



Met Office

# IASI-NG Science Plan

Fiona Smith, Met Office, Exeter, UK

Cyril Crevoisier, LMD, Paris, France

Members of the ISSWG

15 April 2016



# Thank you to all contributors

Cyril Crevoisier, LMD (co-chair) Fiona Smith, Met Office (co-chair)

Claude Camy-Peyret (IPSL)  
Cathy Clerbaux (ULB/LATMOS/UMPC)  
Pierre-François Coheur (ULB)  
Andrew Collard (NESDIS)  
David Edwards (UCAR)  
Antonia Gambacorta (NOAA)  
Vincent Guidard (Météo-France)  
Nicole Jacquinet-Husson (LMD)  
Robert Knuteson (University of Wisconsin, Madison)  
Marco Matricardi (ECMWF)  
Tony McNally (ECMWF)  
Hank Revercomb (University of Wisconsin, Madison)  
Carmine Serio (University of Basilicata)  
Larrabee Strow (University of Maryland, Baltimore)  
Jonathan Taylor (Met Office)  
Dave Tobin (University of Wisconsin, Madison)  
Alexander Uspensky (SRC Planeta)  
Jérôme Vidot (Météo-France)

# The IASI-NG Science Plan (1)

- The purpose of the science plan is to
  - Allow us all to prepare for IASI-NG
  - Identify areas where significant effort is required to advance research in advance of launch
  - Guide EUMETSAT as to how data will be used
    - Implications for L1 products, data dissemination etc
  - Guide EUMETSAT on state-of-the-art methods for generating L2 products

## The IASI-NG Science Plan (2)

- Unlike the IASI Science Plan, the aim is for this plan to be live
- We will review it every couple of years
- The first part of the document will act as a reference on the instrument itself
- The second part is the science plan describing use of the data and derivation of products
- The third part discusses the requirements for calibration, validation and verification of data and products
  - We are currently preparing the Cal/Val section





Met Office

<b>1</b>	<b>Background to the IASI-NG science plan</b>	<b>8</b>
1.1	NWP, atmospheric composition and climate	8
1.2	The structure of this document	8
<b>I</b>	<b>The IASI-NG mission and instrument</b>	<b>10</b>
<b>2</b>	<b>IASI-NG mission rationale and objectives</b>	<b>11</b>
2.1	The EPS-SG Programme	11
2.2	IASI-NG Scientific Objectives	12
<b>3</b>	<b>IASI-NG instrument design</b>	<b>15</b>
3.1	Instrument Overview	15
3.2	Interferometer overview	19
3.3	Detection chain	22
3.3.1	Overview	22
3.3.2	B1 Chain	23
3.3.3	B2 to B4 Chain	23
3.4	Instrument budgets	24
3.5	Main instrument characteristics and comparison with IASI	24
<b>4</b>	<b>Processing from interferogram to Level 1c</b>	<b>26</b>
4.1	Space Segment	26
4.1.1	Objectives and design drivers	26
4.1.2	Sounder interferogram data processing	27
4.1.2.1	Processing presentation and logic	27
4.1.2.2	Processing overview	28
4.1.3	Image data processing	31
4.1.4	Sampling and metrology data processing	31
4.1.4.1	Governing principles	31
4.2	Ground segment	32
4.2.1	Objectives and design drivers	32
4.2.2	Science data processing	32
4.2.2.1	Decompression	32
4.2.2.2	Fast Fourier Transform	32
4.2.2.3	NZPD detection	32
4.2.2.4	Spectral calibration	33
4.2.2.5	Radiometric calibration	35
4.2.2.6	Band merging	35
4.2.2.7	Compression	35
4.2.3	ISRF Estimation Model	35
4.2.3.1	ISRF Model	36
4.2.3.2	Absolute Spectral Shift Estimation	39
4.2.4	Image data processing	40

<b>5</b>	<b>Construction of L1c data files and their dissemination</b>	<b>42</b>
5.1	Scene processing	42
5.1.1	Quality Control Flags	42
5.1.2	Sub-pixel heterogeneity	42
5.1.3	Cloud/Aerosol Detection	43
5.1.4	Land/Sea/Ice mask	43
5.2	Dissemination of L1c data files	44
5.2.1	Compression	44
5.2.1.1	Principal Component compression	44
5.2.1.2	BUFR compression	45
5.2.2	Considerations for direct readout	45
5.2.3	Provision of adequate meta-data including noise specifications	45
5.3	Reprocessing: storage of metadata	45
5.4	Remapping	45
5.5	Information channels	46
<b>II</b>	<b>Science Plan</b>	<b>47</b>
<b>6</b>	<b>Underlying physics: Spectroscopy and Radiative Transfer</b>	<b>48</b>
6.1	Radiative transfer modelling for IASI-NG	48
6.1.1	Line-by-line models	48
6.1.2	Pseudo line-by-line models	53
6.1.3	Narrow-band fast RT models on fixed pressure levels or on levels of fixed absorber amount	54
6.1.4	Library look-up based fast RT models	55
6.1.5	Neural network based fast RT models	55
6.1.6	Fast RT Models based on optimal sampling of absorption coefficients	55
6.1.7	Principal Component Based Radiative Transfer Models	56
6.1.8	Priorities for Future Research	57
6.2	Scattering models	57
6.2.1	Priorities for Future Research	58
6.3	Surface models	59
6.3.1	Surface radiation models	59
6.3.2	Surface emissivity models	60
6.3.3	Priorities for Future Research	61
6.4	Models for the microphysical and optical properties of scattering particles	62
6.4.1	Ice clouds	62
6.4.2	Aerosols	63
6.4.3	Priorities for Future Research	63
6.5	Input data to radiative transfer models	64
6.5.1	Spectroscopic data	64
6.5.1.1	Spectroscopic parameters	64
6.5.1.2	Spectroscopic databases	65
6.5.1.3	The GEISA database	66
6.5.1.4	The HITRAN database	68
6.5.1.5	Priorities for Future Research	69
6.5.2	Optical properties of Cloud and aerosols	70



Met Office

6.5.2.1	Priorities for Future Research	71
6.5.3	Surface emissivity data	71
6.5.4	Datasets of atmospheric profiles	72
6.5.5	Priorities for Future Research	75
6.6	Radiative transfer model validation	75
6.6.1	Priorities for Future Research	77
<b>7</b>	<b>Retrieval of Geophysical Parameters</b>	<b>78</b>
7.1	Retrieval Theory	78
7.1.1	Physical retrieval schemes	78
7.1.1.1	Variational Analysis	79
7.1.1.2	Optimal Estimation and Twomey-Tikhonov approaches	80
7.1.1.3	Generalized noise covariance matrix	81
7.1.1.4	Direct Inversion	82
7.1.2	Parametric approaches	82
7.1.2.1	Regression and Look-up Tables	82
7.1.2.2	Neural Networks	83
7.2	Input data	83
7.2.1	Unprocessed L1c radiance data	84
7.2.1.1	Reducing the vector length via channel selection	84
7.2.1.2	Reducing the vector length via microwindows	85
7.2.2	Transformed datasets	85
7.2.2.1	Principal component scores	85
7.2.3	Interferogram transforms	89
7.2.4	Reconstructed Radiances	91
7.2.5	Superchannels	92
7.3	Specific considerations for retrieval schemes	92
7.3.1	Clouds and aerosols	92
7.3.1.1	Cloud and aerosol detection	92
7.3.1.2	Cloud clearing	93
7.3.2	Computation and correction of radiative biases	93
7.3.3	A priori error characteristics	94
7.3.4	Observation error characteristics	95
7.4	Retrieval of atmospheric and surface properties	96
7.4.1	Thermodynamic Variables	96
7.4.1.1	Temperature and water vapour profiles	96
7.4.1.2	Surface properties	96
7.4.2	Clouds and Aerosols	97
7.4.2.1	Cloud properties	97
7.4.2.2	Aerosols	97
7.4.3	Atmospheric composition	99
7.4.3.1	Ozone (O <sub>3</sub> )	101
7.4.3.2	Carbon Monoxide (CO)	103
7.4.3.3	Methane (CH <sub>4</sub> )	105
7.4.3.4	Methanol (CH <sub>3</sub> OH)	105
7.4.3.5	Nitric Acid (HNO <sub>3</sub> )	105
7.4.3.6	Sulphur Dioxide (SO <sub>2</sub> )	105
7.4.3.7	Ammonia (NH <sub>3</sub> )	106





Met Office

7.5	Synergistic retrievals and applications	106
7.5.1	Temperature and water vapour profiles	106
7.5.2	Volcanic eruptions	106
7.5.3	Wildfires	107
7.5.4	Sandstorms	107
7.5.5	Extreme urban air pollution	107
7.5.6	Climate	108
<b>8</b>	<b>Assimilation of IASI Level 1 and 2 data</b>	<b>109</b>
8.1	Input data	109
8.2	Dimensionality reduction	110
8.2.1	Spectral compression	110
8.2.1.1	Raw radiances	110
8.2.1.2	PC scores	111
8.2.1.3	Reconstructed radiances	112
8.2.1.4	L2 retrievals	112
8.2.2	Observation selection and thinning	114
8.3	Forward model operator	114
8.4	Observation errors	115
8.5	Bins correction	116
8.6	Background errors	118
8.7	Priorities for Research	118
<b>9</b>	<b>Applications of IASI-NG data and products</b>	<b>119</b>
9.1	Numerical Weather Prediction	119
9.1.1	Contamination by unmodelled species	123
9.1.2	The assimilation system	123
9.1.3	Clouds	124
9.1.3.1	Cloudy PC scores	125
9.1.4	Additional considerations	125
9.1.5	Priorities for Research	126
9.2	Detecting climate change and variability	126
9.2.1	Context	126
9.2.2	Establishing long time-series	127
9.2.3	Long-term monitoring of essential climate variables	128
9.2.3.1	Temperature profiles	128
9.2.3.2	Water vapour profiles	129
9.2.3.3	Ozone	131
9.2.3.4	UTLS	131
9.2.3.5	Clouds	132
9.2.3.6	Aerosols	133
9.2.3.7	Greenhouse gases: CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	133
9.2.3.8	Surface	135
9.2.3.9	Earth Radiation budget	137
9.2.3.10	Synergistic use of IASI-NG	138
9.3	Air Quality Events and Environmental Monitoring	139
9.3.1	Volcanic eruptions	140
9.3.2	Wildfires	144





**Met Office**

9.3.3	Sandstorms . . . . .	145
9.3.4	Extreme urban air pollution . . . . .	148
9.3.5	Industrial/nuclear accidents . . . . .	149
9.4	Priorities for Research . . . . .	150
9.5	Process Studies . . . . .	150
9.5.1	Atmospheric Processes . . . . .	150
9.5.2	Processes at the land surface-atmosphere interface . . . . .	151
9.5.2.1	Soil moisture daily cycle and its impact over surface emissivity . . . . .	151
9.5.3	Identifying climate processes and trends coupling observations and models . . . . .	152
9.6	Assessing the impact of IASI-NG . . . . .	153
9.6.1	Assessment of impact in NWP . . . . .	153



**Met Office**

<b>III Instrument Characterisation, Calibration and Validation</b>	<b>155</b>
<b>10 User requirements for instrument characterisation</b>	<b>157</b>
10.1 Random noise on the measurements	157
10.1.1 Causes	157
10.1.2 Assessment	157
10.2 Pseudo-random noise on the measurements	157
10.2.1 Causes	157
10.2.2 Assessment	157
10.3 Measurement bias	157
10.3.1 Causes	157
10.3.2 Assessment	157
<b>11 Operational Calibration and Validation activities</b>	<b>158</b>
11.1 Pre-launch activities	158
11.1.1 Level 1	158
11.1.2 Level 2	158
11.2 Commissioning phase	158
11.2.1 Level 1	158
11.2.2 Level 2	158
11.3 Monitoring of instrument performance	158
11.3.1 Level 1	158
11.3.2 Level 2	158
<b>12 User contributions to calibration and validation activities</b>	<b>159</b>
12.0.3 Synergistic Cal/Val activities	159
12.0.4 Validation of Level 1 Products	159
12.0.4.1 Instrument intercomparison	159
12.0.4.2 Comparison against NWP	160
12.0.4.3 Comparison against radiosondes	160
12.0.4.4 Specific campaigns (aircraft, balloon, surface)	161
12.0.4.5 Level 1 reprocessing	161
12.0.5 Validation of Level 2 Products	161
12.0.5.1 Comparison against NWP/MACC	161
12.0.6 Validation campaigns (aircraft, balloon, surface)	161
12.0.7 Intercomparison with other Level 2 products	161



**Met Office**

12.0.8 Interecomparison with other sources e.g. ISCPP, GEWEX, ESA-CCI . . . .	161
<b>13 The constraints for reliable validation studies</b>	<b>162</b>
13.1 Datasets available for Cal/Val activities . . . . .	162
<b>A IASI-NG specification from the EPS-SG end-user requirements document</b>	<b>163</b>
A.1 Data Acquisition Requirements . . . . .	163
A.2 Quality Criteria . . . . .	163
A.3 Spectral Requirements . . . . .	163
A.4 IAS Level 1 Radiometric Requirements . . . . .	165
A.5 IAS Level 1 Geometric Requirements . . . . .	166
<b>B Members of the ISSWG</b>	<b>168</b>
<b>C Other contributing authors</b>	<b>169</b>
<b>D Acronyms List</b>	<b>170</b>



# ISSWG Meeting on Cal/Val

## *Validation of IASI & IASI-NG L1 & L2 products: current status and identification of potential gaps and limitations, areas to be studied or developed*

Evaluation of L1c products through NWP	Roger Saunders
Evaluation of L2 products through assimilation in numerical model: Weather & AC	Tony McNally (+Richard Engelen)
Intercomparison of satellite products and GSICS activities for L1c monitoring	Denis Jouglet + Dorothée Coppens
Review of experience with balloon campaigns	Claude Camy-Peyret
Airborne campaigns: current status and future plans at MetOffice	Jon Taylor
Experience from the qualification of IASI L2 atmospheric parameters	Thomas August
Validation of IASI T,q,O3 and trace gases products	Carmine Serio
Validating cloud products (coverage, height, phase, LWP)	Cyril Crevoisier
The Role of NWP in Cal/Val: The GAIA-CLIM project	Bill Bell
Ground-based measurements for AC, advantages & limitation, networks & methodology	TBC
Satellite intercomparisons and <i>in situ</i> measurements for AC validation	Cathy Clerbaux (TBC)
Ground-based measurements for T,q profiles and TCWV	Bob Knuteson (remote)
Lessons learnt from CrIS products commissioning	Antonia (remote, TBC)
Experience and references for SST, LST, IST & LSEmissivity validation	Thomas August
Validating aerosol products	Pierre Coheur + Cyril Crevoisier (TE)
Towards using IASI-NG as calibration reference (HAS TO STAY ON FRIDAY MORNING)	John Remedios
Using in-situ T,q measurements: status, limitations & guidelines	Xavier Calbet (remote)
Laser heterodyne radiometer	Damien Weidmann (RAL)