Understanding and predicting regional water and extremes

Presented by

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Understanding and prediction

- Unified approaches for variability and change, across time scales and phenomena
- Tools targeted to research objectives, with clearly defined goals
- Judicious & balanced use of complexity, high resolution and large ensembles
- Application and research connected and complementary
Elements of Prediction System of Systems

**Global observing system:**
Sparse observations of many quantities across globe.

**Dynamical modeling system:**
Allows forward integration from present state, including expected changes in radiative forcing.

**Data assimilation system:**
Combines sparse observations with model, to estimate present state. Usually based on dynamical model.

**Analysis and dissemination system:**
Take output from predictions and produce “useful” information, communicate predictions.
Assimilation and observing system assessment

- Real time prediction and state estimation
  http://www.gfdl.noaa.gov/ocean-data-assimilation

- SLP Assimilation: Towards a coupled climate reanalysis and initialization system

- Observing system assessment (e.g., TAO & Argo evaluation OSE)

- Towards high-resolution assimilation (cf. Shaoqing Zhang poster today)

http://origin.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html
Building on success: Prediction of cold 2013-14 winter

GFDL-CM2.1 yields world class predictions, delivered pseudo-operationally and evaluated through NMME, IRI, GFDL Data Server

Case study: CM2.1 predicted past winter cold from November 2013.

NMME: No model always best; model-mean most reliably good.

Analysis: Emily Becker (NOAA-NCEP)
CM2.5: Among best global surface climate simulations can we harness this for prediction?

**CM2.1:** 2° atmos/land; 1° ocean/ice, LM2

**CM2.5:** 50km atmos/land; 0.25° ocean/ice, LM3

Long-lead research and faster computer (Gaea)

High-resolution CM2.5

Significantly reduced biases relative to CM2.1 (and other models)

*Knutti et al. (2013)*
**GFDL FLOR**: Experimental high-resolution coupled seasonal to decadal prediction system

**Goal**: Build a seasonal to decadal forecasting system to:
- Yield improved forecasts of large-scale climate
- Enable forecasts of regional climate and extremes

Medium resolution (CM2.1)

High resolution (CM2.5-FLOR)

*Delworth et al. (2012), Vecchi et al. (2014), Jia et al. (2014), Yang et al. (2014), Msadek et al. (2014), Wittenberg et al. (2014)*

Modified version of CM2.5 (Delworth et al. 2012):
- 50km cubed-sphere atmosphere (cf. S.J. Lin’s talk)
- 1° ocean/sea ice (low res enables prediction work)

~15-18 years per day. Multi-century integrations. 10,000+ model-years of experimental seasonal predictions completed and being analyzed.
Hypothesis: Enhanced atmos./land resolution improves simulation and prediction

Annual Precipitation (mm/day)

CM2.1: 200km Atm.

FLOR: 50km Atm.

Jia et al. (2014, J. Clim.)
Hypothesis: Enhanced atmos./land resolution improves simulation and prediction

Representation and prediction skill for most predictable pattern of rainfall over land improved in FLOR relative to CM2.1

(see Liwei Jia’s poster today)

(Jia et al. 2014, submitted)
Tour across scales & phenomena

Rest of morning:
Snow, Ice, Extratropical storms, North Atlantic, ENSO, land precipitation and temperature, atmospheric jets, high-resolution assimilation, understanding and evaluating downscaling methods, attribution of global and regional changes.

• Rest of this talk: tropical cyclones across timescales.
Late 21st Century Atlantic Hurricanes: Fewer? Stronger?

NA frequency decrease & intensity increase: strongest TCs may become more frequent

Large spread across various GCM projections.

Adapted from Knutson et al. (2013, J. Clim.). See also: Knutson et al. (2009), Zhao et al. (2009), Bender et al. (2010), Villarini et al. (2011), Villarini and Vecchi (2012, 2013)
Decades: aerosols and variability

Aerosols and GHG change

Only GHG increases

Sources of uncertainty (after Hawkins and Sutton, 2009)

- **Variability:** ~independent of radiative forcing changes
- **Response:** “how will climate respond to changing GHGs & Aerosols?”
- **Forcing:** “how will GHGs & Aerosols change in the future?”

Experimental decadal predictions
Hybrid system: statistical hurricanes, dynamical decadal climate forecasts

- Retrospective predictions encouraging.
- However, small sample size limits confidence
- Skill arises more from recognizing 1994-1995 shift than actually predicting it.
- This is for basinwide North Atlantic Hurricane frequency only.

**EXPERIMENTAL: NOT OFFICIAL FORECAST**

Vecchi et al. (2013 and 2014), Msadek et al. (2014)

Significant deterministic skill ($r=0.51$) & Forecast PDF reliable

FLOR & HyHuFS forecasts fed to NOAA Seasonal Outlook Team

http://gfdl.noaa.gov/HyHuFS

Vecchi et al. (2011), Villarini and Vecchi (2013)
FLOR: Seasonal predictions of regional TC activity

Rank correlation: Can experimental FLOR forecasts distinguish years with many and few storms passing within 10° x 10° of a point?

Vecchi et al. (2014, submitted)
GFDL-FLOR Predicted TC density anomaly for 2014: uncertainty in large-scale impacts TC forecast

Initialized 1-April-2014 Reflects in part prediction of strong El Niño

Initialized 1-May-2014 Reflects prediction for El Niño weakens

Contoured: TC density anomaly (days over 10°×10° box for year) relative 1982-2005. Shaded: retrospective p=0.1 significant correlation. Vecchi et al. (2014, submitted)
High-Resolution Seasonal Predictions for Risk Assessment

**Case Study: What are odds of Sandy-like storm?**

- FLOR spontaneously produces storms with Sandy’s unusual “left hook”
- Retrospective forecasts: 1000s of worlds that “could have been”
- Use these “plausible worlds” to estimate risk of unlikely extremes & understand their causes/predictability.

How do we quantify the uncertainty in these estimates of “unlikely event” return period? We have only seen one real Sandy...
Summary

• Models allow estimates of future TC activity:
  – Next couple of decades: internal variability dominant player (some may be predictable, some not)
  – NA Hurr. Response to CO$_2$: maybe fewer, probably stronger.
  – Aerosol forcing and response may be crucial to next few decades.

• Encouraging results from long-lead (multi-season & multi-year) experimental TC forecasts

• High-resolution coupled model (FLOR) enables predictions of regional tropical cyclone activity.