2022

Impact of HSIR on NWP

Tony McNally ECMWF

**Presented to CGMS-48 Plenary, Session: HSIR observations,
Agenda item 4.1**

Coordination Group for Meteorological Satellites

CGMS

NWP Satellite use…context for HSIR…

OBSERVATION	CONTROL (ECMWF OPS)	EUROPE	USA	ASIA
Atmospheric Motion Vectors	METOP A,B,C,DUAL (AVHRR) METEOSAT 8,11 (SEVIRI) HIMAWARI 8 (AHI) NPP, NOAA 20 (VIIRS) NOAA 15,18,19 (AVHRR) GOES 15,16 (I/ABI) AQUA (MODIS)	METOP A,B,C + DUAL (AVHRR) METEOSAT 8,11 (SEVIRI)	NPP, NOAA 20 (VIIRS) NOAA 15,18,19 (AVHRR) AQUA (MODIS) GOES 15,16 (ABI)	HIMAWARI 8 (AHI)
Atmospheric Sounding radiances	METOP A,B,C (AMSU/MHS/IASI)* NPP, NOAA 20 (ATMS/CrIS)* NOAA 15,18,19 (AMSU/MHS) AQUA (AMSUA/AIRS)* FY3-B,C,D (MWHS/MWHS2) METEOSAT 8,11 (SEVIRI) HIMAWARI 8 (AHI) GOES 15,16 (I/ABI) GCOM-W (AMSR-2) GPM (GMI) DMSP 17,18 (SSM/IS)	METOP A,B,C (AMSU/MHS/IASI) METEOSAT 8,11 (SEVIRI)	NPP, NOAA 20 (ATMS/CrIS) NOAA 15,18,19 (AMSU/MHS) AQUA (AMSUA/AIRS) GOES 15,16 (I/ABI) DMSP 17,18 (SSM/IS)	FY3-B,C,D (MWHS/MWHS2) (+FY-3D MWRI) HIMAWARI 8 (AHI) GCOM-W (AMSR-2)
GPS-RO	METOP A,B,C (GRAS) COSMIC TERRASAR / TANDEM FY3 (GNOS) KOMPSAT5 (GNOS)	METOP A,B,C (GRAS) (+ Spire RO)	COSMIC*	FY3 (GNOS) KOMPSAT5
Scatterometer	METOP 3,4,5 (ASCAT)	METOP A,B,C (ASCAT)		

+ numerous marine satellites (altimeters) and composition satellites (COP)

Coordination Group for Meteorological Satellites

CGMS

2022

HSIR on LEO satellites

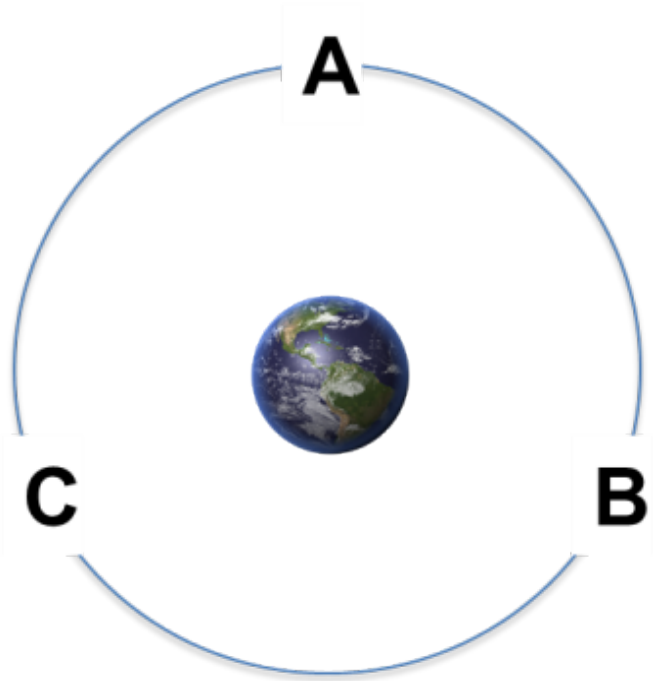
2022

HSIR on LEO satellites

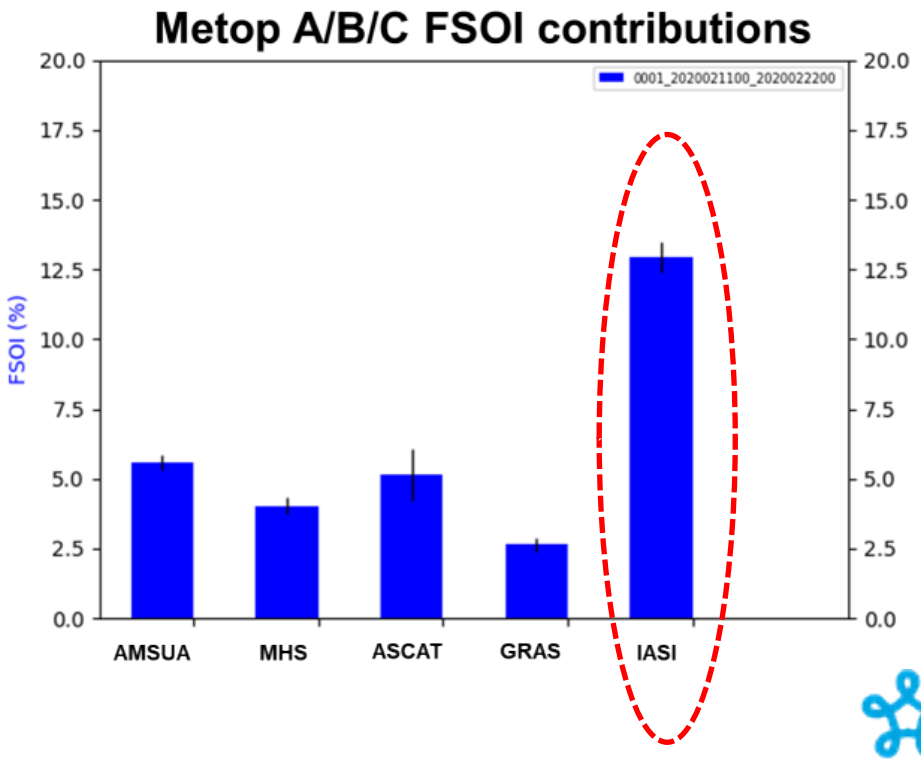
- Current NWP impact of HSIR
- Expanding the network of HSIR

HSIR dominates NWP impact on each individual satellite

Temporary Tristar Formation



Relative sensor impacts

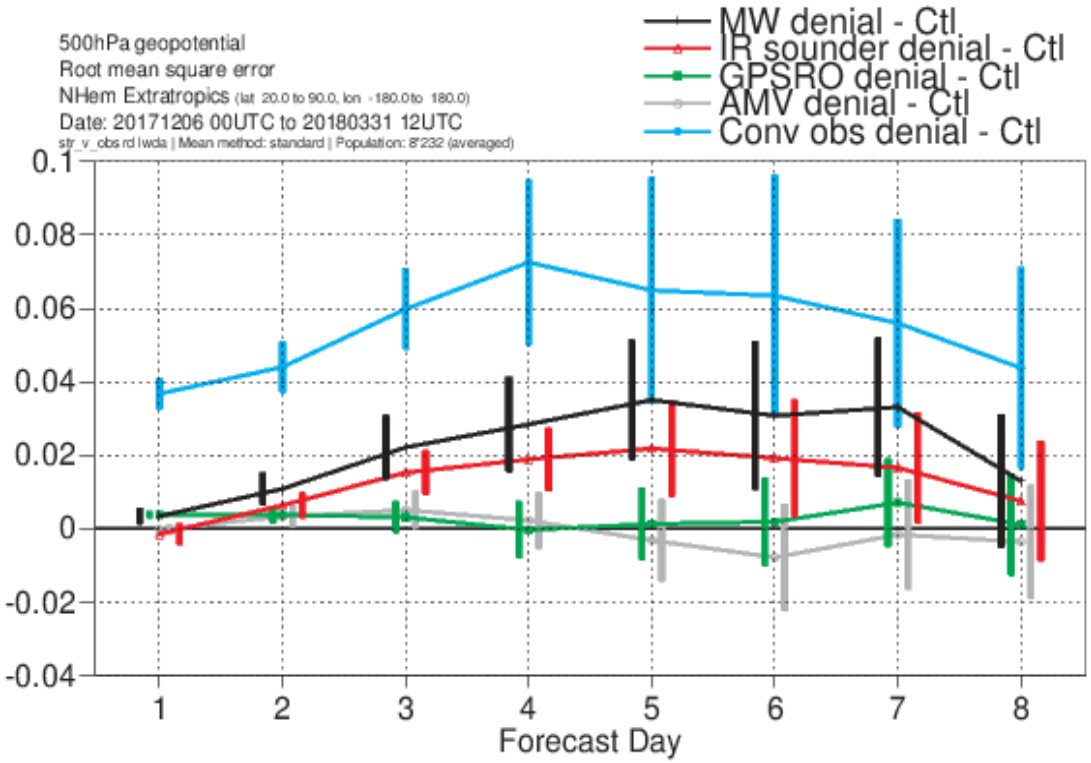


Coordination Group for Meteorological Satellites

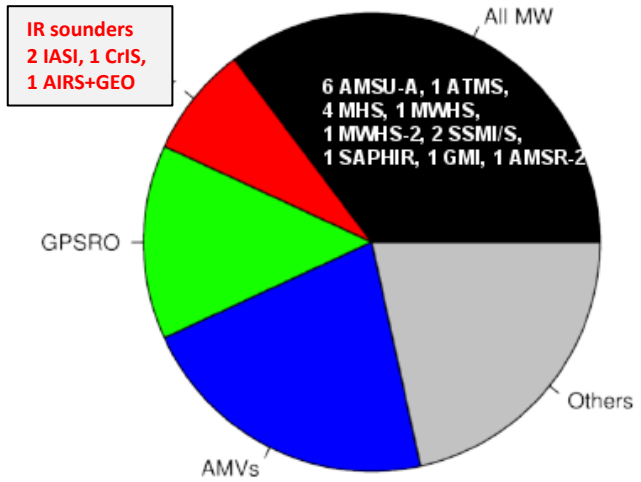
CGMS

…but HSIR lags behind MW overall as we do not have enough HSIR satellites…

NH forecast impact



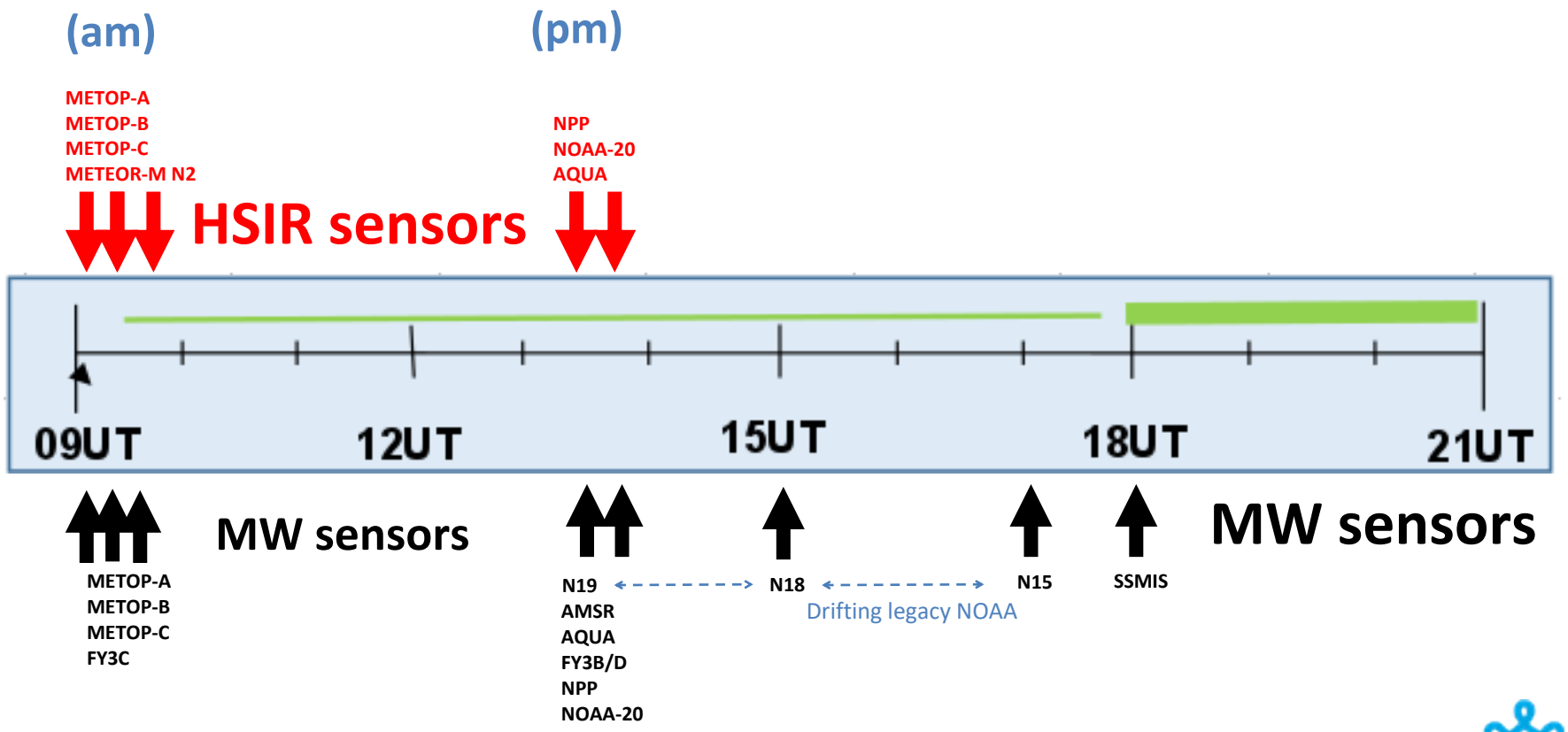
Number of sensors



Coordination Group for Meteorological Satellites

CGMS

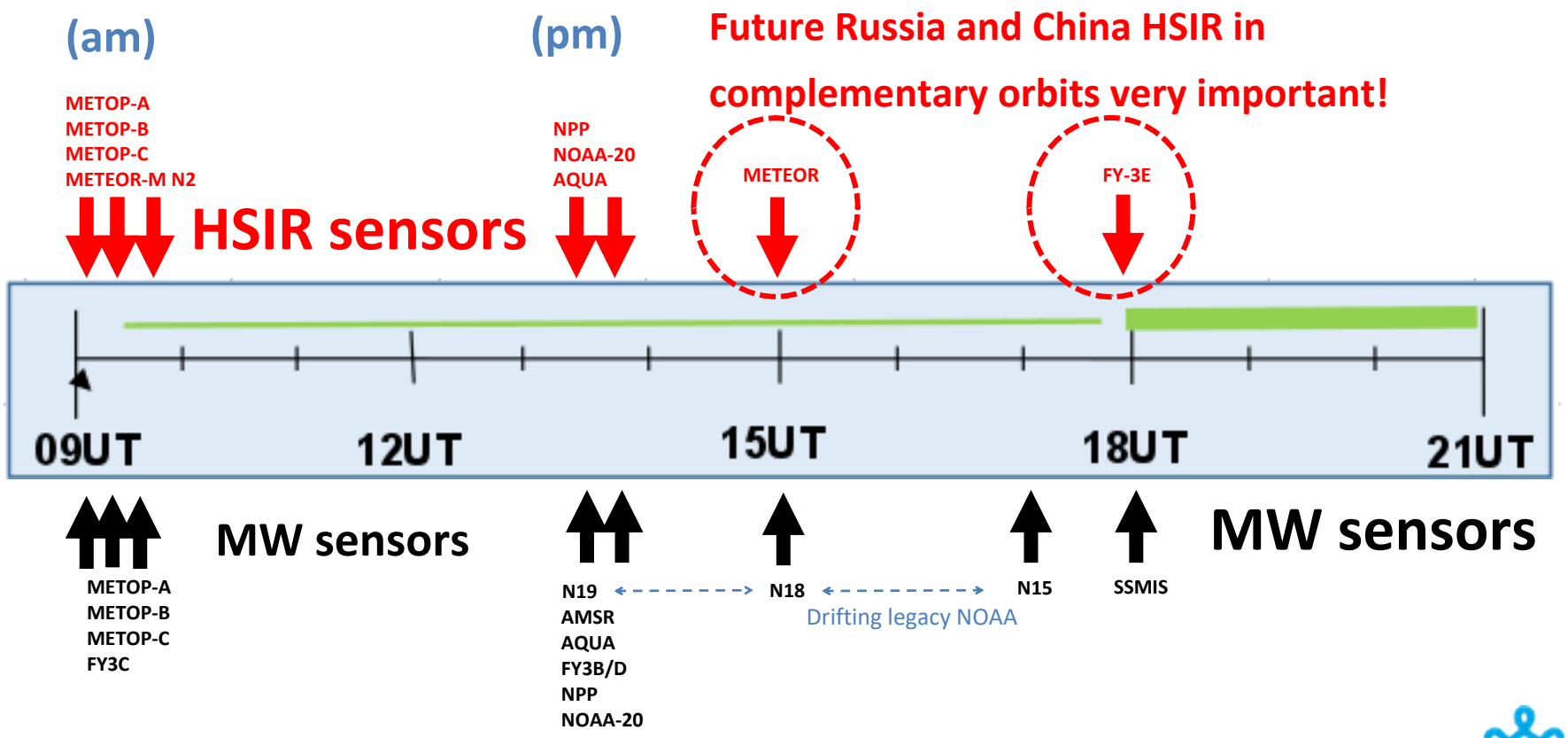
Not simply the number of HSIR sounders, but the orbits matter!



Coordination Group for Meteorological Satellites

CGMS

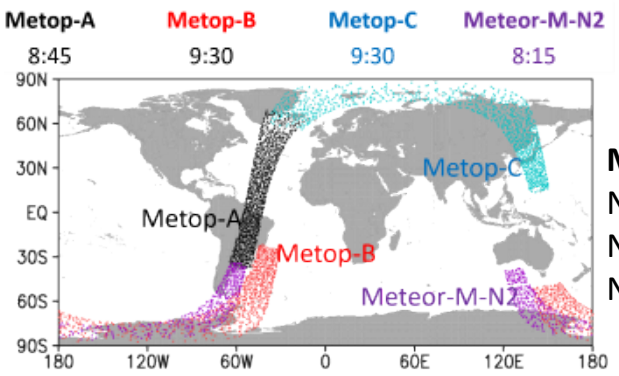
Not simply the number of HSIR sounders, but the orbits matter!



Coordination Group for Meteorological Satellites

CGMS

Positive impact of Russian IKFS at ECMWF

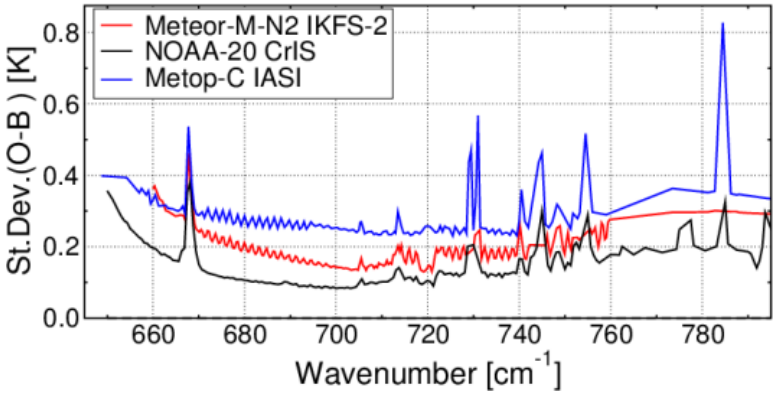


Meteor M-N2 series
N2
N2-1 failed,
N2-2 lost IKFS

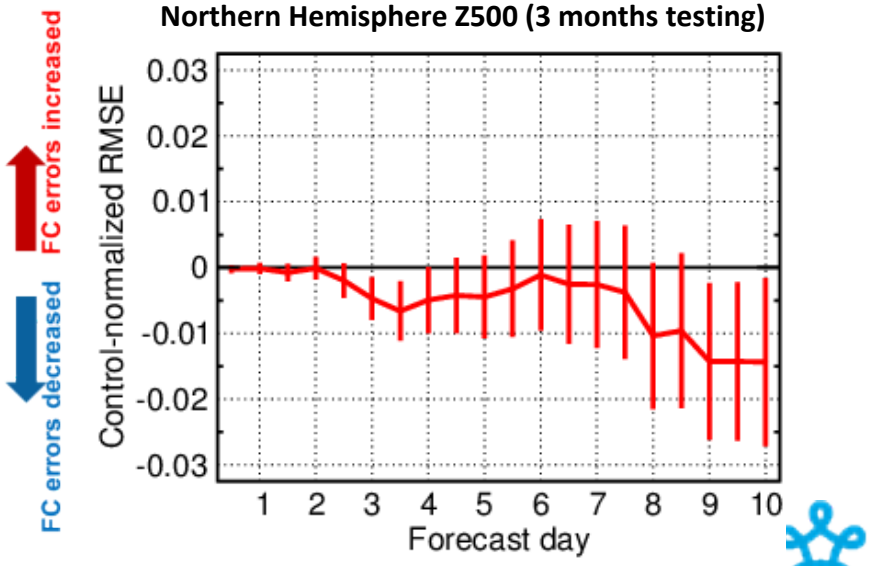
Hyperspectral IR data from Meteor M-N2 is excellent quality and already provides a measurable positive impact (with the prospect of future complementary orbital planes).

But operational exploitation at ECMWF is on hold until NRT data **delivery can be improved**

IKFS instrument noise performance is excellent



Northern Hemisphere Z500 (3 months testing)



Coordination Group for Meteorological Satellites

CGMS

2022

HSIR on GEO satellites

2022

HSIR on GEO satellites

- Simulated impact using LEO HSIR
- Impact of real GIIRS HSIR

2022

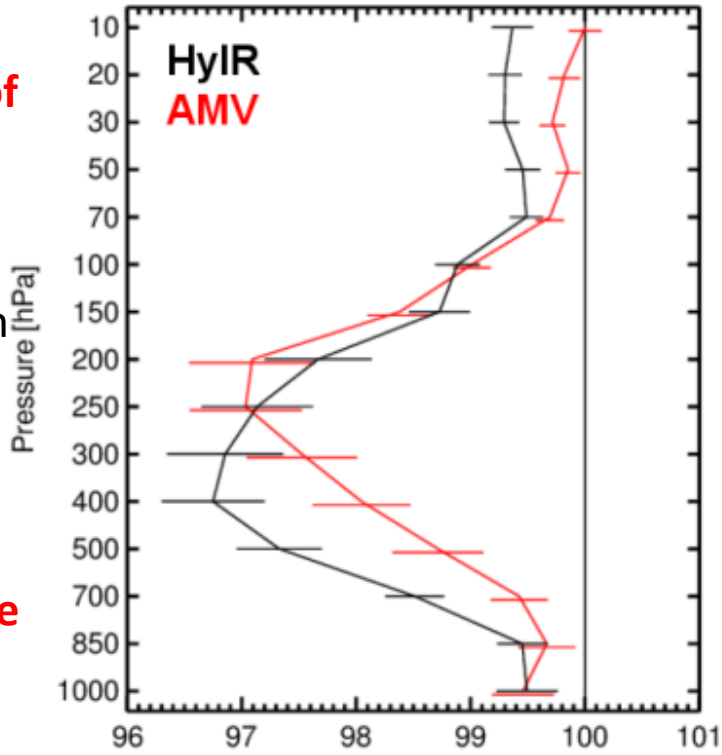
HSIR on GEO satellites

- Simulated impact using LEO HSIR
- Impact of real GIIRS HSIR

4D-Var humidity wind tracing from HSIR

- Current hyperspectral IR sounders onboard LEO spacecraft provide a **significant amount of wind information** to the ECMWF NWP system (more than the entire AMV network)
- Most of this this wind information comes from **4D-Var tracing** the movement of in atmospheric humidity structures in the radiance data
- This impact increases with **more frequent time sampling**

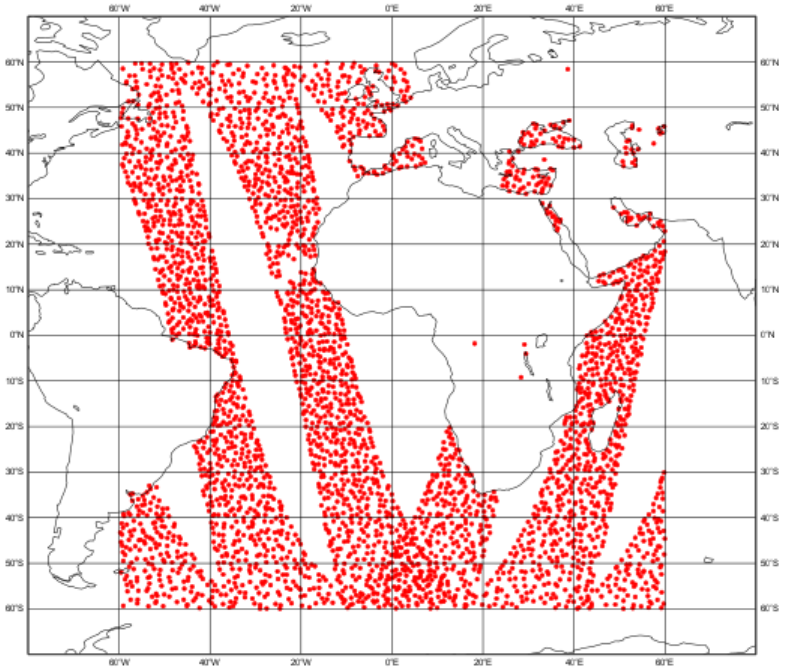
Global impact on wind forecasts verified by comparison radiosonde network



Coordination Group for Meteorological Satellites

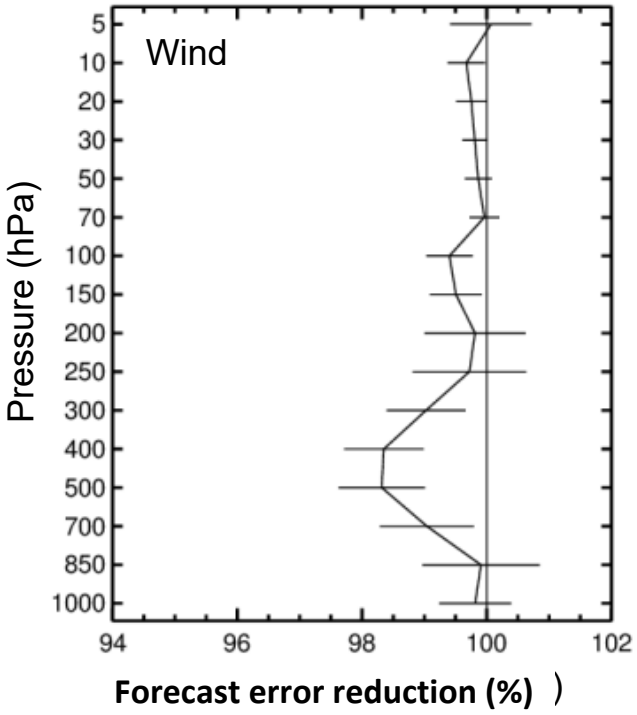
CGMS

HSIR impact increases with time sampling



Metop-A

CTL: Conv + AMSU-A
EXP: CTL + Metop-A IASI

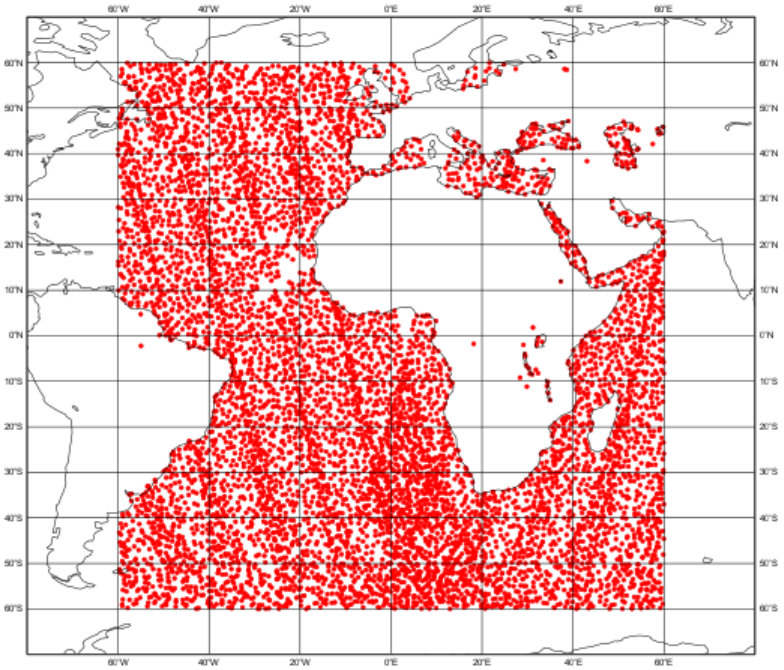


Kirsti Salonen

Coordination Group for Meteorological Satellites

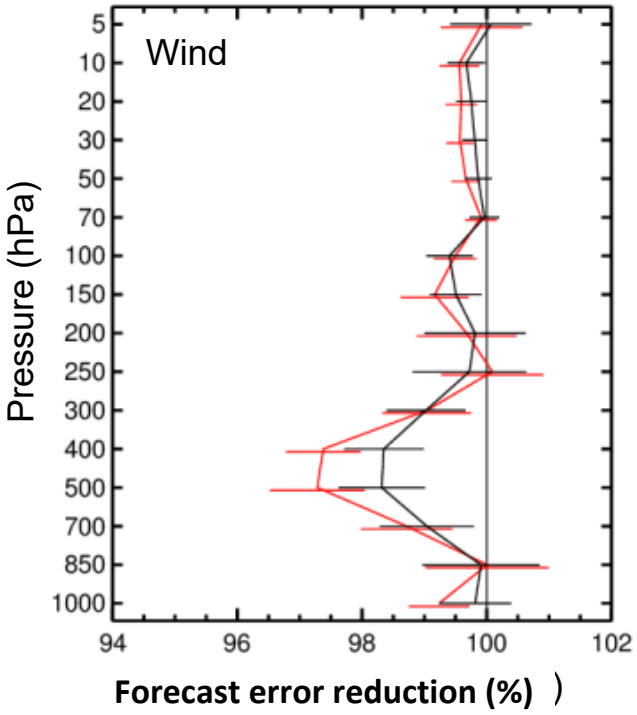
CGMS

HSIR impact increases with time sampling



Metop-A Metop-B

CTL: Conv + AMSU-A
EXP: CTL + 2 IASI

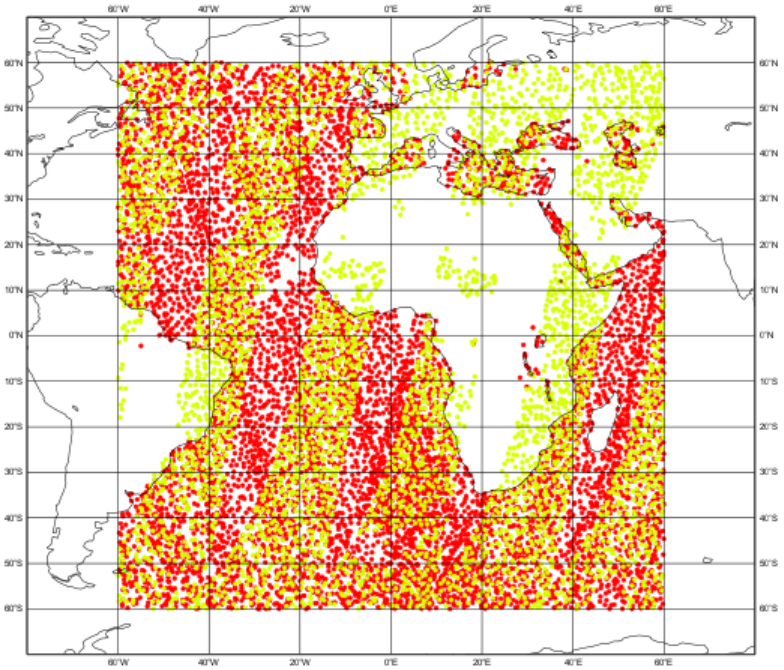


Kirsti Salonen

Coordination Group for Meteorological Satellites

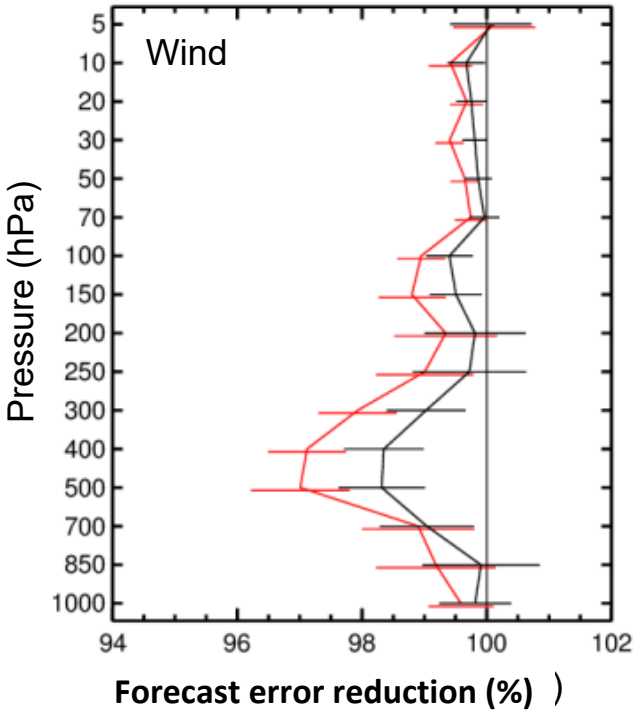
CGMS

HSIR impact increases with time sampling



Metop-A Metop-B CrIS

CTL: Conv + AMSU-A
EXP: CTL + 2 IASI + CrIS

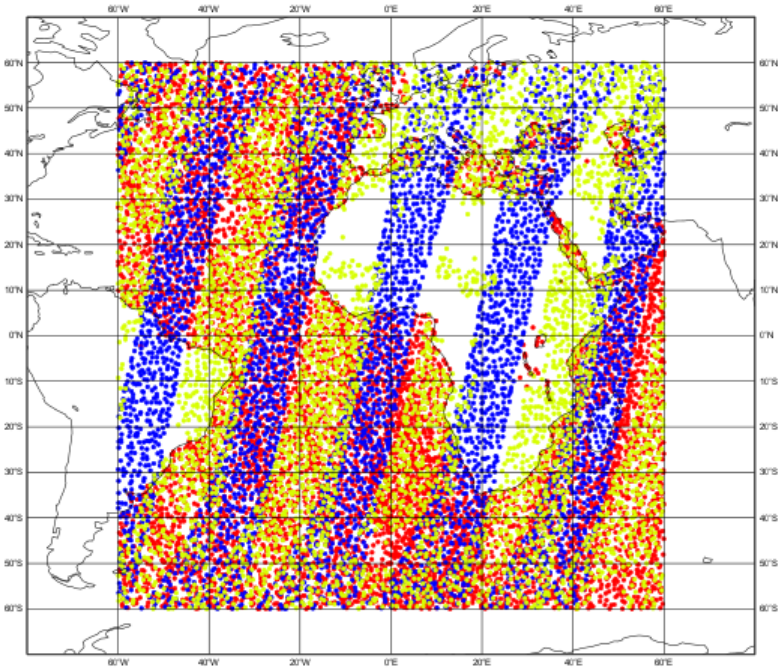


Kirsti Salonen

Coordination Group for Meteorological Satellites

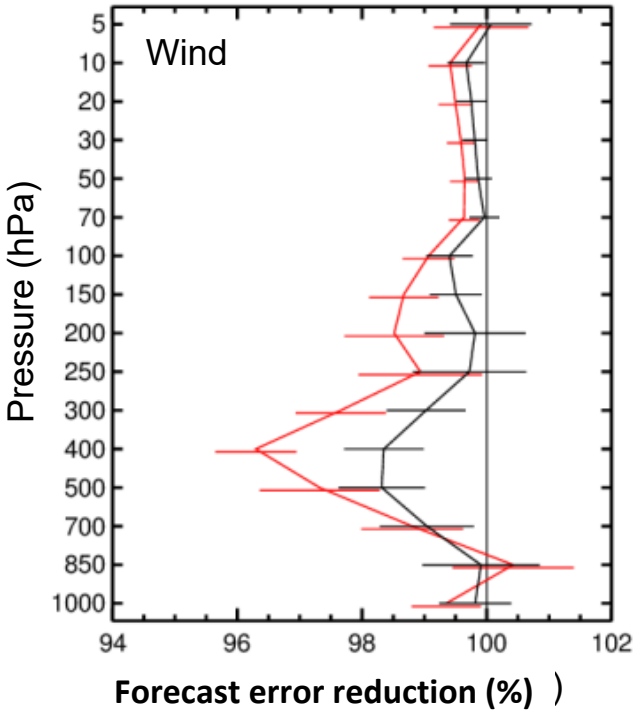
CGMS

HSIR impact increases with time sampling



Metop-A Metop-B CrIS AIRS

CTL: Conv + AMSU-A
EXP: CTL + 2 IASI + CrIS + AIRS



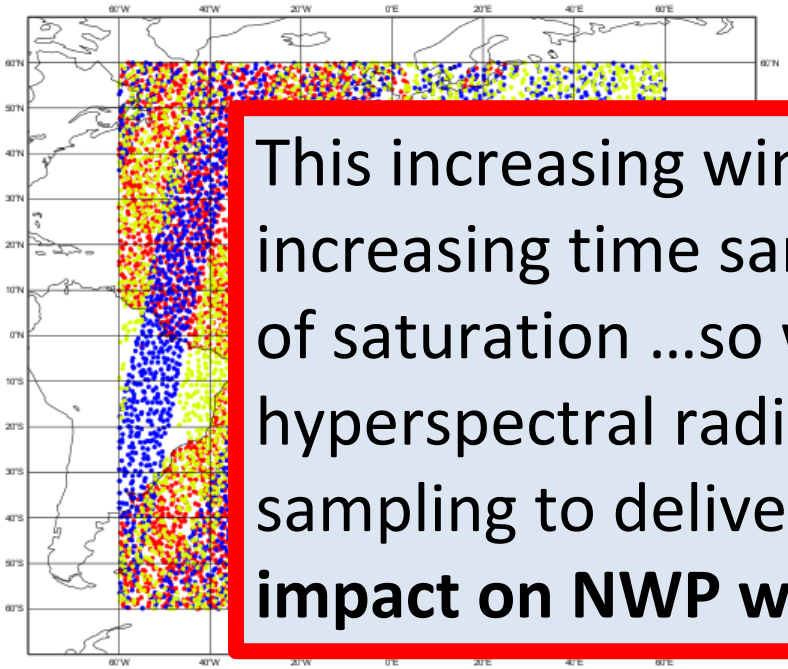
Kirsti Salonen

Coordination Group for Meteorological Satellites

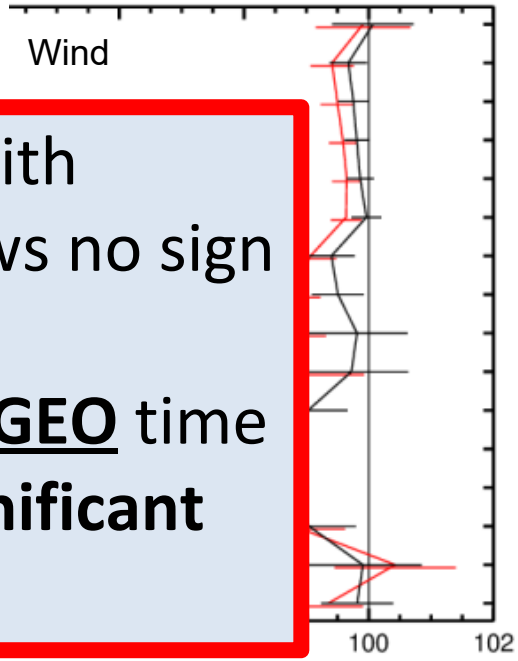
CGMS

We expect a very significant wind impact from GEO HSIR

CTL: Conv + AMSU-A
EXP: CTL + 2 IASI + CrIS + AIRS



Metop-A Metop-B CrIS AIRS



This increasing wind impact with increasing time sampling shows no sign of saturation …so we expect hyperspectral radiances with **GEO** time sampling to deliver a **very significant impact on NWP winds!**

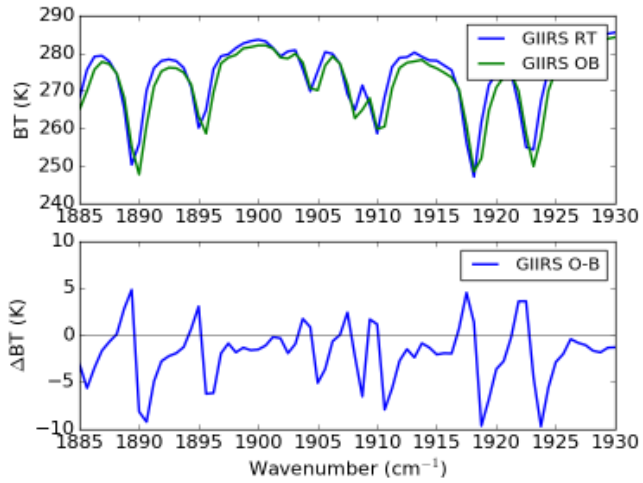
2022

HSIR on GEO satellites

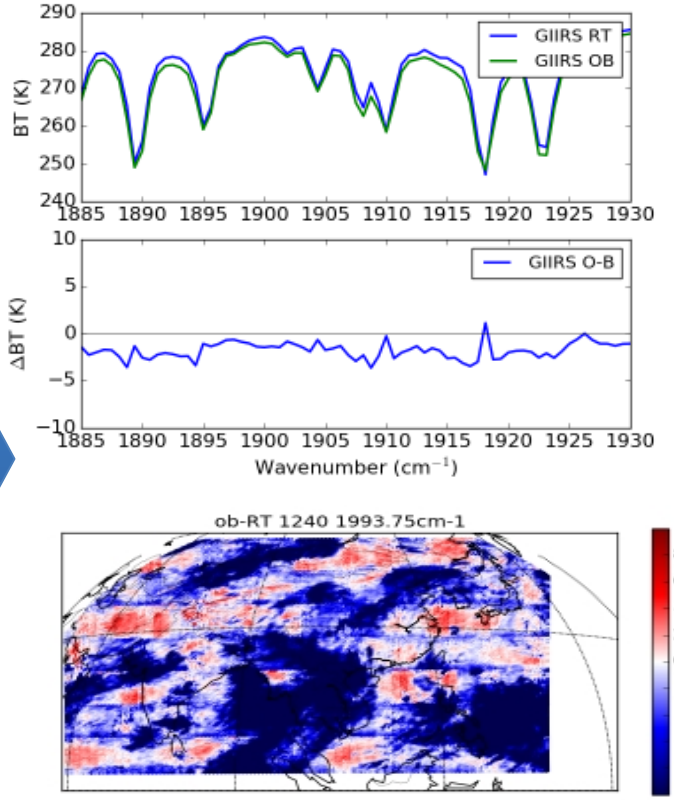
- Simulated impact using LEO HSIR
- Impact of real GIIRS HSIR

Significant improvements to FY-4A GIIRS

Before spectral correction (>5K biases)



After spectral correction



After spectral correction, the cloud-free regions have substantially reduced biases.

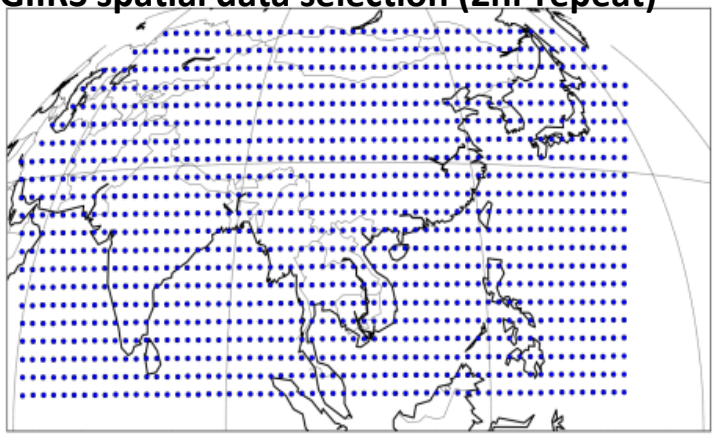
Chris Burrows – EUMETSAT Fellow

Coordination Group for Meteorological Satellites

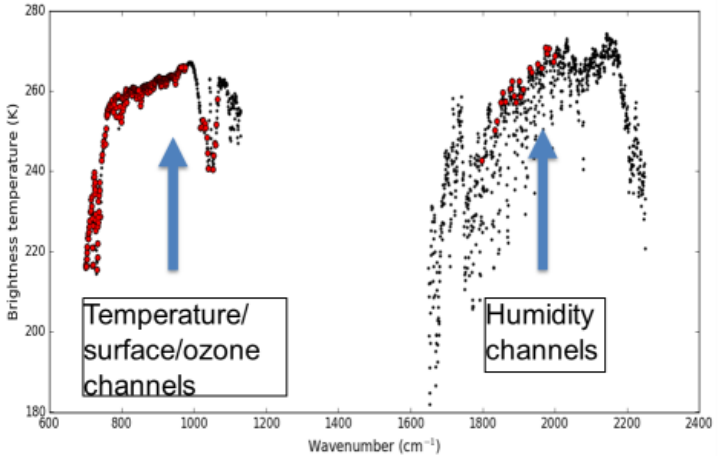
CGMS

Preliminary NWP impact of FY-4A GIIRS

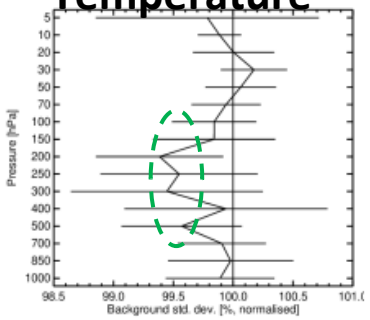
GIIRS spatial data selection (2hr repeat)



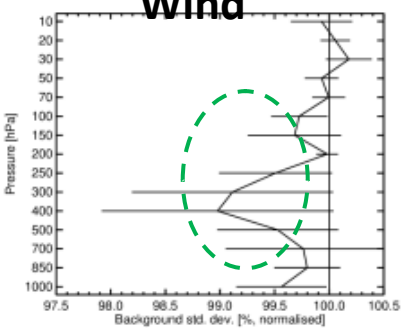
GIIRS spectral channel selection (red)



Temperature



Wind



The GIIRS hyperspectral GEO already showing a positive impact!

Chris Burrows – EUMETSAT Fellow

Coordination Group for Meteorological Satellites

CGMS

2022

HSIR Science Frontiers

Coordination Group for Meteorological Satellites

CGMS

2022

HSIR Science Frontiers

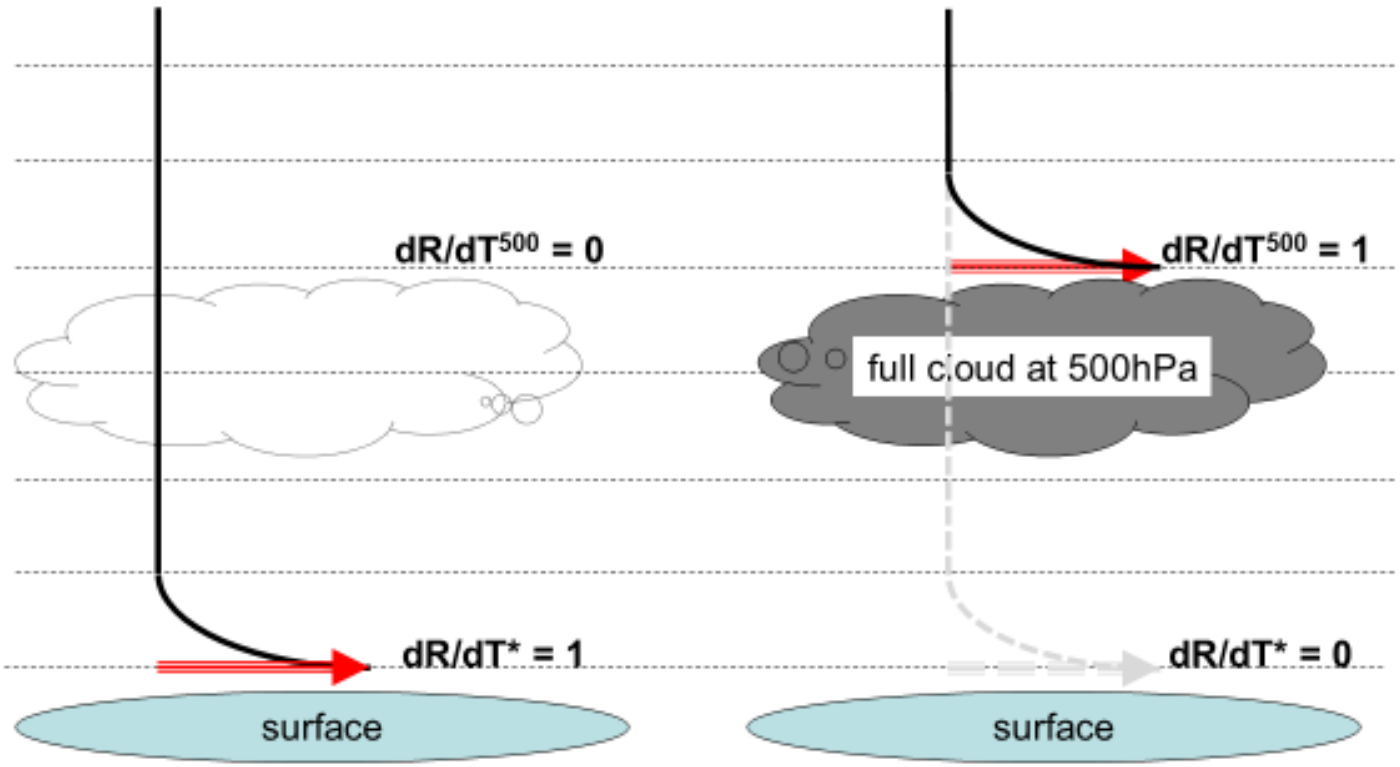
- Dealing with clouds (all sky…not yet!)
- Exploiting spectral resolution (PCA)
- Complex error modelling (correlations)
- Indirect NWP applications (SST and CAMS)

2022

HSIR Science Frontiers

- Dealing with clouds (all sky…not yet!)
- Exploiting spectral resolution (PCA)
- Complex error modelling (correlations)
- Indirect NWP applications (SST and CAMS)

Weighting Functions in clear and cloudy sky



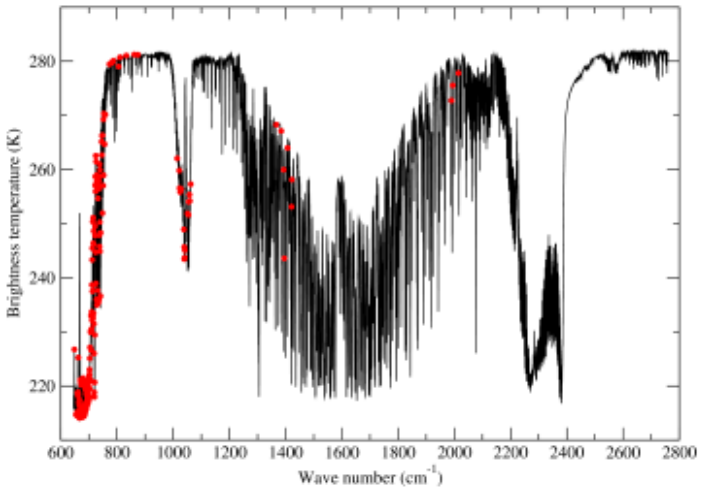
2022

HSIR Science Frontiers

- Dealing with clouds (all sky…not yet!)
- Exploiting spectral resolution (PCA)
- Complex error modelling (correlations)
- Indirect NWP applications (SST and CAMS)

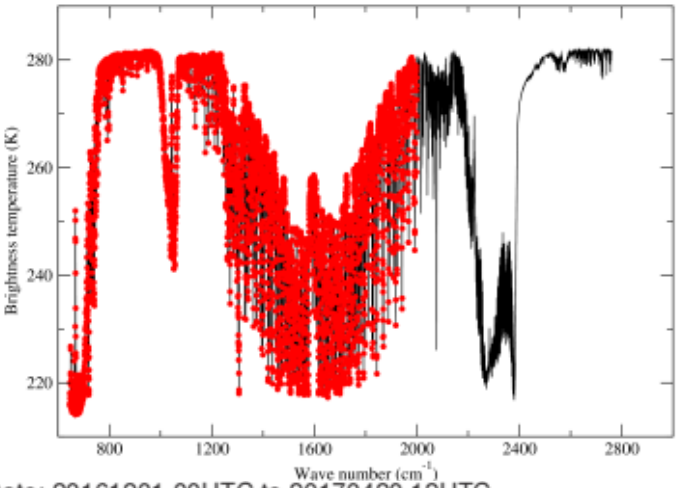
Exploit spectral (vertical) resolution with PCA

The 220 operational IASI channels



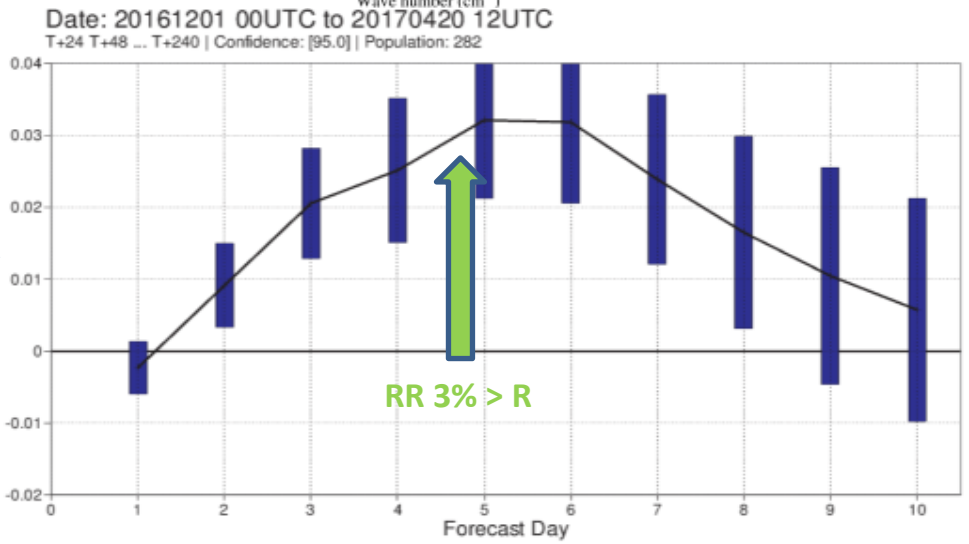
Assimilating 400 reconstructed radiances

Information of 5421 IASI channels



By assimilating the full IASI LW/MW spectrum via reconstructed radiances derived from truncated PCA we can extract even more forecast impact from these observations.

Latest results show **PCA/RR consistently outperforming** traditional radiance channels assimilation



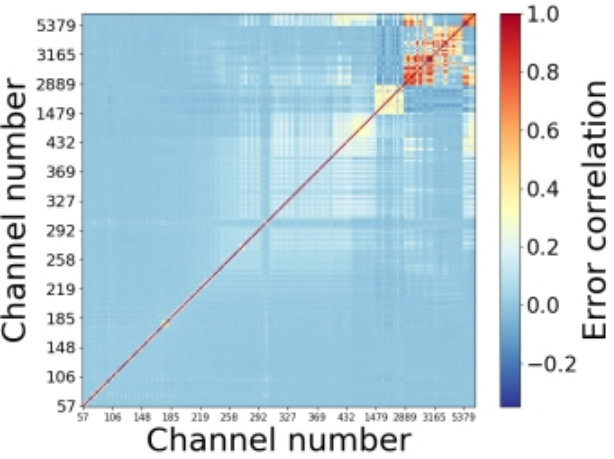
2022

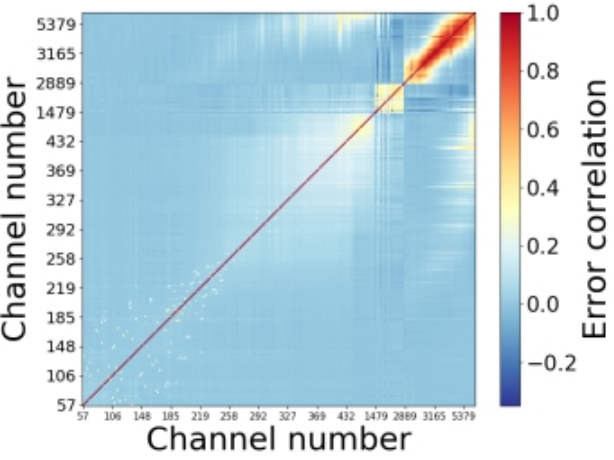
HSIR Science Frontiers

- Dealing with clouds (all sky…not yet!)
- Exploiting spectral resolution (PCA)
- Complex error modelling (correlations)
- Indirect NWP applications (SST and CAMS)

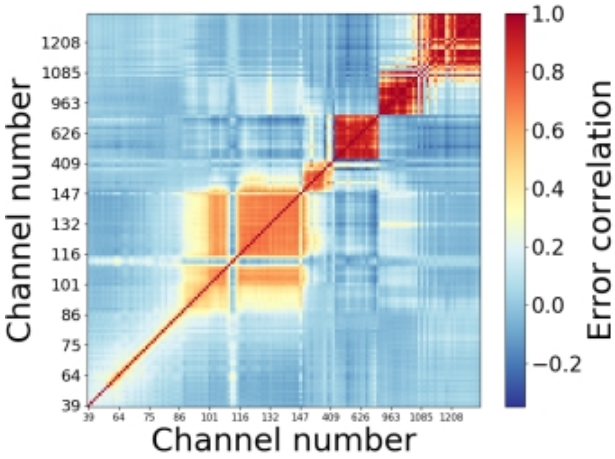
Complex error covariance modelling

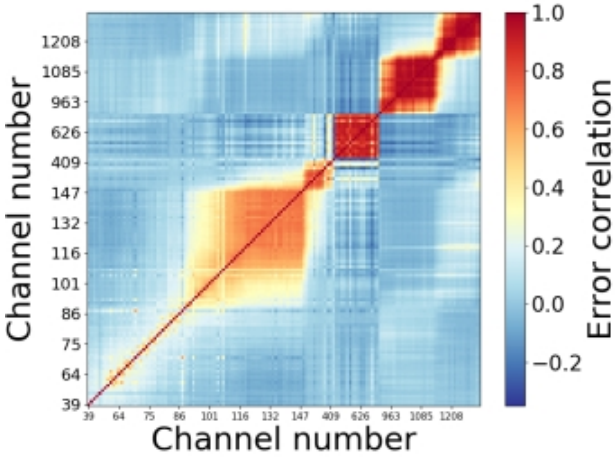
IASI



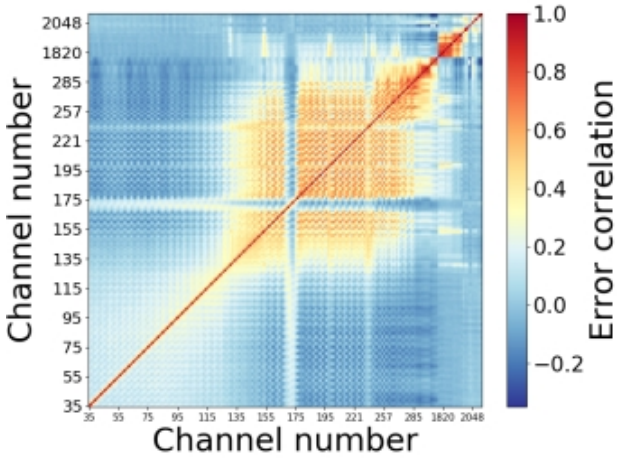


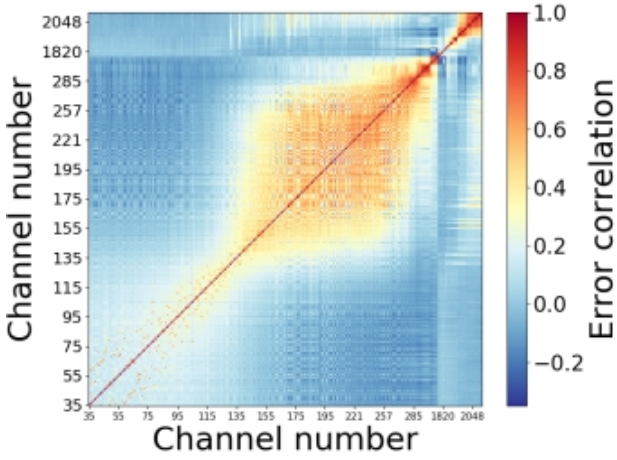
CrIS FSR





IKFS-2





2022

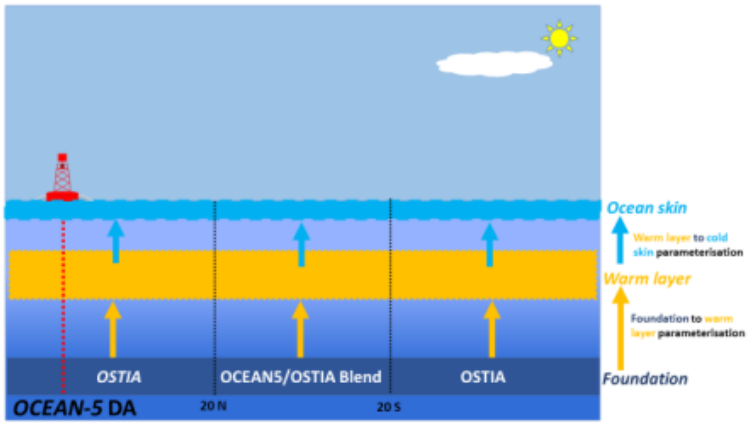
HSIR Science Frontiers

- Dealing with clouds (all sky…not yet!)
- Exploiting spectral resolution (PCA)
- Complex error modelling (correlations)
- Indirect NWP applications (SST and CAMS)

HSIR key to development of the ECMWF in-house SST

Current system:

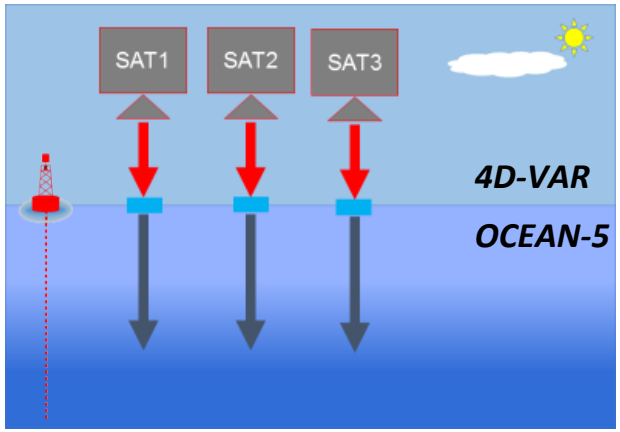
OCEAN-5 SST constrained by OSTIA from below



Satellite information introduced to OCEAN-5 via OSTIA…

Proposed future system:

OCEAN-5 SST constrained by 4D-Var SKT from above



Satellite information introduced to OCEAN-5 via 4D-Var…

Coordination Group for Meteorological Satellites

CGMS

Summary:

- LEO HSIR are the most influential sensors for NWP but impact limited by poor orbital coverage (satellites)
- Simulations suggest GEO HSIR wind impact will be substantial- early experience with GIIRS supports this
- There are still very significant science challenges limiting NWP impact of HSIR

NWP wish list for HSIR:

- **More** LEO HSIR sensors in **complementary** orbital planes
- Acceleration of plans to install HSIR sensors on **GEO satellites**
- Sensors with **smaller pixel sizes** (clouds / SST)
- Balanced **investment** in solving significant HSIR **science challenges**

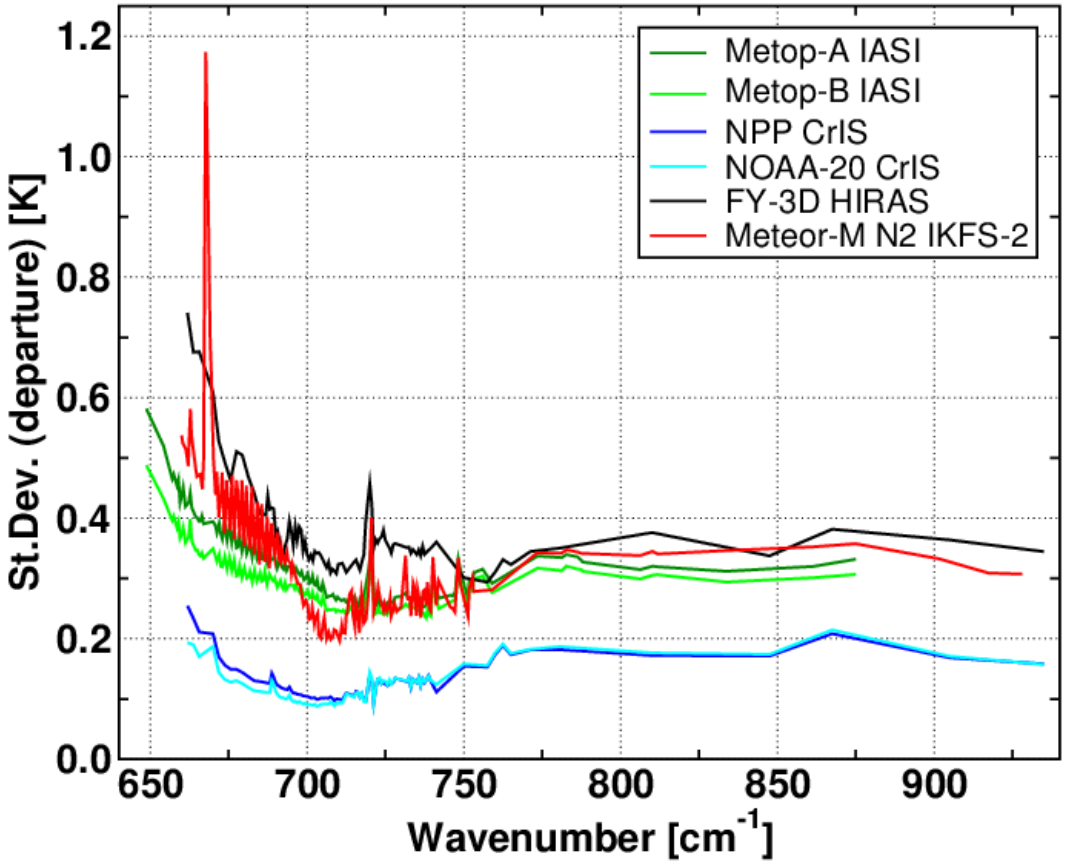
Key issues of relevance to CGMS/for consideration:

- More LEO HSIR sensors in complementary orbital planes
- Acceleration of plans to install HSIR sensors on GEO satellites
- Sensors with smaller pixel sizes (clouds / SST)
- Balanced investment in solving significant HSIR science challenges

2022

Spare slides

Hyper-spectral IR data from Russia and China



Evaluation of sample radiance data from IKFS (Meteor-M) and HIRAS (FY-3D) suggest that data quality is comparable to that from existing hyper-spectral IR sounders.

Coordination Group for Meteorological Satellites

CGMS