Use of Prognostic Met Data for NSR Permitting Modeling - Webinar Logistics

- Webinar audio is available via:
  - Your computer speakers (*preferred option*)
  - or by dialing 1-866-299-3188 and using the conference code 9195411850#.
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- A copy of the webinar presentation is available via:
  - https://www3.epa.gov/ttn/scram/appendix_w/2016/MMIF-WebinarPresentation.pdf

- Questions will be accepted through the webinar chat window and answered later in the webinar or offline afterwards.

Prognostic Data in Dispersion Modeling

Development, Guidance, and Evaluation

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US EPA

March 21, 2017

Meteorological Input Types

- Site-Specific
  - Installed meteorological observation tower measuring:
    - Temperature, Wind Speed, Wind Direction, Humidity, Precipitation, Pressure, and Radiation
  - Provides most accurate meteorological information for source location
  - At least 1 year of data required
  - Installation/maintenance costs and data handling/quality control procedures

Meteorological Input Types

- National Weather Service (ASOS)
  - Routinely available and familiar to most users
  - Generally removed from the specific source's location
  - 5 years worth of data required
  - Use of AERMINUTE required to inform 1-minute wind data
  - May not necessarily be the most adequately representative dataset (e.g., complex terrain, distance, etc.)

Meteorological Input Types

- Prognostic Meteorological Data
  - Generated using three-dimensional mesoscale computer models
  - Typically, WRF (Weather Research and Forecasting) or MM5 (5^{th} Generation Penn State/NCAR Mesoscale Model)
  - 3 years data required
  - Representative site-specific or NWS data still preferred over prognostic data

Prognostic Meteorological Data

- Benefits
  - Able to simulate the source location with relative accuracy
    - Retrospective nature bounds models to ground truth
    - Improved representativeness relative to NWS data
  - Provides upper-air data information at source
    - Similar to rawinsode or balloon observations
  - More cost-effective than installing meteorological tower
    - No long-term maintenance costs

Prognostic Meteorological Models

- WRF (developed by NCAR)
  - Primary meteorological model used by EPA
  - Supported across a broad community
    - Continuous updates to parameterizations
  - Capable of modeling across multiple scales (10s of km to 100s of meters)
  - Numerous datasets for input (landuse, observations, etc.)
  - Straightforward evaluation tools (e.g., AMET, METSTAT)

Prognostic Met Generation

- Guidance available from US EPA*
  - Domain Selection
    - Large enough to capture meteorological phenomena and topographic features that impact source location.
  - Resolution
    - 12km horizontal grid spacing typical in attainment demonstrations. Complex terrain or land/water interfaces may require 4km or finer.
  - Time Period
    - Appendix W requires modeling at least three consecutive years, with the three most recent available as preferred.
    - More than observed site-specific data, but less than observed NWS data located away from source area

**Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze, 2014*

Prognostic Met Generation

- Physics Options
  - Convective Parameterization
    - Influence convective rainfall, mixing
  - Planetary Boundary Layer
    - Diagnosis of boundary layer heights
  - Land Surface Models
    - Interactions between ground and lowest 10-20m
- Typically, options would be tailored to specific applications of the model
  - Done using sensitivity analyses to inform best performance

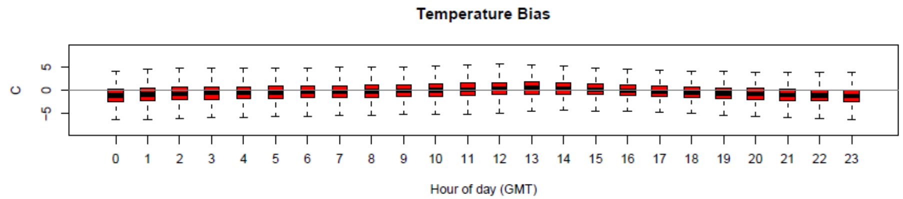
Prognostic Met Generation

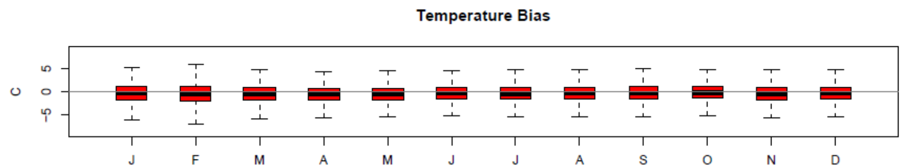
- Input Files
  - Observational Data
    - Four-dimensional data assimilation ingests surface and upper-air observations
    - Works in a way that constrains the model to actual conditions, keeping simulated values within reason
  - Landuse Dataset
    - Typically high-resolution National Landcover Dataset (NLCD) on the order of 30m
    - Includes categories for urban, grasslands, etc.
  - Other Assimilation Techniques
    - Satellite observations, lightning data for convection, sea-surface temperature datasets for near-shore impacts

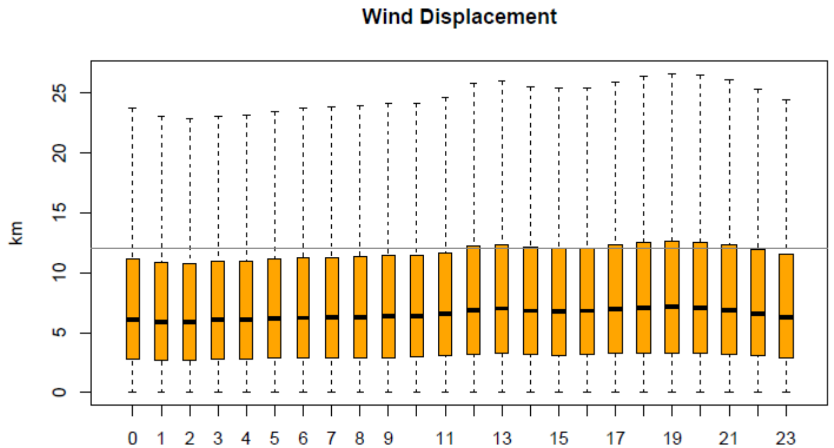
Prognostic Met Evaluation

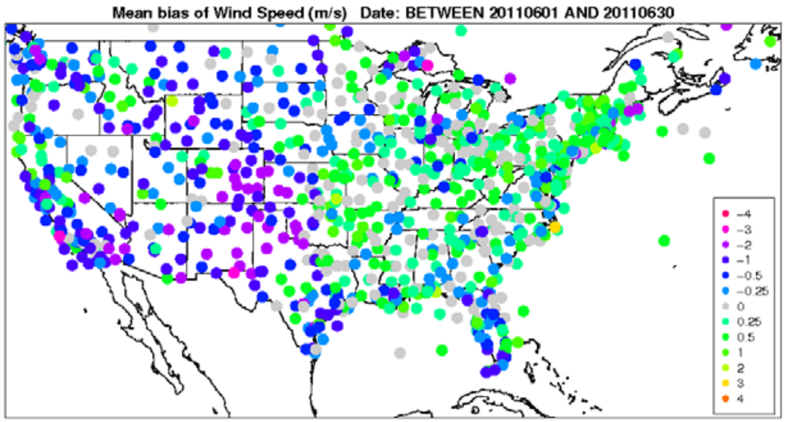
- Per Appendix W (Section 8.4.5.2(a)):
  - *Appropriate effort by the applicant should be devoted to the process of evaluating the prognostic meteorological data. The modeling data should be compared to NWS observational data or other comparable data in an effort to show that the data are adequately replicating the observed meteorological conditions of the time periods modeled.*
- Observational Networks:
  - TDL US and Canada Surface Hourly Observations
  - Cooperative Agency Profilers
  - NOAA Profiler Network
  - State Climate Office observation networks
- Evaluation Methods
  - Quantitative, statistical using mean bias, mean error, or other appropriate statistical technique to determine adequacy
  - Graphical analysis (spatial plots, time series, wind roses)

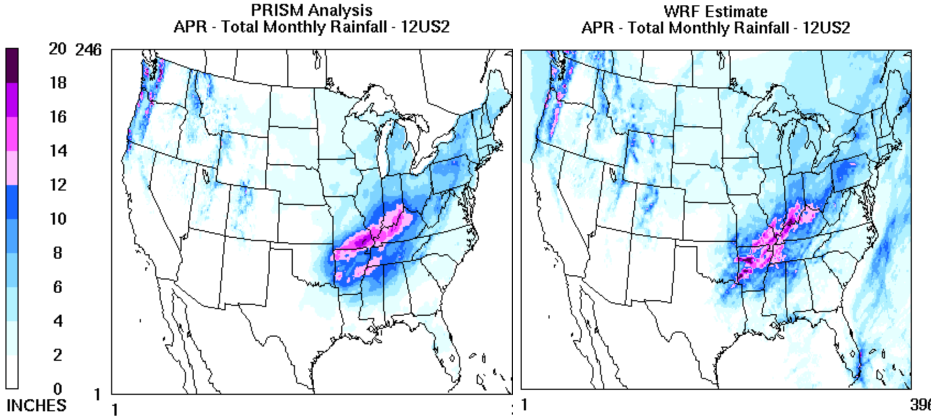
Prognostic Met Evaluation











Prognostic Met Evaluations

- Programs have been developed to aid in evaluation:
  - AMET (Atmospheric Model Evaluation Tool)
    - Developed by US EPA
    - Generally used for meteorological and photochemical simulations
    - Graphical and statistical analyses using a command-line interface
  - METSTAT
    - Developed by Ramboll Environ
    - Performs statistical analysis for temperature, wind speed and direction, and relative humidity
  - Modelers can use these programs and, in concert with reviewing authority, make an effective determination on the adequacy of the prognostic data for use in dispersion applications.

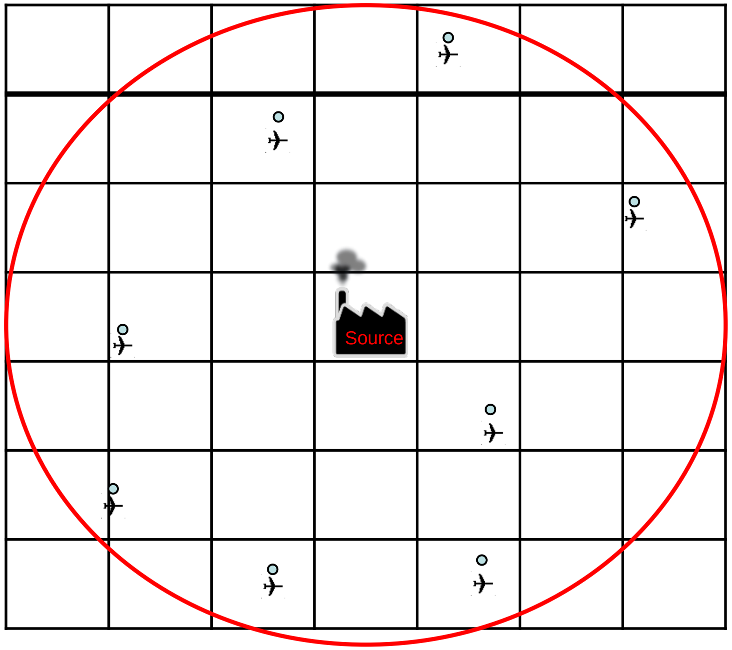
Prognostic Met Evaluations

- EPA is cognizant of the fact that evaluations will be difficult at higher resolutions
  - 1km and finer resolutions may result in few observational sites to compare
- Guidance on performance evaluations likely to evolve over time
  - How many observational sites necessary?
  - What variables most important?
  - Quantitative vs Qualitative?
- Dependent on use of best professional judgement and cooperation with reviewing authority.

Prognostic Met Evaluations

- What if a user has only MMIF outputs and no raw WRF data to evaluate with these tools?
  - In theory, a user may extract MMIF outputs at airport locations within the WRF domain for comparison with airport observations.
  - As an example:

Illustrative purposes only



You’ve got your prognostic data.

Now what?

MMIF

- Mesoscale Model Interface program
  - Developed by Ramboll Environ under direction of US EPA
  - Windows and/or Linux-based environment
  - Capable of generating inputs for AERMET/AERMOD, SCICHEM, and CALPUFF
  - Uses WRF or MM5 simulation data
  - Converts the prognostic data into a format that can then be ingested into AERMOD
    - Does so without altering the data
    - Several options for the user (PBL pass through, vertical layers, etc.)
  - Simple keyword-based namelist

MMIF Installation

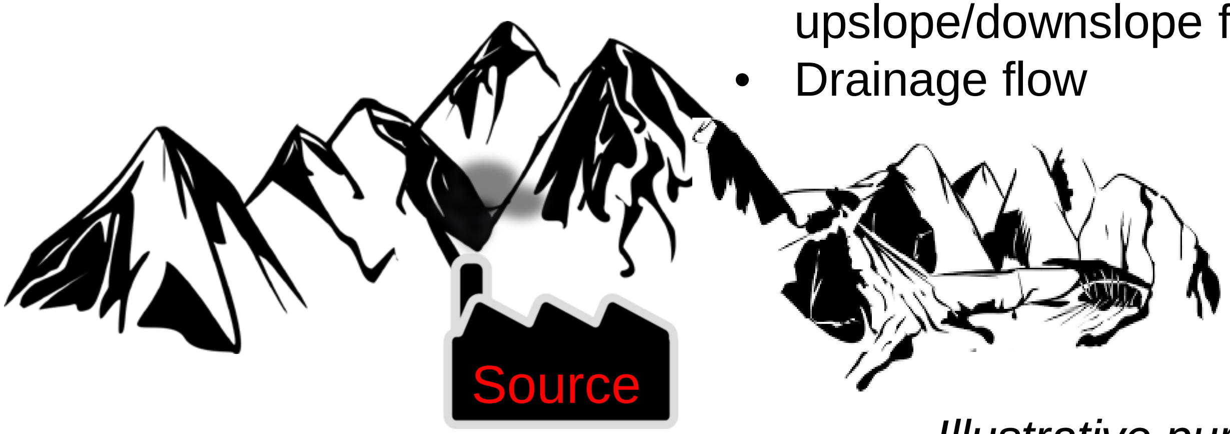
- Windows version comes pre-compiled
  - While available, Windows version not preferred due to difficulties with large datasets
  - Numerous bug reports received by users on Windows machines, primarily due to incorrect compilations
- Linux source code supplied
  - Requires installation of NetCDF libraries compiled with a user's specific FORTRAN compiler (Portland Group, Intel, or GNU)
  - Much more flexible with large datasets and operates on systems generally used to develop WRF/MM5 data
  - Easily edited makefile is provided with the source code to make compilation easier

MMIF

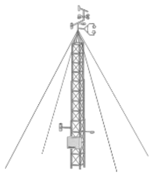
- Appendix W States (Section 8.4.5.1(a)):
  - *For some modeling applications, there may not be a representative NWS or comparable meteorological station available (e.g., complex terrain), and it may be cost prohibitive or infeasible to collect adequately representative site-specific data.*
  - The hierarchy of meteorological input data remains:
    - Site-specific meteorological measurements (1 year)
    - NWS observed meteorological data (5 years)
    - Prognostic meteorological data (3 years)
  - Burden rests with the user to consult with reviewing authority to determine if use of prognostic data is feasible

MMIF Guidance

- When might a NWS station not be adequately representative?
  - Significantly removed, spatially, from source
  - Complex terrain/topographic influences

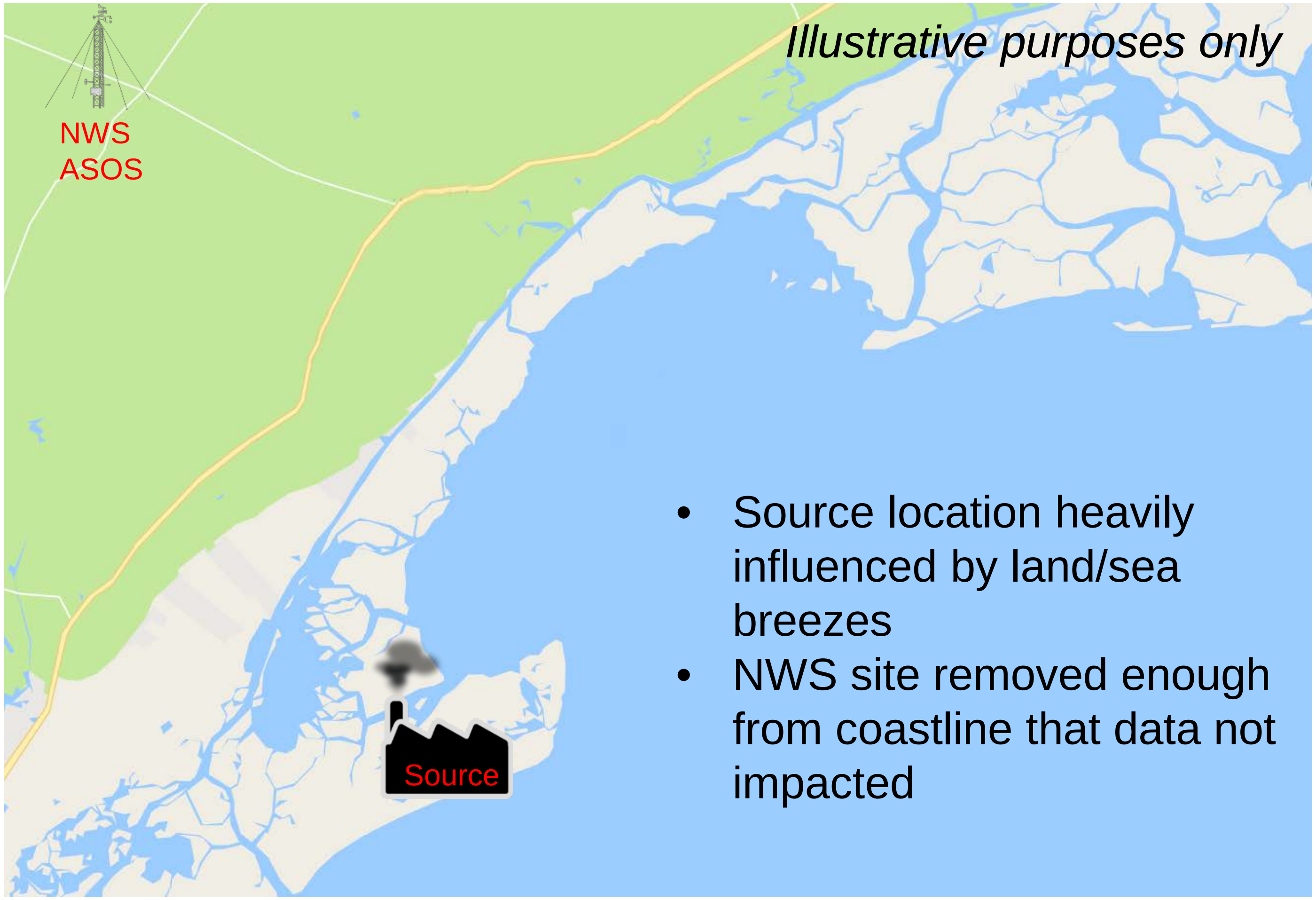


- Source influenced by upslope/downslope flow
- Drainage flow



Illustrative purposes only

MMIF Guidance



- Source location heavily influenced by land/sea breezes
- NWS site removed enough from coastline that data not impacted

MMIF Guidance

- Most input options up to user
- EPA has recommendations on certain keywords
  - OUTPUT
    - Set to 'AERMET'
      - AERMET is the meteorological preprocessor for AERMOD applications (Sections 8.4.2(a) and 8.4.5.1(b) of Appendix W)
      - Allows for use of u* adjustment option
  - LAYERS
    - FLM Guidance of 'TOP' w/ heights of 20, 40, 80, 160, 320, 640, 1200, 2000, 3000, and 4000
    - 'MID' w/ heights at 25, 50, 75, 100, 125, 150, 175, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500, and 5000
      - Mimics the AERMOD vertical structure

MMIF Guidance

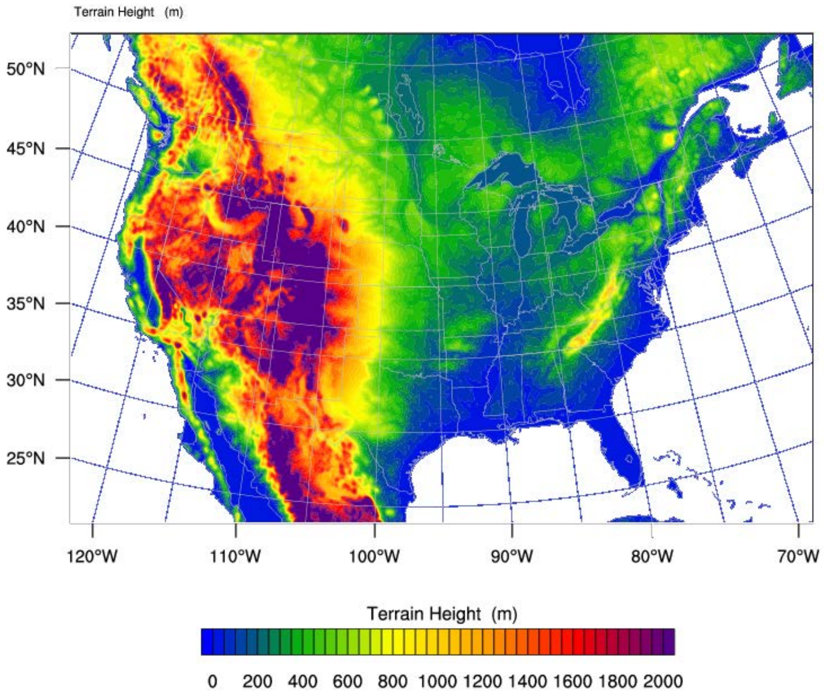
- PBL Options
  - Three options:
    - Use WRF PBL
    - Recalculate PBL height using Bulk Richardson approach
    - None (Use AERMET to generate PBL heights)
  - Discretion is left to the user as to which option is employed
  - EPA evaluations have shown no significant difference in results for any of the approaches
- Grid Cell Representativeness
  - A source may span multiple grid cells in the WRF domain
  - The selected WRF/MMIF grid cell must be adequately representative of the spatial extent of the source domain

EPA Generated MMIF Data

- EPA has created 3 years worth of prognostic meteorological data
  - WRF
    - 12km CONUS simulation
    - Uses a common EPA attainment modeling setup
    - 2013-2015
    - Technical Support Documents (TSDs) created for each simulation outlining performance.
    - User still responsible for performing regional analysis to determine adequacy for source region
    - Requires user to work collaboratively with reviewing authority to determine if prognostic inputs are suitable for particular application.

EPA Generated MMIF Data

- 12km Resolution
  - Most cost-effective resolution for entire country
  - May not be appropriate for all situations
    - Smoothes topographic features
    - May not adequately capture some phenomena
  - Users may find the need to move to finer resolutions
  - Can use 12km WRF data to nest fine domains over area of interest



EPA Generated MMIF Data

- Distribution Process
  - 3 years of WRF data
    - 6TB compressed
  - 3 years of MMIF data
    - 6TB compressed (less efficient ASCII format)
  - Typically, use a hard drive distribution method
  - MJOs have agreed to shepherd data to state agencies, if desired
  - Points of Contact at MJOs/state agencies will help in providing data to a user
  - GIS files are provided as a means to easily identify which cell(s) correspond to source locations

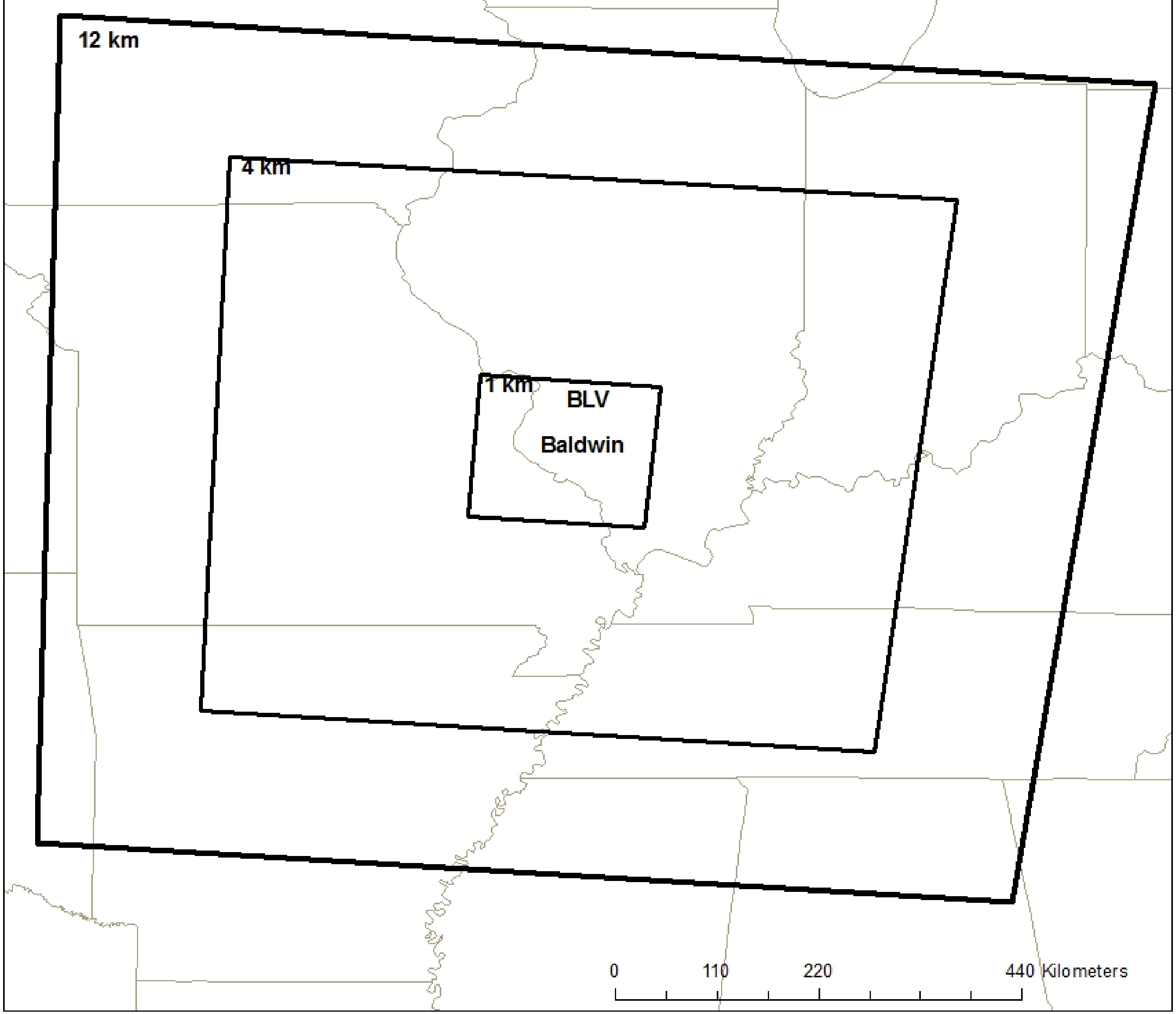
MMIF evaluations

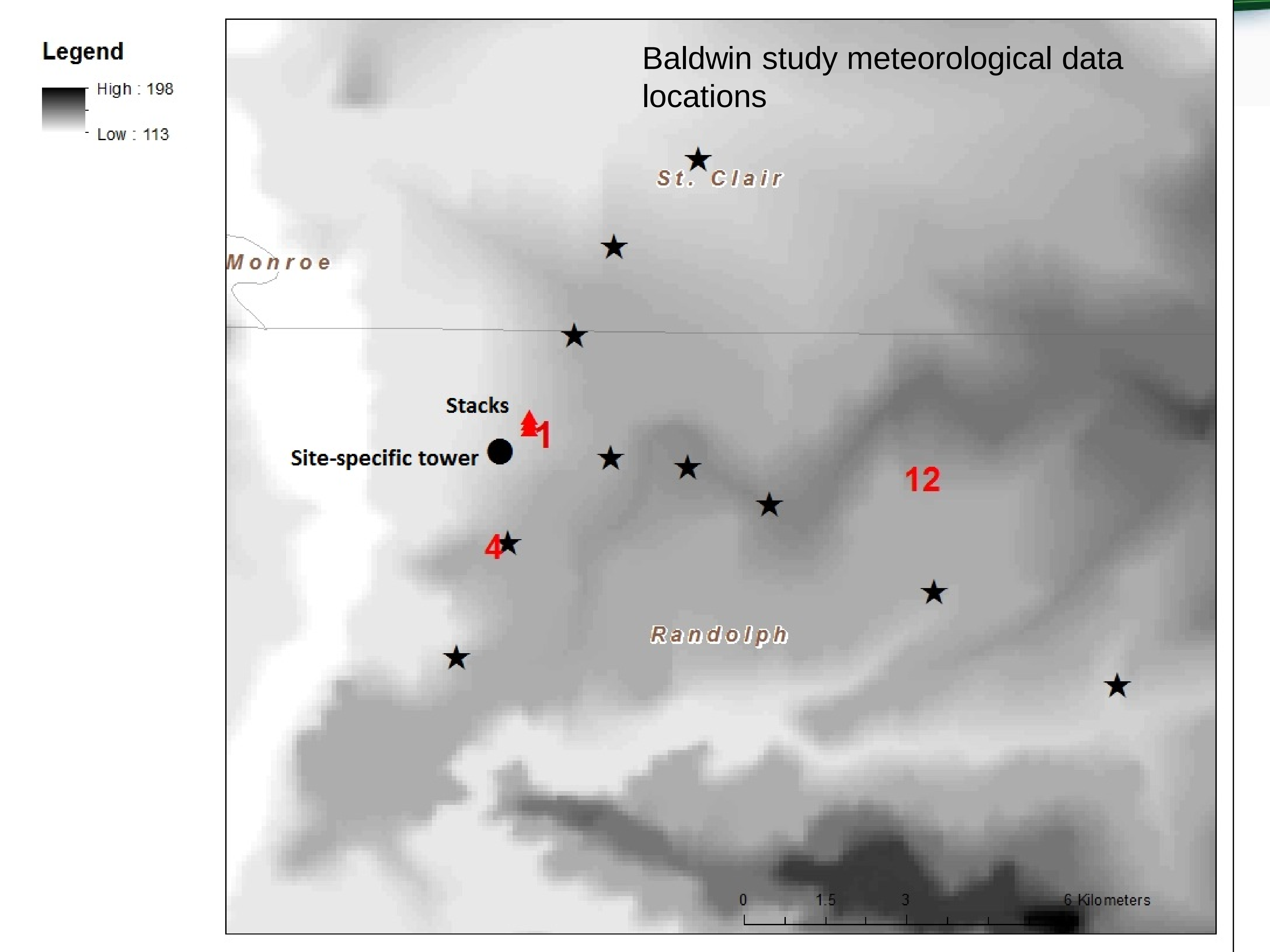
- Baldwin, IL
- Martins Creek, PA
- Compared grid resolution, # of vertical levels from MMIF, PBL pass through, recalculated, and use of AERMET mixing heights using EPA protocol for best performing model
- Details in MMIF evaluation TSD (Appendix C)
  - https://www3.epa.gov/ttn/scram/appendix_w/2016/MMIF_Evaluation_TSD.pdf

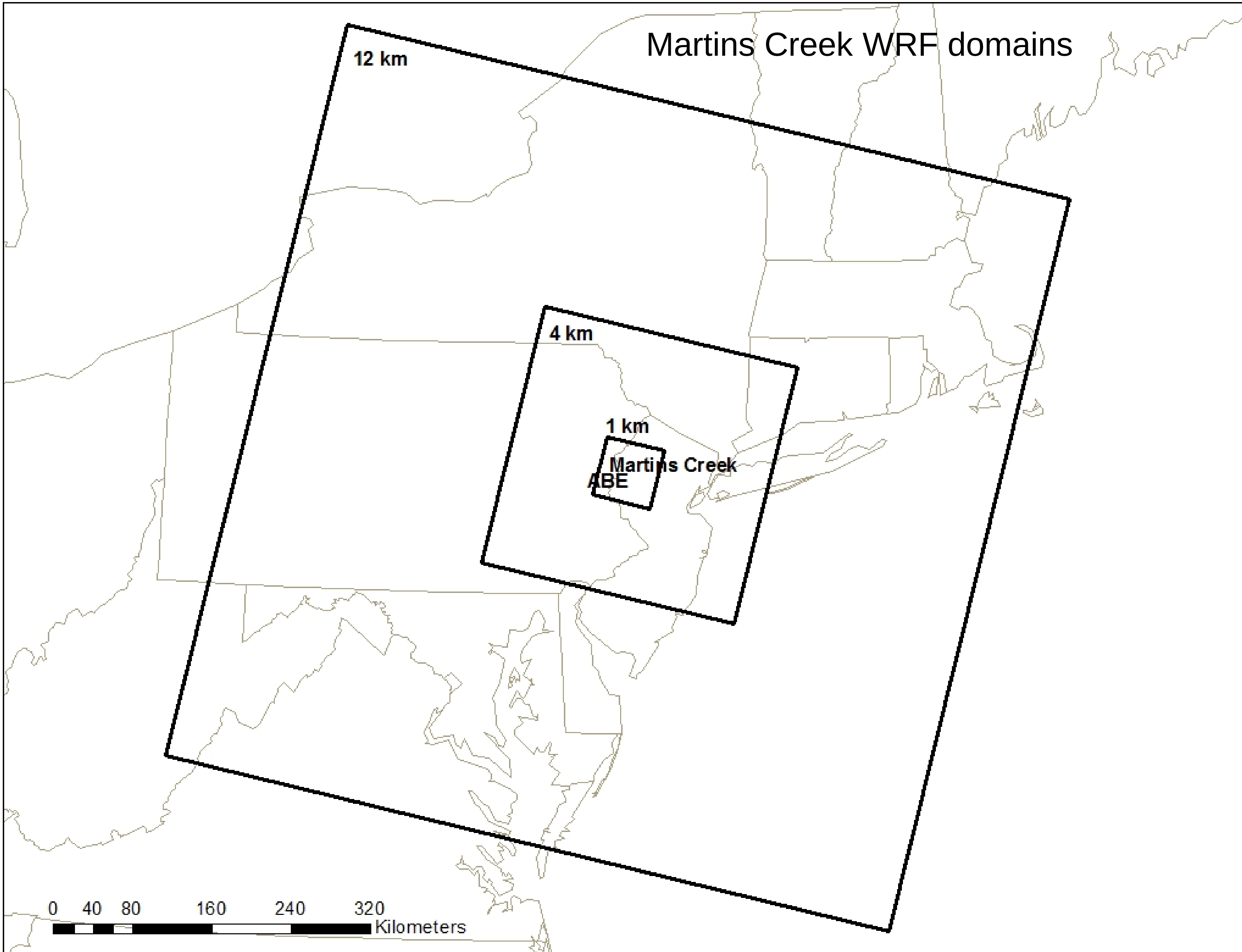
Summary

- Baldwin
  - No clear “winner” for grid resolution
  - PBL recalculation perform better than pass through
  - AERMET mixing heights slightly better
  - Including more levels better than single levels
  - Results not statistically significant
- Martins Creek
  - 12 km better than 4 or 1 km resolution
  - PBL pass through better performer
  - AERMET mixing heights do not perform as well
  - Levels at stack level better performer

Baldwin WRF domains

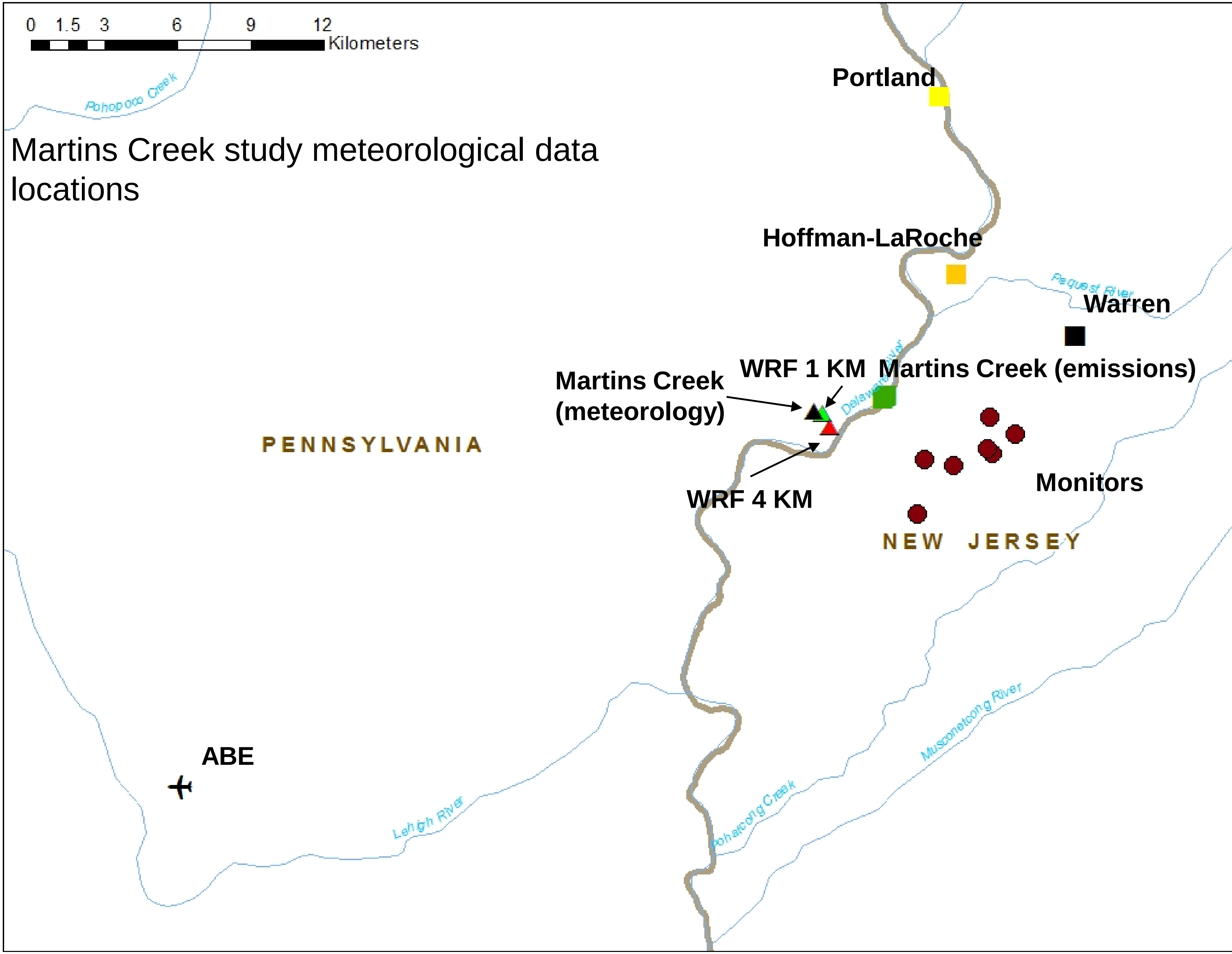


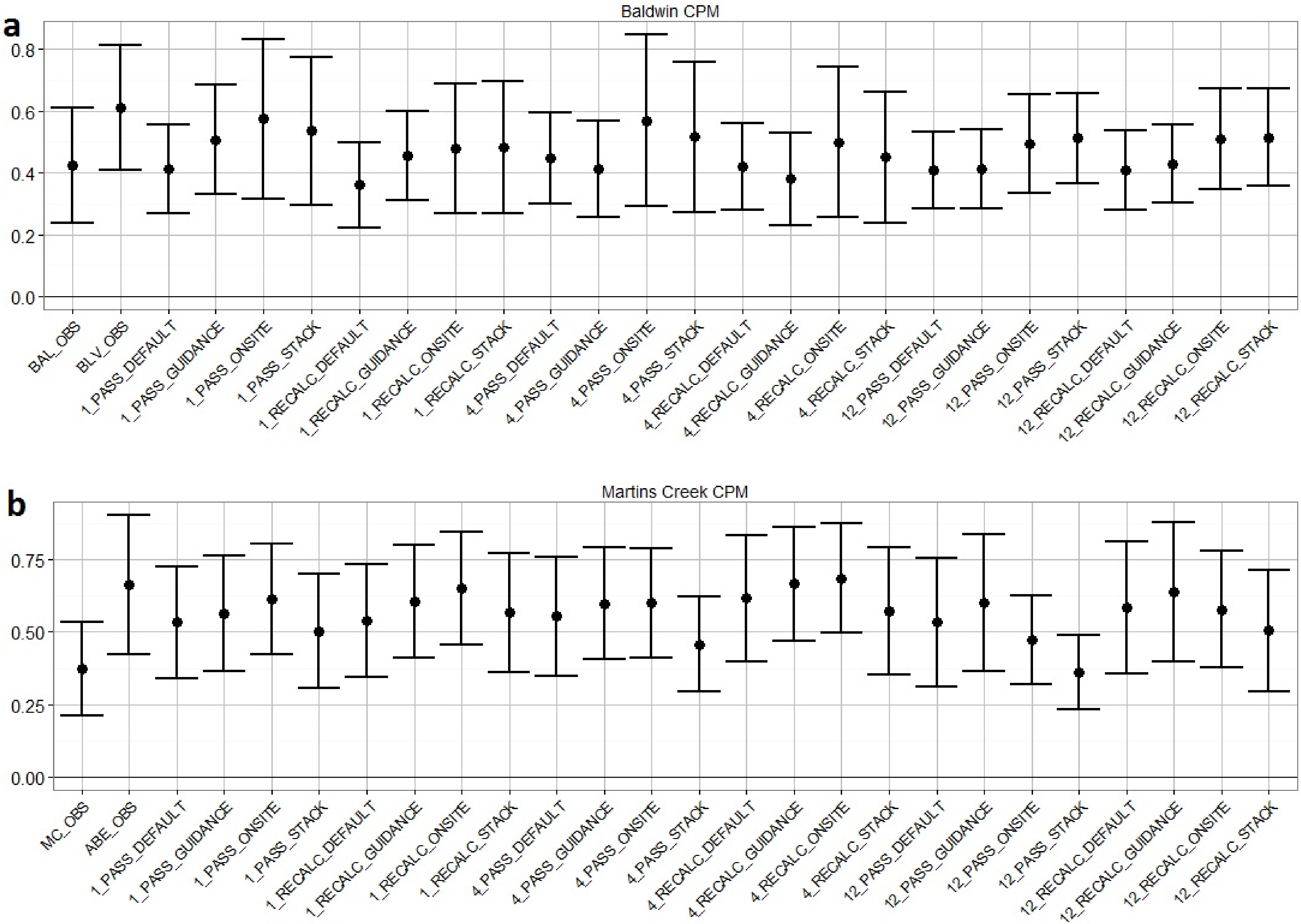

Legend
High : 198
Low : 113
Baldwin study meteorological data locations
St. Clair
Monroe
Stacks
1
Site-specific tower
12
4
Randolph
0
1.5
3
6 Kilometers

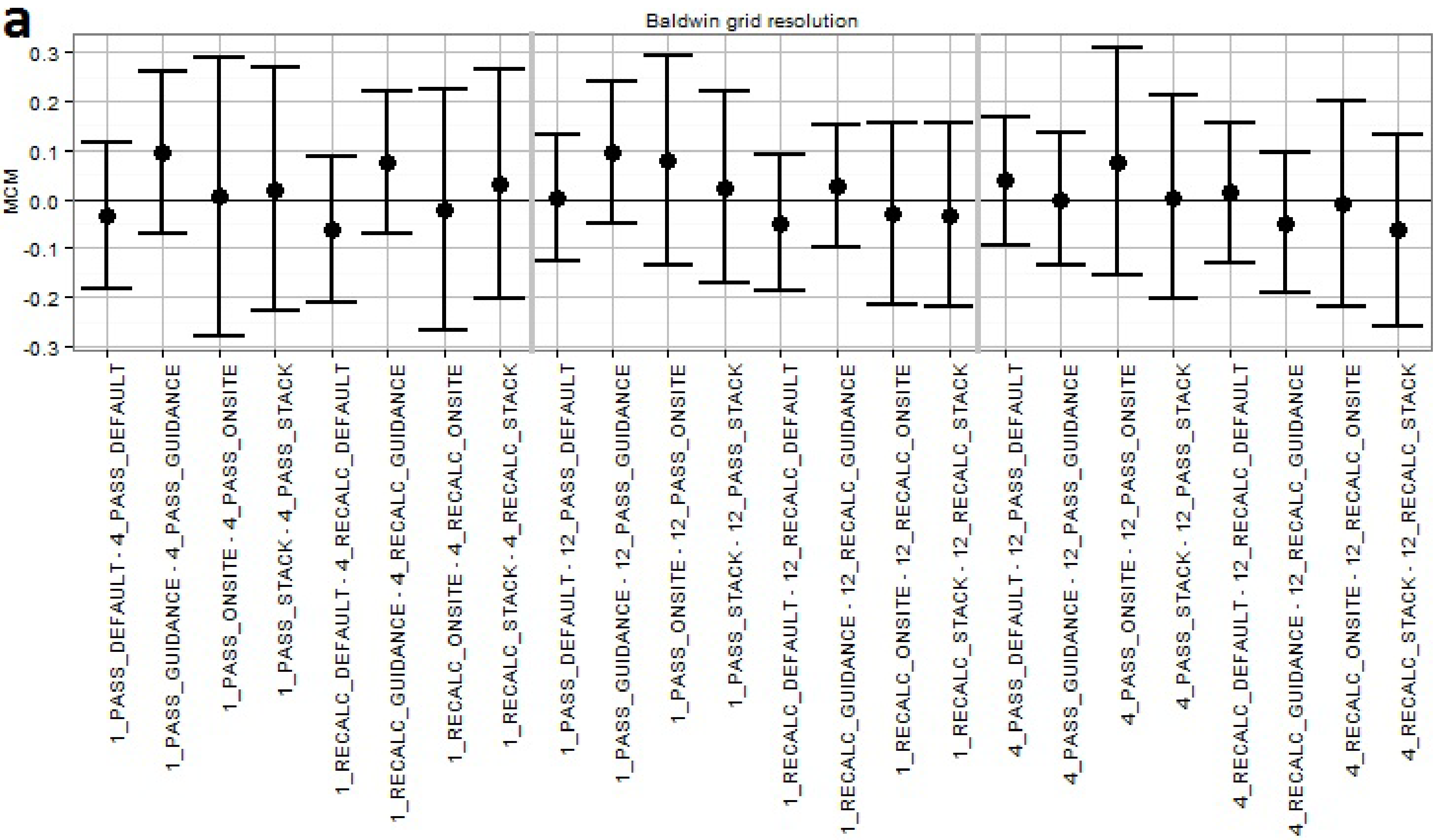


Martins Creek WRF domains
12 km
4 km
1 km
Martins Creek
ABE
0 40 80 160 240 320
Kilometers

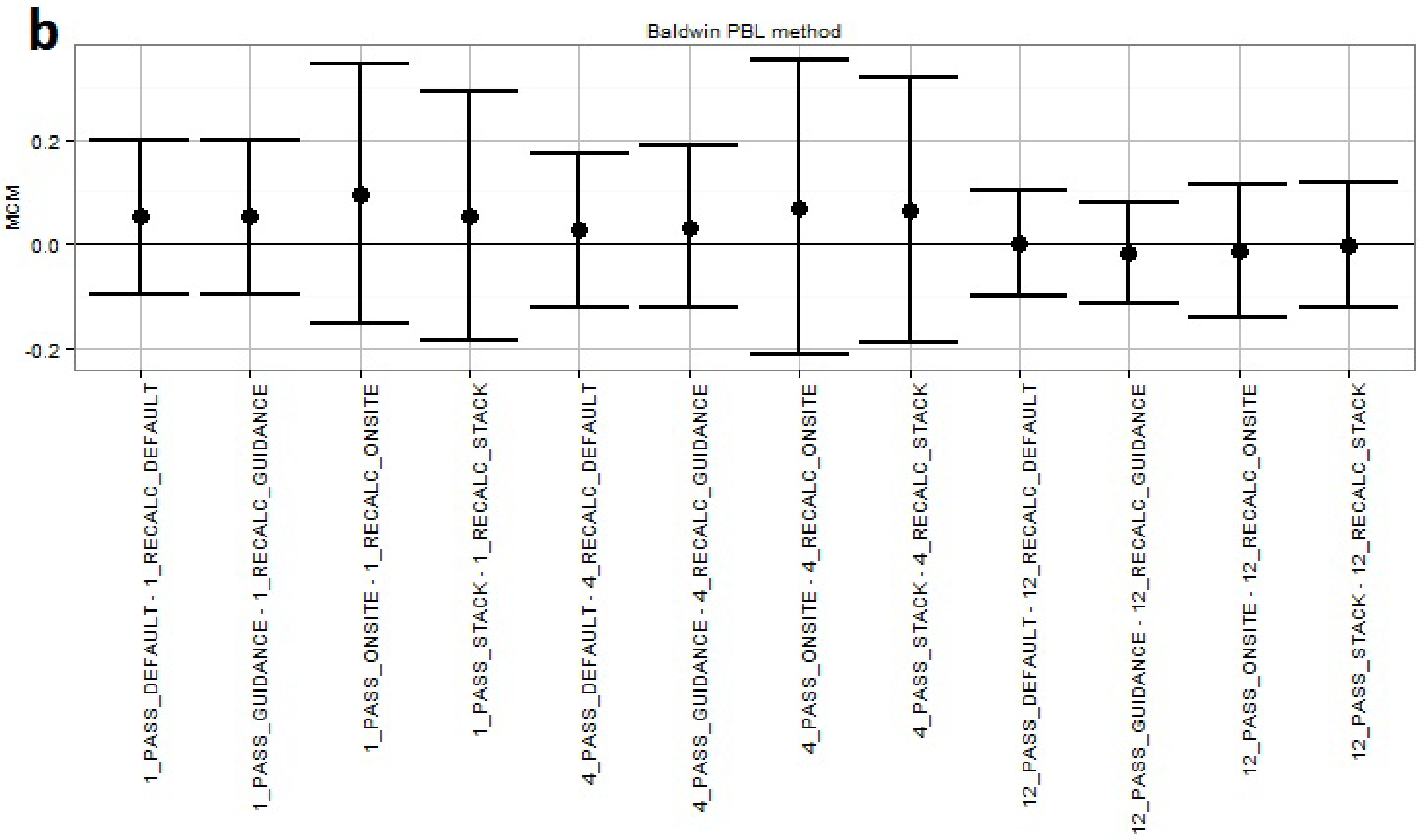
Martins Creek study meteorological data locations



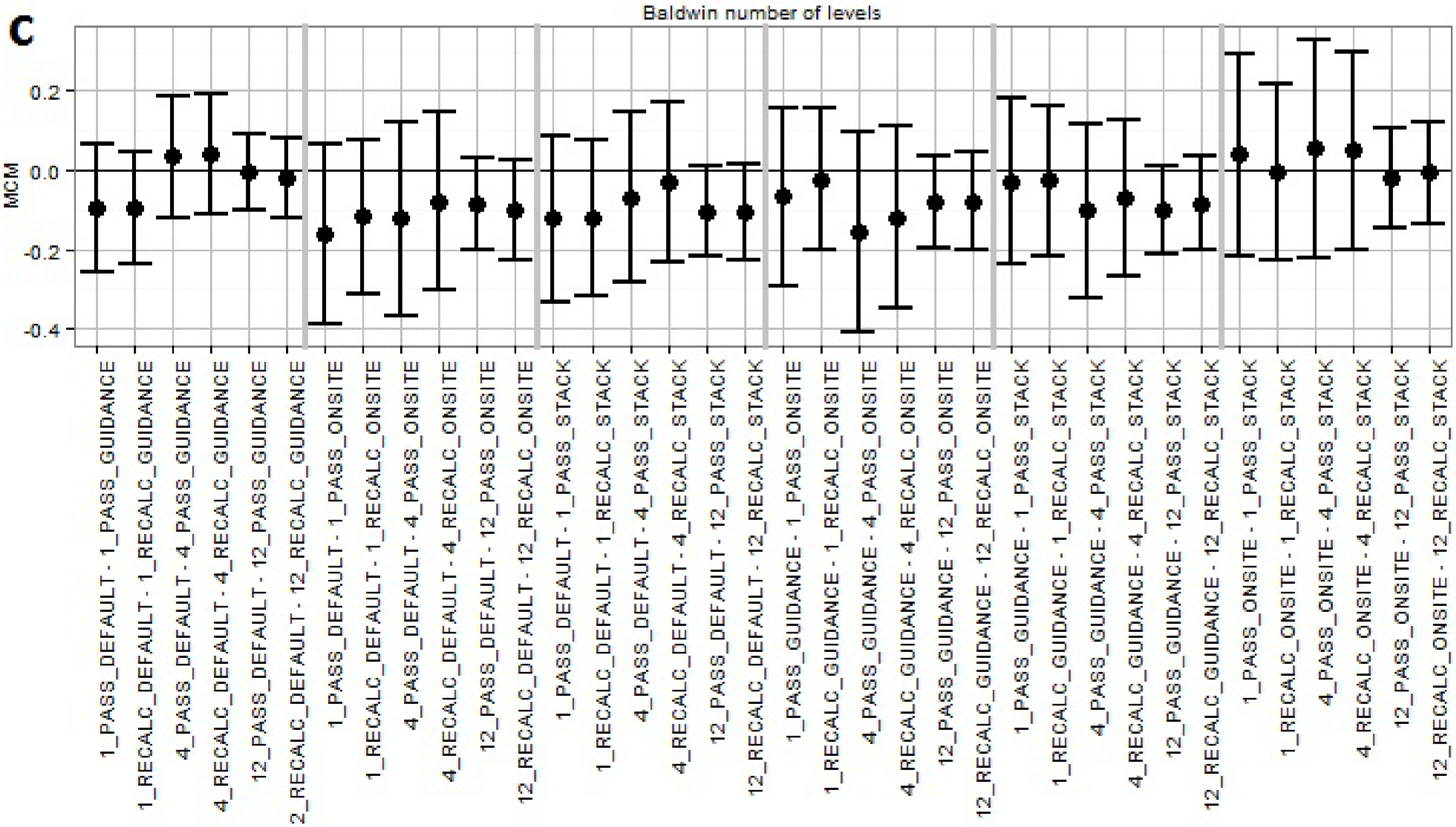

a
Baldwin CPM
0.0
0.2
0.4
0.6
0.8
BAL_OBS
BLV_OBS
1_PASS_DEFAULT
1_PASS_GUIDANCE
1_PASS_ONSITE
1_PASS_STACK
1_RECALC_DEFAULT
1_RECALC_GUIDANCE
1_RECALC_ONSITE
1_RECALC_STACK
4_PASS_DEFAULT
4_PASS_GUIDANCE
4_PASS_ONSITE
4_PASS_STACK
4_RECALC_DEFAULT
4_RECALC_GUIDANCE
4_RECALC_ONSITE
4_RECALC_STACK
12_PASS_DEFAULT
12_PASS_GUIDANCE
12_PASS_ONSITE
12_PASS_STACK
12_RECALC_DEFAULT
12_RECALC_GUIDANCE
12_RECALC_ONSITE
12_RECALC_STACK
b
Martins Creek CPM
0.00
0.25
0.50
0.75
MC_OBS
ABE_OBS
1_PASS_DEFAULT
1_PASS_GUIDANCE
1_PASS_ONSITE
1_PASS_STACK
1_RECALC_DEFAULT
1_RECALC_GUIDANCE
1_RECALC_ONSITE
1_RECALC_STACK
4_PASS_DEFAULT
4_PASS_GUIDANCE
4_PASS_ONSITE
4_PASS_STACK
4_RECALC_DEFAULT
4_RECALC_GUIDANCE
4_RECALC_ONSITE
4_RECALC_STACK
12_PASS_DEFAULT
12_PASS_GUIDANCE
12_PASS_ONSITE
12_PASS_STACK
12_RECALC_DEFAULT
12_RECALC_GUIDANCE
12_RECALC_ONSITE
12_RECALC_STACK



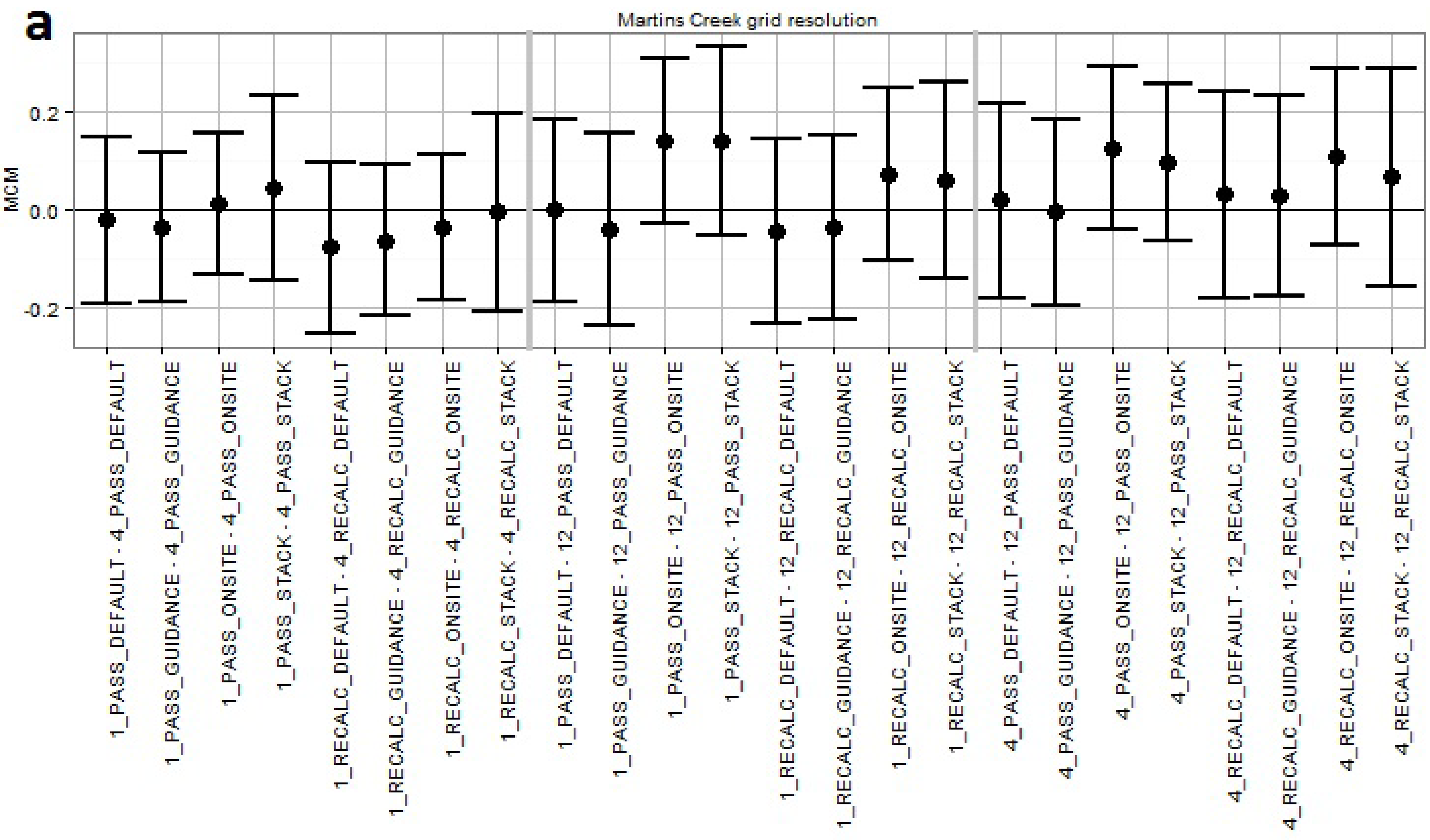
Baldwin grid resolution MCM



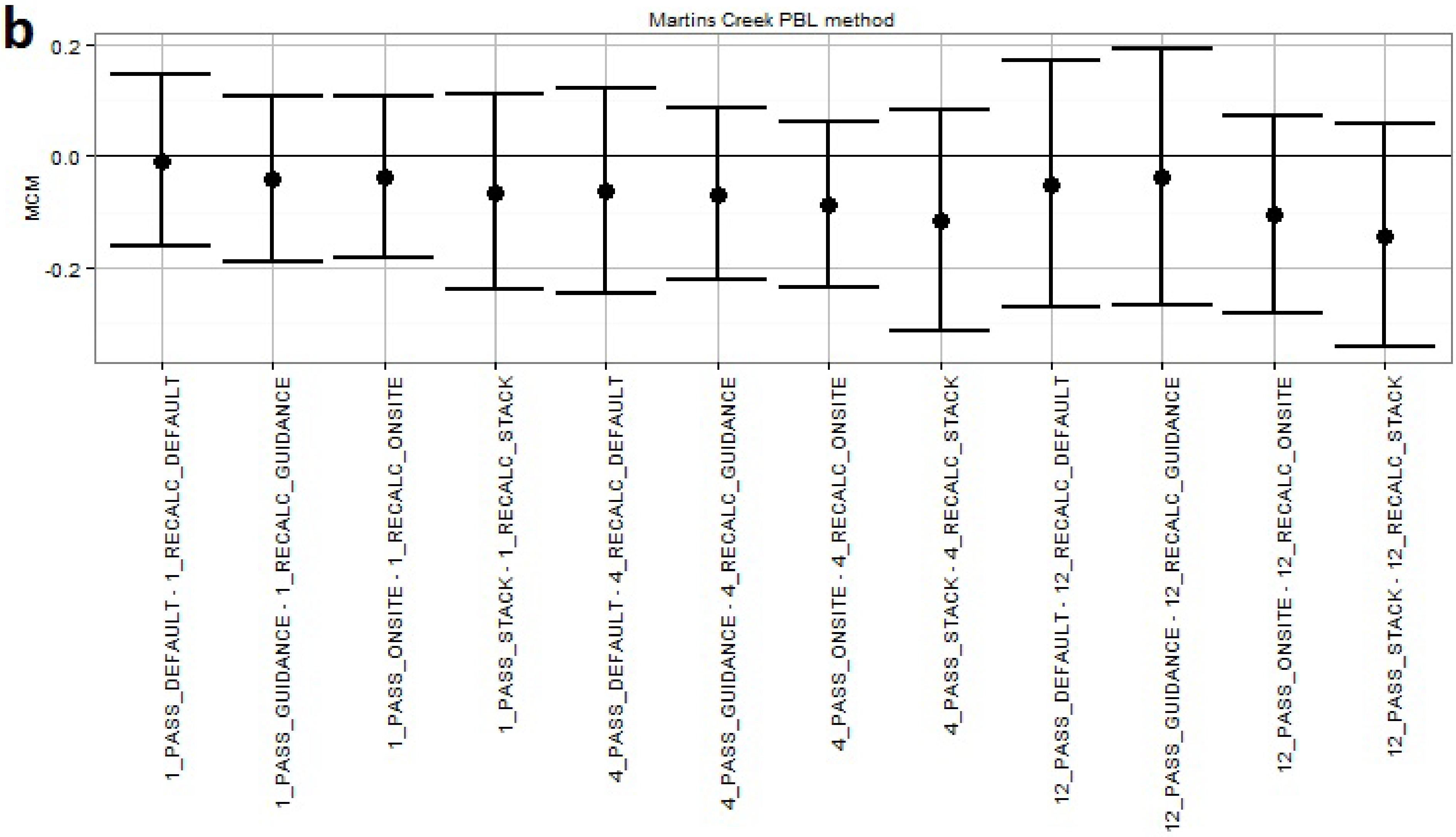
Baldwin PBL method MCM



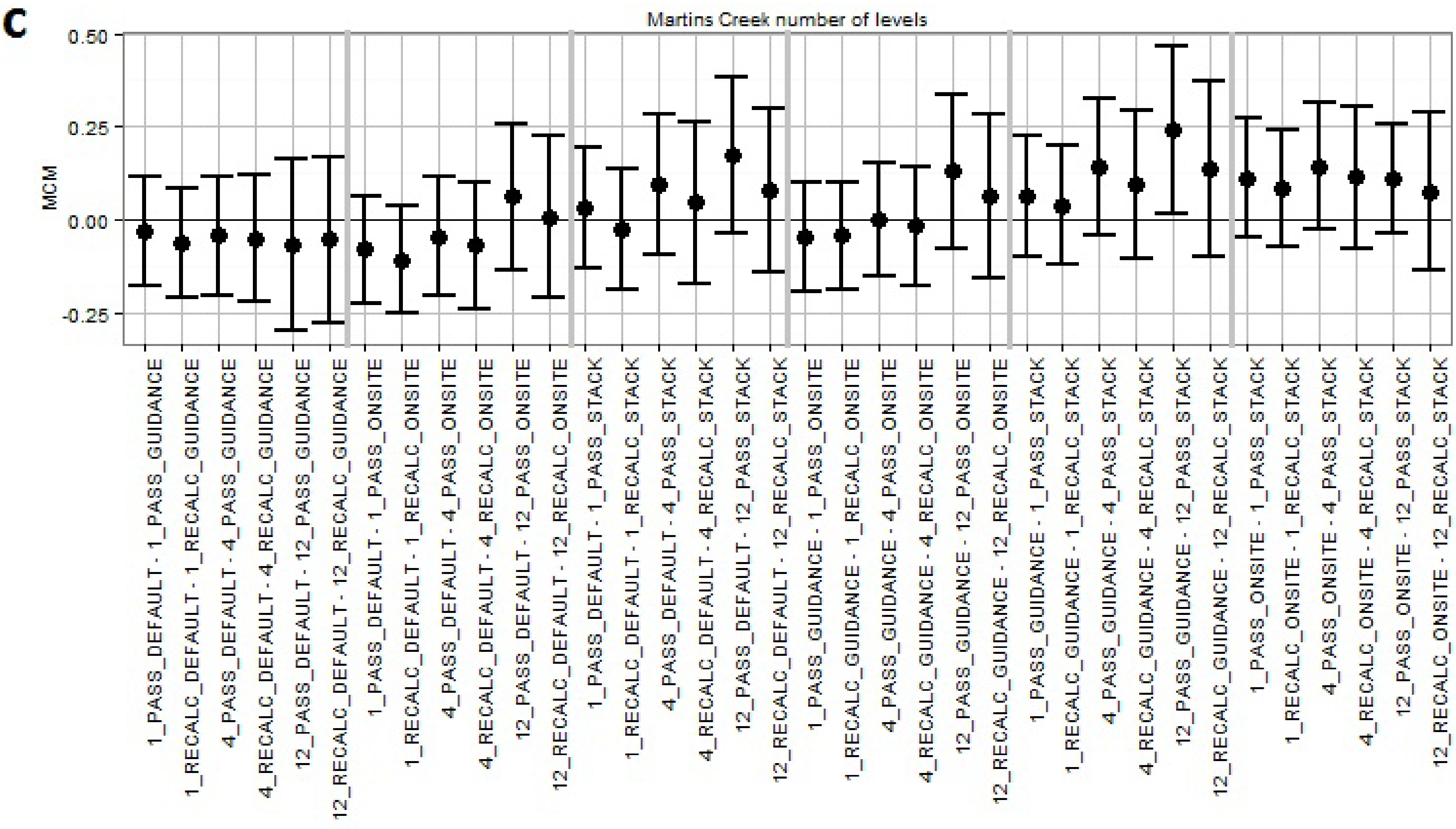
Baldwin # of levels MCM



Martins Creek grid resolution MCM



Martins Creek PBL method MCM



Martins Creek # of levels MCM

Baldwin AERMET mixing ht MCM

Scenario	MCM	Standard error	Ratio
1_PASS_DEFAULT	0.04	0.09	0.44
1_PASS GUIDANCE	-0.07	0.09	-0.78
1_PASS ONSITE	0.01	0.16	0.06
1_PASS STACK	0.01	0.16	0.06
1_RECALC_DEFAULT	0.10	0.09	1.11
1_ RECALC GUIDANCE	-0.02	0.08	-0.25
1_ RECALC ONSITE	0.11	0.15	0.73
1_ RECALC STACK	0.06	0.16	0.38
4_PASS_DEFAULT	0.03	0.08	0.38
4_PASS GUIDANCE	0.08	0.10	0.80
4_PASS ONSITE	0.01	0.17	0.06
4_PASS STACK	0.03	0.15	0.2
4_RECALC_DEFAULT	0.05	0.09	0.56
4_ RECALC GUIDANCE	0.11	0.10	1.1
4_ RECALC ONSITE	0.08	0.16	0.50
4_ RECALC STACK	0.10	0.16	0.63
12_PASS_DEFAULT	-0.03	0.06	-0.50
12_PASS GUIDANCE	-0.04	0.06	-0.67
12_PASS ONSITE	-0.05	0.07	-0.71
12_PASS STACK	-0.06	0.07	-0.86
12_RECALC_DEFAULT	-0.03	0.06	-0.50
12_ RECALC GUIDANCE	-0.06	0.06	-1.00
12_ RECALC ONSITE	-0.07	0.07	-1.00
12_ RECALC STACK	-0.06	0.08	-0.75

Martins Creek AERMET mixing ht MCM

Scenario	MCM	Standard error	Ratio
1_PASS_DEFAULT	-0.02	0.09	-0.22
1_PASS GUIDANCE	-0.02	0.09	-0.22
1_PASS ONSITE	-0.04	0.09	-0.44
1_PASS STACK	-0.11	0.11	-1.00
1_RECALC_DEFAULT	-0.03	0.09	-0.33
1_ RECALC GUIDANCE	-0.06	0.08	-0.75
1_ RECALC ONSITE	-0.08	0.08	-1.00
1_ RECALC STACK	-0.17	0.11	-1.55
4_PASS_DEFAULT	0.04	0.10	0.4
4_PASS GUIDANCE	0.01	0.08	0.13
4_PASS ONSITE	-0.07	0.08	-0.88
4_PASS STACK	-0.12	0.10	-1.2
4_RECALC_DEFAULT	-0.02	0.11	-0.18
4_ RECALC GUIDANCE	-0.06	0.09	-0.67
4_ RECALC ONSITE	-0.16	0.09	-1.78
4_ RECALC STACK	-0.23	0.12	-1.92
12_PASS_DEFAULT	0.01	0.13	0.08
12_PASS GUIDANCE	-0.01	0.13	-0.08
12_PASS ONSITE	-0.04	0.09	-0.44
12_PASS STACK	0.11	0.09	1.22
12_RECALC_DEFAULT	-0.04	0.13	-0.31
12_ RECALC GUIDANCE	-0.04	0.14	-0.29
12_ RECALC ONSITE	-0.14	0.12	-1.17
12_ RECALC STACK	-0.04	0.14	-0.29

Links

- Appendix W:
  - https://www3.epa.gov/ttn/scram/appendix_w/2016/AppendixW_2017.pdf
- MMIF Guidance:
  - https://www3.epa.gov/ttn/scram/appendix_w/2016/MMIF_Guidance.pdf
- MMIF Info and Source Code:
  - https://www.epa.gov/scram/air-quality-dispersion-modeling-related-model-support-programs#mmif
- MMIF User's Guide:
  - https://www3.epa.gov/ttn/scram/models/relat/mmif/MMIFv3.3_Users_Manual.pdf
- EPA MMIF Evaluation:
  - https://www3.epa.gov/ttn/scram/appendix_w/2016/MMIF_Evaluation_TSD.pdf
- EPA Guidance on Photochemical Modeling:
  - https://www3.epa.gov/ttn/scram/guidance/guide/Draft_O3-PM-RH_Modeling_Guidance-2014.pdf
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  - Chris Misenis (misenis.chris@epa.gov)
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