EUMETSAT

3D winds derivation from IASI level 2 products

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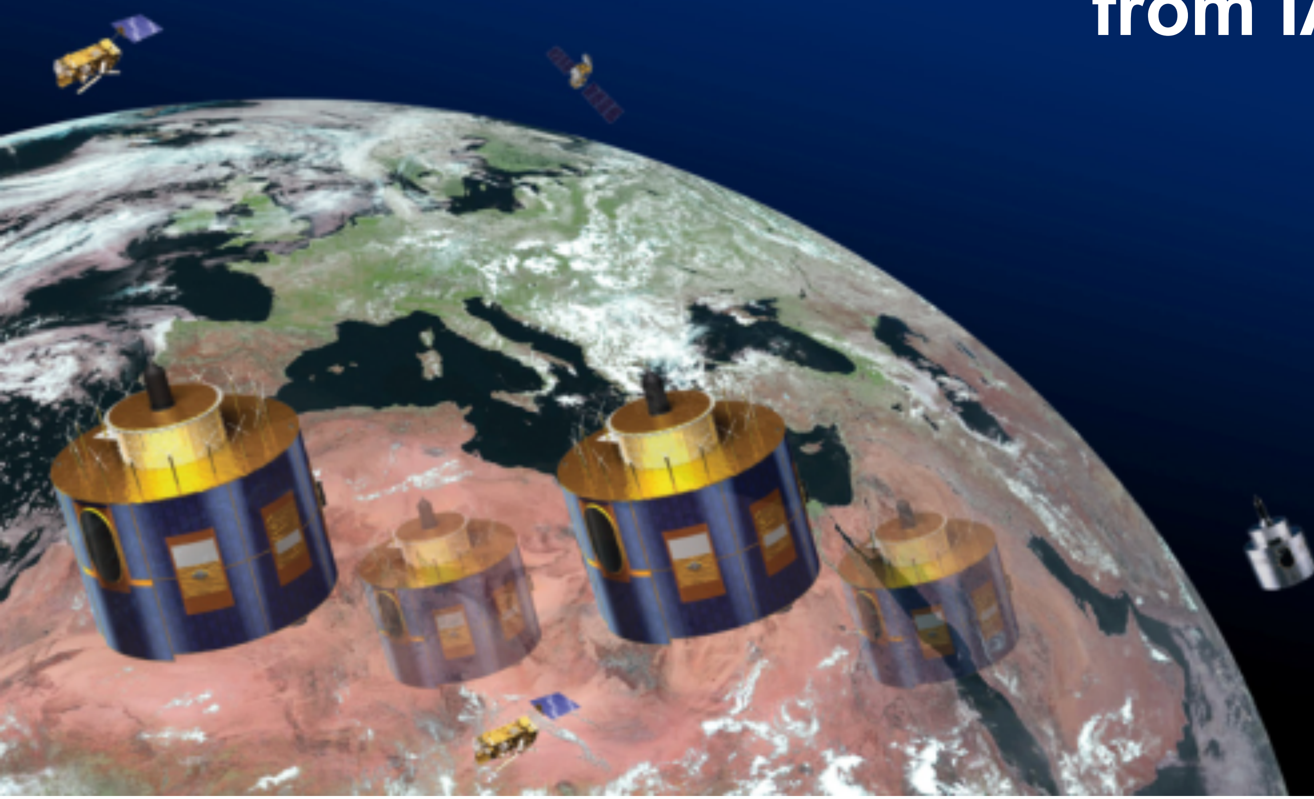
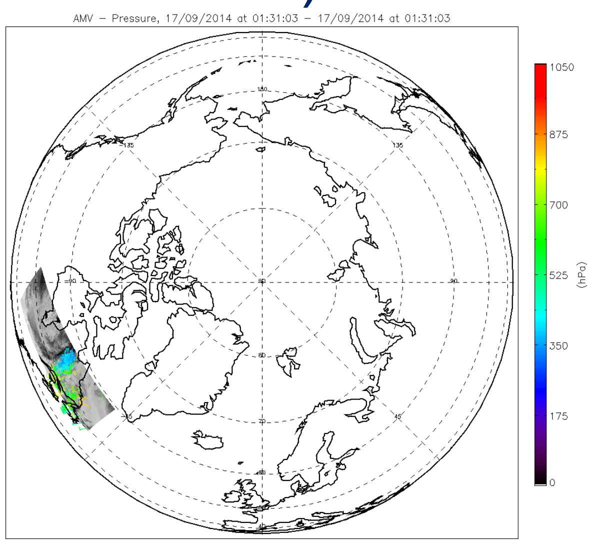
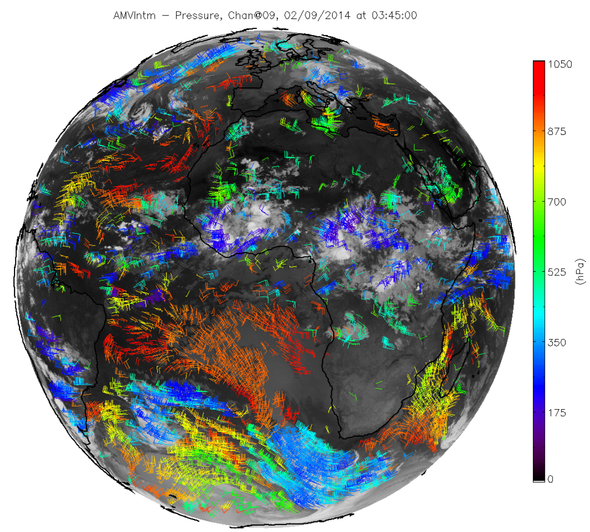


METIS Inria

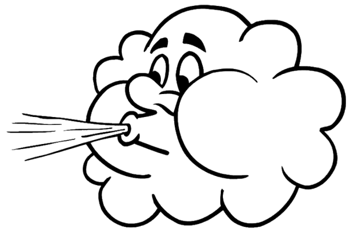
AMV derivation method

- Classical method
  - Cloud tracking between successive images
  - Feature tracking algorithm (local images correlation)
  - Extracted from geostationary and low earth orbiting satellite data
  - Using thermal infrared channel and high resolution visible channel (daytime for low clouds)
  - AMV is:
    - Wind speed
    - Wind direction
    - Altitude (pressure)
    - Quality Index





Current AMV limitations



- Not everywhere
  - Cloudy situation
- Winds extraction at a single level
- Height assignment is known to be a recurrent problem
  - Vertical extension of the clouds
  - The accuracy on HA methods
  - Some dependencies on forecast models
  - Is the cloud a passive tracer?
- Recurrent AMV problems in tropics area
  - Fast speed biases where important mesoscale phenomena impact the medium range forecast.

So let's track fields!

- From two WV channels… to a dozen of levels of physical parameters

- Infrared sounders give access to vertical profiles of geophysical parameters
  - Temperature, Humidity, Gas concentration,…
  - … or stack of parameters fields at different pressure levels
    - ➢ Therefore, height assignment is straightforward

- Candidate missions (for Eumetsat):
  - IASI/Metop
  - IRS/MTG, IASI-NG/EPS-SG

Method in test

- Concept already in test
  - Tests done in US at CIMSS
    - Recent product development base on AIRS data.
  - Fellow at Met Office, L. Stewart,
    - Study done using simulated spectra generated by UKV 1.5km model.
  - External study done by DLR for EUMETSAT in 2006
    - Humidity fields mimicked from Lokall-Modell LM from DWD

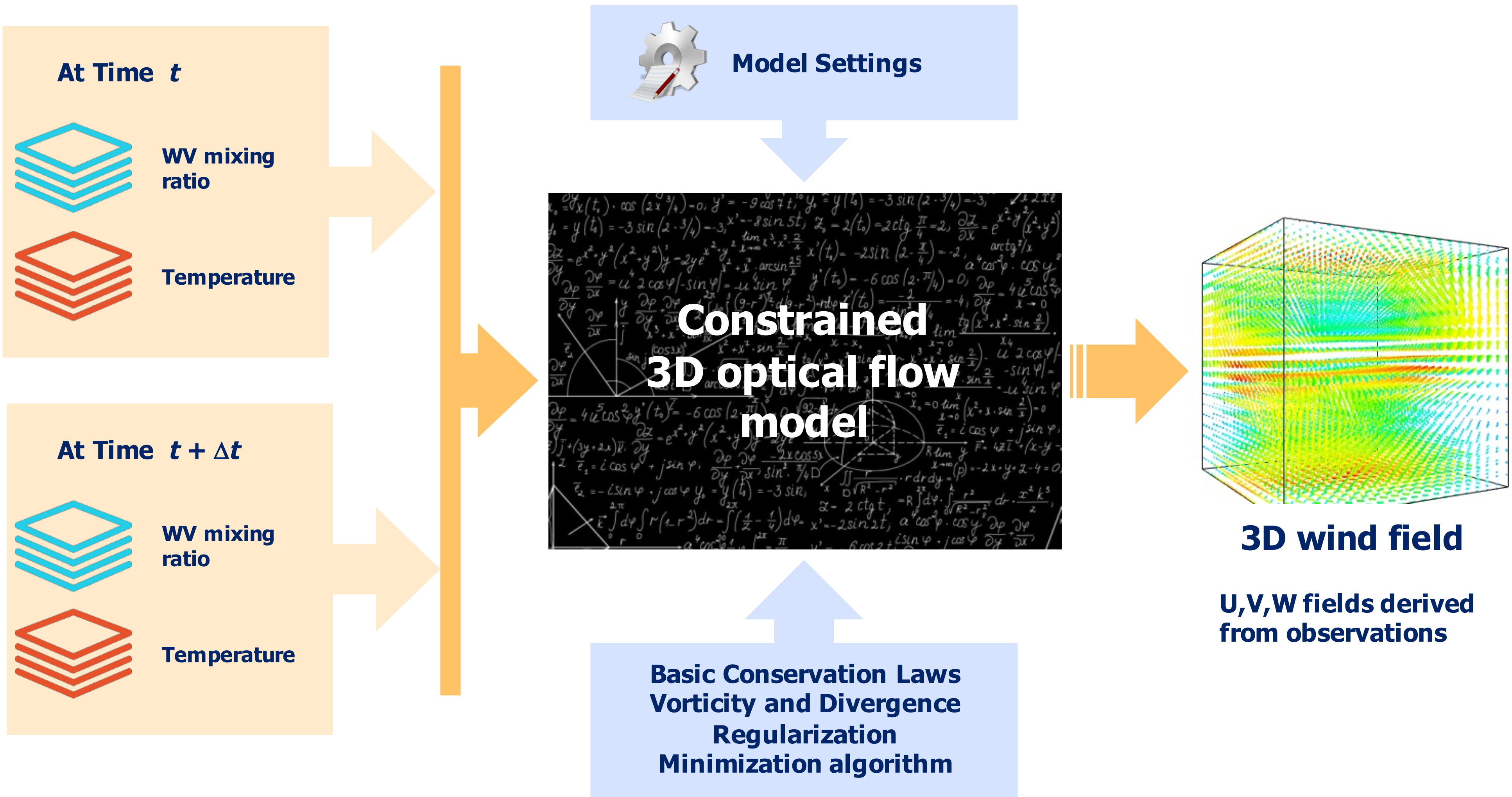
- Limitations
  - Cross correlation tracking methods not very efficient considering smooth temperature/humidity fields.
    - Not enough contrast/entropy for good matching.
  - Each layer is considered separately.
    - Vertical consistency of the different wind fields
  - Really difficult to deal with convection.

3D winds algorithm development at Eumetsat

- Use of a “global” model
  - Based on a Optical Flow model developed at Inria
    - 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

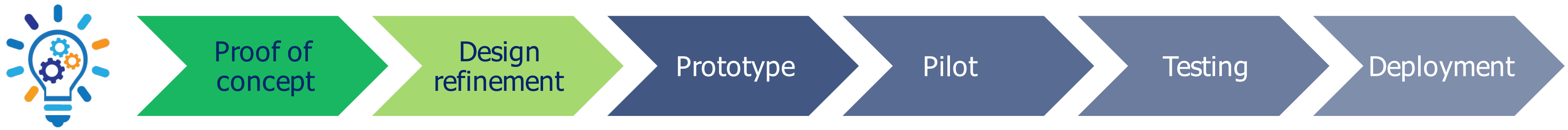
- “Operational model”
  - Can run in real-time with reasonable computing resources
    - Based on modern mathematics

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

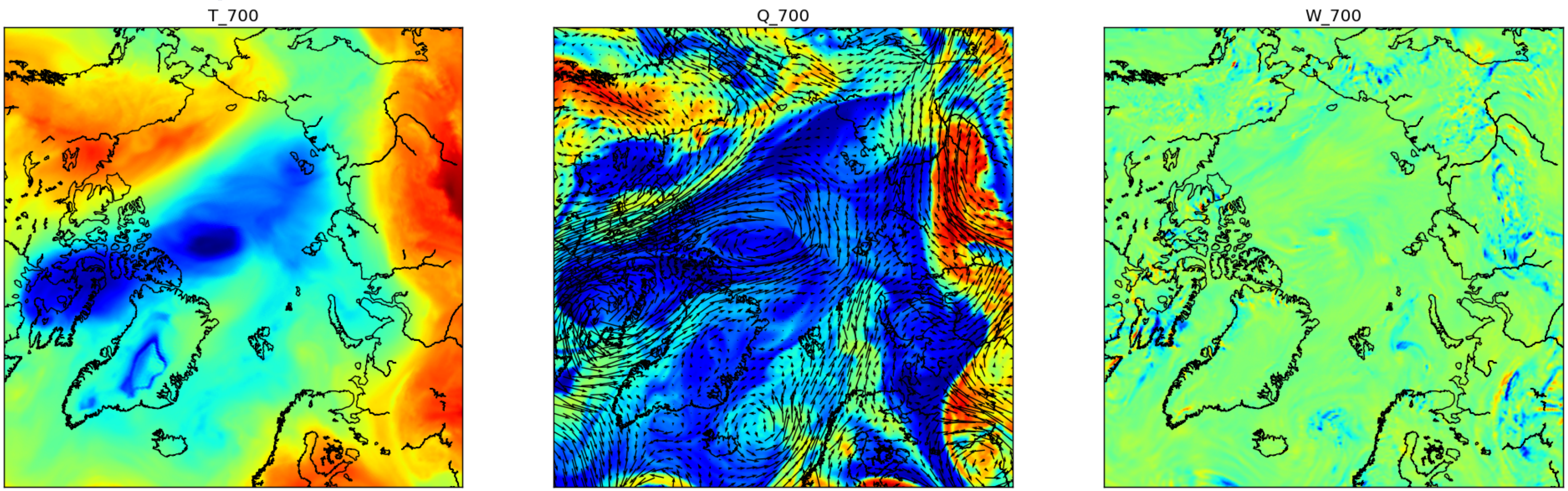


- Proof of concept
  - Adapt the old code to run on multiple levels
    - Tune the regularization settings
  - Test the AMV derivation on forecast fields
    - Based on ECMWF forecast temperature and humidity fields
  - Test the AMV derivation on IASI fields
    - Based on operational IASI level 2 products

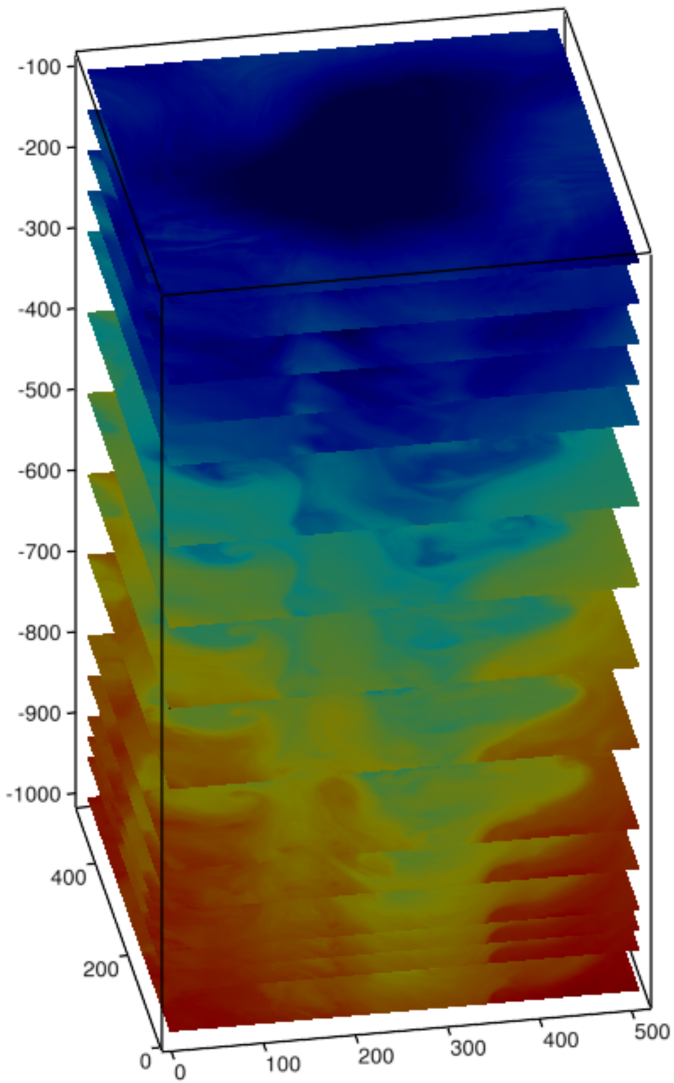
- Specification of the new model
  - Coding and implementation

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
  - Resolution = 20 km
    - (consistent with IASI sampling ~ 25 km)

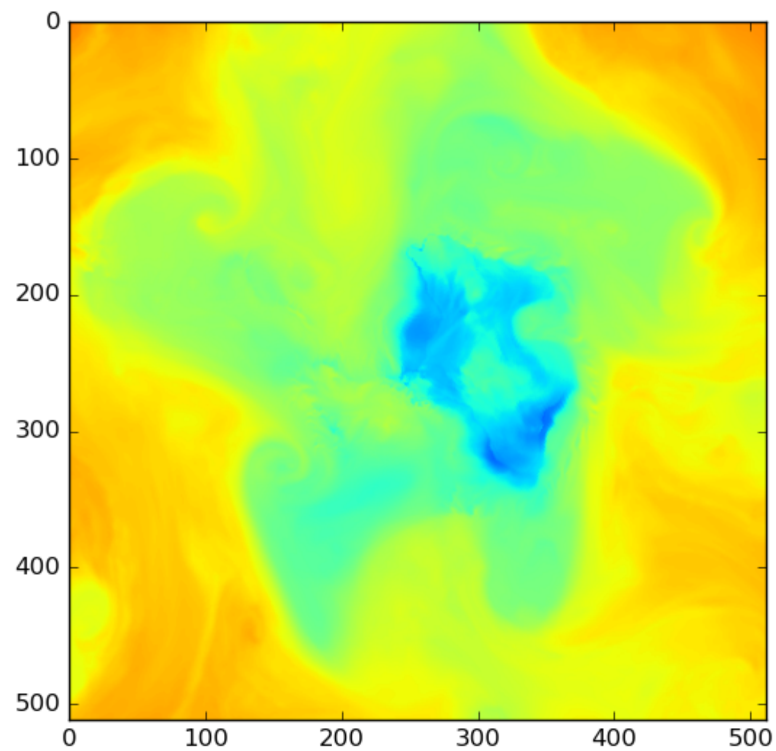


Forecast temperature experiment



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

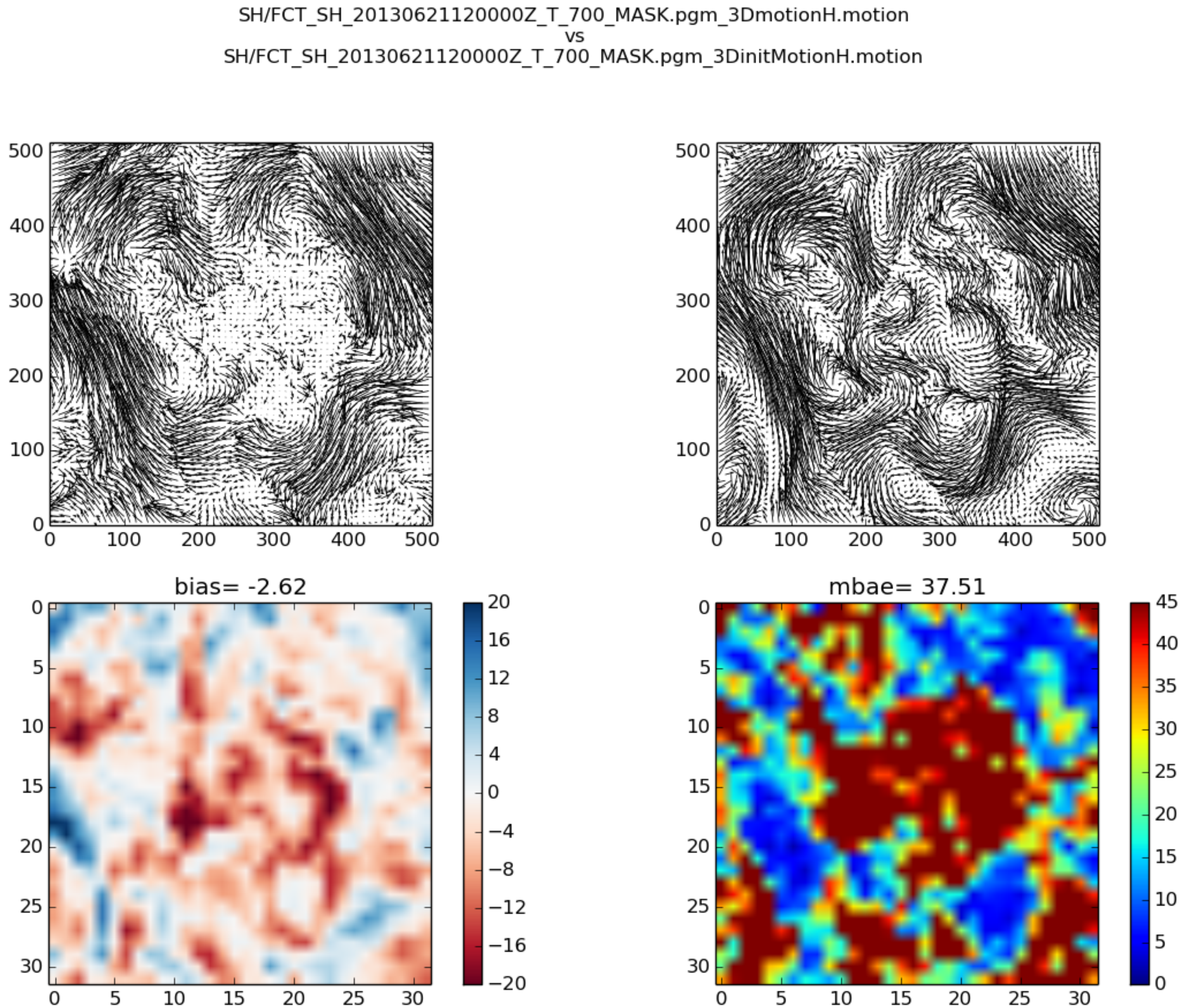
P=700 hPa



Wind derived at 700 hPa from forecast temperature

Derived from temperature fields

No guess!

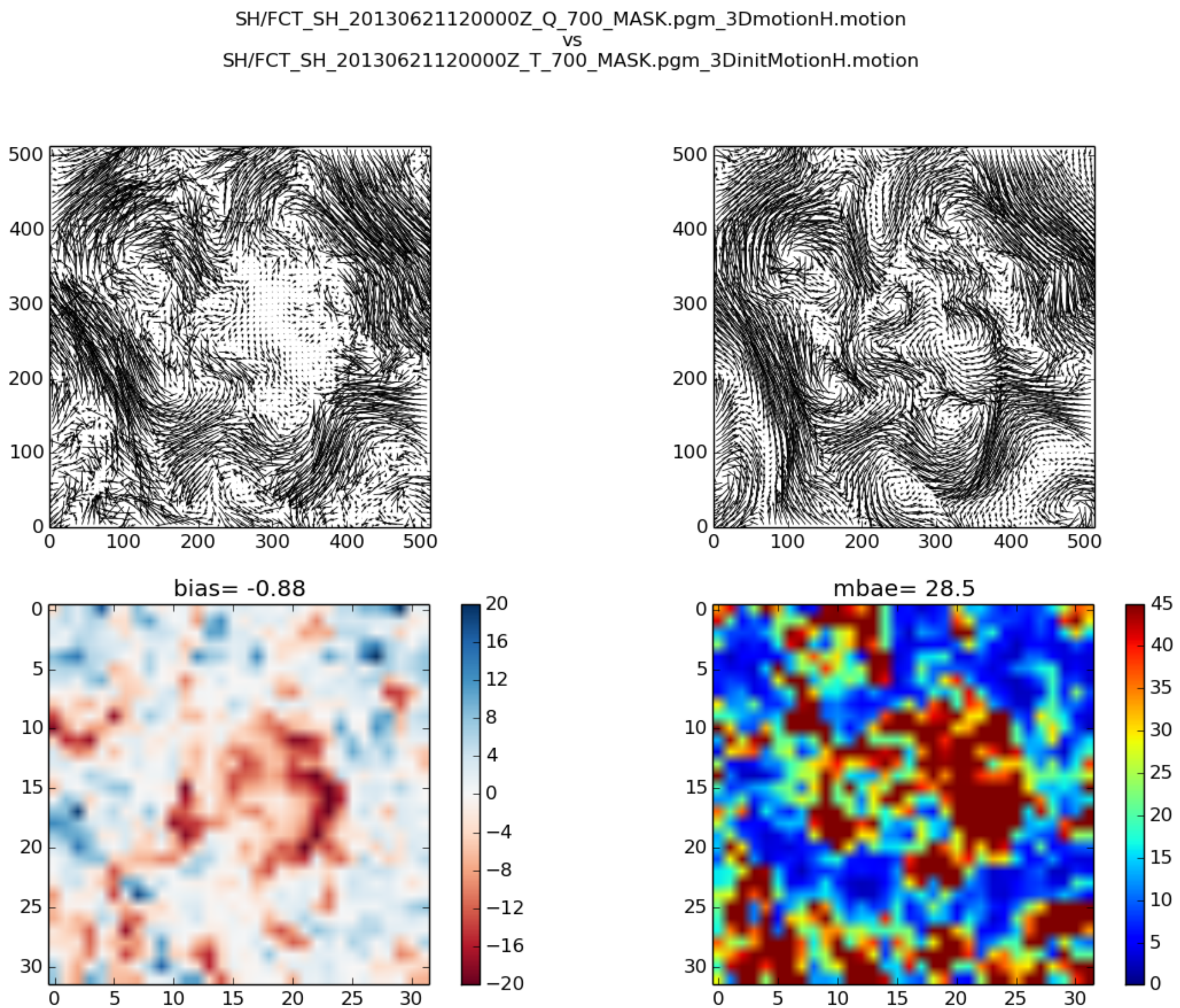


Forecast wind field at 12:00

Wind derived at 700 hPa from forecast humidity

Derived from humidity fields

No guess!



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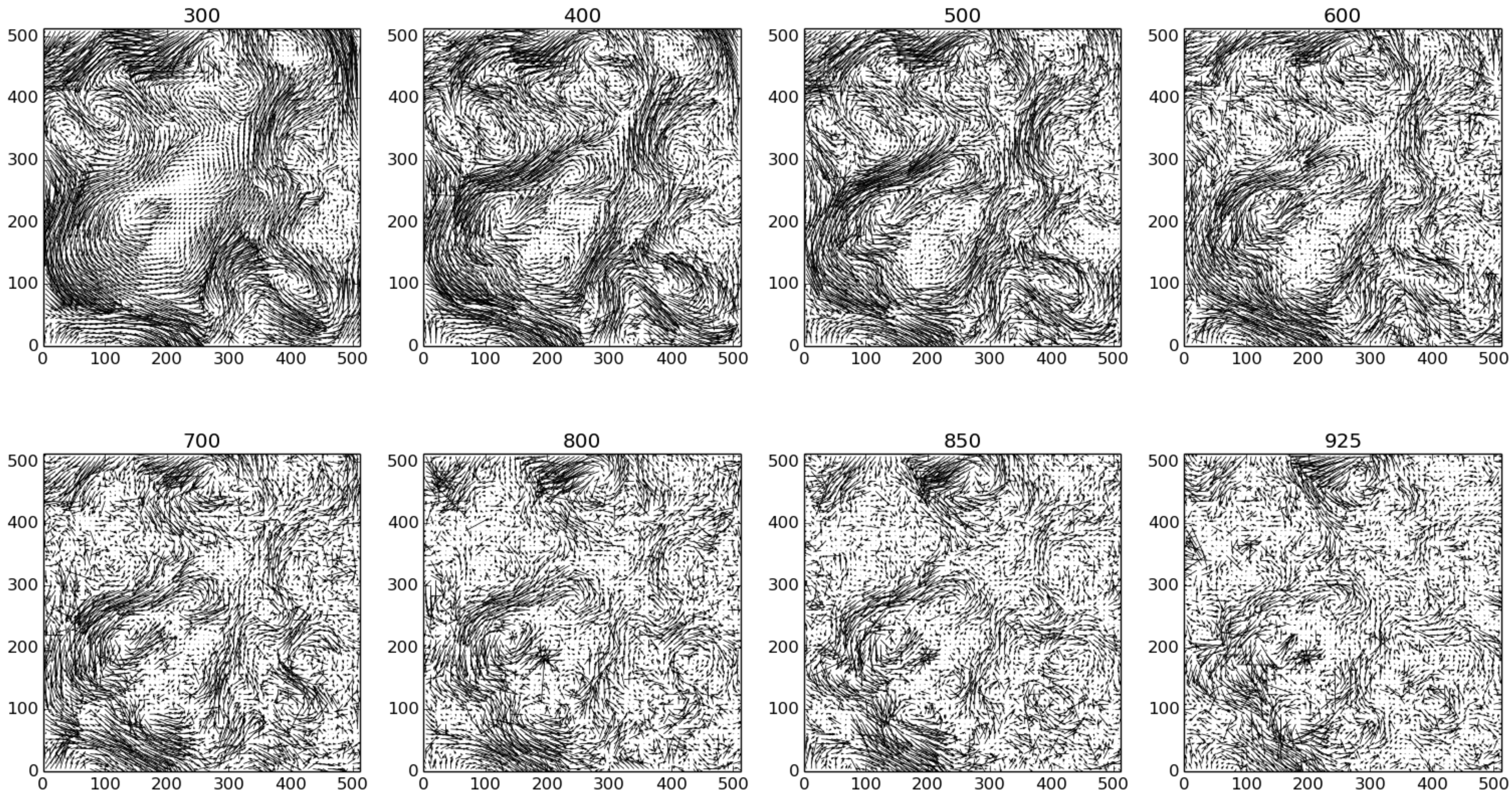
3D winds derived from humidity fields

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

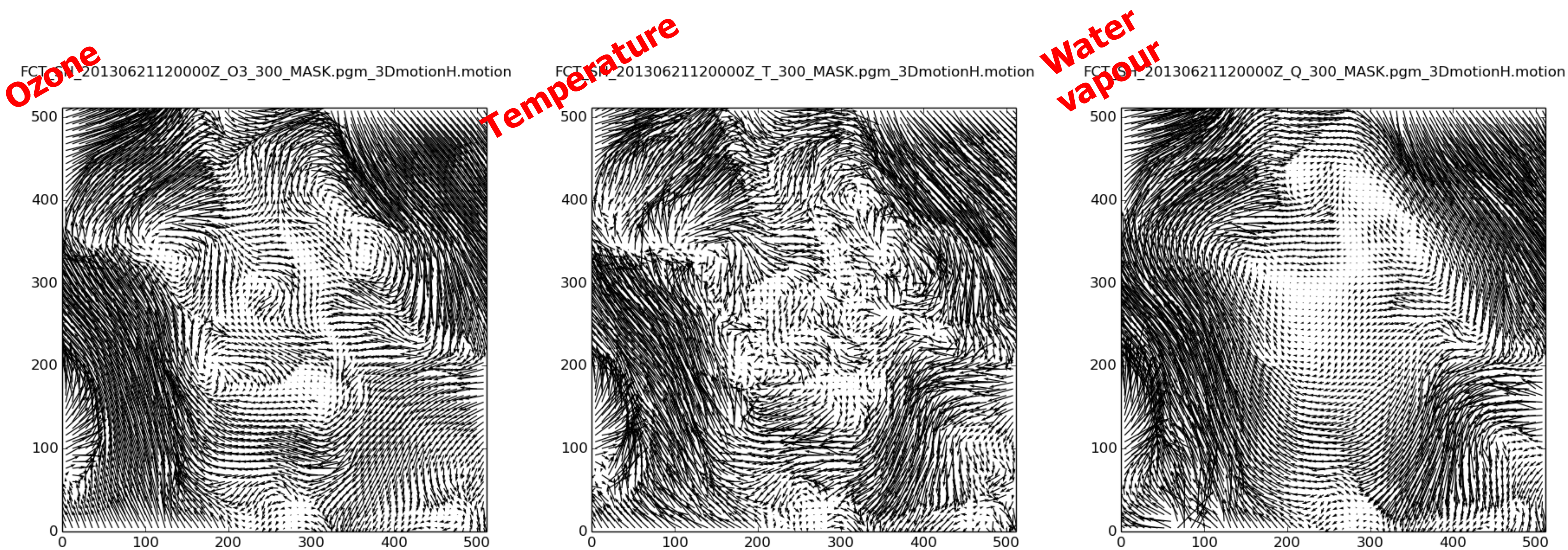
Winds derivation from each parameter, separately

NO GUESS USED

Need of concurrent inversion

- No tracer is perfect to track winds at all levels
- Transition zone around 300 hPa
    - No more water vapor above over polar regions
    - Low concentration of ozone below, even more in the ozone hole

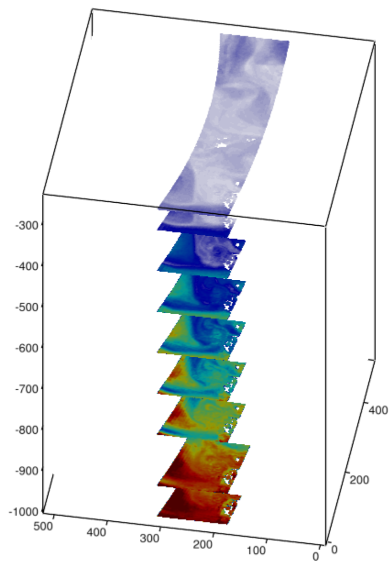
- Temperature and vertical consistency will allow to retrieve the winds even at that intermediate atmospheric levels



Very preliminary comments

- Wind fields structure retrieved
- Inter-comparison with forecast fields are consistent
- Statistics (mean bias and MBAE) lower for highest 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.
    - Review the actual multi-scale initialization, adding “another step”
    - Introduce initialization in the spin-up (not starting from null speed)

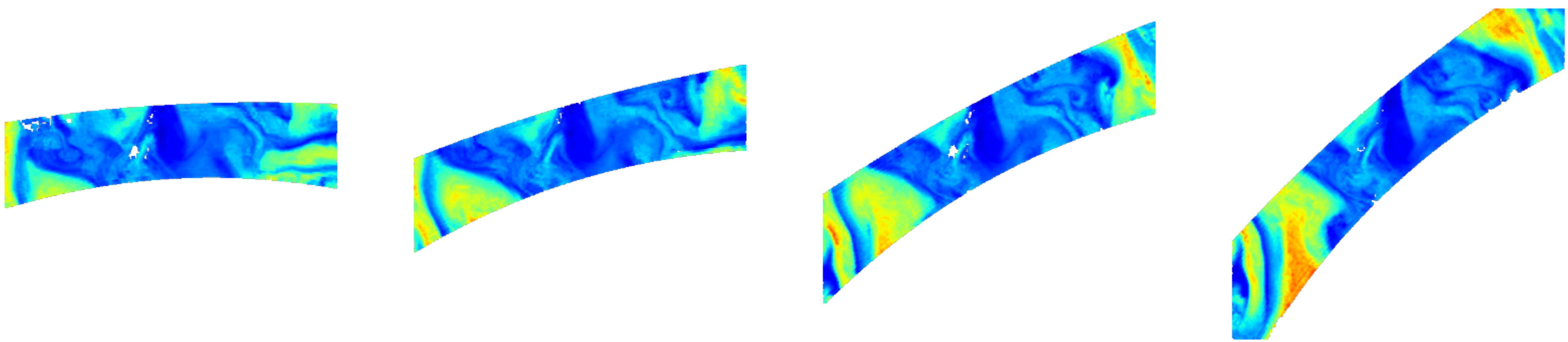
Test on IASI level 2 products



- **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

M01 **M02** **M01** **M02**

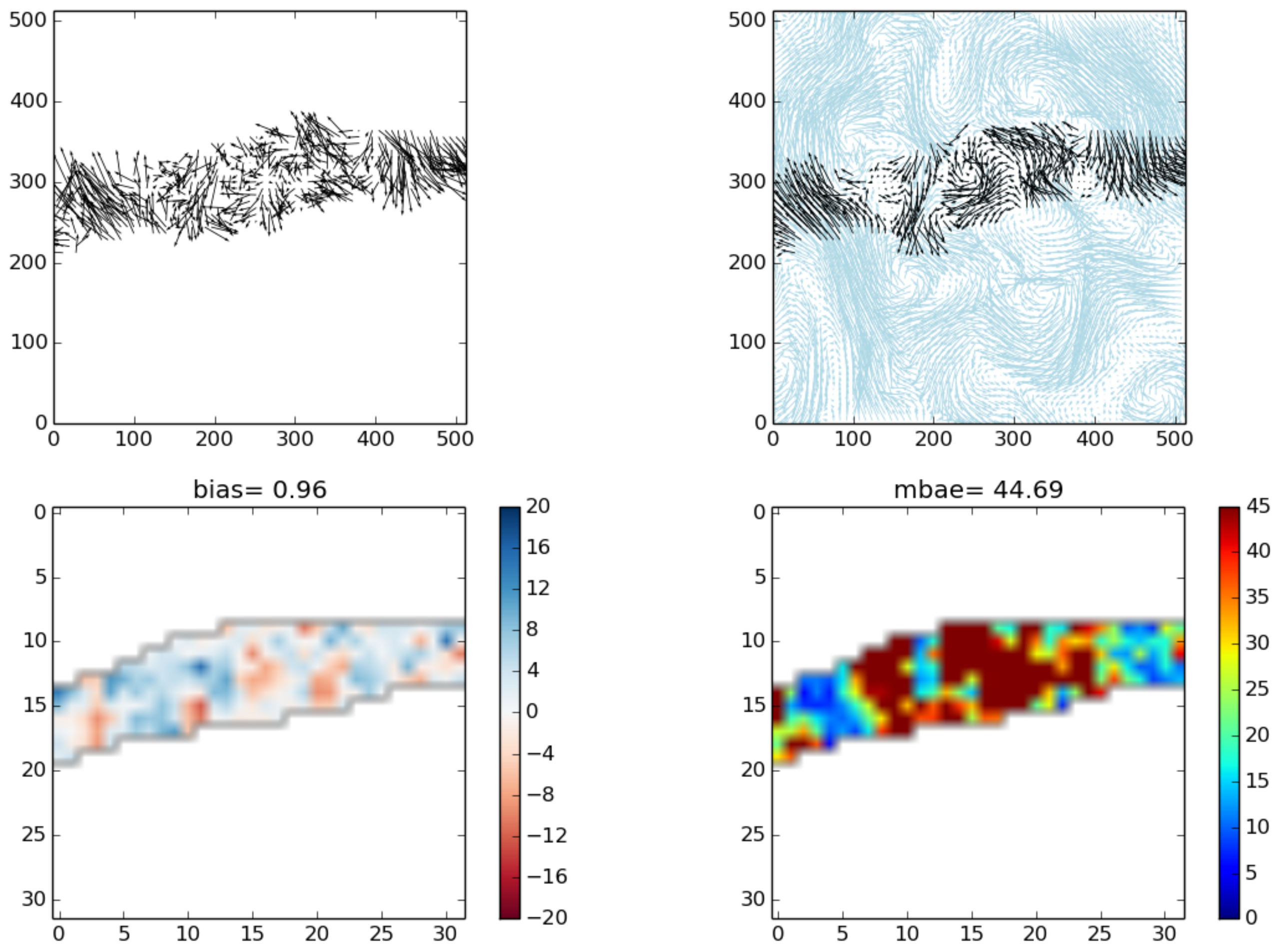


Wind derived from IASI humidity profiles

IASI_SND_02_M02_20130621025657Z_20130621043857Z_N_O_20150601100510Z_Q_0700_MASK.pgm_3DmotionH.motion
vs
../data/FCT_SH_20130621040000Z_T_700_MASK.pgm_3DinitMotionH.motion

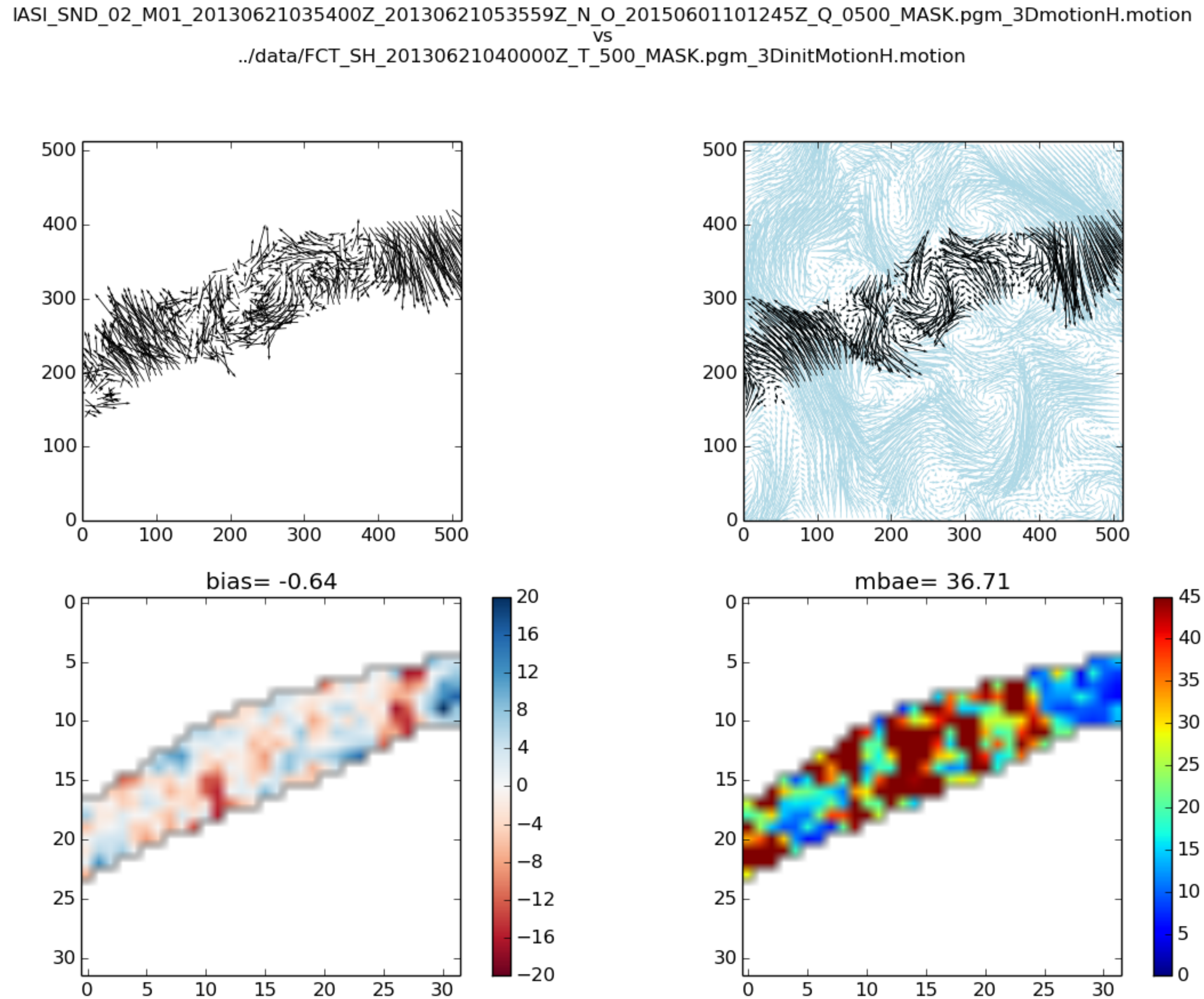
Derived from IASI humidity fields at 700 hPa

Forecast wind field at 04:00



Wind derived from IASI humidity profiles

Derived from IASI humidity fields at 500 hPa



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.

New model specifications

- Works on T, Q and O3 3D fields simultaneously
- Physical regularization
  - Link between the wind and the observed variables
  - Basic conservative laws
  - Thermodynamic energy equation

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} - \omega . S_p = \frac{J}{c_p}$$

- Self-similar regularization
  - Turbulence statistics preserved
  - Depending on the pressure level
- Initialization and spin-up process reviewed
- Same two steps in the main minimization loop
  - Alternating vertical and horizontal minimizations using efficient mathematatical algorithm
    - ➢ Vertical consistency of wind profile derived
    - ➢ Allows sparsity events

Conclusion

- 3D winds retrieval using forecast products is possible
- 3D winds retrieval using IASI level 2 products is also possible based on the same technique

- Next:
  - Prototype
    - Implementation of the new model
  - Test on several months of data
  - Work on quality assessment and associated errors
    - Area with convection
    - Winds close to surface
    - Winds in low stratosphere (10 – 100 hPa)

Adding the true 3rd dimension

- 3D not only means (u,v) profiles
  - Vertical fluxes are also derived