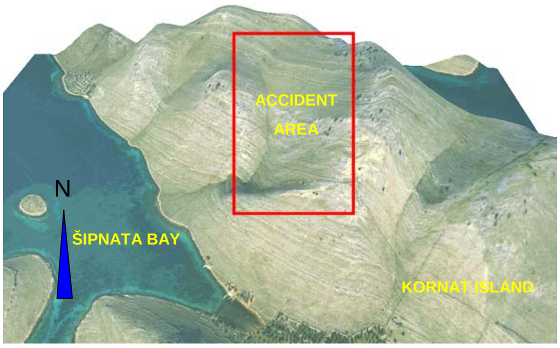
Faculty of Electrical and Mechanical Engineering and Naval Architecture
University of Split - Croatia

WORKSHOP „Forest Fire Behavior Research and Kornati Fire Accident Facts and Preliminary Research Results“



Doc.dr.sc. Branko Klarin

Aerodynamic aspects of the Kornati accident –

Flows prediction in the valley and over the hills

Split, february 2008.

Ver.1.02.

Aerodynamic aspects of the Kornati accident –
Flows prediction in the valley and over the hills

Themes included in presentation:

1. PRESCRIBED AIR FLOWS ABOVE THE ŠIPNATA BAY
2. ASSUMED AIR FLOWS OVER THE VALLEY
3. BASIC FACTS AND ASSUMPTIONS
4. POSSIBLE OCCURENCES IN ASSUMED FLOWS
5. ASSUMED FIRE PROGRESS
6. DISCUSSION

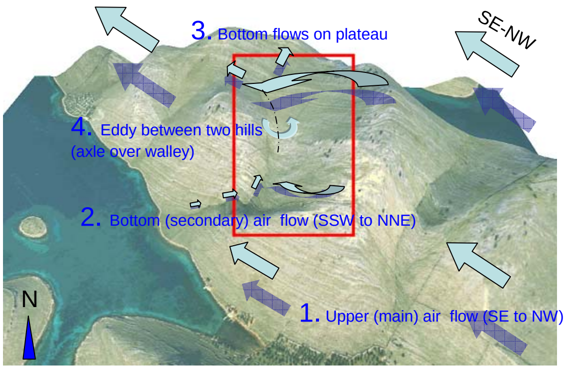
FURTHER RESEARCH PROPOSAL

1. PRESCRIBED AIR FLOWS ABOVE THE ŠIPNATA BAY

Two main flows are present:

a) Primary air flow (atmospheric main stream - SE to NW, source DHMZ),

b) Secondary flows (orography caused streams – different directions).



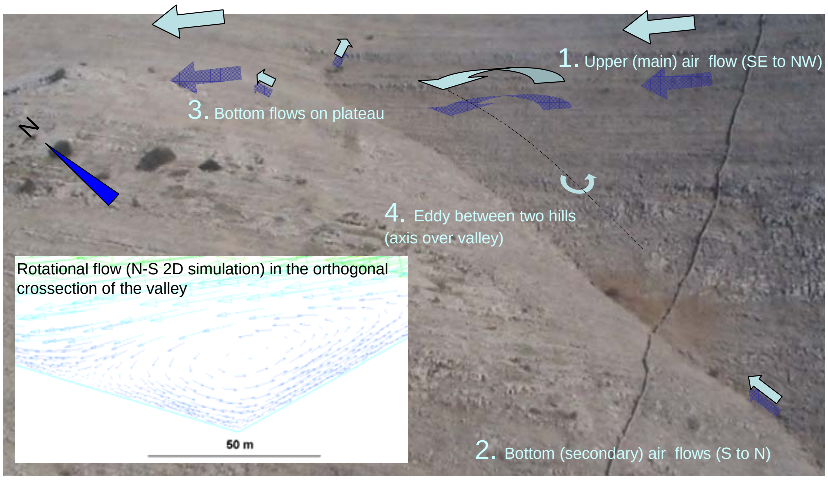
2. ASSUMED AIR FLOWS OVER THE VALLEY

Three flows over the valley:

a) main stream - SE to NW,

b) valley flow, Internal valley flow: b.1) flow along valley axle, b.2) rotational flow

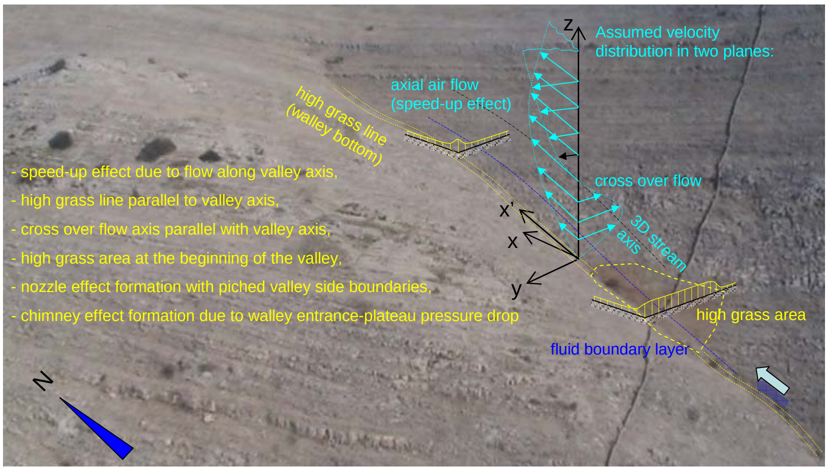
c) plateau flow.



3. BASIC FACTS AND ASSUMPTIONS

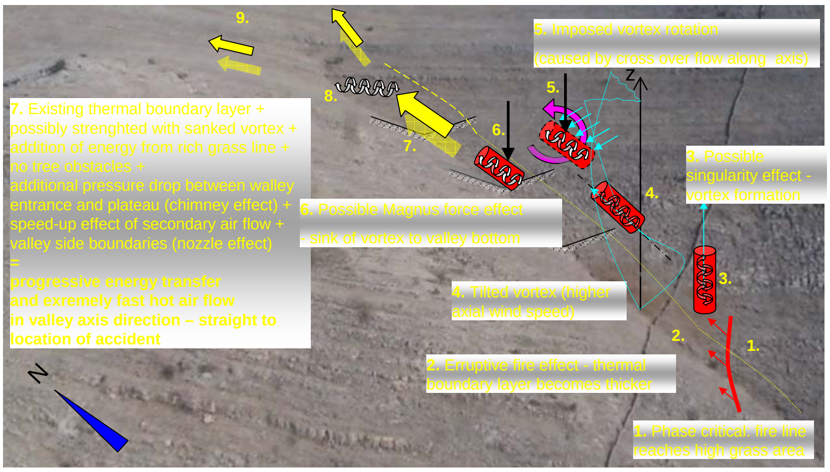
Facts concurance:

flow, walley axle, high grass line, cross over flow axle, high grass area, walley side boundaries



4. POSSIBLE OCCURENCES IN ASSUMED FLOWS

9. Expansion and propagation of fluid and thermal B.L. **8.** Turbulence and vortexes due to ground obstacles - tunneling



5. ASSUMED FIRE PROGRESS

ANNOTATION: followed text mainly based on assumptions, particulary fire line development.

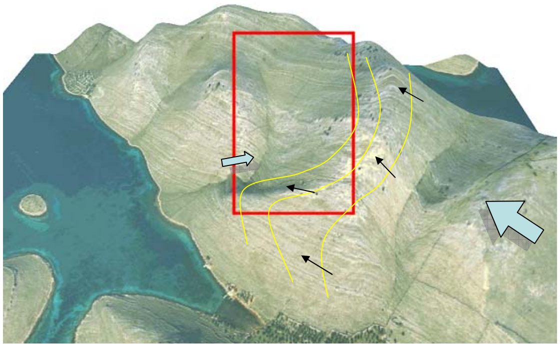
PHASE I - SITE PREHEATING

CONDITIONS:
Fire: expected development
Flow:
- low speed winds, main flow NE to SW, secondary flow through walley S to N
- usual formation of aerodynamic flows (velocity distribution hill and on walley entery),
- slightly exposed aerodynamic boundary layer,
- complex terrain,
- speed-up effect,

INCIDENCE:
Characterized by incidence that nearby at the same time:
- bottom fire line reach first mid-valley grass
- upper fire line reaches plateau above site caused additional pressure drop

OUTCOME:
Formation of rising upward flow.
Main flow characteristics:
- slow speed on valley axes,
- expected grass burning speed.

INDICATION:
Begining of the hot air cummulation.
Rare trees burned up to 0,7 m height
(fluid & thermal B.L. thickness indication).



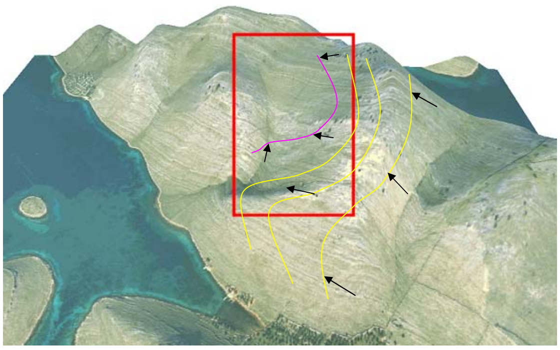
PHASE II – CRITICAL

CONDITIONS:
Fire: Fire line reach high grass area, unexpected and stohastic development
Flow:
- faster winds, main flow NE to SW, secondary flow through valley S to N
- unusual formation of aerodynamic flows (velocity distribution over terrain following walley entery)
- very exposed aerodynamic boundary layer
- complex terrain becomes simple (no exposed obstacles, mainly flat terrain)
- stone wall appearance (local disturbance – no effect).

INCIDENCE:
- bottom fire line reach high grass area,
- developed upper fire line caused additional pressure drop between valley entrance and plateau (chimney effect).

OUTCOME:
Further development and speed up of rising upward flow.
Main flow characteristics:
- moderate speed on valley axis,
- rotation of air by alongside valley axis caused by flow over two hills,
- unexpected grass burning speed (erruptive fire),
- possible singularity effects formation.

INDICATION:
- development of the hot air cummulation,
- preheating and drying on location,
- local progresive burning,
- rare trees burned up to 1,8 m height in the middle of the valley.



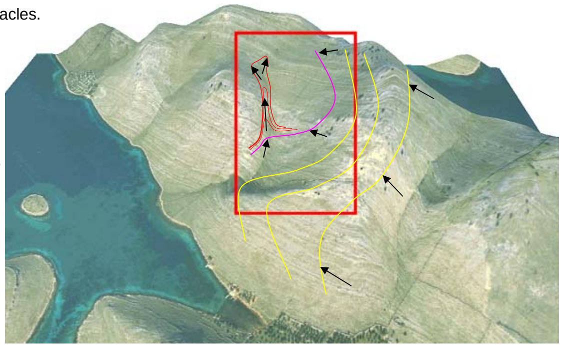
PHASE III - TERMINAL

CONDITIONS:
Fire: Fire line jump over high grass area
Peak flow development
Flow:
- faster winds,
- main flow SE to NW,
- secondary flow through valley S to N,
- thick boundary layer formation (velocity distributions arised by dominant thermal inputs),
- simple terrain with high roughness,
- dispersion of singularities and both boundary layers thickening,
- no tree obstacles.

INCIDENCE:
Characterized by incidence of:
- developed erruptive fire line,
- fire line follows high grass line in valley bottom,
- progressive erruptive burning because of no obstacles.

OUTCOME:
- more thickered both boundary layers,
- possible localised backward flows over layers due to continuity (causing noise),
- layer possibly strenghted with sanked vortex,
- addition of energy from rich grass line,
- additional pressure drop between valley entrance and plateau (chimney effect),
- speed-up effect of secondary air flow,
- tunneling on wall (vortexes on accident location),
- valley side boundaries (nozzle effect).

INDICATION:
progressive energy transfer and exremely fast hot air flow in valley axis direction – straight to location of accident (10–20 seconds duration). Rare trees burn up to 3 m above ground.



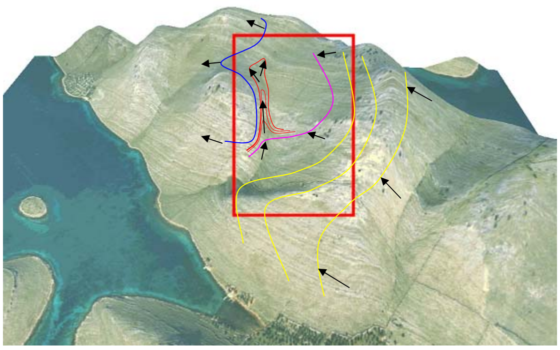
PHASE IV – BURNING OUT

CONDITIONS:
Fire: expected development, further fire line progress.
Flow:
- fast winds at the plateau, NE to SW, secondary flow dissapeared,
- thermal boundary layer stabilisation (velocity distributions predictable),
- moderate complex terrain,
- high terrain wall roughness.

INCIDENCE:
- fire line reach plateau from both sides (from the valley and over the hills).

OUTCOME:
Main flow characteristics:
- high speed on plateau.

INDICATION:
- due to fast winds fire jump over some areas and some grass area untouched,
- wide site area burned out,
- local heat accumulation and development,
- aluminum flange melting.



6. DISCUSSION

POSSIBLE DEDUCTION FOR DISCUSSION:

All mentioned occurances are possible if:
- fire velocity is at least fast as boundary layer flow

$$V_{FIRE} \leq V_{B.L.FLOW}$$

- boundary layer flow has at least speed of hot air

$$V_{B.L.FLOW} \leq V_Q$$

or

$$V_{FIRE} \leq V_{B.L.FLOW} \leq V_Q$$

MAIN ASSUMPTIONS DIRECTLY FROM AERODYNAMIC ASPECTS ANALYSIS:

Firemans injury possible developed in three stages:
1. First unfiting with extremely fast hot air (V_Q),
2. Further burn injuries with turbulent hot air flow ($V_{B.L.FLOW}$),
3. Afterwards burn injuries caused with fire on unmovable bodies (V_{FIRE}).

FURTHER RESEARCH PROPOSAL:

Measurements on location in similar conditions (summer, strong SE wind) if possible.
- all flow and thermal parameters,
- air flow visualisation with smoke on site under similar conditions,
- air flow visualisation on Kornati model,
- burn exeriments in controlled conditions (laboratory),
- numerical modelling and advanced flow simulation.