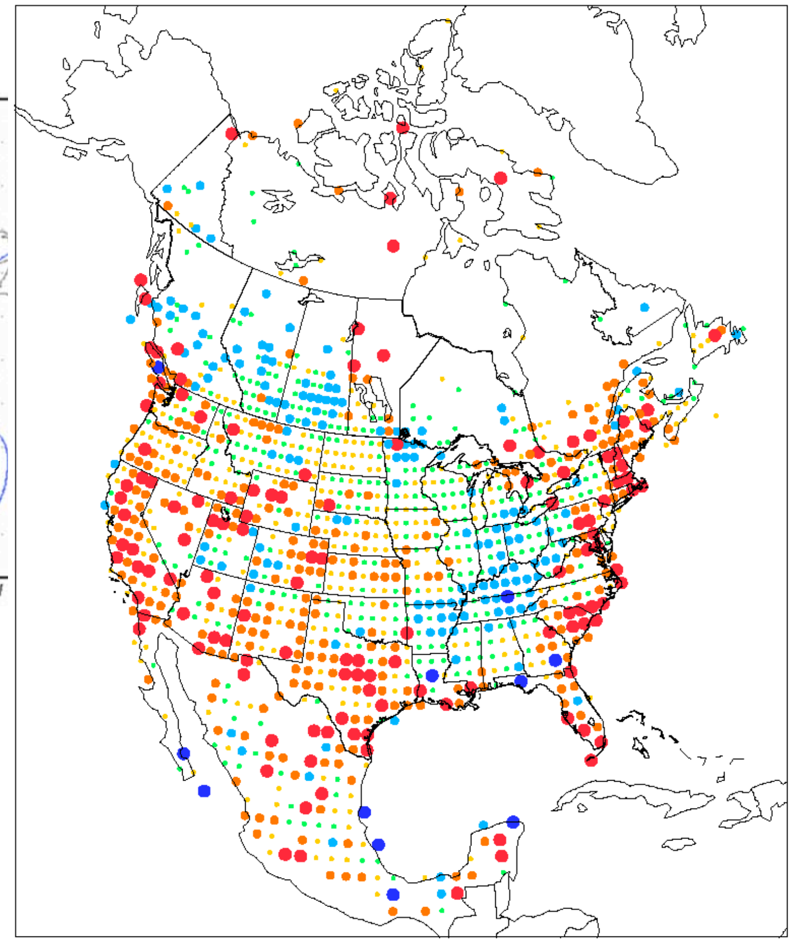
- Daily precipitation over N. America
  - 3 largest precipitation amounts in DJFM
- NCEP reanalysis SLP, Relative Humidity at 850 hPa.
- Many 20th Century Runs

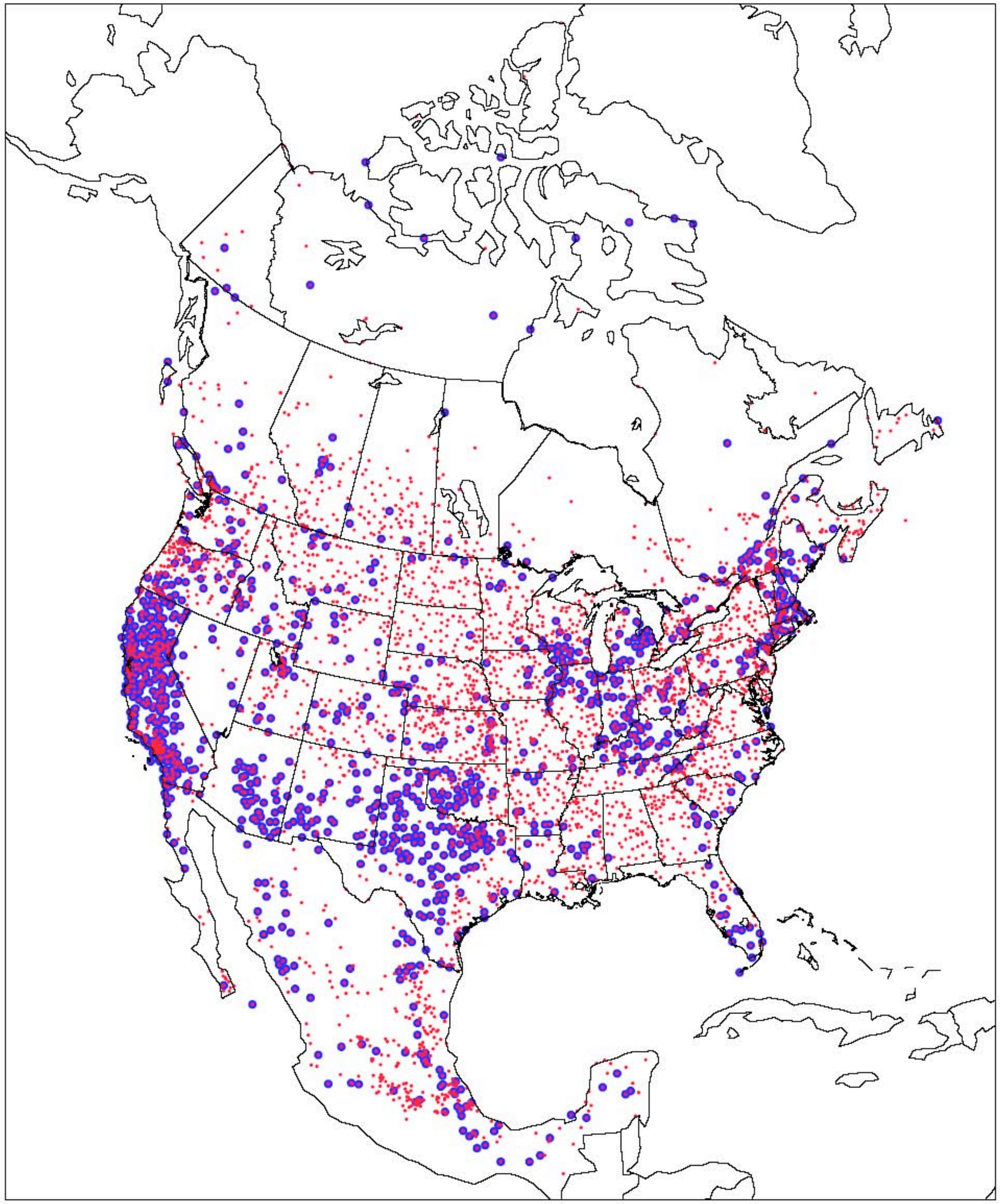
Procedures

- 3 leading rotated PCs from Obs SLP + gridpoint values of relative humidity at 700 hPa level as co-variates (predictors)
- Project SLP changes (2050-2099 minus 1950-1999) to the observed EOFs
- Projected changes in GEV distribution parameters
- Projected changes in the risk of 20-yr return values

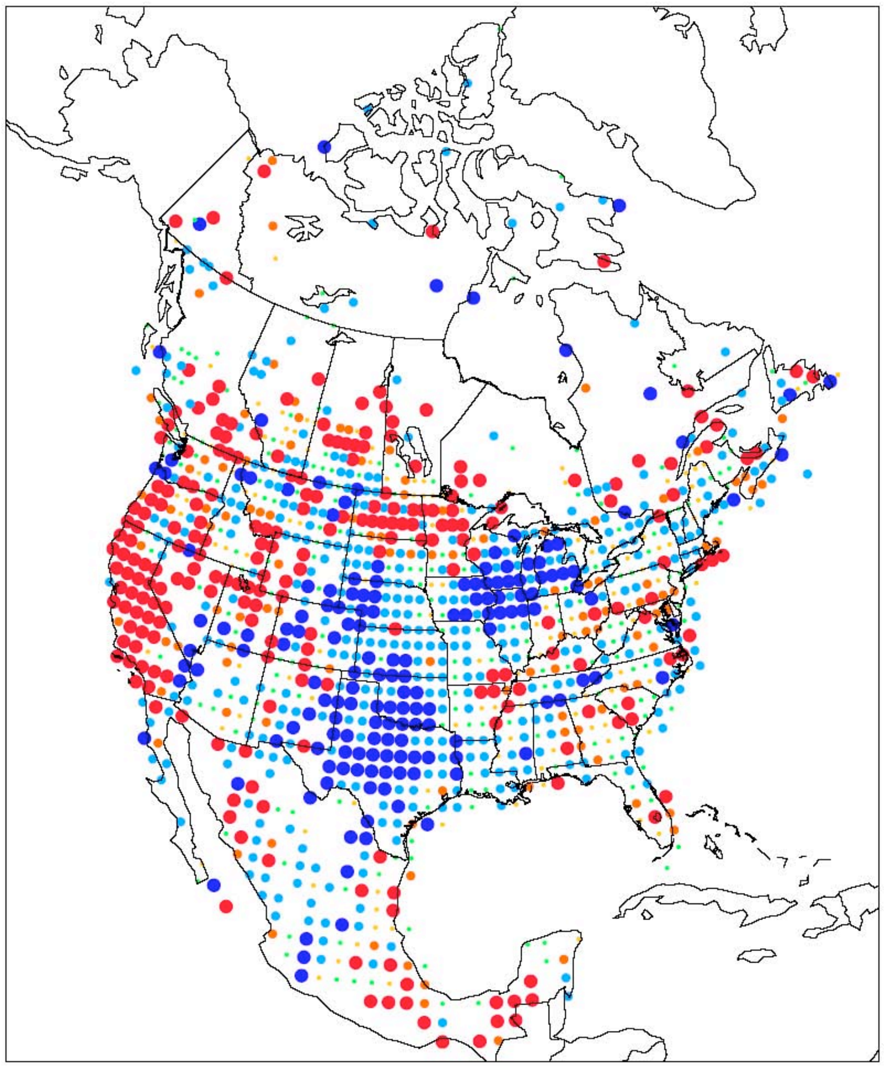
SLP EOF1/Extreme Precip

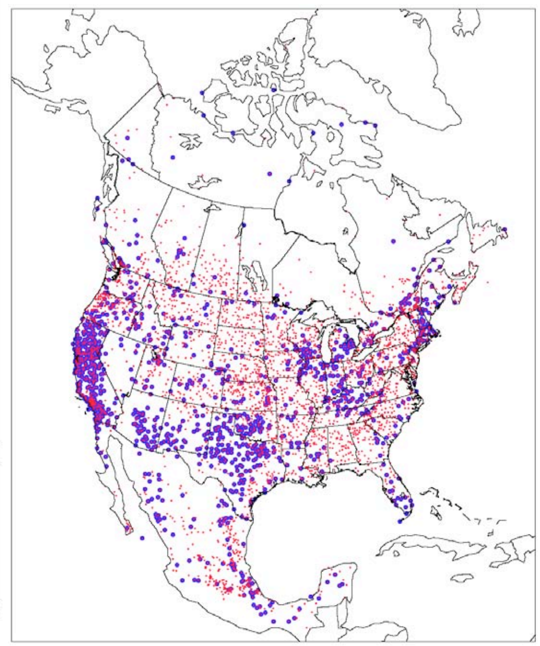




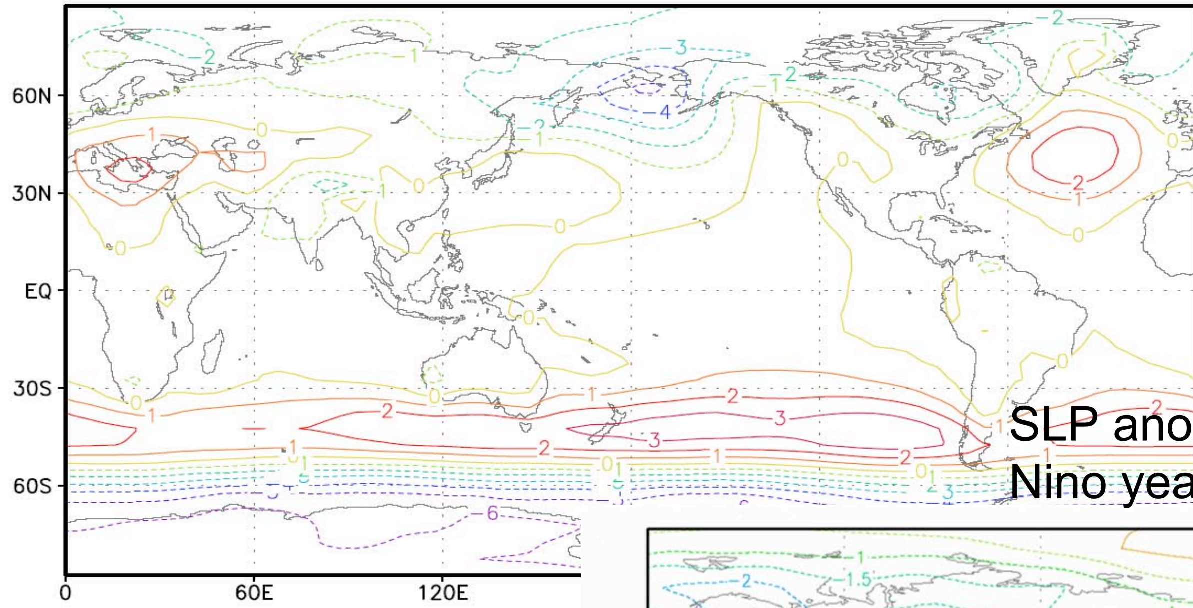


Projected return period for 2050-2099 for current 20-yr return value (CGCM3 results)

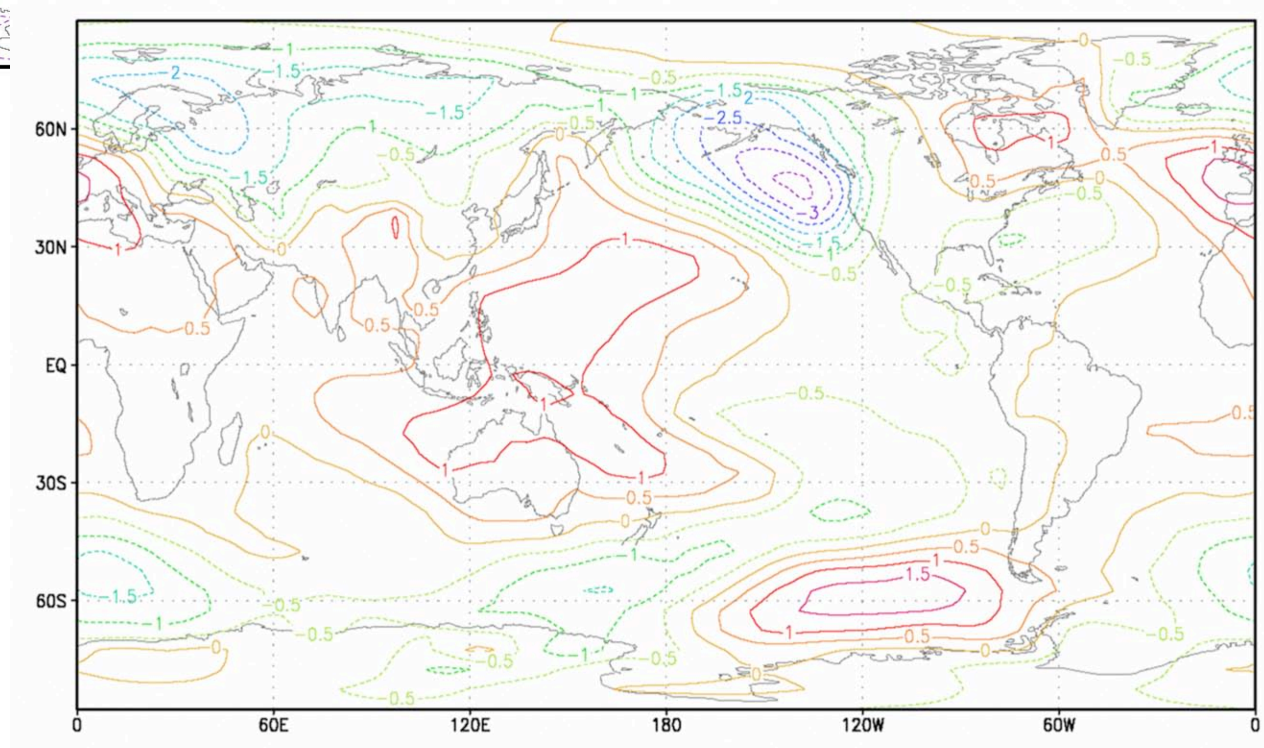




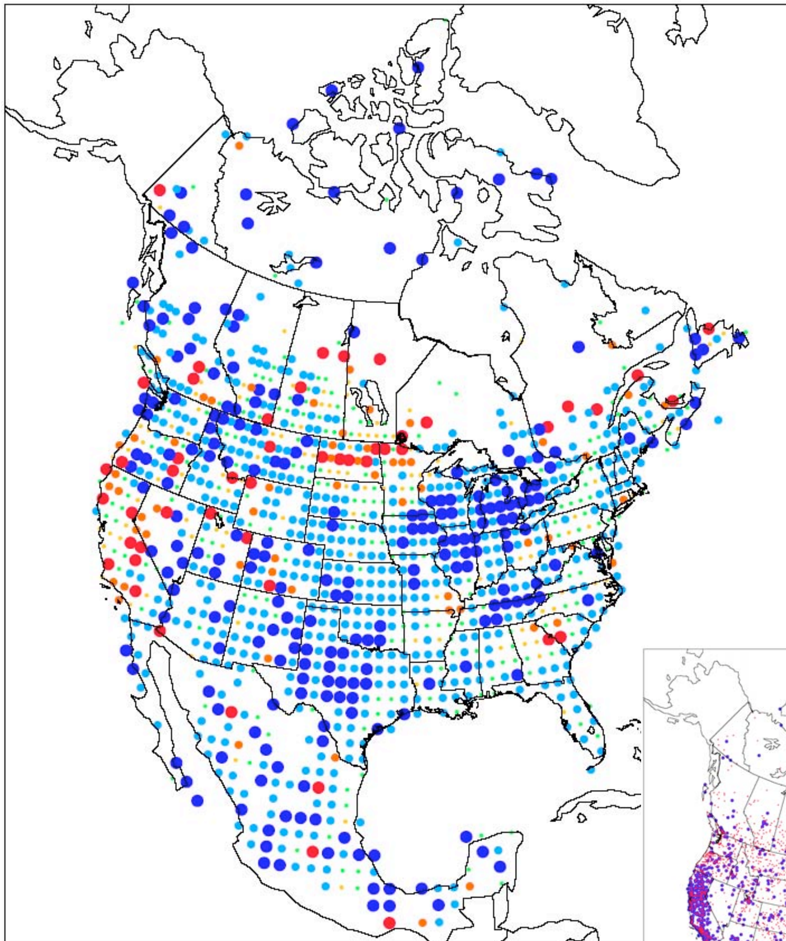
Projected SLP change (2050-2099)

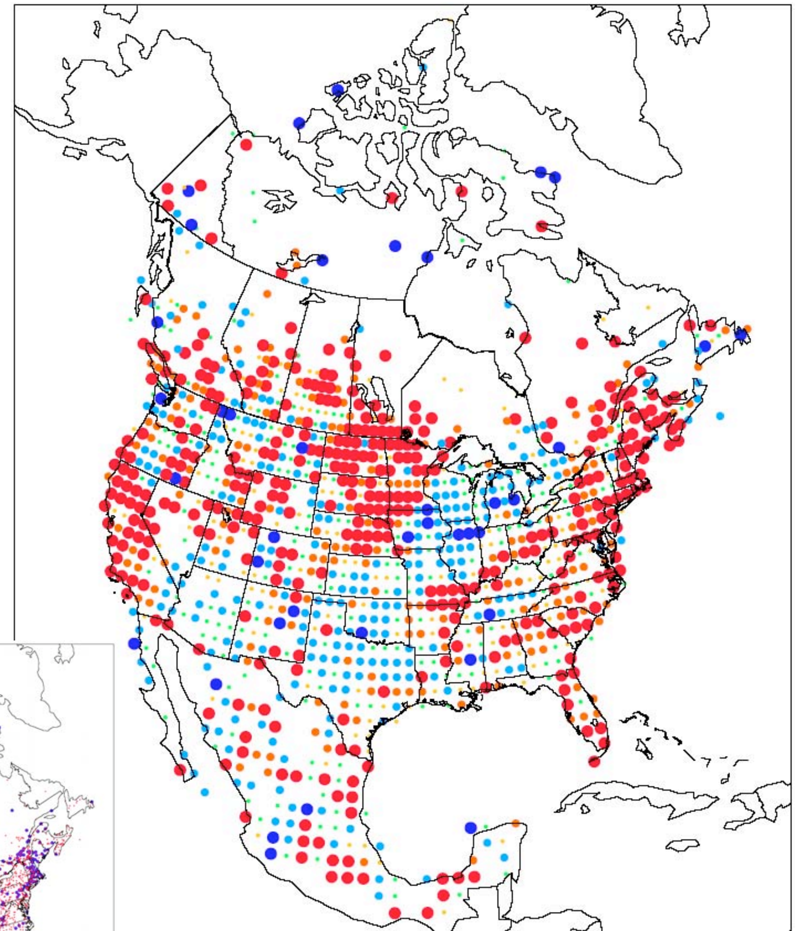


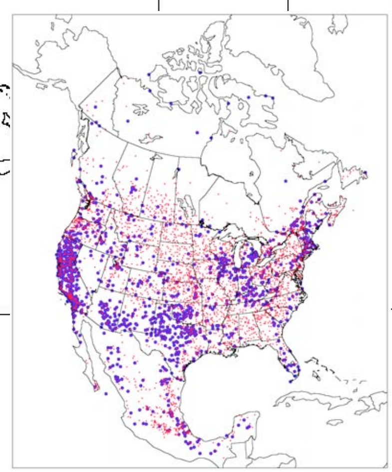
SLP anomalies during El Nino years (1951-2000)



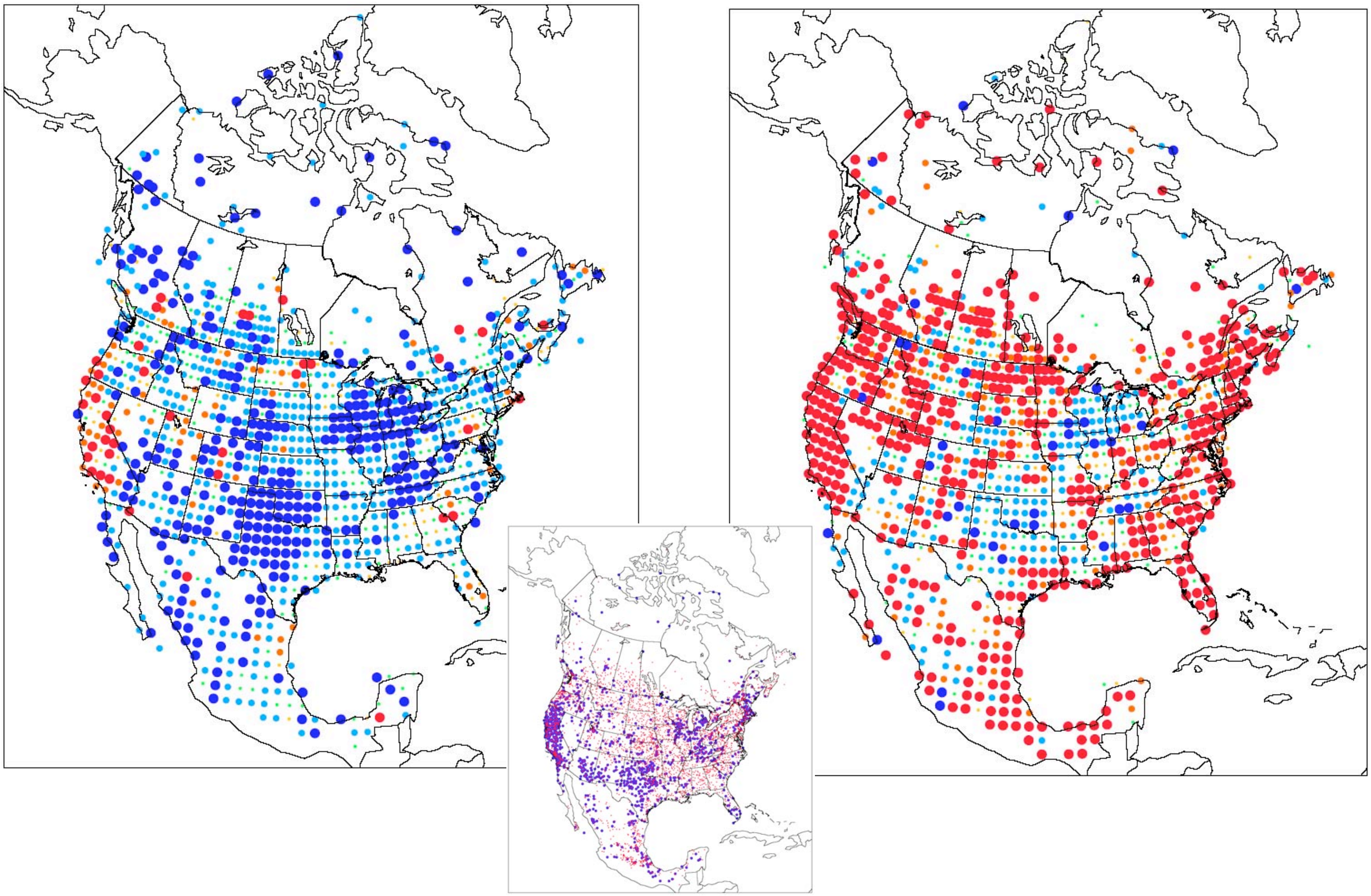
Intra-ensemble uncertainty (CCSM, 5 runs)



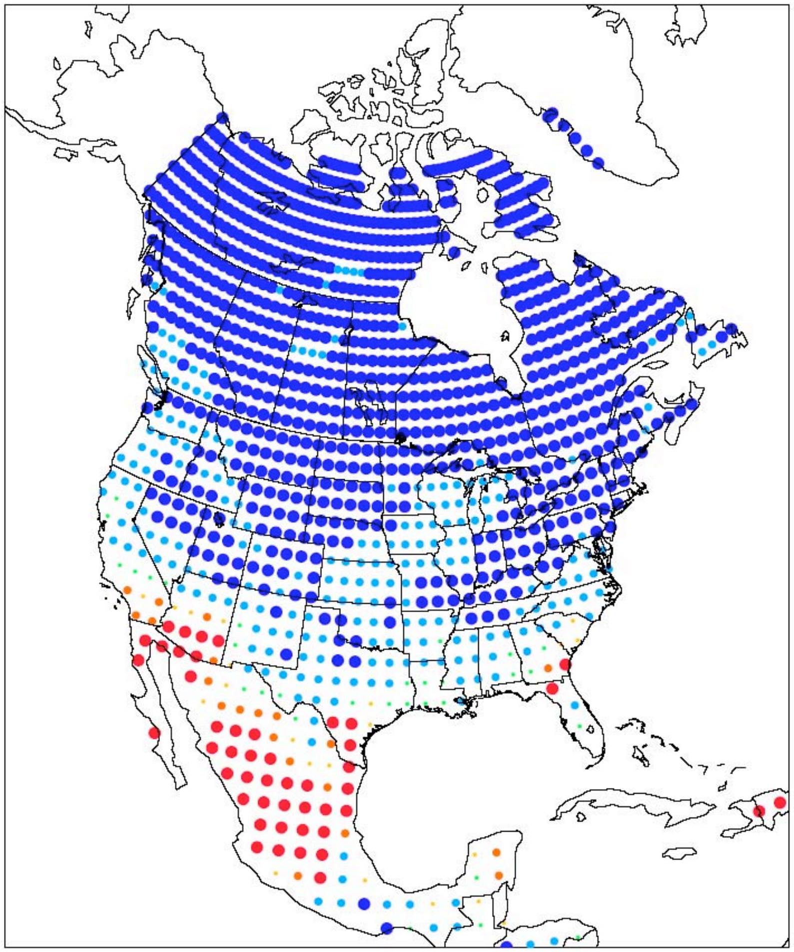


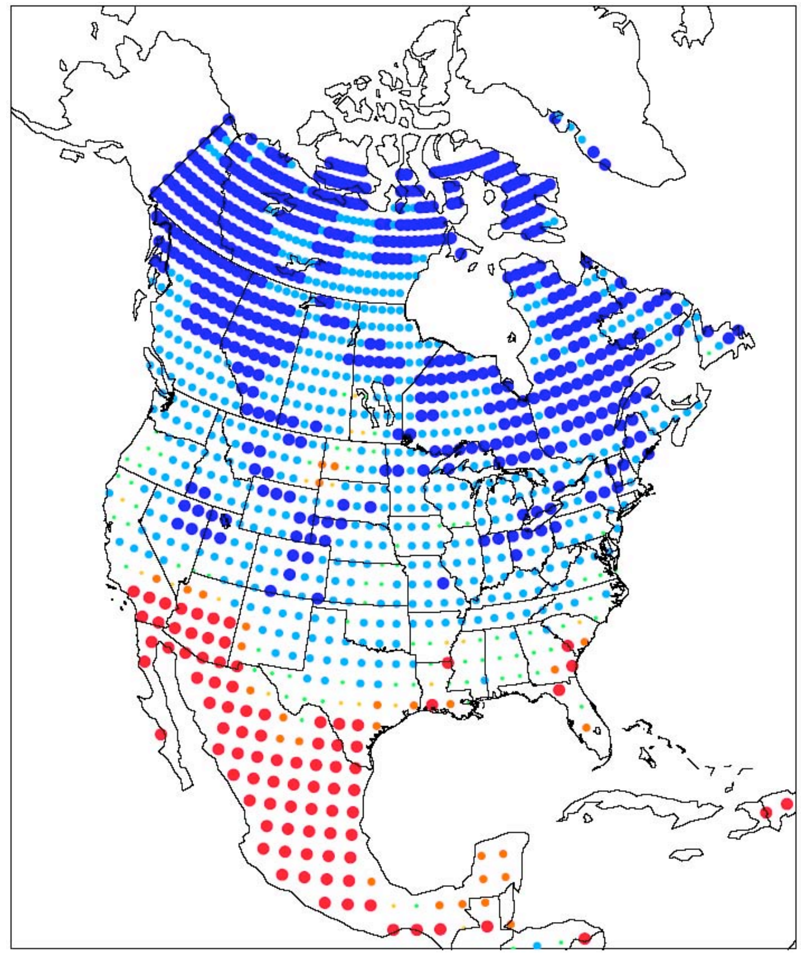


Inter-model uncertainty (6 GCMs)



Extreme precipitation from GCMs (Intra ensemble, CCSM 6 runs)

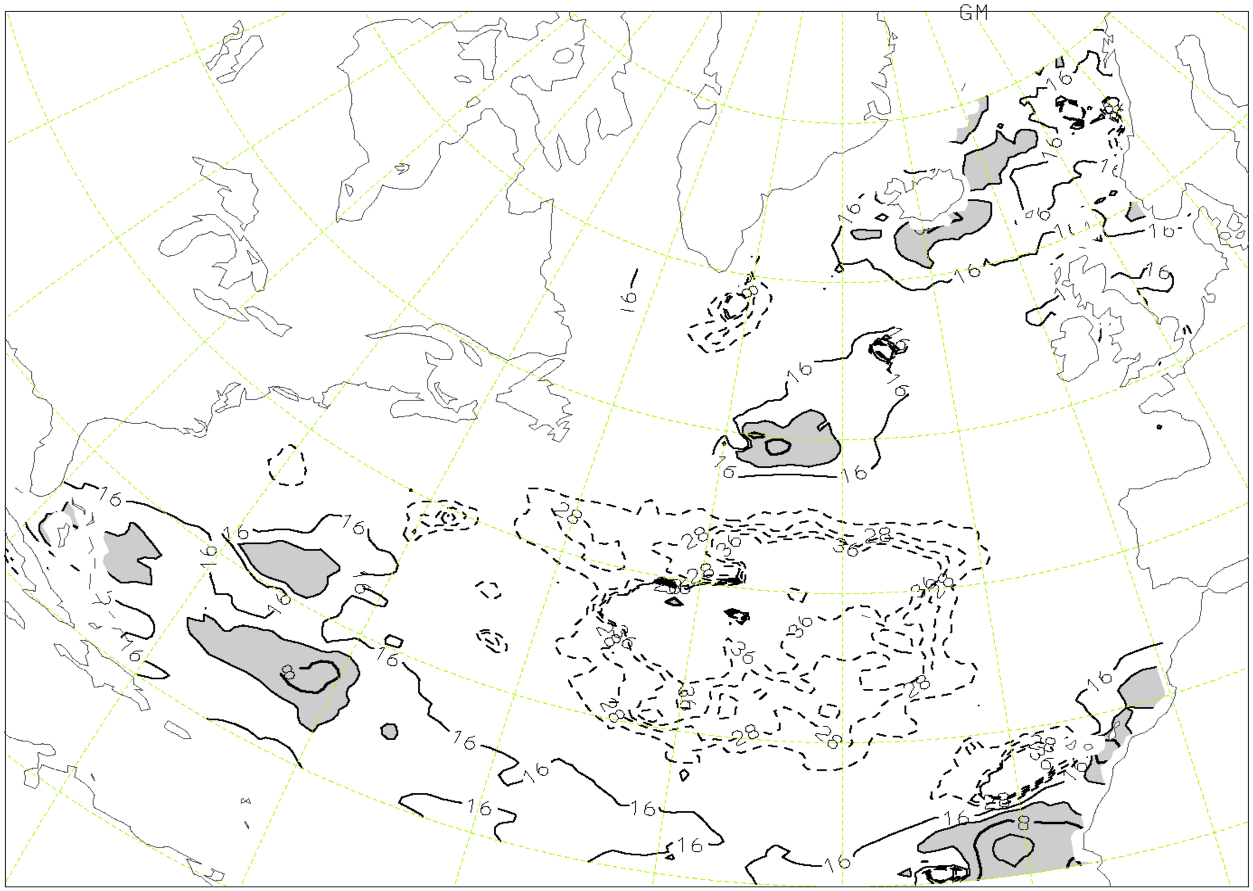




Conclusions

- Possible to assess the changes in risk using statistical downscaling
- Need to understand caveat
  - Good relation between large-scale field and the variable
  - Inherent problems in GCM simulated large-scale field
- Examples show success
- Direct output may be different from downscaled results
  - Other important predictors may have not been included
  - Validity of extrapolation for the future
  - Extremes self-consistent in GCM but that may differ from the real world
  - Who to believe to?

Projected return period of 1990's H20yr for 2080, A2 forcing scenario, JFM



Wang, X. L., F. W. Zwiers and V. R. Swail, 2003: North Atlantic Ocean Wave Climate Change Scenarios for the 21st century. *J. Climate* (submitted).

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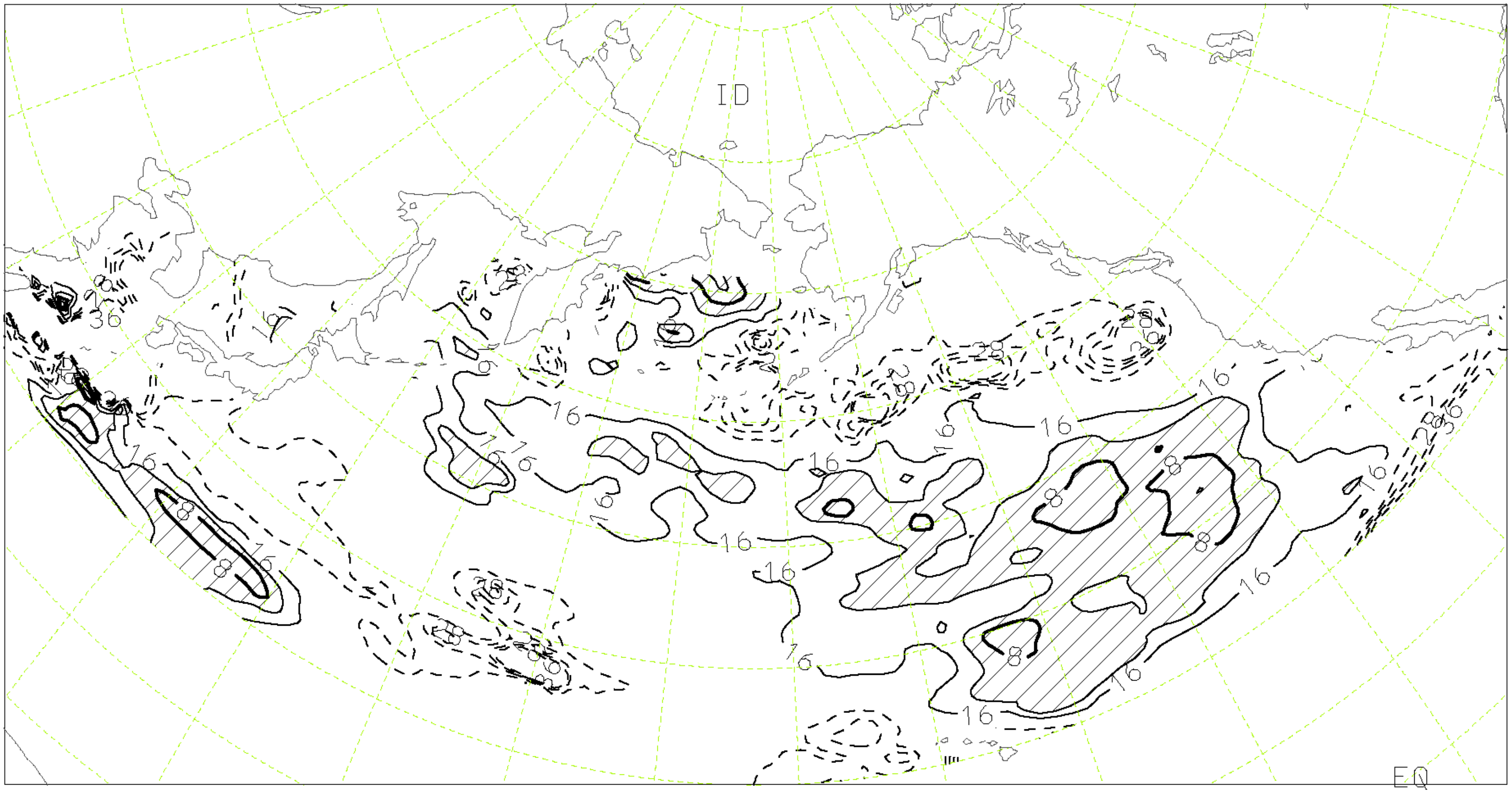

Wang, X. L. and V. R. Swail, 2003: Historical and possible future changes of wave heights in northern hemisphere oceans. *Atmosphere Ocean Interactions – Vol. 2*, ed. W. Perrie, WIT Press - Ashurst Lodge, Ashurst, Southampton, UK (in press).

How often will this occur in the future?

Climate change?

Source: Natural Resources of Canada

Design values and extreme values modeling

- Collect extreme values (e.g. annual maximum daily precipitation)
- Fit the extreme values to an extreme value distribution
- Compute a return value from the fitted probability distribution
- **Assume the future is the same as the past** and use the return value as a design value
- This approach has been used for more than 50 years

But there is a problem with the traditional approach

- Climate has changed in the past
- Climate is changing
- Climate will be different in the future