3D wind fields extracted from EUMETSAT IASI Level 2 products

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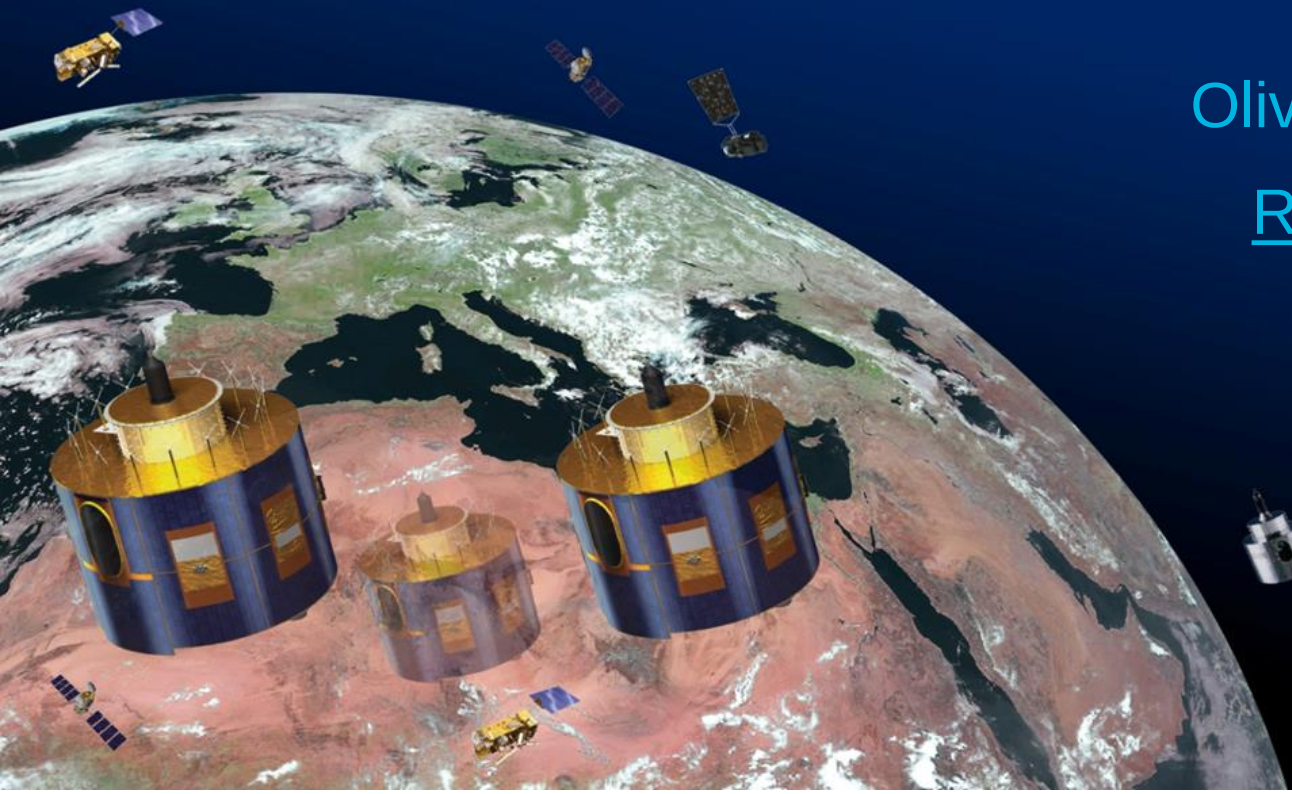


Outline

- General context
  - User requirements for wind profiles
  - State of the art winds extraction from IR sounders
- 3D Wind profiles extraction from IASI Level 2
  - Algorithm description
  - 3D wind product characteristics
  - Performances
- Summary and perspectives

User Requirements

- Requirements extracted from WMO Oscar database
  - For High Troposphere Level (~700 – 200 hPa)

	Application	Uncertainty	Horizontal resolution	Vertical resolution	Observation cycle	Timeliness
Wind (horizontal)	Global NWP	1 $m.s^{-1}$ 3 $m.s^{-1}$ 8 $m.s^{-1}$	15 km 100 km 500 km	0.5 km 1 km 3 km	60 min 6 h 12 h	6 min 30 min 6 h
	High Res NWP	1 $m.s^{-1}$ 3 $m.s^{-1}$ 8 $m.s^{-1}$	2 km 10 km 20 km	0.5 km 0.7 km 1 km	15 min 60 min 12 h	15 min 30 min 2 h
Wind (vertical)	Global NWP	1 $cm.s^{-1}$ 5 $cm.s^{-1}$ 5 $cm.s^{-1}$	15 km 200 km 500 km	0.5 km 2 km 3 km	60 min 6 h 12 h	6 min 30 min 6 h
	High Res NWP	1 $cm.s^{-1}$ 2 $cm.s^{-1}$ 5 $cm.s^{-1}$	5 km 10 km 20 km	0.5 km 0.65 km 1 km	15 min 60 min 12 h	15 min 30 min 2 h

Colors refers to the goal ; breakthrough ; threshold

State of the art winds extraction from IR sounders

- Existing products:
  - AIRS winds operational at CIMSS
- Upcoming products:
  - Lidar mission. Aeolus to be launched in May 2018.
  - IR sounder 3D winds from EPS-IASI at EUMETSAT
  - IR sounder winds from CRiS, IASI at CIMSS
- Potential mid-term products:
  - IR sounder 3D winds from MTG-IRS
  - IR sounder 3D winds from EPS-SG - IASI-NG
  - New spatial missions with 3D winds as primary product

3D winds algorithm at Eumetsat

- Use of a 3D optical flow model
  - Derivation of all pressure levels in one pass
  - Physical regularization introduced
  - Vertical motion is also considered

  ➢ *u, v, w retrieved at each level on each grid pixel*

- "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 $t + \Delta t$

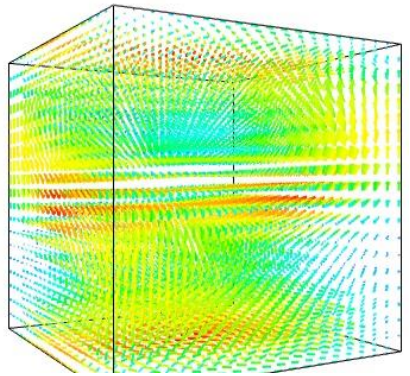
WV mixing ratio

Temperature

Model Settings

Constrained 3D optical flow model

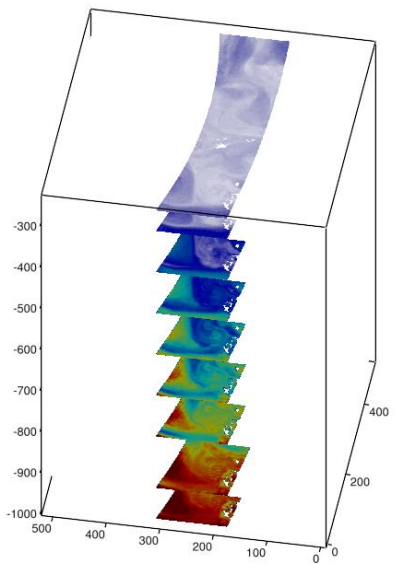
Basic Conservation Laws
Vorticity and Divergence
Regularization
Minimization algorithm



3D wind field

U,V,W fields derived from observations

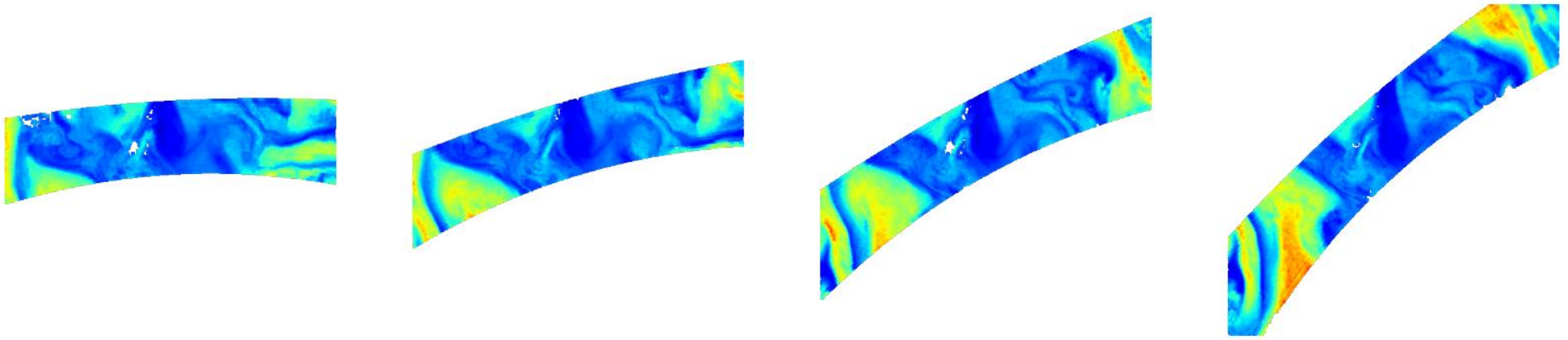
3D winds IASI product



- **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**

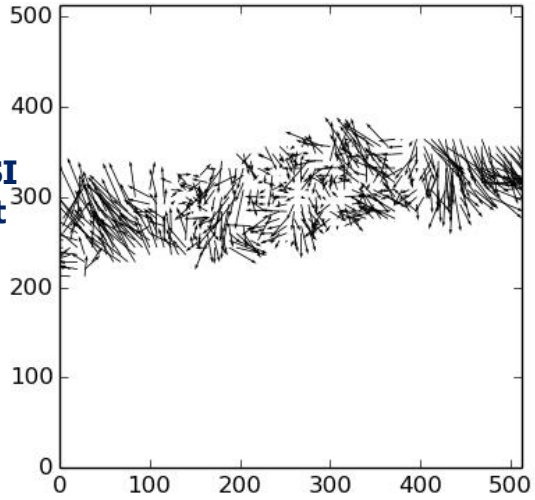
Humidity at 500 hPa for successive overpasses

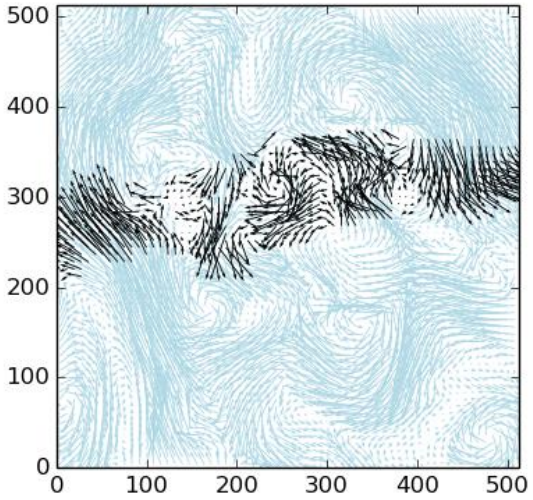
M01 **M02** **M01** **M02**



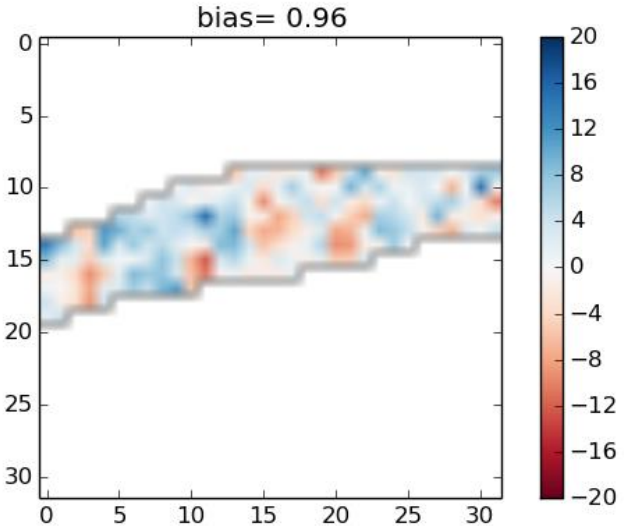
3D winds IASI product actual performances

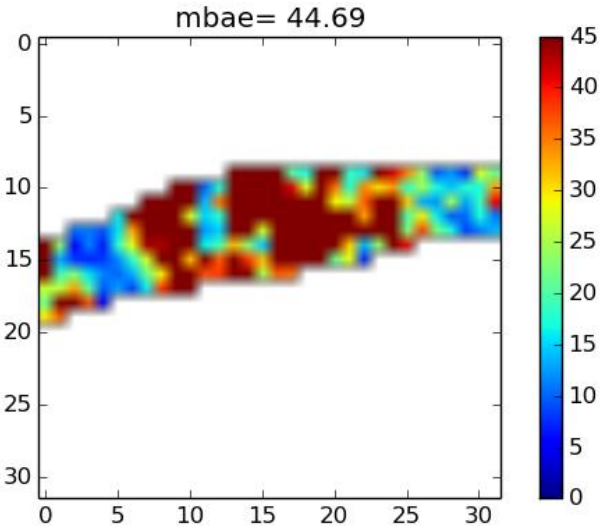
Derived from IASI humidity fields at 700 hPa





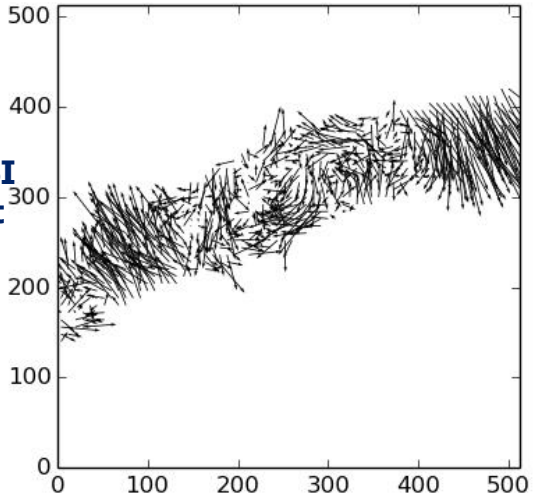
Forecast wind field at 04:00

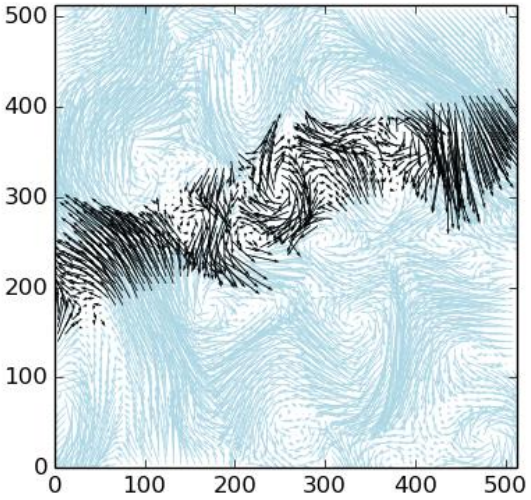


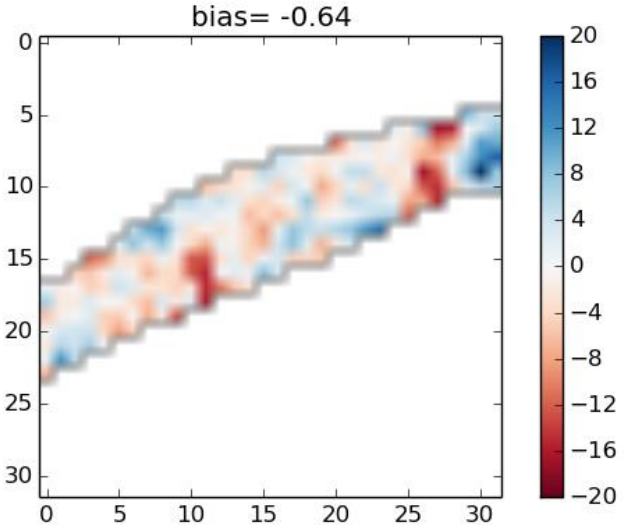


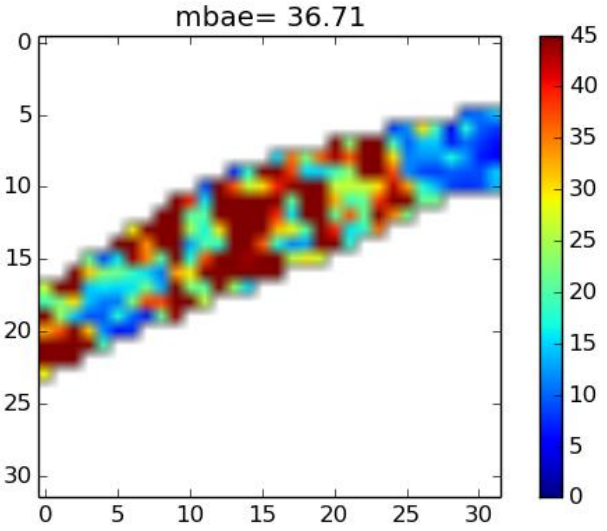
3D winds IASI product actual performances

Derived from IASI humidity fields at 500 hPa









3D winds IASI product characteristics (*Dual*)

- Dual configuration on 9:30 orbit
  - Production in 2018 and reprocessing
  - ~45-55 minutes of separation between successive views

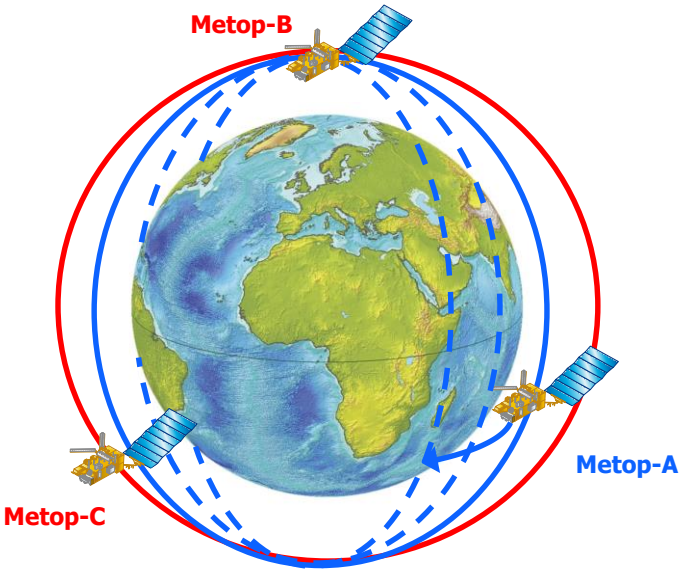
- Coverage
  - Production on Northern and Southern Hemispheres (poleward of 45°)
  - Polar Stereographic grid 512x512 pixels, resolution = 20 km (at the centre)
  - ~1 observation around 9:00-10:00 (local solar time) Same around 21:00-22:00 (ascending part) for latitude 60°.
- Profile
  - 20 levels from 10 to 1000 hPa, covering Low Stratosphere to Surface
  - Vertical resolution: ~0.5 km for LT, ~1.5 km for HT, ~2km for LS
- Timeliness (expected)
  - For SH products: ~1h - 1h30 after South Pole overpass
  - For NH products: ~1h - 2h30 after North Pole overpass (depending on possible secondary dump on McMurdo station)

➢ *Fulfill the Global NWP application requirements*

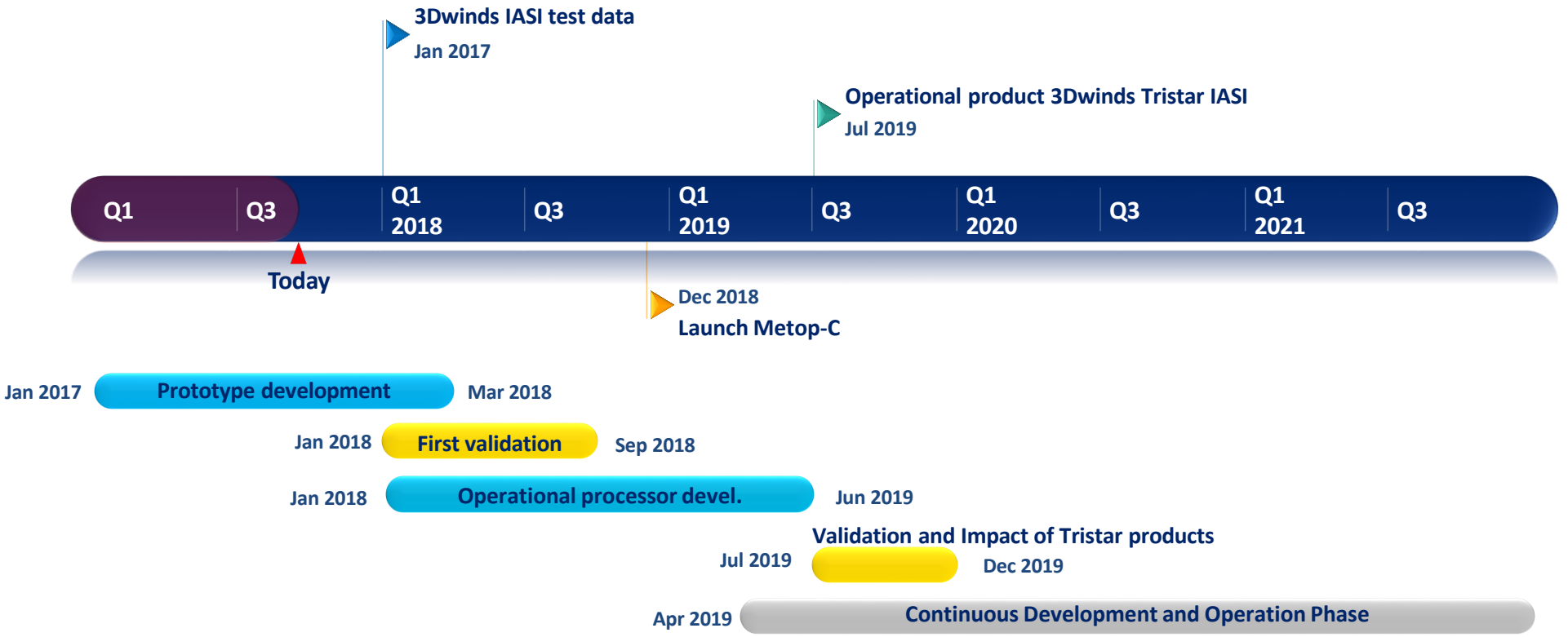
3D winds IASI product characteristics (*Tristar*)

- Tristar configuration on 9:30 orbit
  - Production in 2019 after Metop-C commissioning phase
  - ~30-35 minutes of separation between successive views
  - ➢ *Quality will benefit from the reduced time gap*
- Coverage
  - Production on Northern and Southern Hemispheres (poleward of 45°)
  - Polar Stereographic grid 512x512 pixels, resolution = 20 km (at the centre)
  - ~3-4 successive observations around 9:00-10:00 (local solar time) Same around 21:00-22:00 (ascending part) for latitude 60°.
  - ➢ *Time consistency will benefit from successive observations capability*
- Profile
  - 20 levels from 10 to 1000 hPa, covering Low Stratosphere to Surface
  - Vertical resolution: ~0.5 km for LT, ~1.5 km for HT, ~2km for LS
- Timeliness (expected)
  - For SH products: ~1h - 1h30 after South Pole overpass
  - For NH products: ~1h - 2h30 after North Pole overpass (depending on possible secondary dump on McMurdo station)

➢ *Fulfill the Global NWP application requirements, at threshold for High Res NWP.*



3D winds IASI products development timeline



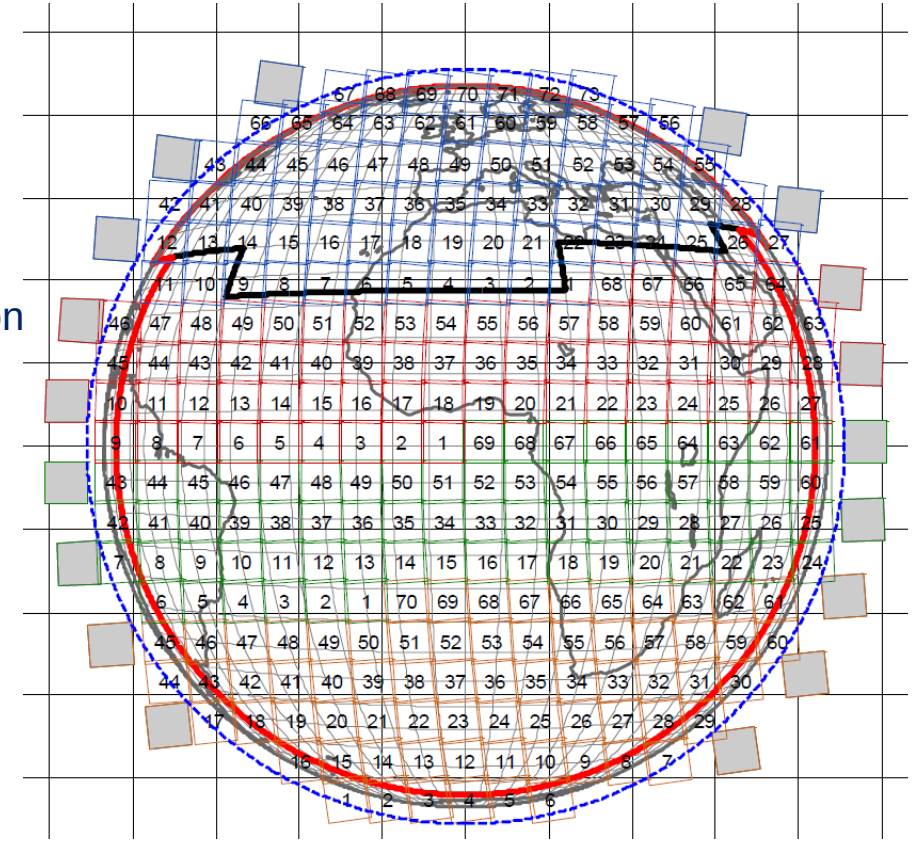
Summary

- Conclusion
  - Test periode of IASI 3D winds available end 2017
  - Tristar configuration production poleward of 45 deg latitude, with 35 min temporal gap between consecutive IASI humidity fields
  - Low Stratospheric winds derived from IASI ozone product
  - …
- Perspectives
  - Scientific validation against lidar network, RadObs, FC, Aeolus
  - Comparison with CIMSS AIRS winds
  - Adaptation to IASI-NG
  - Adaptation to MTG-IRS

3D winds MTG-IRS product characteristics

- Coverage
  - 4 LAC (Local Area Coverage) defined
  - LAC4 covers Europe, Mediterranean Basin and North Atlantic. It is acquired every 30 minutes.
  - Pixel sampling = 4 km at SSP
  - ➢ *Spatial resolution enhanced will allow the use in High Res NWP application*
- Profile
  - 20 levels from 10 to 1000 hPa, covering Low Stratosphere to Surface
- Frequency
  - Number of products per day depends on acquisition scheme.
  - Current baseline:
    - 48 products for LAC4
    - 16 products for LAC3
    - 12 products for LAC2
    - 8 products for LAC1
- Timeliness (expected)
  - ~45 minutes after LAC acquisition

➢ *Fulfill the Global NWP and High Res NWP application requirements*



Thanks

Additional slides

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

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

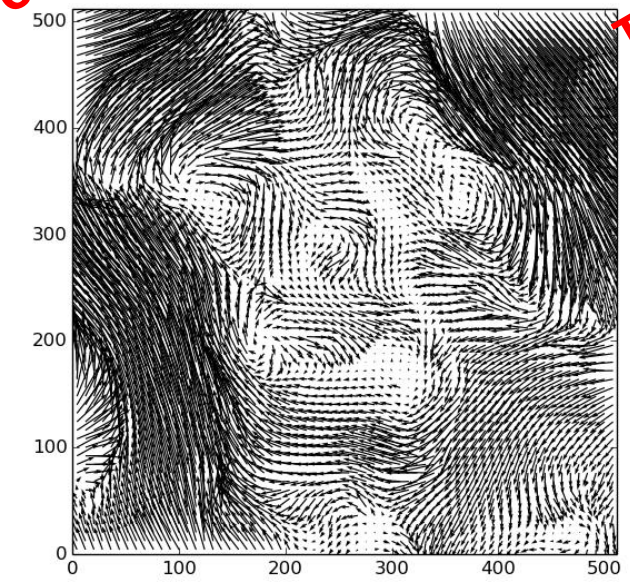
- Self-similar regularization
  - Turbulence statistics preserved
  - Depending on the pressure level
- Initialization and spin-up process reviewed
- Same two steps in the main minimization loop
  - Alternating vertical and horizontal minimizations using efficient mathematical algorithm
    - ➢ Vertical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

Need of concurrent inversion

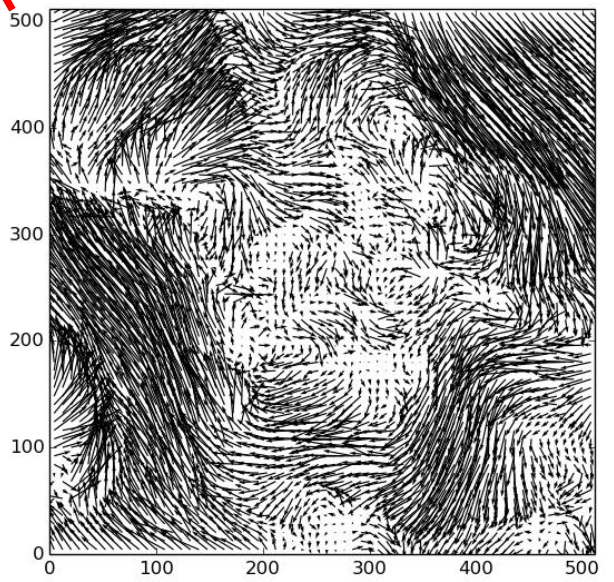
- No tracer is perfect to track winds at all levels
- Transition zone around 300 hPa
  - No more water vapor above over polar regions
  - Low concentration of ozone below, even more in the ozone hole

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

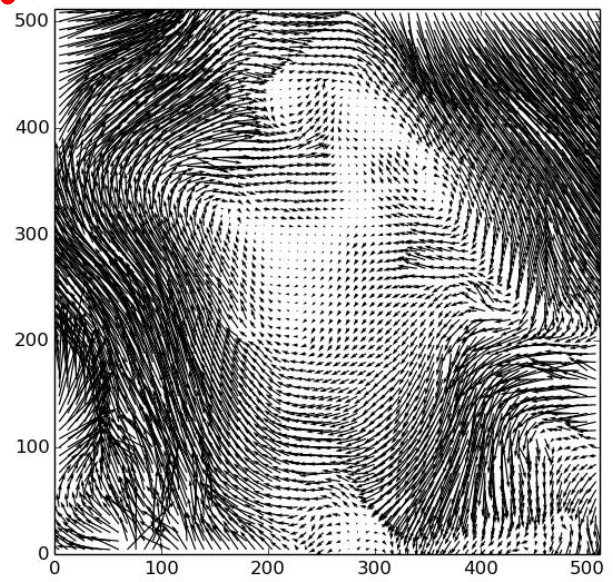
Ozone



Temperature



Water vapour

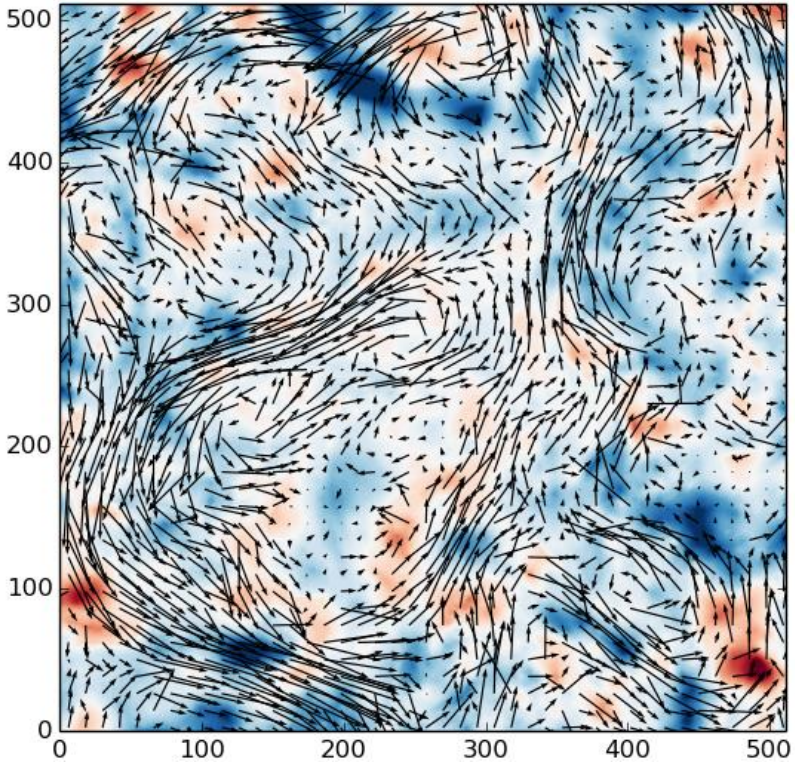


Adding the true 3rd dimension

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

U,V,W at 500 hPa
Northern Polar Region
on 21 June 2013 at 12:00Z

Derived from Q fields



Forecast fields