Agroclimatic Extremes Weather and Climate: Heat Overtakes Frost as Growing Season Constraint

Kaela Lucke[1] and Dr. Alex Ruane[2]

[1]Dept. of Atmospheric Sciences, University of North Dakota

NASA Intern, Research Fellowship and Travel Grant Recipient

[2]NASA Goddard Institute for Space Studies, New York City

ND Space Grant Student Symposium and Affiliates Meeting

April 17, 2021

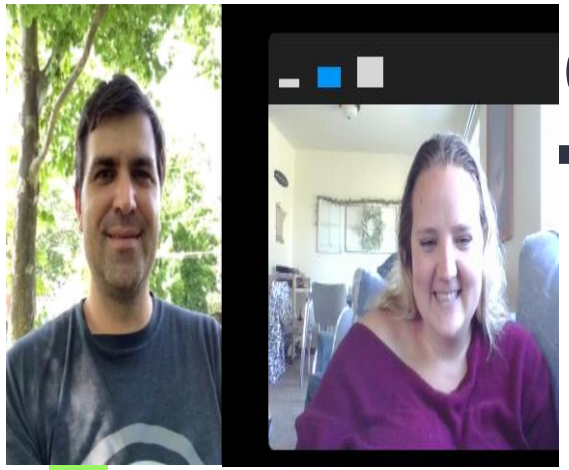
NORTH DAKOTA SPACE GRANT CONSORTIUM

UND UNIVERSITY OF NORTH DAKOTA

AgMIP

NASA

COLLABORATIONS AND OUTREACH



Climate Impacts, AgMIP and Model E Groups:

NASA GISS Calendar

Art and Science COVID Project:

Movie and live exhibit at NASA museum opening fall

NASA Outreach: NASA Astrocamp, ND/MN High School's

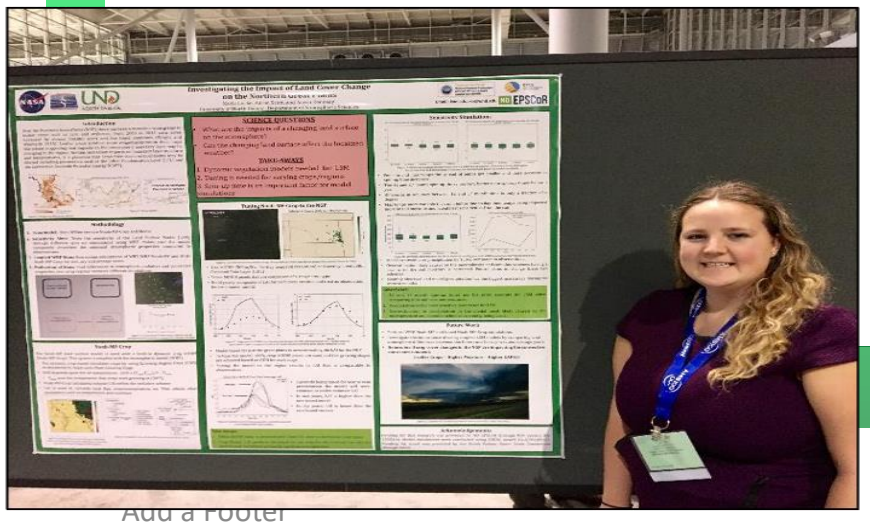
NASA Astrocamp 2020 – (FREE)

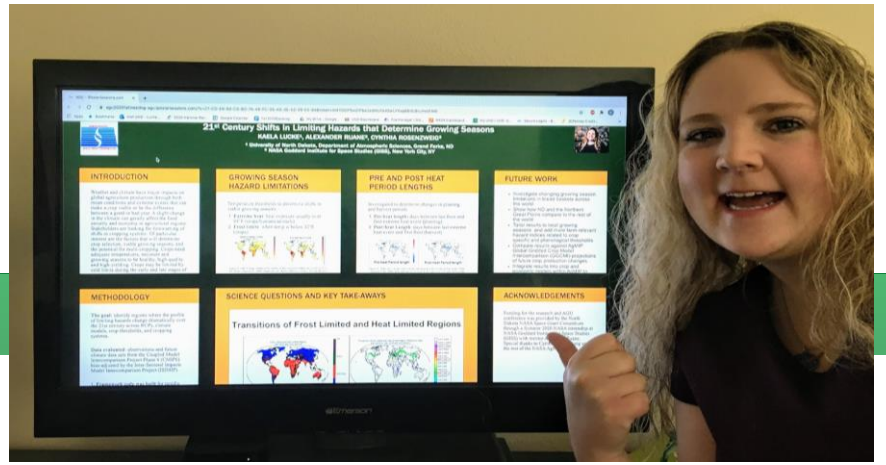
On July 15th GISS NASA Intern and UND Atmospheric Sciences master student Kaela Lucke will be educating kids on the atmosphere, climate, the 5 major gases on earth and on ways to help live an environmentally friendly lifestyle. This talk will be geared towards kids in grade 3-6 and a fun activity will follow the presentation. This whole event will last **1 hr on July 15th from 1-2pm via zoom**. Please sign up for this event at https://gflibrary.beanstack.com.

Movie link: https://blogs.ei.columbia.edu/2021/02/26/video-merges-art-climate-science/?fbclid=IwAR2xwA0YvqVpEnasHD7vZ1boO7pA-NaosuG0yS2hNTOcMbiuR8S2rY8kyTg

BROADER EXPERIENCE

- Workshops and Retreats
- Earth to Sky National/State Parks
- Women in Space and Science group
- **NASA Interns and fellows and Events**
- Workshops and Retreats
- **Presented:**
  - AGU, AMS, Goddard and GISS Seminars





MOTIVATION

- **The world is changing! How will it impact your future?**

- Identify climate change risks for Agriculture regions

- Analyze climate model projections indicate to see how hazards are changing for farmers.
  - Hazards reflect biophysical limits

- Advanced notice of these challenges will aid in future adaption, mitigation and risk management

Kaela.lucke@und.edu

PROJECT GOALS


Courtesy: Ron Stenz

- Evaluate the way climate indices that are important to agriculture and food systems are changing

- Investigate different hazard characteristics by:
  - Examining key thresholds for heat and frost
  - Examining different datasets, different emission pathways and time horizons
  - **Identify regions where deterministic hazards change** (frost limited regions now heat limited)

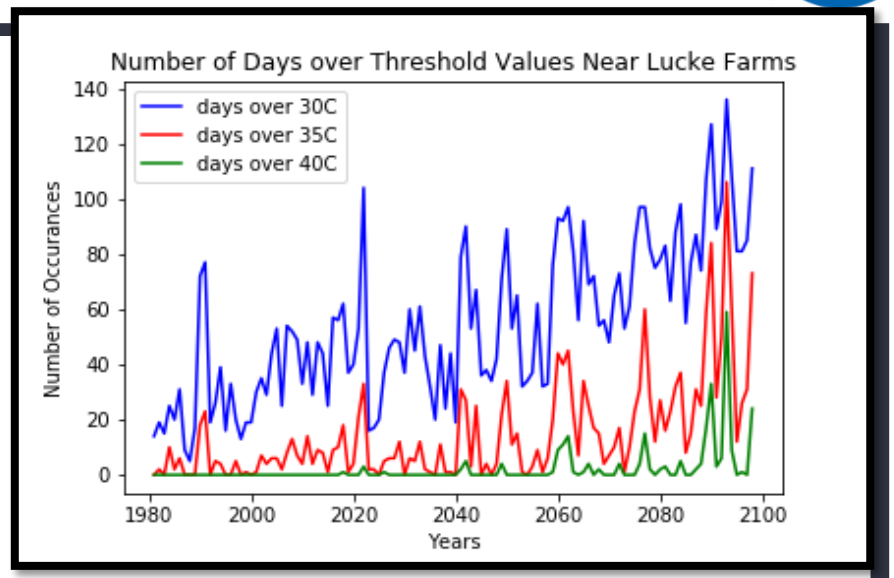
Scientific Questions:

1. How are shifts in season hazards from a changing climate affecting agricultural systems/regions?
2. How will we adapt to these changes in the future?
3. How do changes projected for ND compare to the rest of the world?

Kaela.lucke@und.edu

METHOD:

UNDERSTANDING AG-CLIMATE IMPACTS



- **Different Thresholds:** ex. Above 30°C, 35°C, 40°C
- **Different Hazard Characteristics:**
  - Seasonal timing, duration, frequency, spatial extent, intensity
- **Different Time Slices:** beginning, middle, end of century
- **Different Scenarios:** RCP 2.6, 4.5, 8.5
- **Different Models/Datasets:** NASA GISS Model E, GFDL, AGMIP, GGCMI, IPSL, MPI, MRI…
- **Other Metrics:** Intense rainfall, low humidity, Tmax, Tmin, frost, wet bulb temp
- **Different Regions:** North America, Northern Great Plains, ND, Field

Built a framework code for rapidly evaluating all variations

Extreme Heat: maximum temp usually over 35 °C (crops/humans/animals)

Frost Limits: when minimum temp is below 0°C (crops)

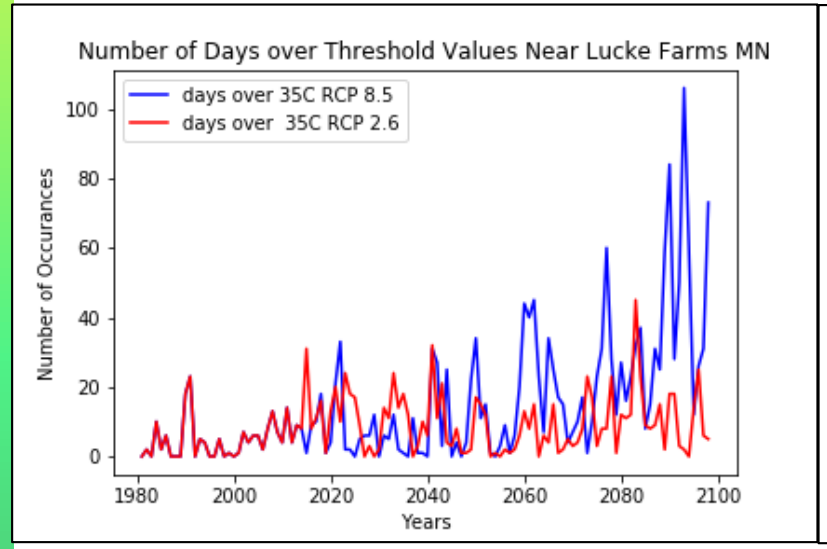
Kaela.lucke@und.edu

RESULTS:

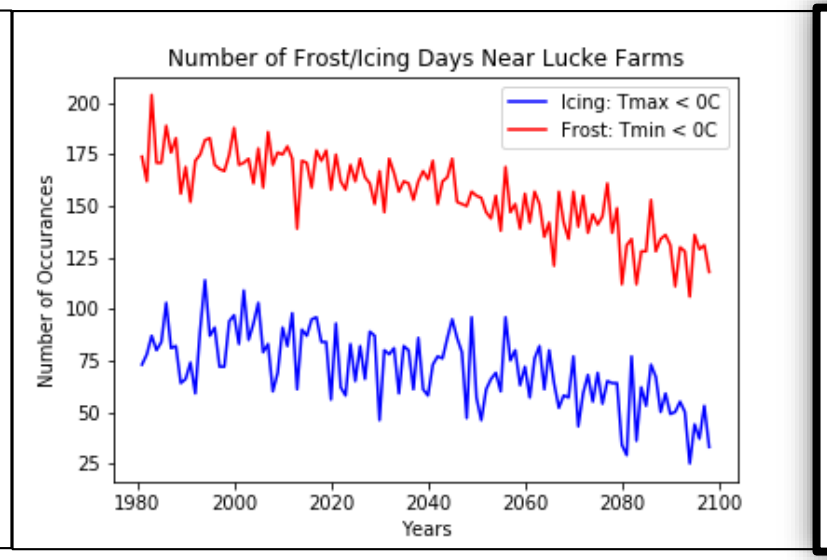
CLIMATE CHANGES ON LUCKE FARMS IN MN

Climate change is happening everywhere and affecting everyone

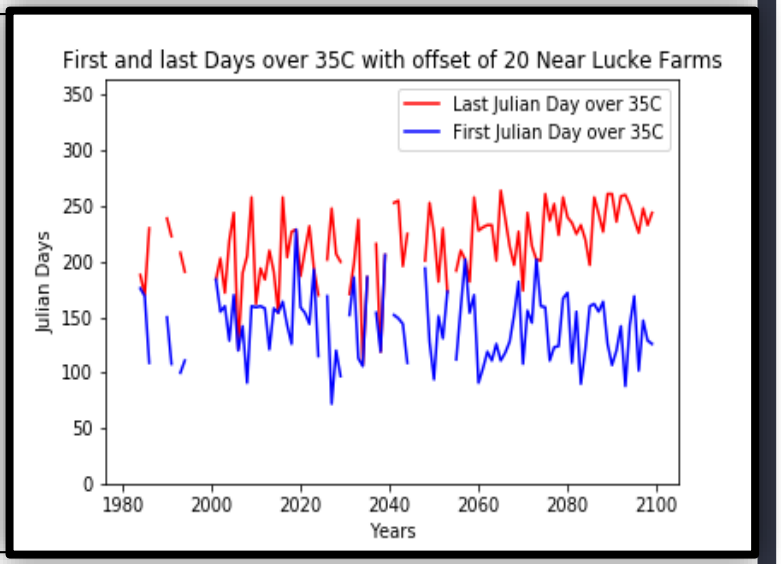
Days Tmax > 35°C



Days Tmax/Tmin < 0°C



First and Last Day Tmax > 35°C



- First day of heat each year is occurring earlier, last day is happening later

Length of extreme heat season and growing season are increasing

Kaela.lucke@und.edu

RESULTS:

CHANGES IN GROWING SEASON LIMITATIONS

Model: GFDL esm4 r1i1p1f1 w5e5 ISIMIP bias adjusted

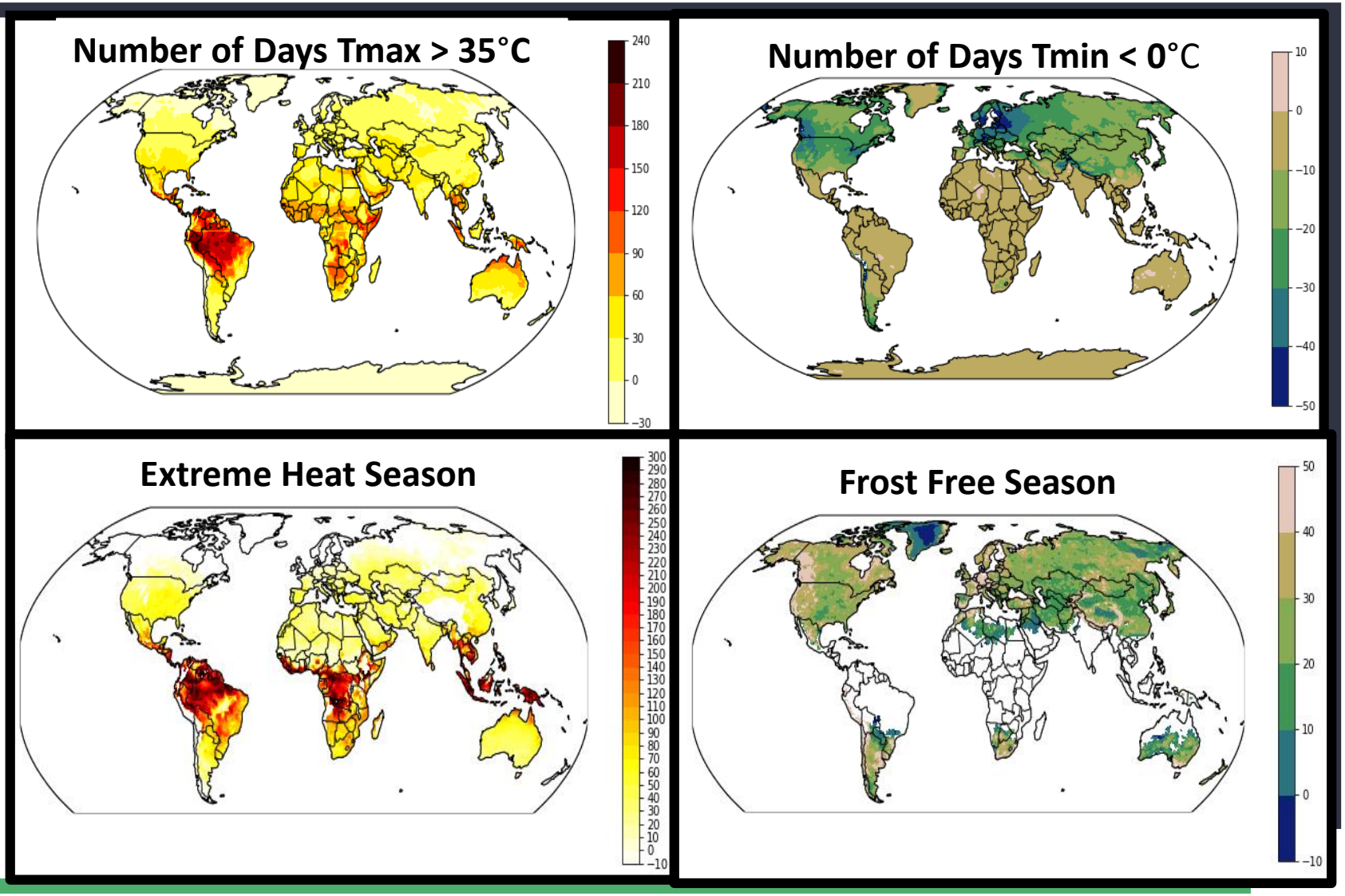
RCP: 8.5 (ssp585)

Time Period: 2050s-2000s

Over-time:

Exposure to extreme heat is dramatically increasing, frost exposure is decreasing

The frost free season and the heat season is increasing

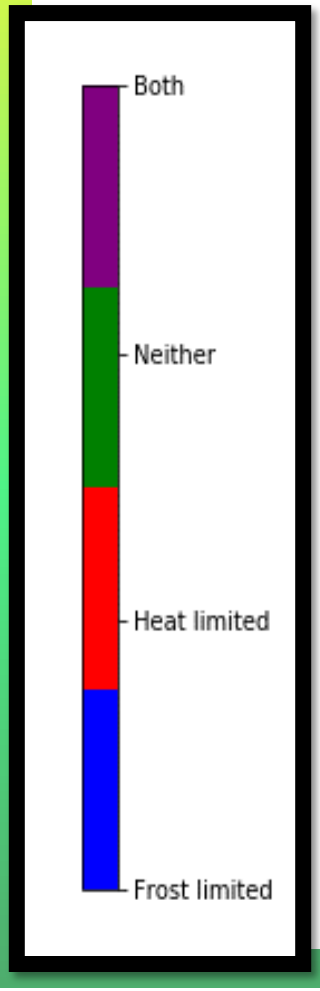


Kaela.lucke@und.edu

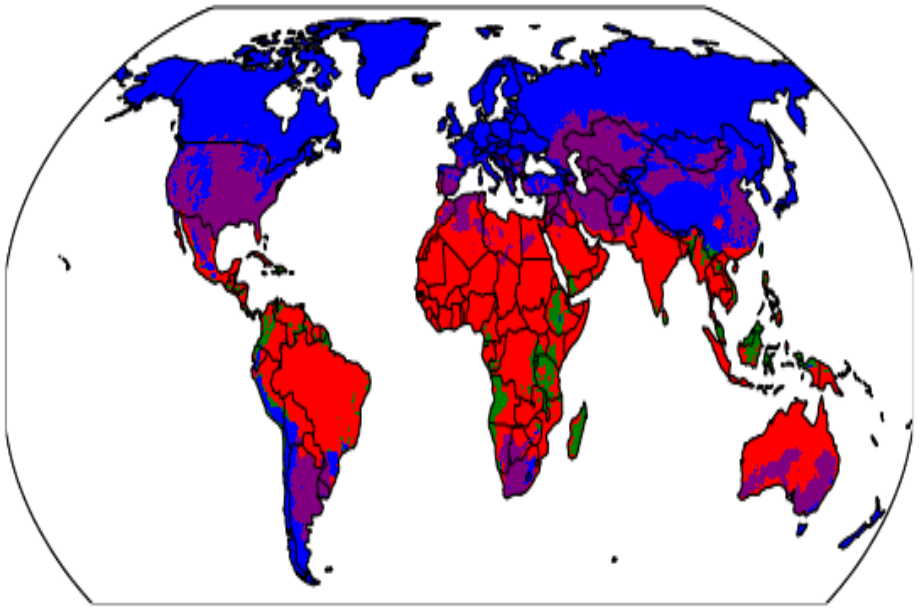
RESULTS:

REGIONAL HAZARD EXPOSURE LIMITATIONS

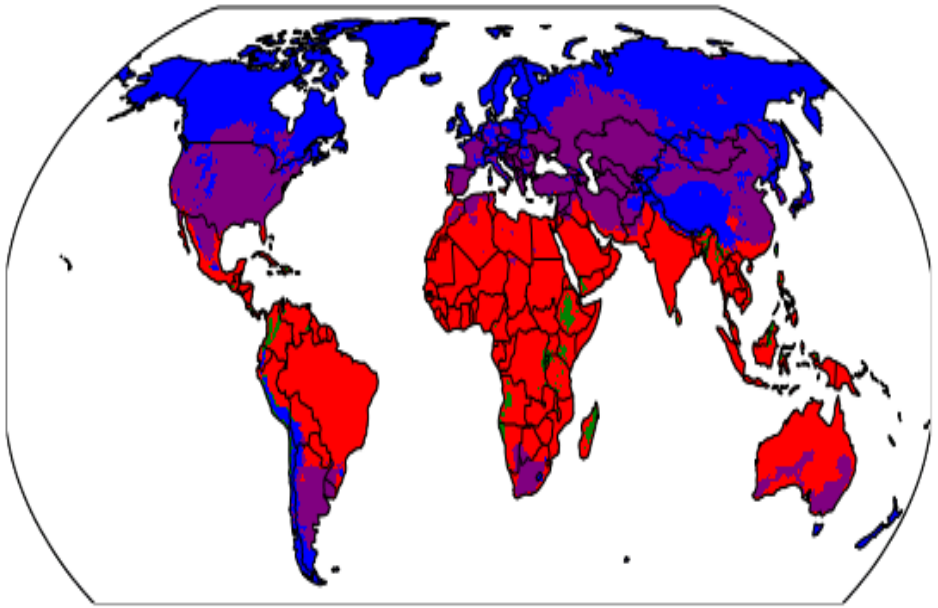
- **Frost only and both heat and frost limited regions of most interest for future**



Frost Limited and Heat Limited
Historical 2000s



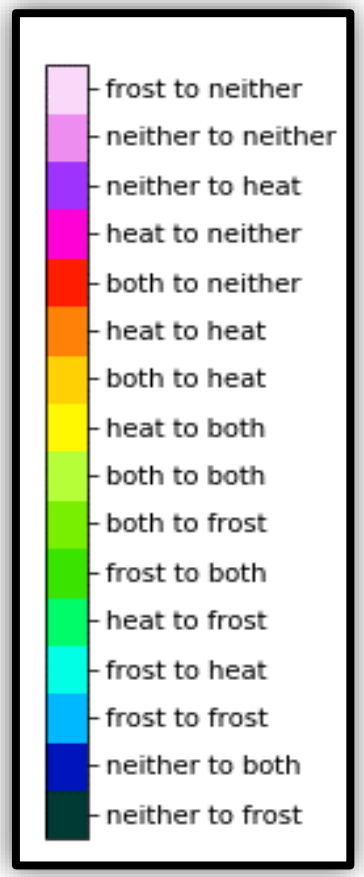
Frost Limited and Heat Limited
Projected 2050s

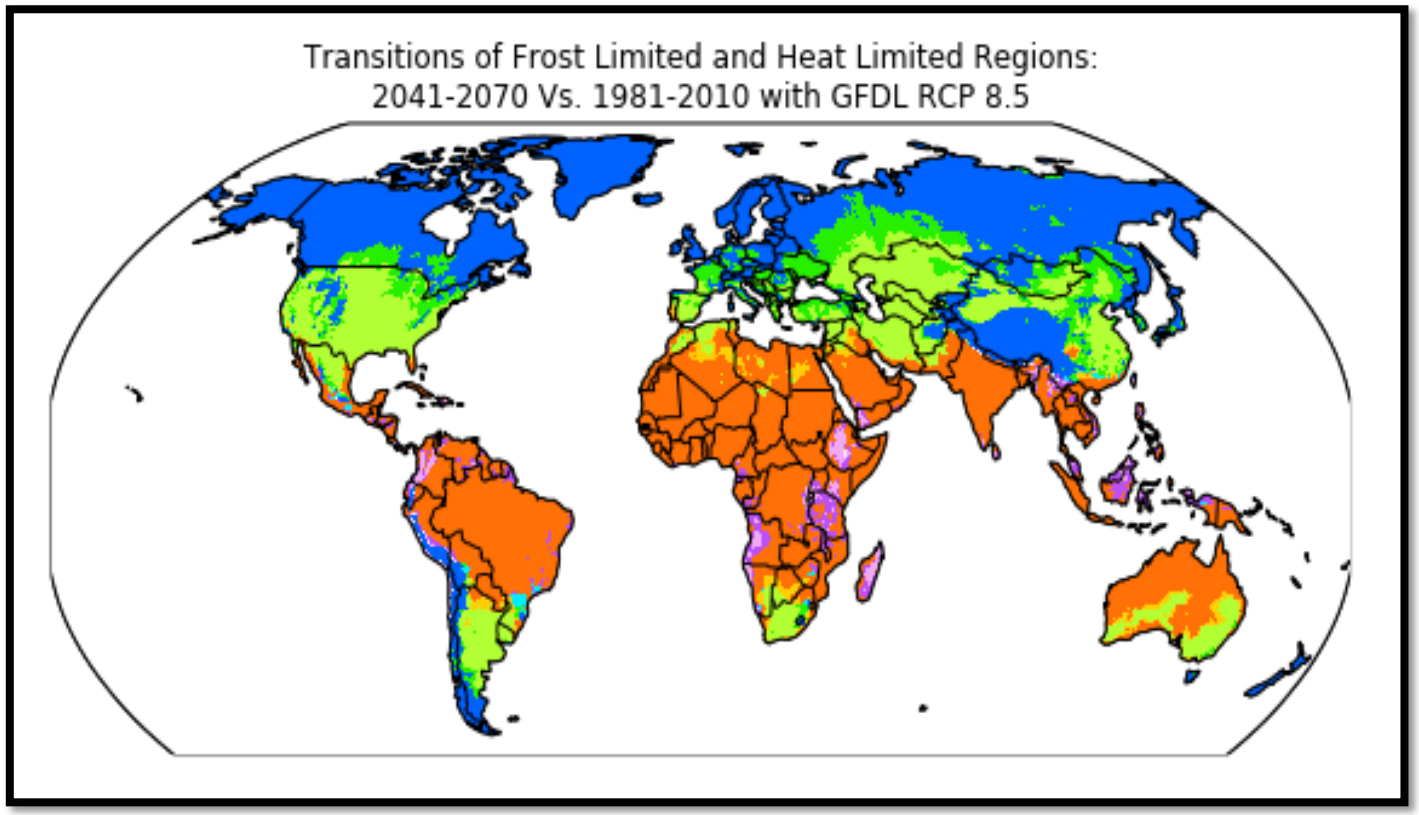


Kaela.lucke@und.edu

RESULTS:

TRANSITIONS IN GROWING SEASON LIMITATIONS

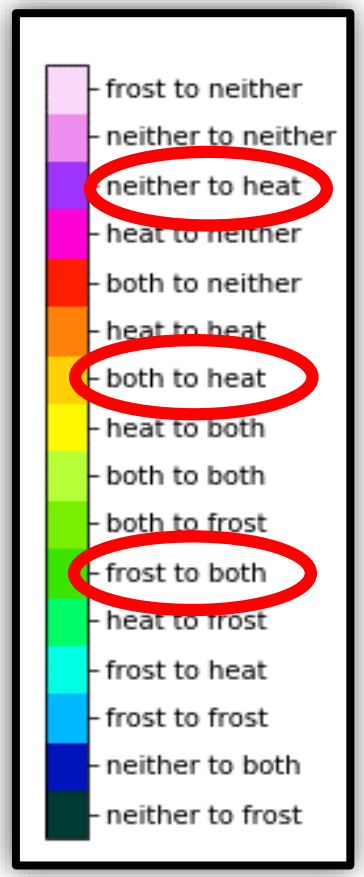


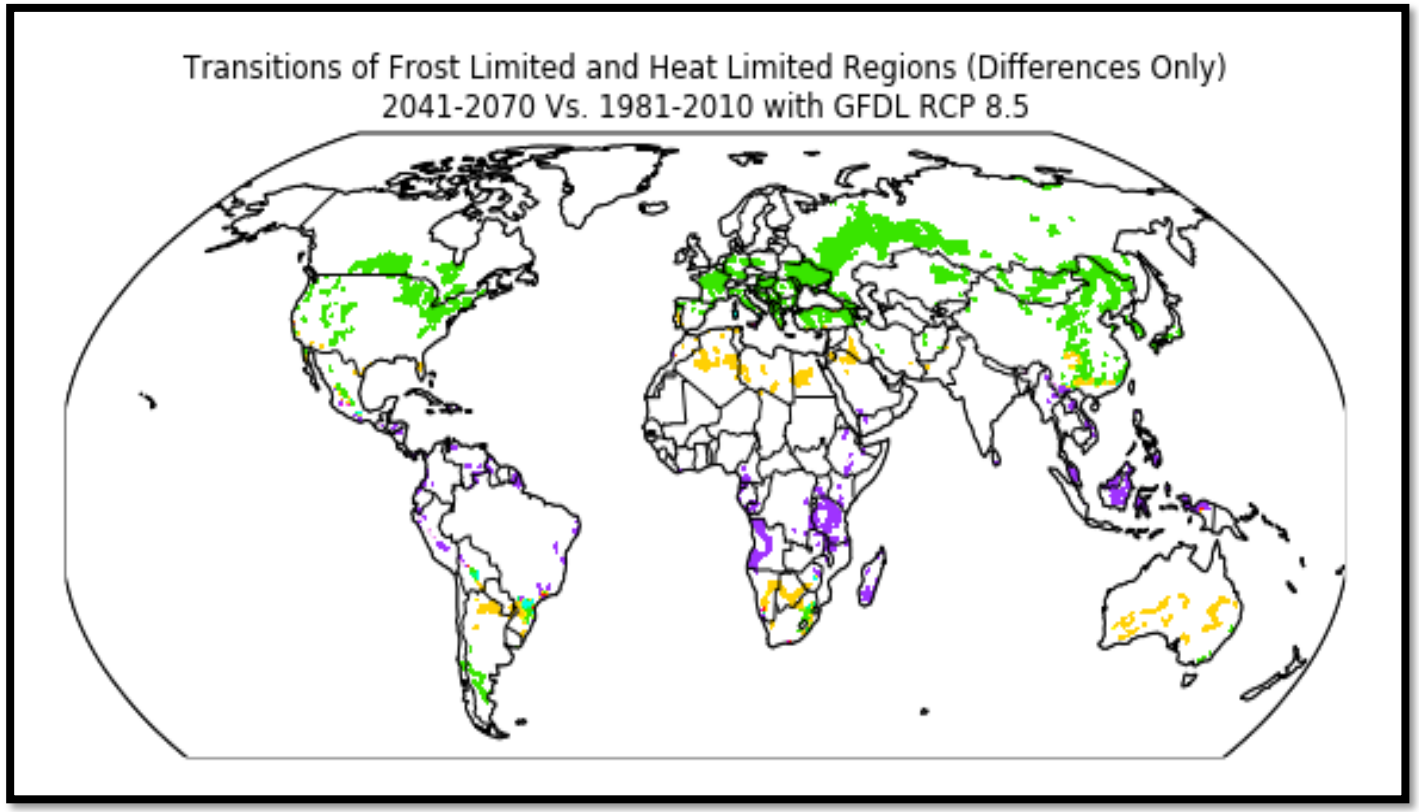


Kaela.lucke@und.edu

RESULTS:

TRANSITIONS IN GROWING SEASON LIMITATIONS





- **Frost limited areas are decreasing and heat limited areas are increasing**
  - Agricultural regions that are not accustomed to heat will have to adapt to extreme heat days in the future.
  - Fewer lower latitude areas are eliminating frost threats as these are changing less rapidly

Kaela.lucke@und.edu

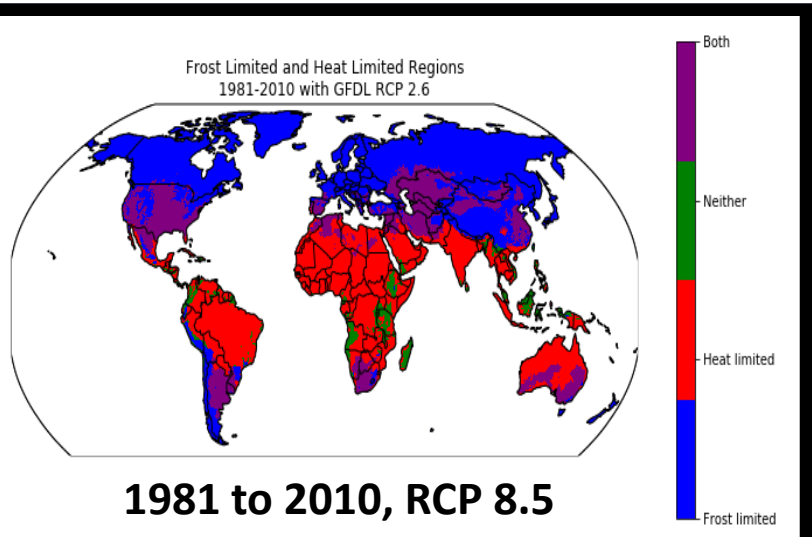
RESULTS:

CHANGES IN GROWING SEASON LIMITATIONS

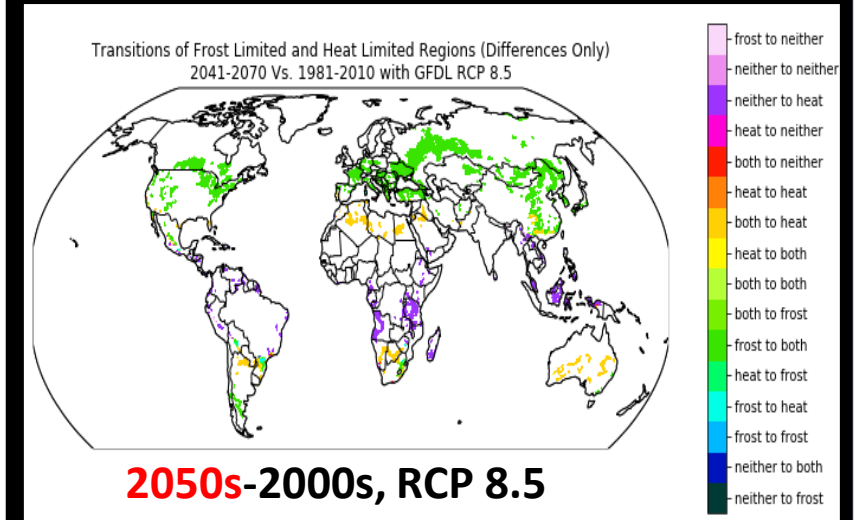
RCP: 8.5 (ssp585)
2.6 (ssp126)

Time Slices:
1981-2010
2041-2070
2071-2100

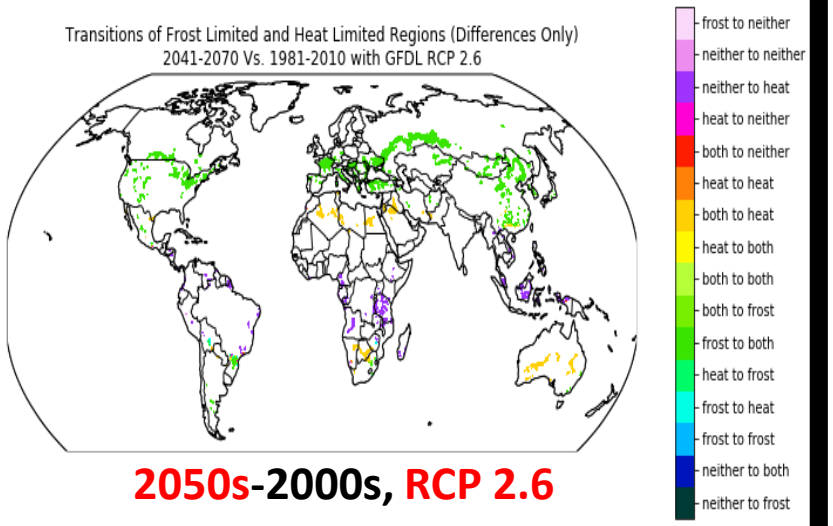
1. Frost limited regions are transitioning to heat limited
2. Higher latitude areas are changing more rapidly
3. As expected, RCP 2.6 has less extreme heat shifts
4. Demonstration of why its beneficial to look at different RCPs, models, time periods.



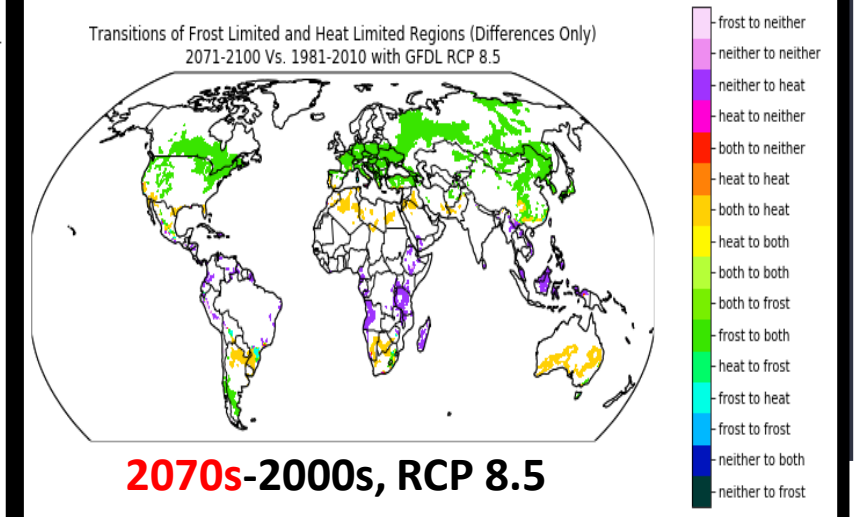
1981 to 2010, RCP 8.5



2050s-2000s, RCP 8.5



2050s-2000s, RCP 2.6



2070s-2000s, RCP 8.5

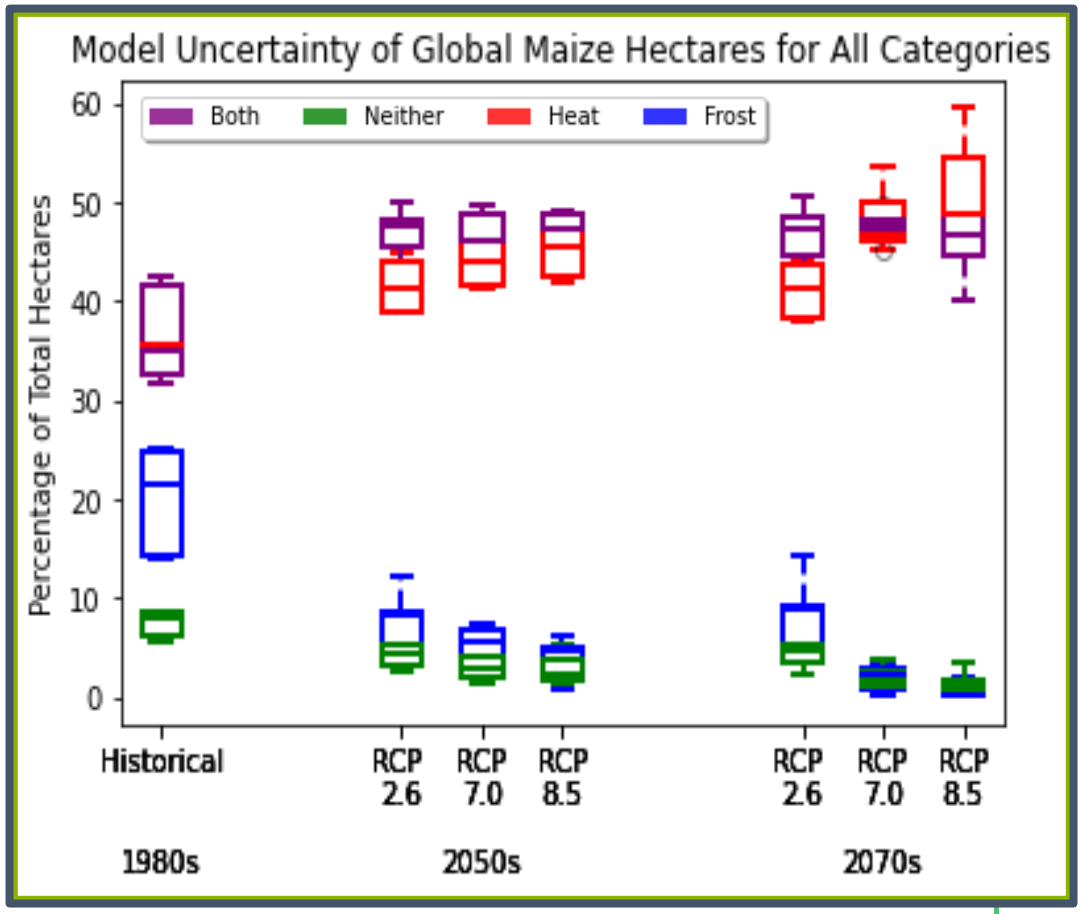
Kaela.lucke@und.edu

RESULTS:

CHANGES IN GROWING SEASON LIMITATIONS

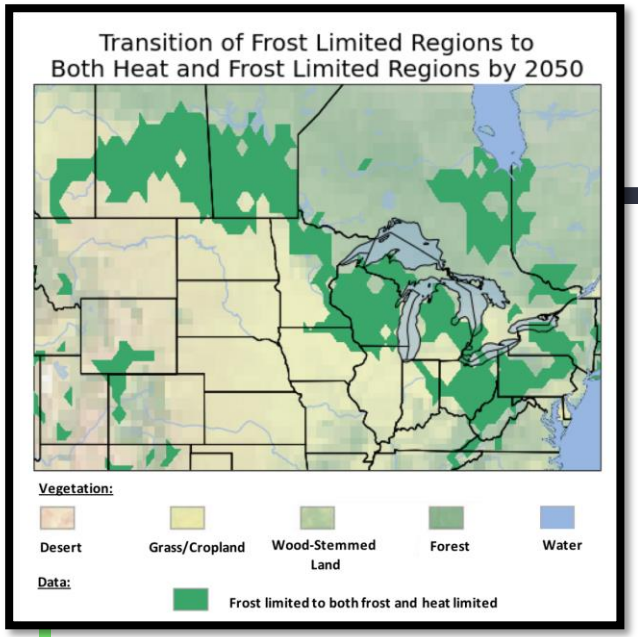
RCP:	8.5 (ssp585)	Models:	Crops:
	7.0 (ssp370)	GFDL	Maize
	2.6 (ssp126)	MRI	Wheat
Time Slices:		IPSL	Soybeans
	1981-2010	MPI	Rice
	2041-2070	UKESM1	
	2071-2100		

1. Frost limited regions are transitioning to heat limited
2. Farmers that are not accustomed to heat will have to adapt to extreme heat in the future
3. The growing season is increasing over time
4. Advanced notice of challenges will aid in future adaption, mitigation and risk management



Blue turns purple, purple turns red

Kaela.lucke@und.edu



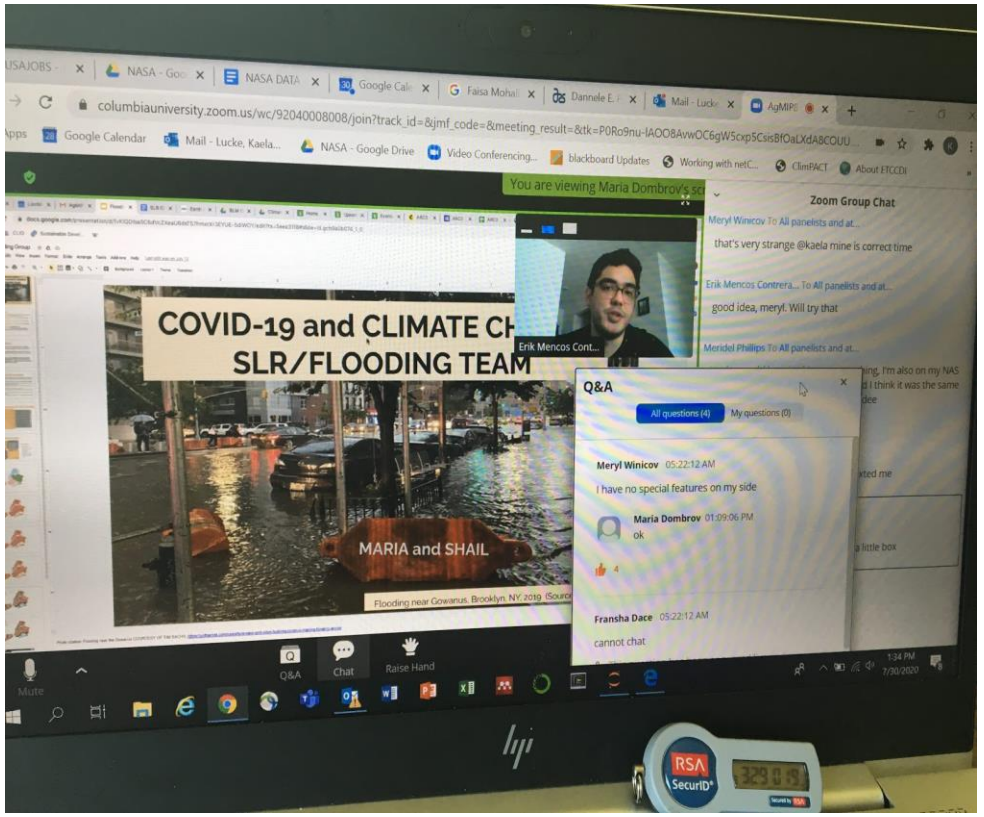
CONCLUSIONS

1. Climate projections indicate increasing hazards in the future for farmers
2. Frost limited regions are transitioning to heat limited
3. Agricultural regions that are not accustomed to heat will have to adapt to extreme heat days in the future.
4. More rapid transitions between winter/summer will occur
5. Higher latitude areas are changing more rapidly, and the growing season is increasing over time
6. Advanced notice of challenges will aid in future adaption, mitigation and risk management

Kaela.lucke@und.edu

CHALLENGES AND LESSONS LEARNED

- **Virtual Challenges:**
  - IT, zoom, NASA security Issues
- **Storage Challenges:**
  - Climate models/ outputs = TBs of Data
- **Research Challenge:**
  - Don’t know about thresholds and the plant responses when crop thresholds are crossed



FUTURE WORK AND CAREER GOALS

- **Different for thresholds pre and post season trends**
- **Split into per decade time periods to find exact time transitions occur**
- Add farm-relevant hazard indices like precip and wet bulb globe temp
- **This projects results:** will be integrated into crop and economic models within AgMIP to identify key vulnerabilities in food systems for the future
- **Peer Reviewed Journal to be published this fall**
- **Live Exhibit:** To open this fall at NASA museum w/ my own little section
- **May Seminar Series Speaker** for Goddard and GISS
- **Future Career:** NASA Extension Position or PhD w/ NASA @ Columbia

Kaela.lucke@und.edu

ACKNOWLEDGEMENTS

- NASA internship, fellowship and travel grants were funded by the ND Space Grant Consortium

- Research was conducted with NASA Climate Impacts, AgMIP, and model e groups at (virtually) NASA Goddard Institute of Space Studies (NASA GISS).

- Special thanks to my mentor and advisors:
  - Alex Ruane, Cynthia Rosenzweig, Carolyn Mutter and Matthew Pearce

Questions?

- Growing season is increasing
- Rapid season changes (winter/summer) in future
- Extreme heat season is increasing
- Frost free season is increasing
- Higher latitudes changing faster than lower latitudes
- Climate change will shift the profile of hazards for ag

Kaela.lucke@und.edu Twitter: @kaelalucke