Unifying Innovations in Forecasting Capabilities Workshop

Emerging Applications 2 - Space Weather

UIFCW 2023

A UFS Collaboration Powered by EPIC

Going Beyond the Terrestrial

Space Weather Verification Using METplus

JONATHAN L. VIGH

PROJECT SCIENTIST I

Joint Numerical Testbed - Research Applications Laboratory – National Center for Atmospheric Research

NCAR | RESEARCH APPLICATIONS LABORATORY

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NCAR and SWPC Team

Jonathan L. Vigh[1], Terrance G. Onsager[2], Tara L. Jensen[1], Dominic J. Fuller-Rowell[3], Jun Wang[3], Mihail Codrescu[2], Tibor Durgonics[3], Charlotte Martinkus[3], Naomi Maruyama[4], Frank Centinello[2], Timothy J. Fuller-Rowell[2], Robert Steenburgh[2]

(1) National Center for Atmospheric Research, Boulder, CO, United States

(2) NOAA Space Weather Prediction Center, Boulder, CO, United States

(3) University of Colorado/CIRES, Boulder, CO, United States

(4) University of Colorado/LASP, Boulder, CO, United States

NASA (Crew of STS-39)

Overview

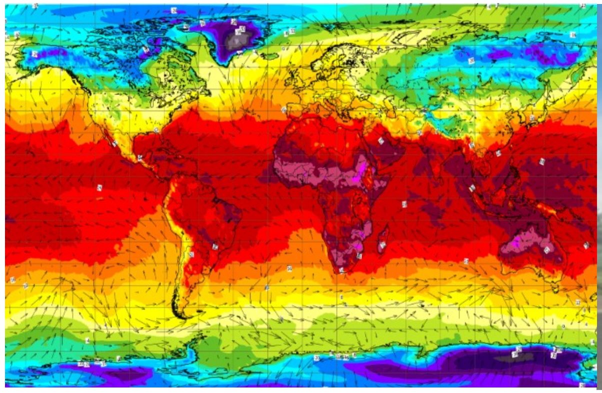
The **Space Weather Prediction Center Real-time Evaluation System (SWPC-RT)** is a platform-independent, container-based verification system whose purpose is to apply advanced methods and techniques to space weather verification

SWPC-RT provides:

- Ability to bring the **capabilities of METplus** to bear on space weather evaluation
- The capability to read analyses, model output, and forecasts in their **native data formats**
- Embedded support to conduct interactive interrogations of verification sets using **METViewer**
- The ability to use **other Python packages** to do complex calculations on geophysical datasets

Why METplus?

Forecasters | *Operational Centers* | *Universities & national labs*



Comprehensive and Unified Verification Tools
***Make R2O more efficient *Provide a consistent set of metrics**

Allows researchers and operational scientists to speak a “common verification” language

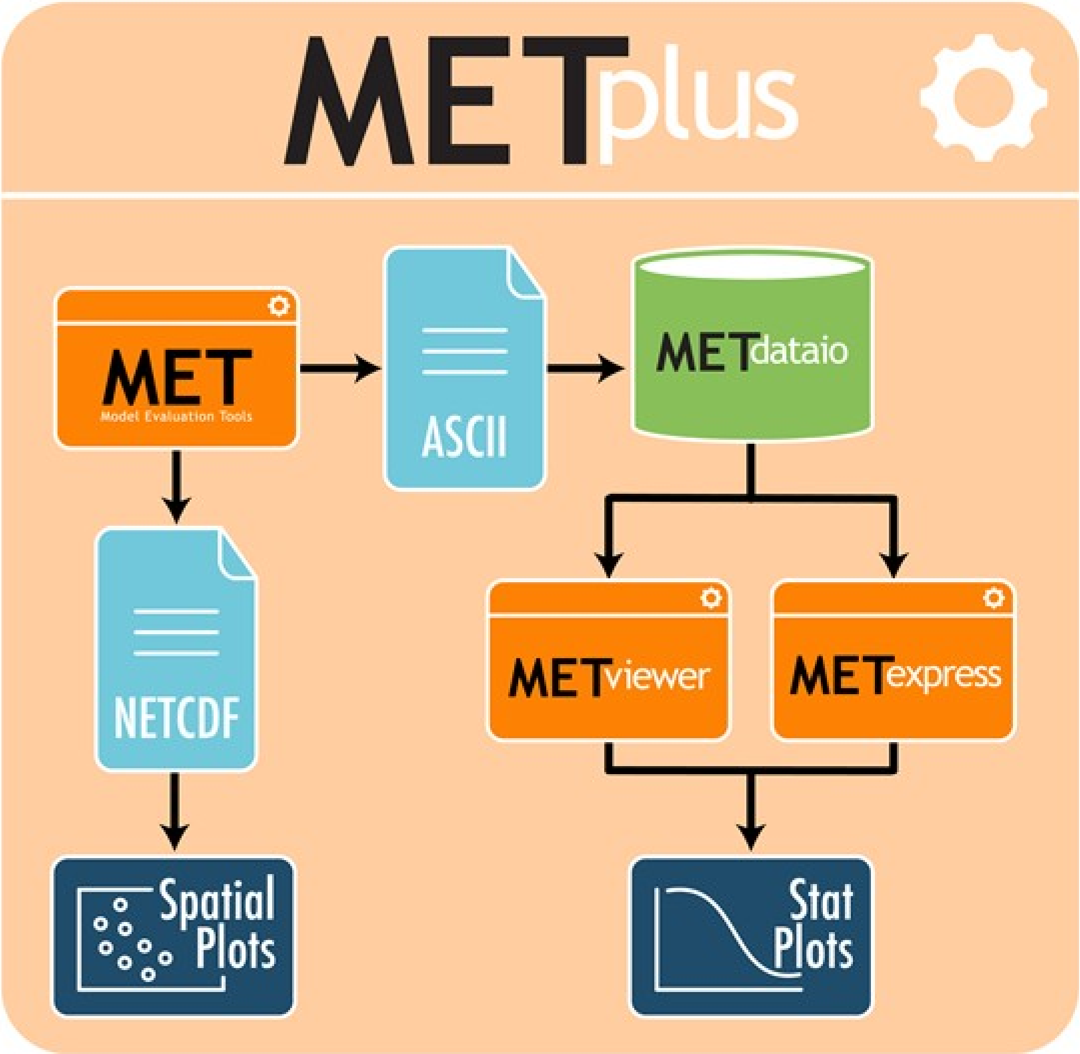
METplus

User support of unified package provides greater opportunity to train all on verification best practices

Highly-configurable, state-of-the-art suite of verification tools, a suite of python wrappers, and other supporting capabilities allow for complex real-time and retrospective verification workflows to be simplified and codified for robustness and reproducibility.

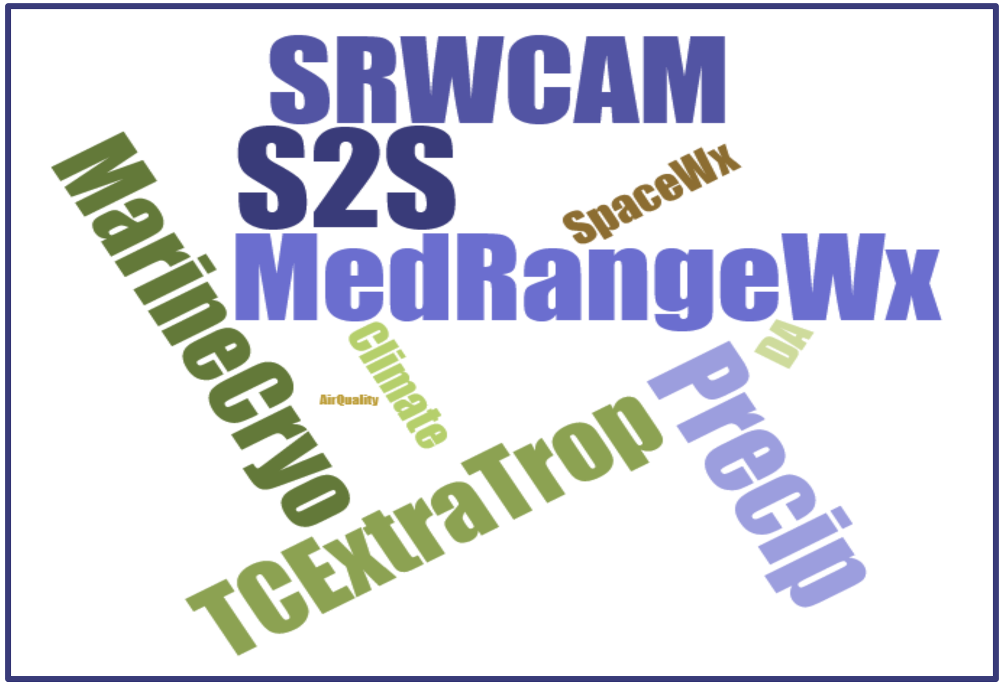
What is METplus?

- Over 100 traditional statistics and diagnostic methods for both point and gridded datasets
- 15 interpolation methods
- Applied to many spatial and temporal scales
- Developed to allow for easy sharing of config files for reproducible results
- 3500+ users; US and International
- At the core of EMC Verification System for UFS



What is METplus?, cont'd

- Suite of Python wrappers around:
  - MET tools (core)
    - Traditional statistics
    - Spatial methods
    - Additional diagnostics
  - Database and display systems
    - METviewer for deep dive data interrogation
    - METexpress for quick analysis
  - Analysis and plotting tools
    - Python tools support database and display systems
    - Developing command line option to run on HPCs and in containers



Design of real-time system

Configuration: Define use cases / dates to run
- Gridded comparisons
- Object-oriented comparisons
- Verification of human forecasts
- Gradient comparisons

One main configuration file

Python driver + METplus

Datasets
- GloTEC
- WAM-IPE
- CTIPe (coming soon)
- COSMIC-II
- MIT gnss

Supported platforms:
- Linux
- MacOSX
- WSL-2

MetPy

Python Embedding
Reads non-standard data and format to pass to MET Tools

MET:
Grid-Stat

MET:
MODE

MET:
Point-Obs
(coming soon)

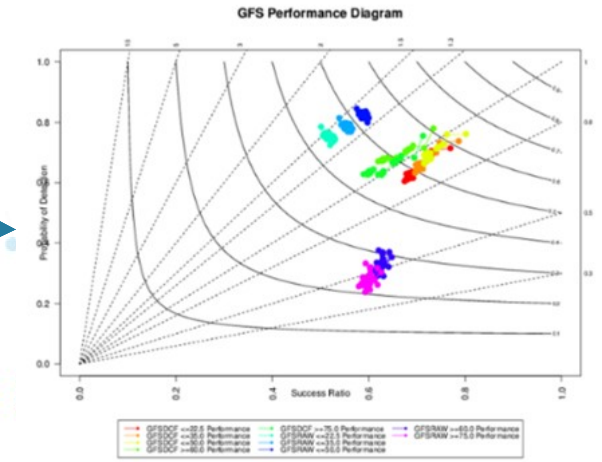
MET:
Stat-Analysis

Statistics

METdataio

METviewer

Graphical Products & Scorecards

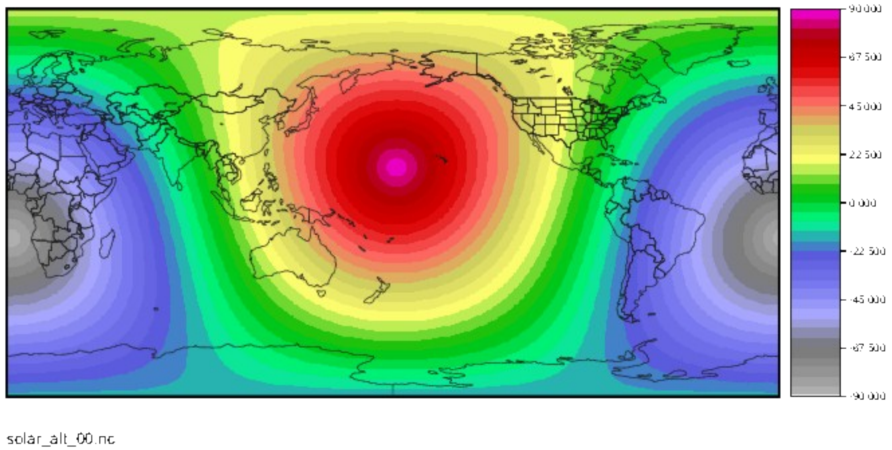


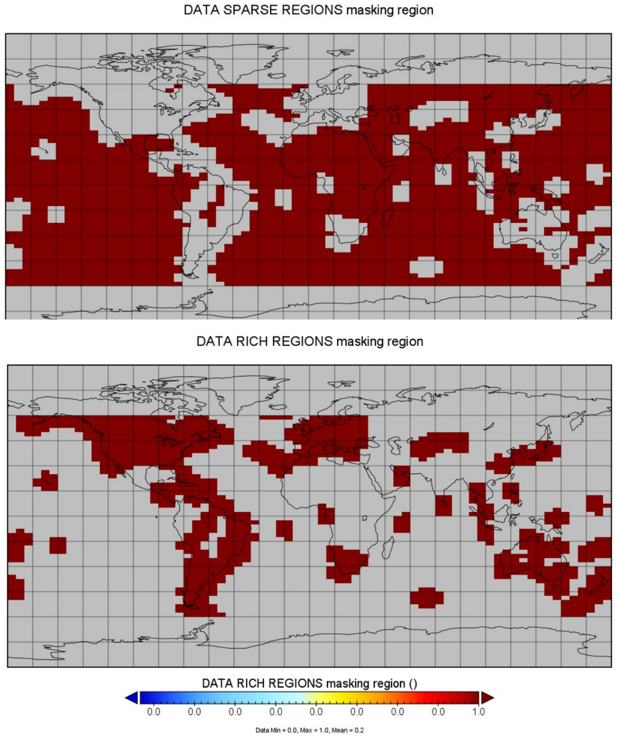
Gridded Comparisons

SWPC-RT uses METplus' GridStat tool to undertake gridded comparisons of models with analyses.

Key adaptations for the space-weather domain include:

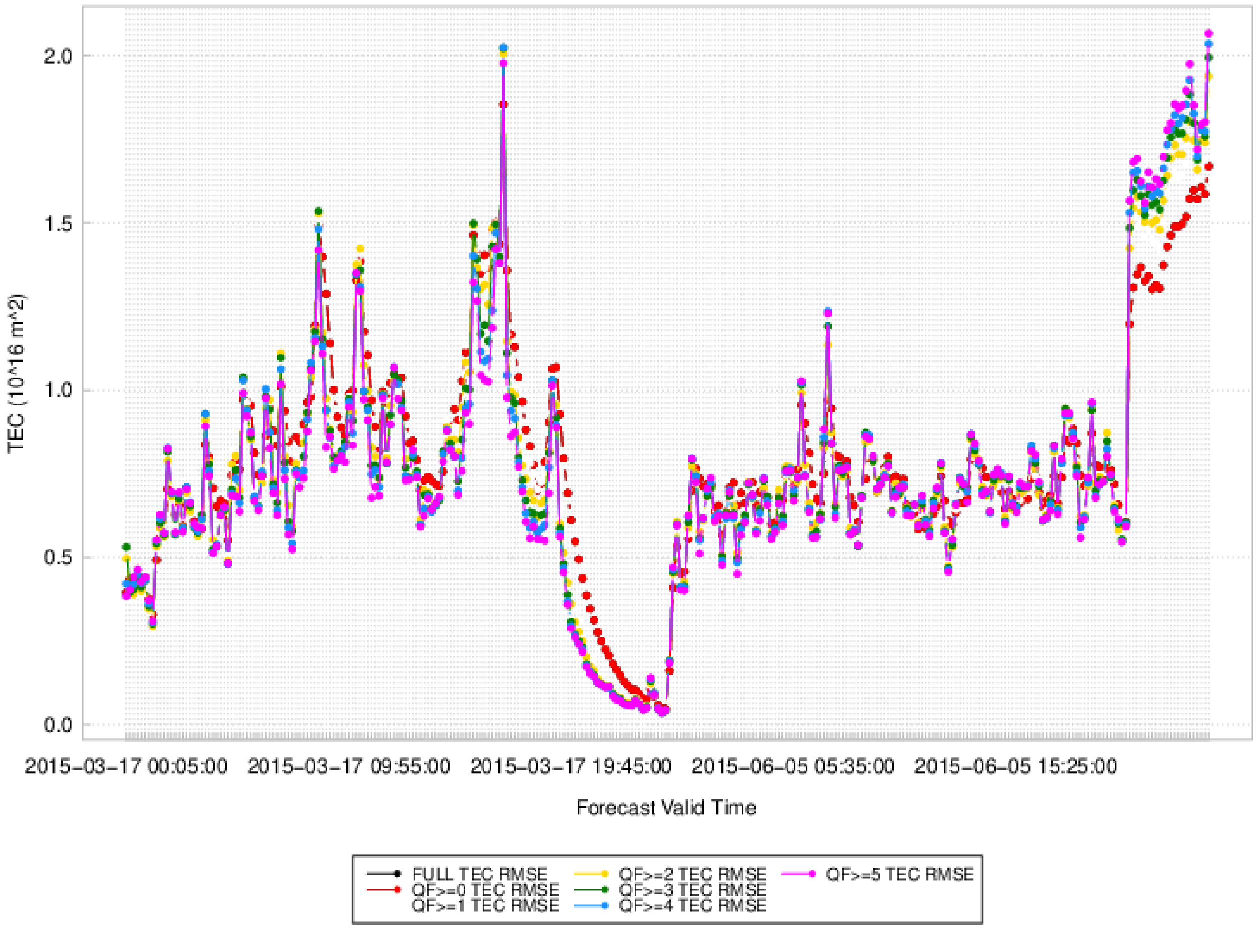
- Adaptation for **space weather variables** like Total Electron Content (TEC)
- **Custom masks**, e.g., distance from ionospheric ground stations
- **Time-dependent masking** by
  - *azimuthal solar angle*
  - *quality flag based on the # of Radio Occultation (RO) rays*
- **Python embedding scripts** to read data in its native format



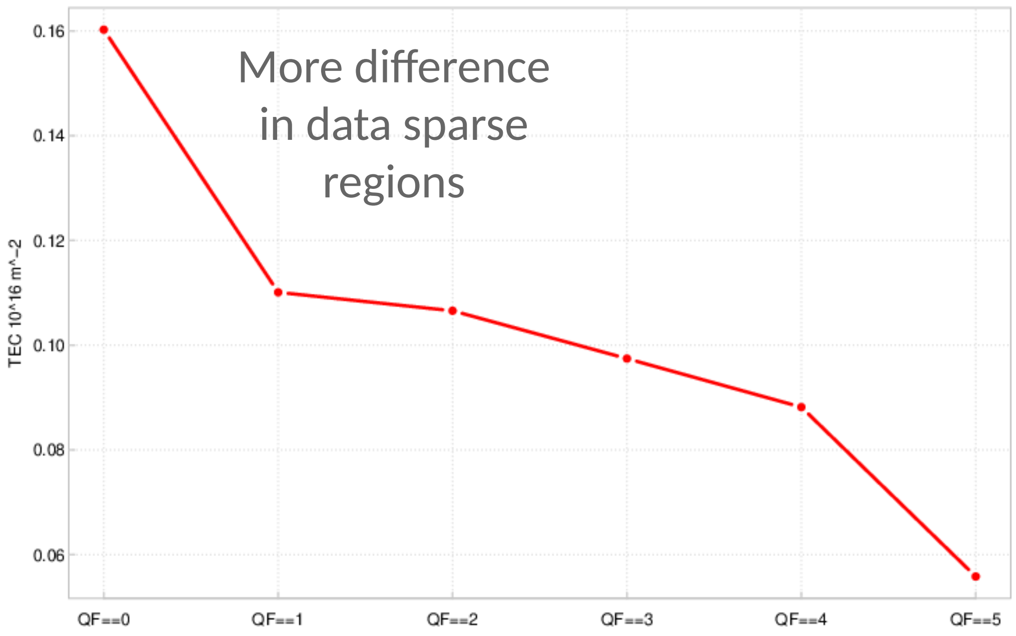


Examples of Gridded Comparisons

GloTEC w/COSMIC vs. w/o – RMSE



Evaluation of impact of Radio Occultation (RO) data on GloTEC analyses



Less difference when ground-based observations available

SWPC has been using these capabilities to evaluate real-time RO data from vendors for the Commercial Weather Data Program (CWDP)

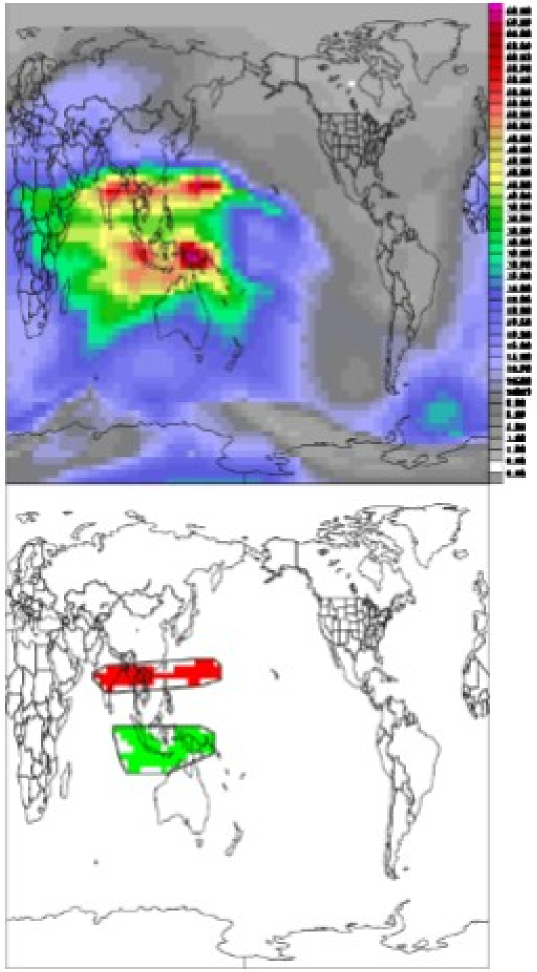
Object-Oriented Comparisons

MET Tool: MODE

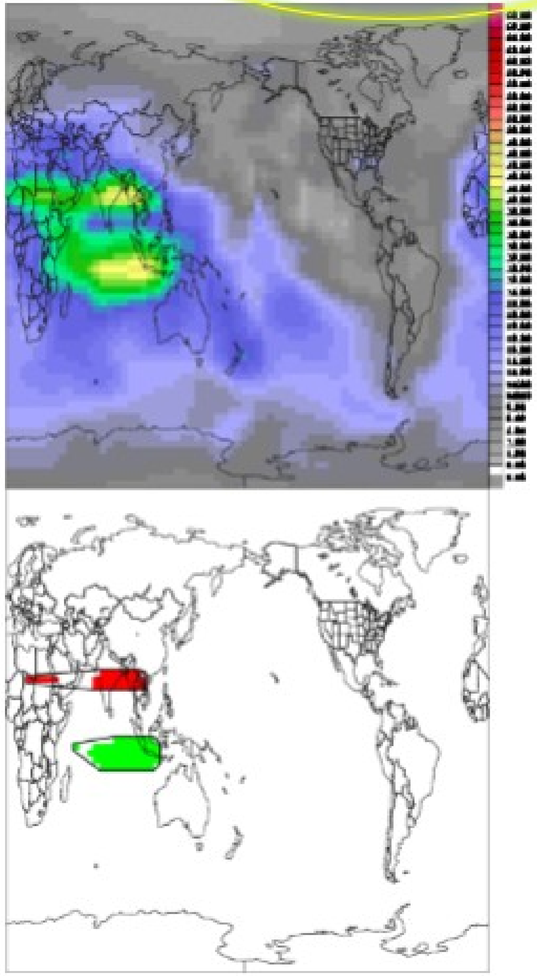
- METplus' MODE tool allows object-oriented comparisons of gridded the physical models (e.g., WAM-IPE) with an empirical model analysis (GloTEC)
- This allows examination of object attributes such as:
  - centroid distance
  - area ratio
  - axis angle
  - intensity ratio

Object-oriented comparisons helped SWPC identify a bias in WAM-IPE in which TEC in high regions was ~10 TEC units greater than GloTEC

WAM-IPE >45 TECunits



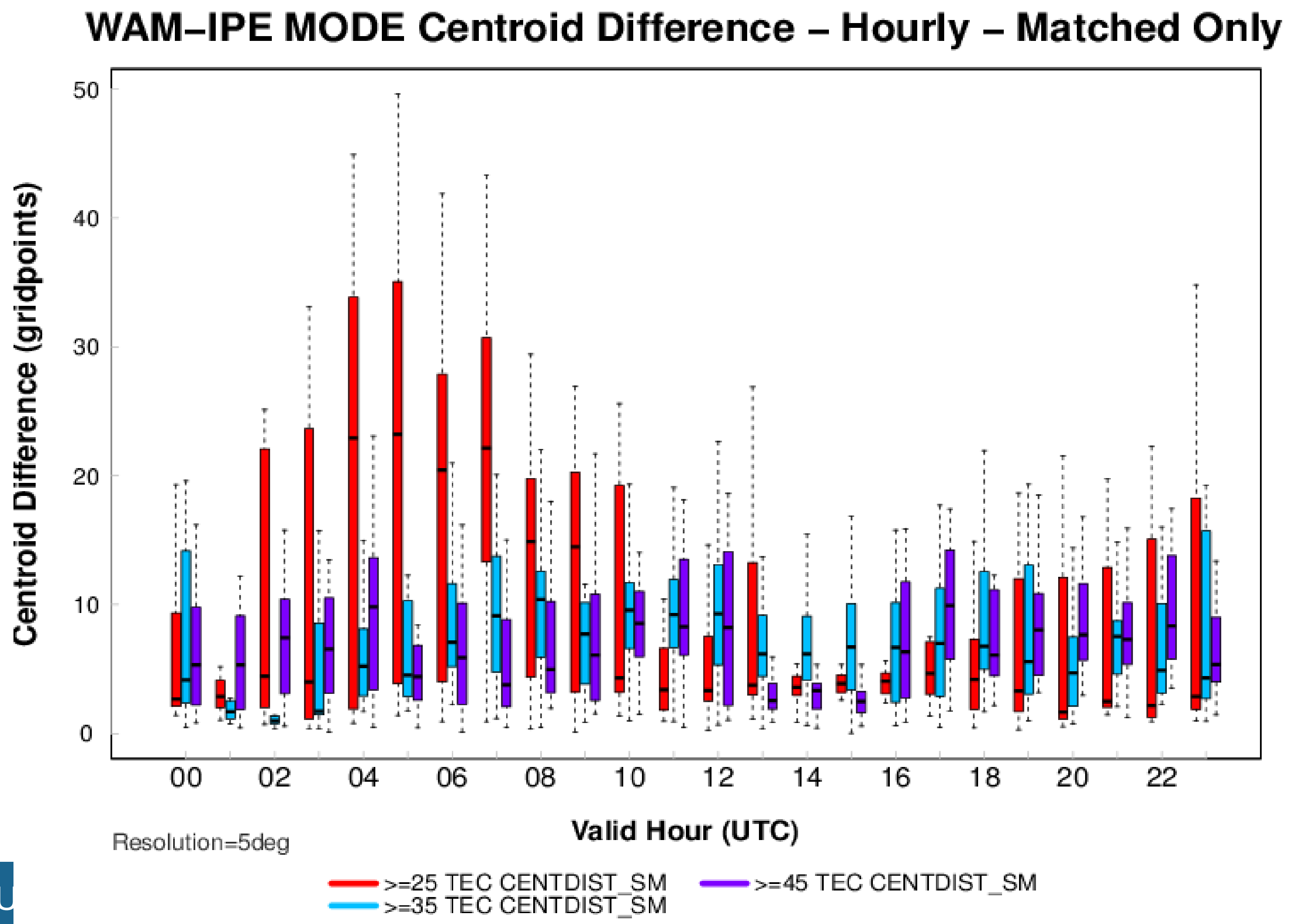
GloTEC >35 TECunits



MODE Example

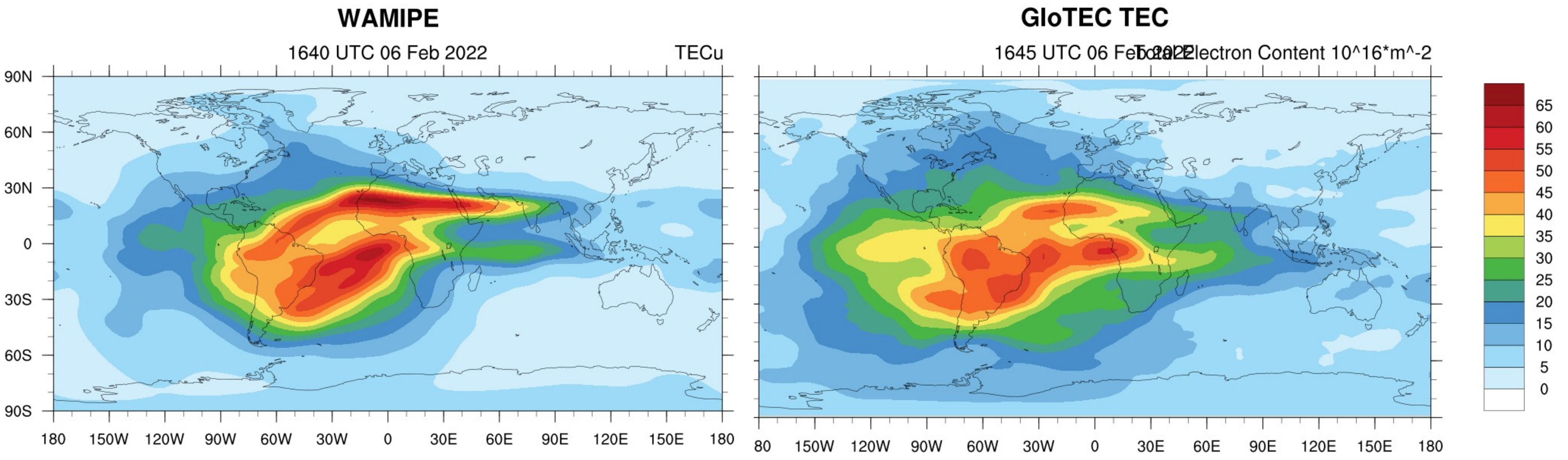
- Distribution of differences in centroid difference between objects in the two models by valid hour for different object thresholds

- Differences are relatively small for the high-value TEC objects. There is quite a bit of diurnal variation at the lower TEC thresholds



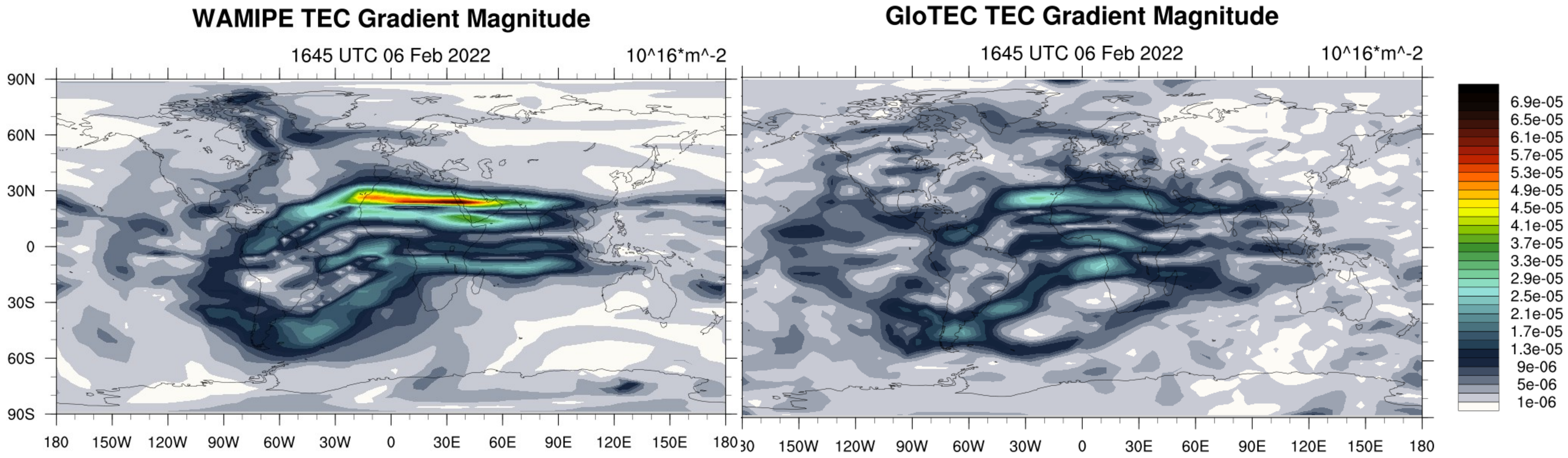
TEC gradient comparisons

- TEC gradients lead to instability which can cause ionospheric irregularities
- The resulting undulations can lead to scintillation, which can significantly impact radio communications
- A new use case allows SWPC-RT to compute the gradient magnitude of TEC and compare these between model and analysis



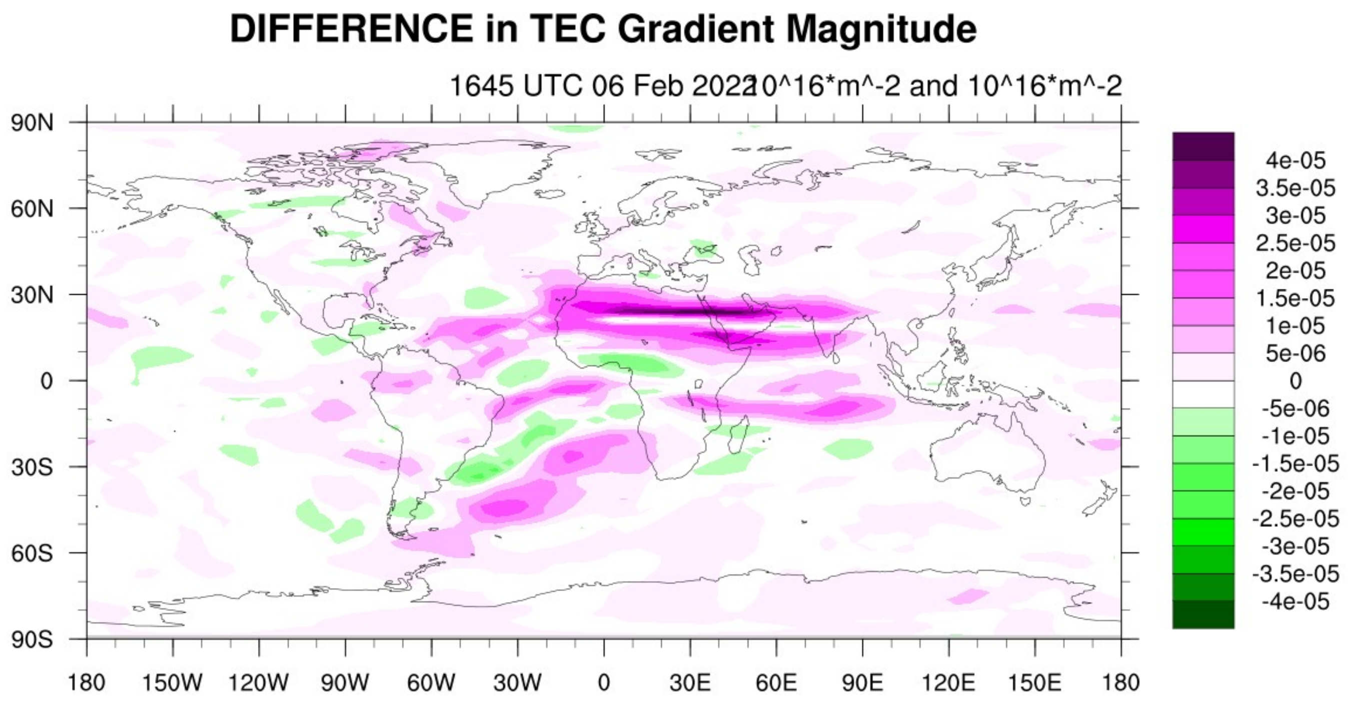
TEC gradients

- MetPy's *geospatial_gradient function* used to calculate the gradient magnitude for each field
- Computation is done at the time it is read into the system using python embedding
- This function computes the gradient accurately on the sphere using map factors.



Scintillation

- Scintillation is likely near areas of high TEC gradients
- Goal of future development is to explore the relationship between TEC gradients and point observations of scintillations

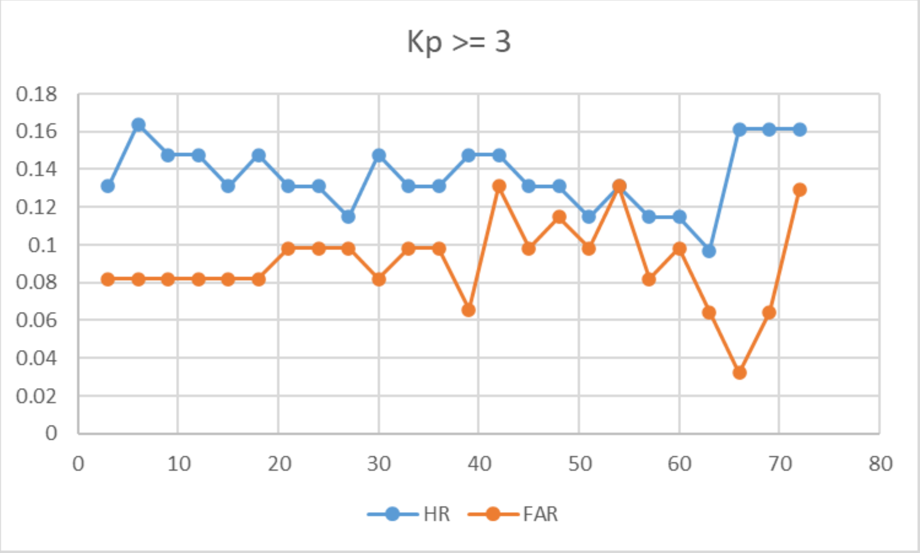


Verification of human forecasts

- SWPC's human forecasters provide forecast the Kp index
- The input data are in Json format
- This use case computes contingency tables by forecast lead time
- Event being forecast is a threshold of Kp >= 3
- Each line is a separate contingency table for the respective forecast lead time
- FY_OY means the event was forecast and it was also observed (a "hit")
- FY_ON gives the number of times that the event was forecast but not observed (a "false alarm"), etc.

Event: Kp >=3

COL_NAME:	FCST_LEAD	TOTAL	FY_OY	FY_ON	FN_OY	FN_ON	EC_VALUE
CTC:	12	61	9	5	5	42	0.5
CTC:	15	61	8	5	6	42	0.5
CTC:	18	61	9	5	5	42	0.5
CTC:	21	61	8	6	6	41	0.5
CTC:	24	61	8	6	6	41	0.5
CTC:	27	61	7	6	7	41	0.5
CTC:	3	61	8	5	6	42	0.5
CTC:	30	61	9	5	5	42	0.5
CTC:	33	61	8	6	6	41	0.5
CTC:	36	61	8	6	6	41	0.5
CTC:	39	61	6	6	7	42	0.5
CTC:	42	61	9	8	4	40	0.5
CTC:	45	61	8	6	5	42	0.5
CTC:	48	61	8	7	5	41	0.5
CTC:	51	61	7	6	6	42	0.5
CTC:	54	61	8	8	5	40	0.5
CTC:	57	61	7	5	6	43	0.5
CTC:	6	61	10	5	4	42	0.5
CTC:	60	61	7	6	6	42	0.5
CTC:	63	31	3	2	4	22	0.5
CTC:	66	31	5	1	2	23	0.5
CTC:	69	31	5	2	2	22	0.5
CTC:	72	31	5	4	2	20	0.5
CTC:	9	61	9	4	5	43	0.5



Thank you for your attention

- Jonathan Vigh, jvigh@ucar.edu
- Tara Jensen, jensen@ucar.edu
- Terry Onsager, terry.onsager@noaa.gov

- METplus Resources
  - METplus home page: https://dtcenter.org/community-code/metplus
  - METplus discussions support: https://github.com/dtcenter/METplus/discussions
  - METplus documentation: https://metplus.readthedocs.io/en/latest/Users_Guide/

METplus

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