Schematic Global Climate Model

Horizontal Grid (Latitude-Longitude)

Vertical Grid (Height or Pressure)

NOAA/ GFDL’s CLIMATE and EARTH SYSTEM MODELING
Understanding the 20\textsuperscript{th} C and 21\textsuperscript{st} C Projected Climate Change
Radiative Forcing Components in 2005 [IPCC AR4, 2007]

(since preindustrial times, ca. 1750)
Results from GFDL Climate Model CM3

[CMIP5; IPCC AR5 report, 2013]
CM3 Coupled Climate Model

- Cubed-sphere dynamical core
- ~200km horizontal resolution
- 48 vertical levels
- Updated moist physics

Solar Radiation
Well-mixed Greenhouse Gases
Volcanic Aerosols

Ozone–Depleting Substances (ODS)

Pollutant Emissions

Atmospheric Dynamics & Physics

Atmospheric Chemistry
80 km

Stratospheric Chemistry

Tropospheric Chemistry (gas-phase and aerosol)

Aerosol-Cloud Interactions

Dry Deposition

Land Model

Ocean and Sea Ice Model

Donner et al., *J. Climate*, 2011
Aerosol-Cloud-Climate Interactions

“DIRECT” effects

Clear Sky

Reflection

Wet Particles

Hygroscopic Growth

SW Radiation

Interstitial Aerosols

Activation

“INDIRECT” effects

Cloudy Sky

Reflection

Droplets

Advection

Emission

Land

Ocean

Emission

Land

SW Radiation

“DIRECT” effects:
- Reflection
- Wet Particles
- Hygroscopic Growth
- SW Radiation

“INDIRECT” effects:
- Reflection
- Activation
- Advection
- Emission
- Land
- Ocean
Surface Air Temperature

Temperature Change (°C)

versus (1901-1950)

CM2.1
CM3
OBS (HadCRU, GISS)

Change (°C) from (1881-1900) to (1981-2000)
CM2.1 = 0.74
CM3 = 0.23
OBS = 0.51
Response to idealized 1%/year increase in CO$_2$

Transient Climate Response (TCR)

CM3 = 2.1°C
CM2.1 = 1.5°C

TCR in CM3 is ~40% greater than that in CM2.1
CM3 has more sensitive NH sea ice cover than *any* other AOGCM (more area loss per degree global warming)

... but obs indicate even more sensitivity than in CM3, possibly due to natural variability

What factors influence ice sensitivity? CM3 and CM2.1 have same sea ice model but simulate sea ice sensitivities at opposite ends of the model spectrum. Atmosphere plays a large role.
A drying trend observed over central-northern India during the second half of the 20th century.
Spatial pattern of linear trends of JJAS rainfall (mm day\(^{-1}\) 50 years\(^{-1}\))

Bollasina et al. (Science, 2011)
Attribution of the recent trend of the S. Asian summer monsoon using CM3 historical simulations

Linear trends of average JJAS rainfall over central-northern Indian (mm day$^{-1}$)

- AERO trend opposite in sign to WMGGO3
- AllForc trend compares well with CRU (Obs)
How Hadley and Walker circulations respond to greenhouse gases and aerosols?

North-South pattern of basic mechanism evident in earlier simulations
Chen and Ramaswamy (1996); Ramaswamy and Chen (1997)
Surface Air Temperature

Temperature Change (°C)
(versus year 2000)

-1 0 1 2 3 4 5
1900 2000 2100 2200 2300
year

RCP8.5
RCP6
RCP4.5
RCP2.6
Historical
Surface Air Temperature

Greater 21st century warming projected by CM3/RCP than CM2.1/SRES
Results from

GFDL High-spatial Resolution
Global Atmospheric Models

[CMIP5; IPCC AR5 report, 2013]
NOAA/ GFDL high-resolution global model (~50 km) used to simulate the severity and duration of summer heat waves. This model was used to produce the bottom figure, from a 30-year simulation of present-day climate. Top figure is based on observational data for a 24-year period.
Midwest Heat Waves

Model vs. Observations

Surface Temperature

Precipitation

°C

mm/dy
## Midwest Heat Waves

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<td><strong>Severity (°C)</strong></td>
<td>35.2</td>
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<td><strong>Duration (days)</strong></td>
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<td><strong>Number of Events per year</strong></td>
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<td>Region</td>
<td>Duration</td>
<td># Events/yr</td>
<td># Heat wave days/yr</td>
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<td>-----------------------</td>
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<tr>
<td>Midwest</td>
<td>1.5</td>
<td>2.7</td>
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<td>Northern Plains</td>
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<tr>
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<td>Southwest</td>
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<td>Wyoming/Montana/Idaho</td>
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<td>2.6</td>
<td>5.7</td>
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</table>
Seasonal hurricane predictions

1990-2010 (Jul-Nov)

North Atlantic Basin (Hurricanes)

- Resolution: 25 km, 32 levels
- 5-members initialized on July 1 with NCEP analysis
- SST anomaly is held constant during the 5-month predictions
- Climatology O3 & greenhouse gases are used

- Corr. = 0.88
- RMSE = 1.91
- Bias = -0.94

1. Chen and Lin 2011, GRL
2. Chen et al., to be submitted
The END

Thank you for your attention!