CERES LEO Clouds Working Group Report

Sunny Sun-Mack
AMA, Hampton, VA

W. L. Smith, Jr. (CWG Chair)
NASA Langley Research Center, Hampton, VA

Q. Trepte (mask), G. Hong (models), P. Minnis (algorithms), Y. Chen (clr props, test runs), C. Yost (val, mask),
B. Scarino (cal, Tskin, GEO), F-L. Chang (CO2, corrk)
AMA, Hampton, VA

R. Smith (proc.), R. Brown (QC), E. Heckert (web), Churngwei Chu (web)
ADNET, Hampton, VA

P. Yang (ice models), *Texas A&M University*

Thanks to Dave Doelling and the TISA/calibration teams!

Fall 2024 CERES Science Team Meeting,
Lawrence Livermore National Laboratory, Livermore, CA
1-3 October 2024

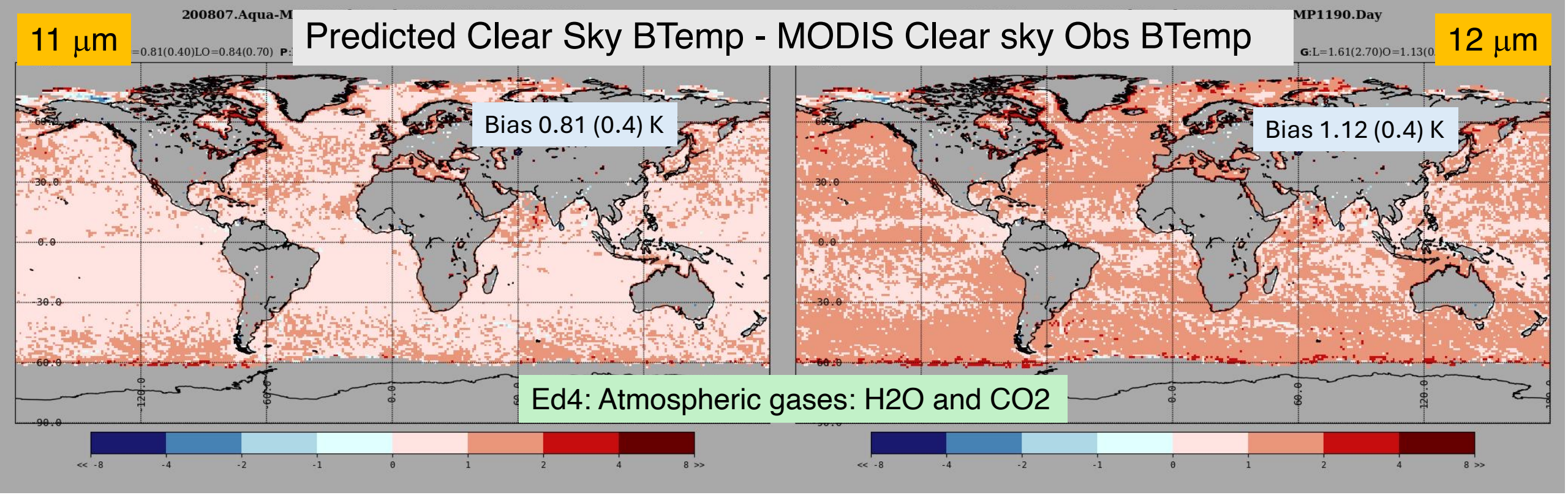
Ed5 Cloud Algorithm Updates and Improvements

- Improved atmospheric corrections
- Use of machine learning for skin temperature used in cloud mask
- Ed5 snow & ice maps
- Use of machine learning for Polar Nighttime Cloud Mask

Predicted Clear Sky BTemp - MODIS Clear sky Obs BTemp

11 μm

12 μm



Predicted Clear Btemp: Skin Temperature with sfc emissivity & forward calculation of Corrk under clear sky condition.

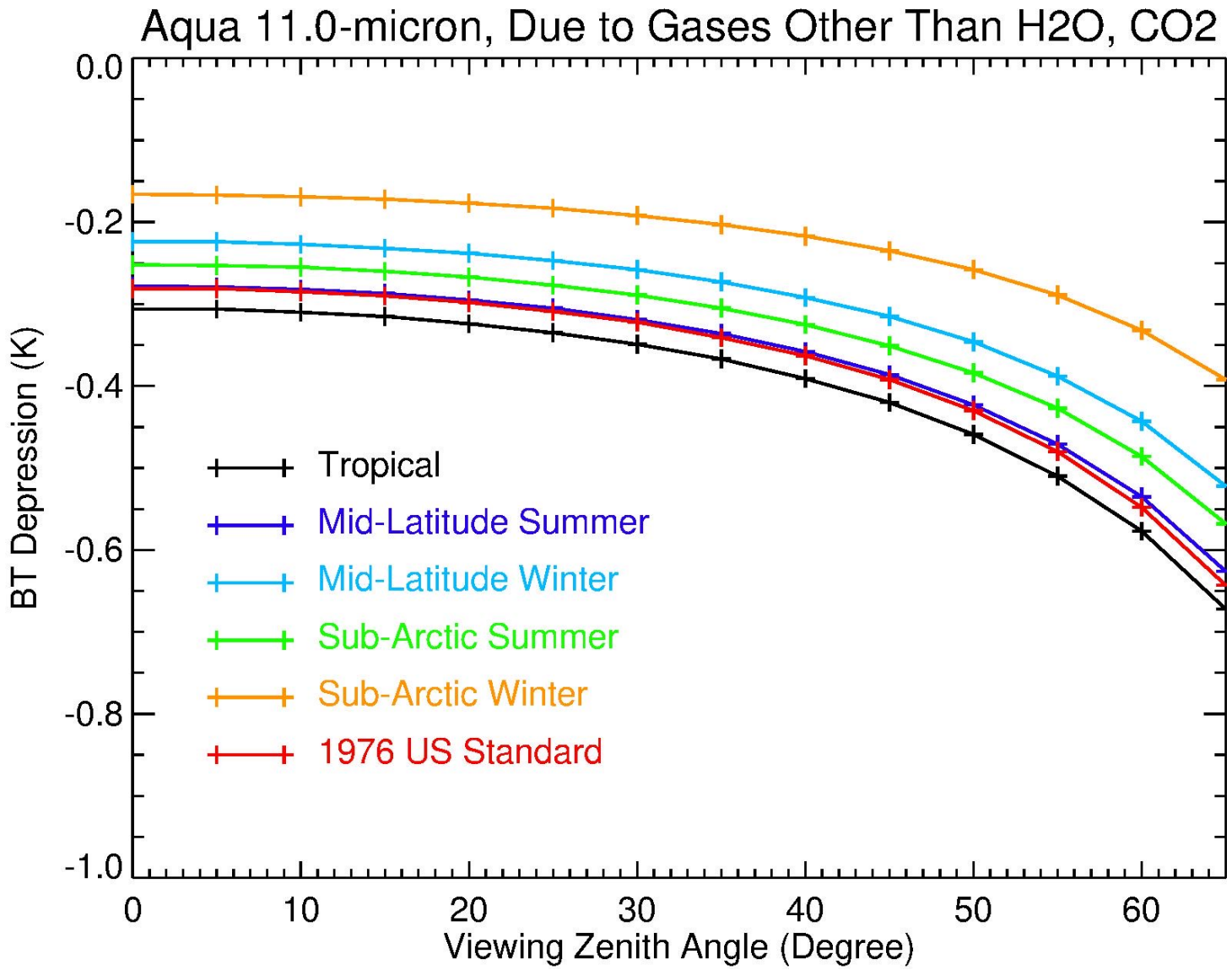
Gas Absorption at MODIS Aqua 11-micron Band

Gases have absorption at MODIS Aqua 11-micron spectral range:

Major absorption gases
H2O, line
H2O, continuum
CO2

Minor absorption gases
F12 (CCl2F2)
HNO3

Essential no absorption gases
O3
F113 (C2Cl3F3)
F114 (C2Cl2F4)
N2O
NO2
NH3

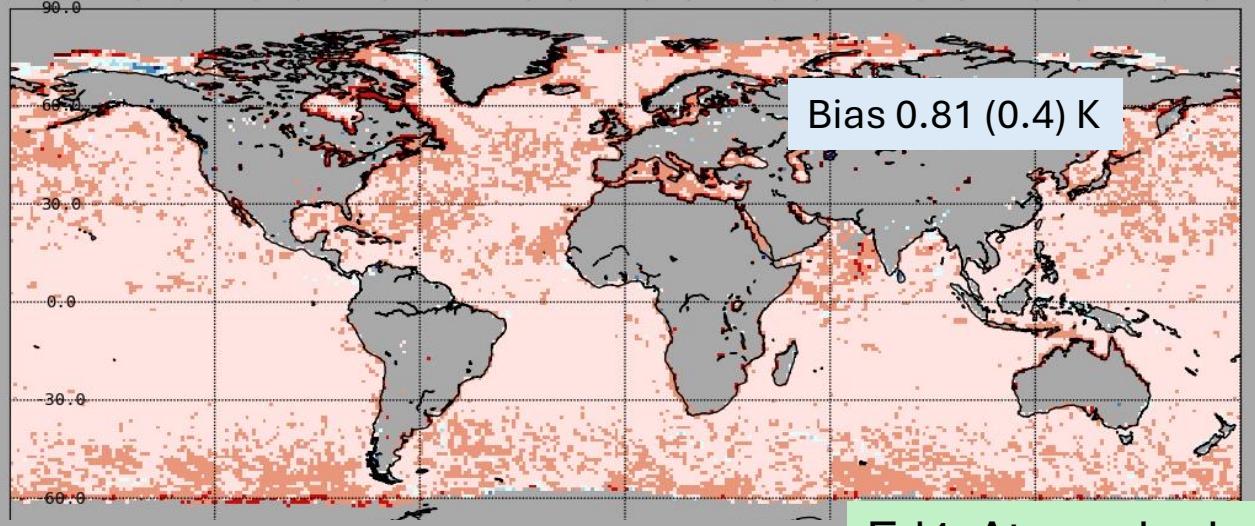


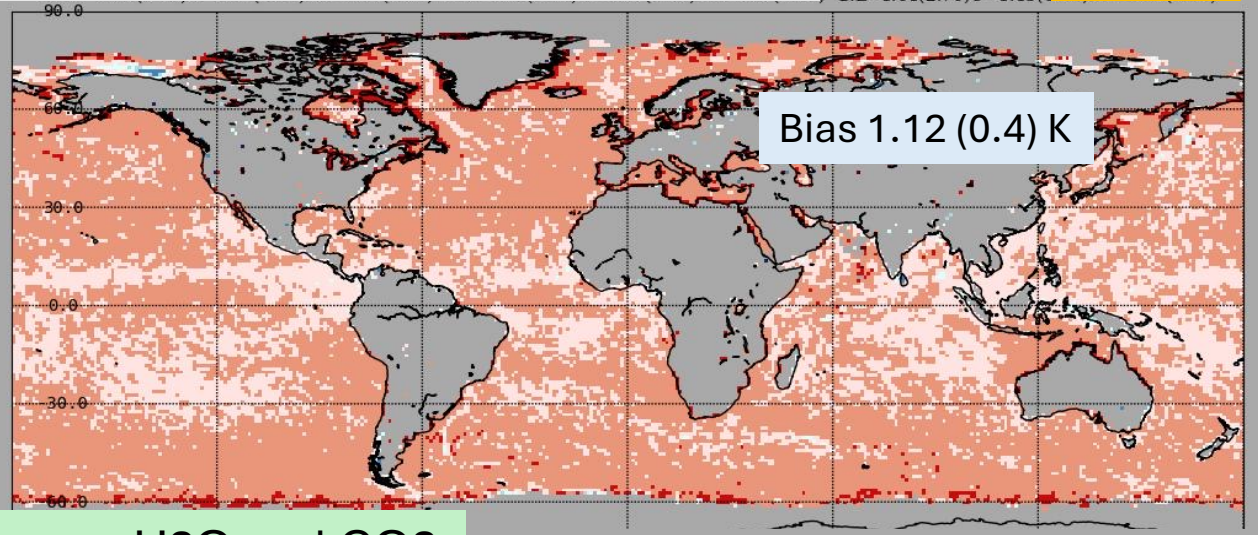
BT Depression With Respect to Surface BT Due to All Absorption at Nadir
TRO: 5.0 K, MLS: 3.7 K, MLW: 0.62 K, SAS: 2.11 K, SAW: 0.24 K, USS: 2.11 K

Predicted Clear Sky BTemp - MODIS Clear sky Obs BTemp

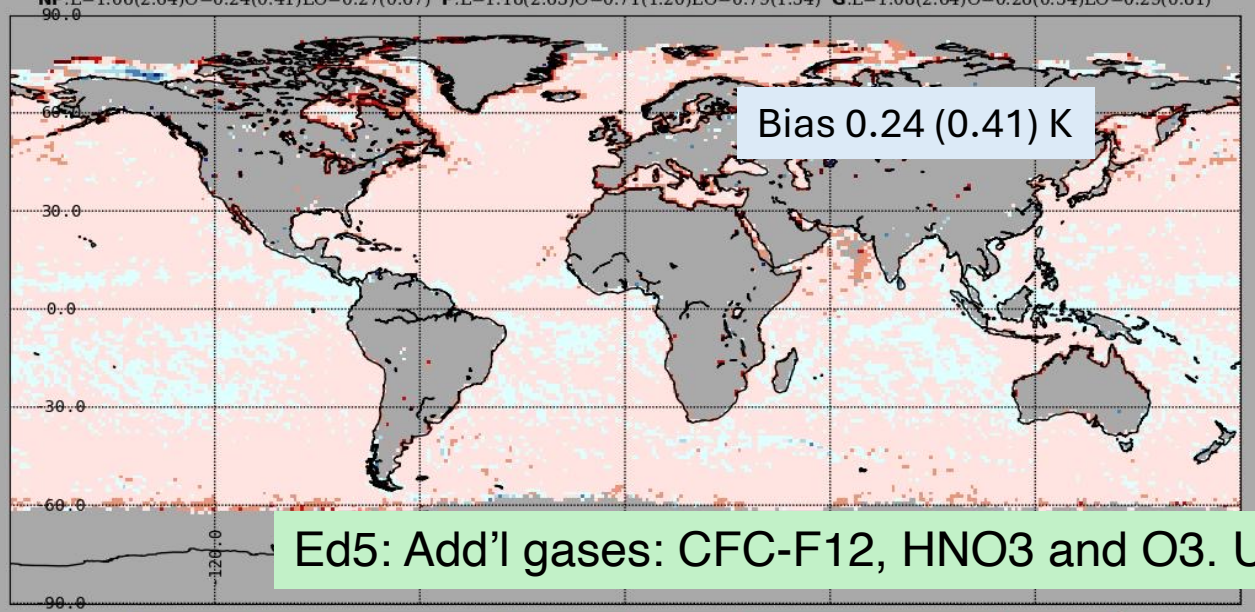
11 μm

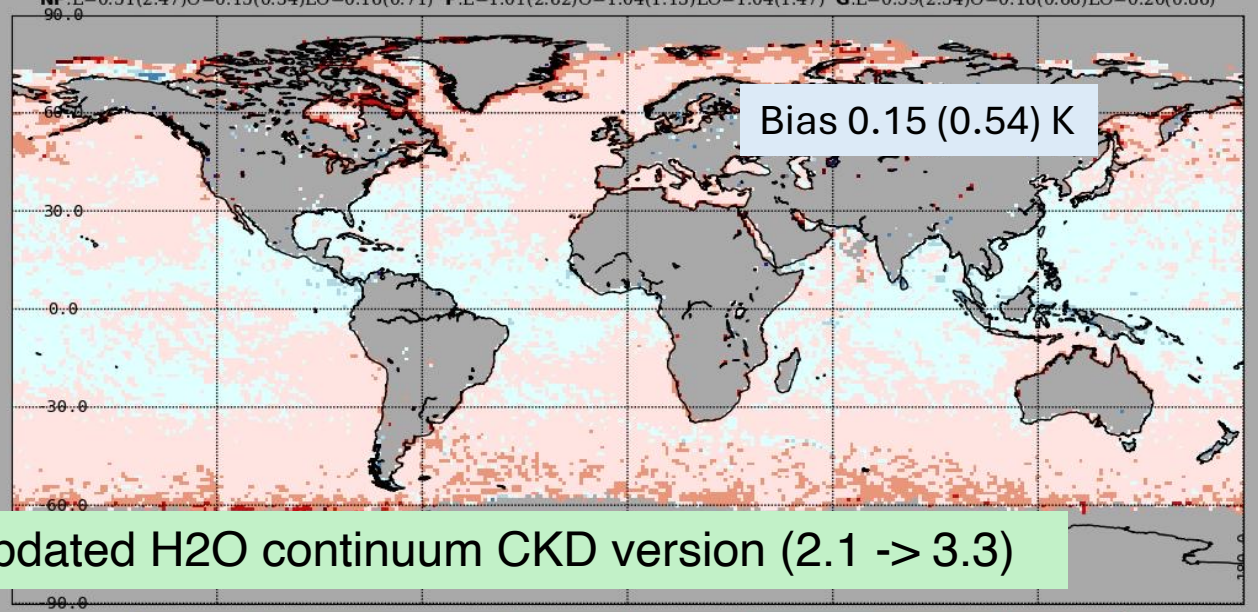
12 μm





Ed4: Atmospheric gases: H2O and CO2





Ed5: Add'l gases: CFC-F12, HNO3 and O3. Updated H2O continuum CKD version (2.1 -> 3.3)

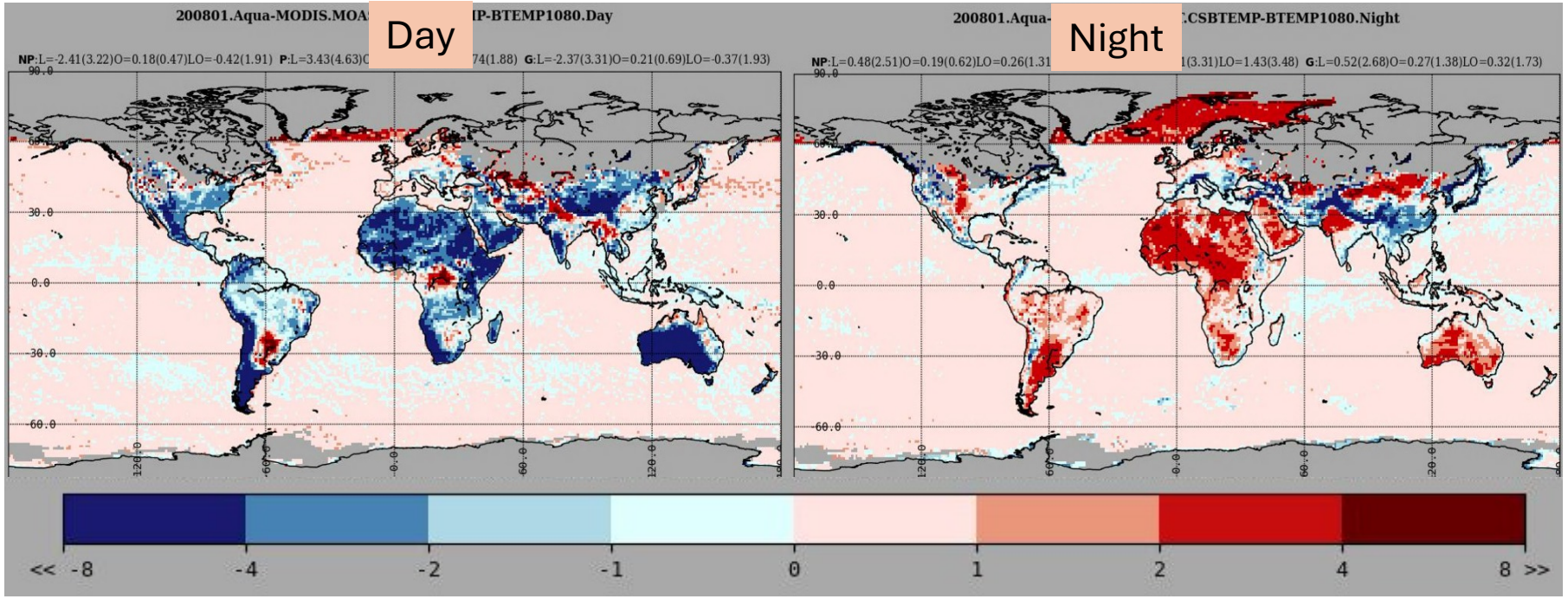
Ed5 Cloud Algorithm Updates and Improvements

- Improved atmospheric corrections
- **Use of machine learning for skin temperature used in cloud mask**
- Ed5 snow & ice maps
- Use of machine learning for Polar Nighttime Cloud Mask

Predicted Clear Sky BTemp - MODIS Clear sky Obs 11 μm BTemp

January 2008, Aqua-MODIS, Snow & Ice Free

GEOS-IT SkinT:
- Forest:
  Bias: -0.13 K
  SDD: 3.37 K
- Desert:
  Bias: -4.97 K
  SDD: 4.70 K
- Rest Land:
  Bias: -2.74 K
  SDD: 4.41 K



GEOS-IT SkinT:
- Forest:
  Bias: -0.35 K
  SDD: 3.0 K
- Desert:
  Bias: 1.37 K
  SDD: 2.47 K
- Rest Land:
  Bias: 0.59 K
  SDD: 2.73 K

- GEOS-IT skin temperatures over ocean agree well with observed brightness temperature from MODIS within +- 0.2 K.
- Over land, GEOS-IT skin temperature has diurnal issue:
  - Too cold during daytime
  - Too warm at night
- CERES cloud mask: Threshold methods requiring good estimates for clear sky predictions

Predicted Clear Btemp: Skin Temperature with sfc emissivity & forward calculation of Corrk under clear sky condition.

Neural Network Algorithm
for skin temperature used in cloud mask

Neural Network Inputs:

- Latitude, longitude, vza, sza, surface type, elevation
- GEOS-IT skin temperature & surface air temperature
- Atmospheric Vertical Profiles from GMAO GEOS-IT

Output:

- Skin temperature (snow-free land)

Training Truth:

- MODIS derived skin temperature (under clear condition, snow free land)

Training Season:

- 4 seasonal Aqua-MODIS months in 2008.

Predicted Clear Sky Btemp - MODIS Clear sky Obs 11 μm BTemp

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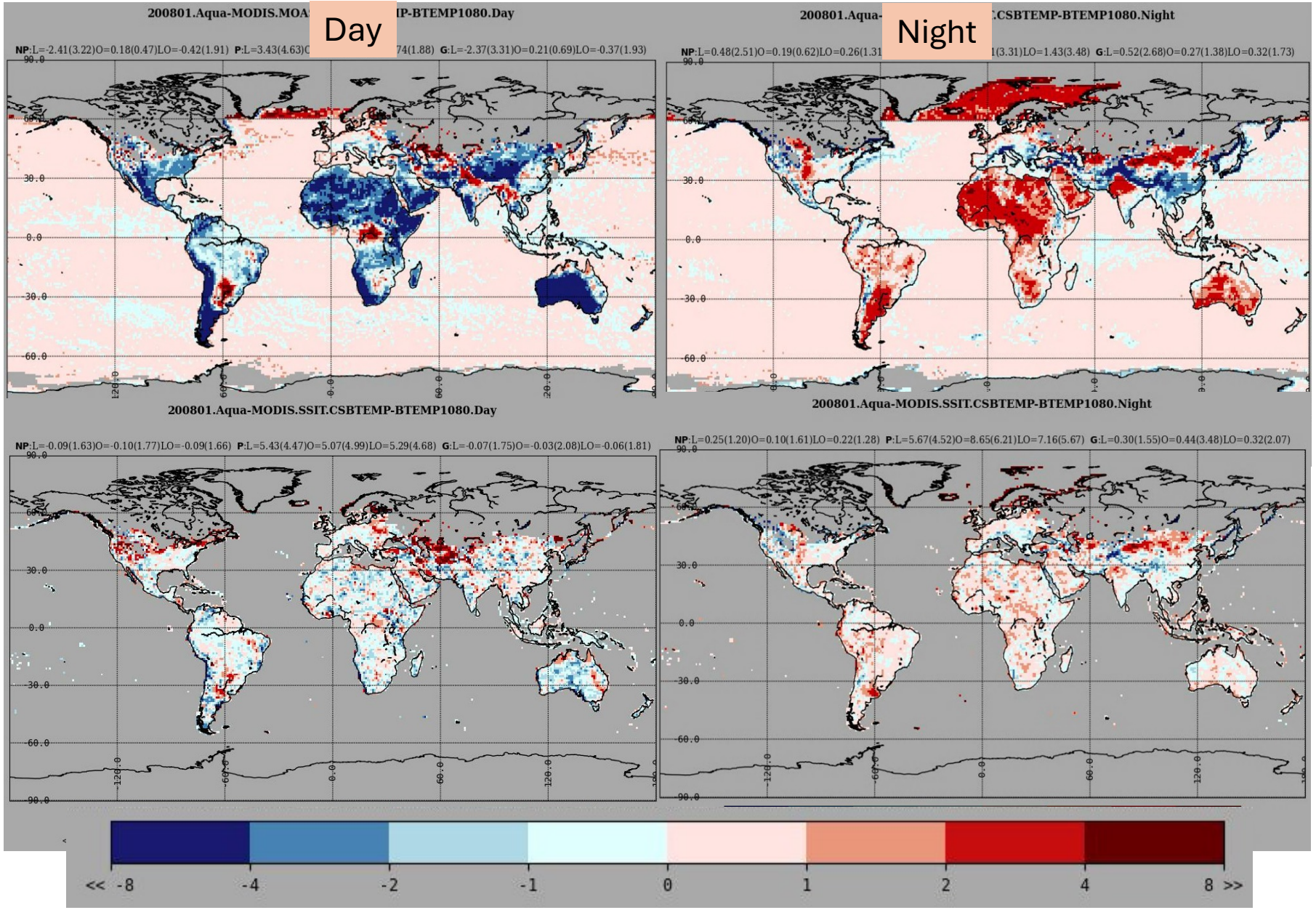
  - Bias: -4.97 K
  - SDD: 4.70 K
- Rest Land:
  - Bias: -2.74 K
  - SDD: 4.41 K

NN SkinT:
- Forest:
  - Bias: 0.11 K
  - SDD: 2.62 K
- Desert:
  - Bias: -0.58 K
  - SDD: 3.11 K
- Rest Land:
  - Bias: -0.32 K
  - SDD: 3.08 K



GEOS-IT SkinT:
- Forest:
  - Bias: -0.35 K
  - SDD: 3.0 K
- Desert:
  - Bias: 1.37 K
  - SDD: 2.47 K
- Rest Land:
  - Bias: 0.59 K
  - SDD: 2.73 K

NN SkinT:
- Forest:
  - Bias: 0.17 K
  - SDD: 1.84 K
- Desert:
  - Bias: 0.33 K
  - SDD: 1.88 K
- Rest Land:
  - Bias: 0.27 K
  - SDD: 1.83 K

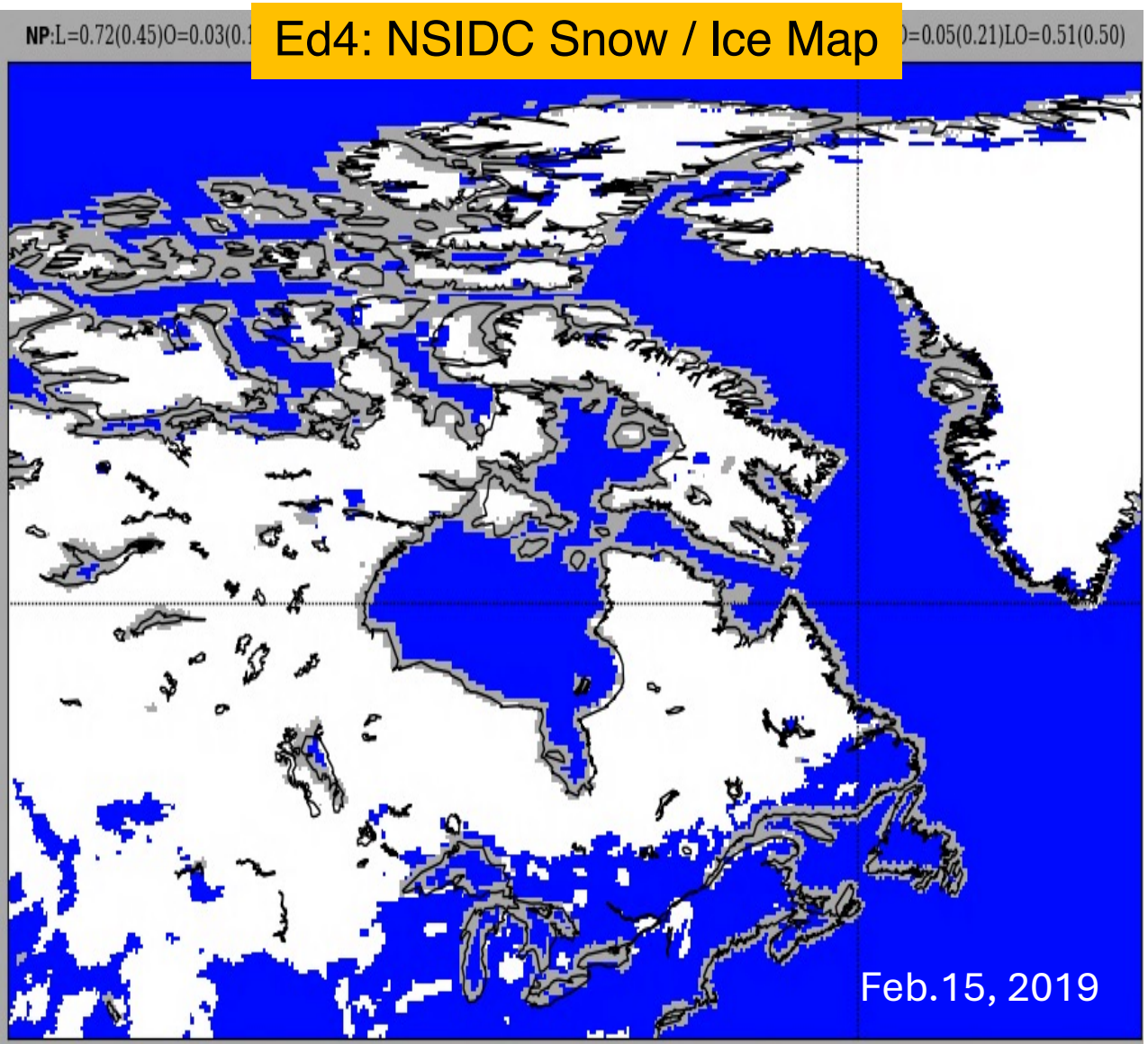
Predicted Clear Btemp: Skin Temperature with sfc emissivity & forward calculation of Corrk under clear sky condition.

Ed5 Cloud Algorithm Updates and Improvements

- Improved atmospheric corrections
- Use of machine learning for skin temperature used in cloud mask
- **Ed5 snow & ice maps**
- Use of machine learning for Polar Nighttime Cloud Mask

Issues:

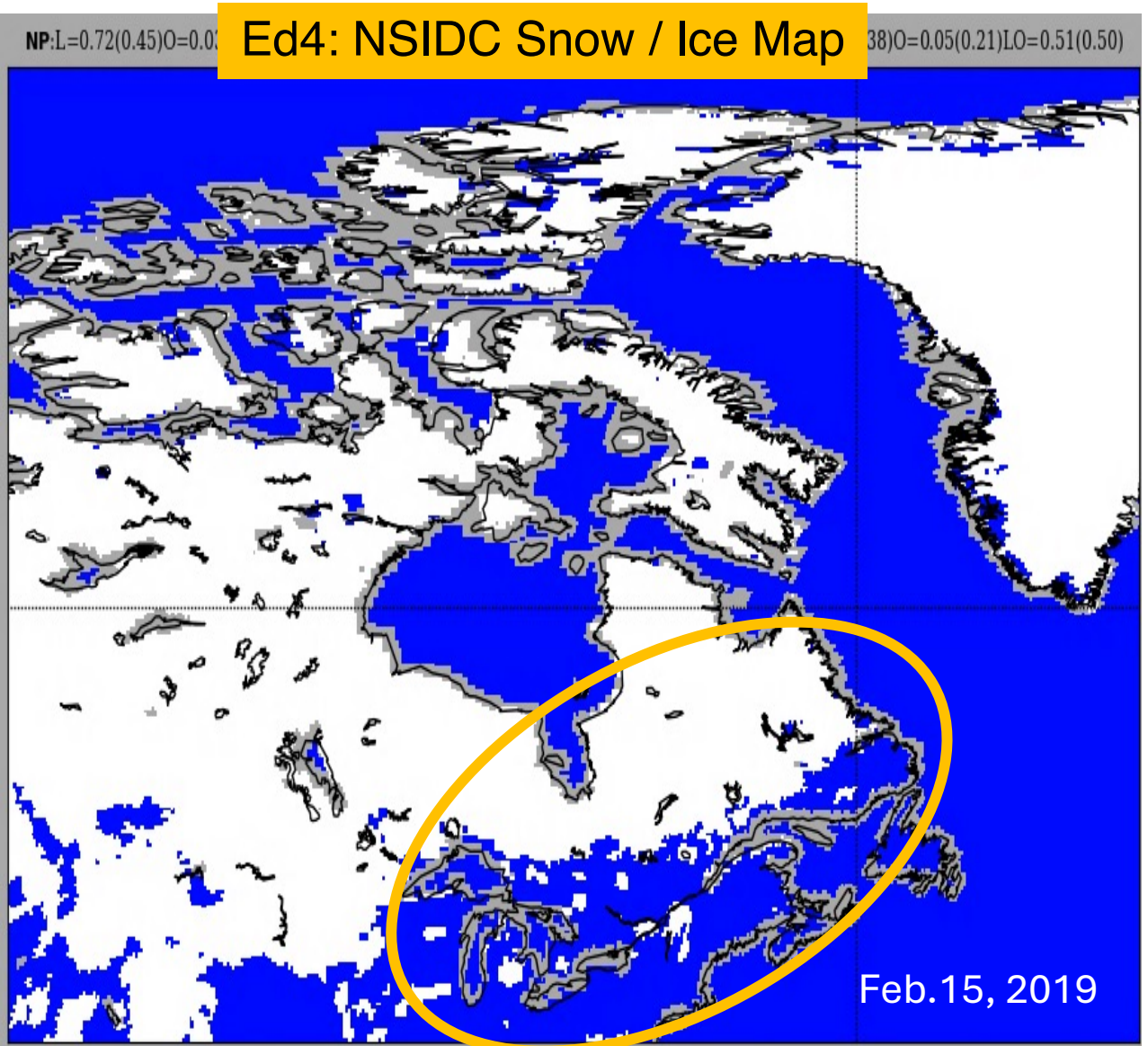
- 50 km unknow regions along the coast
- All lakes are ice free all year around
- It’s known for under-estimating snow

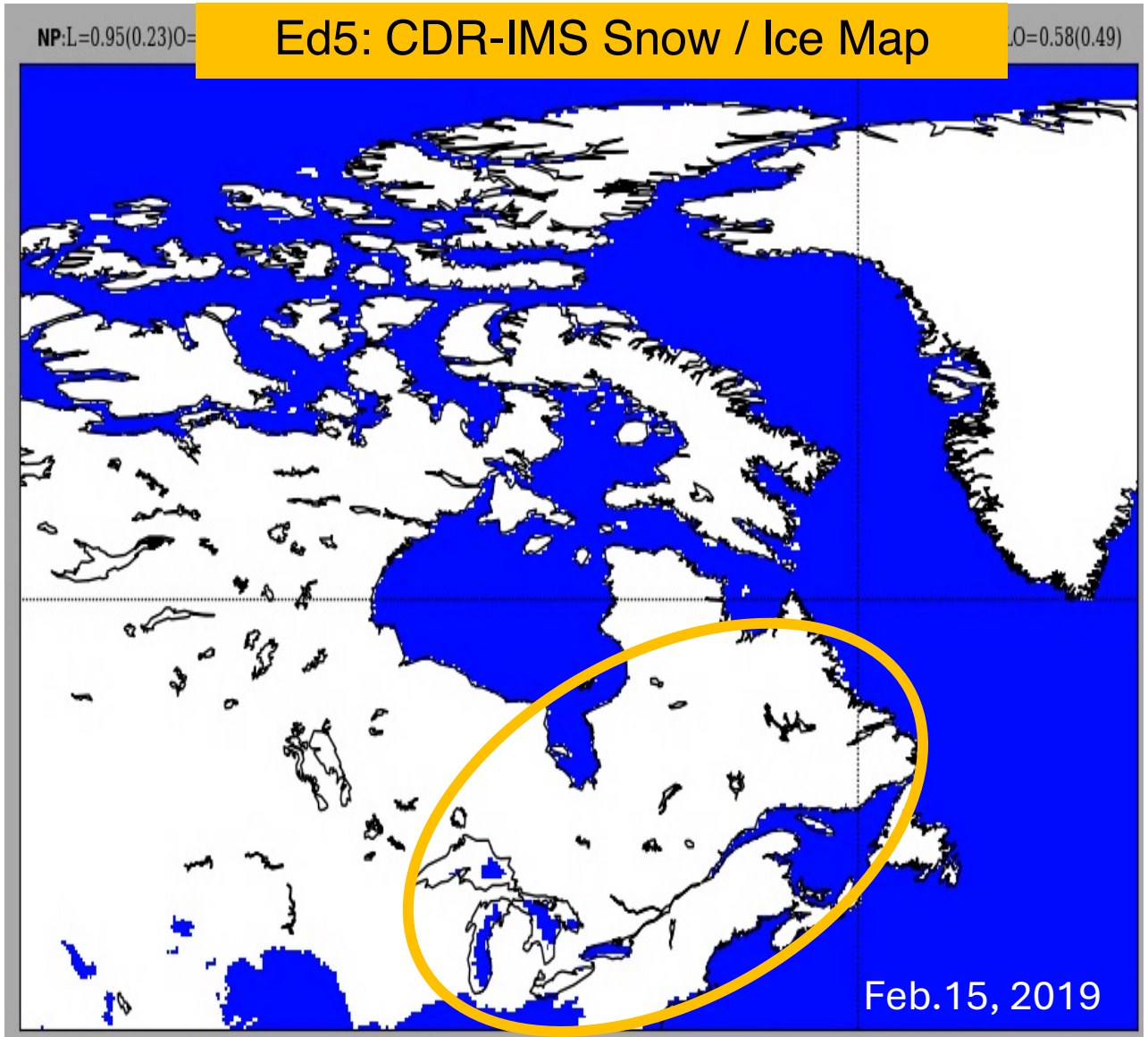


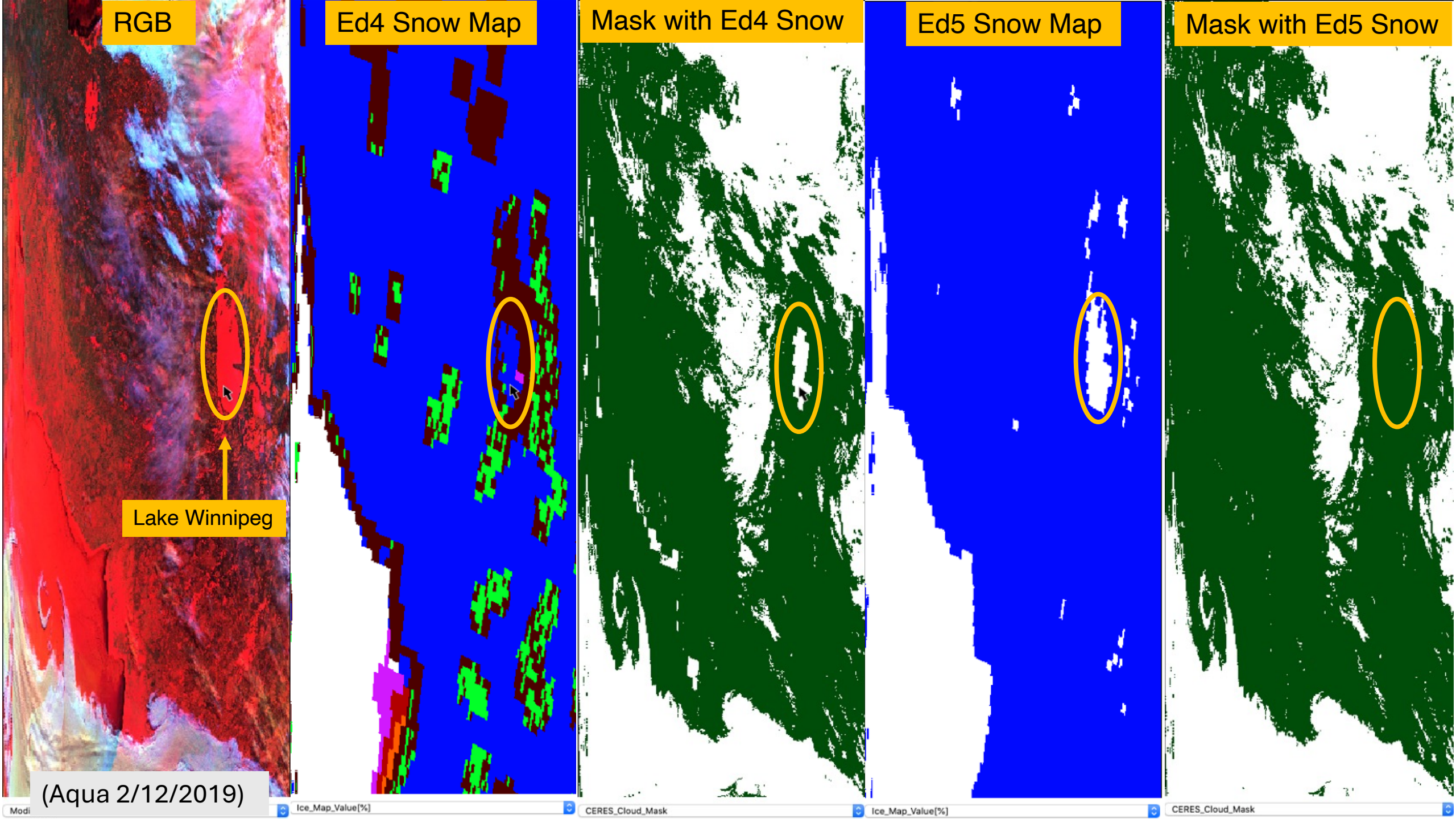
Issues:

- 50 km unknow regions along the coast
- All lakes are ice free all year around
- It's known for under-estimating snow

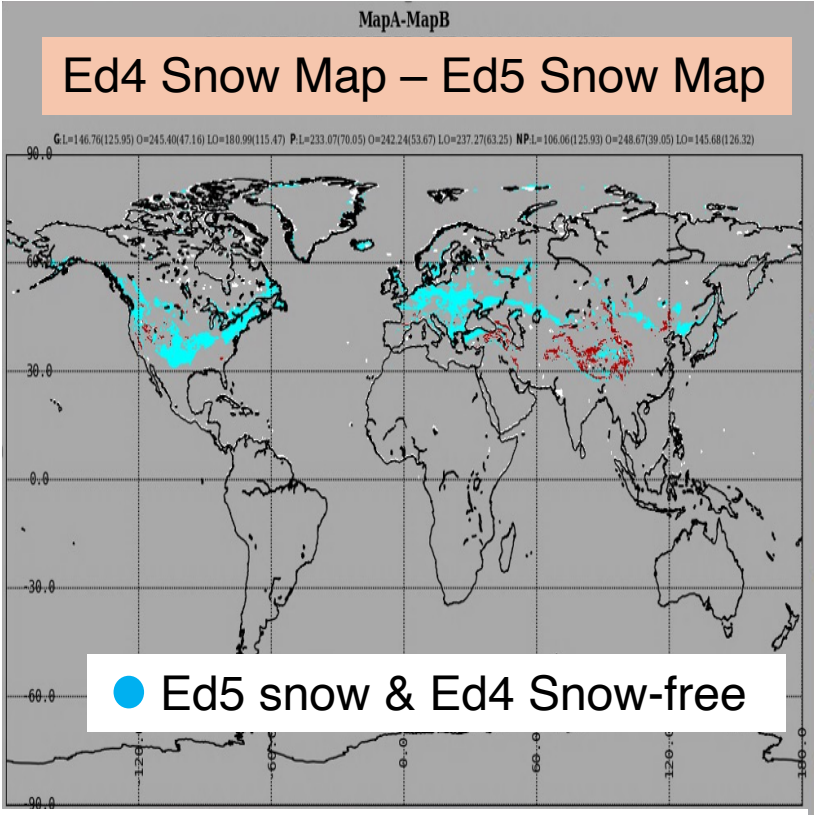
- Ice: NOAA/NSIDC Climate Data Record (CDR) of Passive Microwave Sea Ice Concentration
- Snow: The Interactive Multisensor Snow and Ice Mapping System (IMS) from US National Ice Center





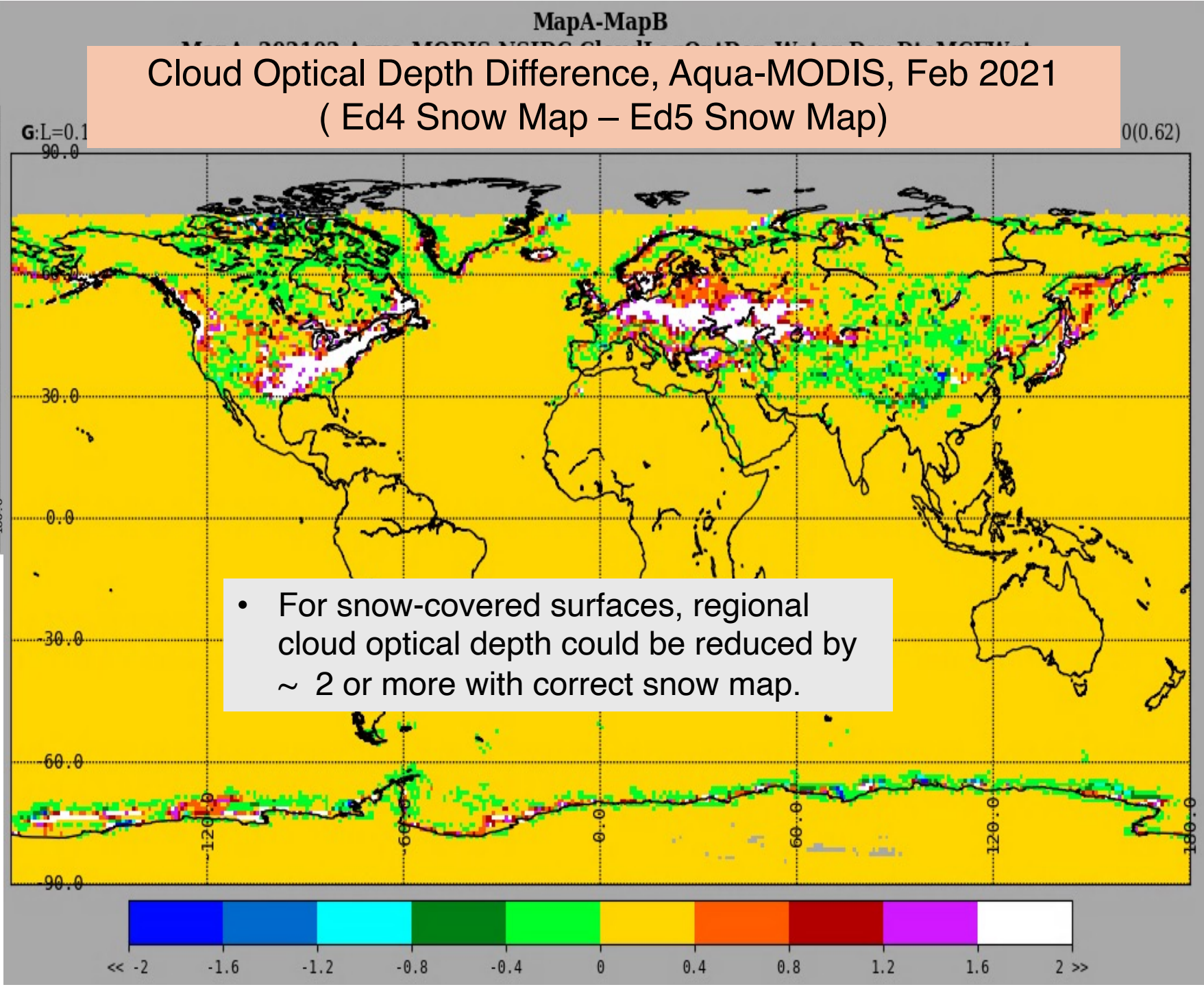

RGB
Ed4 Snow Map
Mask with Ed4 Snow
Ed5 Snow Map
Mask with Ed5 Snow
Lake Winnipeg
(Aqua 2/12/2019)
Ice_Map_Value[%]
CERES_Cloud_Mask
Ice_Map_Value[%]
CERES_Cloud_Mask

Ed4 Snow Map – Ed5 Snow Map



- Snow / ice free:
  0.6 μm optical depth retrieval
- Snow / ice covered:
  1.6 /1.24 hybrid optical depth retrieval

Cloud Optical Depth Difference, Aqua-MODIS, Feb 2021
(Ed4 Snow Map – Ed5 Snow Map)

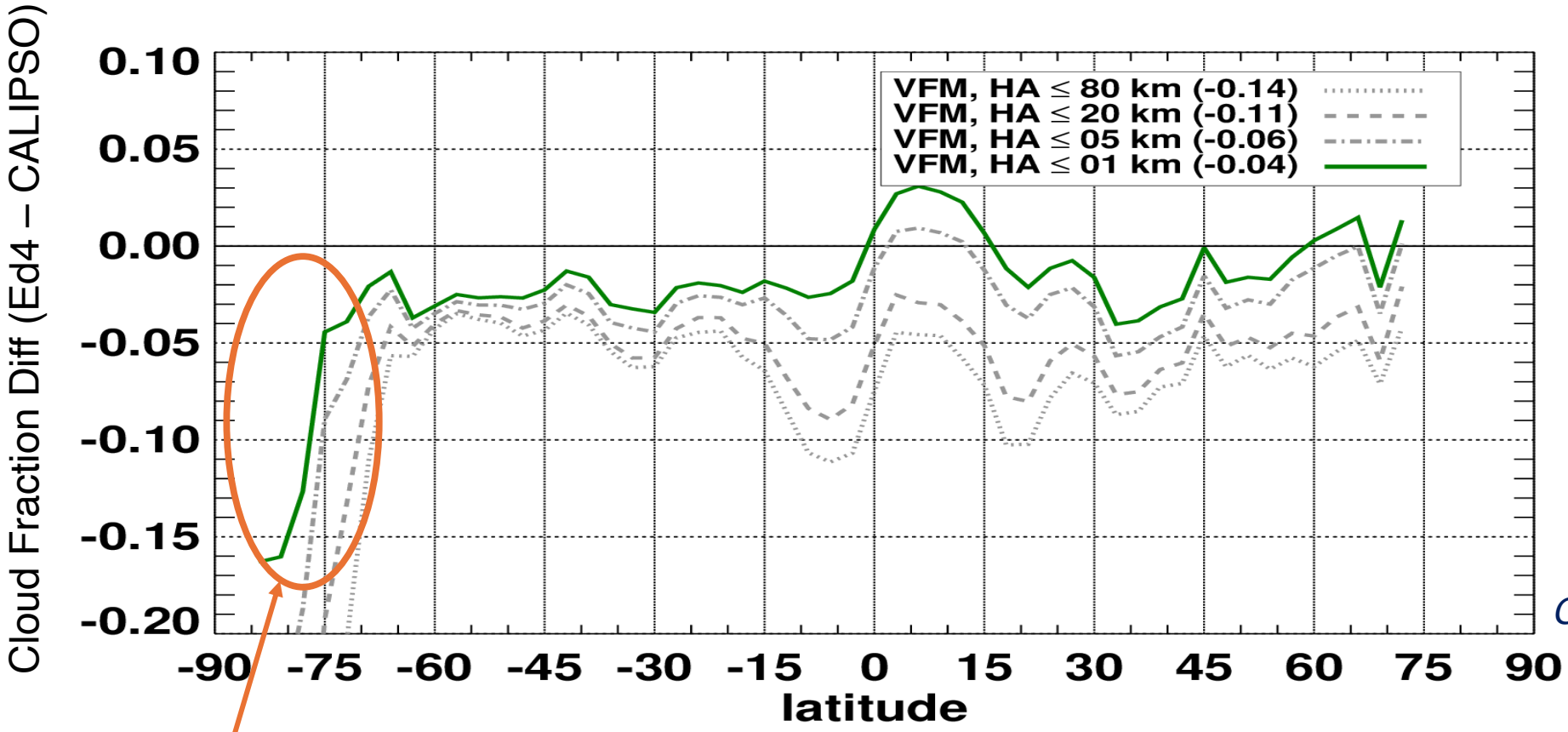


- For snow-covered surfaces, regional cloud optical depth could be reduced by ~ 2 or more with correct snow map.

Ed5 Cloud Algorithm Updates and Improvements

- Improved atmospheric corrections
- Use of machine learning for skin temperature used in cloud mask
- Ed5 snow & ice maps
- **Use of machine learning for Polar Nighttime Cloud Mask**

Mean nighttime cloud fraction differences, CERES-MODIS Ed4 – CALIPSO VFM
Four horizontal averaging scales, July 2015-16



Differences between MODIS and each of the VFM cloud fraction estimates

Courtesy of Chris Yost

0.12 underestimate over Antarctic and Southern Ocean sea ice at night

Ed4 Cloud Mask:

- Threshold method, heavily depends on obs. channels & sfc temp
- 3.7, 6.7 and 8.5 μm often stripping at night over Antarctic
- In case of VIIRS, 3.7 saturates (~206 K for I4) nighttime Antarctic
- Large uncertainty of surface temperature at night over Antarctic

Near nadir Aqua-MODIS NN cloud fraction, compared to CALIPSO VFM
Antarctica, Nighttime, Spring (SON) 2010

Neural Network Ed5 Cloud Detection

CALIPSO / Ed5	Clear	Cloud
Clear	32.2%	7.8%
Cloud	8.7%	51.3%

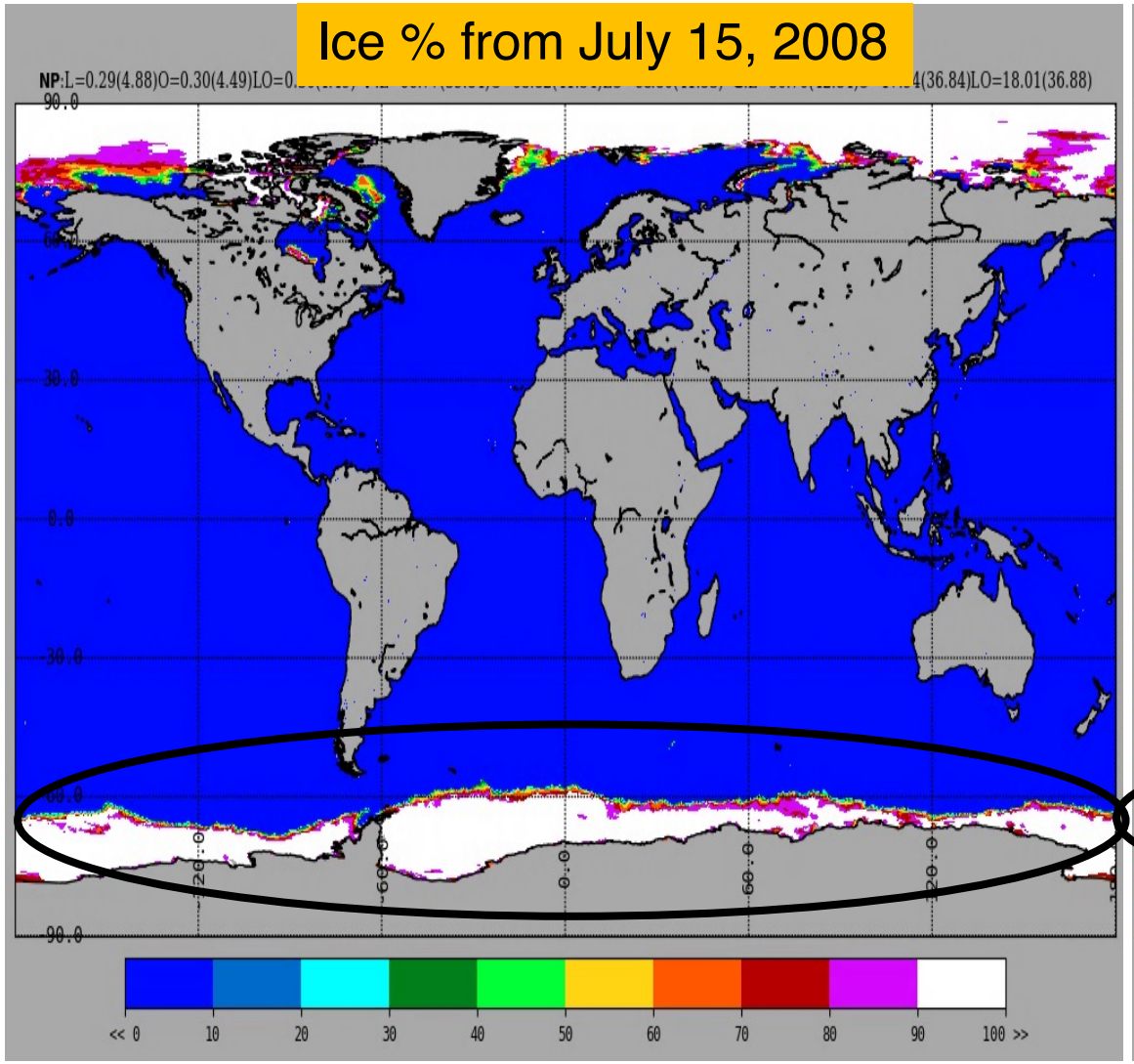
Accuracy
83.5%

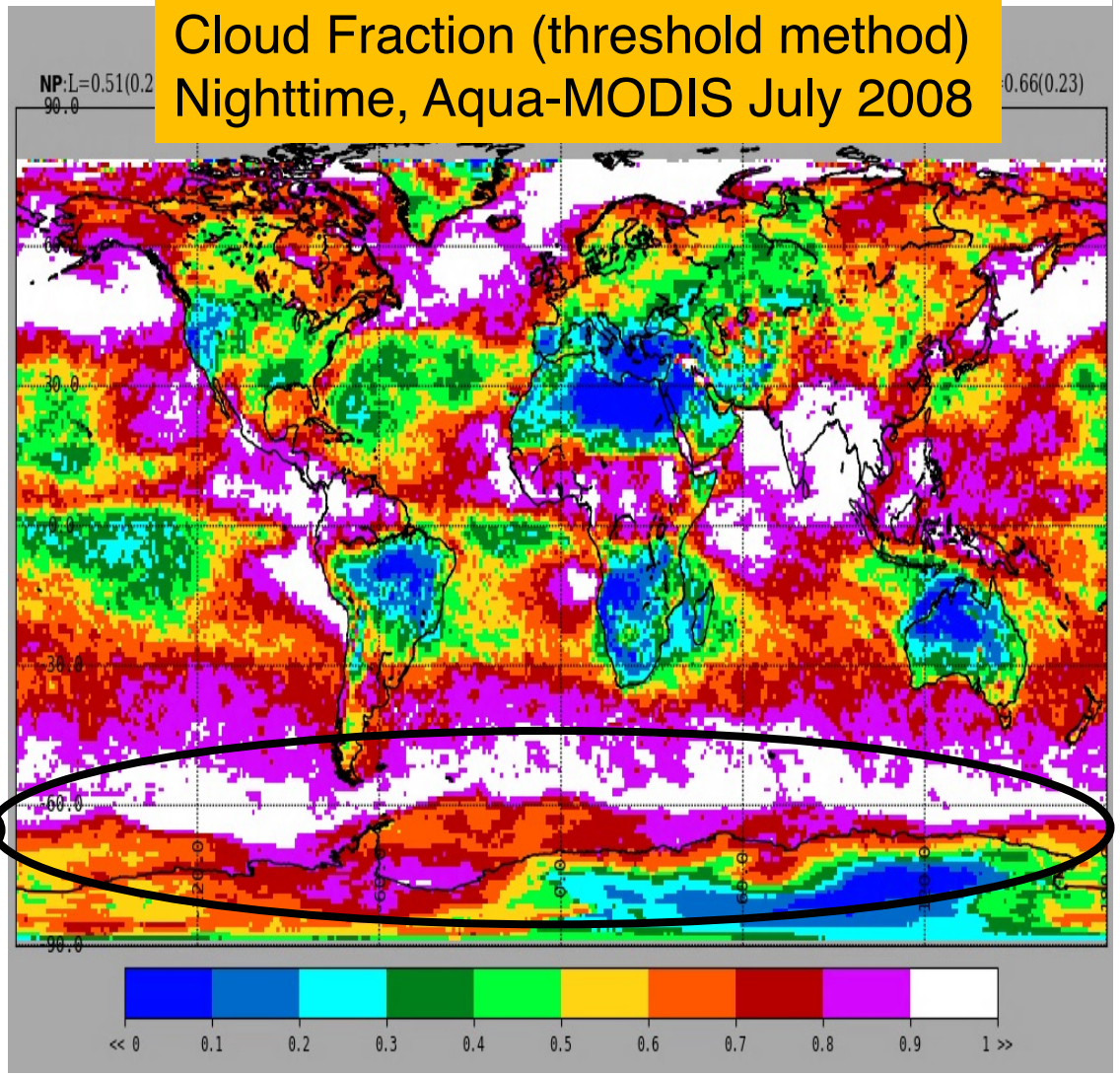
CERES Ed4 Cloud Detection

CALIPSO / Ed4	Clear	Cloud
Clear	32.0%	16.1%
Cloud	9.0%	42.9%

Accuracy
74.9%

Discontinuity in Cloud Fraction (Threshold method) from open ocean to sea ice





Open Ocean

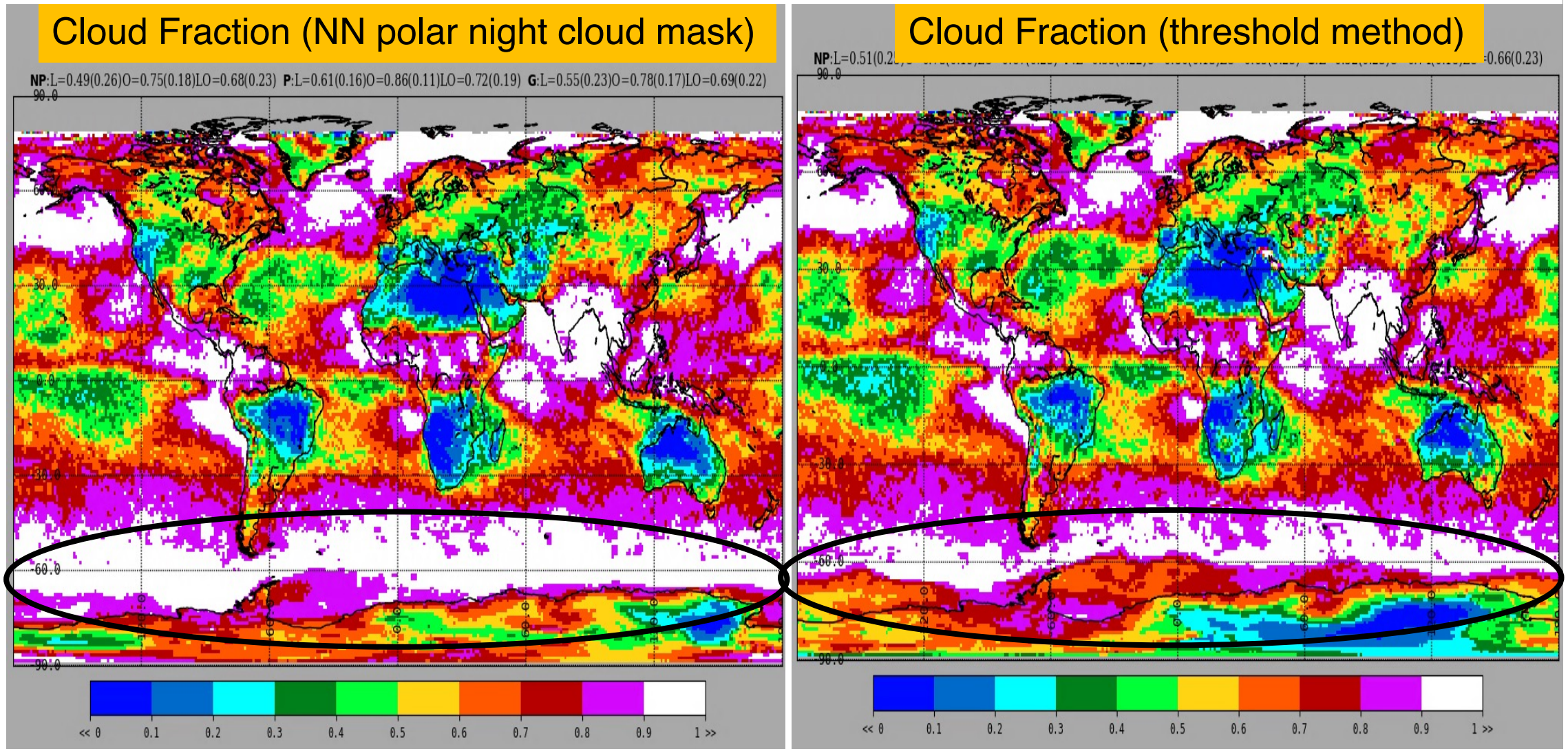
Sea Ice

- Discontinuity between open ocean and sea ice from threshold method cloud mask

Neural network nighttime polar cloud mask
No Discontinuity from open ocean to sea ice

Cloud Fraction (NN polar night cloud mask)

Cloud Fraction (threshold method)



Open Ocean

Sea Ice

- NN nighttime polar cloud mask shows no discontinuity between open ocean and sea ice.
- CF increased by 8% over Antarctic & 6% over Southern Ocean sea ice, better agreement with CALIPSO.

List of Publications

- Sun-Mack, S., P. Minnis, Y. Chen, G. Hong, W. L. Smith Jr., 2024: Identification of ice-over-water multilayer clouds using multispectral satellite data in an artificial neural network. Atmospheric Measurement Techniques, 17(10), 3323-3346. doi: 10.5194/amt-17-3323-2024

- Stubenrauch, C. J., S. Kinne, G. Mandorli, W. B. Rossow, D. M. Winker, S. A. Ackerman, H. Chepfer, L. Di Girolamo, A. Garnier, A. Heidinger, K. Karlsson, K. Meyer, P. Minnis, S. Platnick, M. Stengel, S. Sun-Mack, P. Veglio, A. Walther, X. Cai, A. H. Young, G. Zhao, 2024: Lessons Learned from the Updated GEWEX Cloud Assessment Database. Surveys in Geophysics. doi: 10.1007/s10712-024-09824-0

- Li, D., M. Sato, P. Yang, N. G. Loeb, W. L. Smith, Jr., and P. Minnis, 2024: On the scattering-angle dependence of the spectral consistency of ice cloud optical thickness retrievals based on geostationary satellite observations. IEEE Trans. Remote Sens. Geosci., 61, 12 pp., doi:10.1109/TGRS.2023.3331970.

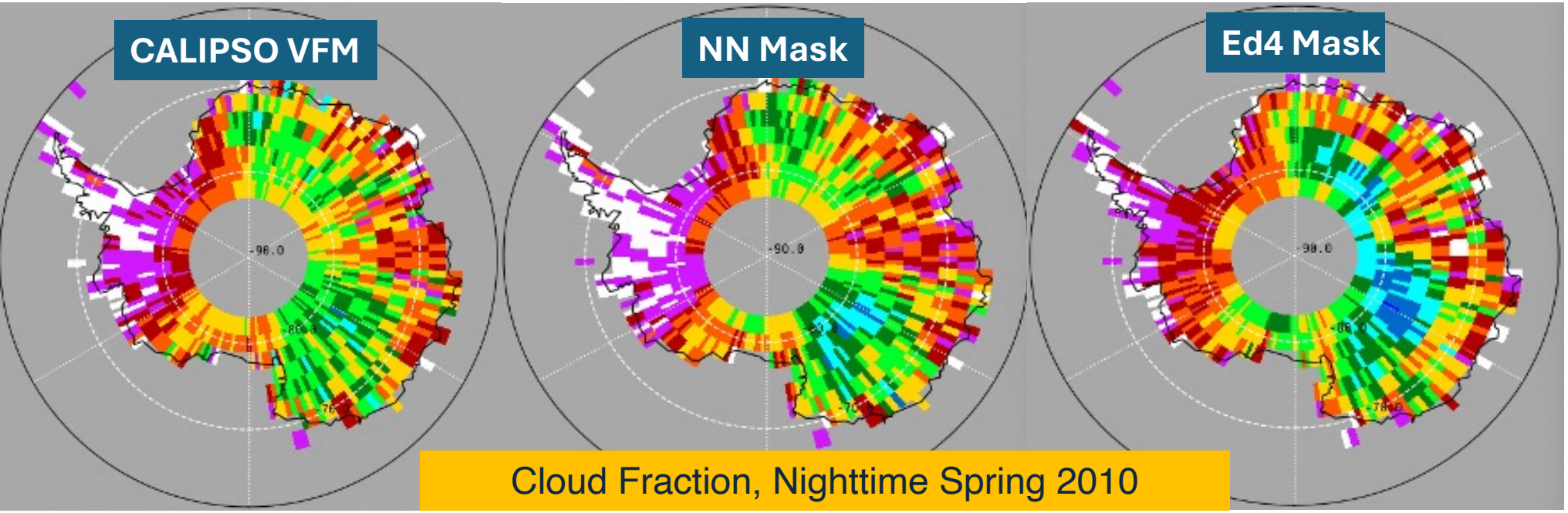
- Minnis, P., 2024: Contrails. Reference Module in Earth Systems and Environmental Sciences, Encyclopedia of Atmospheric Sciences, 3rd Edition, Elsevier Ltd, Oxford, UK, Andrew Detwiler (editor in chief), doi:10.1016/B978-0-323-96026-7.00045-X.

- Dong, X. and P. Minnis, 2023: Chapter 6: Stratus, stratocumulus, and remote sensing, In Fast Processes in Large Scale Atmospheric Models: Progress, Challenges, and Opportunities, L. Donner, Y. Liu, and P. Kollias, Eds., AGU-Wiley Publ., pp.141-200, doi:10.1002/9781119529019.ch6.

QUESTIONS?

Spare:

Nadir Aqua-MODIS cloud fraction compared to CALIPSO VFM, Antarctica



- Other seasons are similar