# Toward the All-Surface Assimilation of Surface-Sensitive Satellite Data from Microwave Temperature- and Humidity-Sounding Channels in CMA-GFS 4D-Var System

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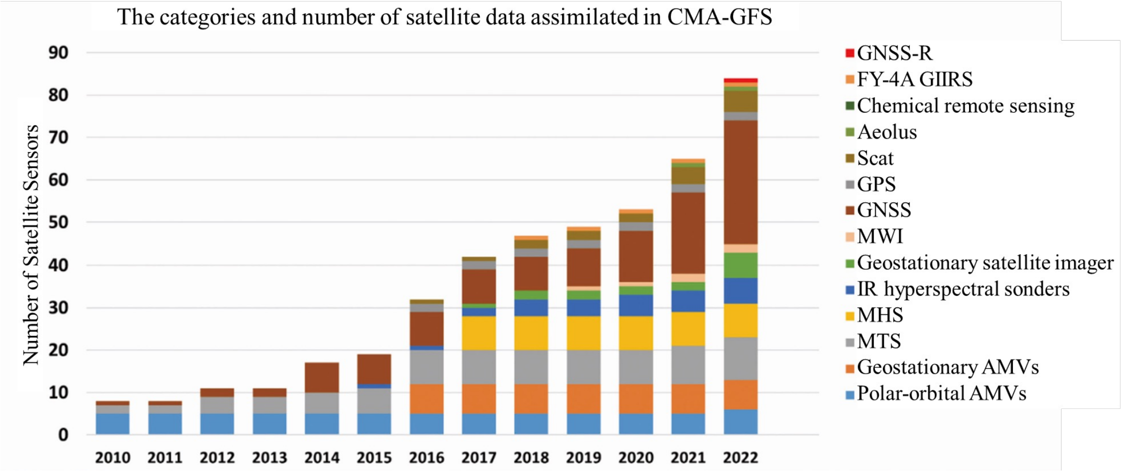
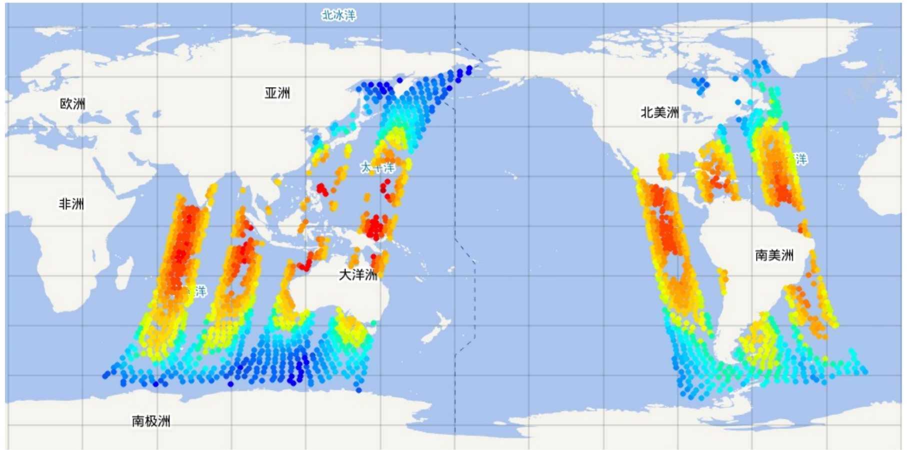
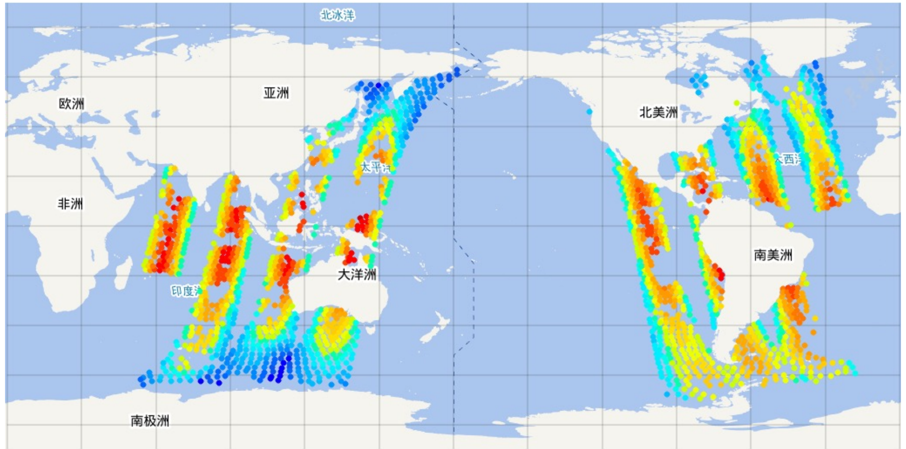
# Introduction : Assimilation of Surface-Sensitive Channels in CMA_GFS over Land



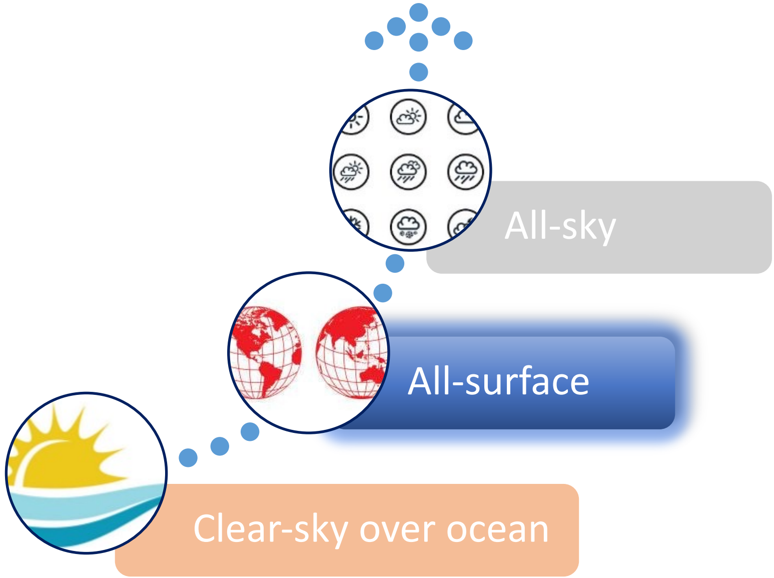

CH5 assimilation till 2021




CH6 assimilation till 2021



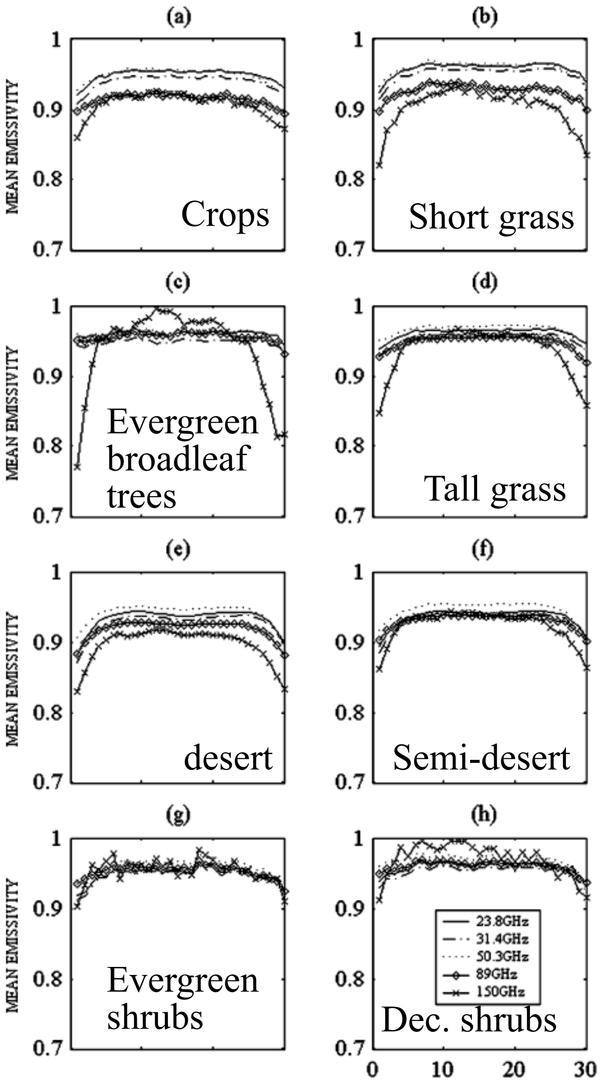

(pictures coming from CMA data assimilation monitoring system)




The observational data affected by land surface is **NOT ACTIVATED**!

# Dynamic Emissivity Scheme (without extrapolation)

## Mechanism of Dynamic Method



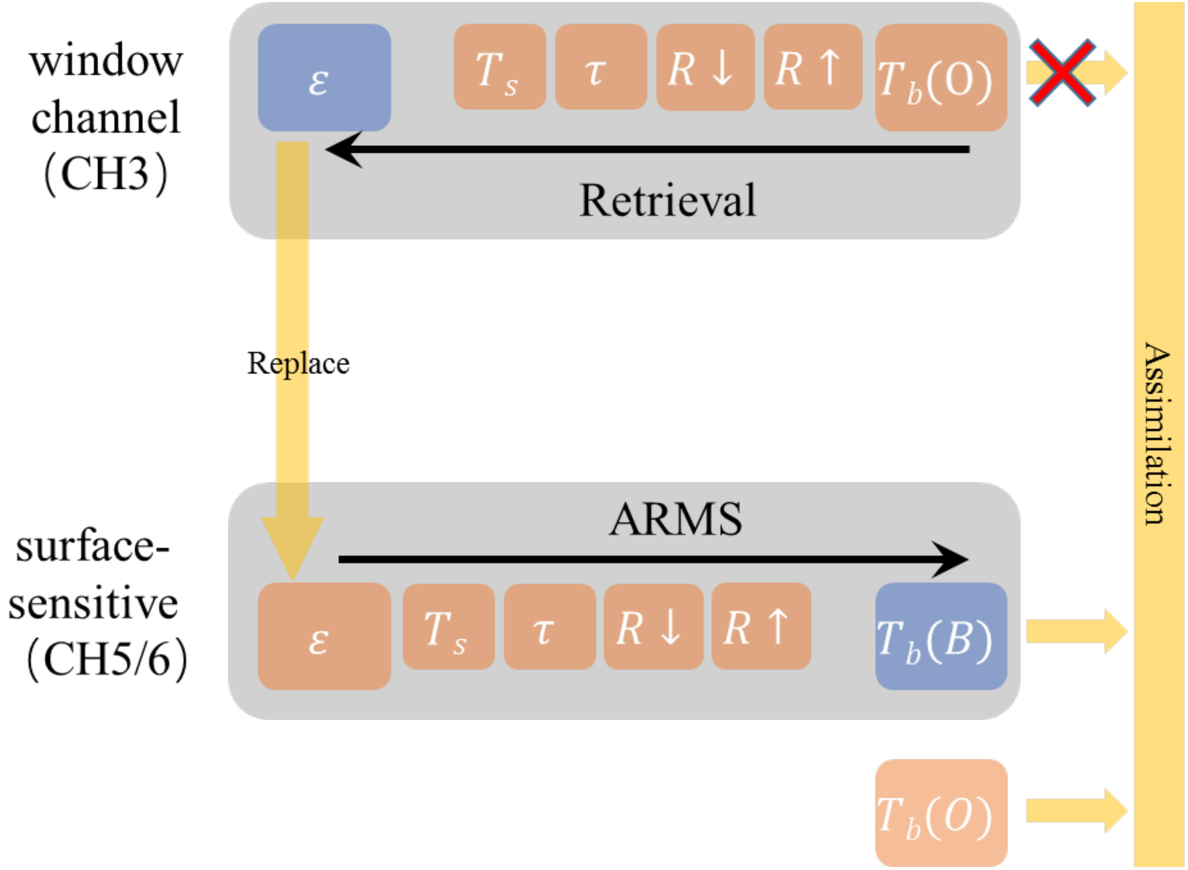

Karbou et al, 2006.

The approximate **constancy of LSE** versus the frequency in the microwave range

### Normal Assimilation




### Assimilation based on Dynamic Emissivity Retrieval Scheme



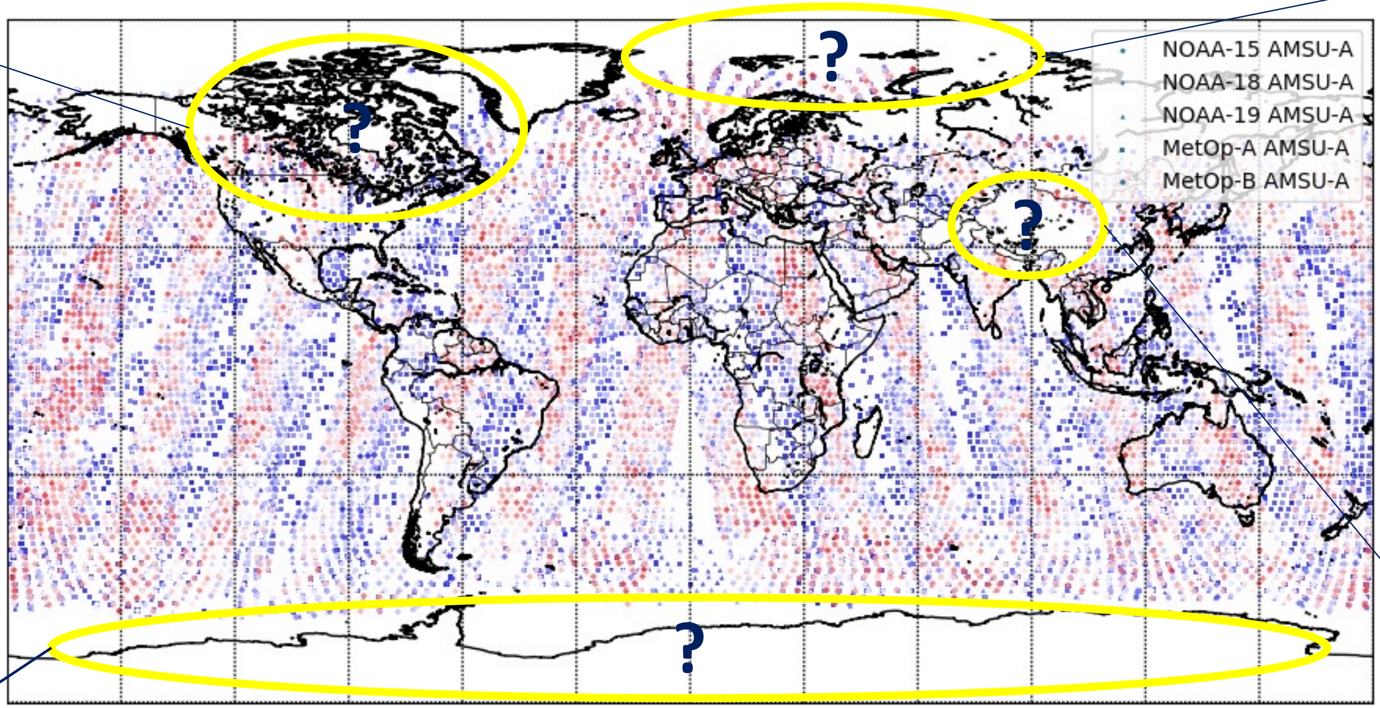

(Hongyi Xiao, et al., 2023)

# The Regions with Sparse Data Assimilated in CMA-GFS

Coast

AMSU-A CH5 assimilated by CMA-GFS in 2023

Sea ice



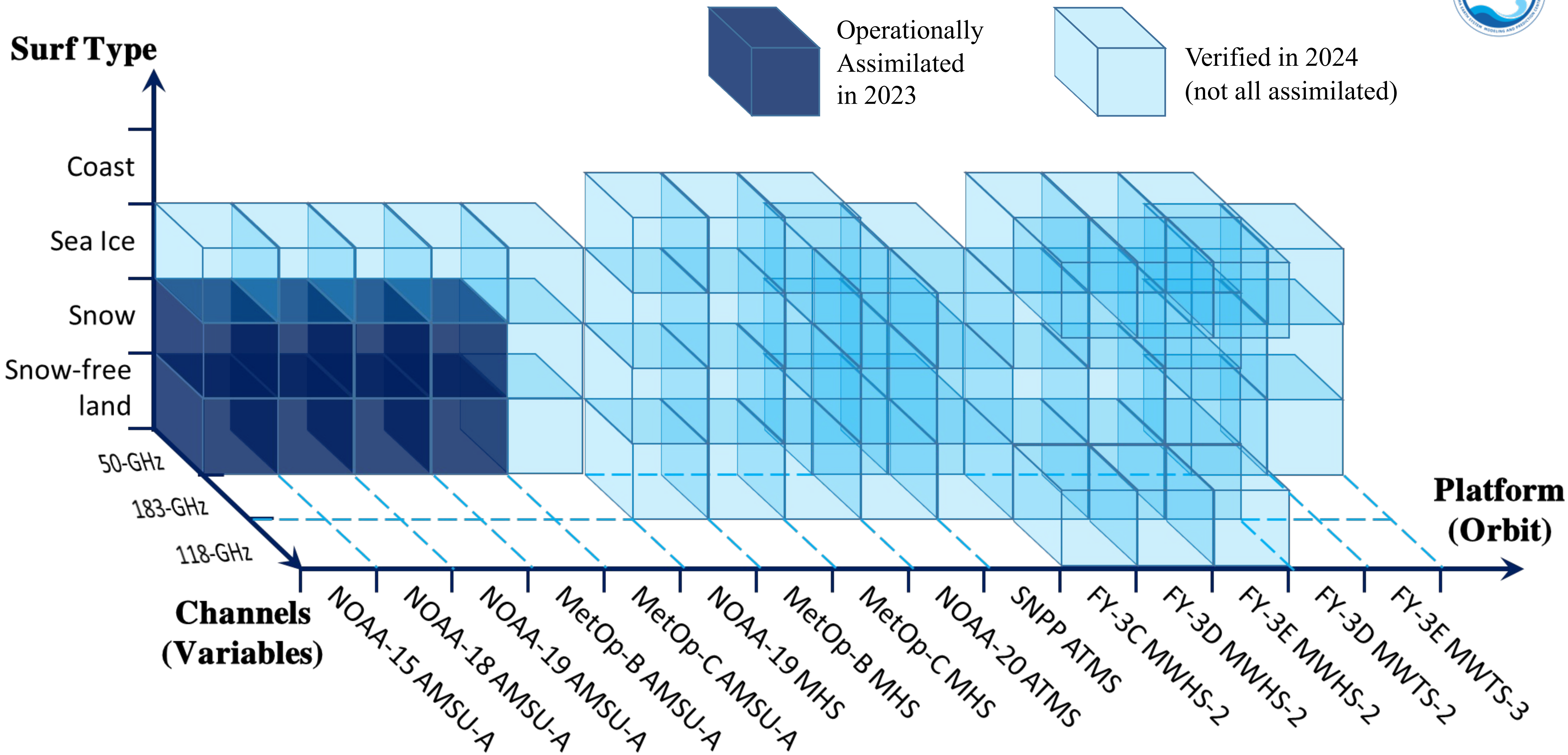

Plateau

Snow

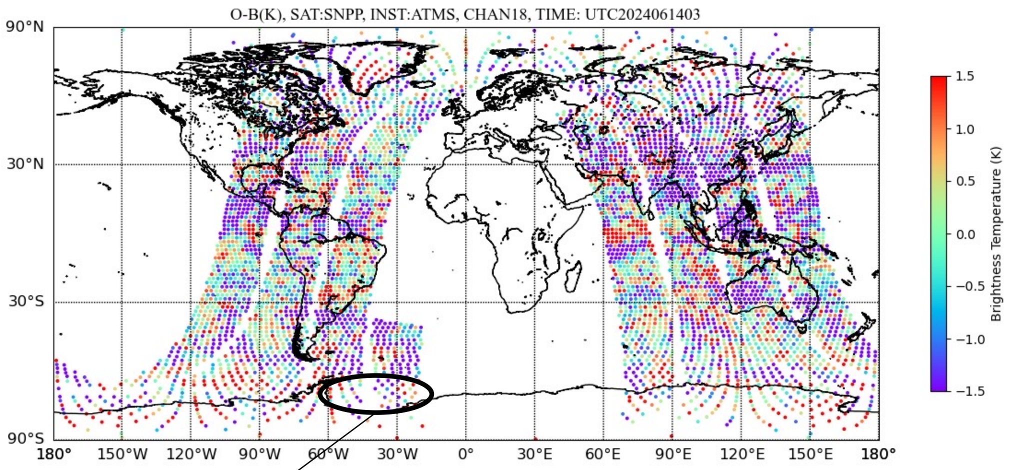
# All-Surface Assimilation Framework

| Platforms & Instruments | Snow-free land | | Coastal Aread | Sea ice | | Snow | |
|---|---|---|---|---|---|---|---|
| | Window CH | Low-layer CH | Low-layer CH | Window CH | Low-layer CH | Window CH | Low-layer CH |
| NOAA-15 AMSU-A | 1[1] | 2-8[1],5-14[4] | | | | | |
| NOAA-18 AMSU-A<br>NOAA-19 AMSU-A<br>~~MetOp-A AMSU-A~~<br>MetOp-B AMSU-A<br>**MetOp-C AMSU-A** | **3**[5,6,7,8,9,11,13] | 5-14[5,6,7,8,11],5-13[9],**5-7**[13] | | **3**[3,7,9,13] | 4-8[3],**5-7**[4,7,13],5-13[9] | **3**[9,10,13] | 5-13[9], 4-5(lam)[10],**5-7**[13] |
| **~~NOAA-18 MHS~~**<br>**NOAA-19 MHS**<br>**~~MetOp-A MHS~~**<br>**MetOp-B MHS**<br>**MetOp-C MHS** | **1**[1,5,6,7,8,9,11,13] | 2-5[1],3-4[4, 8],**3-5**[5,6,7,9,13] | **3-4**[14] | **1**[1,5,6,9] | **3-5**(cor)[3,9],3-4[4],2-5(cor)[5] | 1[9] | 3-4[4,14], **3-5**[9],3[13] |
| | | | **4**[14] | 2[5,7,13] | 1(cor),3-5[5],3-4(cor)[7,13] | **2**[12,13] | |
| **NOAA-20 ATMS**<br>**SNPP ATMS** | **3**[11,12,13] | 6-15[4],**6-9**[11],6-8[13,14] | | **3**[11,13] | 7-15[4],**6-9**[11],7-8[14] | **3**[11,13] | 6-15[4],**6-9**[11] ,6-8[13,14] |
| | **16**[11,12,13] | **18-22**[4,11,13,14] | | **16**[11] | 20-22[4],**18-22**(cor)[11] | 16[11] | **18-22**[4,11] |
| | | | | 17[12,13] | 20-22(lam)[12,14] | **17**[12,13] | 20-22(lam)[12] |
| DMSP-F17 SSMIS | 18[2,13,15,16] | 9-11[2,13,15,16],10-11[4] | 10-11[14] | 8[13] | 10-11[4,13] | 8[12,13] | 10-11[4,13] |
| **FY-3C MWHS-2**<br>**FY-3D MWHS-2**<br>**FY-3E MWHS-2** | **1**[14] | **11-12**[4] | **11-12**[14] | **1** | **11-12**[4] | **10**[12] | **11-12**[4] |
| | | **2-6**[14] | **2-6**[14] | | | | |
| Megha-Tropiques SAPHIR | | | 1-3[14] | | | | |
| **FY-3D MWTS-2** | **1** | **2-6** | | **1** | **2-6** | **1** | **2-6** |
| **FY-3E MWTS-3** | **3** | **4-10** | | **3** | **4-10** | **3** | **4-10** |
| **FY-3G MWRI-RM** | **9** | **10-16** | | **9** | **10-16** | **9** | **10-16** |
| | **23** | **24-26** | | **23** | **24-26** | **23** | **24-26** |
| FY-3F MWTS-III<br>FY-3F MWHS-II<br>FY-3F MWRI-II | | | | | | | |

# Overview of All-Surface Assimilation



# The Extrapolation Correction of Humidity-Sounding Channels over Sea Ice




$$\varepsilon_{150} = \varepsilon_{90}$$

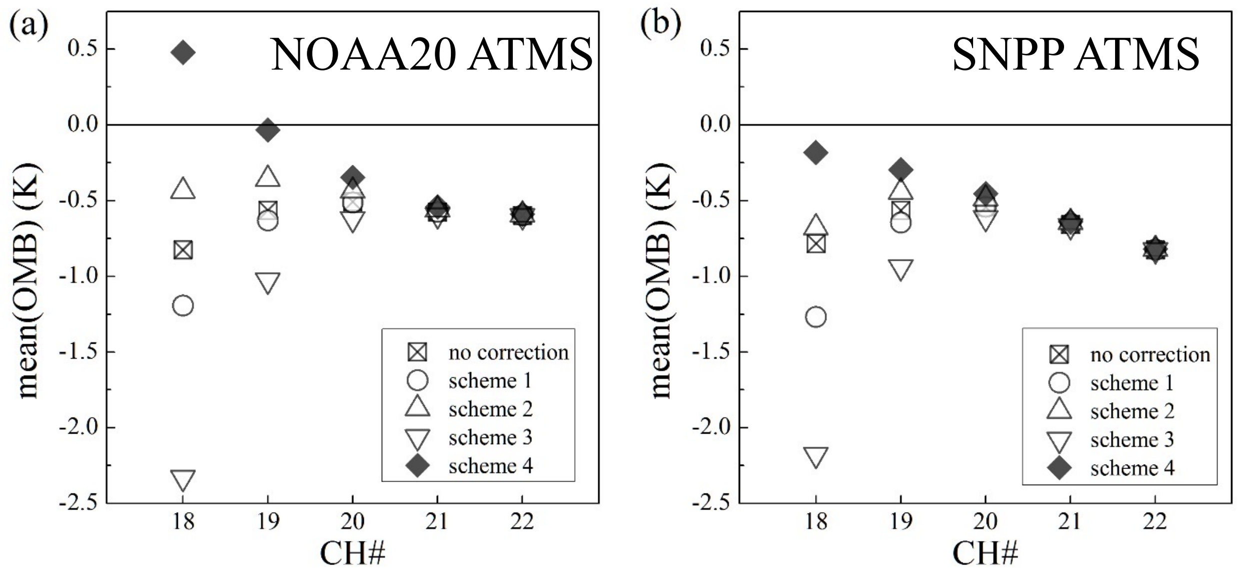
$$\overline{\text{OMB}} = 0.78K$$

Challenges:

- 150-GHz CH should be used for QC.
- 90-GHz CH is far away from 183-GHz CH.

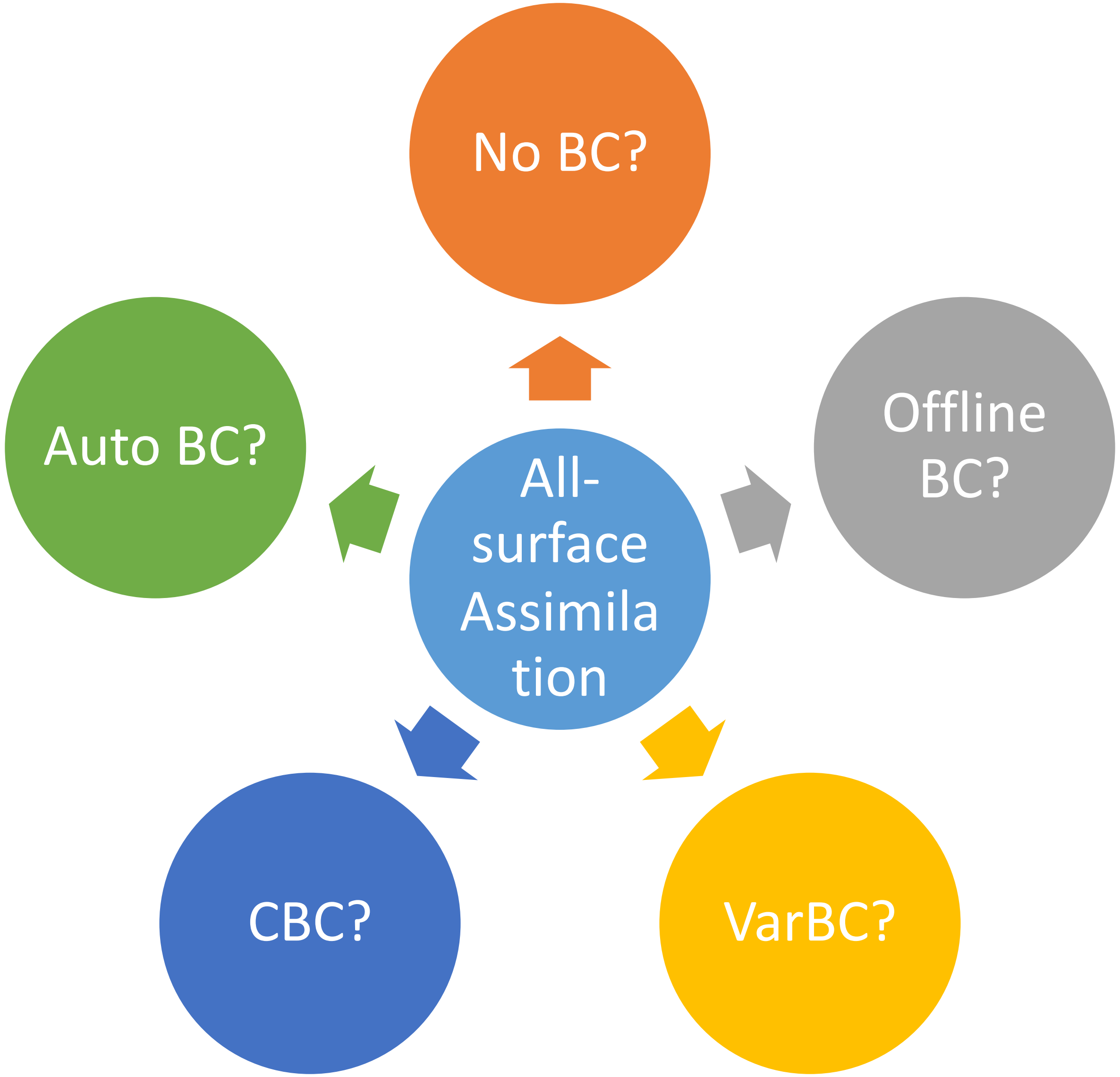
$$C = \frac{TB_{150} - TB_{90}}{TS}$$

| | | |
|---|---|---|
| scheme1 | $\varepsilon_{150} = \varepsilon_{90} + C$ | (Karbou et al., 2014) |
| scheme2 | $\varepsilon_{150} = \varepsilon_{90} + C + \begin{cases} 0.01 & \text{if} \quad TB_{150} > TB_{90} \\ 0.02 & \text{if} \quad TB_{150} \le TB_{90} \end{cases}$ | (Tomaso and Bormann, 2012) |
| scheme3 | $\varepsilon_{150} = \varepsilon_{90} + C + e^{-4.5\varepsilon_{90}}$ | (Tomaso et al., 2013) |
| scheme4 | $\varepsilon_{150} = \varepsilon_{90} + aC + b$ | |



| | QC over snowfree land | QC over sea ice | QC over snow | Generic QC |
|---|---|---|---|---|
| **Identification** | **TS>278K over land** | Land-sea mask < 0.1[5]<br>Sea-ice fraction > 0.5[12](0.01[13])<br>**TS≤271.45K**[5,11]<br>TS≤278K[13] | **TS≤278K over land**[5,12,13]<br>Snow_depth>1mm[12] | |
| **AMSU-A** | H(CH4)<500m[6]<br>**H(CH5)<500m**[6,8,9,10](1500m)[9]<br>**H(CH6)<1500m**[6,8,9,10](2000m)[9](only for Antarctica[13])<br>\|lat(CH7)\|≤30[6,8,10]<br>\|lat(CH8)\|≤30[6,8,10]<br>TB(1)-TB(15)<3.0K(for CH5~6) [13]<br>No Antarctica (CH5) | lat(CH5)> - 60[7](0[13]) | No Antarctica (CH5)<br>**H(CH5)<500m**<br>**H(CH6)<1500m** (only for Antarctica)[13] | **3<scanpos(CH5~13)<28**<br>**\|OMB(CH4)\|<0.7K**[3,7,9,13]<br>\|LSE(retrieval)-LSE(atlas)\|<0.2[11] |
| **MHS** | H(CH2)<500m[6]<br>**H(CH3)<1500m**[6,8,9,10,13](3000m)[9]<br>**H(CH4)<1000m**[6,8,9,10,13](1500m)[9]<br>**H(CH5)**<1000m[5,6,8](**800m**[6,13],1500[9])<br>\|lat(5)\|<55[5,6](60[13])<br>TS>278[5,7] | | **H(CH3)<1500m**[13]<br>**H(CH4)<1000m**[14]<br>**H(CH5)<800m** | **9<scanpos(CH3~5)<82**<br>**\|OMB(CH2)\|<5K**[3,5,9,13]<br>\|LSE(retrieval)-LSE(atlas)\|<0.2[11] |
| **ATMS** | **TB(1)-TB(16)<3.0K(for CH6~7)** [11,13]<br>**H(CH6)<500m**[13,14]**(1000m in tropics**[13]**)**<br>**H(CH7)<1500m**[13,14]**(2000m in tropics**[13]**)**<br>**H(CH18~19)<800m**[13,14]<br>**H(CH20~21)<1000m**[13,14]<br>**H(CH22)<1500m**[13,14]<br>\|lat(CH18~19)\|<60[14] | **OMB(CH18)<2.5K**[12] | **OMB(CH18)<2.5K**[12]<br>**H(CH6)<500m**[13,14]**(1000m in tropics**[13]**)**<br>**H(CH7)<1500m**[13,14]**(2000m in tropics**[13]**)**<br>**H(CH18~19)<800m**[14]<br>**H(CH20~21)<1000m**[14]<br>**H(CH22)<1500m**[14]<br>\|lat(CH18~19)\|<60[14] | **OMB(CH5)<0.7K(for CH6~8)**[11]<br>**OMB(CH17)<5K(for CH16~22)**[11]<br>\|LSE(retrieval)-LSE(atlas)\|<0.2[11] |
| **SSMIS** | H(CH9)<800m[13]<br>H(CH10)<1000m[13]<br>H(CH11)<1500m[13]<br>\|lat(9)\|<60[13] | | H(CH10)<1000m[13]<br>H(CH11)<1500m[13] | |
| **MWHS-2** | **H(CH5)<1500m**[14]<br>**H(CH6)<500m**[14]<br>**H(CH11)<1500m**<br>**H(CH12)<1000m** | | **H(CH5)<1500m**[14]<br>**H(CH6)<500m**[14]<br>**H(CH11)<1500m**<br>**H(CH12)<1000m** | **\|OMB(CH10)\|<5K**<br>**\|OMB(CH15)\|<2.5K**<br>**\|OMB(CH11)\|<2.5K(for CH11)**<br>**\|OMB(CH12)\|<2.5K(for CH12)**<br>**OMB(10)-OMB(1)>20K** |
| **MWTS-2** | **H(CH2~4)<500m**<br>**H(CH5)<1500m**<br>**Cloud percentage<0.76 or \|OMB(CH1)\|<2K** | | **H(CH2~4)<500m**<br>**H(CH5)<1500m** | **\|OMB(CH3)\|<0.7K(for CH2~6)** |
| **MWTS-3** | **H(CH3~8)<500m**<br>**H(CH9)<1500m**<br>**\|OMB(CH3)\|<2K** | | **H(CH3~8)<500m**<br>**H(CH9)<1500m** | **\|OMB(CH5)\|<0.7K(for CH3~10)** |

# Consideration about Bias Correction



# Channel Selection and Experimental Setup

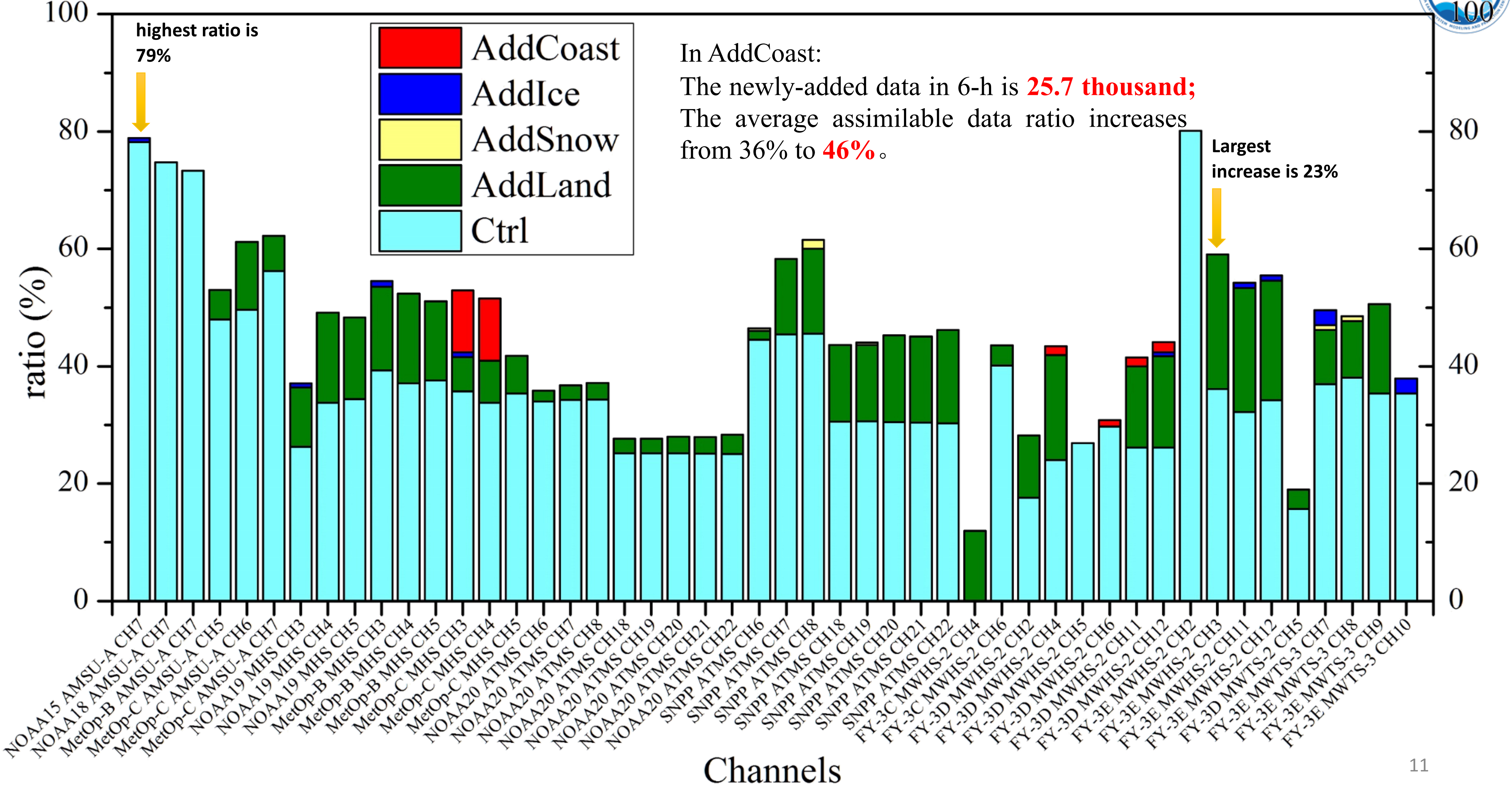
**Channel selection criterion is the OMB after BC:**

① has mean value **<0.1K**; or

② has performance not worse than the oceanic case.

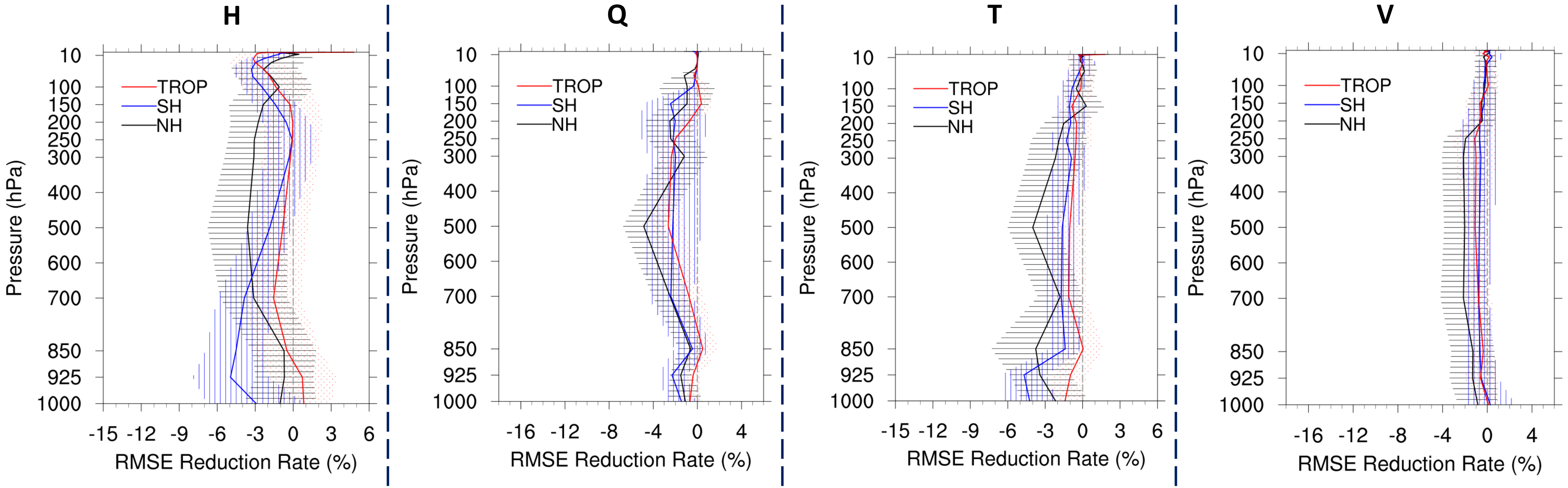
| | CTRL | AddLand (CTRL+snowfree land) | AddSnow (AddLand+snow) | AddIce (AddSnow+sea ice) | AddCoast (AddIce+coast) |
|---|---|---|---|---|---|
| NOAA15 AMSU-A | 5 (land), 7 (land, ice) | 7 | 7 | 7 | |
| NOAA18 AMSU-A | 5–7 (land), 7 (ice) | 7 | 7 | 7 | |
| NOAA19 AMSU-A | 5–6 (land) | | | | |
| MetOp-B AMSU-A | 5 (land), 7 (land, ice) | 7 | | | |
| MetOp-C AMSU-A | 7 (land, ice) | 5,6,7 | | | |
| NOAA19 MHS | 3 (land) | 3,4,5 | 3 | 3 | |
| MetOp-B MHS | 3 (land) | 3,4,5 | 3 | 3 | |
| MetOp-C MHS | 3 (land) | 3,4,5 | | 3 | 3,4 |
| NOAA-20 ATMS | 9(land),6–9&18–22 (ice) | 6,7,8,18,19,20,21,22 | | | |
| SNPP ATMS | 9(land),6–9&18–22 (ice) | 7,8,18,19,20,21,22 | 6,8,19 | | |
| FY-3C MWHS-2 | 11 (land) | 4,6 | | | |
| FY-3D MWHS-2 | | 2,4,5,6,11,12 | 12 | 12 | 4,5,6,11,12 |
| FY-3E MWHS-2 | 2–4 (land), 2 (ice) | 2,3,11,12 | 11,12 | 11,12 | |
| FY-3D MWTS-2 | | 5 | | | |
| FY-3E MWTS-3 | | 7,8,9 | 7,8,10 | 7,10 | |

# Ratio of "Assimilable" Data to Total Data



# Analysis

**AddCoast (assimilating all the newly-added data)**

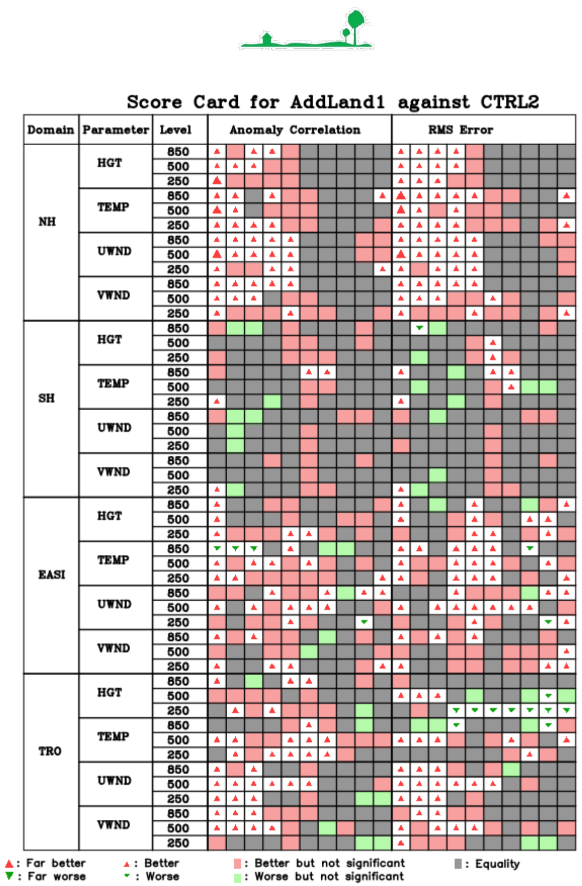



① Analysis of each variables at the whole atmospheric layer are improved in global.
② The results between different experiments is similar; the more the assimilated data, the better the results.
③ The positive impacts in NH are concentrated in middle-layer troposphere, while those in SH and TROP are concentrated in upper layer and lower layer.
④ The improvement in the NH is largest, then the SH, then the TROP.

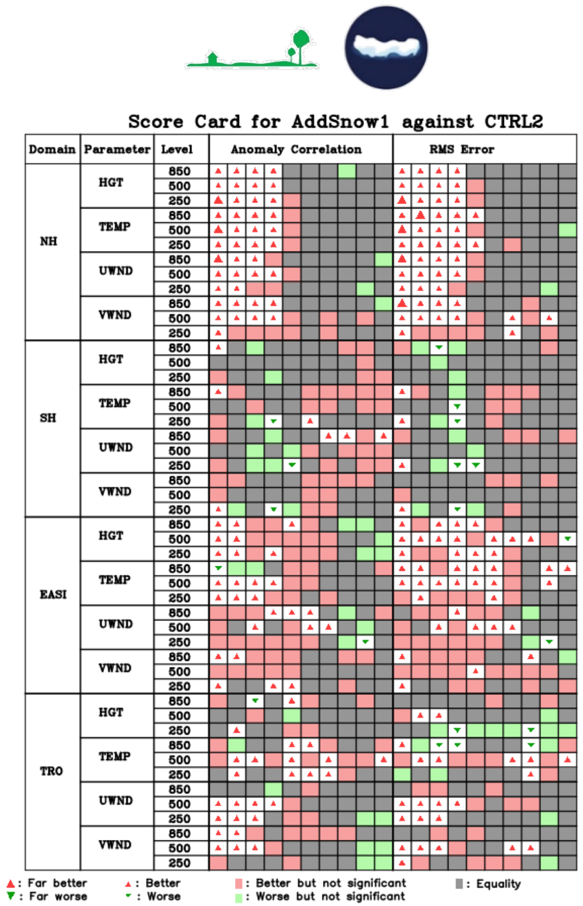
# Forecasting

UTC 0000

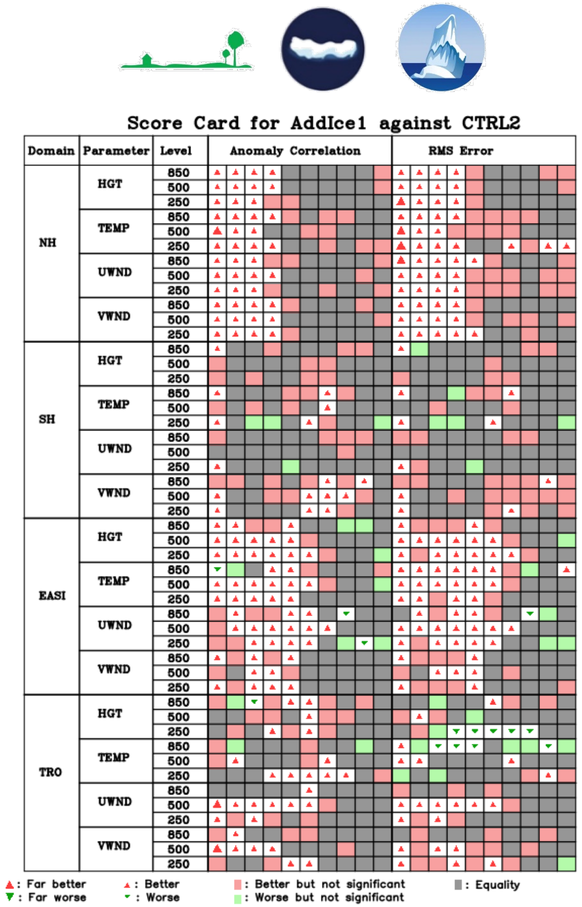
## AddLand



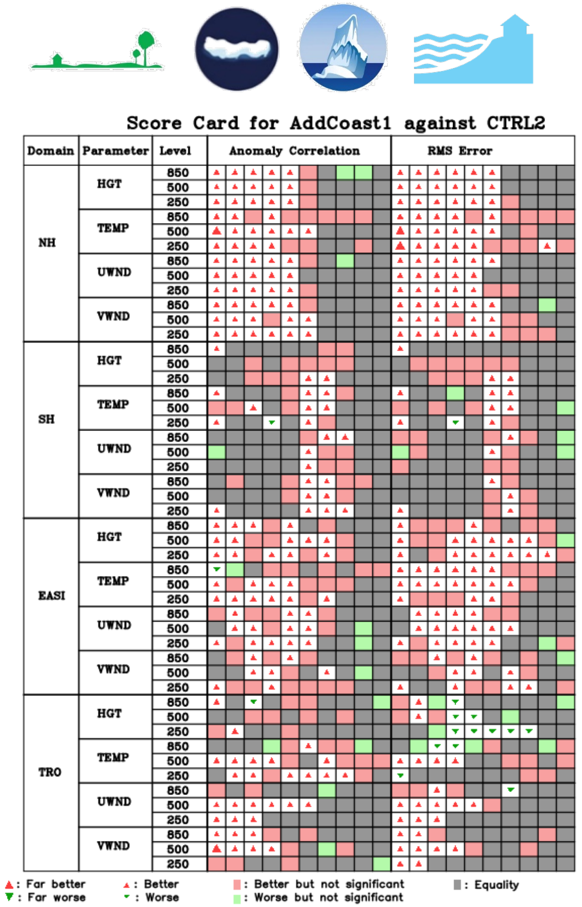

## AddSnow




## AddIce



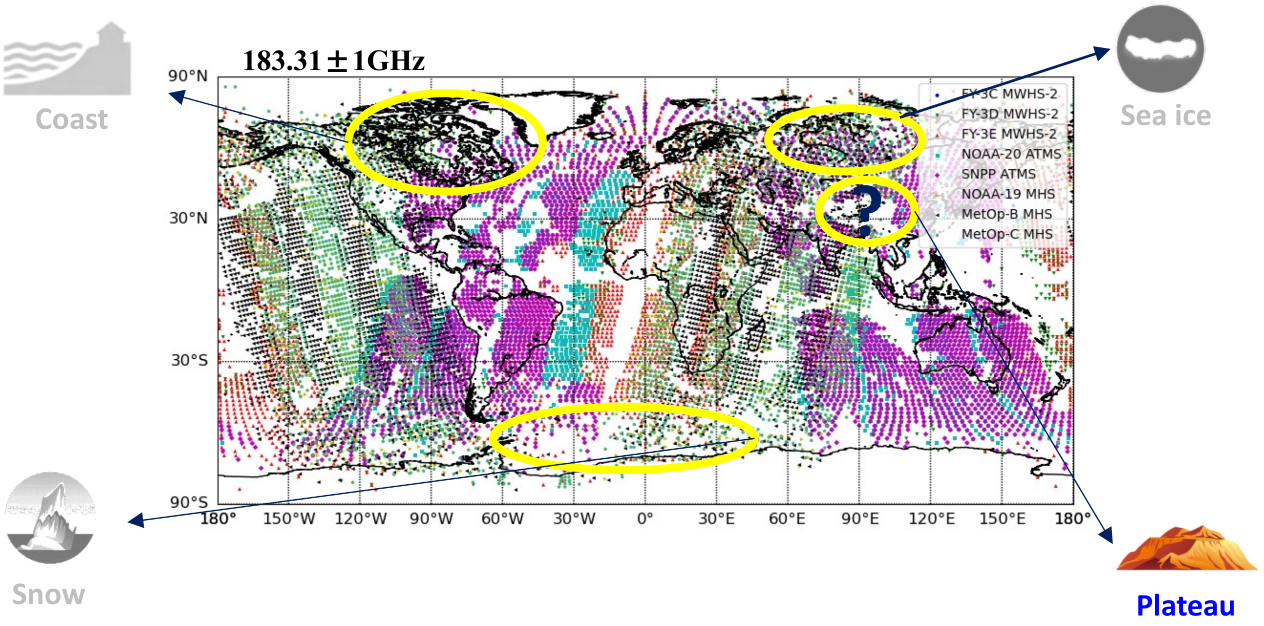

## AddCoast



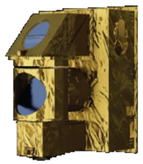

① Forecasting of each variables at the whole atmospheric layer are improved in global.
② The results between different experiments is similar; the more the assimilated data, the better the results.
③ 1-6-day forecasting in NH, 6-8-day forecasting in SH, and short-to-medium-term forecasting in TROP, are improved significantly.
④ Forecasting at higher layer (not shown here) are also improved significantly.

# Future work

## ① About the surface type

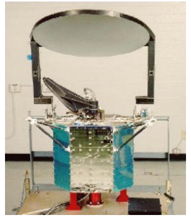



## ② About the instruments



FY3F MWTS-III

FY3F MWHS-III



DMSP-F17/18 SSMIS

GPM GMI

## ③ About the observational error model

# THANKS！