“The Climate That Might Have Been” Approach
Goal in event attribution:

- Determining possible contributing factors on an extreme weather or climate related event e.g.,
  - Anthropogenic forcing (ghgs, ozone, aerosols)
  - Natural external forcings (solar, volcanic)
  - Internal atmospheric noise
  - Internal ocean variability

It is important to properly determining the anthropogenic climate change contribution
Two parallel set of experiments:

1. **Climate that has been experienced**: AMIP-style experiment with observed lower boundary conditions and radiative forcings

2. **Climate that might have been**: AMIP-style experiments with forcings that resemble the climate that might have been without impact of human influence (pre-industrial radiative forcings, modified lower boundary conditions that remove contribution attributable to anthropogenic emissions)
Different approaches to determine SSTs attributable to anthropogenic climate change

- Utilize CMIP3/5 experiments (e.g., Pall et al. 2011, Perlwitz et al. 2009, C20 C&A project)
  - Utilize multimodel ensemble (e.g. Perlwitz et al. and single model estimates (Pall et al. 2011) together with applying scaling factors
  - Determine combined natural and anthropogenic forcing (Perlwitz et al. 2009) versus warming attributable to ghg emissions (Pall et al. 2011)

- Estimate long-term climate change contribution based on observations (Hoerling et al. 2011, Perlwitz et al. 2014)
  - Approach cannot separate between naturally and anthropogenically induced SST change
The Climate of the 20\textsuperscript{th} Century Plus’ Detection and Attribution Project

- An international collaboration to produce a multi-model product to support investigation of extremes under a changing climate
- Generating large ensembles of simulations under historical climate conditions
- Generating large ensembles of simulations under what historical climate conditions might have been without anthropogenic emissions
- Currently 12TB of output on ESGF from two atmospheric models (CAM5.1-1degree, MIROC5). Two more AGCMs expected in 2014 (HadAM3P-N96, HadGEM-3A), at least doubling that in 2015, plus regional downscaling and hydrological models.
C20 D&A Project

• Utilizes skin temperature of CMIP5 Historical +RCP4.5 and HistoricalNat simulations (19 models)
• Determine time varying difference between historical+RCP4.5 and CMIP5 historicalNat simulations=attributable warming signal
• This attributable warming signal will then be subtracted from observed SST values
• Sea ice forcing and related SST in polar regions is also modified (Pall et al. approach)
Issue: Recent Global Warming Hiatus

IPCC WGI AR5: Chapter 9
Contributions to Observed Arctic Tropospheric Warming strongly affected by method

<table>
<thead>
<tr>
<th></th>
<th>OBS Estimate 1</th>
<th>OBS Estimate 2</th>
<th>CCSM4-Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIC</td>
<td>~20%</td>
<td>~20%</td>
<td>~20%</td>
</tr>
<tr>
<td>SST-CC</td>
<td>~25%</td>
<td>~34%</td>
<td>~75%</td>
</tr>
<tr>
<td>Decadal Ocean Variability</td>
<td>~50%</td>
<td>~25%</td>
<td>-20% to +5%</td>
</tr>
</tbody>
</table>
Approach does not affect implications

- Arctic tropospheric warming is mainly caused by processes outside the Arctic
- Observed decrease in westerlies in North Atlantic can be mainly attributed to atmospheric noise and decadal oceanic variability.