3D wind fields extracted from EUMETSAT IASI Level 2 products

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

<table>
<thead>
<tr>
<th>Application</th>
<th>Uncertainty</th>
<th>Horizontal resolution</th>
<th>Vertical resolution</th>
<th>Observation cycle</th>
<th>Timeliness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind (horizontal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global NWP</td>
<td>1 m.s⁻¹</td>
<td>15 km</td>
<td>0.5 km</td>
<td>60 min</td>
<td>6 min</td>
</tr>
<tr>
<td></td>
<td>3 m.s⁻¹</td>
<td>100 km</td>
<td>1 km</td>
<td>6 h</td>
<td>30 min</td>
</tr>
<tr>
<td></td>
<td>8 m.s⁻¹</td>
<td>500 km</td>
<td>3 km</td>
<td>12 h</td>
<td>6 h</td>
</tr>
<tr>
<td>High Res NWP</td>
<td>1 m.s⁻¹</td>
<td>2 km</td>
<td>0.5 km</td>
<td>15 min</td>
<td>15 min</td>
</tr>
<tr>
<td></td>
<td>3 m.s⁻¹</td>
<td>10 km</td>
<td>0.7 km</td>
<td>60 min</td>
<td>30 min</td>
</tr>
<tr>
<td></td>
<td>8 m.s⁻¹</td>
<td>20 km</td>
<td>1 km</td>
<td>12 h</td>
<td>2 h</td>
</tr>
<tr>
<td>Wind (vertical)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global NWP</td>
<td>1 cm.s⁻¹</td>
<td>15 km</td>
<td>0.5 km</td>
<td>60 min</td>
<td>6 min</td>
</tr>
<tr>
<td></td>
<td>5 cm.s⁻¹</td>
<td>200 km</td>
<td>2 km</td>
<td>6 h</td>
<td>30 min</td>
</tr>
<tr>
<td></td>
<td>5 cm.s⁻¹</td>
<td>500 km</td>
<td>3 km</td>
<td>12 h</td>
<td>6 h</td>
</tr>
<tr>
<td>High Res NWP</td>
<td>1 cm.s⁻¹</td>
<td>5 km</td>
<td>0.5 km</td>
<td>15 min</td>
<td>15 min</td>
</tr>
<tr>
<td></td>
<td>2 cm.s⁻¹</td>
<td>10 km</td>
<td>0.65 km</td>
<td>60 min</td>
<td>30 min</td>
</tr>
<tr>
<td></td>
<td>5 cm.s⁻¹</td>
<td>20 km</td>
<td>1 km</td>
<td>12 h</td>
<td>2 h</td>
</tr>
</tbody>
</table>

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

Constrained 3D optical flow model

Basic Conservation Laws
Vorticity and Divergence
Regularization
Minimization algorithm

Model Settings

At Time $t$
- WV mixing ratio
- Temperature

At Time $t + \Delta t$
- WV mixing ratio
- Temperature

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
3D winds IASI product actual performances

Derived from IASI humidity fields at 700 hPa

Forecast wind field at 04:00

bias = 0.96

mbae = 44.69
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
  - \(\sim 45-55\) 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)
  - \(\sim 1\) 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: \(\sim 0.5\) km for LT, \(\sim 1.5\) km for HT, \(\sim 2\) km for LS

- Timeliness (expected)
  - For SH products: \(\sim 1\)h - 1h30 after South Pole overpass
  - For NH products: \(\sim 1\)h - 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

- **3Dwinds IASI test data**
  - Jan 2017

- **Operational product 3Dwinds Tristar IASI**
  - Jul 2019

- **Protoype development**
  - Jan 2017 to Mar 2018

- **First validation**
  - Jan 2018 to Sep 2018

- **Operational processor devel.**
  - Jan 2018 to Jun 2019

- **Validation and Impact of Tristar products**
  - Jul 2019 to Dec 2019

- **Continuous Development and Operation Phase**
  - Apr 2019 onwards
Summary

Conclusion
- Test period 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
Adding the true 3\textsuperscript{rd} dimension

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

\textit{U,V,W at 500 hPa}

Northern Polar Region

\textit{Derived from Q fields on 21 June 2013 at 12:00Z}

\textit{Forecast fields}