Recent results and proposed Observing System Simulation Experiments (OSSE) to link Research and Operation

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ABSTRACT

Observing System Simulation Experiment (OSSE)s are a challenge to operational weather services, because many of the efforts offer long-term rather than short-term benefits. Effective interaction between Research and Operation (R2O and O2R) is required for successful OSSE.

First concept and procedures of OSSE are describer. Overview of OSSEs accomplished at NOAA/NCEP and JCSDA in recent years will be presented. Further proposed OSSEs are also presented.

Key Word: OSSE, O2R, R2O, DWL, GOES-R, PCW, Geostorm

1. INTRODUCTION

Observing System Simulation Experiments (OSSEs) are designed to use data assimilation ideas to investigate the potential impact of future observing systems (observation types and deployments) compared with existing observation systems using a model simulation. OSSEs will speed up the usage of the new data and will also be used to evaluate current observational and data assimilation systems. Detail procedures are described in [2],[7], and [12]. There is interest in OSSEs in both the operational and research communities and collaboration is essential to effective OSSE. However, collaboration between operational and research communities is challenging area. ([16])

OSSEs are a challenge to operational weather services. OSSEs require strong leaders with a clear vision, because many of the efforts offer long-term rather than short-term benefits. Carefully designed OSSEs will enable scientists to make strong and important contributions to the decision making process for future observing systems. Time will be saved in using the new data when compared to the work required to use observing systems that were built without any guidance from OSSEs. However, there is a serious dilemma in spending resources on OSSEs. If operational centers devote their resources to OSSEs, they may not be able to pay enough attention to today's valuable data.

Although operational systems should benefit from carefully executed OSSEs through lower cost of implementation, there are immediate costs to OSSEs. OSSEs will be conducted by various scientists with different interests. Some will want to promote particular instruments. Others may want to aid in the design of the global observing system. Specific interests may introduce bias into OSSEs but they may also introduce strong motivations. Operational centres will perform the role of finding a balance among conflicting interests to seek an actual improvement in weather predictions. Support for OSSE at operational center need to be funded and the fund for OSSE should be integrated with development.

Research community has more freedom to explore the possibility of new observing systems. It is best to use the operational data assimilation system to make the work relevant to operation (R2O). For that purpose close communication and assistance from the operational community is required (O2R). Therefore, OSSE is a very effective tool to bond research and operational communities. Joint Center for Satellite Data assimilation (JCSDA) is one of the best institutes to conduct effective OSSEs to take balance between operations(O) and research(R).

Instrument community has strong motivation toward OSSE. However, they are strongly motivated to use OSSE to justify launching their own instrument. Once it is launched, large resources will be invested to produce positive

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impacts. One goal of the research community is to increase the number of publications and personal promotions. They may be caught in theoretical interests instead of effective recommendation. Although it is heavy work to involve the operational community, without their involvement, effective OSSEs cannot be expected.

2. FULL OSSE

A Nature Run (NR, proxy true atmosphere) is produced from a free forecast run (So called AMIP type run with observed SST, ICE, and Land unless they are not coupled) which is significantly different from the NWP model used in Data Assimilation Systems.

Calibrations need to be performed to provide quantitative data impact assessment. Data impact on analysis and forecast will be evaluated. A Full OSSE is capable of providing detailed quantitative evaluations of the configuration of observing systems. The advantage is that in a full OSSE one can use an existing operational system including diagnostic tools and utilities. OSSE can also help the development of an operational system.

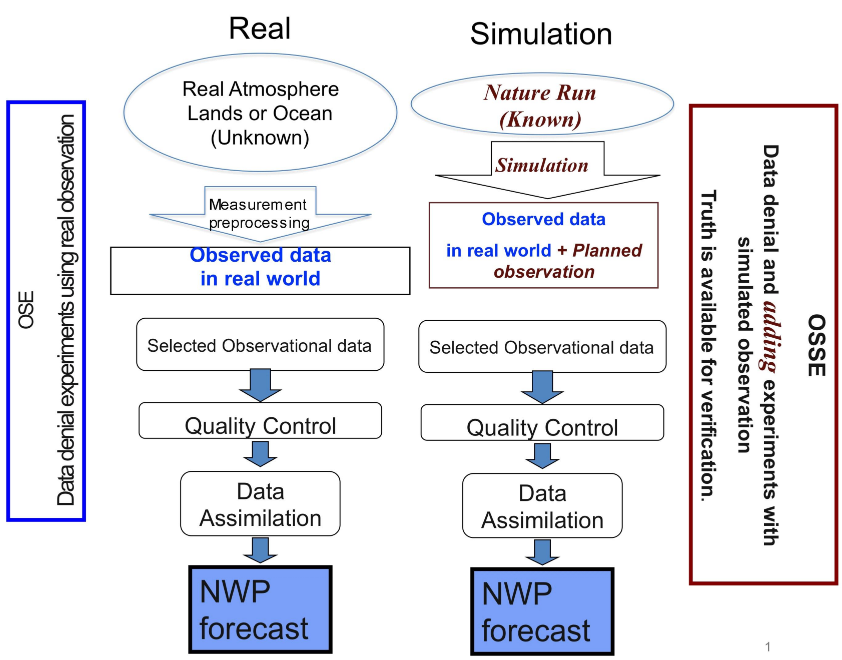

Fig. 1 is a schematic diagram of a full OSSE and the detail of full OSSE is explained in [12] and [15].

3. SELECTION OF NR

The quality of NR determines the quality of OSSE. Following are some consideration regarding selection of NR:

- Well evaluated forecast model with highest forecast skill
  - AMIP type run has to be tested (The latest operational model may not be tested for AMIP run)
  - Lack of state of arts features.
- Research model
  - State of arts feature (non hydrostatic, aerosol, cloud, chemistry, in highest resolution) can be involved.
  - Less confidence in forecast skill
- Do not use Analysis
  - The system is forced by observation
  - May be able to use analysis out side of OSSE area, such as SST and ICE.
- Recent year
  - Use initial condition and SST ICE from recent year and of better quality. This will allow better verification of simulated observations.

It is possible to select one forecast model NR to evaluate large scale data impact and a research model for small scale analysis and short range forecast. Since one NR tends to be used for several years, it is important to select a state of the art numerical model.

In 2006 a T511 (40km) resolution 13 month long NR was provided by the European Center for Medium Range Forcast (ECMWF), which was the state of the art medium range forecast in 2006. The details are described in [1].

In 2014, a high resolution global NR (G5NR)was produced by NASA/GSFC/GMAO ([18]).

- Non-hydrostatic GEOS-5
- Horizontal resolution 7 km with 72 levels
- Period: May 16, 2005-June2007.
- GOCART model with full aerosol, full chemistry, and cloud types.
- Data are available in 0.5deg and model resolution with 30min write up.
- Pressure level data are provided in 0.5 deg
- Various time mean data are also provided
- Data are available through OPeNDAP to registered users.
- For more detail visit: http://gmao.gsfc.nasa.gov/projects/G5NR HYPERLINK "http://gmao.gsfc.nasa.gov/projects/G5NR/"/
- Comprehensive evaluation is published.

Fig. 2 shows 250hPa transient Eddy Kinetic Energy (tEKE) as the square root of variance of wind speed, band-pass filtered for 2-6 days, showing this model does not have serious drift. Transient eddy kinetic energy (tEKE) in band passed fields is one of the standard fields included in ECMWF atlas ([9]). High pass tEKE proved to capture features which are not detected in mean fields. However, Fig. 3 showed G5NR lacks the synoptic scale transient activity in pacific Northern Hemisphere jet region and tropical extratropical interaction in intraseasonal variability.

Current operational forecast models are much evolved from the model used for T511NR, and G5NR is not evaluated thoroughly as far as forecast skill is concerned. Therefore, OSSE community is seeking for NR based on a state-of-art medium range forecast model.

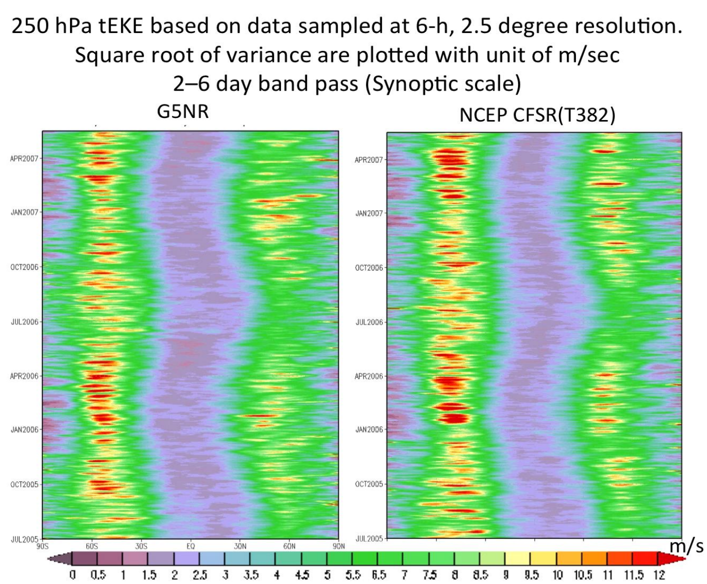

Fig. 2 Time series of zonal mean 250hPa transient Eddy Kinetic Energy (tEKE) as the square root of variance of wind speed, band-pass filtered for 2-6 days, showing this model does not have serious drift. Left G5NR right NCEP reanalysis.

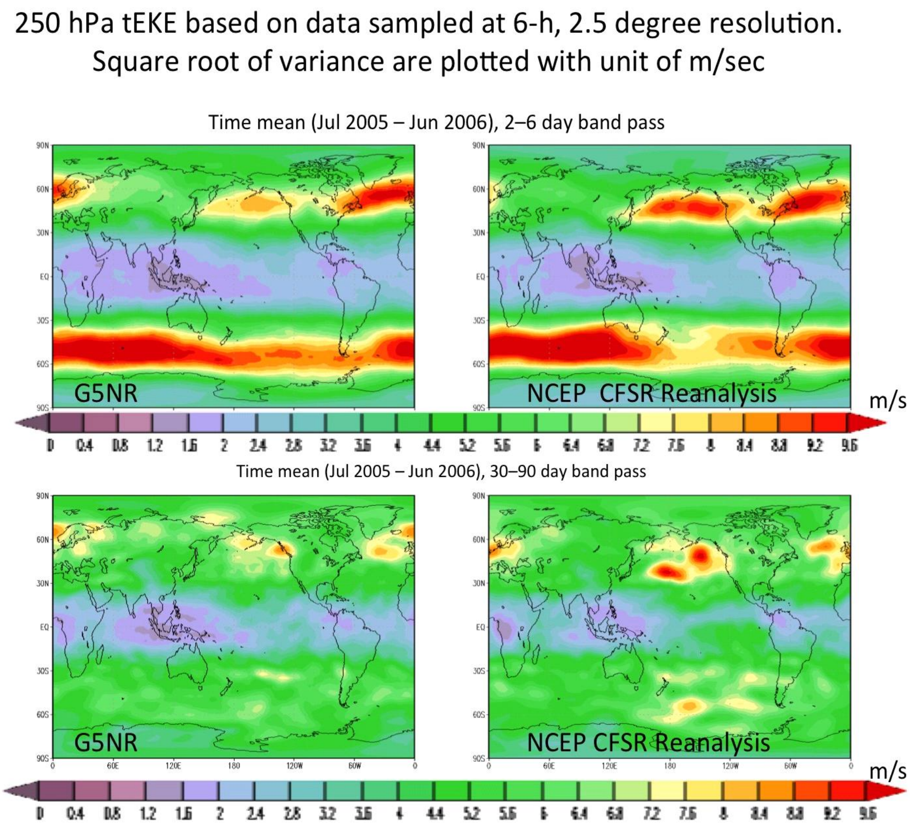

Fig. 3 Comparison of teme mean 250hPa transient Eddy Kinetic Energy (tEKE) between G5NR (left) and NCEP reanalysis. Top band-pass filtered for 2-6 dayst. .B\ottom band path filter between 30 and 90 days.

4. COLLABORATION

Although a full OSSE allows efficient OSSE for various instruments, it requires significant resources in the initial stage. Particularly, a global OSSE requires large resources. On the other hands, a regional OSSE can be done with less resources at smaller institutes. Sharing one global NR and simulated observation saves costs by sharing diverse resources, including storage and simulated control observations.

Sharing will allow OSSE-based decisions have international stakeholders. Decisions on major space systems have important scientific, technical, financial and political ramifications Sharing will results in community ownership and oversight of OSSE capability is important for maintaining credibility. Independent but related data assimilation systems allow us to test the robustness of answers

There are some reservations towards sharing. Since there is competition for OSSE, fund sharing may results in losing one's own funds by sharing the product and resources. Projects received funds by promising to share product may or may not be completed. The quality of OSSE depends on the shared product. Sharing enhances the total interest and total resources to OSSEs but respect toward work by other group have to be observed and often it is a very difficult task.

The T511 NR data set was made available to the scientific community free of charge. A few dozens of OSSE research was conducted using this Nature run and called Joint OSSE (http://JointOSSE.org). Many OSSEs are conducted at NOAA and NASA using G5NR. Various experiences and knowledge are shared as well as simulated observations.

5. DESIGN OF OSSE

In a full OSSE, observations and atmosphere should be as close as possible to the reality. There is a risk to use up resources in minor aspects, which may not affect the results. Clarifying the goal of the experiments and identifying limitations in the specific OSSEs is critical to delivering the results within the limited time and resources. ([7])

- The requirement for the resolution for NR in horizontal, vertical and time depends on the scale event to be evaluated. Low resolution forecast model NR or high resolution research model NR. The optimum resolution for OSSE could be much less than the resolution of NR ([14])
- For an OSSE for wind data, error in radiance data does not have to be perfect. But some observational errors are vital to evaluation of radiance data. We need an effective plan for designing of observational error. ([19], [13], and [5])
- Boundary of NR, climatologically constants, observed SST, ICE and Land are used for NR. These variable for OSSE should be consistent with NR. The difference could ruin the OSSE.

Assessing any simplification and limitations should be an important part of the OSSE project.

Including all currently available observation may not be the best strategy. It is best to use a set of control observations which is available for the time of the new observation.

2polar = a more reasonable data-gap scenario

Control	3polar	2polar (PM Gap)	1polar (Mid-AM Only)	Orbit
F16 (SSMI/S)	F16	F16	F16	Early-AM
F17 (SSMI/S)	F17	F17	F17	Early-AM
F18 (SSMI/S)	F18	F18	F18	Early-AM
Metop-A (AMSU/MHS/IASI/HIRS)	Metop-A	Metop-A	Metop-A	Mid-AM
Metop-B (AMSU/MHS/IASI)	Metop-B	Metop-B	Metop-B	Mid-AM
N15 (AMSU)	N15	N15	N15	Late PM
N18 (AMSU/MHS)	N18	N18	N18	PM
N19 (AMSU/MHS)	N19	N19	N19	PM
SNPP (ATMS/CrIS)	SNPP	SNPP	SNPP	PM
Aqua MODIS IR Winds	Aqua MODIS IR*	Aqua MODIS IR	Aqua MODIS IR	PM
Aqua AIRS	Aqua AIRS	Aqua AIRS	Aqua AIRS	PM
Aqua MODIS WV Winds	Aqua MODIS WV	Aqua MODIS WV	Aqua MODIS WV	PM
Terra MODIS IR/WV Winds	Terra MODIS	Terra MODIS	Terra MODIS	AM
WindSat	WindSat	WindSat	WindSat	Early-AM
GOES Sounder, AMVs	GOES	GOES	GOES	GEO
JMA AMVs	JMA AMVs	JMA AMVs	JMA AMVs	GEO
METEOSAT AMVs	METEOSAT AMVs	METEOSAT AMVs	METEOSAT AMVs	GEO

Fewer repetitive obs, less to simulate and add correlated errors to

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Fig4. Possible future data gap scenario. (Courtesy by NOAA/NESDIS.)

The year for the template for the distribution of observations does not have to be same year as the NR. However, if observation is simulated at the beginning of NR. Simulated observation can be directly compared with real observation. It is worthwhile to produce short NR for the period of OSSE using the same model for the NR to verify simulated observation when NR period and OSSE period are different. They can be compared with real observations.

6. RECENT OSSE

Recently various OSSEs have been conducted at JCSDA. Costly instruments such as Doppler Wind Lidar were evaluated in various configurations. High-resolution hyperspectral sounder, and microwave sounder in Geostational platforms are being evaluated. Effect of additional GPSRO satellites are evaluated with collaboration with NOAA/ESRL. Further OSSEs to evaluate combined effect of these instruments as well as PCW are proposed.

Several unique finding from OSSEs are:

- A non scan DWL (ADM-AEOLS) may not have as much of an impact as RAOBs, even though it was expected to behave as “RAOBs everywhere”. ([11],[13])
- DWL with two looks which produce vector wind increase the impact compared to two looks without match in tropics. The impact is more than double of one look. ([11], [14])
- Number of vertical resolution in analysis is essential. Horizontal resolution is more important for forecast skill. ([20])
- Producing significant impact from targeted observation is not simple even with idealized experiments ([20])
- Impact of satellite data from Early morning orbit at 00Z, 06Z, 12Z, and 18Z are all different and could have significant impact in 18Z ([3], [4]),.

The example of difficulties found in currently conducted OSSEs are:

- OSSE verification involve the area where forecast model and RTM are still under development.
- Data sampling depend on weather pattern is important, this require significant effort and which may not be justified the resource.
- Aircraft data depends on jet location. Cloud track wind depends on cloud. No wind data from center of storm in real world.
- NR grid is much smaller than FOV but treated as one point in JCSDA OSSE.

7. POTENTIAL OSSES

Several plan for OSSEs are proposed. Observing System Simulation Experiment to evaluate and improve the usage ice observations in global weather forecasts is proposed from National Centers for Environmental Prediction (NCEP). Evaluation of ice require development of emissivity from ice. The verification package at NCEP needs improvement in Arctic. Support for development of verification for Arctic and Emissivity model need to be requested. Using OSSE to evaluate degraded ice observations against perfect ice observations, which is same as ice in NR. OSSEs for Arctic observing system is a challenge, given lack of operational tool over Arctic region. A plan for international collaboration in OSSE to improve Arctic observing system is summarized in [15].

Global coverage of three dimensional wind profiles is expected to make the most impact on improving weather forecasts. Space based Doppler Wind Lidar (DWL) has been investigated as the most promising candidate in recent decades. Considering the large cost of a DWL in polar orbit, NASA requested a study for guidance in planning a future space-based DWL mission for the International Space Station (ISS, Fig.5). ISS orbit lacks of observations in high latitude regions. The wind observations from Polar Communications and Weather (PCW, [6]) satellite in a highly elliptical orbit (HEO) will be complementary to wind observations in the ISS orbit. Wind data from PCW extends to 55N which is beyond the coverage by currently available polar wind. (Fig.6)

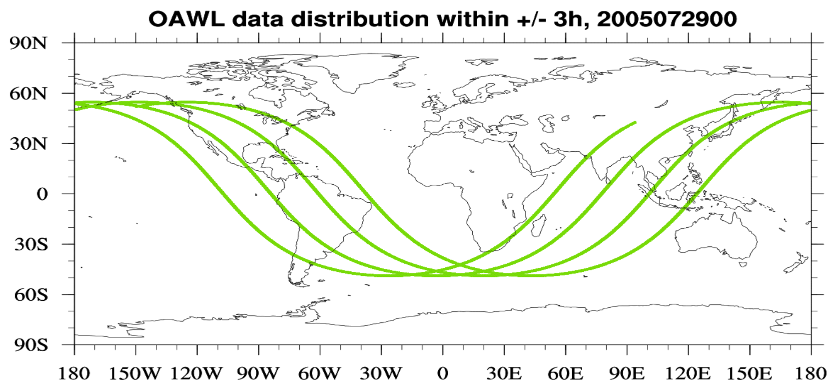

Fig. 5 24 hour OAWL data distribution in ISS orbit.

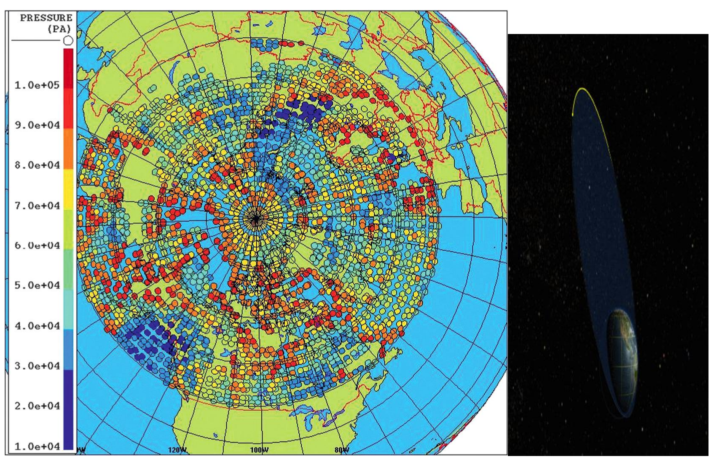

FIG. 6. Left: Example of simulated HEOAMV positions extracted from the NR for the 508–908N region. Pressure height (Pa) is indicated on the left [blue (red) color for highest (lowest) clouds], where e1XX indicates multiplication by 10 raised to the 1XX power. Regions devoid of data represent either clear skies or clouds outside the range 100–925 hPa. Thinning is done for a resolution of 180 km. ([6]) Right: Schematic diagram of the Molniya Orbit

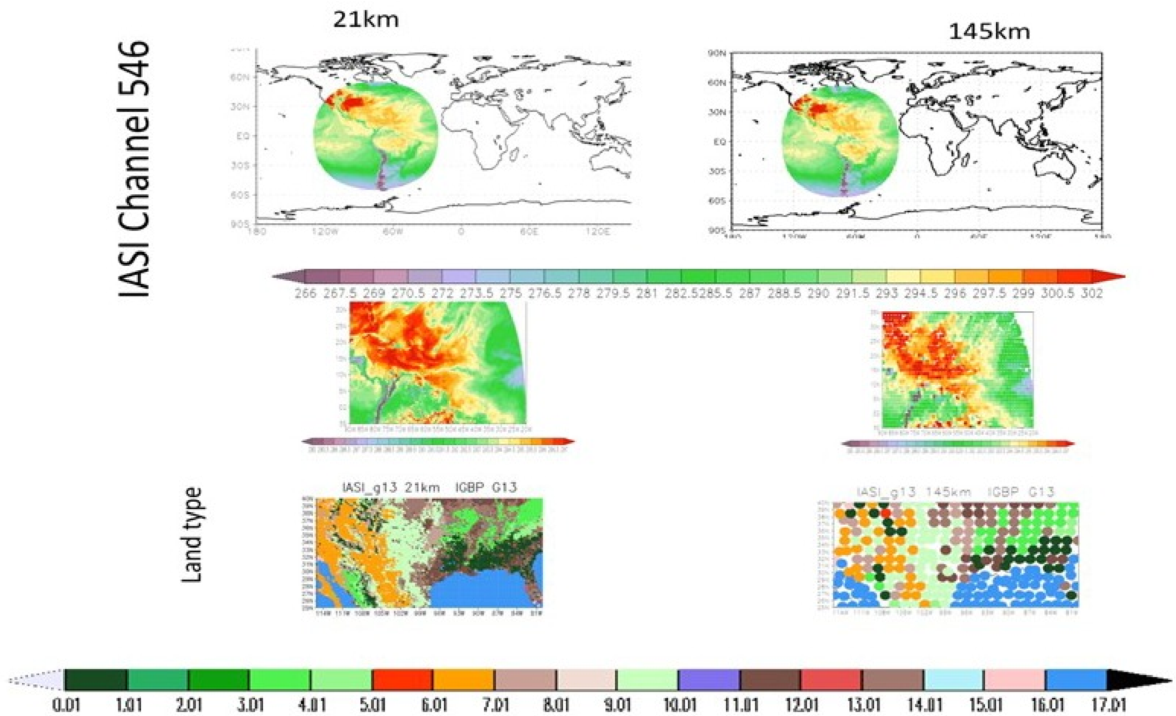

Fig. 7 Simulated IASI channel 546 at geostationary satellite at 75 W . Top: full disk, mid: South East of US, Bot: Land type. Left:21km resolution, Right: 145 Km resolution. Land Type:IGBPClasses :(1) Evergreen Needleleaf Forest (2) Evergreen Broadleaf Forest (3)Deciduous Needleleaf Forest (4) Deciduous Broadleaf Forest (5) Mixed Forest (6) Closed Shrublands (7) OpenShrublands (8) Woody Savannas (9) Savannas (10) Grasslands (11) Permanent Wetlands(12) Croplands (13) Urban Built-Up (14) Cropland Natural Vegetation Mosaic (15) Snow Ice (16) Barren (17) Water Bodies.

Once observational data from GOES-R and other geostationary satellite large amount of high resolution in time and space will become available. From Japanese geostationary satellite Himawari-8/9, full disk scanned data become available every 10 min with horizontal resolution of 2km. For the best use of the data for numerical weather forecast, a sampling strategy needs to be developed. Since the real observations contain unknown error and bias, OSSE will allow one to investigate sampling strategies under ideal conditions. Fig 7 and Fig 8 show simulated brightness temperature of IASI Channel 2701 at 00Z August 1, 2006. Brightness temperature is simulated from G5NR

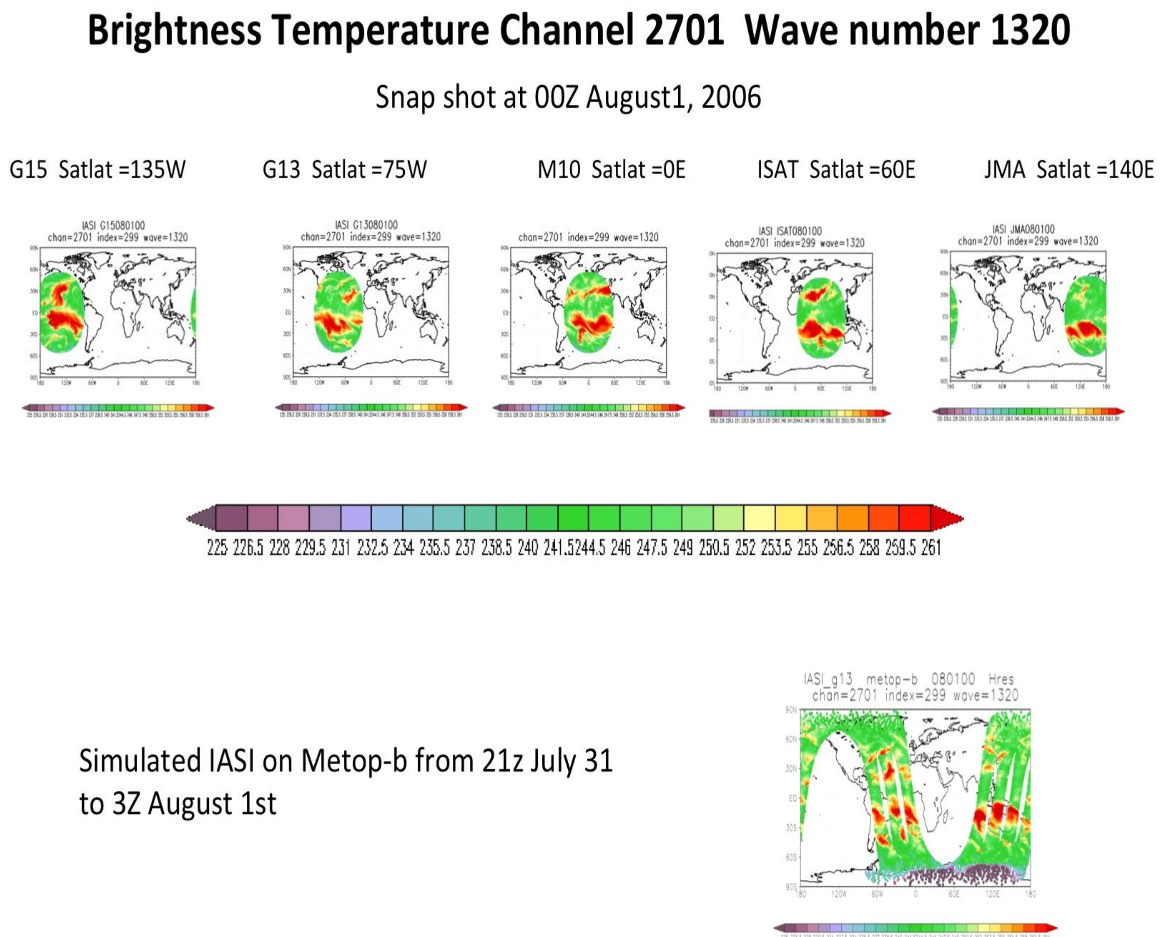

Fig. 8 Top: Simulated IASI channel 2701 at geostationary satellite at 135W, 75 W , 0E, 60E, and 140E at 00Z August 1st. Bottom: Simulated IASI on Metop-B used for analysis at 00Z August 1st (21Z July 31 to 3Z august 1st)

Evaluations are often limited to anomaly correlation (AC) and Root Mean Square Error (RMSE). This is not sufficient for a recommendation for a future observing system particularly only positive impact is reported without comparison. Evaluation of various instruments require numerous experiments. Ensemble Forecast Sensitivity to Observations (EFSO, [8], [10], and [17]), which has been shown to be an effective and inexpensive way to detect detrimental observations, correct the analysis by withdrawing those observations, with clearly positive impacts on the 3-5 day forecasts.

8. CONCLUDING REMARK

Instrument community has strong motivation toward OSSEs. However, they are strongly motivated to use OSSE to justify launching their own instrument. Once it is launched, large resource will be invested to produce positive impact. The goal of research community is to increase the number of publication and personal promotion. They may be caught in theoretical interests instead of effective recommendation. Although it is heavy work to get involve operational community, without their involvement, effective OSSE cannot be expected.

Experiences with OSSEs demonstrates that they often produce unexpected results. Theoretical predictions of the data impact and theoretical backup of the OSSE results are very important as they provide guidance on what to expect. On the other hand, unexpected OSSE results will stimulate further theoretical investigations. When all efforts come together, OSSEs will help with timely and reliable recommendations for future observing systems. ([12])

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