Overview on Climate Predictability and Prediction

CPPA Principal Investigator's Meeting
Silver Spring, Maryland
29 Sep - 1 Oct 2008

S. Schubert, H., H. Wang, M. Suarez, Randy Koster, Y. Chang, and many others

Earth Sciences Directorate, NASA/GSFC
The good news: something is wrong with models

• The model does not have proper ……………, therefore any judgement (in the negative) about predictability is premature.
Examples: MJO, air-sea interaction, marine stratus off continents, projection onto NAO (hobbies of the day)
• If only we had proper ………….. we expect much better predictions (conjecture)
• As long as models do not reproduce reality in some way, there is hope…..

Huug van den Dool: “Prediction and Predictability of Climate Variability”
Outline

• What is wrong with our models for S-I?
  – Focus on atmospheric response to SST
    • Deficiencies in signal
    • Deficiencies in noise

• Touch on emerging areas
  – Predicting MJO/ISO
  – Predicting weather/climate (tropical storms)
  – Decadal predictability

• Is Huug’s optimism well-founded?
USCLIVAR Drought Working Group Coordinated Global Model Experiments with Idealized SST

- Look at model dependence on the response to SSTs (and the role of soil moisture)

- Force with fixed SST anomaly patterns added to seasonally varying SST climatology (+/1 2 standard deviations of leading REOFs of annual mean SST) - looking at far right side of Lisa’s plot

- Participating groups/models: NASA (NSIPP1), Lamont (CCM3), NCEP (GFS), GFDL (AM2.1), NCAR (CAM3.5), and COLA/ Univ. of Miami/ (CCSM3.0)
Leading Rotated EOFs of annual mean SST (1901-2004)

- Linear Trend Pattern (LT)
- Pacific Pattern (Pac)
- Atlantic Pattern (Atl)

$+/- 2\sigma$
Uncertainties in Signal
Annual Mean 200mb Height Response (m)

Pacific Warm

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<th>Model</th>
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Annual Precipitation (mm/day)

Pacific Cold

Annual Mean Precip (ColdPac–Clim)

CCM3

NSIPP1

GFS

GFDL

Pacific Warm

Annual Mean Precip (WarmPac–Clim)

CCM3

NSIPP1

GFS

GFDL

CAM3.5

CAM3.5
Seasonality of Signal
DJF - Warm

All anomalies are wrt control runs with climatological SSTs

Contours: 200mb height anomalies

Vectors: 850mb wind anomalies

Colors: precipitation anomalies

Major differences
MAM - Warm

Seasonal change from wave to zonal structure

Anomaly shifted south compared to others, ridge continues to dominate
JJA - Warm

Anti-cyclonic anomaly developing in IAS
SON - Warm

Anti-cyclonic anomalies in IAS
Weak and shifted anti-cyclonic anomalies
General consistency in height anomalies but CFS again shifted south
Cyclonic anomalies in IAS
SON - Cold

SON Mean precip_z200_wind850 (ColdPac-Clim)

CCM3

NSIPP 1

GFS

GFDEL

CAM3.5

Cyclonic anomalies in IAS
Warm Pacific (Precipitation t-value: signal/noise)

Absolute values > 2 significant at 0.5% level
Cold Pacific (Precipitation \textbf{t-value}: signal/noise)

Seasonality of Regional Mean Precip(t)_land Response over US subregions: ColdPac–Clim

Absolute values $> 2$ significant at 0.5\% level
Uncertainties in Mean Precipitation Response (Signal) over Great Plains

• Models show substantial differences in seasonally dependent controls
  – Cold season (planetary waves/storm tracks)
  – Warm season (land surface memory and feedbacks)
  – Summer/fall (Low level response: LLJ/IAS)

• CFS tends to have the smallest signal/noise
  – Linked in part to southward shift in height response (MAM)
  – Perhaps weaker land/atmosphere feedbacks
Uncertainties in Noise
Noise (Z200mb): Unforced Interannual Variance in Control Runs
Noise (Z200mb): Unforced Interannual Variance in Control Runs
Tsfc and Precip Noise

• Look at Pacific warm and cold SST cases
Pacific Warm: Great Plains

CCM3

DJF

GFS

MAM

GFS

NSIPP1

GFDL

CAM3.5

Precip mm/d

TsfC °C
Pacific Warm: Great Plains

JJA

SON

Precip mm/d

Tsfc °C
Pacific Cold: Great Plains

CCM3 DJF GFS

CCM3 MAM GFS

NSIPP1

GFDL

CAM3.5

Precip mm/d

Tsfc °C

Precip mm/d

Tsfc °C
Pacific Cold: Great Plains

CCM3  JJA  GFS

CCM3  SON  GFS

NSIPP1  GFDL

CAM3.5

Precip mm/d

Precip mm/d

Tsfc °C

Precip mm/d

Tsfc °C
What Are the Determining Factors for Noise (unforced variability)?

Seasonal Dependence?

Impact of SST (a signal in the noise!)
“Noise” in Great Plains in Spring/Summer driven by land/atmosphere feedbacks but also depends on SST Forcing!

Schubert et al. 2008  JCLIM
Subseasonal Noise is the result of barotropic instability of the jet - depends on SST!

200mb $\Psi$ Variability (10-30 days)

Model
120 ensemble members

Obs

Schubert et al. 2001  JCLIM
Uncertainties in Noise

• Models show considerable differences in basic noise levels (unforced inter-annual variability)
  
  – For the upper level circulation this is likely tied to differences in climatological jet structures and related instabilities (weather, PNA, etc)
  
  – For Precip and Tsfc over the Great Plains, land surface interactions may play a role during spring and summer
  
  – What about the low level jet?
Emerging Areas
MJO/ISO
GEOS-5 Tropical Precip hindcasts at 2 weeks

Day-14: PRATE (mm/day) (15S–5N average)

GCPC    Coupled    Uncoupled
MJO/GEOS-5 Predictions

• Coupling improves forecasts

• Skill depends on phase of MJO
  – Dry phase over Indian Ocean => poor predictions
  – Wet phase over Indian Ocean => good predictions
  – May be the result of a model bias (dry phase is too wet)
NCEP – CFS

A dynamical tool for subseasonal prediction

Augustin Vintzileos

EMC/NCEP/NOAA/NWS – SAIC
Retrospective forecast design:

May 23rd to August 11th from 2002 to 2006

1 forecast every 5 days, with additional re-forecasts at the beginning of each month

Forecast lead: 60 days

Model resolution:

**Atmosphere**: T62 = 200Km x 200Km
T126 = 100Km x 100Km
T254 = 50Km x 50Km

**Ocean**: the standard CFS resolution

Initial conditions:

**Atmosphere, Land**: from Reanalysis 2 (CDAS2) and from GDAS (operational NCEP analysis)

**Ocean**: from GODAS
Skill for the MJO mode (verification CDAS2)

Pattern Correlation for the projected mode

RMS Error for the projected mode

Persistence forecast

CDAS2

GDAS

Skill up to 14 – 18 days

Persistence forecast

GDAS

T62

T126

T254
Reasons for the drop in forecast skill:

The Maritime Continent Barrier

As the active phase of the MJO (enhanced convection) approaches the Maritime Continent the forecast skill becomes dependent on the forecast target time rather than depending on forecast lead time. The forecast skill drops to zero when the MJO enters the Maritime Continent even if the model is initialized a few days before.
Summary and work to follow:

The CFS is a skillful tool for forecasting the MJO. This is a solid basis supporting further work for establishing operational subseasonal prediction over North America.

The principal reason for the drop in MJO forecast skill is the Maritime Continent Forecast Barrier. Breaking this barrier will allow for significant improvement of subseasonal forecasting skill.

We have explored the impact of horizontal resolution and initial conditions on MJO forecast skill. Increasing horizontal resolutions up to T254 is not improving the forecast. A set of better atmospheric initial conditions and to an extent better oceanic initial conditions improves forecast skill by 3-6 days.

Further experimentation and especially diagnostic studies comparing diabatic heating profiles in hindcasts with the CFS to those from soundings, TRMM retrievals and global reanalysis in order to understand the reasons for the Maritime Continent Forecast Barrier are on the way.
GEOS-5 and CFS have different dependence on initial conditions!
3) Continue to explore multi-scale interactions … observations and high resolution modeling frameworks … vertical structure and diabatic processes -> CMMAP, YOTC

4) Expand efforts to develop and implement MJO operational forecast -> boreal summer focus -> ICTP Mtg, 4th WMO Monsoon Mtg, AAMP.

5) Hindcast to assess MJO (& impacts) predictability and forecast skill -> ICTP Mtg, 4th WMO Monsoon Mtg, AAMP, 2 Page Pre-Proposal via B. Wang, I.S. Kang, D. Waliser, etc.

Role of MJOWG – Informal continuation?? –

*Note the above types of activities/events existed before but only so effective.*
Climate/Weather
High Resolution Simulations of Tropical Storms
From Jae Schemm

T382 CFS runs for hurricane season prediction

- AGCM - 2007 operational NCEP GFS
- LSM - Noah LSM
- OGCM - GFDL MOM3
- All runs initialized with NCEP/DOE R2 and NCEP GODAS in April, 1981-2007 (May 15 ICs in FY07 experiment)
- AGCM spatial resolution in T382L64, planned for 3 member ensemble
- FY07 experiment was extensively analyzed by the Evaluation Team members
Decadal

Can we begin to unravel the nature of longer term changes/trends?

Important step for improving models
The linear trend of surface temperature during 1950-2000 in (a) observations, (b) AMIP ensemble mean simulations, and AGCM surface temperature responses to the linear trends of SST anomalies during 1950-2000 associated with (c) the global warming pattern, (d) the Pacific Decadal SST pattern, and (e) the Atlantic Multi-decadal SST pattern, for DJF, MAM, JJA and SON. The AGCM is the NASA Seasonal-to-Inter-annual Prediction Project (NSIPP1) model. Units: °K. From H Wang, S.D. Schubert, M. J. Suarez, J. Chen, M. Hoerling, A. Kumar, and P. Pegion, 2008.
Summary/Conclusions

Huug's optimism is well-founded!
Impact of ENSO on Skill

Temperature

Precipitation

Courtesy: Lisa Goddard
Skill increases during ENSO extremes

USA-averaged JFM RPSS relative to ENSO strength

(Temperature : Bayesian MM)

(Tsfc: Skill)

(Precipitation : Bayesian MM)

(Precipitation: Skill)

(ENSO Strength)

Courtesy: Lisa Goddard