Data User Guide

Weather Research and Forecasting (WRF) Model IMPACTS

Introduction

The Weather Research and Forecasting (WRF) Model IMPACTS dataset includes model data simulated by the Weather Research and Forecasting (WRF) model for the Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS) field campaign. IMPACTS was a three-year sequence of winter season deployments conducted to study snowstorms over the U.S. Atlantic Coast (2020-2023). The campaign aimed to (1) Provide observations critical to understanding the mechanisms of snowband formation, organization, and evolution; (2) Examine how the microphysical characteristics and likely growth mechanisms of snow particles vary across snowbands; and (3) Improve snowfall remote sensing interpretation and modeling to significantly advance prediction capabilities. The WRF model provided simulations of the precipitation events that were observed during the campaign using initial and boundary conditions from the Global Forecast System (GFS) model and the North American Mesoscale Forecast System (NAM). The WRF IMPACTS dataset files are available from January 12, 2020, through March 4, 2023, in netCDF-3 format.

Citation

Colle, David and Stacy Brodzik. 2020. Weather Research and Forecasting (WRF) Model IMPACTS [indicate subset used]. Dataset available online from the NASA Global Hydrometeorology Resource Center DAAC, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/IMPACTS/WRF/DATA101

Keywords:

NASA, GHRC, IMPACTS, WRF, numerical weather prediction, parameterizations, precipitation

Campaign

The Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS), funded by NASA's Earth Venture program, is the first comprehensive study of East Coast snowstorms in 30 years. IMPACTS will fly a complementary suite of remote sensing and in-situ instruments for three 6-week deployments (2020-2023) on NASA's ER-2 high-altitude aircraft and P-3 cloud-sampling aircraft. The first deployment began on January 17, 2020, and ended on March 1, 2020. IMPACTS samples U.S. East Coast winter storms using advanced radar, LiDAR, and microwave radiometer remote sensing instruments on the ER-2 and state-of-the-art microphysics probes and dropsonde capabilities on the P-3, augmented by ground-based radar and rawinsonde data, multiple NASA and NOAA satellites (including GPM, GOES-16, and other polar-orbiting satellite systems), and computer simulations. IMPACTS addressed three specific objectives: (1) Provide observations critical to understanding the mechanisms of snowband formation, organization, and evolution; (2) Examine how the microphysical characteristics and likely growth mechanisms of snow particles vary across snowbands; and (3) Improve snowfall remote sensing interpretation and modeling to significantly advance prediction capabilities. More information is available from [NASA's Earth Science Project Office's IMPACTS field campaign webpage].

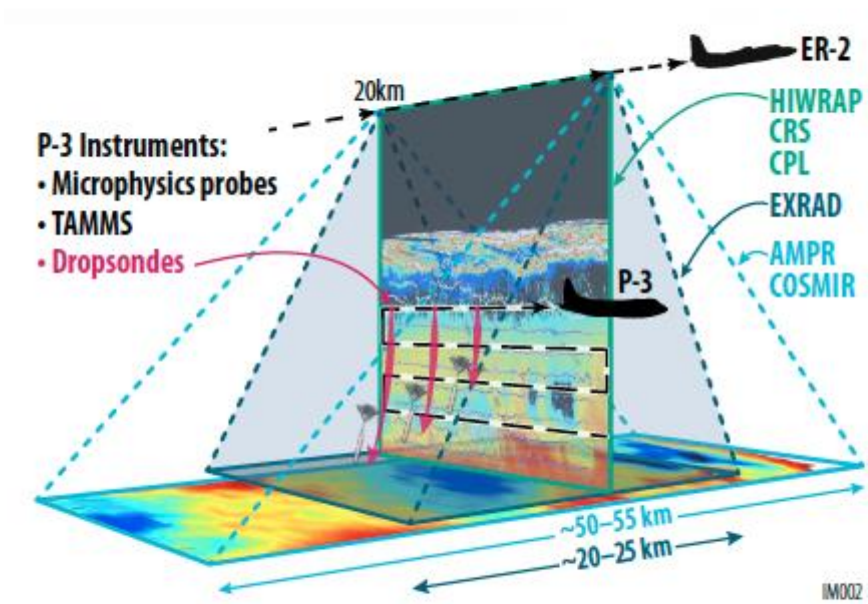

Figure 1: IMPACTS airborne instrument suite
(Image source: [NASA IMPACTS ESPO])

Product Description

The Weather Research and Forecasting (WRF) model is an open-source numerical weather prediction (NWP) model system designed for research and operational applications. Its development involved various organizations including the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Air Force, the U.S. Naval Research Laboratory, the University of Oklahoma, and the Federal

Aviation Administration (FAA). A NWP model is essentially a computer program that runs mathematical simulations of the Earth's atmosphere, largely based on the governing equations of motion, to determine a future state of the atmosphere given a set of initial conditions. These models also include parameterizations which are components of a numerical model that cannot be explicitly calculated because they are too small scale or complex. Their values are therefore determined using a simplified approach. WRF can use actual atmospheric data as initial conditions or use idealized conditions. From there, the model simulates the various atmospheric processes to determine the resulting atmospheric conditions at some time period from the initial state. Because WRF can be used for research or operational purposes, it can take on a wide variety of configurations for use by different user groups. More information about the WRF model is available on the NCAR WRF Model webpage.

Investigators

David Colle
Stony Brook University
Stony Brook, NY

Stacy Brodzik
University of Washington
Seattle, WA

Data Characteristics

The Weather Research and Forecasting (WRF) Model IMPACTS dataset contains WRF forecast data simulated for the IMPACTS campaign. The initial and boundary conditions for WRF were from the Global Forecast System (GFS) model from the National Weather Service and the North American Mesoscale Forecast System (NAM). Each file is valid for a particular hour of the simulation. The WRF is run with 36-km (d01), 12-km (d02), and 4-km (d03) domains. The model is saved every 3 hours for the 36- and 12-km domains (d01 and d02), and saved every hour for the 4-km domain (d03). Ingests occur every 12 hours at 0000 UTC and 1200 UTC. These data are available at a Level 4 processing level. More information about the NASA data processing levels is available on the EOSDIS Data Processing Levels webpage. The characteristics of this dataset are listed in Table 1 below.

Table 1: Data Characteristics

Characteristic	Description
Platform	Weather Research and Forecasting model (WRF)
Spatial Coverage	N: 53.589, S: 22.971, E: -53.798, W: -114.202 (United States)
Spatial Resolution	Domain 1 (d01): 36-km Domain 2 (d02): 12-km Domain 3 (d03): 4-km
Temporal Coverage	January 12, 2020 - March 4, 2023
Temporal Resolution	Hourly

Parameter	Atmosphere and surface variables (e.g. temperature, latent heating, soil moisture)
Version	1
Processing Level	4

File Naming Convention

The Weather Research and Forecasting (WRF) Model IMPACTS dataset files are separated by model. The files are stored in netCDF-3 format and named using the following convention:

Data files: IMPACTS_wrfout_[d01|d02|d03]_YYYYMMDD<**>_<##>_[GFS|NAM].nc

Table 2: File naming convention variables

Variable	Description
[d01|d02|d03]	WRF model domain number d01: 36-km domain d02: 12-km domain d03: 4-km domain
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
**	WRF ingest hour 00: 0000 UTC 12: 1200 UTC
##	WRF Forecast hour (ranging from 00- 48)
[GFS|NAM]	Forecast Model GFS: Global Forecast System NAM: North American Mesoscale Forecast System
.nc	netCDF-3 format

Data Format and Parameters

The Weather Research and Forecasting (WRF) Model IMPACTS dataset files are separated by forecast model: GFS and NAM. Each file contains data valid for a particular hour of the simulation. This dataset contains all the variables from the WRF model on sigma levels. The data fields contained in both the WRF GFS and WRF NAM netCDF-3 files are listed in Table 3 below.

Table 3: WRF GFS/NAM netCDF-3 data fields

Variable	Description	Units
Times	Times	-

LU_INDEX	Land use category	-
ZNU	Eta values on half (mass) levels	-
ZNW	Eta values on full (w) levels	-
ZS	Depths of centers of soil layers	m
DZS	Thicknesses of soil layers	m
VAR_SSO	Variance of subgrid-scale orography	m^2
U	x-wind component	$m\ s^{-1}$
V	y-wind component	$m\ s^{-1}$
W	z-wind component	$m\ s^{-1}$
PH	Perturbation geopotential	$m^2\ s^{-2}$
PHB	Base-state geopotential	$m^2\ s^{-2}$
T	Perturbation potential temperature (theta-t0)	K
HFX_FORCE	SCM ideal surface sensible heat flux	$W\ m^{-2}$
LH_FORCE	SCM ideal surface latent heat flux	$W\ m^{-2}$
TSK_FORCE	SCM ideal surface skin temperature	$W\ m^{-2}$
HFX_FORCE_TEND	SCM ideal surface sensible heat flux tendency	$W\ m^{-2}\ s^{-1}$
LH_FORCE_TEND	SCM ideal surface latent heat flux tendency	$W\ m^{-2}\ s^{-1}$
TSK_FORCE_TEND	SCM ideal surface skin temperature tendency	$W\ m^{-2}\ s^{-1}$
MU	Perturbation dry air mass in column	Pa
MUB	Base state dry air mass in column	Pa
NEST_POS	Nest position	-
P	Perturbation pressure	Pa
PB	BASE STATE PRESSURE	Pa
FNM	Upper weight for vertical stretching	-
FNP	Lower weight for vertical stretching	-
RDNW	Inverse d(eta) values between full (w) levels	-
RDN	Inverse d(eta) values between half (mass) levels	-
DNW	d(eta) values between full (w) levels	-
DN	d(eta) values between half (mass) levels	-
CFN	Extrapolation constant	-
CFN1	Extrapolation constant	-
THIS_IS_AN_IDEAL_RUN	T/F flag: this is an ARW ideal simulation	-
P_HYD	Hydrostatic pressure	Pa
Q2	QV at 2 M	$kg\ kg^{-1}$
T2	TEMP at 2 M	K
TH2	POT TEMP at 2 M	K
PSFC	SFC PRESSURE	Pa
U10	U at 10 M	$m\ s^{-1}$
V10	V at 10 M	$m\ s^{-1}$
RDX	Inverse x grid length	-
RDY	Inverse y grid length	-
RESM	Time weight constant for small steps	-

ZETATOP	Zeta at model top	-
CF1	2nd order extrapolation constant	-
CF2	2nd order extrapolation constant	-
CF3	2nd order extrapolation constant	-
ITIMESTEP	Timestep	-
QVAPOR	Water vapor mixing ratio	kg kg^{-1}
QCLOUD	Cloud water mixing ratio	kg kg^{-1}
QRAIN	Rain water mixing ratio	kg kg^{-1}
QICE	Ice mixing ratio	kg kg^{-1}
QSNOW	Snow mixing ratio	kg kg^{-1}
QGRAUP	Graupel mixing ratio	kg kg^{-1}
QNICE	Ice number concentration	kg^{-1}
QNRAIN	Rain number concentration	kg^{-1}
SHDMAX	Annual max veg fraction	-
SHDMIN	Annual min veg fraction	-
SNOALB	Annual max snow albedo in fraction	-
TSLB	Soil temperature	K
SMOIS	Soil moisture	m^3 m^{-3}
SH2O	Soil liquid water	m^3 m^{-3}
SMCREL	Relative soil moisture	-
SEAICE	Sea ice flag	-
XICEM	Sea ice flag (previous step)	-
SFROFF	Surface runoff	mm
UDROFF	Underground runoff	mm
IVGTYP	Dominant vegetation category	-
ISLTYP	Dominant soil category	-
VEGFRA	Vegetation fraction	-
GRDFLX	Ground heat flux	W m^{-2}
ACGRDFLX	Accumulated ground heat flux	J m^{-2}
ACSNOM	Accumulated melted snow	kg m^{-2}
SNOW	Snow water equivalent	kg m^{-2}
SNOWH	Physical snow depth	m
CANWAT	Canopy water	kg m^{-2}
SSTSK	Skin sea surface temperature	K
COSZEN	COS of solar zenith angle	-
LAI	Leaf area index	m^{-2}/m^{-2}
QKE	Twice TKE from MYNN	m^2 s^{-2}
VAR	Orographic variance	-
TKE_PBL	TKE from PBL	m^2 s^{-2}
EL_PBL	Length scale from PBL	m
O3RAD	Radiation 3D ozone	ppmv
MAPFAC_M	Map scale factor on mass grid	-
MAPFAC_U	Map scale factor on u-grid	-
MAPFAC_V	Map scale factor on v-grid	-

MAPFAC_MX	Map scale factor on mass grid, x direction	-
MAPFAC_MY	Map scale factor on mass grid, y direction	-
MAPFAC_UX	Map scale factor on u-grid, x direction	-
MAPFAC_UY	Map scale factor on u-grid, y direction	-
MAPFAC_VX	Map scale factor on v-grid, x direction	-
MF_VX_INV	Inverse map scale factor on v-grid, x direction	-
MAPFAC_VY	Map scale factor on v-grid, y direction	-
F	Coriolis sine latitude term	s^{-1}
E	Coriolis cosine latitude term	s^{-1}
SINALPHA	Local sine of map rotation	-
COSALPHA	Local cosine of map rotation	-
HGT	Terrain Height	m
TSK	Surface skin temperature	K
P_TOP	Pressure top of the model	Pa
T00	Base state temperature	K
P00	Base state pressure	Pa
TLP	Base state lapse rate	K m^{-1}
TISO	Temp at which the base T turns const	K
TLP_STRAT	Base state lapse rate (dt/d(ln(p)) in stratosphere	K
P_STRAT	Base state pressure at bottom of stratosphere	Pa
MAX_MSTFX	Max map factor in domain	-
MAX_MSTFY	Max map factor in domain	-
RAINC	Accumulated total cumulus precipitation	mm
RAINSH	Accumulated shallow cumulus precipitation	mm
PRATEC	Precip rate from cumulus scheme	mm s^{-1}
PRATESH	Precip rate from shallow cumulus scheme	mm s^{-1}
RAINCV	Time-step cumulus precipitation	mm
RAINSHV	Time-step shallow cumulus precipitation	mm
RAINNCV	Time-step nonconvective precipitation	mm
RAINBL	PBL time-step total precipitation	mm
SNOWNC	Accumulated total grid scale snow and ice	mm
GRAUPELNC	Accumulated total grid scale graupel	mm
HAILNC	Accumulated total grid scale hail	mm
SNOWNCV	Time-step nonconvective snow and ice	mm
GRAUPELNCV	Time-step nonconvective graupel	mm
HAILNCV	Time-step nonconvective hail	mm
REFL_10CM	Radar reflectivity (lamda = 10 cm)	dBZ
CLDFRA	Cloud fraction	-
SWDOWN	Downward short wave flux at ground surface	W m^{-2}
GLW	Downward long wave flux at ground surface	W m^{-2}
SWNORM	Normal short wave flux at ground surface (slope-dependent)	W m^{-2}
ACSWUPT	Accumulated upwelling shortwave flux at top	J m^{-2}

ACSWUPTC	Accumulated upwelling clear sky shortwave flux at top	J m^{-2}
ACSWDNT	Accumulated downwelling shortwave flux at top	J m^{-2}
ACSWDNTC	Accumulated downwelling clear sky shortwave flux at top	J m^{-2}
ACSWUPB	Accumulated upwelling shortwave flux at bottom	J m^{-2}
ACSWUPBC	Accumulated upwelling clear sky shortwave flux at bottom	J m^{-2}
ACSWDNB	Accumulated downwelling shortwave flux at bottom	J m^{-2}
ACSWDNBC	Accumulated downwelling clear sky shortwave flux at bottom	J m^{-2}
SWUPT	Instantaneous upwelling shortwave flux at top	W m^{-2}
SWUPTC	Instantaneous upwelling clear sky shortwave flux at top	W m^{-2}
SWDNT	Instantaneous downwelling shortwave flux at top	W m^{-2}
SWDNTC	Instantaneous downwelling clear sky shortwave flux at top	W m^{-2}
SWUPB	Instantaneous upwelling shortwave flux at bottom	W m^{-2}
SWUPBC	Instantaneous upwelling clear sky shortwave flux at bottom	W m^{-2}
SWDNB	Instantaneous downwelling shortwave flux at bottom	W m^{-2}
SWDNBC	Instantaneous downwelling clear sky shortwave flux at bottom	W m^{-2}
OLR	TOA outgoing long wave	W m^{-2}
ALBEDO	Albedo	-
CLAT	Computational grid latitude, south is negative	degree_north
ALBBCK	Background albedo	-
EMISS	Surface emissivity	-
NOAHRES	Residual of the noah surface energy budget	W m^{-2}
TMN	Soil temperature at lower boundary	K
XLAND	Land mask (1 for land, 2 for water)	-
UST	U* in similarity theory	m s^{-1}
PBLH	PBL Height	m
HFX	Upward heat flux at the surface	W m^{-2}
QFX	Upward moisture flux at the surface	kg m^{-2} s^{-1}
LH	Latent heat flux at the surface	W m^{-2}
ACHFX	Accumulated upward heat flux at the surface	J m^{-2}

ACLHF	Accumulated upward latent heat flux at the surface	J m^{-2}
SNOWC	Flag indicating snow coverage (1 for snow cover)	-
SR	Fraction of frozen precipitation	-
SAVE_TOPO_FROM_REAL	1=original topo from real/0=topo modified by WRF	-
REFD_MAX	Max derived radar refl	dbZ
ISEEDARR_SPPT	Array to hold seed for restart, SPPT	-
ISEEDARR_SKEBS	Array to hold seed for restart, SKEBS	-
ISEEDARR_RAND_PERTURB	Array to hold seed for restart, RAND_PERT	-
ISSEEDARRAY_SPP_CONV	Array to hold seed for restart, RAND_PERT2	-
ISEEDARRAY_SPP_PBL	Array to hold seed for restart, RAND_PERT3	-
ISEEDARRAY_SPP_LSM	Array to hold seed for restart, RAND_PERT3	-
BF	Full levels, bf=0 => isobaric; bf=znw => sigma	-
C1H	Half levels, c1h = d bf / d eta, using znw	-
C2H	Half levels, c2h = (1-c1h)*(p0-pt)	Pa
BH	Half levels, bh=0 => isobaric; bh=znu => sigma	-
C1F	Full levels, c1f = d bf / d eta, using znu	-
C2F	Full levels, c2f = (1-c1f)*(p0-pt)	Pa
C3H	Half levels, c3h = bh	-
C4H	Half levels, c4h = (eta-bh)*(p0-pt)+pt, using znu	Pa
C3F	Full levels, c3f = bf	-
C4F	Full levels, c4f = (eta-bf)*(p0-pt)+pt, using znw	Pa
PCB	Base state dry air mass in column	Pa
PC	Perturbation dry air mass in column	Pa
LANDMASK	Land mask (1 for land, 0 for water)	-
LAKEMASK	Lake mask (1 for lake, 0 for non-lake)	-
SST	Sea surface temperature	K
SST_INPUT	Sea surface temperature from wrflowinput file	K

Algorithm

Numerical weather models utilize governing equations that describe the physical behavior of the atmosphere, numerical methods that allow computers to solve these equations, and parameterizations that are used to account for processes that cannot be explicitly calculated by the model. The Spectral-Bin Microphysics (SBM) parameterization scheme is often used for WRF simulations. The SBM scheme characterizes the microphysical precipitation processes that are simulated within the model. More details about WRF-SBM are available on the [NASA GSFC WRF-SBM webpage](#).

Quality Assessment

Because WRF is a very user-driven model system, the model regularly receives code contributions and improvements. These modifications are required to undergo thorough testing before being submitted for the model. More information about WRF contribution and testing requirements is available on the NCAR WRF User Support & Contributor Information webpage.

Software

This dataset is in netCDF-3 format and does not require any specific software to read. However, the data are easily readable and viewed in Panoply.

Known Issues or Missing Data

There are no known issues with these data or any known gaps in the dataset.

References

NASA ESPO. (2020). IMPACTS.
https://espo.nasa.gov/impacts/content/IMPACTS

NASA GSFC. (2020). WRF-SBM.
https://cloud.gsfc.nasa.gov/index.php?section=35

NCAR. (2020). The Weather Research and Forecasting Model.
https://www.mmm.ucar.edu/weather-research-and-forecasting-model

Related Data

All other datasets collected as part of the IMPACTS campaign are considered related and can be located by searching the term "IMPACTS" in the Earthdata Search. Other WRF datasets can be located by searching the term "WRF" are listed below.

GPM Ground Validation Weather Research and Forecasting (WRF) Images MC3E
(http://dx.doi.org/10.5067/GPMGV/MC3E/WRF/DATA101)

GPM Ground Validation Weather Research and Forecasting (WRF) Model LPVEx
(http://dx.doi.org/10.5067/GPMGV/LPVEX/MODELS/DATA101)

Contact Information

To order these data or for further information, please contact:

NASA Global Hydrometeorology Resource Center DAAC
User Services
320 Sparkman Drive

Huntsville, AL 35805
Phone: 256-961-7932
E-mail: support-ghrc@earthdata.nasa.gov
Web: https://ghrc.nsstc.nasa.gov/

Created: 10/08/2020
Updated: 10/24/2023