DANUBIAN ICE OBSERVATION BY WEBCAMERAS

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ABSTRACT. Danubian Ice Observation by Webcameras. In spite of the process of global warming, that can be concluded by analyzing the data of the past couple of decades, an unfortunate constellation of hydro-meteorological factors can anytime cause serious frosts, and consequently ice floods on Danube river. In 2001, based on earlier experience obtained in the 70s by conventional photography, a web-camera was installed on top of a high building at the riverbank at the town of Baja. Based on the first surveys success and their analysis 5 further cameras were mounted in 2008. The sites to be monitored in such a way are placed at 30-40 km distance from each other, so 130 km reach of the river could be observed. In January 2009 a two week long prevailing ice period was successfully recorded at the 5 sites. Coupled with morphological data as well as with the hydro-meteorological data of the observation period, even a primary analysis showed the potential to derive space-time characteristics of the floating ice, including size composition, motion and rearrangement due to secondary currents and occasional packing or release at places. Efforts are been done on quantifying the above mentioned features, furthermore, improving the recording quality.

Key words: Ice, Floe, Webcamera, Monitoring.

1. Introduction

The importance of exploratory work in the field of river ice has recently been intensified in the south-ern Hungarian reach of river Danube by using up-to-date technology. The reason for that, in fact, is that the most severe floods of the reach in the past were caused by ice jam (Lászlóffy, 1934). In the last 170 years serious ice flood occurred on Da-nube in 1838., 1839., 1850., 1876., 1878., 1883., 1891., 1920., 1923., 1926., 1929., 1940., 1941. and the highest ever experienced in 1956. This used to be so for two main reasons, out of which one is a hydro-meteorological, the other is a mor-phological factor. River training works in the in-vestigated reach have been completed, only main-tenance and small corrections are done from time to time (Keve, 2002.).

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By investigating the ice data of the river reach witch are mainly simple estimation of the observer some experience of the past can be concluded. The frequency of any kind of ice appearance decreased in the last 40 years (Figure 1.). Even the date of the highest probability, when ice could be seen on the investigated area came earlier. Between 14-19 January is the best chance (26%) to see ice on the Danube based on the period 1971-2009. While this value was 60% and between 19-25 January at the first seven decades of the last century.

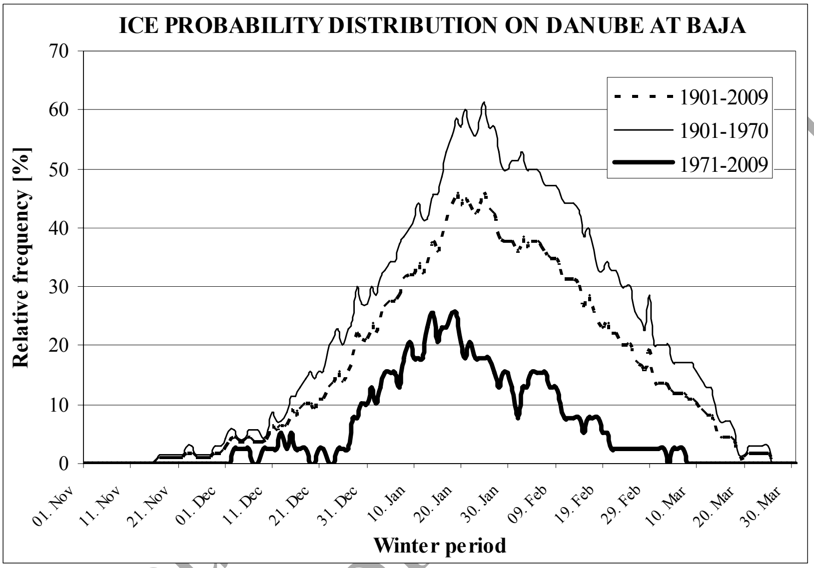

Figure 1. Probability of ice phenomena on Danube at Baja.

In spite of the process of global warming, that can be concluded by analyzing the data of the past couple of decades, an unfortunate constellation of hydro-meteorological factors can anytime cause serious frosts, and consequently, ice floods.

Prevention of flood and its damage is a main task of the hungarian watermanagement service therefore the importance of reliable hydrological observations is extremely high. However the flu-vial ice monitoring is an adverse field of hydrol-ogy. Only estimations are done by the observers during frozen periods. But only objective meas-ures could ensure data for detailed investigations about the whole freezing, floating and jamming processes.

Figure 2. First web-camera at the bank of Danube.

As an initial step, in 2001, based on earlier ex-perience obtained in the 70s by conventional pho-tography, a web-camera was installed (Figure 2.) on top of a high building at the riverbank at the town of Baja. Based on the success of the first surveys and their analysis 5 further cameras were mounted in 2008.

The sites to be monitored in such a way are placed at 30-40 km distance from each other, so an alto-gether 130 km reach of the river could be ob-served. As a fortunate occurrence, even in the first winter in January 2009 a two week long prevailing ice period was successfully recorded at the 5 sites. Coupled with morphological data as well as with the hydro-meteorological data of the observation period, even a primary analysis showed the poten-tial to derive space-time characteristics of the floating ice, including size composition, motion and rearrangement due to secondary currents and occasional packing or release at places. Efforts are been done on quantifying the above mentioned features, furthermore, improving the recording quality thus the image processing results of the observations.

2. Installation of Web-Cameras

2.1. Placing

In 1978 Zsuffa written a technical study about the appropriate methods of ice measuring on rivers. It declares that there are two main task for proper ice observation.

One of them is the qualitative watching of ice, which is done by ice guard person very similar way all over the word. This is a rather subjective observation what is then coned and recorded in hydrological databases. Basically these data can be used later for further investigations. These infor-mation are mostly limited to the surroundings of gauges. Out of it one can see the appearance of ice, ice drift, stopping of ice floes, breaking up, ice jams, disappearance of ice. The percentage of ice cover places to total section is also recorded, but it highly depends on the viewpoint and estima-tion ability of the observer.

Second is the qualitative measure of ice phe-nomena. This technique is not really wide-spread. In this case based on measures and countings ob-jective numbers describe properly the observed ice symptom. Such numbers are the percent of ice cover to the uncovered part of section, percent of drift floe to the standing floes, velocity of drifting floes, ice surface discharge [m2/s], thickness of ice, ice discharge [m3/s].

This last method, the quantitative observation, can be helped with web cameras in very effective way, earlier this was done by photo machines. To computerize the pictures of any kind of camera by photogammetial methods is the function of the ob-servation point where the camera installed. Best would be up above in the middle of the observed section and see perpendicularly to the river. In this situation the perspective error is minimal. Of course satellite pictures or aereal photoes would be fine. But right this moment these are to expen-sive if we take under consideration the resolution and frequency of needed pictures.

Thumb of rule that for observation hight 5-10 % of the total width of river is sufficient for our purpose, but as close to the river as it can. The best installation when the objective can see both river banks and the vision is right angle to the stream. Out of this elevation some of the errors of low perspective can be eliminated. It is recom-mended that the quotient of the length of viewed river reach and picture taking timestepp is in pro-portion to the average surface velocity of the river. As in this case the surface velocity distribution can be counted (or estimated) easily out of two following frames. In the investigated reach of Da-nube the average surface velocity is 0.8-1 m/s, so a 60 m section which can be seen on both bank and 1 frame per minute must be enough for meas-uring conditions. If there is a way use signs on the banks to mark the section and big enough to be recognized on the cameras pictures. Due to this preparation by overlapping two following pictures easy to draw surface velocity distribution even in m/s. As if a recognized displaced floe on both of the pictures took 60 m the velocity is exactly 1 m/s.

There are more limits to install web-cameras on the banks of river, namely the electric supply and the network connection to send the computer sign-s. At the best preparation and design it can happen that the electric supply will pause when we would need the camera mostly. UPS and separate electric connection is recommended. In our case it hap-pened that the electricity was turned of in the whole building because of a serious flood which inundated the place. Better to think about these facts at the planning period.

Figure 3-4. Different views in the same time and section

To place our camera in a proper place described above has a lot of practical obstacles. For example in low flat land it is hard to find a high natural or artificial place on the banks where all conditions can be fullfilled. Grain towers, high buildings or big bridges along the river are the best places. Natural hills or highlands are good to make mov-ies or take photos about the river, but the electric supply is hard if there is lack of houses. So to in-stall web-cams is too difficult in most of the cases. Wireless connection can be used but sufficient and continuous electricity is crucial for these equip-ments. For outdoor cameras heating is a very im-portant fact specially in cold winter when we want to use them. Power must be for signaling and for zooming or moving of newer developed cameras.

The objectives of these outdoor web-cams some-times become dirty. So rarely but within a certain time one must clean the lens. The places which are hard to reach even in summer are hardly can be caught at a frozen winter. Snow or sleet are the worst cases when the cleaning must be taken.

If we can solve all the mentioned problems and we have the best and only place an antenna or any kind of structure can form an obstacle of the view of our river. Even part of the vision can be cov-ered by anything. Wrong reflection of the sun or the water during most of the day also makes our work difficult. Out of these reasons even custom designed placing of cameras are allowed and rec-ommended.

In 2007 Gálai researched the distortion of such cameras. In his work the perspective distortion and the camera self distortion were both investi-gated. With simple linear algebra methods all the distortions were eliminated. This kind of solution is a new way and has not well known yet.

2.2. Types of Web-Camera

There are many web-cams in the market what one can choose, but always must keep in mind the purpouse or goal what it will be used for. If only the quantitative monitoring is the goal the best so-lution a simple fixed camera. It is like a “0” point of a water level gauge. As for the rest of time this camera will make continuous pictures exactly from the same viewpoint. Experiments with mov-able and zoomable cameras proved the advantages of these new techniques too.

For example such a camera was installed on the iron structure of a bridge right in the middle of the bridge faces to the stream. Here the streamline placed at the right bank which was on the left side in the cameras picture. But the ice drift occurred on the left and on the right side periodically. The moving (turn) and zooming facility made it possi-ble to follow the actions of floes where it hap-pened. Naturally we had to renounce the measure information in phenomenon examinations favour.

Resolutions of digital cameras are better and better, but we need to transfer the taken pictures and this needs more and more bandwidth. Tranfer-ing or FTP the pictures can be done to more ad-dress in the same time and online. These are the main viewpoints indicate the use of webserver-cams. In this case there is no need an extra PC to control the camera and everything can be com-manded from a remote place. Hopefully the devel-oping of file and picture compressing techniques will solve many of these problems. And what is more soon the mobile phones can be usable for ta-king adequate pictures and its fast, multiplied and cheap forwarding.

Many problems can be experienced during the operations of cameras. Unsufficiently closed out-door cover can ensure hiding place for insects what is hard to clean then. Pigeons, falcons can sit on the camera (shaking problem) if there is no higher place near it. Electrical short circuit can also make running troubles. But the bigest misfor-tune is the limited daily period and visibility weather conditions when it can be used.

During the night and in foggy situations or bad reflection cases we have no information about the viewed river section. As far as our information are correct the usage of infra cameras for this purpose has not yet worked out. Or the prize of such a camera what can handle more then 500 m distance is rather expensive. Small infra cameras with own infra lamp up to 10-20 m reach are unsufficient for our goals.

2.3. Advantages of online river observation

Our first ice observes webcam was installed in 2001. Since then many, not ice related happening was videod which were also important for water-managers and for the handlers of the river. For ex-ample a ship crashed the pier of bridge and mortal canoe tour accident were recorded. Out of our im-ages the police inspectors could have a real picture about the accidents. Some oil pollution were also detected and the ship was identified which re-leased its waste oil during the night. High-speed movies about hydrograph the periodic change of floods and low water periods could give new in-formation as well. Water quality experts tried to find correlation between the colour of water and its characteristic parameters. Unfortunately the water sampling almost stopped so this research closed. Watermanagers, navigation experts, water police, catastrophe service, meteorology service (cloud and weather image) are the main users. But some of the civil internet users also applied the possibilities of our online camera. Well before the widespread free internet IP telephone technique some local people wave their hands in a boat in front of the camera and talked on their mobile phone to send picture and voice in the same time to their beloved relatives to a different continent. But emigrated or far away working local patriots visited frequently our web page and watched the virtual waves of Danube river.

Following the installation just rare and short periods of time showed ice on the viewed Danube reach. These records were sent to University of Iowa where Muste professor applied PIV (particle Image Velocymetry) methods on them. Muste made velocity vector field out of the sequenced photos immediately and send them back. Unfortu-nately without the proper position of the camera and of some well recognizable field points further calculations were not done (Figure 5.). Ettema and Jasek investigated the contact between surface ve-locity distribution (measured by ice web-cams and PIV) and average velocity of the total cross sec-tion. It is a notable solution to determine discharge of the river as there is hard to find safetyer method on icy period.

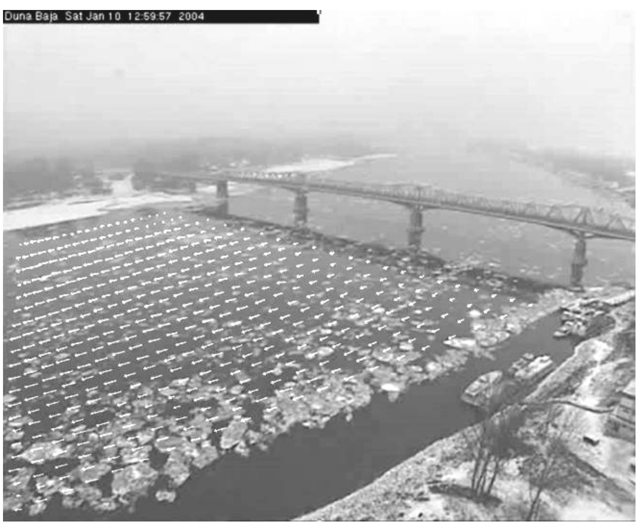

Figure 5. PIV vector field.

Kimura and his colleagues developed this method, they used velocymeters, remote water level gauge, wind sensors and webcam to measure velocity elements and by the known cross section they counted discharge.

To find a reliable contact between surface velocity distribution and average cross section velocity needs more detailed investigations. Moreover a floe in high drifting time can clash to each other and it disturbs the course and speed of a single floe. How can we base the surface velocity distri-bution on this marker. Sokoray-

Varga et al. used PTV (Particle Tracking Velocymetry) method in laboratory conditions to recognize free surface flows. Due to his experience none of the measured speedfields totally same to the real ones as the speed of markers are different from the speed of water.

When the floe drift is slight just part of the sec-tion carries ice (mainly streamline), so there is no information about all the other part of the section. More years of own experience that an equally dis-tributed floe drifts in the investigated reach of Da-nube is very rare.

Second experience that the drift is very various and continuously changing process even in the same conditions. This was the reason why Zsuffa classified this phenomenon to the stochoastic hy-drological processes where the best solution is to characterize it by a statistical number out of many measures.

For such a measure the pictures of webcams are suitable without doubt. Up to now I have not found any software (ready to use) which would solve the total treatment and would give a statisti-cal number for example about the ice cover per-centage.

Back in the time when the first water level ob-servations were done no one knew the future. To-day very nice investigations can be done using old data. The webcam ice measure is at its beginig if the only thing is to measure and save pictures for the future that is great. But more we have the whole record about the investigated icy period. And these pictures are ready for further investiga-tions.

2.4. One or more web-cameras

Experiences with our only one webcam and the increasing number of new questions made clear that the ice observation in time must be spreaded out in space as well. After seven years working of our first webcam an EU INTERREG III/A appli-cation gave good chance to develop our system with 5 more webcams. By this 130 km of Danube reach came under new monitoring. (Figure 6.)

With this improvement a new comfortable way opened to investigate and control the dirfting ice. From the office it was possible to see the whole reach in-time and on-line. The decision makers got a new reliable tool as earlier they hanged on the subjective reports of ice watchers (dike keep-ers). These watchers walked on slow elevation on the river bank and had a less precise estimation about the observed process. The decisions have serious economical effects as an ice defence de-gree costs a lot. It means that ice breaker ships must be heated and moved with their stuff or at least they have to be in readiness. These costs were saved even in the first winter after the instal-lation of new cameras. The quantity and quality of drifting floe on the Danube reach of responsibility were screened to the decision makers who did not ordered ice defence work.

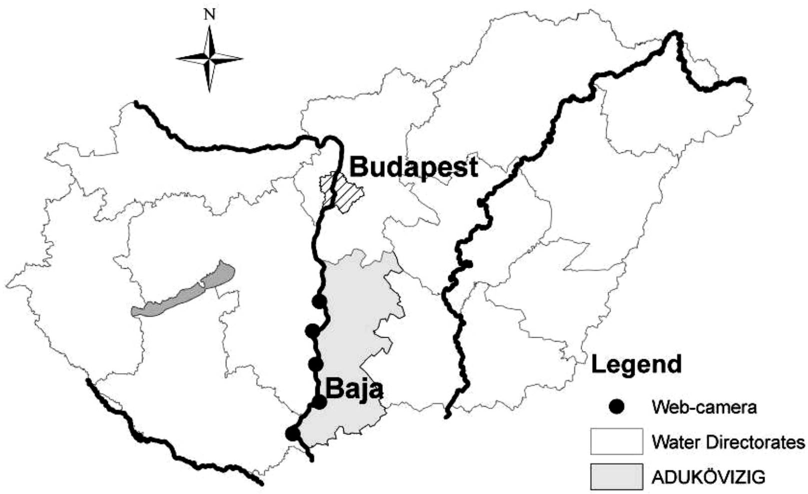

Figure 6. Ice web-cameras along the Danube in Hungary.

What more the ice watchers can be ordered to the hot spots and it is needless to walk all along the bank many kilometers.

There is an advantage of online internet facility as well. The recorded pictures can be analysed anywhere around the world. For example consid-erable decision must be the opening of an ice jam or defence against the developing. More experts can be mobilized and discuss the problems. The ice breaker ships can be ordered on a well pre-pared way.

Space-time ice monitoring gives a good chance to understand and investigate the phenomena on a higher standard. Based on the new experiences the ice forecast and ice modelling technology will de-velop as well hopefully.

2.5. Further develpoments

Vuyovich et al. (2009) studied how web cameras can also be used to investigate river ice processes. Hourly images were taken over three winters at the confluence of the Allegheny River and Oil Creek in Oil City. Each image was manually re-viewed and classified according to surface ice conditions. This is hard and long work what must be automated as it can be.

There are hot spots along the river where the floes could build junction. It would be good to in-stall cameras on these spots. But the profitable ex-periences showed that all places where a camera can be installed must be utilized. Next the system must be spreaded further across borders as de-tailed investigations need more data. A succesfull ice defence work in the investigated region always depended on the good cooperation with Serbian partners. So an equally same and proper monitor-ing system is really important.

Satellite images and infra pictures will not be used at this domain in the near future, but the pos-sibility of using them is a significant fact.

To investigate the drifting processes environ-mental sound floe painting would be a new way. As the painted floe is much more easily recogniz-able on pictures. This marking technology could be done from bridges. In this way the drifting speed and course could be monitored between wabcams.

New method is needed to measure floe width, because to do it from a ship is a hard and slow work. If we only knew the thickness of ice the ice discharge would be countable.

Together with all developments a warning sys-tem would be the goal. Such warning systems work on airports where cameras watch and record all the actions. An automatic software checks the difference between sequenced pictures, if a pack-age left alone somewhere an alarm signs warns the guards.

3. Observation

3.1. Hydrometeorolgy

Many conditions influence the ice forming on the investigated reach of Danube. As it was men-tioned in the introduction mainly hydrometeo-rological processes infulence the evolve of ice. River regulation and due to it river bed morphol-ogy as well as other human effect manipulate ice phenomena. Such effects are the waste water-treatment plant inlets or in the researched area an atom powerplant. The atom powerplant with its cooling water inlet gives considerable heat pollu-tion to the river. This heat pollution effect is up to 30-40 km along the stream but it mainly melts the stopped ice (Keve, 2003). Hirling (1981) devel-oped an ice forecast method for hungarian rivers. This is done by the sum of negative daily average temperature. The sum contains the daily tempera-tures under zero without pozitive interuption in the period. This method is good, but the occurance of ice is not only the function of local temperature. For the Danube section at Baja approximately -70 ˚C negative sum of temperature and river water temperature under 0.5 ˚C must be to have even a piece of ice. The negative sum must build up from cooler elements than -5 ˚C. If the daily average warmer than -5 ˚C no ice occur even at higher negative sum.

Some of the cases there are floes which formed in upper side branches of the river or released from reservoirs. To forecast this kind of drifting has not prepared yet. Barrages of Danube have op-erational plans. They generally release ice from the upper part at melting or breaking up time. These kinds of floes slowly disappear down-stream.

Unfortunately the hydrological service did not recorded these different type of ice phenomena. The only information are the next ones near bank ice, drifting floe, stopped floe, ice jam. These data are usefull to know that the river was either icy or not. Further analyzation impossible to do.

Air temperature and river water temperature are accurate data so it is possible to make calculations and forecast the ice forming or the probability of occurance. These methods can be improved by us-ing the records of webcams from a longer reach of river.

3.2. Experiences

Huge advantage only one camera because the whole ice forming and melting period can be fol-lowed in the viewed section. More camera is even better so it is worth seaching on the internet and find shared webcams. Some of them can contain important information for our research. It hap-pened that a city site camera in Budapest helped us to identify ice at that section of Danube. Now with our installed webcam system the situation even better. Our experience that there are mainly free types of drifting floe at Baja section on Da-nube.

In the first case a long reach of river freeze in the same time. This type of freezing has huge (football field), thin and sharp edge floes. These big floes than soon brake apart by craching piers of bridges or river regulation works. If the naviga-tion not stopped yet even the waves of ships can destory these ice floes. Waves made by wind can also crumble the ice. Out of this reason these great floes occur mostly early in the morning after a calm cold night. As the peacefull but chilly weather can freeze the over-cooled water on big surfaces.

In the second case the ice formated in the river bed. It can be river bottom ice or floes broken down from the bank. At this situation the floes are not always flat under the water they are cone-shaped. Naturally freak forms and colours can also presence. The colour depends on the material where the water frozen up. Suspended ices are in the water body. This means that buoyancy force can lift up the ice mixed with river bed load but not able to keep it on the surface. These blocks float in the middle of rifer downstream and just rarely can be seen on the surface.

In the third situation the floes formed at upper regions of the river or in side branches. The floes sizes are very different, but the edges of them keep debrish ice. These small broken ice pieces come from the many crashes between floes. Big floes are not flat because they always formed from more well recognizable small floes.

On figure 7. the third case presented. Six pictures were taken at six different section of the river at the same time. From left to right and from up to down the images represent the downstream flow. Up the floes are big but down at the last section they broken to pieces and almost disappeared. There are 120 km between the first and the last pictures. In our example the coming ice met with a warm melting weather.

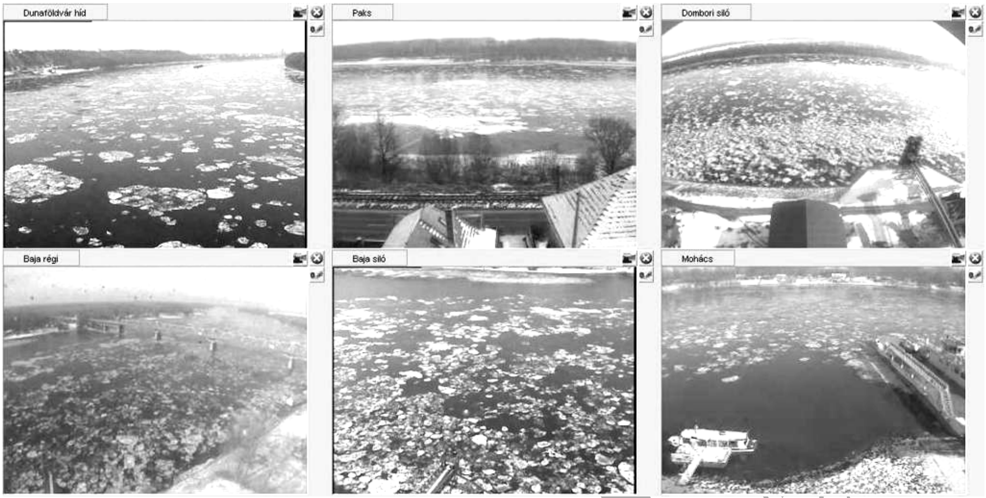

Figure 7. Picture of webcam observation system

Any combination of the describer three base type of ice can occur. The separation of types can help to distinguish ices and can lead us to make accurate forecast for them.

In the hungarian watermanagement practice the drifting floe characterized with its estimated per-centage to the total section width. From the re-corder movies it is clear that the distribution of floes change dynamically. It has daily and even smaller scale more or less periodical changes. Therefore a sudden estimation is not correct, but an observer person does not have more time in a section. The drifting has a same characteristic as the stream velocity. A classical velocymetry in a certain point can not be shorter than 1 minute. The floe observation would be handled on the same way.

Next the observer usually views the river from a lower place and not able to distingues stopped ice from the moving. So he can estimate the drift much bigger than its real value.
For this reason automatic image process from the pictures of webcams recommended. From this hourly statistic can be made which is acceptable result.

3.3 Hydrodinamical cases

In spite of the new installation of cameras even in the first winter some hydrodinamical cases were videod. All of these recorded movies about ice on Danube were examined. Experiences were gained in a table where the rows represented the places of cameras and the lines showed the time. With no expections in all section a daily periodicity were detected. Morning drifting was always more inten-sive than in afternoon.

Uniform distribution of floes in the investi-gated sections was very rare, mostly the streamline lead down the ice pieces. But in some cases the drift changed its structure and from one side of the river flowed to the other side. Streamline follows the concave bank as it was expected floes floats here most of the time. The reason is not exactly clear but in certain cases the floes leaded just on the convex bank. There were cases when both sides close to the banks had ice equally and noth-ing was in the middle of river.

Ships or ferries waiting in front of the cameras formed obstacle against drifting floe. Arched jam shaped suddenly and it helped to investigate this process. This real sample could help us to under-stand the developing events of ice jams and later to modell or defence against them.

4. Results

Although only two week long prevailing ice pe-riod was successfully recorded by our webcams at 5 sites in the first winter. Coupled with morphological data as well as with the hydro-meteorological data of the observation period, even a primary analysis showed the potential to derive space-time characteristics of the floating ice, including size composition, motion and rearrangement due to secondary currents and occa-sional packing or release at places. Efforts are been done on quantifying the above mentioned features, furthermore, improving the recording quality. As a summarization god experiences can be said about the webcam monitoring of rivers. New ways of observations and investigations were pioneered.

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