Requirements for improved seasonal sea ice prediction in the NCEP Climate Forecast System

Wanqiu Wang (CPC/NCEP)

Xingren Wu (EMC/NCEP)

Thomas Collow (CPC/NCEP)

Arun Kumar (CPC/NCEP)

40th Climate Diagnostics and Prediction Workshop
Denver, CO
October 29, 2015
SIPN

2012 Sea Ice Outlook: August Report

September Sea Ice Extent ( Million Square Kilometers)

CFSv2

3.5 ± 0.3
4.0 ± 0.7
4.0 ± 0.3
4.0
4.1 ± 0.1
4.1 ± 0.2
4.2 ± 0.7
4.3 ± 0.6
4.3
4.4 ± 0.4
4.4 ± 0.9
4.5 ± 0.4
4.5 ± 0.3
4.6 (range 4.1 - 5.2)
4.7 ± 0.5
4.7 ± 0.3
4.9 ± 0.6

1979-2007 Average

September 2011

Median of August Outlooks

Obs = 3.62

Outlook Contributor

*Public Outlook

Outlook Method Key

- Statistical
- Modeling
- Heuristic
- Combination of Methods

http://www.arcus.org/search
2012 Sea Ice Outlook: June Report

SIPN

September Sea Ice Extent (Million Square Kilometers)

- 4.1
- 4.2
- 4.3 (range: 3.4-5.1)
- 4.3
- 4.3
- 4.4±0.5
- 4.4±0.9
- 4.4±0.2
- 4.4±0.5
- 4.5±1.0
- 4.6±1.3
- 4.7±0.1
- 4.7
- 4.9
- 4.9±0.4
- 4.9±0.6

CFSv2

Obs=3.62

Outlook Method Key
- Statistical
- Modeling
- Heuristic
- Combination of Methods

CFSv2

http://www.arcus.org/search
Zonal mean sea ice concentration (%) around Bering Sea and Chukchi Sea (170-200E) (2009-2013 average)

- Slow melt in summer
- Slow freeze in fall

Major errors:
1. Causes of the forecast errors
2. Impacts of model configurations
3. Future plans
Causes of the forecast errors

i. Errors in initialization

ii. Inaccurate model physics
Sea ice errors in the initialization

i. Initial sea ice coverage

ii. Initial sea ice thickness
Errors in initialization: Sea ice concentration

Differences in sea ice extent between CFSR and NASA Team (10^6 km^2)

- Significant jumps in 1997 and 2008
- Difficult to remove time-dependent systematic bias.

CFSR: Climate Forecast System Reanalysis providing initial conditions for CFSv2
Errors in initialization: Sea ice thickness trend

Differences in sea ice volume between CFSR and PIOMAS analysis \((10^3 \text{ km}^3)\)

**Differences depending on year and month**
**Difficult to remove time-dependent systematic bias**

**PIOMAS**: University of Washington Pan-arctic Ice/Ocean Modeling and Assimilation System
Impacts of model configuration

i. Inaccurate surface fluxes from the atmosphere and ocean

ii. Insufficient model resolutions
Excessive surface downward solar radiation flux

- CFSv2 produces excessive surface downward solar radiation flux
- The solar radiation flux bias is related to negative bias in cloud amount
Impacts of model configurations

A. Impact of initial sea ice
   • CFSR (Climate Forecast System Reanalysis)
   • PIOMAS (Pan-arctic Ice/Ocean Modeling and Assimilation System)

B. Impact of model physics
   • CFSv2 (Climate Forecast System version 2)
   • CFSv2p (Modified model physics)
     ✓ Use a marine stratus parameterization (Moorthi et al. 2010).
     ✓ Remove water-ice heat flux constraint
Sea ice extent from June 2015 forecast

- Consistent initial sea ice concentration
- More accurate initial sea ice thickness
- More realistic surface fluxes from the atmosphere and ocean
Delayed freeze in all runs

Zonal mean sea ice concentration (170E-200E)

- CFSv2/CFSR: Seasonal cycle too weak
- CFSv2p/CFSR: Seasonal cycle slightly further weakened with changes in physics alone
- CFSv2/PIOMAS: Seasonal cycle enhanced with even stronger melt with changes in IC alone
- CFSv2p/PIOMAS: Seasonal cycle best simulated with changes in both ICs and physics

Initial date: March 12. 2009-2013 average
Possible impact of model resolutions

Sea ice edge (15% concentration)
CFSv2 Forecast from July 2005-2009 average

- Sea ice freeze in CFSv2 is delayed
- Possible reasons
  a. Horizontal resolutions too coarse to resolve land-sea contrast details
  b. Oceanic vertical resolution (10 m) too coarse to correctly ocean surface response to atmospheric cooling
SST bias
November SST bias in forecast from July with different convection schemes

- SAS: Simplified Arakawa Scheme
- RAS: Relaxed Arakawa Scheme
- SAS2: Revised SAS

It is possible to configure the model for improved prediction in both sea ice and SST.
Summary

• Major CFSv2 forecast errors: slow melt and freeze

• The prediction of sea ice melt improves with
  ✓ More consistent initial sea ice concentration
  ✓ More accurate initial sea ice thickness
  ✓ More realistic surface fluxes from the atmosphere and ocean

• These changes did not result in significant improvement in sea ice freeze which may require an increase in model resolutions
Future Plan

• Test impacts of increased model resolutions on the prediction of sea ice freeze

• Develop a sea ice data assimilation system with CFS ocean component that assimilates both sea ice concentration and sea ice thickness

• Develop the CFS version 3 (CFSv3)

  ① Test the CFSv3 with improved atmospheric physics for a better representation of surface fluxes

  ① Test sea ice component model: CICE/SIS/SIS2/KISS