# Atmospheric Motion Vector generation from MTG-IRS

Régis Borde, Olivier Hautecoeur (EUMETSAT)
Patrick Heas (INRIA)

# Outline

- General context
  - Horizontal wind product user requirements
  - Common AMVs derivation at EUMETSAT
  - Current AMVs limitations
- Wind profiles extraction from IR sounders
  - Background and status of the art
  - 3D winds derivation at EUMETSAT (IASI)
- Perspectives for MTG-IRS

# Why do we care about AMVs ?

OSCAR

Observing Systems Capability Analysis and Review Tool

OSCAR/Space v2.0 released

Variable: Wind (horizontal)

## Main Requirements for winds

- Main applications:
  - ✓ Global NWP, High Res NWP, Nowcasting.
  - ✓ Aeronautical Meteorology.
  - ✓ Climate.

Needs important and continous operation activities

- Timeliness and Observation cycle:
  - ✓ From few minutes (Nowcasting) to max 6 hours (Global NWP)

- Requested coverage:
  - ✓ Global coverage

Needs very High level of coordination: CGMS, and IWWG

# EUMETSAT Atmospheric Motion Vectors

- ✓ Extracted from Geostationary satellites (MSG) and Low orbit satellites (Metop AVHRR) following clouds or WV features in consecutives images

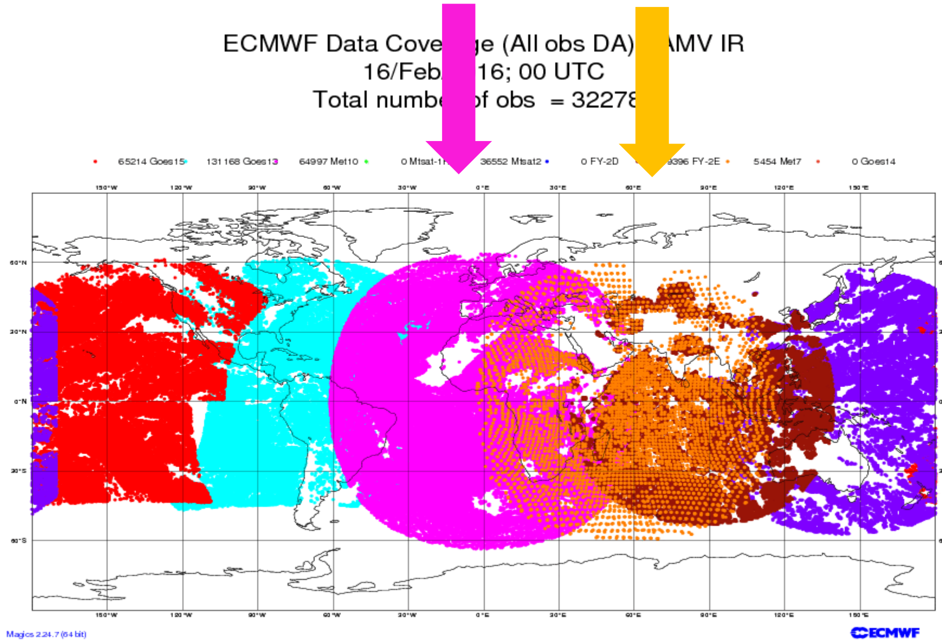
- ✓ Using the channels
  - VIS0.8 during daytime, HRV during daytime for low clouds
  - IR10.8, WV6.2. WV7.3

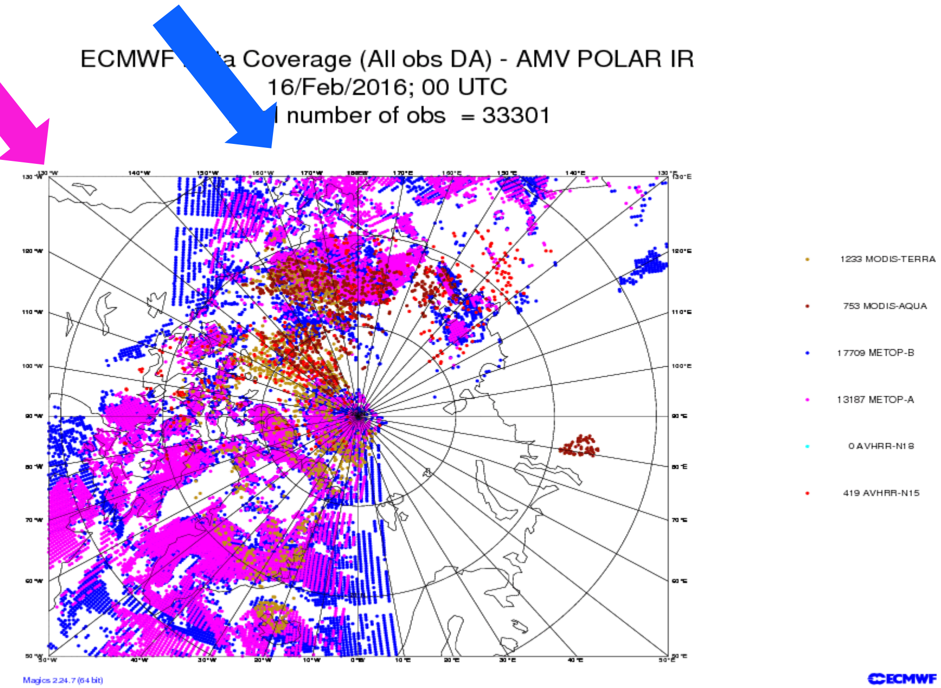
- ✓ Wind product consists of
  - Speed, Direction, Altitude
  - Quality indicator

- ✓ Verification against reliable insitu measurements (Radiosonde, aircraft)

# Current EUMETSAT contribution to AMV production

## Met10, Met7, Metop A, Metop B, + Global AVHRR



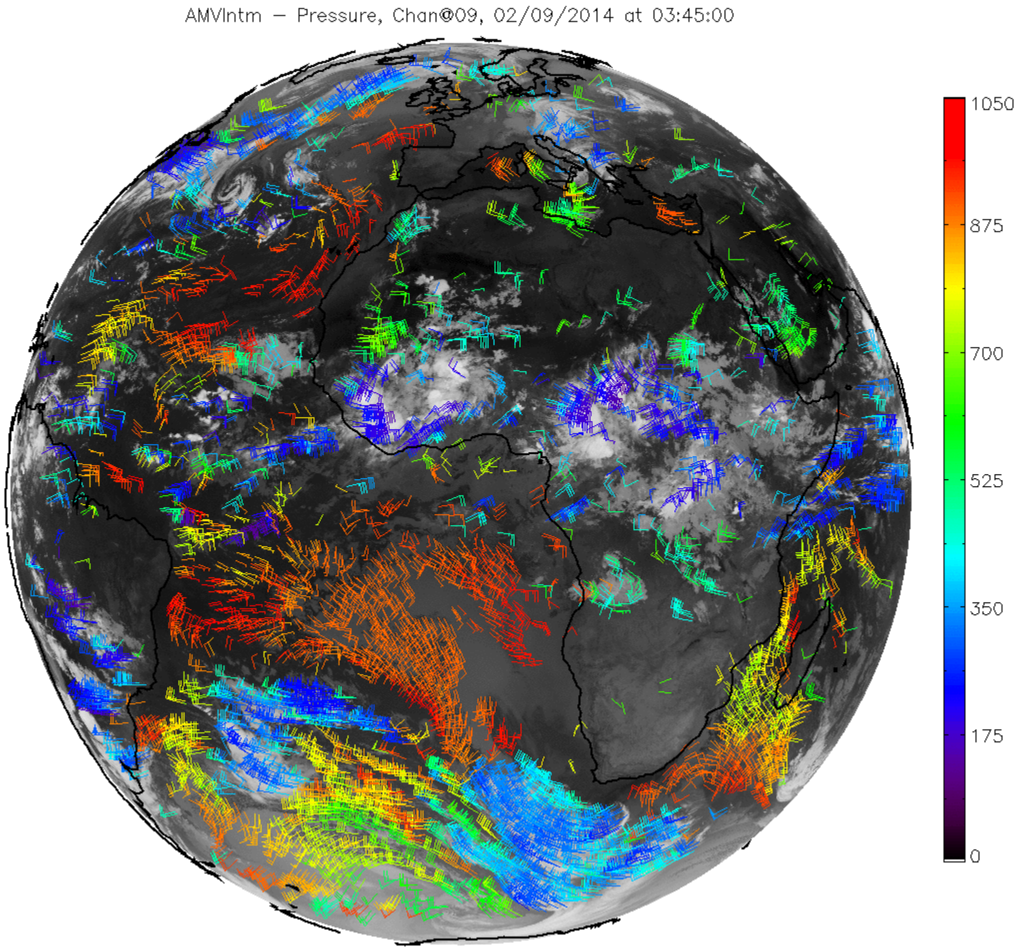




**AMVs assimilated in ECMWF forecast model,16 Feb 2016 at 00:00 UTC.**

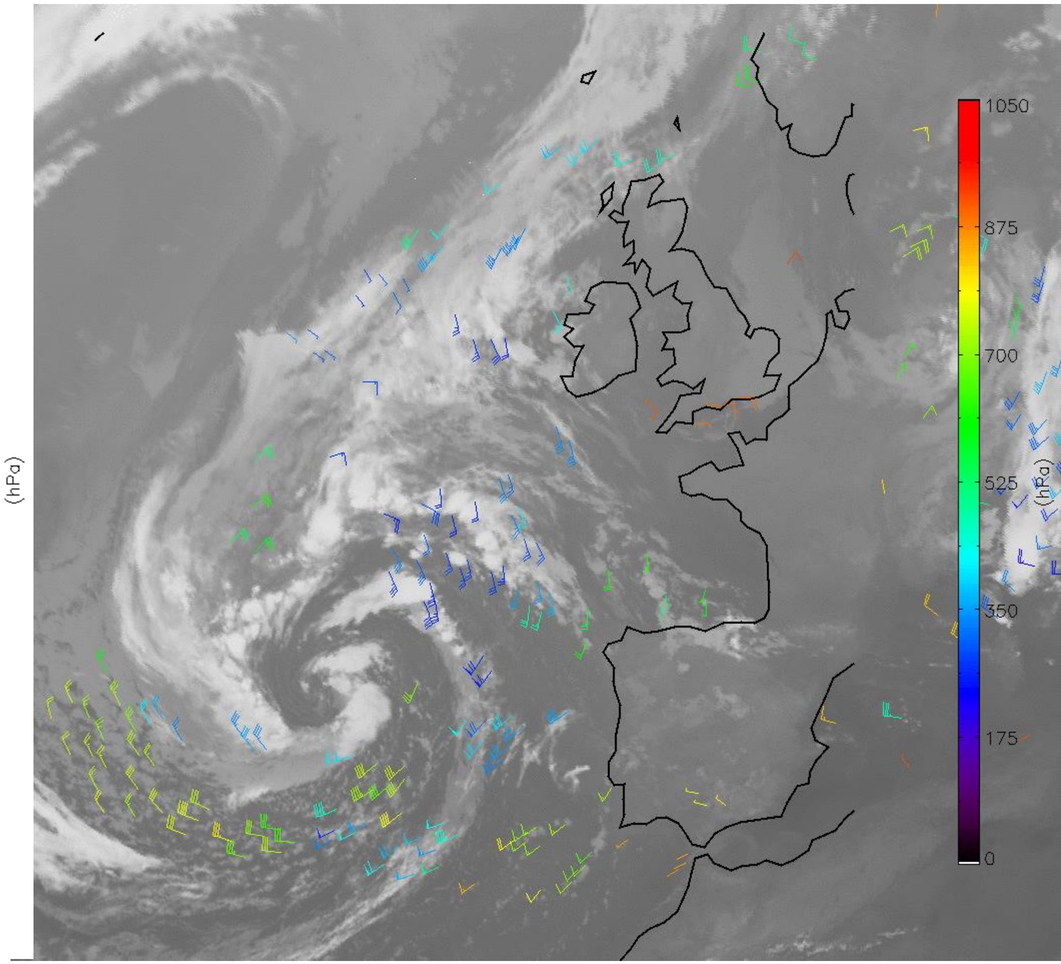
**AMVs are the only observation type to provide good coverage of upper tropospheric wind data over large oceans areas and polar regions.**

# MSG– AMVs Examples

**FES, 02/09/2014, 20:45 – 03/09/2014, 19:45**



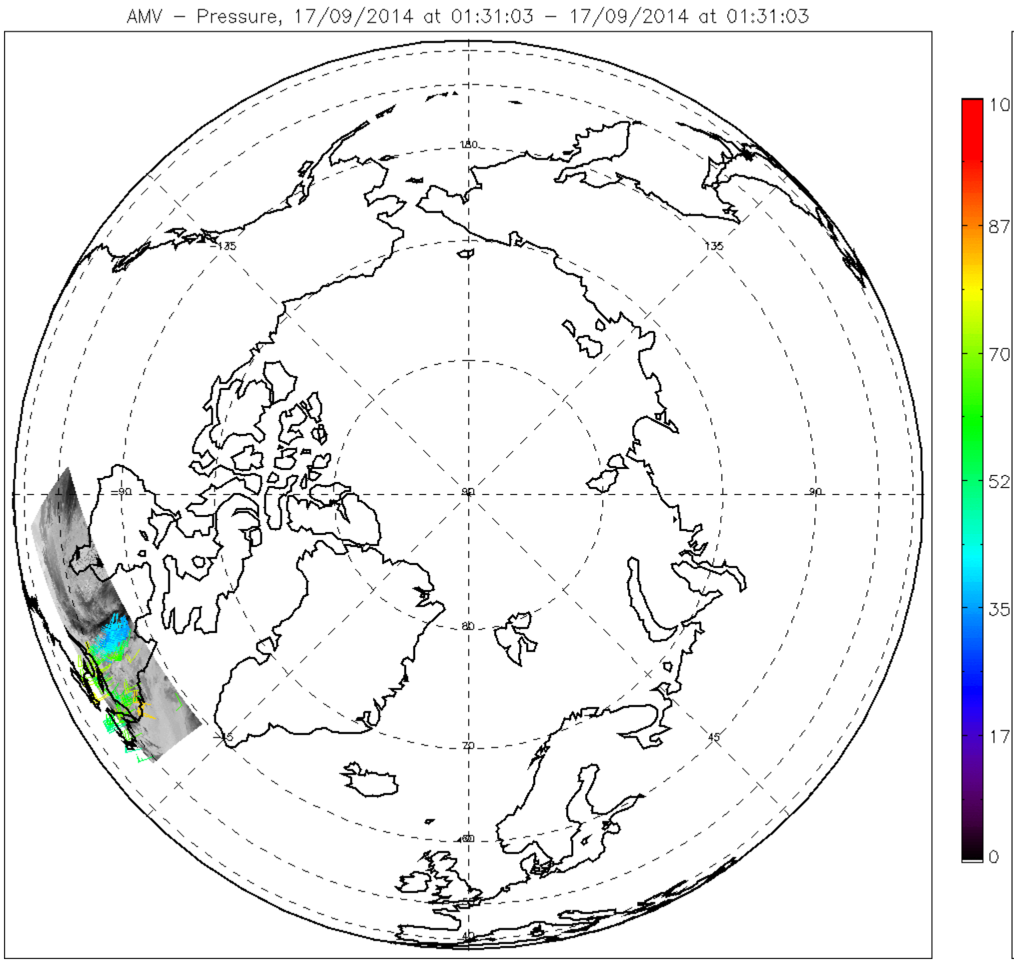

**RSS, 11/09/2014, 6:30 – 12/09/2014, 5:30**



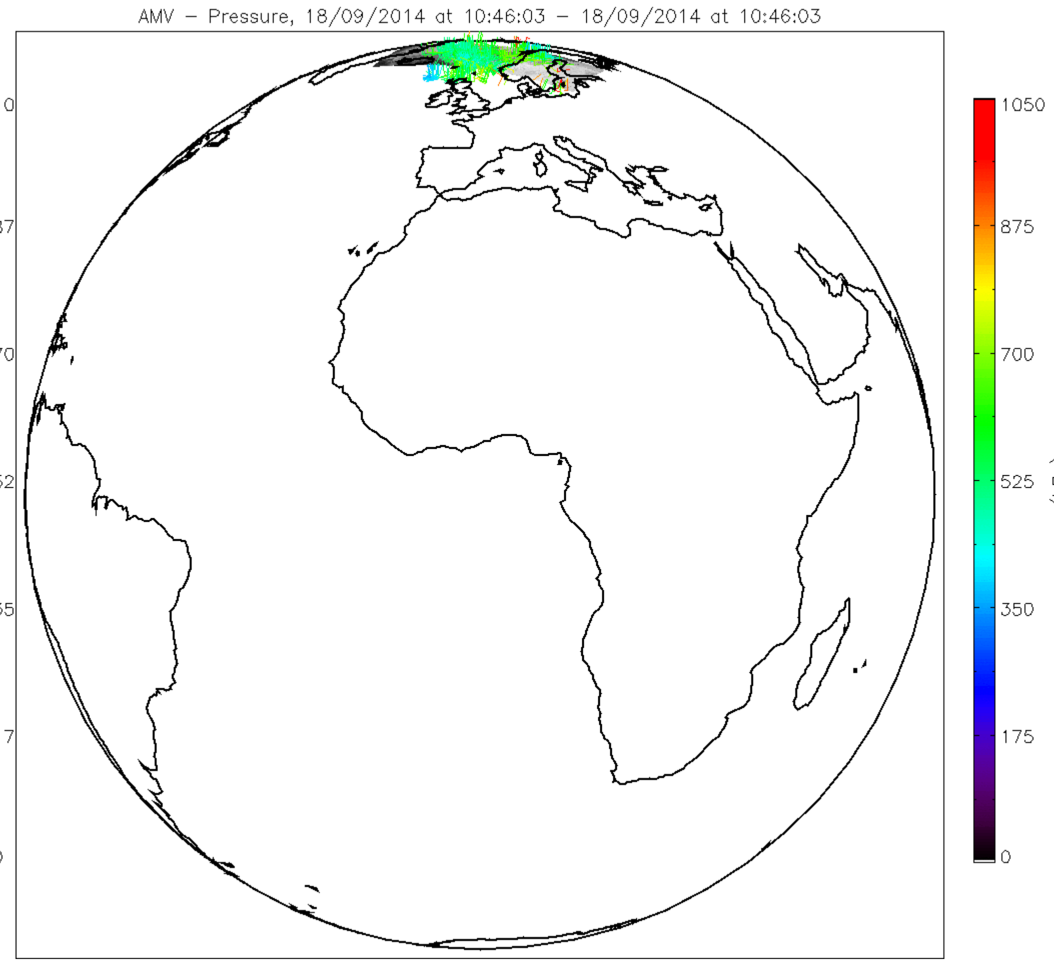

Borde, R., M. Doutriaux-Boucher, G. Dew, M. Carranza, 2014: A Direct Link between Feature Tracking and Height Assignment of Operational EUMETSAT Atmospheric Motion Vectors. J. Atmos. Oceanic Technol., 31, 33–46. doi: ***http://dx.doi.org/10.1175/JTECH-D-13-00126.1***

# AVHRR winds Examples

## Single Metop polar, 17/09/2014, 1:31-1:52




## Global AVHRR , 18/09/2014, 9:04-9:46




Hautecoeur, O., and R. Borde, 2015, Derivation of wind vectors from AVHRR Metop at EUMETSAT, to be published in JTECH
Borde, R., O. Hautecoeur, and M. Carranza, 2015, EUMETSAT Global AVHRR winds product', J. Atmos. Oceanic Technol, 33, 429-438. DOI: [http://dx.doi.org/10.1175/JTECH-D-15-0155.1](http://dx.doi.org/10.1175/JTECH-D-15-0155.1)

# So, why extracting winds from IR sounders ?

- Current AMVs limitations:

✓ AMVs give an information at a single level of the troposphere.

✓ Height assignment (HA) is known to be an important problem.

✓ Recurrent AMV problems in tropics area (fast speed biases) where important mesoscale phenomena impact the medium range forecast.

- IR sounder AMVs expectations:

✓ Vertical wind profiles from IR sounder temperature/humidity fields.

✓ HA less a problem.

✓ Better information in Tropics (MTG IRS)

# MTG-IRS User requirements (EURD Version 2, 2008)

## MTG-IRS products

- **Temperature and Humidity Profile Product (THPP)**:

The Temperature and Humidity Profile Product will provide inform… distribution of temperature and humidity. It will include surf… It will be derived from IRS observations for clear sky fi… layers above selected cloud types. The product … estimation.

- **Clear Sky Wind Profile (CS…**

The clear sky wind profil… …rofile Product and will provide informatio… …otion in clear sky and for atmospheric l…

- …

…ill be derived from IRS observations for clear sky …mation on ozone and co in broad atmospheric layers.

- **…t (IRS-CP):**

…roduct will contain micro and macro physical information of clouds within t… view, like cloud fraction, cloud top height, cloud effective radius. It will be derived fr… the IRS instrument for all <pixels>, and will include an error estimation of the various parameters.

**MTG-IRS wind products are not committed for day 1, but as 'aspirational'.**

**From: EUMETSAT HQ Level 2 Products Generation and Dissemination baseline for MTG (EUM/MTG/DOC/09/0026, 2013)**

# State of the art extracting winds from IR sounders

- BACKGROUND

✓ Product recently developed at CIMSS with AIRS (Santek et al., 2016). Presently in demonstration, showed some potential in assimilation experiment in GEOS-5 model (NOAA/NCEP)

✓ EUMETSAT fellow at Met Office, L. Stewart, study done using simulated spectra generated by Met Office UKV 1.5km model.

✓ External study done by DLR for EUMETSAT in 2006. Humidity fields mimicked from Lokall-Modell LM from DWD.

# Which strategy ?

- Known difficulties

✓Cross correlation tracking methods not very efficient considering smooth temperature/humidity fields. Not enough contrast/entropy for good matching.

✓Really difficult to deal with convection.

✓Each layer is considered separately.

- Present EUMETSAT strategy

✓Test a 3D optical flow software developed by INRIA (France)
http://www.irisa.fr/vista/Papers/2007_IEEEGRS_HeasMemin.pdf

✓Collaboration with P. Héas (INRIA) started in June 2015.

# 3D winds algorithm development at Eumetsat

- Use of a 3D optical flow model
  - Optical Flow technique
    - Optical Flow ≡ Interpolator between two images
    - Study 10 years ago (Heas and Memin, 2007) on motion estimation from successive MSG cloud products
    - Collaboration restored with INRIA in 2015
  - Derivation of all pressure levels in one pass
  - Physical regularization introduced
  - Vertical motion is also considered
    - u, v, w retrieved at each level

- “Operational model”
  - Can run in real-time with reasonable computing resources
    - Based on modern mathematics

# The concept

At Time $t$

WV mixing ratio

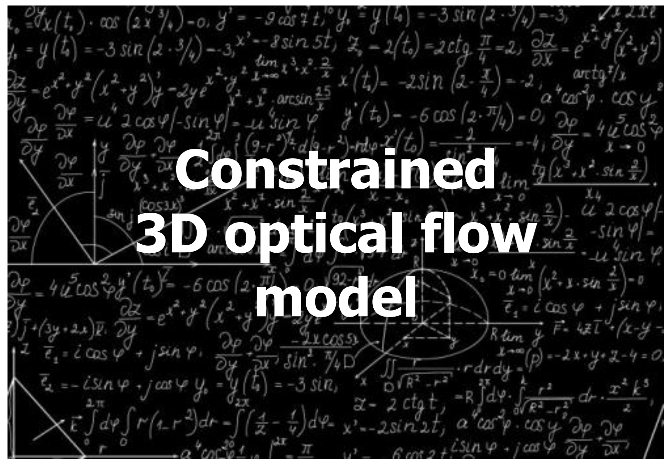
Temperature

At Time $t + \Delta t$

WV mixing ratio

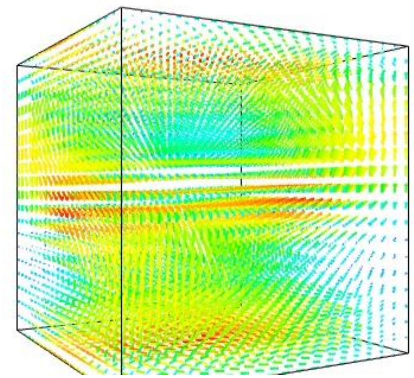
Temperature

Model Settings



**Constrained 3D optical flow model**

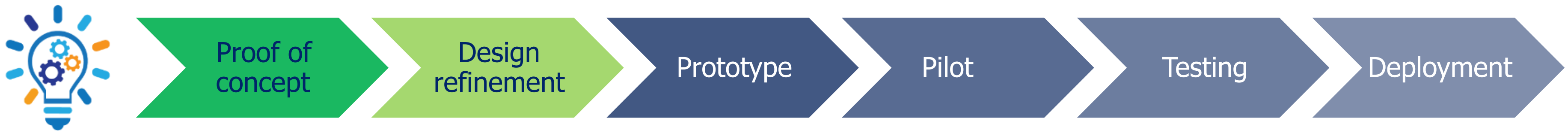
Basic Conservation Laws
Vorticity and Divergence
Regularization
Minimization algorithm



**3D wind field**

U,V,W fields derived from observations

# Workplan as defined in 2015

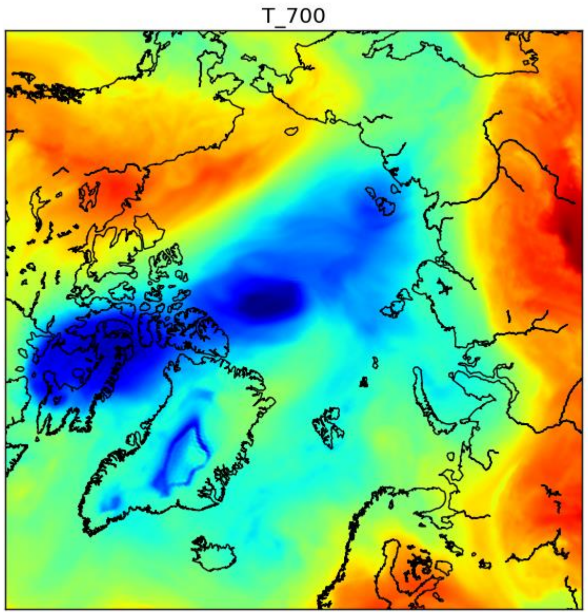


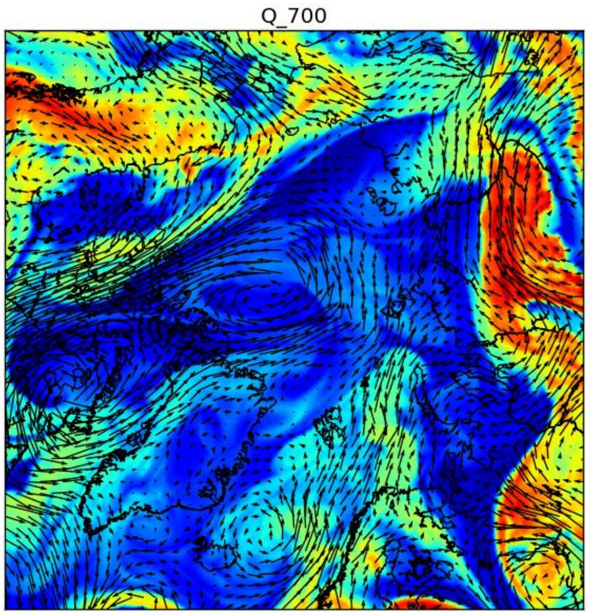

- Proof of concept
  - Adapt the old code to run on multiple levels
    - Tune the regularization settings
  - Test the AMV derivation on filled (gapless) fields
    - Based on ECMWF forecast temperature and humidity fields
  - Test the AMV derivation on IASI fields
    - Based on operational IASI level 2 products

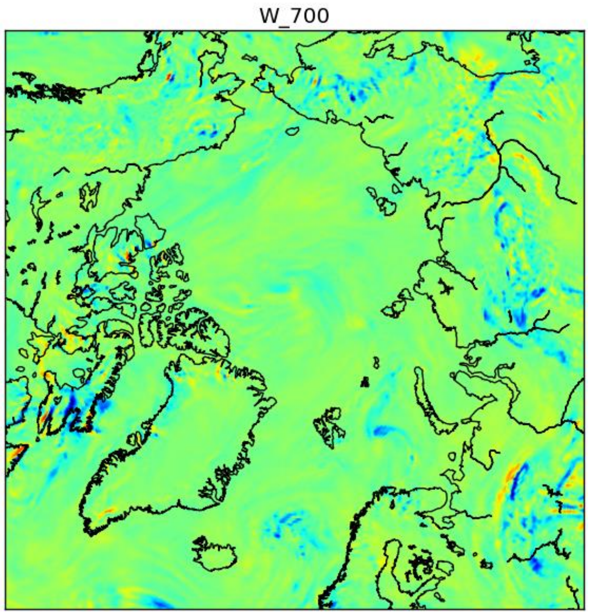
- Specification of the new model
  - Coding and implementation

# Test on model forecast data

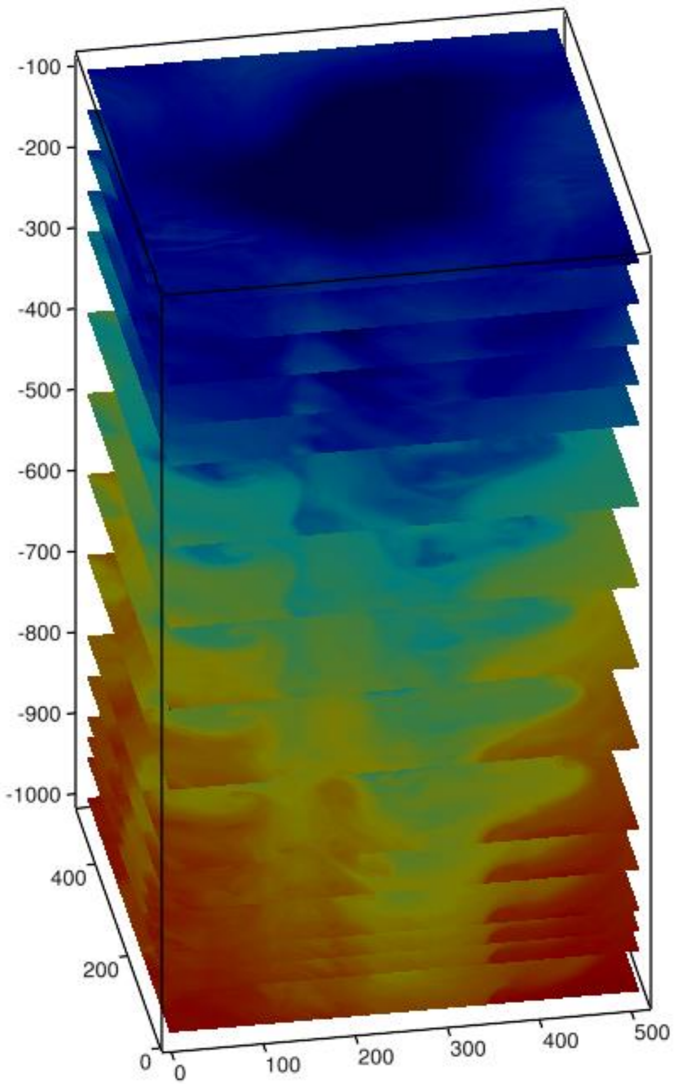
- Source
  - ECMWF operational data, 21 June 2013
  - Standard pressure levels
  - Parameters
    - T, Q
    - Wind fields (U, V, W)
  - Step = 1 hour
- Grid
  - Polar stereographic projection
  - Dimension: 512 × 512
  - Resolution = 20 km
    - (consistent with IASI sampling ~ 25 km)



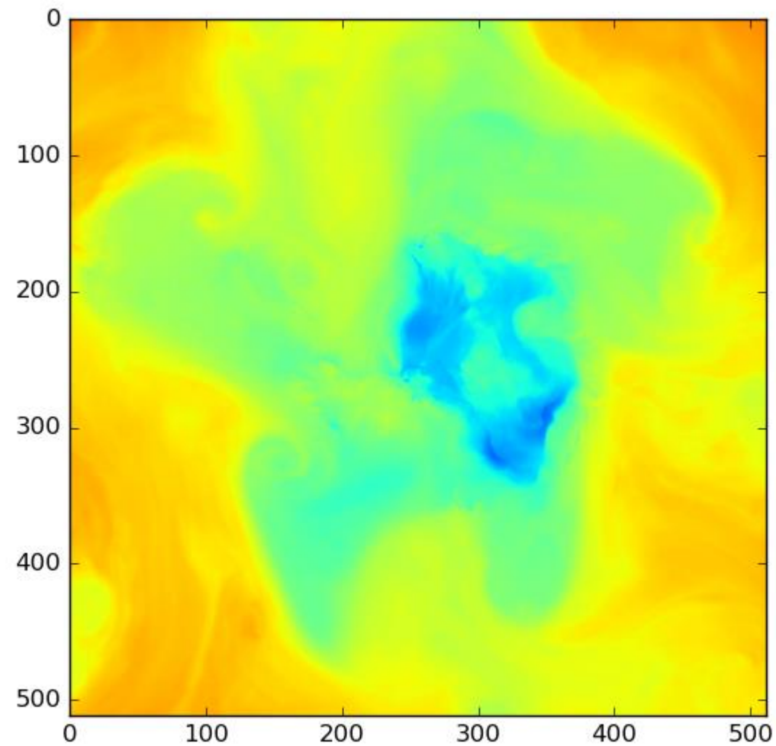



# Forecast temperature experiment




- Grid 512x512 pixels
- 12 levels
- 12:00 → 13:00

**P=700 hPa**

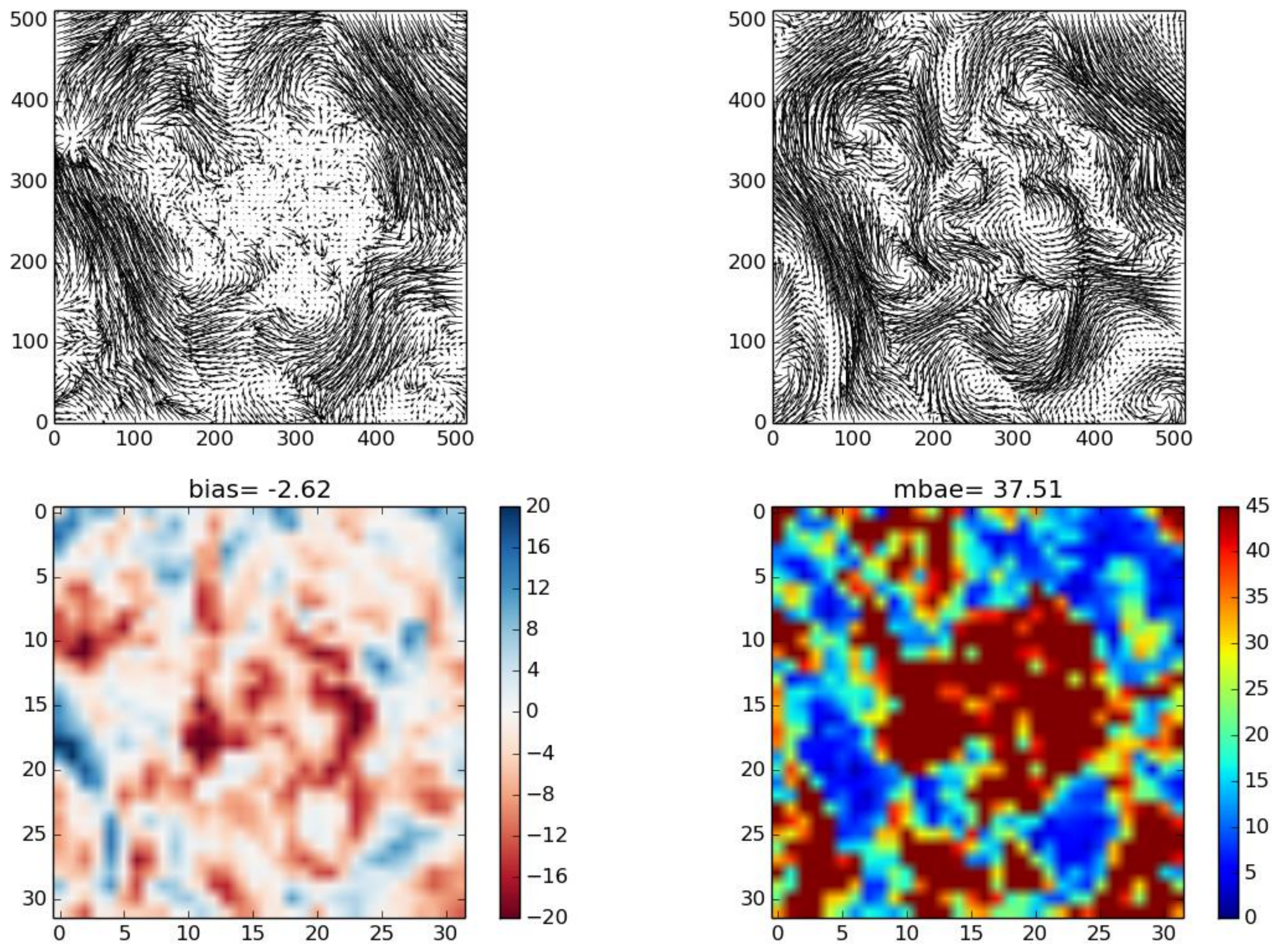


# Wind derived at 700 hPa from forecast temperature

***Winds at 700 hPa***
***Southern Polar Region***
***on 21 June 2013 at 12:00Z***

**Derived from temperature fields**

**No guess used !**



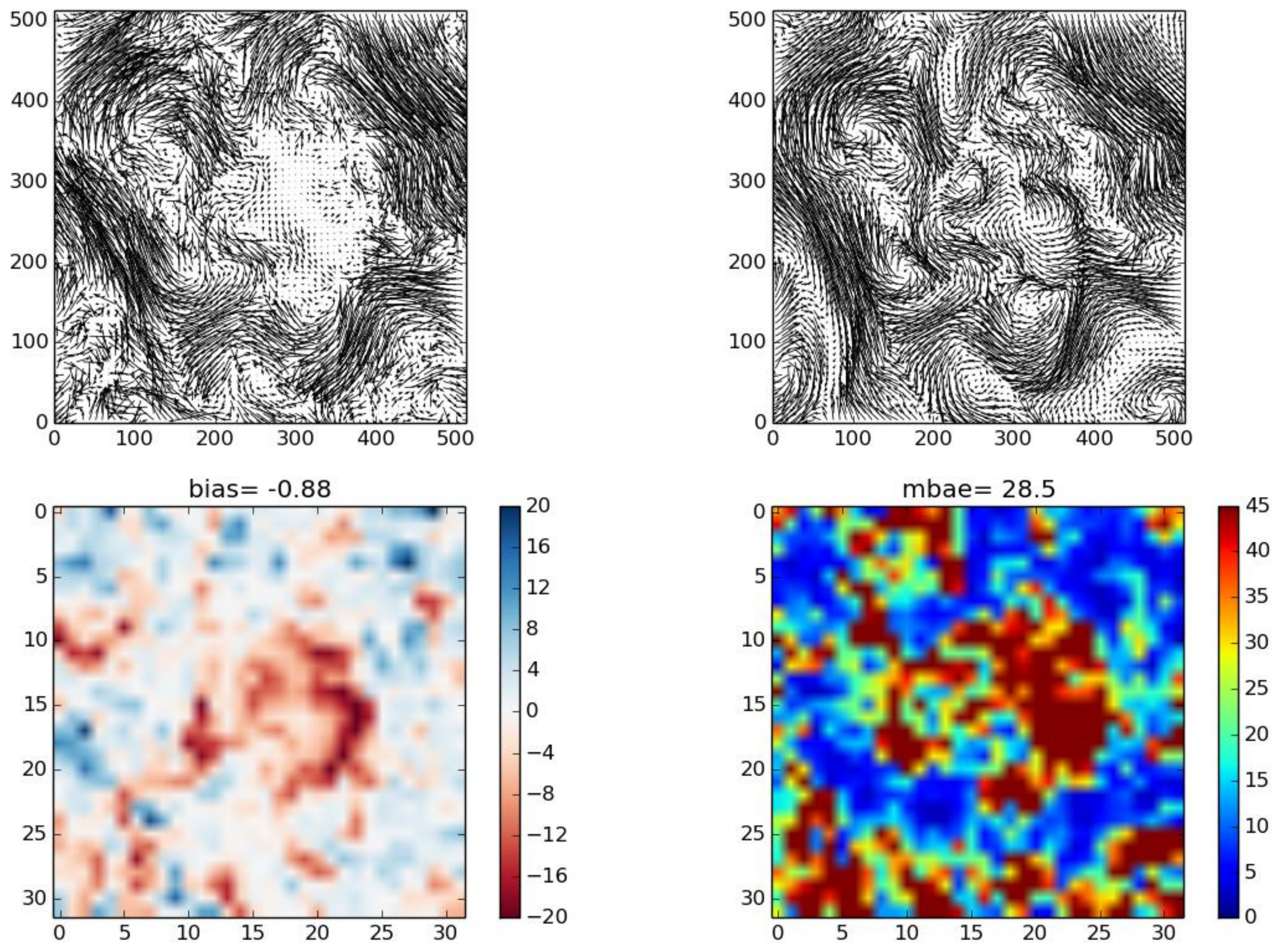

**Forecast wind field**

# Wind derived at 700 hPa from forecast humidity

***Winds at 700 hPa***
***Southern Polar Region***
***on 21 June 2013 at 12:00Z***

**Derived from humidity fields**

**No guess used !**

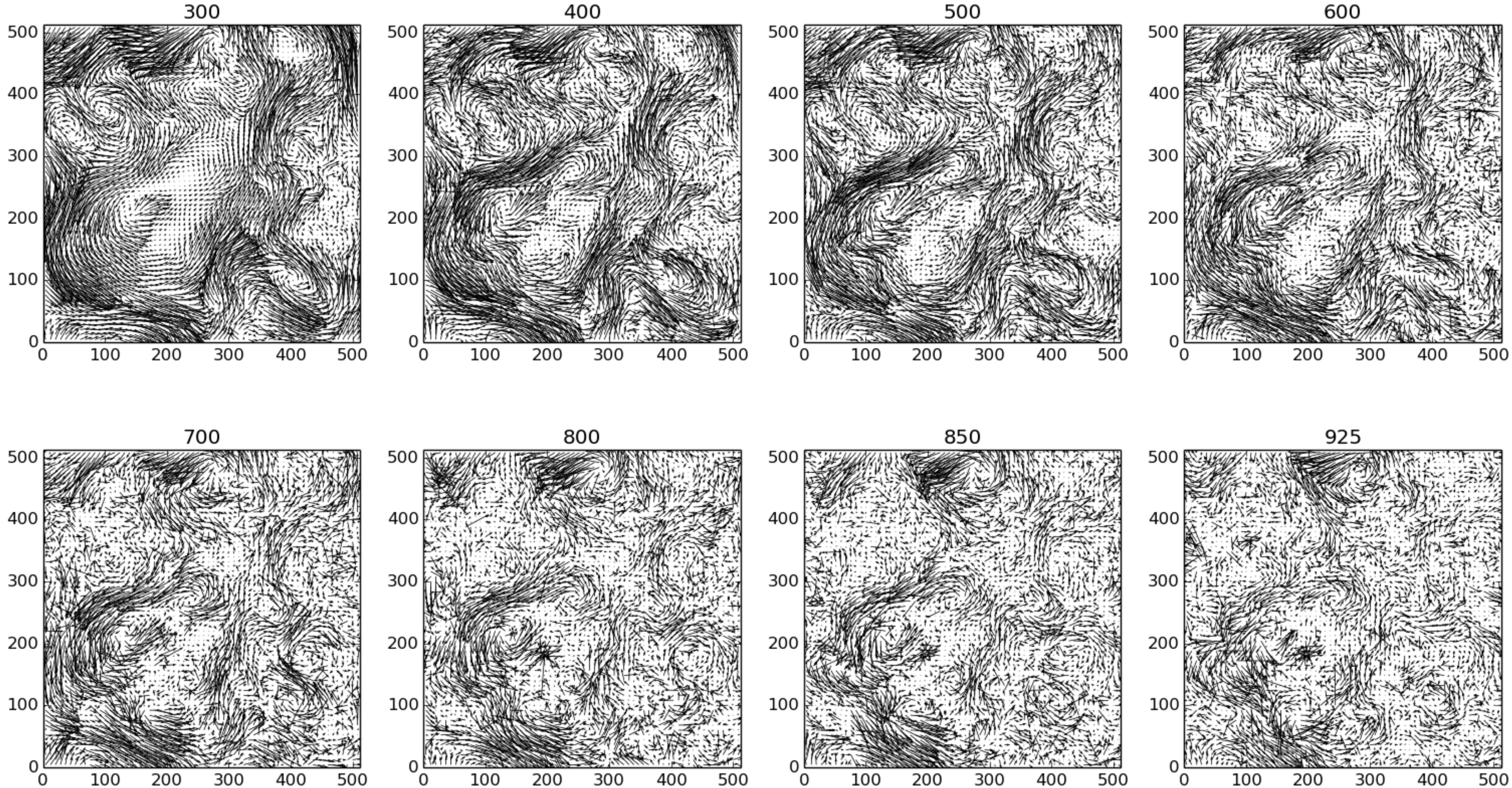



**Forecast wind field**

# 3D winds derived from humidity fields

**Northern hemisphere, 21 June 2013, 12:00 ➔ 13:00 UTC**

***No guess***



# Statistics (O-B) 2013-06-21 NH 12h⇨13h

| Pressure | Ozone | | Temperature | | Water vapor | |
|---|---|---|---|---|---|---|
| hPa | Bias | MBAE | Bias | MBAE | Bias | MBAE |
| 100 | -2.0 | 34 | 1.2 | 90 | | |
| 150 | -3.4 | 18 | -4.2 | 65 | | |
| 200 | -5.4 | 17 | -8.6 | 49 | | |
| 250 | -7.0 | 21 | -9.8 | 35 | -5.8 | 31 |
| 300 | -6.8 | 22 | -8.8 | 32 | -6.0 | 24 |
| 400 | -4.2 | 20 | -5.3 | 31 | -2.1 | 23 |
| 500 | | | -3.4 | 38 | -0.4 | 24 |
| 600 | | | -2.3 | 42 | 0.1 | 28 |
| 700 | | | -1.5 | 44 | 0.7 | 32 |
| 800 | | | -0.8 | 46 | 0.6 | 37 |
| 850 | | | -0.5 | 46 | 0.6 | 38 |
| 925 | | | -0.4 | 50 | 0.3 | 40 |
| 1000 | | | 1.2 | 54 | 1.6 | 52 |

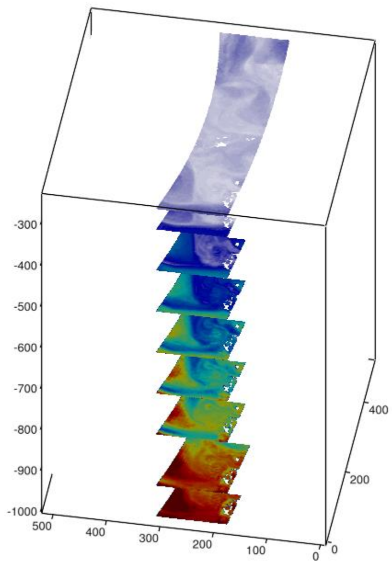
**Winds derivation from each parameter, separately**

**NO GUESS USED**

# Very preliminary comments

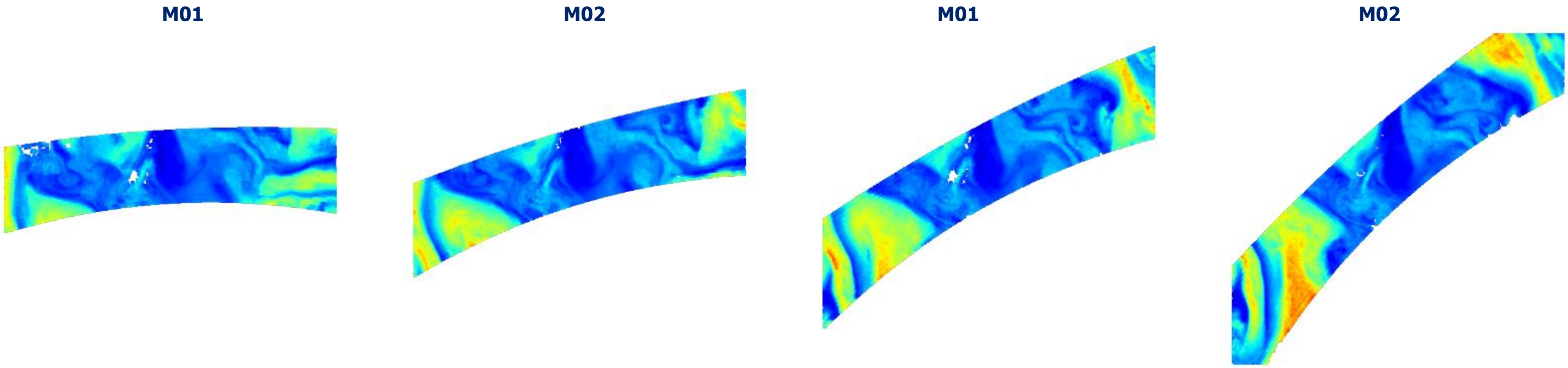
- Wind fields structure retrieved
- Inter-comparison with forecast fields are consistent
- Statistics (mean bias) larger for high levels
  - Temperature field smoother than water vapor content
  - But high atmosphere is dry
  - Ozone is another passive tracker
    - Half-life about one day for mid stratosphere, ten days for low atmosphere
- Q and O3 will be the two main variables tracked
  - With T for consistency.
- No guess means null speed wind
  - Gives negative bias speed for the highest level (highest wind speed)
  - Optical flow technique “doesn’t” like big displacements.

# Test on IASI level 2 products



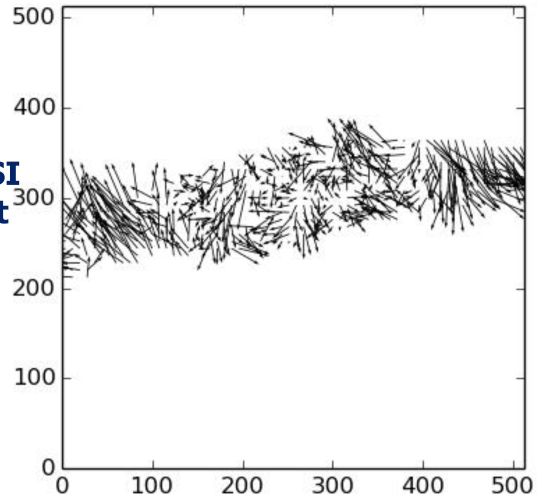

- **Source:**
  **IASI_SND_02 products (operational production at Eumetsat)**
- **Platform:**
  **Metop-A and Metop-B to maximize the overlap between the images**
- **Humidity (water vapor mixing ratio) fields at standard pressure levels**
- **Interpolated data on Polar stereographic grid**

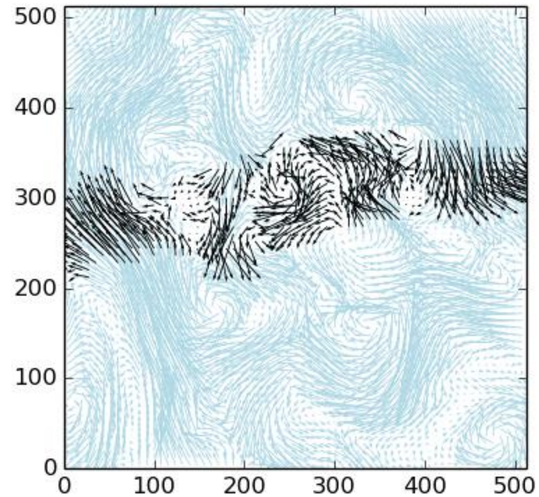
**Humidity at 500 hPa for successive overpasses**



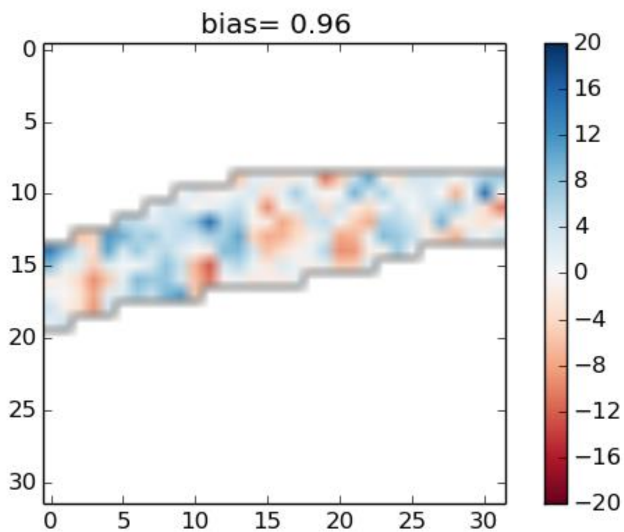
# Wind derived from IASI humidity profiles

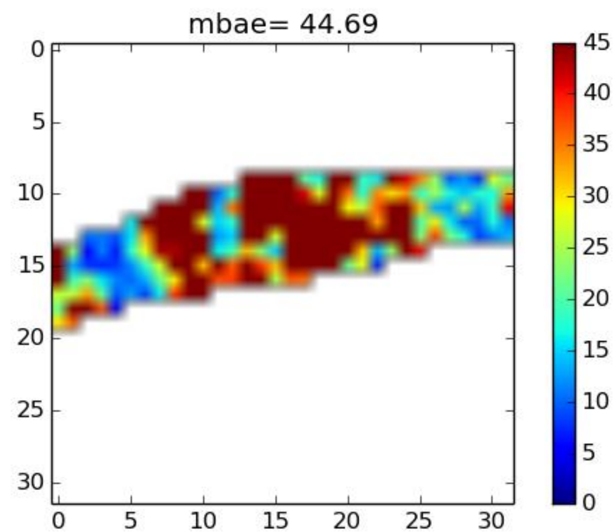
**Derived from IASI humidity fields at 700 hPa**



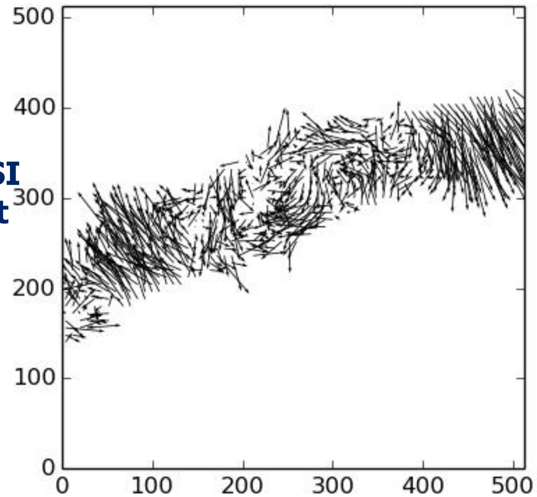

**Forecast wind field at 04:00**



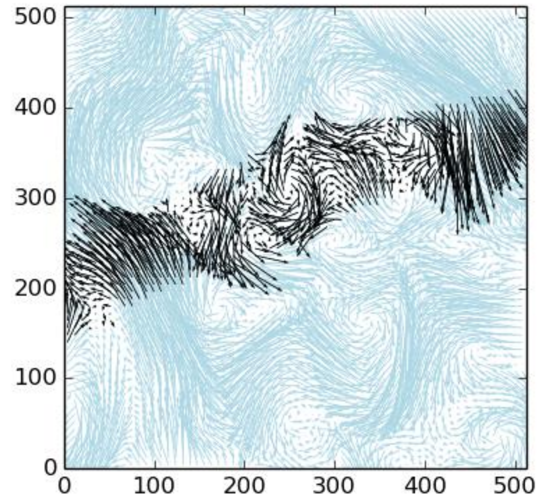



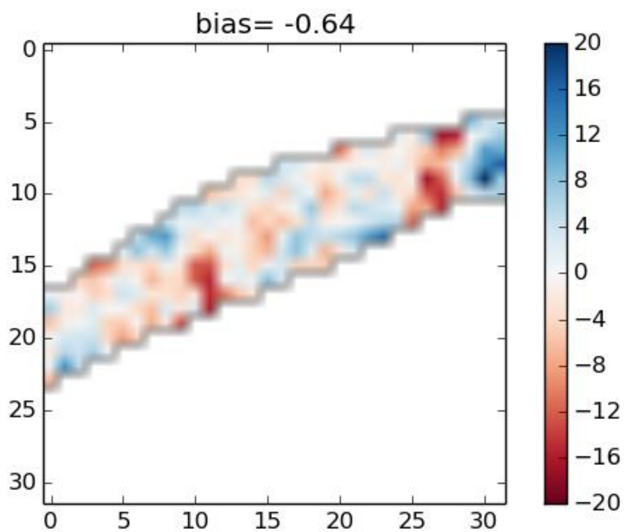
# Wind derived from IASI humidity profiles

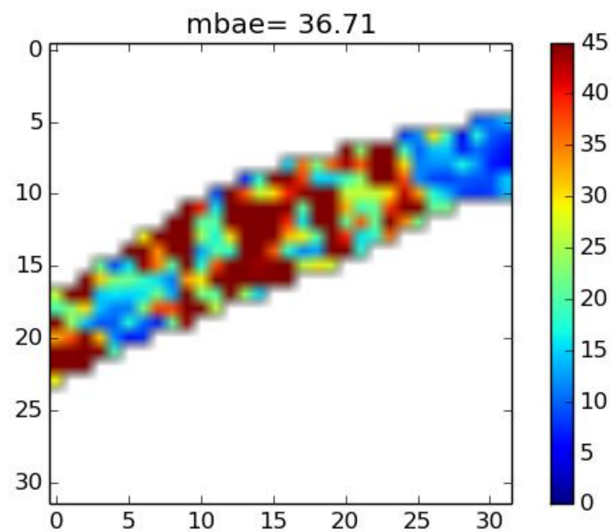
**Derived from IASI humidity fields at 500 hPa**




**Forecast wind field at 04:00**



# Very preliminary comments

- Feasible but more difficult
- Requires stronger regularization
  - The physical regularization shall be tuned in the vertical profile
- Pixel quality index of IASI level 2 should be considered
- Coverage area should be extended to add constraints
  - The output data are therefore screened to reduce the border effect.

- The algorithm is suitable for operational use
  - Actual implementation is not parallelized but the winds derivation takes only 5 minutes to process about 25 minutes of data.

- ‘Demonstrational product’ available by Q3 2017

# Perspectives for MTG-IRS 1/2

- Software can be adapted to MTG-IRS data
  - Dwell of 160x160 pixels (IRS) 2x2 pixel (IASI)
  - Pixel size of 4km (IRS) 12 km (IASI)

- Sparse data not a problem with the new model

- MTG-IRS 3D wind product could be as follow:
  - 4 km resolution
  - Using image pairs (30 min gap) and the current baseline [3-4 3-4 3-4 3-4 3-4; 2-4 2-4 2-4 2-4; 1-4 1-4 1-4] allow a ½ hourly product over Europe (LAC-4) and ~3 series of 3 products per day for LAC-1,2.

# Perspectives for MTG-IRS 2/2

- Validation could be done against
  - Radiosonde Observations
  - Common AMVs from MTG-FCI
  - Lidars network and ADM-Aeolus HLOS winds (if still operating)

- User requirements can be potentially discussed for a better coverage
  - Need only image pairs (30 min gap) to derive winds
  - Different baseline than the current baseline can allow a more frequent wind production for LAC-1,2 and 3.

To be discussed !