Understanding Spread in CMIP5: Sensitivity of North Atlantic Storm Tracks to Projected Surface Temperature (T_S) Changes

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EarthClim

Outline

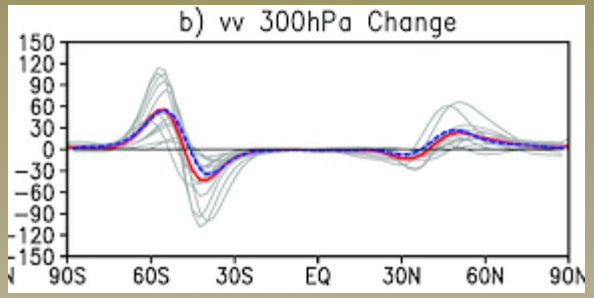
- Identify spread in projected CMIP5 storm track changes
- Diagnose role of T_s projections using AGCM experiments
- Examine which aspects (if any) of T_s projections matter (local vs remote)?

Future Projections of CMIP5 Storm Tracks

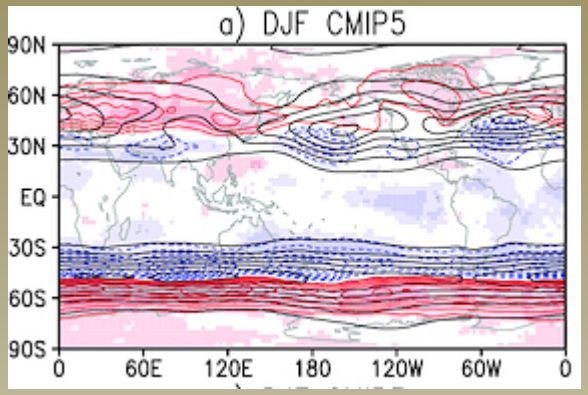
21st Century Projections in High Frequency Storm Track Metrics

- Upper levels: slight poleward intensification; some spread but also some consistency
- Lower levels: ensemble mean shows eastward extension but considerable spread

Zonal Mean



Ensemble Mean

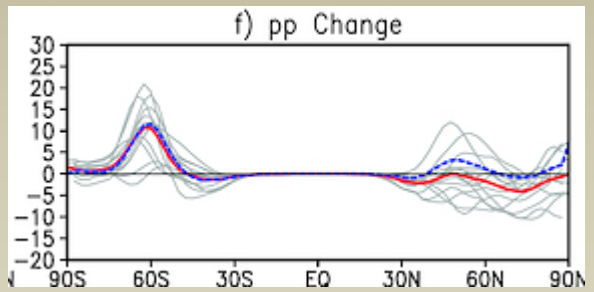


Blue Line: CMIP3 Ensemble Mean

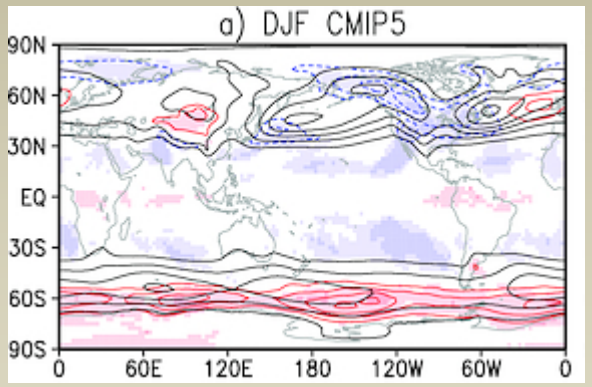
Red Line: CMIP5 Ensemble Mean

Red/blue: projection

Black: Historical



Chang et al 2012



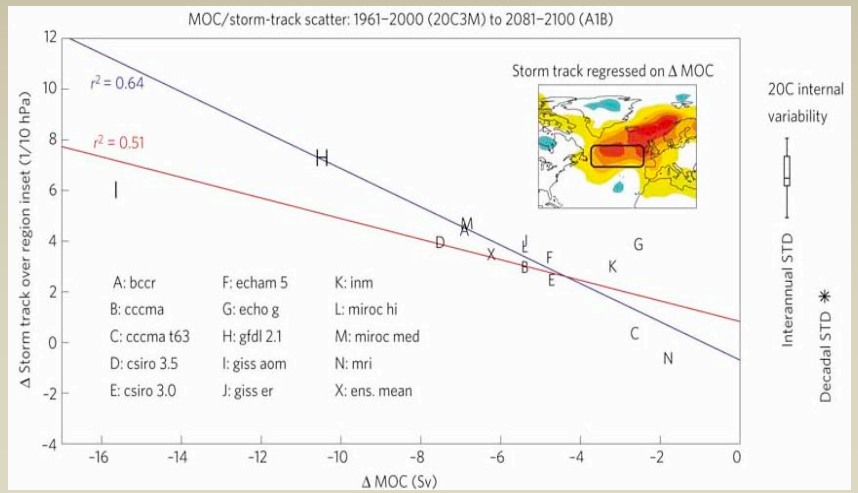
Sources of spread?

Storm track spread-AMOC/T_s connection?

- uncertainties in North Atlantic storm track response would be reduced through tighter constraints on MOC behaviour (Woollings et al 2012)

- Evidence for AMOC→ atmos (via T_s)

- How much of relationship is determined by AMOC/T_s→ atmos (or vice versa)?



CMIP3

Woollings et al (2012)

Key Questions and Methods

Main Question: To what extent is the spread in the projected North Atlantic storm track changes driven by spread in the projected Ts changes?

- Do the storm tracks care about T_s changes?
- Do the storm tracks care about the intermodel differences in T_s changes?

Main Approach: Use CMIP5 and AGCM

- Use a subset of models to focus on sources of spread

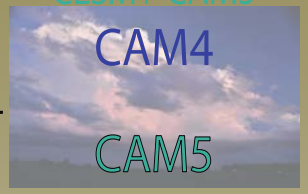
Subset of CMIP5: CESM Family

NCAR Community Earth System Model (CESM)

CCSM4 (or CESM1-CAM4)

CESM1-CAM5

Atmospheric Component



Ocean Component

Norwegian Earth System Model (NorESM)

NorESM1-M

and sea ice components are the same between the two model systems.

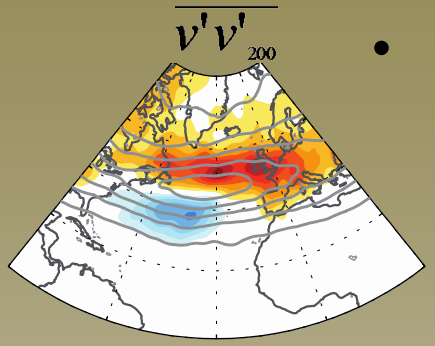
1. Comparison of CMIP5 storm track projected changes
2. AGCM forced with North Atlantic T_s projected changes (TsNATL)
3. AGCM forced with global T_s/SIC projections (TsGLOB)

Storm track metrics (Dec-Feb): $\overline{PSL'^2}$, $\overline{Z'^2}_{500}$, $\overline{v'T'}_{750}$, $\overline{v'v'}_{200}$, (all 2-6 day bandpass-filtered) and u_{200}

1. CMIP5 Comparison

CCSM4

NorESM1-M CESM1-CAM5



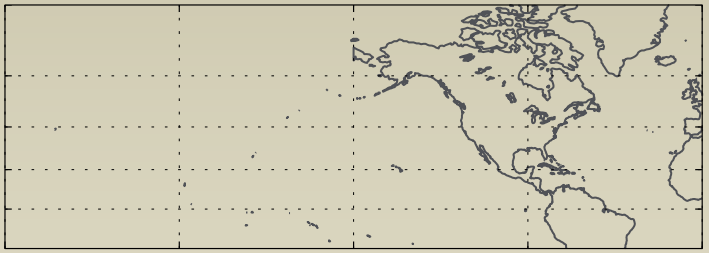
- *21st century projected change definition:* Difference in climatologies between 1980-1999 (Hist) and 2080-2099 (RCP8.5)

u_{200}

CESM1-CAM5 still to be updated

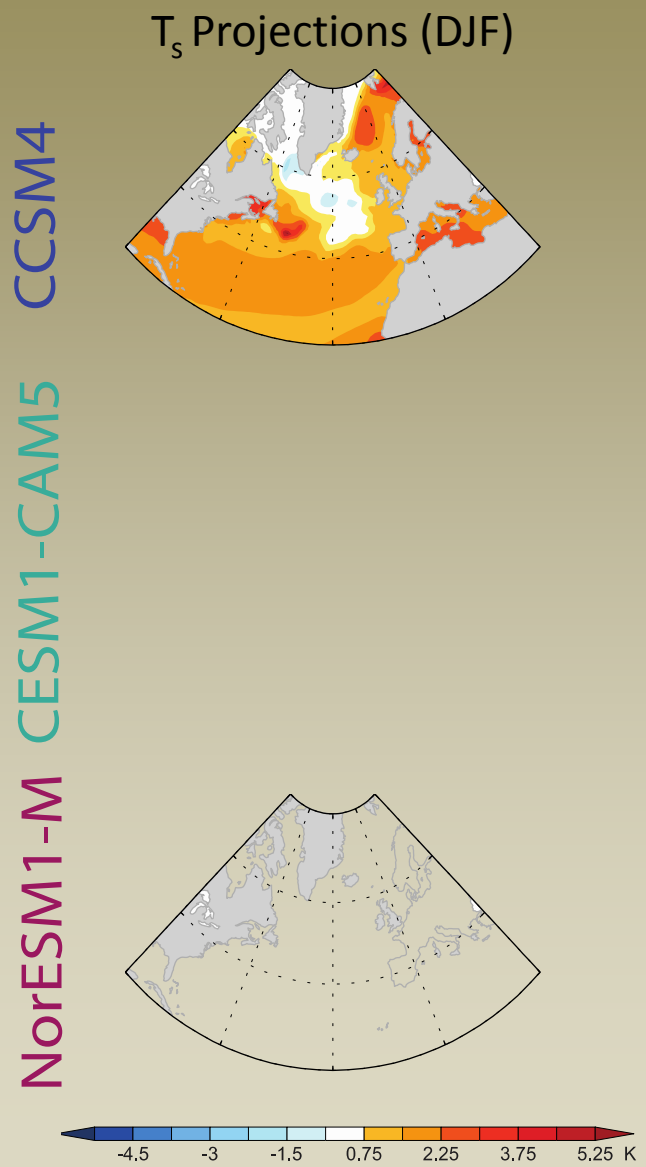
- Spread not enormous but large enough

- How sensitive are these projected changes to Ts and their intermodel differences?



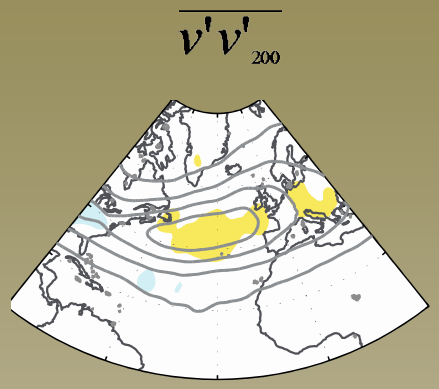
Contours: historical climatology
Shading:21st century projected change

2. AGCM forced with North Atlantic Ts Projections (TsNATL)



- AGCM: CAM4 and <u>CAM5</u>
- 30 member ensemble
- Forcing: seasonal cycle of global T_s/SIC
  1. <u>Control</u>: entirely from HadISST
  2. <u>Perturbation</u>: Control + North Atlantic T_s projected changes from CCSM4, CESM1-CAM5 and NorESM1-M
- GHG are kept at 1990 values

2. TsNATL Response (vv_{200})



- Response: Perturbation-Control
- Much weaker response than CMIP5 projections
- Little evidence of eastward extension

NorESM1-M CESM1-CAM5 CCSM4

Contours: Control
Shading: Response

2. TsNATL Response (U_{200})

NorESM1-M CESM1-CAM5 CCSM4

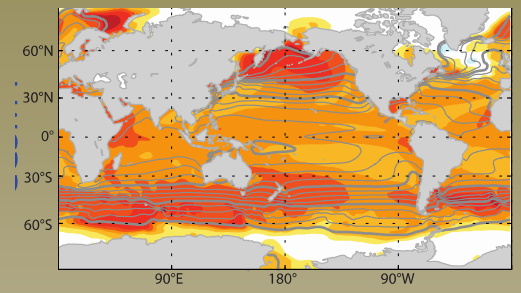
u_{200}

- Weaker but broader jet-related to NA SST gradient changes?
- Not similar to CMIP5 projections
- Why don't AGCM experiments capture projected changes in CMIP5
  - lack of coupling
  - other boundary features

3. AGCM forced with Global Ts/SIC Projections (TsGLOB)

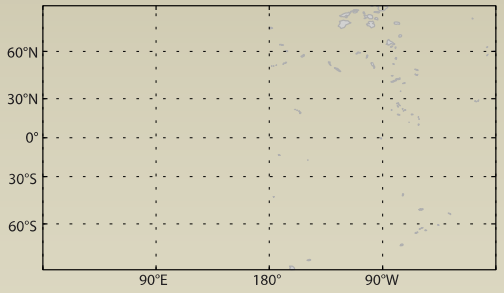
Difference in T_s (RCP8.5-Hist)

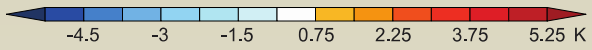
CCSM4



CESM1-CAM5

NorESM1-M





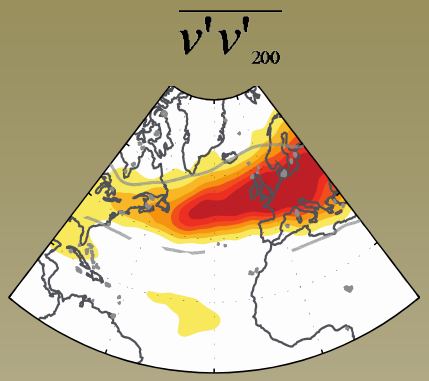
Contours: Historical-T_s forcing

- AGCM: CAM4 and <u>CAM5</u>
- 30 member ensemble
- Forcing: seasonal cycle of global T_s/SIC from CMIP climatologies:
  1. Historical (1980-1999)
  2. RCP8.5 (2080-2099)

Forcings created based on output each of the 3 CMIP models

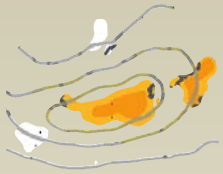
- GHGs averaged over Historical and RCP8.5 periods

3. TsGLOB Response (vv200)



CCSM4

CESM1-CAM5



NorESM1-M

- Response: RCP8.5-Historical
- ALL: general northward/eastward projection
  - Similar to CMIP5 projections
- Similar degree of spread: Storm track response generally weaker when forced by NorESM1-M conditions

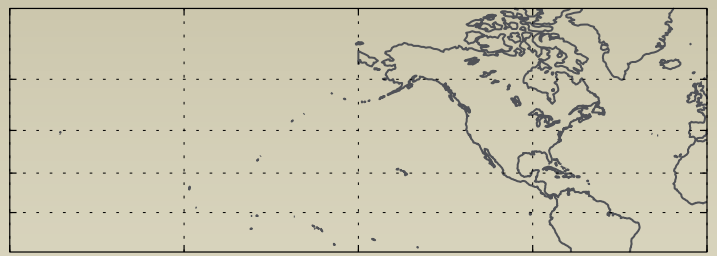
Contours: Historical
Shading: Historical – RCP8.5

3. TsGLOB Response (U_{200})

TsGLOB

CMIP5

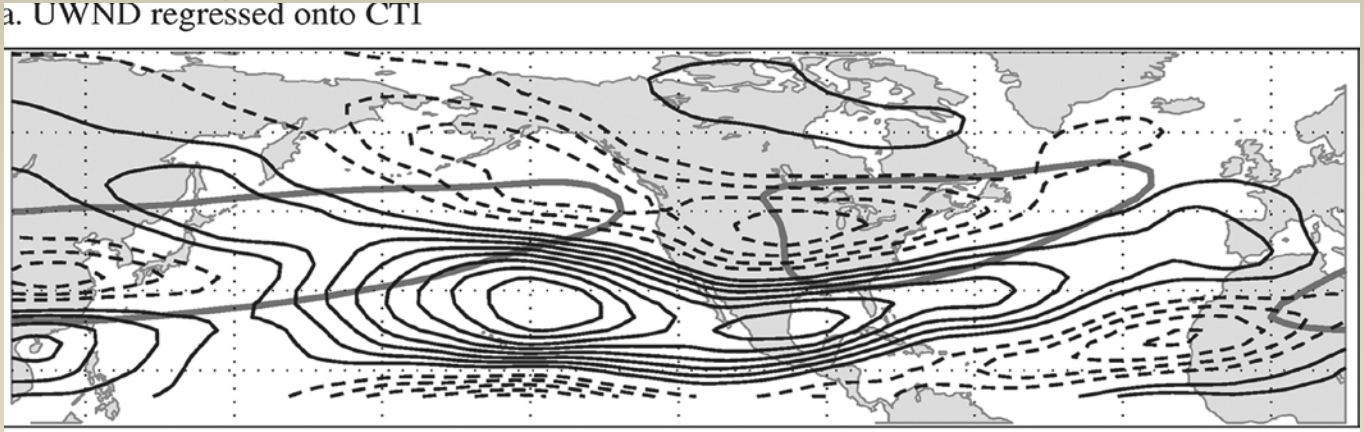
NorESM1-M CESM1-CAM5 CCSM4



Response to global Ts/SIC captures much of the CMIP5 projected changes? Why?

What about TsGLOB influences changes in upper level N. Atlantic storm tracks?

- ~~North Atlantic Ts~~
- Arctic Sea Ice Concentrations
- GHG concentrations
- **Remote T_s(i.e., tropical Pacific)**
  - Increasing evidence of role of tropical Pacific on Arctic climate (Ding et al 2014)
  - uncertainty in Tropical Pacific SST projections influence uncertainty in upper level wind projections (Delcambre et al 2013)



EQ

Role of Cold Tongue Ts?

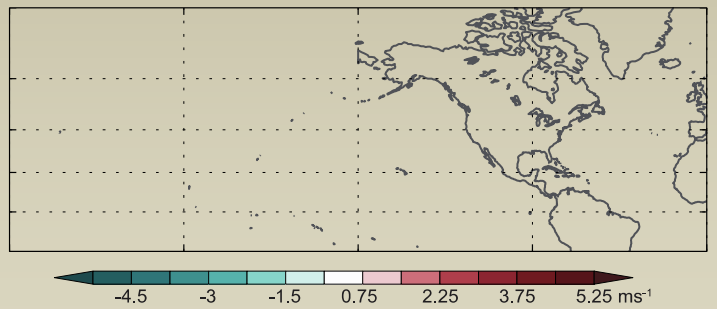
RCP8.5 Regression

TsGLOB

CCSM4

CESM1-CAM5

NorESM1-M



N. Atlantic TsGLOB upper level circulation not strongly related to Ts variability in eastern tropical Pacific.

Role of Warm Pool Ts

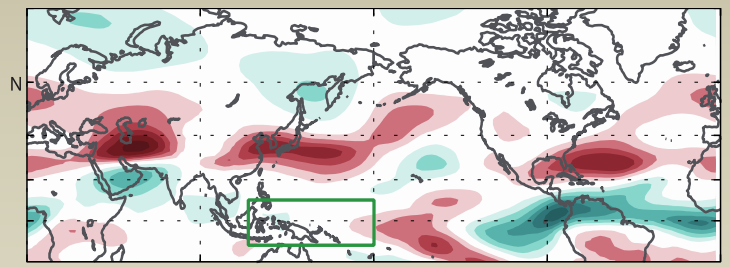
RCP8.5 Regression

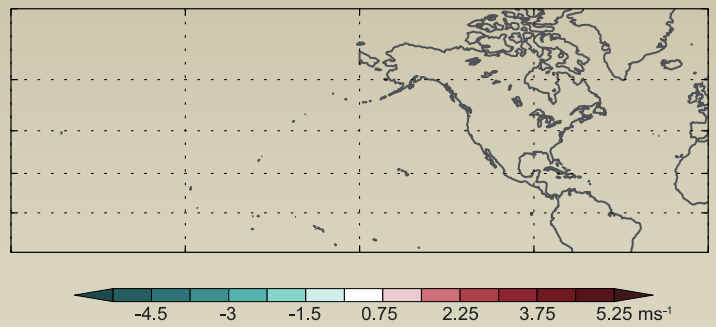
TsGLOB

CCSM4

CESM1-CAM5

NorESM1-M





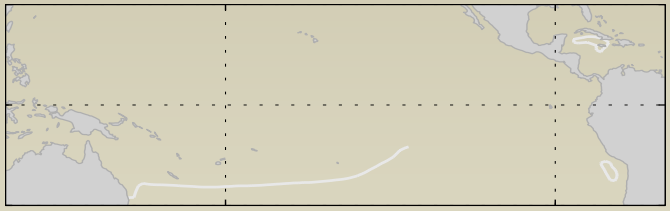
North Atlantic upper level circulation linked to Ts variability in tropical Pacific but….

Does intermodal spread in tropical Pacific Ts drive intermodel spread in N Atlantic?

NorESM1-M CESM1-CAM5 CCSM4

21st century Ts change (DJF)

Grey contour: 27.5C Ts (Historical climatology)
White contour: 27.5C Ts (RCP8.5 climatology)



- Strength of projected changes in tropical Pacific Ts linearly related to strength of changes in North Atlantic storm tracks
  - Strongest changes in CCSM4/CESM1-CAM5 Ts→strongest storm track changes
  - Weakest changes in NorESM1-M Ts→ weakest storm track changes
- Rather handwavy: Need to understand how changing Ts influences North Atlantic

1st Attempt: Changes in Ts→ Changes in OLR

CCSM4

CESM1-CAM5

NorESM1-M

21st century Ts change (DJF)

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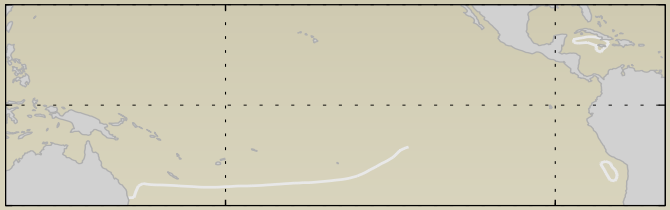
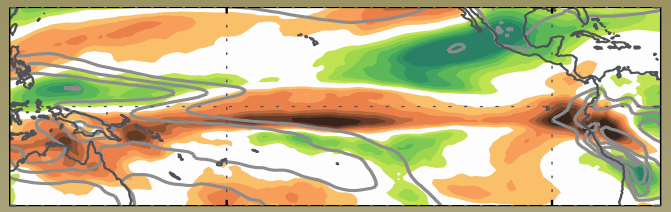
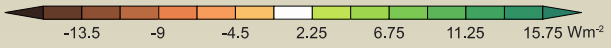
White contour: 27.5C Ts (RCP8.5 climatology)



21st century OLR change (DJF) TsGLOB



Grey contour: OLR climatology (Historical)



Projected changes in OLR are consistent with Ts→ change source region of Rossby waves?

Conclusions

- Do the upper level storm tracks care about T_s changes?
  - Yes… but not necessarily to NA T_s
  - upper storm track activity dominated some aspect of the global Ts/SIC forcing (Warm Pool T_s?);

- Do the upper level storm track changes care about intermodel differences T_s changes? I think so…
  - CESM1-CAM5: strongest warm pool T_S →strongest responses
  - NorESM-1M: weak warm pool → weaker responses
  - Still requires physical link

- Caveats: Is it really all about Ts?→ NO
  - Differences in model design (TsGLOB and TsNATL) allow for other factors (GHG concentrations, Artic Sea Ice)
  - Other sources of uncertainty in CMIP5 (mode variability, natural variability

Take Home Message

- Despite all the potential sources, Ts changes do have some impact on the North Atlantic storm tracks
- Do these conclusions also apply to the relationships between spread in low-level storm tracks and Ts projections? No
- How storm tracks are defined influences the sources of projected model spread