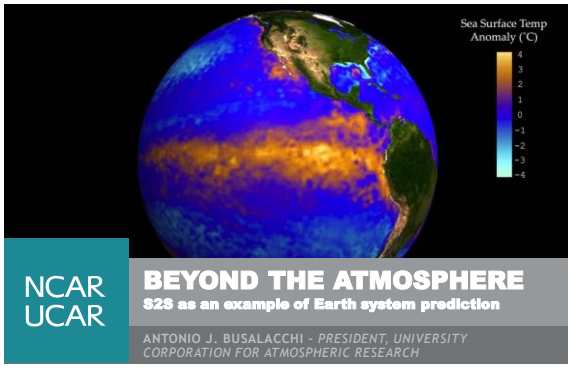


NCAR UCAR

BEYOND THE ATMOSPHERE

S2S as an example of Earth system prediction

ANTONIO J. BUSALACCHI - *PRESIDENT, UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH*

UCAR NCAR

2018 AMS Washington Forum

OVERVIEW: S2S IS EARTH SYSTEM PREDICTION

- Improving seasonal to subseasonal prediction requires an **Earth system approach.**
- Important sources of predictability for droughts, floods, heat waves, and other weather events can be found in the **oceans** and **land surfaces,** along with the **atmosphere.**
- S2S prediction requires bridging temporal and spatial scales between the climate and weather communities.
- Investment needed in **observational networks, Earth system** models, and **data assimilation** techniques.

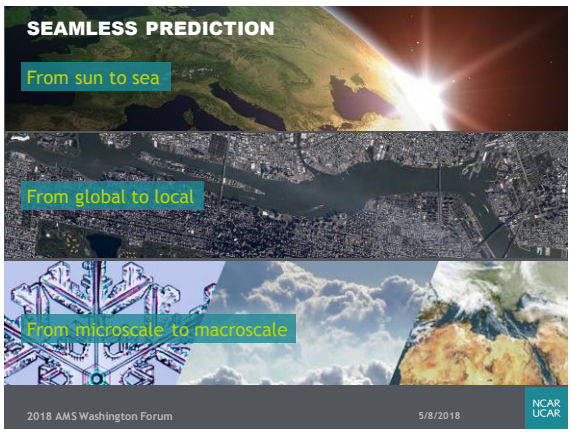
NCAR UCAR

EARTH SYSTEM PREDICTION

The next frontier in prediction integrates all the spheres of our world in a unified system.

GLOBAL IMPACTS

The ability to accurately predict the entire Earth system will have far-reaching benefits.



SEAMLESS PREDICTION

FROM DAYS TO YEARS: SOCIETAL RELEVANCE

- DAYS TO A WEEK
  - Weather forecasts
- SUBSEASONAL
  - Natural hazards preparedness
- SEASONAL TO INTERANNUAL
  - Shifts in likelihood of weather regimes
  - Resource management (water, fire, agriculture)
  - Transportation changes (e.g., Arctic shipping routes)
  - National security

Courtesy Gokhan Danabasoglu, NCAR

S2S PREDICTIONS

CLIMATE + WEATHER COMMUNITIES

day | week | month | season | year | decade | century

Regional to global weather models

- High resolution
- Depend on being "initialized" with accurate knowledge of the current state of the atmosphere

S2S Predictions

Use weather community techniques to initialize global climate models.

Global climate models

- Low resolution
- Depend on "forced boundary conditions," such as changes in solar irradiance and concentrations of greenhouse gases

S2S PREDICTIONS

GOOD FORECASTS REQUIRE...

A GOOD MODEL: The right resolution & right mix of components for target lead time

ENOUGH OBSERVATIONS: Sufficient to constrain the model variables that will lead to some predictive performance

DATA ASSIMILATION: A system for feeding the observations into the model to initialize it

But all beyond just the atmosphere

Subseasonal-to-Seasonal S2S Prediction Project

- A program of the World **Climate** Research program & the World **Weather** Research Program
- Seeks to improve forecast skill and understanding on the subseasonal to seasonal timescale with special emphasis on high-impact weather events

UCAR CONGRESSIONAL BRIEFING

Gokhan Danabasoglu, Chief Scientist, Community Earth System Model (CESM), NCAR - *Computer Modeling Capabilities and Challenges for Seamless Predictions*

Ben Kirtman, Director, Cooperative Institute for Marine & Atmospheric Studies, University of Miami, Rosentiel School for Marine and Atmospheric Science - *The Role of the Ocean in Seamless Prediction from Days to Seasons.*

Chad McNutt, Principal and Co-founder, Livestock Wx - *How Subseasonal to Seasonal Forecasts Drive Analytics in the Cattle Industry.*

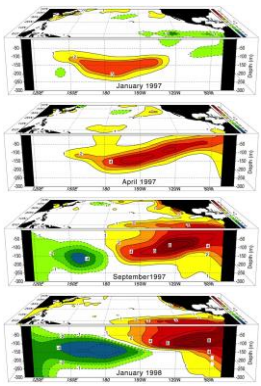
Alicia Karspeck, Staff Climate Scientist and Associate Director of Research Partnerships, Jupiter Technology Systems, Inc. - *The Role of the Private Sector: Bridging the Gap between Climate Model Predictions and Information Uptake by Users.*

OCEANS

EL NIÑO

SOURCE OF SEASONAL PREDICTABILITY

- A warm well of water forms below the surface in advance of an El Niño event.



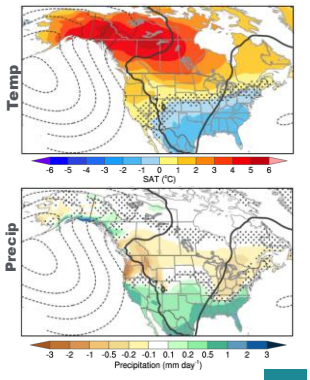
Courtesy Ben Kirtman, University of Miami

OCEANS

EL NIÑO

IMPACTS

- El Niño and its opposite, La Niña, (collectively known as ENSO) affect the North American climate, especially in winter.
- NCAR scientists used an ensemble of model runs to simulate the many ways the climate can respond to ENSO, giving them a much larger and richer data set than using historical observations alone.
- The average results, on right, show departures from normal during December, January, and February for temperature (top) and precipitation (bottom) related to ENSO.

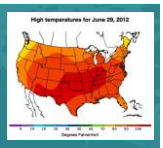


Courtesy Clara Deser, et al., NCAR

OCEANS

SEA SURFACE "FINGERPRINTS"

Sea surface temperature anomalies in the Pacific predicted a heat wave 50 days later, on June 29, 2012.

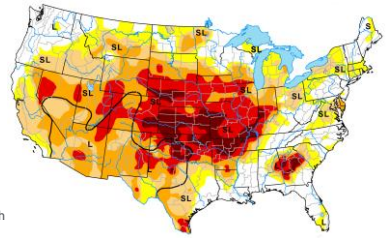


LAND

SOIL MOISTURE

BETTER DROUGHT PREDICTION

- An NCAR study finds that soil moisture and snowpack data can be combined to predict "flash droughts" months in advance.
- The study focused on hindcasting the 2012 flash drought (right) in the U.S., which caused $30 billion in economic losses.

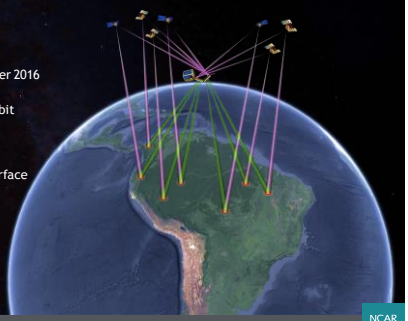


LAND

SOIL MOISTURE

USING CYGNSS DATA

- Launched in December 2016
- 8 satellites in LEO orbit over the tropics
- Optimized for ocean surface, NOT land surface remote sensing
- GNSS reflections are sensitive to water



Slide: Clara Chew, COSMIC Postdoc

LAND

SOIL MOISTURE

BETTER STREAMFLOW PREDICTION

- Knowledge of soil moisture on Jan. 1 increases skill in spring-summer forecasts in the northwestern U.S.
- Initializing models with accurate summer and fall soil moisture information increases streamflow forecast skill for lead times greater than six months.

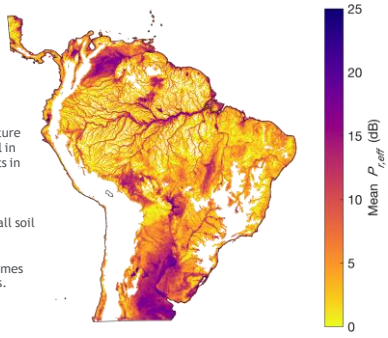
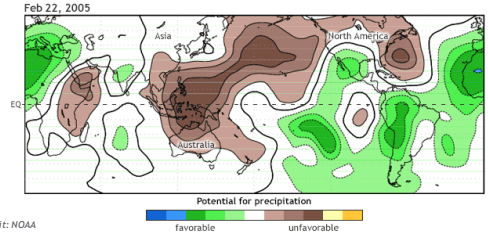


IMAGE: CYGNSS data over South America, courtesy Clara Chew

ATMOSPHERE

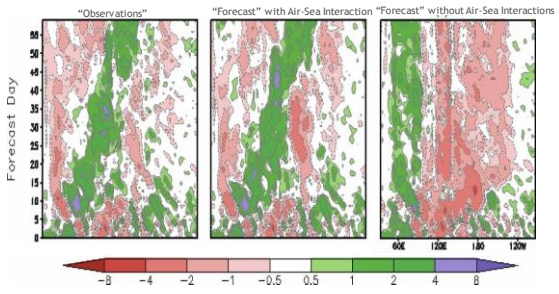
MADDEN - JULIAN OSCILLATION (MJO)

- Has impacts on the midlatitudes that last weeks instead of seasons
- Strong contributor to some extreme events, including Arctic air outbreaks across the central and eastern U.S.
- NCAR's Community Atmosphere Model has shown skill predicting MJO out to 20 days



Credit: NOAA

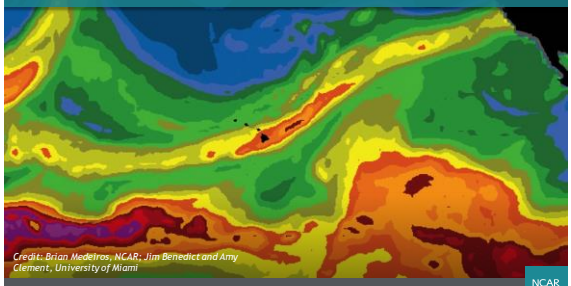
Importance of Air-Sea Interaction: Sub-Seasonal Predictability



ATMOSPHERE

MJO & Atmospheric Rivers

- The Community Earth System Model (CESM2) is being used to study the connections between atmospheric rivers and MJO.
- Atmospheric rivers are more likely to strike the West Coast during phases 1 and 7 of the MJO and less likely during phases 3 and 5.

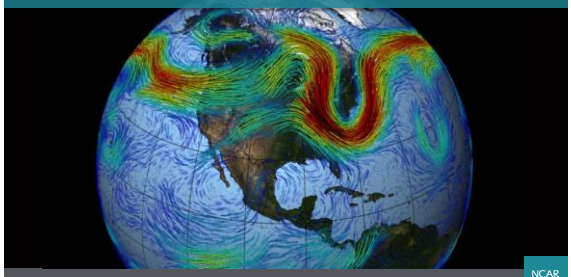


Credit: Brian Medeiros, NCAR; Jim Benedict and Amy Clement, University of Miami

ATMOSPHERE

THE STRATOSPHERE

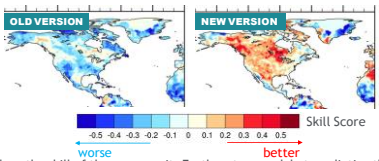
- The stratosphere influences tropospheric jet streams and storm tracks.
- Adding more atmospheric levels (46 instead of 30) to the Community Earth System Model allows for predictability of oscillations in the stratosphere



S2S PREDICTIONS

SURFACE AIR TEMPERATURE FORECASTS over North America with CESM on Monthly Time Scales

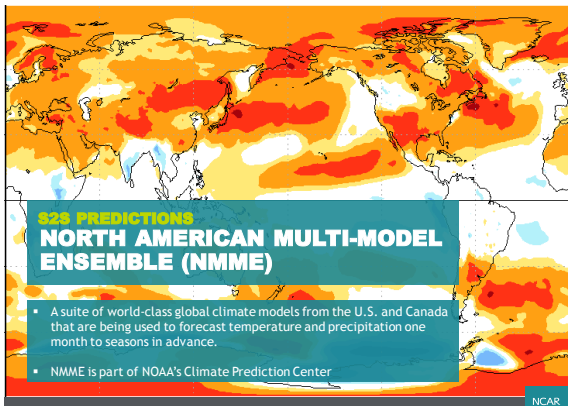
NCAR-based Earth system model



- Images show the skill of the community Earth system model at predicting the average temperature for January on the first day of the month.
- Upgrading the model — from CCSM3 to CCSM4 — and using better initial conditions, especially over the ocean, led to better temperature predictions over land. Better models and better (ocean) initial conditions lead to better surface temperature predictions over land.

01 January starts; verifying January-means for 1982-2010

Courtesy Ben Kirtman, University of Miami



S2S PREDICTIONS

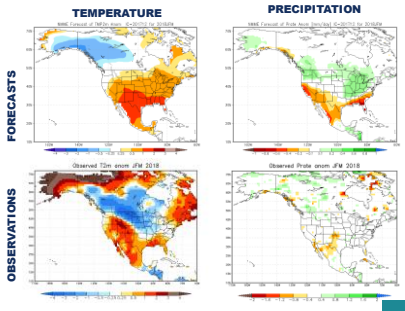
NORTH AMERICAN MULTI-MODEL ENSEMBLE (NMME)

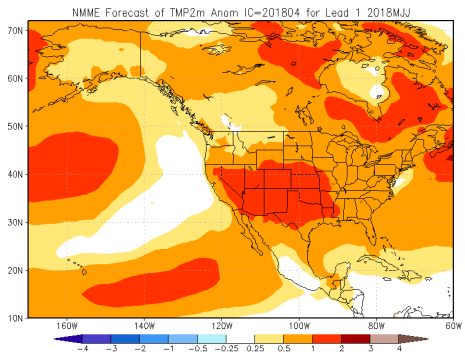
- A suite of world-class global climate models from the U.S. and Canada that are being used to forecast temperature and precipitation one month to seasons in advance.
- NMME is part of NOAA's Climate Prediction Center

S2S PREDICTIONS

NMME FORECAST VERIFICATION

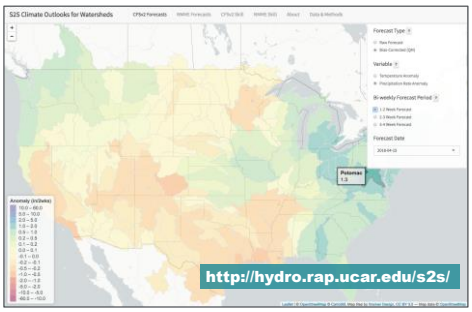
JANUARY, FEBRUARY, MARCH 2018





S2S PREDICTIONS

WATERSHED-SPECIFIC FORECASTS



Credit: Andy Wood, NCAR

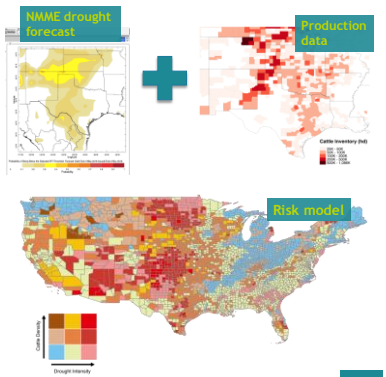
ATMOSPHERE + LAND + OCEAN

A record storm surge combined with torrential, inland rains caused massive flooding of the St. Johns River in Jacksonville, Florida, after Hurricane Irma.

Image: Jacksonville Sheriff's Office

S2S PREDICTIONS

CREATING A RISK MODEL FOR THE CATTLE INDUSTRY

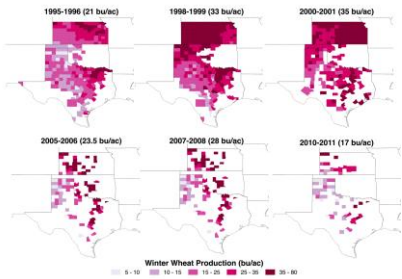


Credit: Chad McNutt, Livestock Wx

OCEANS

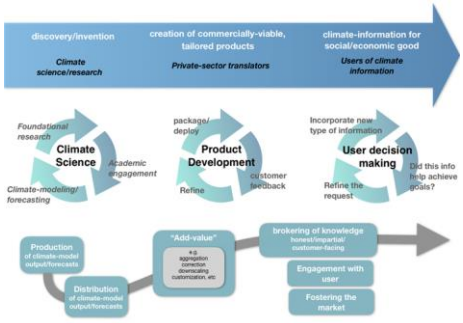
LA NIÑA: WINTER WHEAT PRODUCTION

- Winter wheat is a major feed source for cattle in the winter and spring in Texas, Oklahoma and Kansas.
- An average year results in 30 bu/ac
- Winter wheat production typically drops following La Niña events.



Credit: Chad McNutt, Livestock Wx

COMMERCIALIZING CLIMATE INFORMATION



Credit: Alicia Karspeck, Jupiter

What makes S2S forecast data VIABLE for commercial development?

- **Quality** of climate-forecast data
- **Accessibility** of climate-forecast data
- **Continuity** of climate-forecast data

Jupiter supports federal funding into programs that promote these outcomes

Credit: Alicia Karspeck, Jupiter

NCAR UCAR

S2S IN THE WEATHER BILL

SEC. 201. IMPROVING SUBSEASONAL AND SEASONAL FORECASTS.

PUBLIC LAW 115-25—APR. 18, 2017 131 STAT. 99

''(c) FUNCTIONS.—The Under Secretary, acting through the Director of the National Weather Service and the heads of such other programs of the National Oceanic and Atmospheric Administration as the Under Secretary considers appropriate, shall—

''(1) collect and utilize information in order to make usable, reliable, and timely foundational forecasts of subseasonal and seasonal temperature and precipitation;

''(2) leverage existing research and models from the weather enterprise to improve the forecasts under paragraph (1);

''(3) determine and provide information on how the forecasted conditions under paragraph (1) may impact—

''(A) the number and severity of droughts, fires, tornadoes, hurricanes, floods, heat waves, coastal inundation, winter storms, high impact weather, or other relevant natural disasters;

''(B) snowpack; and

''(C) sea ice conditions; and

''(4) develop an Internet clearinghouse to provide the forecasts under paragraph (1) and the information under paragraphs (1) and (3) on both national and regional levels.

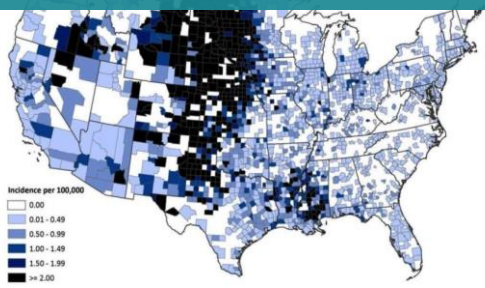
CONCLUSION:

- S2S predictions are already happening as a collaboration between the weather and climate communities taking advantage of coupling across the atmosphere, ocean, and land interfaces.
- S2S predictions are valuable for resource management, transportation planning, and national security.
- S2S predictions will improve as we better understand connections in the entire Earth system.
- Investment is needed in the Earth system sciences, observational networks, modeling, data assimilation, and computational resources.
- Need to sustain S2S capability to maintain and improve the quality, accessibility, and continuity of the information for the private sector and society as a whole

ATMOSPHERE

WEST NILE OUTBREAKS

- Researchers from NCAR and CDC find strong correlations across much of the country between an increased occurrence of West Nile virus disease and above average temperatures in the preceding year.



AVERAGE ANNUAL CASES OF WEST NILE: 1999-2013