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Review of the progress with image processing by Ukraine/France team

Content of the preesentation

- Routine use of the basic algorithm
- Multichannel applications of the basic algorithm
- Image assimilation in the shallow water equations: Euler scheme
- Image assimilation in the shallow water equations: Leap-frog scheme
- NEMO installation in the Black Sea

Routine use of the basic algorithm

Basic Equations

$$\frac{\partial T}{\partial t} + u \cdot \frac{\partial T}{\partial x} + v \cdot \frac{\partial T}{\partial y} = \kappa \cdot \nabla^2 T$$

$$\frac{\partial u}{\partial t} = 0 \qquad \frac{\partial v}{\partial t} = 0$$

Cost Function

$$J = \frac{1}{2} \cdot \sum_{1}^{Q} \iint \left(T(x, y, t_q) - T^*(x, y, t_q) \right)^2 dx \cdot dy$$

$$+ \frac{1}{2} \alpha \cdot \int \iint \left((u_x)^2 + (u_y)^2 + (v_x)^2 + (v_y)^2 \right) \cdot dt \cdot dx \cdot dy$$

$$+ \frac{1}{2} \beta \cdot \int \iint \left(u_x + v_y \right)^2 \cdot dt \cdot dx \cdot dy = \min$$

Adjoint Equations

$$\frac{\partial \tilde{T}}{\partial t} + \frac{\partial\left(\overline{u} \cdot \tilde{T}\right)}{\partial x} + \frac{\partial\left(\overline{v} \cdot \tilde{T}\right)}{\partial y} + \kappa \cdot \nabla^2 \tilde{T} = \sum_{1}^{Q} \int \left(\overline{T}(x, y, t) - T^*(x, y, t)\right) \cdot \delta(t - t_q) \cdot dt$$

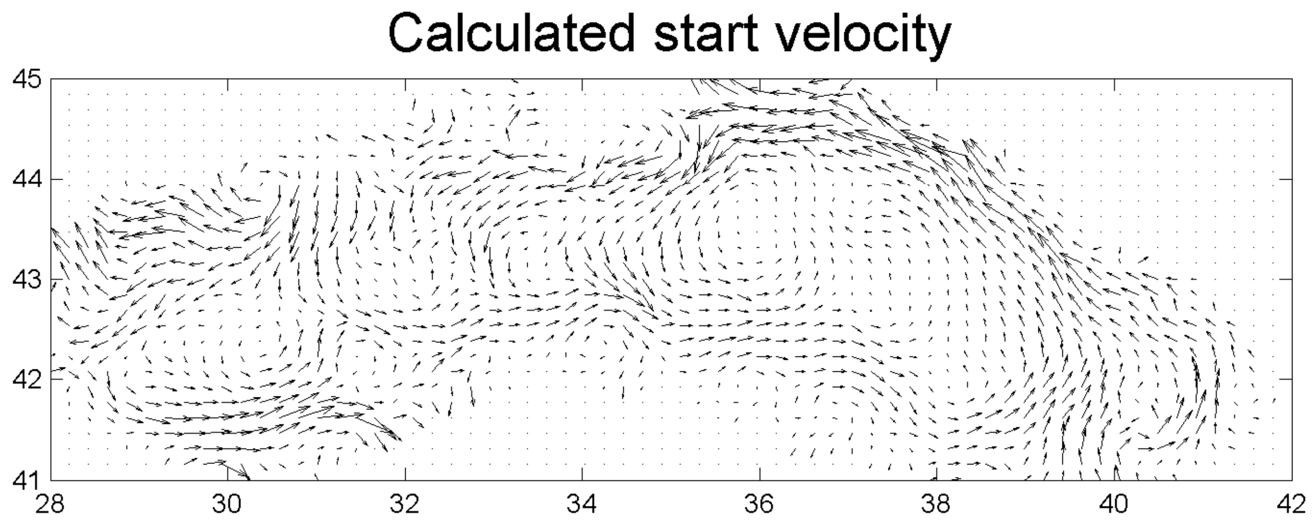
$$\frac{\partial \tilde{u}}{\partial t} - \tilde{T} \cdot \frac{\partial \overline{T}}{\partial x} + \alpha \cdot \nabla^2 \overline{u} + \beta \cdot \left(\frac{\partial^2 \overline{u}}{\partial x^2} + \frac{\partial^2 \overline{v}}{\partial x \partial y} \right) = 0$$

$$\frac{\partial \tilde{v}}{\partial t} - \tilde{T} \cdot \frac{\partial \overline{T}}{\partial y} + \alpha \cdot \nabla^2 \overline{v} + \beta \cdot \left(\frac{\partial^2 \overline{u}}{\partial x \partial y} + \frac{\partial^2 \overline{v}}{\partial y^2} \right) = 0$$

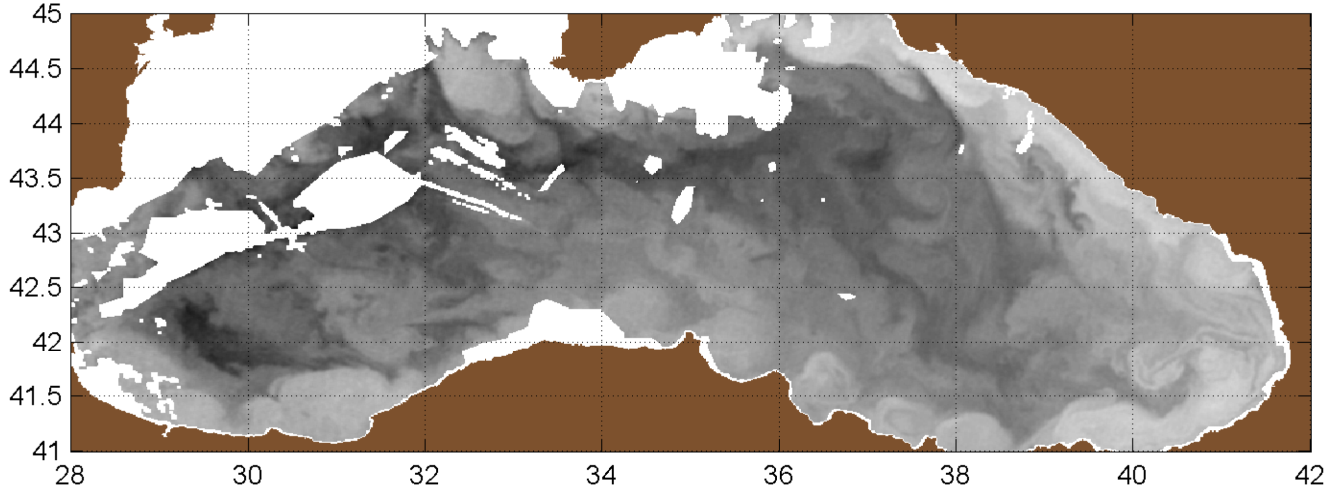
Improvement of the code

- Korotaev – initial code
- Huot – improved code (partly cloudy images)
- Plotnikov – code revision for the routine use

Basin-scale image processing



SST reconstruction under clouds



Problems

- Stops at the local extreme
- Look on the improved version of M1QN3 for the search of the global extreme

Multichannel applications
of
the basic algorithm

Simple Generalization

$$\frac{\partial T}{\partial t} + u \cdot \frac{\partial T}{\partial x} + v \cdot \frac{\partial T}{\partial y} = \kappa \cdot \nabla^2 T$$

$$\frac{\partial S}{\partial t} + u \cdot \frac{\partial S}{\partial x} + v \cdot \frac{\partial S}{\partial y} = \kappa \cdot \nabla^2 S$$

New Cost Function

$$J = \frac{1}{2} \cdot \sum_{1}^{Q} \iint \left(T(x, y, t_q) - T^*(x, y, t_q)\right)^2 dx \cdot dy + \frac{K}{2} \cdot \sum_{1}^{Q} \iint \left(S(x, y, t_q) - S^*(x, y, t_q)\right)^2 dx \cdot dy$$

$$+ \frac{1}{2} \alpha \cdot \int \iiint \left((u_x)^2 + (u_y)^2 + (v_x)^2 + (v_y)^2 \right) \cdot dt \cdot dx \cdot dy$$

$$+ \frac{1}{2} \beta \cdot \int \iiint (u_x + v_y)^2 \cdot dt \cdot dx \cdot dy = \min$$

Adjoint Equations

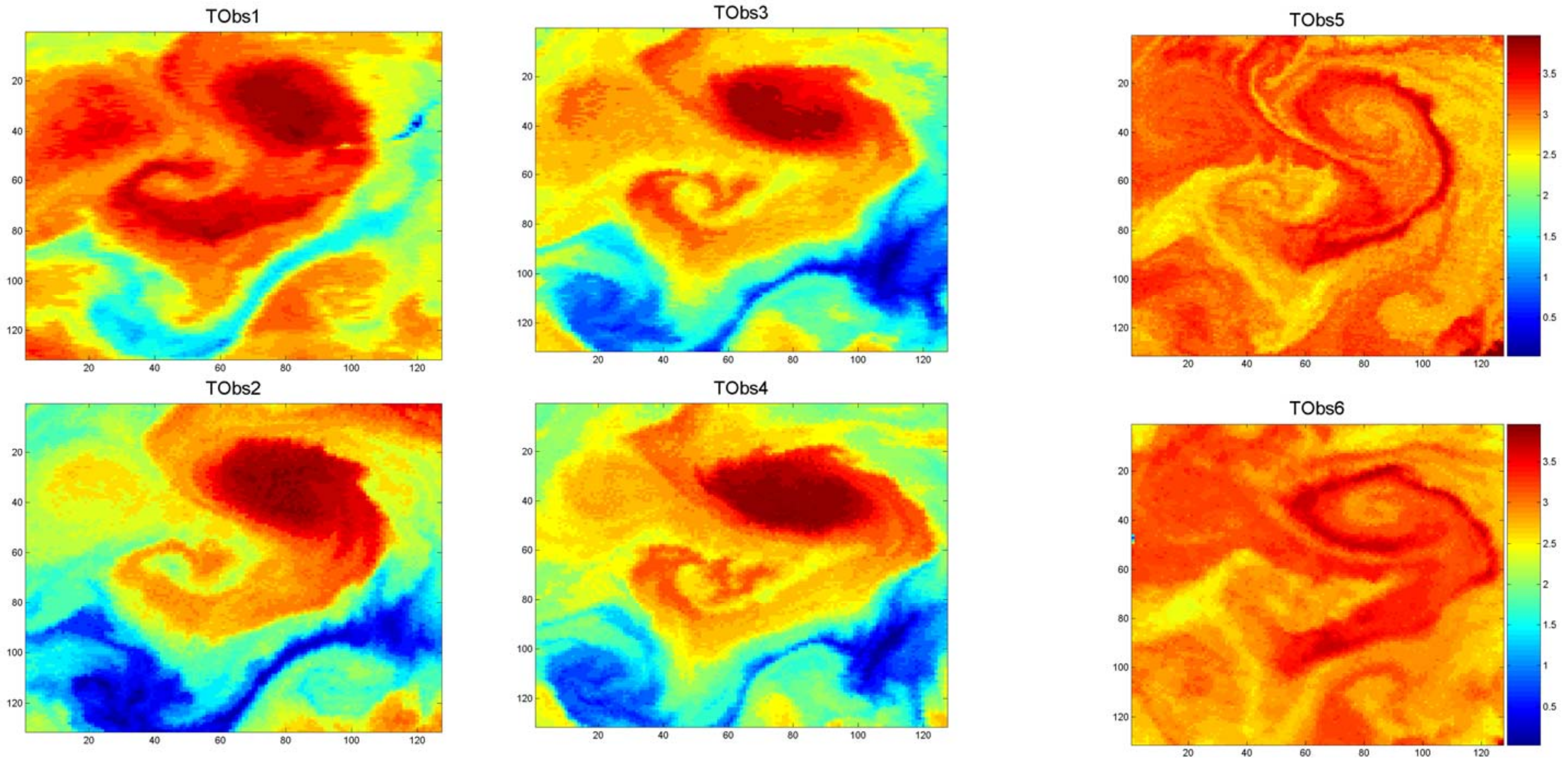
$$\frac{\partial\tilde{T}}{\partial t}+\frac{\partial\left(\overline{u}\cdot\tilde{T}\right)}{\partial x}+\frac{\partial\left(\overline{v}\cdot\tilde{T}\right)}{\partial y}+\kappa\cdot\nabla^2\tilde{T}=\sum_1^Q\int\left(\overline{T}(x,y,t)-T^*(x,y,t)\right)\cdot\delta(t-t_q)\cdot dt$$

$$\frac{\partial\tilde{S}}{\partial t}+\frac{\partial\left(\overline{u}\cdot\tilde{S}\right)}{\partial x}+\frac{\partial\left(\overline{v}\cdot\tilde{S}\right)}{\partial y}+\kappa\cdot\nabla^2\tilde{S}=\sum_1^Q\int\left(\overline{S}(x,y,t)-S^*(x,y,t)\right)\cdot\delta(t-t_q)\cdot dt$$

$$\frac{\partial\tilde{u}}{\partial t}-\tilde{T}\cdot\frac{\partial\overline{T}}{\partial x}-\tilde{S}\cdot\frac{\partial\overline{S}}{\partial x}+\alpha\cdot\nabla^2\overline{u}+\beta\cdot\left(\frac{\partial^2\overline{u}}{\partial x^2}+\frac{\partial^2\overline{v}}{\partial x\partial y}\right)=0$$

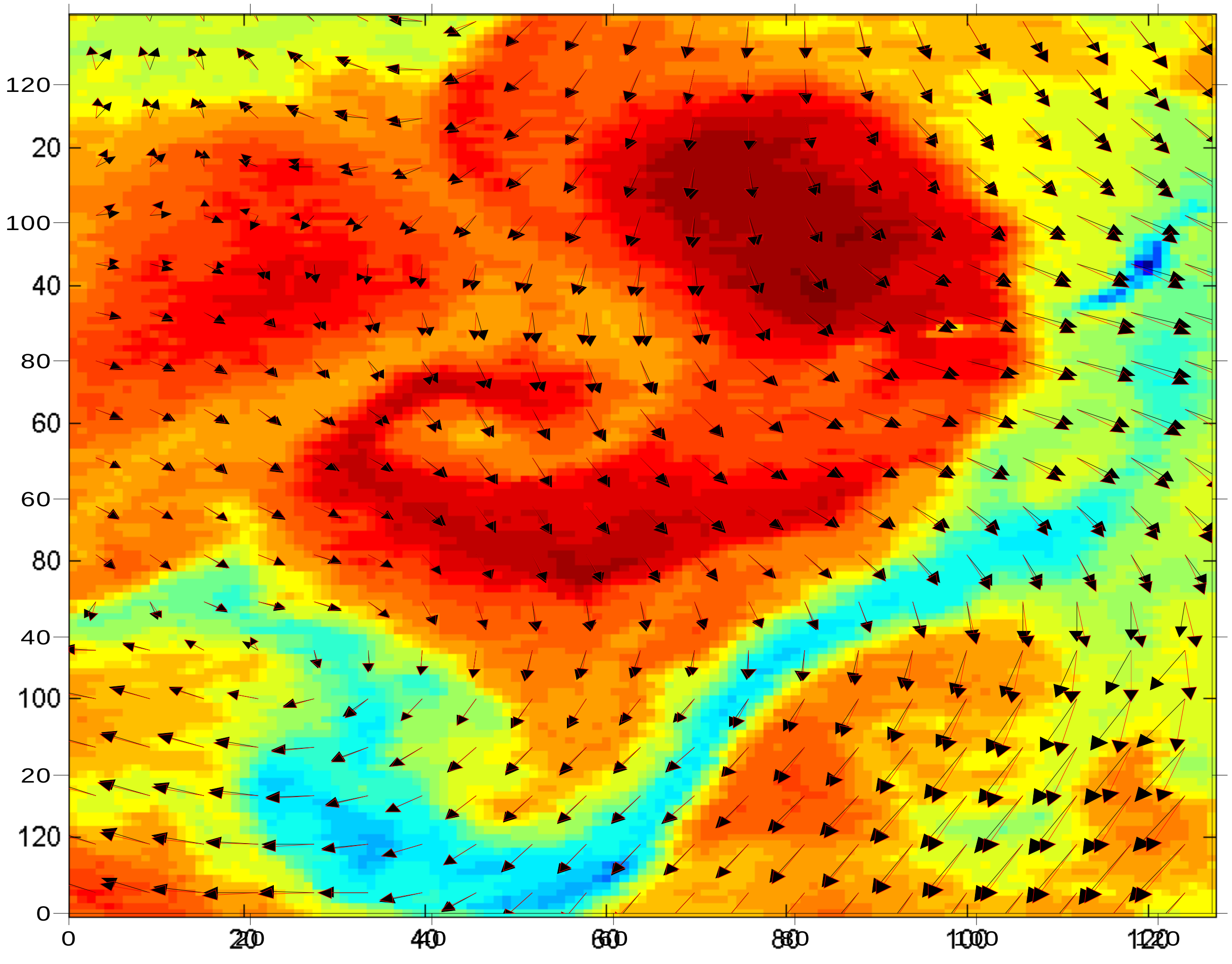
$$\frac{\partial\tilde{v}}{\partial t}-\tilde{T}\cdot\frac{\partial\overline{T}}{\partial y}-\tilde{S}\cdot\frac{\partial\overline{S}}{\partial y}+\alpha\cdot\nabla^2\overline{v}+\beta\cdot\left(\frac{\partial^2\overline{u}}{\partial x\partial y}+\frac{\partial^2\overline{v}}{\partial y^2}\right)=0$$

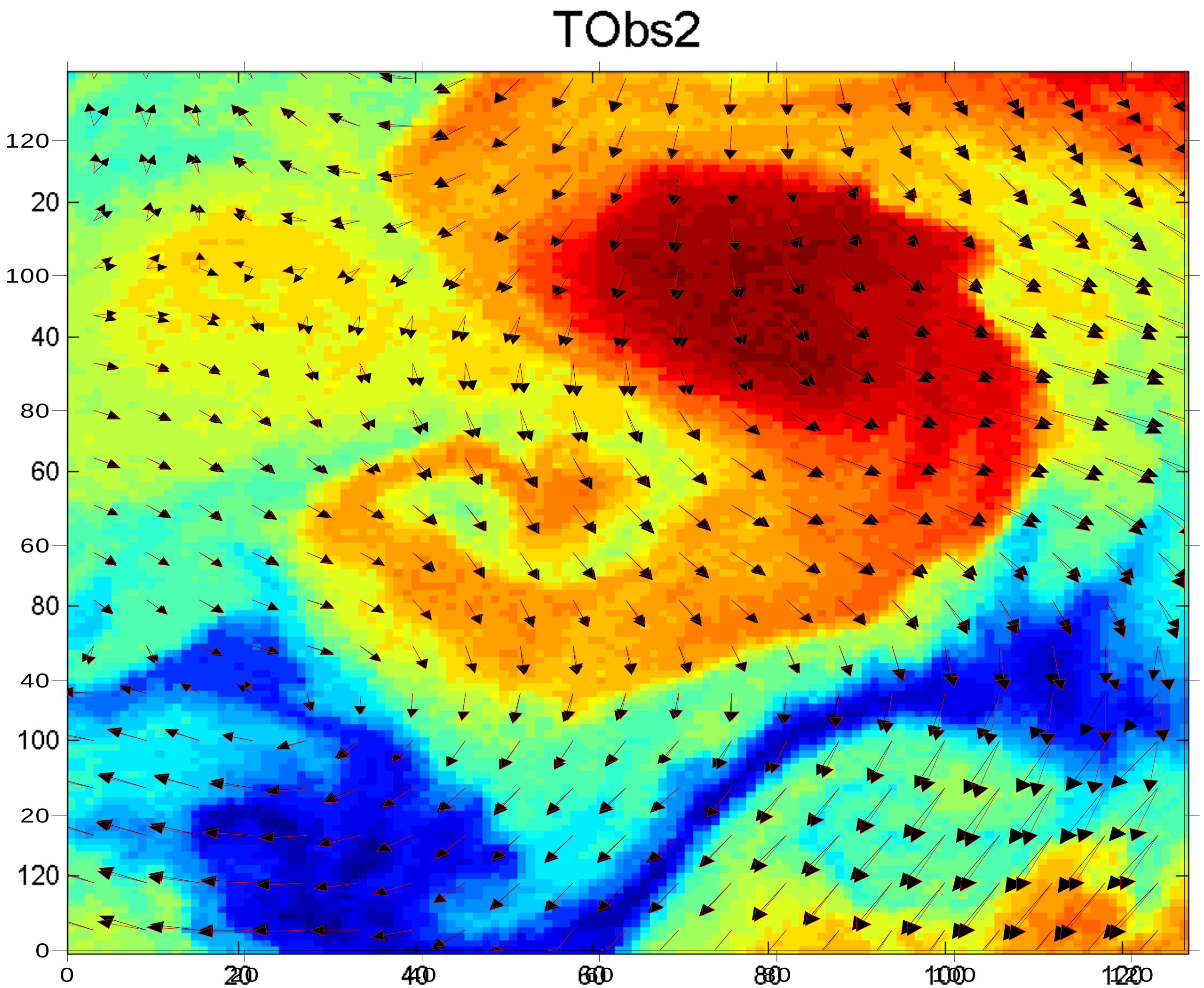
Example 2. Processing of four IR images and two visible band images

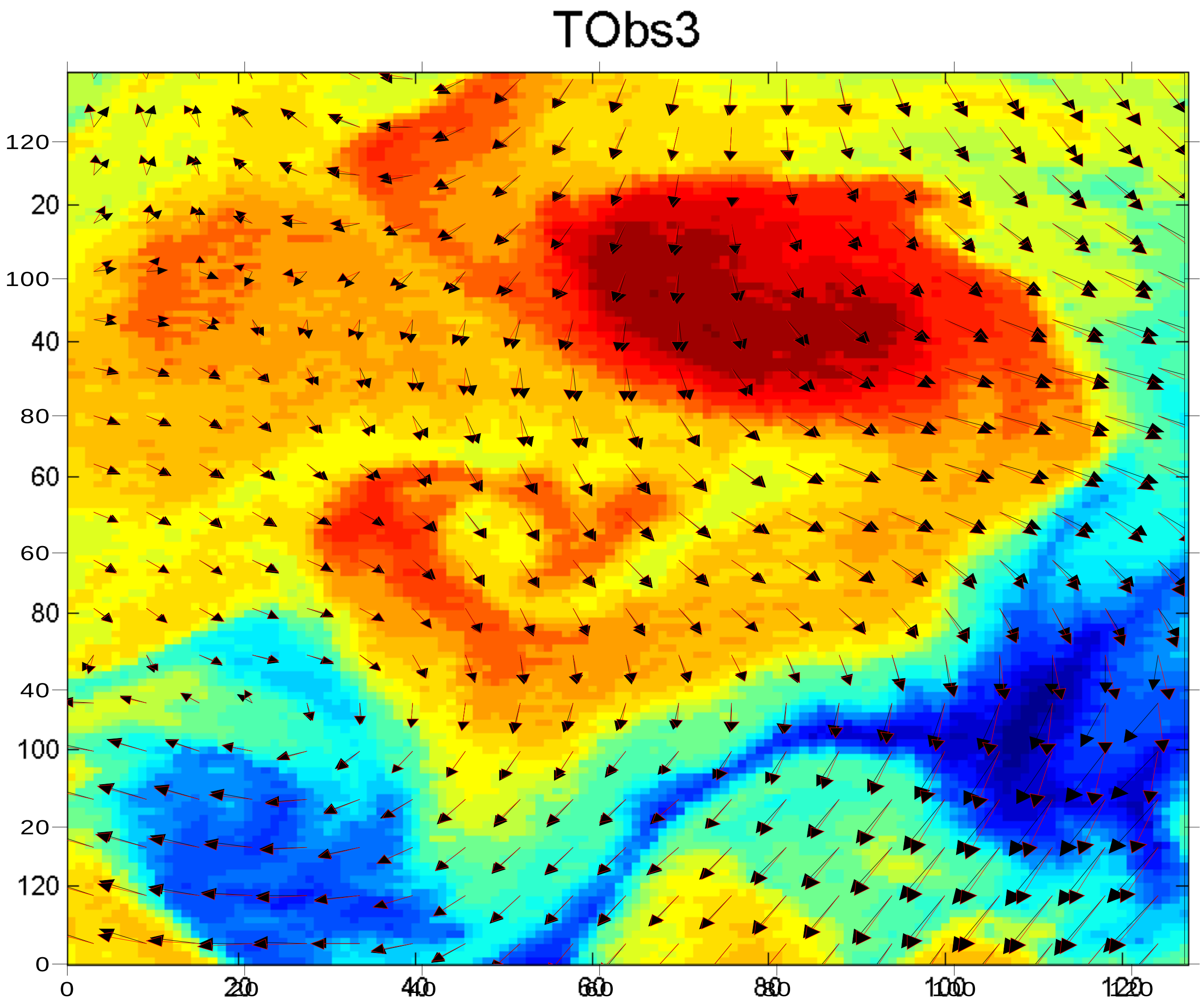


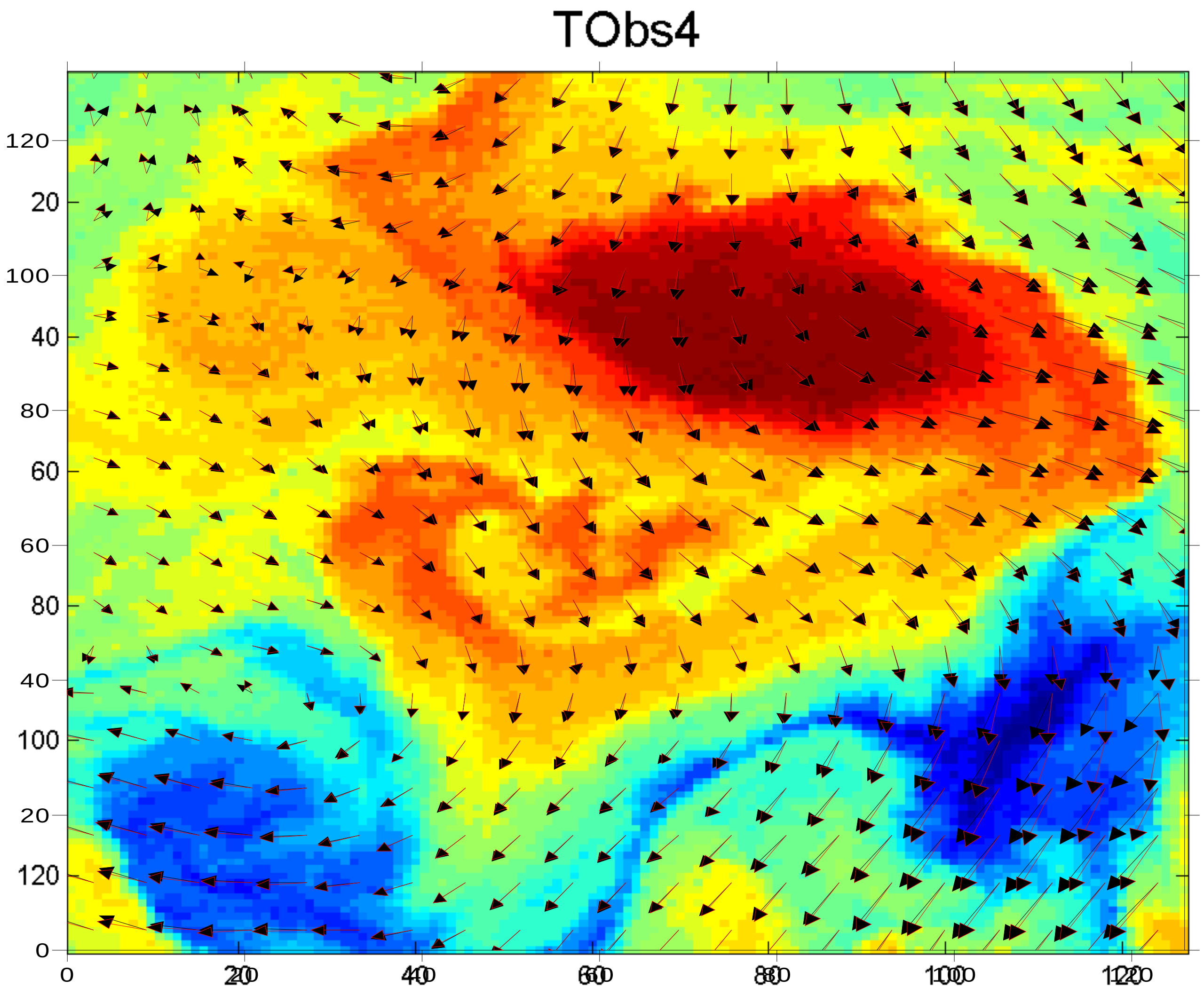
Simulated velocities overlapped on the IR images

TObs1



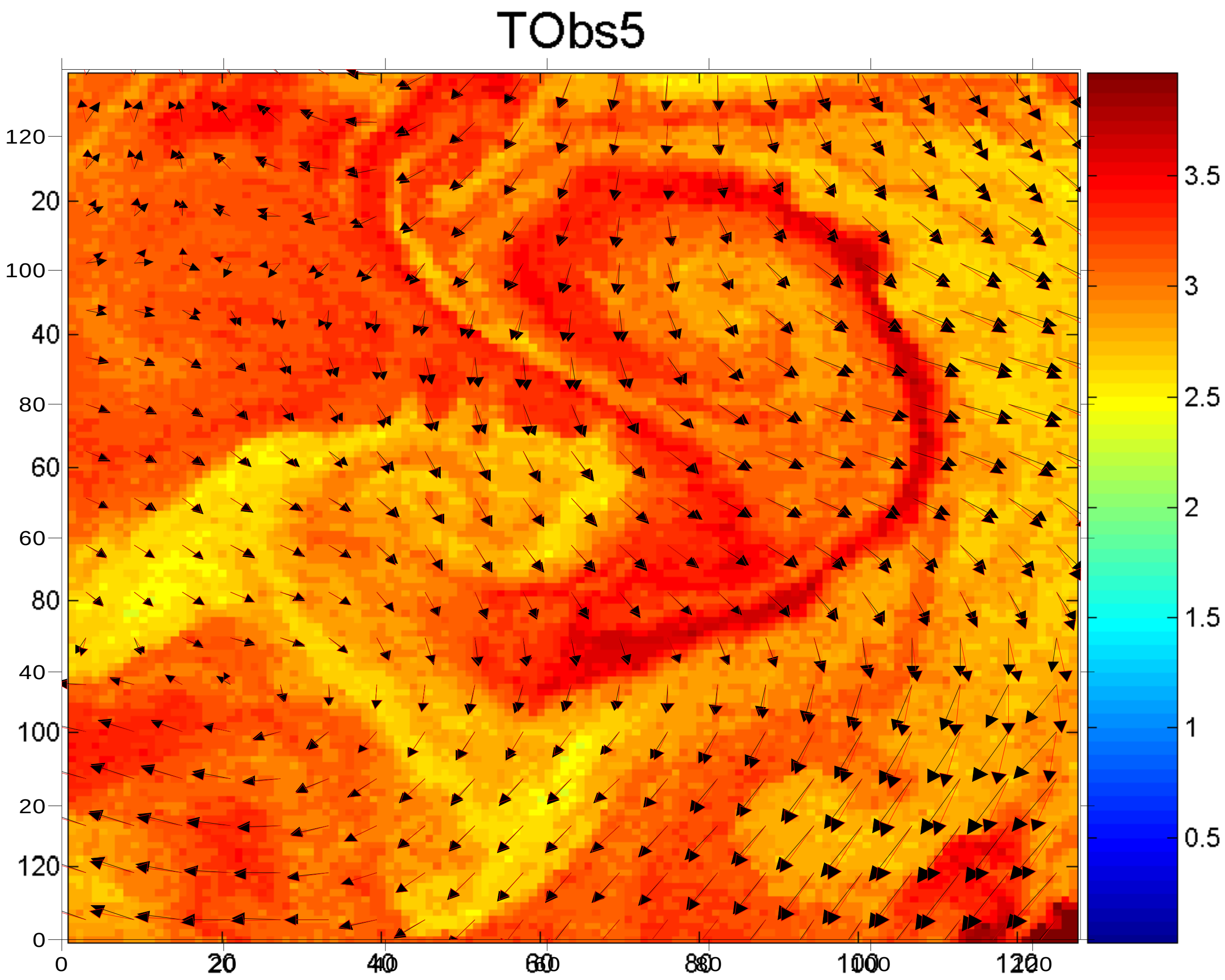

TObs2
120
20
100
40
80
60
60
80
40
100
20
120
0
0
20
40
60
80
100
120


TObs3
120
20
100
40
80
60
60
80
40
100
20
120
0
0
20
40
60
80
100
120

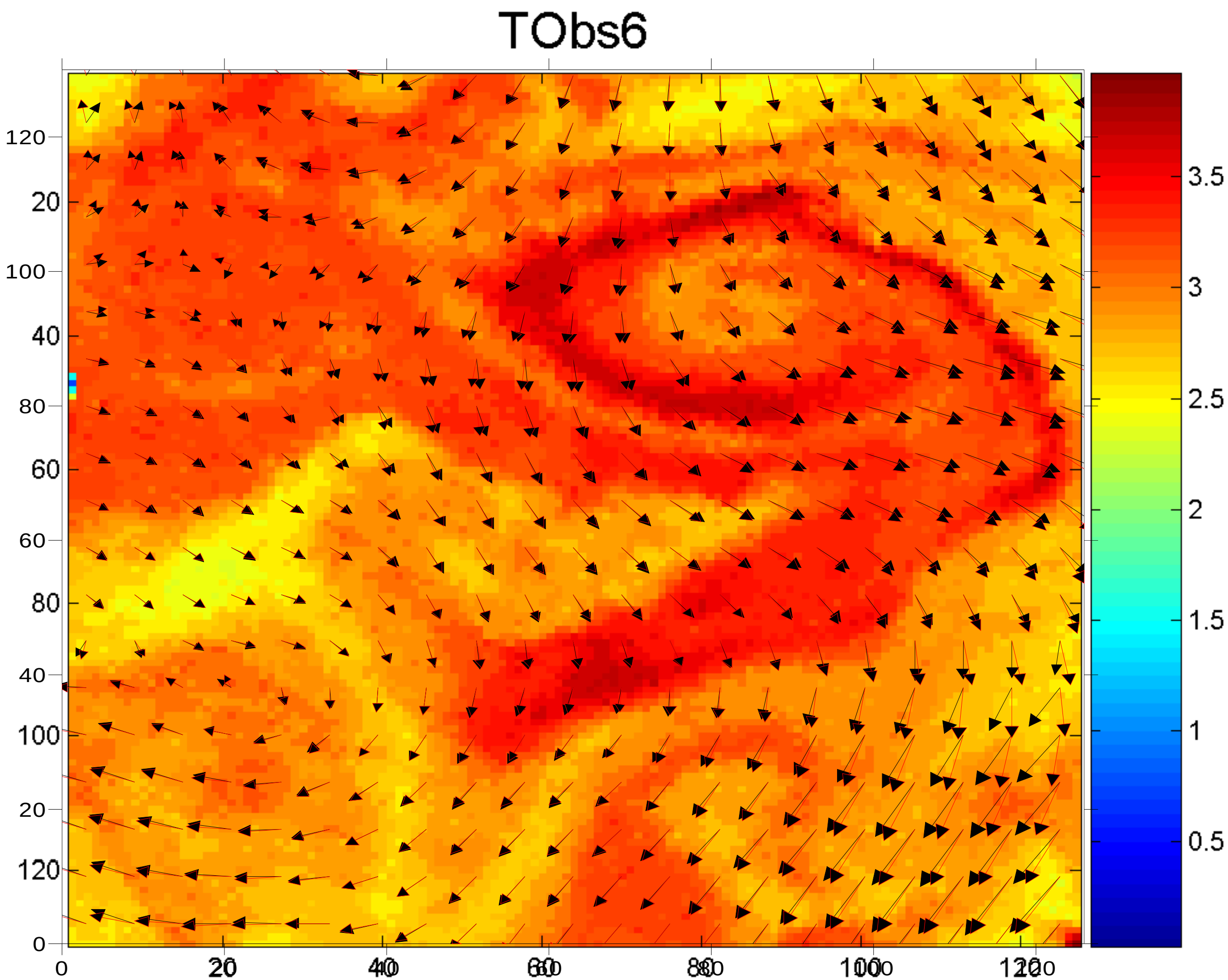


TObs4
120
20
100
40
80
60
60
80
40
100
20
120
0
0
20
40
60
80
100
120

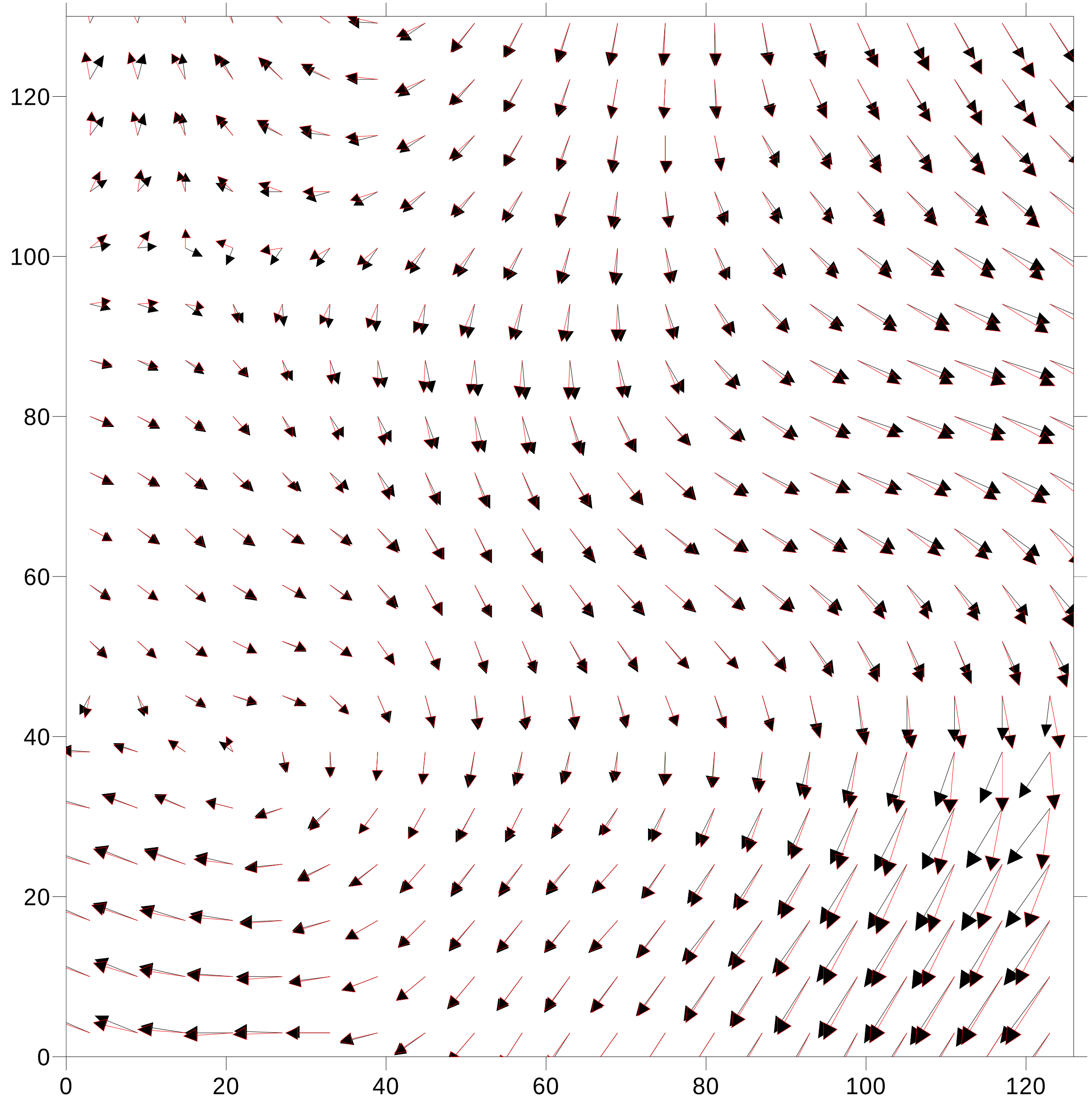
Simulated velocities overlapped on the visible band images



TObs5
120
20
100
40
80
60
60
80
40
100
20
120
0
0
20
40
60
80
100
120
3.5
3
2.5
2
1.5
1
0.5


TObs6
3.5
3
2.5
2
1.5
1
0.5

Simulated velocity based on the processing of IR or IR and visible band images



- Multichannel images can be efficiently processed
- More images can be collected during one-two days
- Algorithm looks more stable when more images is processed
- Prospect of the atmospheric correction

Image assimilation in the shallow water equations: Euler scheme

- Algorithm is ready
- Finding with rescaling- need to look on the covariance matrix introduction
- Still too slow and seems not very stable

Image assimilation in the shallow water equations: Leap-frog scheme

- Numerical algorithm with Iceling filter is converted to the two layer scheme in time
- Algorithm is prepared
- Code should to be written

NEMO installation in the Black Sea

- Arthur inviteed Artem in Grenoble
- NEMO code is adapted to the Black Sea geography
- Intercomparison runs with MHI model are on the way
- Expectation is to use NEMO data assimilation algorithm to assimilate images in 3D model

Resume

- Soon will be possible assimilate image sequence in 3D model
- “Basic” algorithm is too restrictive by amount of cloud-free image sequences
- Parameters of the Image Data Base for the processing using Shallow Water equations should be defined and its efficiency should be evaluated
- Single image processing concept should be elaborated in future