MPAS Testing in AMPS

Jordan G. Powers
Kevin W. Manning

Mesoscale and Microscale Meteorology Laboratory
National Center for Atmospheric Research
Boulder, Colorado, USA
Background

• **MPAS: Model for Prediction Across Scales**
  – MPAS= Global atmospheric model

• **Current Study: Initial Comparison of MPAS and WRF**
  – Testing: 5-day forecasts over Antarctica
  – Setup: MPAS approximates WRF setup, but not identical
  – Caveats w/use of MPAS
    - Cost, physics limitations, performance
    - MPAS *not* a replacement for WRF anytime soon
MPAS— Background

• MPAS: Numerical weather prediction model engineered to operate from the global scale to the cloud scale

“MPAS-A”= MPAS-Atmosphere

• MPAS system jointly developed by NCAR and Los Alamos National Laboratory (LANL)

• NCAR: MPAS-A primary development and support

See MPAS: http://mpas-dev.github.io/
MPAS— Background

• MPAS: Run at NCAR for real-time NWP and research
  
  Ex: Support of NOAA/SPC Hazardous Weather Testbed Spring Experiment

• Current MPAS: Global mesh w/regional refinements
  
  – No standalone limited-area grids

• MPAS System Components
  
  – MPAS Infrastructure
  – MPAS— Atmosphere MPAS-A
  – MPAS— Ocean MPAS-O
  – MPAS— Ice MPAS-I

♦ MPAS-I not connected to MPAS-A

♦ MPAS-I being linked to a different atmospheric model by LANL in CESM
MPAS: Global → Cloud Scale

Moore, OK Tornado  20 May 2013

MPAS 3-km reflectivity
70-hr fcst

22 UTC 20 May

Obsv’d composite reflectivity

MPAS 50-km/3-km Variable Mesh
500 mb Relative Vorticity
01 UTC 18 May–11 UTC 21 May 2013 (22 h)

500 hPa dx, rel vort 2013-05-18_01:00:00  [1/s]

Mesh spacing contours:
40, 30, 20, 12, 8 & 4 km
Model Setups

**WRF**
- 30-km/10-m grids
- 60 vertical levels
- Data assimilation
- GFS first guess

**MPAS**
- 60-km/15-km variable global mesh
- 46 vertical levels
- No DA
- GFS first-guess

**WRF Domains**

**MPAS Antarctic Mesh**

Terrain height (m)

15-km Antarctic refinement
Note: Model Physics

(i) MPAS has a narrow set of options taken from WRF
(ii) MPAS versions not the latest

Forecast Review

1) Subjective Forecast Analyses
   – Review of MPAS runs since October 2015

2) Statistical Verification
   • AWS Surface Verifications: T, Wind speed, Pressure
     Statistics: Bias, RMSE, Correlation
   • Verification Periods
Case Review: 0000 UTC 8 April 2016 Forecast

- Hours shown: 24, 72, 120
- Sfc and 500 mb analyses
WRF & MPAS 24-hr Forecasts  SLP and 3-Hr Precip

0000 UTC 9 Apr 2016  (8 Apr 0000 UTC Init)

Forecasts aligned at 24h

Contour interval= 4 mb
MPAS & WRF 72-hr Forecasts     SLP and 3-Hr Precip
0000 UTC 11 Apr 2016     (8 Apr 0000 UTC Init)

WRF

MPAS

Forecasts similar, but WRF shows an extended trough and suggests secondary development (x)

Contour interval= 4 mb
MPAS & WRF 120-hr Forecasts     SLP and 3-Hr Precip
0000 UTC 13 Apr 2016     (8 Apr 0000 UTC Init)

WRF: Two lows, with a significant (959) center in western Ross Sea

Contour interval = 4 mb
AMPS Analysis  SLP
0000 UTC 13 Apr 2016

MPAS
120 h

WRF
120 h

Contour interval= 4 mb
WRF: Two circulation centers
AMPS Analysis

500 mb GHT, Wind

0000 UTC 13 Apr 2016

MPAS
120 h

WRF
120 h
Surface Verifications

• Verifications performed with AWS obs at 70–80 sites
• Oct.—Dec. 2015 and Feb.—Mar. 2016 periods
• Variables: Temperature, Pressure, Wind speed
• To do: Upper-air verification comparisons
McMurdo — Temperature

Oct.–Dec.

Bias:  WRF= -2.8C  MPAS= -4.0 C
RMSE: WRF= 4.0 C  MPAS= 5.1 C

Feb.–Mar.

Correlation:  WRF= .89  MPAS= .86

MPAS: Increased cold bias & RMSE
South Pole—Temperature

Oct.–Dec.

Bias: WRF = 3.7 °C  
      MPAS = 3.4 °C

RMSE: WRF = 4.6 °C  
       MPAS = 4.9 °C

Bias:   WRF=    3.7 C  
       MPAS=  3.4 C

RMSE:  WRF=    4.6 C  
       MPAS=  4.9 C

Correlation: WRF = .94  
             MPAS = .91

MPAS: Decreased warm bias

Feb.–Mar.
McMurdo Pressure

Oct.–Dec.

Bias: WRF = 1.0 mb  
MPAS = 1.0 mb

RMSE: WRF = 2.7 mb  
MPAS = 2.6 mb

Correlation: WRF = .96  
MPAS = .97

Feb.–Mar.

Correlation: WRF = .96  
MPAS = .97

MPAS & WRF: Similar, small biases
South Pole—Wind Speed

Oct.—Dec.

MPAS: Greater bias (negative) and RMSE

WRF
MPAS
Obs

WRF
MPAS
Obs

Bias: WRF = 0.5 ms⁻¹
MPAS = -1.6 ms⁻¹

RMSE: WRF = 1.7 ms⁻¹
MPAS = 2.3 ms⁻¹

Feb.—Mar.

WRF
MPAS
Obs

WRF
MPAS
Obs

Bias: WRF = 0.5 ms⁻¹
MPAS = -1.6 ms⁻¹

RMSE: WRF = 1.7 ms⁻¹
MPAS = 2.3 ms⁻¹
Temperature—Bias

Oct.—Dec: WRF slightly better
Feb.—Mar: WRF better
Wind Speed—Bias

Oct.—Dec.

Oct.—Dec: MPAS slightly better

Feb.—Mar.

WRF / MPAS comparable
Summary

• MPAS Test Forecasts

  – Subjective reviews: MPAS and WRF daily forecasts consistent through about 72 hrs, but can diverge for longer lead times

    ♦ MPAS daily operation reliable
    ♦ No strange behavior in MPAS
    ♦ No big performance dropoff with MPAS

  – Surface verifications: WRF overall better than MPAS statistically

    ♦ Station results vary with parameter/season
    ♦ To do: Upper-air verification & additional periods
Summary (cont’d)

• MPAS Testing and Implementation in AMPS: Caveats
  – Setups not identical: Compute and model constraints
    ♦ MPAS resolution coarser than WRF: 15 km v. 10 km
    ♦ MPAS physics limited
  – MPAS significantly more expensive than WRF
    ♦ Estimate: MPAS ~6X computational cost of WRF for a 10-km Antarctic mesh
  – Further testing and evaluation necessary
End
Model Physics

MPAS Physics

(i) Uses a narrow set of physics options taken from WRF
(ii) MPAS versions not the latest

Shared Package Areas

- LSM Noah (MPAS V3.3.1, WRF V3.7.1)
- Cu Kain-Fritsch (MPAS V3.5, WRF V3.7.1)
- LW rad RRTMG LW (MPAS V3.4.1, WRF, V3.7.1)
- Surface layer (Eta) (MPAS V3.5, WRF, V3.7.1)

Different Package Areas

- PBL MPAS: YSU WRF: MYJ
- Microphysics MPAS: WSM-6 WRF: WSM-5
- SW rad MPAS: RRTMG WRF: Goddard
Why Voronoi Grids?

- **Lat-Lon Grid Issues**
  - Poor scaling on computers with large numbers $O(10^4 \text{–} 10^5)$ of processors because of necessity of a polar filter
  - Local refinement is limited to nesting or problematic coordinate transformations

- **Advantages of MPAS Grid over Lat-Lon Grid**
  - MPAS scales well on MPP architectures (no poles)
  - MPAS offers flexible local refinement (variable resolution grids)