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Discussion paper on injection height of fire emission

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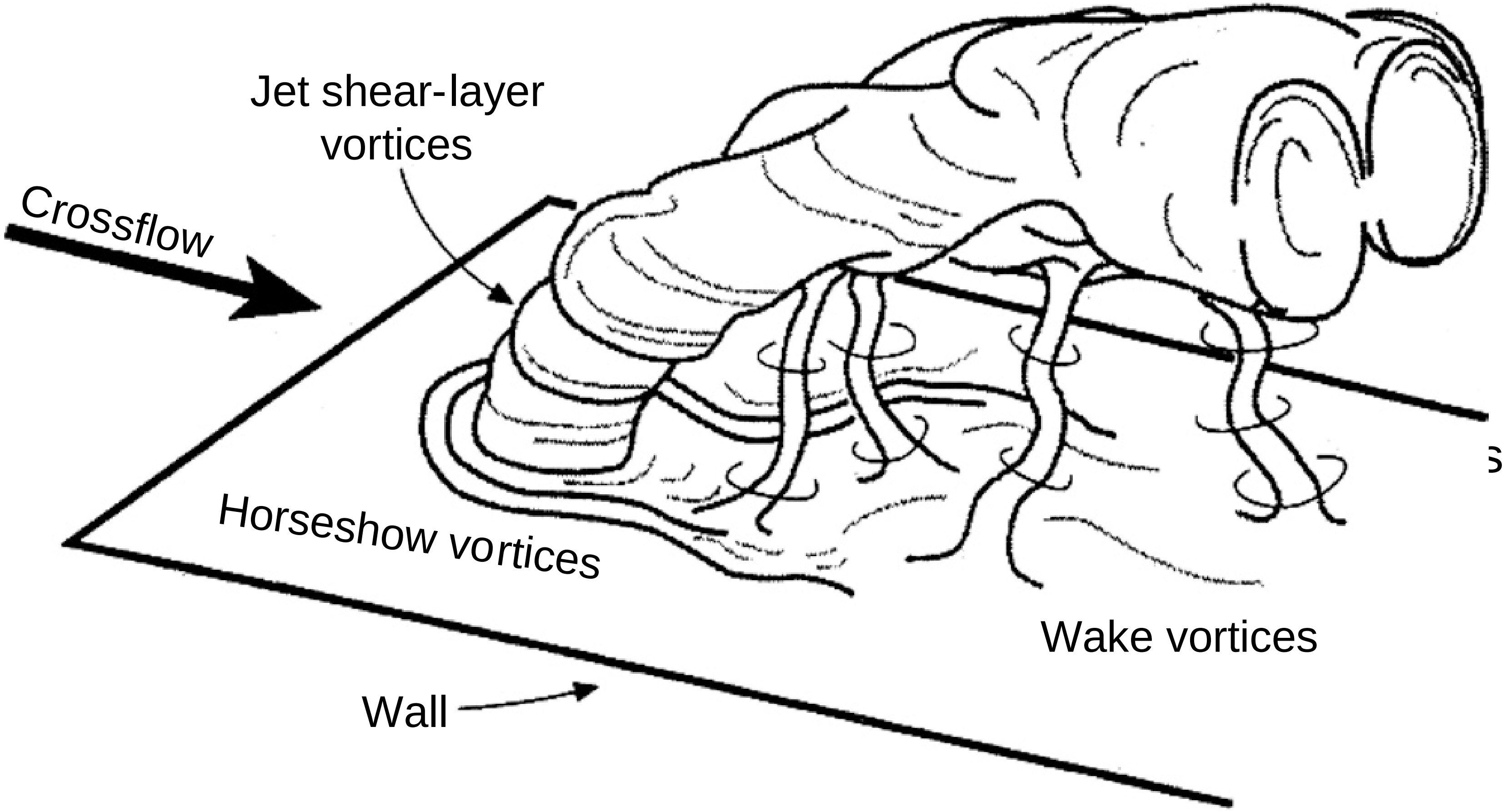
Content

- Injection height assessment by means of plume-rise models
- Example of BUO-FMI plume computations
- Input data needed for the assessments
- Possible sources of information in fire satellite retrievals
- Recommendations

Injection height assessment

- Basic terms



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Injection height assessment (2)

- Mathematically, the plume rise process is described by a set of partial differential equations
- Numerically, models can be grouped as following
  - ➢ Straightforward solution of the thermodynamic equations
    - – Solution of the Navier-Stokes equation
    - – Solution of basic conservation equations for mass, moment, enthalpy, etc.
    - – Search for an equilibrium between the buoyancy and drag forces
  - ➢ Application of analytical solutions of the above eqs for some idealized conditions (e.g. Briggs formula)

Injection height assessment (3)

- To our knowledge, NONE of currently existing plume rise models was specifically developed for forest fires
- Specifics of the wild-land fires plume height evaluation
  - ➢ distributed buoyant source: much wider hot area than in case of industrial fires or volcanoes (standard sources for plume-rise models)
  - ➢ complicated, time-dependent and largely unknown shape of hot area
    - – plume elevation may strongly depend on the wind direction vs burning area extension inter-action
  - ➢ strongly time-dependent release intensity with limited information on its development
  - ➢ very limited, if any, information on details of the release: heat released at a particular time, fumes temperature, initial velocity, etc.

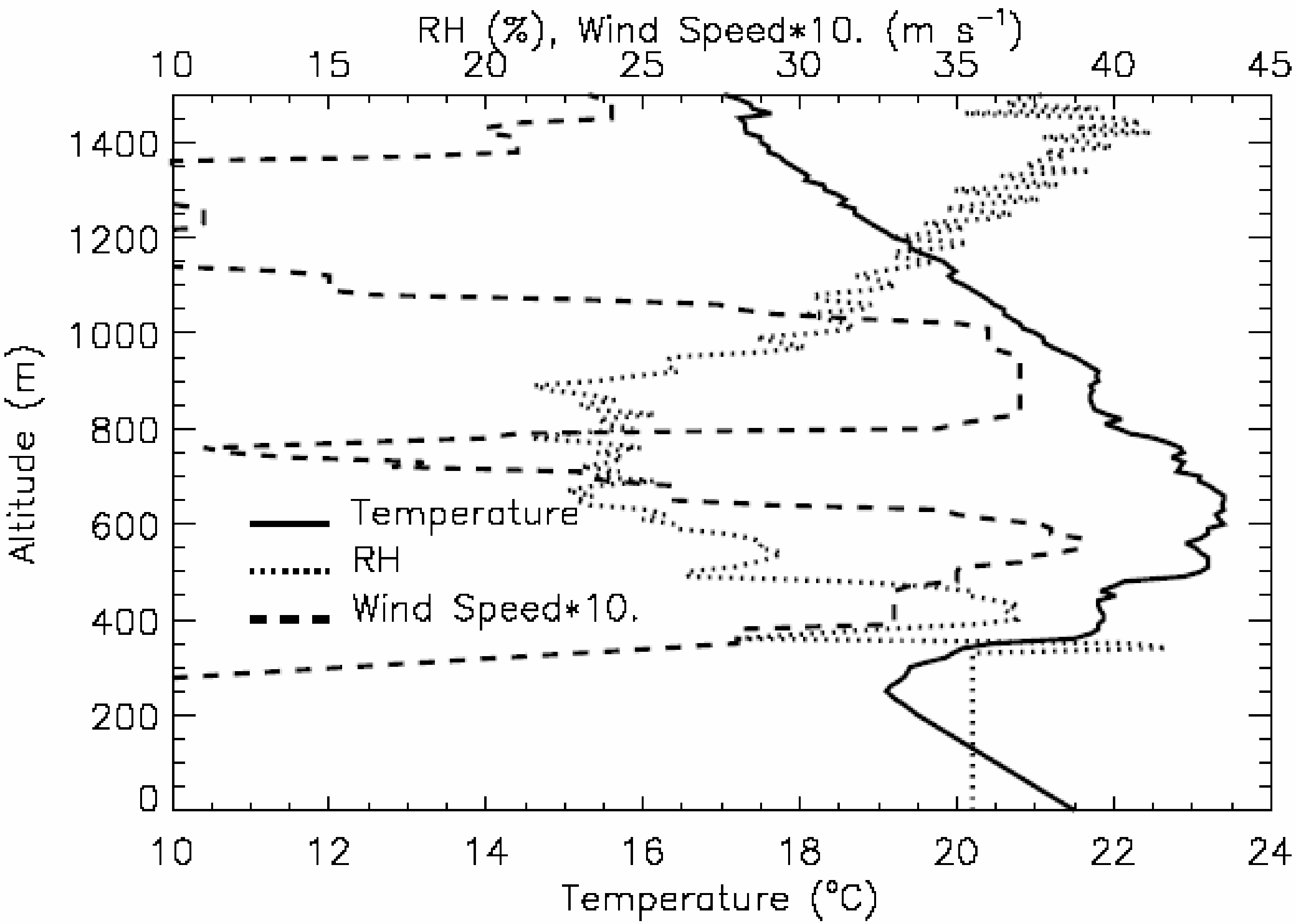
Typical input data for a plume-rise model

- Meteorological data
  - wind profile
  - temperature profile
  - often: integrated boundary layer characteristics
  - rare: humidity profile
- Release specification
  - total released mass
  - initial temperature of the emitted mass
  - released heat flux
  - horizontal size of the emitting area
  - initial velocity of the emitted mass

Evaluation of the BUO-FMI plume model

- Objectives:
  - Evaluate general applicability of comparatively sophisticated plume-evaluation model to wild-land fires
  - List necessary model improvements
  - Find out the most important parameters of the fires to be retrieved
  - Find a way to get the key fire parameters from satellite data
  - Suggest cheap methodology for making-up the secondary-importance parameters
- Methodology
  - Simulation of controlled experiments described in literature
  - Analysis of available and emerging satellite fire retrievals

A validation experiment: FMI BUOYANT model



Results of BUOYANT and other models

T **(°C)**	***q*** **(kg s[-1])**	z_h **(m)**			x_h **(m)**			t_h **(s)**
		BUOYANT	**BUO-FMI**		**BUOYANT**	**BUO-FMI**		**BUO-FMI**
500	**6250**	**918**	**378**		**404**	**48**		**28**
600	**5170**	**686**	**386**		**121**	**38**		**22**
700	**4410**	**631**	**392**		**67**	**28**		**17**

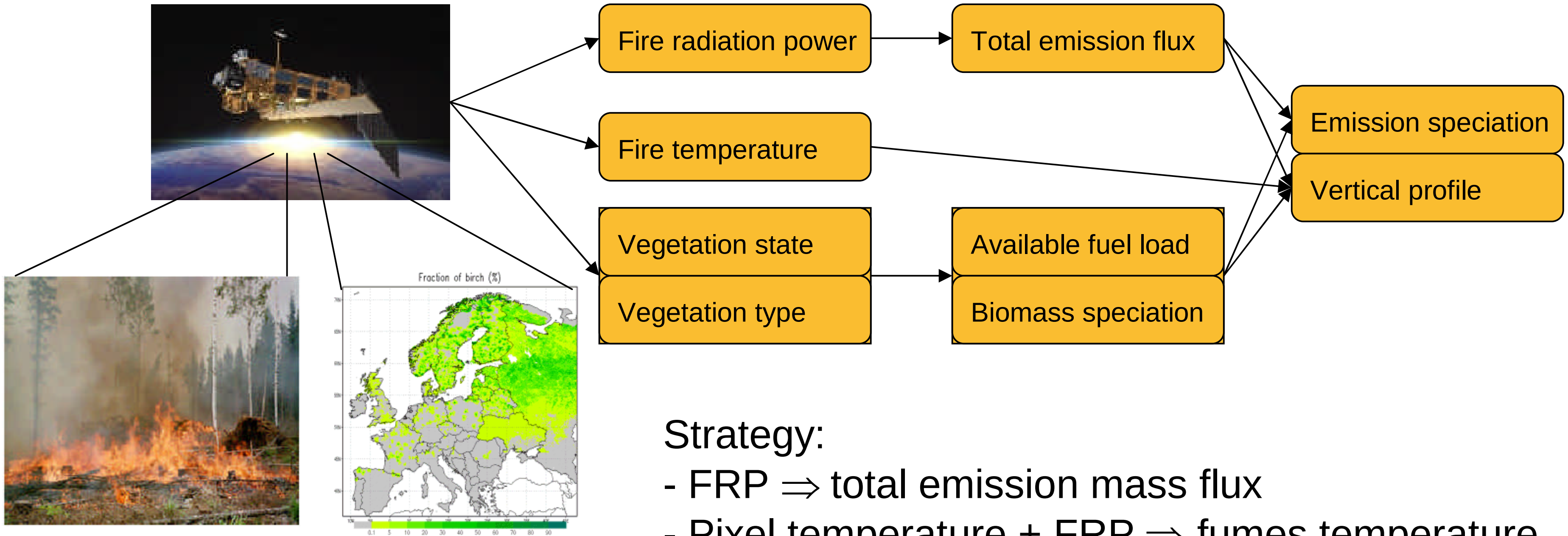
ERA-40 meteorological data

T **(°C)**	***q*** **(kg s[-1])**	z_h **(m)**		x_h **(m)**		t_h **(s)**
		BUO-FMI		**BUO-FMI**		**BUO-FMI**
500	**6250**	**626**		**484**		**112**
600	**5170**	**680**		**372**		**86**
700	**4410**	**761**		**270**		**62**
observation (Kaufmann et al., 1996)		**< 1300**		**-**		**-**

First conclusions and work to do

- Small-to-mid-size fires can be well represented with BUO-FMI as well as by other sufficiently sophisticated plume-rise models
  - pre-cooked formulae are likely to fail from time to time
- Power of mid-size fire is next to or already sufficient to penetrate the BL top inversion
  - considerable sensitivity to the governing parameters: strength of the inversion, released convective heat and total mass, etc
  - update of BUO-FMI model needed to bring the BL-penetration process in
- More detailed evaluation against carefully-selected observation cases is needed after the model update

Possible links btw needed and available data



Strategy:
- FRP ⇒ total emission mass flux
- Pixel temperature + FRP ⇒ fumes temperature
- total mass flux + fumes temperature + FRP ⇒ total convective heat released
- total emission mass flux + land use + vegetation maps ⇒ emission speciation

Input and output of a Fire Assimilation System

- Input meteorological data:
  - wind, temperature and humidity profiles
  - boundary layer characteristics
  - precipitation
- Input satellite-born products
  - active fire counts
  - fire radiation power
  - land cover and vegetation maps
- Output
  - 4D emission fluxes of the main released substances
  - short-term forecast of the fire development

Main modules of a FAS

- Pre-requisites:
  - the satellite fire-characterizing retrievals
  - land cover and vegetation maps
  - meteorological fields
- Speciation-resolving emission flux model
- Injection height model
- Fire propagation model
- Gridding system that merges the derivatives from individual fires to 4D grid

User (atmospheric modeller's) needs

- Requirements strongly depend on application (and on person asking the data).
- Spatial resolution: now: 20-30km; sufficient for near future: 10km
- Time resolution: one day plus typical diurnal variation
- Availability: forecasting: less than 24 hours; re-analysis: any
- Fire characteristics
  - total amount and speciation of emitted mass
  - vertical distribution of emission
  - fire development in-between the observation slots (means of interpolation of ALL above data)
  - quantitative assessments of accuracy (first of all, bias) of ALL above data