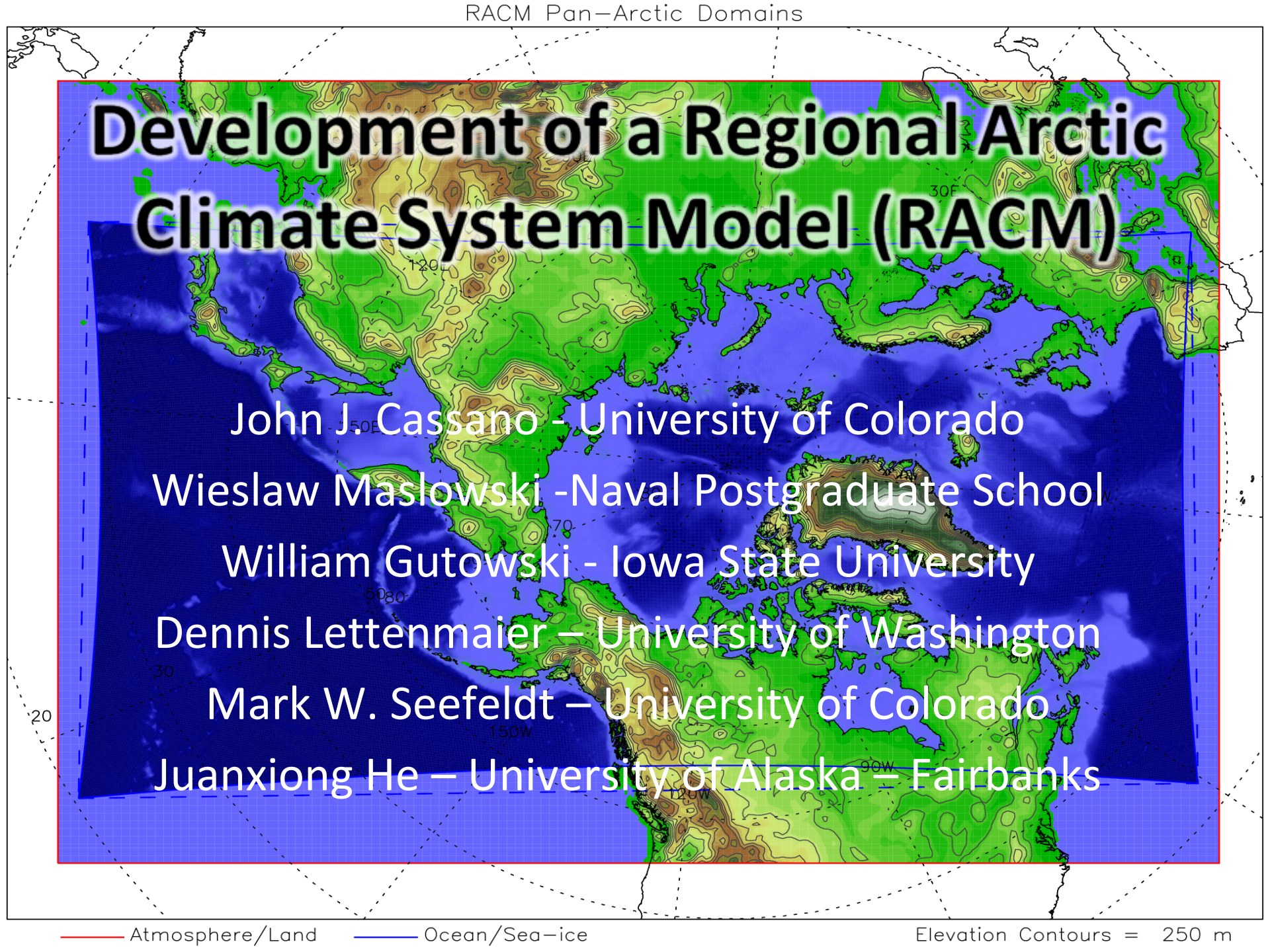

RACM Pan-Arctic Domains
Development of a Regional Arctic Climate System Model (RACM)
John J. Cassano - University of Colorado
Wieslaw Maslowski -Naval Postgraduate School
William Gutowski - Iowa State University
Dennis Lettenmaier – University of Washington
Mark W. Seefeldt – University of Colorado
Juanxiong He – University of Alaska – Fairbanks
Atmosphere/Land
Ocean/Sea-ice
Elevation Contours = 250 m

Need for Regional Arctic Climate System Model

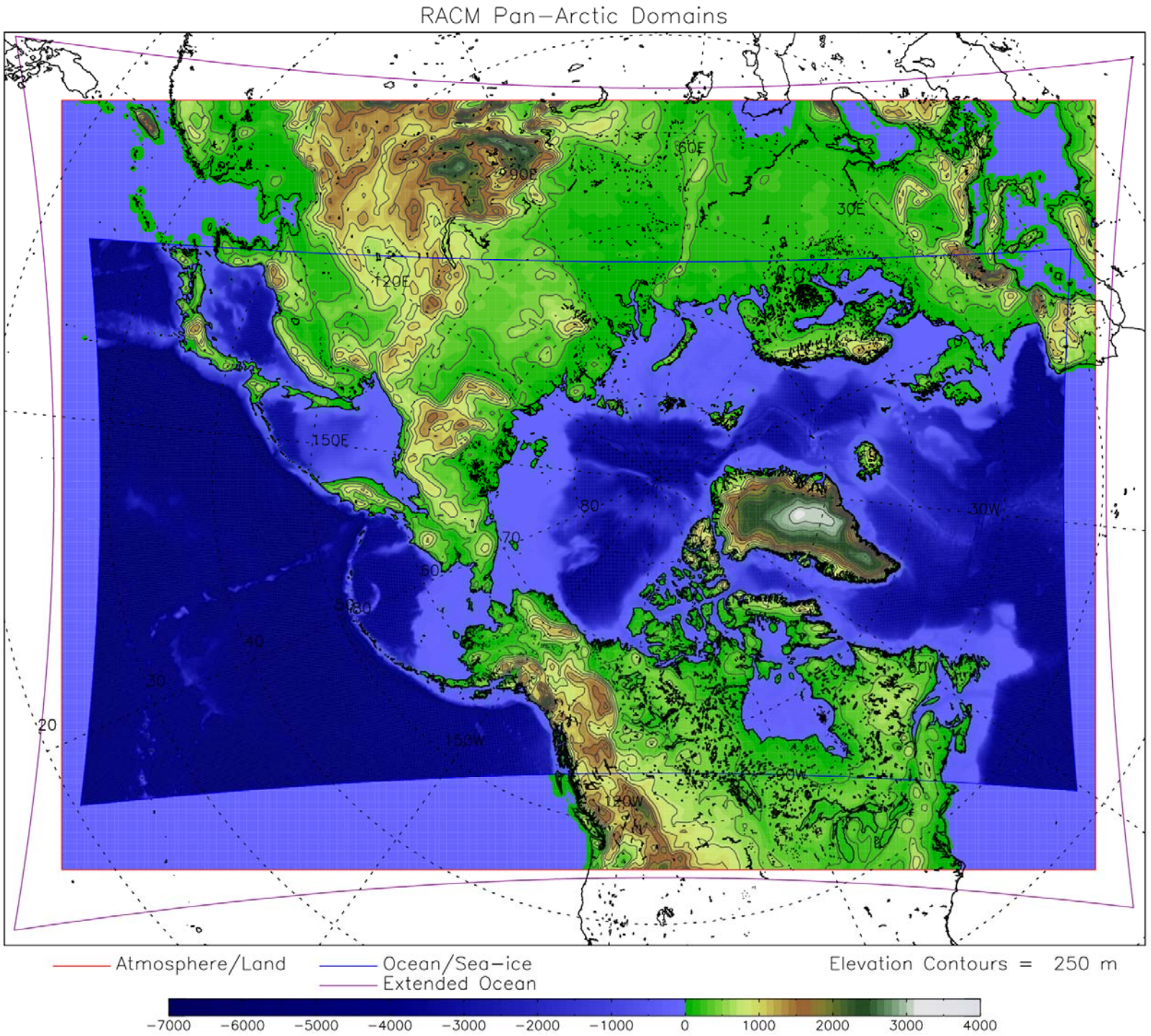
- There are large errors in global climate system model simulations of the Arctic
- Observed rapid changes in Arctic climate system
  - Sea ice decline
  - Greenland ice sheet melt
  - Temperature
- Arctic change has global consequences
  - e.g. Sea ice change can alter the global energy balance and thermohaline circulation

Project Goals

- Develop a state-of-the-science regional Arctic climate system model (RACM)
- Include high resolution model components:
  - Atmosphere (Polar WRF – 50 km)
  - Ocean (POP – 9 km)
  - Sea ice (CICE – 9 km)
  - Land (VIC – 50 km)
- Model components coupled using NCAR CCSM4 coupler (CPL7)

Science Objectives

- Perform multi-decadal simulations to:
  - Gain improved understanding of coupled Arctic climate system processes responsible for changes in
    - Arctic sea ice cover
    - hydrologic cycle
    - freshwater export
  - Improve predictions of Arctic climate change
  - Identify limitations and physical and numerical requirements of global climate system model simulations of Arctic


RACM Pan-Arctic Domains
60E
90E
30E
120E
150E
80
30W
70
60
50
40
30
20
150W
120W
90W
Atmosphere/Land
Ocean/Sea-ice
Extended Ocean
Elevation Contours = 250 m
-7000
-6000
-5000
-4000
-3000
-2000
-1000
0
1000
2000
3000
4000

Accomplishments to Date

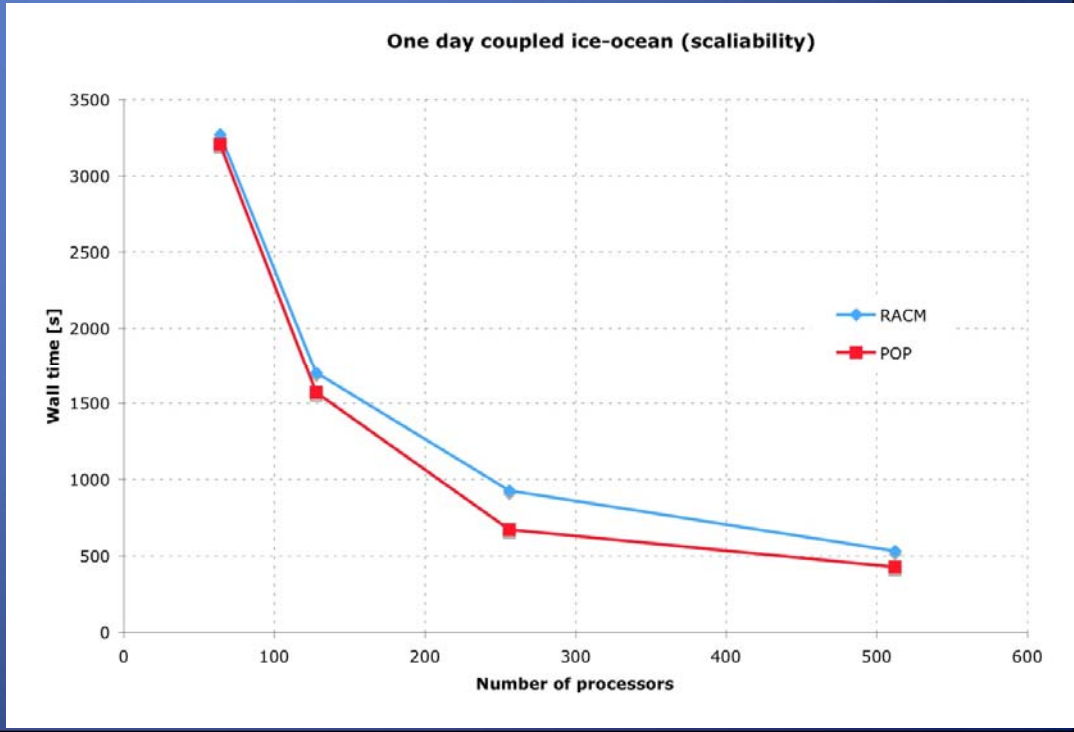
- 2nd year of 4 year DOE funded project
- Coupling of individual model components to CPL7
- Model component evaluation studies
  - Polar WRF development and climatology
  - Simulation of sea ice loss with POP/CICE
  - Oceanic heat transport

Coupling of VIC and CPL7

- Led by Dennis Lettenmaier and Chunmei Zhu with Tony Craig
- Currently have VIC coupled to CPL7
- Have completed experiments with VIC coupled to CAM for global domain
- Next step is to resolve issues with regional domain for VIC / atmosphere simulations

Coupling of POP / CICE with CPL7

- Led by Wieslaw Maslowski, Jaromir Jakacki, Gabriele Jost, and Tony Craig
- POP/CICE successfully runs with CPL7 in “data” mode
- Found minimal additional computational cost using CPL7



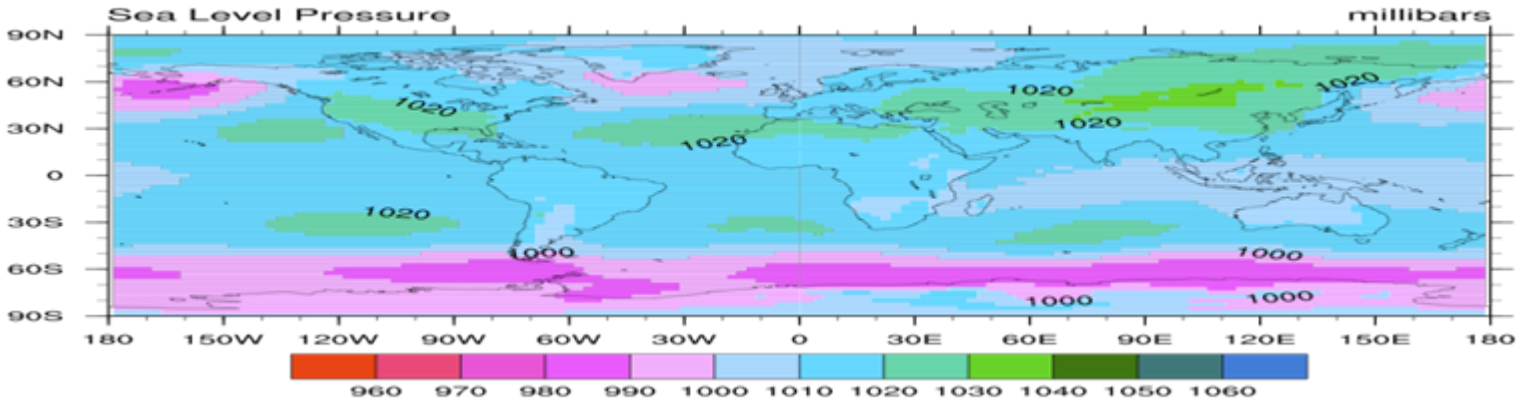
Coupling of WRF and CPL7

- Led by Juanxiong He with contributions from Tony Craig and Mark Seefeldt
- Minimize changes to WRF and CPL7
- Add new surface routine to WRF to accept fluxes from CPL7
- Currently WRF/CPL7 working in global and regional domain configurations
- Next step is to implement regional domain coupling with all other component models

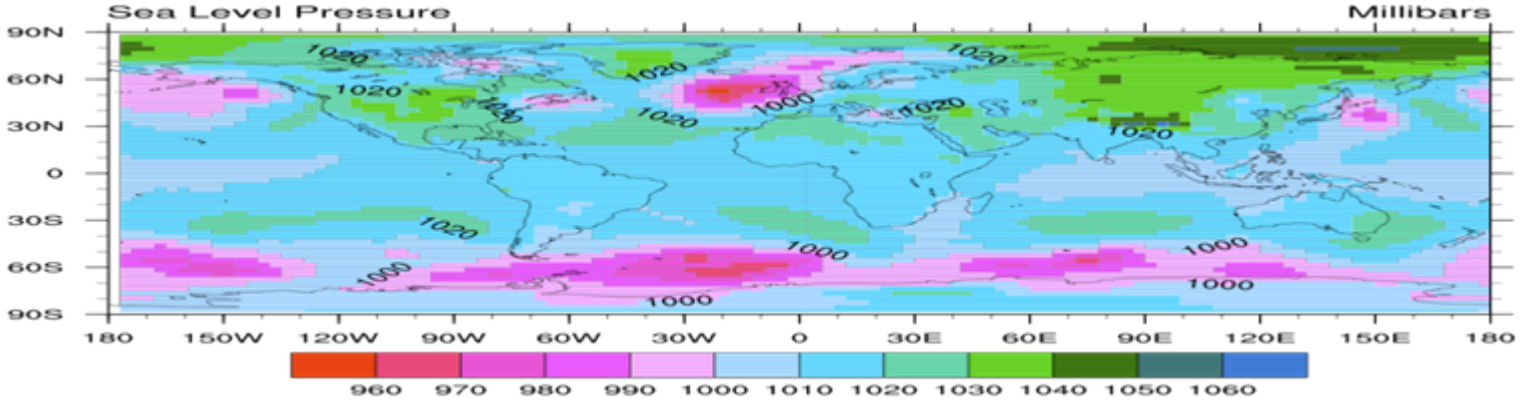
Coupling of WRF and CPL7

- Variables passed from WRF to CPL7
  - PBL height
  - Zonal and meridional wind
  - Surface pressure, SLP
  - Potential temperature
  - Density
  - Humidity
  - SWD (NIR and Visible, direct and diffuse)
  - LWD
  - Convective and large scale precip, snow
- Variables passed to WRF from CPL7
  - Sensible heat
  - Latent heat
  - Zonal and meridional wind stress
  - LWU
  - Albedo (NIR and VIS, direct and diffuse)
  - Tsfc, T2m, q2m
  - SST
  - Snow depth
  - Sea ice and land mask

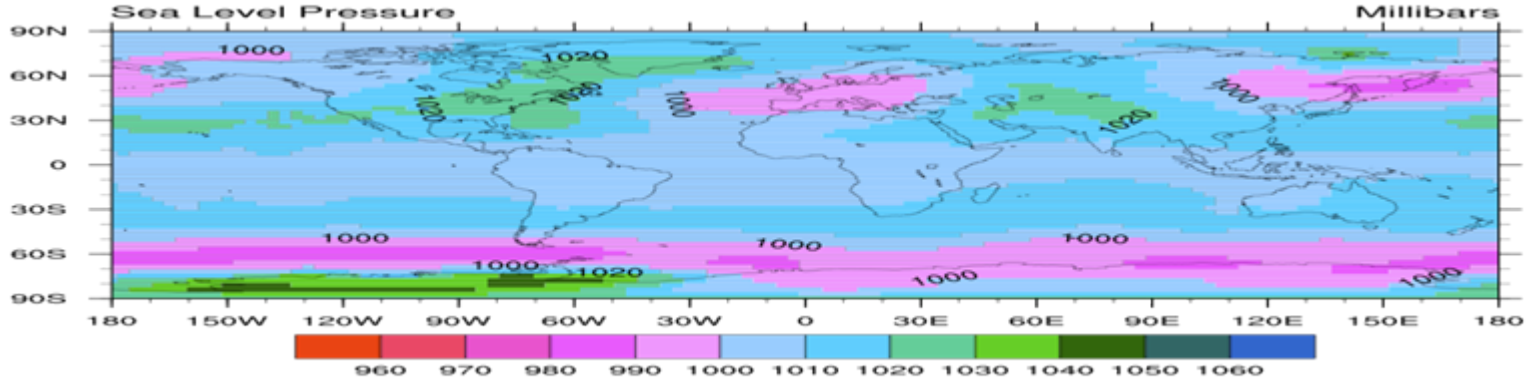
Sea level Pressure (January)



Re-analysis



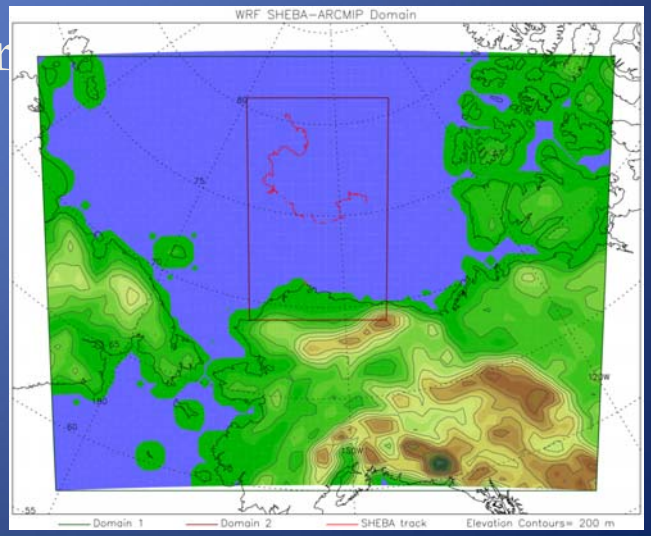
Coupling



WRF alone

Barrow / SHEBA WRF Evaluations

- Goal: identify preferred radiation and microphysics parameterizations
  - radiation – 5 combinations (lw-sw): RRTM-Dudhia, RRTM-Goddard, RRTM-CAM, CAM-Goddard, CAM-CAM
  - microphysics – 6 schemes: Lin, WSM5, WSM6, Goddard, Thompson, Morrison
- Observations: Barrow (BSRN), SHEBA (surface met, clouds)
- Evaluate: temp., pres., SW_d, LW_d, LWP (SHEBA), IWP (SHEBA)
- Evaluate: over different months: Januar
- Evaluate: 10 km versus 50 km domain



Seefeldt and Cassano – P2B.13

Shortwave and Longwave Radiation Rankings

Shortwave Downward

Total		avg
1	lw_3-sw_3-mp_7	5.93
2	lw_3-sw_3-mp_6	7.24
3	lw_3-sw_3-mp_4	7.29
4	lw_1-sw_3-mp_7	8.39
5	lw_3-sw_3-mp_2	8.51
6	lw_1-sw_3-mp_4	8.72
7	lw_1-sw_3-mp_2	8.96
8	lw_1-sw_3-mp_6	10.46
9	lw_1-sw_2-mp_7	10.54
10	lw_3-sw_2-mp_7	10.89
11	lw_3-sw_2-mp_6	13.01
12	lw_3-sw_2-mp_4	13.54
13	lw_1-sw_2-mp_4	14.15
14	lw_1-sw_2-mp_2	14.17
15	lw_1-sw_3-mp_8	14.21
16	lw_3-sw_3-mp_8	14.39
17	lw_3-sw_2-mp_2	14.94
18	lw_1-sw_2-mp_6	15.17
19	lw_1-sw_2-mp_8	16.54
20	lw_3-sw_2-mp_8	17.42
21	lw_1-sw_2-mp_10	18.15
22	lw_3-sw_2-mp_10	19.14
23	lw_3-sw_3-mp_10	19.75
24	lw_1-sw_1-mp_2	20.56
25	lw_1-sw_3-mp_10	21.35
26	lw_1-sw_1-mp_6	25.17
27	lw_1-sw_1-mp_4	25.17
28	lw_1-sw_1-mp_7	25.47
29	lw_1-sw_1-mp_8	26.69
30	lw_1-sw_1-mp_10	29.00

- The CAM-CAM (3-3) radiation combination shows consistently the best performance
- Overall, the CAM-Goddard (3-2) and RRTM-CAM (1-3) radiation schemes perform well
- The RRTM-Dudhia (1-1) and RRTM-Goddard radiation combinations do not do well
- The microphysics results are all over the place and inconclusive

Longwave Downward

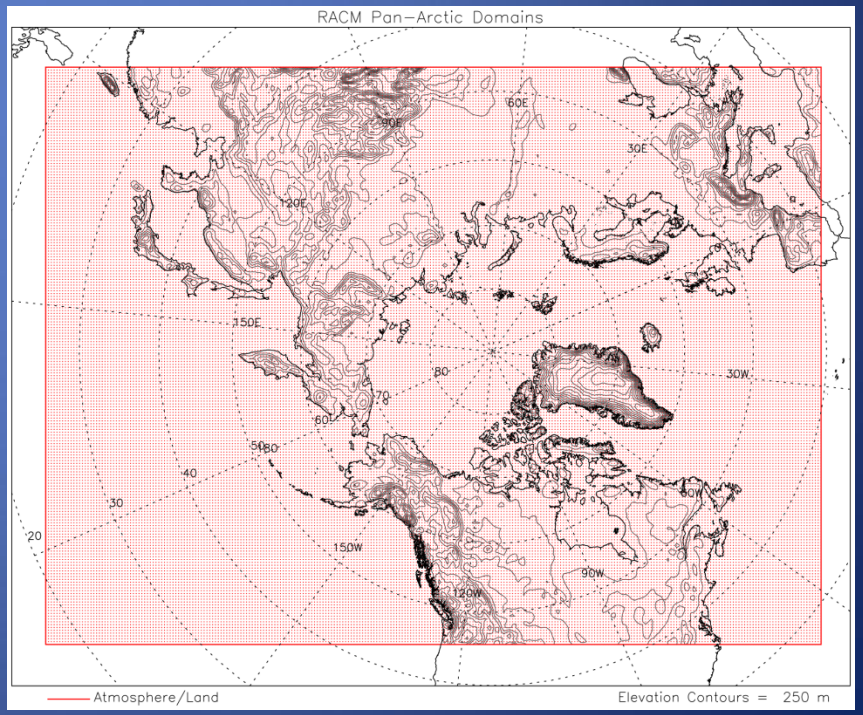
Total		avg
1	lw_3-sw_2-mp_7	10.20
2	lw_3-sw_2-mp_8	10.42
3	lw_3-sw_3-mp_7	11.40
4	lw_1-sw_1-mp_4	11.80
5	lw_1-sw_1-mp_2	12.01
6	lw_1-sw_1-mp_8	12.05
7	lw_1-sw_1-mp_6	12.19
8	lw_1-sw_1-mp_7	12.41
9	lw_3-sw_3-mp_8	12.51
10	lw_3-sw_2-mp_10	12.87
11	lw_3-sw_2-mp_6	13.73
12	lw_3-sw_3-mp_10	13.96
13	lw_1-sw_3-mp_2	14.11
14	lw_3-sw_2-mp_4	14.42
15	lw_1-sw_3-mp_4	14.66
16	lw_3-sw_3-mp_4	14.83
17	lw_1-sw_3-mp_7	14.90
18	lw_1-sw_2-mp_2	14.92
19	lw_3-sw_3-mp_6	15.30
20	lw_1-sw_2-mp_6	15.31
21	lw_1-sw_2-mp_8	15.32
22	lw_3-sw_2-mp_2	15.40
23	lw_3-sw_3-mp_2	15.42
24	lw_1-sw_2-mp_4	15.69
25	lw_1-sw_3-mp_6	16.00
26	lw_1-sw_3-mp_8	16.07
27	lw_1-sw_1-mp_10	16.35
28	lw_1-sw_2-mp_7	16.74
29	lw_1-sw_2-mp_10	18.51
30	lw_1-sw_3-mp_10	20.12

Key	lw_1-sw_1: RRTM-Dudhia	lw_1-sw_2: RRTM-Goddard	lw_1-sw_3: RRTM-CAM	lw_3-sw_2: CAM-Goddard	lw_3-sw_3: CAM-CAM	
	mp_2: Lin	mp_4: WSM5	mp_6: WSM6	mp_7: Goddard	mp_8: Thompson	mp_10: Morrison

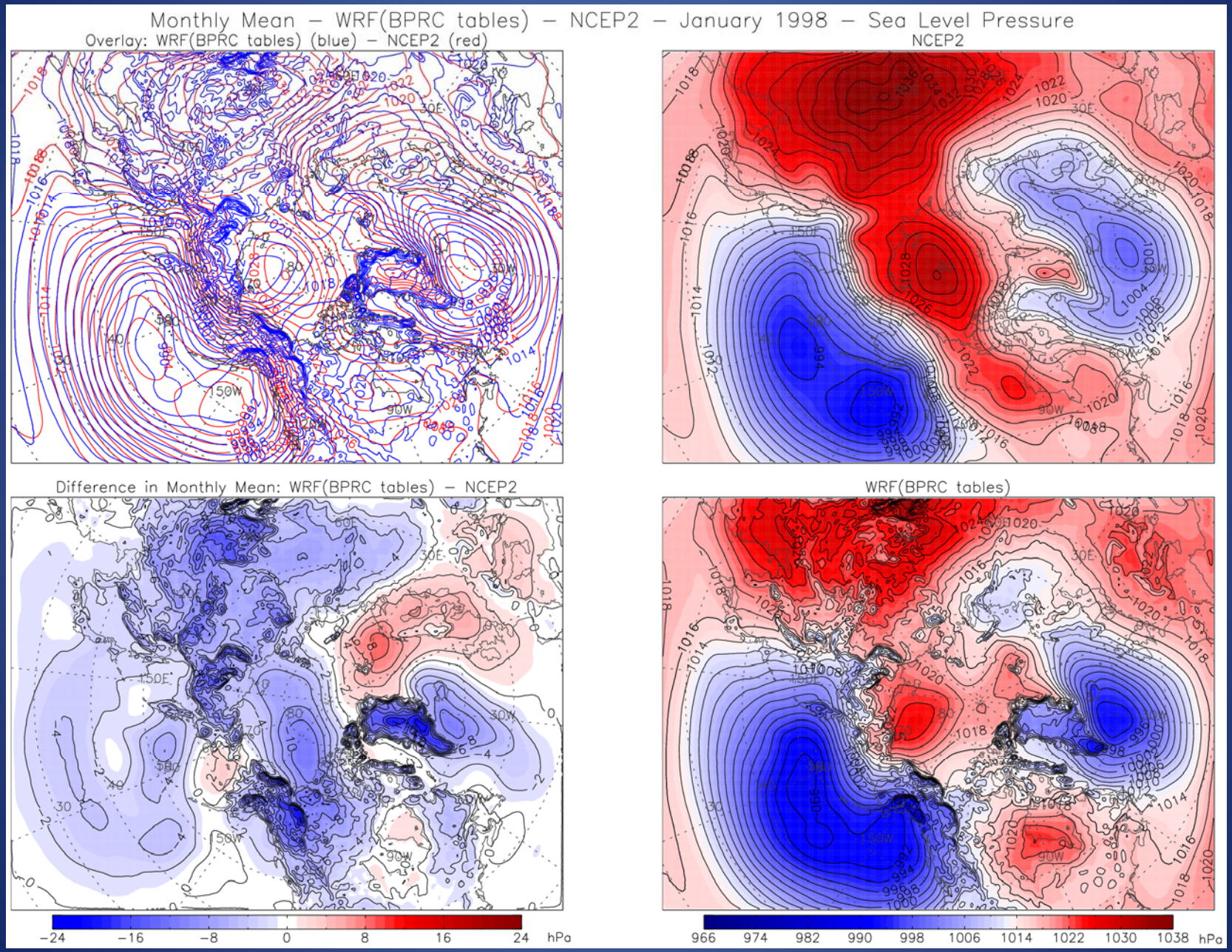
WRF Pan-Arctic Simulations

- WRF 3.0.1.1 - ARW dynamical core (native WRF code)
- Model forcing: NCEP2
- Horizontal domains: 50 km (wr50a)
- Vertical: 31 levels, 50 mb top
- 31-day simulations for January 1998
- Physics parameterizations:

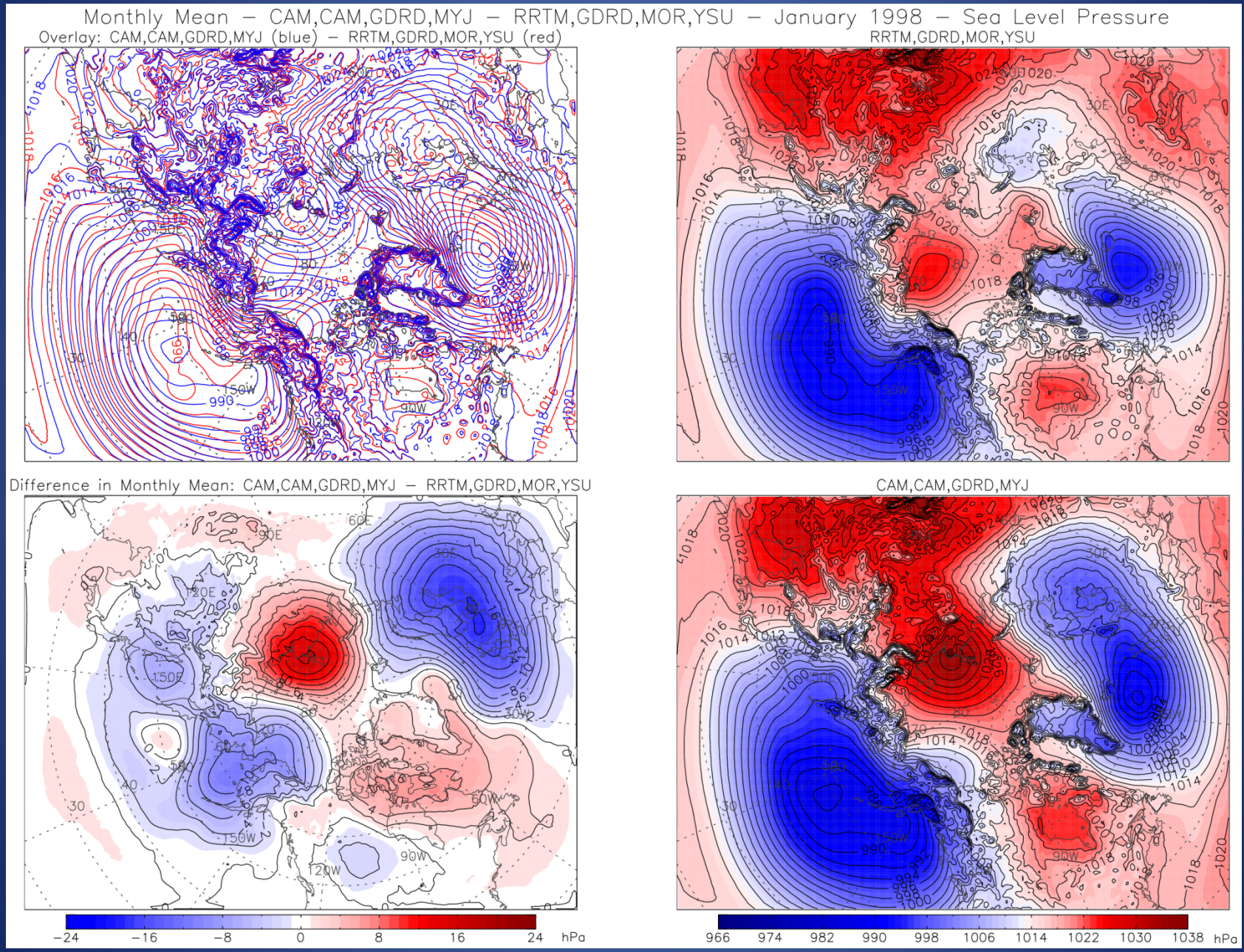
Longwave Rad.: CAM (3)
Shortwave Rad.: CAM (3)
Microphysics: Goddard (7)
Cumulus: G-D (3)
Boundary Layer: MYJ (2)
Land surface: Noah (3)



WRF Pan-Arctic Simulations – Sea-Level Pressure



WRF Pan-Arctic Simulations – Sea-Level Pressure



Next Steps

- Finalize component model / CPL7 coupling
- Fully coupled simulations
  - Evaluation of fully coupled model
  - Multi-decadal simulations
    - Retrospective
    - Future climate
- Long-term goals
  - Regional simulations for next IPCC report
  - Additional climate system components
    - Ice sheets
    - Biogeochemistry