Estimating the regional response to global warming using pattern-scaled sea surface temperatures and sea ice

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- Prescribing SSTs for climate attribution and prediction.
- Method description.
- Applications to past regional climate.
- Key points.

LST Trends (1951-1999)



Shin and Sardeshmukh 2011

LST Trends (1951-1999)

 Simulations that use observed global or tropical SSTs as boundary conditions can capture continental hydroclimate trends.



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Global Land Surface Temperature



Shin and Sardeshmukh 2011

 Simulations that use observed global or tropical SSTs as boundary conditions can capture continental hydroclimate trends. LST Trends (1951-1999)



Shin and Sardeshmukh 2011

- Simulations that use observed global or tropical SSTs as boundary conditions can capture continental hydroclimate trends.
- But coupled models struggle with tropical SST trends.
- This leads to poor coupled model simulation of continental trends.

LST Trends (1951-1999)





Using the time history of observed SSTs in atmospheric GCMs give us insight into continental hydroclimatic trends.

What other insight can we get from observed SSTs?

Separating Short- and Long-Term Variability

1950-1980

1980-2010



- SST decadal variability includes forced and internal parts.
- Can we estimate the long-term variability associated with global warming, S_{GW}, from obs?
- Can we use S_{GW} for attribution and near-term prediction? (Hoerling et al. 2011, Bichet et al. 2015)

• Observed SST decomposed into long term (GW) and residual:

 $S(x,t) = S_{GW} + S_{residual}$ Residual includes internal variability and short-term forcings

• S_{GW} modelled as time-independent pattern h(x) scaled by timedependent gain g(t):

$$S_{GW} \approx h(x) g(t)$$

- g(t) is low-pass filtered global mean SST from obs (Bichet et al. 2015) or from CMIP5 (Bichet et al. in prep)
 - Linear, cubic and Thompson et al. methods tested ... Cubic used.



• h(x): regression of Hurrell SST/SICE on g(t)

Testing our estimate of S_{GW} with large ensembles



- Shown is spatial correlation of h(x) of individual large- ensemble members with remaining members' ensemble mean h(x).
- Using recent improvements, our estimate now captures over 70% of spatial variance of S_{GW} .

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Global Warming Pattern of SST

AMIP SST Trends 1980-2010



Hurrell SST trends

GW SST Trends 1980-2010



The pattern of S_{GW} is also from Hurrell SST

- S_{GW} pattern is from obs (20th century Hurrell SST). S_{GW} scale is from models [CMIP5 g(t)].
- S_{GW} features broader warming, relatively warm SH, coastal hot spots, no PDO trend (reduced east Pacific cooling), relatively weak AMO trend (reduced North Atlantic warming).

S_{GW} for sea ice

a) AMIP: Hurrell SICE 1980-2010









b) GW SICE 1980-2010



Using S_{GW} in Practice: AGCM Experiments

- CAM5, 2^{0} , 1980-2010, historical forcing, N=10.
- AMIP: Observed SST and sea ice
- **GW**: Our estimate of GW SST and sea ice (S_{GW}).
- ★We now survey regions and variables where
 - 1. AMIP resembles observations and
 - Where trends are consistent across ensemble (signal-to-noise > 1).
 - Gray shading indicates signal-to-noise<1.
 - Trends aren't typically locally significant for this short period.

1980-2010 JFM Temperature

CRU

AMIP

GW







Bichet et al. in prep



- AMIP simulation captures basic obs pattern.
- GW signal shifts peak warming to central Eurasia
- Western North American cooling attributable to PDOrelated East Pacific cooling.

PDO = Pacific Decadal Oscillation

1980-2010 JFM Precipitation

- AMIP captures some of CRU.
- Internal variability, short-term forcing drive much of recent precip trend.



1980-2010 JFM Snow Cover Fraction



1980-2010 JAS African Precip

- AMIP captures observed trends.
- Increase in precip in central Africa attributable to AMV+, whether forced or internal.
- GW signal in West Africa is a drying that opposes some of the AMV effect.









Summary

- We test and extend Hoerling et al.'s method to estimate the global warming part of SST variability in observations.
- We use the resulting S_{GW} in AGCMs to attribute regional responses in various regimes (high latitude temperature, snowcover, tropical precip, etc.)
- Much of the North American winter hydroclimate signal appears to be linked to PDO - internal variability.
- Recent wetting trends in sub-Sahel Africa run counter to long-term GW signal.

Why not use coupled models to estimate S_{GW}?



- CMIP5 multimodel mean S_{GW} is large in the tropics and the North Atlantic.
- It's quite distinctive from the pattern we get from obs.

Key Points

- We can reliably estimate the observed pattern of longterm (>70 y) SST response to global warming.
- This pattern allows us to attribute GW related component of past hydroclimatic trends.
- We are also able to use the same method for regional climate projections of the forced component (Bichet, 5 p.m. Thursday)
- This pattern of observed long-term SST trends is different from those simulated in coupled ocean atmosphere models
- There is a lot of insight to be gained on forced DCV from existing SST observations!

Extra Slides

Initial Tests of the Method



• Spatial patterns obtained from different methods are similar.

• The gain factor affects the timing of the hydroclimate response to the SST forcing.

1980-2010 JFM Precipitation



 Increased precip in northern South America attributable to PDO-related variability.

Large Ensemble Evaluation of Method

h(*x*), CCSM4 LENS 1960-2005 Run X



h(*x*), CESM1 LENS 1960-2005 Run X





• Internal variability interferes with our ability to confidently estimate S_{GW} from observations.

Preliminary Results on Near Term Climate Projections

- We have extended the GW integrations to 2010-2040 and expect the forced trends to be quite similar to the past GW trends, by construction.
- The trends we obtain form an interesting point of comparison to CMIP5 trends.

ANN Precip 2010-2040





ANN Precip 2010-2040

GW v. CMIP5:

- More North American drying
- Less South American drying
- West African drying
- Indian subcontinent drying

MMM



Conclusion/Discussion

- The framework could help quantify how internal variability of SSTs in PDO and AMO interferes with the hydroclimate response to global warming.
- We can also tweak the *timing* of regional responses based on different g(t).
- We are exploring this method for purposes of decadal prediction.
- ★ Extensions of framework: moving beyond prescribed SSTs, distinguishing different radiative forcings (ANT vs. historical), applying to other models (CanESM, etc.).