Developments in Satellite Observations

JCSDA Summer Colloquium, Stevenson, WA, 07/09/2009

Lars Peter Riishojgaard

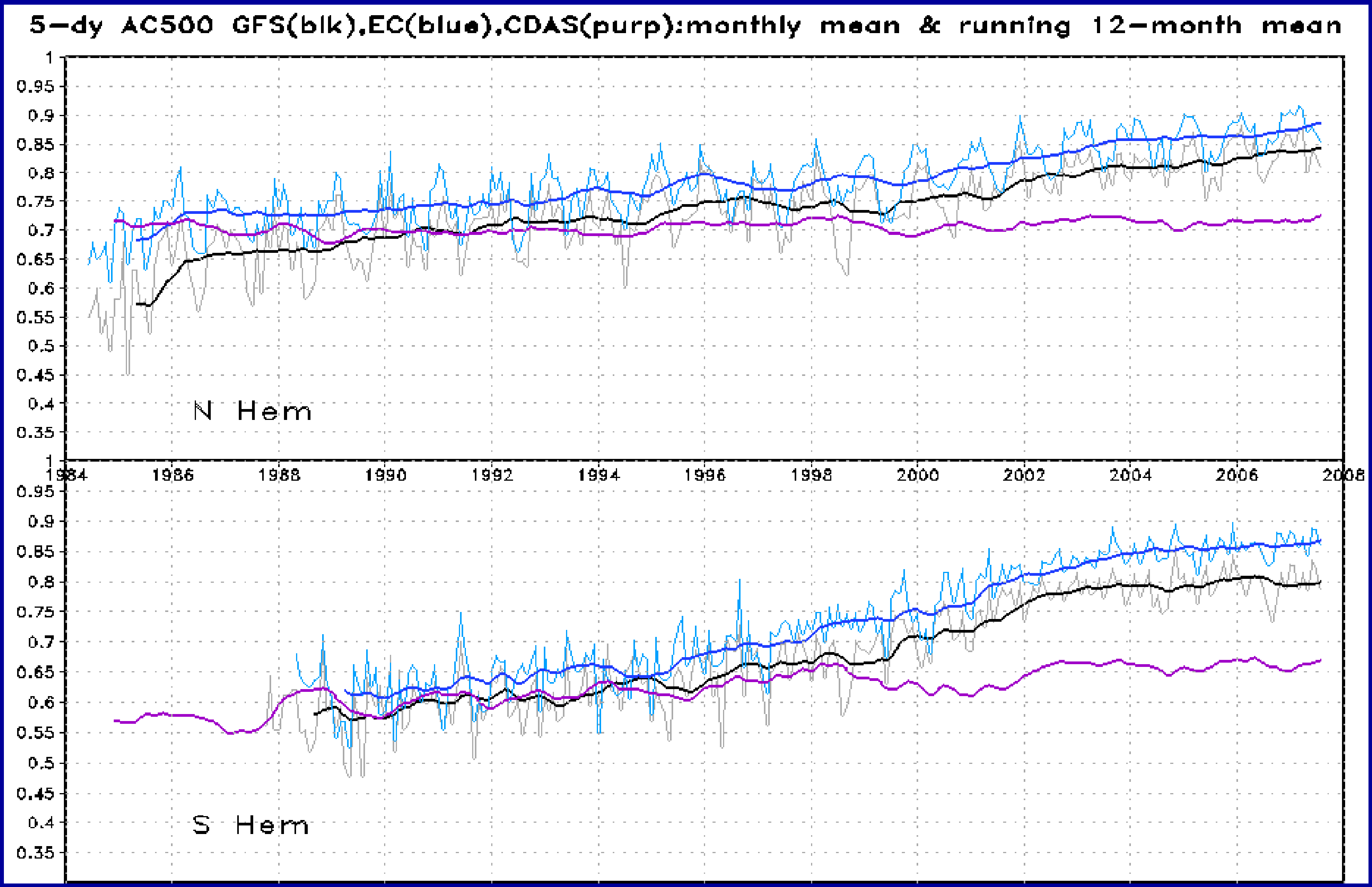
Overview

- Part I; Future Satellite Systems
  - Planned
  - Proposed or in development
- Part II; Role of the Data Assimilation Community
  - Observing System Simulation Experiments
  - "Joint OSSE"

Part I; Future Systems

- Planned systems
  - GEO
  - LEO
- Systems in development
  - GEO
  - LEO
  - Other

NOAA/NCEP vs. ECMWF skill over 20+ years



Caveats

- SH skill does progress with time, even with constant DA and model resolution
  - Satellite data
- The GOS is evolving, not necessarily growing monotonically
  - Number of radiosondes decreasing
  - Number of AMSU-A like instruments will go from 6 (currently 5) down to 3 over the next few year
  - AIRS, MODIS to be replaced with different (and in some respects less capable) instruments
- Reanalysis/hindcasting is not forecasting
  - No credit given for improvements in data latency
  - You don't have years to tinker with methodology for real-time forecasting

Unmet requirements

(WMO Expert Team on the Evolution of the Global Observing System, Chair, J. Eyre)

- "The critical atmospheric variables that are not adequately measured by current or planned systems are (in order of priority):
  - wind profiles at all levels;
  - temperature and humidity profiles of adequate vertical resolution in cloudy areas;
  - precipitation;
  - snow equivalent water content;
  - soil moisture."

Source: WMO Statements of Guidance for Global and Regional NWP

Why fly a given satellite mission?

- User driven; to meet observational data needs for NWP *and other applications*
  - E.g. because coverage requirement is best met from space
  - *Continuity*; new measurements face a higher bar than existing ones
- Engineering driven
  - Government-sponsored R&D to stimulate industrial competitiveness
- Politically driven
  - Sovereignty and security
  - Matter of prestige - nationally or community-wise
  - “Geographic return”, e.g. nationally (ESA) or by state/voting district (US Congress)

Planned systems, GEO

- GOES-R; Next-generation US operational satellite system
  - Advanced Baseline Imager (continuity)
  - GOES Lightning Mapper (new capability)
- MTG (Meteosat Third Generation); Next-generation European operational system
  - Imager
  - Lightning Mapper
  - Hyperspectral IR sounder (similar to IASI/AIRS/CrIS)
- MTSAT-3; Japan
- FY-4; China

The Advanced Baseline Imager:

	ABI	Current
Spectral Coverage		
	16 bands	5 bands
Spatial resolution		
0.64 μm Visible	0.5 km	Approx. 1 km
Other Visible/nearIR	1.0 km	n/a
Bands (>2 μm)	2 km	Approx. 4 km
Spatial coverage		
Full disk	4 per hour	Every 3 hours
CONUS	12 per hour	~4 per hour
Visible		
On-orbit calibration	Yes	No
Low-light imaging	Yes	No

ABI Bands

Future GOES Imager (ABI) Band	Wavelength Range (µm)	Central Wavelength (µm)	Sample Objective(s)
1	0.45-0.49	**0.47**	Daytime aerosol-over-land, Color imagery
2	0.59-0.69	**0.64**	Daytime clouds fog, insolation, winds
3	0.84-0.88	**0.86**	Daytime vegetation & aerosol-over-water, winds
4	1.365-1.395	**1.38**	Daytime cirrus cloud
5	1.58-1.64	**1.61**	Daytime cloud water, snow
6	2.235 - 2.285	**2.26**	Day land/cloud properties, particle size, vegetation
7	3.80-4.00	**3.90**	Sfc. & cloud/fog at night, fire
8	5.77-6.6	**6.19**	High-level atmospheric water vapor, winds, rainfall
9	6.75-7.15	**6.95**	Mid-level atmospheric water vapor, winds, rainfall
10	7.24-7.44	**7.34**	Lower-level water vapor, winds & SO_2
11	8.3-8.7	**8.5**	Total water for stability, cloud phase, dust, SO_2
12	9.42-9.8	**9.61**	Total ozone, turbulence, winds
13	10.1-10.6	**10.35**	Surface properties, low-level moisture & cloud
14	10.8-11.6	**11.2**	Total water for SST, clouds, rainfall
15	11.8-12.8	**12.3**	Total water & ash, SST
16	13.0-13.6	**13.3**	Air temp & cloud heights and amounts

Based on experience from:

Current GOES Imagers

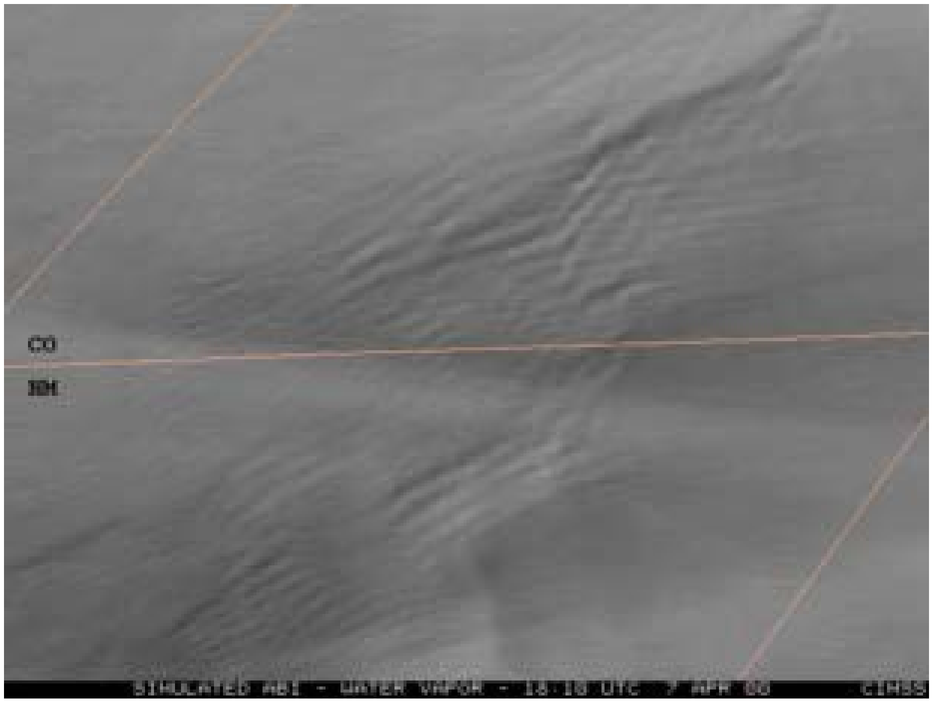
MSG/AVHRR/ Sounder(s)

MODIS, Aircraft, etc

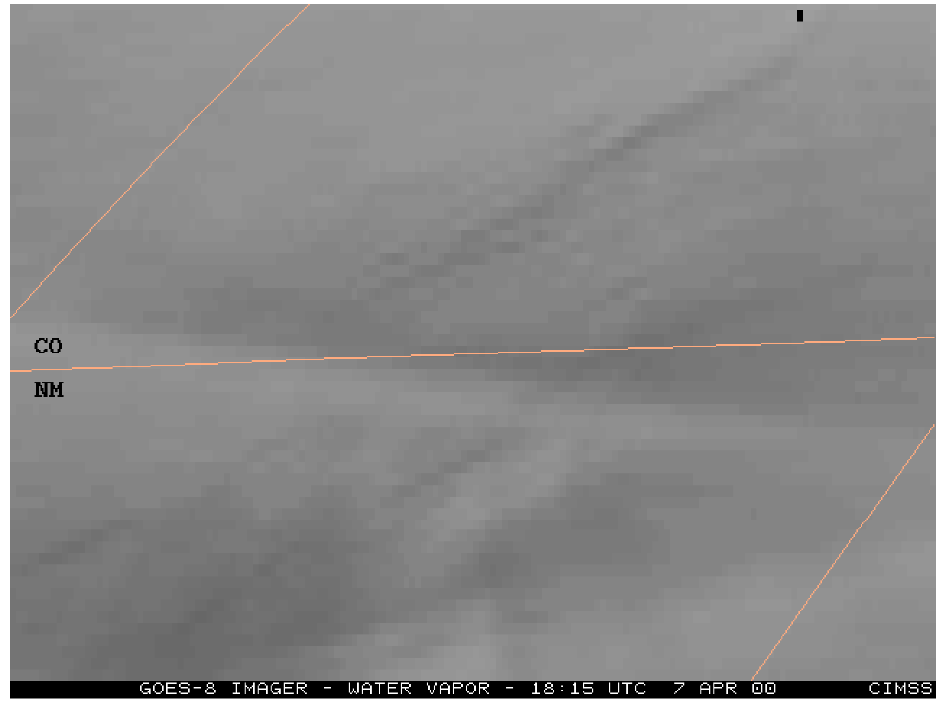
Mountain Waves in WV channel (6.7 µm)

7 April 2000, 1815 UTC

Simulated ABI



Actual GOES-8



Mountain waves over Colorado and New Mexico were induced by strong northwesterly flow associated with a pair of upper-tropospheric jet streaks moving across the elevated terrain of the southern and central Rocky Mountains. The mountain waves appear more well-defined over Colorado; in fact, several aircraft reported moderate to severe turbulence over that region.

Both images are shown in GOES projection.

UW/CIMSS

Planned systems (LEO)

- NPP/NPOESS; Next-generation US operational system
- Post-EPS; Next-generation European operational system
- ADM; European wind lidar demonstration mission (R&D)
- GPM; NASA constellation precipitation mission (R&D)
- SMAP; NASA soil moisture mission (R&D)
- Russia
- China
- …

National Polar Orbiting Environmental Satellite System (NPOESS)

- Next generation US operational polar orbiting system
  - First satellite scheduled for launch in 2013
  - Operated jointly by DoD and NOAA
  - Four critical sensors to be demonstrated on orbit by NASA pre-operational “NPOESS Preparatory Project” (NPP) mission in 2011
- VIIRS - imager, follow-on to AVHRR and MODIS
- ATMS - microwave sounder, follow-on to AMSU
- CrIS - hyperspectral IR sounder, follow-on to AIRS/IASI
- OMPS - ozone, follow-on to SBUV, TOMS, OMI, GOME

Sensor Suite for NPP, C1, C2

NPOESS

Environmental Sensors developed through EMD contract

VIIRS

(3)

CrIS

(2)

OMPS

(2)

ATMS**

(2)

** 1st procured by NASA 2nd by NG

Government Furnished Sensors delivered for integration

CERES

(1)

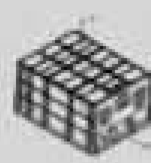
MIS

(1)

SEM

(2)

A-DCS



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SARSAT

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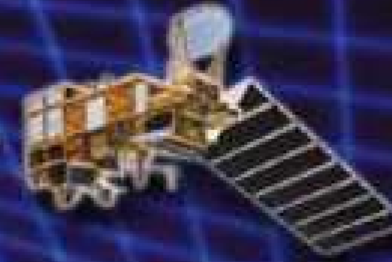
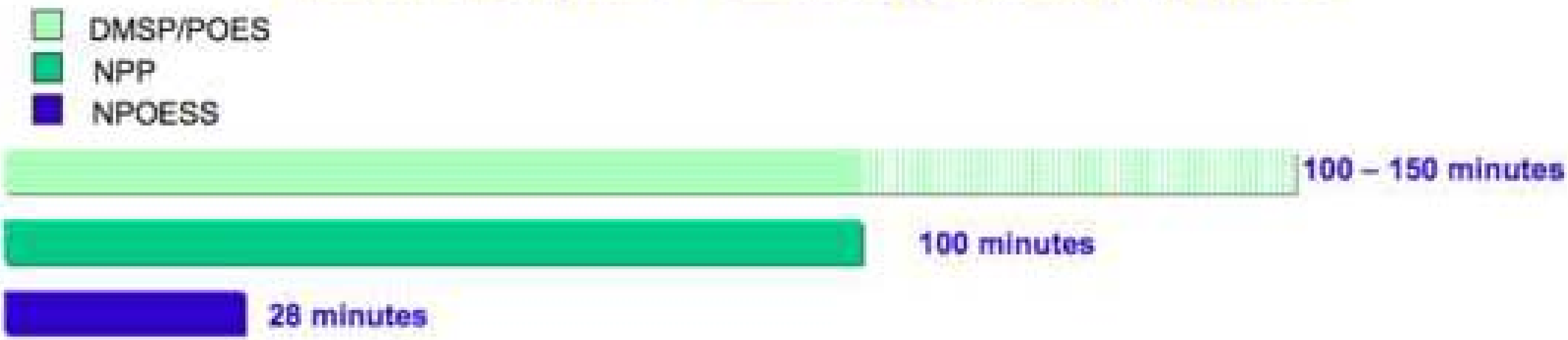


NPOESS Sensor suite delivers 38 Environmental Data Records and 14 Essential Climate Variables

NPOESS Data Delivery

DATA LATENCY – Delivery Of Data To Users



Improvements Over Heritage	Data Rate	Data Volume	Encryption	Spectral Capability	Vertical Resolution
Heritage	1.5 Mbps	6.3 GB/Day	Total	5 bands	40 bands
NPOESS	20 Mbps	5.4 TB/Day	Selective	22 bands	1300 bands

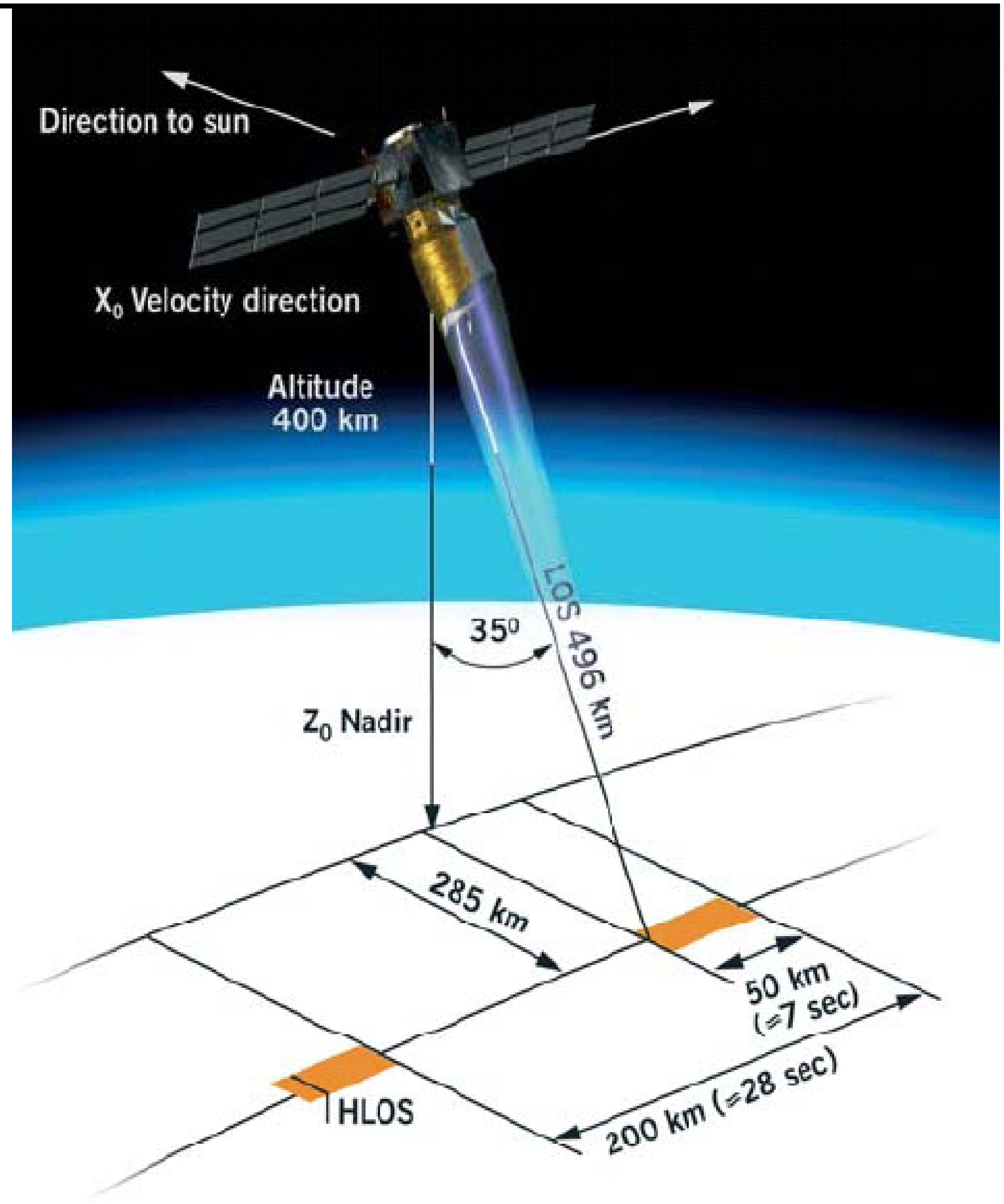
NPOESS improves robustness, accuracy, and timeliness of delivery of essential weather and climate data

ADM-Aeolus

- **D**oppler **W**ind **L**idar
- Cross-track HLOS winds
- σ_{HLOS} (z) = 2-3 m/s
- Profiles 0–30 km@0.5-2 km
- Once every 200 km length
- Aerosol and molecular measurement channel
- Dawn-dusk polar-orbiter
- Launch date June 2011

www.esa.int/esaLP/LPadmaeolus.html

(Stoffelen et al., BAMS, 2005)



Global Precipitation Measurement

Mission Science Objective: Initiates the measurement of global precipitation, providing uniformly calibrated measurements every 3 hours for scientific research and societal applications.

Key Science Products: Precipitation intensity and distribution, instantaneous precipitation rate, 3-hourly precipitation rate, daily and monthly precipitation accumulation, latent heat distribution and outreach precipitation products

Mission Description:

S/C: Core (GSFC-industry) Constellation (GSFC/RSDO)

Instruments:

- Core: Dual-frequency PR (JAXA) GMI (Ball)
- Constellation: GMI (Ball)

Launch Vehicle:

- Core - H-IIA 202A (JAXA - TBD)
- Constellation -Taurus

Orbit: 65º inc., 400 km (Core), 30º inc., 635 km (Const.)

Mission Life: 3 years (for both Core and Constellation)

Mission Project Management: GSFC

Launch Date: 06/01/13 (Core), 06/01/14 (Const.)

Status: Formulation (Phase B) in preliminary design

Systems in development

- US hyperspectral IR sounder (third attempt)
- US geostationary microwave sounder (GEOSTAR)
- GPSRO COSMIC follow-on mission
- NRC Decadal Survey (NASA, NOAA)
  - US multi-perspective wind lidar mission (GWOS)
  - Ocean surface winds mission (NOAA)
- High-latitude imaging
  - Molniya orbit (PCW)
  - LEO swarm (Iridium-NEXT)
- …

Hyperspectral IR sensor in GEO

- AIRS/IASI like, but much higher temporal resolution (~30 minutes for full-disk coverage)
- ABS - original “Advanced Baseline Sounder” concept for GOES-R
- GIFTS - NASA New Millennium Program instrument development project
  – Instrument mostly built, not integrated and tested
  – Canceled due to cost overruns
- HES - recent GOES-R sensor concept
  – Requirements collected prior to industry consultation
  – Canceled due to spiraling cost
- Next attempt TBA

Why GEO hyperspectral IR sounding system ?

- To support regional and convective-scale NWP over CONUS, through unprecedented detail on 3D fields of wind, temperature and humidity, at high vertical, horizontal and temporal resolution.
- To support nowcasting and very-short range forecasting (VSRF). For example, to use 3D fields of wind, temperature and humidity for monitoring moisture convergence and convective instability, to help improve warnings of location and intensity of convective storms.
- High spatial and temporal resolution GEO soundings with high accuracy provide important information for hurricane track and intensity forecast. This has been demonstrated by single field-of-view AIRS soundings.

Slide by Li et al.

Summary

- **It is now feasible to implement a GEO/MW in the near future**
  - We must move quickly to take advantage of the current GOES-R/S opportunity
  - 4-year development: can be ready for 2014 launch
  - Risk is moderate: mature design & technology, many descope options & fallback solutions are available
- **Benefits: Brings LEO capabilities to GEO ⇒ "Geosynchronous AMSU"**
  - Primary focus on *hurricanes:* now-casting, rapid intensification, model & forecast improvements
  - Significant impact expected on both global and regional NWP - *no data gaps in cloudy scenes, storms*
  - Greatly-improved boundary layer, cloud and precipitation process *models;* climate variability; ENSO
  - Provides *advanced sounder* solution while waiting for HES
- **Instrument concept & technology developed by NASA, endorsed by NOAA**
  - Proven instrument concept meets measurement requirements and is ready for flight development
  - Flexible design with a number of descope options to match available resource allocations
  - Flexible architecture with a number of accommodation options to match available platform space
  - No moving parts; no interference with other payloads
- **NASA-NOAA teaming opportunity**
  - Urgent action required to use ex-HES slot for GeoSTAR as MoO on GOES-R or GOES-S
  - Unique opportunity to greatly enhance cloudy & hurricane remote sensing at low incremental cost
  - *Decisive action required!*
    - User community must speak up
    - NOAA must communicate with NASA
    - *"We need this!"*

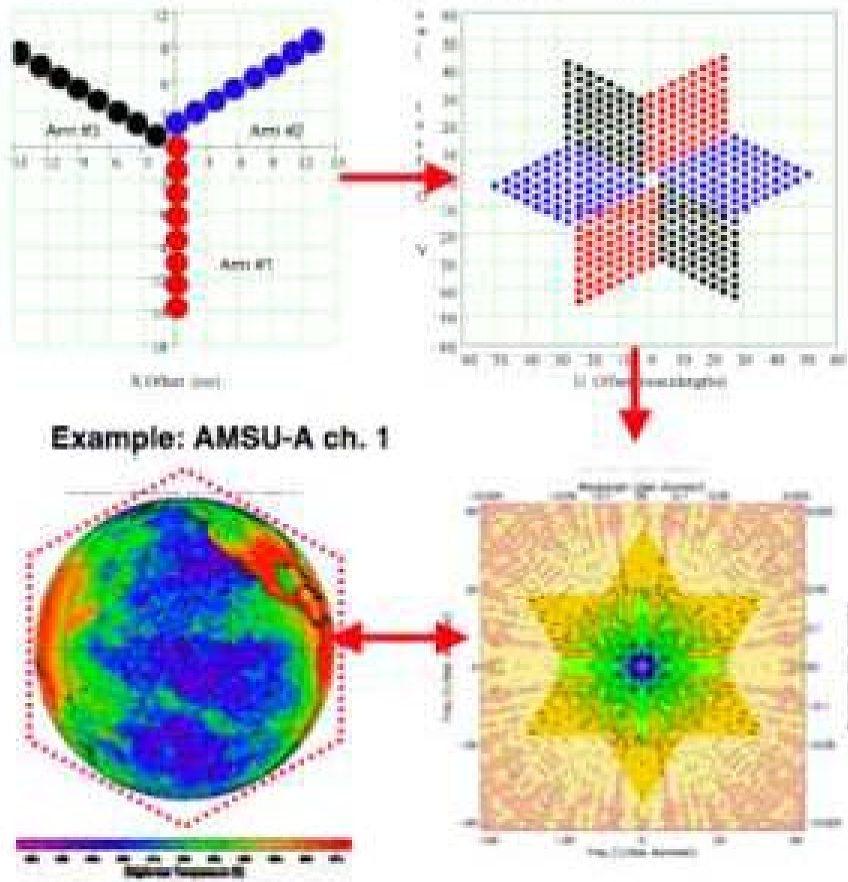
From "GEOSTAR" presentation, courtesy of Lambrigtsen

GeoSTAR System Concept

- **Aperture-synthesis concept**
  - Sparse array employed to synthesize large aperture
  - Cross-correlations -> Fourier transform of Tb field
  - Inverse Fourier transform on ground -> Tb field
- **Array**
  - Optimal Y-configuration: 3 sticks; N elements
  - Each element is one I/Q receiver, 3.5λ wide (2.1 cm @ 50 GHz; 6 mm @ 183 GHz!)
  - Example: N = 100 ⇒ Pixel = 0.09° ⇒ 50 km at nadir (nominal)
  - One "Y" per band, interleaved
- **Other subsystems**
  - A/D converter; Radiometric power measurements
  - Cross-correlator - massively parallel multipliers
  - On-board phase calibration
  - Controller: accumulator -> low D/L bandwidth

No moving parts!

Receiver array & resulting uv samples



NASA/NOAA/NRC Decadal Survey

- Broad canvassing of US Earth science research community done by NRC on behalf of NASA and NOAA
- More than 100 missions proposed in response to invitation to submit White Papers
- Report issued December 2006
  - 15 large missions recommended for NASA, 2 for NOAA
  - Competitive opportunity for smaller mission recommended ("Venture class")
  - Several other opportunity/joint missions identified

NASA Near-Term Missions (4/15 total)

Decadal Survey Mission	Mission Description	Orbit	Instruments
CLARREO (NASA portion)	Solar and Earth radiation: spectrally resolved forcing and response of the climate system	LEO, Precessing	Absolute, spectrally-resolved interferometer
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer
ICESat-II	Ice sheet height changes for climate change diagnosis	LEO, Non-SSO	Laser altimeter
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health	LEO, SSO	L-band InSAR Laser altimeter

NASA Mid-Term Missions (5/15 total)

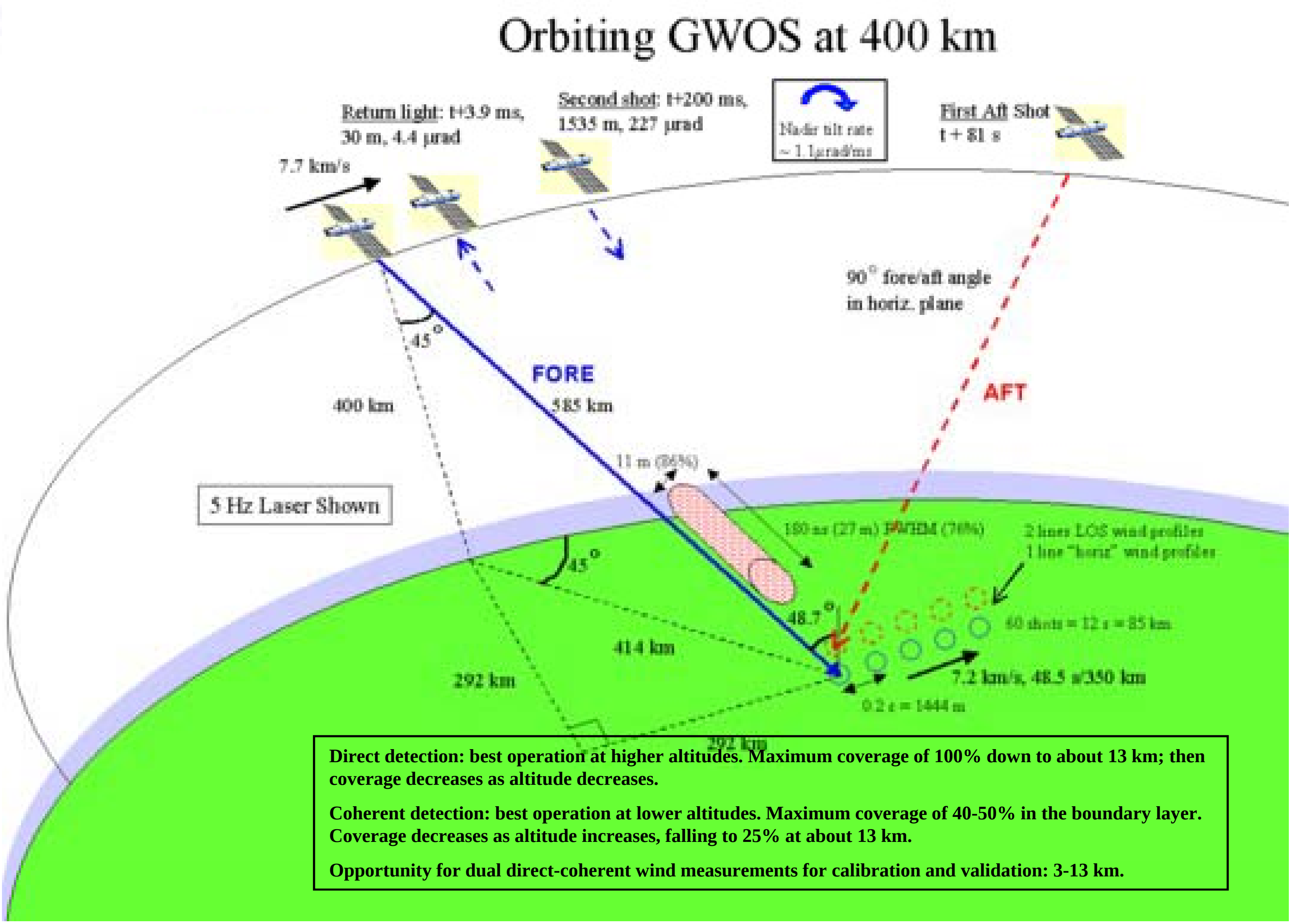
Decadal Survey Mission	Mission Description	Orbit	Instruments
HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health	LEO, SSO	Hyperspectral spectrometer
ASCENDS	Day/night, all-latitude, all-season CO_2 column integrals for climate emissions	LEO, SSO	Multifrequency laser
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics	LEO, SSO	Ka-band wide swath radar C-band radar
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	GEO	High and low spatial resolution hyperspectral imagers
ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry	LEO, SSO	Backscatter lidar Multiangle polarimeter Doppler radar

NASA Far-Term Missions (6/15 total)

Decadal Survey Mission	Mission Description	Orbit	Instruments
LIST	Land surface topography for landslide hazards and water runoff	LEO, SSO	Laser altimeter
PATH	High frequency, all-weather temperature and humidity soundings for weather forecasting and SST*	GEO	MW array spectrometer
GRACE-II	High temporal resolution gravity fields for tracking large-scale water movement	LEO, SSO	Microwave or laser ranging system
SCLP	Snow accumulation for fresh water availability	LEO, SSO	Ku and X-band radars K and Ka-band radiometers
GACM	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction	LEO, SSO	UV spectrometer IR spectrometer Microwave limb sounder
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport	LEO, SSO	Doppler lidar

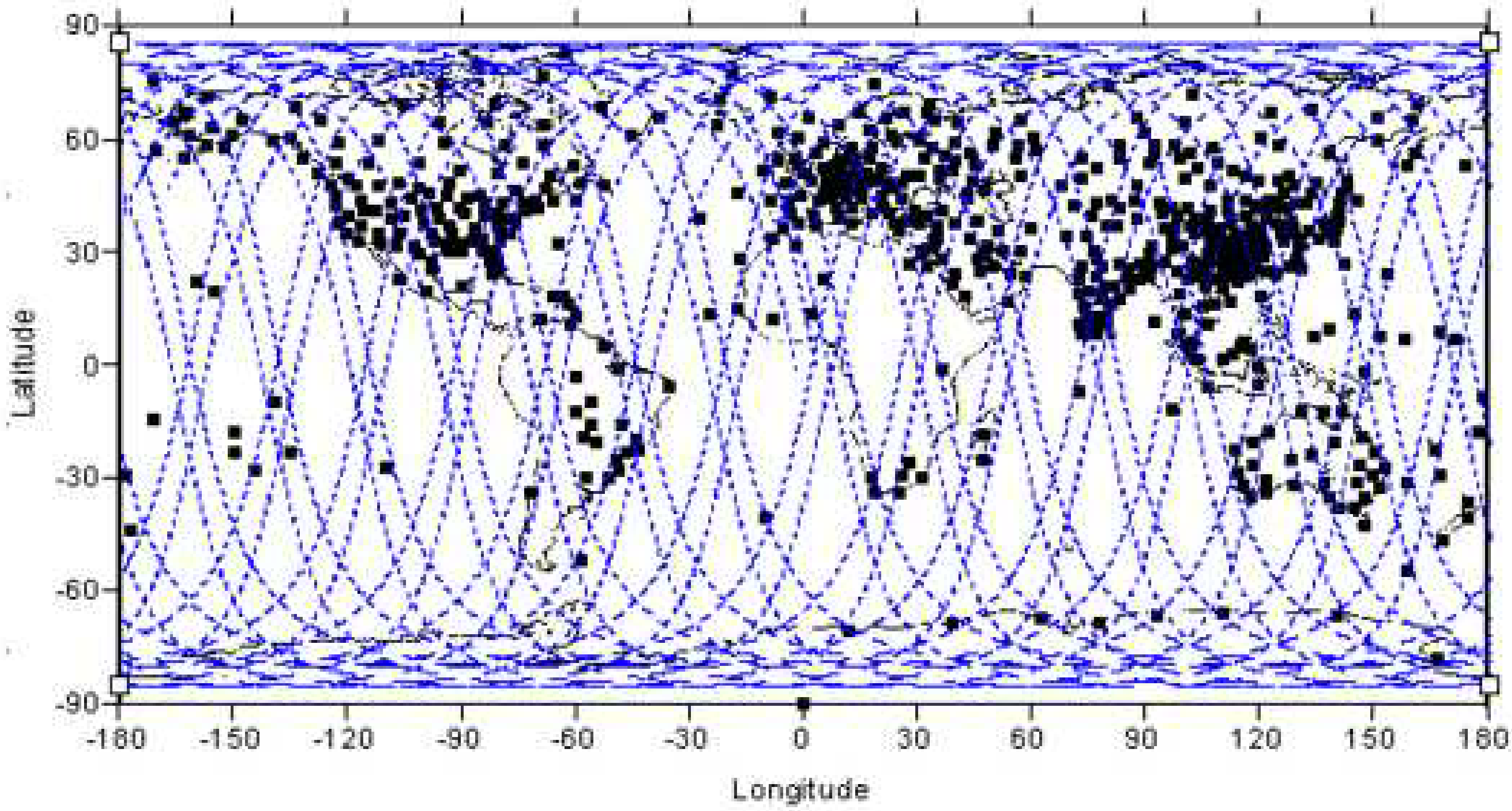
*Cloud-independent, high temporal resolution, lower accuracy SST to complement, not replace, global operational high-accuracy SST measurement

Mission Concept

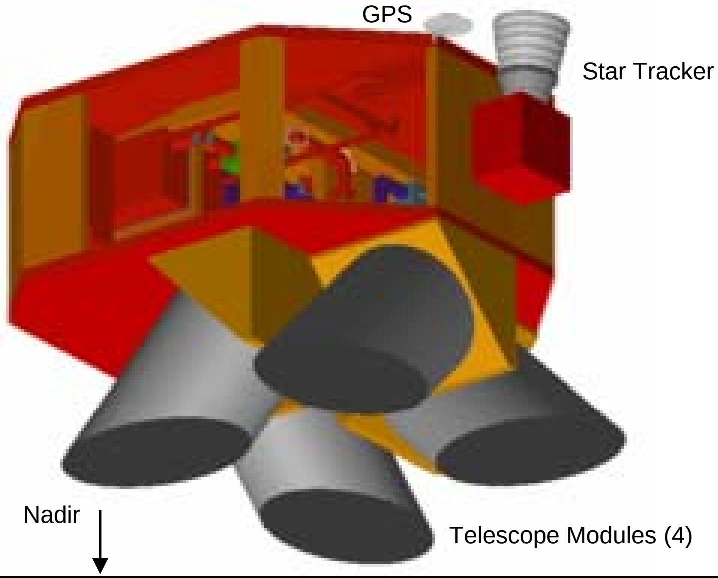


GWOS Coverage

- Around 600 radiosonde stations (black) provide data every 12 h
- GWOS (blue) would provide ~3200 profiles per day



GWOS ISAL Instrument Quad Chart



Features of the Instrument Concept

- Utilizes Doppler lidar detection method
  - Coherent (aerosol) detection @ 2 µm
  - Direct (molecular) detection @ 355 nm
- Direct channel laser based on GLAS;
- Direct channel receiver based on TWiLiTE IIP
- Coherent channel laser and receiver based on DAWN IIP
- Telescopes are shared among all lasers
- Pointing and knowledge requirements met with co-located star tracker and GPS

Payload Data

Dimensions	1.5m x 2m x 1.8m
Mass	567 Kg
Power	1,500 W
Data Rate	4 Mbps

Technology Development Needs

- Direct detection system requires 6 billion shots for mission lifetime (2 years)
  - Direct channel baseline is 3 lasers + 1 backup
  - Demonstration of reliable performance at higher or lower lifetimes will determine number of lasers for direct detection channel, impacting mission cost
- Coherent detection system requires demonstration of the 316M shot lifetime in a fully conductively cooled laser
- Both Lidar technologies require aircraft validation flights

High-latitude imaging

- GEO is good for
  - Staring
  - Tracking features
  - Animating/monitoring/studying processes
- GEO is bad for
  - Middle and high-latitude coverage
  - Depending on application and longitude, no coverage poleward of 45 to 60 degrees of latitude

- How we get GEO-type coverage for high latitudes?

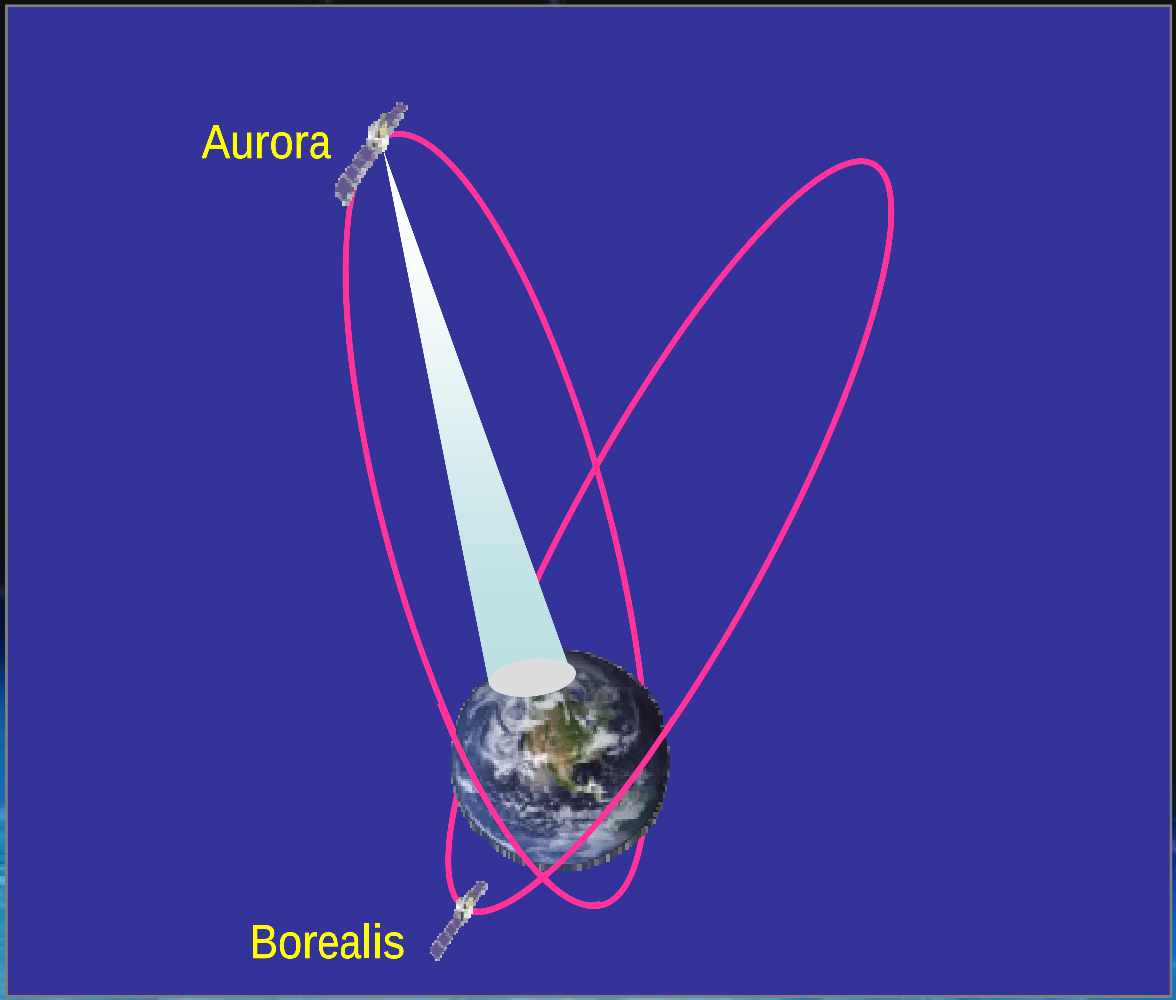
Molniya Orbit Imager mission highlights

- High-latitude quasi-geostationary imager ("GOES to the pole")
  - Full-disc image every 15 minutes at 1 km (VIS channel) and 2 km (5 IR channels) horizontal resolution
- High-latitude winds => improved weather forecasts (fewer busts) also at low latitudes
  - MODIS winds => better forecasts overall, hurricane landfall prediction
- Near-perfect high-latitude complement to GOES => support of many additional scientific and operational applications
  - Sea ice, snow cover, vegetation/hot spots, volcanoes, space weather, etc.
- Quasi-stationary vantage point ideal for imaging and real-time data dissemination
  - Experience, investment and technology from geostationary programs can be carried over

A spacecraft in Molniya orbit will spend close to 70% of the time hovering in quasi-geostationary mode over the high latitudes

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

PCW: Constellation in Molniya Orbit



PCW slides courtesy of Gurnnadi Kroupnik, CSA and Louis Garand, EC

QuickTime™ and a
decompressor
are needed to see this picture.

Animation courtesy of Louis Garand, EC

Part II; OSSEs

- What are OSEs and OSSEs?
- What is the role of OSSEs in system development?
- What are the ingredients?
  - Nature run
    - Validation
  - Simulated observations
    - Calibration

Much of the material provided by Joint OSSE team

Joint OSSE Team

NCEP:	Michiko Masutani, John S. Woollen, Yucheng Song, Stephen J. Lord, Zoltan Toth
ECMWF:	Erik Andersson
KNMI:	Ad Stoffelen, Gert-Jan Marseille
JCSDA:	Lars Peter Riishojgaard, Lidia Cucurull
NESDIS:	Fuzhong Weng, Tong Zhu, Haibing Sun,
SWA:	G. David Emmitt, Sidney A. Wood, Steven Greco
NASA/GFSC:	Ron Errico, Oreste Reale, Runhua Yang, Emily Liu, Joanna Joiner, Harper Pryor, Alindo Da Silva, Matt McGill,
NOAA/ESRL:	Tom Schlatter, Yuanfu Xie, Nikki Prive, Dezso Devenyi, Steve Weygandt
MSU/GRI:	Valentine Anantharaj, Chris Hill, Pat Fitzpatrick,
JMA	Takemasa Miyoshi , Munehiko Yamaguchi
JAMSTEC	Takeshi Enomoto

So far most of the work is done by volunteers.

Joint OSSE collaboration has been going on for close to three years, funding and management support remains work in progress

OSE/OSSE prerequisites

1. A prediction problem (e.g. weather)
2. An quantitative prediction system (GFS)
3. A set of observations used as input to the prediction system (GOS)
4. An objective way of assessing the quality of the prediction (forecast verification)

OSEs

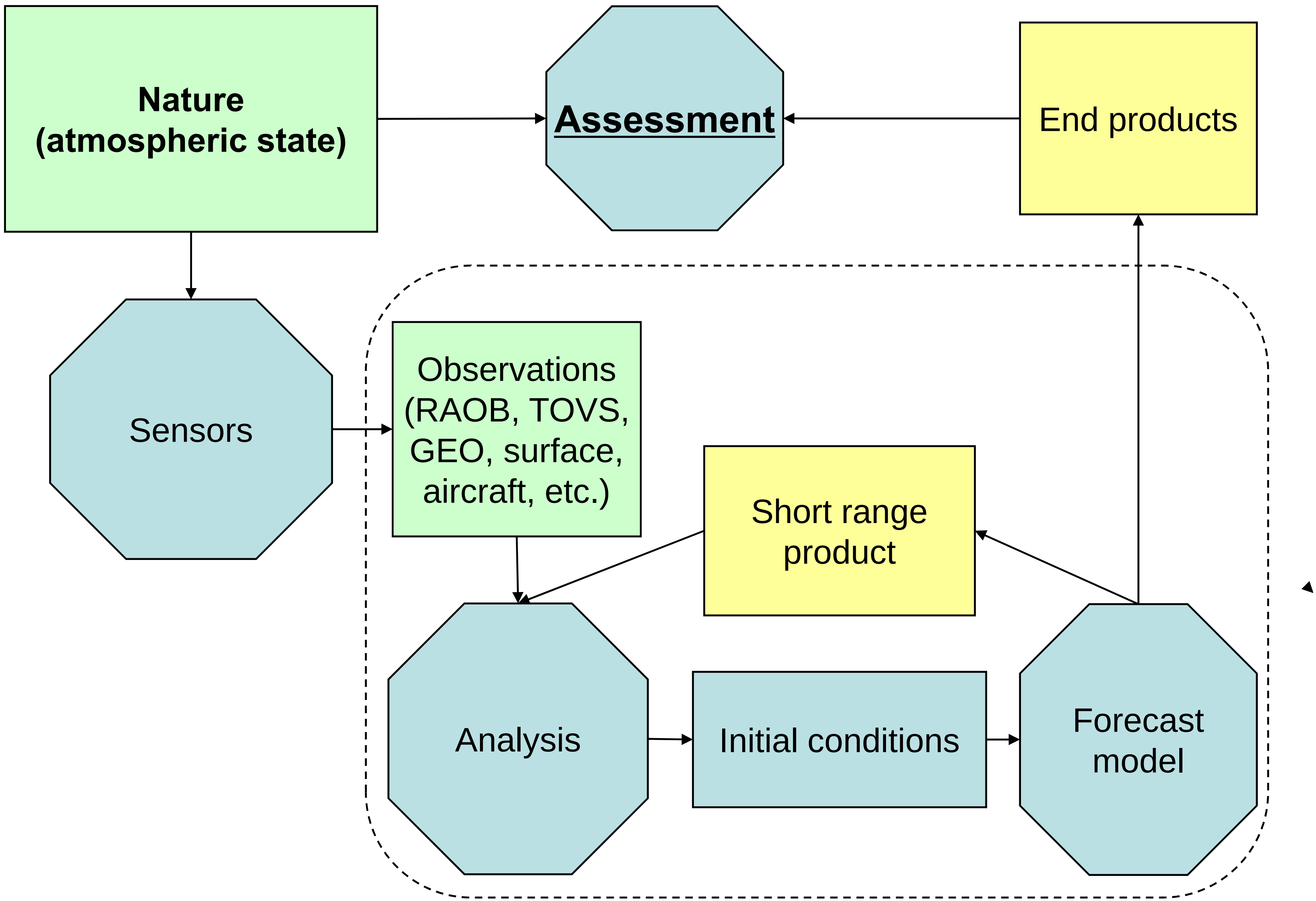
- **Observing System Experiments**
  - Typically aimed at assessing the impact of a given *existing* data type on a system
  - Relatively straightforward
  - Using existing observational data and operational analyses, the candidate data are either added to withheld from the forecast system, and the impact is assessed

  - Control run (all operationally used observations)
  - Perturbation run (control plus candidate data)
  - Compare!

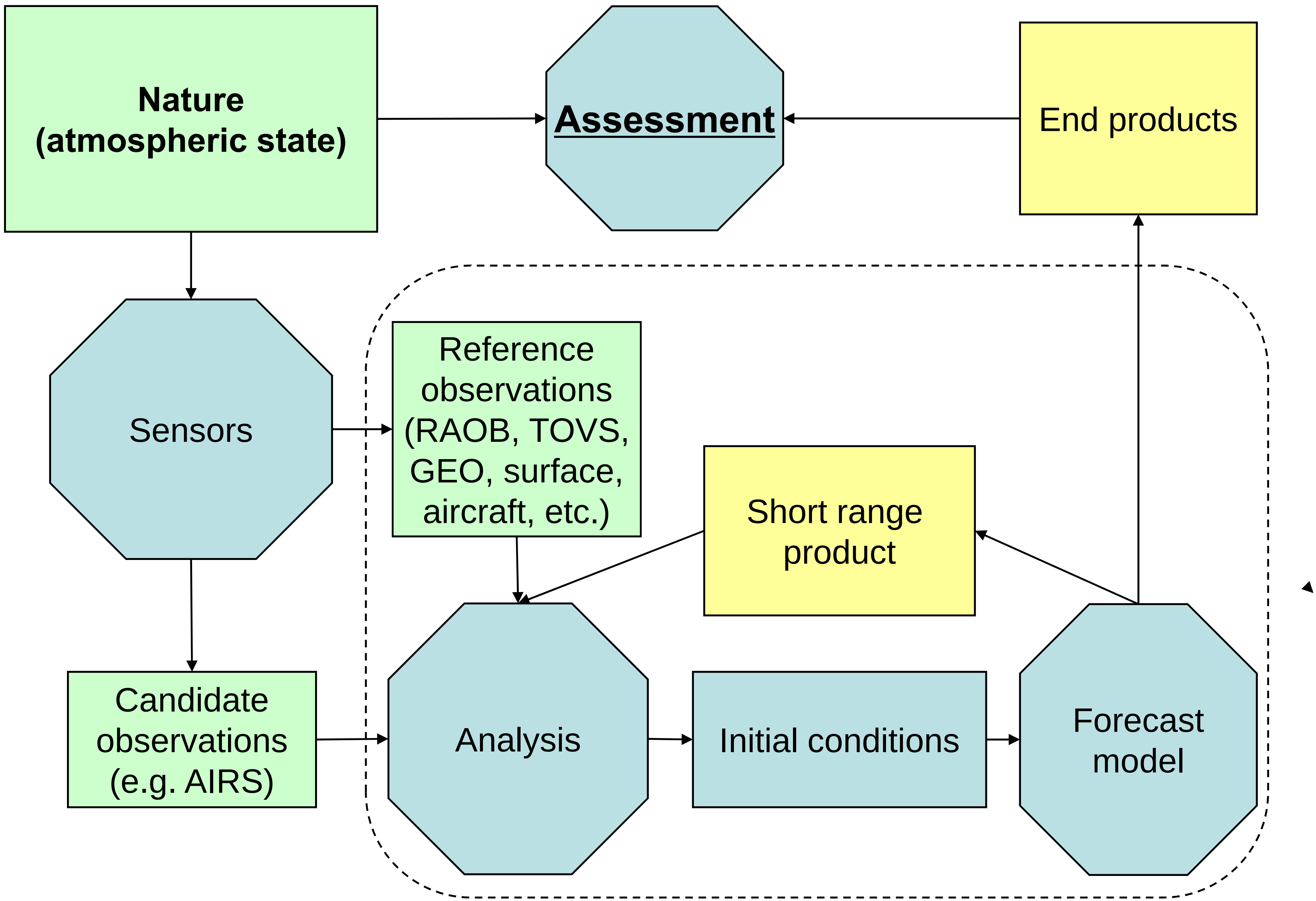
OSSEs

- **Observing System *Simulation* Experiment**
  - Typically aimed at assessing the impact of a *hypothetical* data type on a forecast system
    - Not straightforward; EVERYTHING must be simulated
      - Simulated atmosphere (“nature run”)
      - Simulated reference observations (corresponding to existing observations)
      - Simulate perturbation observations
      - (object of study)
  - => Costly in terms of computing and manpower

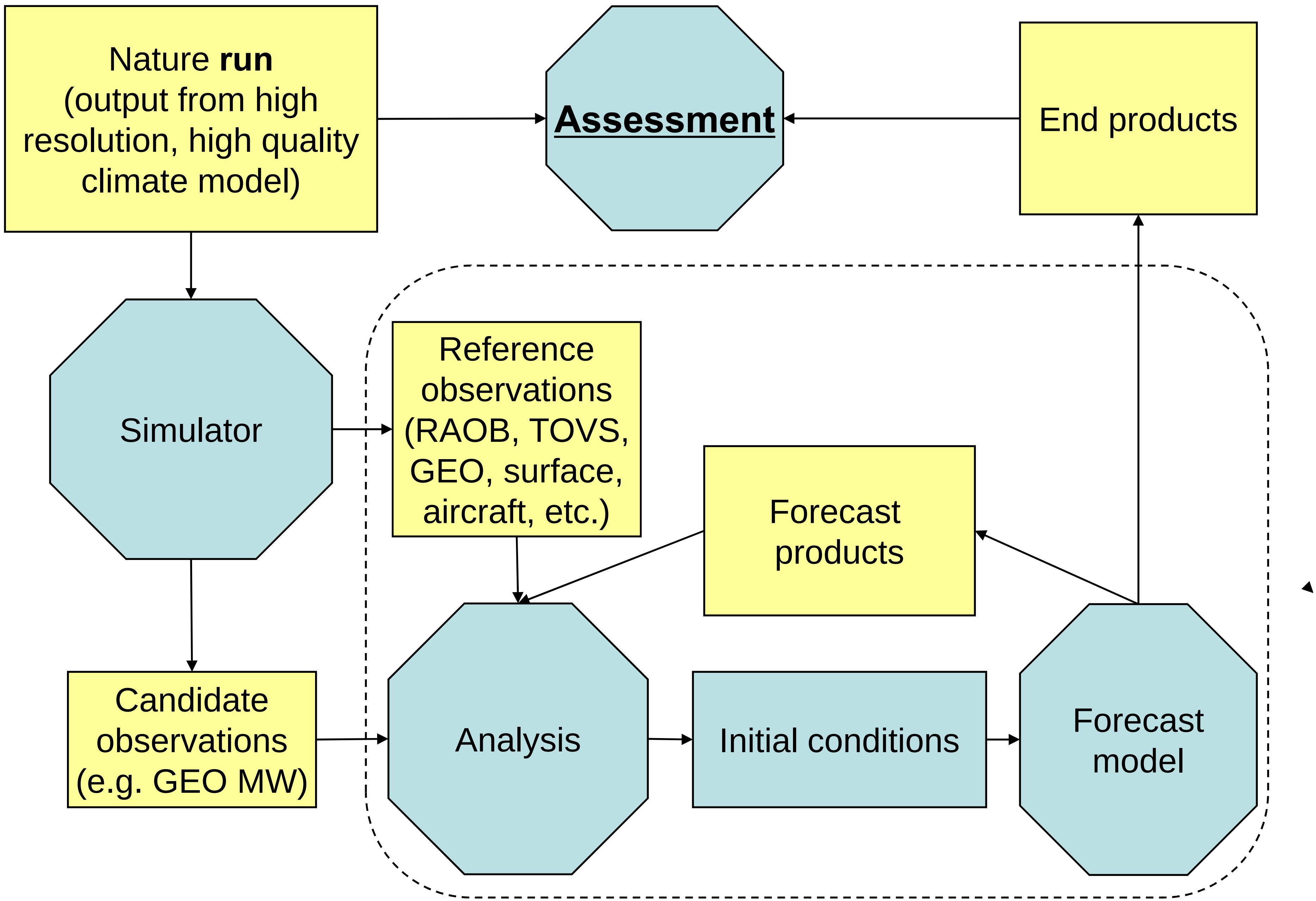
Data assimilation



OSE, conceptual model



OSSE, conceptual model



Frequently asked question about OSSE

- "Why not use real atmospheric situations and real data?"
  - *OSSE are designed to test the impact of <u>hypothetical</u> observations on the forecast; how would we simulate those?*
- "Just simulate these new observations based on the atmospheric state (analysis) and add them to the assimilation and forecast"
  - *But the only basis for we have for simulating them is the analysis which already captures everything we know about the atmospheric state - by definition we cannot know what additional information additional observations would have provided*

Contributions of an OSSE Capability

- Quantitative forecast (NWP) impact assessment of future missions
  - Decadal Survey and other science and/or technology demonstration missions (NASA)
  - Future operational systems (NOAA/NESDIS, NPOESS)
- Objective way of establishing scientifically sound and technically feasible user requirements for observing systems
- Tool for assessing performance impact of engineering decisions made throughout the development phases of a space program or system
- Preparation/early learning pre-launch tool for assimilation users of data from new sensors

Why a (national) Joint OSSE capability?

- OSSEs are expensive
  - Nature run, entire reference observing system, additional observations must be simulated
  - Calibration experiments, perturbation experiments must be assessed according to standard operational practice and using operational metrics and tools
- OSSE-based decisions have many stakeholders
  - Decisions on major space systems have important scientific, technical, financial and political ramifications
  - Community ownership and oversight of OSSE capability is important for maintaining credibility
- Independent but related data assimilation systems allows us to test robustness of answers

Main OSSE components

- Data assimilation system(s)
  - NCEP/EMC GFS
  - NASA/GMAO GEOS-5
  - NCAR WRF-VAR
- Nature run
  - ECMWF
  - Plans for embedded WRF Regional NR
- Simulated observations
  - Reference observations
  - Perturbation (“candidate”) observations
- Verification capability (calibration)
  - “Classical” OSE skill metrics
  - Adjoint sensitivity studies

ECMWF Nature Run *(Erik Andersson)*

- Based on recommendations/requirements from JCSDA, NCEP, GMAO, GLA, SIVO, SWA, NESDIS, ESRL

- “Low Resolution” Nature Run
  - Free-running T511 L91 w. 3-hourly dumps
  - May 12 2005 through June 1 2006

- Two “High Resolution” periods of 35 days each
  - Hurricane season: Starting at 12z September 27,2005,
  - Convective precipitation over CONUS: starting at 12Z April 10, 2006
- T799 L91 levels, one-hourly dump
- Initial condition from T511 NR

Nature Run validation

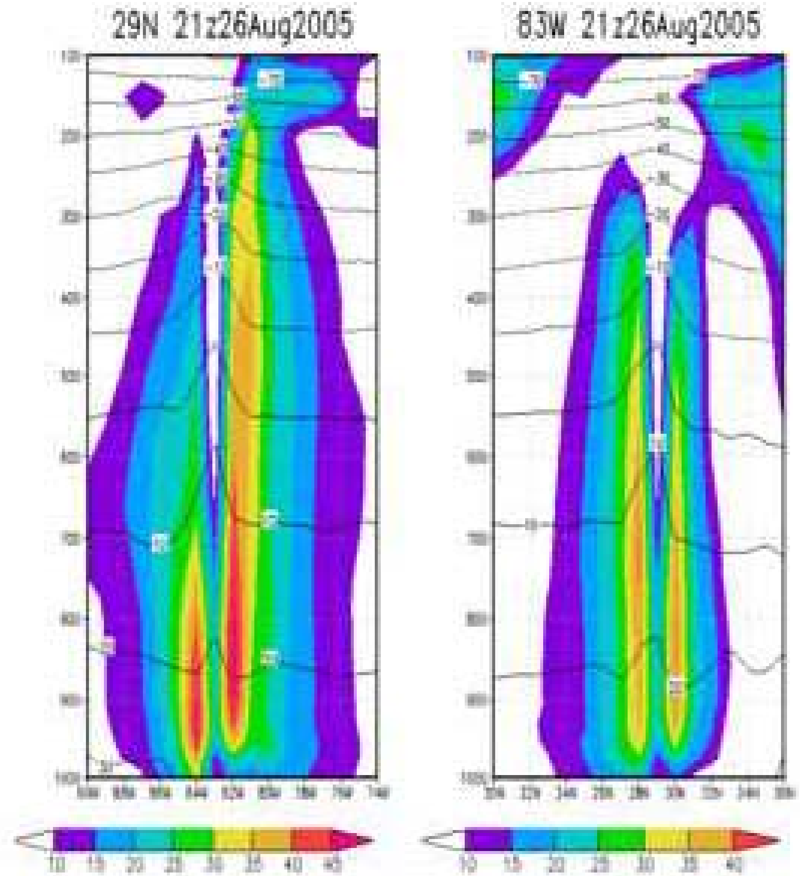
- Purpose is to ensure that pertinent aspects of meteorology are represented adequately in NR

- Contributions from Emmitt, Errico, Masutani, Prive, Reale, Terry, Tompkins and many others

- Clouds
- Precipitation
- Extratropical cyclones (tracks, cyclogenesis, cyclolosis)
- Tropical cyclones (tracks, intensity)
- Mean wind fields
- ….

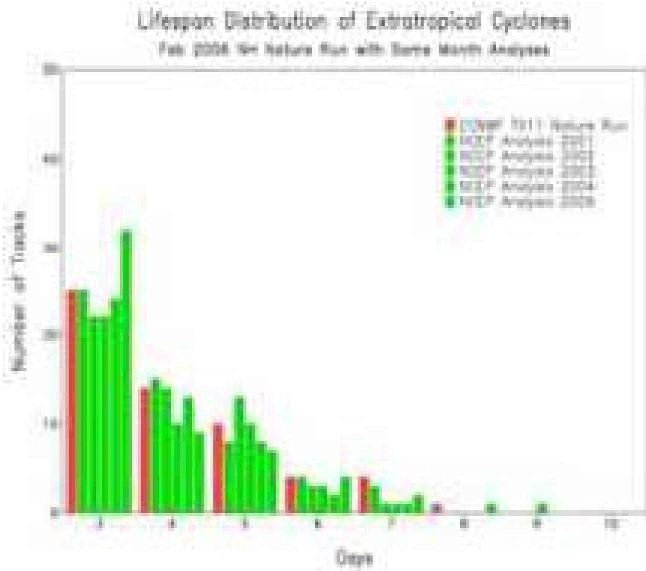
Tropical cyclone NR validation

Preliminary findings suggest good degree of realism of Atlantic tropical cyclones in ECMWF NR.

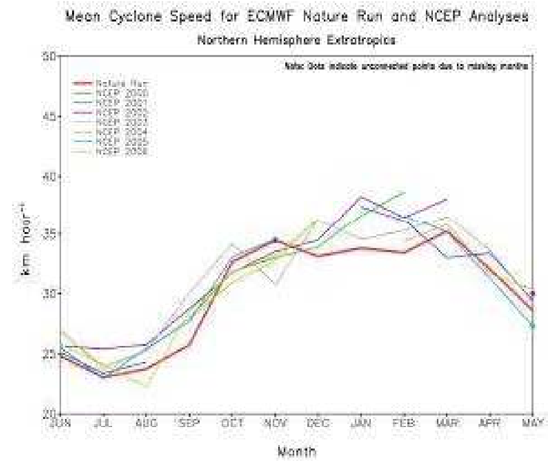


Vertical structure of a HL vortex shows distinct eye-like feature and prominent warm core; low-level wind speeds exceed 55 m/s

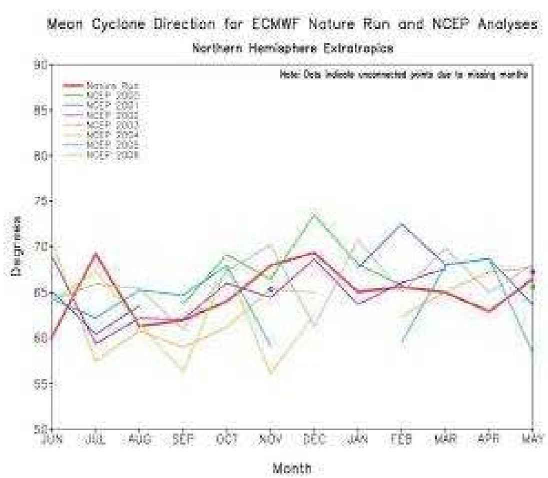
Reale O., J. Terry, M. Masutani, E. Andersson, L. P. Riishojgaard, J. C. Jusem (2007), Preliminary evaluation of the European Centre for Medium-Range Weather Forecasts' (ECMWF) Nature Run over the tropical Atlantic and African monsoon region, Geophys. Res. Lett., 34, L22810, doi:10.1029/2007GL031640.



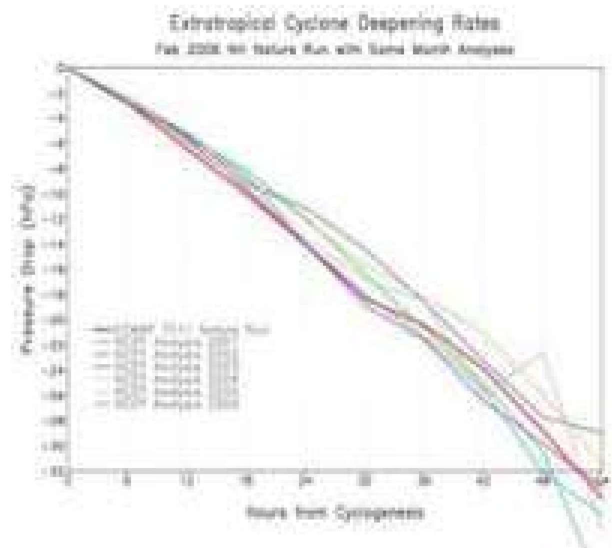
Lifespan Distribution of Extratropical Cyclones
Feb 2006 NH Nature Run with Same Month Analyses
Number of Tracks
Days



Mean Cyclone Speed for ECMWF Nature Run and NCEP Analyses
Northern Hemisphere Extratropics
Note: Dots indicate unconnected points due to missing months
km hour⁻¹
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
Month



Mean Cyclone Direction for ECMWF Nature Run and NCEP Analyses
Northern Hemisphere Extratropics
Note: Dots indicate unconnected points due to missing months
Nature Run
NCEP 2000
NCEP 2001
NCEP 2002
NCEP 2003
NCEP 2004
NCEP 2005
NCEP 2006
Degrees
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
Month

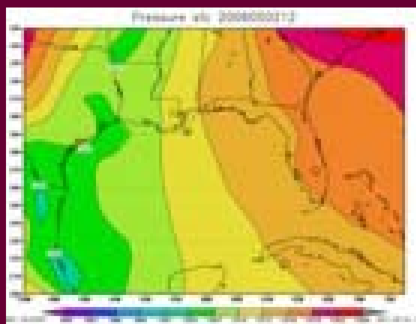


Extratropical Cyclone Deepening Rates
Feb 2006 NH Nature Run with Same Month Analyses
Pressure Drop (hPa)
Hours from Cyclogenesis

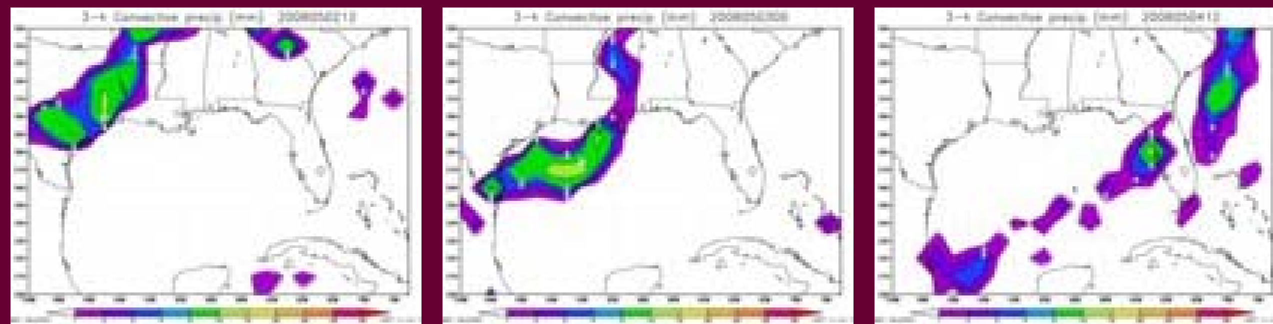
Case Events Identified from ECMWF HRNR

(Plotted from 1x1 data)

May 2-4: squall line affecting all points along US Gulf coast

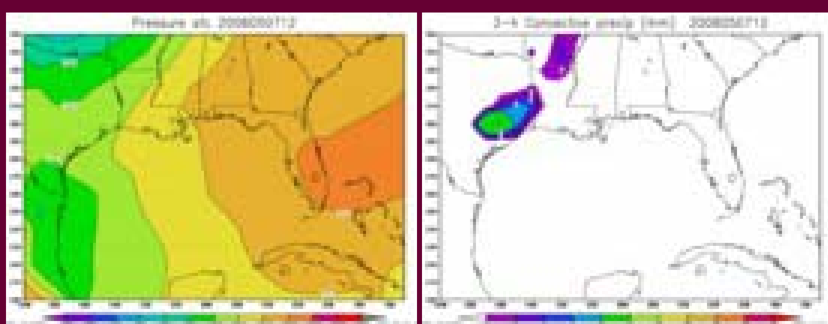


MSLP (hPa)

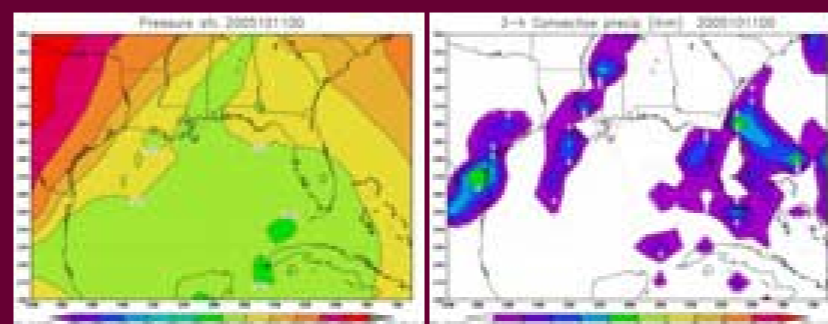


3-h convective precipitation (mm)

May 7-8: decaying squall line over TX



Oct 10-11: squall line / tropical wave



Christopher M. Hill, Patrick J. Fitzpatrick, Valentine G. Anantharaj
Mississippi State University

Simulation of observations

- Conventional observations (non-radiances)
  - "Resample NR at OBS locations and add error"
  - Problem areas:
    - Atmospheric state affects sampling for RAOBS, Aircraft observations, satellite AMVs, wind lidars, etc.
    - Correlated observations errors
  - J. Woollen (NCEP), R. Errico (GMAO)

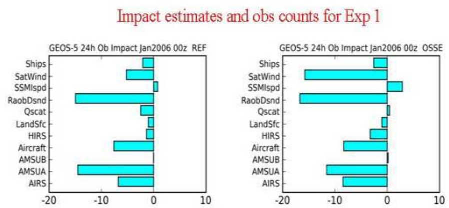
- Radiance observations
  - "Forward radiative transfer on NR input profiles"
  - Problem areas:
    - Treatment of clouds has substantial impact on availability and quality of observations
    - Desire to avoid "identical twin" RTMs
  - H. Sun (NESDIS), R. Errico (GMAO)

OSSE (observation error) calibration

- Purpose is to ensure realistic forecast skill of the OSSE system
  - Forecast skill of OSSE should be roughly comparable to real-world skill obtained with same assimilation system
  - Also realistic decrease in skill when classes of simulated observations are withheld (RAOBS, AMSU, AMDAR,SATWINDS, etc.)
- Obtained via tuning of simulated observation error

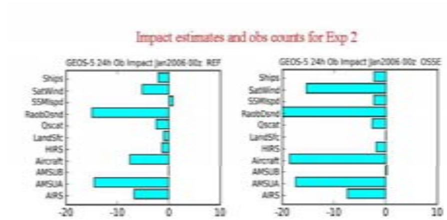
Calibration for Joint OSSEs at NASA/GMAO

Version 1



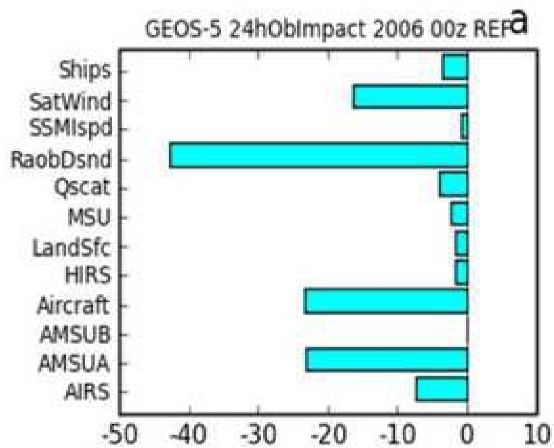
REAL OSSE

Version 2

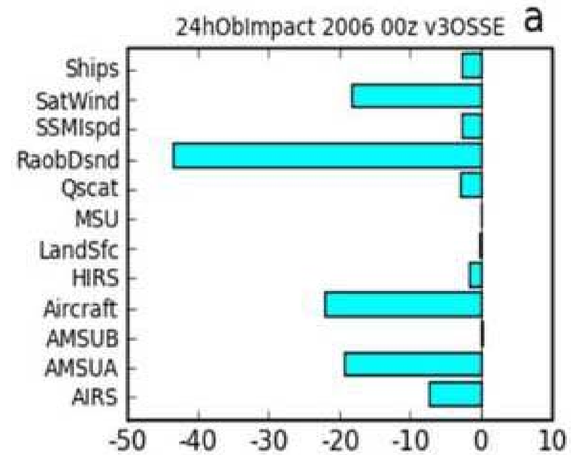


REAL OSSE

Latest version



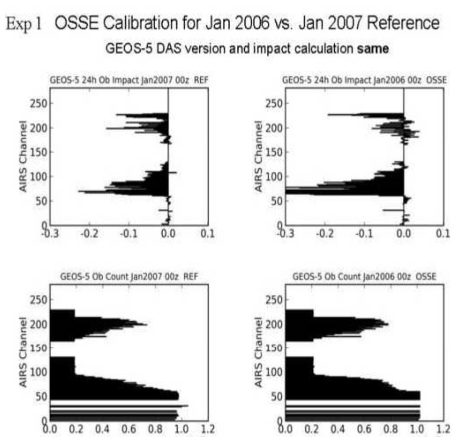
Real Data



OSSE

Calibration using adjoint technique

Version 1



- **Overall impact of simulated data seems realistic**
- **Tuning parameter for cloud clearing**
- **Surface emissivity**
- **Improved simulation of AMVs**

(courtesy of Ron Errico)

Planned OSSEs

- Wind Lidar (GWOS) impact and configuration experiments (NASA)
- NPP (CrIS and ATMS) regional impact studies (NASA)
- Future GPSRO constellation configuration and impact (NOAA/NESDIS)
- GOES-R preparation experiments (NOAA/NESDIS)
- UAS impact (NOAA/OAR)
- …

Issues

- Funding
  - Joint OSSE collaboration remains largely unfunded; not sustainable in the long term
- Agency and inter-agency coordination
  - Informal OSSE Steering Group in existence
- Computing
  - Embedded in larger JCSDA computing shortfall

Summary

- OSSEs are a cost-effective way to optimize investment in future observing systems (e.g. NPOESS, Decadal Survey missions)
  - Represent our best shot to be heard as data assimilation/NWP community
- OSSE capability should be broadly based (multi-agency)
  - Credibility
  - Cost savings
- Substantial and growing agency interest in OSSE, both nationally and internationally